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FEASIBILITY AND CRITERIA FOR LAND MOBILE AND TV BROADCAST SPECTRUM SHARING

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FEASIBILITY AND CRITERIA FOR LAND MOBILE AND TV BROADCAST SPECTRUM SHARING

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EXECUTIVE SUMMARY

A. SUMMARY

The rapid growth of the spectrum requirements for the land mobile service has compelled Administrations to find additional spectrum for this service. One possible source for this additional spectrum is that part of the TV spectrum, either unusable as a result of TV taboos, or as presently allocated but not assigned for use by the broadcasting service (television) in the VHF and UHF frequency bands. In a particular geographical area, only a few channels of these allocated bands are assigned; the results of the study suggest that the unused channels in that particular geographical area could perhaps be used by the land mobile service.

This study examines the frequency planning criteria which apply to protect the land mobile service and broadcasting service from mutual interference where portions of the spectrum may be shared.

These planning criteria for inter-service sharing are then applied to the Montreal, Toronto, and Vancouver areas to establish which VHF and/or UHF television channels could be used by the land mobile service in each of these three urban areas.

The study concludes that, if all TV channels were assigned in accordance with the Canadian TV allotment plan, it would preclude the sharing of spectrum with LMS. However, since a few allotments are as yet unassigned a number of windows whereby allotted TV spectrum could be operated by LMS users are potentially available.

B. DISCUSSION OF THE REPORT

In Chapter I, existing criteria used by different administrations for the licensing of the TV broadcast service and the land mobile service are reviewed at length. The various factors to be considered are identified and ranked. In its basic form, frequency planning is concerned with the determination of the relative levels of the desired and undesired signals at the receiver input. Factors affecting these signal levels, and the criteria for establishing acceptable grades of service are examined.

Also included in the Appendix is a detailed summary of the propagation characteristics in the 30 MHz to 1 GHz portion of the spectrum as applied to the land mobile and TV broadcasting service.

Chapter II investigates the technical considerations involved in possible sharing of the spectrum between the two services. The existing licensing criteria used by the D.O.C. and the F.C.C. for each service by itself is reviewed. The experiences and criteria for inter-service sharing in the U.S.A. and the U.K. are then examined. The main technical parameters involved in inter-service sharing are then

developed. These include the minimum desired signal strength, the maximum interfering (or undesired) signal strength, the protected contours for the services, and finally the minimum separation distances between transmitters of the shared services. The establishment of these parameters involves a detailed review of television and LMS signal characteristics, propagation characteristics, antenna discrimination factors, transmitter and receiver characteristics, and the protection ratios for each service.

With the objective of first identifying all candidate channels, the separation distances between TV broadcasting and LMS were calculated using the assumptions listed in Chapter II, Paragraph 6.5.1 of the report.

Provided that these separation distances are maintained, the reciprocal protection will also be achieved. That is to say, the LMS will be protected from interference from the broadcasting service for greater than 90 percent of the time.

Finally, in Chapter III, the results of the first two chapter s are applied to determining the most suitable VHF and UHF channels that could be used by the LMS in Toronto, Montreal and Vancouver. Average terrain characteristics were used to represent each of the three urban areas. Based on this statistical approach, UHF television channels available for use by the LMS within a 30 km radius of the three city centres were identified. See Chapter III, Tables 4.1 through 4.3. (No VHF channels were found to be available in any of these areas.)

The set of available channels common to all three cities totals only sixteen. Of these sixteen, Channels 14, 15, 41, 42, 43, 52, 53, and 54 are the most attractive. The first pair (14, 15) would represent a continuation of the 450-470 MHz LMS allocation and would require minimal modification to existing radio products in order to extend their coverage. The last six channels are attractive since they represent two sets of contiguous 18 MHz blocks in the spectrum. None of the available spectrum would appear to be compatible with wide area LMS systems, primarily due to the limited geographic expansion possible without infringing on protection ratios.

It is noted that the 16 channels identified as available in all three cities are either restricted by TV taboos or are included in the Canadian TV channel allotment plan. They are only available at this time since they are as yet unassigned. Failure to reconsider the allotment plan in a timely manner will make future reassignment to LMS difficult, if not impossible, to implement.

C RECOMMENDATIONS FOR FURTHER STUDIES

The results of the study are generally believed to be conservative. Marginal areas could be fine-tuned with additional study in several areas. Five of the more important of these are outlined here.

1. Analysis of the requirement for special sharing criteria arising from anomalous UHF TV signal propagation modes, especially tropospheric bending, and atmospheric ducting, but also possibly aurora, sporadic-E and others, would lead to more realistic protection criteria/separation distances. This may be particularly true of the Toronto area where ducting from U.S. cities over Lake Ontario is a potential problem.

2. Verification of the protection ratios used for the two services by performing worst case measurements is an area which demands further investigation. This includes investigation of the effect on the LMS signal of the discrete line components of the TV spectrum and the verification of the NTSC spectrum and analysis of optimum parts of this spectrum with a view toward interleaving LMS channel assignments between TV signal spectral lines.

3. While current land mobile operation in Canada uses frequency modulation with 25 KHz channel spacing, characteristics of, and sharing criteria for other modulation techniques which are likely to be more widely used in future should also be examined. These techniques include 12.5 KHz FM channels, single sideband, amplitude companded single sideband, digital modulation techniques (TFM, MSK, etc) and frequency hopping.

4. Tests of TV receive antennas in their "installed environment" are required to establish more reliable criteria for interference rejection. Directivity measurements, and especially polarization discrimination, are key areas to identify. Tests of the latter characteristic are particularly important in the presence of multipath propagation, where polarization shift may occur. The land mobile signal at the TV receive antenna may be polarized horizontally, vertically, or somewhere in between at a given instant.

5. Finally, the use of actual terrain characteristics and antenna heights/erp for marginal cases, esp Vancouver (terrain), Montreal (to a lesser extent) and Toronto (Ant. ehaat) would provide higher confidence in identifying some channels which are borderline.

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CHAPTER I

REVIEW OF EXISTING CRITERIA

FOR THE LICENSING OF

TV BROADCAST SERVICE AND LAND MOBILE SERVICE

CHAPTER I

REVIEW OF EXISTING CRITERIA FOR THE LICENSING OF TV BROADCAST SERVICE AND LAND MOBILE SERVICE

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

This report is Chapter I of a three-chapter report of a study to determine the feasibility of spectrum sharing between TV broadcasters and Land Mobile Radio Services.

The purpose is to review the existing criteria used by different administrations for the licensing of terrestrial TV broadcast services, the low-power TV broadcast service and the land mobile services. Each service is discussed separately; the problems of inter-service operation are considered in the chapter 2 report. The main thrust of this chapter is to identify the system characteristics and parameters involved in determining how the frequency assignments of a particular service allotment are shared among the users and yet provide an acceptable grade of service to all users.

1.2 DESCRIPTION OF CHAPTER I REPORT FORMAT

Sections 1 and 2 provide the introduction and list reference documents used in the study. Section 3 introduces, in general terms, most of the significant parameters that have to be considered in frequency coordination. Section 4 considers the land mobile service and describes all the factors and parameters involved in the frequency planning for this service. Sections 5 and 6 does the same for the full-power TV broadcast service and the low-power TV service respectively. The licensing criteria for DOC, CCIR and, where data are available, for the FCC are summarized in Section 7. Since the propagation characteristics are of paramount importance in determining the service contours and signal levels, this was treated in some detail in the Appendix A.

2.0 DOCUMENTATION

2.1 REFERENCE DOCUMENTATION

The following documents, among others, were used in the preparation of this report:

1. DOC, RSS 119, Issue 3, August 1985
2. DOC, RSS 120, Issue 2, April 1972
3. DOC, RSS 121, Issue 1, April 1972
4. DOC, BP-5, Issue 3, June 1984
5. DOC, BP-22, Issue 5, October 1983
6. DOC, RSS-154, Issue 2, March 19847.DOC, RSS-157, Issue 1, December 1978
7. DOC, RSS-157, Issue 1, December 1978
8. DOC, BS-11, Issue 1, April 1953
9. FCC, Rules & Regulations, Vol III, 1982, Subparts E & G
10. DOC, SRSP 501, Issue 2, January 1983
11. DOC, SRSP 502, Issue 1, January 1983
12. CCIR, Chapter V, 1982, Propagation in Non-ionized Media
13. CCIR, Chapter VIII, 1982, Mobile Services
14. CCIR, Chapter XI, 1982, Broadcasting Service - Television

2.2 DEFINITIONS

Allocation: Provision of a band of frequencies for a particular purpose or service.

Allotment: Provision of a specific channel for a particular community.

Assignment: Authorized use of an allotment ~~for a TV station~~.

Service Contours: Service contours of a broadcast station are the boundaries or contours at which the field strength of the station's emission are at a specified value for 50% of the locations at that contour and for 50% of the time. The service contour defines the service area for that broadcast station and is denoted by F (50,50) contour.

Interfering Signal Contour: The contour (from the interfering broadcast station) at which the specified interfering signal field strength is received at 50% of the locations for 10% of the time. It is denoted by F(50,10) contour of the interfering station.

Protection Ratio: The ratio of the desired signal to the undesired (or interfering) signal at the receiver input required to produce a specified impairment of the output signal. It is referred to as (C/I) or (D/U) in the text.

Polarization: The direction of the electric field strength vector of a radiated wave.

2.3 ABBREVIATIONS

ERP	Effective radiated power which is the product of the transmitter power at the input to the transmit antenna and the gain of the antenna relative to that of a half wave dipole antenna.
EHAAT	Effective height of the antenna above the average terrain.
FM	Frequency modulation.
VSBAM	Vestigial sideband amplitude modulation
LPTV	Low-power television
LMS	Land mobile service
SNR	Signal-to-noise ratio
F(50,50)	The field strength at the service contour or boundary of a broadcast station which is received at 50% of the locations at the contour and for 50% of the time.
DOC	Department of Communications, Canada
FCC	Federal Communications Commission, USA
dBμ	Measure of the electric field strength in dB's relative to 1μV/m

3.0 FREQUENCY PLANNING

3.1 QUALITY OF SERVICE FACTORS

The main objective in frequency planning (or coordination) is to ensure that mutual interferences between the user systems of a frequency allotment do not unduly degrade the quality of service provided to the users. In the absence of all other user systems of a service; i.e. in the absence of all interference, the signal quality is degraded chiefly by "noise" at the receiver input. This "noise" would consist of the receiver internal thermal noise, cosmic noise, man-made noise, and, in the case of the land mobile service, multi-path noise. The effect of this noise at the receiver input on a typical user is determined by subjective testing. A five-point scale: excellent, good, fair, poor, bad, can be used to rate the quality. A grade 4 (good) is usually specified for a service. This minimum RF signal level at the receiver input is called the minimum usable sensitivity and is defined as the weakest RF input signal level required to provide a grade 4 quality of service in the presence of "noise." When interfering signals are present, there will be a degradation in the quality of service as observed by a user. The effect of interference on signal quality is also obtained by subjective testing. In some cases, a grade 3.5 is considered acceptable quality in the presence of "noise" and interference for short periods of time. The level of the desired signal relative to the level of the interfering signal at the receiver input is called the protection ratio. To conclude, the minimum usable receiver sensitivity gives the lowest or minimum level of the desired signal to give a grade 4 quality in the presence of noise, while the protection ratio gives the ~~maximum~~ minimum level of the desired signal, relative to the undesired signal, required to provide "acceptable" service quality. Frequency coordination is concerned with the determination of these two levels: desired signal and the interfering signal, at the receiver input.

?

yes for TV
no for LM

The signal level at any point in an electromagnetic field depends on the transmitted effective radiated power (product of transmitter power at the antenna input and the antenna gain in the direction of the receiver), the propagation or transmission path loss and the receiver antenna gain. In line-of-sight transmission paths, the propagation loss can be calculated quite easily. In the land mobile service and in the TV broadcast service, the receive antenna is usually well below the height of its surrounding structures; and the signal it receives is the result of multiple reflections, diffractions, and in some cases refractions of the transmitted wave. The Propagation loss cannot be determined analytically. Statistical mean values with fluctuations in value with time and location are used to describe this loss. These statistical mean values are obtained by extensive measurements on many different locations and environments. The main problem in the determination of signal levels in the land mobile and TV broadcast service is in finding the propagation loss between the transmit and receive antennas.

3.2 INTERFERENCE FACTORS

The effect of interference on a particular user system depends on the transmitter characteristics of the interfering system, the propagation loss and the receiver characteristics of the user system.

A transmitter radiates not only its authorized signal in its authorized bandwidth but also many spurious signals that fall outside the authorized bandwidth. The spurious signals consist of:

A. Out-of-band emissions which include the amplitude and phase noise on the unmodulated carrier, modulation components that spill over the authorized bandwidth, discrete amplitude and phase modulation components on the carrier, intermodulation products of the desired signal spectral components, etc. These affect user systems that utilize the adjacent channels. The transmit carrier frequency instability increases the interference into the adjacent channels.

B. Spurious emissions which includes harmonics of the signal frequency, intermodulation products, discrete AM and PM spurious modulation components, and other components which alter channels beyond those adjacent to the authorized channel.

The quality of a transmitter depends on how low the level of these unwanted signals are. Filtering is the main technique used to ameliorate the situation.

The propagation path loss affects the level of the interfering signals at the receiver input. This loss is increased by increasing the separation distance between the interfering transmitter and the desired receiver.

The receive antenna directivity and the receiver selectivity are the main receiver characteristics that affect the level of the interference signal at the receiver output. The receiver selectivity at the adjacent channels and beyond is required to be high. The receive antenna directivity discrimination may, in some services, e.g. television broadcast, be a factor in reducing the level of the received interfering signal. In some cases, the receiver acts as a source of interference to other receivers. In TV receivers, the local oscillator leakage from the receiver front end is transmitted via the receive antenna and effects other TV receivers in the vicinity.

All the foregoing factors have to be taken into account in frequency planning.

3.3 INTERFERENCE AND SERVICE CONTOURS

The F(50,50) value of field strength for a given grade of service is used to define the service area contour for TV. This ensures that 50% of the locations at the given contour will receive that field strength for 50% of the time.

This contour is also used to define the protected area in that the interference signal level at this contour must not exceed the value determined by the level of the desired signal less the protection ratio for more than 90% of the time. For interference, the F(50,10) curves for the interfering system must be used.

The F(50,50) curves of the desired system and the F(50,10) curves for the interfering system are used for frequency coordination purposes only. Administrations are free to provide much higher grades of service within that assigned coverage area.

4.0 CHARACTERISTICS OF THE LAND MOBILE SERVICE

4.1 GENERAL DESCRIPTION OF THE SERVICE

In land mobile services, two-way speech communications take place between a fixed base station and a large number of mobile stations that are continually moving in the service coverage area of that system. In most systems, the communications are between the base station and the mobile stations and vice versa. However, in some systems, communication between the mobile stations is also provided.

The fixed base station radiates at an effective power level as authorized by DOC and not exceeding 125 watts and uses a relatively high antenna (typically over one hundred feet). The effective radiated power (ERP) and the effective height of the antenna above the average terrain (EHAAT) used at the base station depends on the service area to be covered. The mobile stations radiate at relatively low power (maximum 25 watts but frequently less) using relatively low antennas (typically 1.5 to 3 metres).

The mobile stations are, in general, in continual motion within the coverage area of the base station so their electromagnetic environment is continually changing. The propagation loss in the transmission path between the two antennas (base station and mobile station), therefore, fluctuates considerably from instant to instant during each conversation. Moreover, the low mobile antenna height, relative to the surrounding buildings and structure, causes the propagation loss to be much more than would exist in the broadcast television service. The relative motion between the base and mobile stations' antennas causes the received signals to be "smeared" in frequency due to the Doppler effect. All these factors contribute to making the detection of the received signals in the land mobile service a complex and challenging design problem. The relatively low levels of the

received signals, especially at the base station, render this service particularly susceptible to degradation due to interference from other services, especially the broadcast television service which uses relatively high RF powers.

4.2 FREQUENCY PLAN OR SPECTRUM UTILIZATION

The land mobile service uses two modes of operation:

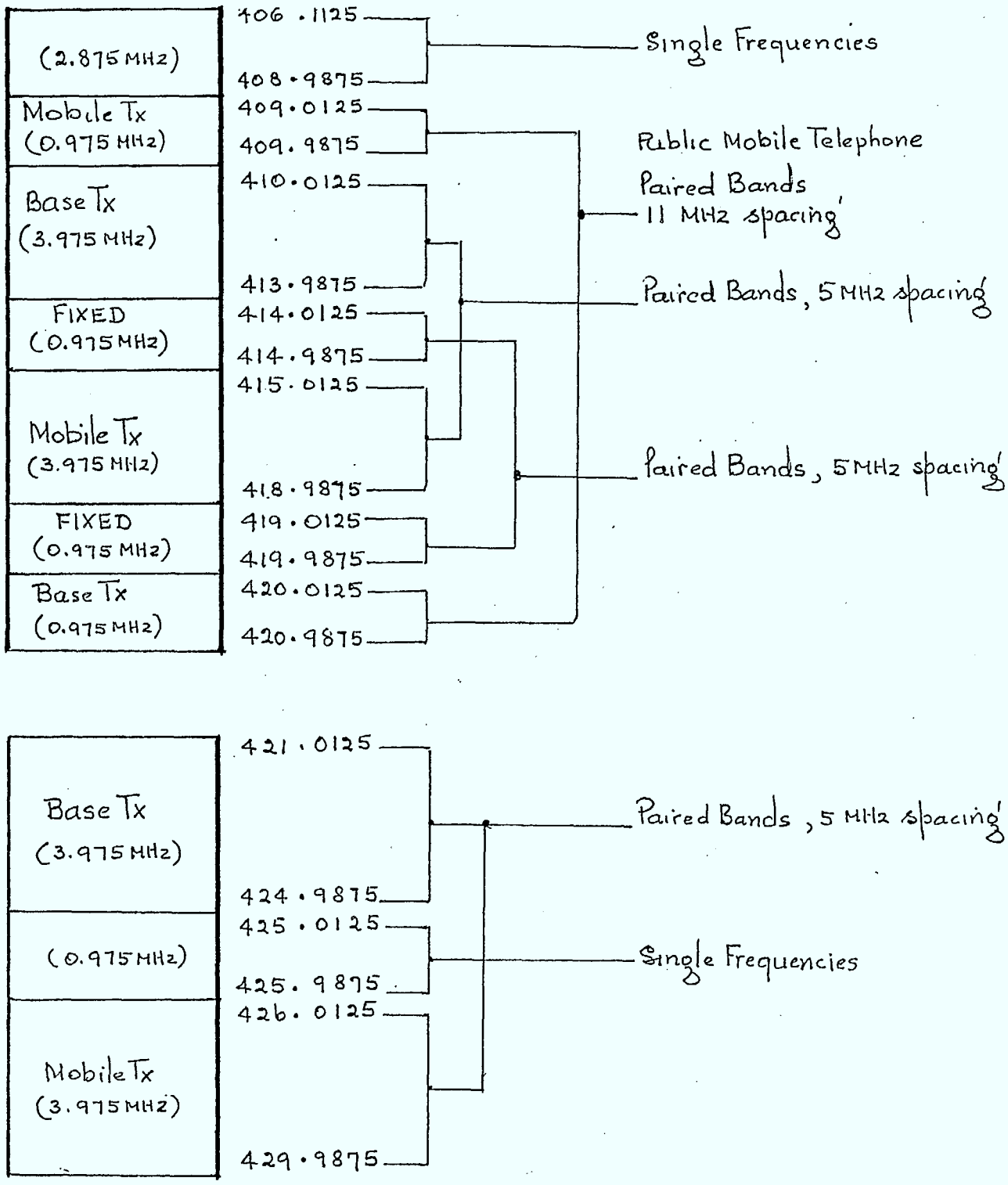
- single-frequency operation,
- two-frequency operation.

The single frequency mode of operation, in which both the base and mobile transmit on the same carrier frequency, is primarily used in the VHF band in systems wherein communications are between a base (dispatcher) and a mobile or between mobiles operating at short range. Although apparently attractive from a spectrum conservation point of view, there are a number of practical difficulties in achieving optimum frequency coordination with other users in the same geographic area. As a result, DOC has recently favoured the use of two-frequency operation. This has been particularly successfully applied to the opening of new frequency bands; e.g. 410-430 MHz and more recently the 806-890 MHz bands. Typical allocation of frequencies showing both single and two-channel operation is given in Tables 4.2a, b, and c. The principle advantage is that the higher power base station transmitters operate in a separate frequency range from the sensitive base station receiver. Hence, multiple transmitters and receivers may be co-sited on a non-interfering basis. This co-siting contributes greatly to the economic operation of base stations from the small number of suitable base station sites.

The two-frequency mode, in which base and mobile transmitters are assigned frequencies separated by 5 MHz (UHF), 45 MHz (806-890 MHz) or some lesser amount in the VHF bands, can be used for operation via a repeater. In this manner, mobile-to-mobile operation is possible over the same geographic area as mobile-to-base.

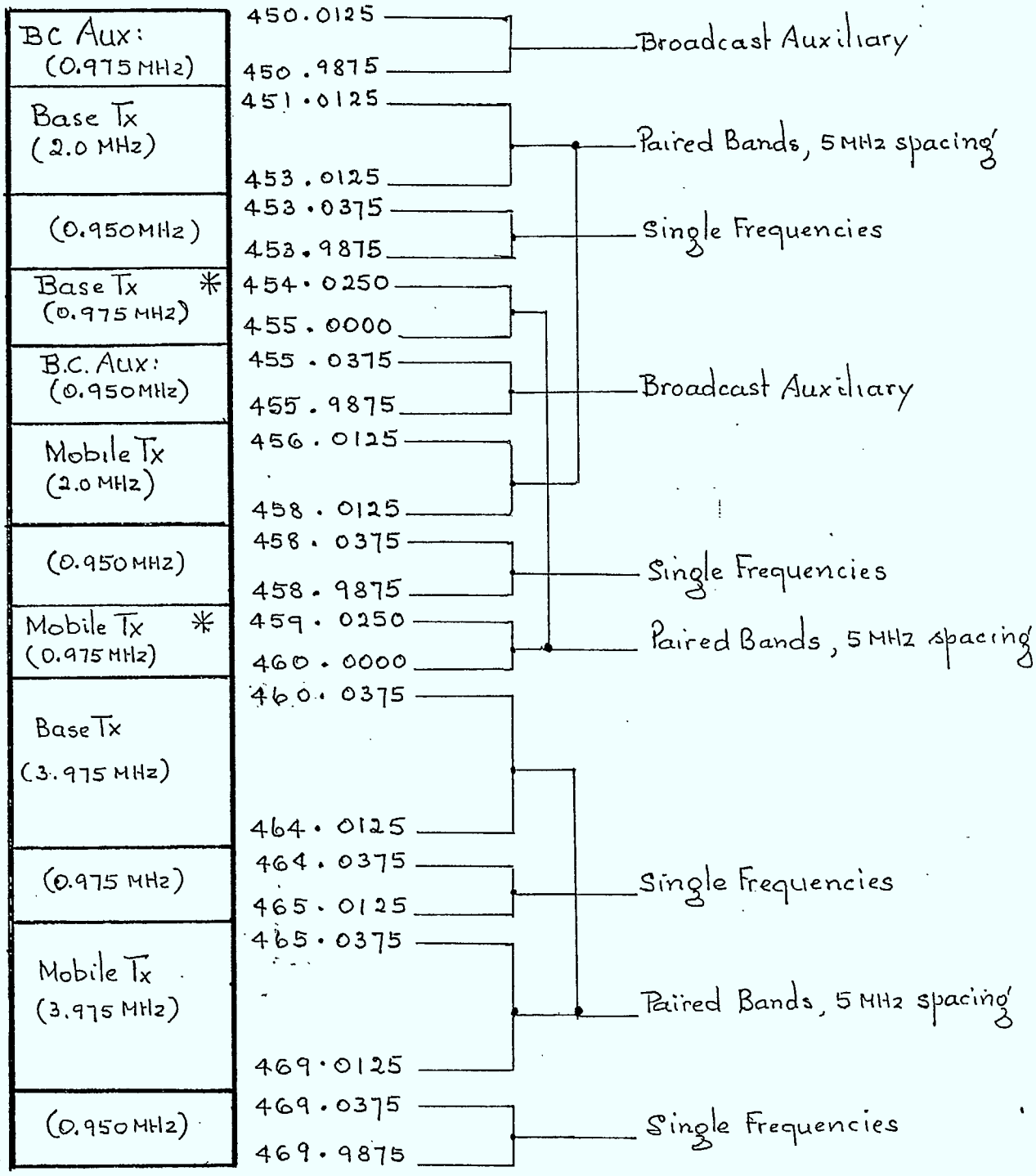
The frequency separation between two adjacent channels is normally 30 KHz, VHF and cellular and 25 KHz, UHF. Recently, some band splitting has been introduced so that channel separations of 15 KHz, VHF and 12.5 KHz, UHF may be found in heavily congested areas.

In all land mobile systems, vertically polarized transmission is used.



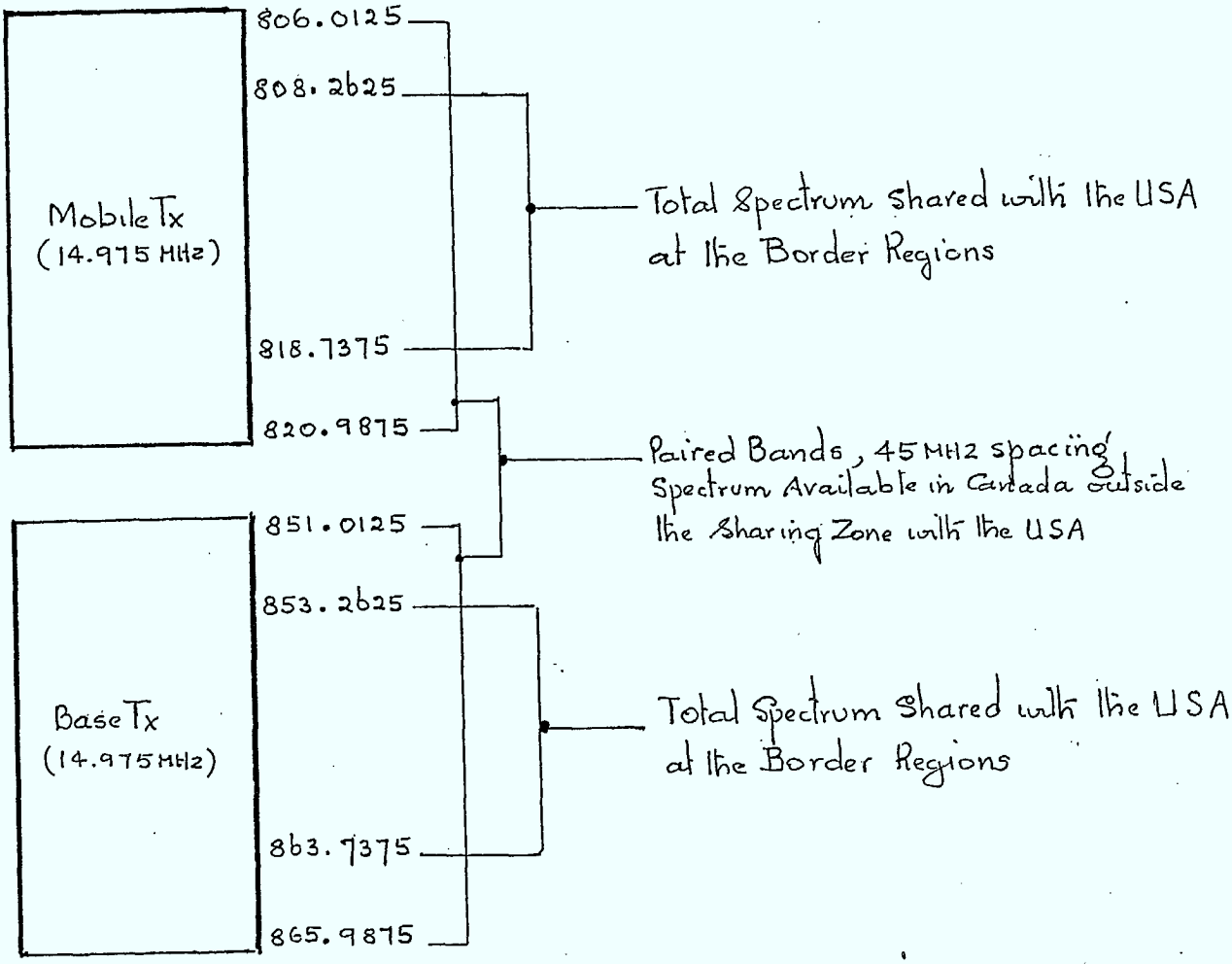
Note: 25 KHz spacing between channels

Figure 4.2a: Frequency Plan for Assignment of Frequencies to Land Mobile Systems in the 406.1 - 430 MHz Band



Notes:
1. 25 KHz spacing between channels,
2. All channels offset by 12.5 KHz from USA channels except those indicated by *.

Figure 4.2b: Frequency Plan for Assignment of Frequencies to Land Mobile Systems in the 450 - 470 MHz Band



Note: 25 KHz spacing between channels

Figure 4.2c: Frequency Plan for the Assignment of Frequencies to the Land Mobile Systems in the 806-821 MHz and 851 - 866 MHz Bands

4.3 CHARACTERISTICS OF THE TRANSMITTERS AND ANTENNAS

The design objective of the transmitter of a base station is to ensure that a specified field strength is maintained at all mobile stations in the design coverage area for that system. The grade of service is related to the electric field strength (in dB relative to 1 μV/m or dBμ) at the mobile station antenna. The electric field strength at a point in the coverage area depends on the effective radiated power (ERP) of the base and the mobile station. The base station antenna height affects both the propagation loss and the coverage. Therefore the most significant parameters of the transmitter are:

- Effective radiated power (ERP) which includes both the transmitter output power and the antenna power gain, and
- Effective height of the antenna above the average terrain height (EHAAT)

The transmitter, however, is also the generator of spurious emissions which interfere with signals from other services or systems. The following parameters are generally controlled by specifications to minimize the effects of this interference:

- Occupied bandwidth of the desired signal,
- Wideband noise floor,
- Harmonic rejection,
- Intermodulation characteristics of the power amplifier, and
- Transmit frequency stability and accuracy.

4.3.1 ERP and EHAAT

The ERP and EHAAT are selected to ensure that the required field strength is provided in a certain percentage (90 to 100) of all the locations within the desired coverage area (usually defined in terms of the radial distance from the base station) for a certain percentage of the time (typically 90%). It would also be desirable that the field strength decay rapidly outside this desired coverage area to minimize interference with other services. The minimum ERP and EHAAT, compatible with the grade of service and the coverage area, should be used.

4.3.2 Signal Bandwidth

For a top audio bandwidth frequency of 3 kHz and a peak frequency deviation of 5 kHz, the necessary bandwidth is 16 kHz.

It is desirable to ensure that the transmitted signal components outside this 16 kHz are at a minimum. This is achieved by:

- severely filtering all the frequency components of the speech signal above 3 kHz,

- ensuring that the frequency deviation does not exceed its specified value through the use of peak clipping,

- ensuring that residual modulation on the unmodulated carrier due to random noise modulation on the carrier, and spurious discrete amplitude and phase modulation components on the carrier are minimized.

4.3.3 Transmit Frequency Tolerance

Drift in the transmit carrier frequency will cause spectral components to fall into the adjacent channels causing degradation in those channels. This must be carefully controlled.

4.3.4 Intermodulation Products

The base station transmitter is frequently closed sited, or even co-sited, with other transmitters or receivers. The use of a common antenna or closely spaced antennas results in cross coupling of the transmitted signals to both the output stages of the transmitters and input stages of the receivers. In both cases, intermodulation products must be prevented from falling onto the desired receive frequencies. Usually, low order products can be prevented from causing interference by the appropriate selection of the frequency set. However, as the order of the intermodulation product increases, then for more than about three of four frequencies, selection of a non-interfering frequency set becomes unduly restrictive and some means of increasing the transmitter-to- transmitter and transmitter-to-receiver isolation becomes necessary.

The most usual technique is the use of high Q cavity filters. These not only reduce the level of cross coupling of the transmitter carrier signal but greatly reduce the transmission of wideband noise and transmitter harmonic and spurious emissions.

4.3.5 Out-of-Channel Spurious Emissions

The out-of-channel spectrum most serious are the adjacent channels that are spaced ±25 kHz from the transmit frequency channel. The sources of the signals that fall into these adjacent channels were given in Paragraph 4.3.2 and by intermodulation products. Filtering at radio frequency is generally not feasible because of the high Q that would be required by the filters.

Spurious emissions falling into the other nearby channels in the assigned band cannot, in general, be reduced by filtering either. The main contributors, intermodulation products and discrete and random spurious modulation components of the unmodulated carrier, must be reduced at their sources.

The spurious emission components falling more than about 1% from the assigned channel can be reduced by filtering, and this is the remedy usually employed on multichannel sites or if operational problems occur.

Since all the undesired emissions are related to the level of the transmitted carrier (especially the intermodulation products), it is advisable to use the lowest transmitter power and the highest base station antenna, consistent with the grade of service in the coverage area, to minimize the interference effects of out-of-channel spurious emissions on other systems and services.

4.3.6 Typical Transmitter Characteristics for the Land Mobile Service

Table 4.3-1 gives typical specifications for transmitters used in the land mobile service as per CCIR Recommendation H78-3.

Table 4.3-2 gives the characteristics of the transmitters for the land mobile service as recommended by DOC in RSS119.

4.4 CHARACTERISTICS OF THE RECEIVERS

The purpose of the receivers used in the land mobile service is to provide an acceptable grade of service of speech signals at the output when the input consists of:

- Weak desired signal (typically 0.7 µV into 50 ohms), widely fluctuating in amplitude with time due to Rayleigh fading;
- Receiver, cosmic and man-made noise, and distortion components falling in the channel bandwidth;
- Interference signals from other systems and services and from intermodulation products falling in the channel bandwidth causing co-channel interference;
- Interference signals falling in the adjacent channels, causing adjacent channel interference;
- Interference signals falling in the image frequency band;
- Interference signals falling in the spectrum outside the desired channel but excluding the adjacent and image channels and of significant magnitude to cause distortion in the receiver. The main component is usually the carrier of co-sited transmitters.

The rejection of the out-of-channel spurious components is achieved by filtering. A separate filter is usually required at the receiver input to minimize the impact of the co-sited transmitters. The ability to discriminate between the desired and unwanted signals is usually expressed as the selectivity of the receiver to the relevant signal.

PARAMETERS	VALUES	REMARKS
Frequency Tolerance		
• 35 MHz	±70 Hz or ±20 ppm	
• 80 MHz	±160 Hz or ±20 ppm	
• 160 MHz	±1600 Hz or ±10 ppm	
• 300 MHz	±2100 Hz or ±7 ppm	
• 450 MHz	±2250 Hz or ±5 ppm	
• 900 MHz	±2700 Hz or ±3 ppm	
Adjacent Channel Rejection		
• 25 – 500 MHz	> 70 dB	Relative to In-channel Insertion Loss
• 500 – 1000 MHz	> 65 dB	
Coupled Discrete Frequency Spurious Emission		
• Tx Power < 25 W	< 2.5 μW	
• Tx Power > 25 W	-70 dBc	Relative to In-channel Unmodulated Carrier
Inter-channel Spacing	25 KHz.	20 kHz and 30 kHz also possible
Channel Bandwidth necessary	16 KHz	

Table 4.3-1: Land Mobile Service Transmitter Characteristics (CCIR) Recommendation 478-3)

PARAMETERS	VALUES
Transmit Frequency Stability	
• 27.41 – 50 MHZ	± 545 Hz to ± 1000 Hz (linear interpolation)
• 138 – 174 MHz	
• 406.1 – 430 MHz	± 1740 Hz
• 450 – 470 MHz	± 2350 Hz
• 806 – 821 MHz	± 2350 Hz
• 851 – 866 MHz	± 2.5 ppm
Out-of-Band Emissions	
27.41 – 174 MHz	F_0 to $F_0 \pm 5$ kHz 0 dB
	$F_0 \pm 10$ kHz −25 dB to −28 dB
	$F_0 \pm 25$ kHz −50 dB
	Beyond $F_0 \pm 25$ kHz −50 dB
406.1 – 866 MHz	F_0 to $F_0 \pm 10$ kHz 0 dB
	$F_0 \pm 10$ kHz −25 dB
	$F_0 \pm 21$ kHz and beyond −62.5 dB
Spurious Emissions	Less than 25 μW (includes all emissions outside $F_0 \pm 25$ kHz)

Table 4.3-2: Land Mobile Service Transmitter Characteristics
(DOC, RSS, Issue 3)

4.4.1 Sensitivity to In-channel Noise

The sensitivity of the receiver is defined as the level of weakest input signal, in the absence of any external source of noise, that

produces an acceptable grade of service for the speech signal at the receiver output.

In the real-life case, "noise" is always present at the receiver input in the desired channel. The "noise" contributors are receiver thermal, atmospheric, man-made and in-channel distortion. This "noise" is present even in the absence of all other emissions. In the presence of this "noise," the sensitivity is expressed as the input signal level (generally expressed in X μV into 50 ohms impedance) required to provide a specified signal-to-noise ratio at the receiver output. The signal-to-noise ratio is actually:

$$\left(\frac{S + N + D}{N + D}\right) \text{ or SINAD}$$

where N = thermal + cosmic + man-made noise
D = in-channel distortion

A SINAD ratio of 20 dB is taken as the lower limit for acceptability.

12dB SINAD or 20dB quieting

4.4.2 Susceptibility to Interference

The susceptibility of the receiver to interference from the out-of-channel spurious emissions, and co-channel emissions, is sometimes referred to as its protection ratio. The radio frequency protection ratio is the value of the radio frequency wanted-to-interfering signal ratio or (C/I) at the receiver input to achieve a subjectively defined reception quality. The measurement is usually made by injecting signals at the frequency of interest into the receiver input and adjusting its level till the specified amount of degradation is noticed in the output signal. The protection ratio for that receiver is the ratio of the desired carrier level to the level of the interfering, unwanted carrier at the receiver input.

Interference emission that falls in the receiver passband of the RF channel of the desired signal is called co-channel interference. The co-channel protection ratio is the ratio of the desired-to-undesired signals that produces a specified reception quality at the receiver output. Unlike the out-of-channel interference, co-channel interference cannot be reduced by filtering. The effect of co-channel interference, for a given modulation can be minimized by increasing the protection ratio; i.e. by ensuring that the level of the interfering signal at the receiver input is low and by offsetting the frequency of the interferer from the desired carrier by half, a channel bandwidth.

Another source of interference that cannot be filtered out is the intermodulation products generated in the receiver input low noise amplifier and/or mixer. The levels of the intermodulation products generated in the receiver can be reduced by ensuring that the receiver is operated in the linear region of its power transfer characteristic.

4.4.3 Typical Receiver Characteristics for the Land Mobile Service

Table 4.4-1 gives the characteristics of the receivers used in the land mobile service as per CCIR Rec 478-3, while Table 4.4-2 gives the corresponding values for the receivers as recommended by DOC in RSS119.

4.5 CHARACTERISTICS OF THE PROPAGATION PATH

The propagation path characteristics between the base station and a mobile station antenna of a land mobile system differs considerably from that of a line-of-sight path in that the signal received by a mobile antenna is not the sum of a relative strong direct and relative weak reflected wave. The signal received by a mobile antenna consists of a predominant wave and the sum of many reflected and diffracted waves, all of approximately the same level. Moreover, since a mobile station is continually on the move, the propagation path, with its characteristic reflecting and diffracting obstacles, is continually changing even at a fixed distance from the transmitter. For this reason, an analytical expression for the propagation loss is not possible so it is described in statistical terms.

Several administrations have produced prediction curves to determine the loss for a given distance from the transmitter. These predictions are the average of a large number of measurements made by different investigators in different parts of the world. These prediction curves are generally used in frequency planning.

The propagation loss is such a significant parameter in frequency coordination that a detailed description of all the factors concerned was provided in Appendix I.

The prediction curves provided by CCIR are given in Section 4.5.1.

4.5.1 Field Strength Prediction Standard Curves

4.5.1.1 Definition of Coverage Area

The main design objective of a land mobile system is to provide an "acceptable" grade of service over a specified coverage area. For planning purposes, the "acceptable" grade of service is expressed as the electric field strength. The field strength at a fixed radial distance from a base station varies with a log-normal distribution with a standard deviation given by σ_2. The grade of service in the coverage area is expressed as that minimum field

strength which is received by at least X% of the locations for at least Y% of the time; the contour around the base station at which this condition holds then describes the coverage area. Most administrations, for interference purposes, define the coverage area or that area bounded by a contour at which the specified field strength is exceeded for at least 50% of the locations and for at least 50% of the time. This is denoted by F(L,T) where F is the minimum field strength, L the percentage of locations and T the percentage of time; i.e. in our case, $F_d(50,50)$. If the environment around the base of station is uniform in all radial directions, then the coverage area consists of finding that radial distance, R, from the base station at which Fd(50,50) exists. (The suffix d is used to indicate the field strength of the radiation from the desired base station.)

The determination of $F_d(50,50)$ depends on the values of the parameters that affect the median field strength. The data presented were obtained from a variety of sources with considerable spread in the data. For frequency planning purposes, it is desirable that a standard set of curves be used. Most administrations issue their own standard set of curves; but in this study, the CCIR procedure to compute $F_d(50,50)$ for the land mobile service will be explained.

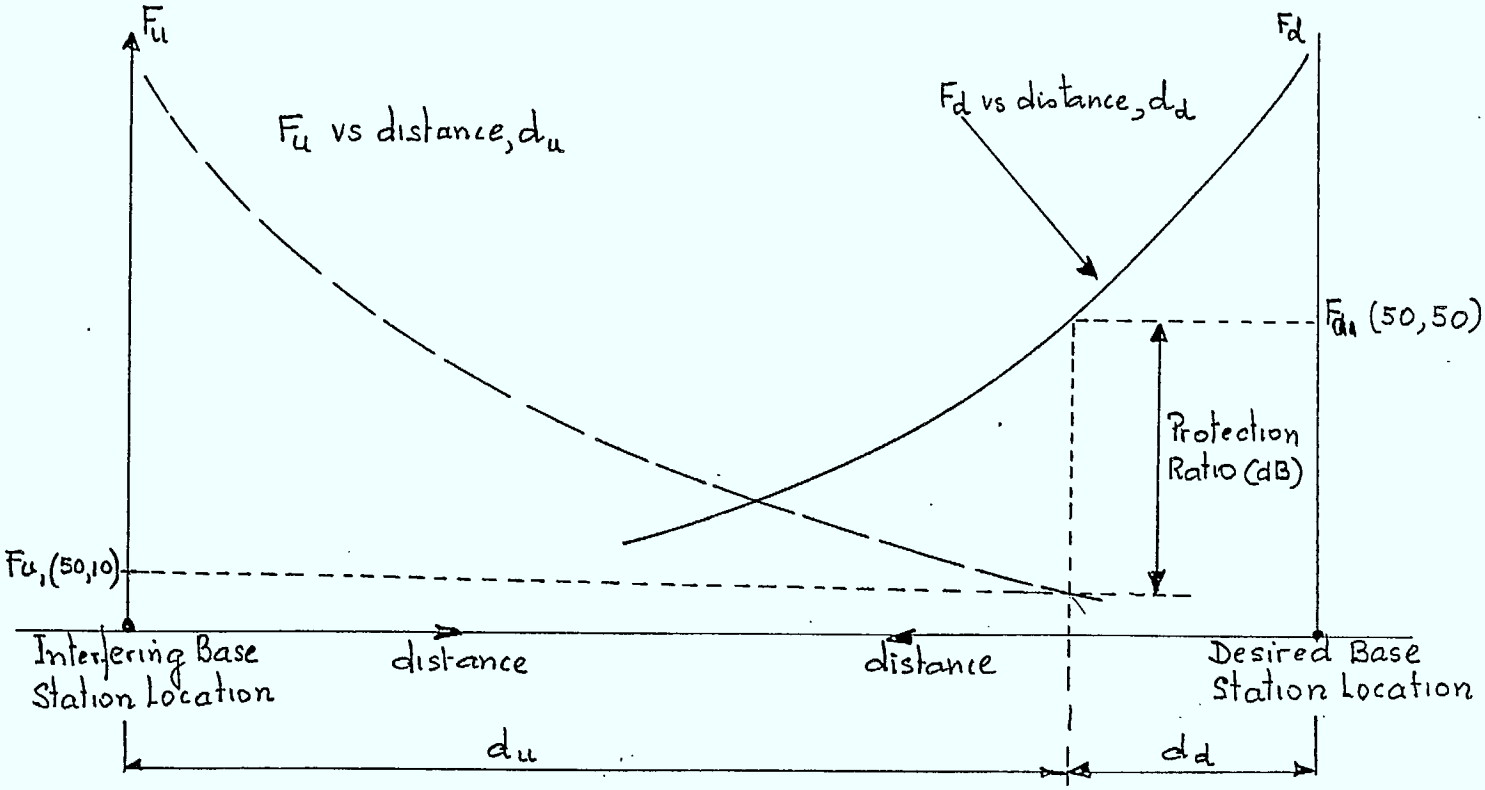
For protection from interference, it is generally required that the field strength from the interfering base station be at a certain level below that of the desired field strength at its $F_d(50,50)$ contour for at least 90% of the time; i.e. we have to determine the $F_u(50,10)$ contour for the interfering base station and ensure that it falls on the $F_d(50,50)$ contour. This is explained in Figure (4.5-1).

PARAMETER	VALUES
Receiver Sensitivity	< 2.0 μV in 50 ohms for a reference SNR output of 20 dB
Adjacent channel Selectivity	> 70 dB rejection
RF Intermodulation	< −70 dB relative to desired carrier
Spurious Responses	> 70 dB rejection for channels beyond the adjacent channels
Conducted Spurious Emissions at Receiver Antenna Input	< 2.0 nW
Separation of Rx Band from the Tx Band	
• 35 MHz	4 MHz
• 80 MHz	3 MHz
• 160 MHz	3 MHz
• 300 MHz	4 MHz
• 450 MHz	5 MHz
• 900 MHz	45 MHz

Table 4.4-1: Land Mobile Service Receiver Characteristics
(CCIR Recommendation 478-3)

PARAMETERS	VALUES
Receiver Sensitivity	< 0.75 μV in 50 ohms (1.0 μV if diplexer used) to give a reference ~~SNR of 20 dB~~ SINAD of 12 dB
Adjacent channel Selectivity	
27.41 MHz - 470 MHz	> 70 dB
806 MHz - 866 MHz	> 65 dB
Intermodulation Spurious Response	
27.41 MHz - 470 MHz	-60 dB relative to desired carriers
806 MHz - 866 MHz	-55 dB relative to desired carriers
Antenna Conducted Spurious Emissions	
27.41 MHz - 470 MHz	< 2000 pW (< 316 μV in 50 ohms)
806 MHz - 866 MHz	< 20 nW (< 1000 μV across 50 ohms)
Spurious Responses	
27.41 MHz - 470 MHz	> 70 dB rejection } all channels beyond the adjacent channels
806 MHz - 866 MHz	> 60 dB rejection } all channels beyond the adjacent channels

Table 4.4-2: Land Mobile Service Receiver Characteristics
(DOC, RSS 119, Issue 3)



$d = d_u + d_d$

d = minimum separation required between the two base stations to ensure that the grade of service $[F_{ui}\ 50,50)]$ is maintained at the outermost contour, denoted by d_d, for 90% of the time in the presence of interference from an undesired base station.

Procedure:

a) From the desired base station propagation characteristics, determine d_d for a specified grade of service, $F_{ui}50,50)$.

b) Determine $F_{ui}(50,10)$ from the desired protection ratio at d_d.

c) From the undesired base stations propagation characteristics, determine d_u given $F_{ui}(50,10)$.

d) Then the minimum separation required between the two base stations is $d = d_d + d_u$.

Figure 4.5 - 1: Illustrating How the Coverage Areas (Radial Distance from the Base Station) are Computed in the Presence of Interference from the Base Station of Another System

4.5.1.2 CCIR Procedure for Frequency Planning in the Land Mobile Service

The CCIR procedure for frequency planning in the land mobile service is contained in the following documents:

- Recommendation 370-4
- Recommendation 529
- Report 239-5
- Report 567-2

The above documents provide most of the information required to predict F(L,T) as a function of distance, d, from the base station for a given set of the following parameters:

- base station antenna height, h_b
- mobile station antenna height, h_m
- base station effective radiated power from a half-wave dipole, ERP
- environmental type: urban, suburban or rural

Correction factors are also provided for:

- terrain irregularities, $\Delta h(m)$
- terrain clearance angle
- composite land-sea paths

Alternatively, if F(L,T) is given, then the distance, d, from the base station can be determined, and from it, the service coverage contour that will provide a grade of service defined by F(L,T)

4.5.1.2.1 Prediction Curves for VHF (30-250 MHz)

A. The following information is required in order to use the prediction curves:

a) Base station antenna height, h_b. What is required in the effective height of the base station antenna above the average height of the surrounding terrain (EHAAT) from 3 to 15 km away from the base station. This is obtained by measuring the average terrain height along eight radial lines from the base station, equally spaced by 45°, and then obtaining the average of those eight means.

b) Effective radiated power (ERP) which is the product of the transmitter r.f. power at the antenna input and the transmit antenna power gain (relative to the gain of a half-wave dipole antenna) in the direction of the mobile station. The prediction curves are based on an ERP of 1 KW so the field strength obtained from the curves will require a correction of the actual ERP is not 1 KW.

c) Effective height of the mobile station antenna h_m which is the height of the mobile unit's antenna above the local

terrain. The prediction curves are based on a height of 3 m and 1.5 m.

d) Frequency of operation. The prediction curves are valid for any frequency in the range from 80-250 MHz.

e) Field strength to be met at the required contour. The may be expressed as F(50,50) or, interference, F(50,10). The standard curves are based on 50% of the location and for 50, 10, 5 and 1% of the time. If other than 50% of the locations is required, a correction factor will be required.

f) Environmental type: urban, suburban, rural. The standard curves are based on rural areas.

g) Terrain irregularity, Δh(m). The standard curves are based on a relatively smooth terrain in which h = 50 m.

h) Terrain slope angle from the base station, $\Theta = 0$.

B. The standard prediction curves enable the distance, d(km), to be determined at which the field strength is F(50,50), F(50,10), F(50,5) or F(50,1). This value of the field strength is based on:

- ERP = 1 kw
- h_m = 1.5 m or 3 m
- Δh = 50 m
- environmental type: rural
- terrain slope angle $\Theta = 0$ degrees
- actual base station effective antenna height

The curves are given in Figures 4.5-2a, 4.5-2b, 4.5-2c and 4.5-2d.

C. Correction curves will be required when the assumed values in the standard curves differ from the actual values.

- The ERP correction is straight forward since the field strength will vary dB for dB as the actual ERP differs from the standard

- The correction factor for other percentages of the locations is given in Figure 4.5-3.

- The mobile station antenna height correction factor is given in Figure 4.5-4.

- The terrain irregularity correction factor is given in Figure 4.5-5.

- The terrain slope factor is given in Figure 4.5-7.

4.5.4.2.2 Prediction Curves for UHF (450 - 1000 MHz)

The standard prediction curves are given in Figure 4.5-8a for F(50,50), Figure 4.5-8b for F(50,10) and in Figure 4.5-8c for F(50,1).

The correction curves for other percentages of locations than 50% are given in Figure 4.5-9.

The correction curves for terrain irregularities other than Δh = 50 m are given in Figure 4.5-6.

The correction curves for the terrain slope angle are given in Figure 4.5-7.

4.6 QUALITY OF SERVICE IN THE LAND MOBILE SYSTEM

The quality of service is usually determined by subjective evaluation by a large population of listeners of the speech signal at the output of the receiver as various impairments are added to the system at radio frequencies. A five-point scale is used to denote the quality.

There is little or no data on the subjective measurements of speech quality in the land mobile service. Consequently, several administrations have submitted the results of measurements using an alternative concept of signal-to-interference protection ratio. This is based on electrical measurements, using appropriate test signals, of the degradation of the signal-to-noise ratio of the wanted test signal, when a co-channel (or other channel) interfering signal is superimposed on the latter. A degradation of the initial signal-to-noise ratio of 20 dB to a signal-to-noise plus interference ratio of 14 dB is sometimes taken as the criterion. This criterion is considered to correspond with the minimum acceptable grade of service.

CMR

In the tests, frequency deviations of 60-70% of the maximum specified frequency deviations are used on both the wanted and unwanted signals. From the results of the tests that were submitted to CCIR, slight differences in measurement conditions and in the characteristics of the receivers used accounted for a ±3 dB spread in the results. Based on these measurements, it was proposed in CCIR SGVIII, Report 358-4, that a RF protection ratio of 8 dB be used for co-channel interference between two land mobile systems using the 25-kHz spacing and 5 kHz peak frequency deviation. Figure 4.6-1 gives the audio signal-to-interference ratio versus RF signal-to-interference ratio with the ratio of the RF bandwidth to the audio bandwidth as the parameter. The $B/B_o = 5$ curve approximately applies to the 25 KHz spacing system. The figure supports the claims made in the proposal for an 8dB RF protection ratio in CCIR Report 358-4.

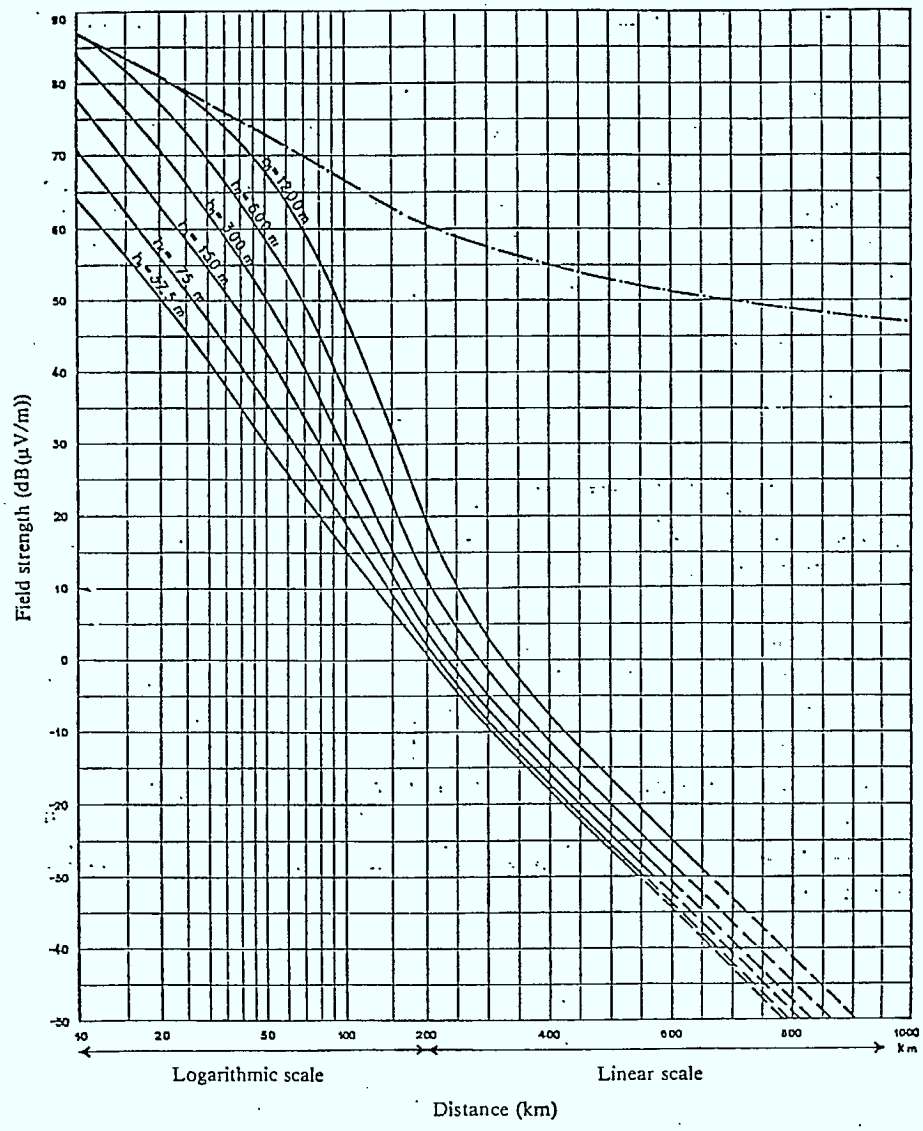


Figure 4.5-2a: F(50,50) vs Distance, d, as a Function of h_b

For: ERP = 1 kW from /2 dipole antenna
h_m = 10 m
Δh = 50 m
environmental type
frequency: 30-250 MHz

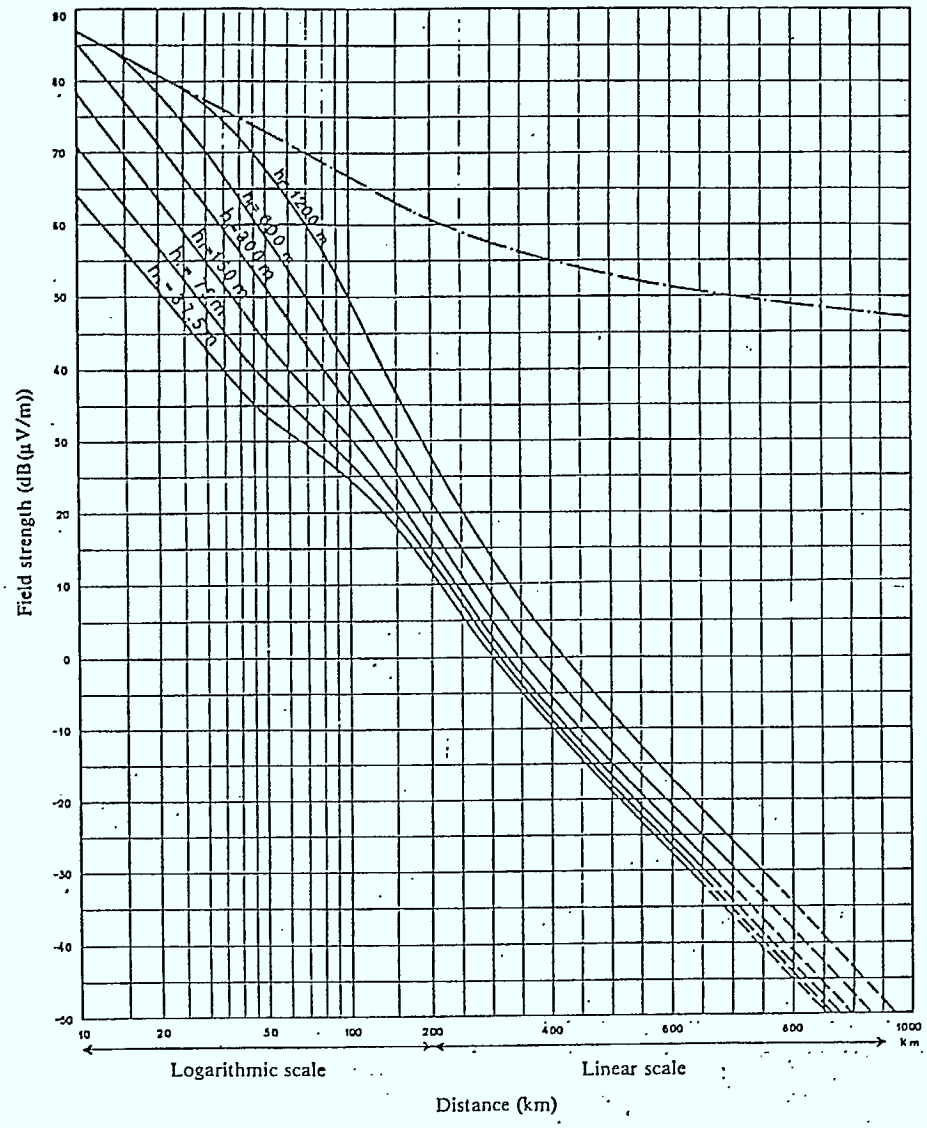


Figure 4.5-2b: F(50,10) vs Distance, d, as a Function of h_b

For: ERP = 1 kW from /2 dipole antenna
h_m = 10 m
Δh = 50 m
environmental type
frequency: 30-250 MHz

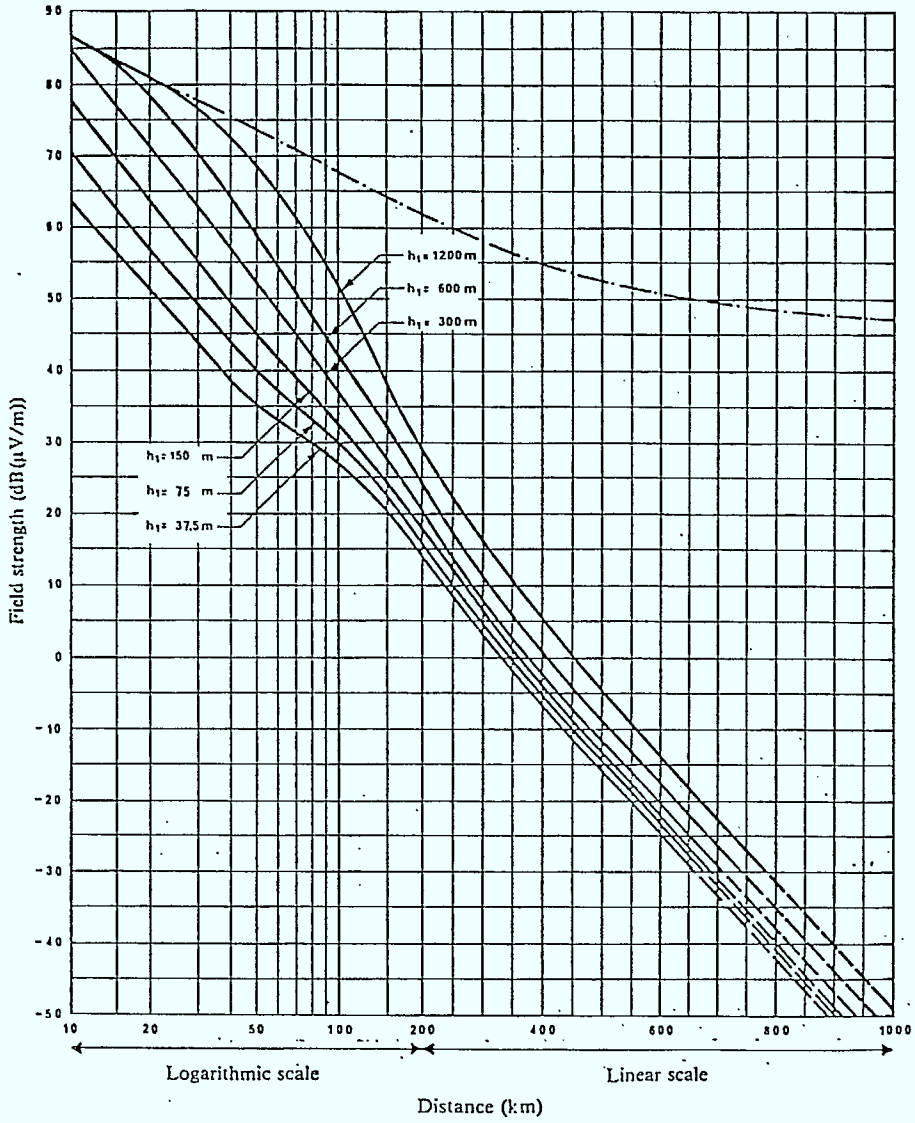


Figure 4.5-2c: F(50,5) vs Distance, d, as a Function of h_b

For: ERP = 1 kW from /2 dipole antenna
h_m = 10 m
Δh = 50 m
environmental type
frequency: 30-250 MHz

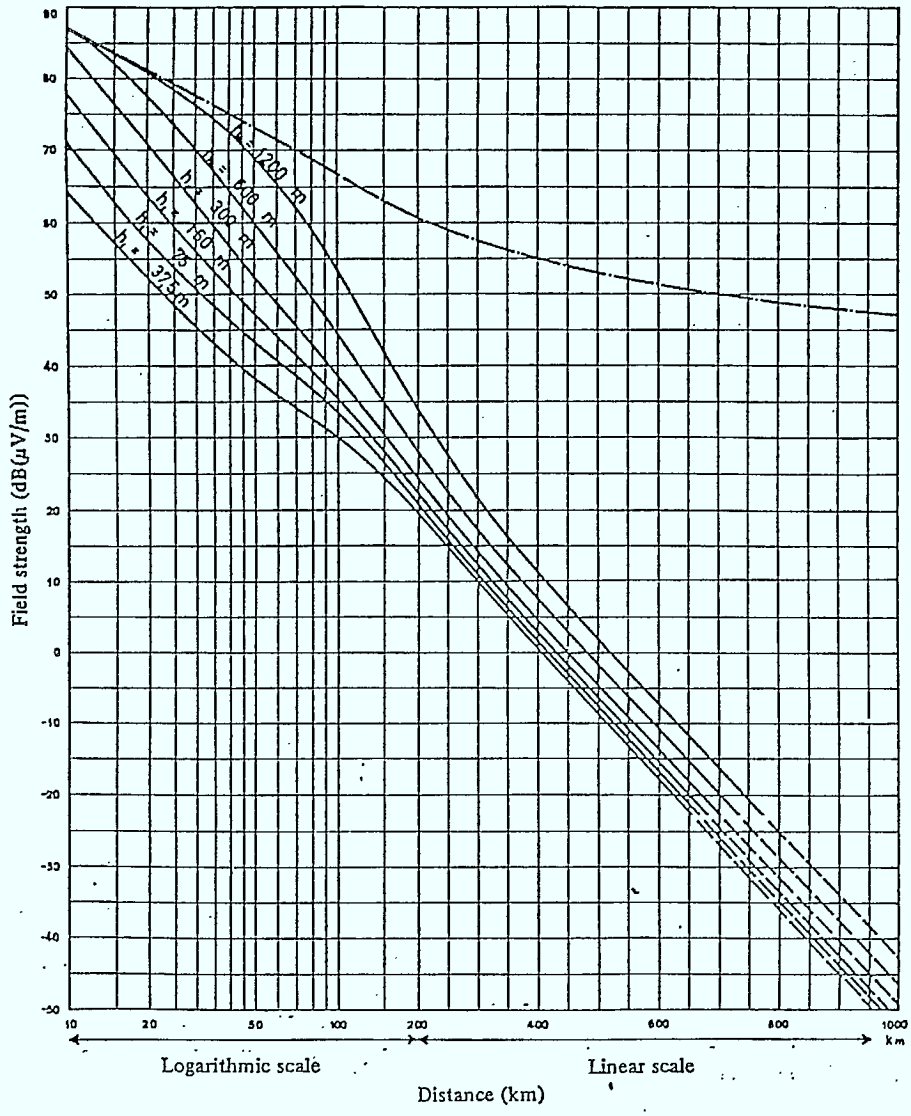


Figure 4.5-2d: F(50,1) vs Distance, d, as a Function of h_b

For: ERP = 1 kW from /2 dipole antenna
h_m = 10 m
Δh = 50 m
environmental type
frequency: 30-250 MHz

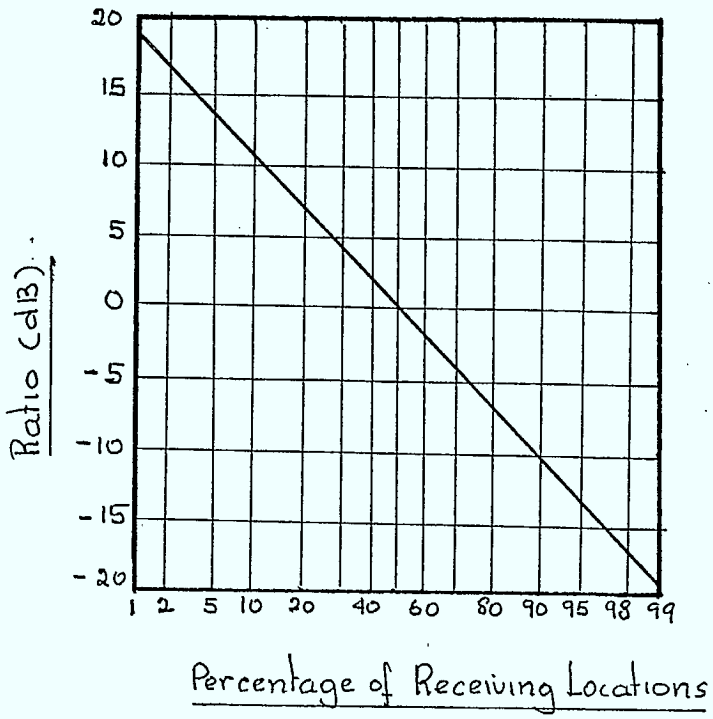


Figure 4.5-3 Ratio (dB) of the Field Strength for a Given Percentage of the Receiving Locations to the Field Strength for 50% of the Receiving Locations

(Frequency: 30 to 250 MHz)

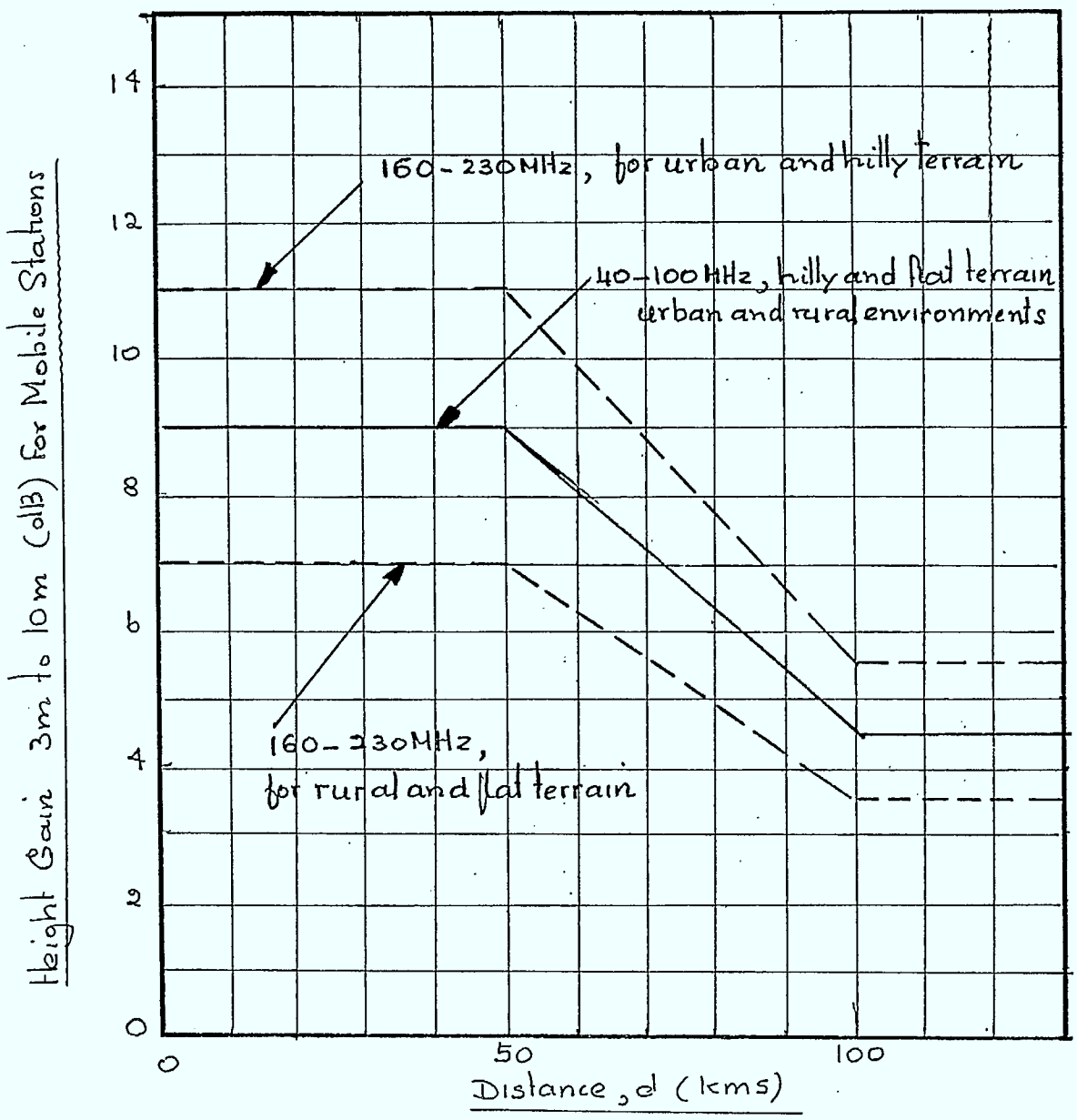


Figure 4.5-4: Height Gain Factor (dB) in Changing the Mobile Antenna Height from 3 m to 10 m

Note: To change from 3 m to 1.5 m for both frequency ranges and in all types of terrain and environments, the received field strength will decrease by 3 dB.

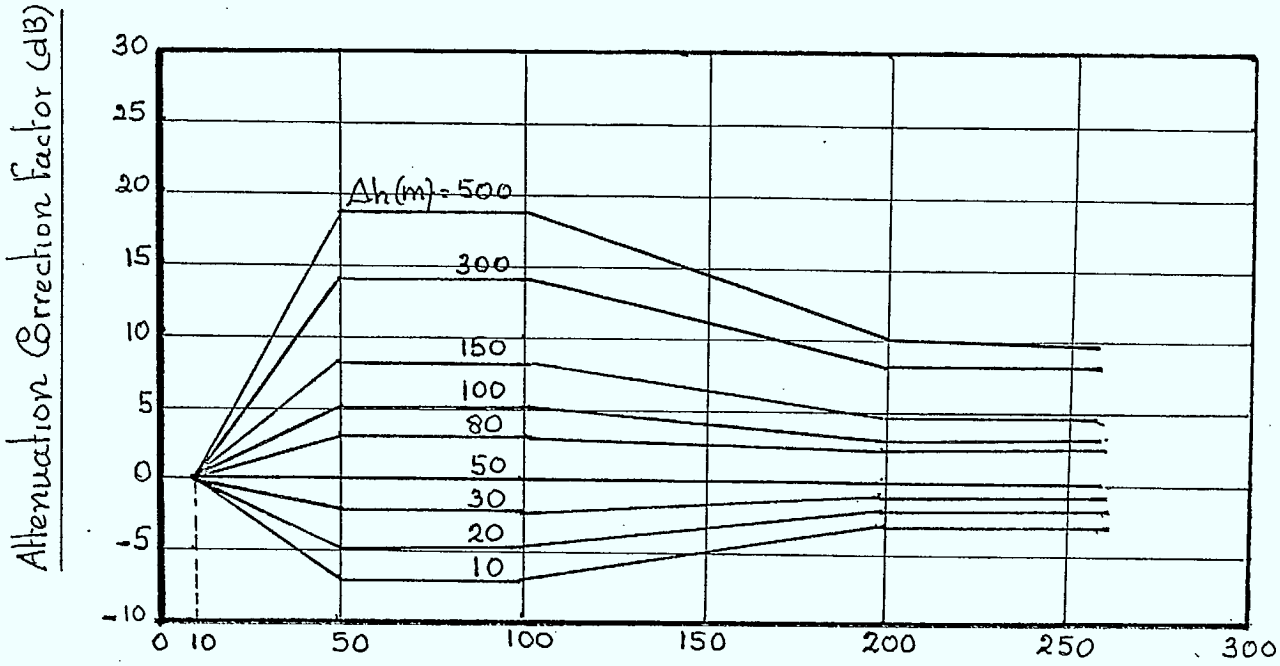


Figure 4.5-5: Attenuation Correction Factor as a Function of Δh (metres)

(Frequencies - 80-250 MHz)

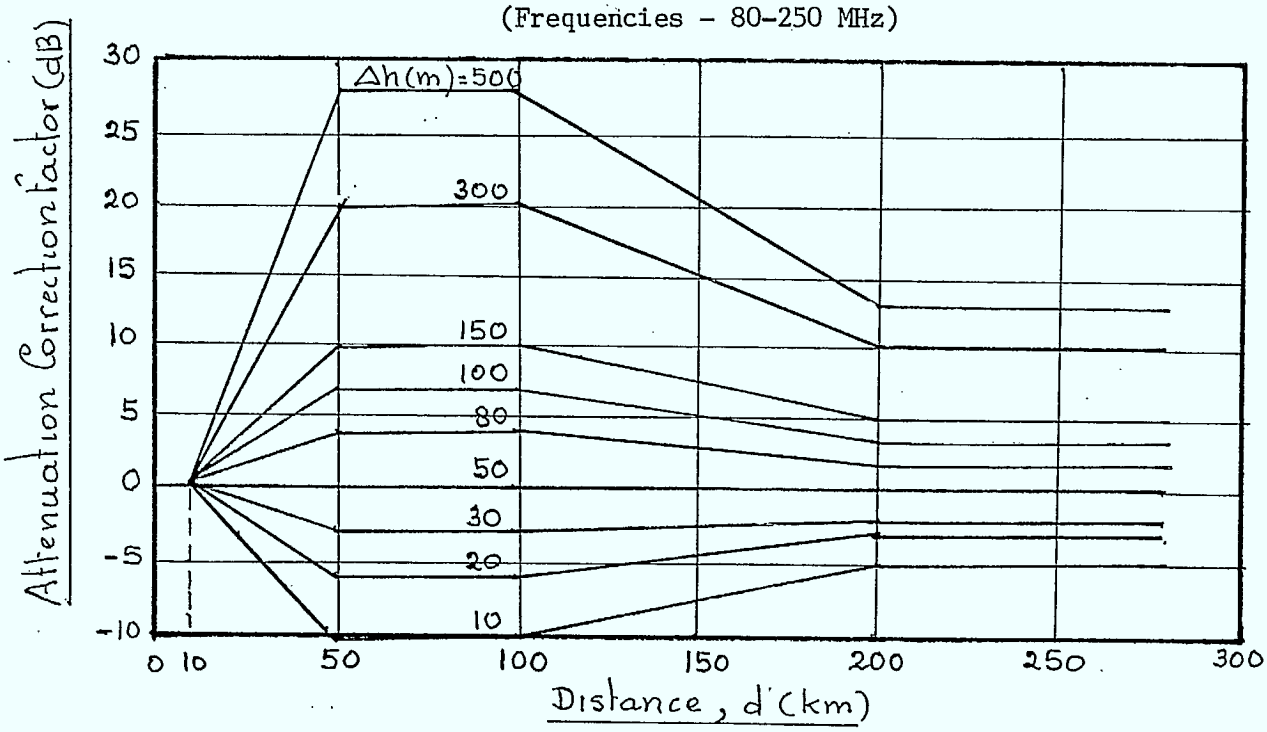


Figure 4.5-6: Attenuation Correction Factor as a Function of Δh (metres)

(Frequencies - 450-1000 MHz)

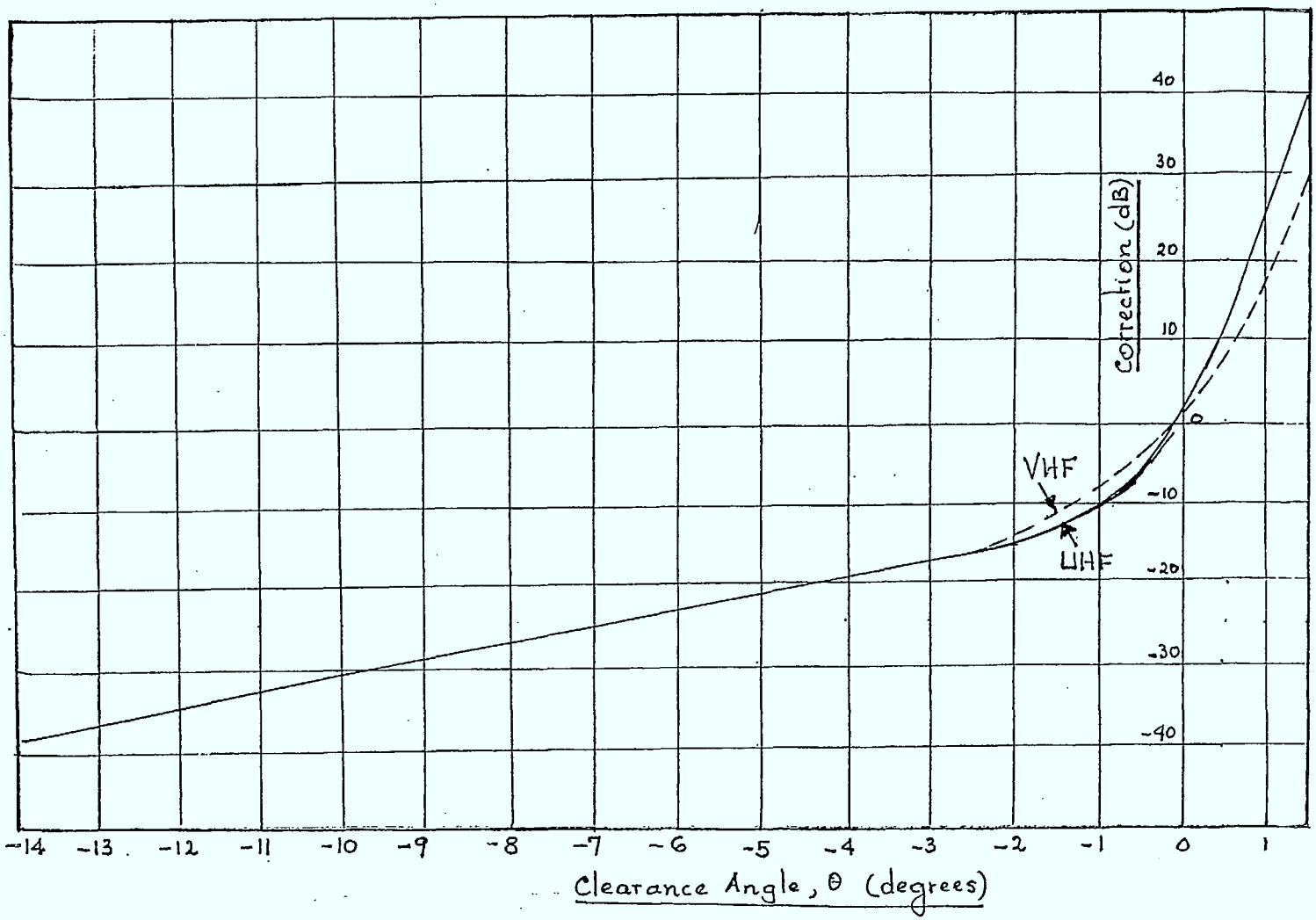
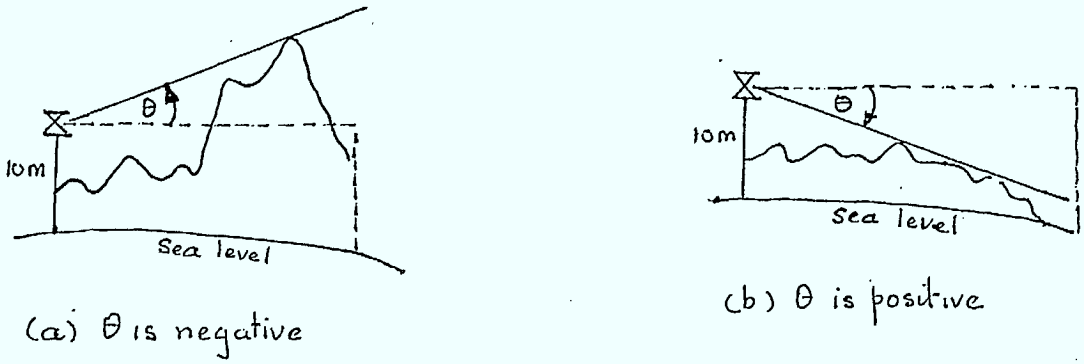


Figure 4.5-7: Receiving Terrain Clearance Angle Correction



(a) θ is negative

(b) θ is positive

Illustrating Receiving Terrain Clearance Angle and Sign

(From CCIR, Volume 5, Draft Report 239-4)

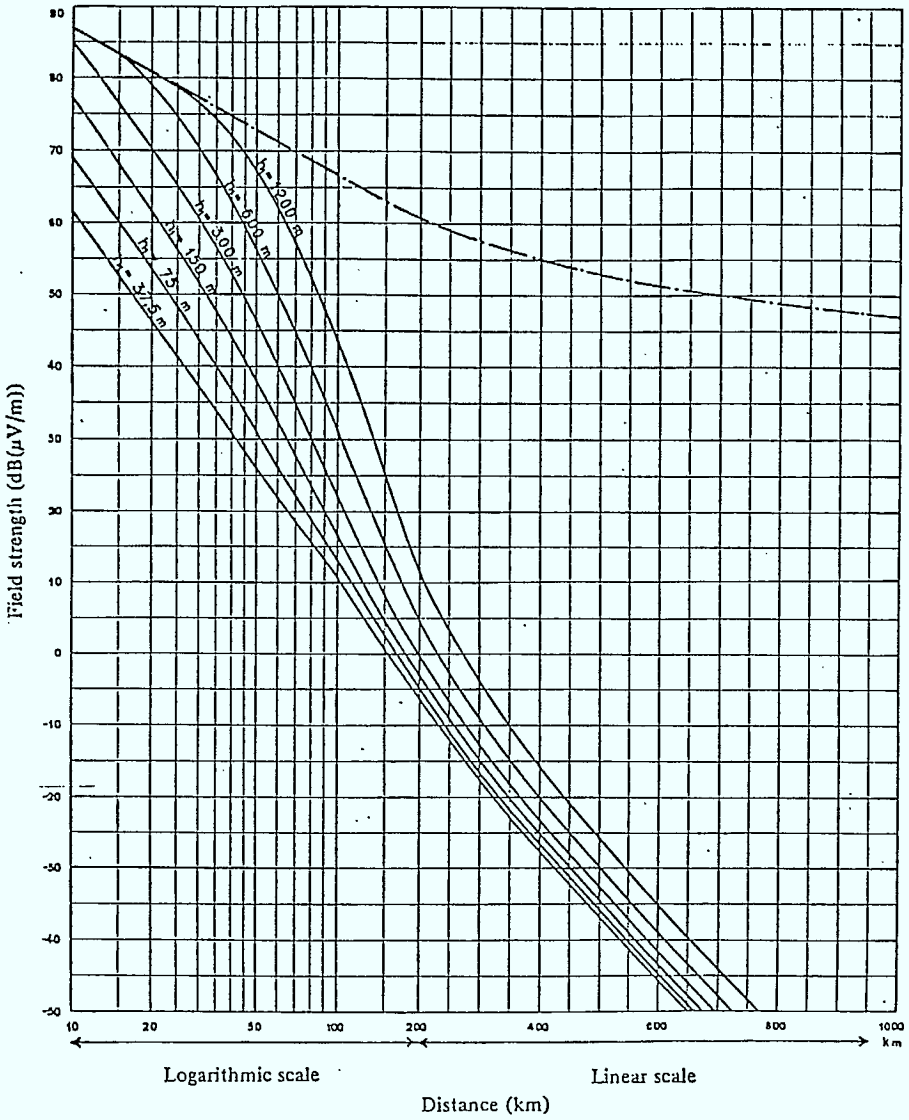


Figure 4.5-8a: F(50,50) vs Distance, d, as a Function of h_b

For: ERP = 1 kw from /2 dipole antenna
h_m = 10 m
Δh = 50 m
environment type: rural
frequency: 450–1000 MHz

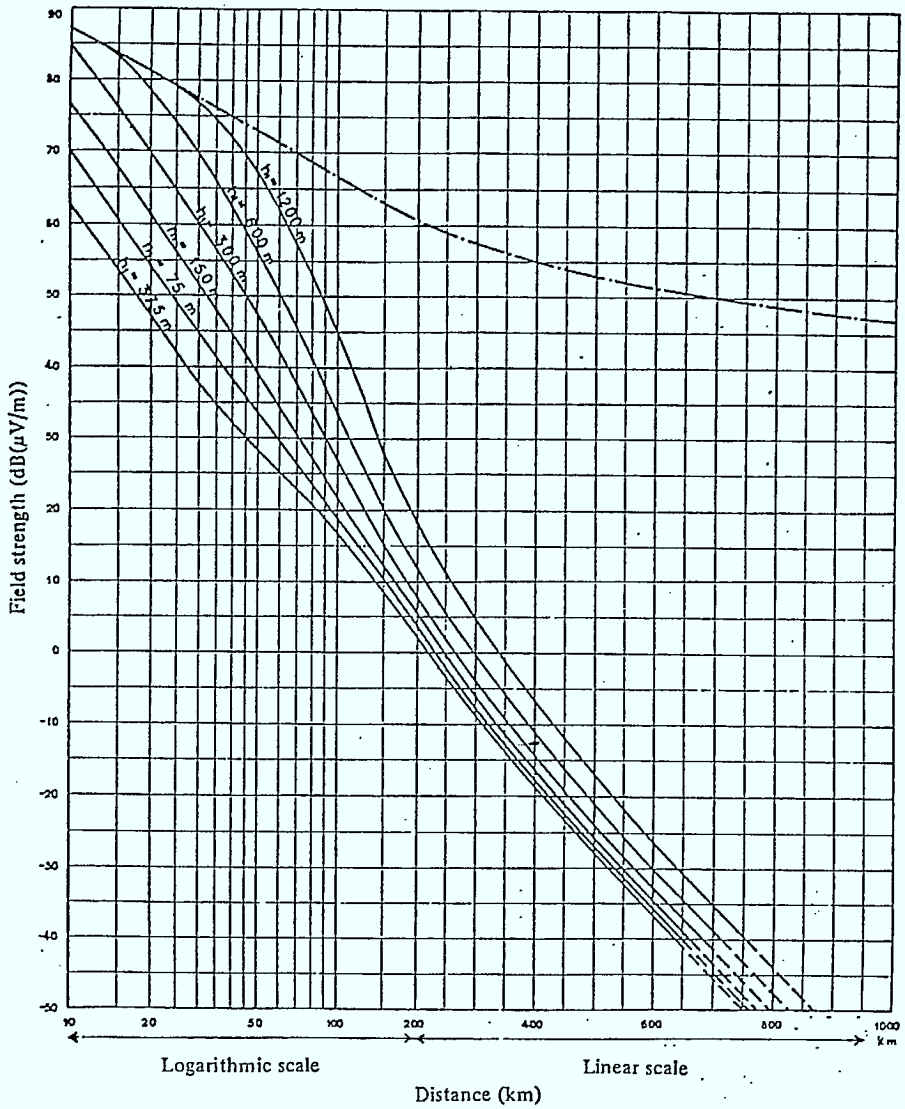


Figure 4.5-8b: F(50,10) vs Distance, d, as a Function of h_b

For: ERP = 1 kw from /2 dipole antenna
h_m = 10 m
Δh = 50 m
environment type: rural
frequency: 450-1000 MHz

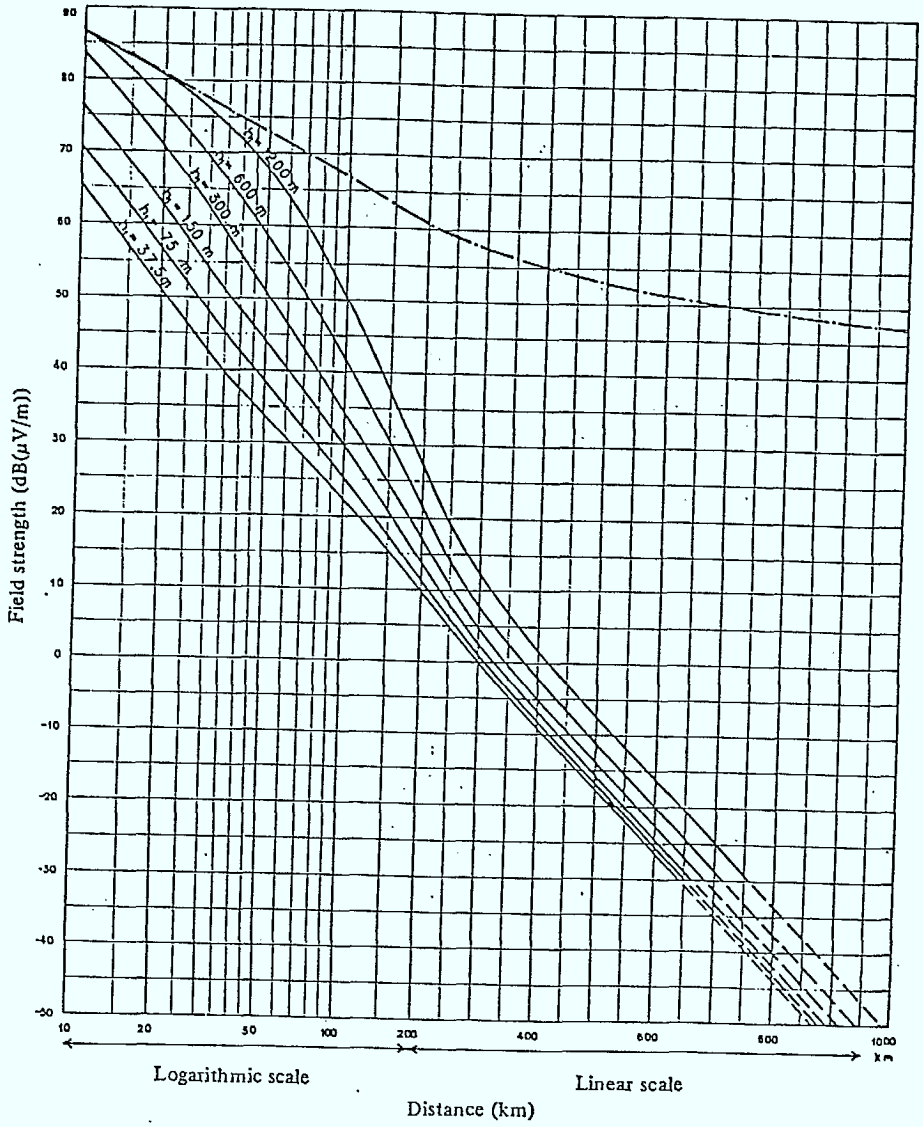


Figure 4.5-8c: F(50,1) vs Distance, d, as a Function of h_b

For: ERP = 1 kw from /2 dipole antenna
h_m = 10 m
Δh = 50 m
environment type: rural
frequency: 450-1000 MHz

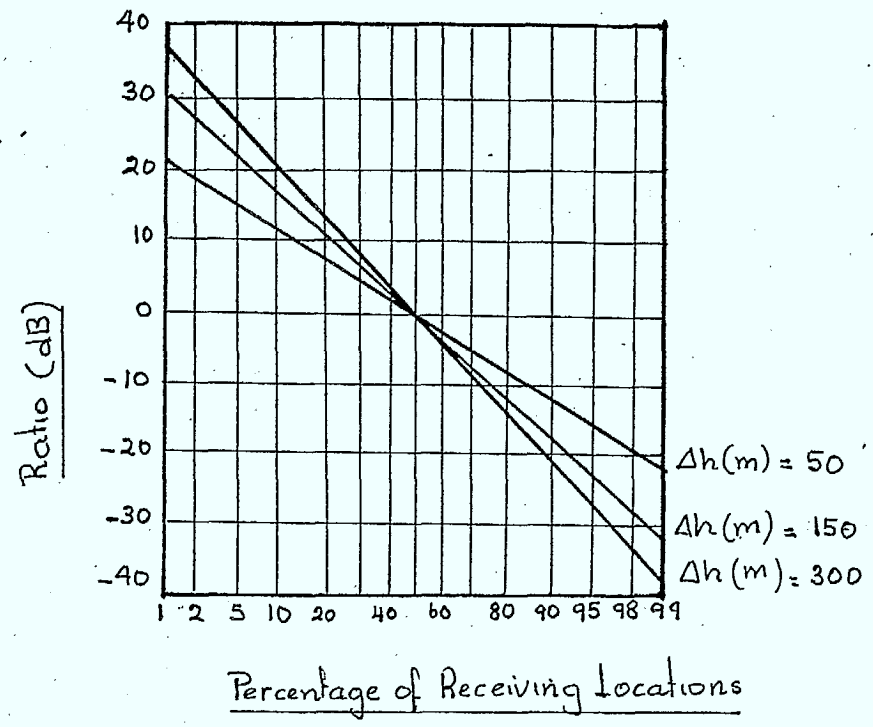


Figure 4.5-9: Ratio (dB) of the Field Strength for a Given Percentage of the Receiving Locations to the Field Strength for 50% of Receiving Locations

(Frequency: 450-1000 MHz)

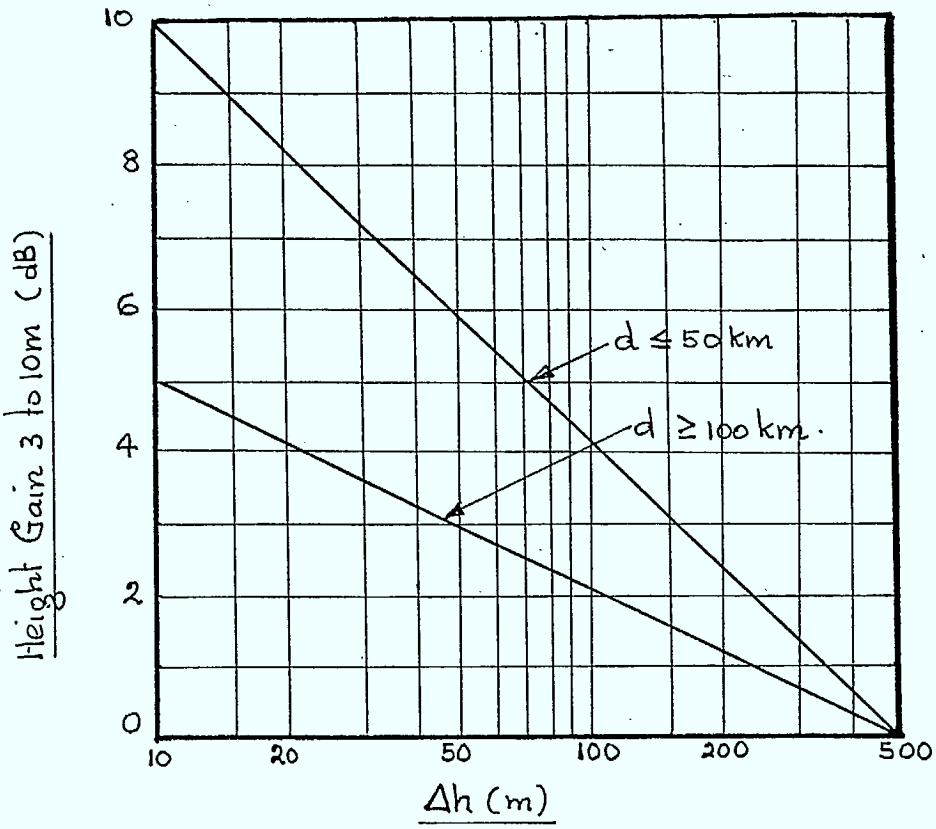


Figure 4.5-10: Height Gain Factor 3-10 m as Function of Δh(m) for Frequency 450-1000 MHz

(Parameter d represents distance from the transmitter)

- Rural Areas only

Note: For suburban areas, the median value may be taken as 7 dB and in urban areas as 14 dB for distances up to 50 km. In excess of 100 KHz, the values should be halved with linear interpolation for intermediate distances.

4.6.1 Minimum Values of Field Strength to be Protected

The main noise contributors at the input to a land mobile receiver are:

- receiver internal noise
- cosmic noise
- man-made noise generated largely by the ignition systems of motor vehicles and depends on the traffic density expressed in vehicles per km.
- multi-path noise generated when the vehicle or mobile station is in motion and has characteristics similar to man-made noise in that it is impulsive in nature. The noise amplitude distribution (NAD) is used to characterize noise which are impulsive in nature. The NAD gives the spectrum amplitude versus the number of impulses per second.

A convenient measure of the threshold performance for a narrowband receiver is a specified value of SINAD.

The conventionally accepted value (as per CCIR, SGVIII, Recommendation 331-3) is 12 dB. This defines the minimum usable field strength for a particular installation in the absence of man-made noise. The minimum usable and median field strengths (based on minimum usable input of 0.7 µV into 50 ohms in the absence of man-made noise) for typical hand portable stations is given in Figure 4.6-2.

Man-made noise is a significant source of degradation in signal quality. Figure 4.6-3 gives the noise amplitude distribution at a base station at 150 MHz and for three traffic densities.

Multi-path distortion is also a significant source of degradation in the land mobile system, which is absent when the mobile station is stationary.

The median field strength required for a given grade of service (4 or 3) by a mobile station under various situations is given in Figures 4.6-4 and 4.6-5. Conversion of degradation to field strength is expressed as:

$$\text{Field strength} = -41 + d + 20 \log f \ (\text{dB}\mu) \quad (4.6\text{-}1)$$

The median field strength required at a base station for grades of service 4 and 3 under various conditions are given in Figures 4.6-6 and 4.6-7 respectively. The same expression as in Equation 4.6-1 is used to obtain the field strength from the degradation and frequency.

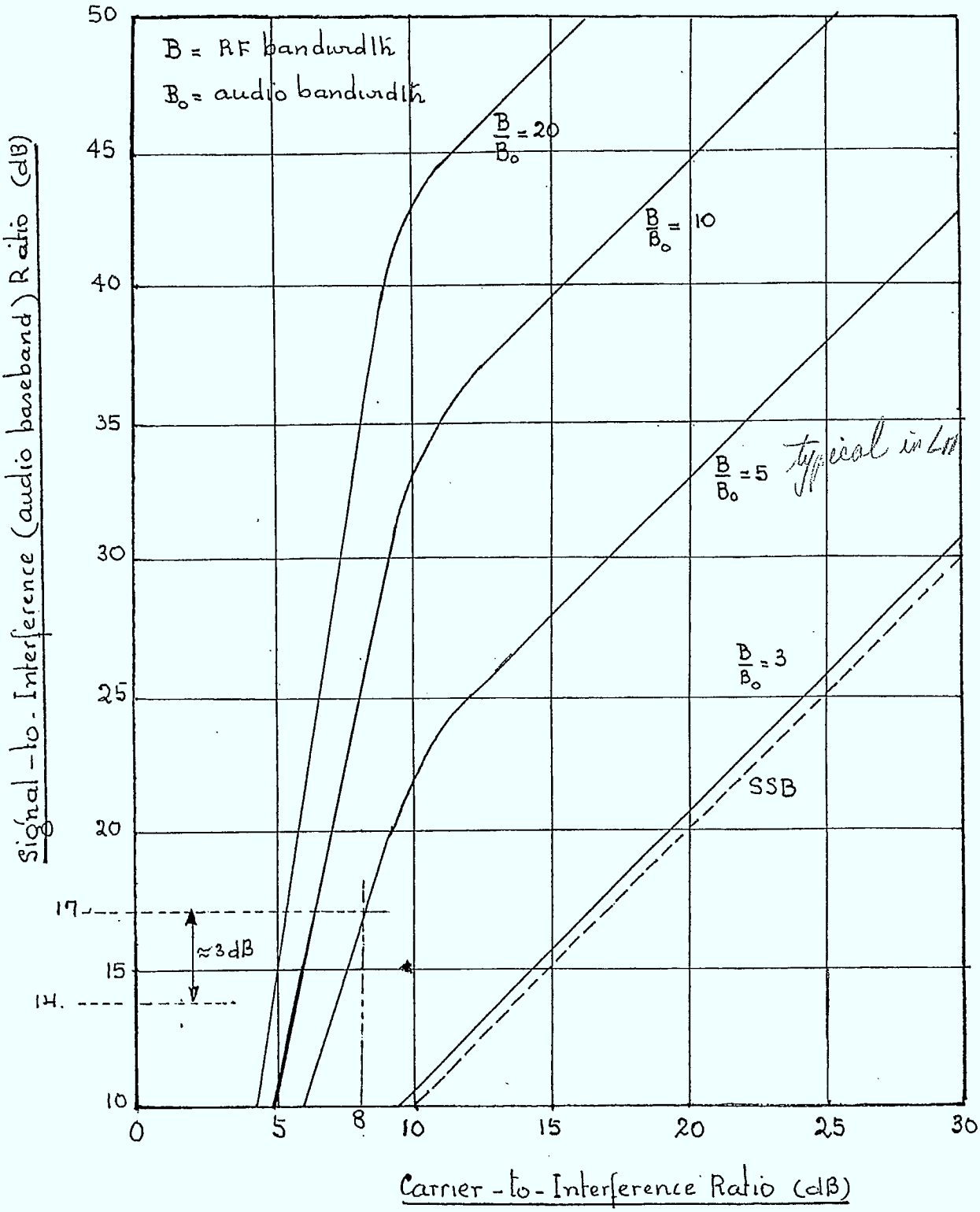


Figure 4.6-1: Relationship between S/X and C/I for FM Systems

(Source: CCIR SGVIII, Draft Report 319-4)

8 dB: protection ratio (suggested)

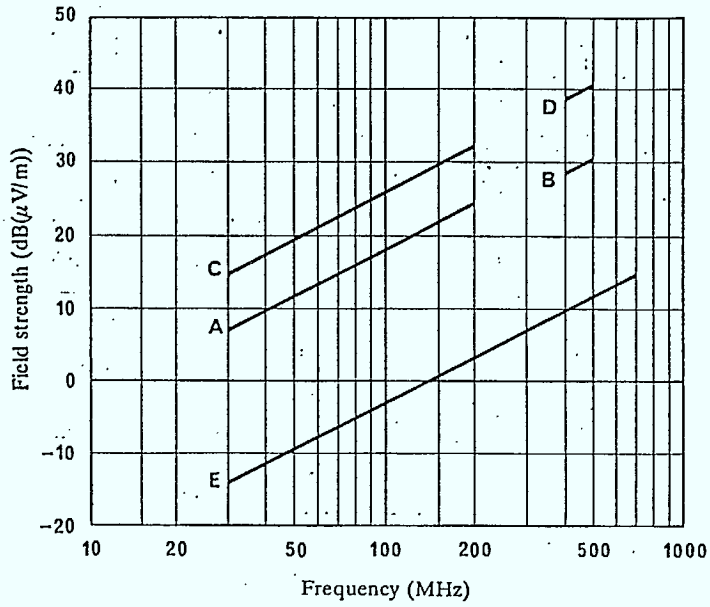


Figure 4.6-2: Minimum Usable and Median Field Strengths for Typical Hand-portable stations

Characteristics assumed: antenna gain [A and C: -9dB
[B and D: -6dB

A,B: median, normal grade
D,D: median, high grade
E: minimum usable field strength (dipole antenna)

(Source: CCIR SGVIII, Report 358-3)

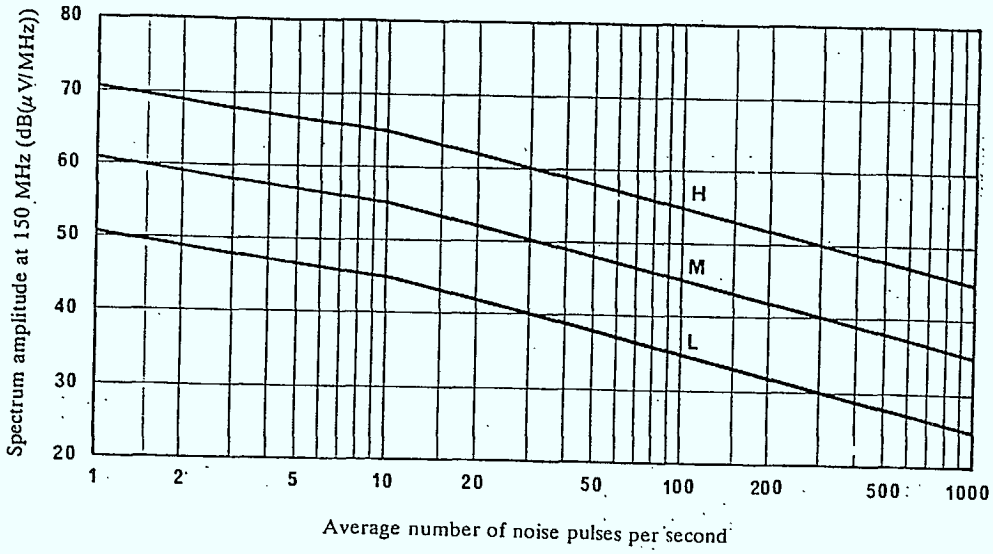


Figure 4.6-3: Noise Amplitude Distribution at Base Station (150 MHz)

For Frequencies other than 150 MHz, raise or lower curves H, M and L in accordance with the formula below.

A = C÷10 log V-28 log f (where A = dB (μV/MHz) at 10 pps)
C = 106 dB (μV/MHz) is tentative value used in the absence of data

Curve H: High noise location (V = 100)
Curve M: Moderate noise location (V = 10)
Curve L: Low noise location (V = 1)

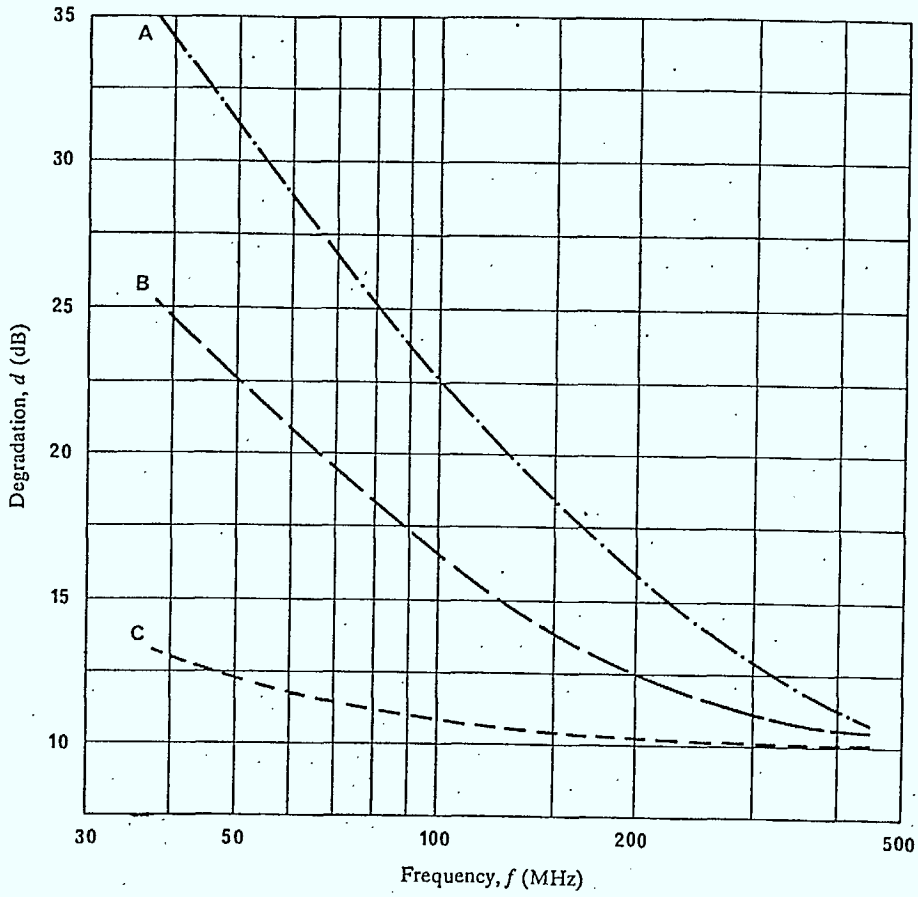


Figure 4.6-4: Variation of Degradation of Mobile Reception and Minimum Values of Field Strength to be Protected for Signal Quality Grade 4 and Receiver Sensitivity of 0.7 μV e.m.f.
(Field Strength = -41+d+20 log f dB(μV/m)

A: Mobile vehicle stationary within a high noise area
B: Mobile vehicle in motion within a high noise area
C: Mobile vehicle in motion within a low noise area

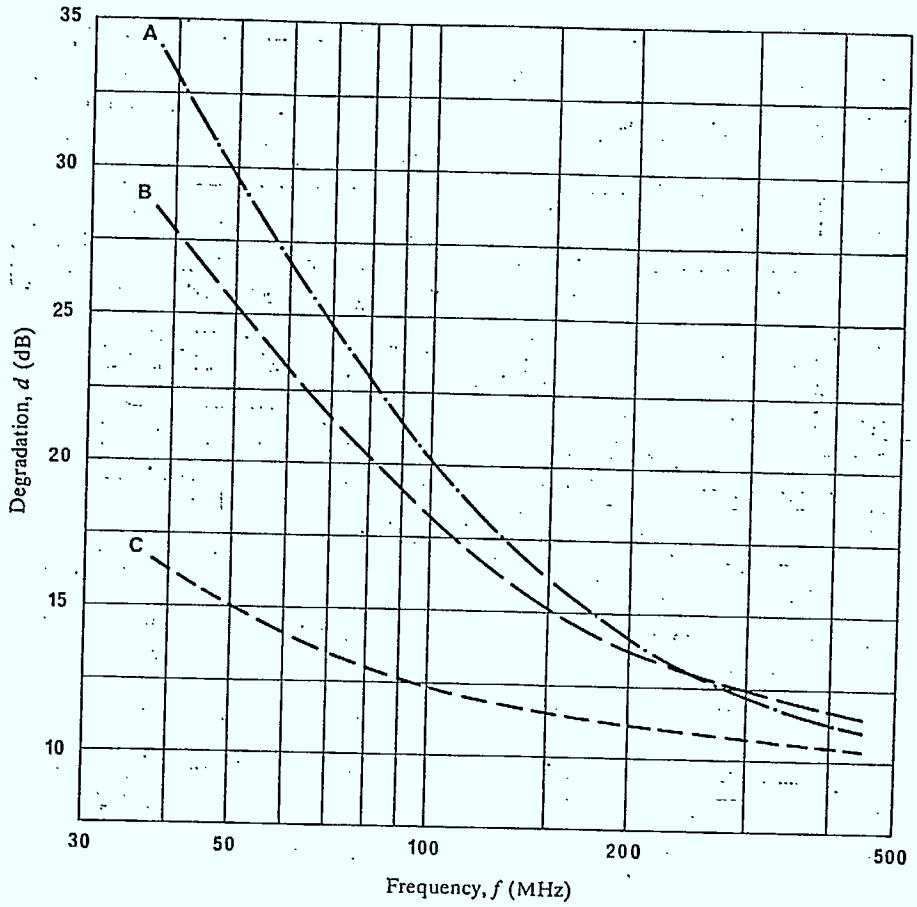


Figure 4.6-5: Variation of Degradation of Mobile Reception and Minimum Values of Field Strength to be Protected for Signal Quality Grade 3 and Receiver Sensitivity of 0.7 μV e.m.f.

(Field Strength = $-41+d+20 \log f$ dB(μV/m)

A: Mobile vehicle stationary within a high noise area
B: Mobile vehicle in motion within a high noise area
C: Mobile vehicle in motion within a low noise area

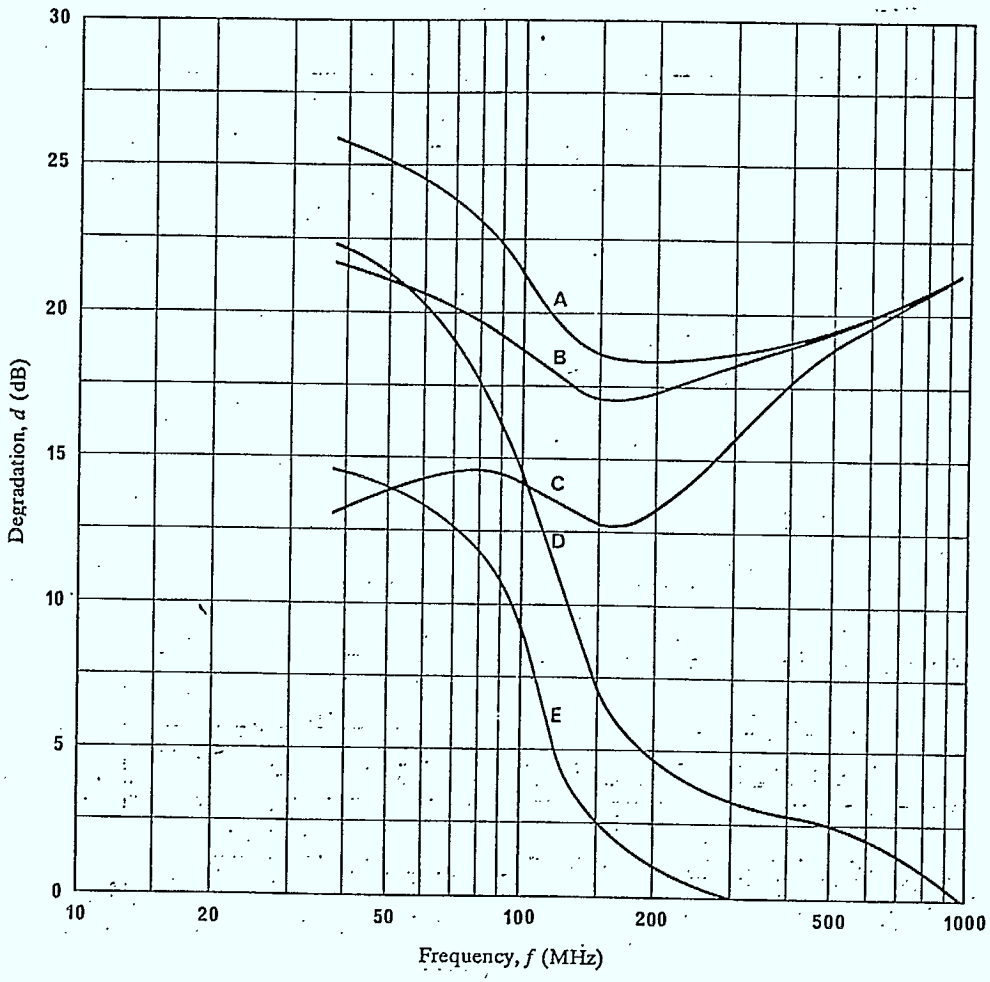


Figure 4.6-6: Variation of Degradation of Mobile Reception and Minimum Values of Field Strength to be Protected for Signal Quality Grade 4 and Receiver Sensitivity of 0.7 μV e.m.f.

(Field Strength = $-41+d+20 \log f$ dB(μV/m)

A: Mobile vehicle moving, traffic rate is 2 vehicles/s
B: Mobile vehicle moving, traffic rate is 1 vehicle/s
C: Mobile vehicle moving, no ignition or ambient noise
D: Mobile vehicle stationary, traffic rate is 2 vehicles/s
E: Mobile vehicle stationary, traffic rate is 1 vehicle/s

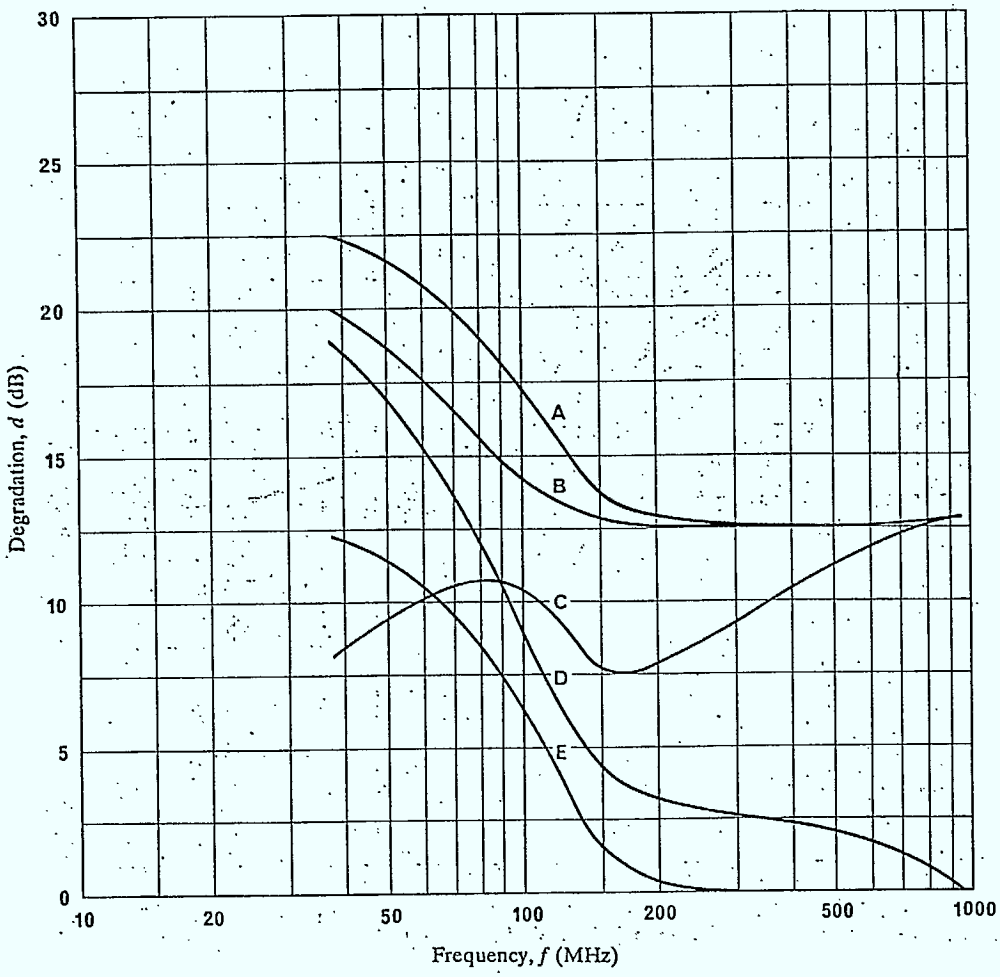


Figure 4.6-7: Variation of Degradation of Mobile Reception and Minimum Values of Field Strength to be Protected for Signal Quality Grade 3 and Receiver Sensitivity of 0.7 μV e.m.f.

(Field Strength = $-41+d+20 \log f$ dB(μV/m)

A: Mobile vehicle moving, traffic rate is 2 vehicles/s
B: Mobile vehicle moving, traffic rate is 1 vehicle/s
C: Mobile vehicle moving, no ignition or ambient noise
D: Mobile vehicle stationary, traffic rate is 2 vehicles/s
E: Mobile vehicle stationary, traffic rate is 1 vehicle/s

The foregoing are all based on a SINAD of 12 dB as the threshold performance. Moreover, the data on NAD of man-made noise and on multi-path distortion were obtained from a single source. Much more data are required before the minimum median field strength for specified grade of service can be determined for use on a general basis for degradation due to noise.

4.6.3 Comparison of Quality of Service with Protection Ratios of Different Administrations

CCIR reports indicate that a baseband SINAD ratio of 20dB provides Grade 4 quality service for speech signals and a protection ratio of 8 dB is adequate to provide acceptable quality. Also, the minimum field strength required to provide Grade 4 quality is given as 25 dBμ.

DOC (Canada) recommends a minimum field strength of 38 dBμ for particularly noisy environments to achieve the same grade of service.

5.0 CHARACTERISTICS OF THE TV BROADCAST SERVICE

5.1 DESCRIPTION OF THE TELEVISION (TV) BROADCAST SERVICE

In the TV broadcast service, the information that is conveyed consists of picture and sound signals. It is a one-way communication system in that the information is transferred from a central broadcast transmitter to a host of fixed receivers located in the service coverage area of that transmitter.

The transmitter station uses an antenna which normally has a radiation pattern that is omnidirectional in the azimuth plane and has a certain amount of directivity in the elevation plane. The receiver antennas, on the other hand, may be directional in both the azimuth and elevation planes. The polarization used is generally horizontal, though circular polarization is also permitted.

There are several types of TV transmission systems in use; but the type we shall be concerned with is the Type M/NTSC, 525 line system with a line rate of 15.75 kHz and a frame rate 30 Hz. The modulation scheme used is the vestigial sideband amplitude modulation (VSBAM). The sound subcarrier is frequency modulated by an aural baseband signal extending in bandwidth from 50 Hz to 15 kHz. The maximum frequency deviation is ±25 kHz. The sound subcarrier is located at 4.5 MHz with respect to the picture frequency. The video signal (luminance plus chrominance signals) occupy a bandwidth of 4.2 MHz with the chrominance carrier located 3.58 MHz above the unmodulated visual carrier. The transmitted signal therefore consists of three carriers: visual, colour (or chrominance) and the sound (or aural) carriers.

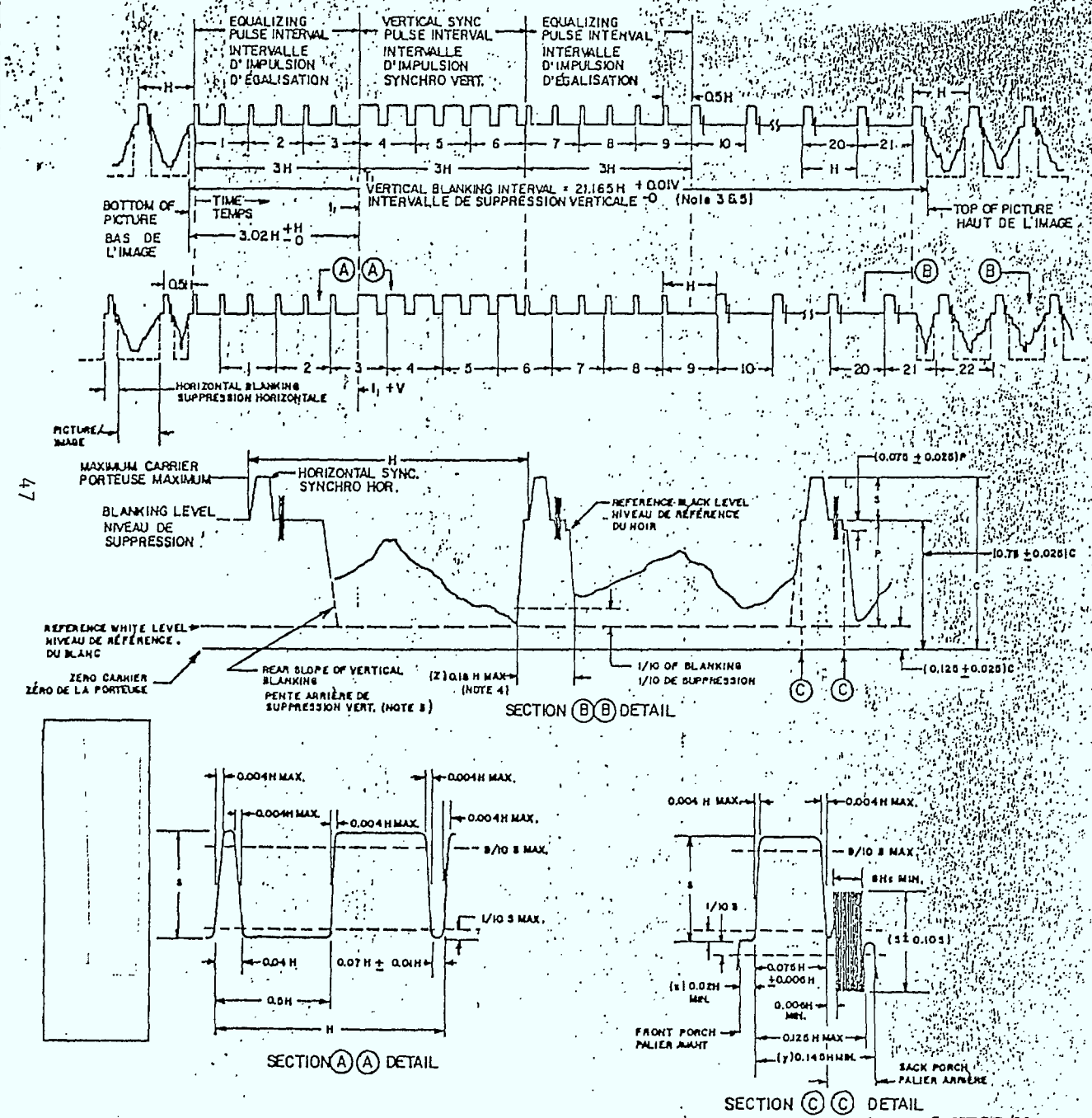


FIGURE 5.1-1 Waveform Characteristics of NTSC/M Signal

1. H = TIME FROM START OF ONE LINE TO START OF NEXT LINE.

   H = TEMPS DEPUIS LE DÉBUT D'UNE LIGNE JUSQU'AU DÉBUT DE LA LIGNE SUIVANTE.

2. V = TIME FROM START OF ONE FIELD TO START OF NEXT FIELD.

   V = TEMPS DEPUIS LE DÉBUT D'UNE TRAME JUSQU'AU DÉBUT DE LA TRAME SUIVANTE.

3. LEADING AND TRAILING EDGES OF VERTICAL BLANKING SHOULD BE COMPLETE IN LESS THAN 0.1 H.

   LES FLANCS AVANT ET ARRIÈRE DES IMPULSIONS DE SUPPRESSION VERT. DOIVENT ÊTRE COMPLETÉS EN MOINS DE 0.1 H.

4. LEADING AND TRAILING SLOPES OF HORIZONTAL BLANKING MUST BE STEEP ENOUGH TO PRESERVE MINIMUM AND MAXIMUM VALUES OF (X + Y) AND (Z) UNDER ALL CONDITIONS OF PICTURE CONTENT.

   LES PENTES AVANT ET ARRIÈRE DES IMPULSIONS DE SUPPRESSION HOR. DOIVENT ÊTRE SUFFISAMMENT RAIDES POUR CONSERVER LES VALEURS MINIMALES ET MAXIMALES DE (X + Y) ET DE (Z) QUEL QUE SOIT LE CONTENU DE L'IMAGE.

5. TOLERANCES GIVEN ARE PERMITTED ONLY FOR LONG TIME VARIATIONS AND NOT FOR SUCCESSIVE CYCLES.

   LES TOLÉRANCES DONNÉES NE SONT PERMISES QUE POUR LES VARIATIONS DE LONGUE DURÉE ET NON POUR LES CYCLES SUCCESSIFS.

6. EQUALIZING PULSE AREA SHALL BE BETWEEN 0.45 AND 0.5 OF AREA OF A HORIZONTAL SYNC. PULSE.

   L'AIRE DES IMPULSIONS D'ÉGALISATION DOIT ÊTRE COMPRISE ENTRE 0.45 ET 0.5 DE L'AIRE D'UNE IMPULSION SYNCHRO HOR.

7. COLOUR BURST FOLLOWS EACH HORIZONTAL PULSE, BUT IS OMITTED FOLLOWING THE EQUALIZING PULSES AND DURING THE BROAD VERTICAL PULSES.

   LA SALVE DE COULEUR SUIT CHAQUE IMPULSION HOR., MAIS EST OMIS APRÈS LES IMPULSIONS DÉGALISATION ET PENDANT LES IMPULSIONS VERT. LARGES.

8. THE BURST FREQUENCY SHALL BE 3.579545 MHz ± 10 Hz WITH A MAXIMUM RATE OF CHANGE OF FREQUENCY NOT TO EXCEED 0.1 Hz.

   LA FRÉQUENCE DE LA SALVE DE COULEUR SERA DE 3.579545 MHz ± 10 Hz AVEC UN TAUX MAXIMUM DE CHANGEMENT DE FRÉQUENCE N'EXCÉDANT PAS 0.1 Hz.

9. THE HORIZONTAL SCANNING FREQUENCY SHALL BE 2/455 TIMES THE BURST FREQUENCY.

   LA FRÉQUENCE D'EXPLOITATION HORIZONTALE SERA ÉGALE À 2/455 FOIS LA FRÉQUENCE DE LA SALVE DE COULEUR.

10. THE DIMENSIONS SPECIFIED FOR THE BURST DETERMINE THE TIMES OF STARTING AND STOPPING THE BURST, BUT NOT ITS PHASE. THE COLOUR BURST CONSISTS OF AMPLITUDE MODULATION OF A CONTINUOUS SINEWAVE.

    LES DIMENSIONS MENTIONNÉES POUR LA SALVE DE COULEUR DÉTERMINENT LE DÉBUT ET LA FIN DE CETTE SALVE, MAIS NON SA PHASE. LA SALVE DE COULEUR CORRESPOND À LA MODULATION EN AMPLITUDE D'UNE ONDE SINUSOÏDALE CONTINUE.

11. DIMENSION "P" REPRESENTS THE PEAK EXCURSION OF THE LUMINANCE SIGNAL FROM BLANKING LEVEL, BUT DOES NOT INCLUDE THE CHROMINANCE SIGNAL. DIMENSION "S" IS THE SYNC AMPLITUDE ABOVE BLANKING LEVEL. DIMENSION "C" IS THE PEAK CARRIER AMPLITUDE.

    LA DIMENSION "P" REPRÉSENTE L'EXCURSION DE CRÊTE DU SIGNAL DE LUMINANCE À PARTIR DU NIVEAU DE SUPPRESSION MAIS NE COMPREND PAS LE SIGNAL DE CHROMINANCE. LA DIMENSION "S" EST L'AMPLITUDE DES IMPULSIONS DE SYNCHRONIZATION AU-DESSUS DU NIVEAU DE SUPPRESSION. LA DIMENSION "C" EST L'AMPLITUDE DES IMPULSIONS DE CRÊTE DE LA PORTEUSE.

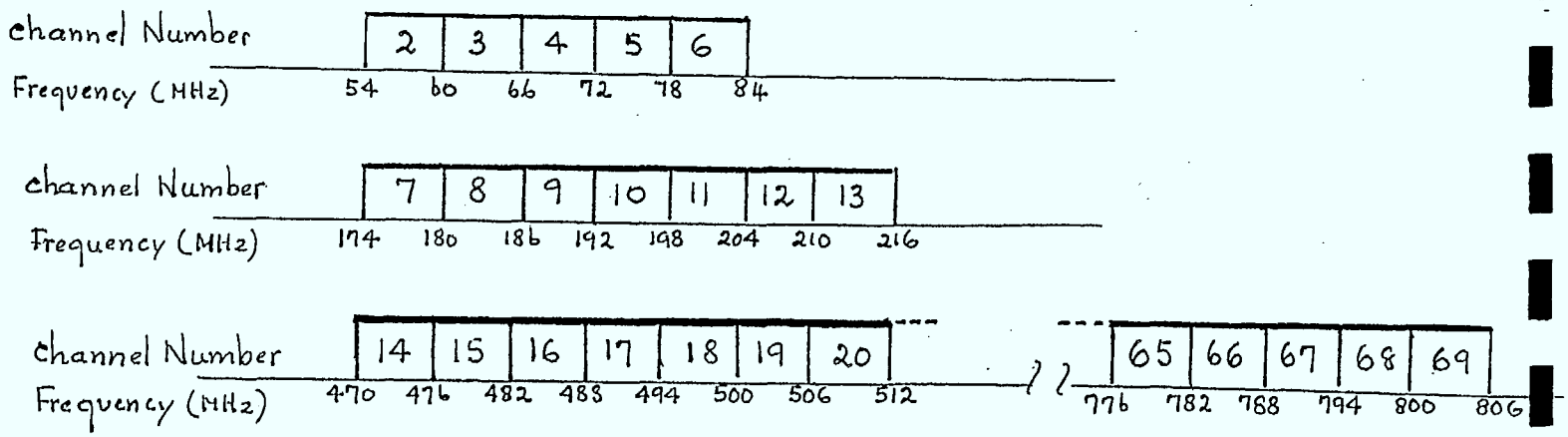


FIGURE 5.2-1 Numerical Designation of TV Channels in North America

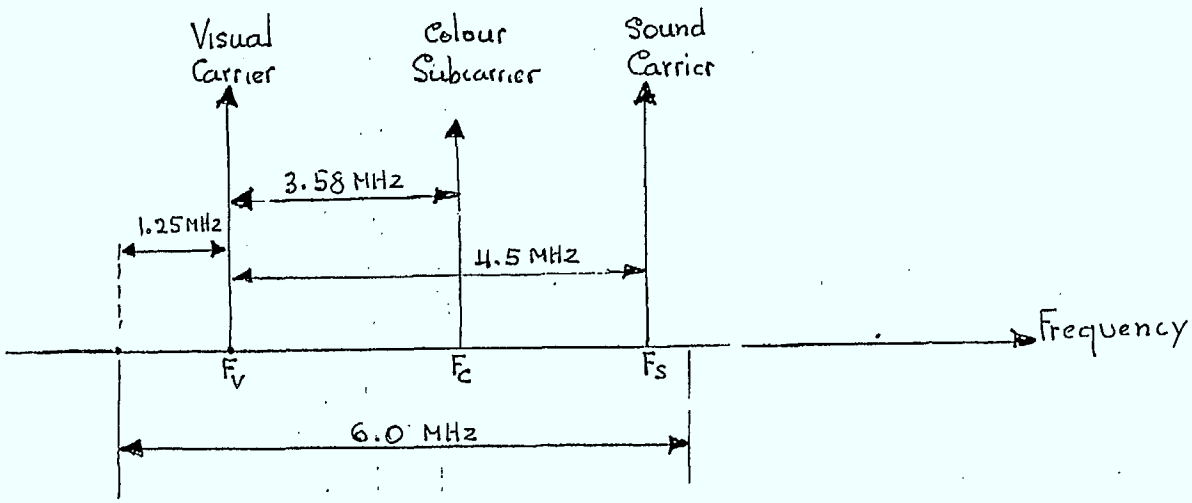


FIGURE 5.2-2 Significant Spectral Components in a TV Channel

suburban and rural

In the TV broadcast service, the effective radiated powers vary from 10 to 1000 KW, while the effective height of the transmit antenna above the average terrain varies from 100 to 600 metres. The receiver antennas are typically 10 metres above the local terrain.

5.2 FREQUENCY PLAN OR SPECTRUM UTILIZATION

The numerical designation of the TV channels and the channel spacing as used in North America are shown in Figure 5.2-1. The VHF channels are numbered from 2 to 13, while the UHF channels are numbered from 14 to 69.

The main spectral components of the unmodulated carriers are shown in Figure 5.2-2. The visual carrier is the strongest carrier with a power level 8 dB below that of the total transmitter output power; the colour subcarrier is 3.58 MHz above the visual carrier and has a power level typically 30 dB less than the visual carrier, while the sound carrier is about 7 dB less than the visual carrier and is located 4.5 MHz above it in frequency.

5.3 CHARACTERISTICS OF THE TRANSMITTERS AND ANTENNAS

The design objective of a TV broadcast service transmitter is to ensure that all the receivers located in its specified service coverage area receive a signal of sufficient field strength to provide an "acceptable" grade of service. In this respect, the main parameters of the transmitter are the effective radiated power (ERP) and the effective height of the antenna above the average terrain height (EHAAT). Transmitters, however, tend to emit spurious signals that fall outside its assigned bandwidth; and the spurious emission cause interference with TV broadcast systems using the other TV channels. The spurious emissions from a TV transmitter must therefore be strictly controlled by specifications.

5.3.1 Classes of Transmitters

TV broadcast service transmitters are categorized according to the standard parameters permitted for a station. The standard parameters permitted for a TV station are as follows:

A. For VHF:
- Channels 2-6: ERP = 100 KW, EHAAT = 300 m
- Channels 7-13: ERP = 325 KW, EHAAT = 300 m

B. For UHF:
- Class A: ERP = 10 KW max., EHAAT = 100 m
- Class B: ERP = 100 KW max., EHAAT = 150 m
- Class C: ERP = 1000 KW max., EHAAT = 300 m
- Super-class C: ERP = 5000 max., EHAAT ≥ 300 m

The operating parameters (ERP, EHAAT) used by a TV station will depend on the coverage area (defined by a service contour) permitted to that station. The operating ERP shall not exceed the standard ERP. The operating EHAAT may exceed the standard EHAAT;

but when it does, the ERP must be accordingly reduced from the standard value.

5.3.2 Unwanted Emissions from a Transmitter

From the standpoint of interference into other TV broadcast systems using any of the other TV channels, the following factors are significant and should be controlled by specifications.

A. Carrier Frequency Stability: This factor is important since off-setting the visual carrier frequencies of two systems using the same TV channel is a recognized method of reducing co-channel interference between the two systems. Carrier frequency instability would reduce the advantage gained by off-setting. Very large instabilities would, of course, cause the spectrum to drift into the adjacent channels, increasing the interference to these adjacent channels.

B. Intermodulation: Any amplitude non-linearity in the transmitter will generate beat products of the three carriers: visual, colour, and sound. The six predominant products for the NTSC system, with respect to the visual carrier frequency are ±920 kHz, ±2.66 MHz, +5.42 and +7.16 MHz. If a TV station transmits on more than one channel but uses the same antenna, then intermodulation products, at the beat frequencies of the TV channels radiated, may also be generated.

C. Spurious Emissions: These are unwanted emissions occurring at the transmitter output at frequencies other than those at the predominant intermodulation products given in Para 5.3.2(b).

The DOC specifications on the above characteristics are given in Table 5.3-1, while the CCIR specifications on spurious emissions are given in Figures 5.3-1 and 5.3-2.

5.4 CHARACTERISTICS OF THE RECEIVERS

Receivers in the TV broadcast service (as in other services) are designed to be sensitive to weak on-channel signals and to be insensitive to all emissions outside the desired channel.

5.4.1 Receiver Sensitivity

Two receiver sensitivity characteristics are often provided:

A. The weakest input signal (μV into 300 ohms), the presence of RF internal and cosmic noise but excluding RF man-made noise, that will produce an output signal-to-unweighted noise ratio of 30 dB. The output signal is the peak-to-peak picture signal (0.7V), while the noise signal is the rms output noise voltage. The latter sensitivity is referred to as noise-limited sensitivity. Typical values for the noise-limited sensitivities of receivers range from -55 dBm to -65 dBm (or from 1 mV to 0.3 mV into 300 ohms).

B. is missing

PARAMETERS	SPECIFICATIONS	
	CONDITIONS	VALUES
Carrier Frequency Stability	Applies for both the visual and aural carriers	± 500 Hz
Intermodulation Products	Measured relative to the visual carrier level and given relative to the visual carrier frequency, F_V	
	$F_V \pm 920$ kHz	
	$F_V \pm 2.66$ MHz	-51 dB
	$F_V + 5.42$ MHz	
	$F_V + 7.16$ MHz	-60 dB
Spurious Emissions	Tx Power — Components	
	Above 25W • $F_V - 4.5$ MHz, $F_V + 9.0$ MHz	-40 dB
	• All Harmonics	$-(43 + 10\log P)$ dB or -60 dB whichever is stronger
	• All other Spurious	-60 dB
	Below 25W • $F_V - 4.5$ MHz, $F_V + 9.0$ MHz	-40 dB
	• all Harmonics	-46 dBW
	• all other Spurious	-46 dBW

Note: These specifications apply for the 54-88 MHz, 174-216 MHz and 470-806 MHz frequency bands

Table 5.3-1: Canadian TV Transmitter Characteristics

(RSS 154, Issue 2, March 25, 1984)

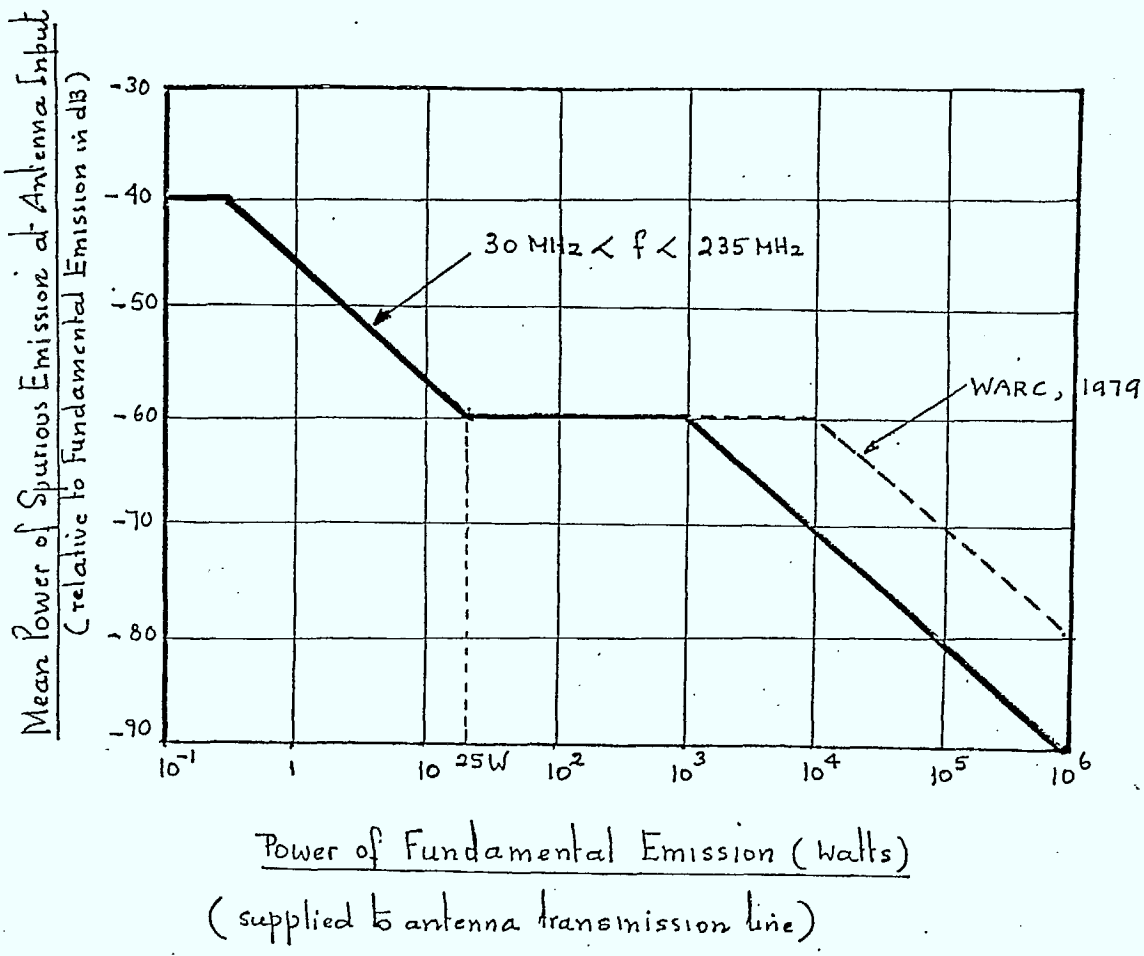


Figure 5.3-1: Spurious Emission from CCIR Rec: 329-4 (30 to 235 MHz)

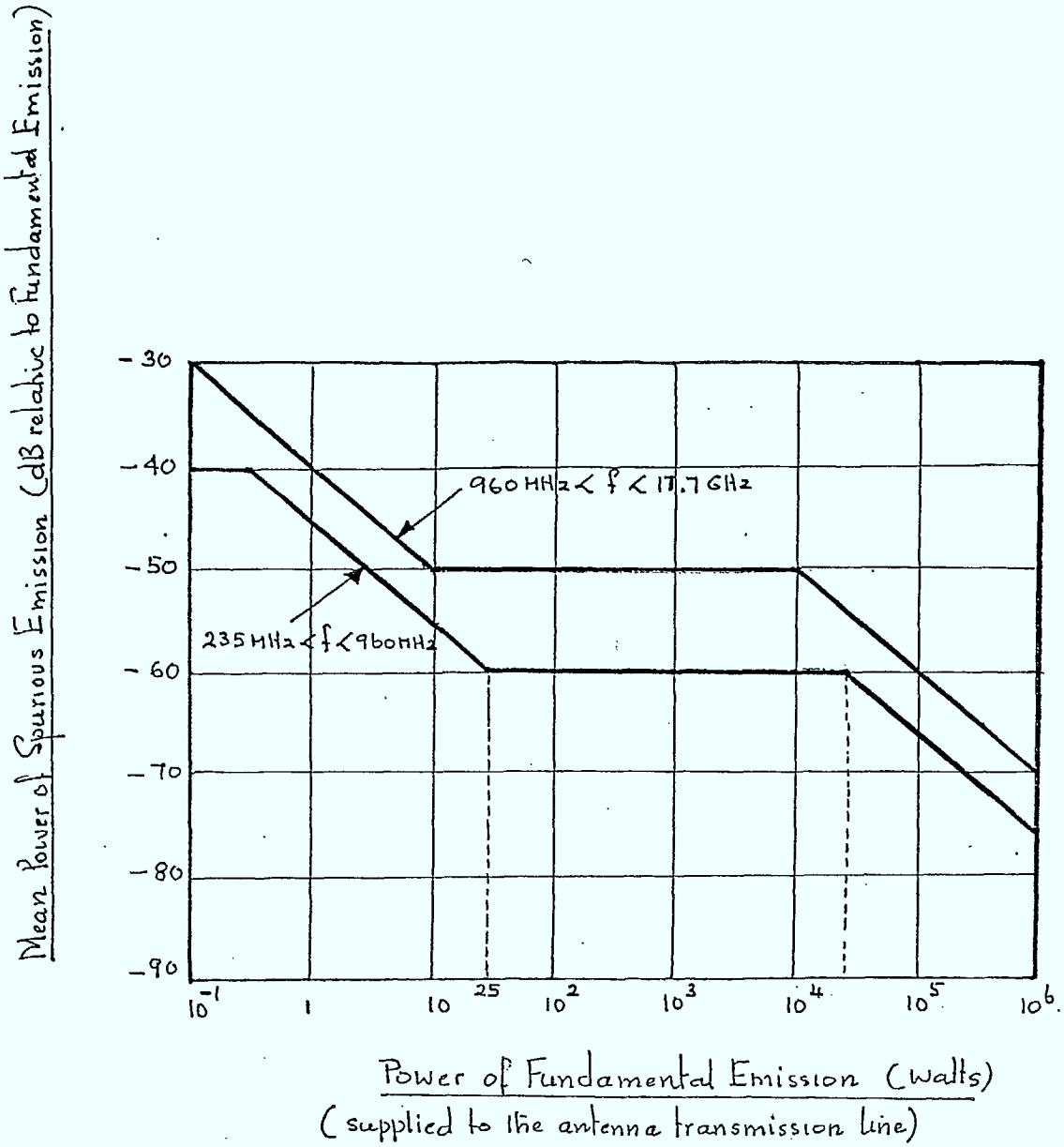


Figure 5.3-2: Spurious Emission from CCIR Rec: 329-4 (235 to 17,700 MHz)

CHARACTERISTICS	FREQUENCY BANDS			REMARKS
	Band 1 (41-68 MHz)	Band III (162-230 MHz)	Band IV/V (470-960 MHz)	
Noise Limited Sensitivity (dBm)	-60	-60	-55/-65	Based on Luminance SNR = = 30 dB, unweighted
Co-channel Protection Ratio (dB)				
Rejection of Adjacent Picture Carrier (dB)	-35	-35	-35	
Rejection of Adjacent Sound Carrier (dB)	-40	-40	-40/-43	
Image Frequency Rejection (dB)	-40	-40	-30/-51	
Intermediate Freq: Rejection (dB)	-30	-30	-45/-47	
Oscillator Position relative to the Desired Signal Frequency	high	high	high	
Tuning Tolerance (kHz)	±350	±350	±350	
Receiver Radiation				
Susceptibility to External Interference				Interference not entering by by the antenna
IF Frequency Values				Varies over a wide range from 25 MHz to 60 MHz

Note:

1. The data were provided by Italy and UK. More data are required.
2. The above characteristics are the significant ones that affect frequency planning.

Table 5.4-1: TV Broadcast Receiver Characteristics (CCIR Report 625-2)

FREQ: BAND	INTERFERENCE SOURCES		Rejection (dB) by 90% of Receivers Measured.
	Channel Separation of Interferer from the Wanted Channel	Type of Interference	
VHF	0	co-channel	0
	±1	adjacent channels	50
UHF	0	co-channel	0
	±1	adjacent channels	50
	±2, ±3, ±4, ±5	intermodulation	50
	±7, ±8	IF beat and ½ IF beat	30
	±14	sound image	8
	±15	picture image	-9. ? worse than co-chan.
	±7	receiver local oscillator radiation level at the input to the receiver	- 17 mV into 300 ohms

does not agree with Table 5.4.1

Table 5.4-2: Interference Sources into TV Receivers and their Rejection Characteristics as Measured in Canada

5.4.2 Receiver Susceptibility to Interference

In this phase of the study, we will be concerned with interference from other TV broadcast systems of the same characteristics (i.e. Type M/NTSC, 525-line) alone since the present licensing criteria apply only to interference from such systems.

Table 5.4-1 gives some receiver characteristics as given in CCIR Report 625-2. The data were provided by Italy and the UK.

Table 5.4-2 gives some receiver characteristics as measured in Canada. Because an IF frequency of 45 MHz is employed by receivers in North America, the channels that cause interference in North American receivers will, in general, differ from those in Europe where the IF frequencies are different.

For controlling the effect of interference, however, the parameter that is more useful than the rejection characteristics is the RF protection ratio which is the ratio of wanted-to-unwanted signal levels at the receiver input, required to produce a specified grade of picture (or sound) impairment. The RF protection ratio cannot, in general, be determined from objective measurements made of the parameters used to define receiver performance such as sensitivity, overload, rejection, etc., but can only be obtained by subjective tests. The value will depend, among other things, on the nature of the wanted signal (monochrome, PAL, NTSC, etc, and its modulation scheme), type of unwanted signal (TV, sound, pure CW, etc.) and the frequency separation. The RF protection ratio is the parameter required for frequency planning.

5.4.3 Receiver Antenna Characteristics

In frequency planning, it is important to ensure that the levels of all interfering signals, at the input to a receiver on the service contour, are sufficiently small that they introduce an "acceptable level" of impairment. The two-system parameters used to ensure this are:

A. Separation distance between the interfering source and the receiver,
B. Receive antenna directivity - more specifically, the antenna front-to-back gain ratio.

The receive antenna directivity discrimination to be used for frequency planning purposes is given in CCIR Recommendation 419, which has been reproduced in Figure 5.4-1.

Typical TV broadcast receiver antenna characteristics are given in Table 5.4-3. These values were obtained from measurements on a list range. However, when installed in an operational environment, the surroundings will affect the radiation pattern so the gain (main lobe) and the front-to-back ratios will, in general, be worse than those given in the table.

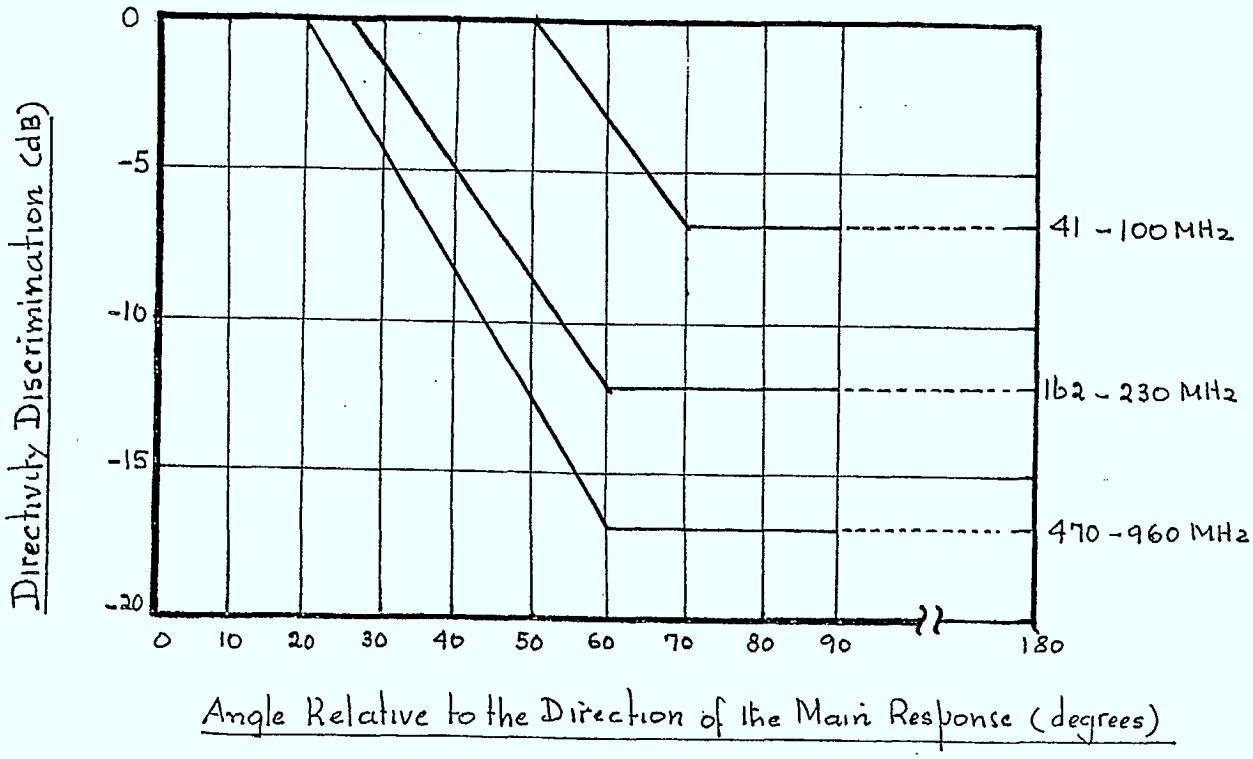


Figure 5.4-1: Receive Antenna Directivity Discrimination to be Used for Frequency Planning (as per CCIR Recommendation 419)

CHARACTERISTICS	FREQUENCY BANDS					
	Band I (41 - 68 MHz)		Band III (162 - 230 MHz)		Bands IV/V (470 - 960 MHz)	
Number of Elements	2	4	3	10	8	22
Impedance (ohms)	75	300	75	300	75	75
Gain Relative to $\frac{\lambda}{2}$ dipole (dB)	4	8	5	12	6	10
Passband (MHz)	11	8	15	15	80	80
Angle of Aperture (degs)	59	52	58	36	46	26
Back-Lobe Attenuation (dB)	10	16	>20	32	>20	>22
Cross-polarization Discrimination (dB)	15	20	20	>20	>20	>20

Table 5.4-3: Typical TV Broadcast Receive Antenna Characteristics

(CCIR Report 625-2)

5.5 CHARACTERISTICS OF THE PROPAGATION PATH

Over the same frequency band and over similar terrain characteristics, the TV broadcast service and the land mobile service have the same propagation characteristics between the transmitting and receiving antennas. However, for a given path, the propagation loss in the TV service is less because both the central transmitter and receiver antenna are higher than in the land mobile service.

For frequency planning, the same prediction curves (field strength versus distance) may be used for the two services provided the appropriate correction factors for the different transmitter and receiver antenna heights are applied.

- The CCIR recommended prediction curves were given in Figures 4.5-29(a) to (d), 4.5-30 to 4.5-34, 4.5-35(a) to (c), 4.5-36 and 4.5-37.
- The DOC (Canada) recommended prediction curves are given in Figures 5.5-1(a) to 5.5-1(f).
- The FCC (USA) recommended prediction curves are given in Figures 5.5-2(a) to 5.5-2(h).

5.6 QUALITY OF SERVICE DESCRIPTORS FOR INTERFERENCE

In the TV broadcast service, the output signals consist of picture and aural signals. The picture signals, being amplitude modulated, is far more sensitive to impairment than the aural signal which undergoes an additional frequency modulation. Emphasis will, therefore, be placed on the impairment to the picture signal.

5.6.1 Quality of Service

The earliest scale used to rate the picture quality is the TASO twin scale which is given in Table 5.6-1. The CCIR has recommended that a five-point scale be used by all administrations to provide some compatibility between the quality assessments made on different TV systems by the different administrations. The CCIR recommended five-point scale is given Table 5.6-2.

The picture quality is assessed by subjective tests made by a large population of viewers. The various sources of impairments are injected with the desired signal, at the input to the receiver and the viewers are requested to rate the picture quality according to the five-point scale for various baseband signal-to-noise ratios at the output. Figure 5.6-1 gives the results of such an assessment made by three different administrations for the case in which thermal noise was the source of impairment. The noise was weighted so that if the baseband signal-to-unweighted noise is required, 10.2 dB should be subtracted from the values given in that figure. A signal-to-unweighted noise ratio of 30 dB (which is generally used to define the sensitivity of a receiver) corresponds to a quality of service of grade 3.5 on the CCIR scale.

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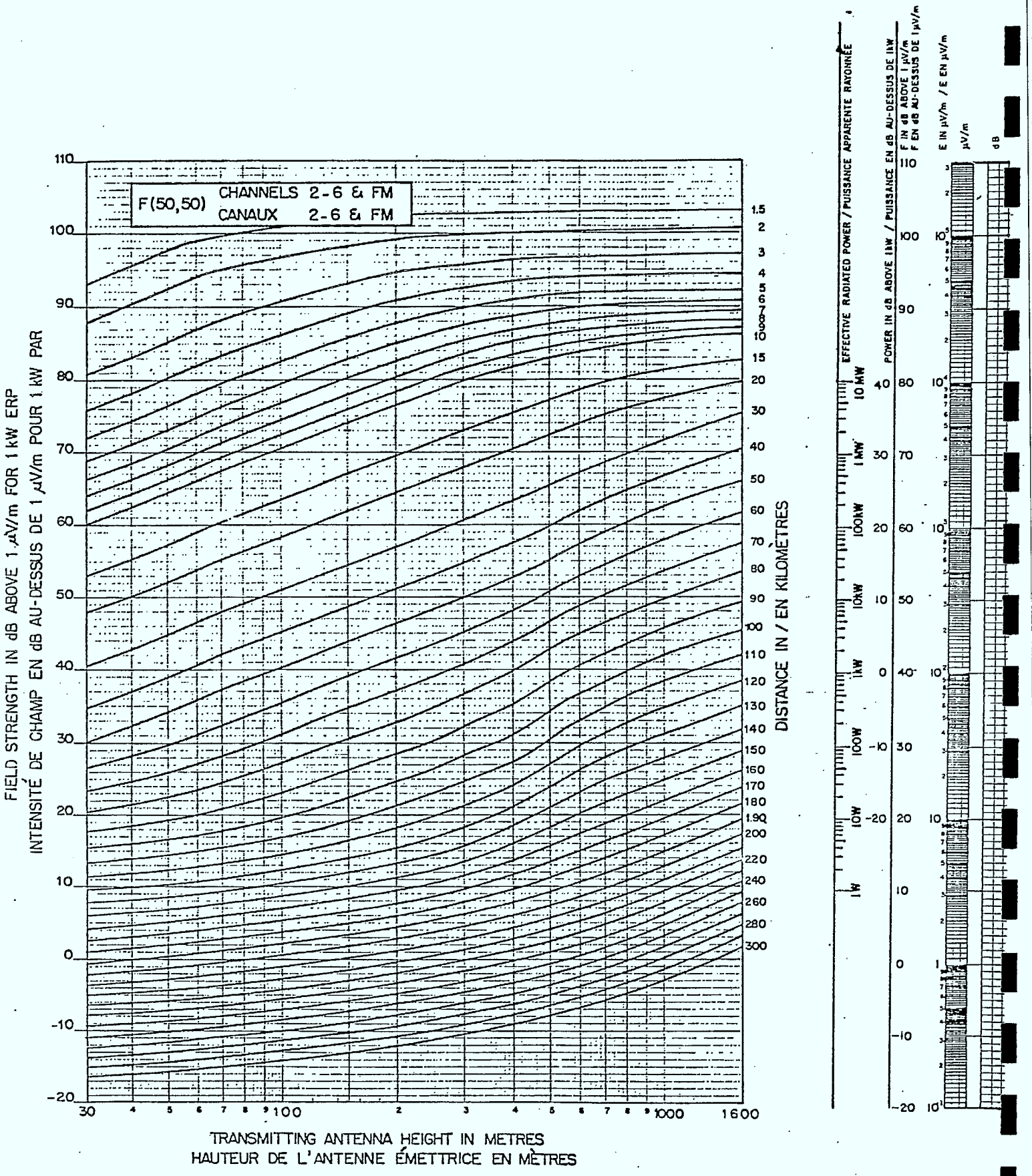

FIGURE 5.5-1(a) Estimated Field Strength Exceeded at 50% of the Potential Receiver Locations for at least 50% of the Time at a Receiving Antenna Height of 9.1 Metres.

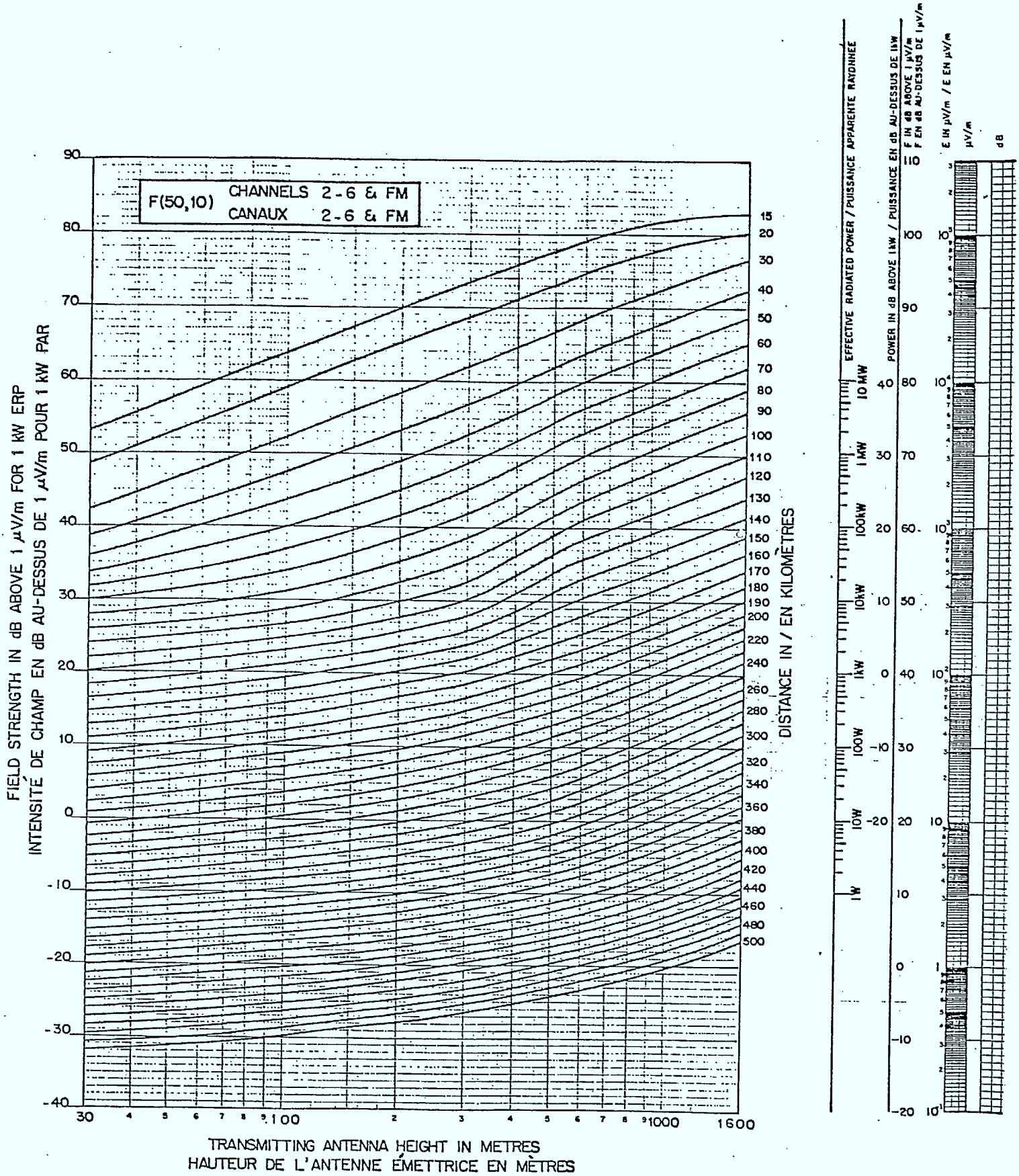

FIGURE 5.5-1(b) Estimated Field Strength Exceeded at 50% of the Potential Receiver Locations for at Least 10% of the Time at a Receiving Antenna Height of 9.1 Metres.

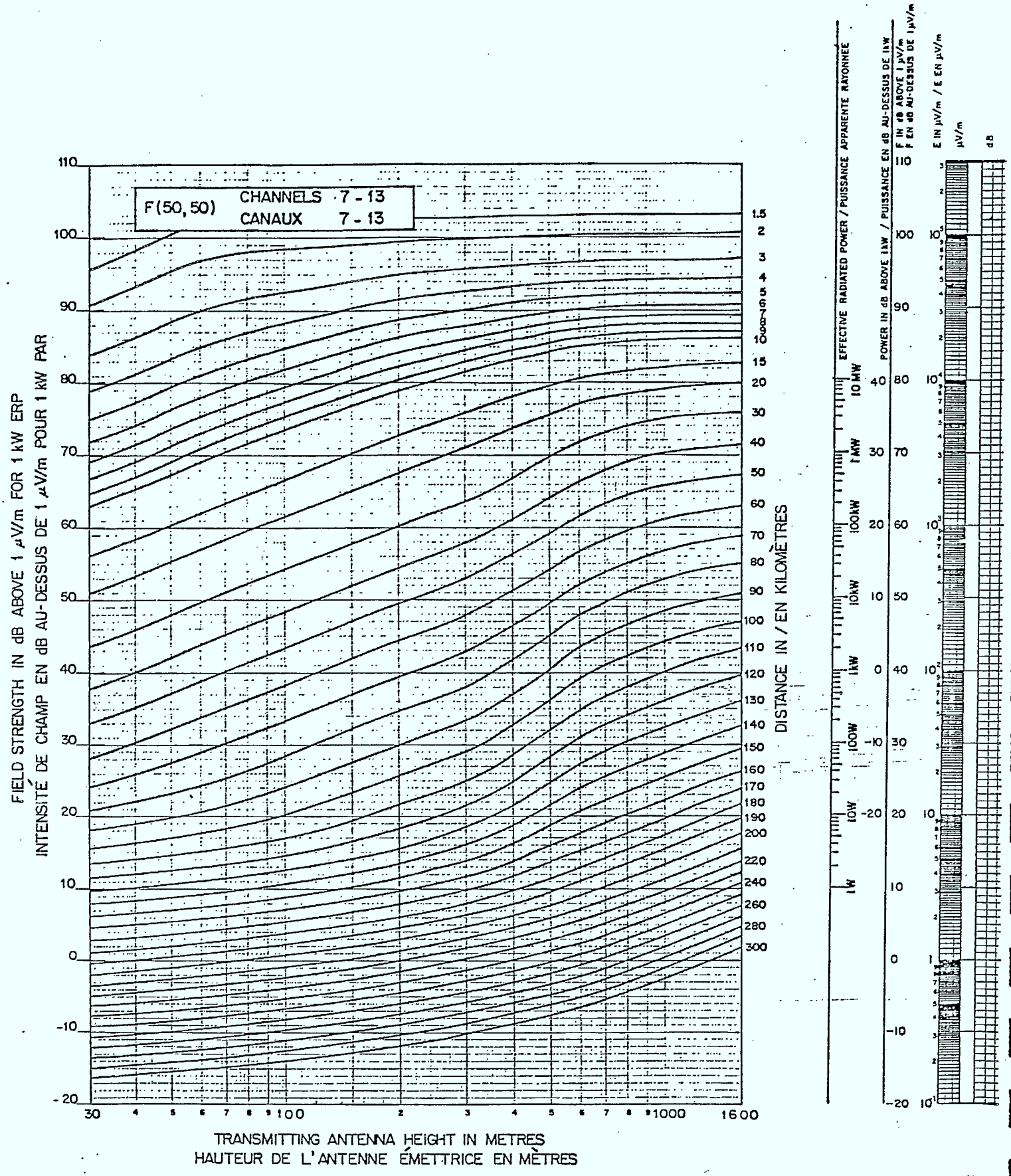

FIGURE 5.5-1(c) Estimated Field Strength at 50% of the Potential Receiver Locations for at Least 50% of the Time at a Receiving Antenna Height of 9.1 Metres.

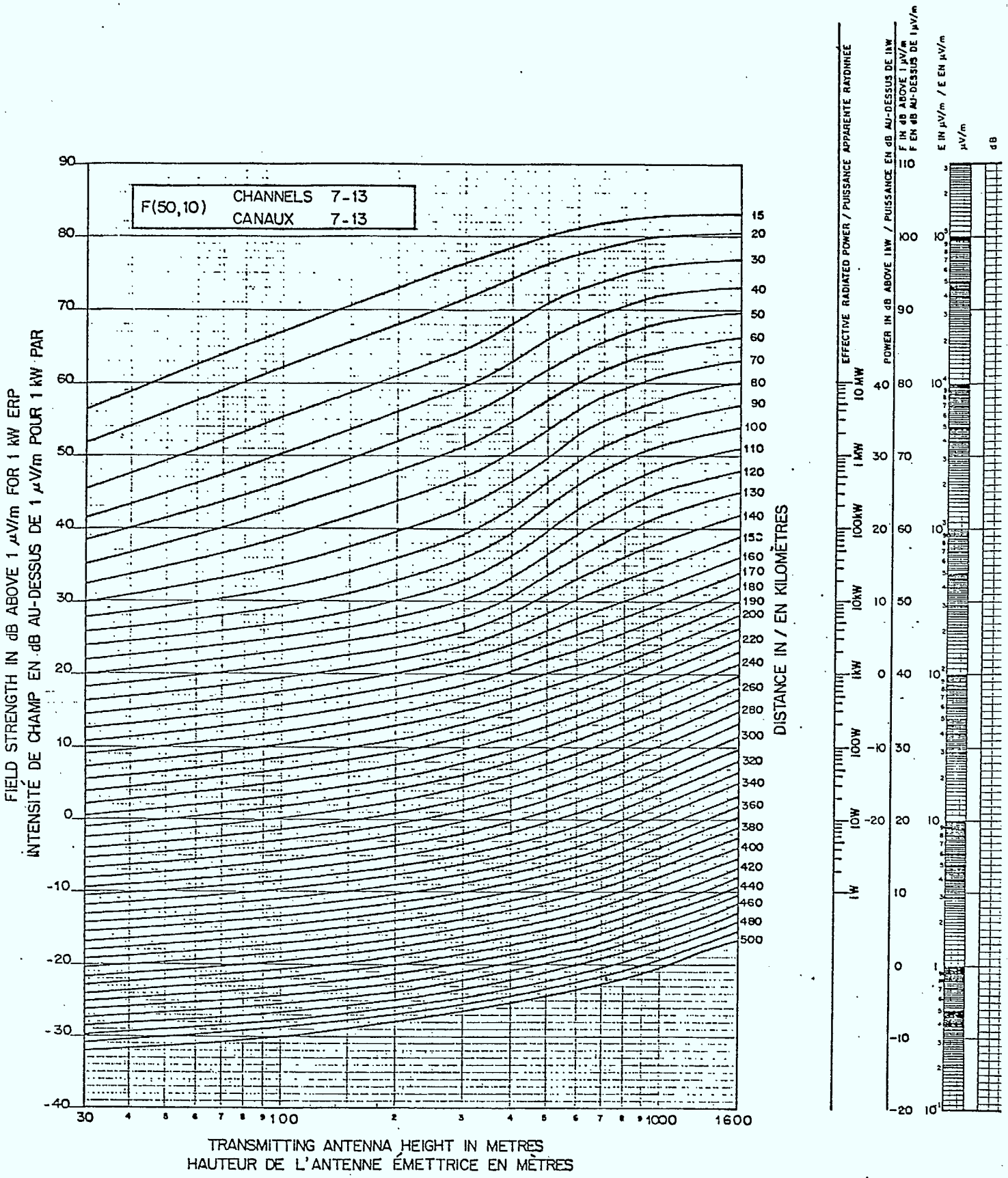

FIGURE 5.5-1(d) Estimated Field Strength Exceeded at 50% of the Potential Reveiver Locations for at Least 10% of the Time at a Receiving Antenna Height of 9.1 Metres.

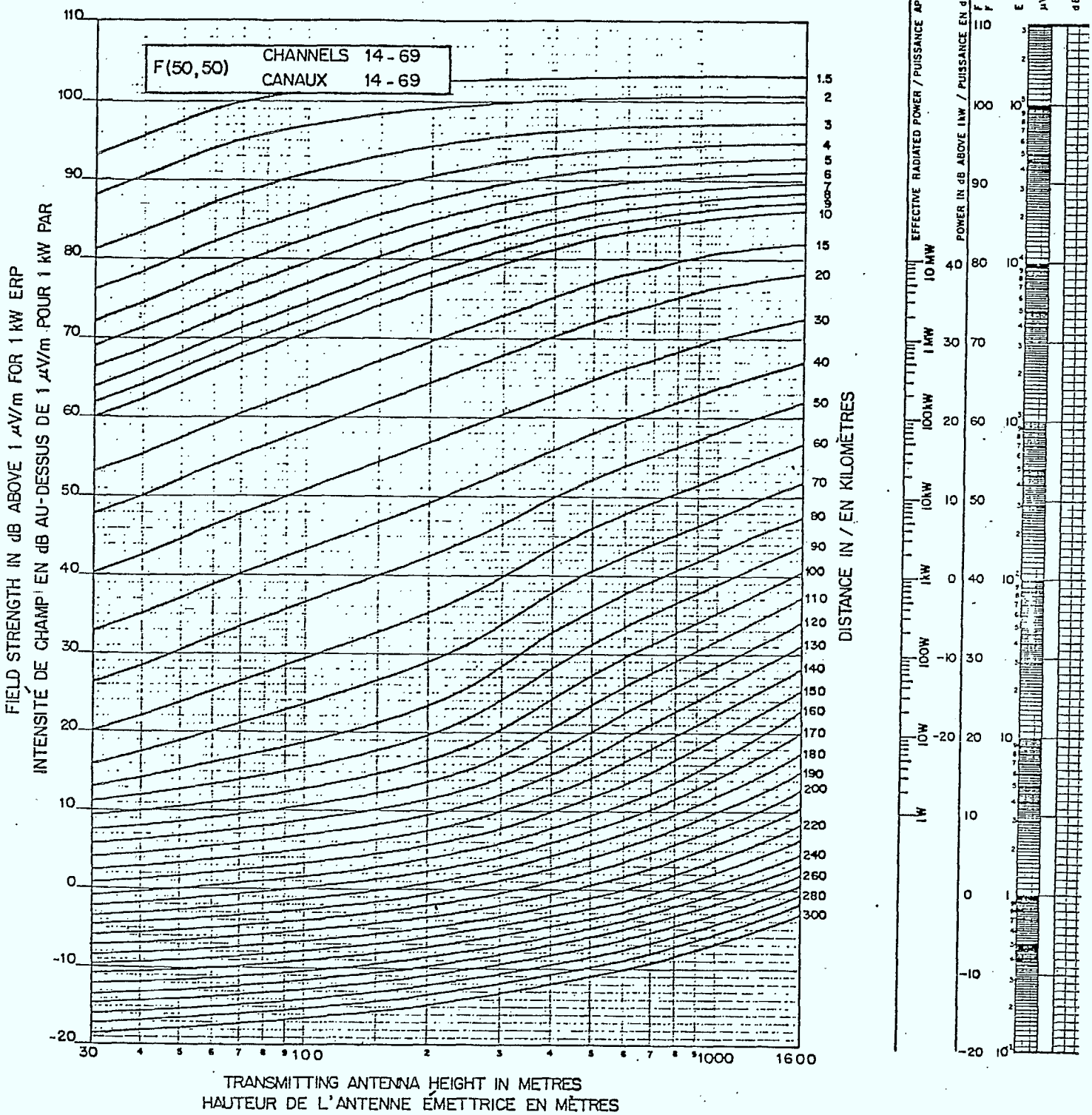

FIGURE 5.5-1(e) Estimated Field Strength Exceeded at 50% of the Potential Receiver Locations for at least 50% of the Time at a Receiving Antenna Height of 9.1 Metres.

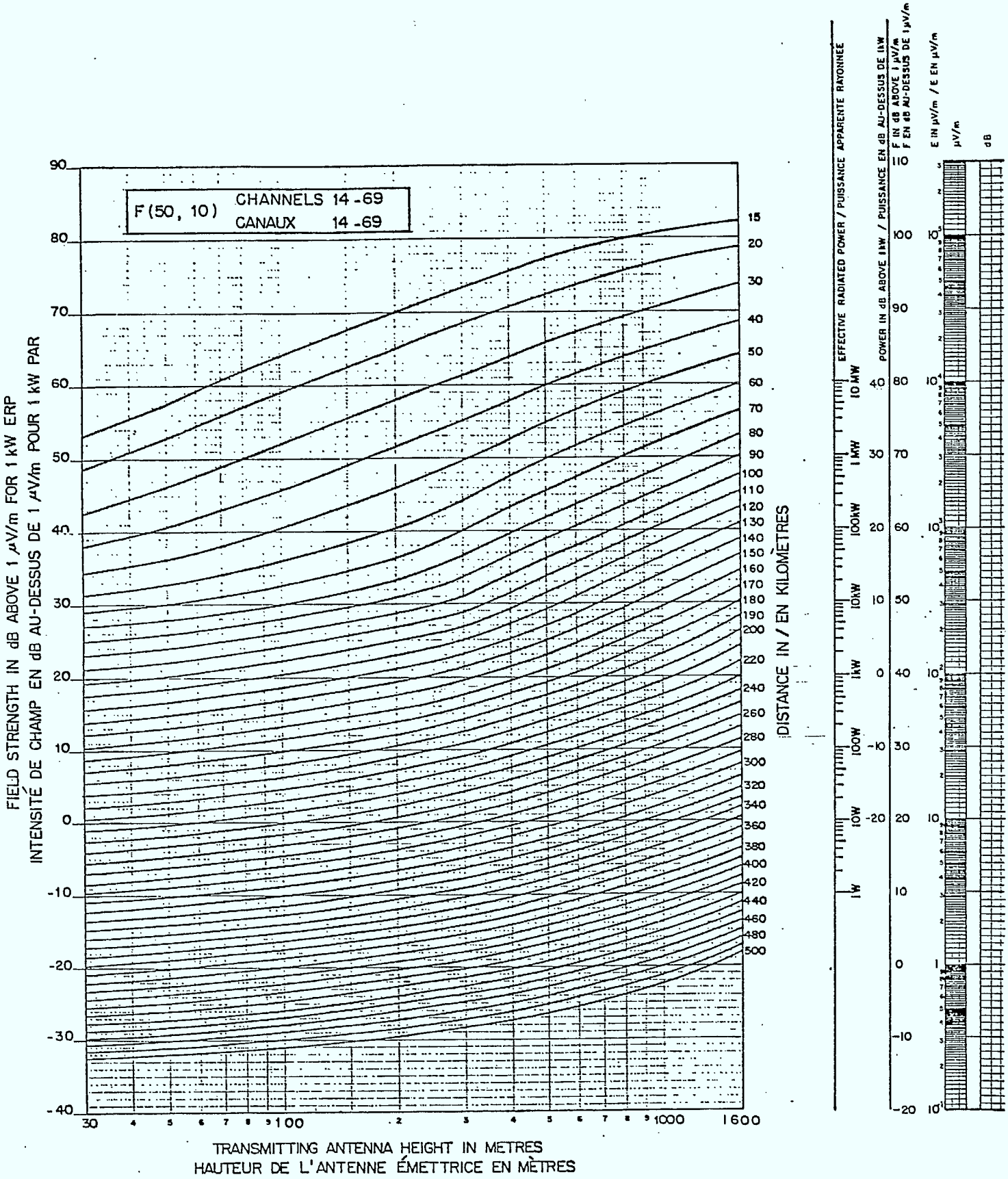

FIGURE 5.5-1(f) Estimated Field Strength Exceeded at 50% of the Potential Receiver Locations for at Least 10% of the Time at a Receiving Antenna Height of 9.1 Metres

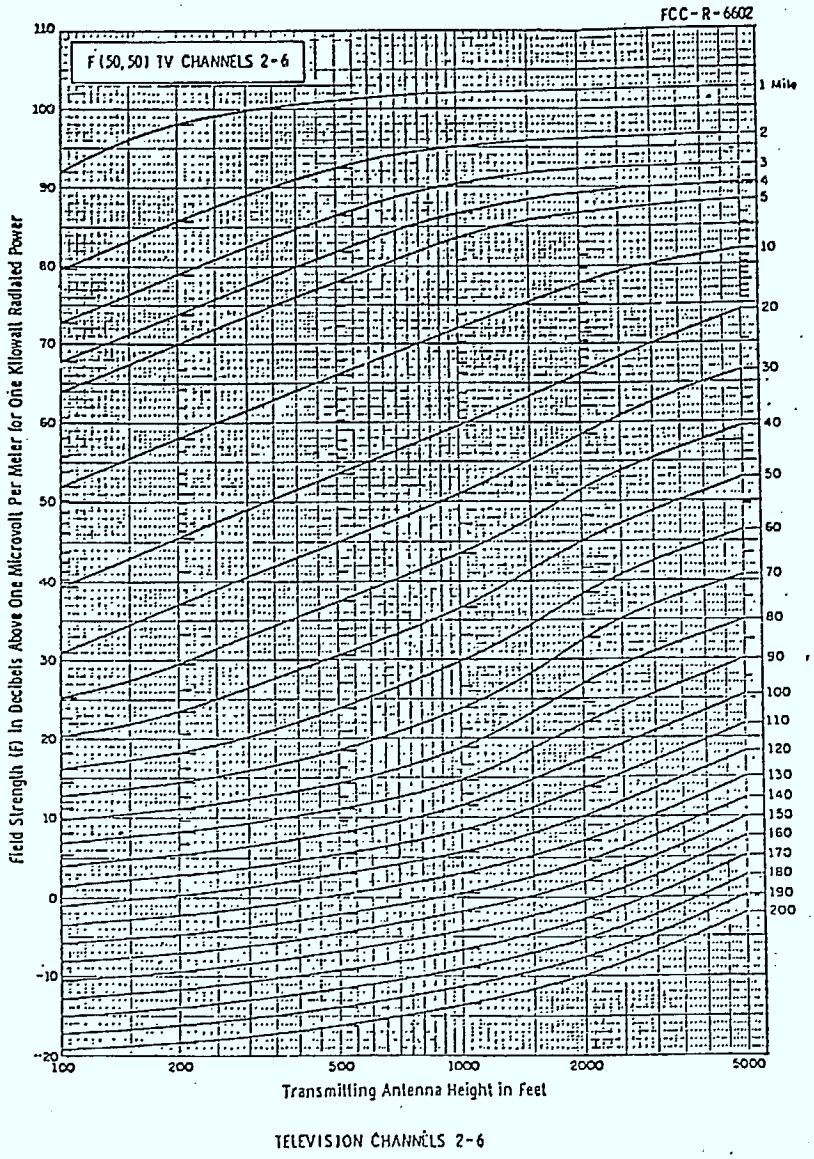

Figure 5.5-2(a): Estimated Field Strength Exceeded at 50% of Potential Receiver Locations for at least 50% of time at Receiving Antenna Height of 30 feet.

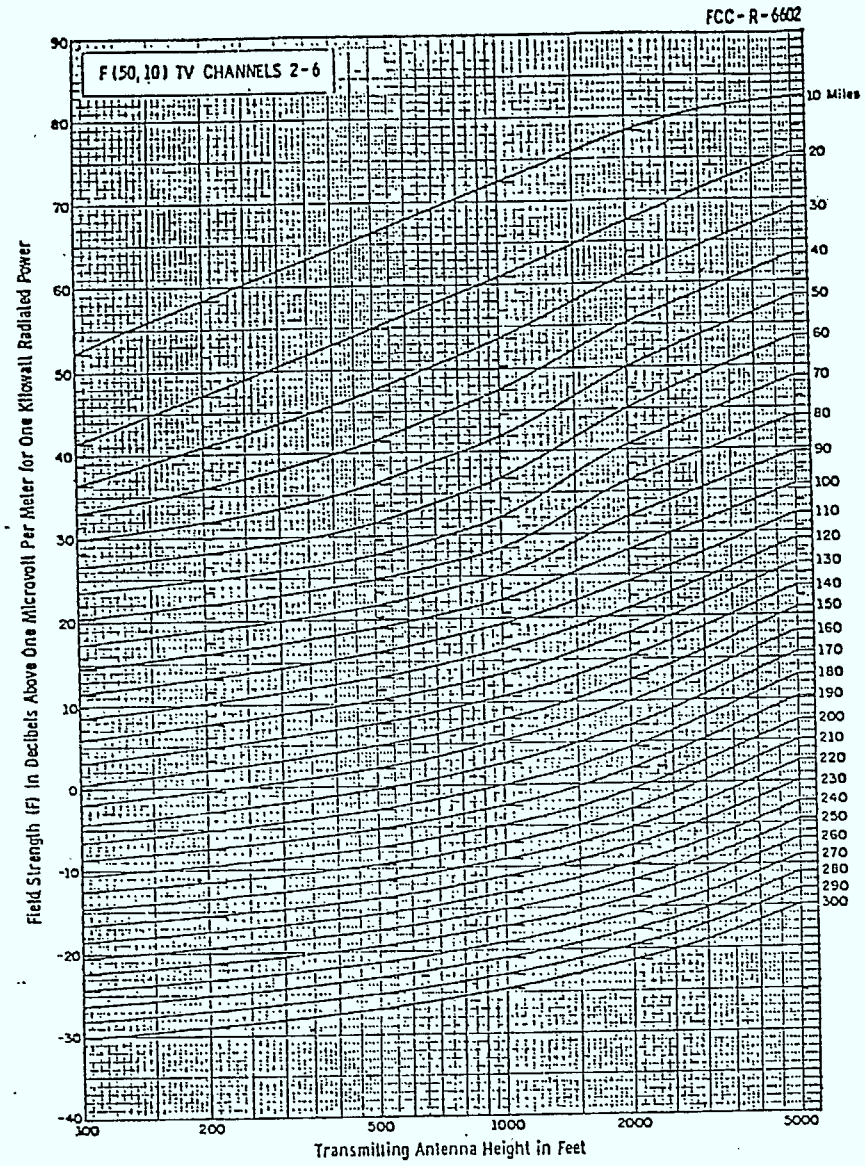

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Figure 5.5-2(b): Estimated Field Strength Exceeded at 50% of Potential Receiver Locations for at Least 10% of Time at Receiving Antenna Height of 30 Feet.

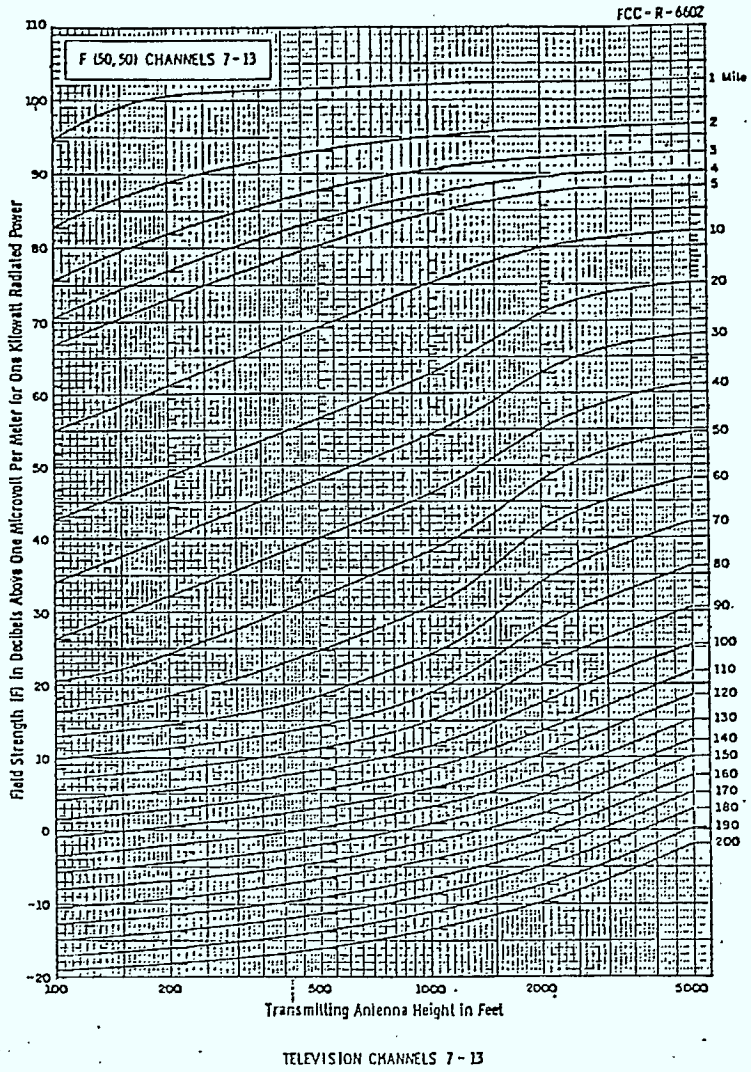

Figure 5.5-2(c): Estimated Field Strength Exceeded at 50% of Potential Receiver Locations for at Least 50% of Time at Receiving Antenna Height of 30 Feet.

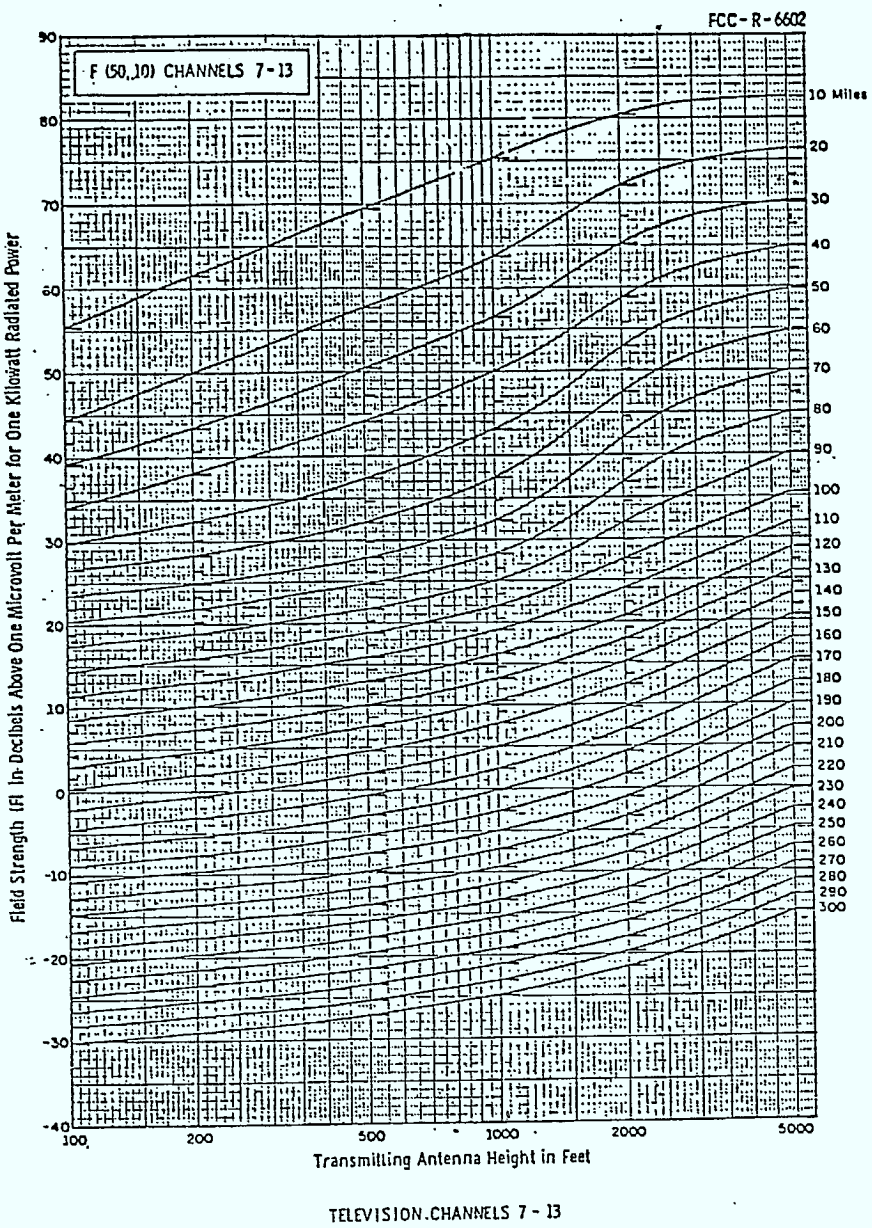

Figure 5.5-2(d): Estimated Field Strength Exceeded at 50% of Potential Receiver Locations for at Least 10% of Time at Receiving Antenna Height of 30 Feet.

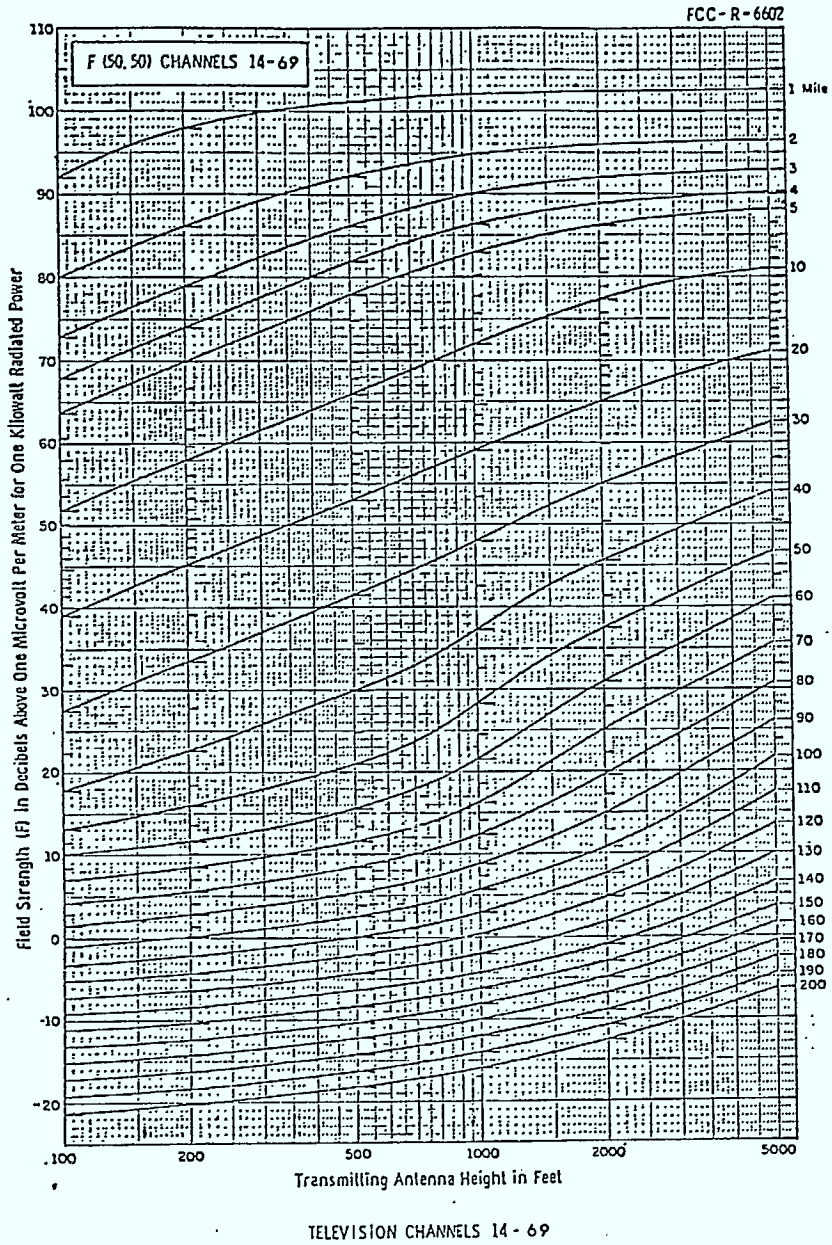

Figure 5.5-2(e): Estimated Field Strength Exceeded at 50% of Potential Receiver Locations for at Least 50% of Time at Receiving Antenna Height of 30 Feet.

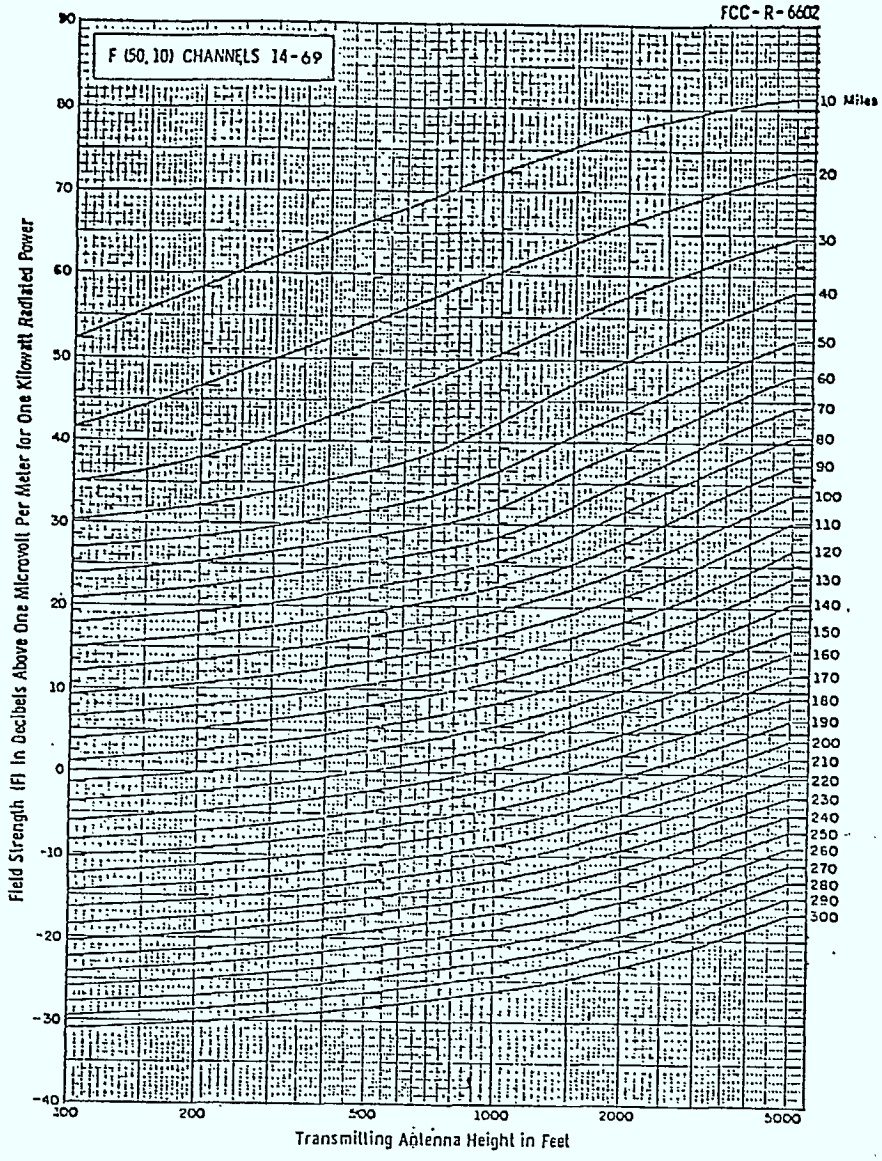

Figure 5.5-2(f): Estimated Field Strength Exceeded at 50% of Potential Receiver Locations for at Least 10% of Time at Receiving Antenna Height of 30 Feet.

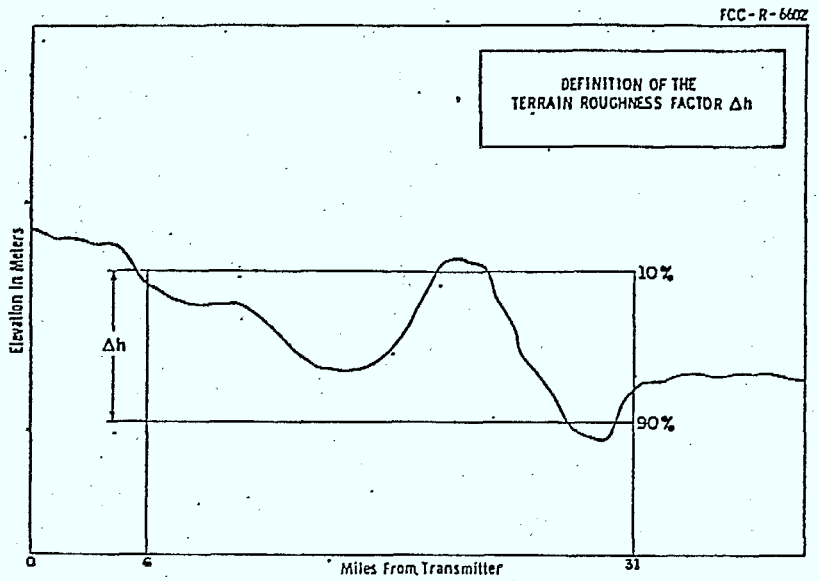

Figure 5.5-2(g): Definition of Terrain Roughness

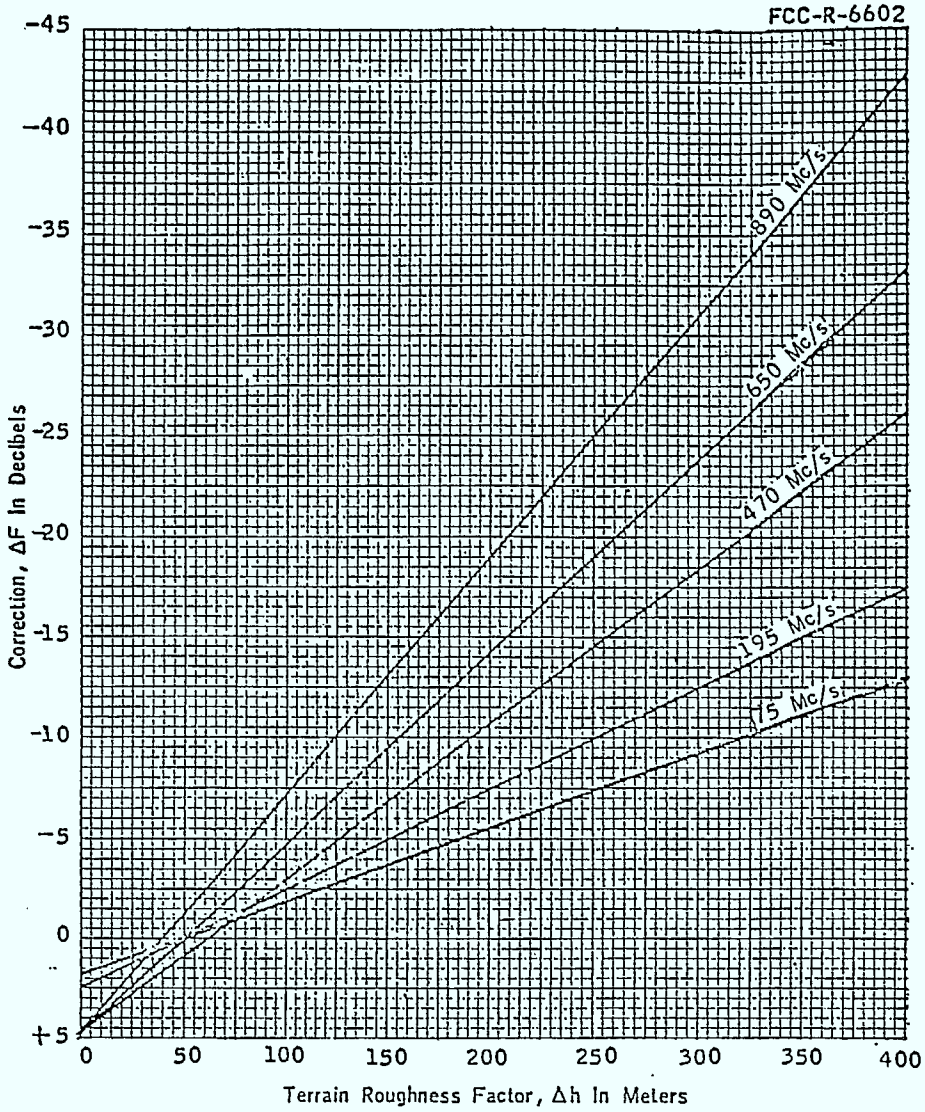

Figure 5.5-2(h): Terrain Roughness Correction

The same subjective assessment technique is used to judge the effect of interference on picture impairment. The picture quality is then related to the signal-to-interference ratio at the input to the receiver; i.e. the RF protection ratio. The RF protection ratio is the parameter used in frequency planning to determine the maximum permissible interference level at the receiver input.

The above quality assessment technique requires a large population of viewers to obtain relatively stable statistics and is consequently very expensive and time consuming. It has been observed that if a "just perceptible change in impairment" is used as the criterion, then only one or two observers are required. The particular RF protection ratio obtained with this criterion can be related to the TASO 3 grade ("passable") by subtracting 12 to 15 dB to the "just perceptible" RF protection ratio.

The grade of service that is considered "acceptable" in the presence of noise and interference appears to be between 3.5 and 4 on the CCIR five-point scale or 3 on the TASO scale.

5.6.2 Field Strengths Required for "Acceptable" Picture Quality

The measured RF protection ratios required for a specific grade of service are converted into minimum required signal field strength and the maximum permissible interference field strength.

In Canada, two grades of service are defined. Grade A service is considered the acceptable service in an urban area, while Grade B service is considered adequate service in low noise environments or where out-door antennas are used; that is, in rural or low-density areas. Table 5.6-3 gives the minimum field strengths recommended for the signal boundaries of the two service areas. The values of the field strength at the contours are designed to be protected from interference for 90 to 99% of the time.

The CCIR recommended field strengths are given in Table 5.6-4. The values correspond to the Canadian Grade B contour values.

Number	Quality of Scale	Impairment Scale
1	Excellent	Picture as good as one can desire
2	Fine	Interference is perceptible but the picture provides enjoyable viewing
3	Passable	Picture is acceptable in quality and the interference is not objectionable
4	Marginal	Picture is poor in quality and the interference is somewhat objectionable
5	Inferior	Picture is very poor but watchable. Interference is objectionable
6	Unusable	Picture is so bad that you cannot watch it

Table 5.6-1 TASO Twin Scale Grades of Service

Number	Quality Description	Impairment Description
5	Excellent	Impairment imperceptible
4	Good	Impairment perceptible but not annoying
3	Fair	Impairment slightly annoying
2	Poor	Impairment annoying
1	Bad	Impairment very annoying

Table 5.6-2: CCIR Recommended Grades of Service

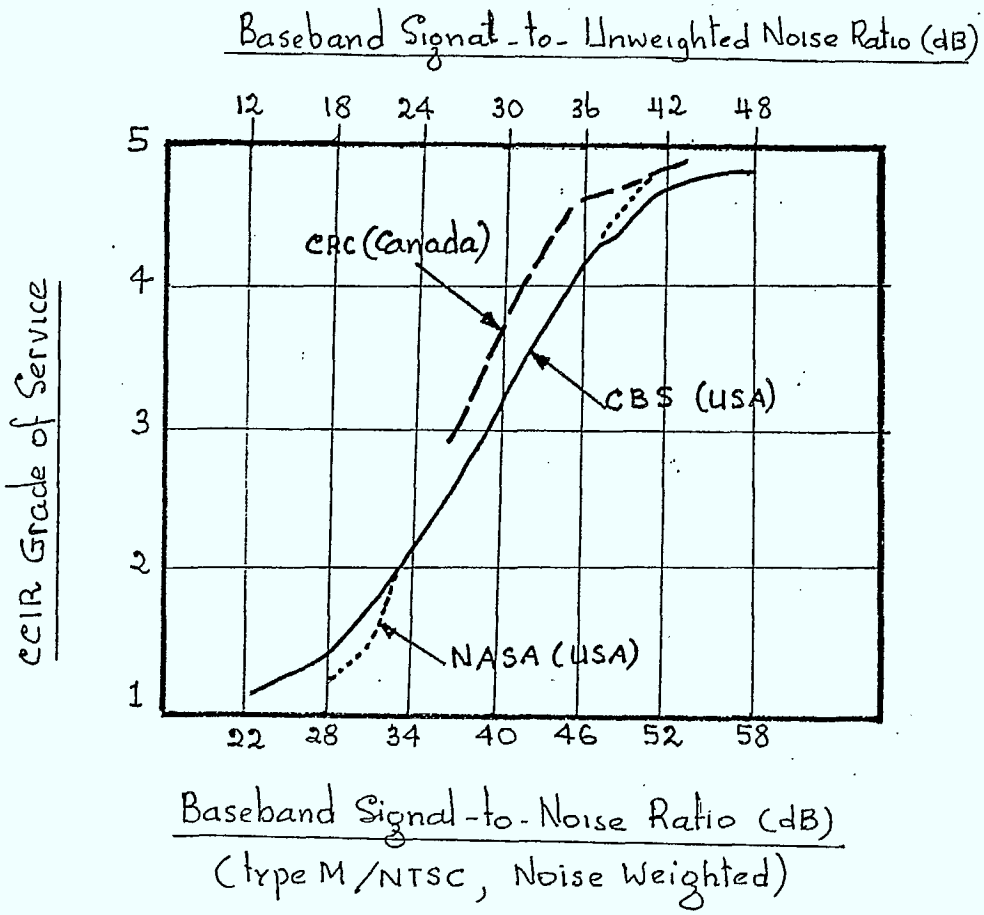

Figure 5.6-1: Measured Grade of Service vs Baseband SNR for Thermal Noise Interference

FREQUENCY	GRADES OF SERVICE	
	Grade A (dBu)	Grade B. (dBu)
channels 2 - 6 (54 - 84 MHz)	68	47
channels 7 - 13 (174 - 216 MHz)	71	56
channels 14 - 69 (470 - 806 MHz)	74	64

Table 5.6-3: DOC Grades of Service

Note:

1. The service contours of a TV station are the Grade A or B signal contours which are the boundaries (or contours) at which the field strength of a TV station, as determined by the F(50,50) propagation curves are as given in the table.

2. The FCC uses the same values as given in the table.

3. The Grade B contour is protected from interference for 90% of the time.

PARAMETERS	FREQUENCY BAND			
	Band 1 (41-68 MHz)	Band 111 (162-230 MHz)	Band 1V (470-582 MHz)	Band V (582-960 MHz)
Minimum Field Strength in the Presence of Internal and Cosmic Noise but Excluding Man-made Noise and Interference (dBu)	47	53	62	67.
Minimum Field Strength when Interference is also Present (dBu) (CCIR REC: 417-2)	48	55	65	70
Minimum Field Strength in Rural Districts (dBu) (CCIR REPORT 409)	46	49.	-	-

Table 5.6-4: CCIR Recommended Minimum Field Strengths to be Protected

Notes:

1. The minimum median field strengths at a receiver antenna height of 10 metres.
2. In arriving at the values, the receive antenna gain and the feeder loss were also considered.
3. The percentage of time for which protection may be sought lie between 90 and 99%.
4. For rural districts, it was assumed that better receivers and antenna installations are likely to be employed.
5. In a practical frequency plan, because of interference from other TV transmissions, the field strengths to be protected will generally be higher than those given above.

FREQ: BAND	Channel Separation Relative to Desired Signal Channel.	Description of Interference	RF Protection Ratio (dB)	Remarks
VHF	0	co-channel	35 (25)	no frequency offset (with 10 kHz offset)
	±1	adjacent channels	-16	
UHF	0	co-channel	28 (18)	no frequency offset (with 10 kHz offset)
	±1	adjacent channels	-16	
	±2, ±3, ±4, ±5	intermodulation	0 (D=100 dBu; U=100dBu)	The intermodulation products are generated by transmitters using different channels but located near each other. There should be no overlap of the 100 dBu, F(50,50) contours
	+7	local oscillator leakage	0 (D=74 dBu; U=74 dBu)	This is the leakage from the Receiver and is more significant in the Grade A coverage area where the Receivers are close together
	±7, ±8	IF beat and ½ IF beat		
	±14	Sound Image	-46	
	± 15	Picture Image	-28	

TABLE 5.6-5 Protection Ratios Used in Frequency Planning by D.O.C.

is this correct?
does not fit with Table 5.4.2

5.6.3 Frequency Planning Criteria

In frequency planning, TV channels and service coverage areas are assigned to different TV broadcasting systems, and technical criteria are established to ensure that mutual interference between the systems are tolerable.

The service coverage area is defined by the boundary or contour around the TV transmitter at which for 50% of the locations at this contour and for 50% of the time, the field strength of the desired signal is at the specified value. For example, for Grade B coverage, at UHF frequencies, the minimum field strength should not exceed 64 dBμ. The TV stations ERP, EHAAT, receiver HAAT, etc., are selected to ensure that the specified field strength is achieved at the service area boundary. The contour is usually defined in terms of the distance, d_w, from the transmitter. This distance is found from the F(50,50) prediction curves.

The distance, thus obtained, defines the protected contour for that TV system. It is usually required that it be protected from interference for 90% of the time. The location of the interfering transmitter, using another (or the same) TV channel relative to this contour is found thus.

1. Knowing the signal field strength at this contour and the required RF protection to provide an "acceptable" level of interference, the level of the interfering signal at this contour can be determined.

2. Using the F(50,10) prediction curves for the interfering TV system and the computed level of interference, the radial distance, d_u, between the interfering TV transmitter and the above-mentioned contour can be determined.

3. The minimum separation distance, d, between the two TV systems can thus be determined from $d = d_w + d_u$.

Frequency coordination between the different TV systems is then expressed in terms of the minimum separation distances between the transmitters of the different systems.

6.0 CHARACTERISTICS OF THE LOW POWER TELEVISION SERVICE

6.1 DESCRIPTION OF THE SERVICE

Low Power Television (LPTV) systems are intended for use in areas which have insufficient TV service, particularly in the "shadow" regions of a full-power television broadcast system. LPTV stations may retransmit the programmes and signals of a full-power TV station and may also originate programming and/or operate a subscription signal.

Like full-power TV systems, LPTV stations may provide a Grade A or Grade B quality of service at its service area contour. However, for the LPTV station, the service contour distance is restricted to 12 km in any direction from the transmitter.

LPTV systems use the same signal structure as full-power TV stations.

LPTV systems are considered to be secondary systems; i.e. established on an unprotected basis. Should the operation of an LPTV station cause interference to full-power TV stations operated on allotted channels, whether established before or after the licensing of the LPTV station, or to other radio services, remedial measures should be taken by the LPTV station to the extent of closing the station if another suitable channel cannot be found. Conversely, the LPTV station is not entitled to protection from interference from full-power TV stations on allotted channels, only from other LPTV stations.

6.2 FREQUENCY PLAN

LPTV systems may be allotted any of the channels, numbered 2 to 14 (VHF band) and 14 to 69 ((UHF band). An LPTV station will be assigned only one channel.

6.3 CHARACTERISTICS OF THE TRANSMITTER

6.3.1 Effective Radiated Power (ERP)

The ERP permitted to an LPTV station is that value required to provide a Grade B service at a contour 12 km from the transmitter, when the effective height of the antenna above average terrain is 30 metres.

The ERP's are:	Typical	Standard
Channels 2-6	50 W	100 W
Channels 7-13	400 W	100 W
Channels 14-69	500 W	5 W

FREQ: BAND	Frequency Channel Spacing of LPTV channel relative to the desired Grade B Full Power TV channel	Description of Interference	DOC (CANADA)		FCC (USA)	
			Protection Ratio (dB)	Max: Level of Interference Signal at Grade B contour (dBu)	Protection Ratio (dB)	Max: Level of Interference Signal at Grade B contour (dBu)
VHF ch: 2 - 6	0	cochannel	35 (25*)	12		
	±1	adjacent channel	-16	63		
ch: 7 - 13	0	co channel	35 (25*)	21		
	±1.	adjacent channel	-16	74		
UHF (ch: 14 - 69)	0	cochannel	28 (18*)	36	45 (28*)	19
	±1	adjacent channel	-16	80	-15	79
	±2, ±3, ±4, ±5	intermodulation	(min: separation: 20 km)		(min: separation: 20 miles)	
	+7	local oscillator radiation	(min: separation: 60 km)		(min: separation: 60 miles)	
	±14	sound image	-28	92	-23	87
	±15	picture image	-10	74	-6	71.

NOTE: * indicates the protection ratio when an offset in visual carrier frequency of 10 KHz ±1 KHz is used

Table 6.6-1: Interference Levels from a Low-Power TV Station at the Grade B Contour of a Full-Power TV Station

The effective antenna height above average terrain is determined using four radials (0°, 90°, 180° and 270°), and the average height of the terrain on each radial is calculated over a distance of 0 to 5 km from the transmitter. The average of the terrain heights of the four radials is then found and used as the average terrain height.

6.3.2 Other Parameters

The values of the other transmitter parameters, e.g. transmit frequency stability and spurious emissions are the same for the LPTV station as for the full-power TV station.

6.3.3 Antenna Radiation Pattern

The radiation pattern for LPTV transmit antennas may be omnidirectional in azimuth as in the full-power TV stations. However, in some cases, depending on the service area, the radiation pattern may be directive in azimuth.

6.4 CHARACTERISTICS OF THE RECEIVER

The same characteristics are required for the LPTV receiver as for the full-power TV transmitter.

6.5 PROPAGATION CHARACTERISTICS

The same prediction curves used for the land mobile and full-power TV broadcast services apply for the LPTV service if due allowance is made for the relatively low (30 metre) antenna height of the LPTV station.

6.6 QUALITY OF SERVICE DESCRIPTIONS FOR INTERFERENCE

The Grade B service contour of the full-power TV station is protected from interference for 90% of the time. The interference levels, protection ratios and station separation distances employed by DOC (Canada) and by FCC (US) are given in Table 6.6-1.

7.0 REVIEW OF LICENSING CRITERIA

7.1 INTRODUCTION

In planning the frequency spectrum allocation between services and its assignment between users of the same service, the prime consideration is to ensure that mutual interferences do not degrade the quality of service of the users beyond what is considered acceptable.

Most administrations use the same procedure to determine the minimum coordination distances required between two transmitters in the same service, but the actual coordination distances will differ largely because of the differences in the protection ratios

and in the prediction curves used to determine the propagation loss of a path. The protection ratio depends on the modulation used, the type of transmission (PAL, SECAM, NTSC, etc.), and even the viewing habits of the observers who grade the impairment. The prediction curves will vary depending on the terrain type, structure density, environmental type, etc., where the measurements were made. Each administration generally uses the data derived from measurements made in their countries. These factors make it difficult to compare the coordination practices of different administrations.

In what follows, the Canadian licensing criteria will be provided and, where applicable, the criteria of other administrations will be discussed.

7.2 LAND MOBILE SERVICE LICENSING CRITERIA

The minimum median field strength at the service area contour of a land mobile system is strongly dependent on the man-made and multi-path noise at the receiver input. These noise components, in turn, are influenced by several factors; e.g. traffic density, environmental type, speed of the mobile unit, etc. CCIR Report 358-3 provides curves that may be used to compute the required field strength for a Grade 4 signal quality under various conditions and for various frequencies. These curves indicate that a median field strength from 21 to 26 dBμ at the service area contour will give a signal quality of Grade 4. The DOC uses the values of receiver input powers as given in Table 7.2-1. Most administrations require that this signal quality be protected from interference for 90% of the time. In the land mobile service, the base station receiver is generally more susceptible to interference than the mobile receivers; and hence, it is the base station, rather than its service contour which requires protection. The protection ratio (RF) of 8 dB, minimum, is used by most administrations.

The contour radius in most administrations seldom exceeds 30 km or 20 miles.

Frequency Range (MHz)	Receiver Input Power (dBW) for SINAD = 12 dB			
	Base Station			Mobile Station
	High Noise	Average Noise	Low Noise	
22 – 50	-131	-139	-143	-127
150 – 170	-132	-141	-148	-137
450 – 470	-138	-145	-146	-146

Table 7.2-1: Minimum Receiver Input Power (dBW) for the Land Mobile Service

7.3 TV BROADCAST SERVICE LICENSING CRITERIA

CCIR, DOC and FCC all specify practically the same minimum median field strength at the service area contour. In Canada and the US, this is called the Grade B contour; in these countries, there is also a higher quality, Grade A, which requires a higher level of minimum median field strength at its boundary. The Grade B contour is required to be protected from interference for 90% of the time.

The protection ratios used by FCC are slightly higher than those used by DOC as shown in Table 6.6-1. The coordination distances recommended by DOC for frequency planning purposes are given in Tables 7.3-1 and 7.3-2.

7.4 LOW POWER TV SERVICE LICENSING CRITERIA

The low-power TV service is considered a secondary service in both Canada and the US; and a licence to operate an LPTV station, is granted providing that it does not cause "excessive" interference with existing and planned full-power TV broadcast stations and other radio services.

In Canada, the service contour for an LPTV station is restricted to 12 km in any direction from the transmitter. By common agreement, all proposed LPTV assignments in Canada, with 32 km of the common border with the US, must be cleared with the US.

Both the US and Canada require that the Grade B contour of the full-power TV station be protected for 90% of the time. However, Table 6.6-1 indicates that Canada, by specifying lower protection ratios, permits larger levels of interference at the Grade B contour.

The coordination distances between LPTV stations and full-power TV stations, as used in Canada, are given in Tables 7.4-1 to 7.4-3.

Parameters			channels 2-6 (54-88 MHz)	channels 7-13 (170-220 MHz)
Coverage characteristics	Transmitter, ERP	(KW)	100	325
	Antenna Height, EHAAT	(m)	150	150
	Grade B Field Strength	(dBu)	47	56
	Distance to Grade B Contour	(km)	89	82
Minimum Separation Distance	Co-channel – no offset $\left(\frac{D}{u} = 35\,dB\right)$	(km)	(420 *)	(350 *)
	Co-channel – offset $\left(\frac{D}{u} = 18\,dB\right)$	(km)	(310 *)	(250 *)
	Adjacent Channel $\left(\frac{D}{u} = -46\,dB\right)$	(km)	96	96

NOTE : * These distances are well beyond the horizon.

TABLE 7.3-1 Standard Separation distances for VHF

Class of Allotment/Assignment		Channel separation r, number of channels above (+) or below (-) the reference channel n										
		0		±1	±2, ±3,	+4	-4	±7	+14	+15	-14	-15
		Co-channel		Adjacent	IM	Adjacent	Adjacent*	Oscillator	Sound	Picture	Sound	Picture
Channel Accorded Protection n Desired(D)	Potential Interfering Channel n+r Undesired(U)	No-offset D/U=35dB D=64dBu U=29dBu	Offset D/U=18dB D=64dBu U=46dBu	D/U=-16dB at D=74dBu and D/U=-36dB at D=64dBu	No overlap D=100dBu U=100dBu	Locate Outside D=74dBu	Locate Outside D=74dBu	No overlap D=74dBu U=74dBu	Image D/U=-46dB D=64dBu U=110dBu	Image D/U=-28dB D=64dBu U=92dBu	Image * D/U=-46dB D=64dBu U=110dBu	Image * D/U=-28dB D=64dBu U=92dBu
C	C	353	250	88	36	54	54	106	80	99	80	99
C	B	328 *	225 *	77	25	54	30	83	74	82	55	74
C	A	308 *	205 *	73	21	54	14	68	72	75	35	54
B	C	328	225	77 *	25	30	54	83	55	74	74	82
B	B	248	153	52	14	30	30	60	49	57	49	57
B	A	228 *	133 *	48	10	30	14	45	47	50	29	37
A	C	308	205	73 *	21	14	54	68	35	54	72	75
A	B	228	133	48 *	10	14	30	45	29	37	49	50
A	A	163	85	28	6	14	14	30	27	30	27	30

* Protection Provided at Potential interfering Channel's 64 or 74dBu Contour.

TABLE 7.3-2 Standard Separation Distances in km Required between Canadian Classes of UHF Television Allotments and Assignments.

TABLE 7.4-1

MINIMUM DISTANCE SEPARATIONS IN KILOMETRES REQUIRED

BETWEEN A LOW-POWER UHF TELEVISION STATION AND OTHER

CLASSES OF UHF TELEVISION ALLOTMENTS OR ASSIGNMENTS

Class of Station/System		Channel separation r, number of channels above (+) or below (-) the reference channel n						
		0 Co-channel		±1 Adjacent	±2, ±3, ±4 Inter-modulation	-7 Oscillator Radiation	+14 Sound Image	+15 Picture Image
Channel Accorded Protection n Desired (D)	Channel Applied For n + r Undesired (U)	Non-offset D/U = 28dB D = 64dBu U = 36dBu	Offset D/U = 18dB D = 64dBu U = 46dBu	D/U = -16dB D = 64dBu U = 80dBu	D/U = 0dB D = 100dBu U = 100dBu	D/U = 0dB D = 74dBu U = 74dBu	D/U = -28dB D = 64dBu U = 92dBu	D/U = -10dB D = 64dBu U = 74dBu
C	LP	140	107	75	20	60	72	77
B	LP	115	82	50	9	37	47	52
A	LP	95	62	30	5	22	27	32
LP	LP	82	49	17*	3*	14	14*	19

Note 1: Distances are based on a UHF low-power station operating at 5 kW ERP and 30 metres EHAAT (with a Grade B contour of 12 kilometres) and other UHF stations operating with parameters according to the class designations shown in paragraph 4.8. For other low-power parameters the desired-to-undesired (D/U) ratios in the Table must be satisfied at the desired contour.

Note 2: In principle, those distances marked with an asterisk (*) may be eliminated if stations are co-sited.

Note 3: Offset operations require a frequency stability of ±1000 Hz.

TABLE 7.4-2

MINIMUM DISTANCE SEPARATIONS IN KILOMETRES REQUIRED

BETWEEN LOW-POWER (LP) VHF AND OTHER CLASSES OF VHF TELEVISION ALLOTMENTS OR ASSIGNMENTS

Class of Station/System		Channels 2 - 6			Channels 7 - 13		
		Channel Separation r, number of channels above (+) or below (-) the reference channel n					
		0 Co-channel		±1 Adjacent	0 Co-channel		±1 Adjacent
		Non-offset	Offset		Non-offset	Offset	
Channel Accorded Protection n Desired (D)	Channel Applied For n + r Undesired (U)	D/U = 35dB D = 47dBu U = 12dBu	D/U = 25dB D = 47dBu U = 22dBu	D/U= -16dB D = 47dBu U = 63dBu	D/U = 35dB D = 56dBu U = 21dBu	D/U = 25dB D = 56dBu U = 31dBu	D/U = -16dB D = 56dBu U = 72dBu
Regular	LP	209	159	94	158	123	85
LP	LP	132	82	17*	84	49	11*

Note 1: Distances are based on VHF low-power operations having 100 watts ERP and 30 metres EHAAT and regular stations operating with the maximum values given in paragraph 4.8. For other low-power parameters, the desired-to-undesired (D/U) ratios in the table must be satisfied.

Note 2: The Grade B contour is 12 kilometres and 8 kilometres respectively for channels 2-6 and 7-13.

Note 3: In principle, those distances marked with an asterisk (*) may be eliminated if stations are co-sited.

Note 4: Offset operations require a frequency stability of ±1000 Hz.

TABLE 7.4-3

DISTANCE SEPARATIONS IN KILOMETRES REQUIRED TO ASSURE MINIMUM INTERFERENCE WITHIN THE GRADE B (64 dBu) SERVICE AREA OF LOW POWER UHF TELEVISION BROADCASTING STATIONS FROM OTHER CLASSES OF UHF TELEVISION ALLOTMENTS OR ASSIGNMENTS

Class of Station/System		Channel separation r, number of channels above (+) or below (-) the reference channel n						
Channel Applied For n Desired (D)	Channel Causing Interference n + r Undesired (U)	0 Co-channel Non-offset D/U = 28dB D = 64dBu U = 36dBu	0 Co-channel Offset D/U = 18dB D = 64dBu U = 46dBu	±1 Adjacent D/U= -16dB D = 64dBu U = 80dBu	±2, ±3, ±4 Inter-modulation D/U = 0dB D = 100dBu U = 100dBu	-7 Oscillator Radiation D/U = 0dB D = 74dBu U = 74dBu	+14 Sound Image D/U= -28dB D = 64dBu U = 92dBu	+15 Picture Image D/U = -10dB D = 64dBu U = 74dBu
LP	C	252	192	62	20	60	41	72
LP	B	175	122	35	9	37	24	44
LP	A	114	72	22	5	22	17	27
LP	LP	82	49	17*	3*	14	14*	19

Note 1: Distances are based on a UHF low-power station operating at 5 kW ERP and 30 metres EHAAT (with a Grade B contour of 12 kilometres) and other UHF stations operating with parameters according to the class designations shown in paragraph 4.8. For other low-power parameters, the desired-to-undesired (D/U) ratios in the Table must be satisfied at the desired contour.

Note 2: In principle, those distances marked with an asterisk (*) may be eliminated if stations are co-sited.

Note 3: Offset operations require a frequency stability of ±1000 Hz.

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CHAPTER II

INVESTIGATION OF TECHNICAL CONSIDERATIONS INVOLVED IN THE POSSIBLE SHARING OF THE SPECTRUM BETWEEN THE TWO SERVICES - PHASE II

CHAPTER II

INVESTIGATION OF TECHNICAL CONSIDERATIONS INVOLVED IN THE POSSIBLE SHARING OF THE SPECTRUM BETWEEN THE TWO SERVICES

PHASE II

1.0 INTRODUCTION

1.1 PURPOSE

In Chapter I, the existing licensing criteria used by different administrations for the TV Broadcast Service and for the Land Mobile Service were reviewed and the significant technical parameters were clearly defined. In the first phase of the study, interference was considered between systems in the same service- i.e. TV interfering with TV and land mobile service (LMS) with LMS. The purpose of the second phase of the study was to consider mutual interference between signals from the two services and to establish technical criteria for the possible sharing of the VHF and UHF TV broadcast spectrum between the two services.

Sharing between a high power service (TV) and a low power service (LMS) in the same spectrum is far from ideal. TV services use considerably higher radiated power than mobile services (typically 40dB more) and mobile services operate at considerably lower usable field strengths (typically 30dB less). The resulting 70 dB difference in the planning criteria suggest that only limited sharing will be possible. However, in practice several factors help to make sharing between these two services feasible:

- the mobile service requires a much lower protection ratio (typically 40 dB less) than TV
- the mobile service coverage areas are smaller
- TV bandwidths are much larger than the mobile service bandwidth (6 MHz versus 16 KHz)
- TV may use horizontal polarization to obtain further signal discrimination from the vertical polarization used by the mobile service.

The purpose of this chapter is to document the conditions under which sharing becomes feasible.

1.2 CHAPTER FORMAT

Section 1 provides an introduction and Section 2, the reference information used during the study. Section 3 reviews the existing licensing criteria for the FCC and the D.O.C. for the two services independently. This has been included in this chapter for completeness. Section 4 considers the experiences and criteria used for inter-service sharing by the UK administration and by the FCC. Section 5 considers the main technical parameters involved in inter-service sharing while Section 6 gives the proposed licensing criteria for Canada for inter-service sharing.

2.0 DOCUMENTATION

2.1 REFERENCES:

CCIR Documents: √ - Rec 370 (5)
√ - Report 567 (2)
× - Report 358 (4)
√ - Report 417 (6)
× - Report 899

FCC Documents √ - FCC Docket: 18261
√ - FCC Report: R-6602 (1966)
√ - FCC/OST: r-83-3, Oct. 1983
√ - FCC 85-289 (35820)
- FCC Report - Project 2229-63 (1968/69

√ D.O.C. Documents - CRTPB Ad Hoc Committee Report: project 6
- "Image Interference to UHF TV Reception from Land Mobile operation in the 806-890 MHz Band," Oct. 1979 (TK 6643)

√ "E.M.C Handbook" by White, Volume 3, p. 5.83.

× - Conf: BCC (1985). John Durkin and Roger Skiffins "Band III - A New Mobile Radio Service for the United Kingdom"

× - IEEE Trans: V.T, November 1974, pp 129-134, John H. McMahon "Interference and Propagation formulas and Tables used in the FCC Spectrum Management Task Force Land Mobile Frequency Assignment Model"

× - IEEE Trans: V.T, November 1974, pp 135-138, Edward A. Neham "An Approach to Estimating Land Mobile Radio Coverage"

- IEEE Trans V.T, May 1973, pp 21-29, Albrecht P. Barsis "Determination of Service Area for VHF/UHF Land Mobile and Broadcast Operations Over Irregular Terrain"

× - Proc IRE, October 1957, pp 1,383-1,391, John J. Egli "Radio Propagation Above 40 MHz Over Irregular Terrain"

- IEEE Trans: V.T, Mar. 1983, pp 206-208, S.N. Ahmed and P. Constantinou
  "A Mobile Interference Model into UHF Television Receivers"

- IEEE Trans: V.T, August 1984, pp 244-249, Reed E. Fisher
  "UHF Television Interference Associated with Cellular Mobile Telephone System"

2.2 DEFINITIONS

Allocation:	provision of a band of frequencies for a particular purpose or service
Allotment:	provision of a specific channel for a particular community
Assignment:	the authorized use of a allotment for a TV station
Service Contours:	the service contours of a broadcast station are the boundaries or contours at which the field strength of the station's emissions are at a specified value for X% of the locations at that contour and for Y% of the time. for interference purposes, the F(50,50) contour is used. The service contour defines the outer limit of the protected service area
Interfering Signal Contour:	OL is the contour (from the interfering broadcast station) at which the maximum specified interfering signal field strength is received for 50% of the locations and for 10% of the time. It is the F(50,10) contour of the interfering station.
Protection Radio:	the RF protection ratio is the ratio of the desired signal to the undesired (or interfering) signal at the receiver input required to produced an acceptable degree of impairment to the output signal.
Polarization:	direction of the electric field strength vector of a radiated field
Inter-Service Sharing:	use of the same spectrum by the TV broadcast service and the land mobile service

2.3 ABBREVIATIONS

ERP	effective radiated power which is the product of the transmitter and power at the input to the transmit antenna and the gain of the antenna relative to that of a half-wave dipole antenna in the direction of the receive antenna
EHAAT	effective height of the antenna above the average terrain
FM	frequency modulation
VSB-AM	vestigial sideband, amplitude modulation
dBμ	level of field strength in decibels above 1 V/m.
LPTV	low power television
LMS	land mobile service
D.O.C.	Dept. of Communications, Canada
F.C.C.	Federal Communications Commission, U.S.A.
F(50,50)	the field strength at the service contour which is received by 50% of the locations at the contour for 50% of the time
F(50,10)	the field strength at the service contour which is received by 50% of the locations at the contour for 10% of the time
SNR	signal-to-noise ratio
S/X	signal-to-interference ratio at the receiver output
C/I	RF desired carrier to interference signal ratio at the receive input

3.0 REVIEW OF LICENSING CRITERIA FOR THE SERVICES

3.1 INTRODUCTION

This information was presented in Chapter I in greater detail. It is included here for completeness and for comparison with the information proposed for inter-service sharing licensing criteria.

3.2 PROTECTION OF THE TV BROADCAST SERVICE

VHF channels (Regular Transmitters)

Table 3-1 gives the separation requirements for VHF transmitters in Canada

Table 3-2 gives the separation distance requirements between VHF transmitters in Canada and the U.S.A.

UHF channels (Regular Transmitters)

Table 3-3 gives the separation distances for UHF transmitters in Canada

Table 3-4 gives the separation distances for UHF transmitters in Canada and U.S.A.

LowPower TV Transmitters

Table 3-5 gives the separation distances between LPTV transmitters and regular transmitters in the VHF channels

Table 3-6 gives the separation distances between LPTV transmitters and the regular transmitters in the UHF channels

Parameters		channels 2-6 (54-88MHz)	channels 7-13 (170-220MHz)
standard ERP (kW)		100	325
standard EHAAT (m)		300	300
Max: Protected Grade B Contour (km)		89	82
Minimum Separation for Adj: channel (km)		96	96.
Max: Permissible Co-channel Inter-ference Levels at Grade B Contour	No offset	15 dBu	24 dBu
	offset (10 or 20 kHz)	32 dBu	41 dBu
	Precision offset	39 dBu	48 dBu

Table 3-1: Separation Requirements for VHF Allotments

Frequency Relationships	Separation (KM)
Co-channel; Zone 1 or 2, Canada	275 for Zone 1, USA
Co-channel: Zone 2, Canada	305 for Zone 2, USA
Co-channel: Zone 1, Canada	275 for Zone 2, USA
Adjacent Channel	95

Table 3-2: Separation Requirements Canada/USA for VHF

Class of Assignment		Minimum Separation Distance (Kms)										
		Co-channel $n = 0$		Adjacent channel	Intermod:			Oscillator	Sound Image	Picture Image	Sound Image	Picture Image
Desired	Undesired	No Offset	Offset	$n \pm 1$	$n \pm 2, \pm 3$	$n+4$	$n-4$	$n \pm 7$	$n+14$	$n+15$	$n-14$	$n-15$
C	C	353	250	88	36	54	54	106	80	99	80	99
C	B	328	225	77	25	54	30	83	74	82	55	74
C	A	308	205	73	21	54	14	68	72	75	35	54
B	C	328	225	77	25	30	54	83	55	74	74	82
B	B	248	153	52	14	30	30	60	49	57	49	57
B	A	228	133	48	10	30	14	45	47	50	29	37
A	C	308	205	73	21	14	54	68	35	54	72	75
A	B	228	133	48	10	14	30	45	29	37	49	50
A	A	163	85	28	6	14	14	30	27	30	27	30
Protection Ratios	D	64 dBu	64 dBu	64 dBu	100 dBu	Locate outside D = 74 dBu	Locate outside D = 74 dBu	74 dBu	64 dBu	64 dBu	64 dBu	64 dBu
	U	29 dBu	46 dBu	100 dBu	100 dBu			74 dBu	110 dBu	92 dBu	110 dBu	92 dBu
	D/U	35 dB	18 dB	−36 dB				No Overlap	−46 dB	−28 dB	−46 dB	−28 dB

Table 3.3: Standard Separation Distances of UHF TV Allotments and Assignments

Frequency Relationship	Separation (KM)
Co-channel ; Zone 1 or 2 (Canada)	250 for Zone 1 (USA)
Co-channel : Zone 2 (Canada)	280 for Zone 2 (USA)
Co-channel : Zone 1 (Canada)	250 for Zone 2 (USA)
Adjacent channel , $n \pm 1$	90
Intermodulation , $n \pm 2, \pm 3, \pm 4, \pm 5$	30
Local Oscillator , $n \pm 7$	95
Intermediate Frequency Beat , $n \pm 8$	30
Sound Image ($n \pm 14$)	95
Picture Image ($n \pm 15$)	120

Table 3.4: Separation Requirements Canada/USA for UHF

Desired channel	Undesired channel		Minimum Separation Distance (KM)					
			CHANNELS 2 - 6			CHANNELS 7-13		
			Co-channel, n=0		Adjacent channel n±1	Co-channel, n=0		Adjacent channel n±1
			No offset	Offset		No offset	Offset	
Regular	LP		209	159	94	158	123	85
LP	LP		132	82	17	84	49	11
Signal Levels and Protection Ratios		D	47 dBu	47 dBu	47 dBu	56 dBu	56 dBu	56 dBu
		U	12 dBu	22 dBu	63 dBu	21 dBu	31 dBu	72 dBu
		D/U	35 dB	25 dB	-16 dB	35 dB	25 dB	-16 dB

Table 3.5: Minimum Separation Distances Between LPTV Transmitters and Regular TV Broadcast Transmitters at VHF

Desired	Undesired		Minimum Separation Distances (km)						
			Cochannel n = 0		Adjacent channel	Intermod.	Oscillator	Sound Image	Picture Image
			No offset	offset	n ± 1	n ±2, ±3, ±4	n-7	n + 14	n+15
C	LP		140	107	75	20	60	72	77
B	LP		115	82	50	9	37	47	52
A	LP		95	62	30	5	22	27	32
LP	LP		82	49	17	3	14	14	19
Signal Levels and Protection Ratios		D	64 dBu	64 dBu	64 dBu	100 dBu	74 dBu	64 dBu	64 dBu
		U	36 dBu	46 dBu	80 dBu	100 dBu	74 dBu	92 dBu	74 dBu
		D/U	28 dB	18 dB	-16 dB	0 dB	0 dB	-28 dB	-10 dBu

Table 3-6: Minimum Separation Distances between LPTV and TV Broadcast Transmitter at UHF

4.0 VIEW OF INTER-SERVICE SHARING CRITERIA BY OTHER ADMINISTRATIONS

4.1 INTRODUCTION

The rapid growth of both public and private land mobile services has forced administrations to find additional spectrum for this service. This situation has been foreseen at the ITU World Administrative Radio Conference in 1979. The CCIR in draft Question BA/8 has requested members to investigate "what planning criteria apply for the protection of the mobile service and broadcasting service (television and sound) from mutual interference in those parts 8 and 9 that may be shared, taking into account where appropriate, the mobile satellite service."

The two countries in which the investigation has been pursued most vigorously are the United Kingdom and the USA. In the UK, Band III (162-230 MHz) has been allocated entirely to the Land Mobile Service but the neighbouring countries still use this band for the TV Broadcast Service. This has led to mutual interference problems between the two services and has spurred the administration to investigate the problems. In the USA, the growth of the Land Mobile Service has been phenomenal. Moreover, many of the services provided by the LMS have now been considered as essential services for the community. Since a considerable portion of the preferred spectrum has already been allocated to the TV Broadcast Service, additional spectrum for the LMS can only be obtained by inter-sharing the available spectrum between the two services.

4.2 U.K./EUROPE INTER-SERVICE SHARING CRITERIA

4.2.1 Introduction

In the UK, the land mobile service is expanding at a rate of 8-10% per annum and it has been predicted that by the end of 1990, the number of mobiles would exceed 700,000 and by the end of the century the number could exceed two million. the number of two-way channels required by the end of 1990 to accommodate the traffic has been predicted to be 1784 i.e. 27 MHz of additional spectrum would be required for a system using 15 KHz channel separation.

The International Table of Frequency Allocations, in a footnote, has enabled the land mobile service to operate in several European countries in television Bands I (41-68 MHz) and III (162-230 MHz) and the upper part of Band V (582-960 MHz). The UK administration accordingly recommended that the TV broadcasting be withdrawn from Bands I and III by the end of 1984 and these bands be re-used thereafter for mobile services. Band III is still used by western Europe, France and Ireland for 625-line television broadcasting. The inter-service sharing of the Band III spectrum between UK and France is shown in Figure 4.2-1.

4.2.2 Protecting the Land Mobile Service

4.2.2.1 Determining the Maximum Interfering Field Strength

In order to determine the levels of interference to the Land Mobile Service, it is first necessary to establish the level of minimum usable signal CCIR Rep. 358 (4) gives the minimum median usable field strength, Emin, as:

$$Emin = -41 + d + 20\log F \quad (dB\mu) \qquad 1)$$

where F = frequency in MHz
d = degradation factor in dB providing a margin for fading due to multi-path propagation and man-made noise

Assuming a grade 4 quality, the minimum median field strength for Band III is:

Emin = 22 dBμ (as per Equation (1))

The maximum permissible interfering signal level can be determined from:

$$Emax = Emin - a - hg + b \quad (dB\mu)$$

where a = carrier to interference protection ratio
hg = height gain factor with respect to 10 m.
b = antenna discrimination factor due to cross-polarization

Table 1 gives the values for Emax for both the base station and the mobile station.

4.2.2.2 Determining the Minimum Separation Distance

Knowing the maximum interfering field strength, Emax, the required minimum separation distances to protect land mobile services can be established. For a narrowband channel (12.5 KHz spacing, 7 KHz UK bandwidth, the interfering field strength for any given mobile channel will depend on its portion within the television channel

Figure 4.2-2 shows the maximum power spectral density of a SECAM TV signal, as used in France, measured in 7 KHz bandwidth for a normal average picture content. For much of the TV channel between the vision and the sound carriers, the power is at least 40 dB below the total power except in the vicinity of the colour sub-carrier where the value is 30 dB down.
Assuming an ERP of 250 KW and EHAAT of 300m for a typical TV transmitter, receive antenna heights of 1.5m (mobile stations) and 20m (base stations) and the maximum interfering field strengths, Emax, of Table 2, the minimum separation distance from the TV transmitter can be determined using the F(50,10) prediction curves of CCIR Rec 370 (5). The results are given in Table 2.

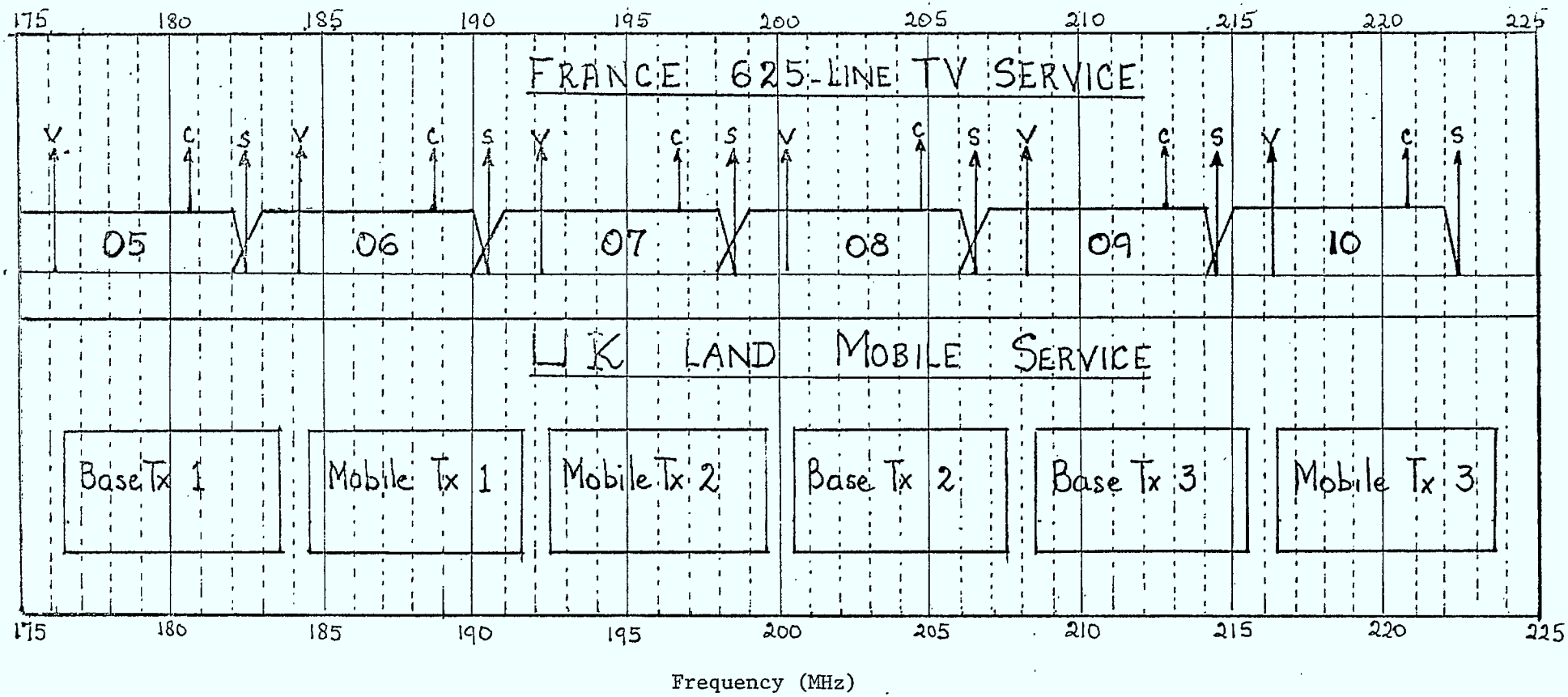


Figure 4.2-1: Use of Band III By UK and France

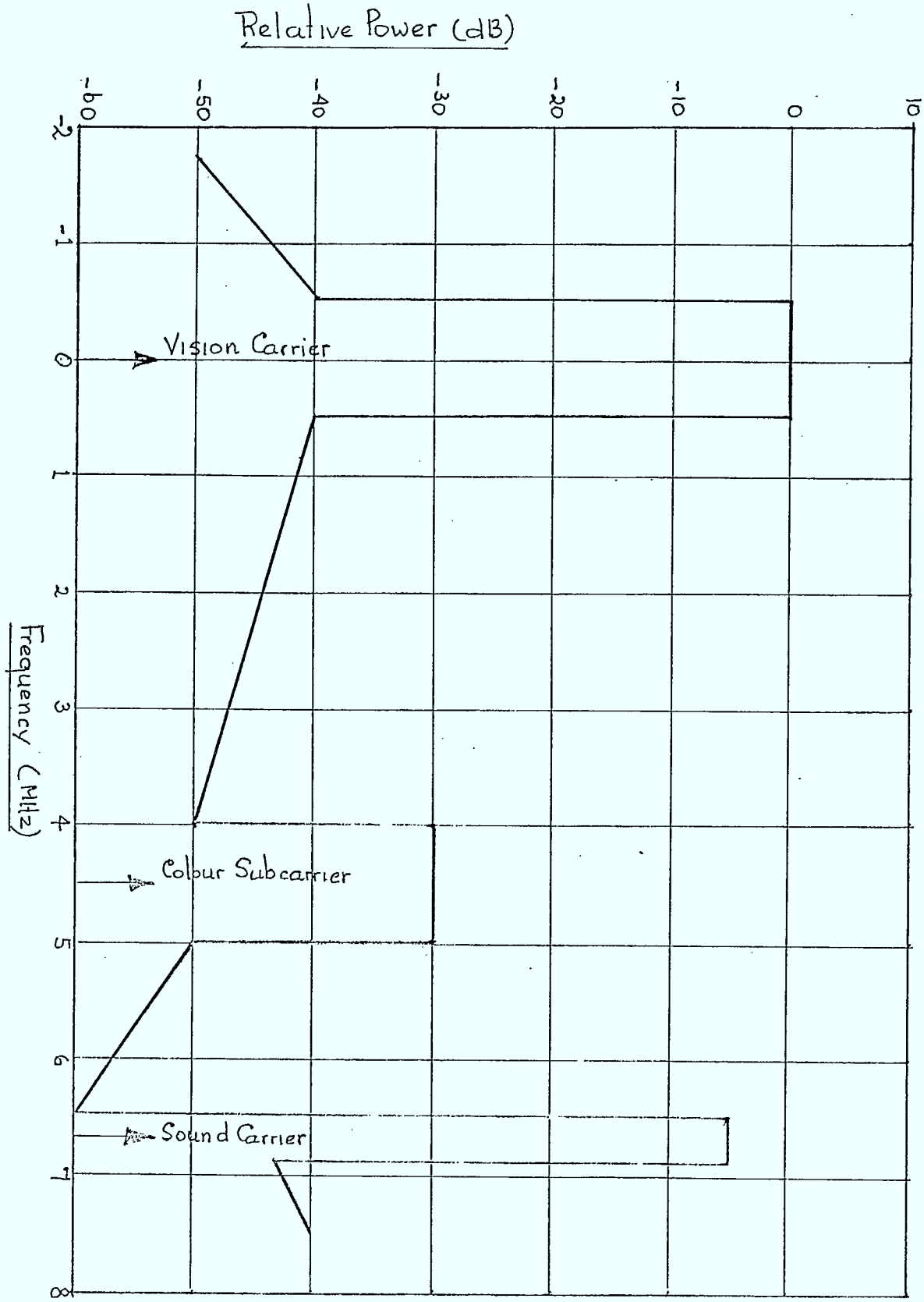


Figure 4.2-2: Power in a Television Signal Measured in a 7 kHz Bandwidth

Parameters	Base Station		Mobile Station	
	VP	HP	VP	HP
E_{min} (dBu)	22	22	22	22
a (dB)	10	10	10	10
hg (dB)	6	6	-4.5	-4.5
b (dB)	0	18	0	8
E_{max} (dBu)	6	24	16.5	24.5

Notes:
1. The desired signal is FM and the interferer is AM
2. Base antenna height = 20 m
3. Mobile antenna height = 1.5 m
4. The LMS polarization is VP, but the TV signal polarization may be VP or HP
5. A protection ratio of 10 dB for an AM interferer is proposed in CCIR Report 358(4)

Table 1: Maximum Interfering Field Strength

TV Polarization	"ON" TV Carrier	"BETWEEN" TV Carriers*
Vertical	530 km	250 km
Horizontal	350 km	120 km

* TV radiated power assumed to be 30 dB below total radiated power

Table 2: Minimum Separation Distances

4.2.3 Protecting the Television Signal

CCIR Rec 417 (6) provides values of minimum median usable field strength to be protected for use in planning TV services. For Band III, this value is 55 dBμ. The percentage of time for which protection is given is recommended to be between 90% and 99% and a figure of 95% may be assumed particularly since a sea path is involved between the interfering signal (from UK) and the TV service area (in France).

CCIR Rep 306 (7) and Rec 418 (8) provide signal to interference protection ratios which, for narrowband interference leads to a maximum value of 50 dB at the carriers with correspondingly lower values elsewhere in the TV channel. A protection ratio curve for the L/SECAM system used in France is shown in Figure 4.2-3. The assumption in Figure 2 is of a single source of interference whereas, due to the large differences in bandwidth between the mobile and the television services, it is likely that between 300 and 400 mobile transmitters could abe operating within a single television channel.

CCIR Rep 945 (9) outlines a simplified multiplication method for dealing with multiple interfering sources and this method has been adopted for Band III planning. The method has the advantage over a direct power summation of taking account of the statistical variation in the locations of offending transmitters. The "nuisance" field (e) from each base station site is first calculated from:

$$e = \sqrt{\sum_{i=1}^{n} (a_i \, b_i \, E_{ni})^2} \qquad 3$$

where I = number of co-sited transmitters

a_i = protection ratio associated with the base transmitter

b_i = receive antenna discrimination factor (15dB for orthogonal polarization)

Eni = field strength at the edge of the TV service area for the i-th transmitter

The usable field strength, Eu, is then calculated from:

$$P_c = \prod_{j=1}^{j=n} L(E_u - E_{sj})$$

where P_c = coverage probability (typically 50% of locations)

L = probability integral force normal distribution

Eu = usable field strength in dBμ

Esj = nuisance field associated with the j-th base station in dBμ as given by "e" in Equation (3)

The problem of protecting TV services has to consider the effect of emissions from the mobile stations. In this case, the interfering field strength ("e") varies as the location of a mobile changes. It has been shown that the average interfering field strength from a mobile station is at least 20 dB below the field strength of its associated base station. Calculations can be made, as for the base stations, but with interference levels reduced by 20dB.

To minimize the effects of interference into the TV channels in France, the procedure included:

1) restricting the heights of the base station antennas

2) using directional antennas at the base stations

3) using that part of the TV spectrum with the lowest protection ratio (near the sound carrier as can be seen from Figure 2) for the base station transmitters' frequency band.

The usable field strength determined from the accumulated nuisance fields in Eq (4) cannot exceed 55 dBμ although agreements had been reached with the French Administration to plan for 70 dBμ at Boulogne and 65 dBμ at certain other parts of the French coast.

Consider the case of a base station in London and another in Dover. Table 3 shows that the nuisance field in the Boulogne area is 38 dBμ for the London base station. This is 32 dB below the agreed usable field strength of 70 dBμ. Some 1,500 transmitters could be operating in London before the interference limit is exceeded. For the Dover base station, the nuisance field for a single base station exceeds the usable field strength value, due, in part, to the high protection required for a non-fading path.

A usable mobile service can be obtained in the South East of England, however, by:

- reducing base station antenna heights (below 150m)

- employing directional antennas

- using frequencies (of the TV channel) which require lower protection ratios (lower than 45 dB). For example, a protection ratio of 35 dB could be used.

i.e. If the Dover station uses h_T = 35 m, ERP = 2.5W and directional antenna discrimination of 10 dB, the nuisance field would be reduced to some 22 dB below the usable field strength of 70 dBμ.

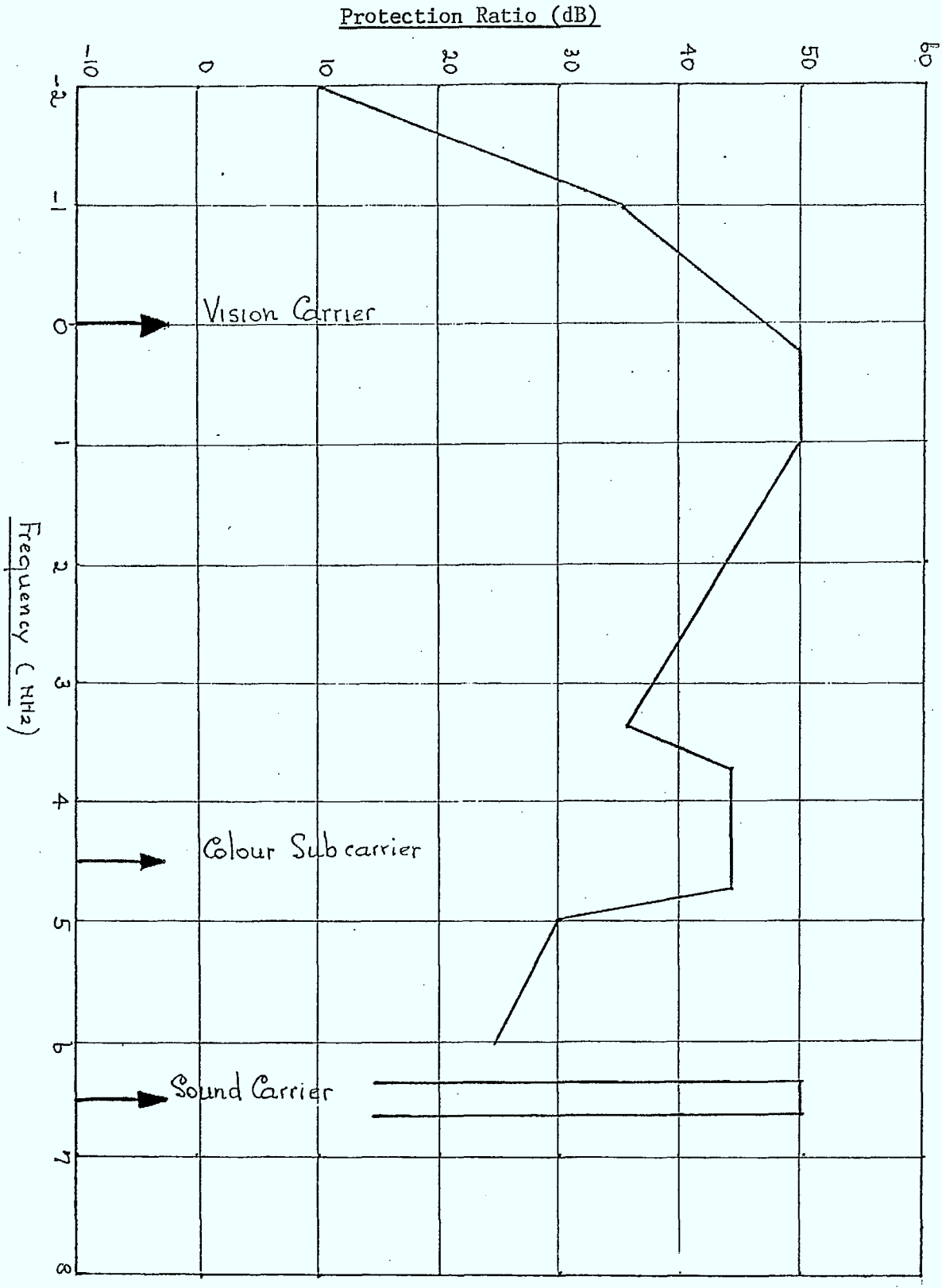


Figure 4.2-3: Protection Ratios Required for L/SECAM Television

Parameters	London	Dover
H_{eff}	150 m	150 m
d	150 Km	30 Km
CCIR Rec 370	land, 5% of time	sea, 5% of time
erp	25W	25W
Ei	8 dBu	40 dBu
a (protection ratio)	45 dB	55 dB
b	-15 dB	-15 dB
Esj	38 dBu	80 dBu

Table 3: Nuisance Fields - Boulogne Region

4.2.4 Summary of the Inter-Service Sharing Criteria

The following are some of the criteria developed, so far, for inter-service sharing of the Band III spectrum between UK and France.

4.2.4.1 Protection of the Land Mobile Service in the UK

a) The desired signal level for the LMS for Grade 4 quality is 22 dBμ

b) A protection ratio of 10 dB

c) antenna polarization discrimination of the base station antenna is 18 dB and of the mobile antenna is 8 dB (assuming the TV broadcast uses horizontal polarization and the LMS uses vertical polarization)

d) The maximum interfering signal field strength should not exceed 24 dBμ at the base station and 24.5 dBμ at the mobile station

e) The LMS to use only that part of the TV spectrum that avoids the visual carrier and the sound carrier, i.e. only 5 MHz of the available 8 MHz spectrum of a TV channel may be used.

f) The LMS characteristics are:

- inter-channel spacing: 12.5 KHz
- channel bandwidth: 7 KHz
- peak frequency deviation: ± 2.5 KHz
- base station antenna height: 20 metres
- mobile station antenna height: 1.5 metres

g) Propagation characteristics used are from CCIR Rec 370 (5)

4.2.4.2 Protection of the TV Broadcast Service in France

a) The desired signal level is the Grade B contour value of 55 dBμ

b) The accumulated nuisance fields from all the LMS sources in the UK are not to exceed 55 dBμ. However, agreement has been reached for this limit to be extended to 70 dBμ in boulogne and 65 dBμ at certain parts of the French coast. The TV service is to be protected for 95% of the time, since a sea path is involved.

c) A co-channel protection ratio of 50 dB is used, i.e. the total power of the LMS signals falling in the one TV channel, at any one time, should be 50 dB down on the desired TV carrier signal. This provides a 5 dB margin , with respect to the 45 dB protection ratio required within the 5 MHz portion of the TV channel, to be used by LMS.

d) For base stations near the French coast, the antenna heights should be kept low and/or directional antennas should be employed. Moreover, the base station transmit frequencies should be located near that part of the TV channel spectrum above which the protection ratio is least (around 35 dB) i.e. near the colour sub-carrier and the sound carrier.

e) TV transmitter characteristics:

ERP = 250 kw
EHAAT = 300 m

4.3 F.C.C. INTER-SERVICE SHARING CRITERIA

4.3.1 Introduction

The inter-service sharing criteria proposed by the FCC has been extracted largely from the following documents:

- F.C.C. Docket No: 18261

- FCC/OST Report R-83-3 "Analysis of Technical Possibilities for Further Sharing of the UHF TV Band by the Land Mobile Services in the Top Ten Land Mobile Markets" October 1983

- FCC General Docket No. 85-172, June 1985

"Notice of Proposed Rule Making in the Matter of Further Sharing Between Private Land Mobile Services and the UHF TV Broadcast Service"

- FCC Docket No. 21039, FCC-78-713
  "Memorandum of Opinion and Order in the Matter of Amendment of Part 21 of the Rules to Reflect the Availability of Land Mobile Channels in the 470-512 MHz Band in Thirteen Urbanized Areas of the U.S.A."

Unlike the previous inter-service sharing criteria of Section 4.2, which concentrated on Band III sharing, the FCC criteria deal with the sharing of the UHF band, 450-960 MHz.

4.3.2 Protection of the Television Broadcast Service

The amount of sharing between the TV broadcast service and the land mobile service that is possible in a given geographical area depends on:

- the values assumed for the various technical parameters
- the degree of protection afforded to the TV service

- the permissible locations of the land mobile base stations

- the permitted operating range of the mobile stations

4.3.2.1 Protected Coverage Area

a) The area of the TV coverage that is to be protected from interference by the land mobile service is that covered by the Grade B contour, which is approximately 55 miles (for Class C transmitters) distant from the TV transmitter and which has a minimum field strength of 64 dBμ.

This service is to be protected from interference for 90% of the time.

b) The protection ratio for co-channel interference from the LMS is a minimum of 40 dB and that for the adjacent channel interference is 0 dB. To improve the protection, the LMS may be restricted to that part of the TV channel between the visual and sound carriers, where the required protection ratio is less.

c) At the Grade B contour, the antenna discrimination factor of 10 dB was assumed for both polarization discrimination and directivity discrimination; though measurements on a test range showed that polarization discrimination of 20 to 30 dB and front-to-back gain of 10 to 20 dB were achievable.

d) The characteristics assumed for the land mobile stations were:

(1) Base Stations: ERP = 1 KW

EHAAT = 500 ft.

(2) Mobile Stations: ERP = 100 W

EHAAT = 100 ft.

e) The location of base stations were restricted to within 30 miles of the centre of the city, and mobile operations to 50 miles of the centre of the city.

f) The propagation curves, as given in F.C.C Report R-6602, Sept. 7, 1966 "Development of VHF and UHF Propagation curves for TV and FM Broadcasting," were used to compute the radiated field strengths.

4.3.3 Protection of the Land Mobile Service

In general, it was felt that the requirements for protecting the TV service imposed sufficiently great separation distances that the reciprocal protection of the land mobile service from the TV service would automatically be taken care of. This supposed, however, that the LMS frequencies were selected to avoid predictable inter-modulation problems and able to avoid frequencies near the visual and aural carriers. Should interference to a base station receiver occur, it was felt that the use of several remote receivers rather than a single receiver at an elevated height could remedy the problem.

4.3.3.1 Main Sources of Interference from TV into the Land Mobile Service

The main sources are:

(1) co-channel TV video and sound carrier, their sidebands and harmonics

(2) TV transmitter sideband noise falling outside the desired TV channel

(3) local area TV receiver oscillator radiation

(4) intermodulation products of TV signals

(5) enhancement of VHF TV signals due to anomalous propagation conditions

The potential for co-channel interference is minimized if the LMS assignments avoid that part of the TV channel occupied by the visual and aural carriers and the colour subcarrier. The interference would then be from the visual carrier sidebands, which are at least 30 dB below the visual carrier level. The TV transmitters would typically be separated from a co-channel LMS base station by 90 miles (to meet the TV protection criteria) which is well beyond the horizon in many cases, so co-channel interference into the base station receiver is not likely to be a problem.

The TV transmitter sideband radiation falling outside the desired TV channel can cause harmful interference to LMS receivers operating in the same area. It is felt that the geographical separation for adjacent channel operations proposed in Docket 18261 are adequate to prevent this type of interference.

Radiation from the local oscillator of TV receivers could interfere with LMS stations operating in the same area, especially if the transmitter and receiver are on top of the same building. This could affect LMS frequencies in the seventh channel above the TV channel being received by the UHF TV receiver. Should base station transmitters be so located, then that particular TV channel (45.75 MHz above the TV receiver channel) must be left unassigned.
Intermodulation products from two adjacent TV transmitters could fall within an adjacent channel used by the LMS. In addition, a number of intermodulation products between adjacent LMS and TV transmitters in the same area could fall on LMS frequencies. The intermodulation interference problems could be considerably reduced by careful selection of the LMS base station sites and frequencies.

Enhanced propagation of VHF TV signals caused by tropospheric conditions is, by far, the most difficult to identify and resolve. It may be necessary to develop special sharing criteria for them

reduced by careful selection of the LMS base station sites and frequencies.

Enhanced propagation of VHF TV signals caused by tropospheric conditions is, by far, the most difficult to identify and resolve. It may be necessary to develop special sharing criteria for them but at present, the problem is insufficient data on which to base a solution.

In brief, interference into the land mobile service is not the limiting consideration in the inter-service sharing; it is automatically protected when the geographical separations required to protect the TV broadcast service are imposed. On the special occasions when interference does occur, economical remedies are available. Since the base station receiver is more vulnerable than the mobile station receiver, if the base station satisfies the interference criteria, then the mobile station is considered to be automatically protected.

4.3.4 Sharing Between LMS and Low Power TV Broadcast Service

4.3.4.1 Protection of the Low Power TV Broadcast Service

Grade A

The LPTV broadcast service is protected up to the contour at which the field strength drops to 74 dBμ. The service is protected for 80% of the time from interference, largely from other LPTV broadcast systems, since it is a secondary service.

The minimum separation between a LPTV transmitter and a base station transmitter could be as little as 40 miles. This could present a problem especially if both the LMS base station transmitter are at elevated sites. To prevent interference of this type, it may be necessary, in some situations, to forego the use of elevated sites.

The protection adopted for current shared LMS operations on channels 14 to 20 from LPTV stations does not consider protection for LMS base station receivers located at elevated sites. they permit an F(50,50) field strength of 52 dBμ for the LPTV signal at the LMS protected contour in co-channel cases. Similarly, they allow 76 dBμ for the LPTV signal in adjacent channel cases. These criteria represent a concept which would provide "equivalent protection" to an LMS receiving antenna 30 ft. above the ground. This is a typical height for roof-top TV antennas but is much lower than typical base station antennas.

5.0 DETERMINATION OF SHARING CRITERIA FOR CANADA

5.1 INTRODUCTION

The significant parameters that have to be determined for inter-service sharing are:

a) minimum field strength of the desired signal at the receiver for an acceptable grade of service. The receiver is assumed to be located at the outermost rim or contour of the coverage area

b) maximum field strength of the interfering signal at the protected contour of the desired signal. This involves knowing the protection ratio required to ensure that, with the interference, the quality is still acceptable

c) from a) using the F(50,10) curves for the desired transmitter, the distance of the protected contour from the transmitter can be determined

d) from b) using the F(50,50) curves for the interfering transmitter, the distance of the interfering transmitter from the protected contour can be determined

e) from c) and), the minimum separation distance required between the live transmitters - desired and interfering - can be determined, which will ensure that the protected contour is protected from interference for 90% of the time

Since the protection ratio for the TV signal from interference from a land mobile signal is crucial, this has been considered in some detail in Appendix A. There, the results of several subjective tests on the effect on TV picture impairment from a wide variety of interference signals, is analyzed with a view to lending plausibility to the protection ratios used for this study.

Another critical parameter is the propagation loss from transmitter to receiver. This is given in Appendix B.

5.2 PROTECTION OF THE TV BROADCAST SERVICE

5.2.1 Introduction

The significant parameters to be determined to ensure adequate protection of the TV broadcast service from the land mobile service are:

a) the field strength of the desired signal to be protected.

b) the protection ratio.

c) the maximum permissible interference from the land mobile service at this protected contour for less than 10% of the time

d) the TV transmitter characteristics and the LMS transmitter characteristics

e) the propagation characteristics

f) from the above, the minimum separation distances between the desired and interfering transmitters can be determined

To gain insight into the effect of interfering signals on a TV picture, the characteristics of a TV signal is first described and then the effect of an interfering CW signal on picture quality is then described.

5.2.1.1 Characteristics of a Television Signal

A black and white (monochrome) television picture consists of 3 component waveforms:

- a "picture" signal which describes the brightness variations along the scan lines
- a "sync" signal which provides synchronization information for reassembling the scans into a picture
- a "sound" or audio signal

For colour television, two additional waveforms are required in conjunction with the brightness signal to specify, for each picture element, the three characteristics of its colour: brightness, hue and saturation. In this case, it is the combination of these three waveforms that is called the "picture" signal.

In distributing television signals from studio to the broadcast stations, the "sound" waveform is usually sent separately over an independent channel, but the "picture" and "sync" signals are always sent together and called the "video" signal.

Monochrome TV

Consider the monochrome TV baseband signal. There, the "picture" signal describes only the brightness variations in the image being transmitted. It is obtained using a scanner that moves a spot across the picture in a series of vertically separated, horizontal lines and yields an instantaneous voltage proportional to the image brightness at the spot location. Scanning is from left to right beginning at the top, and the successive lines are separated by about twice the spot diameter which, in turn, is about 1/500 the height of the picture. At the end of each line, during the time required to sweep the scanning spot back for the start of the next line, a blanking pulse is sent. This means that the "picture" signal drops to a so-called "blanking level" which lies

below the level corresponding to black (zero picture brightness), and ensures that the return trace on the picture tube will be invisible. When the bottom of the picture is reached, a much longer blanking pulse is sent and the spot is returned to the top of the picture for the next series of line scans. The lines of the next series do not retrace those just scanned but rather lie half-way between them, a technique called "interlacing." Each top to bottom scan is called a "field" and a complete scan of the picture, a so-called "frame," consists of two successive interlaced fields.

A new frame is scanned every 1/30 of a second and the scanning rate is such that this is exactly 525 times the interval between successive line scans. For this reason, the type M system (used in Canada and the USA) is said to provide a 525 line picture. In practice, the blanking pulse at the end of each field has a duration of from 13 to 21 times the line-scanning period, which leaves only 483 to 499 lines to form a complete frame. Moreover, although the interval between successive lines is 1/(30X525) secs or 63.5 µsecs, the line blanking pulse lakes about 11 µs, leaving only 52.5 µs to write each line of picture information.

The "sync" waveform consists of a short "horizontal sync tube" at the end of each line for triggering the next horizontal line sweep at the receiver, and a series of six longer "vertical sync pulses" at the end of each field for triggering the next vertical sweep. The latter are placed between two sets of 6 short pulses called equalizing pulses, and the whole 18-pulse sequence is then followed by, from 4 to 12 line sync pulses. The synchronizing pulses occur during the corresponding blanking pulses of the picture signal. The combination of the "picture" waveform and the "sync" waveform is called the "video" signal which may be considered as a time-division multiplex of these two waveforms.

The "sync" signal is distinguished from the "picture" signal not only in time, but also in amplitude. Unlike "voice" signals, the video signal has well-defined maximum and minimum values. In particular, when the video signal polarity is "positive" (signal level increases in transition from black to white), the maximum or peak amplitude is called the "peak white level" and represents the amplitude corresponding to maximum picture brightness. The minimum amplitude is the "sync-peak level" which corresponds to the tips of the sync pulses. The difference between these two levels is the "peak-to-peak amplitude" of the video signal. It is the amplitude normally used in describing the overall magnitude of the video signal or the power it represents.

The blanking level is customarily taken as the reference level for signal measurement. It is so positioned that the nominal amplitude of the picture signal (measured from blanking level to the peak white amplitude level) is about 70% of the peak-to-peak video amplitude while the sync signal amplitude (measured from the blanking level to the peak sync level) is about 30% of the peak-to-peak video amplitude. A fourth reference level, the "black

level," corresponds to zero picture brightness, lies just above the blanking level and as close to it as the state of the art permits.

When used with vestigial side-band amplitude modulation (VSBAM) for TV broadcast in Canada and the USA, the video signal is reversed in polarity (negative modulation). The peak sync level then becomes the positive peak of the modulation envelope and all levels are measured with reference to the zero carrier level. Specifically, if the peak sync level is labelled 100%, then blanking level is 75%, and the peak white level would lie between 0 and 15%.

The third component of the monochrome TV signal, the "sound" waveform, is located exactly 4.5 MHz above the video carrier and ratio of sound carrier power to the peak power of the modulated video carrier is kept at a fixed value, -6 dB. The sound carrier is frequency-modulated with a peak frequency deviation of ± 25 KHz.

The spectrum of a monochrome video baseband signal is rather complicated. It is basically a line, rather that a continuous, spectrum because of the periodically repetitive nature of the video waveform. The line duration is 63.5µS so the fundamental frequency of the repetitive signal is 15.75 KHz. Both the "sync" pulses and the brightness information in the line scans are repetitive with the same fundamental frequency. The video baseband spectrum consists of discrete frequency components space 15.75 KHz apart; each discrete frequency component has discrete sideband components with a fundamental frequency of 60 Hz. The striking feature of the video spectrum is that most of the space between the dominant spectral lines is free of energy. figure 5.2-1 shows a typical spectrum of a monochrome video signal. The relative amplitudes of the discrete lines are determined by such things as the maximum rate of change of the waveform e.g. pulse rise and fall times, and by, its "duty cycle" (ratio of pulse duration to pulse spacing). The vertical blanking part of the picture signal imposes a 60 Hz square-wave modulation on the brightness information and, hence each harmonic of 15.75 KHz is accompanied by symmetrical sidebands consisting of lines spaced 60 Hz apart. The location of the first zero in the envelope of these sidebands is determined by the duty-cycle of the vertical blanking pulses and occurs at the 14th harmonic of 60 Hz or about ±840 Hz on the 15.75 KHz line. The bulk of the space between the 15.75 KHz harmonics is empty.

The foregoing applies when the image is a "still" picture, typically a grey scale. However, when there is motion, the modulation sidebands on the discrete lines spread out, thus filling up the empty spaces between the discrete lines. The baseband frequency range of a monochrome TV signal is taken as 4.2 MHz.

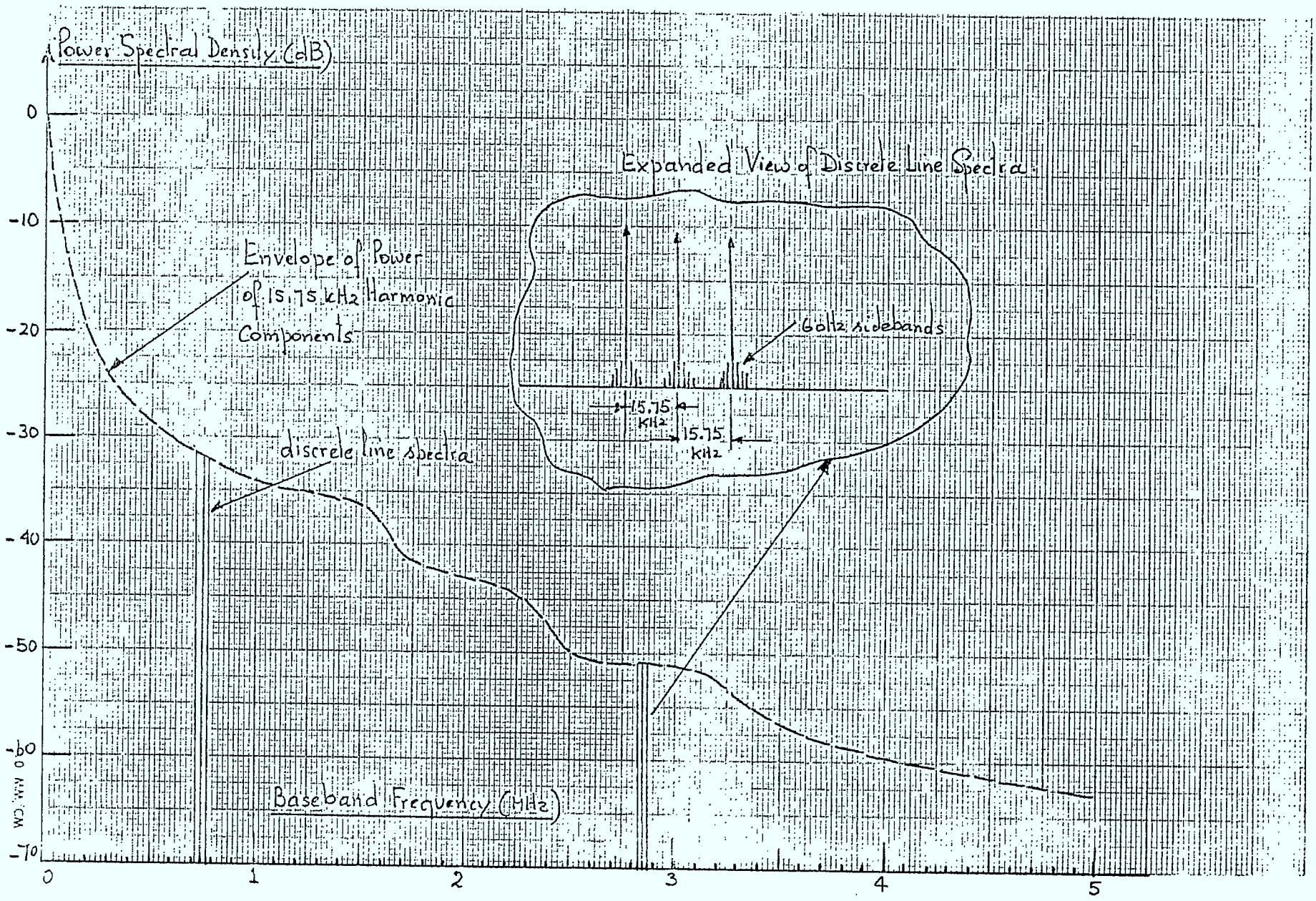


Figure 5.2-1: Typical Monochrome TV Spectrum

Colour TV

In a colour TV signal, the brightness information is contained in the monochrome TV signal. It is called the "luminance" signal. The colour (or chrominance) information is contained in two other signals called the "hue" and "saturation" signals. The two chrominance signals modulate a colour sub-carrier which is located in the same bandwidth as the luminance signal.

The spectrum of the modulated subcarrier also is a line spectrum with each line, in turn, modulated by a 30 Hz square-wave to produce symmetrical sidebands about the line component. The chrominance sub-carrier frequency is chosen to be an odd-multiple of one-half the line scan frequency so that its line spectrum components fall in between the luminance line spectrum components. The chrominance sub-carrier frequency was chosen to be the 455th harmonic of half-the-line frequency (15.75 KHz), i.e. 3.583125 MHz.

The "sound" carrier is located 4.5 MHz above the "picture" carrier. To ensure that interference due to possible beats between the chrominance sub-carrier and the sound will produce only low-visibility patterns on the picture tube, the difference between these two carriers is also made an odd-multiple of one-half the line scan frequency. To accommodate this, the line scan frequency is changed from 15.75 KHz to 15.734264 KHz. and the frame rate is changed to 15.734264 KHz/525 = 29.97 Hz. The chrominance sub-carrier frequency becomes 3.579545 MHz. Figure 5.2-2 gives a typical spectrum of an AMVSB, colour TV signal of the Type M, 525 line NTSC system.

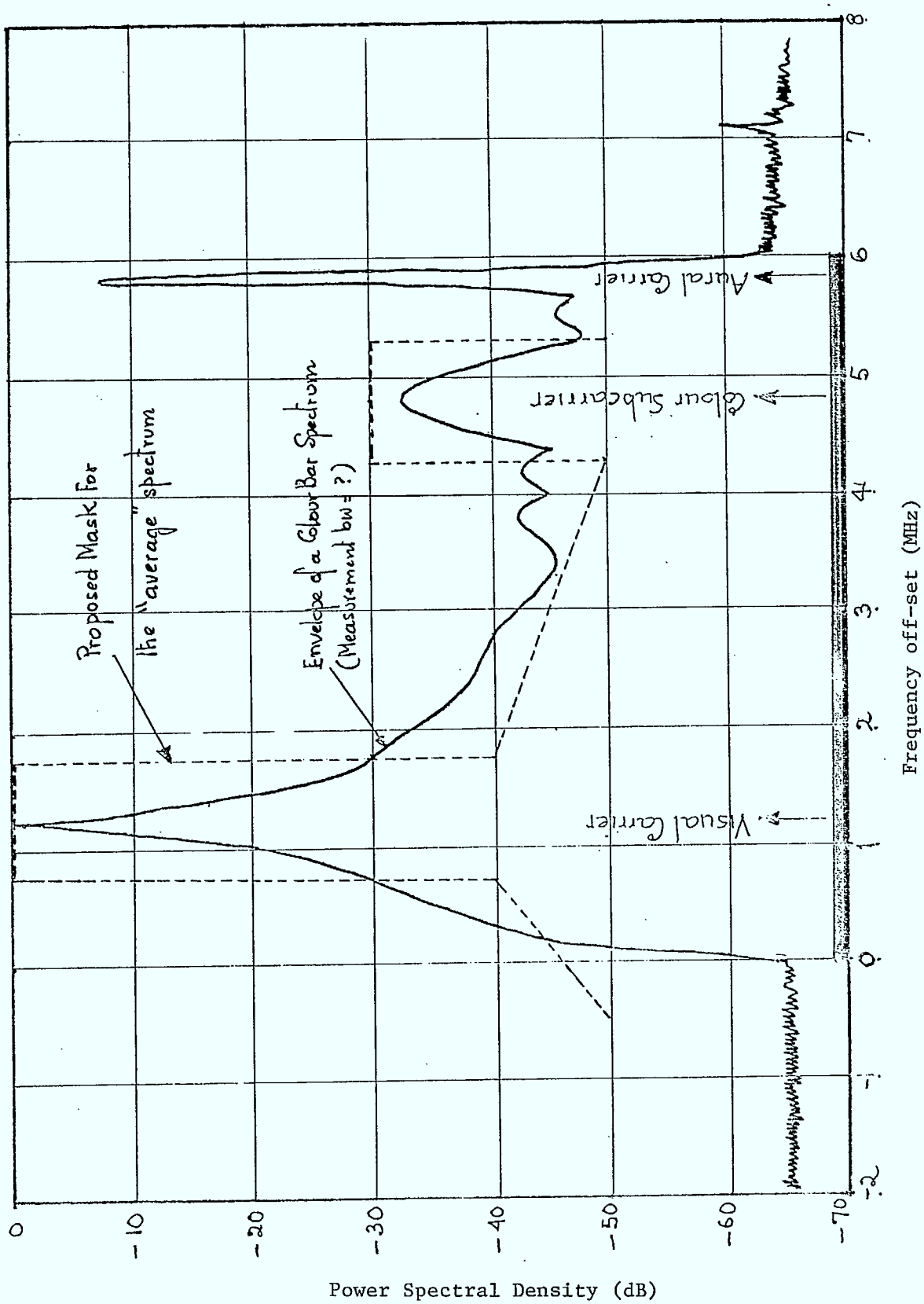


Figure 5.2-2: Spectrum of a Type M, 525-line, NTSC Television Signal

5.2.1.2 Effect of a CW Signal on a Monochrome TV Signal

Imagine a scene of uniform luminance and chrominance. The colour sub-carrier in this case is unmodulated (since chrominance is uniform) and will be considered to be an interfering CW signal.

Since the luminance or brightness is uniform, the luminance signal will consist of a fixed d.c. level. The combined video signal (monochrome picture + interfering CW) will have a waveform as shown in Figure 5.2-3A for each line. The interfering CW will produce alternating light and dark spots on every line. These form a regular pattern which is more or less visible, depending on the relation between the line frequency, f_L, and the chrominance sub-carrier frequency, f_{sc}. Various relationships give minimum visibility. The one chosen in the NTSC system is:

$f_{sc} = \frac{1}{2}(2n + 1)\ f_L$, where n is an integer

i.e. the chrominance sub-carrier is located half-way between two successive discrete line harmonics.

There is, therefore, an odd number of half-cycles of carrier (colour) frequency in one line, and since the total number of lines in a complete picture is odd, it takes two pictures (four fields) for the complete pattern of dots to repeat itself. This can be seen by studying the raster shown in Figure B which consists of 9 complete lines (4½ per field) and for which n = 4, giving $f_{sc} = 4\frac{1}{2}\ f_L$. In each consecutive field the dots are staggered, both vertically and horizontally, with respect to the previous field. There is therefore, on average, no static pattern of bright and dark patches. There is, however, a stroboscopic effect which causes the spots to appear to move up and down the screen at the rate of one line per field. The "dot" crawl can be visible in monochrome pictures, but only in regions corresponding to extended areas of uniform colour. Rapid changes of colour causes shifts in the phase of the modulated subcarrier which prevent regular, and hence discernible, patterns from being formed.

The higher the CW frequency (sub-carrier frequency) is, the finer the dot pattern will be, and hence the less visible. As the CW frequency approaches a line harmonic, the interference pattern becomes more static and hence more visible.

Any other interfering signal with modulation will cause the "dot" pattern to be more diffuse and, hence, less visible that a CW dot pattern. Again, the higher the frequency of the interferer, the less visible is its interference pattern on a monochrome TV picture; and the closer its frequency is to the mid-point between two discrete line harmonics, the less visible is its interference pattern.

In a colour TV picture, the effect of a CW interferer is most pronounced when the frequency of the CW signal is located at, or near, the luminance carrier frequency or the colour sub-carrier frequency and less pronounced as the frequency is offset from those two carrier frequencies. This is shown in Figure 5.2-4. The effect on picture impairment of a single land mobile service FM carrier will be very similar to that of a CW interferer, but with the peaks and troughs somewhat smoothed out. However, as more FM carriers are introduced, the interfering signal will tend to resemble a spread-spectrum signal and result in less impairment to the picture for a given desired signal-to-undesired signal power ratio at the receiver input.

i.e. each individual interference source has a lower power

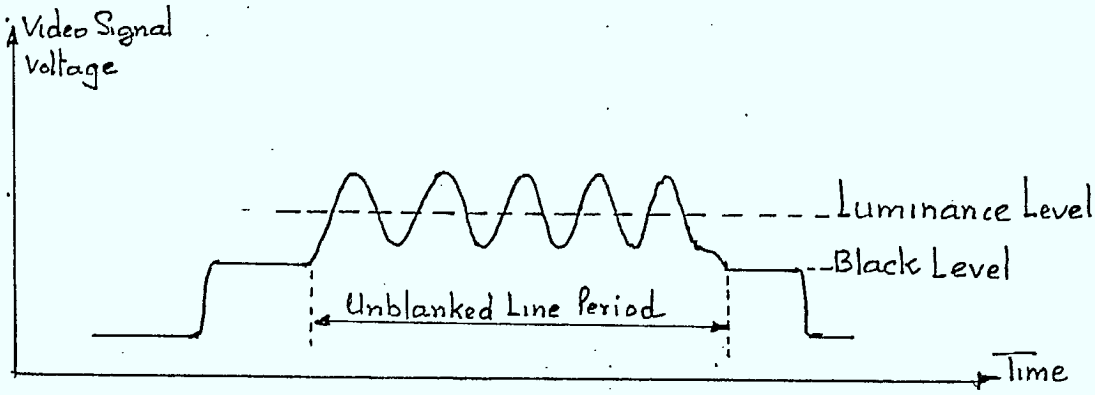


Figure 5.2-3A: Video Signal for a Scene of Uniform Luminance and Chrominance

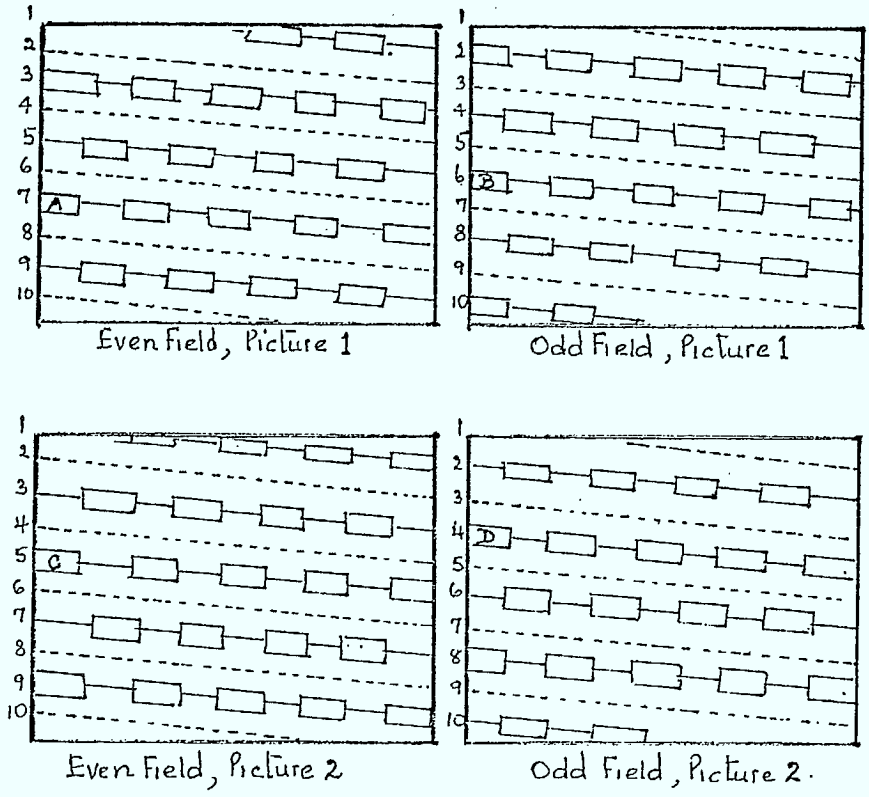
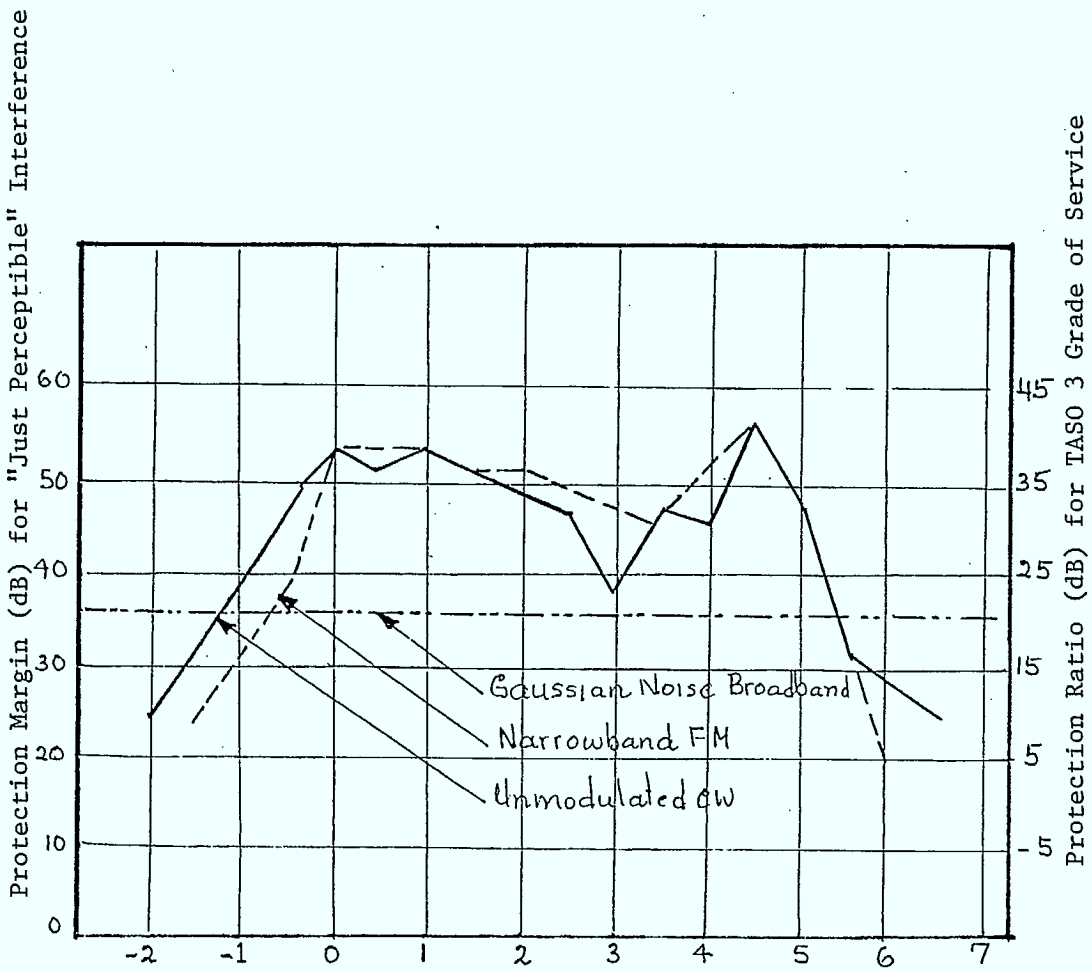


Figure 5.2-3B: Dot Pattern due to Unmodulated Chrominance Subcarrier. A Sequence of dots such as A,B,C,D is seen as single dot moving vertically upwards



Frequency Offset (MHz) of Interference Relative to Visual Carrier

Figure 5.2-4: Protection Margin as a Function of Frequency Offset for a PAL, 625-line, TV System Against Interference

From: Unmodulated CW
Narrowband FM
Broadband Gaussian Noise

Source: R.F. Ormondroyd and M.S. Shipton
"Subjectively Assessed Impairment of TV Signals By Co-Channel Operation of Spread Spectrum Radio Systems"

5.2.2 Susceptibility to Interference of a TV Signal

5.2.2.1 Introduction

The effect of an interfering signal on the quality of a television signal depends, among other factors, on the nature of the interfering signal: its power level, its spectrum and its frequency location in the video bandwidth. Figure 5.2-3 shows the protection ratio (desired signal/interfering signal power ratio) required to produce a "just perceptible" degradation in the picture for three different types of interfering signals:

- wideband random noise (uniform RF spectrum)
- spread spectrum signal with a $\left(\frac{\text{SinX}}{\text{X}}\right)^2$ spectrum located with the first nulls at the visual and colour carrier
- Sinusoidal CW

The figure shows that CW is the "worst interferer." Interfering signals with modulation will have an effect equal to, or less than, the CW signal, depending on the spectral width of the interferer. The effect on TV picture quality of a land mobile service signal will lie somewhere between that of the CW signal and the spread-spectrum signal depending on the total bandwidth of the land mobile service signal and its location in the video bandwidth.

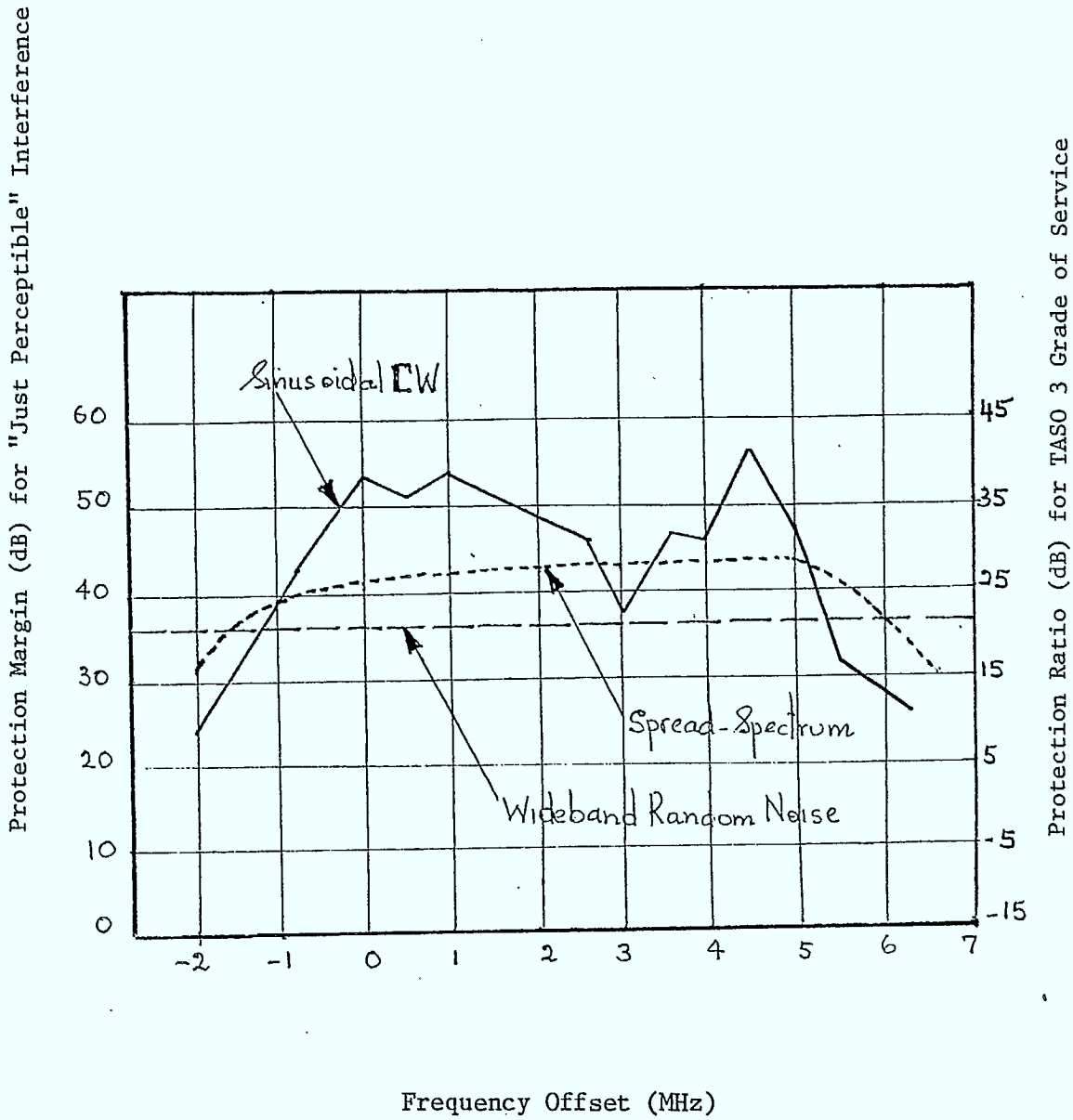


Figure 5.2.3: Protection Margin for "Just Perceptible" Interference into 625 line, PAL, System I Television

Source: "Subjectively Assessed Impairment of TV Signals by Co-Channel Operation of Spread-Spectrum Radio Systems" R.F. Ormondroyd, M.S. Shipton

5.2.2.2 Protection Ratios and Antenna Discrimination

5.2.2.2.1 Protection Ratios for TV Signals

The protection ratios, as given in Table 5.2 were derived in Appendix A and apply when the land mobile service uses only that part of a TV channel from 2.0 to 4.5 MHz. By using this part of the TV spectrum, the TV picture carrier located at 1.25 MHz and the aural carrier located at 5.75 MHz, are avoided.

Interfering LMS Channel	Protection Ratio (dB)		
	ch 2-6	ch 7-13	ch 14-69
co-channel, n = 0	40	40	40
adjacent channel, n = ±1	-5	-5	-5
*picture image channel, n = ±15	.	.	10

See recent tests in Denver

Note: * The protection ratio for the picture image channel was obtained from one source only and is the average value of the measured data in that source. Further tests should be performed to verify this value.

Table 5.2: Protection Ratios for AM-VSB TV from LMS

5.2.2.2.2 Antenna Discrimination

The antenna discrimination of the TV receiver antenna consists of two components:

- antenna directivity (or gain) component
- antenna cross-polarization component

The F.C.C. reports indicate that the measured values of the main lobe, on-axis gain for TV receiver antennas varies from 10 to 20 dB and the cross-polarization isolation (also measured on the on-axis) varies from 20 to 30 dB. The additional information that is required are the gain and polarization isolation in other directions and, more specifically, in the 180° direction from the on-axis direction. Figure 5.2.2-4 shows the radiation pattern of

a typical double bow tie antenna at 650 MHz. A corner reflector antenna has higher gain and better cross-polarization isolation.

The double bow tie antenna radiation pattern shows that:

1) if the interfering base station transmitter is interposed between the TV receiver antenna and the TV transmitter antenna (as would occur if the base station transmitter was radiating on the adjacent channel or the picture image channel of the TV transmit frequency), then the level of the interference signal relative to the desired signal level is determined largely by the polarization discrimination which is approximately 18 dB for the on-axis case. A value of 10 dB was assumed for the analysis for the whole of the main lobe (≈ ± 30°).

2) if the interfering base station is located outside the main lobe, then level of the interference signal relative to the desired signal level is determined by the antenna front-to-back gain ratio only. A directivity discrimination factor of 10 dB was conservatively estimated for this analysis for all the off-main-beam directions. This applies regardless of whether the two services use the same polarization or orthogonal polarizations. This applies largely when considering co-channel interference from LMS into the TV service.

5.2.2.2.3 Adjacent Channel and Picture Image Channel Interference

When considering co-channel interference only, the LMS base station transmitter must be located outside the TV coverage area circumscribed by the Grade B contour.

However, when considering the cases when the base station transmitter radiates on the adjacent channel or the picture image channel, the base transmitter may be located outside the Grade B contour or inside the Grade B contour. In the tables that follow, the separation distances are given for the case when the base transmitter is located outside the Grade B contour.

For cases, when the base transmitter is located inside the Grade B contour, the LMS will cause interference into TV receivers in a small area around the base station transmitter. The size of this area depends on how far the base transmitter is located from the TV transmitter. The farther it is from the TV transmitter, the larger will be the interference area or zone because the desired TV signal level is lower in this area. this is shown in Figure 5.2-5. The actual size of these interference zones or packets depends on the amount of shielding by the topography and the parameters of the TV transmitter and the base transmitter.

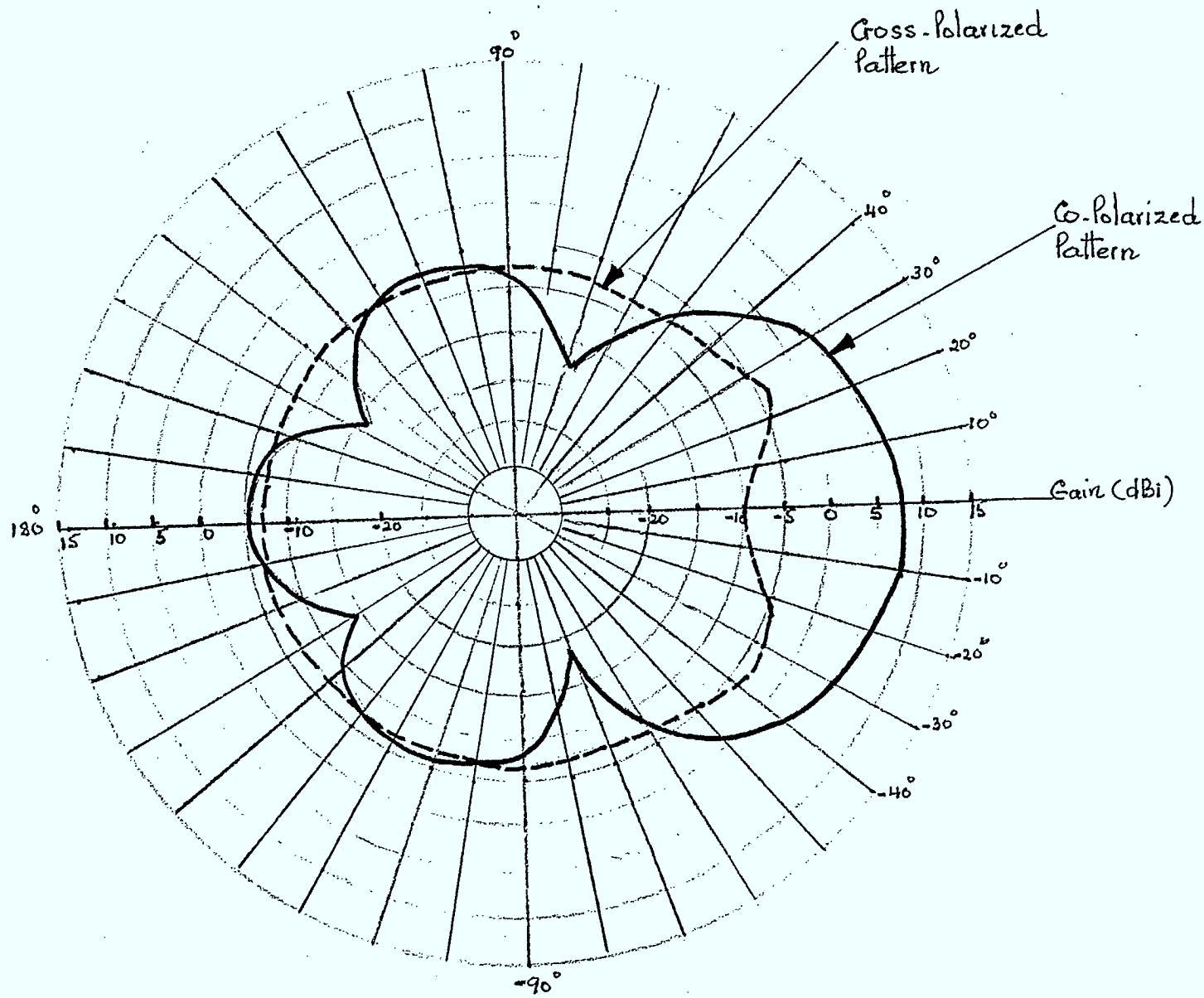


Figure 5.2.2-4: Typical Radiation Patterns for a Double Bow Tie Antenna at UHF

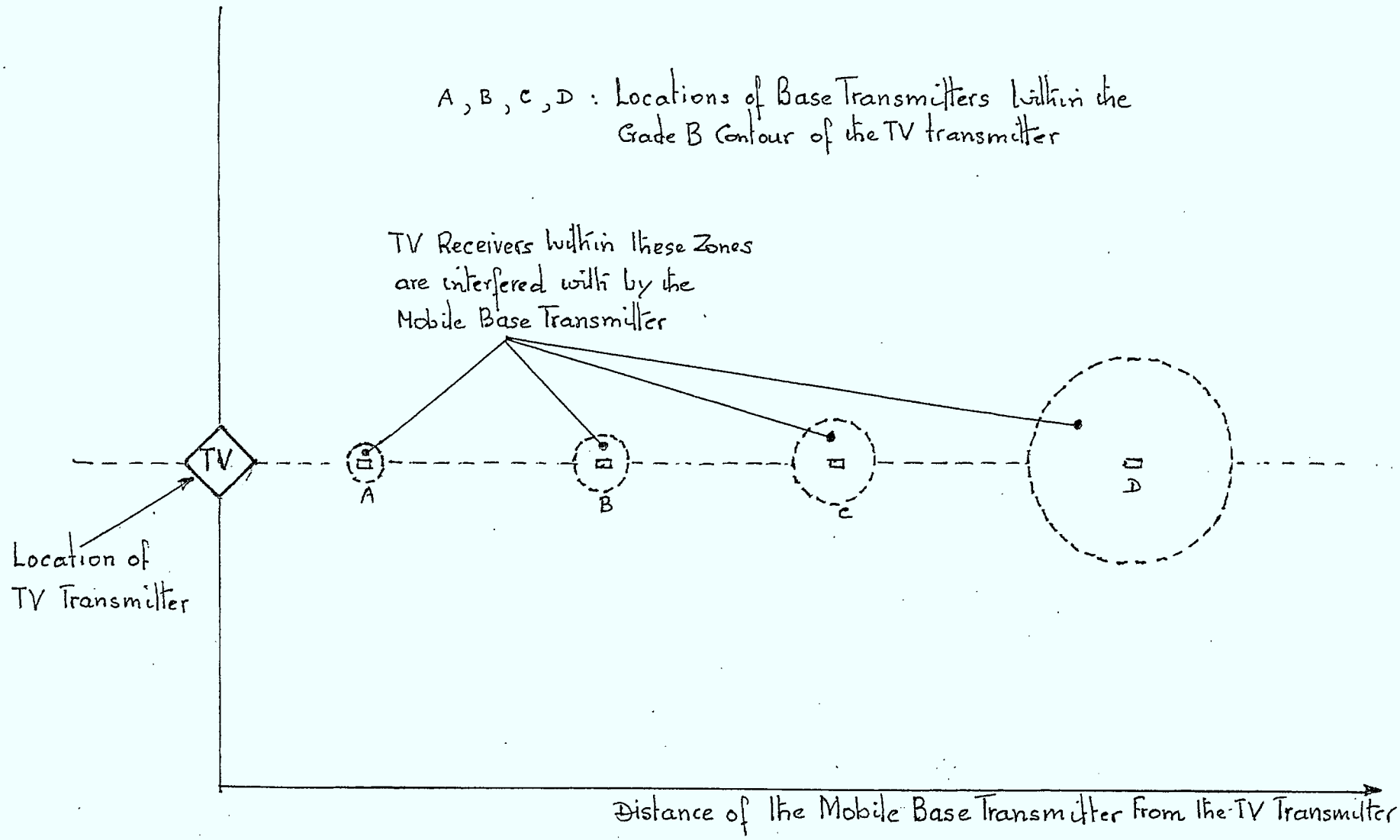


Figure 5.2-5: Illustrating the Interference Zones Due to Adjacent Channel or Picture Image Channel Utilization by the Mobile Base Transmitters

5.3 PROTECTION OF THE LAND MOBILE SERVICE

5.3.1 Description of the LMS Signal

The land mobile service is assumed to have the following characteristics:

- separation between channels: 25 KHz
- signal bandwidth: 16 KHz
- peak test tone frequency deviation: 5 KHz

The long-term frequency spectrum of a voice-modulated FM carrier contains a relatively large residual carrier in conjunction with the continuous part of the spectrum. The results of measurements made at the University of Essex of the long-term spectrum for different talker volumes are shown in Figures 5.3-1 and 5.3-2. The long-term spectrum is measured by recording a long conversation with all the inter-sentence pauses removed. However, the inter-syllabic pauses are retained. The residual carrier spike occurs during the inter-syllabic pauses when no modulation is impressed on the carrier when averaged over a long interval, the result is a residual spike at the unmodulated carrier frequency. This could cause problems when the interference itself is a CW signal located within ± 3 KHz of the FM carrier. The long-term spectrum of a voice-modulated carrier with the above characteristics is given in Figure 5.3.3.

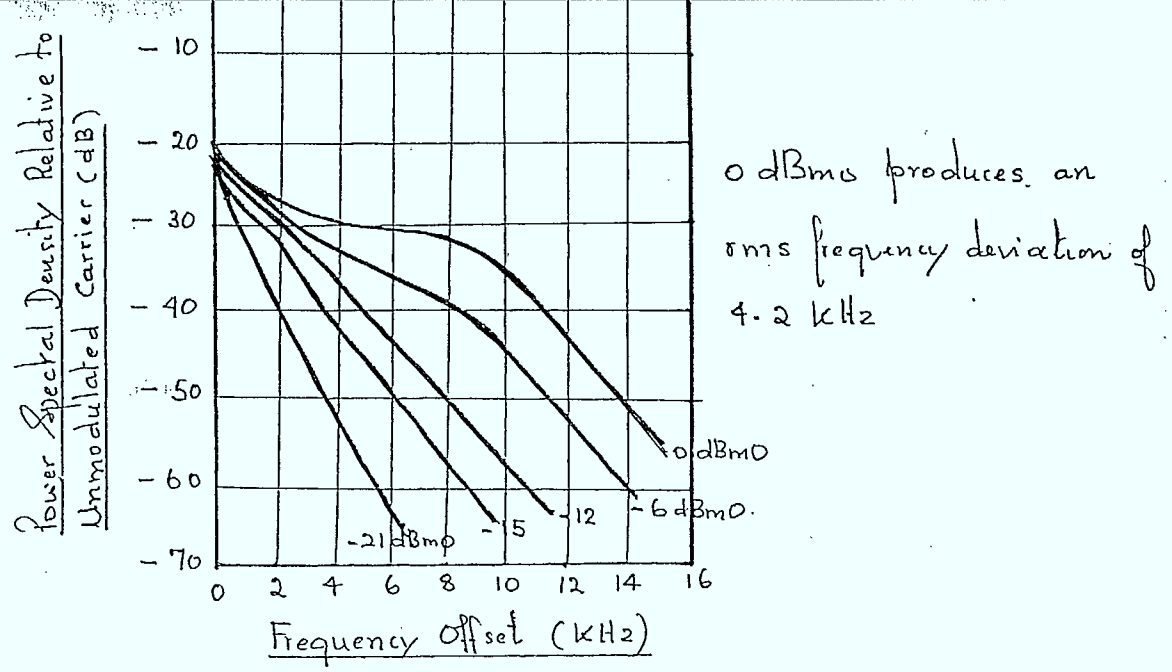


Figure 5.3-1: Power Spectral Density of a Voice-Modulated FM/Signal -Continuous Spectrum

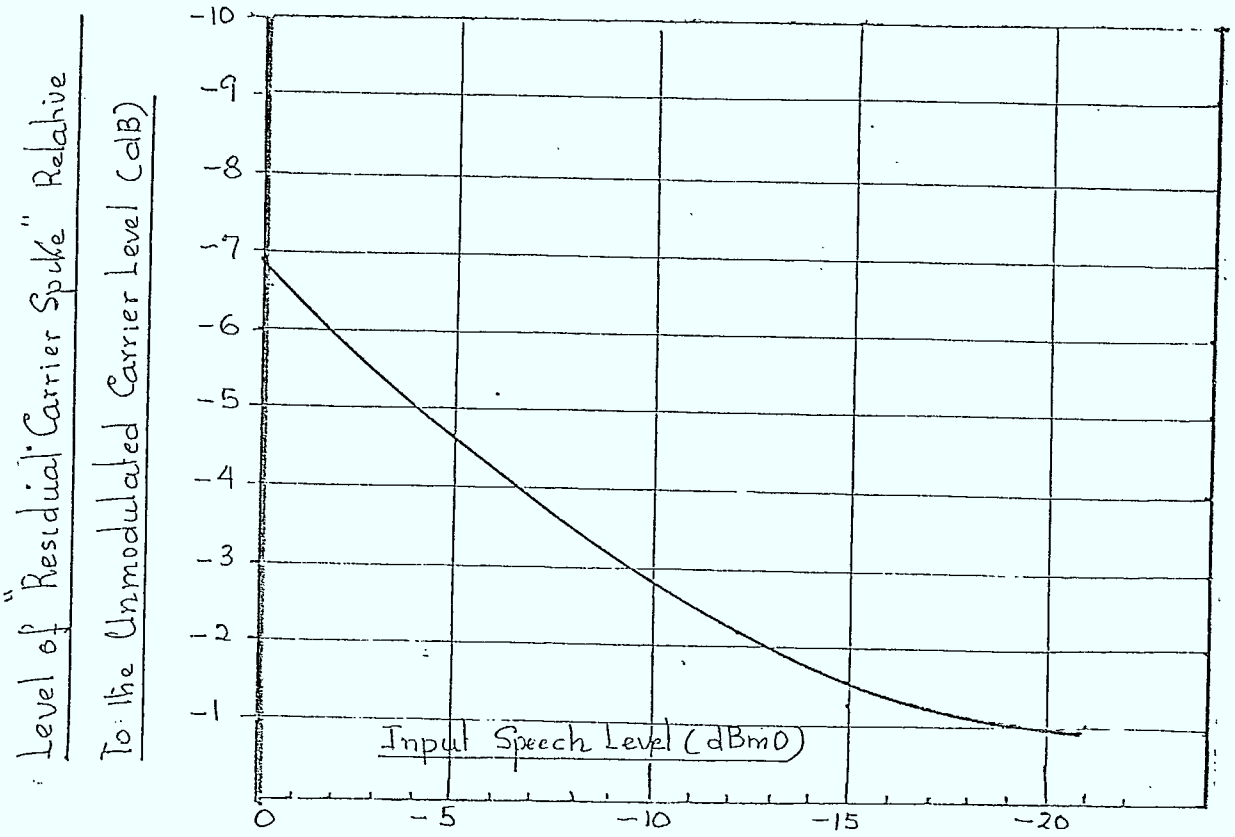
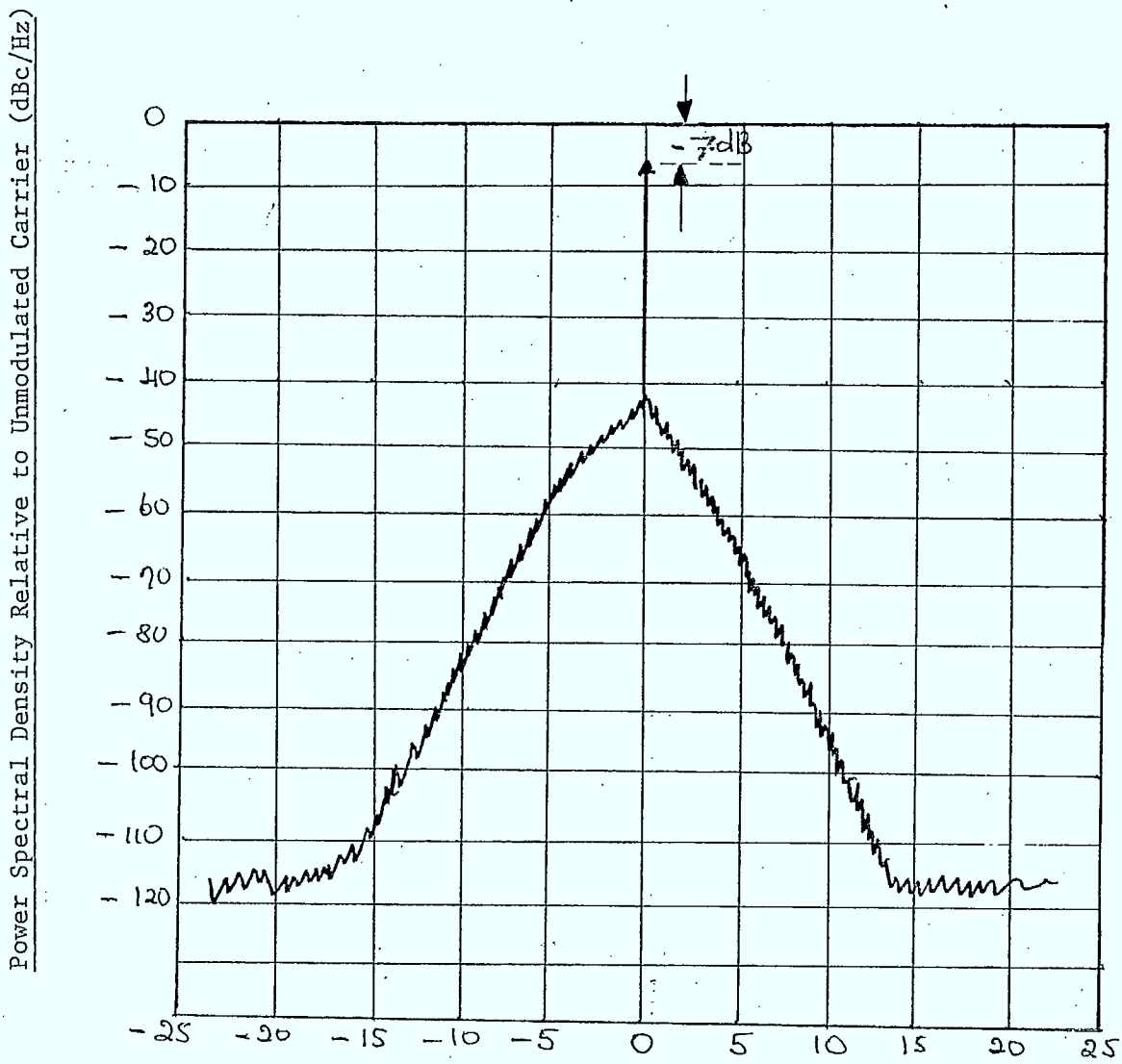


Figure 5.3-2: "Residual Carrier Spike" Level of a Voice-Modulated FM Signal



Note: 25% of the power is in the residual carrier (-7dBc)

75% of the power is in the continuous spectrum (-1dBc)

Figure 5.3-3: Typical Spectrum (long-term) of a Voice Modulated FM Carrier with Peak Frequency Deviation of 5 KHz

5.3.2 Interference Susceptibility of a LMS Signal

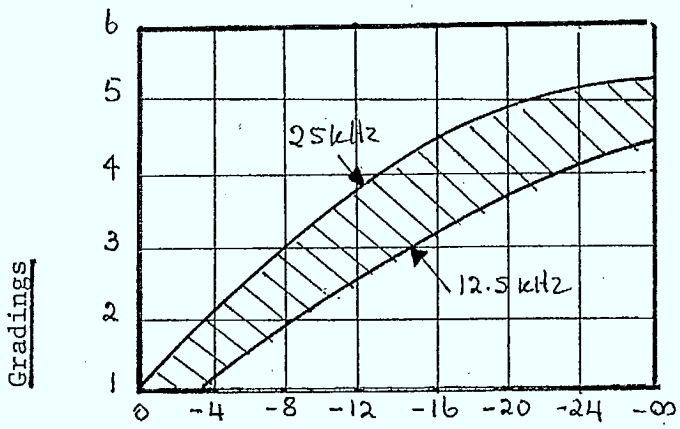
Several publications in the CCIR contain information on the protection ratio required by the land mobile signal.

Figure 5.3-4 shows that for a Grade 3 service (passable) a protection ratio of 8 dB is required when the interfering signal is another LMS signal in the same channel. The same report, CCIR Rep 899 gives the protection ratio in the presence of Rayleigh fading. This is shown in Figure 5.3-6. Figure 5.3-5 gives the sensitivity of the same receiver when the interference is wideband random noise.

When considering interference from a TV signal, the foregoing need not be directly applicable. If the LMS spectrum is located in the TV channel between 2 and 4.5 MHz from the start of the TV channel, then the interference would be an amplitude-modulated signal with a line frequency harmonic serving as the interfering carrier and the 30Hz sidebands serving as the amplitude modulation. CCIR has suggested in Rep 358(4) that a protection ratio of 10 dB be assumed when the interference is a narrowband AM signal. The UK administration used this value in their analysis of TV interference into LMS.

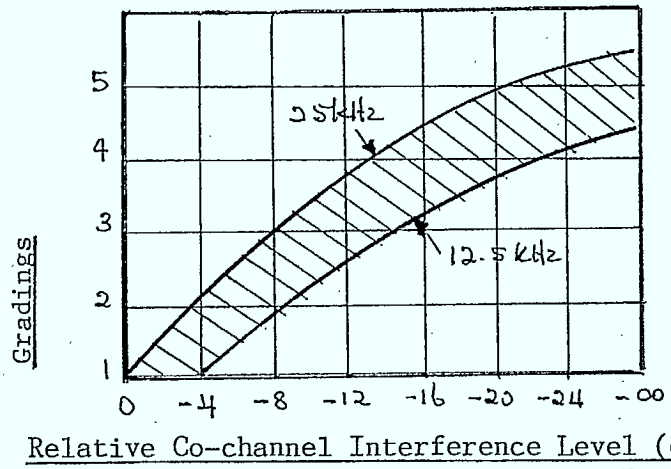
Under very special conditions - modulation on the TV carrier and when an LMS channel is located within ± 3 KHz of a discrete line component - the residual carrier spike could cause a single audio tone to occur at the receiver output. Figure 5.3-7 gives the audio S/N versus RF C/I for this case. This tone will occur in the inter-syllabic pauses when its presence will be most objectionable. Tests will have to be performed to check if this does, in fact, occur and what the protection ratio should be. In the analysis performed for the areas of Montreal, Toronto and Vancouver, (see Chapter III) a protection ratio of 10 dB will be assumed for interference from TV.

In a TV channel, the line harmonics in the region from 2-4.5 MHz are more than 30 dB below the level of the picture carrier. For the line harmonic to be 10 dB below the LMS signal, the TV picture signal. The protection ratio in terms of the LMS signal and the TV signal becomes - 20 dB.



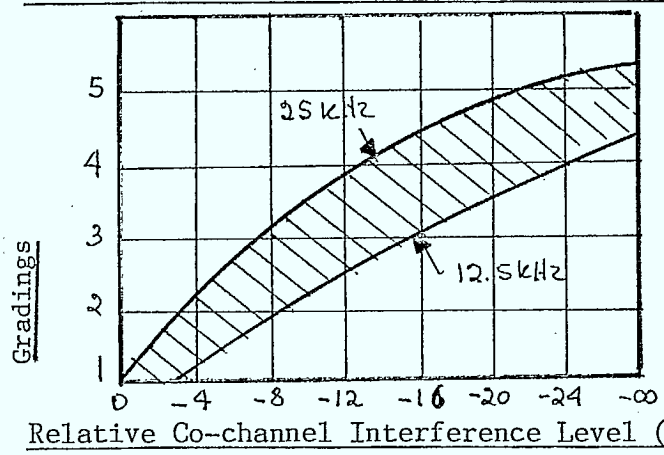
(A)

- Wanted Signal: 10 µV
- Carrier Offset: 0 Hz
- FM Carriers: 25 KHz and 12.5 KHz



(B)

- Wanted Signal: 3 µV
- Carrier Offset: 500 Hz
- FM Carriers: 25 KHz and 12.5 KHz



(C)

- Wanted Signal: 10 µV
- Carrier Offset: 500 Hz
- FM carriers: 25 KHz and 12.5 KHz

Figure 5.3-4: Grade of Service for Co-channel Interference for LMS FM Carriers (25 KHz and 12.5 KHz spacings)

Source: CCIR Report 899

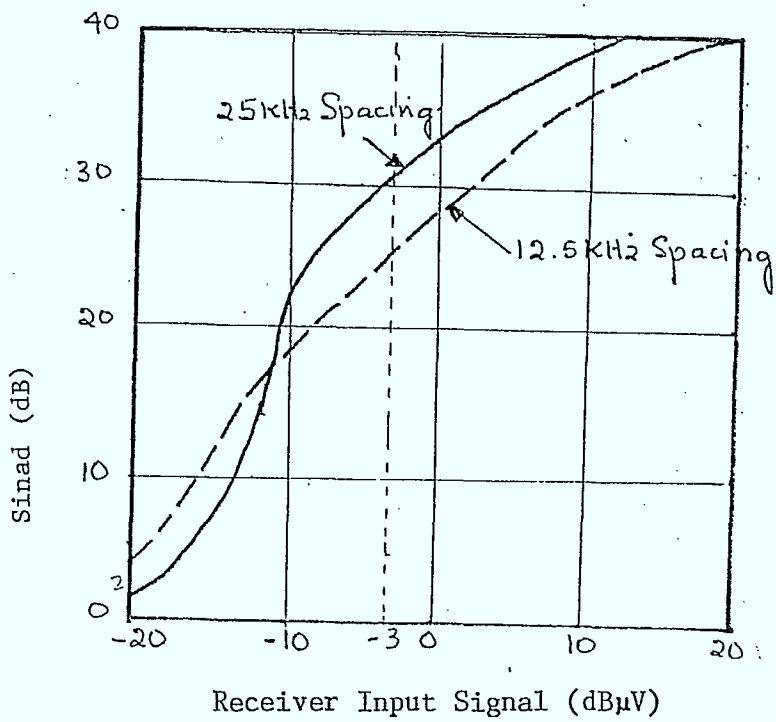


Figure 5.3-5: Receiver Sensitivity to LMS FM Signals

(Nominal Input Level = −3 dBμV or + 0.7 μV)

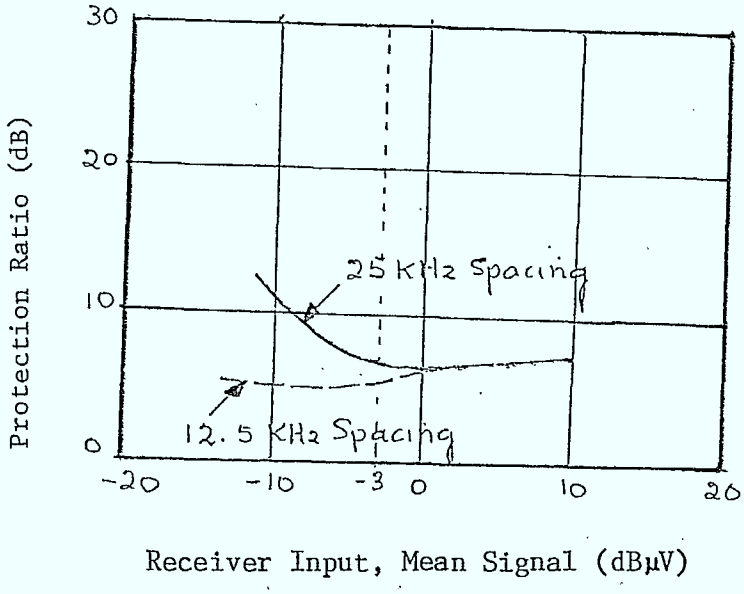
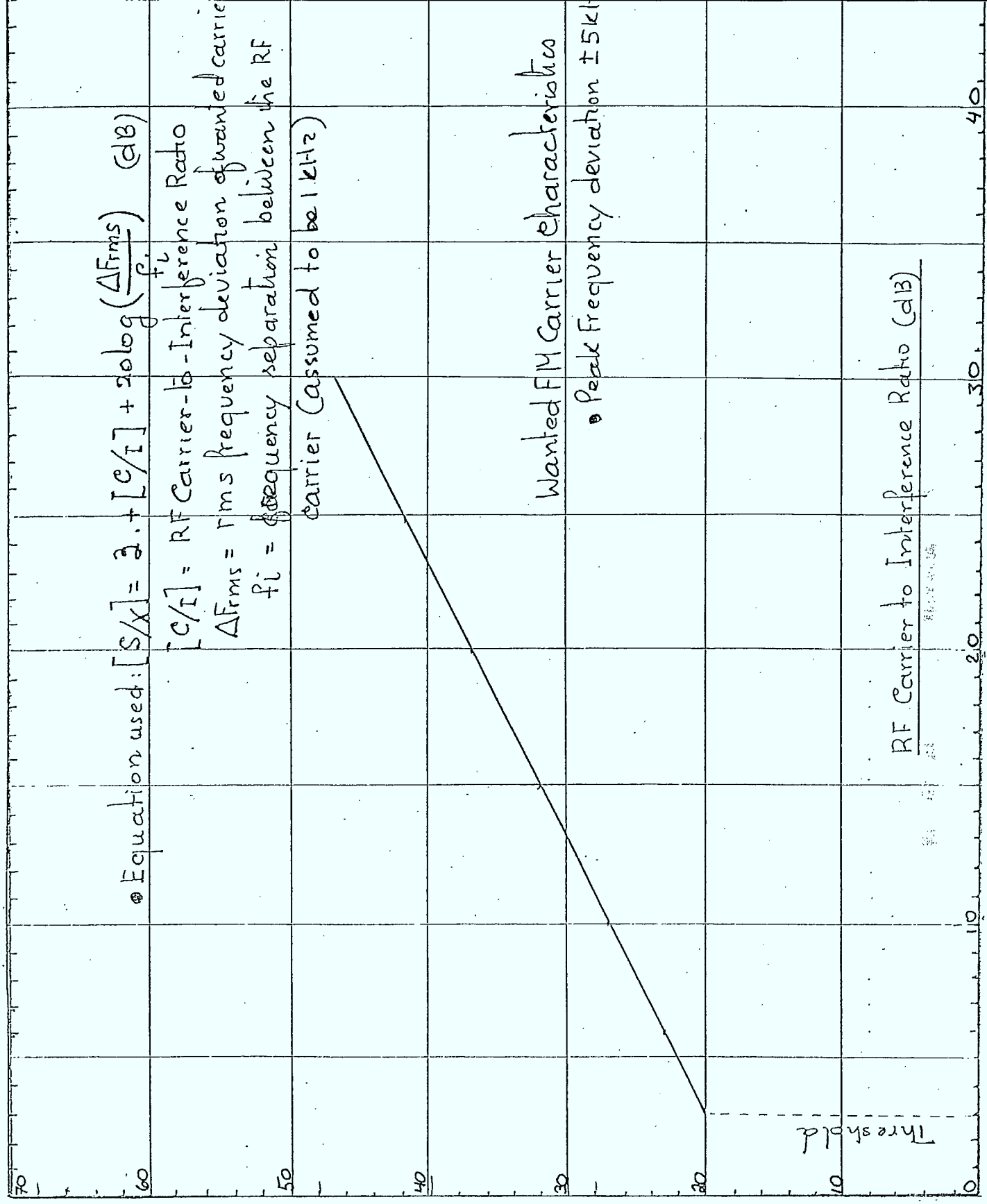


Figure 5.3-6: Co-channel Protection Ratio Voice Modulation, and Rayleigh Fading

Source: CCIR Report 899



Audio Signal to Interference Tone (1KHz) Ratio (dB)

Figure 5.3-7: Audio (S/x) vs RF (c/I) When Carrier and Interference are CW Signals

5.3.3 Protection Contours for the LMS

The following characteristics are assumed for the LMS:

- Base Station: ERP = 150 W

  EHAAT = 150 ft.

  Receiver input level for 12 dB SINAD: (Table 5.3-1)

- Mobile Station: ERP = 25 W

  EHAAT = 6 ft.

  Receiver input level for 12 dB SINAD: (Table 5.3-1)

The minimum field strength at the protected contour is also given in Table 5.3-1. The conversion from LMS receiver input power to the field strength in dBμ was effected using Figure 5.3-8. The CCIR Report 358 (4) provides data to determine the minimum required field strengths for base stations to have a Grade 4 (on a point scale) quality of service. This data is given in Figure 5.3-9. It is proposed to use the highest values. i.e.:

	Channels 2-6	Channels 7-13	Channels 14-69
Base Station, E(dBμ)	22	22	26
Mobile Station, E(dBμ)	18	18	18

The protected field strength shall be protected for 90% of the time from interference.

Parameters		channels 2-6 54-88 MHz	channels 7-13 170-220 MHz	channels 14-69 470-806 MHz
Base ① station	Input Power (dBW)	-131	-132	-138
	Field strength (dBu)	16	22	26
Mobile ① station	Input Power (dBW)	-127	-137	-146
	Field Strength (dBu)	18	17	18
② Base Station Field Strength (dBu)		22	21	26

Note: 1) From McMahon and Neham

2) CCIR Report 358 (4)

Table 5-3-1: Minimum Field Strengths for LMS Receivers

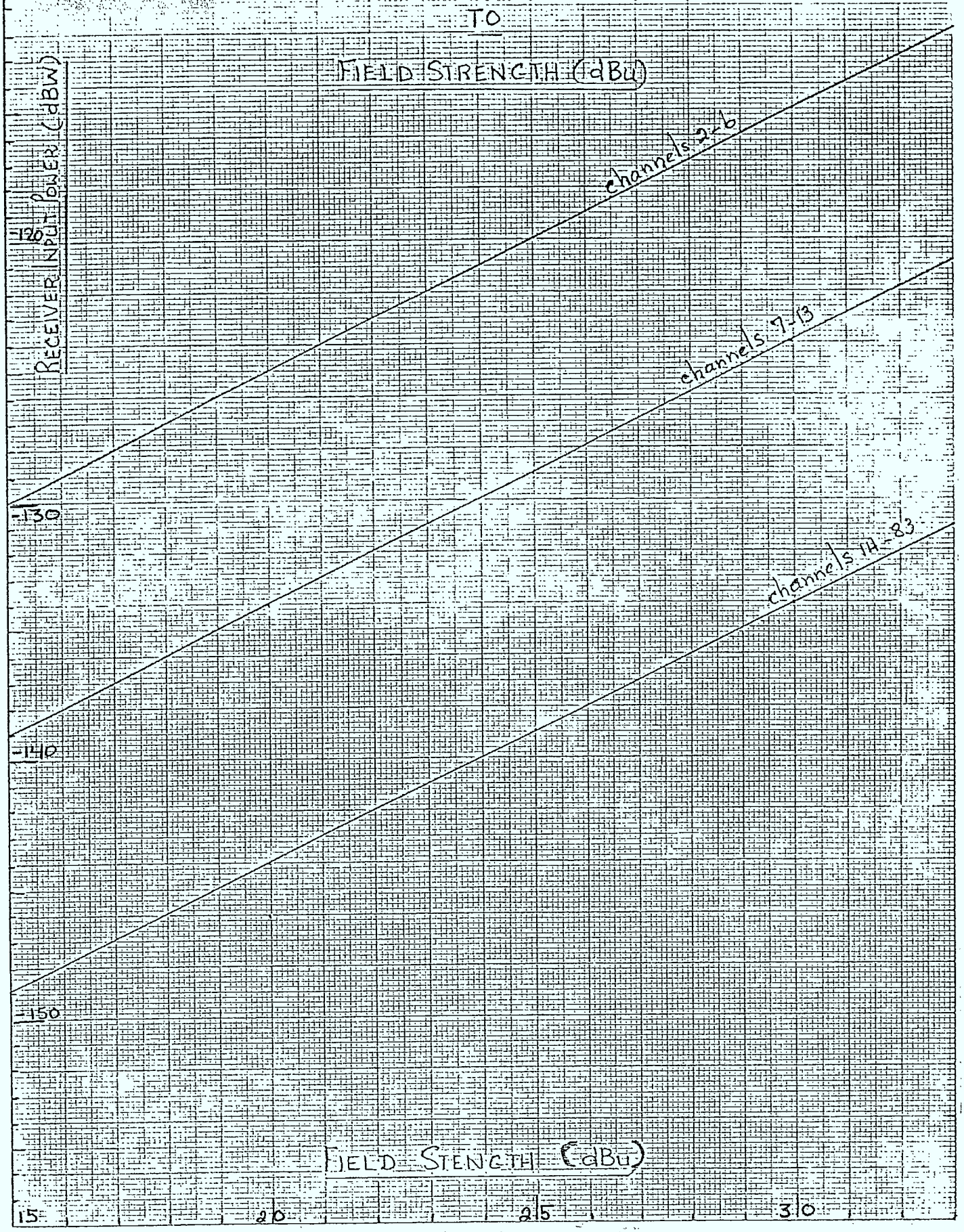


Figure 5.3-8: Conversion from Receiver Input Power (dBW)

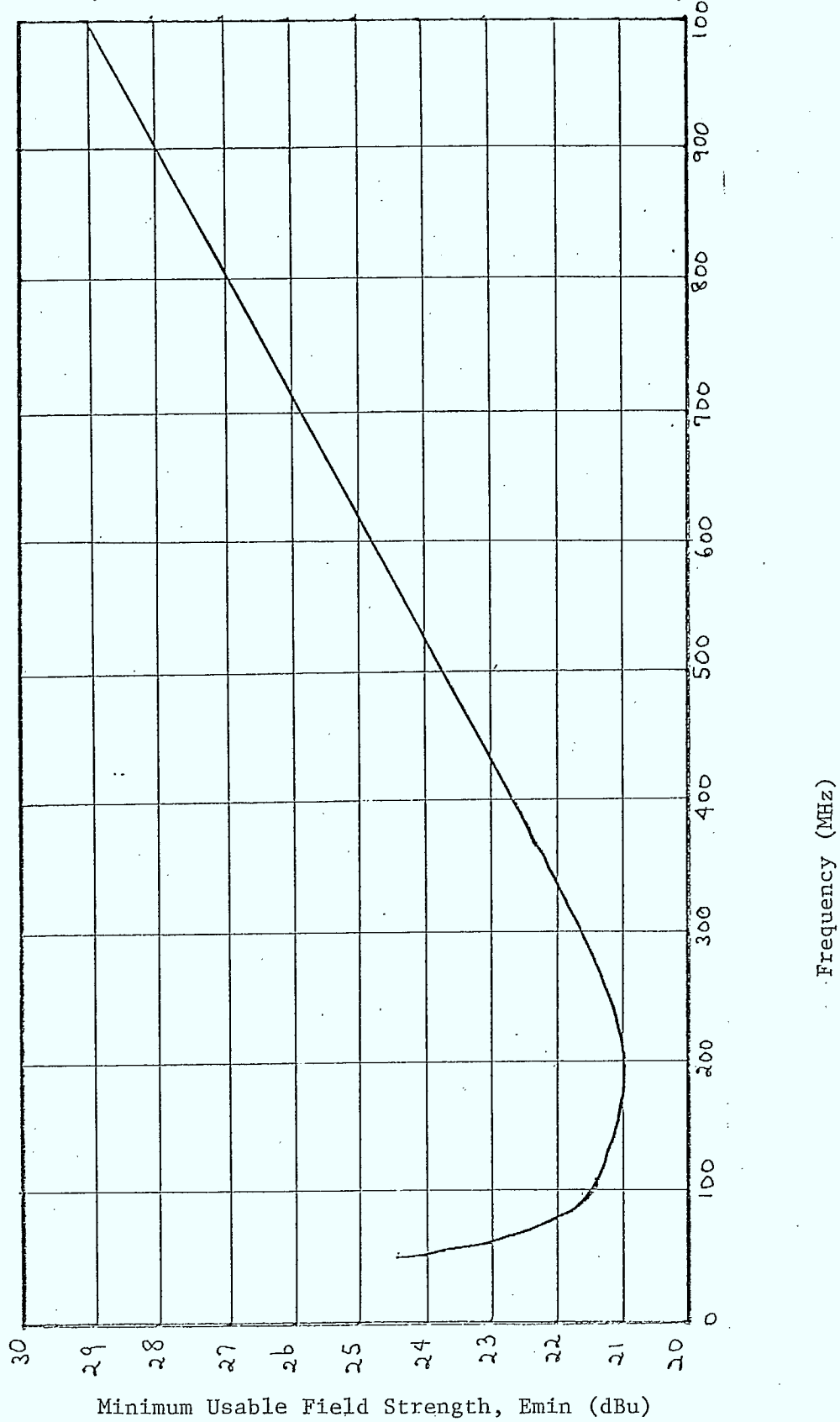


Figure 5.3-9: Minimum Usable Field Strength, Emin, vs Frequency for LMS

Source: CCIR Report 358 (4)

5.4 PROTECTION OF THE LOW POWER TV SERVICE

The Low Power TV (LPTV) service uses the same Grade B contour values and protection ratio as the TV Broadcast service. Its standard parameters are:

- Transmit ERP: channels 2-6: 100W

  channels 7-13: 100W

  channels 14-69: 5KW

- Antenna EHAAT: 100ft. for all frequency bands

6.0 PROPOSED LICENSING CRITERIA FOR TV/LMS INTERSERVICE SHARING

6.1 INTRODUCTION

This section gives the minimum separation distances required between the transmitters of the two different services for acceptable inter-service sharing. The various tables give the values of all the parameters used in arriving at the separation distances.

6.2 PROTECTION OF THE TV BROADCAST SERVICE FROM LMS

The minimum separation distance required to protect the TV coverage at its Grade B contour from the LMS base station was computed by ensuring that the F(50,10) prediction value of the field strength, from the base station transmitter, complied with:

$$E_u(50,10) = E_d\ (50,50) - PR + AD \quad (dB\mu)$$

where

$E_d(50,50)$ = Grade B contour field strength

PR = protection ratio in dB

AD = antenna discrimination factor in dB including cross-polarization and directivity discrimination

A value of 10 dB was assumed for AD? knowing E_u (50,10), the distance of the protected contour from the base transmitter was then determined.

Tables 6.2-1, 6.2-2 and 6.2-3 give the computed values for the co-channel, adjacent channel and the picture image channels respectively. Table 6.2-4 summarizes the results.

For the case of interference into the TV receiver from a mobile unit transmitter, Table 6.2-5 gives the margin when a mobile unit is at the closest point to the Grade B contour.

PARAMETERS		CHANNELS 2-6 55-88 MHz	CHANNELS 7-13 170-220 MHz	CHANNELS 14-69 470-806 MHz
Distance of Protected Contour from the Desired Transmitter	Desired Transmitter, ERP (KW)	100	316	1000
	Desired Transmitter, EHAAT (ft)	1000	1000	1000
	Desired Receiver, H_R (ft)	30	30	30
	Grade B Contour Field Strength (dBu)	47	56	64
	Distance to Contour (miles)	65	62	43
Max: Interference Level at the Protected Contour	Min: Desired Field Strength (dBu)	47	56	64
	Protection Ratio (dB)	40	40	40
	Antenna Discrimination Factor (dB)	10	10	10
	Max: Unwanted Field Strength (dBu)	17	26	34
Distance of Protected Contour from the Undesired Transmitter	Undesired Transmitter, ERP (W)	150	150	150
	Undesired Transmitter, EHAAT (ft)	150	150	150
	Desired Receiver, H_R (ft)	30	30	30
	Max: Field Strength at Contour (dBu)	17	26	34
	Distance to Contour (miles)	65	45	23
MINIMUM SEPARATION BETWEEN TXS (miles)		130	107	66

Table 6.2-1: LMS Interference into TV at Co-channel of TV

Table 6.2-1: LMS Interference into TV at Adjacent Channels of TV

PARAMETERS		CHANNELS 2-6 55-88 MHz	CHANNELS 7-13 170-220 MHz	CHANNELS 14-69 470-806 MHz
Distance of Protected Contour from the Desired Transmitter	Desired Transmitter, ERP (KW)	100	316	1000
	Desired Transmitter, EHAAT (ft)	1000	1000	1000
	Desired Receiver, H_R (ft)	30	30	30
	Grade B Contour Field Strength (dBu)	47	56	64
	Distance to Contour (miles)	65	62	43
Max: Interference Level at the Protected Contour	Min: Desired Field Strength (dBu)	47	56	64
	Protection Ratio (dB)	-5	-5	-5
	Antenna Discrimination Factor (dB)	10	10	10
	Max: Unwanted Field Strength (dBu)	62	71	79
Distance of Protected Contour from the Undesired Transmitter	Undesired Transmitter, ERP (W)	150	150	150
	Undesired Transmitter, EHAAT (ft)	150	150	150
	Desired Receiver, H_R (ft)	30	30	30
	Max: Field Strength at Contour (dBu)	62	71	79
	Distance to Contour (miles)	4.5	3	0.6
MINIMUM SEPARATION BETWEEN TXS (miles)		70	65	44

PARAMETERS		CHANNELS 2-6 55-88 MHz	CHANNELS 7-13 170-220 MHz	CHANNELS 14-69 470-806 MHz
Distance of Protected Contour from the Desired Transmitter	Desired Transmitter, ERP (KW)	100	316	1000
	Desired Transmitter, EHAAT (ft)	1000	1000	1000
	Desired Receiver, H_R (ft)	30	30	30
	Grade B Contour Field Strength (dBu)	47	56	64
	Distance to Contour (miles)	65	62	43
Max: Interference Level at the Protected Contour	Min: Desired Field Strength (dBu)	47	56	64
	Protection Ratio (dB)	10	10	10
	Antenna Discrimination Factor (dB)	10	10	10
	Max: Unwanted Field Strength (dBu)	47	56	64
Distance of Protected Contour from the Undesired Transmitter	Undesired Transmitter, ERP (W)	150	150	150
	Undesired Transmitter, EHAAT (ft)	150	150	150
	Desired Receiver, H_R (ft)	30	30	30
	Max: Field Strength at Contour (dBu)	47	56	64
	Distance to Contour (miles)	11	6	4
MINIMUM SEPARATION BETWEEN TXS (miles)		76	68	47

Table 6.2-3: LMS Interference into TV at Picture/Aural Image Channels of TV

149

? Could be lower

	Parameters	channels 2 - 6 (55 - 88 MHz)	channels 7 - 13 (170 - 220 MHz)	channels 14 - 69 (470 - 806 MHz)
Desired Tx characteristics	ERP (KW)	100	316	1000
	EHAAT (ft)	1000	1000	1000
	Rx Antenna Height, H_R (ft)	30	30	30
	Grade B Contour F(50, 50) (dBu)	47	56	64
	Distance to Contour (miles)	65	62	43
Undesired Tx characteristics	ERP (W)	150	150	150
	EHAAT (ft)	150	150	150
Minimum Separation Distance (miles)	Co-channel (n=0)	130 miles	107 miles	66 miles
	Adjacent channel (n=±1)	70 miles	65 miles	44 miles
	Picture Image (n=±15)	76 miles	68 miles	47 miles

Table 6.2-4: Minimum Separation Distances between Transmitter for the Protection of TV from LMS

Parameters	channels 2-6 (54-88 MHz)	channels 7-13 (170-220 MHz)	channels 14-69 (470-806 MHz)
Grade B contour from TV transmitter (miles)	65	62	43
LMS TV Tx from TV Tx (miles)	130	107	66
Mobile Unit from Base Tx (miles)	24	24	19
Mobile Unit from Grade B Contour (miles)	41	21	4
Max: Interference Signal at Contour (dBu)	17	26	34
Max: Interference From Mobile Unit at Contour (dBu)	-12.5	0	27
Margin (dB)	29.5	26	7

Table 6.2-5: Interference from LMS Mobile Unit into TV Receiver at the Grade B Contour for the Co-channel Case

Note: The horizon is 8 miles from the 30 ft. antenna and 4 miles from the 6 ft. antenna so for the channels 2-6 and channels 7-13, the TV receiver antenna is well below the horizon. Additional losses will occur due to diffraction at the horizon

6.3 PROTECTION OF THE LMS FROM THE TV BROADCAST SERVICE

6.3.1 Protection of the Base Station Receiver

The parameters and their values involved in determining the interference into the LMS base station receiver from a TV transmitter are given in Table 6.3-1. This table shows that for an acceptable level of interference, the distances between the stations should not be less than 110 miles, 130 miles and 120 miles for the VHF low-band, VHF high-band and the UHF bands respectively. However, from Table 6.2-1, the minimum, separation distances, to avoid unacceptable interference into TV from the LMS, are 130 miles, 107 miles and 66 miles, respectively. Therefore, problems could arise in the VHF high-band and the UHF band.

An alternative way of looking at this is given in Table 6.3-2

However, with the separations determined in Table 6.2-1, the LMS base station, with antenna heights of 100 feet, is well below the lens sight of 63 miles. If Bullington's nomograph can be used to compute the additional diffraction loss introduced, the additional loss is 45 dB for the VHF lowband, 49 dB for VHF highband and 23 dB for the UHF band. If this additional loss is included, then the negative margins disappear.

In the FCC reports (TV transmitter ERP = 1,000 KW, EHAAT = 1,000 ft. and LMS base ERP = 1 KW, EHAAT = 500 ft.), the minimum separation distance was found to be 90 miles. This was beyond the line of sight horizon of 78 miles and was considered to provide the LMS base station with sufficient protection from the TV transmitter.

6.3.2 Protection of the Mobile Unit Receiver

Table 6.3-3 gives the margins for the protection of the mobile unit receiver. The margins for the highband VHF and UHF are insufficient. However, in the case of the highband VHF, the line of sight horizon is 48 miles, while the minimum separation distance from the transmitter is 83 miles. For the UHF band case, the minimum separation distance corresponds to that of the line of sight horizon, in which case, an additional loss of 20 dB will be incurred.

Table 6.3-1: TV Interference into the LMS Base Station Receiver

Parameters	channels 2-6 (55 - 88 MHz)	channels 7-13 (170 - 220 MHz)	channels 14 - 69 (470 - 806 MHz)
Interfering TV Transmitter ERP (kW)	100	316	1000
Interfering TV Transmitter EHAAT (ft)	1000	1000	1000
Base Station Receiver H_R (ft)	150	150	150
Distance between stations D (miles)	130	107	66
E (50, 10) at Base Station Receiver (dBu)	46	60	73
Max. Permissible Interference (dBu) (1)	52	52	56
Margin (dB)	+6	-8	-17
Additional Loss due to Transhorizon Loss (2)	49	49	23
Real Margin (dB)	56	41	+6

does not match!

UHF: E_D: 25 dB
protection ratio: -20 dB
pol disc: -20 dB
E_U: 66 dB

Notes: 1. The minimum field strength in the VHF low, VHF high and UHF bands were respectively 22 dBu, 22dBu and 26dBu and the protection ratios were 20 dB for all bands and a polarization discrimination of 20dB for all bands.

2. The path between the two antennas is intercepted by the horizon. Use of Bullington's nomograph for computation of the additional loss for a smooth, curved earth gave the loss values shown.

note: 1. pol discr of 20 dB is high

2. prot ratio of -20 dB is valid if LMS is operating between picture and color carriers where TV signal is 30 dB down from picture carrier level: 30 - 10 (protection ratio) = 20

	channels 2-6 (54 - 88 MHz)	channels 7-13 (170 - 220 MHz)	channels 14-69 (470 - 806 MHz)
Max: Level of Interference for Acceptable Quality (dBu)	52	52	56
Interference Level from TV Transmitter (dBu)	46	60	73
Margin (dB)	6	-12	-17

Table 6.3-2: Interference Levels at the Base Station Receiver

Parameters	channels 2-6 (55-88 MHz)	channels 7-13 (170-220 MHz)	channels 14-69 (470-806 MHz)
Interfering TV Transmitter ERP (kW)	100	316	1000
Interfering TV Transmitter EHAAT (ft)	1000	1000	1000
Mobile unit Receiver antenna height H_R (ft)	6	6	6
Distance between the stations (miles)(1)	106	83	47
Interfering Field Strength at Receiver (dBu)	33.	47	57
Minimum Desired Field Strength (dBu)	18	17	18
Protection Ratio (dB)	-20	-20	-20
Antenna Discrimination (polarization) (dB)	10	10	10
Max: Permissible Interference Level (dBu)	48	47	48
Margin (dB)	15	0	-9.

f in between picture and color carriers

30-10=20

Note: See Table 6.3-3a for the distance between the base transmitter and the mobile unit on the protected contour

Table 6.3-3: TV Interference into LMS Mobile Unit Receiver

PARAMETERS		CHANNELS 2-6 55-88 MHz	CHANNELS 7-13 170-220 MHz	CHANNELS 14-69 470-806 MHz
Distance of Protected Contour from the Desired Transmitter	Desired Transmitter, ERP (W)	150	150	150
	Desired Transmitter, EHAAT (ft)	150	150	150
	Desired Receiver, H_R (ft)	6	6	6
	Grade B Contour Field Strength (dBu)	18	17	18
	Distance to Contour (miles)	24	24	19

Table 6.3-3a: Protected Contour Field Strength and Distance from Base Tx of LMS

6.3.3 Protection of the Mobile Unit Receiver from TV Receiver L.O

The radiation from TV receiver's local oscillators affect the UHF band only. The frequency of the radiation from the local oscillators is 45.75 MHz above the frequency of the TV channel being received.

(A) The following discussion is intended to give an indication of the effect of such radiation. The level of the local oscillator at the TV receiver input was measured to be 18 mV maximum in Project 6: CRTPB Ad Hoc Committee's Report.

This amounts to a power level of 1μW (-60dBW) into a 300 Ω resistance. Allowing a cable loss of 2 dB, the level at the TV receiver antenna is -62 dBW.

The antenna directivity gain can be taken as +8 dB in the direction of the mainlobe and -8 dB in all other directions, giving an ERP of -54 dBW in the mainlobe and -70 dBW in all other directions.

The electric field strength at any distance, d (in miles) from the TV receiver can be computed from:

$$E\ (dB\mu) = 10\log Perp + 20\log H_t + 20\log H_R - 40\log d - 7.0$$

when H_T and H_R are in feet

For the particular case when H_T = 30ft. and H_R = 6ft., the electric field strength becomes:

$$E\ (dB\mu) = 10\log Perp - 40\log d + 45.4 \qquad (1)$$

The following table gives the interference field strength at the mobile unit which should not be exceeded.

Table 6.3-4: Maximum Interference Level at the Mobile Unit

Minimum desired Signal (dBμ)	18
Required Protection Ratio (dB) *	10
Receive Antenna Polarization Discrimination (dB)	0
Max: permissible Interference Level (dBμ)	~~28~~ 8 or 2.5 μV/m

Note: * see Section 5.3-2

Using the values given in Table 6.3-4 for E in Equation (1), the following values of d, separation between the TV receiver and Mobile unit, were determined:

- Main beam direction: 642 feet
- Off-main beam direction: 255 feet

This may be somewhat conservative since the maximum local oscillator leakage was used in the analysis.

(B) FCC Part 15 has specified that the local oscillator radiation from a TV receiver should not exceed 350 μV/m at a distance of 100 feet from the receiver.

If the maximum permissible radiation at the mobile unit is to be 18 dBμ, the equivalent field strength is 7.8 μV/m; then assuming a d^{-4} propagation loss, the permissable value of field strength will exist at a distance of 258 feet from the receiver.

(C) In the foregoing paragraphs (A) and (B), it was assumed that the whole spectrum of the TV channel would be used by the land mobile service. If, however, only that part of the TV channel from 2.0 to 4.5 MHz is used, then the land mobile service will not be affected by the TV receiver local oscillator radiation.

→ then protection ratio becomes = (30-10) = 20

6.4 PROTECTION OF THE LOW POWER TELEVISION SERVICE

6.4.1 Protection of the TV Service from the LMS Base Transmitter

The standard parameters assumed for the LPTV transmitter are as given in Table 6.4-1.

Parameters	channels 2-6 (54-88 MHz)	channels 7-13 (170-220 MHz)	channels 14-69 (470-806 MHz)
ERP	100 W	100 W	5 KW
EHAAT	100 ft.	100 ft.	100 ft.
Field Strength at Grade B Contour	47 dBμ/m	56 dBμ/m	64 dBμ/m
Distance to Grade B Contour	7.5 miles	5 miles	7.5 miles

Table 6.4-2 gives the minimum separation distances required between the LPTV transmit antenna and the LMS base station transmitter to ensure that the Grade B contour is protected for 90% of the time from interference from the land mobile service. Tables 6.4-3, 6.4-4 and 6.4-5 indicate how these separation distances were derived. Figures 6.4-1, 6.4-2 and 6.4-3 give the propagation characteristics of the LPTV service.

Table 6.4-1: Standard Parameters for LPTV Transmitters

6.4.2 Protection of the LMS from the LPTV Broadcast Service

6.4.2.1 Protection of the Base Station Receiver

Table 6.4-6 gives a detailed breakdown of the computation involved in determining the interference into the LMS base station receiver from the LPTV transmitter for the co-channel case, for the minimum separation distances given in Section 6.4.1

The table shows that there is adequate margin for channels 2-6 and channels 7-13 but for the UHF case, the margin is not adequate. Adequate margin can be obtained by:

- reducing the height of the LPTV transmitter antenna from 100ft.
- reducing the ERP of the LPTV transmitter from 5 KW

Parameters		channels : 2 - 6 (54 - 88 MHz)	channels : 7 - 13 (170 - 220 MHz)	channels : 14 - 69 (470 - 806 MHz)
Desired LPTV Tx Characteristics	Transmitter ERP (W)	100	100	5,000
	Transmitter EHAAT (ft)	100	100	100
	Receiver Antenna Height H_R (ft)	30	30	30
	Reqd: F(50,50) at Grade B Contour (dBu)	47	56	64
	Distance of Contour from LPTV Tx (miles)	7.5	5.0	7.5
Undesired Transmitter Characteristics	Transmitter ERP (W)	150	150	150
	Transmit Antenna EHAAT (ft)	150	150	150
Minimum Separation Distance Between Tx	Co-channel Case ($n = 0$)	72.5	50	30.5
	Adjacent Channel Case ($n = \pm 1$)	12	8	8
	Picture Image Case ($n = \pm 15$)	18.5	11.0	11.5

Table 6.4-2: Minimum Separation Distances Between the LPTV Transmitter and the LMS Base Staiton Transmitter

Table 6.4-3: LMS Base Transmitter Interference into LPTV - Co-channel Case

PARAMETERS		CHANNELS 2-6 55-88 MHz	CHANNELS 7-13 170-220 MHz	CHANNELS 14-69 470-806 MHz
Distance of Protected Contour from the Desired Transmitter	Desired Transmitter, ERP (kW)	0.1	0.1	5
	Desired Transmitter, EHAAT (ft)	100	100	100
	Desired Receiver, H_R (ft)	30	30	30
	Grade B Contour Field Strength (dBu)	47	56	64
	Distance to Contour (miles)	7.5	5.0	7.5
Max: Interference Level at the Protected Contour	Min: Desired Field Strength (dBu)	47	56	64
	Protection Ratio (dB)	40	40	40
	Antenna Discrimination Factor (dB)	10	10	10
	Max: Unwanted Field Strength (dBu)	17	26	34
Distance of Protected Contour from the Undesired Transmitter	Undesired Transmitter, ERP (W)	150	150	150
	Undesired Transmitter, EHAAT (ft)	150	150	150
	Desired Receiver, H_R (ft)	30	30	30
	Max: Field Strength at Contour (dBu)	17	26	34
	Distance to Contour (miles)	65	45	23
MINIMUM SEPARATION BETWEEN TXS (miles)		72.5	50	30.5

Table 6.4-4: LMS Base Transmitter Interference into LPTV: Adjacent Channel Case

PARAMETERS		CHANNELS 2-6 55-88 MHz	CHANNELS 7-13 170-220 MHz	CHANNELS 14-69 470-806 MHz
Distance of Protected Contour from the Desired Transmitter	Desired Transmitter, ERP (kW)	0.1	0.1	5
	Desired Transmitter, EHAAT (ft)	100	100	100
	Desired Receiver, H_R (ft)	30	30	30
	Grade B Contour Field Strength (dBu)	47	56	64
	Distance to Contour (miles)	7.5	50	7.5
Max: Interference Level at the Protected Contour	Min: Desired Field Strength (dBu)	47	56	64
	Protection Ratio (dB)	-5	-5	-5
	Antenna Discrimination Factor (dB)	10	10	10
	Max: Unwanted Field Strength (dBu)	62	71	79
Distance of Protected Contour from the Undesired Transmitter	Undesired Transmitter, ERP (W)	150	150	150
	Undesired Transmitter, EHAAT (ft)	150	150	150
	Desired Receiver, H_R (ft)	30	30	30
	Max: Field Strength at Contour (dBu)	62	71	79
	Distance to Contour (miles)	4.5	3	0.6
MINIMUM SEPARATION BETWEEN TXS (miles)		12	8	8

PARAMETERS		CHANNELS 2-6 55-88 MHz	CHANNELS 7-13 170-220 MHz	CHANNELS 14-69 470-806 MHz
Distance of Protected Contour from the Desired Transmitter	Desired Transmitter, ERP (KW)	0.1	0.1	5
	Desired Transmitter, EHAAT (ft)	100	100	100
	Desired Receiver, H_R (ft)	30	30	30
	Grade B Contour Field Strength (dBu)	47	56	64
	Distance to Contour (miles)	7.5	5.0	7.5
Max: Interference Level at the Protected Contour	Min: Desired Field Strength (dBu)	47	56	64
	Protection Ratio (dB)	10	10	10
	Antenna Discrimination Factor (dB)	10	10	10
	Max: Unwanted Field Strength (dBu)	47	56	64
Distance of Protected Contour from the Undesired Transmitter	Undesired Transmitter, ERP (W)	150	150	150
	Undesired Transmitter, EHAAT (ft)	150	150	150
	Desired Receiver, H_R (ft)	30	30	30
	Max: Field Strength at Contour (dBu)	47	56	64
	Distance to Contour (miles)	11	6	4
MINIMUM SEPARATION BETWEEN TXS (miles)		18.5	11.0	11.5

Table 6.4-5: LMS TX Interference into LPTV - Picture Image Channel

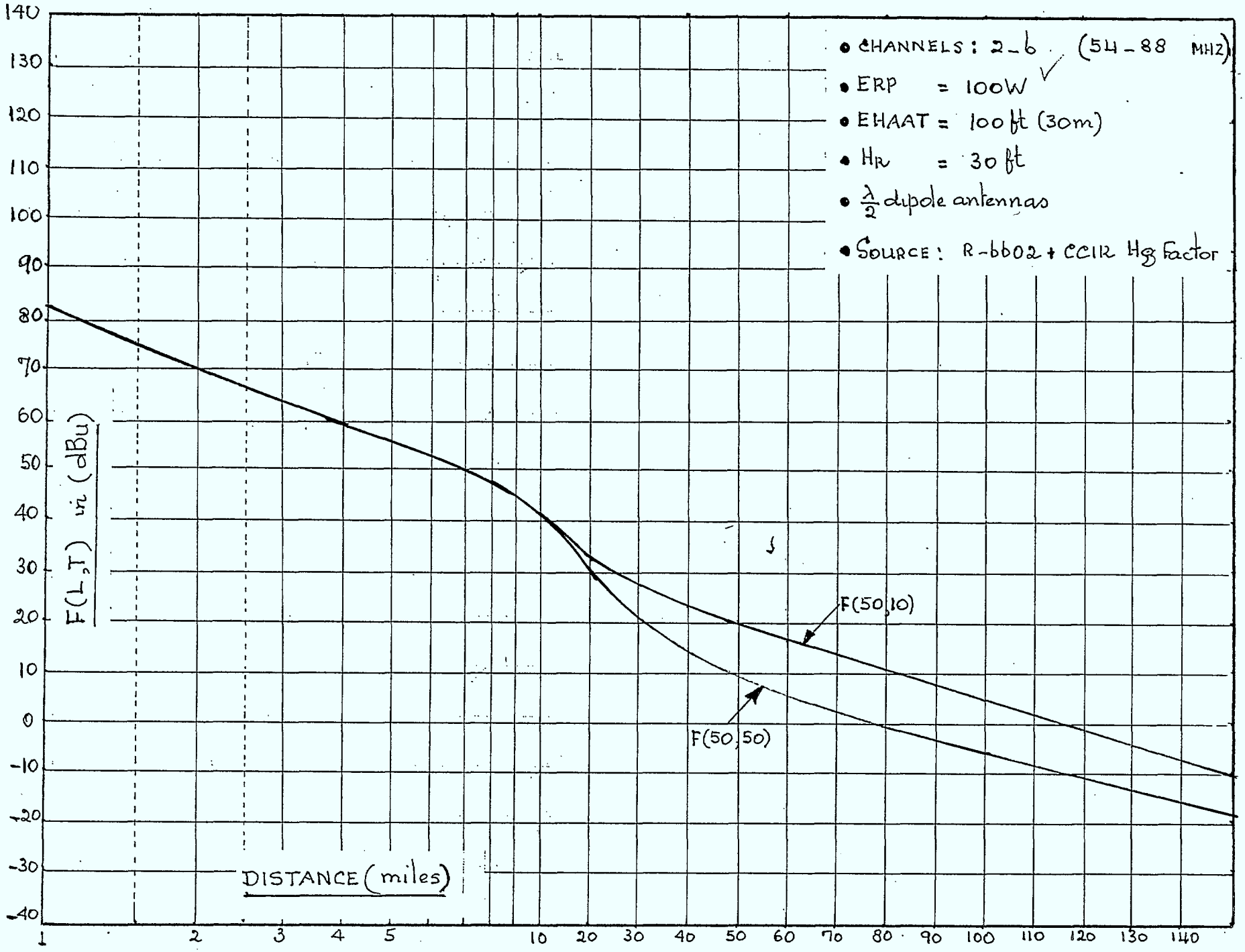


Figure 6.4-1: Field Strength vs Distance: LPTV TX to TV Receiver

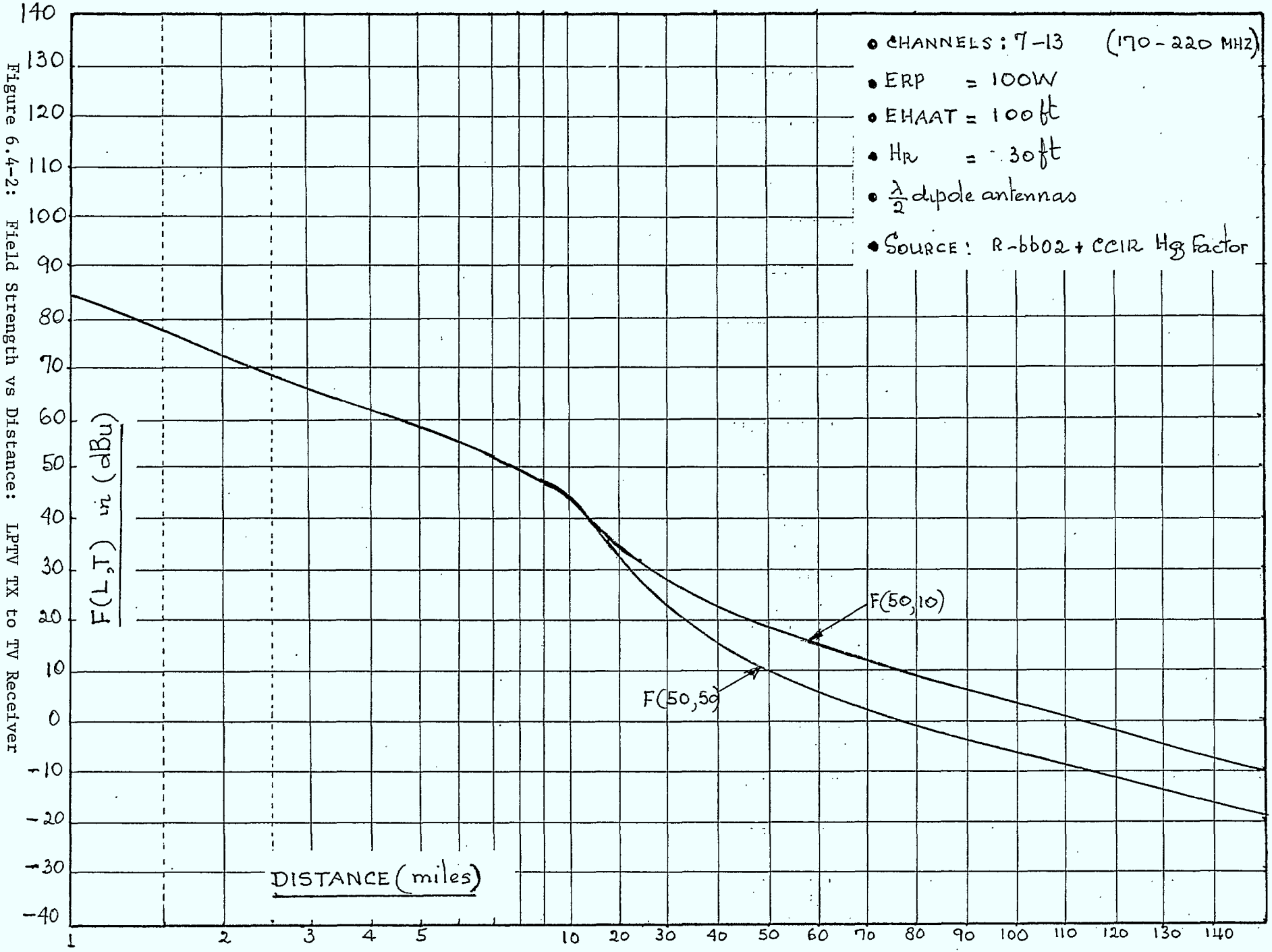


Figure 6.4-2: Field Strength vs Distance: LPTV TX to TV Receiver

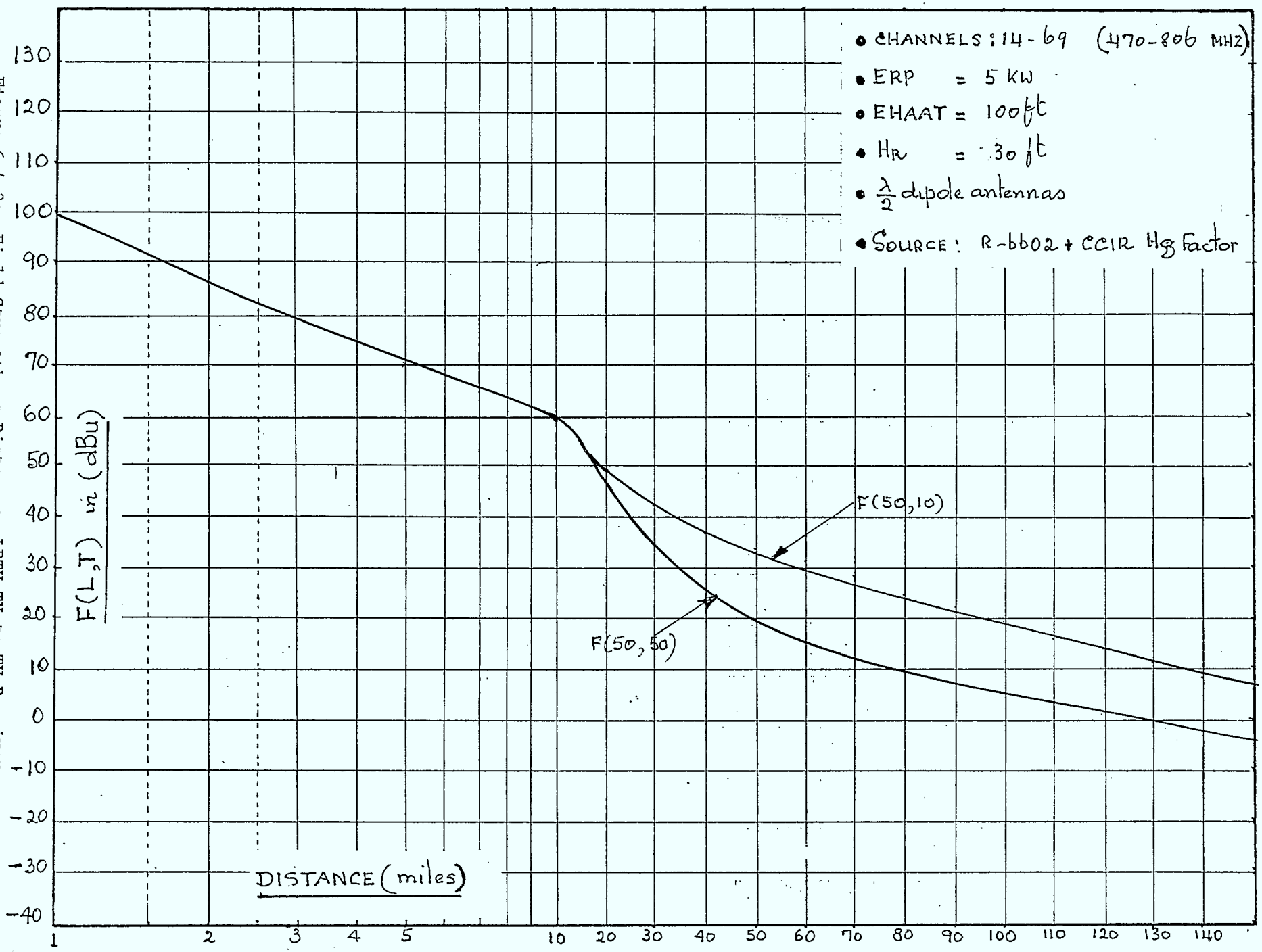


Figure 6.4-3: Field Strength vs Distance: LPTV TX to TV Receiver

- reducing the height of the base station receive antenna from 150ft.

- use of directional antennas with a null in the direction of the base station antenna

The margin gained in reducing the antenna height (LPTV Tx or Base Rx) is $20\log_{10}(H/H_0)$ where H is the reduced height and H_0 is the standard parameter height. For example, reducing the base station antenna height to 100ft. will give a margin of 3.5 dB. The margin gained by reducing the LPTV transmitted ERP is $10\log(P/P_0)$ dB.

6.4.2.2 Protection of the Mobile Unit Receiver from the LPTV Transmissions

Table 6.4-7 gives the computed details of the interference from the LPTV transmitter into the LMS mobile unit receiver at its closest point to the transmitter. The margin is adequate since the mobile unit will only receive this interference when it is at its closest point to the LPTV transmitter and when it is operating.

6.5 CONCLUSIONS

6.5.1 INTRODUCTION

The analysis presented in this report is based on the following:

OK 1) the propagation curves for the different transmission paths are valid

— to be verified 2) the protection ratios are valid

— to be verified 3) the antenna discrimination factor is valid

— to be verified 4) the transmitter and receiver characteristics are valid

to image

The propagation curves, used in the analysis, were checked against those available in published literature and give good agreement. However, published curves do not always state the conditions for which their curves are valid. This is an area in which the uncertainty could be ± 5 dB.

The protection ratios, used, were obtained from subjective test results by several different administrations under various test conditions. The values used in this report are conservative, probably, by at least 5 dB.

The antenna discrimination factor of 10 dB was assumed for both directivity and cross-polarization discriminations. Tests on a test range indicate that the back-to-front ratios could vary from 10 to 20 dB and the cross-polarization discrimination from 20 to 30 dB for the TV receiver antenna. Cross-polarization

also sharing of TV & LM will usually take place in urban areas i.e. most likely in Grade A contours of TV stations so $E_{d_{TV}}$ is higher

Parameters		channels 2-6 (54-88 MHz)	channels 7-13 (170-220 MHz)	channels 14-69 (470-806 MHz)
Base Station Receiver characteristics	Minimum Field Strength Required (dBu)	22	22	26
	Protection Ratio from TV (dB)	-20	-20	-20
	Antenna Polarization Discrimination (dB)	10	10	10
	Max: Interference Field Strength (dBu)	52	52	56
Interfering LPTV Tx characteristics	LPTV transmitter ERP (W)	100	100	5,000
	LPTV transmitter EHAAT (ft)	100	100	100
	Base Receiver Antenna Height (ft)	150	150	150
	F(50,10) at Base Receiver (1) (dBu)	17.5	30	56
MARGIN (dB)		34.5	22	0

Table 6.4-6: LPTV Tx Interference into LMS Base Receiver for the Co-channel Case

Note: (1) The f(50,10) values were obtained form Figure 6.4-4, 6.4-5, 6.4-6. The co-channel transmitters minimum separations were 72.5 miles, 50 miles and 30.5 miles respectively for channels 2-6, channels 7-13, and channels 14-6a; see Tanle 6.4-2.

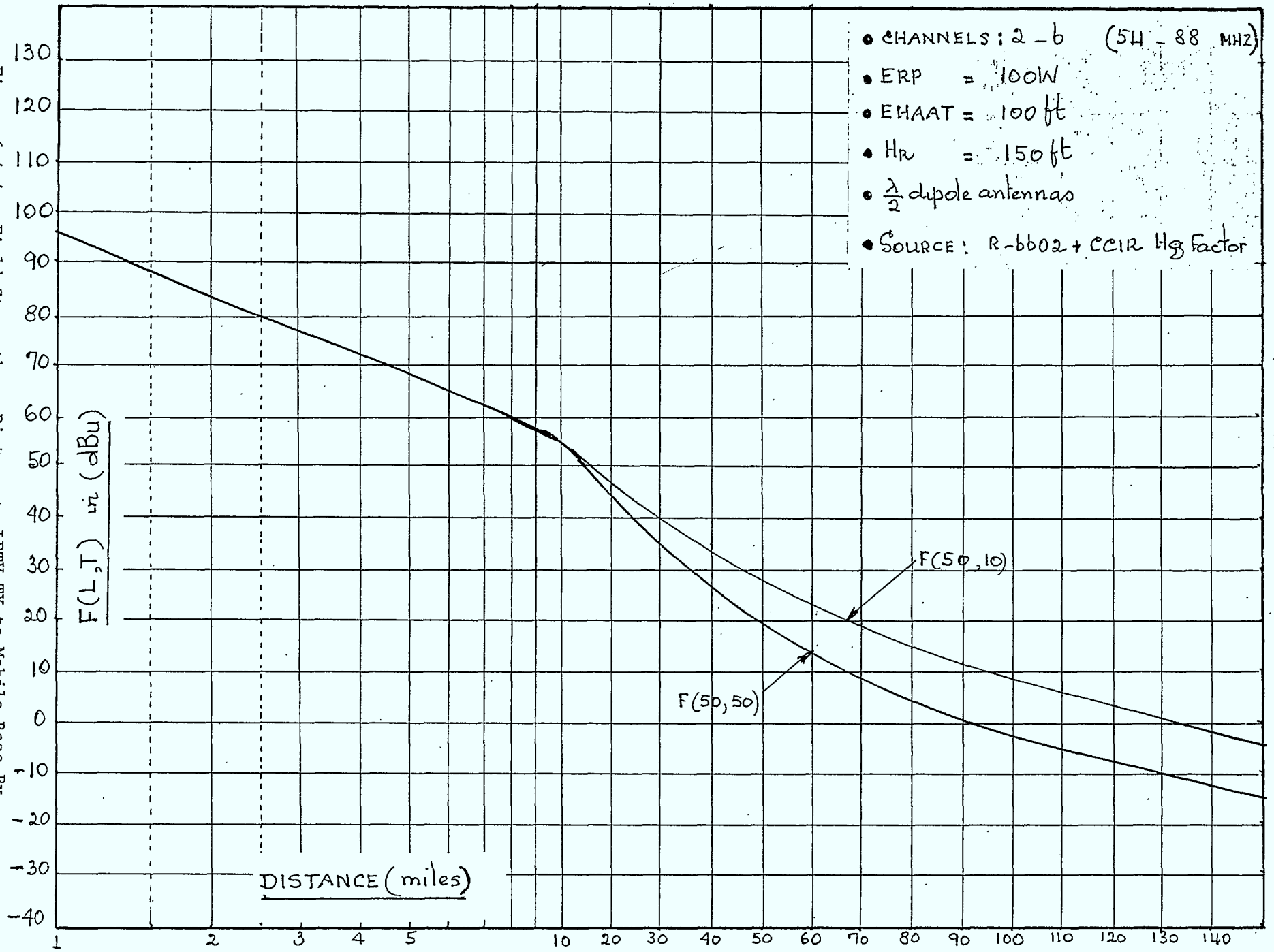


Figure 6.4-4: Field Strength vs Distance: LPTV TX to Mobile Base Rx

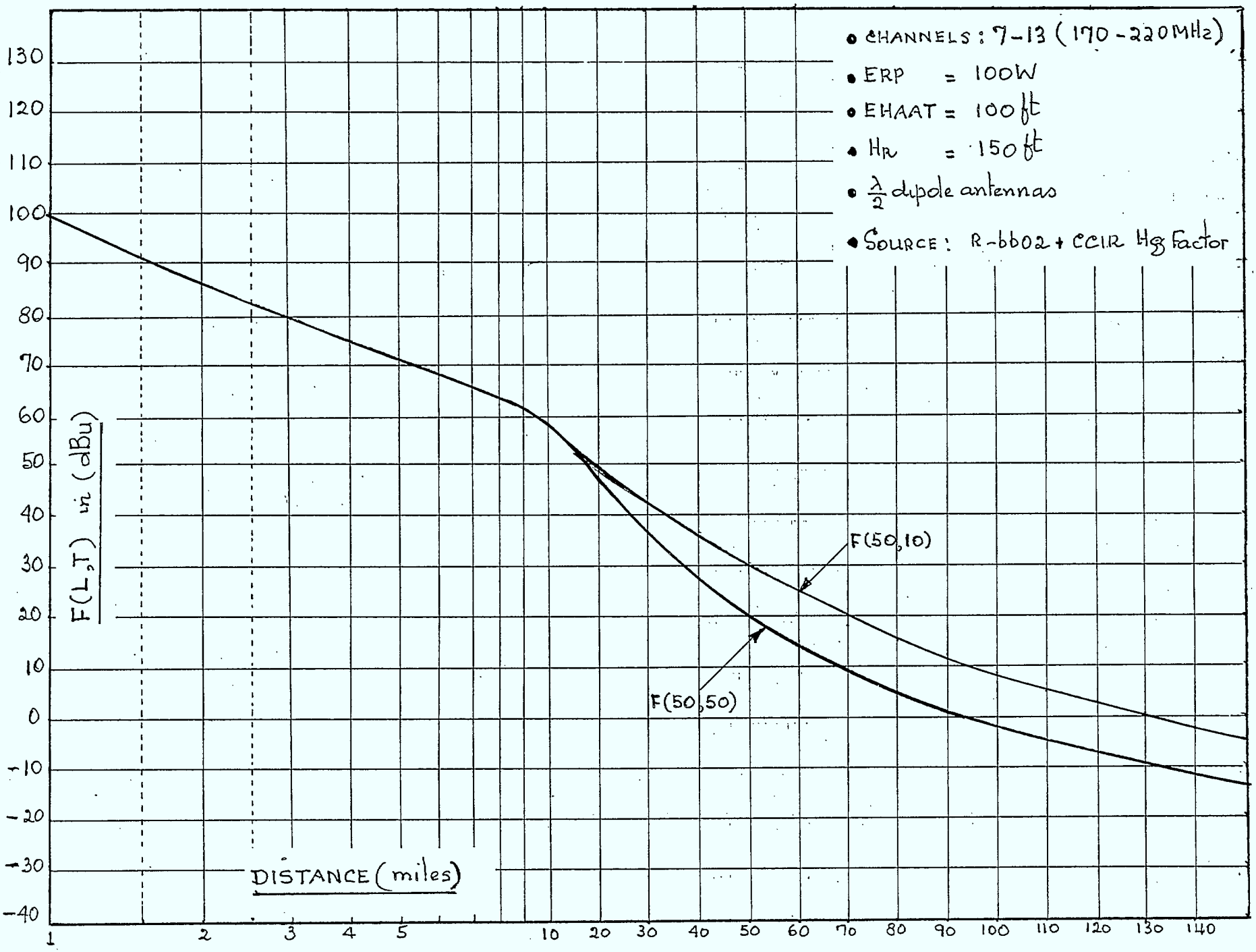


Figure 6.4-5: Field Strength vs Distance: LPTV TX to Mobile Base Station Rx

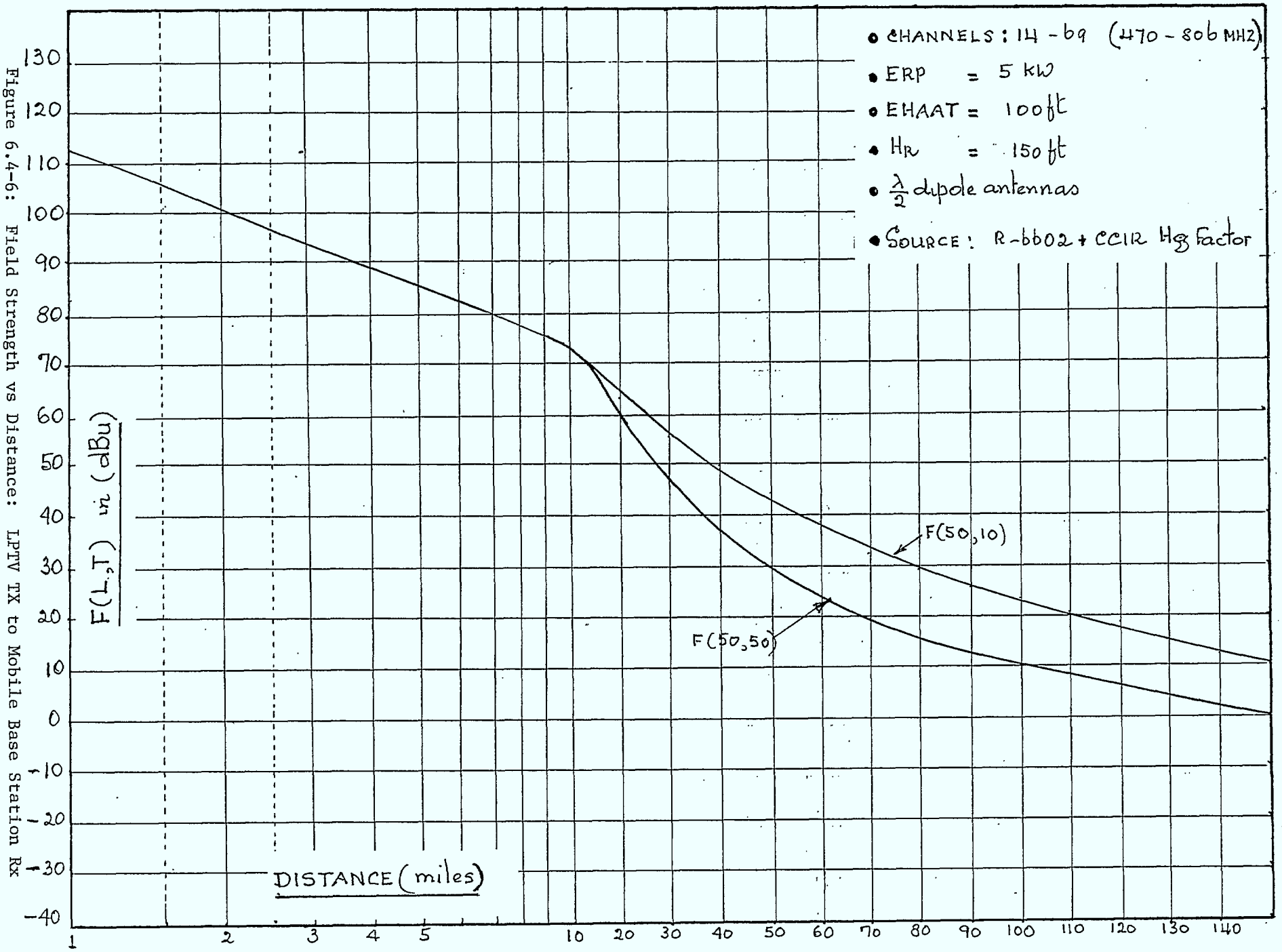


Figure 6.4-6: Field Strength vs Distance: LPTV TX to Mobile Base Station Rx

Parameter		channels 2-6 (54-88 MHz)	channels 7-13 (170-220 MHz)	channels 14-69 (470-806 MHz)
Maximum Permissible Interfering Field Strength	Minimum Field Strength Required (dBu)	18	17	18
	Protection Ratio from TV (dB)	-20	-20	-20
	Antenna Polarization Discrimination (dB)	10	10	10
	Max: Interference Field Strength (dBu)	48	47	48
Actual Interfering Field Strength	LPTV Tx ERP (W)	100	100	5 000
	LPTV Tx EHAAT (ft)	100	100	100
	Mobile Rx Antenna Height, H_R (ft)	6	6	6
	F(50,10) Field Strength at Rx (1) (dBu)	10	20	40
MARGIN (dB	(dB)	38	27	8

Table 6.4-7: LPTV Tx Interference into LMS Mobile Unit Receiver

Note: (1) The f(50,10) values were obtained from Figures 6.4-7, 6.4-8 and the minimum separation of the mobile unit from the LPTB Tx was 48.5 miles, 24 miles and 11.5 miles for channels 2-6, channels 7-13, and channels 14-6a respectively.

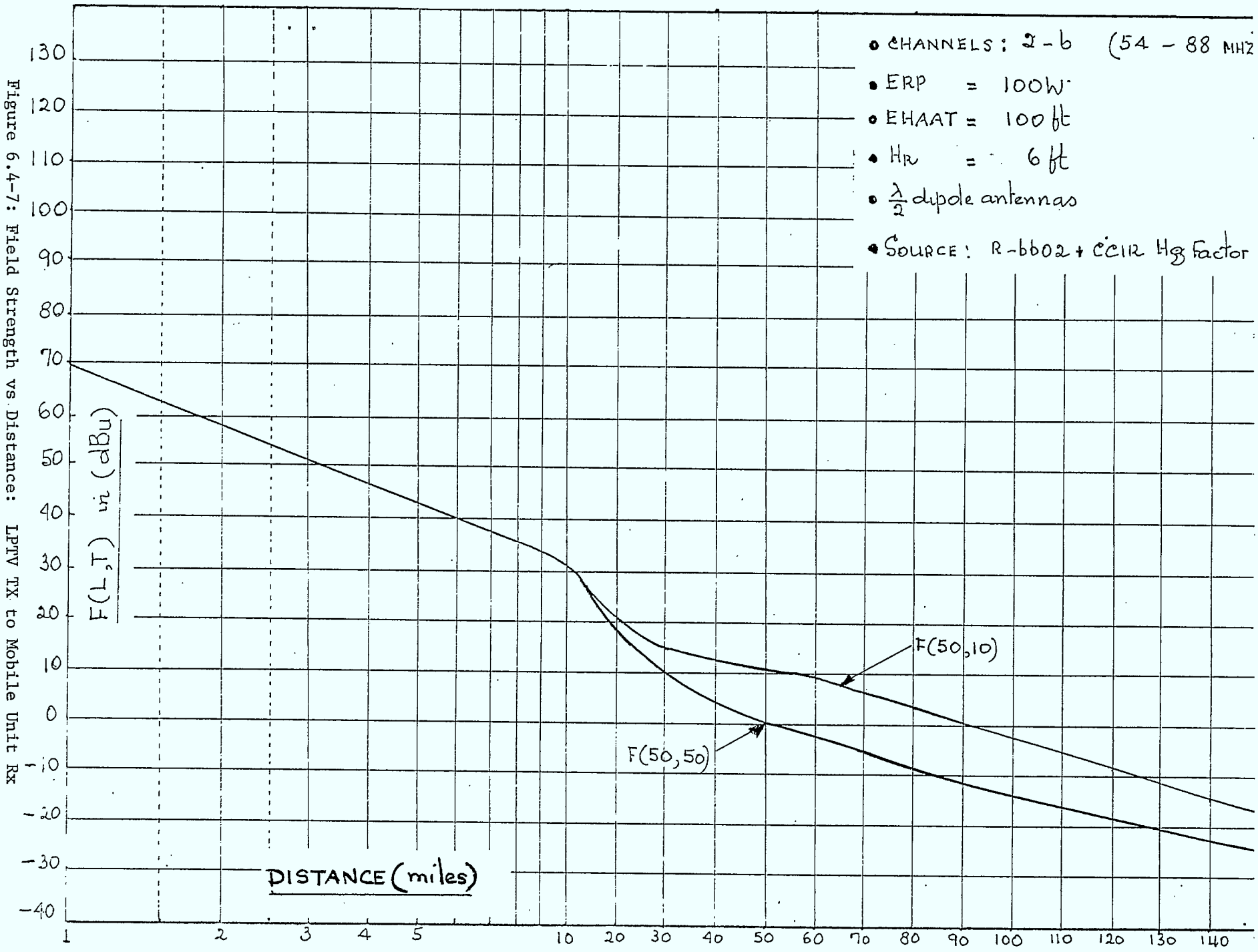


Figure 6.4-7: Field Strength vs Distance: LPTV TX to Mobile Unit Rx

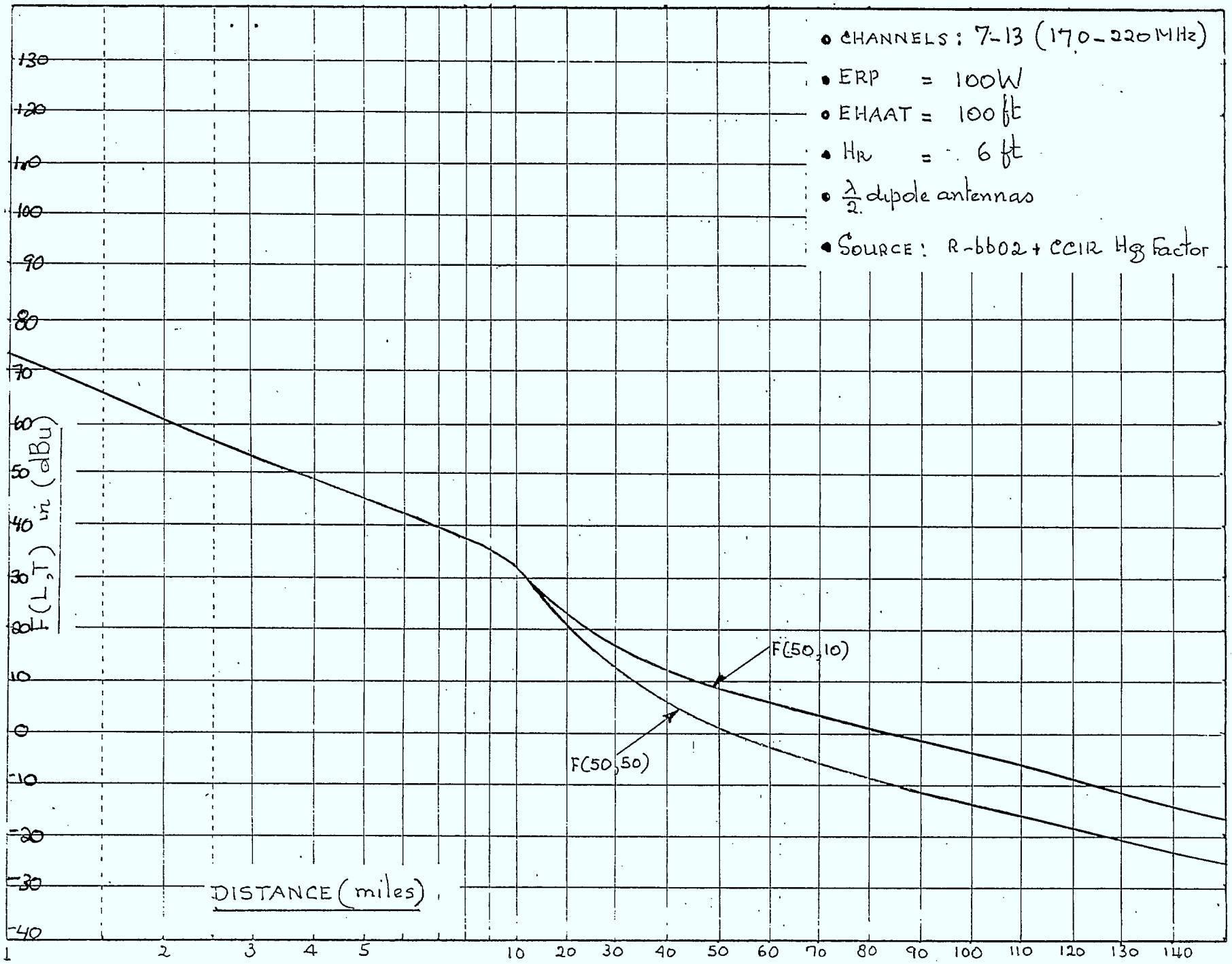


Figure 6.4-8: Field Strength vs Distance: LPTV TX to Mobile Unit Rx

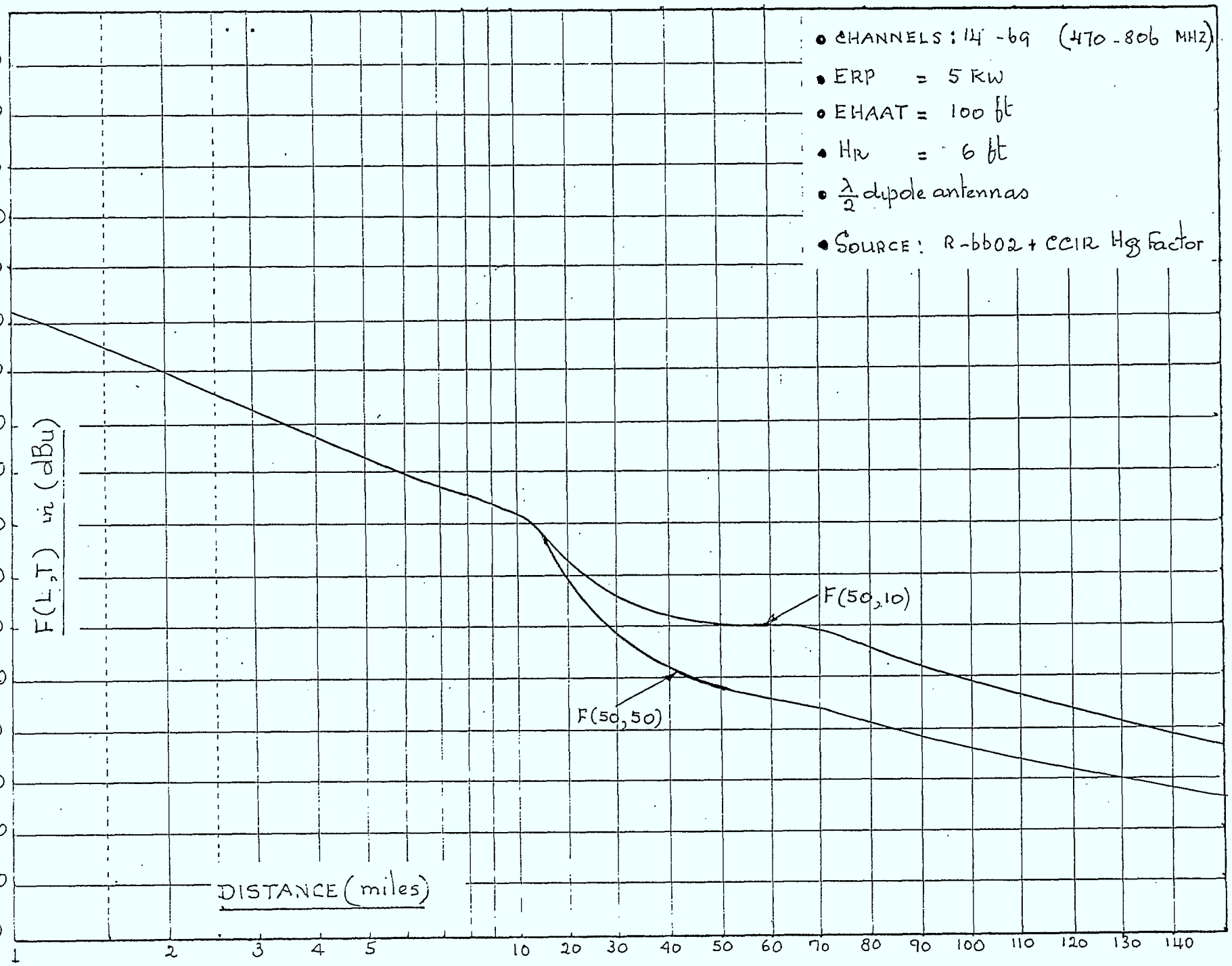


Figure 6.4-9: Field Strength vs Distance: LPTV TX to Mobile Unit Rx

discrimination for the mobile antennas of 10 dB was assumed. In all cases, it was assumed that the TV service would use horizontal polarization. For the TV receive antenna, a value of 10 dB is probably conservative by 15 dB. However, no measured data is available of the antenna discrimination of a TV receiver antenna in its installed environment. For the mobile receivers, 10 dB is probably 8 dB conservative for the base station and 5 dB optimistic for the mobile unit. Again, data on actual in-site measurements are not available.

The analysis also assumes that the LMS spectrum in the TV channel would be from 2.0 MHz to 4.5 MHz. This is the part of the TV channel in which the transmitted ERP is the least and the required TV receiver protection ratio is the least. Extending this bandwidth by 0.5 MHz on each side will not invalidate the results so carrier frequency tolerance is not a critical factor. It is felt that a conservative approach has been taken throughout.

6.5.2 Protection of the TV Broadcast Service from LMS

All data required for licensing is presented in Table 6.5-1. Only the significant interference channels were considered. For the VHF channels, the picture image channel does not exist but data was included for interest, only. For the case of adjacent channel interference and picture image interference, the base station transmitter may be located inside or outside the Grade B contour. The separation distances given in the table are for the case when the base transmitter is outside the Grade B contour.

6.5.3 Protection of the Low Power TV Broadcast Service from LMS

The licensing criteria is given in Table 6.5-2. The same comments apply for the VHF channels (i.e. picture image interference)

6.5.4 Protection of the LMS

The analysis, based on the propagation curve, but excluding the effect of horizon shielding, indicates that the upper VHF and UHF channels of a TV transmitter could create unacceptable levels of interference at the base receiver. However, since the distances involve trans-horizon transmission and if the diffraction loss from a smooth, curved earth surface could be used, then the interference will be within the acceptable limits.

The mobile receiver also appears to have problems at UHF but, again, the transmission path is trans-horizon and, consequently, this interference will only occur when the mobile unit is at its outermost point in its coverage area. i.e. nearest to the TV transmitter and only when it is operating at this point. It is felt that this is not a significant point.

As regards protection from Low Power TV transmitters, the separation distances appear to be adequate.

Using only the limited part of the TV channel (2.0 to 4.5 MHz) also renders the LMS immune from TV receiver L.O radiations.

Table 6.5-1: Protection of TV Broadcast Service from LMS

Parameters			CH: 2-6 (54-88 MHz)	CH: 7-13 (170-220 MHz)	CH 14-69 (470-806 MHz)
Desired System characteristics	Desired Tx, ERP	(kW)	100	316	1000
	Desired Tx, EHAAT	(ft)	1000	1000	1000
	Desired Rx, H_R	(ft)	30	30	30
	E_{min} at Grade B Contour	(dBu)	47	56	64
	Distance to Grade B contour	(miles)	65	62	43.
Undesired Transmitter Characteristics	Undesired Tx, ERP	(W)	150	150	150
	Undesired Tx, EHAAT	(ft)	150	150	150
	Desired Rx, H_R	(ft	30	30	30
Co-channel Case	E_{min} at Grade B Contour	(dBu)	47	56	64
	Protection Ratio	(dB)	40	40	40
	Antenna Discrimination	(dB)	10	10	10
	Max: Permissible Undesired E_{max}	(dBu)	17	26	34
	Distance to Grade B contour	(miles)	65	45	23
	Min: Separation between Txs	(miles)	130	107	66
Adjacent channel Case	E_{min} at Grade B contour	(dBu)	47	56	64
	Protection Ratio	(dB)	-5	-5	-5
	Antenna Discrimination	(dB)	10	10	10
	Max: Permissible Interference E_{max}	(dBu)	62	71	79
	Distance to Grade B Contour	(miles)	4.5	3	0.6
	Min: Separation between Txs	(miles)	70	65	44
Picture Image channel Case	E_{min} at Grade B Contour	(dBu)	47	56	64
	Protection Ratio	(dB)	10	10	10
	Antenna Discrimination	(dB)	10	10	10
	Max: Permissible Interference E_{max}	(dBu)	47	56	64
	Distance to Grade B Contour	(miles)	11	6	4
	Min: Separation between Txs	(miles)	76	68	47

Table 6.5-2: Protection of the Low-Power TV Service from LMS

Parameters			CH: 2 - 6 (54 - 88 MHz)	CH: 7 - 13 (170 - 220 MHz)	CH 14 - 69 (470 - 806 MHz)
Desired System characteristics	Desired Tx, ERP	(kW)	0.1	0.1	5
	Desired Tx, EHAAT	(ft)	100	100	100
	Desired Rx, H_R	(ft)	30	30	30
	Emin at Grade B Contour	(dBu)	47	56	64
	Distance to Grade B contour	(miles)	7.5	5.0	7.5
Undesired Transmitter Characteristics	Undesired Tx, ERP	(W)	150	150	150
	Undesired Tx, EHAAT	(ft)	150	150	150
	Desired Rx, H_R	(ft	30	30	30
Co-channel Case	Emin at Grade B Contour	(dBu)	47	56	64
	Protection Ratio	(dB)	40	40	40
	Antenna Discrimination	(dB)	10	10	10
	Max: Permissible Undesired E_{max}	(dBu)	17	26	34
	Distance to Grade B contour	(miles)	65	45	23
	Min: Separation between Txs	(miles)	72.5	50	30.5
Adjacent channel Case	Emin at Grade B contour	(dBu)	47	56	64
	Protection Ratio	(dB)	-5	-5	-5
	Antenna Discrimination	(dB)	10	10	10
	Max: Permissible Interference E_{max}	(dBu)	62	71	79
	Distance to Grade B Contour	(miles)	4.5	3	0.6
	Min: Separation between Txs	(miles)	12	8	8
Picture Image channel Case	Emin at Grade B Contour	(dBu)	47	56	64
	Protection Ratio	(dB)	10	10	10
	Antenna Discrimination	(dB)	10	10	10
	Max: Permissible Interference E_{max}	(dBu)	47	56	64
	Distance to Grade B Contour	(miles)	11	6	4
	Min: Separation between Txs	(miles)	18.5	11	11.5

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CHAPTER III

DETERMINATION OF MOST SUITABLE VHF AND UHF CHANNELS FOR USE BY LAND MOBILE SERVICE

CHAPTER III

DETERMINATION OF MOST SUITABLE VHF AND UHF CHANNELS FOR USE BY LAND MOBILE SERVICE

1.0 INTRODUCTION

1.1 PURPOSE

In Chapter II, licensing criteria for inter-service sharing were established assuming standard parameters for the transmitters and receivers and assuming a uniform terrain irregularity factor of 50 metres. The minimum signal field strength at the receiver, the protection ratios and the maximum field strength of the interfering signal at the receiver were determined; and based on the foregoing, the minimum separation distances between the transmitters of the two services (TV broadcast and land mobile) required for inter-service sharing of the same spectrum were determined.

In a practical situation, however, the parameters need not have the standard values, and the actual terrain irregularity must be taken into consideration. In Chapter III, the actual station parameters and terrain characteristics are used, in conjunction with the maximum interference levels as determined in Chapter II.

1.2 FORMAT

Section 2 gives all the documents used in the analysis, while Section 3 gives all data in which the minimum separation distances between transmitters of the two services are based. The transmission path loss prediction curves are given in Appendix B to Chapter II. Section 4 shows how the channels available for land mobile use were determined.

2.0 DOCUMENTATION

2.1 REFERENCE DOCUMENTS

1. DOC Provided Channel Allocations and Assignments for Toronto, Montreal and Vancouver.

2. Hufford, G.A., Longley, A.G. and Kissick, W.A., "A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode," NITA Report 82-100: April 1982.

3. Longley, A.G. and Rice, P.L., "Prediction of Tropospheric Radio Transmission Loss and Computer Method," ESSA Technical Report, ERL 79 - ITS 67: 1982.

4. Relevant Topographical Maps.

5. Sams, Howard W., Reference Data for Radio Engineers, Fifth Edition, I.T.T.: 1968.

6. Volume II.

2.2 ABBREVIATIONS

ERP	effective radiated power
EHAAT	effective height above average terrain (of the transmit antenna)
H_R	height of receive antenna
Δh	terrain irregularity factor
dBμ	decibels above 1 μV/m (measure of field strength)
F(50,50)	field strength received at 50% of the locations for 50% of the time
F(50,10)	field strength received at 50% of the locations for 10% of the time.
LP	low power (TV transmitter)
VLP	very low power (TV transmitter)
LMS	land mobile service

3.0 DETERMINATION OF INTER-SERVICE SHARING CRITERIA

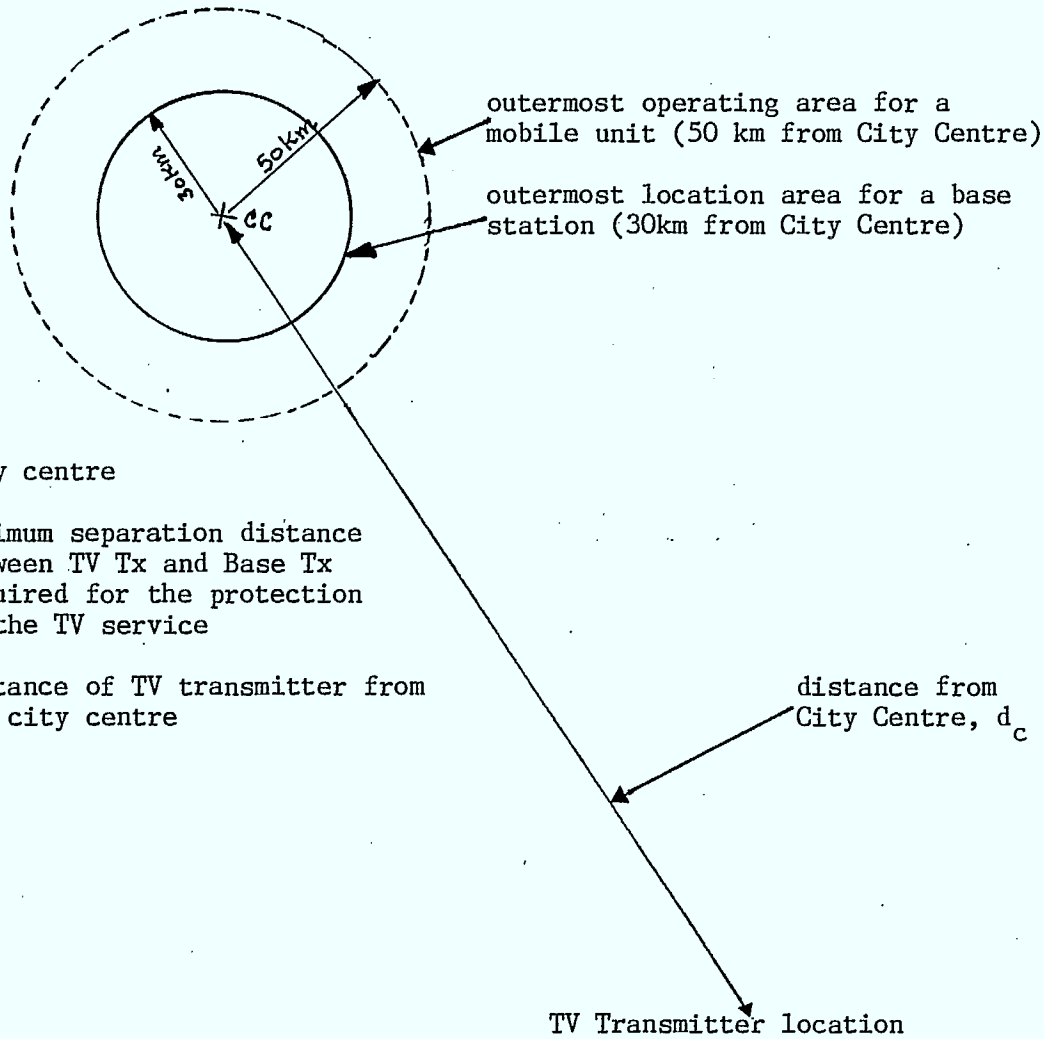
3.1 INTRODUCTION

To evaluate the possibility of inter-service (TV and LMS) sharing in specific cities (Toronto, Montreal, and Vancouver), it was necessary to establish the locations and operating areas for the land mobile service. It was assumed that the base station could be located anywhere within a radius of 30 km from the city centre and that the mobile units would operate in an area within a radius of 20 km from the associated base station. To avoid intermodulation problems with TV transmitters located in the same area, but at different frequencies, the base station should be at least two miles from a TV transmitter.

The method used to check whether a particular TV channel could be used by a land mobile system in the locations areas indicated, is illustrated in Figure 3-1. In Case I, the TV transmitter is located far enough from the base station operating area that interference into its Grade B contour receivers is acceptable. In Case II, the TV transmitter is close enough that base transmitters in the city centre area will cause unacceptable interference; and hence, a TV channel cannot be used by the LMS. In III, the interference into the TV service may be acceptable provided the base stations are located in a restricted area of the proposed operating area. In such cases, more careful examination of the shielding factors, etc., will be required to firmly establish whether the channel, if indeed the channel, may be used by the LMS and under what conditions.

The analysis employed is really a statistical one in the sense that for each city, an average terrain irregularity factor and average height (both derived from topographical maps) were used to characterize the terrain. The actual terrain characteristics from a particular transmitter to a particular receiver were not used. This may be done, at a later date, for the marginal cases should it be required. The characteristics used for the transmitters, receivers and transmission path loss are given in Appendix B to Chapter II.

A check of the tables of assignments for Toronto, Montreal, and Vancouver revealed that there were no channels available at VHF (Channels 2-13) for use by the land mobile service so the effort was largely concentrated in the UHF band.



*cc = city centre

*d_{min} = minimum separation distance between TV Tx and Base Tx required for the protection of the TV service

*d_c = distance of TV transmitter from the city centre

Figure 3-1: Diagram Illustrating How TV Channel Availability Was Determined For Co-channel Interference

Case I : (d_c − 30km) > dmin, the TV channel can be used for LMS

Case II : (d_c + 30km) < dmin, the TV channel cannot be used for LMS

Case III: d_c ≈> dmin, then only part of the area within the 30km radius from the city centre can be used for the location of a base station. In the tables, this is denoted by P.

3.2 DETERMINATION OF MINIMUM SEPARATION DISTANCES BETWEEN SERVICES

The following interference limits were considered:

A. Base transmitter interference into TV receiver,
B. Mobile transmitter interference into TV receiver,
C. TV transmitter interference into base receiver,
D. TV transmitter interference into mobile receiver.

A preliminary investigation indicated that the interference from and to a mobile unit could be omitted so emphasis was placed on A and C.

3.2.1 Protection of the LMS from the TV Service

Table 3-1A, 3-1B, and 3-1C give the minimum separation distances required to protect the base station receiver from the TV transmitter when TV services use vertical polarization. In this case, the maximum interference level permitted at the base antenna is 41 dBμ.

Table 3-2A, 3-2B, and 3-2C give the minimum separation distance required between the TV transmitter and the base station receiver to protect the LMS when the TV service uses horizontal polarization. In this case, a higher level of interference (51 dBμ) is permitted because a polarization discrimination of 10 dB was assumed for the base station receive antenna. The minimum separation distances in this case are less than when both services used vertical polarization.

3.2.2 Protection of the TV Service

Tables 3-3A, 3-3B and 3-3C give the minimum separation distances required between the TV transmitter and the Grade B contour, base transmitter and the Grade B contour, and the TV transmitter and base transmitter to ensure that the TV service is protected on the Grade B contour.

A 10 dB antenna discrimination was assumed for the TV receive antenna for radiations from the base transmitter. This was used for both cases of TV service polarization (VP and HP). If vertical polarization is used, then the antenna discrimination is largely the front-to-back gain (or directivity) ratio; if horizontal is used, then the antenna discrimination comes largely from the polarization discrimination.

3.2.3 Significant Minimum Separation Distances

Table 3-4A gives the minimum separation distances required between the TV and base transmitter when TV service uses vertical polarization, for the protection of the TV service and LMS. Table 3-4B provides the same information for horizontal polarization.

From the information provided in the tables, it can be seen that the TV service is the more sensitive one; and hence, the minimum separation distances required between the TV and base transmitter for the protection of the TV service was used in the analysis. If the TV service is protected, the LMS is automatically protected. Table 3-5 gives the minimum separation distances between the TV and base transmitter required to protect the TV services when the interfering LMS signal is co-channel (n = 0) picture-image channel (n = ±15) and adjacent channel (n = ±1) relative to the desired TV channel.

For the adjacent and picture-image channel, it was assumed that the base transmitter was located outside the Grade B contour of the TV coverage area. However, for these interference channels, the base transmitter may also be located inside the Grade B contour; in this latter case, the base transmitter will cause interference into TV receivers in its immediate vicinity. The size of the interference zone around the base transmitter will vary depending on the distance of the base transmitter from the TV transmitter, the TV receiver antenna discrimination characteristic, the electromagnetic shielding, etc. For this analysis, it was assumed that if a TV transmitter was located in the region within 30 km radius of the city centre and the LMS could not use the adjacent channels and the picture-image channels of that TV transmitter channel.

Protected Service	DESIRED SIGNAL					UNDESIRED SIGNAL						MARGIN or $\frac{F_d}{F_u}$ at Rx of LMS (dB)
	ERP (W)	EHAAT (m)	H_R (m)	F(50,50) at Protected Contour (dBu)	Distance to Protected Contour (KM)	Class of TV Station	ERP (KW)	EHAAT (m)	H_R (m)	F(50,10) at Receiver (dBu)	Distance Between Tx and Rx (KM)	
Protection of LMS Base Rx from TV Service	125	75	2	19	45	A	10	100	75	41	50	
	125	75	2	19	45	B	100	150	75	41	75	
	125	75	2	19	45	C	1000	300	75	41	117	
	125	75	2	19	45	D	5000	600	75	41	179	
	125	75	2	19	45	LP	1	100	75	41	33	
Protection of LMS Mobile Rx from TV Service	15.8	2	75	21	31	A	10	100	2	39	.	
	15.8	2	75	21	31	B	100	150	2	39	.	
	15.8	2	75	21	31	C	1000	300	2	39	.	
	15.8	2	75	21	31	D	5000	600	2	39	.	
	15.8	2	75	21	31	LP	1	100	2	39	.	
Protection of LMS Rx from Very Low Power TV	125	75	.	.	.	VLP	.1	100	75	41	17	
	15.8	2	.	.	.	VLP	.1	100	2	39	.	

CONDITIONS
- TV Interference channel: CO-CHANNEL.
- TV Polarization : VP

Does not match with Part II Table 6.3.1 6.3.3

TABLE 3-1a Minimum Separation Distances for the Protection of LMS from TV at UHF: Toronto

Protected Service	DESIRED SIGNAL					UNDESIRED SIGNAL						MARGIN or $\frac{F_d}{F_u}$ at Rx of LMS
	ERP (W)	EHAAT (m)	H_R (m)	F(50,50) at Protected Contour (dBu)	Distance to Protected Contour (KM)	Class of TV Station	ERP (kW)	EHAAT (m)	H_R (m)	F(50,10) at Receiver (dBu)	Distance Between Tx and Rx (KM)	(dB)
Protection of LMS Base Rx from TV Service	125	75	2	19	37	A	10	100	75	41	45	
	125	75	2	19	37	B	100	150	75	41	70	
	125	75	2	19	37	C	1000	300	75	41	113	
	125	75	2	19	37	D	5000	600	75	41	161	
	125	75	2	19	37	LP	1	100	75	41	29	
Protection of LMS Mobile Rx From TV Service	15.8	2	75	21	24	A	10	100	2	39	·	
	15.8	2	75	21	24	B	100	150	2	39	·	
	15.8	2	75	21	24	C	1000	300	2	39	·	
	15.8	2	75	21	24	D	5000	600	2	39	·	
	15.8	2	75	21	24	LP	1	100	2	39	·	
Protection of LMS Rx from Very Low Power TV	125	75	·		·	VLP	·1	100	75	41	15	
	15.8	2	·	·	·	VLP	·1	100	2	39	·	

CONDITIONS
- TV Interference Channel: CO-CHANNEL
- TV Polarization : VP

TABLE 3-1b Minimum Separation Distances for the Protection of LMS from TV at UHF: Montreal

Protected Service	DESIRED SIGNAL					UNDESIRED SIGNAL						MARGIN or $\frac{F_d}{F_u}$ at Rx of LMS
	ERP (W)	EHAAT (m)	H_R (m)	F(50,50) at Protected Contour (dBu)	Distance to Protected Contour (KM)	Class of TV Station	ERP (kW)	EHAAT (m)	H_R (m)	F(50,10) at Receiver (dBu)	Distance Between Tx and Rx (KM)	(dB)
Protection of LMS Base Rx from TV Service	125	75	2	19	18	A	10	100	75	41	37	
	125	75	2	19	18	B	100	150	75	41	60	
	125	75	2	19	18	C	1000	300	75	41	100	
	125	75	2	19	18	D	5000	600	75	41	159	
	125	75	2	19	18	LP	1	100	75	41	21	
Protection of LMS Mobile Rx from TV Service	15.8	2	75	21	9	A	10	100	2	39	.	
	15.8	2	75	21	9	B	100	150	2	39	.	
	15.8	2	75	21	9	C	1000	300	2	39	.	
	15.8	2	75	21	9	D	5000	600	2	39	.	
	15.8	2	75	21	9	LP	1	100	2	39	.	
Protection of LMS Rx from Very Low Power TV	125	75	.		.	VLP	.1	100	75	41	8	
	15.8	2	.	.	.	VLP	.1	100	2	39	.	

CONDITIONS • TV Interference channel : CO-CHANNEL
• TV Polarization : VP.

TABLE 3-1c Minimum Separation Distances for the Protection of LMS from TV at UHF:Vancouver

Protected Service	DESIRED SIGNAL					UNDESIRED SIGNAL						MARGIN or $\frac{F_d}{F_u}$ at Rx of LMS
	ERP (W)	EHAAT (m)	H_R (m)	F(50,50) at Protected Contour (dBu)	Distance to Protected Contour (KM)	Class of TV Station	ERP (KW)	EHAAT (m)	H_R (m)	F(50,10) at Receiver (dBu)	Distance Between Tx and Rx (KM)	(dB)
Protection of LMS Base Rx from TV Service	125	75	2	19	45	A	10	100	75	51	33	
	125	75	2	19	45	B	100	150	75	51	52	
	125	75	2	19	45	C	1000	300	75	51	90	
	125	75	2	19	45	D	5000	600	75	51	145	
	125	75	2	19	45	LP	1	100	75	51	18	
Protection of LMS Mobile Rx from TV Service	15.8	2	75	21	31	A	10	100	2	41	•	
	15.8	2	75	21	31	B	100	150	2	41	•	
	15.8	2	75	21	31	C	1000	300	2	41	•	
	15.8	2	75	21	31	D	5000	600	2	41	•	
	15.8	2	75	21	31	LP	1	100	2	41	•	
Protection of LMS Rx from Very Low Power TV	125	75	•		•	VLP	.1	100	75	51	4	
	15.8	2	•	•	•	VLP	.1	100	2	41	•	

CONDITIONS
- TV Interference channel: CO-CHANNEL
- TV Polarization : HP

Table 3-2a Minimum Seperation Distances for the Protection of LMS from TV at UHF: Toronto

Protected Service	DESIRED SIGNAL					UNDESIRED SIGNAL						MARGIN or $\frac{F_d}{F_u}$ at Rx of LMS
	ERP (W)	EHAAT (m)	H_R (m)	F(50,50) at Protected Contour (dBu)	Distance to Protected Contour (KM)	Class of TV Station	ERP (kW)	EHAAT (m)	H_R (m)	F(50,10) at Receiver (dBu)	Distance Between Tx and Rx (KM)	(dB)
Protection of LMS Base Rx from TV Service	125	75	2	19	37	A	10	100	75	51	30	
	125	75	2	19	37	B	100	150	75	51	50	
	125	75	2	19	37	C	1000	300	75	51	91	
	125	75	2	19	37	D	5000	600	75	51	132	
	125	75	2	19	37	LP	1	100	75	51	15	
Protection of LMS Mobile Rx From TV Service	15.8	2	75	21	24	A	10	100	2	41		
	15.8	2	75	21	24	B	100	150	2	41		
	15.8	2	75	21	24	C	1000	300	2	41		
	15.8	2	75	21	24	D	5000	600	2	41		
	15.8	2	75	21	24	LP	1	100	2	41		
Protection of LMS Rx from Very Low Power TV	125	75	.	.	.	VLP	.1	100	75	51	4	
	15.8	2	.	.	.	VLP	.1	100	2	41		

CONDITIONS
- TV Interference channel: CO-CHANNEL
- TV Polarization : HP

TABLE 3-2b Minimum Seperation Distances for Protection of LMS from TV at UHF: Montreal

Protected Service	DESIRED SIGNAL					UNDESIRED SIGNAL						MARGIN or $\frac{F_d}{F_u}$ at Rx of LMS
	ERP (W)	EHAAT (m)	H_R (m)	F(50,50) at Protected Contour (dBu)	Distance to Protected Contour (KM)	Class of TV Station	ERP (kW)	EHAAT (m)	H_R (m)	F(50,10) at Receiver (dBu)	Distance Between Tx and Rx (KM)	(dB)
Protection of LMS Base Rx from TV Service	125	75	2	19	18	A	10	100	75	51	21	
	125	75	2	19	18	B	100	150	75	51	41	
	125	75	2	19	18	C	1000	300	75	51	76	
	125	75	2	19	18	D	5000	600	75	51	126	
	125	75	2	19	18	LP	1	100	75	51	7	
Protection of LMS Mobile Rx From TV Service	15.8	2	75	21	19	A	10	100	2	41	.	
	15.8	2	75	21	9	B	100	150	2	41	.	
	15.8	2	75	21	9	C	1000	300	2	41	.	
	15.8	2	75	21	9	D	5000	600	2	41	.	
	15.8	2	75	21	9	LP	1	100	2	41	.	
Protection of LMS Rx from Very Low Power TV	125	75	.		.	VLP	.1	100	75	51	.	
	15.8	2	.	.	.	VLP	.1	100	2	41	.	

CONDITIONS
- TV Interference channel : CO-CHANNEL
- TV Polarization : HP

TABLE 3-2c Minimum Separation Distances for the Protection of LMS from TV at UHF: Vancouver

Protected Service	DESIRED SIGNAL						UNDESIRED SIGNAL					Minimum Separation Distance Between Transmitters (KM)
	class of TV Station	ERP (KW)	EHAAT (m)	H_R (m)	F(50,50) For Grade B (dBu)	Distance to Grade B Contour (Km)	ERP (W)	EHAAT (m)	H_R (m)	F(50,10) at Grade B Contour (dBu)	Distance to Grade B Contour (km)	
Protection of TV Service from LMS Base Station Interference	A	10	100	10	64	40	125	75	10	34	66	106
	B	100	150	10	64	60	125	75	10	34	66	126
	C	1000	300	10	64	93	125	75	10	34	66	159
	D	5000	600	10	64	130	125	75	10	34	66	196
	LP	1	100	10	64	29	125	75	10	34	66	95
Protection of TV Service From LMS Mobile Stn Interference	A	10	100	10	64	40	15.8	2	10	.	.	
	B	100	150	10	64	60	15.8	2	10	.	.	
	C	1000	300	10	64	93	15.8	2	10	.	.	
	D	5000	600	10	64	130	15.8	2	10	.	.	
	LP	1	100	10	64	29	15.8	2	10	.	.	
	VLP	.1	100	10	64	19	125	75	10	34	66	85
	LVP	.1	100	10	64	19	15.8	2	10	.	.	

CONDITIONS : Interference Channel : CO-CHANNEL
TV Polarization : } 10 dB
TV Receiver Front-back Ratio ;

TABLE 3-3a Minimum Separation Distances for the Protection of TV from LMS at UHF: Toronto

$E_U = E_D$ - Prot Ratio + Ant Discr

64 - 40 + 10 = 34

Protected Service	DESIRED SIGNAL						UNDESIRED SIGNAL					Minimum Separation Distance Between Transmitters (KM)
	Class of TV Station	ERP (KW)	EHAAT (m)	H_R (m)	F(50,50) For Grade B (dBu)	Distance to Grade B Contour (Km)	ERP (W)	EHAAT (m)	H_R (m)	F(50,10) at Grade B Contour (dBu)	Distance to Grade B Contour (km)	
Protection of TV Service from LMS Base Station Interference	A	10	100	10	64	37	125	75	10	34	63	100
	B	100	150	10	64	58	125	75	10	34	63	121
	C	1000	300	10	64	87	125	75	10	34	63	150
	D	5000	600	10	64	125	125	75	10	34	63	188
	LP	1	100	10	64	26	125	75	10	34	63	89
Protection of TV Service From LMS Mobile Stn Interference	A	10	100	10	64	.	15.8	2	10	.	.	.
	B	100	150	10	64	.	15.8	2	10	.	.	.
	C	1000	300	10	64	.	15.8	2	10	.	.	.
	D	5000	600	10	64	.	15.8	2	10	.	.	.
	LP	1	100	10	64	.	15.8	2	10	.	.	.
	VLP	.1	100	10	64	16	125	75	10	34	63	79
	LVP	.1	100	10	64	.	15.8	2	10	.	.	.

CONDITIONS : Interference Channel : CO-CHANNEL
TV Polarization : } 10 dB
TV Receiver Front-back Ratio : }

TABLE 3-3b Minimum Separation Distance for the Protection of TV from LMS at UHF: Montreal

Protected Service	DESIRED SIGNAL						UNDESIRED SIGNAL					Minimum Separation Distance Between Transmitters (KM)
	Class of TV Station	ERP (KW)	EHAAT (m)	H_R (m)	F(50,50) For Grade B (dBu)	Distance to Grade B Contour (Km)	ERP (W)	EHAAT (m)	H_R (m)	F(50,10) at Grade B Contour (dBu)	Distance to Grade B Contour (km)	
Protection of TV Service from LMS Base Station Interference	A	10	100	10	64	22	125	75	10	34	36	58
	B	100	150	10	64	39	125	75	10	34	36	75
	C	1000	300	10	64	67	125	75	10	34	36	103
	D	5000	600	10	64	101	125	75	10	34	36	137
	LP	1	100	10	64	13	125	75	10	34	36	49
Protection of TV Service From LMS Mobile Stn Interference	A	10	100	10	64	.	15.8	2	10	.	.	.
	B	100	150	10	64	.	15.8	2	10	.	.	.
	C	1000	300	10	64	.	15.8	2	10	.	.	.
	D	5000	600	10	64	.	15.8	2	10	.	.	.
	LP	1	100	10	64	.	15.8	2	10	.	.	.
	VLP	.1	100	10	64	6	125	75	10	34	36	42
	LVP	.1	100	10	64	.	15.8	2	10	.	.	.

CONDITIONS : Interference channel : CO-CHANNEL
TV Polarization : } 10dB
TV Receiver Front-back Ratio }

TABLE 3-3c Minimum Separation Distance for the Protection of TV from LMS at UHF: Vancouver

Service Protected	TV Transmitter			Base Transmitter		Minimum Separation Distance (km)		
	Class	ERP (kW)	EHAAT (m)	ERP (W)	EHAAT (m)	Toronto	Montreal	Vancouver
Minimum Separation Distance Between TV and Base Tx For Protection of The TV Service	D	5000	600	125	75	196	188	137
	C	1000	300	125	75	159	150	103
	B	100	150	125	75	126	121	75
	A	10	100	125	75	106	100	58
	LP	1	100	125	75	95	89	49
	VLP	0.1	100	125	75	85	79	42
Minimum Separation Distance Between TV and Base Tx For The Protection of The LMS.	D	5000	600	125	75	179	161	159
	C	1000	300	125	75	117	113	100
	B	100	150	125	75	75	70	60
	A	10	100	125	75	50	45	37
	LP	1	100	125	75	33	29	21
	VLP	0.1	100	125	75	17	15	8

TABLE 3-4a: Minimum Separation Distances For TV with VP

- Interference channel : Co-channel.
- Antenna Discrimation (TV)
  Directivity : 10 dB
  Polarization : 0 dB

Service Protected	TV Transmitter			Base Transmitter		Minimum Separation Distance (km)		
	Class	ERP (kW)	EHAAT (m)	ERP (W)	EHAAT (m)	Toronto	Montreal	Vancouver
Minimum Separation Distance Between TV and Base Tx For Protection of The TV Service	D	5000	600	125	75	196	188	137
	C	1000	300	125	75	159	150	103
	B	100	150	125	75	126	121	75
	A	10	100	125	75	106	100	58
	LP	1	100	125	75	95	89	49
	VLP	0.1	100	125	75	85	79	42
Minimum Separation Distance Between TV and Base Tx For The Protection of The LMS.	D	5000	600	125	75	145	132	126
	C	1000	300	125	75	90	91	76
	B	100	150	125	75	52	50	41
	A	10	100	125	75	33	30	21
	LP	1	100	125	75	18	15	7
	VLP	0.1	100	125	75	4	4	·

TABLE 3-4b: Minimum Separation Distances for TV with HP

- Interference Channel : CO-CHANNEL
- Antenna Discrimation (TV)
  Directivity : 10 dB
  Polarization : 0 dB

LOCATION OF LMS CHANNEL	CLASS OF TV	MINIMUM SEPARATION DISTANCE (KM) FOR PROTECTION OF TV		
		TORONTO	MONTREAL	VANCOUVER
CO-CHANNEL (n=0)	VLP	85	79	42
	LP	95	89	49
	A	106	100	58
	B	126	121	75
	C	159	150	103
	D	196	188	137
PICTURE IMAGE (n = ±15)	VLP	38	33	12
	LP	48	43	19
	A	59	54	28
	B	79	75	45
	C	112	104	93
	D	147	142	107
ADJACENT CHANNEL (n = ±1)	VLP	27	22	7
	LP	37	32	14
	A	48	43	23
	B	68	64	40
	C	101	93	68
	D	138	131	102

TABLE 3-5 Minimum Separation Distances Between TV Tx and Base Tx for Inter-Service Sharing

4.0 DETERMINATION OF TV CHANNELS AVAILABLE FOR THE LMS

4.1 INTRODUCTION

The data of Section 3 and the tables giving the TV assignments for Toronto, Montreal, and Vancouver were used to determine which TV channels could be used by the LMS operating in the area enclosed with the 30 km radius from the city centre.

In each case, the co-channel interference was first considered to obtain which assigned channels could be re-used by the LMS. The criteria as explained in Figure 3.1 was used. Only the operational (OP) and temporarily operational (TO) assignments given in the assignment tables were considered. Some of the OP and TO assignments were located within the metropolitan areas, proposed, to be used by the LMS base stations. For these assignments, since the separation distances are in general less than those required for adjacent channel and picture-image channel interference, the adjacent and picture-image channels for that particular assignment were considered unusable for the LMS.

4.2 RESULTS

Tables 4-1A, 4-1B, 4-1C give the assigned channels, unusable because of co-channel interference, adjacent channel interference and picture-image channel interference and the channels available for the use by LMS in each of the cities.

The crosses: "X" indicate the channels assigned in Column 1, the channels unusable because of co-channel interference in Column 2, the channels unusable because of adjacent channel interference in Column 3, the channels unusable by the LMS due to picture-image channel interference in Column 4 and the channels available for LMS use in Column 7. The "P" in the columns indicated that only part of the circular area can be used for the location of base stations. A more detailed analysis of these assignments are required to verify this in a practical situation.

Table 4.2 gives the channels that may be used by the LMS at the three cities. Again, only the operational and temporarily operational assignments were considered.

Tables 4-3A, 4-3B and 4-3C give the same information as Tables 4-1A, 4-1B, and 4-1C; but when all the operational, temporarily operational, approved, under consideration, authorized, referred to CRTC, etc., assignments are all taken into account. Only co-channel interference was considered. This information may be of interest for long-term frequency planning.

TV Channel Numbers	Bandwidth (MHz)	Channels Assigned to TV	Channels Unavailable To LMS Due to Interference From: Co-channel into TV	Adj. Channel into TV	Picture Image into TV	Co-channel into Base	Co-channel into Mobile	Channels Available For LMS
14	470–476	•	•					X
15	476–482	X	•					X
16	482–488	•	•	X				•
17	488–494	X	X					•
18	494–500	X	•	X				•
19	500–506	X	X					•
20	506–512	•	•	X				•
21	512–518	X	X	X				•
22	518–524	X	X					•
23	524–530	•	•	X				•
24	530–536	X	P	X				•
25	536–542	X	X					•
26	542–548	X	P	X				•
27	548–554	•	•					X
28	554–560	X	P					P
29	560–566	X	X					•
30	566–572	•	•		X			•
31	572–578	X	X					•
32	578–584	•	•		X			•
33	584–590	•	•					X
34	590–596	X	P		X			•
35	596–602	X	P					P
36	602–608	•	•					X
37	608–614	•	•		X			•
38	614–620	•	•					X
39	620–626	•	•					X
40	626–632	X	P		X			•
41	632–638	•	•					X
42	638–644	•	•					X
43	644–650	•	•					X
44	650–656	X	X					•
45	656–662	•	•					X
46	662–668	•	•	X				•
47	668–674	X	X					•
48	674–680	•	•	X				•
49	680–686	X	X					•

TV Channel Numbers	Bandwidth (MHz)	Channels Assigned to TV	Channels Unavailable to LMS Due to Interference From: Co-channel into TV	Adj. Channel into TV	Picture Image into TV	Co-channel into Base	Co-channel into Mobile	Channels Available For LMS
50	686–692	•	•					X
51	692–698	X	X					•
52	698–704	•	•					X
53	704–710	•	•					X
54	710–716	X	•					X
55	716–722	X	X					•
56	722–728	X	•	X				•
57	728–734	X	X					•
58	734–740	•	•	X				•
59	740–746	•	•					X
60	746–752	•	•					X
61	752–758	X	X					•
62	758–764	X	•					X
63	764–770	•	•					X
64	770–776	•	•		X			•
65	776–782	•	•					X
66	782–788	X	•					X
67	788–794	•	•					X
68	794–800	•	•					X
69	800–806	•	•					X
70	806–812	•	•					X
71	812–818	•	•					X
72	818–824	•	•					X
73	824–830	•	•					X
74	830–836	•	•		X			•
75	836–842	•	•					X
76	842–848	•	•					X
77	848–854	•	•					X
78	854–860	•	•					X
79	860–866	•	•					X
80	866–872	•	•					X
81	872–878	•	•					X
82	878–884	•	•					X
83	884–890	•	•					X

Table 4-1A: TV Channels Available for LMS in UHF at Toronto

any channel in Grade A could be used; needs to be studied

TV Channel Numbers	Bandwidth (MHz)	Channels Assigned to TV	Channels Unavailable To LMS Due to Interference From: Co-channel into TV	Adj. Channel into TV	Picture Image into TV	Co-channel into Base	Co-channel into Mobile	Channels Available For LMS
14	470–476	•	•					X
15	476–482	•	•					X
16	482–488	X	•	X				•
17	488–494	X	X					•
18	494–500	X	P	X				•
19	500–506	•	•					X
20	506–512	X	P					P
21	512–518	X	•					X
22	518–524	X	X					•
23	524–530	•	•					X
24	530–536	X	X					•
25	536–542	•	•					X
26	542–548	•	•					X
27	548–554	•	•					X
28	554–560	X	P					P
29	560–566	•	•					X
30	566–572	X	P					P
31	572–578	•	•					X
32	578–584	X	•		X			•
33	584–590	X	X					•
34	590–596	•	•					X
35	596–602	•	•					X
36	602–608	•	•					X
37	608–614	•	•					X
38	614–620	•	•					X
39	620–626	•	•					X
40	626–632	X	P					P
41	632–638	•	•					X
42	638–644	•	•					X
43	644–650	•	•					X
44	650–656	•	•					X
45	656–662	X	X					•
46	662–668	•	•					X
47	668–674	•	•					X
48	674–680	•	•					X
49	680–686	X	•					X

TV Channel Numbers	Bandwidth (MHz)	Channels Assigned to TV	Channels Unavailable to LMS Due to Interference From: Co-channel into TV	Adj. Channel into TV	Picture Image into TV	Co-channel into Base	Co-channel into Mobile	Channels Available For LMS
50	686–692	X	P					P
51	692–698	•	•					X
52	698–704	•	•					X
53	704–710	•	•					X
54	710–716	•	•					X
55	716–722	•	•					X
56	722–728	•	•					X
57	728–734	X	X					•
58	734–740	•	•					X
59	740–746	•	•					X
60	746–752	X	P					P
61	752–758	X	P					P
62	758–764	X	X					•
63	764–770	•	•					X
64	770–776	•	•					X
65	776–782	•	•					X
66	782–788	X	P					P
67	788–794	•	•					X
68	794–800	X	•					X
69	800–806	•	•					X
70	806–812	•	•					X
71	812–818	•	•					X
72	818–824	•	•					X
73	824–830	•	•					X
74	830–836	•	•					X
75	836–842	•	•					X
76	842–848	•	•					X
77	848–854	•	•					X
78	854–860	•	•					X
79	860–866	•	•					X
80	866–872	•	•					X
81	872–878	•	•					X
82	878–884	•	•					X
83	884–890	•	•					X

Table 4-1B: TV Channels Available for LMS in UHF at Montreal

TV Channel Numbers	Bandwidth (MHz)	Channels Assigned to TV	Channels Unavailable To LMS Due to Interference From: Co-channel into TV	Adj. Channel into TV	Picture Image into TV	Co-channel into Base	Co-channel into Mobile	Channels Available for LMS
14	470 – 476	X	P					P
15	476 – 482	•	•					X
16	482 – 488	•	•					X
17	488 – 494	X	•					X
18	494 – 500	•	•					X
19	500 – 506	X	P					P
20	506 – 512	•	•					X
21	512 – 518	X	X					•
22	518 – 524	•	•					X
23	524 – 530	X	X					•
24	530 – 536	•	•					X
25	536 – 542	X	•					X
26	542 – 548	X	X					•
27	548 – 554	•	•					X
28	554 – 560	X	•					•
29	560 – 566	•	•					X
30	566 – 572	•	•					X
31	572 – 578	X	P					P
32	578 – 584	•	•					X
33	584 – 590	X	•					X
34	590 – 596	•	•					X
35	596 – 602	X	P					P
36	602 – 608	X	•					X
37	608 – 614	•	•					X
38	614 – 620	•	•					X
39	620 – 626	•	•					X
40	626 – 632	•	•					X
41	632 – 638	•	•					X
42	638 – 644	•	•					X
43	644 – 650	•	•					X
44	650 – 656	•	•					X
45	656 – 662	•	•					X
46	662 – 668	•	•					X
47	668 – 674	•	•					X
48	674 – 680	•	•					X
49	680 – 686	X	•					X

TV Channel Numbers	Bandwidth (MHz)	Channels Assigned to TV	Channels Unavailable to LMS Due to Interference From: Co-channel into TV	Adj. Channel into TV	Picture Image into TV	Co-channel into Base	Co-channel into Mobile	Channels Available for LMS
50	686 – 692	•	•					X
51	692 – 698	X	•					X
52	698 – 704	•	•					X
53	704 – 710	•	•					X
54	710 – 716	•	•					X
55	716 – 722	X	•					X
56	722 – 728	•	•					X
57	728 – 734	X	•					X
58	734 – 740	•	•					X
59	740 – 746	X	•					X
60	746 – 752	•	•					X
61	752 – 758	•	•					X
62	758 – 764	•	•					X
63	764 – 770	•	•					X
64	770 – 776	•	•					X
65	776 – 782	•	•					X
66	782 – 788	•	•					X
67	788 – 794	•	•					X
68	794 – 800	•	•					X
69	800 – 806	•	•					X
70	806 – 812	X	•					X
71	812 – 818	•	•					X
72	818 – 824	•	•					X
73	824 – 830	•	•					X
74	830 – 836	•	•					X
75	836 – 842	•	•					X
76	842 – 848	•	•					X
77	848 – 854	•	•					X
78	854 – 860	•	•					X
79	860 – 866	•	•					X
80	866 – 872	•	•					X
81	872 – 878	•	•					X
82	878 – 884	•	•					X
83	884 – 890	•	•					X

Table 4-1C TV Channels Available for LMS in UHF at Vancouver

TV Channel Numbers	Bandwidth (MHz)	UHF TV Channels Available for Use by LMS			TV Channel Numbers	Bandwidth (MHz)	UHF TV Channels Available for Use by LMS		
		Toronto	Montreal	Vancouver			Toronto	Montreal	Vancouver
14	470 – 476	X	X	P	50	686 – 692	X	P	X
15	476 – 482	X	X	X	51	692 – 698	•	X	X
16	482 – 488	•	•	X	52	698 – 704	X	X	X
17	488 – 494	•	•	X	53	704 – 710	X	X	X
18	494 – 500	•	•	X	54	710 – 716	X	X	X
19	500 – 506	•	X	P	55	716 – 722	•	X	X
20	506 – 512	•	P	X	56	722 – 728	•	X	X
21	512 – 518	•	X	•	57	728 – 734	•	•	X
22	518 – 524	•	•	X	58	734 – 740	•	X	X
23	524 – 530	•	X	•	59	740 – 746	X	X	X
24	530 – 536	•	•	X	60	746 – 752	X	P	X
25	536 – 542	•	X	X	61	752 – 758	•	P	X
26	542 – 548	•	X	•	62	758 – 764	X	•	X
27	548 – 554	X	X	X	63	764 – 770	X	X	X
28	554 – 560	P	P	•	64	770 – 776	P	X	X
29	560 – 566	•	X	X	65	776 – 782	X	X	X
30	566 – 572	•	P	X	66	782 – 788	X	P	X
31	572 – 578	•	X	P	67	788 – 794	X	X	X
32	578 – 584	P	P	X	68	794 – 800	X	X	X
33	584 – 590	X	•	X	69	800 – 806	X	X	X
34	590 – 596	P	X	X	70	806 – 812	X	X	X
35	596 – 602	P	X	P	71	812 – 818	X	X	X
36	602 – 608	X	X	X	72	818 – 824	X	X	X
37	608 – 614	P	X	X	73	824 – 830	X	X	X
38	614 – 620	X	X	X	74	830 – 836	X	X	X
39	620 – 626	X	X	X	75	836 – 842	X	X	X
40	626 – 632	P	P	X	76	842 – 848	X	X	X
41	632 – 638	X	X	X	77	848 – 854	X	X	X
42	638 – 644	X	X	X	78	854 – 860	X	X	X
43	644 – 650	X	X	X	79	860 – 866	X	X	X
44	650 – 656	•	X	X	80	866 – 872	X	X	X
45	656 – 662	X	•	X	81	872 – 878	X	X	X
46	662 – 668	•	X	X	82	878 – 884	X	X	X
47	668 – 674	•	X	X	83	884 – 890	X	X	X
48	674 – 680	•	X	X					
49	680 – 686	•	X	X					

Table 4-2 TV Channels Available for LMS in UHF

TV Channel Numbers	Bandwidth (MHz)	Channels Assigned to TV	Channels Unavailable To LMS Due to Interference From: Co-channel into TV	Adj. Channel into TV	Picture Image into TV	Co-channel into Base	Co-channel into Mobile	Channels Available for LMS
14	470 – 476	X	X					•
15	476 – 482	X	•					X
16	482 – 488	•	•					X
17	488 – 494	X	X					•
18	494 – 500	X	X					•
19	500 – 506	X	X					•
20	506 – 512	X	X					•
21	512 – 518	X	X					•
22	518 – 524	X	X					•
23	524 – 530	X	X					•
24	530 – 536	X	X					•
25	536 – 542	X	X					•
26	542 – 548	X	P					P
27	548 – 554	X	X					•
28	554 – 560	X	X					•
29	560 – 566	X	X					•
30	566 – 572	X	X					•
31	572 – 578	X	X					•
32	578 – 584	•	•					X
33	584 – 590	X	X					•
34	590 – 596	X	X					•
35	596 – 602	X	X					•
36	602 – 608	X	X					•
37	608 – 614	•	•					X
38	614 – 620	X	•					X
39	620 – 626	X	X					•
40	626 – 632	X	P					P
41	632 – 638	X	X					•
42	638 – 644	X	P					P
43	644 – 650	X	P					P
44	650 – 656	X	X					•
45	656 – 662	X	P					P
46	662 – 668	X	X					•
47	668 – 674	X	X					•
48	674 – 680	•	•					X
49	680 – 686	X	X					•

TV Channel Numbers	Bandwidth (MHz)	Channels Assigned to TV	Channels Unavailable to LMS Due to Interference From: Co-channel into TV	Adj. Channel into TV	Picture Image into TV	Co-channel into Base	Co-channel into Mobile	Channels Available for LMS
50	686 – 692	X	•					X
51	692 – 698	X	X					•
52	698 – 704	X	X					•
53	704 – 710	X	P					P
54	710 – 716	X	X					•
55	716 – 722	X	X					•
56	722 – 728	X	P					P
57	728 – 734	X	X					•
58	734 – 740	X	P					P
59	740 – 746	X	P					P
60	746 – 752	X	X					•
61	752 – 758	X	X					•
62	758 – 764	X	•					X
63	764 – 770	X	X					•
64	770 – 776	X	•					X
65	776 – 782	X	X					•
66	782 – 788	X	P					P
67	788 – 794	•	•					X
68	794 – 800	X	X					•
69	800 – 806	X	P					P
70	806 – 812	•	•					X
71	812 – 818	•	•					X
72	818 – 824	•	•					X
73	824 – 830	•	•					X
74	830 – 836	•	•					X
75	836 – 842	•	•					X
76	842 – 848	•	•					X
77	848 – 854	•	•					X
78	854 – 860	•	•					X
79	860 – 866	•	•					X
80	866 – 872	•	•					X
81	872 – 878	•	•					X
82	878 – 884	•	•					X
83	884 – 890	•	•					X

Table 4-3A TV Channels Available for LMS in UHF at Toronto

TV Channel Numbers	Bandwidth (MHz)	Channels Assigned to TV	Channels Unavailable To LMS Due to Interference From: Co-channel into TV	Adj. Channel into TV	Picture Image into TV	Co-channel into Base	Co-channel into Mobile	Channels Available for LMS
14	470 – 476	X	X					•
15	476 – 482	X	X					•
16	482 – 488	X	X					•
17	488 – 494	X	X					•
18	494 – 500	X	P					P
19	500 – 506	X	X					•
20	506 – 512	X	P					P
21	512 – 518	X	•					X
22	518 – 524	X	X					•
23	524 – 530	X	X					•
24	530 – 536	X	X					•
25	536 – 542	X	X					•
26	542 – 548	X	X					•
27	548 – 554	X	X					•
28	554 – 560	X	P					P
29	560 – 566	X	X					•
30	566 – 572	X	X					•
31	572 – 578	X	X					•
32	578 – 584	X	X					•
33	584 – 590	X	X					•
34	590 – 596	X	X					•
35	596 – 602	X	X					•
36	602 – 608	X	X					•
37	608 – 614	•	•					X
38	614 – 620	X	•					X
39	620 – 626	X	P					P
40	626 – 632	X	P					P
41	632 – 638	X	X					•
42	638 – 644	X	X					•
43	644 – 650	X	X					•
44	650 – 656	•	•					X
45	656 – 662	X	X					•
46	662 – 668	X	X					•
47	668 – 674	X	X					•
48	674 – 680	X	X					•
49	680 – 686	X	P					P

TV Channel Numbers	Bandwidth (MHz)	Channels Assigned to TV	Channels Unavailable to LMS Due to Interference From: Co-channel into TV	Adj. Channel into TV	Picture Image into TV	Co-channel into Base	Co-channel into Mobile	Channels Available for LMS
50	686 – 692	X	P					P
51	692 – 698	X	X					•
52	698 – 704	X	X					•
53	704 – 710	X	X					•
54	710 – 716	X	X					•
55	716 – 722	X	X					•
56	722 – 728	X	X					•
57	728 – 734	X	X					•
58	734 – 740	X	P					P
59	740 – 746	X	X					•
60	746 – 752	X	X					•
61	752 – 758	X	•					X
62	758 – 764	X	X					•
63	764 – 770	X	X					•
64	770 – 776	X	X					•
65	776 – 782	X	X					•
66	782 – 788	X	P					P
67	788 – 794	•	•					X
68	794 – 800	X	X					•
69	800 – 806	X	X					•
70	806 – 812	•	•					X
71	812 – 818	•	•					X
72	818 – 824	•	•					X
73	824 – 830	•	•					X
74	830 – 836	•	•					X
75	836 – 842	•	•					X
76	842 – 848	•	•					X
77	848 – 854	•	•					X
78	854 – 860	•	•					X
79	860 – 866	•	•					X
80	866 – 872	•	•					X
81	872 – 878	•	•					X
82	878 – 884	•	•					X
83	884 – 890	•	•					X

Table 4-3B TV Channels Available for LMS in UHF at Montreal

TV Channel Numbers	Bandwidth (MHz)	Channels Assigned to TV	Channels Unavailable To LMS Due to Interference From: Co-channel into TV	Adj. Channel into TV	Picture Image into TV	Co-channel into Base	Co-channel into Mobile	Channels Available for LMS
14	470–476	X	P					P
15	476–482	X	X					•
16	482–488	•	•					X
17	488–494	X	•					X
18	494–500	X	P					P
19	500–506	X	P					P
20	506–512	X	•					X
21	512–518	X	X					•
22	518–524	X	•					X
23	524–530	X	P					P
24	530–536	X	X					•
25	536–542	X	•					X
26	542–548	X	X					•
27	548–554	•	•					X
28	554–560	X	•					X
29	560–566	X	X					•
30	566–572	X	P					P
31	572–578	X	P					P
32	578–584	X	X					•
33	584–590	X	P					P
34	590–596	X	X					•
35	596–602	X	P					P
36	602–608	X	P					P
37	608–614	•	•					X
38	614–620	X	•					X
39	620–626	X	•					X
40	626–632	X	P					P
41	632–638	X	•					X
42	638–644	X	X					•
43	644–650	X	•					X
44	650–656	X	P					P
45	656–662	X	•					X
46	662–668	X	P					P
47	668–674	X	P					P
48	674–680	X	P					P
49	680–686	X	•					X

TV Channel Numbers	Bandwidth (MHz)	Channels Assigned to TV	Channels Unavailable to LMS Due to Interference From: Co-channel into TV	Adj. Channel into TV	Picture Image into TV	Co-channel into Base	Co-channel into Mobile	Channels Available for LMS
50	686–692	X	X					•
51	692–698	X	•					X
52	698–704	X	X					•
53	704–710	•	•					X
54	710–716	X	P					P
55	716–722	X	X					•
56	722–728	•	•					X
57	728–734	X	•					X
58	734–740	X	X					•
59	740–746	X	•					X
60	746–752	X	X					•
61	752–758	X	•					X
62	758–764	X	•					X
63	764–770	X	X					•
64	770–776	X	X					•
65	776–782	•	•					X
66	782–788	X	X					•
67	788–794	X	•					X
68	794–800	X	X					•
69	800–806	X	P					P
70	806–812	X	•					X
71	812–818	•	•					X
72	818–824	•	•					X
73	824–830	•	•					X
74	830–836	•	•					X
75	836–842	•	•					X
76	842–848	•	•					X
77	848–854	•	•					X
78	854–860	•	•					X
79	860–866	•	•					X
80	866–872	•	•					X
81	872–878	•	•					X
82	878–884	•	•					X
83	884–890	•	•					X

Table 4-3C TV Channels Available for LMS in UHF at Vancouver

5.0 CONCLUSIONS

Based on the "statistical" approach used in the analysis, the UHF TV channels available for use by the land mobile service (located within 30 km from the city centre) in Toronto, Vancouver and Montreal and given in Table 4.2

The operational requirement that the base transmitters use a channel, a fixed frequency away from the mobile transmitters, will impose an additional constraint on the usable channels in the UHF band.

In the analysis, "micro" terrain features were not considered; rather, a "macro" characteristic was used. This approach will affect the results for Vancouver and, to a lesser extent, those of Montreal.

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LIST OF APPENDICES

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Appendix A to Chapter I

PROPAGATION CHARACTERISTICS FOR THE LAND MOBILE SERVICE AND THE TV BROADCAST SERVICE OPERATING IN THE FREQUENCY BAND FROM 30 MHZ TO 1000 MHZ

Appendix A to Chapter I

PROPAGATION CHARACTERISTICS FOR THE LAND MOBILE SERVICE AND THE TV BROADCAST SERVICE OPERATING IN THE FREQUENCY BAND FROM 30 MHZ TO 1000 MHZ

1.0 Characteristics of the Propagation Path

The propagation characteristics of the transmission path between base station antenna and the mobile station antenna largely determine the quality of service and the coverage area of the land mobile service. For this reason, the propagation characteristics will be studied in detail.

Section 2.0 is intended to introduce the various factors that are involved in the propagation loss. Simple models of the path will be used to obtain analytical expressions for the loss due to the factors. Section 3.0 considers the path characteristics in an actual environment where the received signal is due to multiple specular and diffuse reflections, multiple diffractions, etc. The received field strength in such an environment can only be estimated from the results of many experiments, since an analytical expression is impossible. Because of the continually changing environment, the median field strength will fluctuate from location to location; it can only be described by statistical means. This is considered in Section 4.

2.0 Factors Affecting Transmission

2.1 Free-Space Transmission Formula

If the transmitting and receiving antennas are isotropic and there are no objects in the region that absorb or reflect energy, then the power received by the receiving antenna is:

$$P_1 = P_t \left(\lambda / 2\pi d \right)^2 \qquad (2\text{-}1)$$

where P_t is the power radiated by the transmitting, isotropic antenna (W)

d is the line-of-sight separation between the two antennas

λ is the wavelength in the same units as d.

If the two antennas are not isotropic, then the equation becomes

$$P_o = P_t \left(\lambda / 2\pi d \right)^2 \cdot g_b \cdot g_m = P_1 \cdot g_b \cdot g_m \qquad (2\text{-}2)$$

where g_b and g_m are the power gains of the base (transmitting) and the mobile (receiving) antennas, respectively, in the direction of the line-of-sight path.

The received power varies as d^{-2}, i.e. it obeys the inverse square law relationship with distance. If the received power is expressed in decibels relative to one watt, then it decreases by 6 dB for each doubling of the distance or 6 dB per octave.

In the real-life situation, even when there are no reflecting or obstructing objects between the two antennas, the transmission medium will consist of atmosphere. The absorption loss of water vapour and oxygen gases in the atmosphere is given in Figure 1. For the frequencies under consideration (less than 1 GHz) and for the distances relevant in land mobile systems (less than 100 km.), the transmission path losses in the atmosphere are negligible. The transmission medium between the two antennas may also consist of precipitation such as rain, snow, etc.: The absorption loss in rain is given in Figure 2. The transmission path loss due to absorption by rain is also negligible for the frequency range and the distances (path lengths) involved in the land mobile systems under consideration. We can therefore assume that the line-of-sight transmission path loss (for the path loss of the unobstructed direct-ray) is as given in Equation 2-2 for free space.

2.2 Propagation Over a Plane Earth

When propagating over a plane earth as shown in Figure 3, the earth serves as a reflecting surface and as a conducting path and thereby creates additional transmission paths between the two antennas.

The power received by the receiving antenna becomes:

$$P_r = P_t \left(\frac{\lambda}{4\pi d}\right)^2 g_b \cdot g_m \cdot \left|\underbrace{1}_{\text{direct wave}} + \underbrace{Re^{j\Delta}}_{\text{reflected wave}} + \underbrace{(1-R)A.e^{j\Delta}}_{\text{surface wave}} + \underbrace{\ldots\ldots}_{\text{induction field and secondary ground effects}}\right|^2 \qquad (2\text{-}3)$$

The reflection coefficient, R, of the ground depends on the angle of incidence, Θ, the polarization of the wave, and the ground characteristics and is given by:

$$R = \frac{\sin\Theta - z}{\sin\Theta + z} \tag{2-4}$$

where $z =$

$$\frac{\sqrt{\epsilon_o - \cos^2\Theta}}{\epsilon_o} \quad \text{for vertical polarization}$$

$$= \sqrt{\epsilon_o - \cos^2\Theta} \quad \text{for horizontal polarization}$$

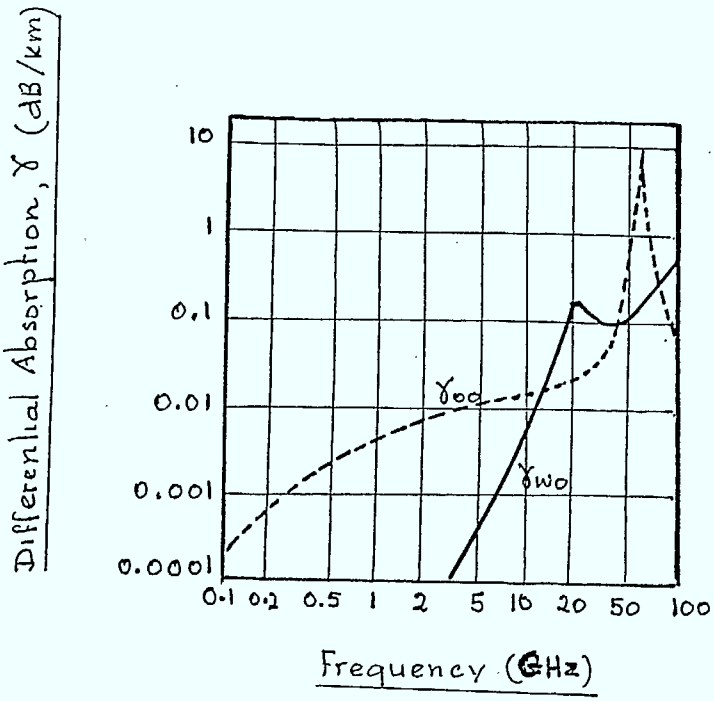


Figure 1: Signal Attenuation from Oxygen and Water Vapour in the Atmosphere

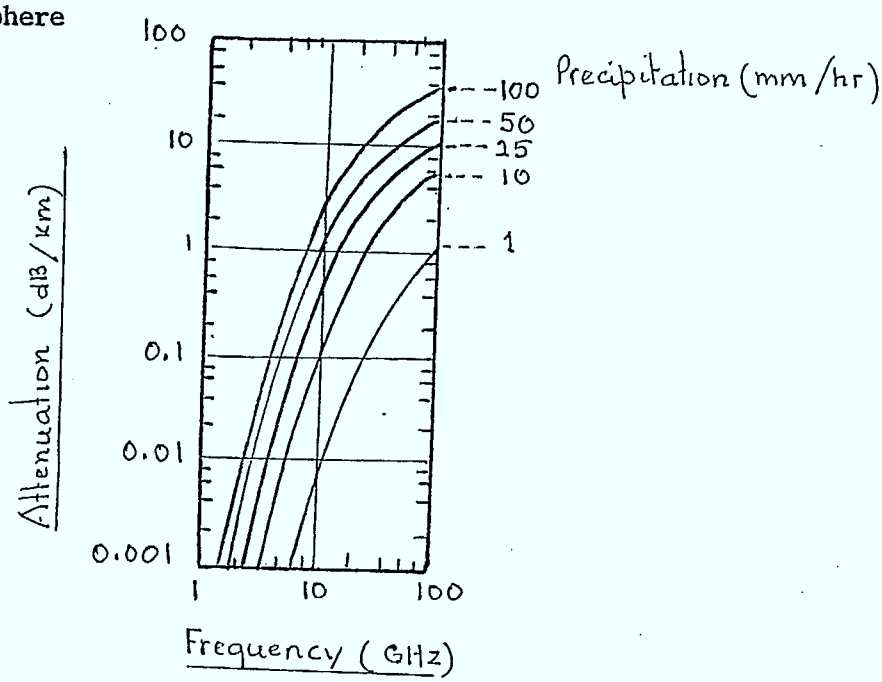


Figure 2: Signal Attenuation for Various Rainfall Rates

(Source: "Microwave Mobile Communications" by W.C. Jakes)

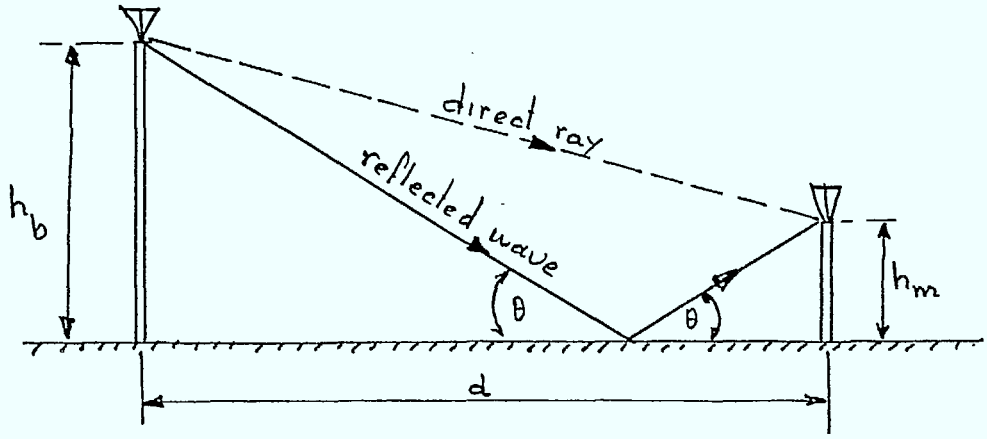


Figure 3: Propagation Paths over a Plane Earth

Type of Surface	σ (mho/m)	ε
Poor ground	0.001	4
Average ground	0.005	15
Good ground	0.02	25
Sea water	5	81
Fresh water	0.01	81

Table 2-1: Typical Ground Constants

$\epsilon_o = \epsilon - j60\sigma\lambda$

ϵ = dielectric constant of the ground relative to free space

σ = conductivity of the ground in mhos per metre

The quantity, Δ , is the phase difference between the reflected and the direct paths between transmitting and receiving antennas. From Figure 3:

$$\Delta = \frac{2\pi d}{\lambda}\left[\left(\frac{h_b - h_m}{d}\right)^2 + 1\right]^{\frac{1}{2}} - \frac{2\pi d}{\lambda}\left[\left(\frac{h_b - h_m}{d}\right)^2 + 1\right]^{\frac{1}{2}} \qquad (2\text{-}5)$$

$$\text{For } d > 5h_b.h_m,\ \Delta \approx \frac{4\pi h_b.h_m}{\lambda d} \qquad (2\text{-}6)$$

Since the earth is not a perfect conductor, some energy is transmitted into the ground, setting up ground currents that distort the field distribution relative to what it would have been over a perfectly reflecting surface. The surface wave attenuation factor, A, depends on frequency, polarization, and the ground constants. An approximate expression for A is given by:

$$A \approx \frac{-1}{1 + j\left(\frac{2\pi d}{\lambda}\right)(\sin\theta + z)^2} \qquad (2\text{-}7)$$

which is valid for $|A|<0.1$. The effect of this surface wave is only significant in a region a few wavelengths above the ground. This effect can be neglected except for very low frequencies. Typical ground constraints are given in Table 1.

It is of interest to note that in the limit of grazing angle of incidence, the value of the reflection coefficient, R, approaches -1 independent of the polarization. For frequencies above 100 MHz and for an "average" earth with constraints as given in Table 2-1 and for vertical polarization, $|R|$ exceeds 0.9 for angles less than 10° above the horizon. For horizontal polarization above 100 MHz, $|R|$ exceeds 0.5 for angles less than 5° but must be of the order of a degree or less for $|R|$ to exceed 0.9.

Under the conditions that R = -1 and A can be neglected, then:

$$P_r = 4 \cdot P_o \cdot \sin^2\left(\frac{2\pi h_b h_m}{\lambda d}\right) \qquad (2\text{-}8)$$

where P_o is the expected power over a free space path and is given in Equation (2-2). In most mobile radio applications, except very near the base station antenna, $\sin \frac{\Delta}{2} \approx \frac{\Delta}{2}$; thus the transmission loss over a plane earth is given approximately by:

$$P_r = P_t \cdot g_b \cdot g_m \left(\frac{h_b \cdot h_m}{d^2}\right)^2 \qquad (2\text{-}9)$$

This yields an inverse fourth-power relationship of received power with distance from the base station antenna.

2.3 Rough Surface Reflections

At higher frequencies, where the wavelengths are small, the earth can no longer be considered as a plane surface even for small surface irregularities. A measure of the surface "roughness" that provides an indication of the range of validity of range of validity of Equation 2-3 is given by the Rayleigh criterion, which is:

$$C = \frac{4\pi\sigma\Theta}{\lambda} \qquad (2\text{-}10)$$

where σ is the standard deviation of the surface irregularities relative to the mean height of the surface, is the wavelength, and Θ is the angle of incidence measured in radians from the horizontal. Experimental evidence shows that for $C<0.1$, the reflection can be regarded as specular and the surface as smooth. For specular reflections, Snell's Law may be used to compute the reflected ray's path. For $C > 10$, the surface may be regarded as "rough." For "rough" surfaces, Snell's Law does not apply, and the reflection is regarded as diffuse. Diffuse reflection scatters energy in all directions so the actual amount reflected in the direction of the receiving antenna is small; and hence, the reflection coefficient is low in amplitude. Bullington has found that most practical paths at microwave frequencies are relatively "rough" with reflection coefficients in the range of 0.2 - 0.4.

2.4 Refraction and Equivalent Earth's Radius

Because the index of refraction of the atmosphere is not constant but decreases (except during unusual atmospheric conditions) with increasing height above the earth, electromagnetic waves are bent as they propagate. The mean variation in refractive index can be considered linear with a constant gradient g of the form:

$$n = n_o + gh \qquad (2\text{-}11)$$

where H is the height above the earth's surface.

In a medium where there are abrupt changes in index of refraction, Descarte's law applies:

$$n(a + h) \cos\alpha = n_o a \cos\alpha_o \tag{2-12}$$

where α and α_o are the angles at the discontinuity at height h above the surface of the earth of radius a. (See Figure 4) If the atmosphere is uniform, the equation for rectilinear propagation is:

$$\left(1 + \frac{h}{a}\right) \cos\alpha \approx \cos\alpha_o \tag{2-13}$$

When n has a constant gradient, the propagation is given approximately by:

$$\left[1 + \left(h \frac{1}{a}\right) + g\right] \cos\alpha \approx \cos\alpha_o \tag{2-14}$$

If we replace the earth's radius, a, by a fictitious value, a', where:

$$a' = \left(\frac{1}{a} + g\right)^{-1} \tag{2-15}$$

we now have an expression in the same form as for rectilinear propagation.

Since the index of refraction in the troposphere is very nearly unity, the N unit has been defined for convenience:

$$N_s = (n - 1) \times 10^6 \tag{2-16}$$

where n is the index of refraction in the atmosphere. Values of the minimum monthly mean value of N_s throughout the world have been published. The most commonly used value for N is 301. This gives a value for the effective earth's radius a' which corresponds to the four-thirds of the actual earth's radius a. The empirical formula for a' is given by:

$$a' = 6370 \; [1 - 0.04665 \exp (0.005577 Ns)]^{-1} \text{ (km)} \tag{2-17}$$

where 6370 km is used for the earth's radius.

Some of the energy radiated by a transmitting antenna will be at elevation angles greater than the local horizontal. This energy will, in some cases, be bent sufficiently in the atmosphere to arrive at the receiving antenna providing yet another transmission path between the two antennas. Since the index of refraction changes with time, refracted waves are a major source of time-dependent anomalous propagation to distances well beyond the horizon. Under certain conditions an inversion in the index of refraction occurs at certain heights. The phenomenon of "ducting" is then said to occur in which electromagnetic waves are propagated over long distances. "Ducting" is another source of anomalous propagation to distances well beyond the local horizon of a smooth spherical earth.

2.5 Transmission Over a Smooth Spherical Earth

At microwave frequencies, diffraction due to the earth severely limits the amount of energy that propagates beyond the horizon. Considerable work has been done in an attempt to predict the signal attenuation over transhorizon paths. Generally speaking, these are semi-empirical formulas which apply for frequencies below 1000 MHz. It is possible to obtain analytical expressions for the diffraction over a perfectly conducting sphere; however the expressions are not simple relationships between the factors of frequency, conductivity of the earth, antenna height, and distance which govern the attenuation.

It is, however, desireable to be able to estimate signal strengths beyond the horizon, particularly for cases where the same frequencies are being used at separated base stations. Bullington has reduced the involved analytical relationships for the propagation over a smooth spherical earth to various asymptotic forms. Figure 6 is a nomograph, accurate to ±2 dB, which was derived from his approximations. The parameters involved in this nomograph are shown in Figure 5.

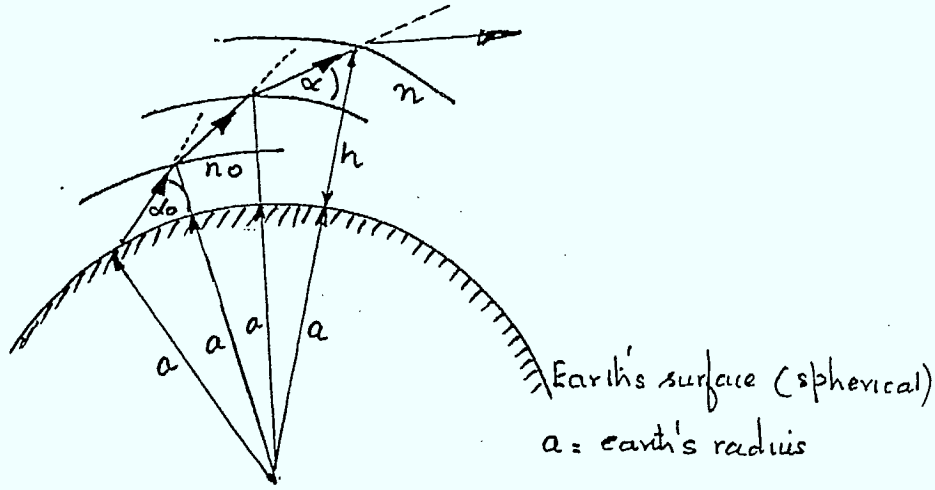


FIGURE 4: Ray Bending from Propagation through the Atmosphere

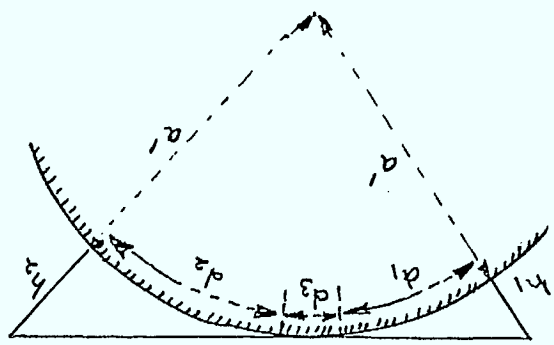


FIGURE 5: Loss Relative to Free Space for Propagation Over a Smooth Spherical Earth

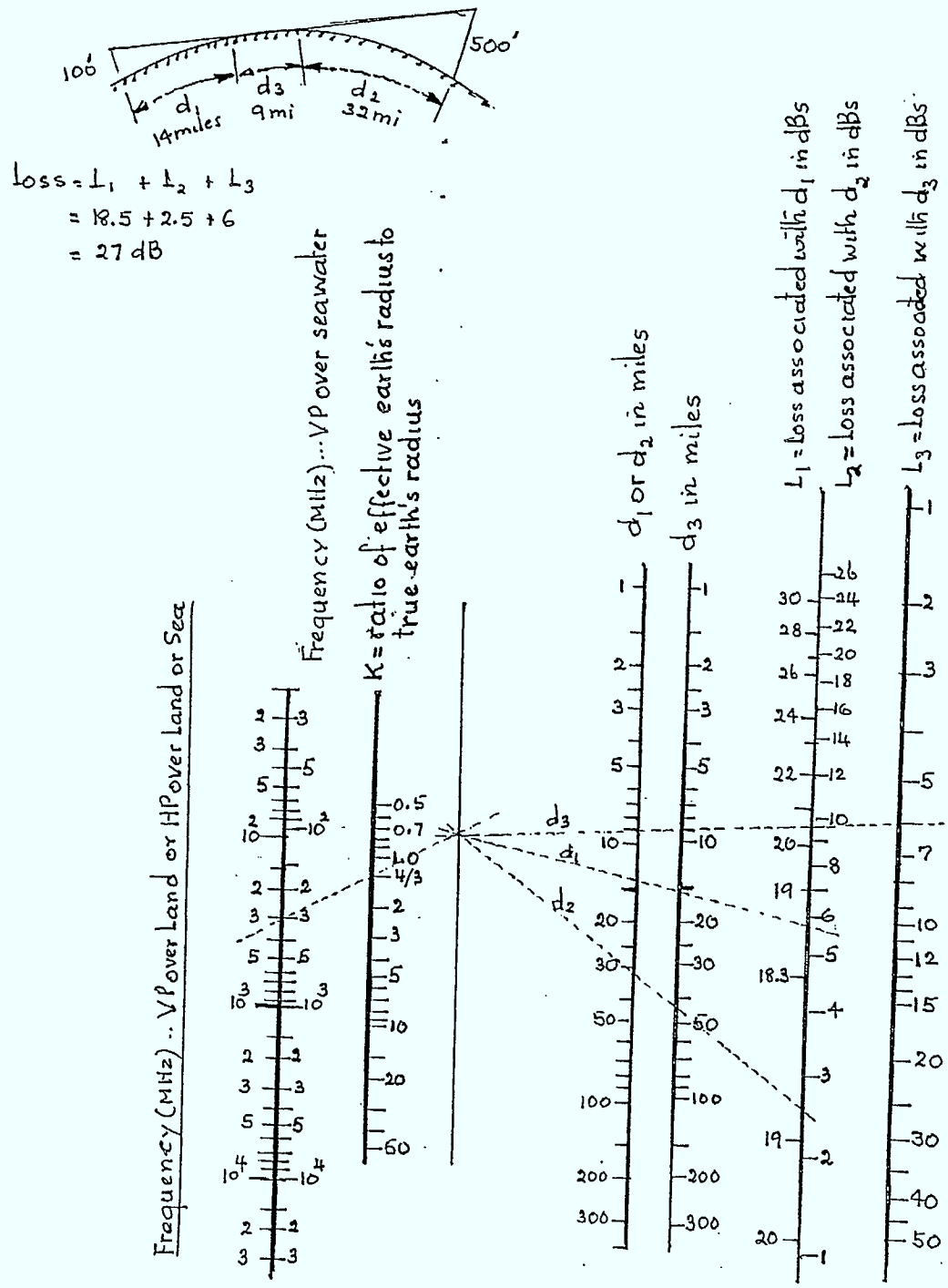


FIGURE 6: Diffraction Loss Relative to Free Space Transmission at all Locations Beyond Line-of-Sight over a Smooth Sphere

2.6 Knife Edge Diffraction

Very often in the mobile radio environment a line-of-sight path to the base station is obscured by obstructions such as hills, trees and buildings. When the shadowing is caused by a single object such as a hill, it is instructive to treat the object as a diffracting knife edge to estimate the amount of signal attenuation.

Within the shadow region of the knife edge, the electric field strength E, can be represented as:

$$\frac{E}{E_o} = A \exp(j\Delta) \tag{2-18}$$

where E_o is the value of the electric field at the knife edge, A is the amplitude, and Δ the phase angle with respect to the direct path. The expressions for A and Δ are obtained in terms of the Fresnel integrals:

$$A = \frac{S + \frac{1}{2}}{\sqrt{2}\sin\left(\Delta + \frac{\pi}{4}\right)} \tag{2-19}$$

$$\Delta = \tan^{-1}\left(\frac{S + \frac{1}{2}}{C + \frac{1}{2}}\right) - \frac{\pi}{4} \tag{2-20}$$

where

$$C = \int_0^{h_o} \cos\left(\frac{\pi}{2} v^2\right) .dv \tag{2-21}$$

$$S = \int_0^{h_o} \sin\left(\frac{\pi}{2} v^2\right) .dv \tag{2-22}$$

$$h_o = h \sqrt{\frac{2}{\lambda}\left(\frac{1}{d_1} + \frac{1}{d_2}\right)} \tag{2-23}$$

For microwave mobile radio applications several assumptions can be made to simplify the calculations. Consider an infinite completely absorbing (rough) half-plane that divides space into two parts as in Figure 7. When distances d_1 and d_2 from the half-plane to the transmitting antenna and the receiving antenna are large compared to the height h, and h itself is large compared to the wavelength, , that is

$$d_1, d_2 \gg h \gg \lambda \tag{2-24}$$

then the diffracted power can be given by the expression:

$$\frac{P}{P_o} = \frac{1}{2\pi^2 h_o^2} \tag{2-25}$$

This result can be considered independent of polarization as long as the conditions of Equation 2-24 are met. In cases where the earth's curvature has an effect, there can be up to four paths. Closer agreement with data over measured paths has been obtained by calculations that better describe the geometry of the diffracting obstacle and are given in CCIR, SGV, Report 715-1, 1982. Bullington has developed a nomograph to compute the losses due to a knife-edge diffraction. This nomograph is given in Figure 8.

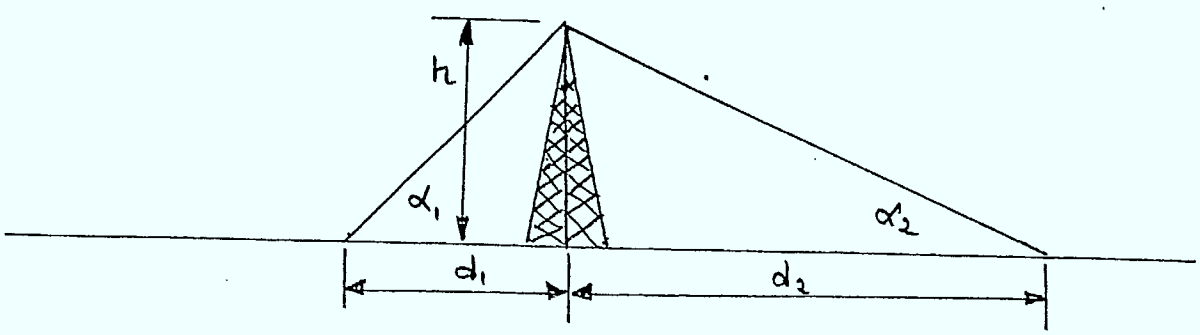


FIGURE 7: Geometry for Propagation over a Knife Edge

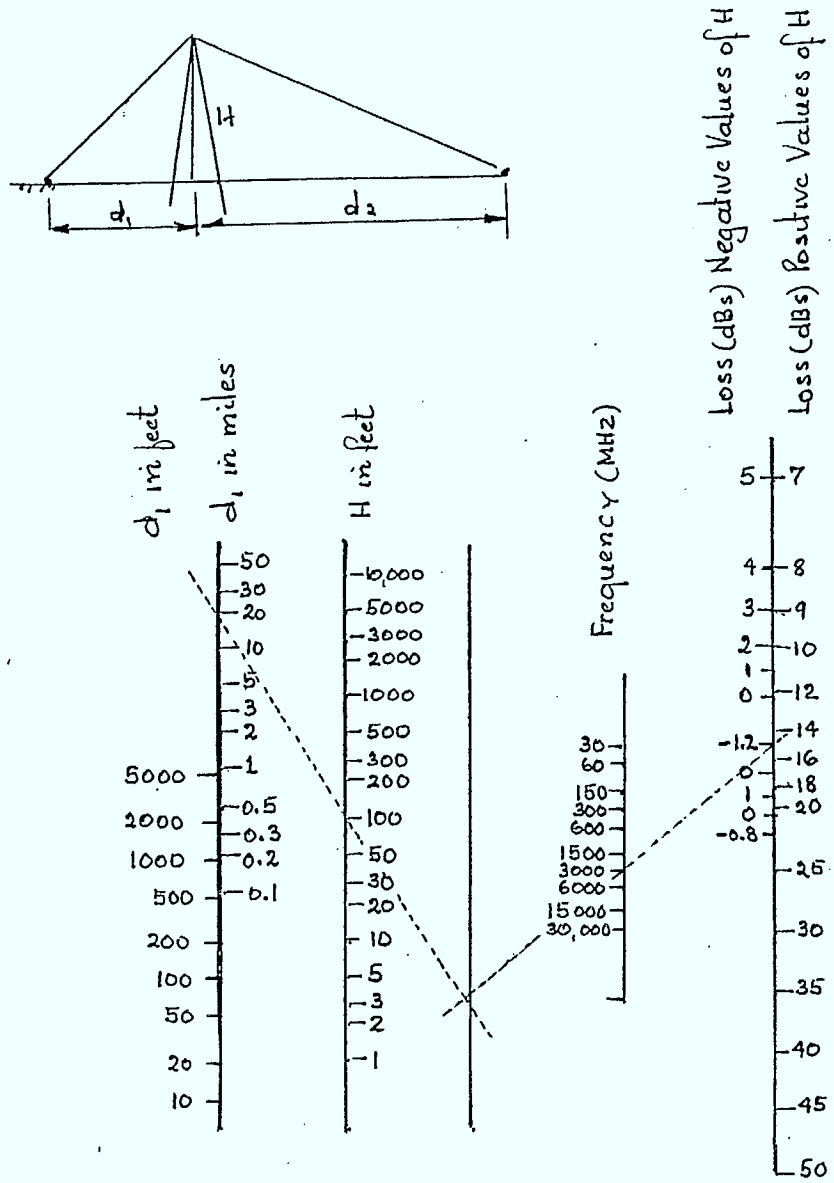


Figure 8: Knife-Edge Diffraction Loss Relative to Free Space

2.7 Effects of Rain and the Atmosphere

Mobile radio signals are attenuated by the presence of rain, snow and fog. Losses depend on the frequency and upon the amounts of moisture in the path. The effects of the oxygen and water vapour in the atmosphere is given in Figure 1. while the effects of rain are given in Figure 2. Compared to other sources of losses the losses due to the gases in the atmosphere and in rain are relatively insignificant for frequencies below 1 GHz.

2.8 Depolarization

The depolarization of the transmitted wave is another source of loss in the transmission path. Polarization discrimination is better in the open country and with high signal levels than when field strengths are low as, for example, when the UHF receiving antenna is surrounded by obstacles. The nature of the receiving site is also significant. Observations in Germany at VHF has shown that in shadow regions, the reflections have very little effect on horizontal polarization but their effects on vertical polarization are often great enough to seriously distort FM reception. However, measured data on this source of loss is scanty.

3.0 Observed Attenuation on Mobile Radio Paths over Smooth Terrain

It has been shown that using simple, idealized models for the transmission path, it is possible to calculate the transmission path loss relative to the free-space path loss between two antennas. In the real-life situation, the signal attenuations over actual mobile radio paths result from the presence of radio wave scatterers along the path within the mobile radio environment. Variations in the contour and "roughness" of the terrain cause changes in the propagation loss as a result of specular reflection, diffuse reflection and diffraction. This loss varies from place to place in the environment and from time to time for the same place; it can only, at best, be described statistically and the statistical values should be derived from extensive measurements in the field.

To study the propagation characteristics over actual mobile radio paths, we shall first assume that the terrain is relatively smooth. We define the terrain to be "quasi-smooth" when the undulations of the ground about the average ground height are less than 20 metres. This definition would still allow the actual surface to be either "smooth" or rough according to the Rayleigh criterion. Furthermore, the undulations should be "gentle" in the sense that the distance between the peak and trough should be much larger than the height of the undulations. The average ground level should also remain constant to within 20 metres for a distance of the order of 10 kilometres.

The position of an antenna above the terrain affects transmission. A transmitting antenna, located 100 metres atop a mountain will propagate signals differently than an antenna located 100 metres above a flat plane. A definition of antenna height that accounts for this discrepancy is therefore required. The effective antenna height above the average terrain is illustrated in Figure 9.

Some sort of classification of the environment is also required since the signal attenuation varies depending upon the type of objects that obstruct the path. The environmental types are conveniently classed under three broad classes:

1. Open areas: areas where there are very few obstacles such as tall trees or buildings in the path. Examples are farm land or open fields.

2. Suburban areas: areas with houses, small buildings and trees, often near the mobile unit.

3. Urban areas that are heavily built up with tall buildings and multi-story residences.

Transition regions will occur between the above classification types. However, the results obtained for the above types can be used to estimate the signal attenuations for these transition regions.

The signal attenuation characteristics given in this section were determined by extensive measurements on radio transmission loss over various terrains in the frequency range from 20 to 10,000 Hz. To date, the most extensive work in the field has been reported by Okumura et. al. Okumura's results will be used to generate the prediction curves that are provided in the last portion of this section.

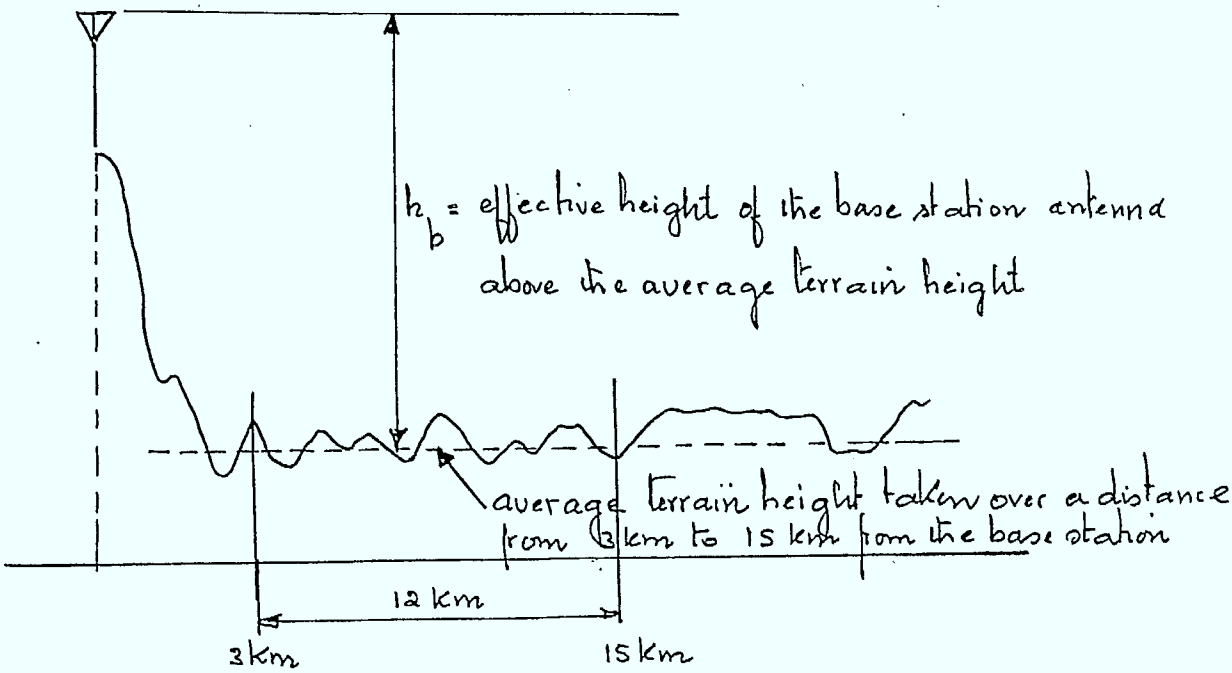


FIGURE 9: Definition of Effective Base Station Antenna Height

3.1 Field Strength Variation in Urban Areas

Since most mobile units are concentrated within large metropolitan centres, it is reasonable to use, for a basis of comparison, the median field strengths measured in quasi-smooth urban environments and then express suburban and open area measurements as departures from the baseline environment. Within the urban environment the received field strength is found to vary with the base station and mobile antenna heights, transmitting frequency, the distance from the transmitter and the width and orientation of the streets. The median field strengths in a quasi-smooth urban area show a relatively continuous change with frequency, antenna height, and distance, while other effects appear less simply related.

3.2 Distance Dependence of the Median Field Strength

The signal received by the mobile units will fluctuate markedly (even when the Rayleigh fading is averaged out) since building heights, street widths and terrain features are not constant. It has been found from experiments that the median values of the received signals tend to decrease, rapidly, the further the mobile unit is separated from the base station. Figure 10 is a plot of the received signal power versus distance as measured by independent workers in three different cities: New York, Philadelphia and Tokyo. All the measurements were made at approximately 900 MHz from relatively high base-station locations. This remarkably consistent trend of both the fall-off of the median signal value with distance and the excess attenuation relative to free space leads one to hope that signal strength parameters in different cities will likewise exhibit consistent traits.

The rate of signal decrease with distance does not appear to change significantly with increasing antenna height. However, raising the base station antenna height does tend to decrease the attenuation relative to free space, as shown in Figures 11 and 13. For antenna separation distances between 1 and 15 km, the attenuation of median signal power with distance changes from nearly an inverse fourth power decrease for very low base-station antenna heights to a rate only slightly faster that the free-space decrease for extremely high base-station antennas. For antenna separations greater than 40 km, the signal attenuation is very rapid.

3.3 Frequency Dependence of the Median Field Strength

Signal attenuation increases in urban areas as the frequency increases. For a fixed antenna height, the signal attenuation as a function of frequency can be expressed in terms of n($P_r \alpha f^{-n}$, where P_r is the median received signal power) for varying frequencies. Figures 12 and 14 show that n is roughly constant for distances under 10 km from the base station. As the separation increases, the decrease in signal strength with frequency becomes more rapid.

Figure 15 is a prediction curve derived by Okumura for the basic median signal attenuation relative to free space in quasi-smooth urban areas as it varies with both distance and frequency. These curves provide the starting point for predicting signal attenuation.

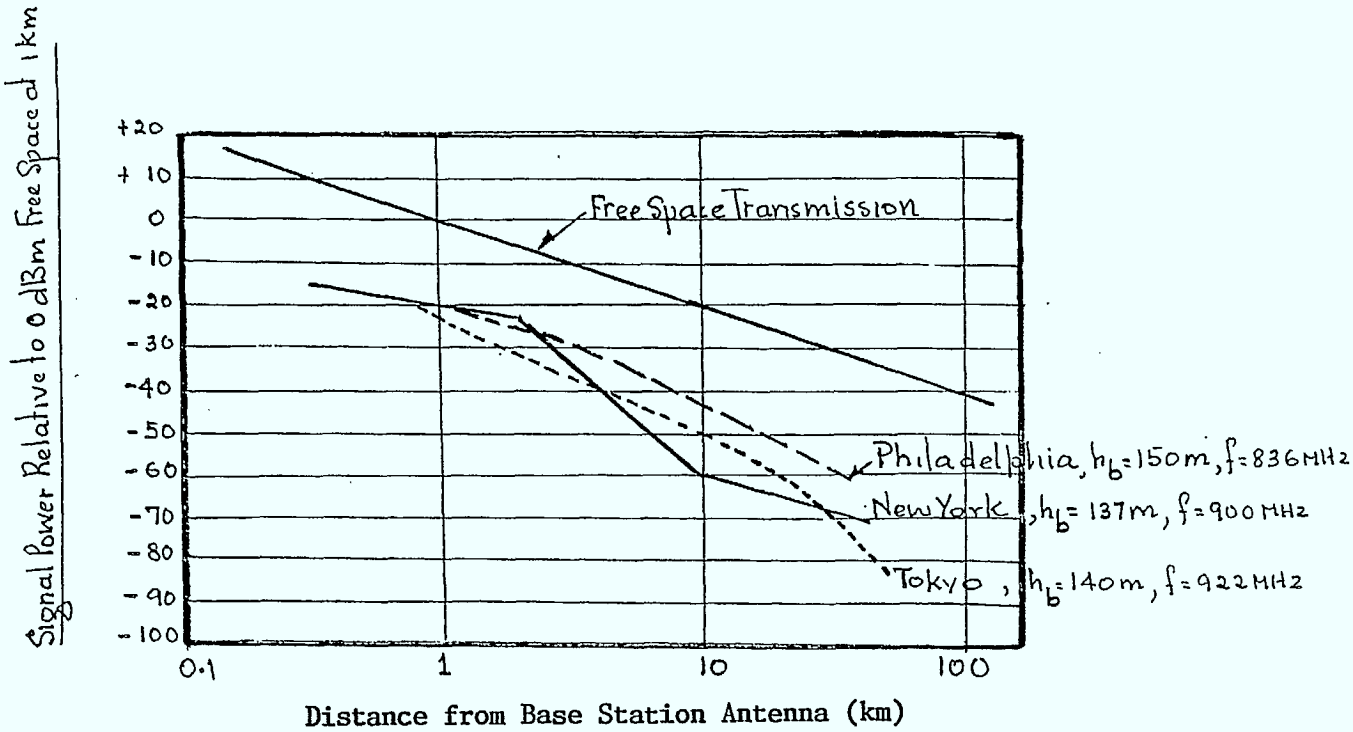


FIGURE 10: Examples of Transmission Loss with Distance

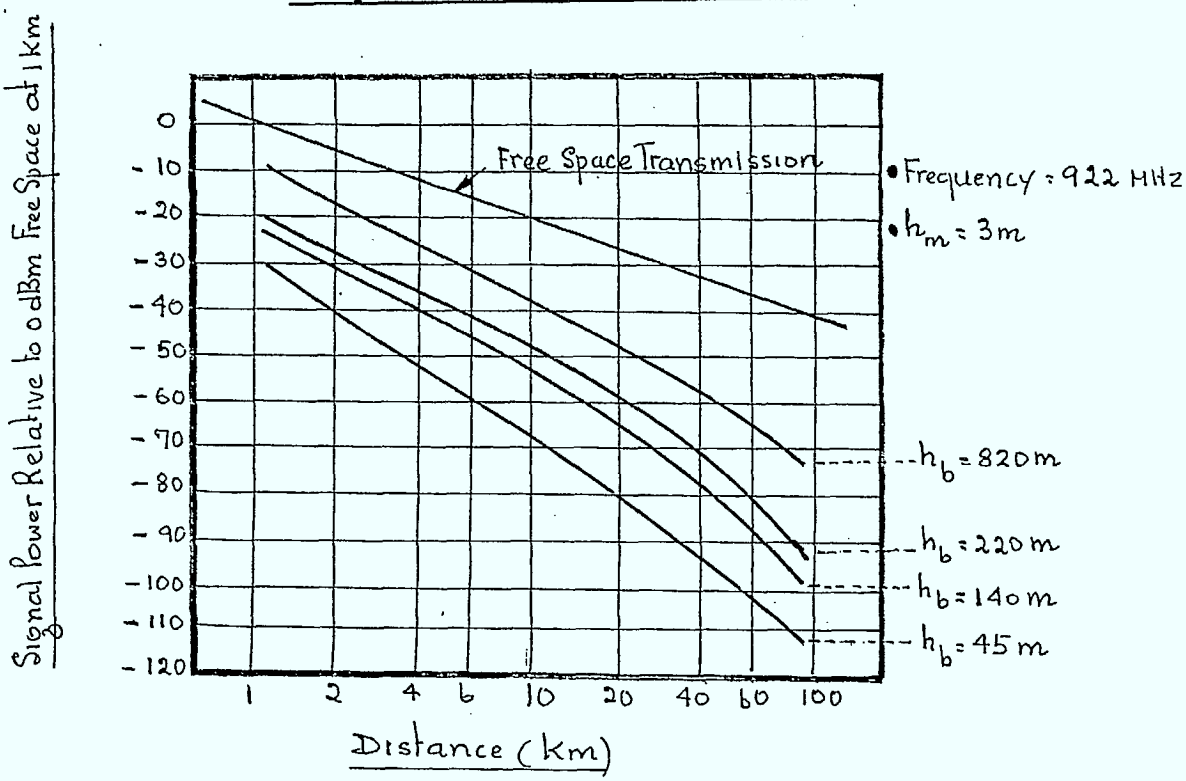


FIGURE 11: Median Field Strengths in an Urban Area for Various Antenna Antenna Heights

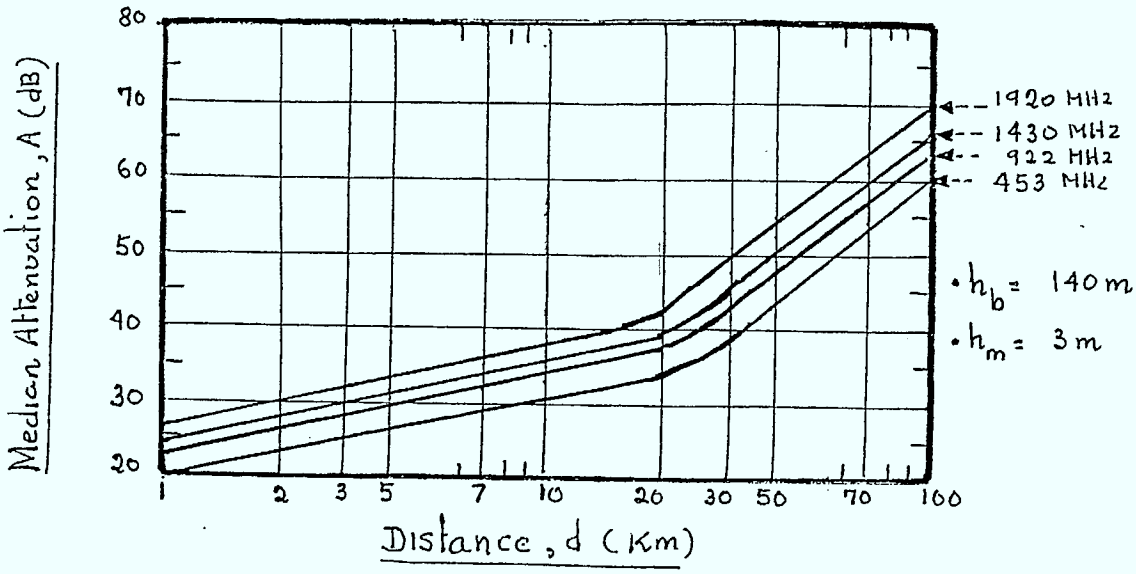
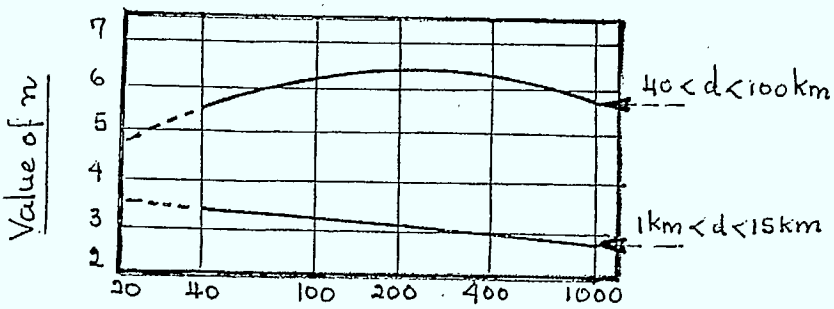


FIGURE 12: Distance and Frequency Dependence of Median Field Strength Attenuation (relative to free space) in Urban Area



Base Station Antenna Height, (m)

FIGURE 13: Distance Dependence of Median Field Strength in an Urban Area ($P_r \alpha d^{-n}$)

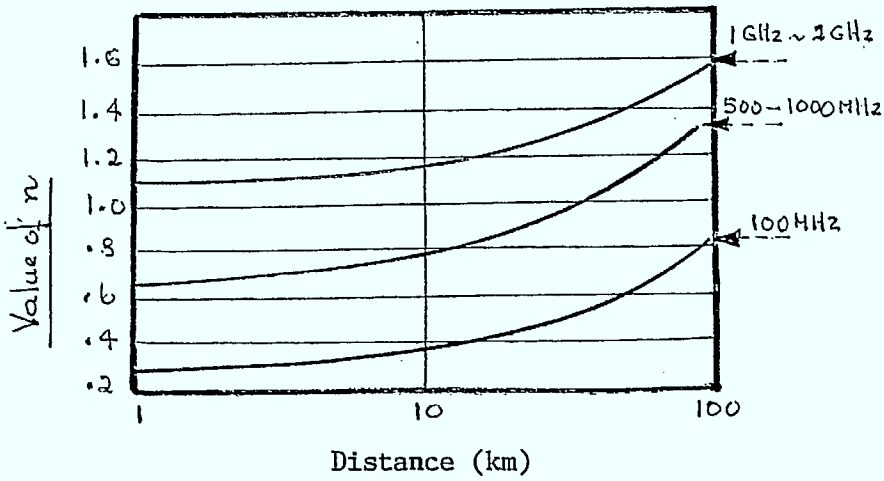


FIGURE 14: Frequency Dependence of Median Field Strength in an Urban Area

($P_r \alpha f^{-n}$)

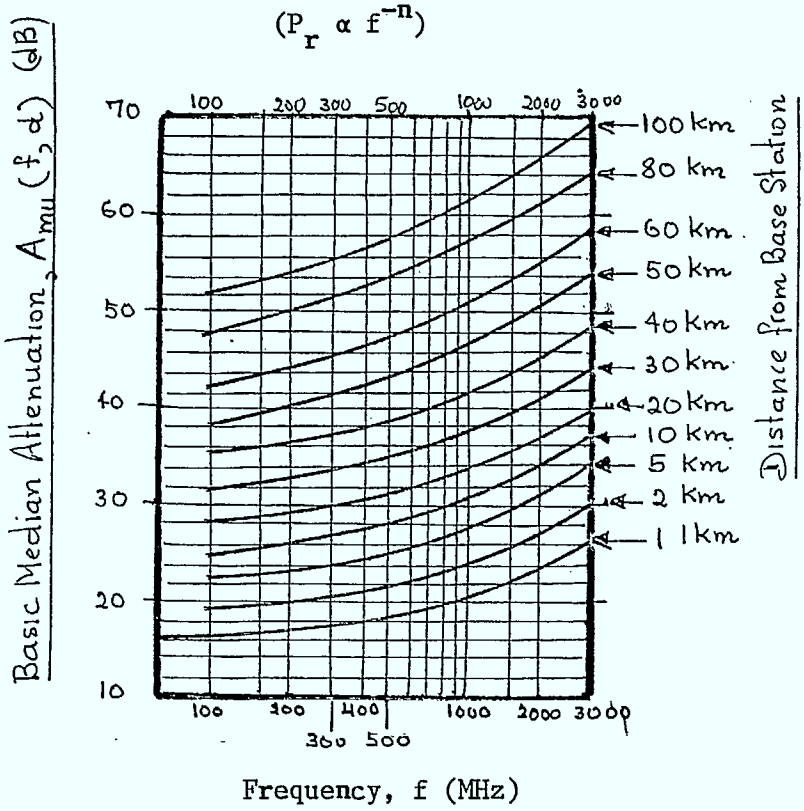


FIGURE 15: Prediction Curve for Basic Median Attenuation Relative to Free Space in an Urban Area over Quasi-smooth Terrain, Referred to h_b = 200 m, h_m = 3m

(Source: "Microwave Mobile Communications" by W.C. Jakes)

The curves assume a base-station antenna height of 200 metres and a mobile antenna height of 3 metres. Adjustments to these basic curves for different base-station antenna heights and mobile antenna heights are considered in the paragraphs that follow.

3.4 Antenna Height Dependence of the Median Field Strength

In typical real-life situations the mobile antenna is likely to be buried within the confines of its surroundings while the base-station antenna will be elevated to some extent above local obstacles. The effect of the change of elevation is different in the two instances.

The prediction curves for the base-station height-gain factor referred to the effective height of 200 metres are given in Figure 16, as a function of antenna separation distance. For separation distances between antennas of less than 10 km, the received signal power varies almost proportionally with the square of the base-station antenna height (i.e. 6 dB per octave). For very high base station antennas and for large separation distances (greater than 30 km), the received power tends to be proportional to the cube of the height of the base station antenna (i.e. 9 dB per octave). The prediction curves may be used for frequencies in the range from 200 to 2000 MHz.

The prediction curves for the mobile-station height-gain factor referred to a mobile station antenna height of 3 metres are given in Figure 17. The height-gain factor, if a 1.5 metre mobile antenna height is used, is -3 dB over a wide range of frequencies and for several base-station antenna heights. For mobile station heights greater than 3 metres, the height-gain factor becomes dependent not only on the frequency but also on the environment.

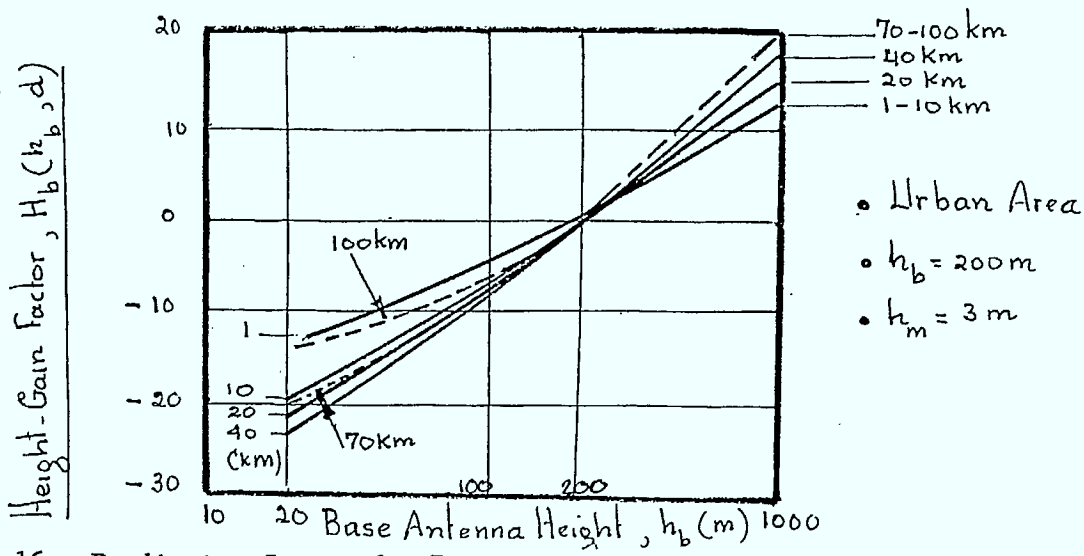


FIGURE 16: Prediction Curves for Base Station Height-Gain Factor Referred to h_b = 200m

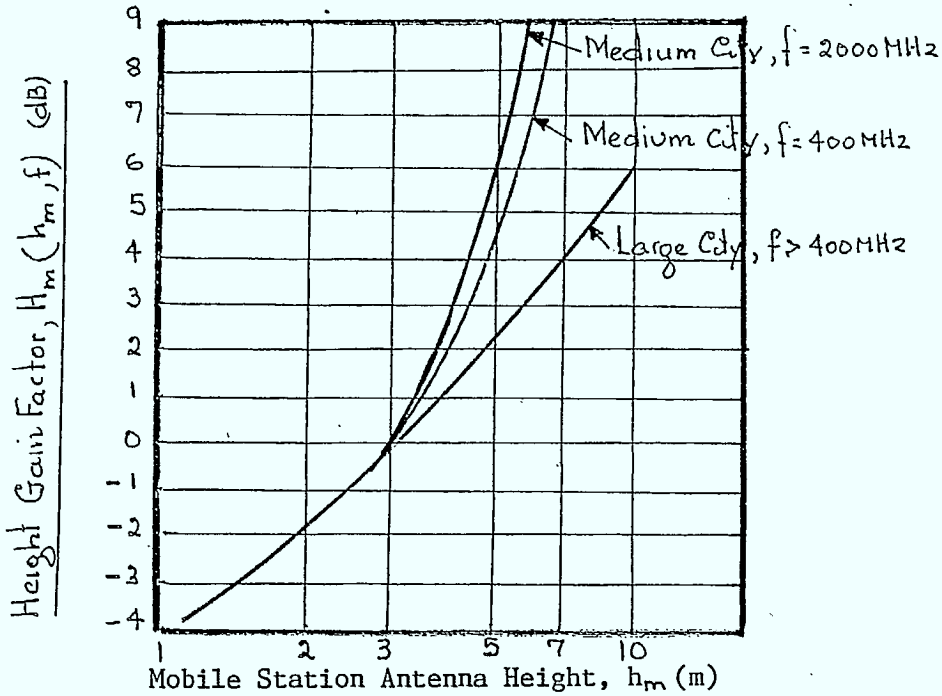


FIGURE 17: Prediction Curves for Mobile Station Height Gain Factor Referred to $h_m = 3m$

3.5 Correction Factor for Suburban and Open Areas

Suburban areas are generally characterized by lower buildings and generally less congestion of obstacles than in cities. Consequently, one should expect the radio signals would propagate better in such environments. Okumura has found that there is practically no change in the difference between urban and suburban median attenuation (suburban correction factor) and changes in base-station antenna height or with separation distances between the base and mobile antennas. The suburban propagation does depend somewhat on the frequency and increases to some extent at the higher frequencies. A plot of the suburban correction factor is shown in Figure 18.

Open areas tend to have significantly better propagation paths than urban and suburban areas and, typically, the received signal strengths run nearly 20 dB greater for the same antenna height and separation distances. The open area correction factor is shown as the upper curve in Figure 18.

3.6 Effects of Street Orientation

It has been observed that radio signals in urban areas tend to be channeled by buildings so that the strongest propagation paths are not necessarily the direct paths diffracted over the edge of nearby obstructing buildings, but are found to be from directions parallel to the streets. Streets that run radially or approximately radially from the base station are most strongly affected by this channeling phenomenon. This causes the median received signal strength to differ by as much as 20 dB at locations near the transmitter, as shown in the signal strength model in Figure 15.

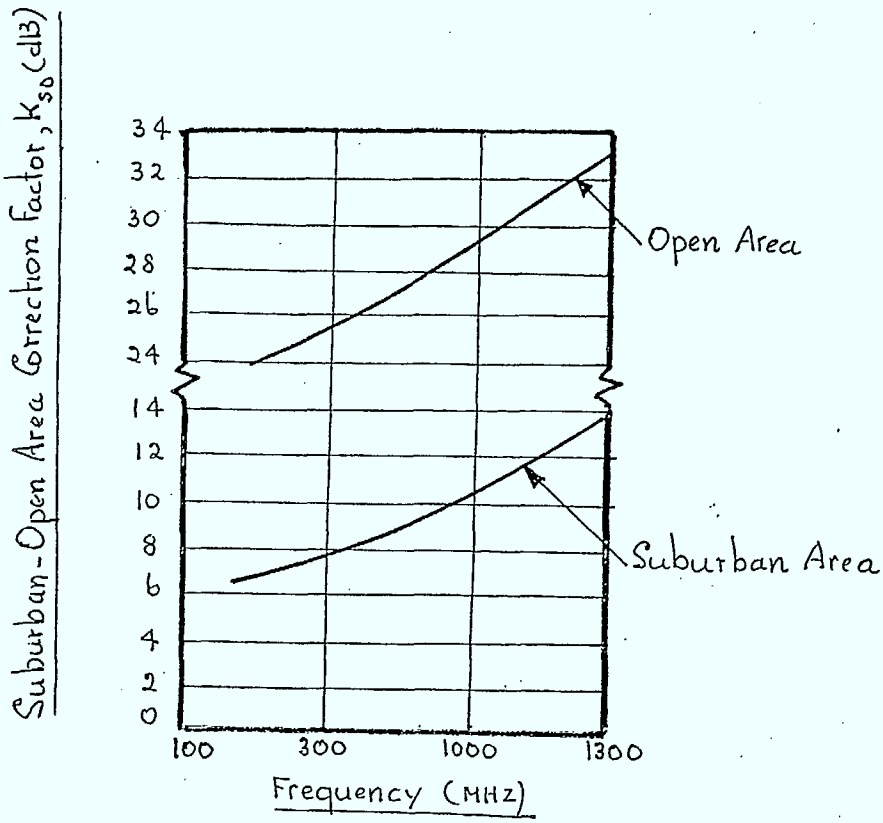


FIGURE 18: Prediction Curves for Suburban and Open Area Correction Factor, k_{so}

Source: "Microwave Mobile Communications" by W.C. Jakes)

3.7 Effects of Foliage

There are a great many factors that affect propagation behind obstacles such as a grove of trees. Precise estimates of attenuation are difficult because tree heights are not uniform; also the type, shape, density, and distribution of the trees influence the propagation. In addition, the density of the foliage depends on the season of the year. However, some success has been obtained by treating trees as diffracting obstacles with an average effective height. Figure 19 shows a case in which this was done.

3.8 Signal Attenuation in Tunnels

It is known that frequencies in the VHF region, commonly used for mobile communications, are severely attenuated in tunnel structures. However, at microwave frequencies tunnels are effective guiding or channeling mechanisms and can offer significant improvement over VHF communications. Figure 20 gives the loss characteristics in a tunnel, as measured in the Lincoln tunnel under the Hudson River.

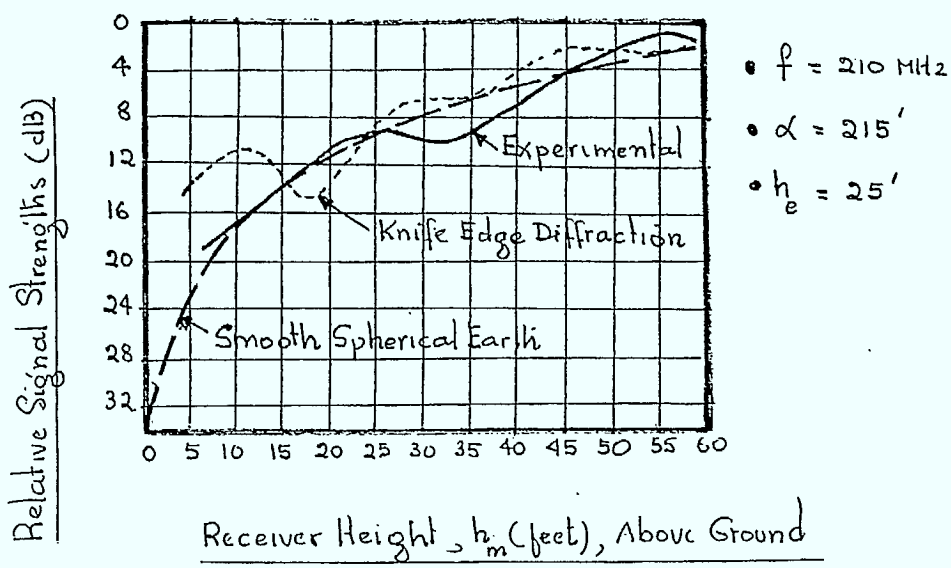
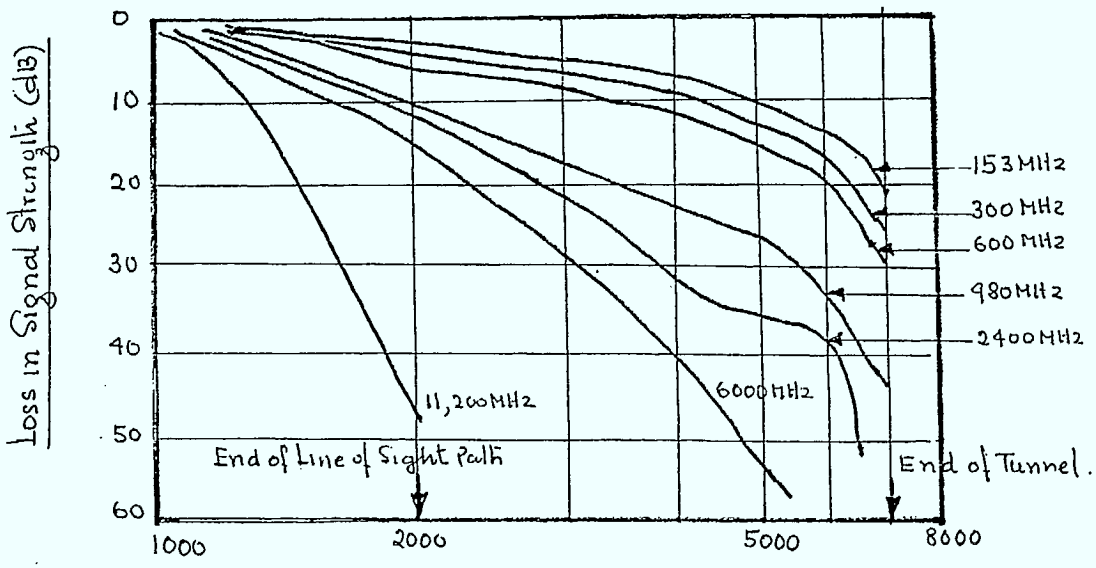


FIGURE 19: Signal Propagation Behind Trees

(Source: "Microwave Mobile Communications" by W.C. Jakes)



Distance Between Antennas (feet)

FIGURE 20: Signal Loss vs Log of Antenna Separation for Seven Frequencies

(Source: "Microwave Mobile Communications" by W.C. Jakes)

3.9 Effects of Irregular Terrain on Median Field Strength

A computer programme has been published by Longley and Rice that predicts the long-term median radio transmission loss over irregular terrain. The method predicts median values of attenuation relative to free-space transmission loss and requires the following: transmission frequency, the antenna separation, the height of the transmitting and receiving antennas, the mean surface refractivity, the conductivity and dielectric constant of the earth, polarization, and a description of the terrain. The programme was based on thousands of measurements and compares well with measured data over the following ranges:

Parameter	Range
Frequency	20 MHz to 40 GHz
Antenna Height	0.5 to 3000 metres
Separation Distance	1 to 2000 km
Surface Refractivity	250 to 450 N units

The critical parameters necessary in any prediction of path loss are those which characterize the terrain. The "interdecile" range, Δh (d) of terrain heights above and below a straight line is a parameter often used in prediction formulas and is calculated at fixed distances, d, along the path. Longley and Rice have found that the values of Δh (d) increase with path length to an asymptotic value Δh according to the formula:

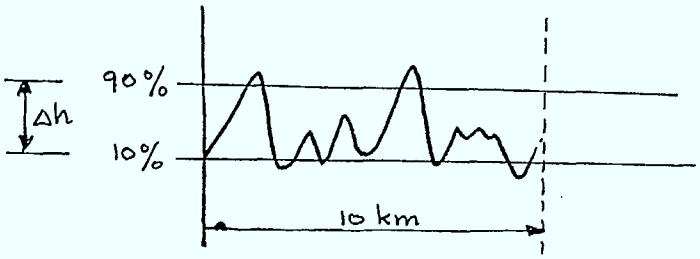
$$\Delta h\ (d) = \Delta h\ [1 - 0.8 \exp(-0.02d)] \qquad (3\text{-}1)$$

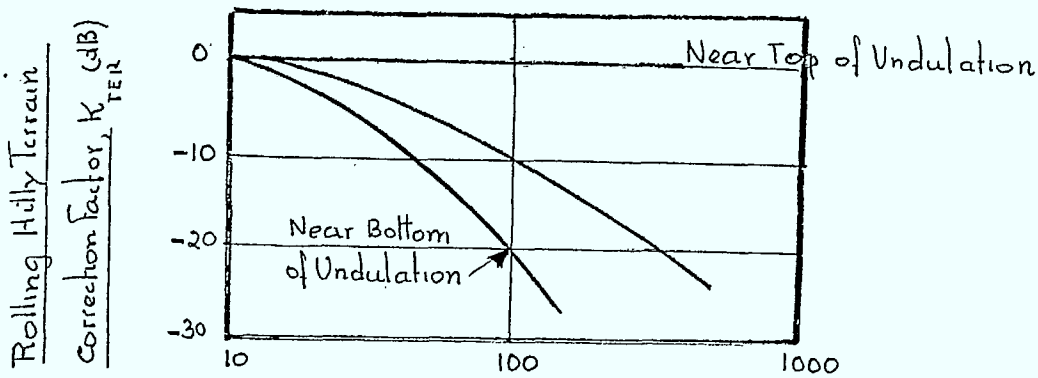
where Δh (d) and Δh are in metres and the distance d is in km. For a particular path where profiles are available, Δh (d) can be calculated precisely. In other cases or for area predications for planning purposes, estimates of Δh are given in Table 2.

The computer method of Longley and Rice provides both point-to-point and area predictions that agree well with experiments, abut the calculation is complicated. An approximate predication curve for undulating terrain is given in Figure 21.

The propagation loss also varies when the median height of the ground is not flat but slopes for distances of the order of 5 km. Figure 22 gives the terrain slope correction factor, K_{sp}, that could be used for planning purposes.

The propagation loss also depends on whether the path is over land or over water. Usually on propagation paths where there is an expanse of water between the transmitting and receiving stations, the received signal strength tends to be higher than for cases where the path is only over land. The change in signal strength depends on the antenna separation distance and whether the water lies closer to the mobile receiver or the base station transmitter, or somewhere in between. The land-sea correction factor, k_{ls}, is given in Figure 23; this factor may be used for frequency planning purposes.





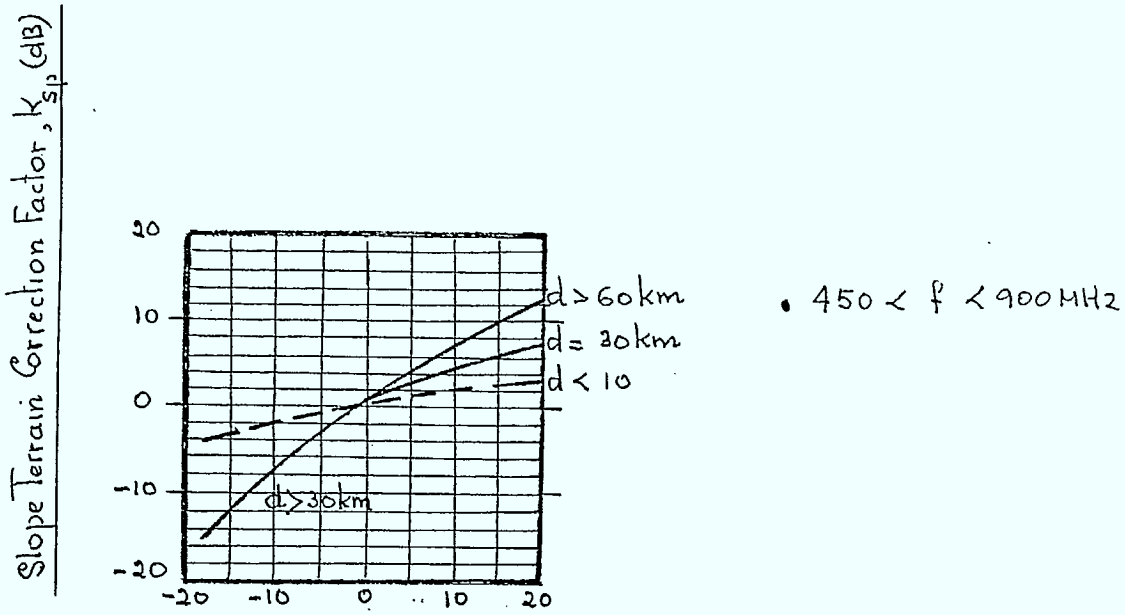
Terrain Undulation Height, Δh (m)

FIGURE 21: Rolling Hilly Terrain Correction Factor, K_{TER}

Type of Terrain	Δh (metres)
Water or very smooth plains	0 ~ 5
Smooth plains	5 ~ 20
Slightly rolling plains	20 ~ 40
Rolling plains	40 ~ 80
Hills	80 ~ 150
Mountains	150 ~ 300
Rugged Mountains	300 ~ 700
Extremely Rugged Mountains	>700

TABLE 2: Estimates of Δh

(a) Positive Slope (+Θm) Negative Slope (-Θm)



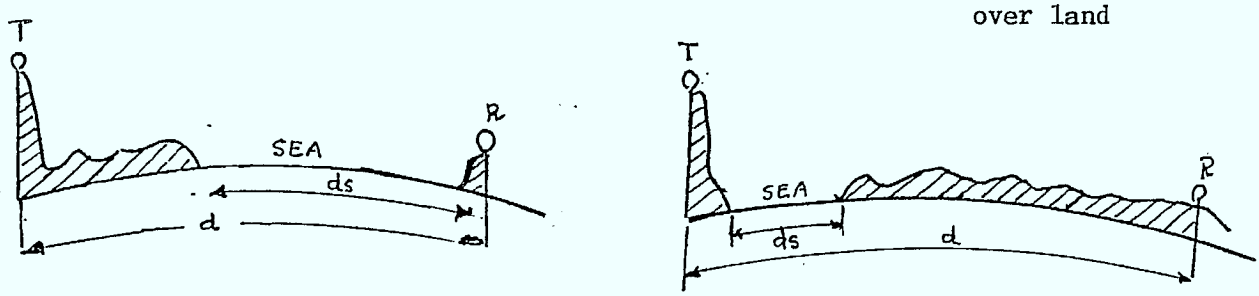
Average Angle of Slope, Θm (mr)

FIGURE 22: Measured Value and Prediction Curves for "Slope Terrain Correction Factor," K_{sp}

(Source: "Microwave Mobile Communications by W.C. Jakes)

Case A: Latter portion of path over sea

Case B: Latter portion of path over land



$\beta = \frac{(ds)}{d}$ % = distance ratio

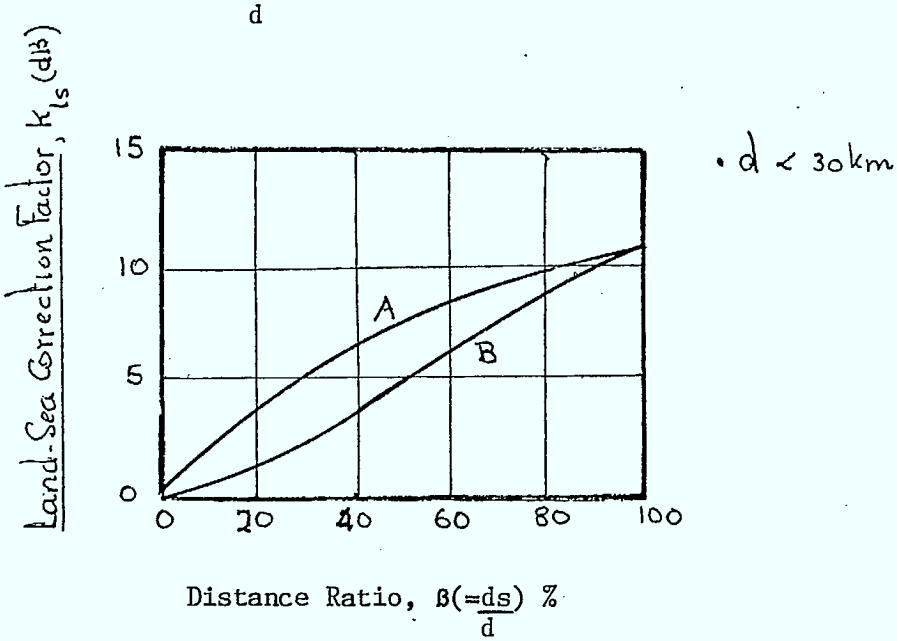


FIGURE 23: Prediction Curves for Land-Sea Correction Factor, k_{ls}

(Source: "Microwave Mobile Communications" by W.C. Jakes)

4.0 Prediction of Field Strength

4.1 Statistical Distribution of the Local Mean Signal

So far, only experimental evidence of the behavior of median signal levels obtained by averaging received signals over a distance of 10 to 20 metres has been presented. Smooth curves were obtained relating the variation of the median received signal with distance, base-station antenna height, frequency and environment: urban, suburban and rural areas. Consistent but less accurate predictions were found for median received signal dependence on street orientation, isolated ridges, rolling hills and land-sea paths. However, little or no data has been presented about the fluctuation of the received signal about the mean value. What is required is a knowledge of the signal distribution as a function of the above parameters.

One consistent result that has been observed is that the distribution of the received signals at fixed base and mobile antenna heights, frequency, and separation distance from the base station within the same environmental class (urban, suburban or rural) have very nearly a normal distribution when the distribution is plotted for the received signal measured in decibels. Such a probability distribution is referred to as log-normal. Also, the excess path loss, that is, the difference in decibels between the computed value of the received signal strength in free space and the actual measured value of the local mean received signal has been observed to be log-normally distributed. Figure 24 gives typical measured excess path loss characteristics measured in New Providence and New York city at 11.2 GHz. The distributions are log-normal with means of 37 dB and 46 dB, respectively, and with a standard deviation of 10 dB for both cities.

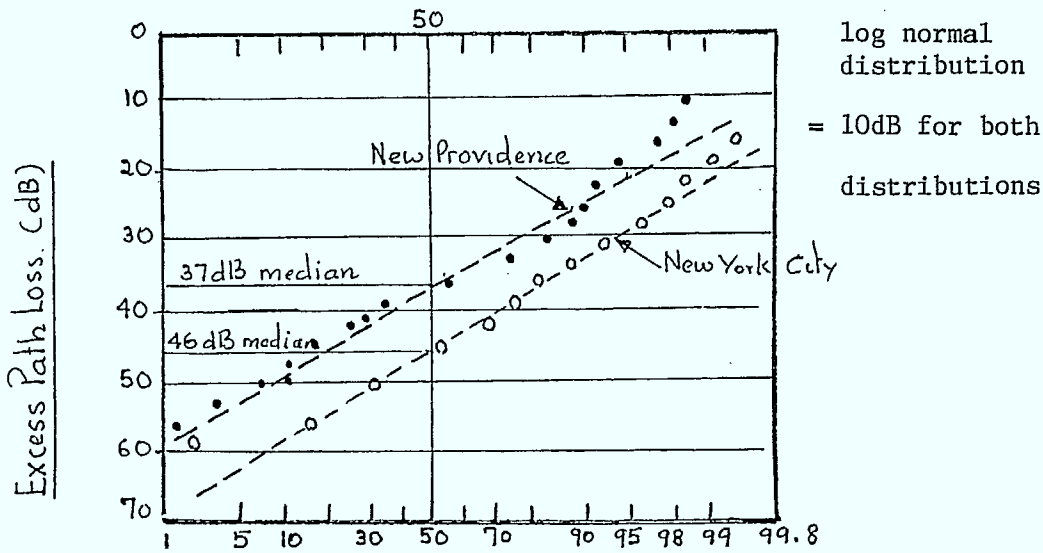


FIGURE 24: Distributions of Excess Path Loss in New Providence, N.J. and New York City

Okumura has measured the standard deviation of the median field strength variations in Tokyo and has found that the mean values of the standard deviation are not strongly dependent upon the base-station antenna height or antenna separation distance but do have a slight dependence with frequency. In these measurements base-station antenna heights ranged from 140 to 820 metres. For lower base-station antenna heights where there are obstacles in the path comparable in height to the base-station antenna height, one would suspect that the standard deviation would increase somewhat. Ott made measurements in Philadelphia for base-station antenna heights from 15 to 25 metres. His results show a standard deviation that decreased very slightly with distance from a normal value of 8.2 dB at 1.5 km to 7 dB at 15 km. A partial explanation for this distance dependence of the standard deviation in Philadelphia is that the average building height was greater at a distance of 1.5 km from the base-station than at 15 km.

A prediction curve for the standard deviation, σ, of the log-normal distribution that describes the variation of the median signal strength values in suburban areas, as given by Okumura, is shown in Figure 25. The data spreads at 850 MHz are from the data of Black and Ott, while those at 127 and 510 MHz are from work by Egli and the data at 11.2 GHz are from the data by Reudink.

In urban environments, the median field strengths vary depending on the percentage of land covered by buildings or the building density. Figure 26 gives a correction factor to be applied for various building densities.

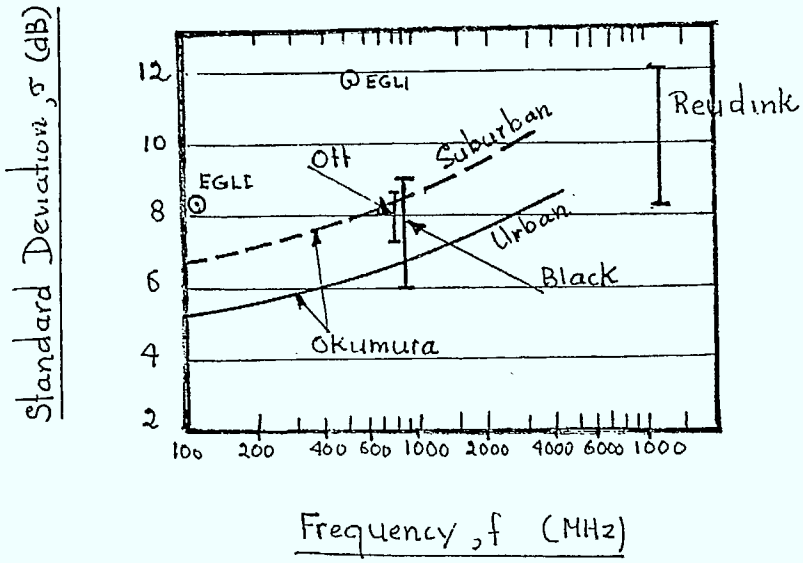


FIGURE 25: Prediction Curves for Standard Deviation of Median Field Strength Variation in Urban, Suburban, and Rolling Hilly Terrain

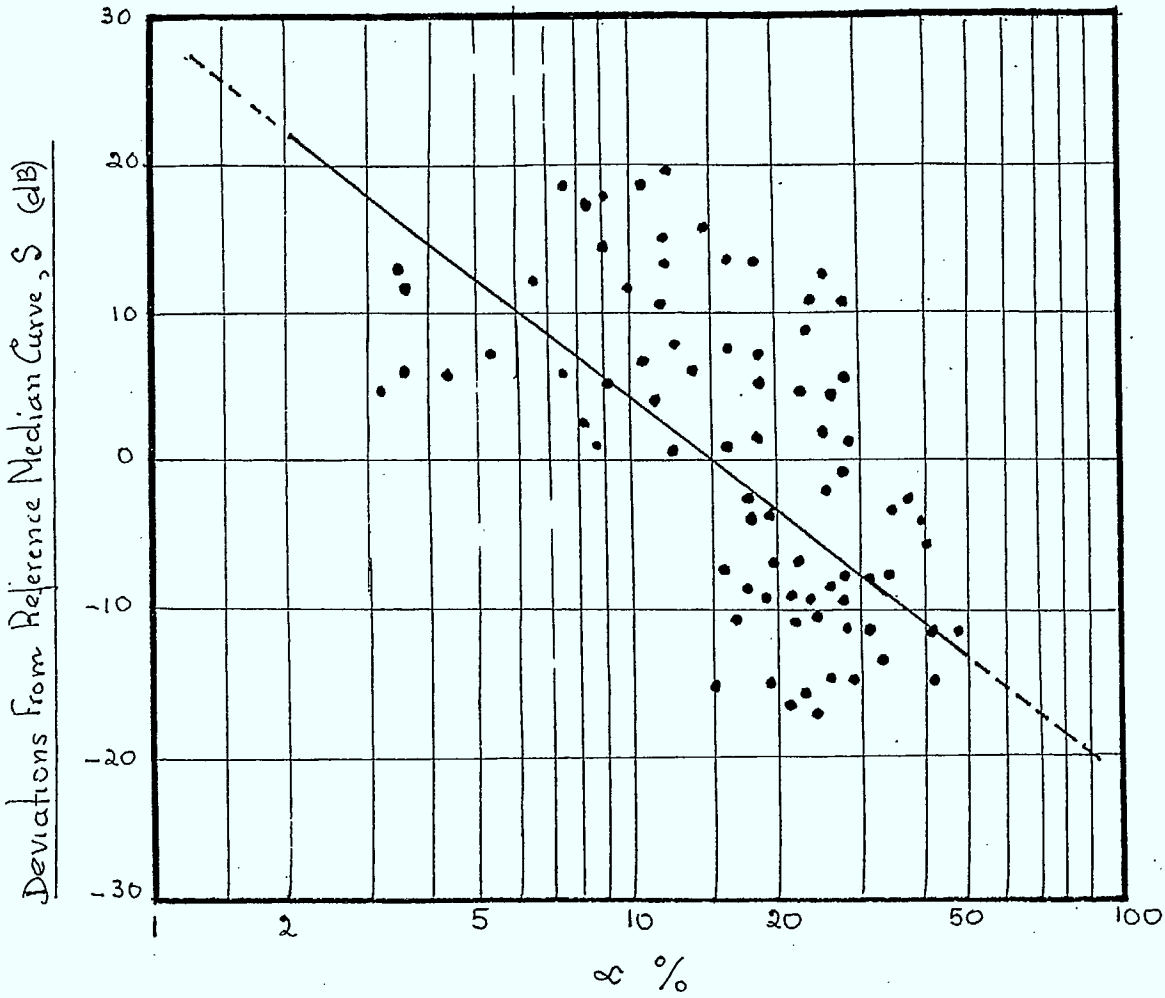


FIGURE 26: <u>Deviation from Median Field Strength Curve due to Buildings Surrounding Mobile Stations</u>

Regression Curve Formula: $S = 30 - 25 \log \alpha$

$f = 450$ MHz

$3\% < \alpha < 50\%$

α = percentage of area covered by buildings

(Source: CCIR SGV, Report 567-2, 1982)

4.2 Prediction of Median Signal Strength

In order to predict the median power received by a mobile unit from a base-station antenna in a basic urban environment, the following equation, with all quantities in decibels, may be used:

$$P_r = P_o - A_m (f,d) + H_b (h_b,d) + H_m (h_m,f) \tag{4-1}$$

where

P_r is the value of the predicted received power in an isotropic antenna

P_o is the power received for free space transmission by the same antenna

Am (f,d) is the median attenuation relative to free-space in an urban area where the effective base-station antenna height is 200 m and the mobile-station height is 3 m. These values are expressed as a function of distance and frequency and can be obtained from the curves of Figure 15.

H_b (h_b,d) is the base-station height-gain factor expressed in decibels relative to a 200 m high base-station antenna in an urban area. This factor is dependent upon distance and has been plotted in Figure 16.

H_m (h_m,f) is the mobile-station height-gain factor expressed in decibels relative to a 3 m high mobile station antenna in an urban area. This factor is dependent upon frequency and has been plotted in Figure 17.

If the particular propagation path happens to be over a different environment type than urban, or to involve terrain that is not "quasi-smooth," the prediction formula for P_r must be amended by adding one or more correction factors that were described earlier.

Thus the "corrected" predicted received power P_{rc} is:

$$P_{rc} = P_r + K_{so} + K_{sp} + K_{ls} + K_{ter} \tag{4-2}$$

where

K_{so} is the "correction factor for suburban and open terrain" which is plotted in Figure 18.

K_{sp} is the "correction factor for sloping terrain" which can be obtained from Figure 22.

K_{ls} is the "land-sea correction factor," which provides a correction to the signal attenuation when there is an expanse of water in the

propagation path. This correction factor can be obtained from Figure 23.

K_{ter} is the "correction factor for rolling hilly terrain" which can be obtained from Figure 21.

In addition to these factors, there are other factors such as isolated mountain ridges, street orientation relative to the base-station, the presence or absence of foliage, the effects of atmosphere, and in the case of undulating terrain, the position of the mobile station relative to the median height. These additional effects, together with the fact that the correction factors are indeed the basic transmission factors Am, H_b and H_m are average values based upon empirical data, should indicate that discrepancies between measured and predicted values are still possible. However, the predicted values given in the foregoing (which are largely based on the work by Okumura), and measured data obtained from measurements made by different investigators over a variety of environments, antenna heights, antenna separation distances and frequencies, are in close agreement.

4.3 Determination of Signal Coverage in a Small Area

Let us assume that the local mean signal strength in an area at a fixed radius from a particular base-station antenna is log-normally distributed. Let the local mean (that is, the signal strength averaged over the Rayleigh fading) in decibels be expressed by the normal random variable x with mean $\bar{x}$ (measured in dBm, for example) and a standard deviation σ (dBs). The mean value, $\bar{x}$, would, for instance, be the "corrected" predicted received power, P_{rc}, given in Equation (4-2). As was shown earlier, $\bar{x}$ depends upon the distance (r) from the base station as well as several other parameters. Let x_o be the receiver "threshold." We shall determine the fraction of the locations (at r = R) wherein a mobile unit would experience a received signal above "threshold." The "threshold" value chosen need not be the receiver noise threshold, but may be any value that provides an acceptable signal under Rayleigh fading conditions. The probability density of x is:

$$p(x) = \frac{1}{\sqrt{2\pi}\sigma} \cdot \exp\left[-\frac{(x-\bar{x})^2}{2\sigma^2}\right] \qquad (4\text{-}3)$$

Note that since x, $\bar{x}$ and σ are all expressed in decibels, this is a log-normal distribution.

The probability that x exceeds the threshold x_o is:

$$P_{x_o}(R) = P[x \geq x_o] = \int_{x_o}^{\infty} p(x).dx \qquad (4\text{-}4)$$

$$= \tfrac{1}{2} - \tfrac{1}{2}\,\mathrm{erf}\left(\frac{x_o - \bar{x}}{\sqrt{2}\,\sigma}\right)$$

If we have measured or theoretical values for $\bar{x}$ and σ in the area of interest, we can determine the percent of the area for which the average signal strength exceeds x_o. For example, at a radius where the median (and hence the mean of the log-normal) signal strength is -100 dBm (i.e. $\bar{x}$ = -100 dBm at some particular separation distance R and for some radiated power) and assuming our threshold happens to be -110 dBm, then if we assume σ = 10 dB, we have:

$$P_{x_o}(R) = \tfrac{1}{2} + \tfrac{1}{2}\,\mathrm{erf}\left(\frac{1}{\sqrt{2}}\right) = 0.84 \text{ or } 84 \text{ percent}$$

4.4 Determination of the Coverage Area from a Base Station

It is also of interest to determine the percentage of locations <u>within</u> a circle of radius R in which the received signal strength from a radiating base-station antenna exceeds a particular threshold value. Let us define the fraction of useful service area F_u as that area, within a circle of radius R, for which the signal strength received by a mobile antenna exceeds a given threshold x_o. If P_{xo} is the probability that the received signal, x, exceeds x_o in an incremental area dA, then

$$F_u = \frac{1}{\pi R^2}\int P_{x_o} \cdot dA \qquad (4\text{-}5)$$

In a practical situation one would probably be required to break the integration into small areas in which P_{xo} can be estimated and then summed over all such areas within a circle of radius R. For purposes of illustration, let us assume that the behavior of the mean value of the signal strength, $\bar{x}$, follows an r^{-n} law with distance from the base-station.

Then $$\bar{x} = \alpha - 10n \log_{10} \frac{r}{R} \qquad (4\text{-}6)$$

where α, expressed in dBs, is a constant determined from the transmitter power, antenna heights and gains, etc. Then

$$P_{x_o} = \tfrac{1}{2} - \tfrac{1}{2}\,\mathrm{erf}\left[\frac{x_o - \alpha + 10n \log_{10} \frac{r}{R}}{\sqrt{2}.\sigma}\right] \qquad (4\text{-}7)$$

Then letting $a = \left(\frac{x_o - \sigma}{\sqrt{2}\,\sigma}\right)$ and $b = 10\,n \log_{10} e/\sqrt{2}\,\sigma$, we get

$$F_u = \tfrac{1}{2} - \frac{1}{R^2}\int_o^R d\,\mathrm{erf}\left(a + b \log \frac{r}{R}\right) \cdot dr$$

The integral can be evaluated by substituting $t = a - b \log_e \left(\frac{r}{R}\right)$, so that

$$F_u = \tfrac{1}{2} - \frac{2e^{2a/b}}{b} \cdot \int_a^{\infty} e^{-2t/b} \cdot \mathrm{erf}(t).dt \qquad (4\text{-}8)$$

giving

$$F_u = \tfrac{1}{2} \left\{1 + \mathrm{erf}(a) + \exp\left(\frac{2ab + 1}{b^2}\right) \left[1 - \mathrm{erf}\left(\frac{ab + 1}{b}\right)\right]\right. \qquad (4\text{-}9)$$

For example, let us choose α such that $x = x_o$ at $r = R$, then $a = 0$ and

$$Fu = \tfrac{1}{2} + \tfrac{1}{2} \exp\left(\frac{1}{b^2}\right) \left[1 - \mathrm{erf}\left(\frac{1}{b}\right)\right] \qquad (4\text{-}10)$$

Let us assume that $n = 3$ and $\sigma = 9$; then $F_u = 0.71$, or about 71% of the area within a circle of radius R has signal above threshold when half the locations in the circumference have a signal above threshold.

For the case where the propagation follows a power law, the important parameter is (σ/n). Figure 27 is a plot of the fraction of the area within a circle of radius R that has a received signal above a threshold for various fractions of coverage on the circle.

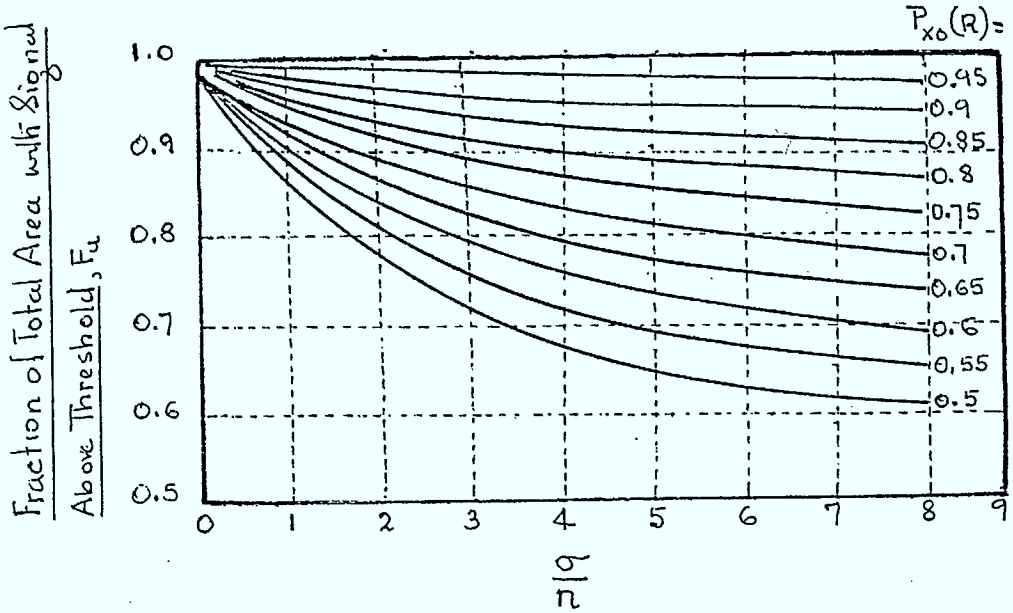


FIGURE 27: Fraction of Total Area with Signal Above Threshold, F_u

σ = standard deviation, dB

path loss varies as r^{-n}

P_{x_o} (R) = coverage probability on area boundary (r = R)

4.5 Variation of the Local Median Field Strength with Time and Location

The local median field strength at any location in the coverage area also varies diurnally and seasonally as the properties of the reflecting, refracting, diffracting and conducting surfaces vary. This variation, too, has been observed to be log-normally distributed for time percentages between 5% and 50%.

The dependence of the median field strength on location, time and nature of terrain is summarized in Table 3 which was obtained from CCIR, SG5, Volume V, Report 567-2.

Longley has made an analysis of a large amount of measurement data in the United States and has derived the following expression relating location variability (standard deviation), σ_L, to the transmission wavelength, λ, and terrain irregularity, Δh

$$\sigma_L = 6 + 0.69 \left(\frac{\Delta h}{\lambda}\right)^{1/2} - 0.0063 \left(\frac{\Delta h}{\lambda}\right) \text{(dB)}, \quad \frac{\Delta h}{\lambda} \leq 3000 \qquad (5\text{-}1)$$

$$= 25 \quad \text{(dB)} \qquad , \quad \frac{\Delta h}{\lambda} > 3000$$

The data used in the study were spot measurements obtained over paths ranging from 0.5 to 120 km in length, with antenna heights from 0.6 to 15 metres, over terrain ranging from plains to rugged mountains and at frequencies from 30 MHz to 10 GHz.

Band	σ_L (dB)				σ_t (dB)				
VHF	8				d (km)	50	100	150	175
					Land and Sea	3	7	9	11
UHF	Δh(m)	50	150	300	Land	2	5	7	
		10	15	18	Sea	9	14	20	

TABLE 3: Field Strength Dependence on Location, Time and Terrain

- σ_L = standard deviation with location
- σ_t = standard deviation with time
- d = path distance between antennas
- Δh = terrain irregularity factor
- The values given in the above table apply to rural areas only.
- For the evaluation of the probability of interference when preparing frequency plans for mobile radio, the following approximations may be used:
  - the time and location distributions are assumed to be Gaussian (dB) in the range of interest (5% to 50% time distribution)
  - standard deviations of the location and time distributions (σ_L, σ_t) are derived from Rec 370, assuming a Gaussian time distribution for time percentages between 5% and 50% (Table 3)
  - the combined standard deviation is given by $\sigma = \sqrt{\sigma_L^2 + \sigma_t^2}$

adga

Appendix A to Chapter II

INTERFERENCE SUSCEPTIBILITY OF THE 525-LINE NTSC TV SIGNAL

Appendix A to Chapter II

INTERFERENCE SUSCEPTIBILITY OF THE 525-LINE NTSC TV SIGNAL

A1 INTRODUCTION

The protection ratio, which is the ratio of the desired TV signal level to the undesired interfering signal level at the TV receiver RF input, required to provide an acceptable picture quality in the presence of interference and noise is a critical parameter in frequency planning. Unfortunately, this parameter can only be arrived at by subjective testing and this leads to considerable uncertainties, largely due to the different conditions employed during the tests. The factors affecting the subjectively measured protection ratio are:

- picture quality assessment scale
- viewers
- receivers
- viewing conditions
- wanted signal characteristics
- carrier frequency offset
- video signal-to-noise ratio at time of tests
- presence of other interference and picture degradation sources such as multi-path, receiver distortion and other interference mechanisms such as power line hum, etc.

To arrive at a protection ratio for 525-line NTSC TV signals when the interference is that from an operating LMS system, the measured protection ratios obtained from a wide variety of measurements performed by different administrations and using a wide variety of interfering signals, will be investigated.

A2 TV Interference Into TV

A2-1 FM TV Interference Into AM-VSB TV

The results given here were conducted by NASA/FCC and submitted to the CCIR in Report 388 to show the effect of interference from a satellite TV system into a terrestrial broadcast TV system, both using the 525-line, NTSC picture. The interfering FM, TV signal had a peak frequency deviation of ± 18 MHz. The results can be

related to interference from an LMS system signal since an FM signal may be regarded as a CW signal being swept across the TV channel.

Figure A2-1 shows the effect of the TV picture used in the tests. A "white" window is more susceptible to interference than a picture with a lot of detail or variation in the colour content of the picture.

Figure A2-2 shows the effect of "still" pictures relative to off-the-air programmes which contain "moving" elements in the picture. "Still" pictures are approximately 5 dB more sensitive to interference.

Figure A2-3 shows the effect of frequency offset between the carriers for a wide variety of test signals.

Figure A2-4 shows the effect of the video signal-to-thermal noise ratio present at the time of the tests on the protection ratio. The more "noise" that is present, the lower the protection ratio required, since "noise becomes the principal interferer.

The test results show that:

a) Interference is more easily perceived on dark-coloured areas than in light-coloured areas.

b) Pictures having large areas of uniform colour show interference more readily than scenes with multi-coloured detail.

c) "Still" pictures show interference more readily than "moving" pictures which are the main feature of off-the-air programmes.

d) Interference is less visible on pictures when the video SNR is reduced.

Since most of the subjective tests use "still" pictures, the measured protection ratio could be conservative by, from 5 to 10 dB when off-the-air programmes are viewed as is the case in actual practice.

In the results, the protection ratio for TASO 3 grade of service never exceeded 35 dB (corresponds to 50 dB of "just perceptible interference"). This was largely because the FM carrier was not always in the TV channel, since it was swept over a band of approximately ± 6 MHz (pre-emphasized bandwidth).

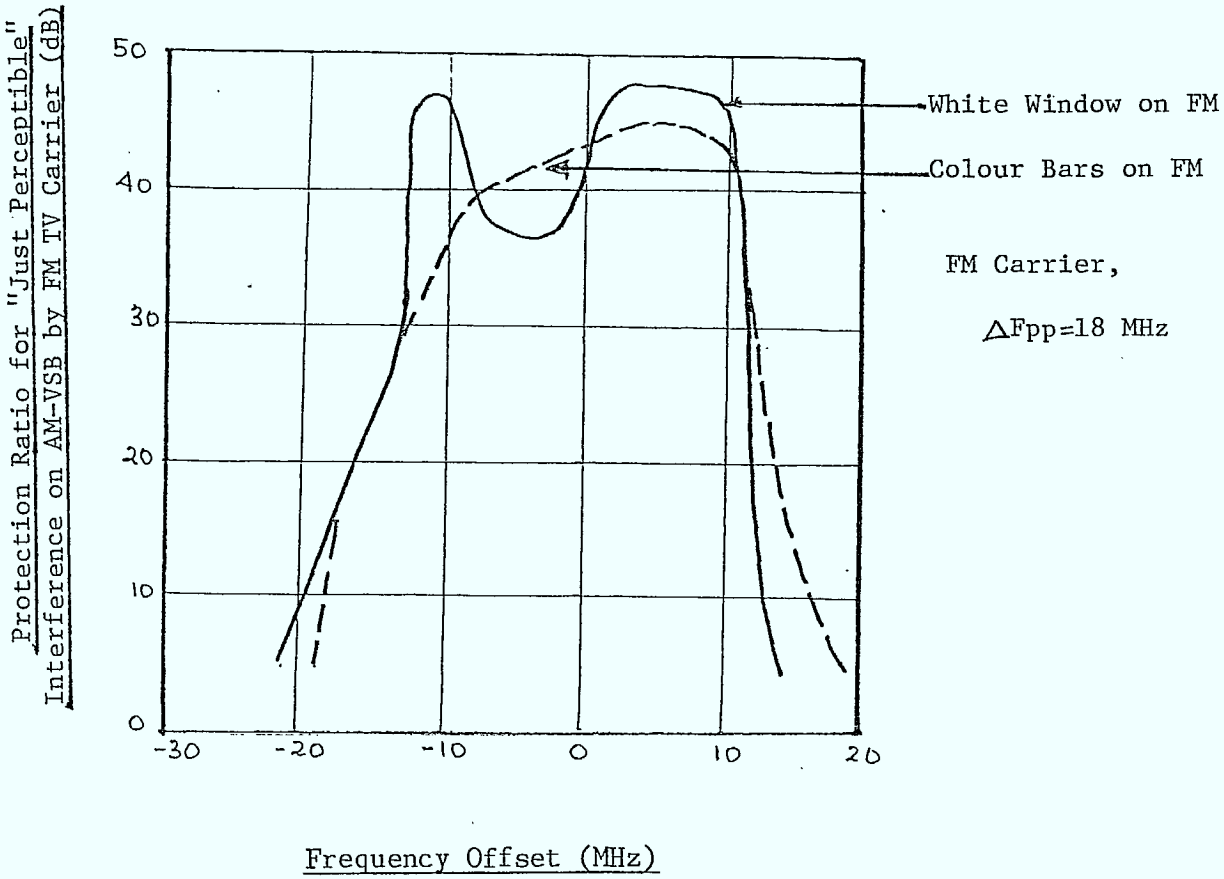


Figure A2-1: Effect of Modulation on the Interfering FM Carrier

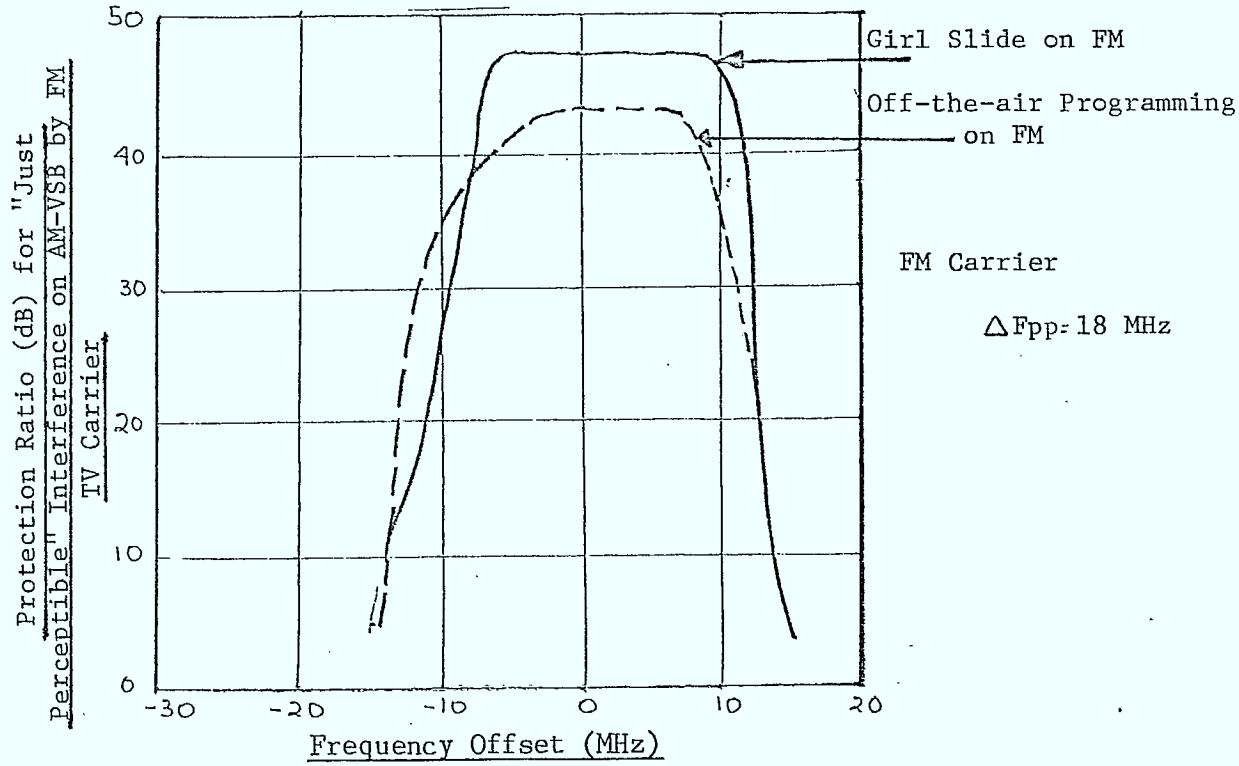


Figure A2-2: Effect of "Still" and "Moving" Modulation on the Interfering Carrier

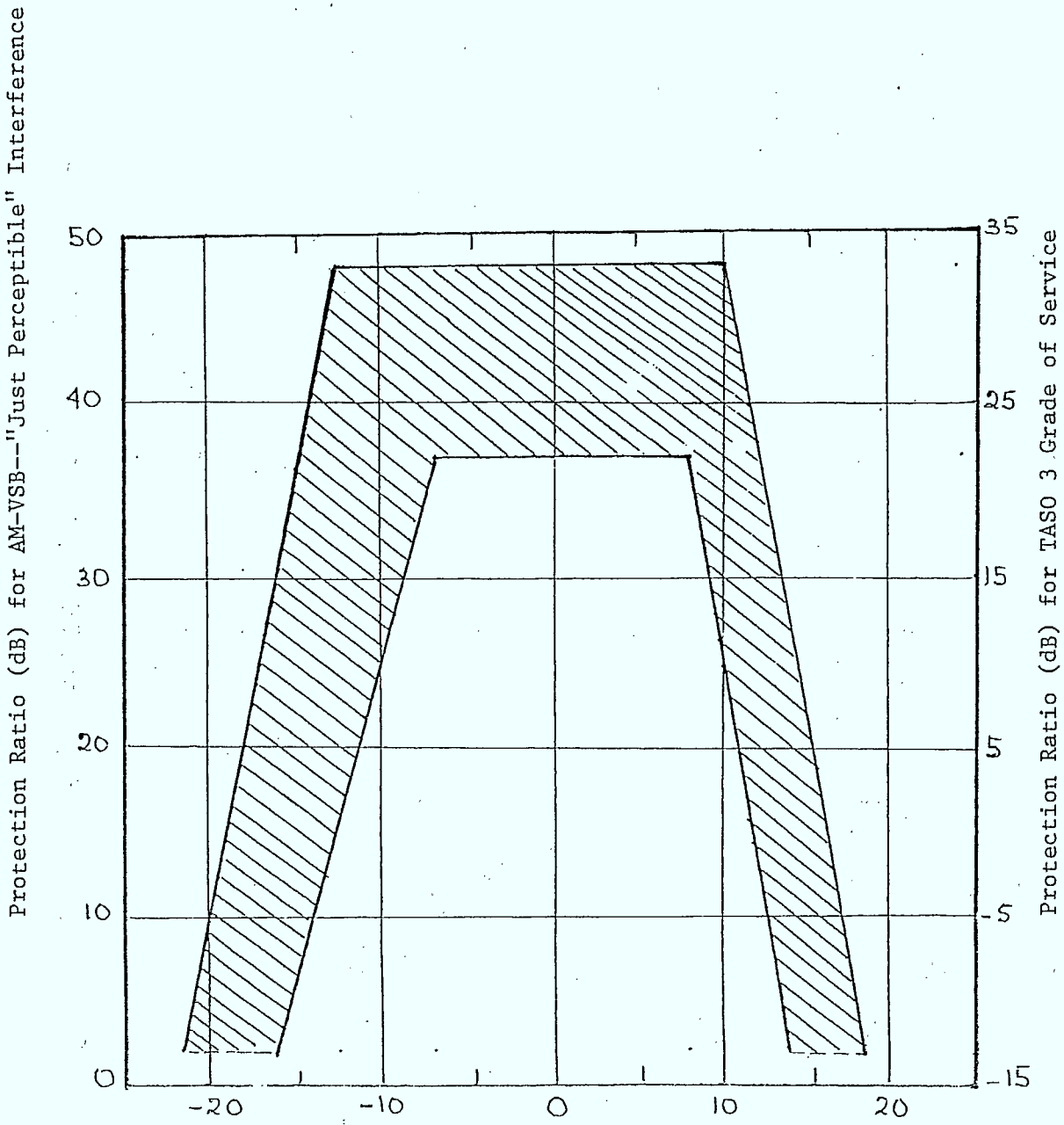


Figure A2-3: Protection Ratio Required for "Just Perceptible" Interference in AM-VSB Systems being Interfered on by an FM TV System (Peak-to-Peak Frequency Deviation: 18 MHz)

Note:
- Signal-to-Weighted Random Noise Ratio = 49 dB
- AM-VSB System: 525-line, NTSC

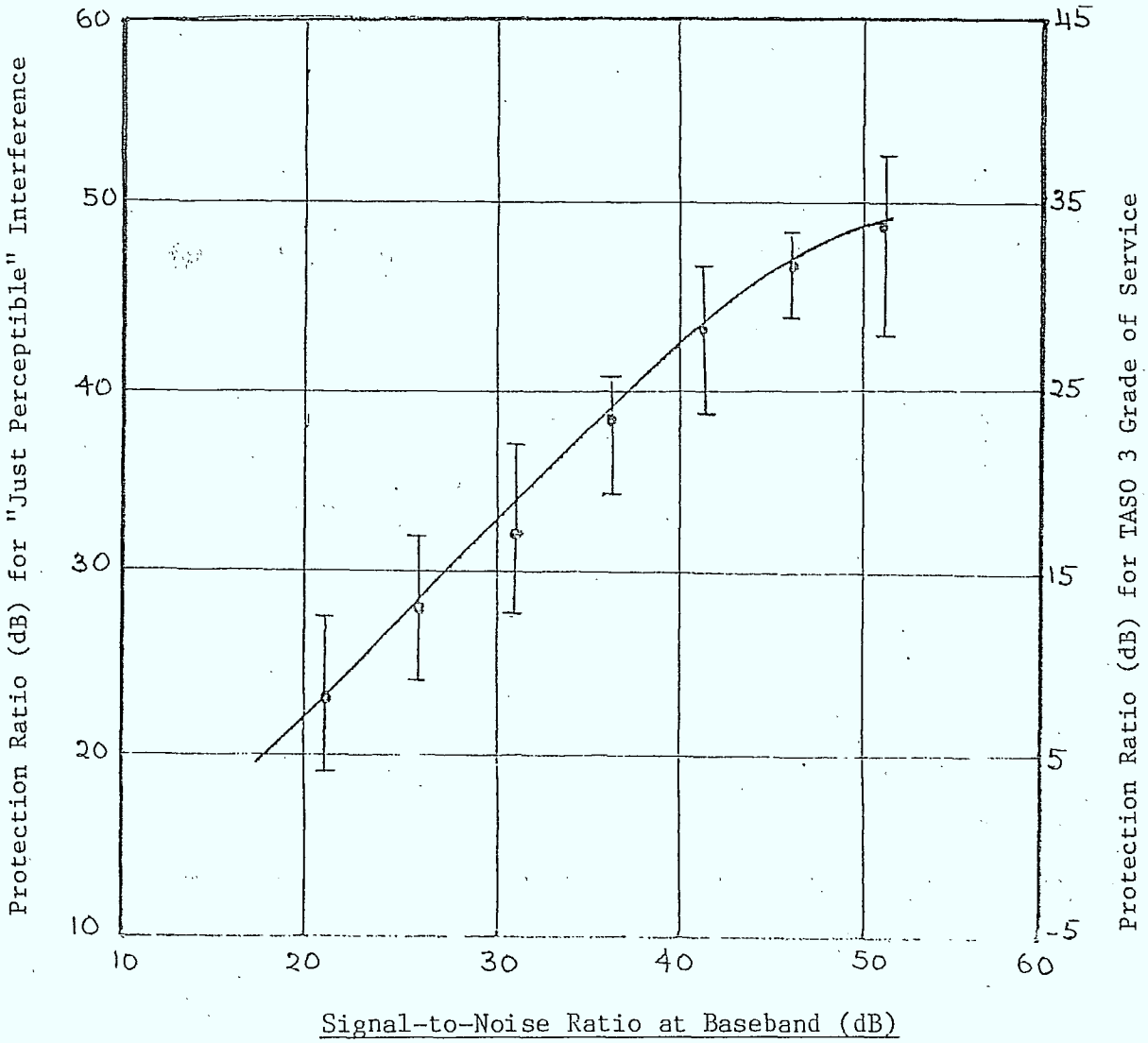


Figure A2-4: Protection Ratio Required for "Just Perceptible" Interference in AM-VSB System as a Function of Signal-to-Weighted Noise in the TV Channel

Note: Interferer: FM TV, F_{pp} = 18 MHz, Carrier Frequency Offset = 0.5 MHz

No Pre-emphasis

Protection Ratio = $(SNR)_{weighted}$ + 2 dB -for "just perceptible" interference

= $(SNR)_{weighted}$ + 7 dB for "no perceptible" interference

A2-2 AM-VSB TV Interference into AM-VSB TV Signal

Under project 2229-45, F.C.C. labs conducted extensive tests on TV receivers in 1968/1969 to determine the protection ratio required for the "UHF taboo" channels.

The results are summarized in Table A2-1.

Since a TV signal may be regarded as an LM signal with added components (visual and sound carrier components) located at the most sensitive frequencies in a TV channel, it is expected that an interfering LM signal will require less protection ratio than an interfering TV signal. The assumption made here is that the LM signal, consisting of several channels, can be represented by the harmonics of the line frequency and the harmonics of the modulation on the colour sub-carrier.

Interference Type	Interference Signals Injected into	Protection Ratio (dB) for TASO 3 Quality
CO-CHANNEL	n = 0, no offset	·
	n = 0, offset	·
ADJACENT CHANNEL	n+1	-15
	n-1	-15
INTERMODULATION	n+1 and n+2	-16
	n-1 and n-2	-13
	n+2 and n+4	-28
	n-2 and n-4	-35
	n+3 and n+6	-38
	n-3 and n-6	-40
	n+4 and n+8	-30
	n-4 and n-8	-40
	n+8 and n+16	-44
	n-8 and n-16	-40
CROSS-MODULATION	n+2	-45
	n-2	-46
	n+4	-30
	n-4	-47
	n+16	-65
	n-16	<-65
IF BEAT	n+8	-64
	n-8	-58
	n+4 and n-3	-28
	n+3 and n-4	-27
	n+7	-56
SOUND IMAGE	n+14	-22
PICTURE IMAGE	n+15	-6

Table A2-1: Measured Protection Ratios for TV Interference into TV

		F.C.C	D.O.C
co-channel	n = 0, no offset	45	35
	n = 0, with offset (1)	28	18
Adjacent Channel	n = ±1	-15	-36
Intermodulation	n = ±2	(2)	(2)
	n = ±3	(2)	(2)
	n = ±4	(2)	(2)
	n = ±5	(2)	(2)
IF Beat	n = ±7	(3)	(3)
	n = ±8	(3)	(3)
Sound Image	n = ±14	-23	-46
Picture Image	n = ±15	-6	-28

Table A2-2: Protection Ratios for TV Interference into TV Used in Frequency Planning

Note

1) The co-channel, with offset, protection ratio is used in calculating the minimum separation distance between transmitters.

2) Minimum separation distance for intermodulation channels is 20 miles.

3) Minimum separation distance for IF beat channels is 60 miles.

A3 Multiple CW Interference into AM-VSB TV

A3-1 Voice-Modulated FM Interference into AM-VSB TV

These results were extracted from FCC project 2229-45 "Interference to TV from Other Services" but the curves presented here were obtained from F.C.C. Report "A Preliminary Estimate of the Effect of Spread Spectrum Interference on TV".

All the figures give the co-channel protection ratio to provide a TASO 3 grade service.

Figure A3-1 gives the protection ratio as a single voice-modulated FM signal injected into the TV channel at various frequency locations. This is the worst interference case. From 2 to 4.5 MHz in the TV channel, the protection ratio is less than 40 dB.

Figure A3-2 gives the protection ratio when a single voice-modulated FM signal and an unmodulated CW signal, located 15 KHz apart, are used as the interferers, while Figure A3-3 uses three interfering signals, located 30 KHz apart. The protection ratio characteristic becomes more uniform as the number of interferers is increased largely because the envelope of the interfering signal begins to approach the characteristics of random noise. The protection ratio in the region from 2 to 4.5 MHz is below 35 dB.

While Figures A3-1, 2 and 3 were measured on a VHF channel, Figure A3-4 gives the corresponding result of Figure A3-1 but measured on a UHF channel, where the presence of a converter could affect the performance. There is an anomalous peak at 3 MHz.

Figures A3-5 and A3-6 compare the measured data with the CCIR mask and the FCC mask, respectively.

From the foregoing, it can be seen as the number of interfering LM signals is increased (i.e. more LMS channels are activated), the interfering signal tends to approximate to wideband gaussian noise with the effect that the protection ratio is reduced. Figure A3-7, taken from another source, shows the protection ratio variation across the TV channel for interference from a CW, a spread-spectrum signal with its first nulls located at the visual and colour sub-carrier, and from random noise. An operational LMS signal will tend to resemble a spread-spectrum signal, so a protection ratio of 35 dB could be adequate.

From the measured data, the following protection ratios are indicated:

co-channel	n = 0 :	40 dB
adjacent channel	n = -1:	-10 dB
	n = +1:	- 7 dB
alternate adjacent channel	n = -2:	-
	n = +2:	-

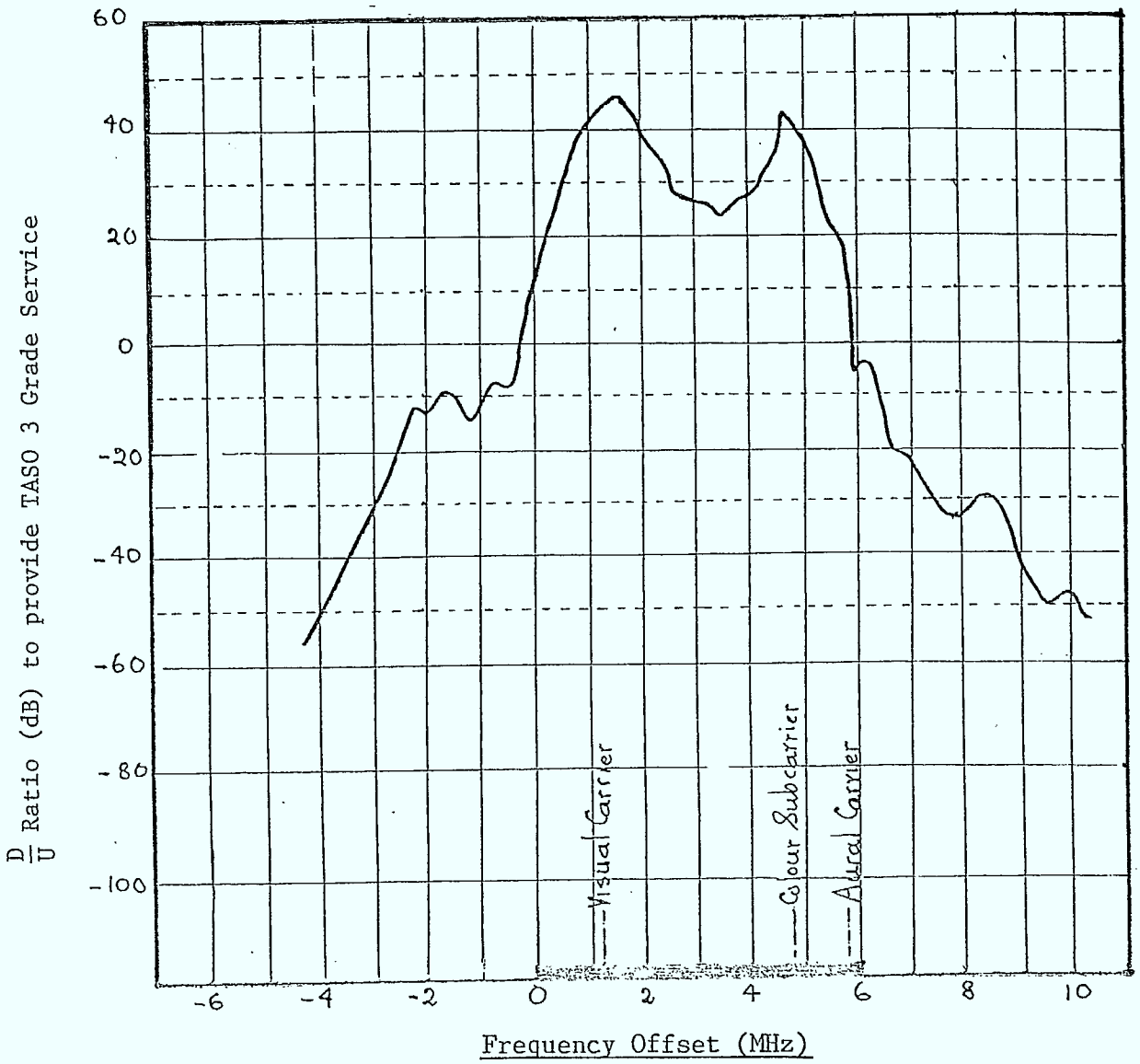


Figure A3-1: Protection Ratio for a TV Signal when the Interferer is a Voice-Modulated FM Signal with 5 KHz Peak Frequency Deviation (Measured on VHF Channel)

Note: U is the total power of the interferer

Source: "A Preliminary Estimate of the Effect of Spread Spectrum Interference on TV" (TK 6643 J86)

(Curves extracted from FCC Project 2229-45: "Interference to TV From Other Services")

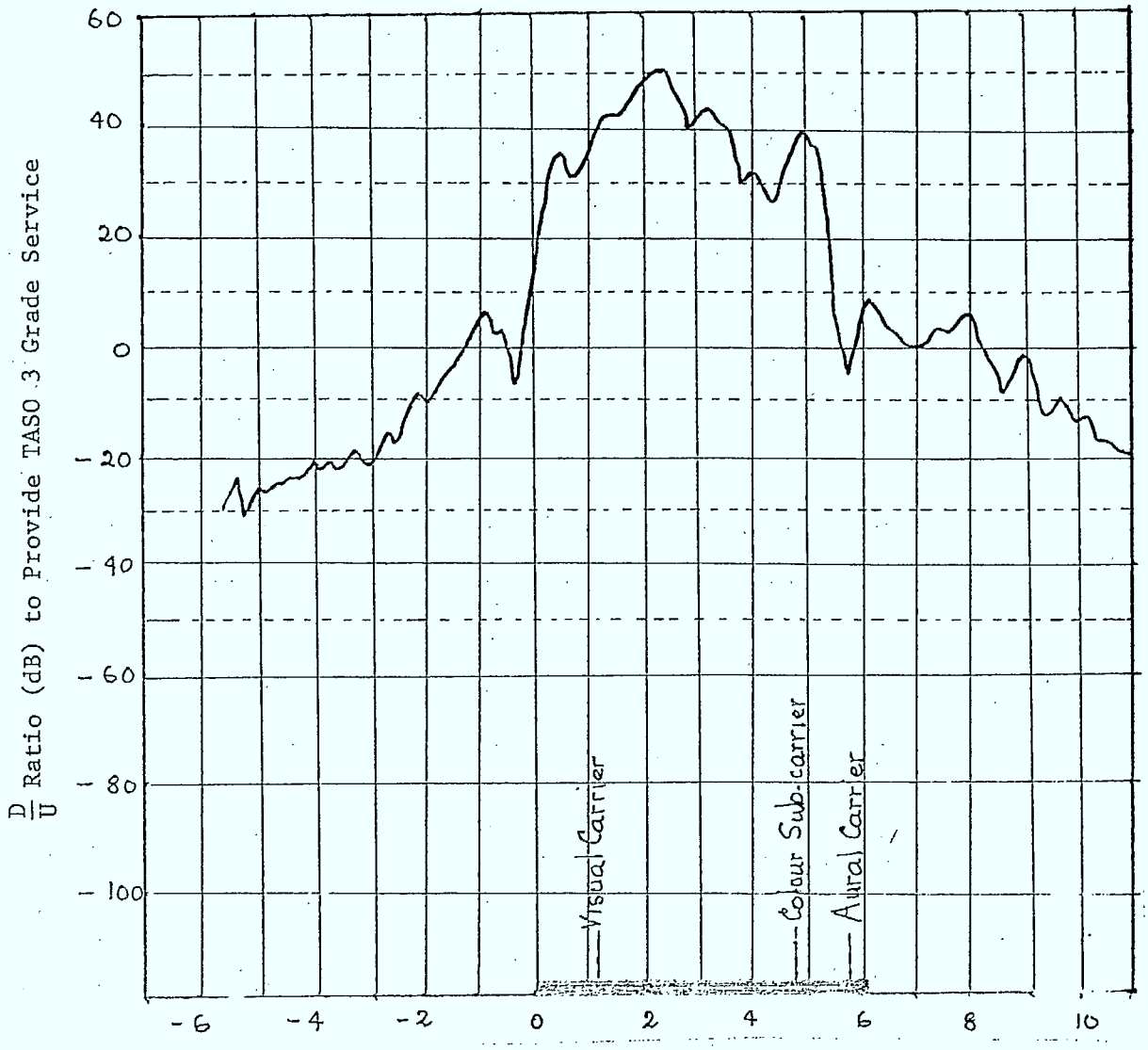


Figure A3-2: Protection Ratio for a TV Signal When the Interference Consists of: Voice-Modulated FM Signal, 5 KHz Frequency Deviation plus Equal-Level CW Signal, located 15 KHz apart (Measured on VHF Channel)

Note: U is the total power of the two interferers.

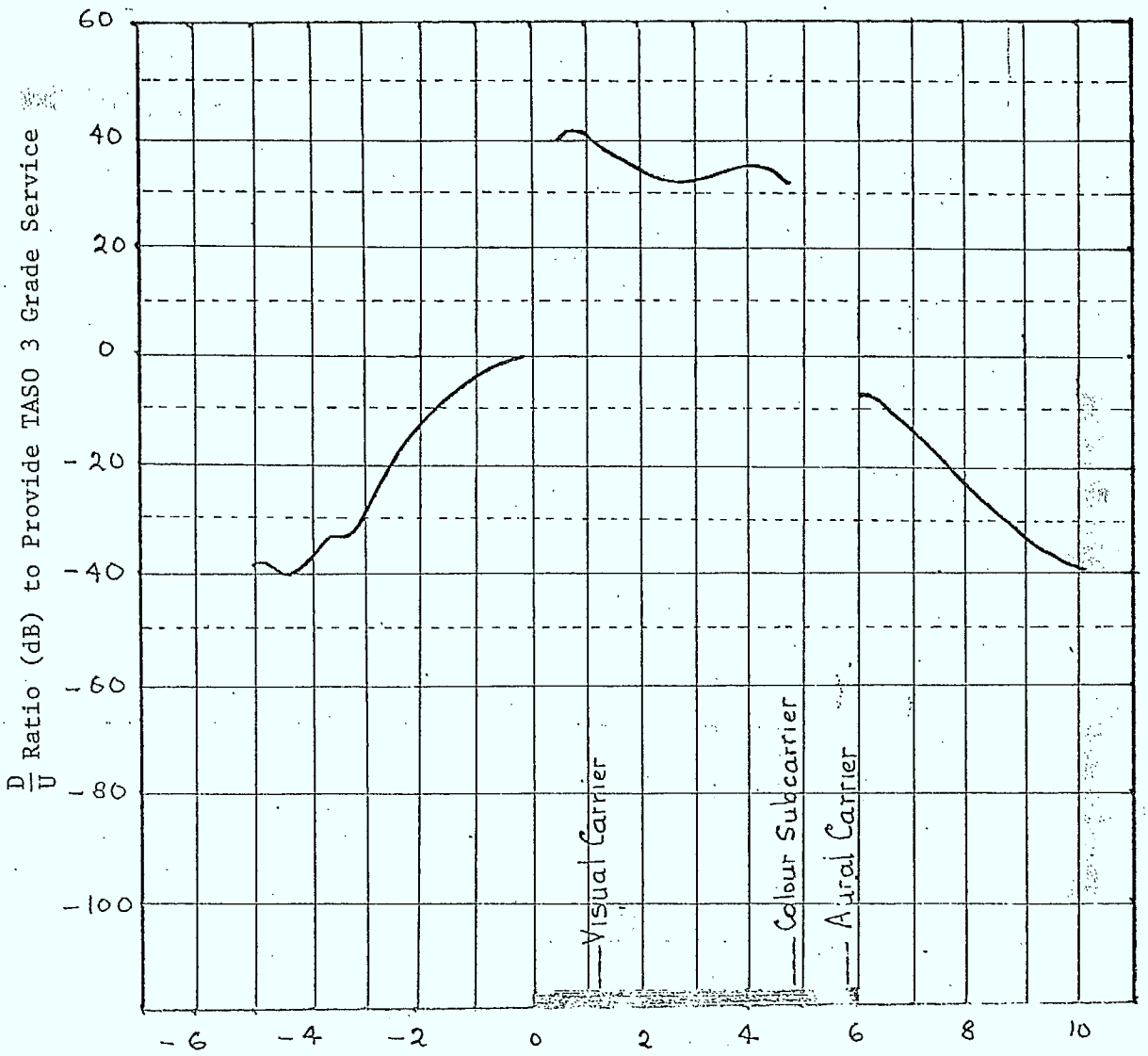
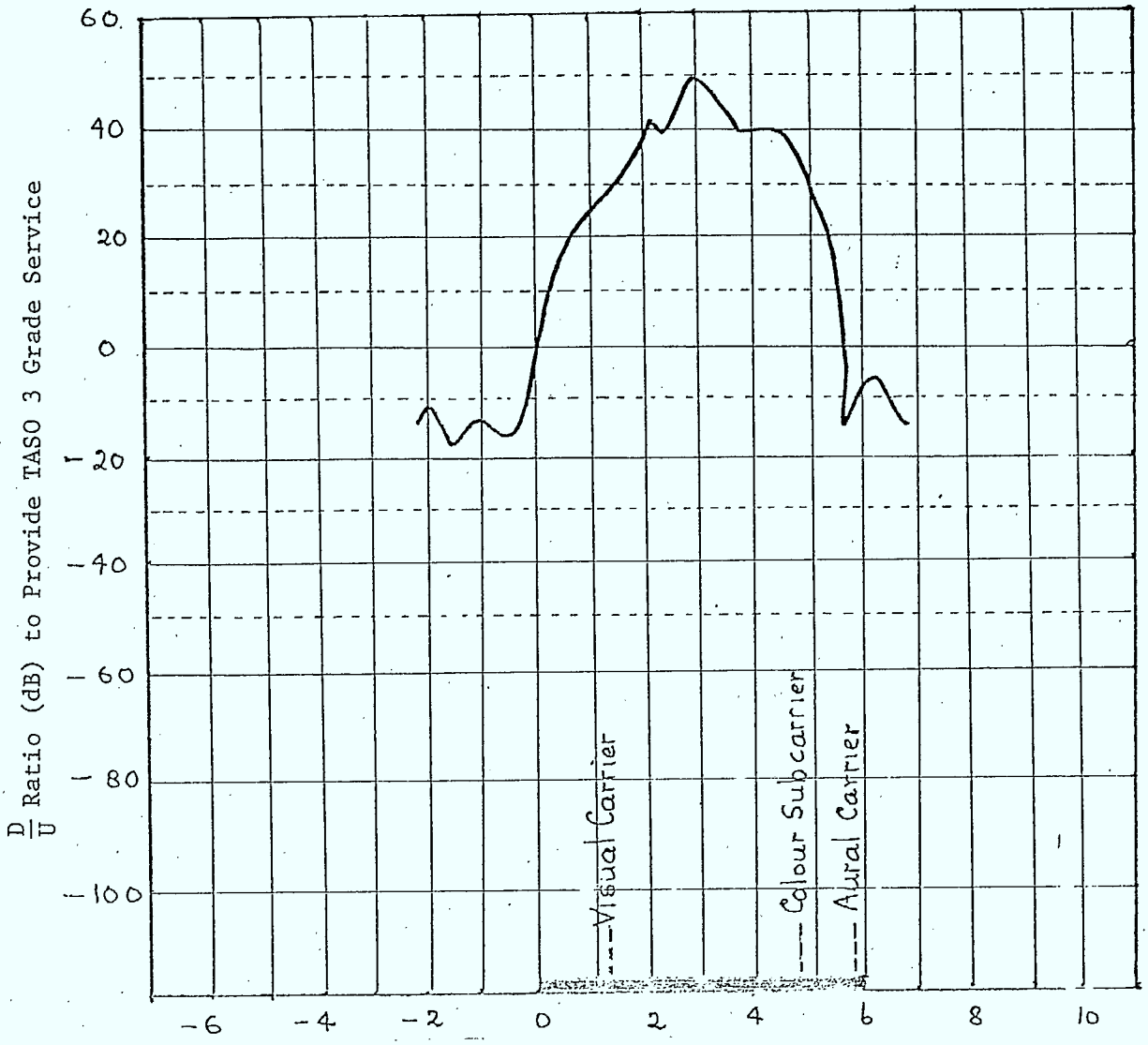


Figure A3-3: Protection Ratio for a TV Signal when the Interference Consists of: Voice-Modulated FM Signal, 5 KHz Peak Frequency Deviation plus Two Equi-Level CW Signals, located ± 30 KHz From the FM Signal (Measured on a VHF Channel)

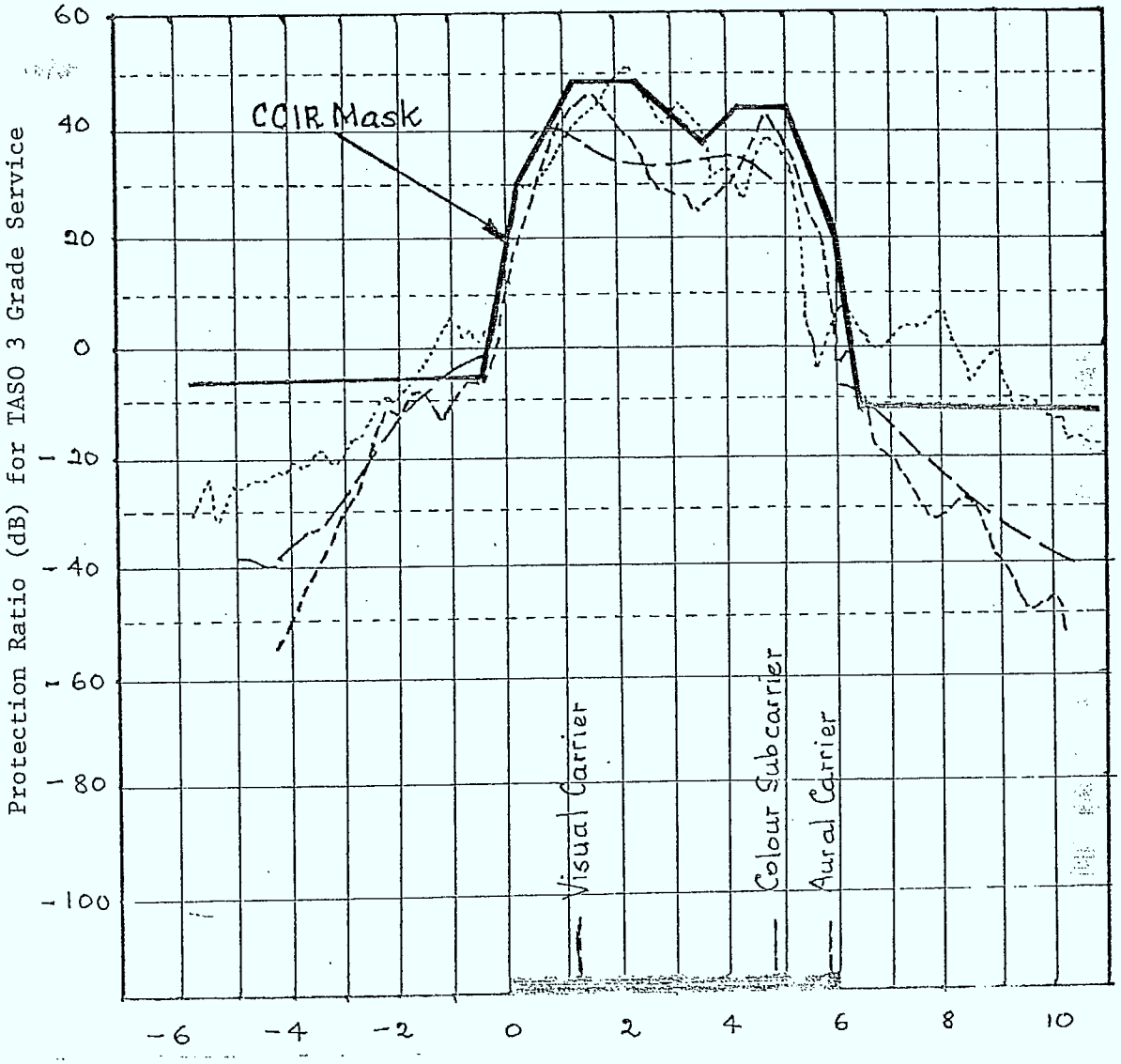
Note: U is the total power of the three interferers.



Frequency Offset (MHz)

Figure A3-4: Protection Ratio for a TV Signal when the Interference Consists of: Voice-Modulated FM Signal, 5 KHz Peak Frequency Deviation

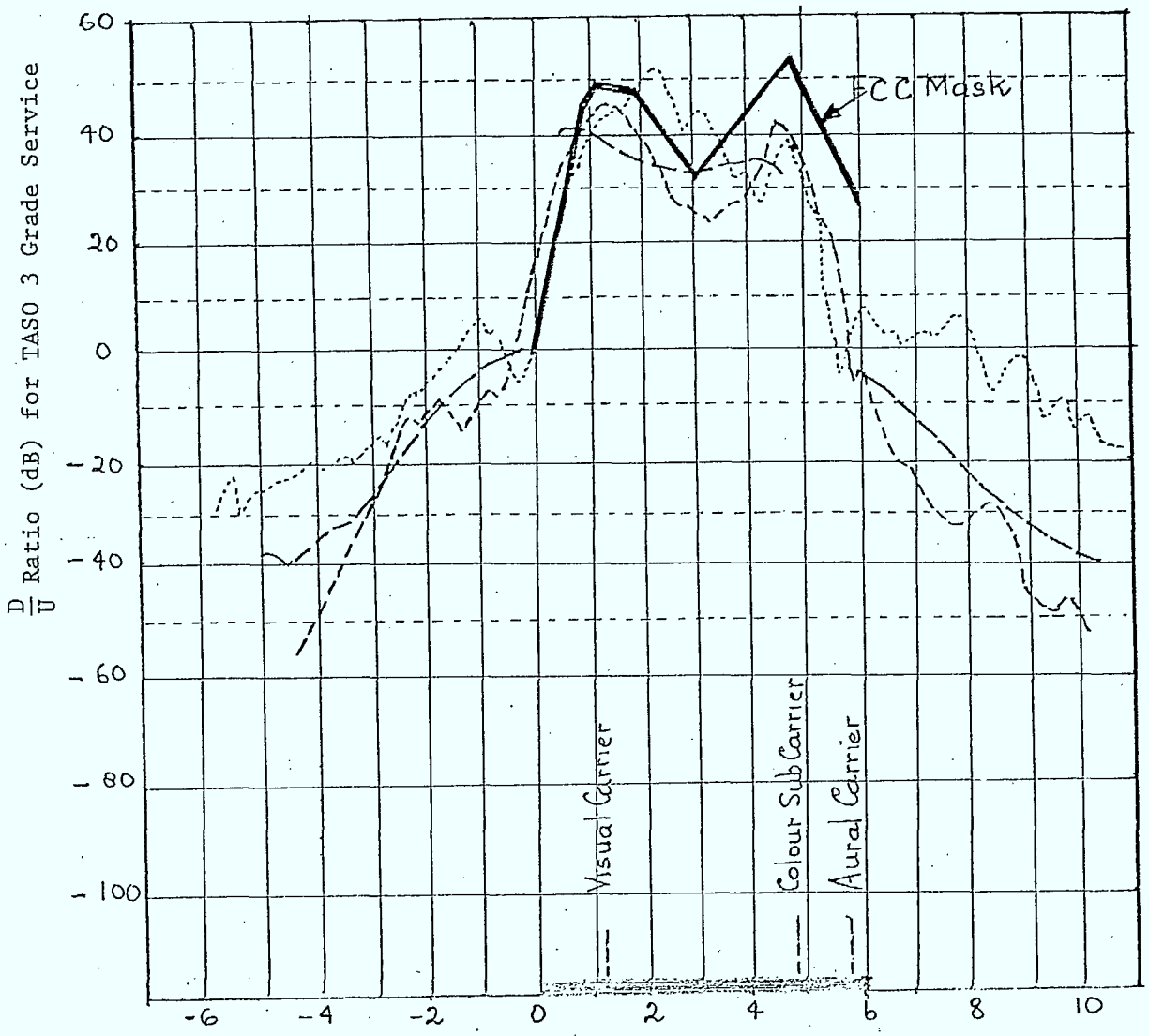
(Measured on a UHF Channel, No: 41)



Frequency Offset (MHz)

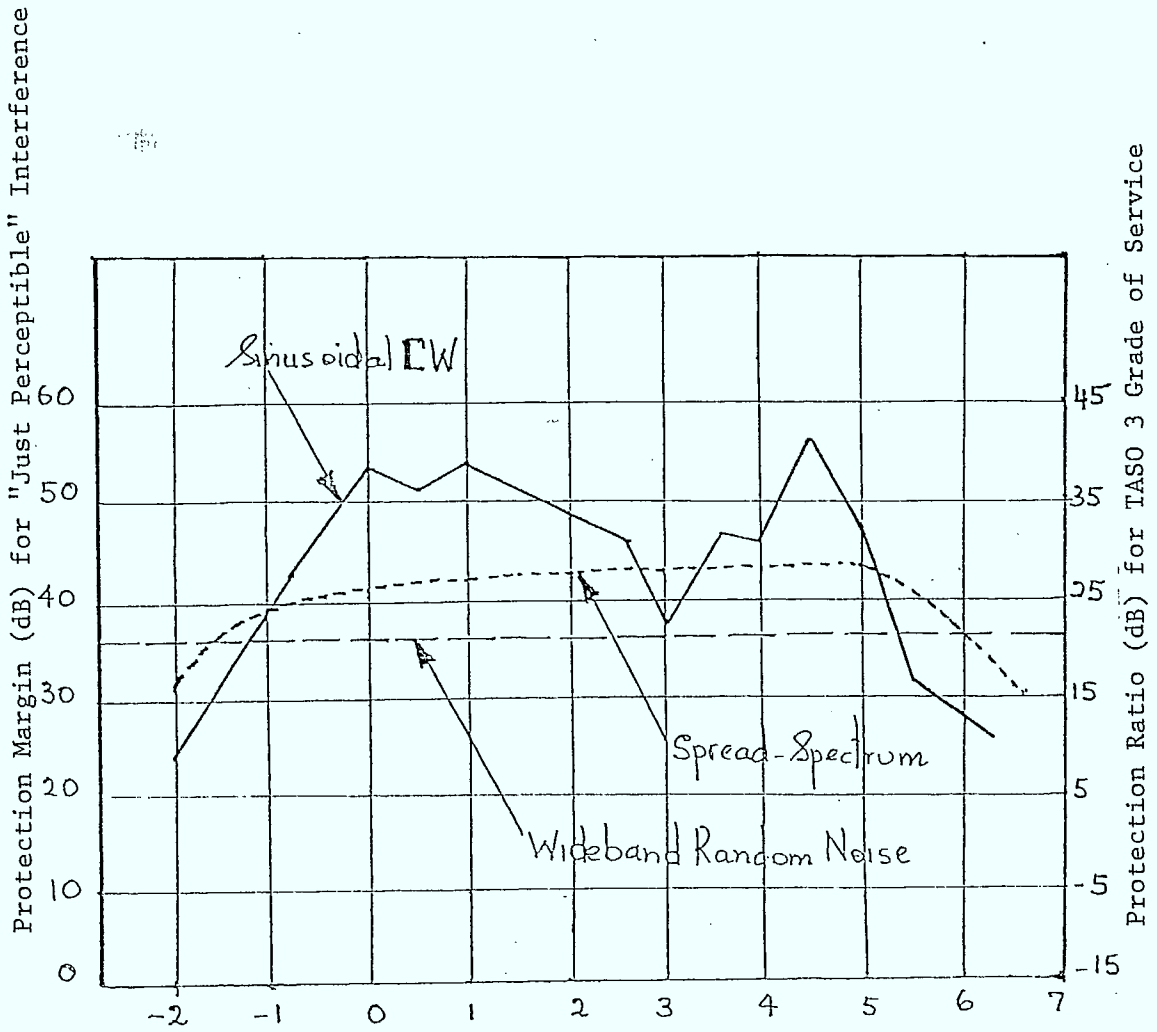
Figure A3-5: CCIR Mask for the Protection Ratio for Colour TV from Interference from a CW Signal

Note: The measured protection ratios for single FM Carrier, single FM carrier + single CW carrier and for single FM carrier plus two CW carriers are shown for reference.



Frequency Offset (MHz)

Figure A3-6: F.C.C. Mask for the Protection Ratio for Colour TV From Interference from a CW Signal



Frequency Offset (MHz)

Figure A3-7: Protection Margin for "Just Perceptible" Interference into 625 line, PAL, System I Television

Source: "Subjectively Assessed Impairment of TV Signals by Co-Channel Operation of Spread-Spectrum Radio Systems"
R.F. Ormondroyd, M.S. Shipton

A3-2 Two Equi-Level, FM Signals Interference into AM-VSB TV

Tests were also conducted at the DOC (Canada) Labs under project 6-Part B "LM Interference to UHF-TV." The attached results were extracted from the Report of the CRTPB Ad Hoc Committee.

Measurements were performed not only on the co-channel (n = 0), but also on the adjacent channels (n ± 1) and the alternate adjacent channels (n ± 2). Two equi-level FM signals were used as the interference signal. The results are given in Figures A3-8, A3-9, A3-10 and A3-11.

The results indicate that the following protection ratios are adequate if the LM signal is confined to the TV channel spectrum between 2 MHz and 4.5 MHz:

co-channel (n = 0)		: 40 dB
adjacent channel	(n-1)	: -5 dB
	(n+1)	: -20 dB
alternate adjacent channel	(n-2)	: -40 dB
	(n+2)	: -40 dB

A3-4 LM Interference into TV when the LM Interference is Located in the TV Image Band

This information was extracted from D.O.C. Report "Image Interference to UHF TV Reception From LMS in the 806-890 MHz Band," October 1979.

The image frequency band is one of the "UHF taboo" channels. Measurements were performed with the LMS signal located 91.5 MHz above the desired TV channel (i.e. 45.75 MHz above the local oscillator frequency for the desired TV channel). The result is shown in Figure A3-12, which indicates a protection ratio of 10 dB would be adequate.

This value of protection ratio for the image (picture) channel appears to be high. The source article states that this protection ratio is required for "perceptible" interference. This was interpreted to be TASO 3 grade of service. However, if it was meant to be "just perceptible" interference, then the protection ratio for TASO 3 quality would be -5 dB. The value of 10 dB was used to be conservative but this value requires further investigation.

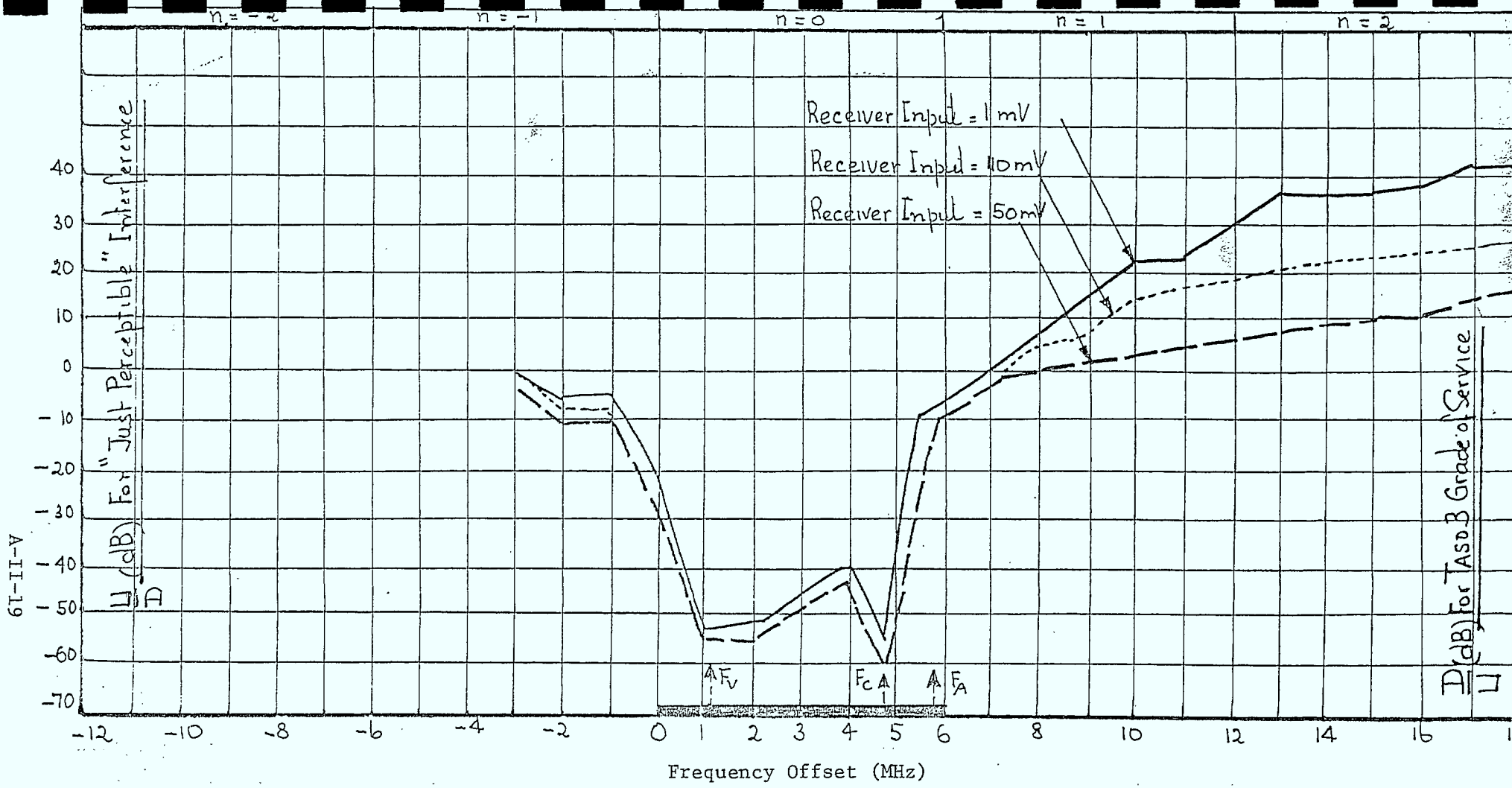


Figure A3-8: Protection Ratio for LM Interference into TV
Source: D.O.C. CRTPB Ad Hoc Committee Report

Test Conditions: Desired Signal: TV Channel 18(494-500MHz)
Undesired Signal: Two, Equi-Level, FM Signals
50% of 16 Colour TV sets gave the results indicated
Test Signal: Colour Bar Pattern

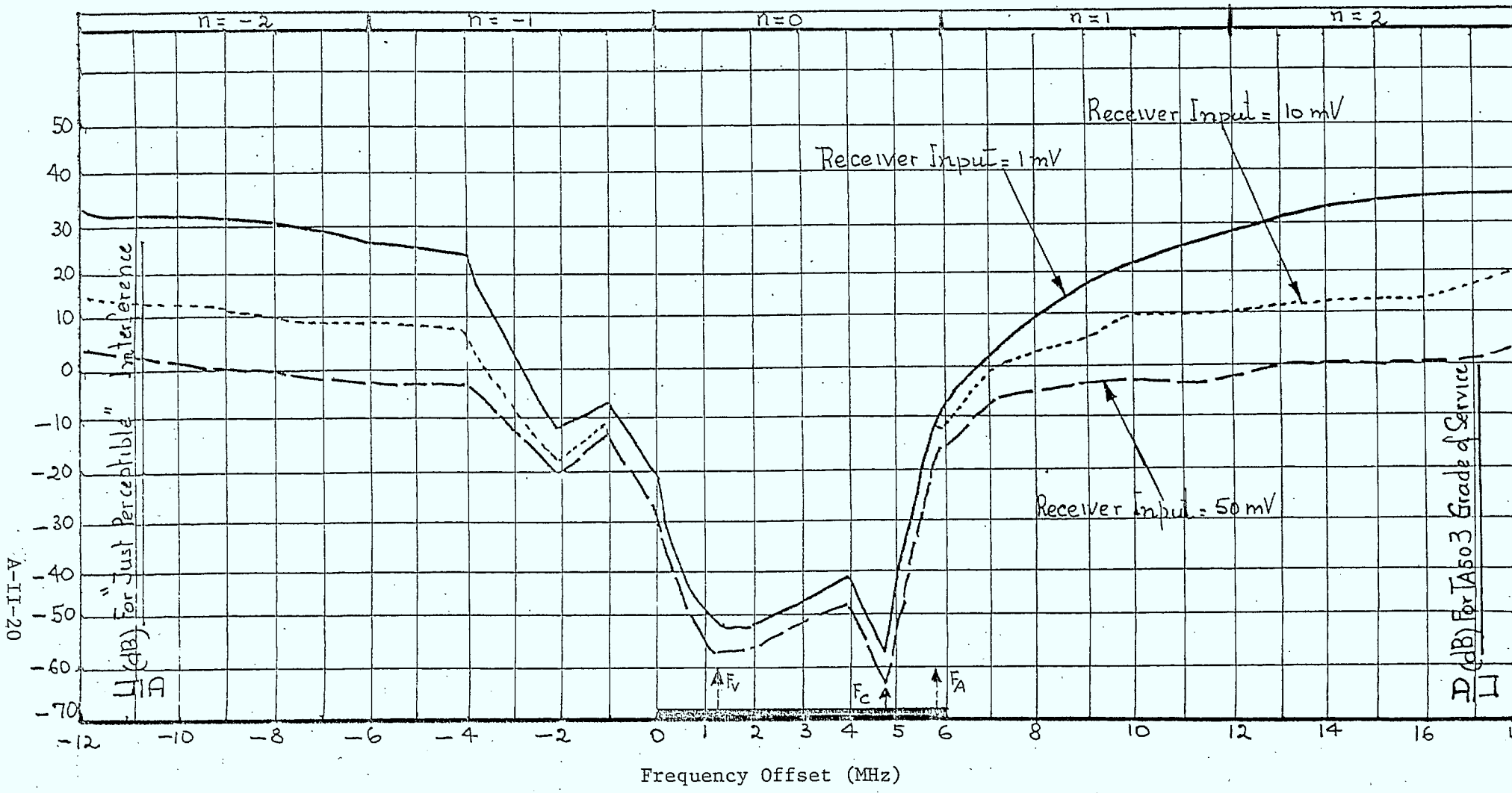


Figure A3-9: Protection Ratio for LM Interference into TV

Test Conditions: Desired Signal: TV Channel 72(181-824MHz)
Undesired Signal: Two, Equi-Level FM Signals
50% of 23 Colour TV Sets gave the results Indicated
Test Signal: Colour Bar Pattern

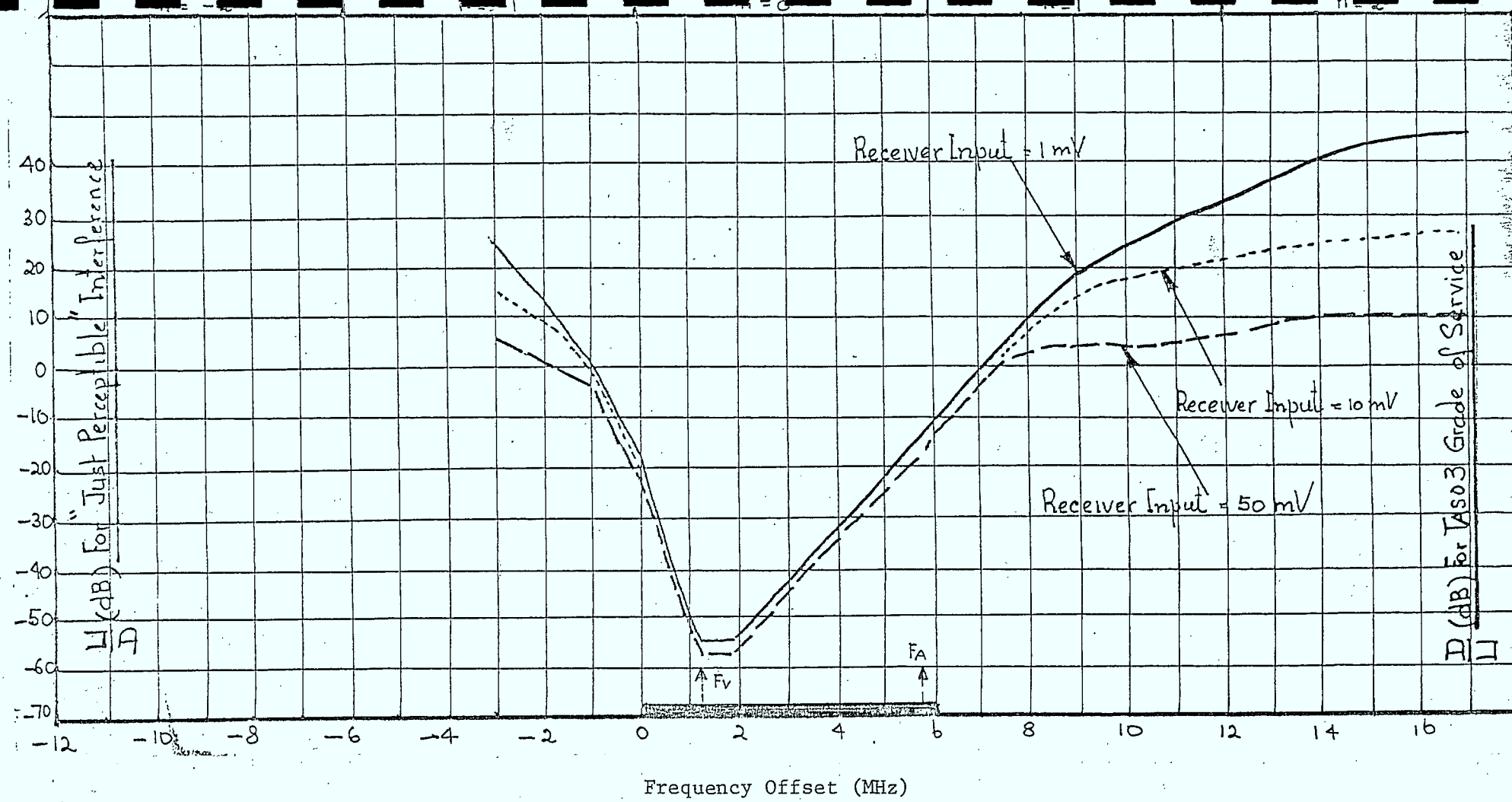


Figure A3-10: Protection Ratio for LM Interference into TV

Test Conditions: Desired TV Channel: 18(494-500MHz)
Undesired Signals: Two, Equi-Level FM Signals
50% of 15 Monochrome TV Sets gave the results indicated
Test Signal:

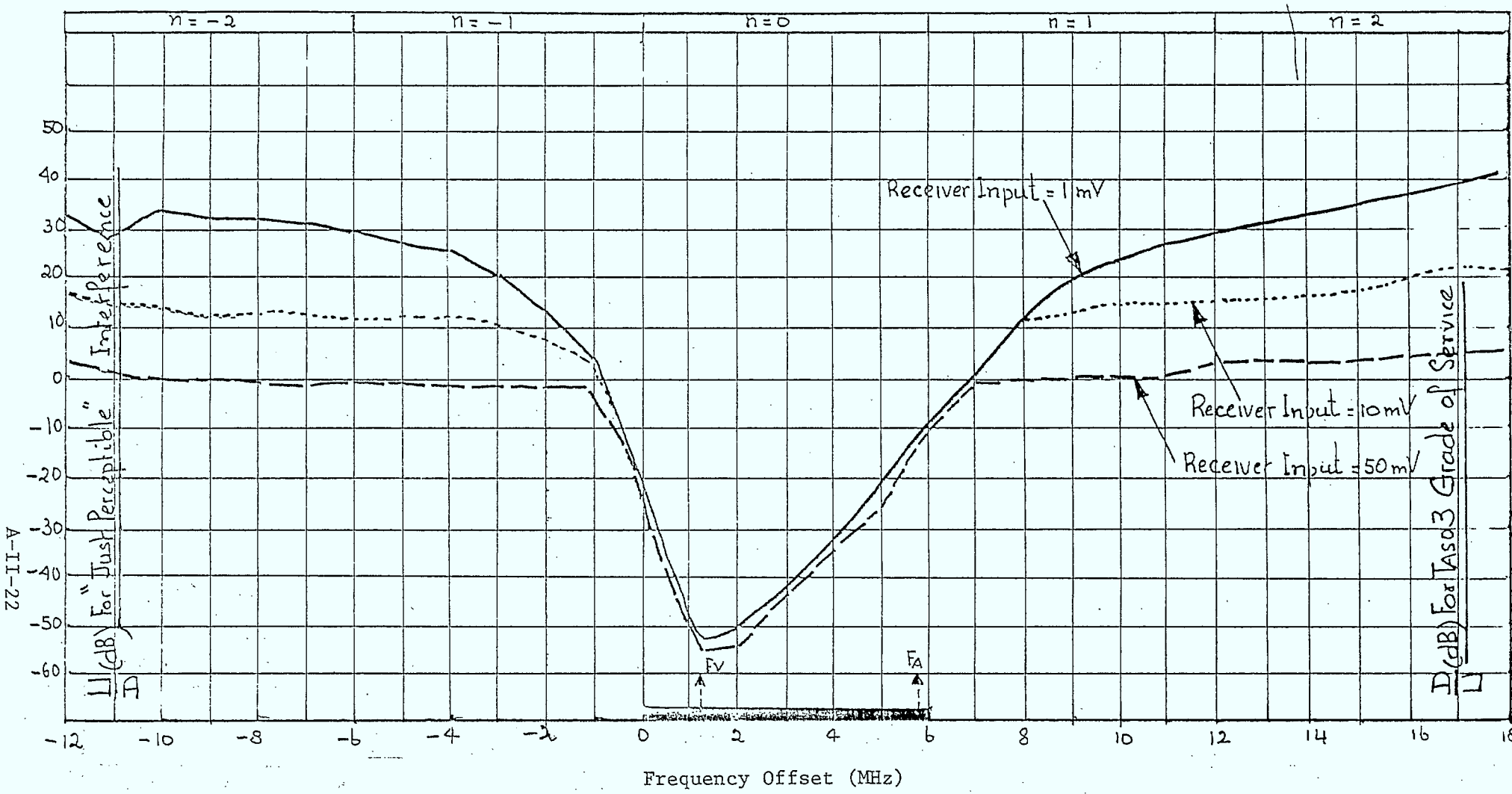


Figure A3-11: Protection Ratio for LM Interference into TV

Test Conditions: Desired TV Channel: 72(818-824 MHz)
Undesired Signals: Two, Equi-Level FM Signals
50% of 15 Monochrome TV Sets gave the results indicated
Test Signal:

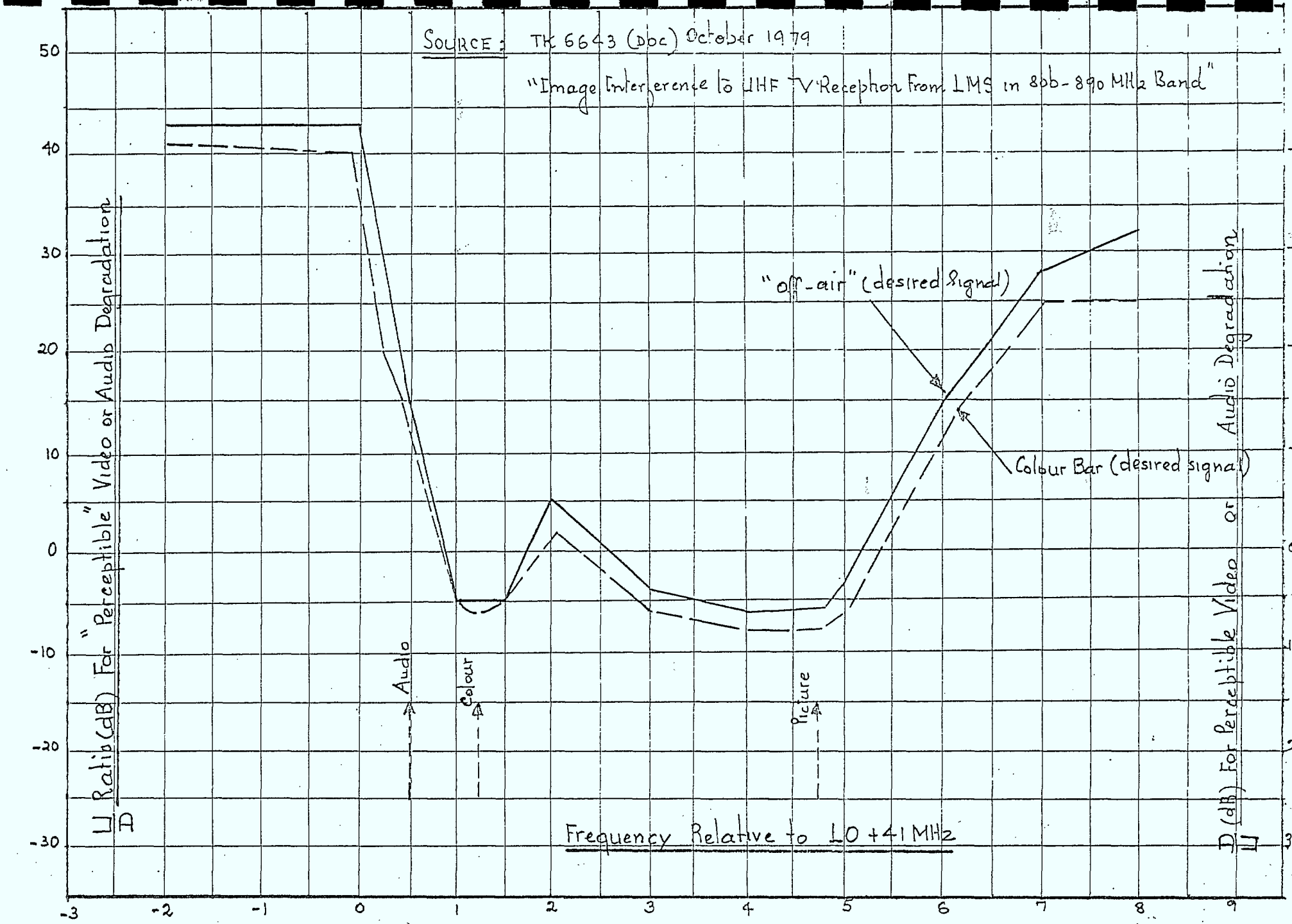


Figure A3-12: The Effect on TV Reception by LMS Interference in the Image Band

The base transmitter may be located inside or outside the Grade B contour. The separation distances given are for the case when the base transmitter is located outside the Grade B contour. When it is located inside the Grade B contour, the base transmitter will create "pockets" of interference zones, depending on the distance from the TV transmitter, the shielding and the TV receiver antenna discrimination.

A3-5 Conclusions

Measured data from various sources and under various conditions indicate that the following protection ratios are adequate for protection of TV signals from LMS signal interference provided that the LMS uses only that portion of a TV channel spectrum from 2 MHz to 4.5 MHz:

co-channel interference (n=0)	:	+40 dB
adjacent channel interference (n = ±1)	:	-5 dB
alternate adjacent channel interference (n = ±2)	:	-40 dB
Sound and Picture Image channel interference (n = ±15)	:	+10 dB

Appendix B to Chapter II

FIELD STRENGTH PREDICTION CURVES

Appendix B to Chapter II

FIELD STRENGTH PREDICTION CURVES

B1 Introduction

The propagation curves were derived from the following sources:

a) FCC R-6602 from FCC Rules and Regulations, 1983

b) S. Ahmed and P. Constantinou. "A Mobile Interference Model into UHF TV Receivers," IEEE Trans VT, March 1983

c) White: E.M.C. Handbook, Vol. 3, p.5.83.

However, several other sources were investigated. Among them were:

d) CCIR Rec 370 (4), Rep 567 (2), Rep 239 (5)

e) Egli. "Radio Propagation Above 40 MHz Over Irregular Terrain," Proc IRE, October 1957

f) J. McMahon. "Interference and Propagation Formulas and Tables Used in the FCC Spectrum Management Task Force LM Frequency Assignment Model," IEEE Trans VT, November 1972

g) E.A. Neham. "An Approach to Estimating Land Mobile Radio Coverage", IEEE Trans VT, November 1974

h) A.P. Barsis. "Determination of Service Area for VHF/UHF LM and Broadcast Operations over Irregular Terrain," IEEE Trans VT, March 1973

i) D.O.C. Report. "Image Interference to UHF TV Reception from LM Operation in the 806-890 MHz Band," October 1979

The curves were checked against source (i) and are in good agreement.

B2 Propagation Curves and Station Parameters

In arriving at the field strengths versus distance curves, the following station parameters were assumed.

Channels 2-6 (54-88 MHz)

TV Transmitter:	ERP	=	100 KW
	EHAAT	=	1000 ft.
TV Receiver:	H_R	=	30 ft.
Mobile Base Transmitter	ERP	=	150 W
	EHAAT	=	150 ft.
Mobile Transmitter	ERP	=	25 W
	H_T	=	6 ft.

Channels 7-13 (170-220 MHz)

TV Transmitter	ERP	=	316 KW
	EHAAT	=	1000 ft.
TV Receiver	H_R	=	30 ft.
Mobile Base Transmitter	ERP	=	150 W
	EHAAT	=	150 ft.
Mobile Unit Transmitter	ERP	=	25 W
	H_T	=	6 ft.

Channels 14-69 (470-806 MHz)

TV Transmitter	ERP	=	1000 KW
	EHAAT	=	1000 ft.
TV Receiver	H_R	=	30 ft.
Mobile Base Transmitter	ERP	=	150 W
	EHAAT	=	150 ft.
Mobile Unit Transmitter	ERP	=	25 W
	H_T	=	6 ft.

Channels 2-6 (54-88 MHz)

Fig. B1-1 gives F(50,50) and F(50,10) for TV Transmitter to TV Receiver

Fig. B1-2 gives F(50,50) and F(50,10) for Base Transmitter to TV Receiver

Fig. B1-3 gives F(50,50) and F(50,10) for Base Transmitter to Mobile Receiver

Fig. B1-4 gives F(50,50) and F(50,10) for TV Transmitter to Base Receiver

Fig. B1-5 gives F(50,50) and F(50,10) for TV Transmitter to Mobile Receiver

Channels 7-13 (170-220 MHz)

Fig. B2-1 gives F(50,50) and F(50,10) for TV Transmitter to TV Receiver

Fig. B2-2 gives F(50,50) and F(50,10) for Base Transmitter to TV Receiver

Fig. B2-3 gives F(50,50) and F(50,10) for Base Transmitter to Mobile Receiver

Fig. B2-4 gives F(50,50) and F(50,10) for TV Transmitter to Base Receiver

Fig. B2-5 gives F(50,50) and F(50,10) for TV Transmitter to Mobile Receiver

Channels 14-69 (470-806 MHz)

Fig. B3-1 gives F(50,50) and F(50,10) for TV Transmitter to TV Receiver

Fig. B3-2 gives F(50,50) and F(50,10) for Base Transmitter to TV Receiver

Fig. B3-3 gives F(50,50) and F(50,10) for Base Transmitter to Mobile Receiver

Fig. B3-4 gives F(50,50) and F(50,10) for TV Transmitter to Base Receiver

Fig. B3-5 gives F(50,50) and F(50,10) for TV Transmitter to Mobile Receiver

Fig. B4-1 gives F(50,50) for Mobile Unit Transmitter to TV Receiver

Fig. B4-1 applies for the above three bands. For the figure, two expressions are given: one from the EMC Handbook by White and the other from the article by Ahmed and Constantinou. The equations are given on the graphs.

Figure B5-1 gives the height gain factors used to convert the field strengths from 30-ft. receive antenna heights to 6-ft. heights.

Figure B5-2 gives the distance to the local horizon from the transmitter antenna of various heights. The information for this was obtained from Bullington.

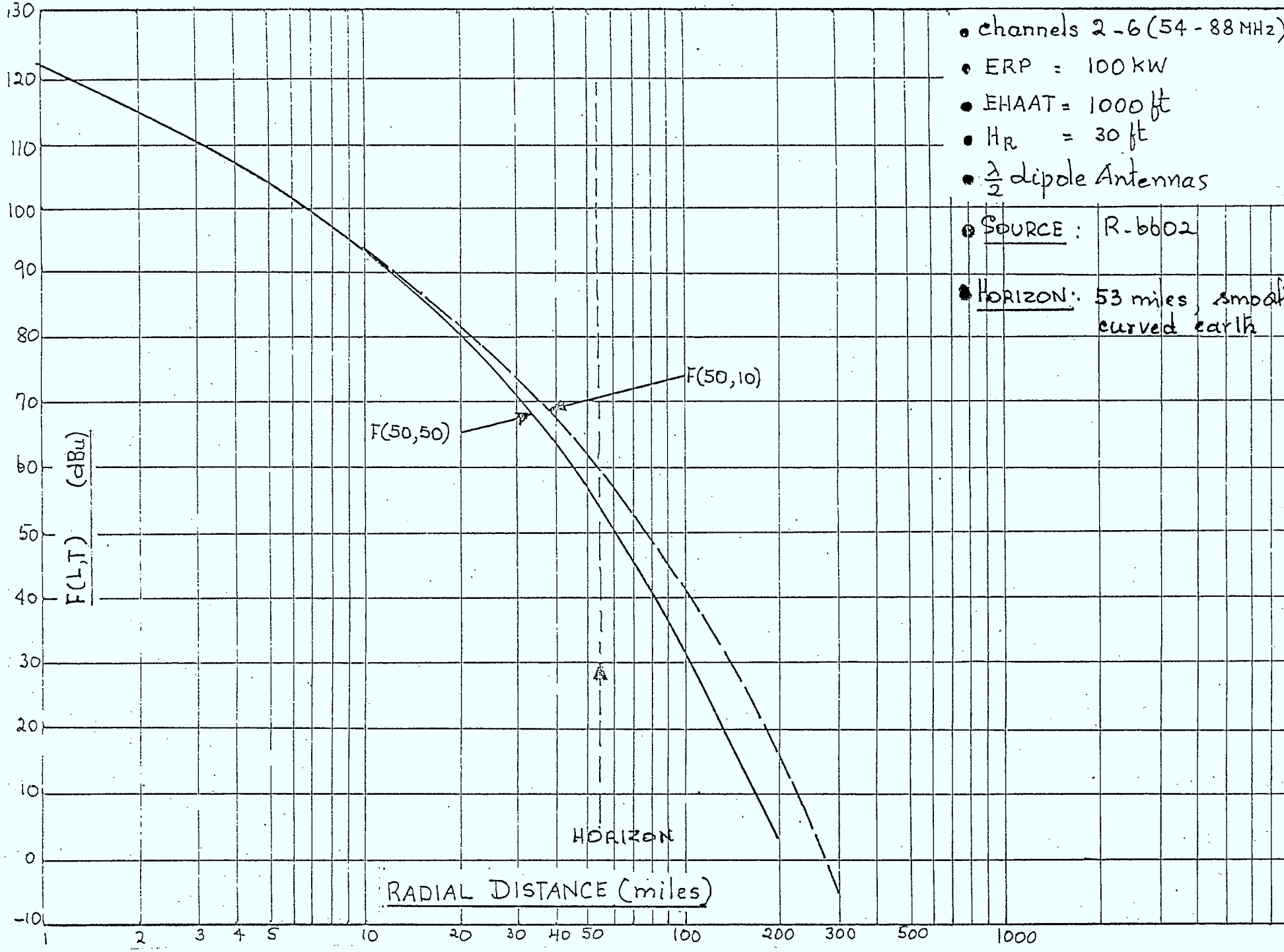


Figure B1-1: Field Strength vs Distance: TV Tx to TV Rx

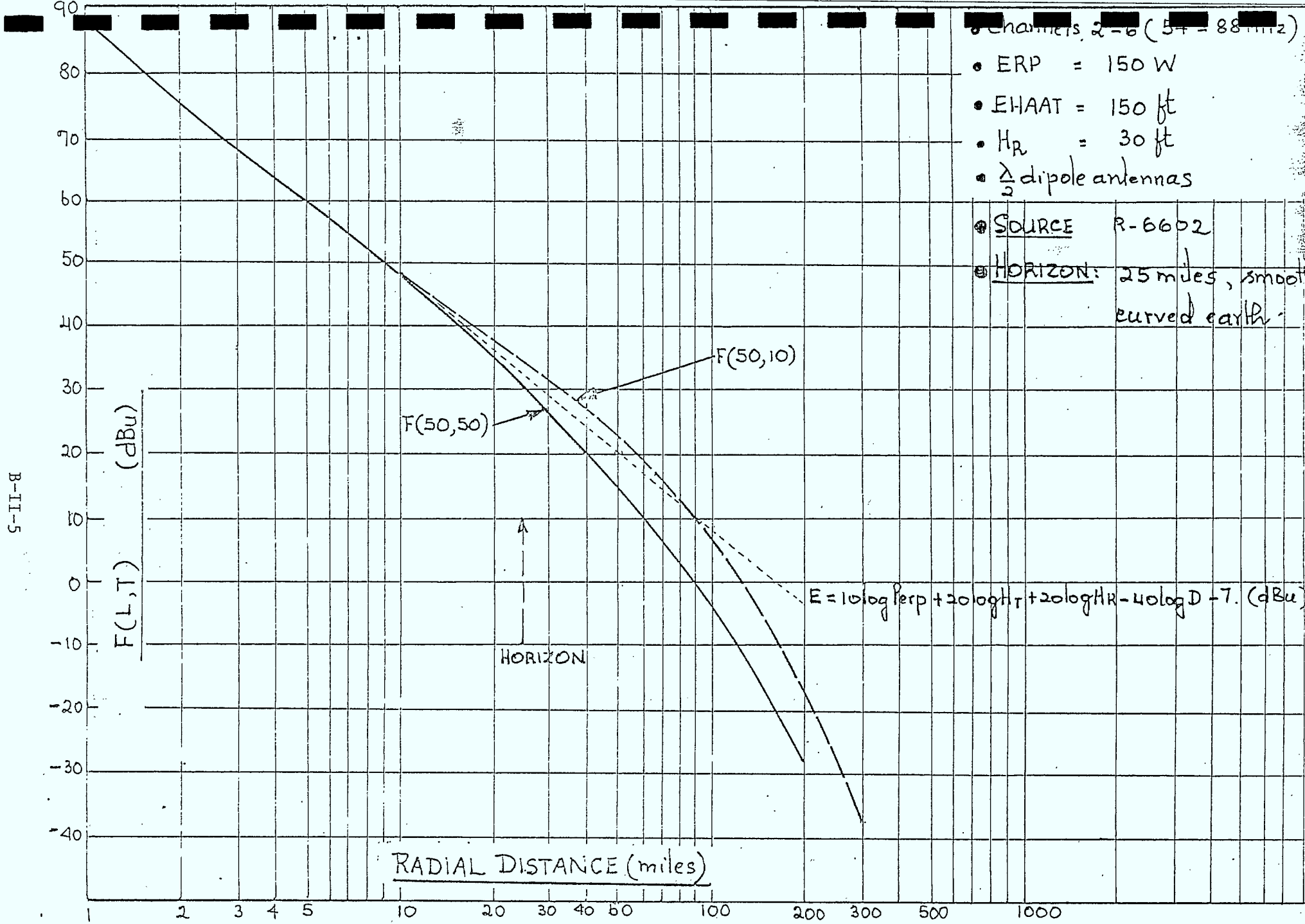


Figure B1-2: Field Strength vs Distance: Base Tx(Mobile) to TV Rx

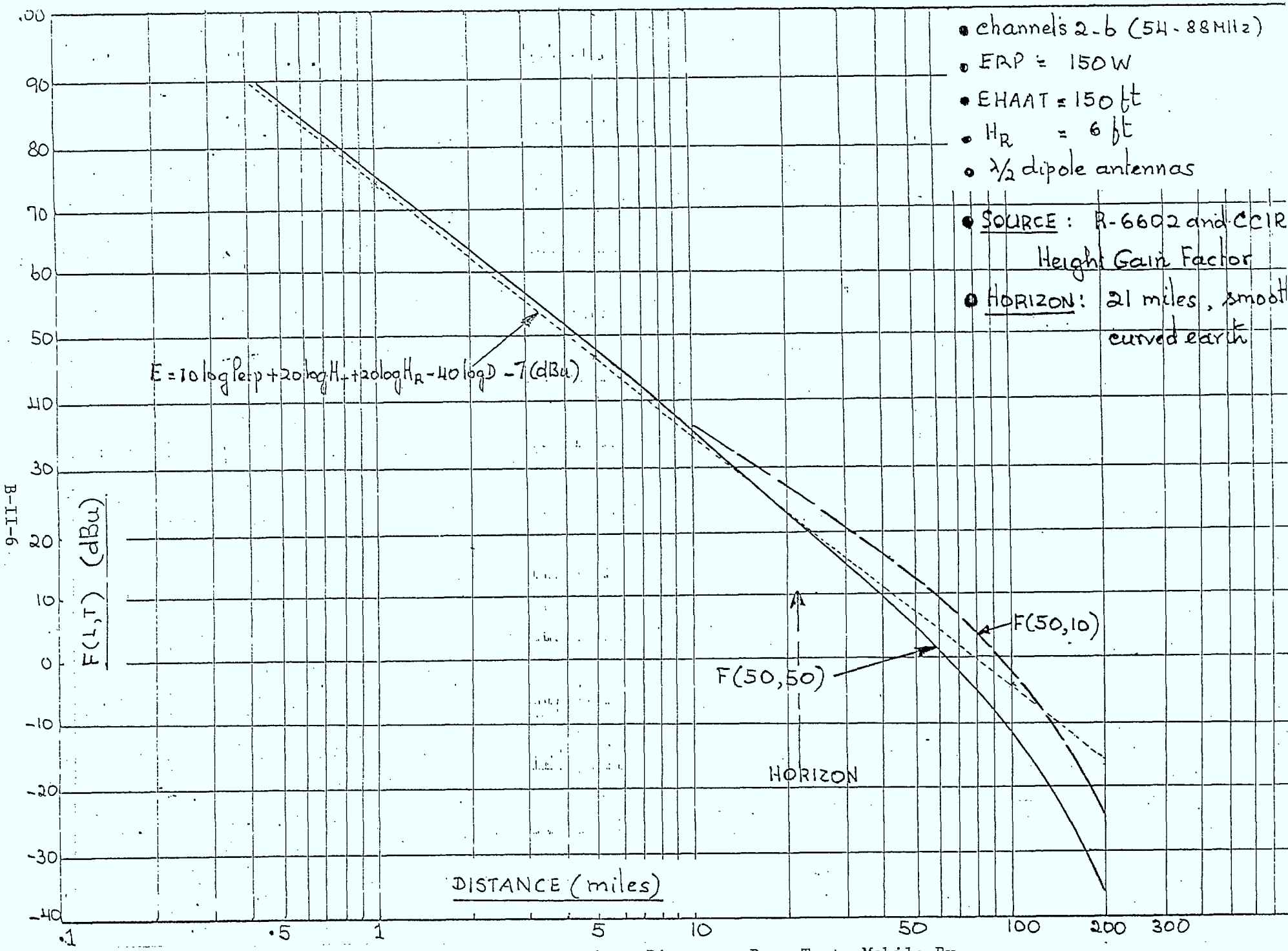


Figure B1-3: Field Strength vs Distance: Base Tx to Mobile Rx

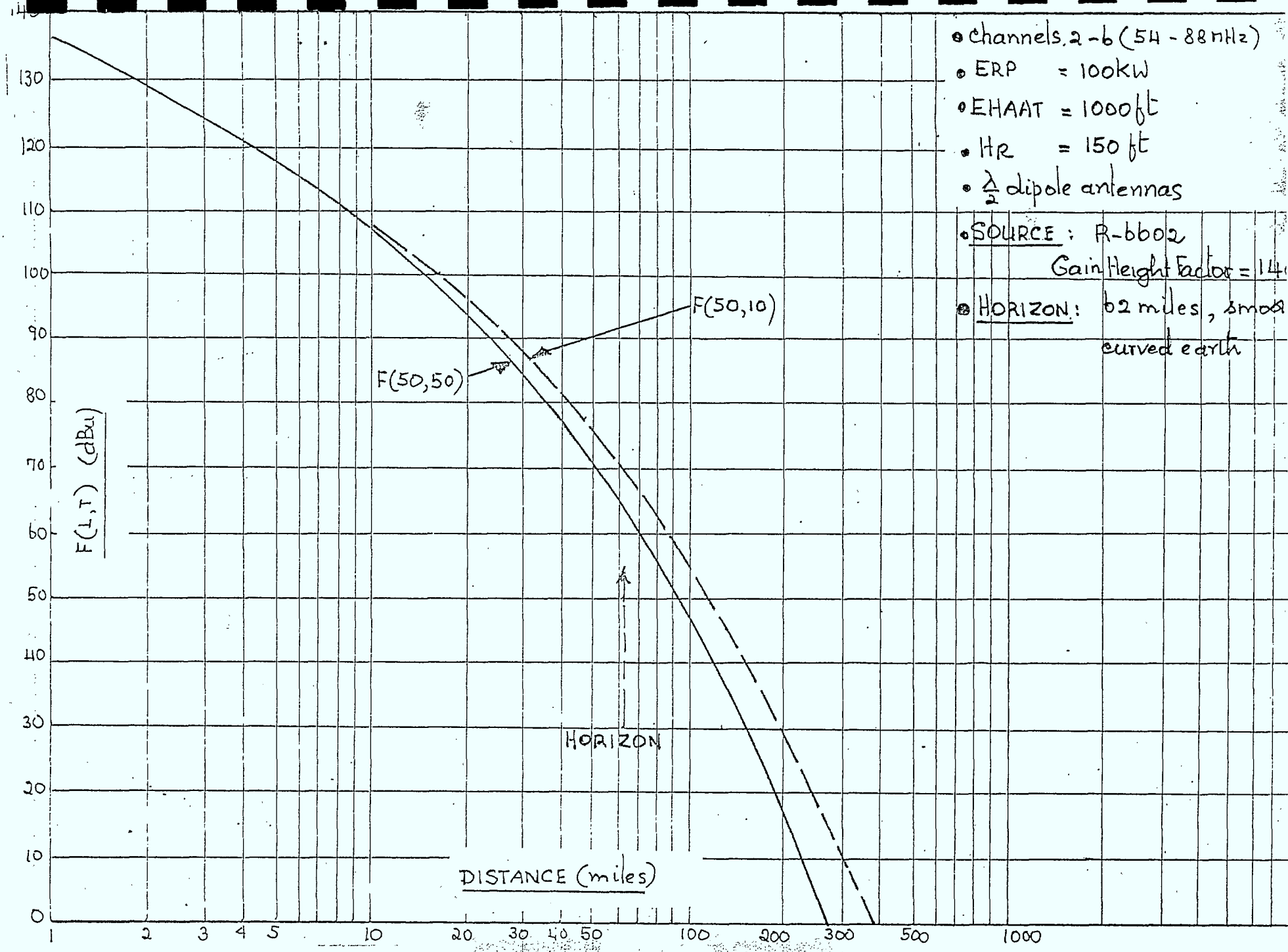


Figure B1-4: Field Strength vs Distance: TV Tx to Mobile Base Rx

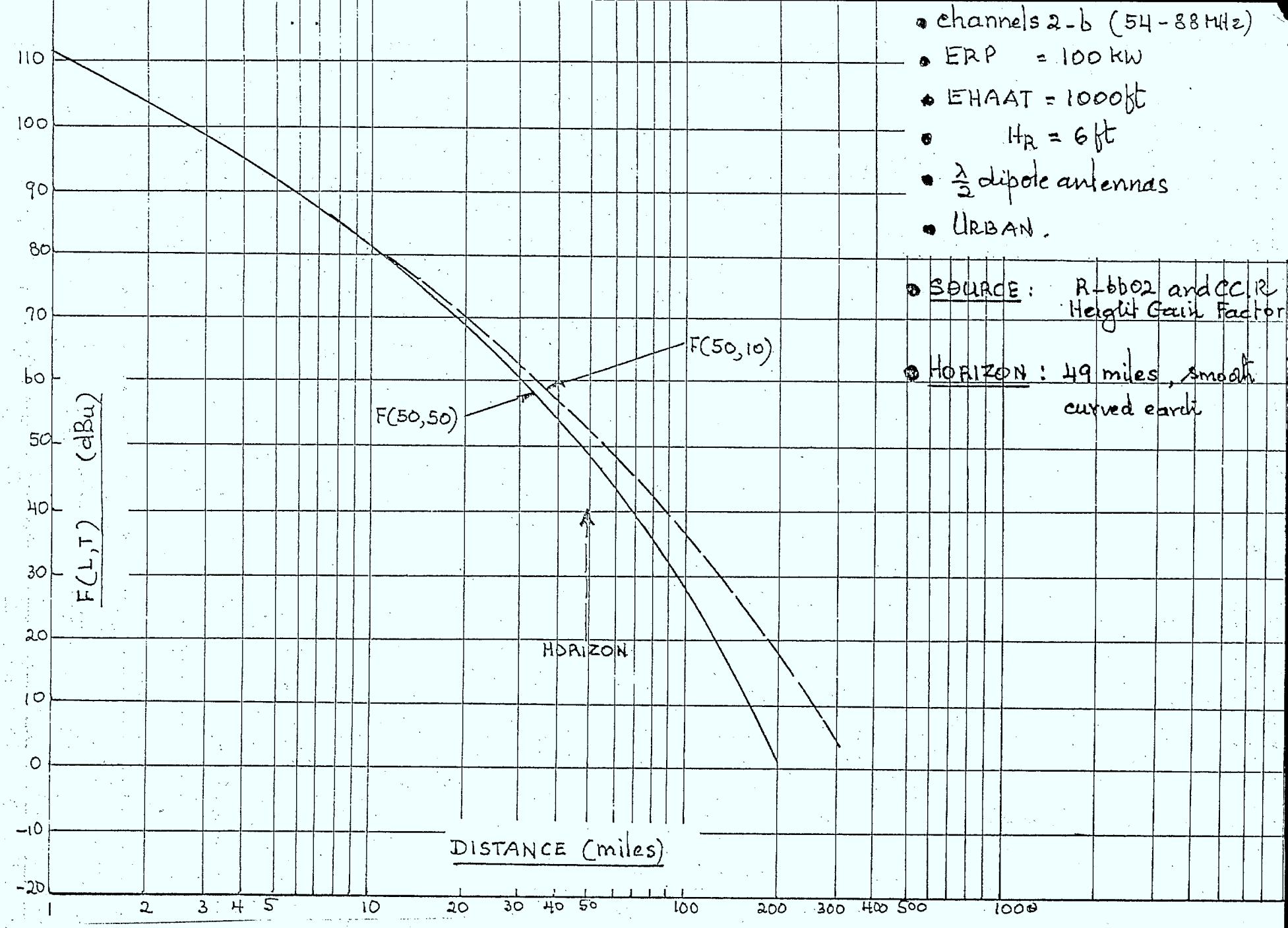


Figure B1-5: Field Strength vs Distance: TV Tx to Mobile Unit Rx

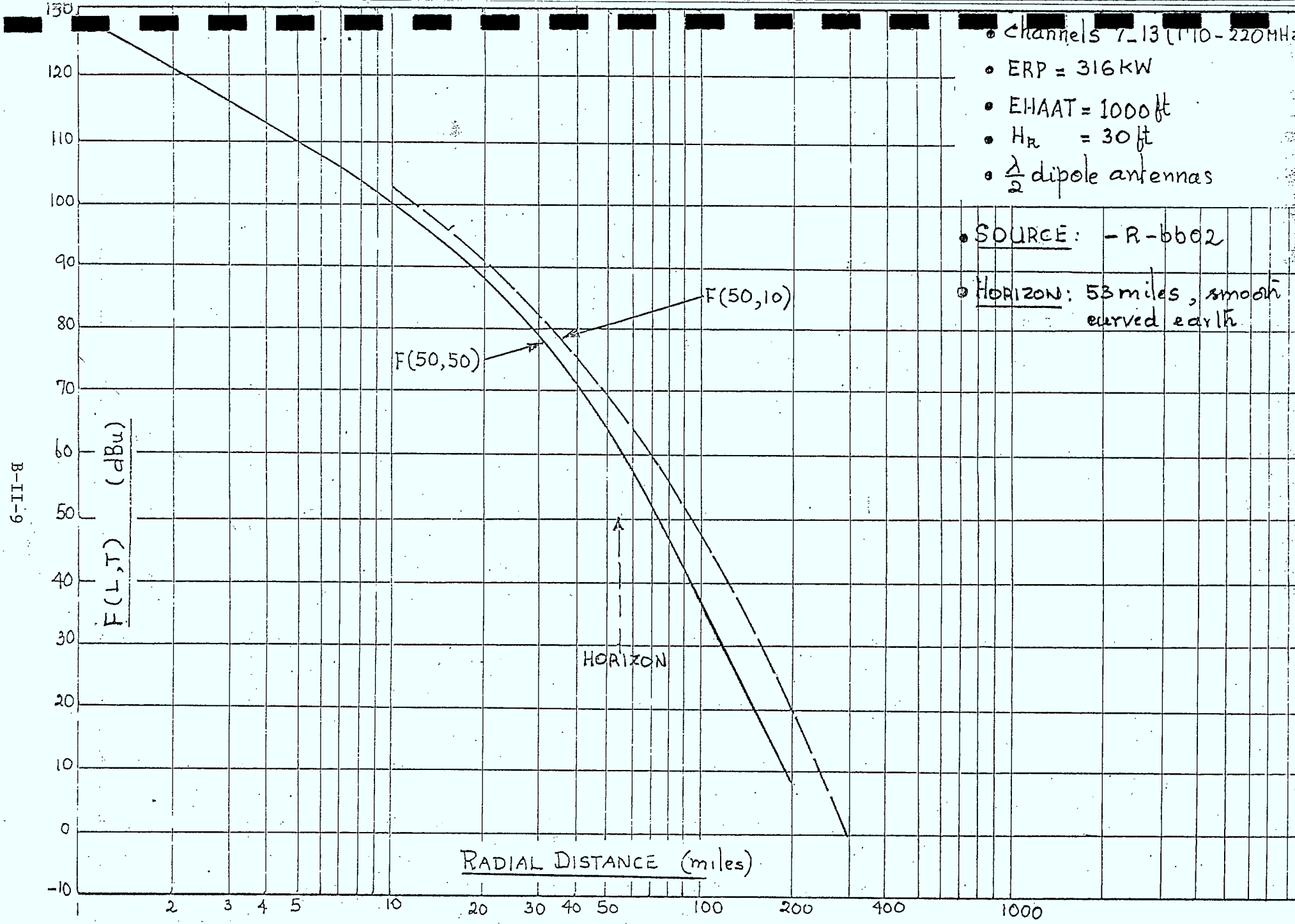


Figure B2-1: Field Strength vs Distance: TV Tx to TV Rx

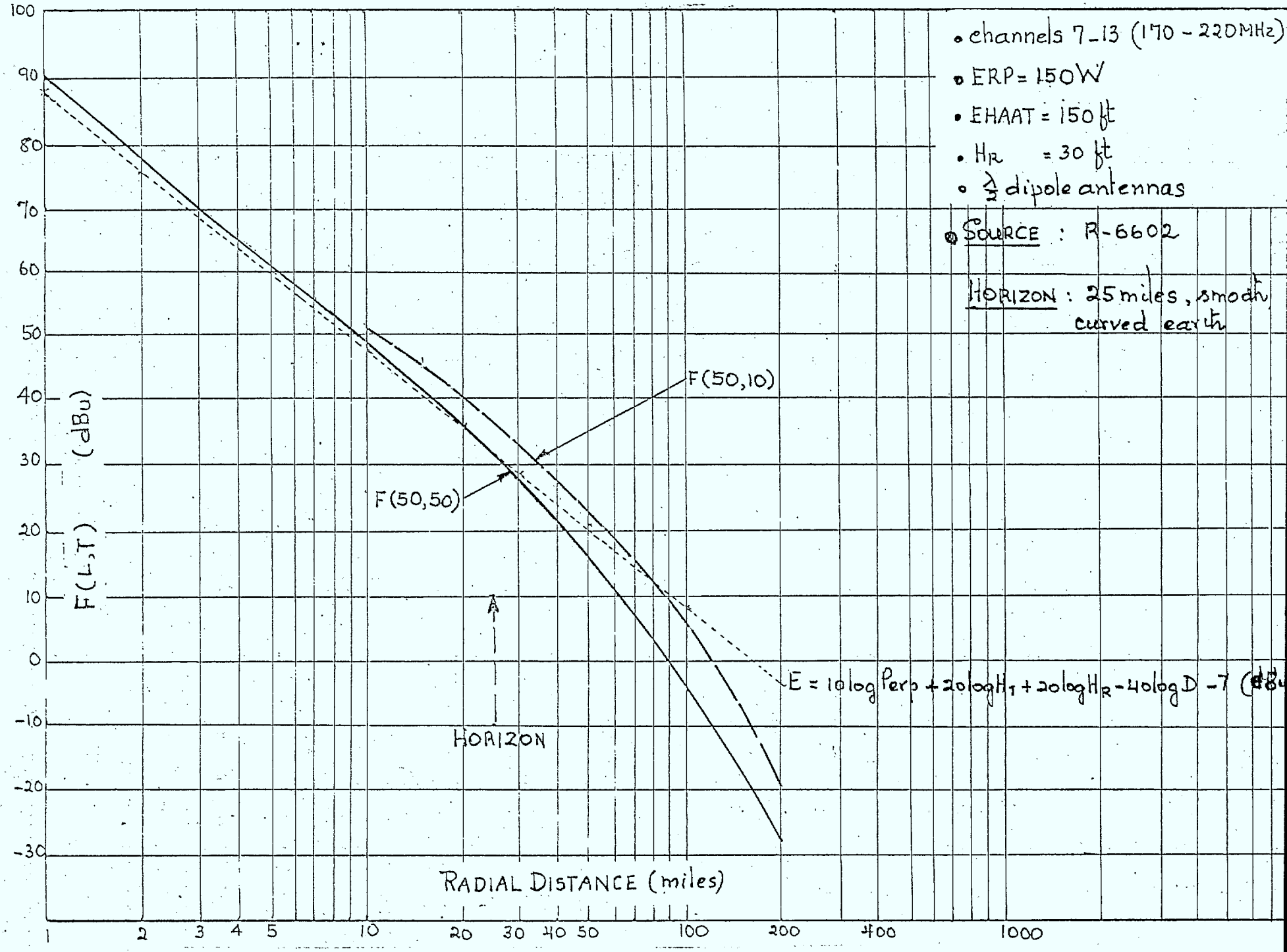


Figure B2-2: Field Strength vs Distance: Mobile Base Tx to TV Rx

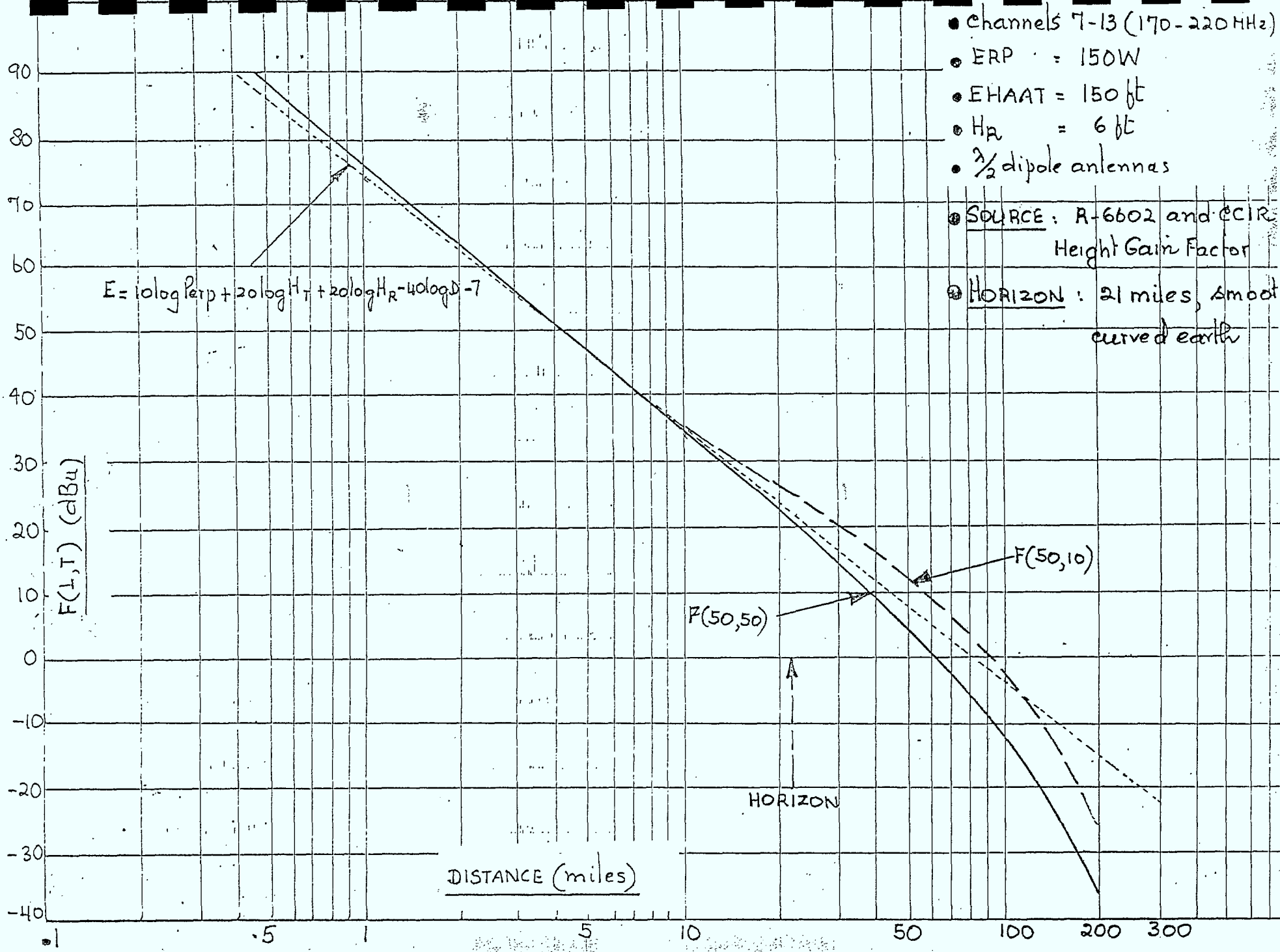


Figure B2-3: Field Strength vs Distance: Base Tx to Mobile Rx

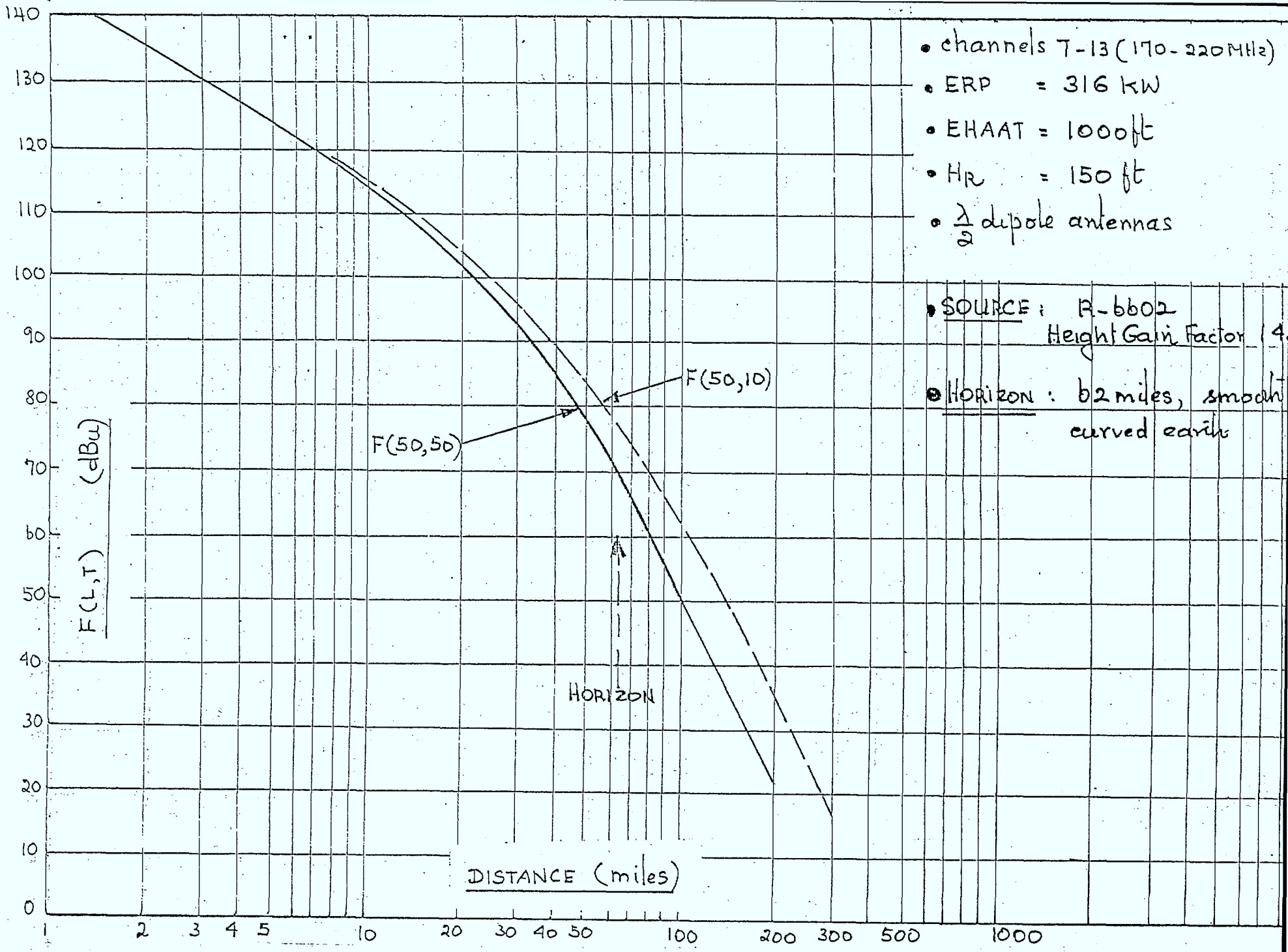


Figure B2-4: Field Strength vs Distance: TV Tx to Mobile Base Rx

[redacted]

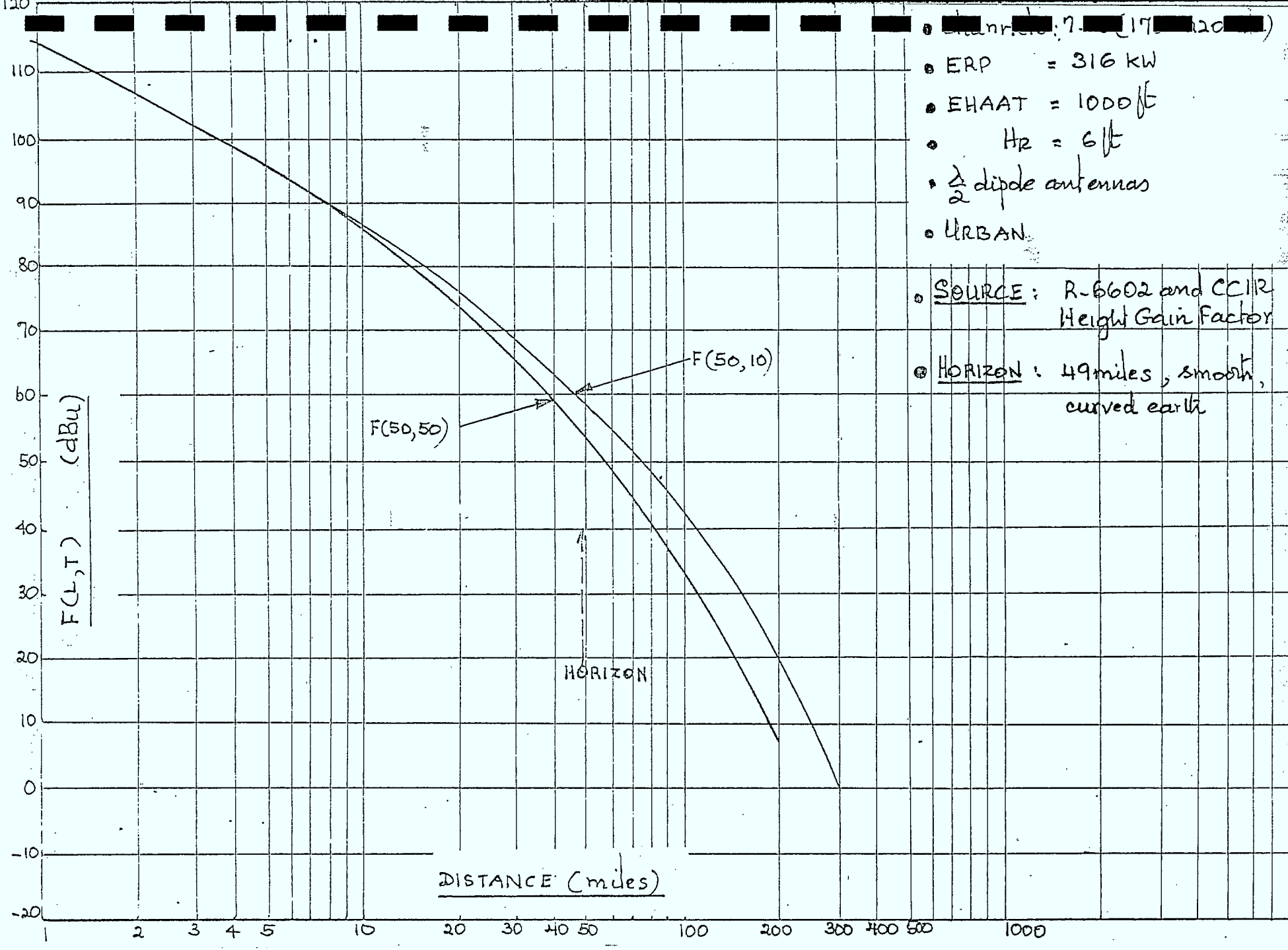


Figure B2-5: Field Strength vs Distance: TV Tx to Mobile Unit Rx

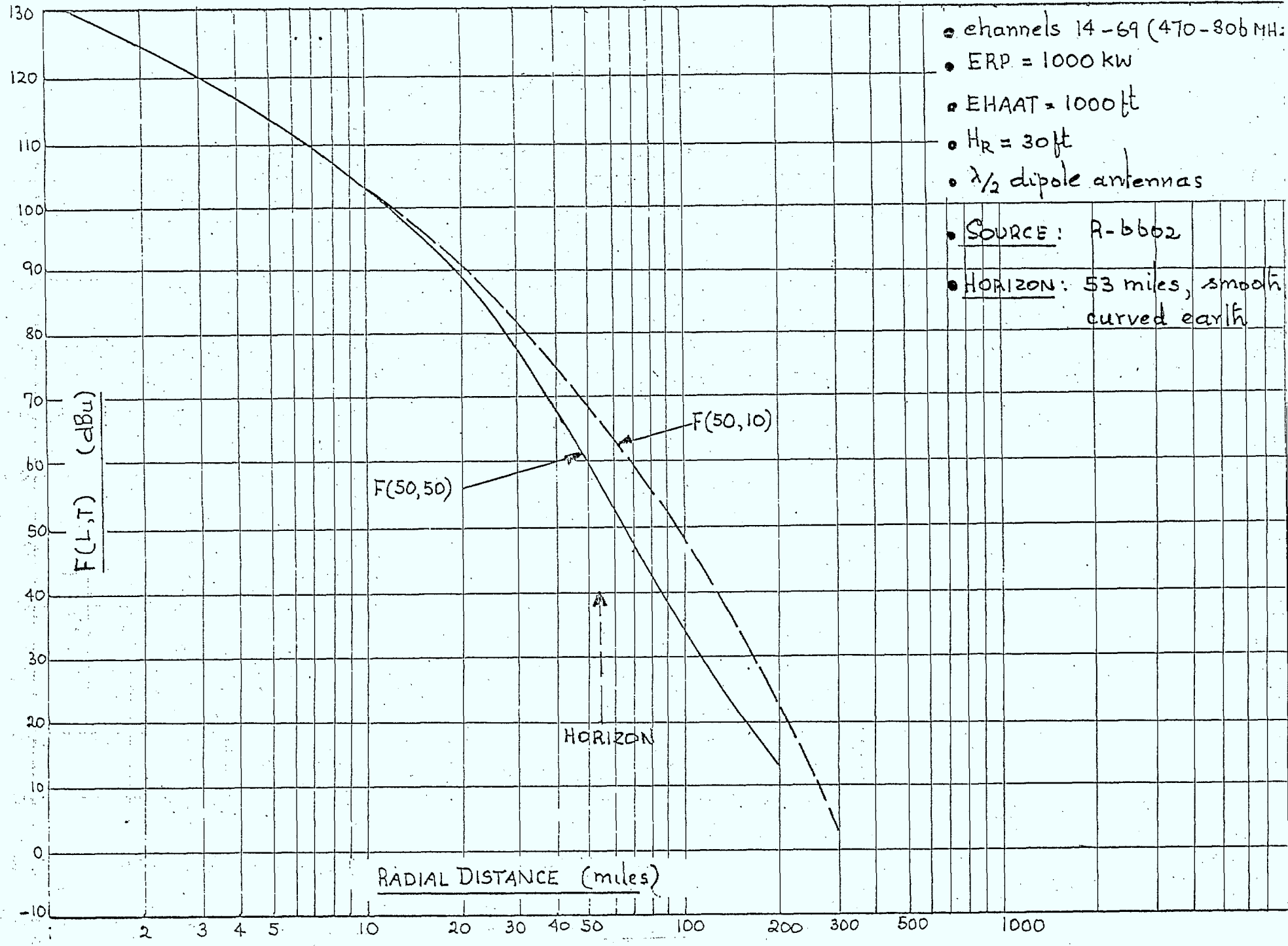


Figure B3-1: Field Strength vs Distance: TV Tx to Mobile Base Rx

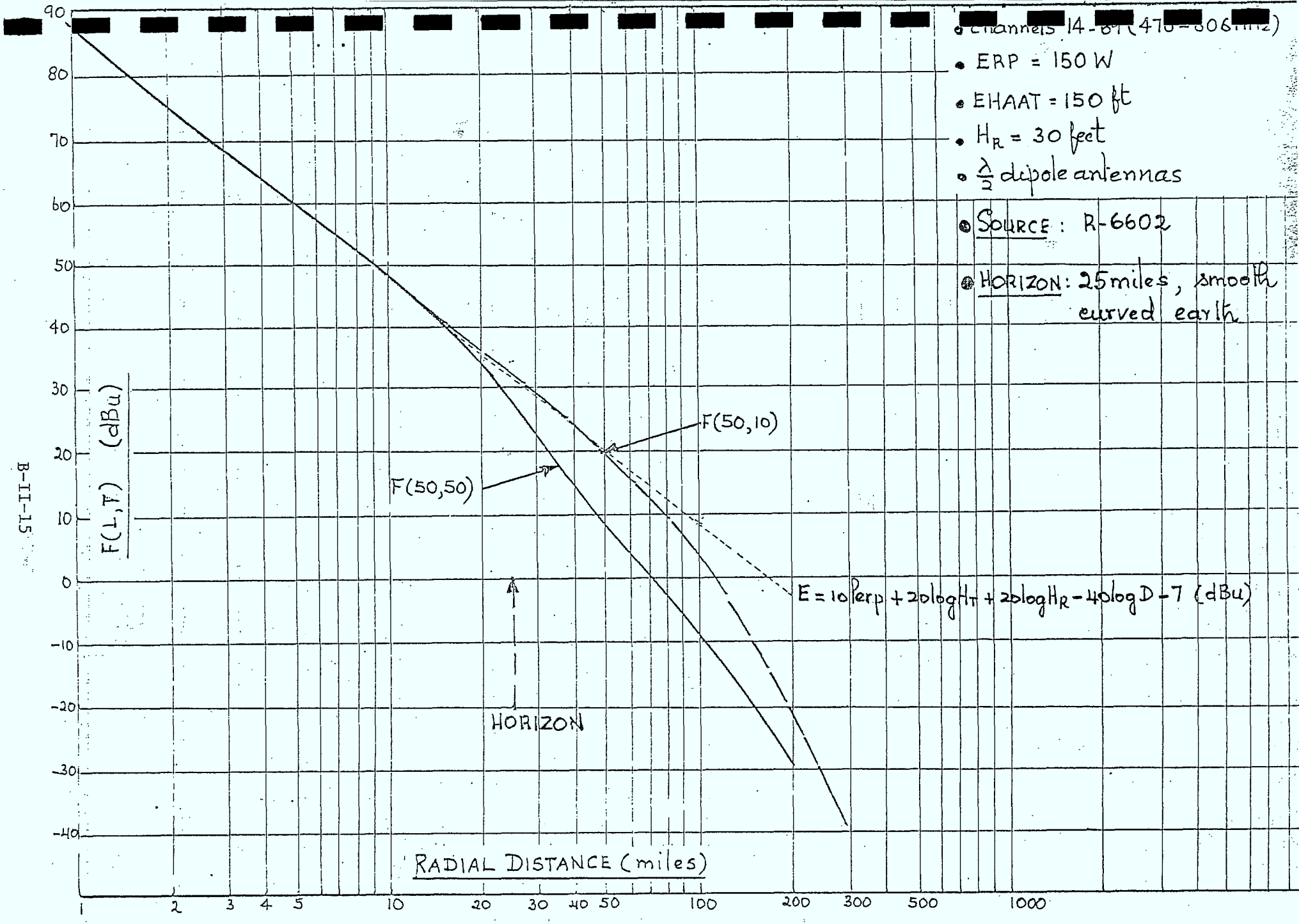


Figure B3-2: Field Strength vs Distance: Mobile Base Tx to TV Rx

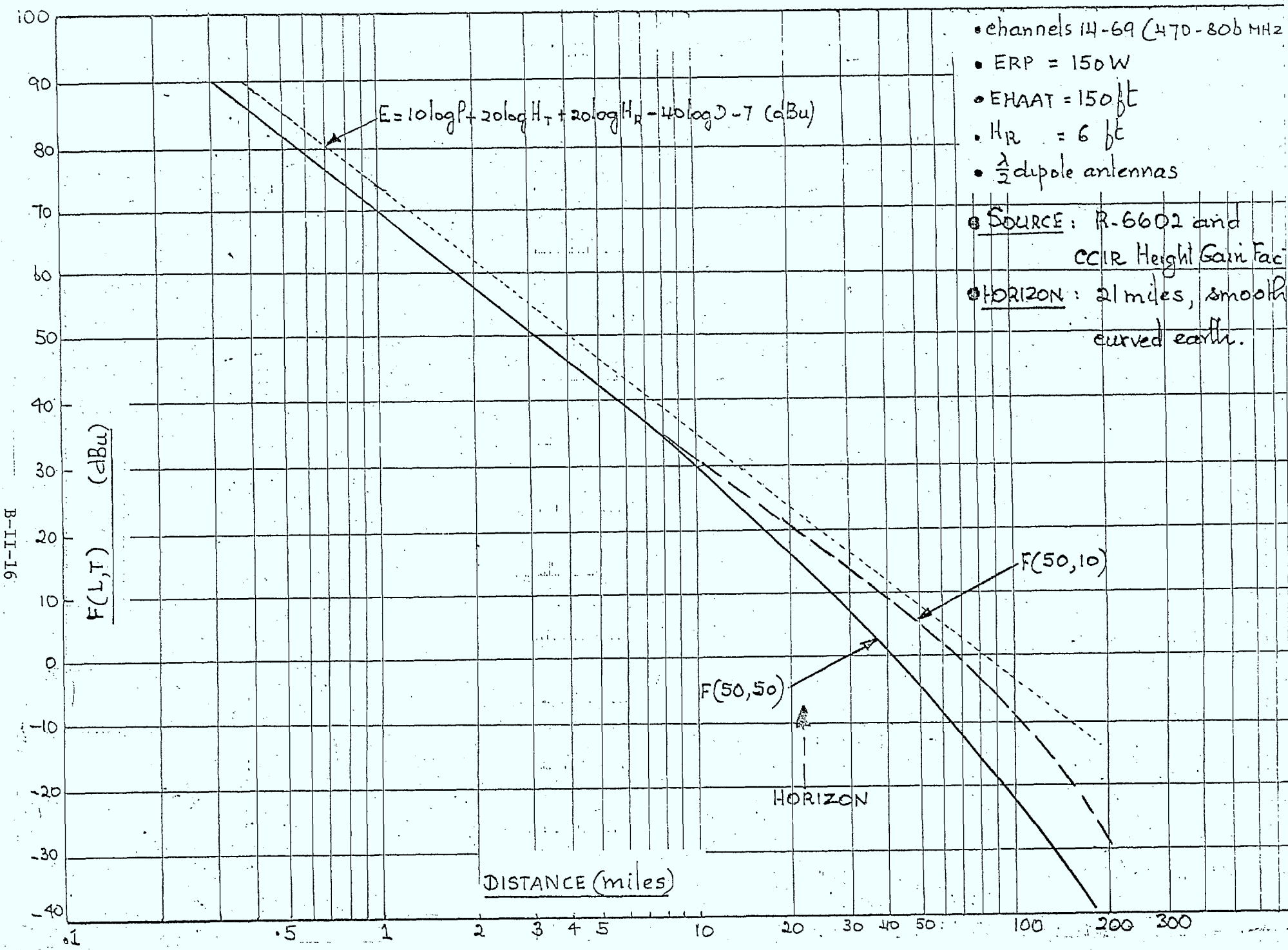


Figure B3-3: Field Strength vs Distance: Base Tx to Mobile Rx

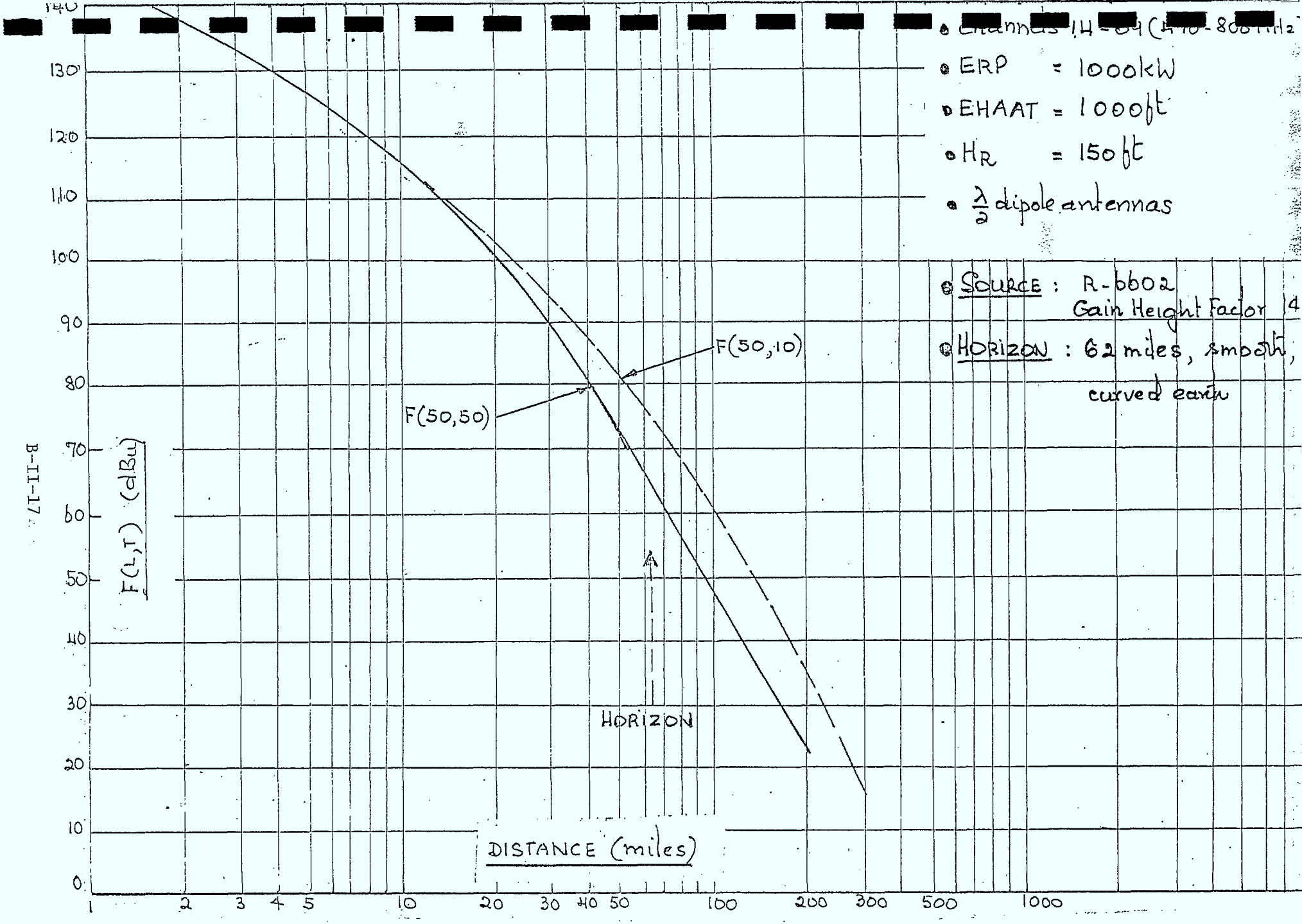


Figure B3-4: Field Strength vs Distance: TV Tx to Mobile Base Rx

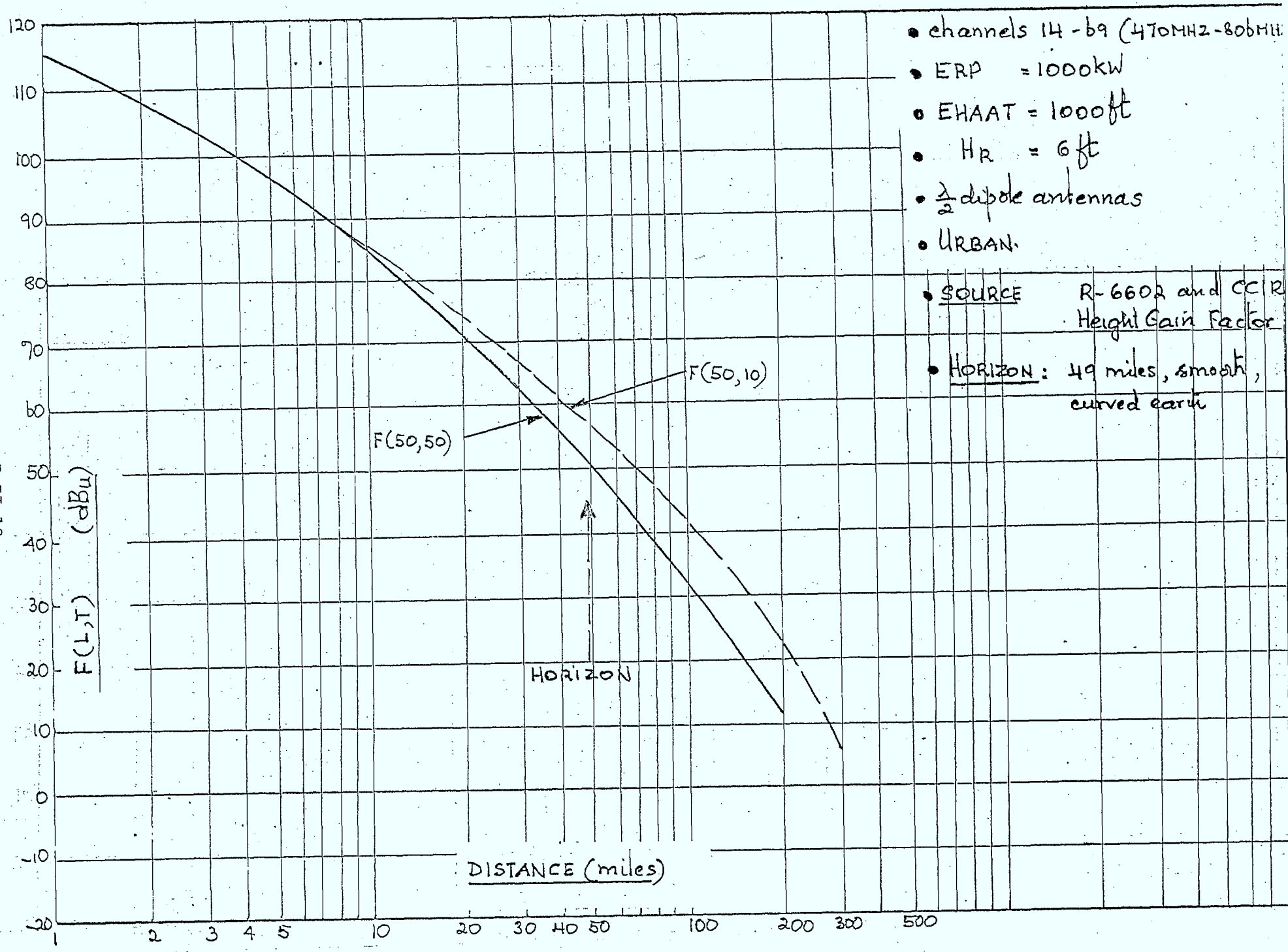


Figure B3-5: Field Strength vs Distance: TV Tx to Mobile Unit Rx

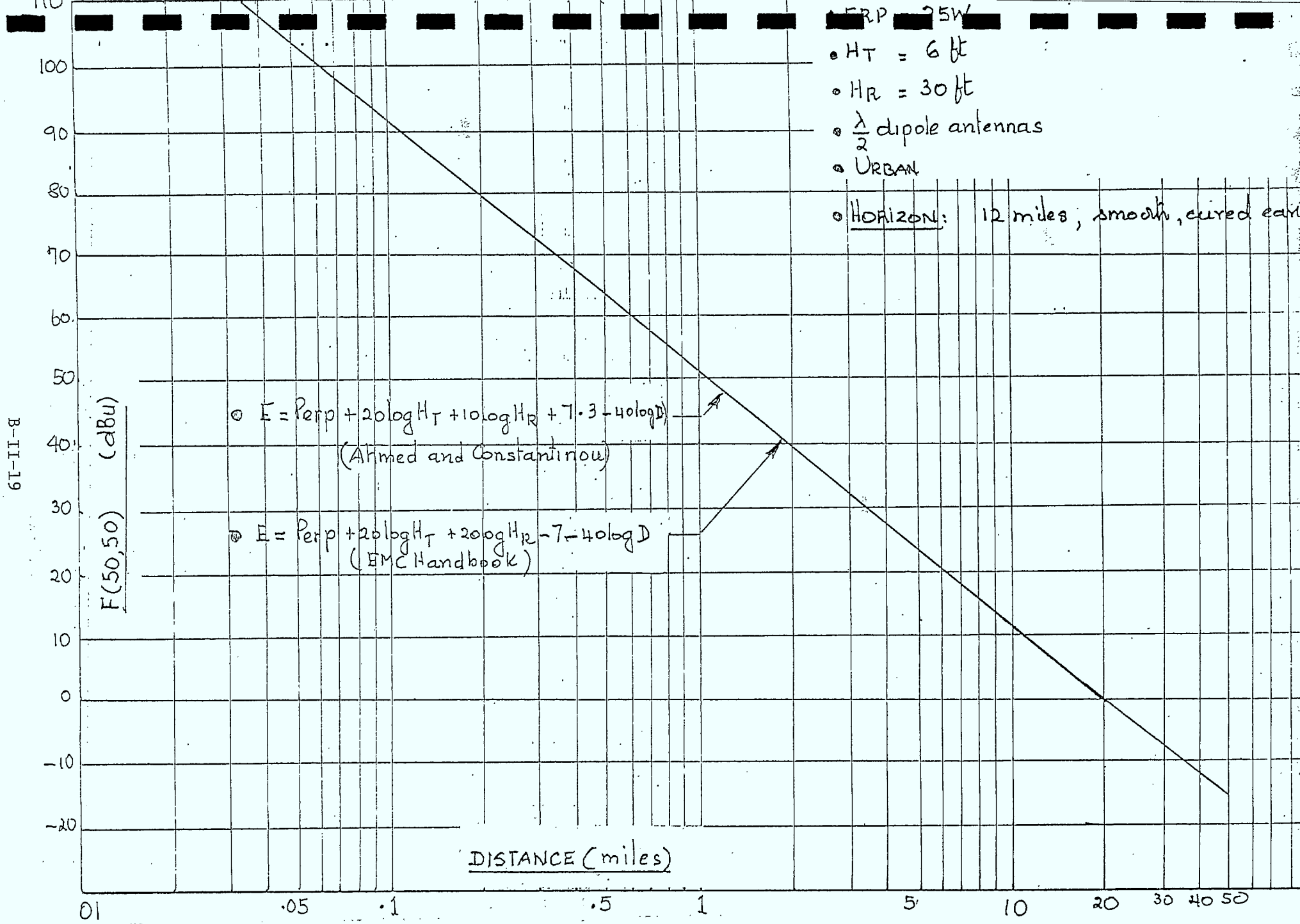
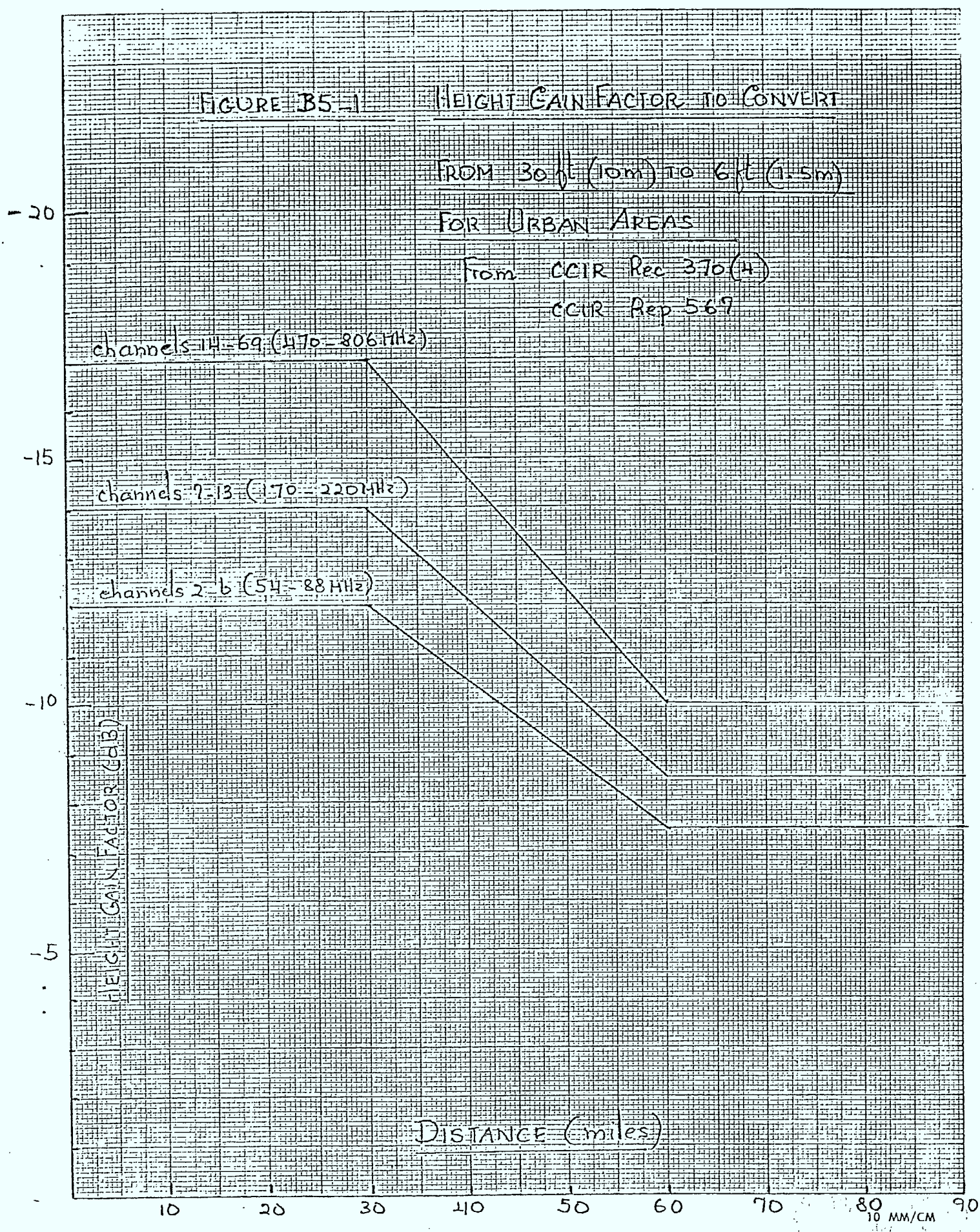


Figure B4-1: Field Strength vs Distance for Mobile Interference into TV

FIGURE B5-1 HEIGHT GAIN FACTOR TO CONVERT FROM 30 ft (10m) TO 6 ft (1.5m) FOR URBAN AREAS

From CCIR Rec 370 (4)
CCIR Rep 569



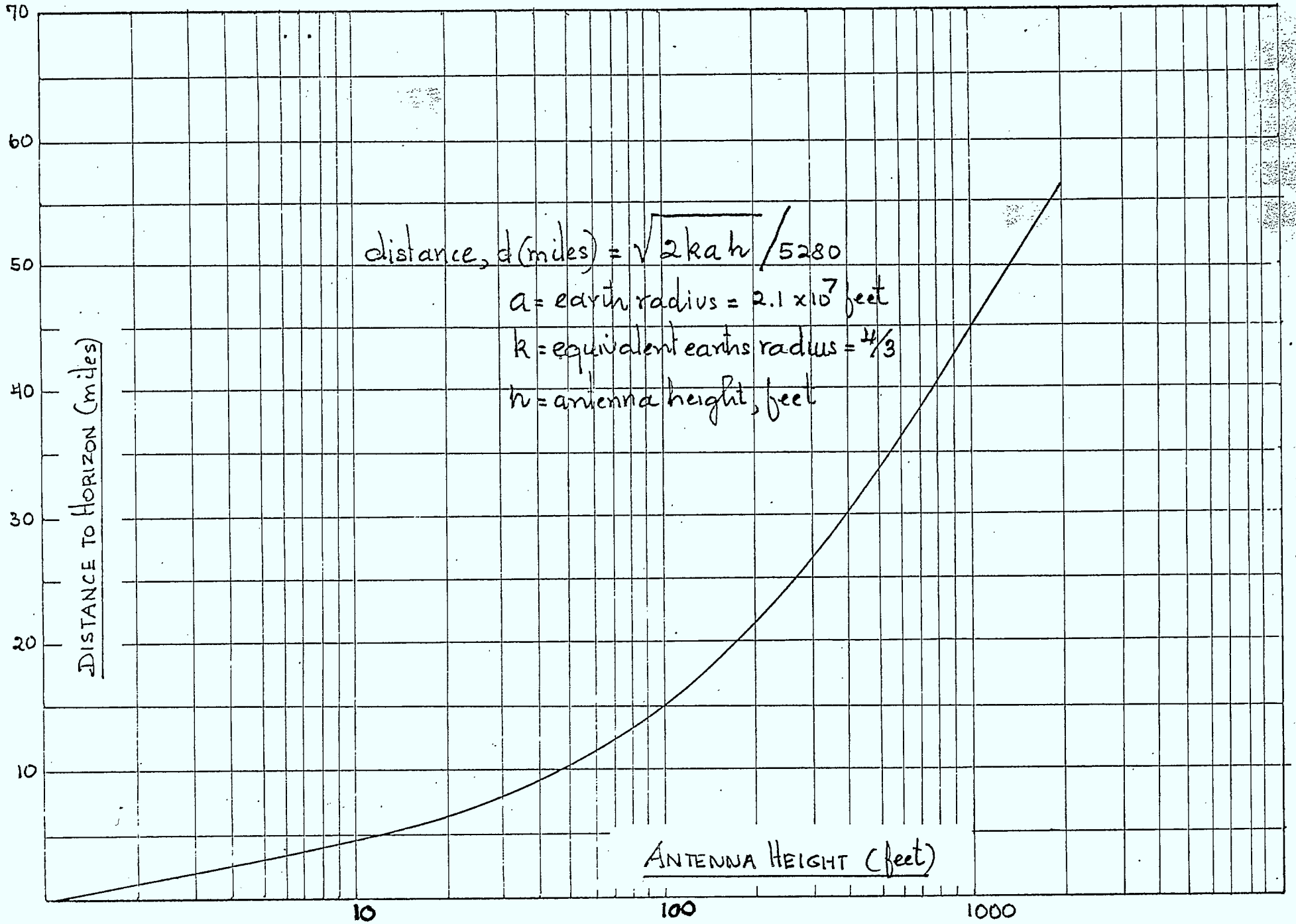


Figure B5-2: Distance to Horizon of Smooth Curved Earth

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APPENDIX A to CHAPTER III

TRANSMISSION PATH LOSS PREDICTIONS

APPENDIX A to CHAPTER III

TRANSMISSION PATH LOSS PREDICTIONS

A1 INTRODUCTION

The computer predictions for the transmission path loss were based on the following two documents:

1. "Prediction of Tropospheric Radio Transmission Loss and Computer Method"

2. "A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode"

The values of the transmitter, receiver, and terrain characteristics used in arriving at the transmission path loss curves are given in Tables A-1, A-2 and A-3 respectively.

A2 TRANSMISSION PATH LOSS CURVES

For each city (Toronto, Montreal, and Vancouver), the following transmission path characteristics were computed.

A. TV transmitter to receiver (to obtain the distance to the Grade B contour).

B. Base transmitter to TV receiver (to obtain the distance from the base transmitter to Grade B contour. The sum of the distance from A and B gave the minimum separation between the TV and base transmitters to ensure protection for the TV service).

C. TV transmitter to base receiver (to obtain the minimum distance to ensure the protection of the LMS).

D. Base transmitter to mobile receiver (to obtain the distance of the protected contour of the LMS from the base transmitter).

E. Mobile transmitter to base receiver (to obtain the actual operating contour).

Figures A1-1 to A1-5 give the above data for Toronto, while Figures A2-1 to A2-5 give the data for Montreal and Figures A3-1 to A3-5 give the data for Vancouver.

SERVICE	FREQUENCY RANGE	CLASS OF TRANSMITTER	CHARACTERISTICS	
			ERP	EHAAT
TV Broadcast	channels 2-6 (54-88 MHz)	Low Power (LP)	1 kW	100 m
		Regular (R)	100 kW	150 m
	channels 7-13 (170-220 MHz)	Low Power (LP)	1 kW	100 m
		Regular (R)	325 kW	150 m
	channels 14-69 (470-806 MHz)	Very Low Power (VLP)	100 W	100 m
		Low Power (LP)	1 kW	100 m
		class A (A)	10 kW	100 m
		class B (B)	100 kW	150 m
		class C (C,N)	1000 kW	300 m
		class D (D)	5000 kW	600 m
Land Mobile	VHF and UHF	Base	125 W	75 m
		Mobile	15.8 W	2 m

Table A-1: Transmitter Characteristics

CLASS OF RECEIVER	CHARACTERISTICS			
	Antenna Height, HR	Emin (dBu)	Max: Interference Level, Emax (dBu)	
			TV POL: VP	TV POL: HP
TV Receiver	10 m	64	34	34.
Base Receiver	75 m	21	41	51
Mobile Receiver	2 m	19	39	49.

Table A-2: Receiver Characteristics

PARAMETERS.	MONTREAL	TORONTO	VANCOUVER	SOURCE
Terrain Irregularity, Δh (m)	115	50	300	MAP
Average Elevation (m)	100	50	200	MAP
Surface Refractivity at Sea Level (N)	310	310	320	ITS
Climate	Continental Temperate	Continental Temperate	Maritime Temperate	ITS
Ground Dielectric Constant	15	10	15	RDRE
Ground Conductivity (S/m)	0.005	0.005	0.005	RDRE

Note: MAP topographical maps

ITS "A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode"

RDRE "Reference Data for Radio Engineers"

Table A-3: Terrain Parameters

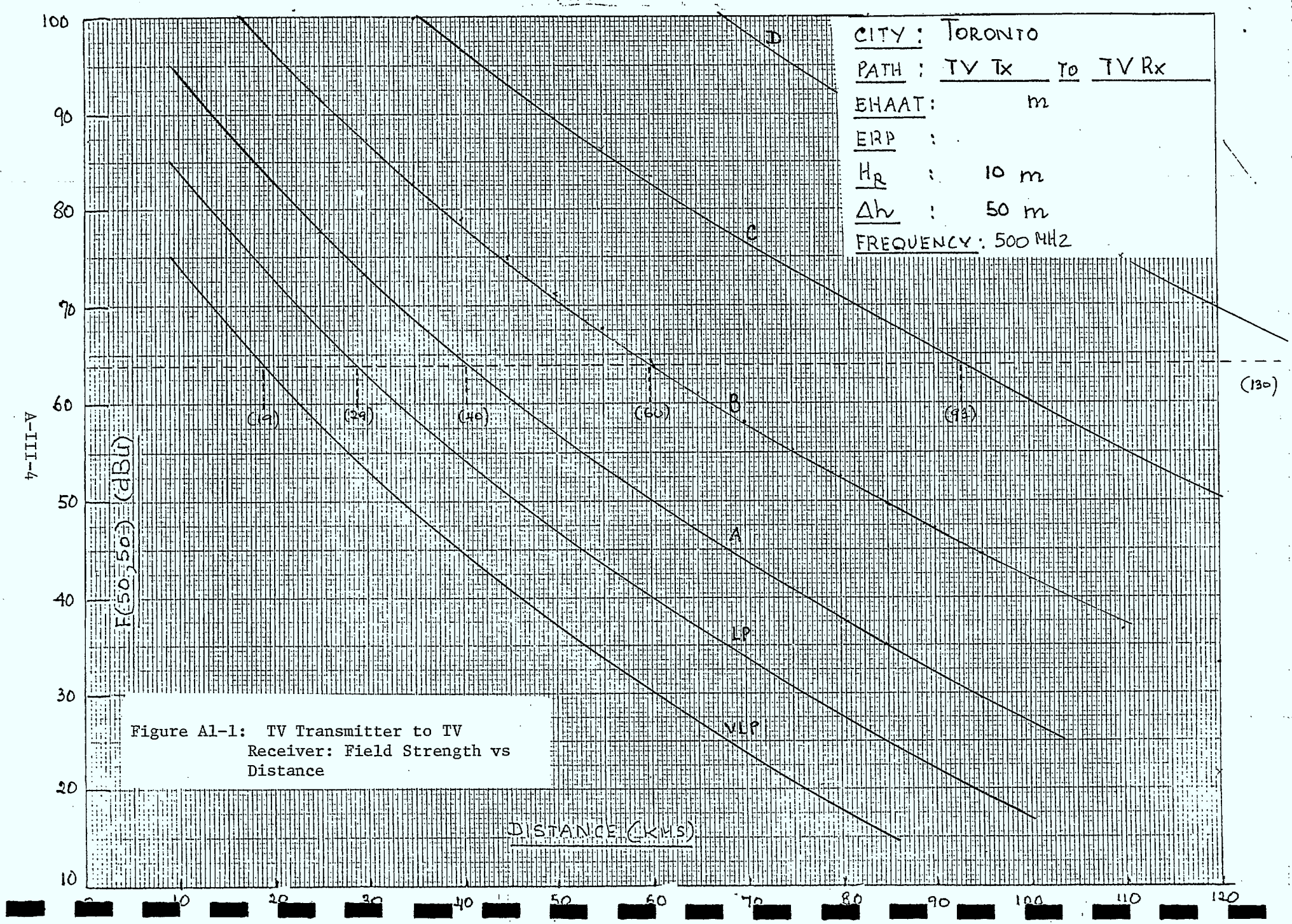

Figure A1-1: TV Transmitter to TV Receiver: Field Strength vs Distance

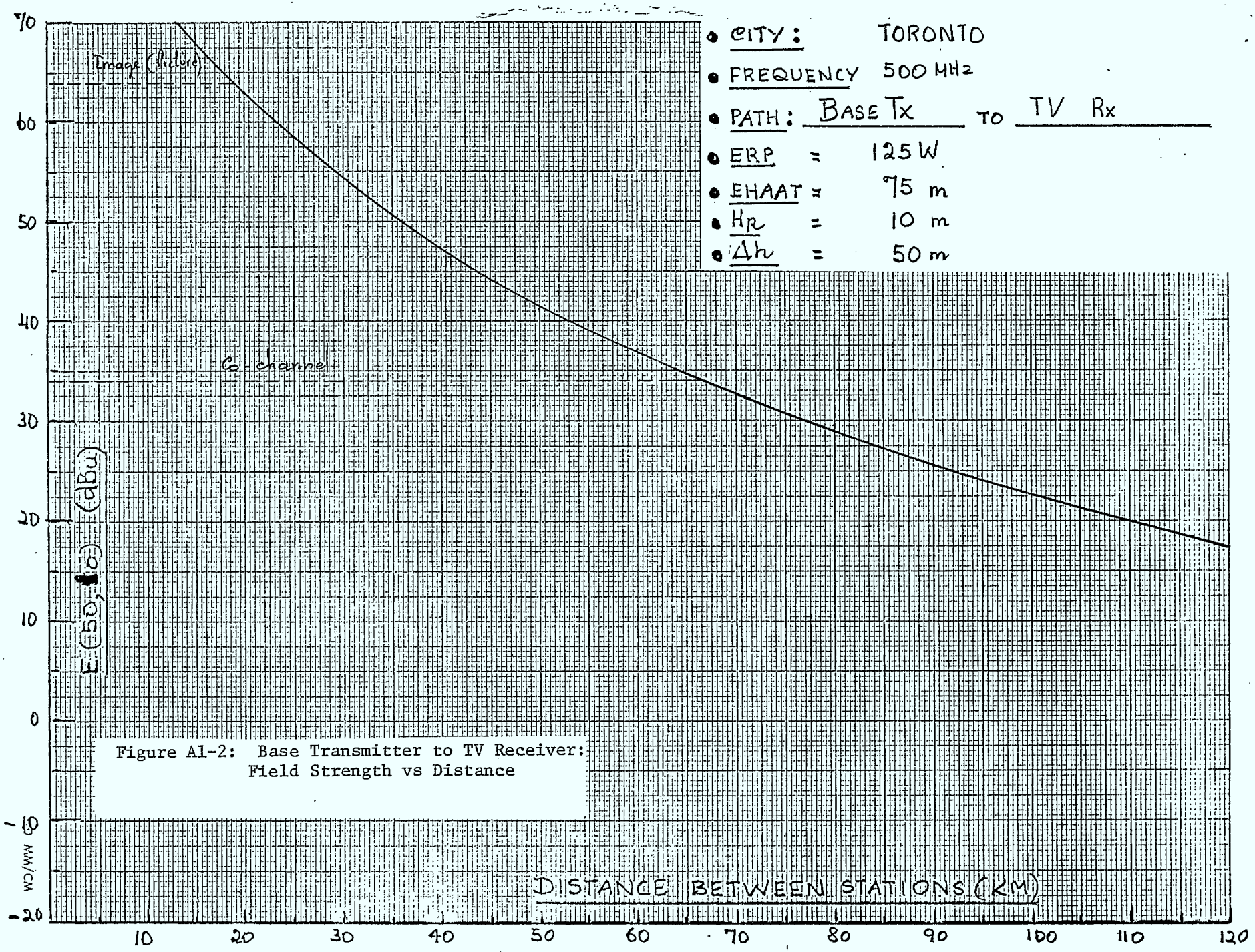

Figure A1-2: Base Transmitter to TV Receiver: Field Strength vs Distance

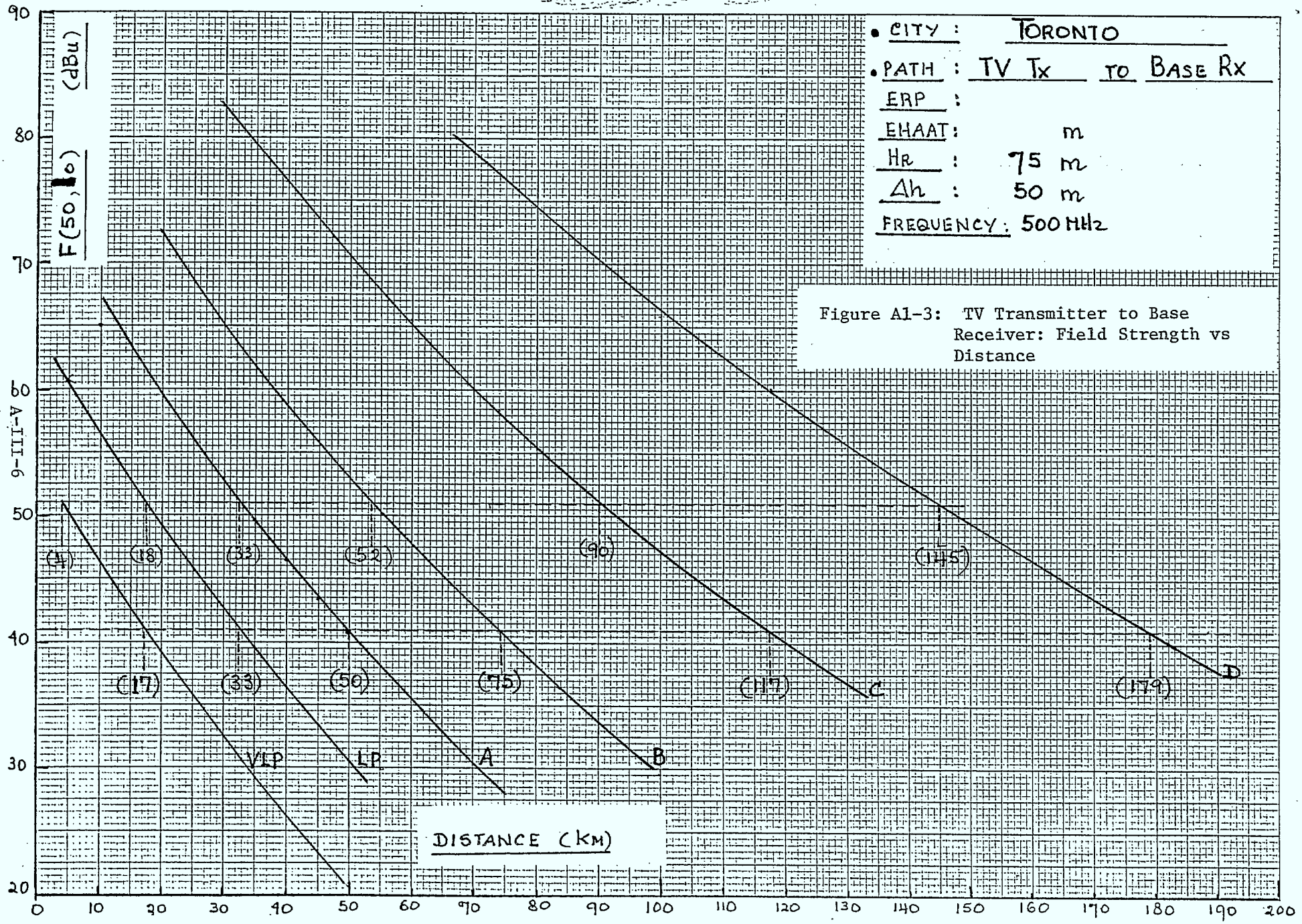

Figure A1-3: TV Transmitter to Base Receiver: Field Strength vs Distance

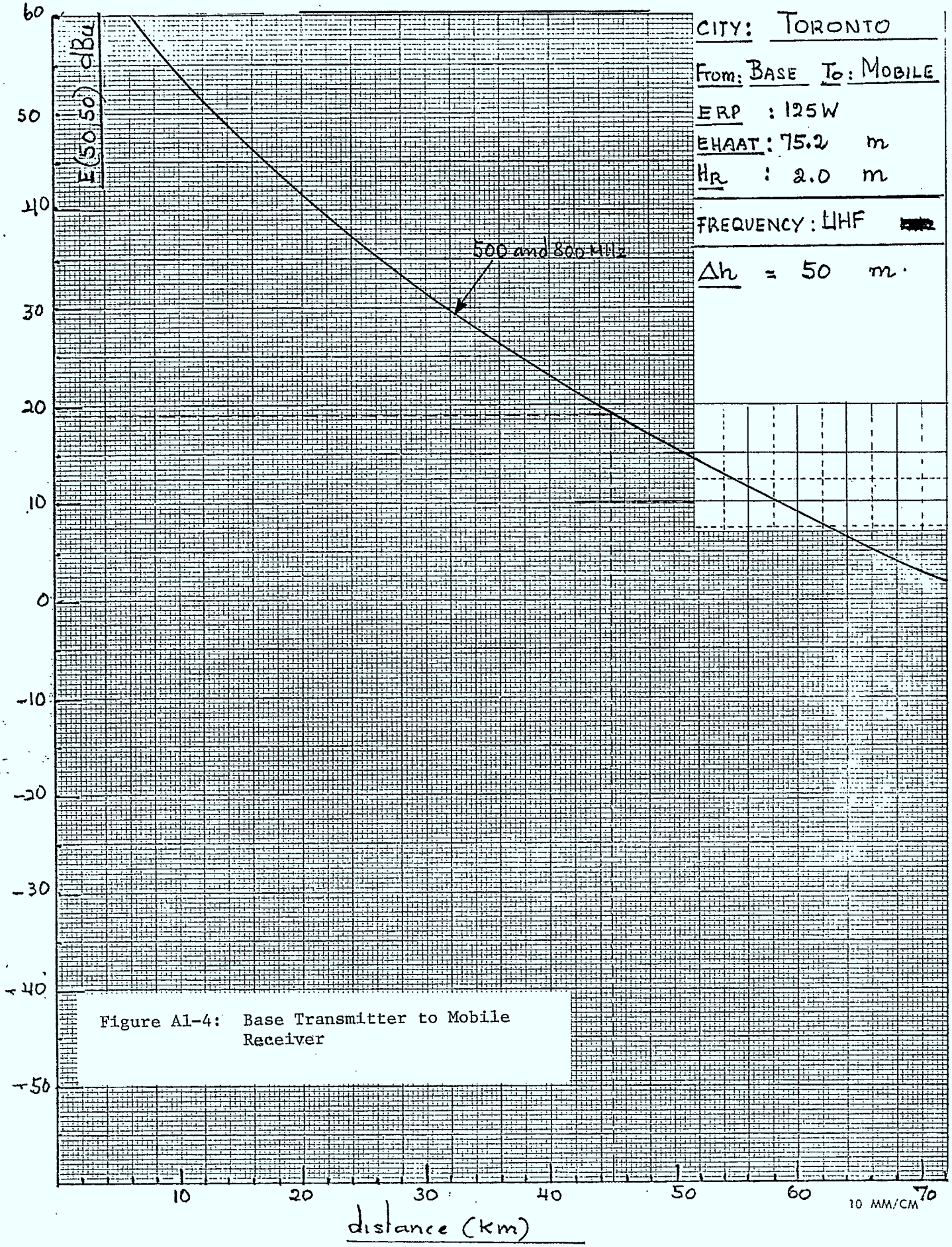

Figure A1-4: Base Transmitter to Mobile Receiver

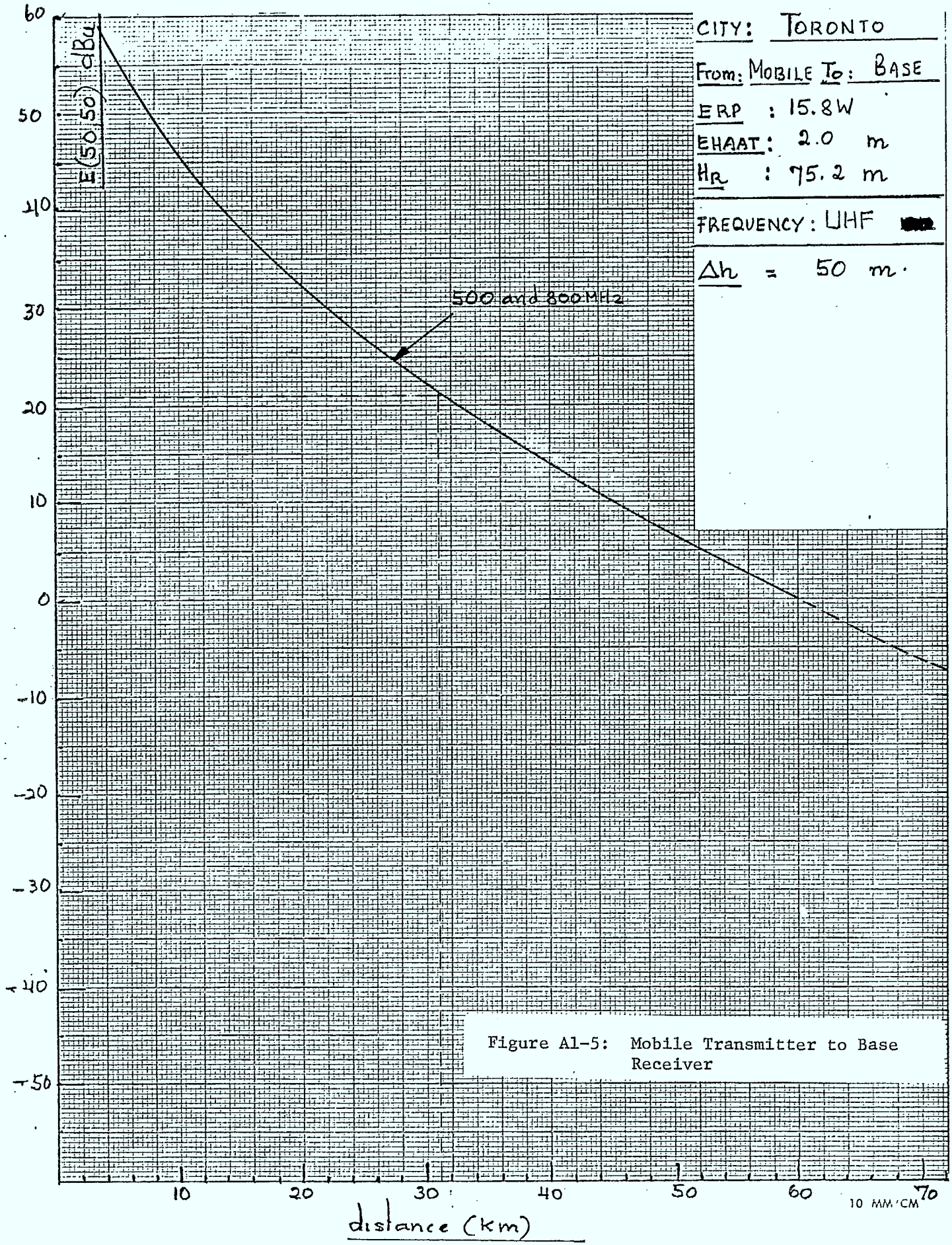

Figure A1-5: Mobile Transmitter to Base Receiver

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

46 1331

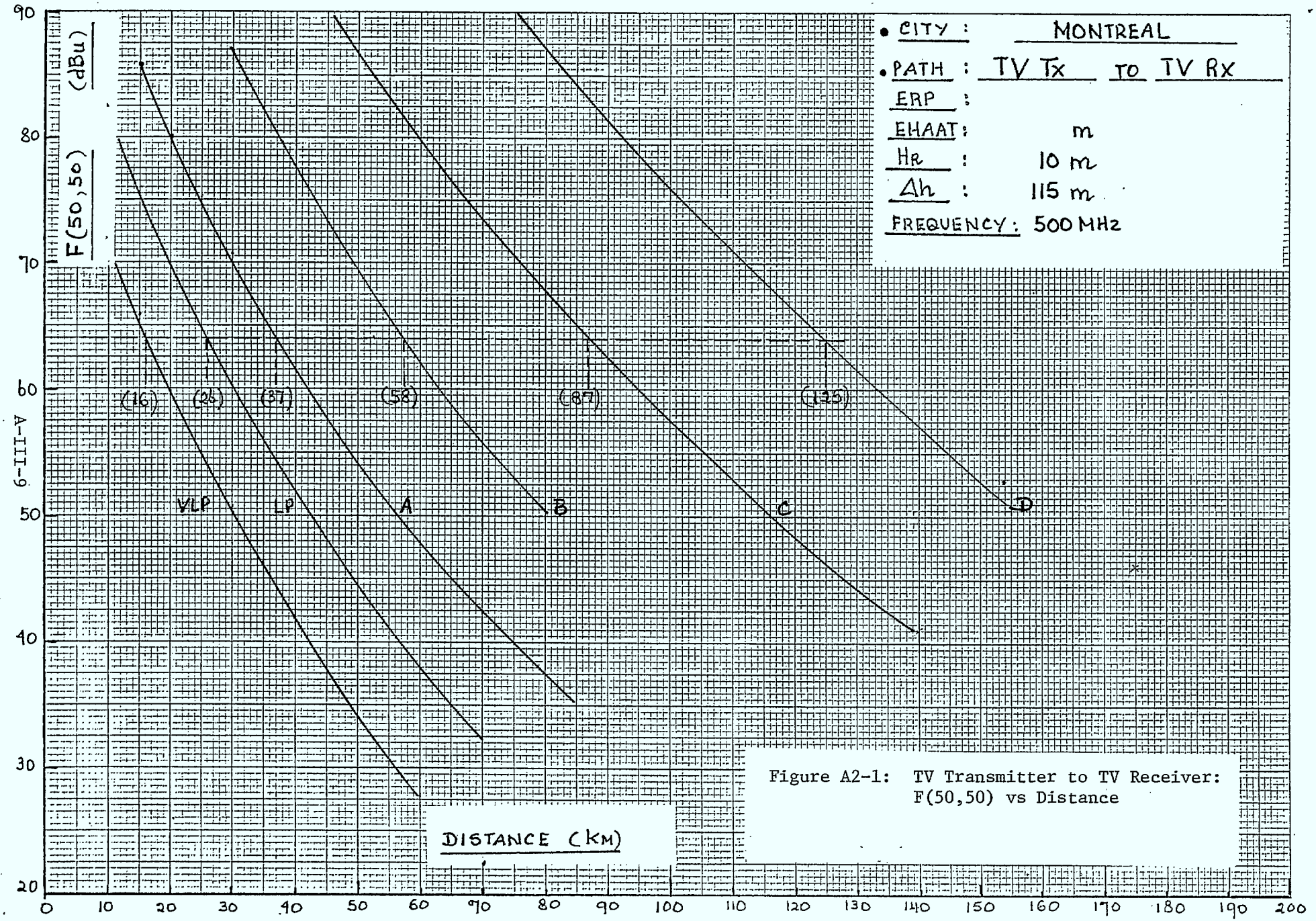

Figure A2-1: TV Transmitter to TV Receiver: F(50,50) vs Distance

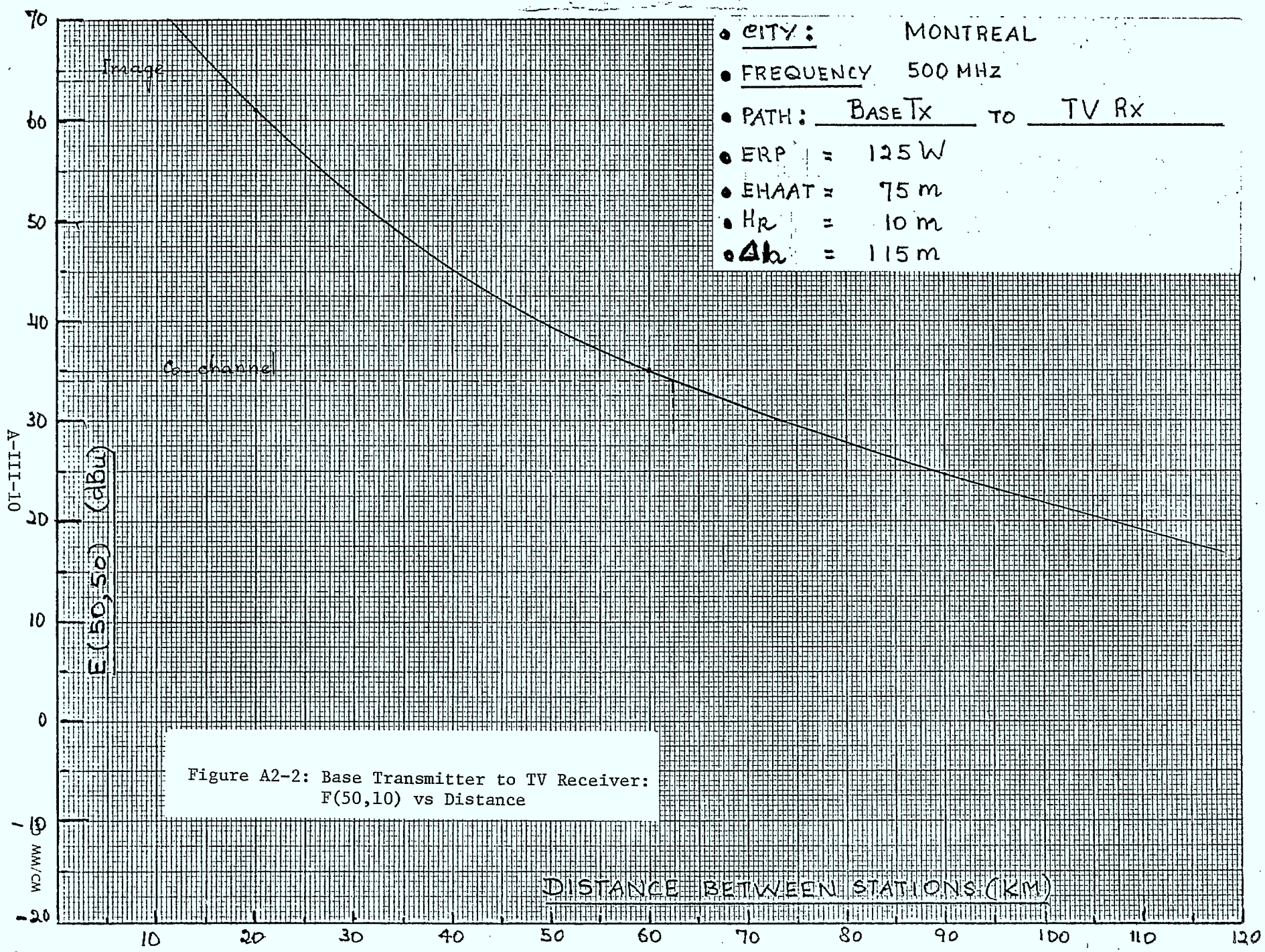

Figure A2-2: Base Transmitter to TV Receiver: F(50,10) vs Distance

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

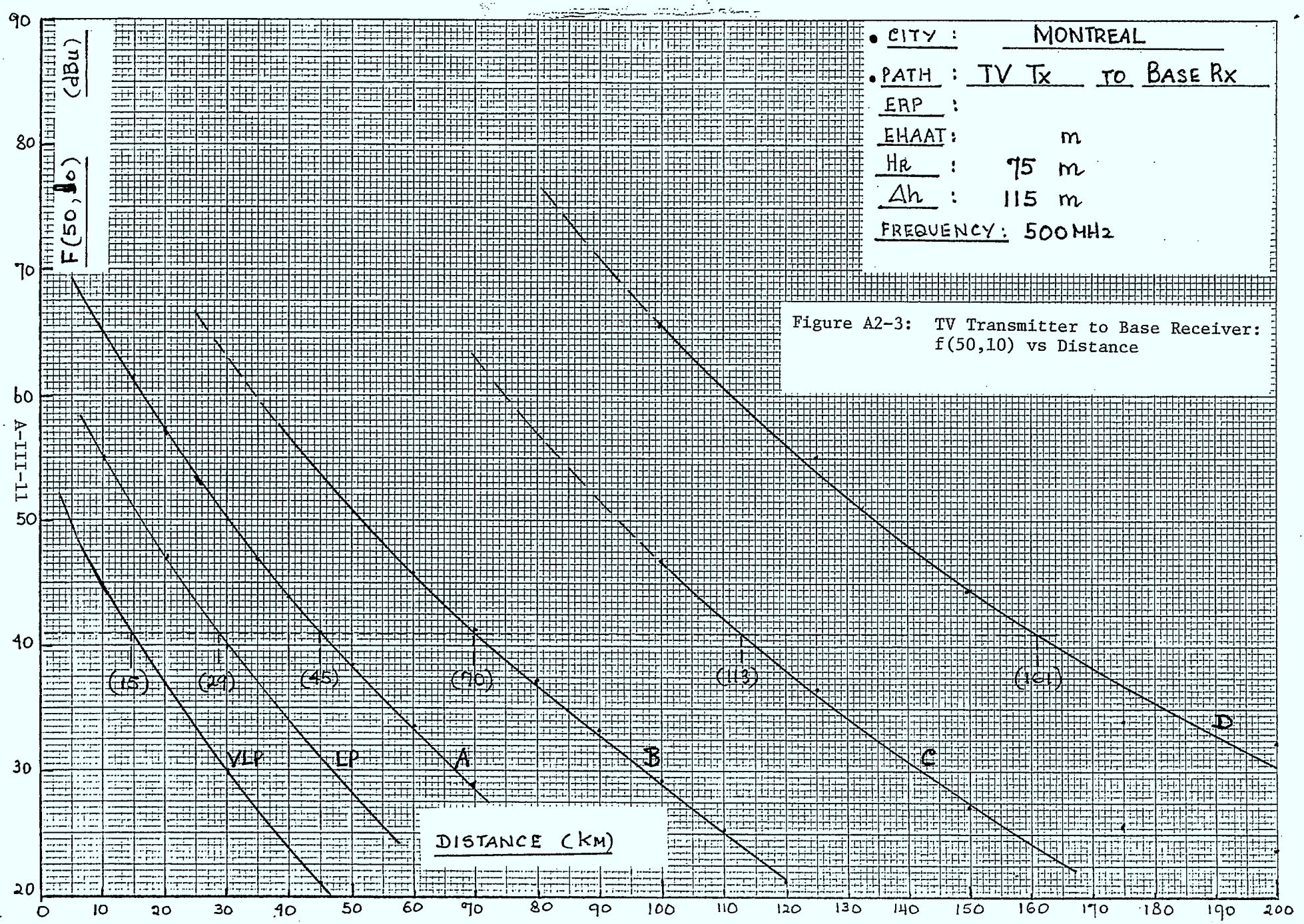

Figure A2-3: TV Transmitter to Base Receiver: f(50,10) vs Distance

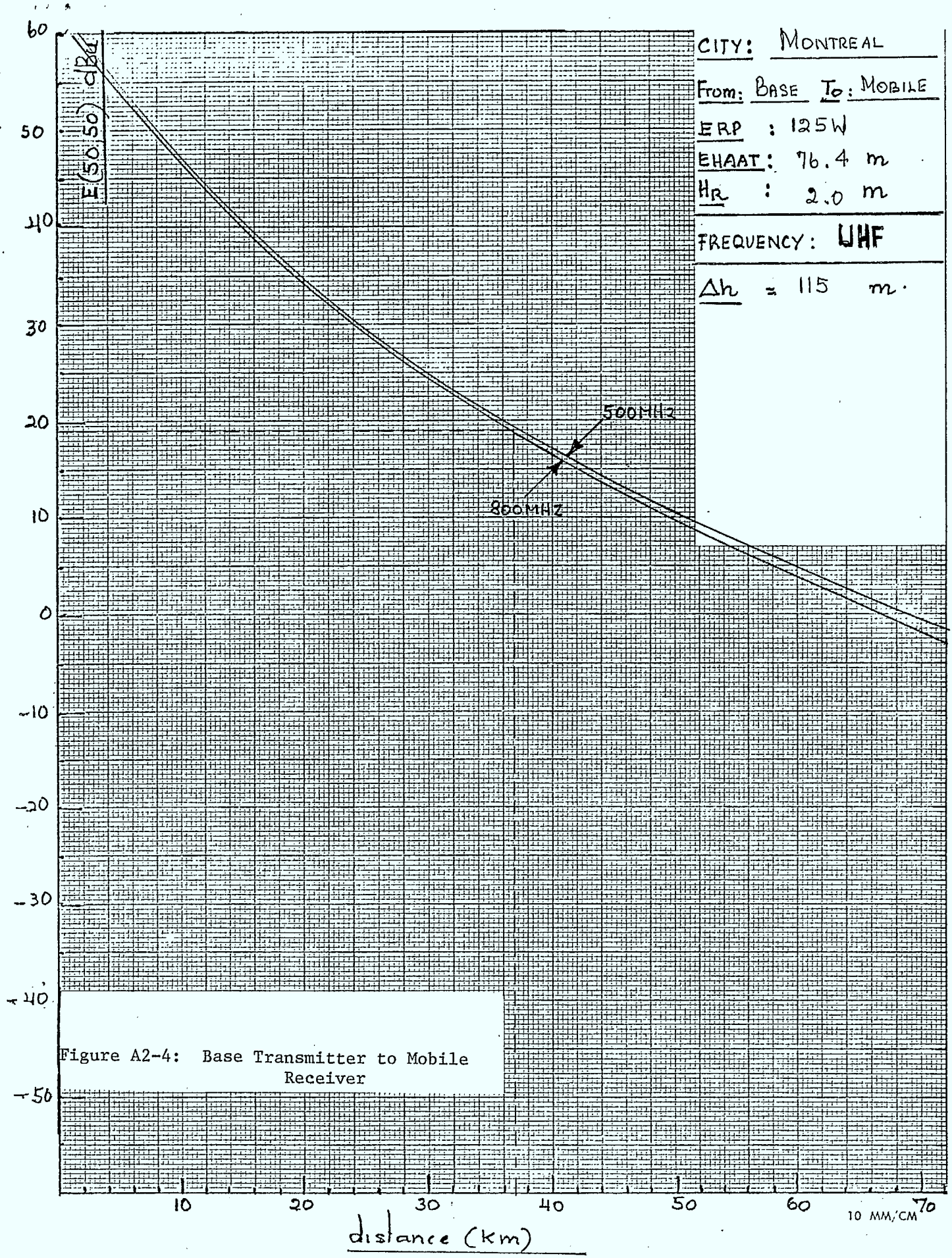

Figure A2-4: Base Transmitter to Mobile Receiver

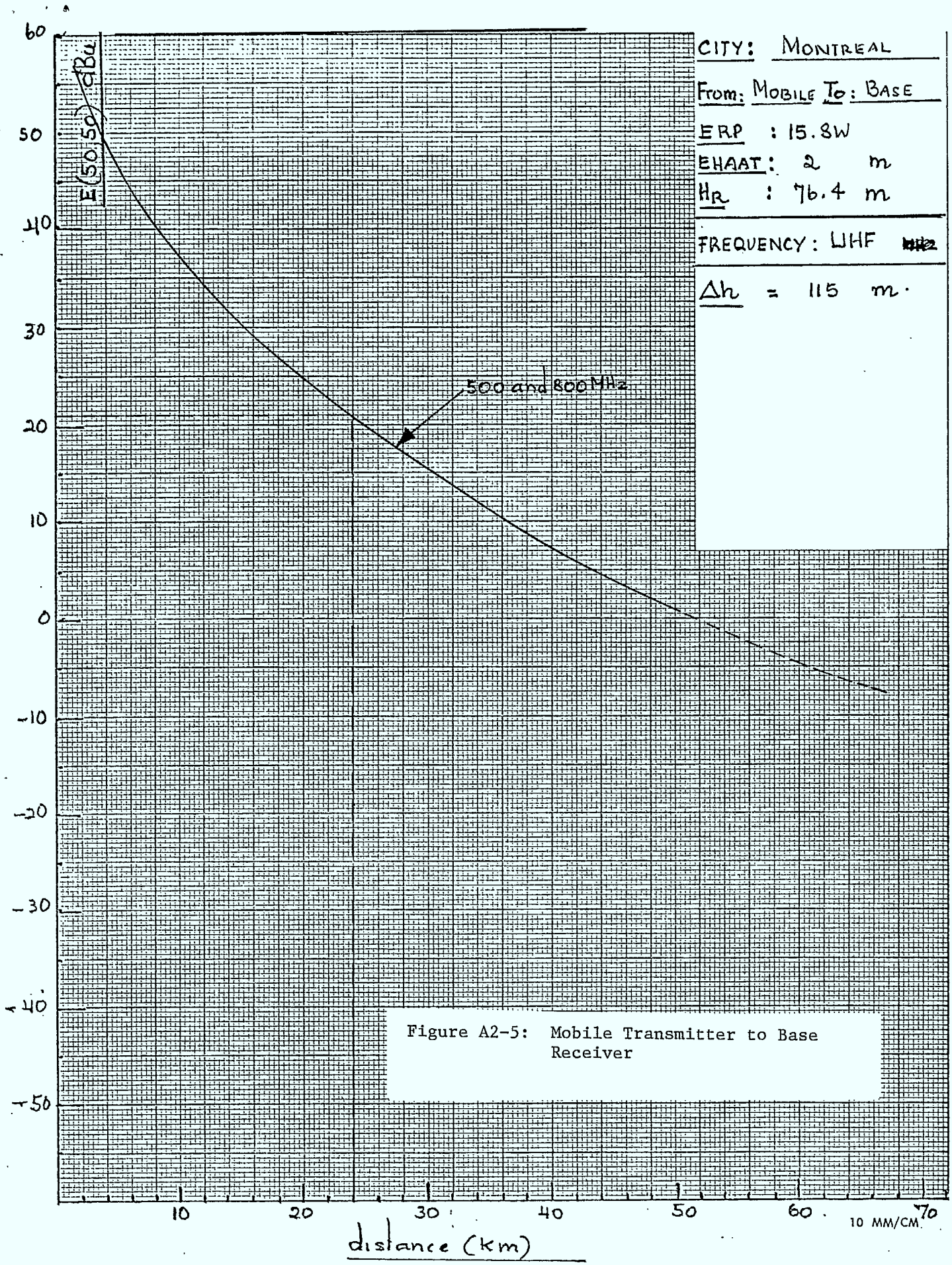

Figure A2-5: Mobile Transmitter to Base Receiver

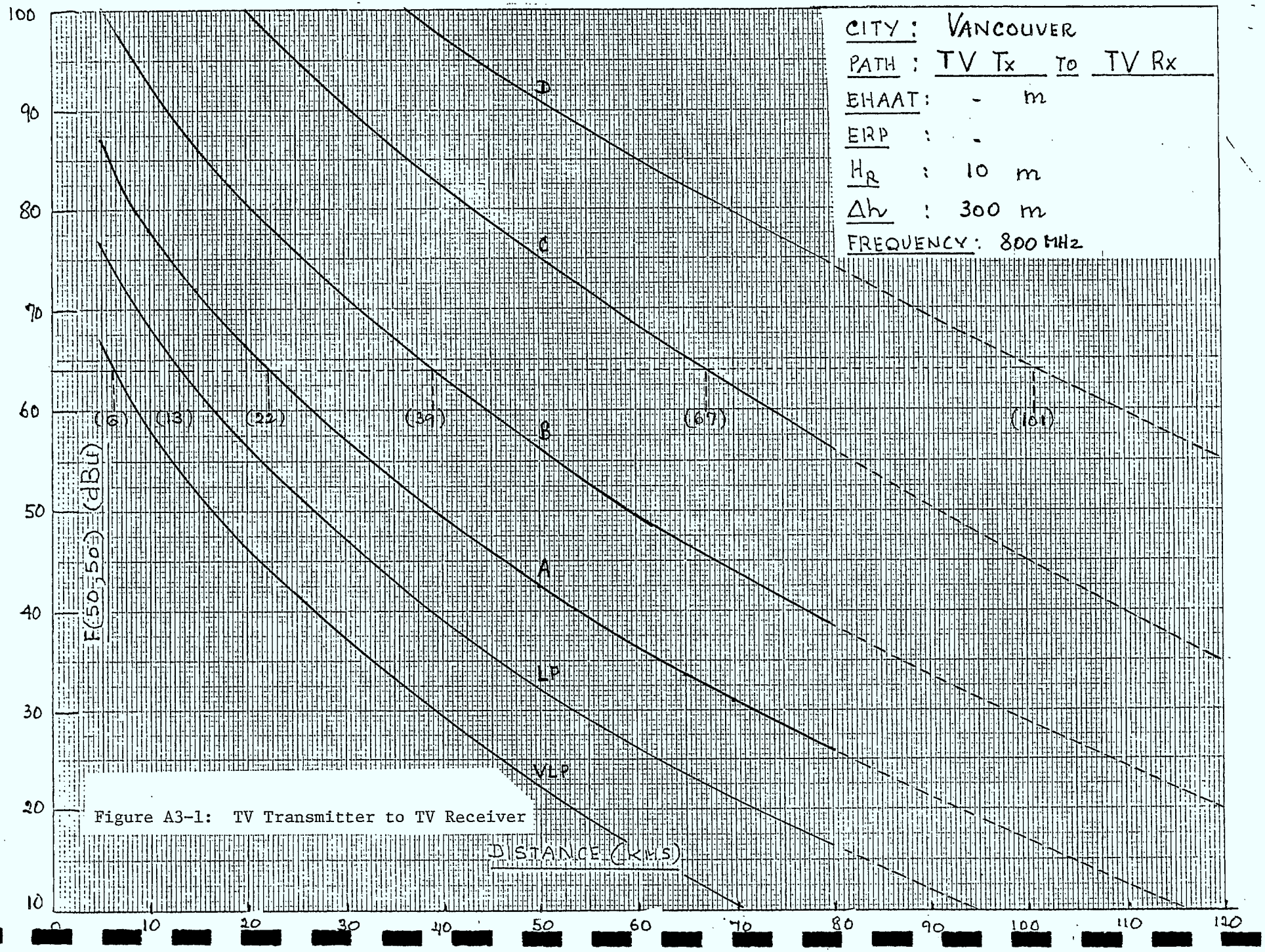

Figure A3-1: TV Transmitter to TV Receiver

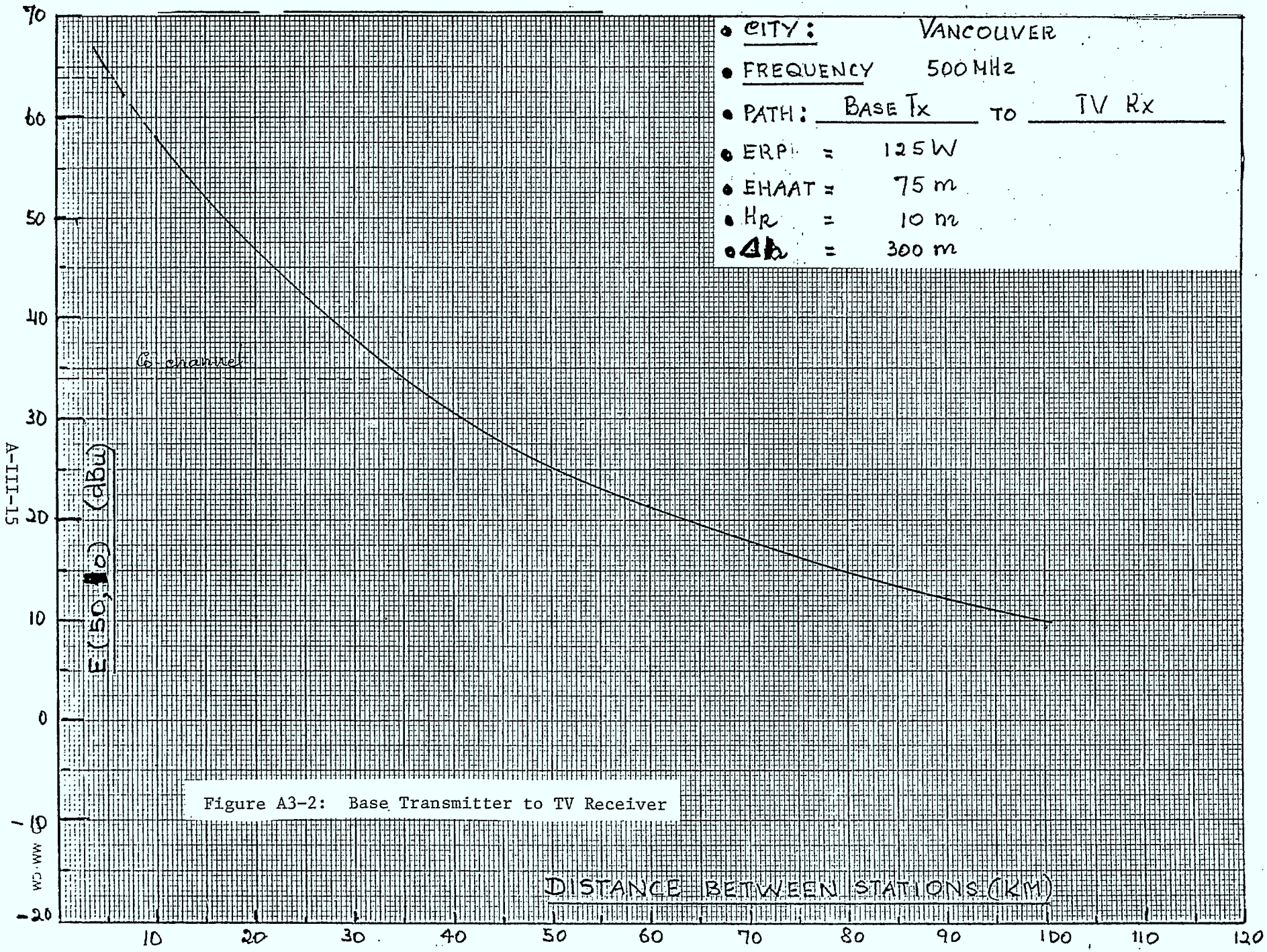

Figure A3-2: Base Transmitter to TV Receiver

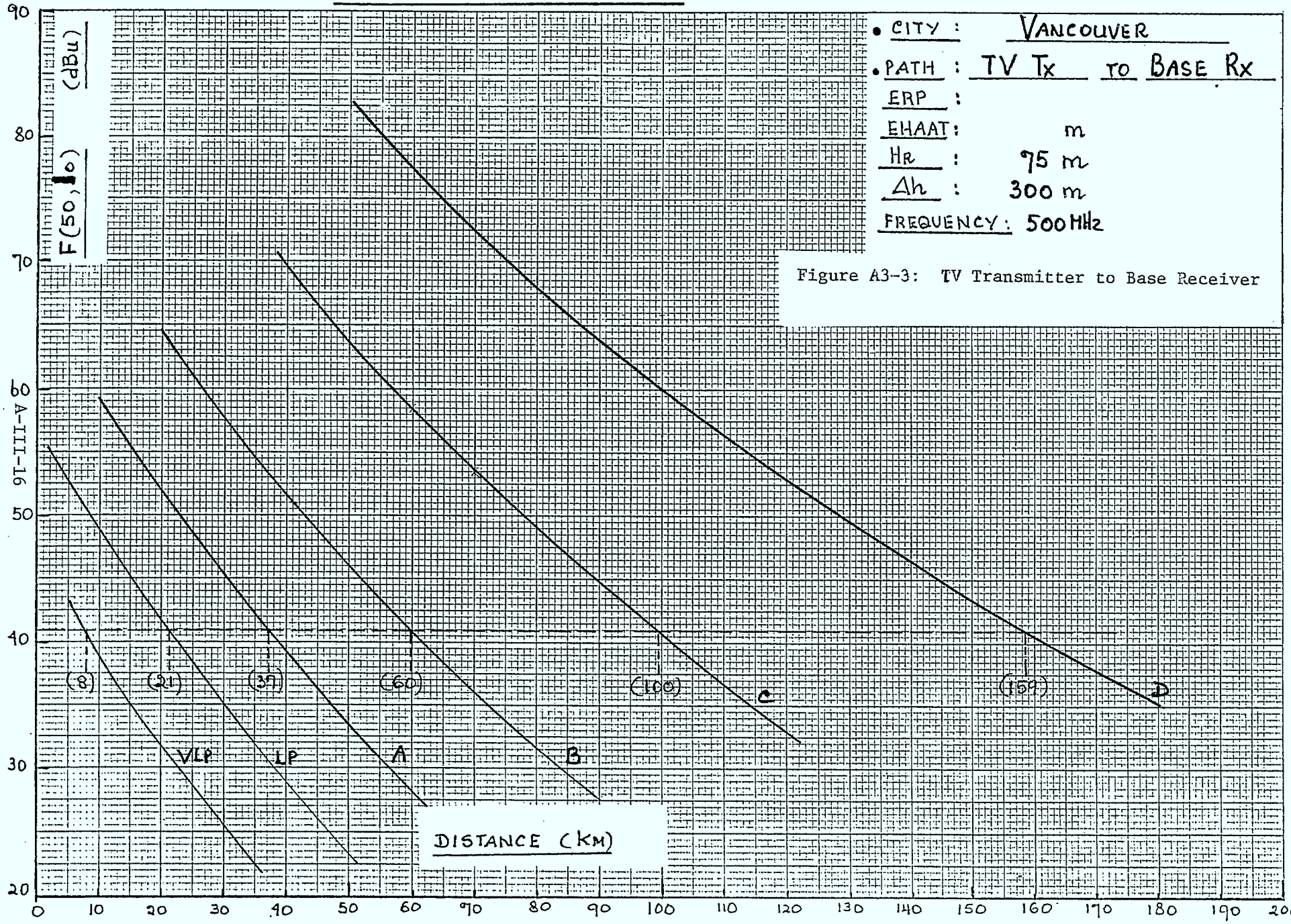

Figure A3-3: TV Transmitter to Base Receiver

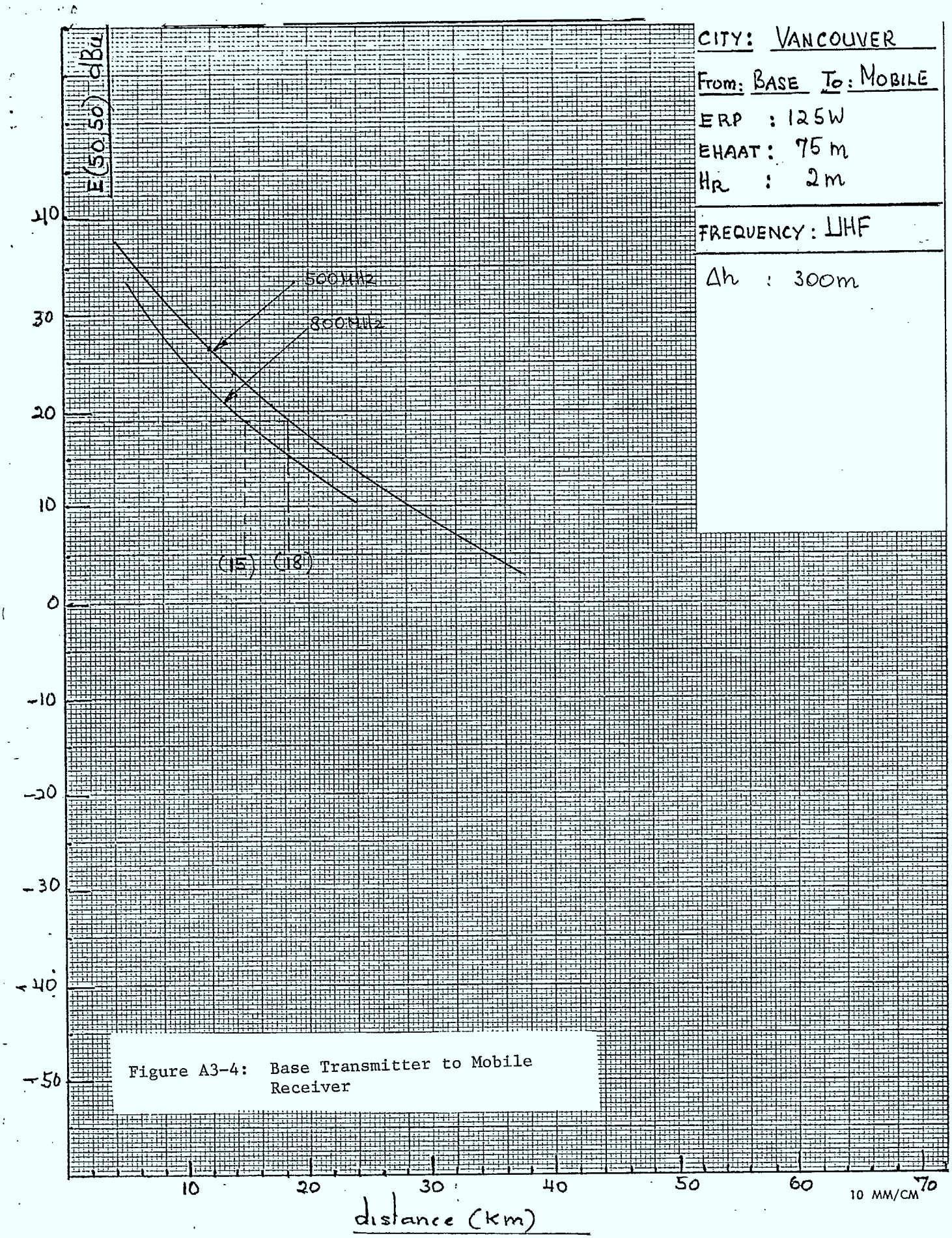

Figure A3-4: Base Transmitter to Mobile Receiver

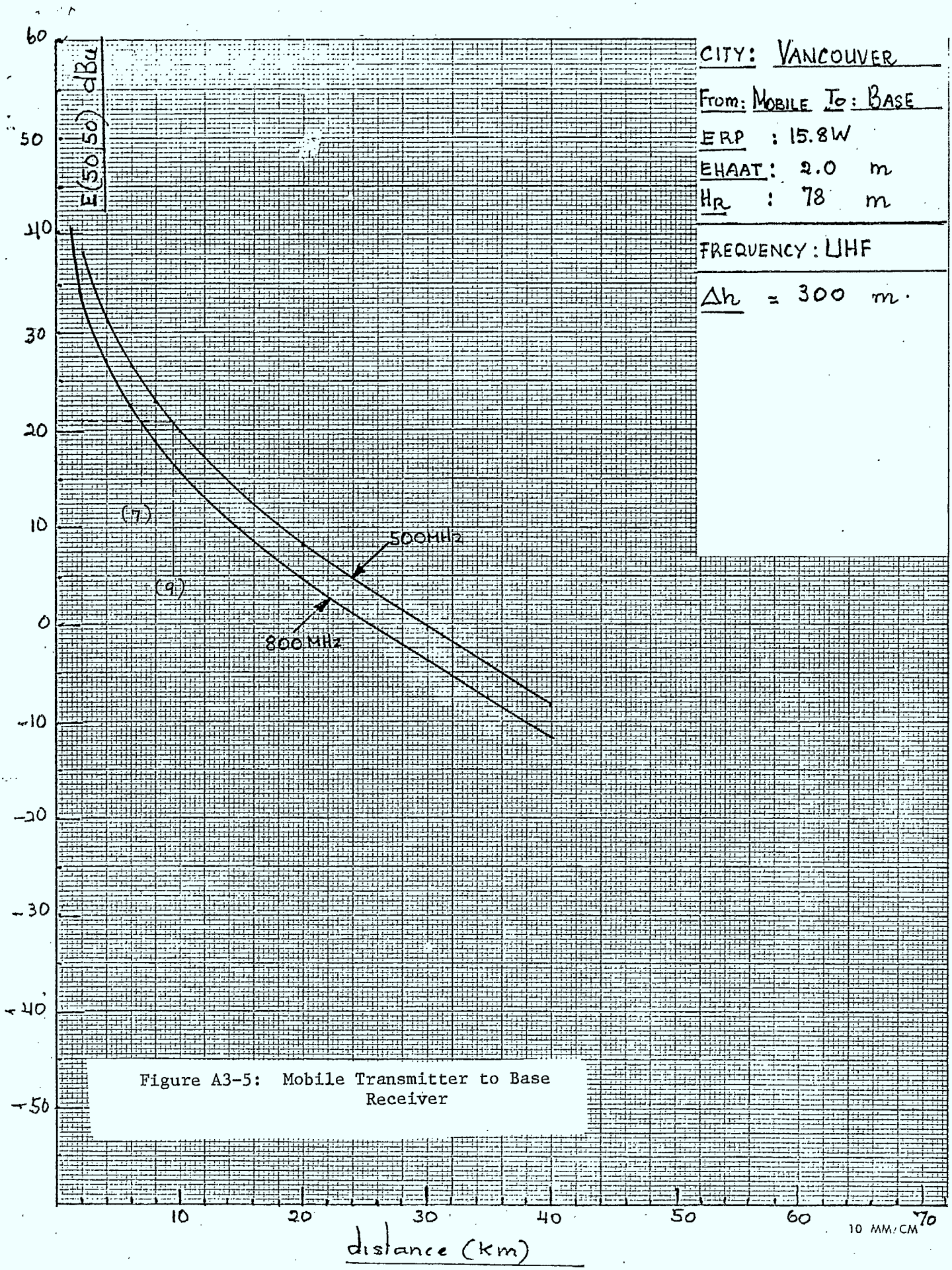

Figure A3-5: Mobile Transmitter to Base Receiver

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--Feasibility and criteria for land mobile and TV broadcast spectrum sharing

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