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CANADIAN PROPOSALS

PROPOSED TECHNICAL BASIS FOR THE FIRST SESSION OF THE REGIONAL ADMINISTRATIVE MF BROADCASTING CONFERENCE (REGION 2)

OTTAWA, CANADA. OCTOBER 1979

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Introduction

On August 18, 1979, the Department of Communications published a public notice in the Canada Gazette (Notice No. DGTR-018-79) requesting comments from all interested parties for the preparation of the Canadian proposals for the Regional Administrative MF Broadcasting Conference (Region 2) which is going to take place in Buenos Aires (Argentina) in March 1980.

The Department, after considering the comments received, has prepared the Canadian proposals based on Annex D of the Final Report of the Fifth Meeting of the Working Group of Radiobroadcasting (CITEL Permanent Technical Committee II: Radiobroadcasting) to which the Canada Gazette notice was referring. The Canadian proposals were forwarded to the International Telecommunication Union secretariat in Geneva on October 15, 1979. They will be circulated to all Region 2 (The Americas) administrations.

The Canadian proposals were prepared in order to protect the Canadian AM broadcasting system as it now stands while at the same time integrating some changes which would permit the entry into a regional frequency assignment plan of enough new stations to meet our requirements for the coming fifteen to twenty years.

In December, we should start receiving other Region 2 countries' proposals. After full study, Canadian positions on contentious issues will be developed in order to minimize incompatibilities between our proposals and those of other countries while protecting the Canadian interests in the MF band (535 to 1605 KHZ).

The format of the attached proposals is based on Annex D of the Final Report of the Fifth Meeting of the Working Group on Radiobroadcasting. (CITEL Permanent Technical Committee II: Radiobroadcasting). RCBC-5

Deletions to the Annex D text are indicated by dashes covering the deleted words.

New text is indicated by words underlined.

Reasons are indicated for all changes to the original text.

TABLE OF CONTENTS

Page

I - DEFINITIONS AND SYMBOLS..... 1

II - TECHNICAL STANDARDS AND CRITERIA FOR USE IN REGIONAL PLANNING... 4

1. Class of Emission..... 4
2. Bandwidth of Emission..... 4
3. Channel Separation..... 4
4. Frequency Tolerance..... 4
5. Protection Ratios..... 4
6. Application of Protection Criteria..... 5
7. Maximum Station Power..... 5A
8. Nominal Usable Field Strength..... 6
9. Calculation of Ground-Wave Field Strength..... 7
10. Calculation of Reflected Wave Field Strength.....32

III- FORMAT FOR NOTIFYING MF BROADCASTING STATIONS.....48

PROPOSED TECHNICAL BASIS FOR THE FIRST SESSION OF THE

REGIONAL ADMINISTRATIVE MF BROADCASTING

CONFERENCE (REGION 2)

I - DEFINITIONS AND SYMBOLS

1 DEFINITIONS

In addition to the definitions given in the Radio Regulations the following apply to the Plan for Region 2:

1.1 Channel (in AM broadcasting): Part of the frequency spectrum, the width of which is equal to the necessary bandwidth of the AM broadcasting emission, and which is characterized by the nominal value of the carrier frequency.

1.2 Class A station: A station intended to provide coverage over ~~protected against interference so that it can cover~~ extensive primary and secondary service areas and which is protected against interference accordingly.

Reason: Editorial changes to emphasize the concept of coverage in relation to interference.

1.3 Class B station: A station intended to provide coverage over ~~protected against interference so that it can cover~~ one or more population centres, and the rural areas contiguous to them, located in its primary service area and which is protected against interference accordingly.

Reason: See 1.2

1.4 Class C station: A station intended to provide coverage over ~~protected against interference so that it can cover~~ a city or town and the contiguous suburban areas, located in its primary service area and which is protected against interference accordingly.

Reason: See 1.2

1.5 Station power: unmodulated power supplied to the antenna system.

1.6 Intermodulation products: Spurious emission generated by the modulation of each component of a complex wave by the effect of the other components, producing waves whose frequencies are equal to the sums and differences of the multiples of the components of the original complex wave.

1.7 Harmonic emission: (of a radio-electrical emission): Spurious emission in multiple frequencies of the frequency band occupied by an emission.

1.8 Parasitic emission: (of a radio-electrical emission): Spurious emission generated accidentally in frequencies that are both independent from the carrier, characteristic or harmonic frequencies and independent of the frequencies of the oscillations in the carrier or characteristic frequencies.

1.9 Characteristic field strength: The field strength in the horizontal plane of an unattenuated ground-wave signal radiated by an omnidirectional antenna with an homogeneous ground system when fed with 1 kilowatt, at a reference distance of one kilometre.

1.10 Protected contour: Continuous line that determines the areas of primary or secondary service that is protected from objectionable interference.

1.11 Radio-Frequency protection ratio: Ratio of the desired signal to the radio-frequency interference signal which, in well-defined conditions, makes it possible to obtain the audio-frequency protection ratio at the output of a receiver. These specified conditions include various parameters such as the frequency separation between the desired carrier and the interference, the emission characteristics (type and percent of modulation, etc.), levels of carrier input and output, the characteristics of the receiver (selectivity, sensitivity to intermodulation, etc.).

1.12 Nominal usable field strength (Enom): Minimum conventional value of field strength required to provide satisfactory reception, under specified conditions, in the presence of natural noise, industrial noise and interference from other transmitters. The value of nominal usable field strength is that employed as reference for planning.

1.13 Usable field strength (Eu): Minimum value of the field strength required to provide satisfactory reception, under specified conditions in the presence of natural noise, industrial noise, and interference in a real situation (or resulting from a frequency plan).

1.14 Ground-wave signal: Radiated signal that is propagated along the surface of the earth or near it and that has not been reflected by the ionosphere.

1.15 Reflected wave (sky-wave) signal: Radiated signal that has been reflected by the inosphere.

1.16 Primary service area: Service area delimited by the contour within which the calculated level of the ground-wave field strength is equal to or greater than the nominal usable field strength.

1.17 Secondary service area: Service area delimited by the contour within which the calculated level of field strength from the reflected wave is equal to or greater than the nominal usable field strength. The signal is subject to intermittent variations in the field strength.

1.18 Objectionable interference: Interference caused by a signal exceeding the maximum permissible field strength at and within the protected contour according to the terms of this Agreement.

1.19 Daytime operation: Operation between the times of local sunrise and local sunset.

1.20 Night-time operation: Operation between the times of local sunset and local sunrise.

1.21 Reflected wave signal, 10% of the time: The value of a reflected wave signal that is not exceeded more than 10% of the period of observation.

1.22 Reflected wave signal, 50% of the time: The value of a reflected wave signal that is not exceeded more than 50% of the period of observation.

1.23 Synchronous operation: The operation of two or more broadcasting transmitters whose carrier frequencies are identical (or differ only slightly, usually by a fraction of a hertz) and which broadcast the same programme simultaneously.

2. SYMBOLS

Hz	hertz
kHz	kilohertz
W	watt
kW	kilowatt
~~V/m~~	~~volt/metre~~
mV/m	millivolt/metre
uV/m	microvolt/metre
dB	decibel
dBu	decibels above 1 uV/m
mS/m	millisiemens/metre

Reason: to conform with use in text.

II - TECHNICAL STANDARDS AND CRITERIA FOR USE IN REGIONAL PLANNING

1. CLASS OF EMISSION

The Plan will be established for a system with double sideband amplitude modulation with full carrier (A3).

Note 1: Classes of emission other than A3, for instance to accommodate stereophonic systems, may also be used on the conditions that the energy level outside the necessary bandwidth does not exceed that normally expected in an A3 emission, and that ~~it~~ the emission be receivable ~~comply with the condition of being able to be received~~ by receivers with envelope detectors without increasing appreciably the level of distortion.

Reason: To clarify the meaning of the Note.

~~Note 2: Some delegations reserved their position regarding the permission to use systems other than A3. The agreement of all the administrations concerned should be obtained before a class of emission other than A3 is brought into operation.~~

Reason: Note 1 adequately covers the Canadian position

2. BANDWIDTH OF EMISSION

The Plan will be drawn for a necessary bandwidth of 10 kHz. However, the occupied bandwidth of an emission may be increased by agreement between an administration wishing to do so and another administration whose stations, operating in accordance with the Plan, would thereby be adversely affected ~~which considers that such increase could adversely affect its emissions which are in accordance with the Plan~~.

Reason: To clarify the meaning of the Section

3. CHANNEL SEPARATION: 10 kHz

~~Note: As an alternative, 9 kHz channel separation is being studied. Pending completion of these studies, the USA reserves its position on channel separation.~~

Reason: Canada supports retention of 10 kHz channel separation

4. FREQUENCY TOLERANCE: ±10 Hz

5. PROTECTION RATIOS

5.1 Co-channel Protection Ratio

The Plan will be based on a co-channel protection ratio of 26 dB.

5.2 Adjacent Channel Protection Ratio

- protection ratio for the first adjacent channel: 0 dB
- protection ratio for the second adjacent channel: -29.5 dB

5.3 Protection Ratio for Stations Belonging to a Synchronized Network

- the recommended value is 8 dB.

6. APPLICATION OF PROTECTION CRITERIA

6.0 Value of Protected Contours

Inside the national boundary of a country, the protected contour shall be determined by using the pertinent value of nominal usable field strength as specified in Section 8.

Reason: To relate the term "protected contour" to the pertinent value of the nominal usable field strength.

6.1 Co-channel Protection

The protection ratio shall be applied at the protected contours from interfering daytime ground-wave and night-time reflected wave signals.

In the case of daytime ground-wave interference to all classes of stations, and in the case of night-time reflected wave protection to Class A stations, the protection ratio shall be applied separately to each interfering signal; the presence of interference from existing stations in excess of the amount allowed will not reduce the requirement for limitation of interference from proposed stations.

Reason: To further define other co-channel protection requirements in view of Canada's proposal for night-time protection of class B and class C stations, as per Section 8 Note 1, and Section 10.3.

6.2 Adjacent Channel Protection

a) ~~The protection ratios as specified in Section 5.2 shall be applied at the protected daytime contour from interfering daytime ground-wave signals.~~

Reason: Covered in amended Section 6.2 b)

b) ~~For Class A channels.~~ The protected ratios ~~for the first adjacent channel~~ as specified in Section 5.2 shall be applied only from interfering ground-wave signals at the 500 uV/m ground-wave contour, ~~from interfering ground-wave signals~~ or as specified in Section 6.3, whichever is applicable.

Reason: To apply adjacent channel protection to all classes of stations and to be consistent with proposal for border protection in new Section 6.3

~~c) No broadcasting station will be assigned on or within the 0.5 mV/m contour of a broadcasting station in another country with a frequency separation of 20 kHz, unless higher values are established through bilateral or multilateral agreements.~~

Reason: Partly covered in 6.2 d) and not consistent with proposed Section 6.3.

d) No broadcasting station will be assigned for operation with a separation of 30 kHz or less from a broadcasting station in another country if the areas enclosed by the 25 mV/m ground-wave contours of the two broadcasting stations overlap.

Reason: To prevent intermodulation interference with stations on first, second and third adjacent channels.

6.3 Border Protection

Where the protected contour extends beyond the boundary of the country in which the station is located, the calculated field strength along the boundary shall be protected on the basis of the ratios specified in Sections 5.1 and 5.2. For the purpose of this Section, the boundary of a country shall be deemed to encompass only its land area. Where a country requires protection outside the boundary of its country this shall be the subject of bilateral or multilateral agreements with each of the affected countries.

Reason: To create more channels and therefore make a more efficient use of the spectrum.

7. ~~LIMITATION OF~~ MAXIMUM STATION POWER ~~OF A STATION~~

7.1 Class A: The maximum station power shall be 50 kW ~~200 kW~~. However, ~~for new~~ existing stations with station power exceeding 50 kW ~~it is recommended that the maximum limit be 50 kW~~ may retain their existing power up to a maximum of 200 kW.

~~Note: With regard to the proposal that the maximum station power for Class A stations be limited to 200 kW, the United States reserves its position pending further study.~~

Reason: To clarify the intent of the Working Group decision which Canada supports.

7.2 Class B: The maximum station power shall be 50 kW.

~~Note: Some administrations proposed a maximum limit of 10 kW during night-time for stations using non-directional arrays.~~

Reason: Canada favours similar treatment for all types of antenna systems.

7.3 Class C: The maximum station power shall be 1 kW during daytime. ~~except~~ In areas of low conductivity or high atmospheric noise ~~where~~ the limit ~~will~~ shall be 5 kW during the day provided the protection criteria in ~~paragraphs~~ Sections 5 and 6 are met. The maximum station power shall be 1 kW during night-time.

Reason: Editorial

8. NOMINAL USABLE FIELD STRENGTH

The values recommended for this parameter, for planning purposes, will depend on the class of station as follows:

8.1 Class A Stations

- daytime operation: 100 uV/m ground-wave
- night-time operation: 500 uV/m ground-wave or 500 uV/m reflected wave 50% of the time whichever is at the greatest distance.

8.2 Class B Stations

- daytime operation: 500 uV/m ground-wave
- night-time operation: 2500 uV/m ground-wave

8.3 Class C Stations

- daytime operation: 500 uV/m ground-wave
- night-time operation: 4000 uV/m ground-wave

Note 1: ~~Some delegations supported the viewpoint that~~ After the effective date of the Plan, the protected contour during night-time operation for Class B and C stations ~~should~~ shall be: ~~T~~the higher of the 2500 and 4000 uV/m ground-wave contour respectively, or the ground-wave contour corresponding to the RSS night-time limitation of the station as defined in ~~paragraph~~ Section 10.

Reason: To permit optimum saturation of the Plan after its effective date.

Note 2: Regions subject to high radioelectric noise, such as in the tropical zone and other areas affected by adverse meteorological and radioelectric conditions, could adopt other values of usable field strength calculated in accordance with CCIR recommendations. The tropical zone is defined in Radio Regulations 135 and 136.

~~Note 3: The Working Group has so far not reached a consensus regarding the time percentage to be used for the reflected wave signal. The delegations from Argentina, Brazil, Colombia, Ecuador and Paraguay support the use of a 50% time value for the purpose of calculation, whereas, the Canadian, United States and Mexican delegations support the use of a 10% time value. A proposed alternative which, however, needs further study, is the adoption of a 50% time value for non-directional systems and of 10% when directional antennas are used to assure protection for stations of Administrations which signed the Agreement.~~

Reason: Covered by changes in Sections 10.2 c) and 10.3.

9. CALCULATION OF GROUND-WAVE FIELD STRENGTH

9.1 Charts Used

Electric field strength values for ground-wave propagation are obtained from the curves in Figures 9.1 to 9.20 (see Note 1).

The vertical component of the electric field strength for a homogeneous path is represented in these figures as a function of distance, for various values of ground conductivity.

The distance in kilometres is shown on a logarithmic scale on the abscissa ~~axis~~. The electric field strength is shown, on a linear scale on the ordinate ~~axis~~, in decibels above 1 uV/m. There is also, on the right hand side of each graph, a logarithmic scale ranging from 0.001 to 100 mV/m. Graphs are standardized for a characteristic field strength of 100 mV/m. ~~at 1 km~~.

For omnidirectional antenna systems having a different characteristic field, corrections must be made according to the following formula:

$$E = E_o \times \frac{E_c}{100} \times \sqrt{P}$$

~~where~~ ~~E = resulting electric field strength~~

~~E_o = electric field strength read from the graphs~~

~~E_c = characteristic field strength in mV/m at 1 km~~

~~P = station power in kw~~

For directional antenna systems, the correction must be made according to the following formula:

$$E = E_o \times \frac{E_R}{100}$$

where E = resulting electric field strength

E_o = electric field strength read from figures 9.1 to 9.20

E_R = actual radiated field strength at a particular azimuth in mV/m at 1 km

E_c = characteristic field strength in mV/m at 1 km

P = station power in kW

The dielectric constant of the ground is fixed at $\varepsilon_o = 15$, and of the sea at $\varepsilon_o = 80$.

The straight line marked "100 mV/m at 1 km" is the field strength on the assumption that the antenna is resting on a sphere of perfect conductivity.

Reason: Editorial re-arrangement for clarification

Note 1: ~~The adopted curves have a limited range of 1000 km. However, within the alternatives available to date, the ones adopted were considered the most appropriate. It was learned that the FCC has developed and is reviewing a series of similar graphs obtained from computerized calculations, based on the metric system that range up to 10,000 km. If the necessary information is available for the next meeting of the Working Group they could be adopted.~~ Curves of Figures 9.1 to 9.20 shall be replaced by similar curves derived from computerized calculations showing conductivity values of: 0.1, 0.5, 1, 2, 3, 4, 6, 8, 10, 15, 20, 30, 40, 60 and 5000 mS/m.

Reason: Canada favours the revised curves to obtain increased accuracy and potential simplicity using computerized calculations. Extra conductivity values are proposed for greater precision in the calculation of field strength.

9.2 Examples of field strength calculations for homogeneous paths

a) Determination of the electric field strength at a certain distance from a station.

Let us consider a station with a power of 5 kW at 1240 kHz whose antenna has a characteristic field strength of 254 mV/m.

Let us suppose that we want to know the electrical field strength at a distance of 40 km and that the conductivity is 4 mS/m throughout the path.

From figure 9.15 (1180 - 1240 kHz) we obtain a field strength of 45.8 dBu (195 uV/m) from the curve corresponding to 5 mS/m.

Therefore $E = E_o \times \frac{E_c}{100} \times \sqrt{P}$

$$= 195 \times \frac{254}{100} \times \sqrt{5} = \underline{1108} \quad \cancel{1107.5} \text{ uV/m}$$

b) Determination of the distance at which a certain electric field strength is obtained.

Based on the data from the preceeding example, at what distance can a field strength of 500 uV/m (54 dBu) be obtained?

Since the antenna involved has a characteristic field strength of 254 mV/m and the ~~operational~~ station power is 5 kW, i.e. conditions different from those of figures 9.1 to 9.20 (100 mV/m at 1 km ~~and 1 kW)~~. the field strength value must be standardized before referring to the corresponding figure.

The standardized value is

$$E_o = \frac{100\ E}{E_c \sqrt{P}} = \frac{100 \times 500}{254 \times \sqrt{5}} = \underline{88 \text{ uV/m}} \quad (39 \text{ dBu})$$

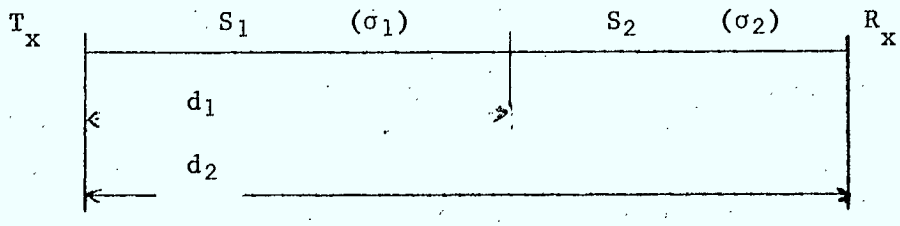
Taking the corresponding curve at 4 mS/m in figure 9.15, we arrive at 39 dBu at 57 km.

Reason: Editorial

9.3 Field strength calculations for mixed paths

Figures 9.1 to 9.20 can be used to determine the field strength in mixed conductivity paths by the "equivalent distance" or Kirke method.

Let us consider a path whose sections S_1 and S_2 have end-point distances corresponding to d_1 and d_2, and conductivities σ_1 and σ_2 respectively, as shown on the following figure:



The method is applied as follows:

a) Starting from the transmitter end, ~~T~~taking section S_1 first, we read the field strength corresponding to conductivity σ_1 at distance d_1 on the figure corresponding to the operational frequency (figure 9.1 to 9.20).

b) As the electric field strength remains constant at the soil discontinuity, the value immediately after the point of discontinuity must be equal to that obtained in a). As the conductivity of the second path is σ_2, from the curve corresponding to conductivity σ_2, is found the "equivalent distance" to that which would be obtained at the same electric field strength arrived at in (a). The "equivalent distance" is d. Distance "d" is larger than d_1 when σ_2 is larger than σ_1. Otherwise, "d" is less than d_1.

c) The electric field strength at true distance d_2 is arrived at through the corresponding curve at conductivity σ_2 similar to that obtained at "equivalent distance" $d + (d_2-d_1)$.

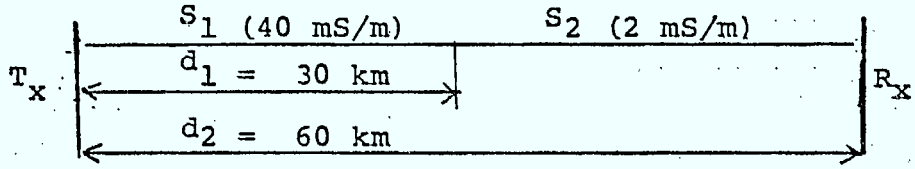
d) For successive paths with different conductivities, procedures (b) and (c) are repeated.

e) Antenna systems other than those with a single vertical monopole or those having a characteristic field other than 100 mV/m, are destandardized in accordance with explanation given in ~~paragraph~~ Section 9.1.

Reason: To clarify meaning

Example :

Let us consider the following path:



For a 25 kW station at 1000 kHz and an antenna with a characteristic field strength of 100 mV/m, what field strength is obtained at 60 km?

a) In figure 9.12 we obtain on the 40 mS/m curve a field strength of 68.4 dBu (2.63 mV/m) at the point of discontinuity (30 km).
Reason: Typographical error.

b) We obtain the same field strength at 10 km (d = 10 km) on the 2 mS/m curve.

c) The "equivalent distance" for d_2 = 60 km is $d + (d_2 - d_1)$ = 10 + (60 - 30) = 40 km.

From the 2 mS/m curve we obtain a field of 43.3 dBu (146 uV/m) at 40 km.

Reason: Typographical error

Lastly, we destandardize the field.

$$E = E_o \times \frac{E_c}{100} \sqrt{P} = 146 \times \frac{100}{100} \times \sqrt{25} = 730 \text{ uV/m}$$

Taking the preceding example, at what distance will the 500 uV/m contour be?

First we standardize the electric field strength:

$$E_o = \frac{100E}{E_c \sqrt{P}} = \frac{100}{100 \sqrt{25}} \times 500 = 100 \text{ uV/m}$$

Following the 40 mS/m curve of figure 9.12, we note that at 30 km the electric field strength is 68.4 dBu (2.63 mV/m). This value is higher than the one we seek (0.1 mV/m), therefore we shall have a distance over 30 km. The equivalent distance for a 2 mS/m conductivity is 10 km.

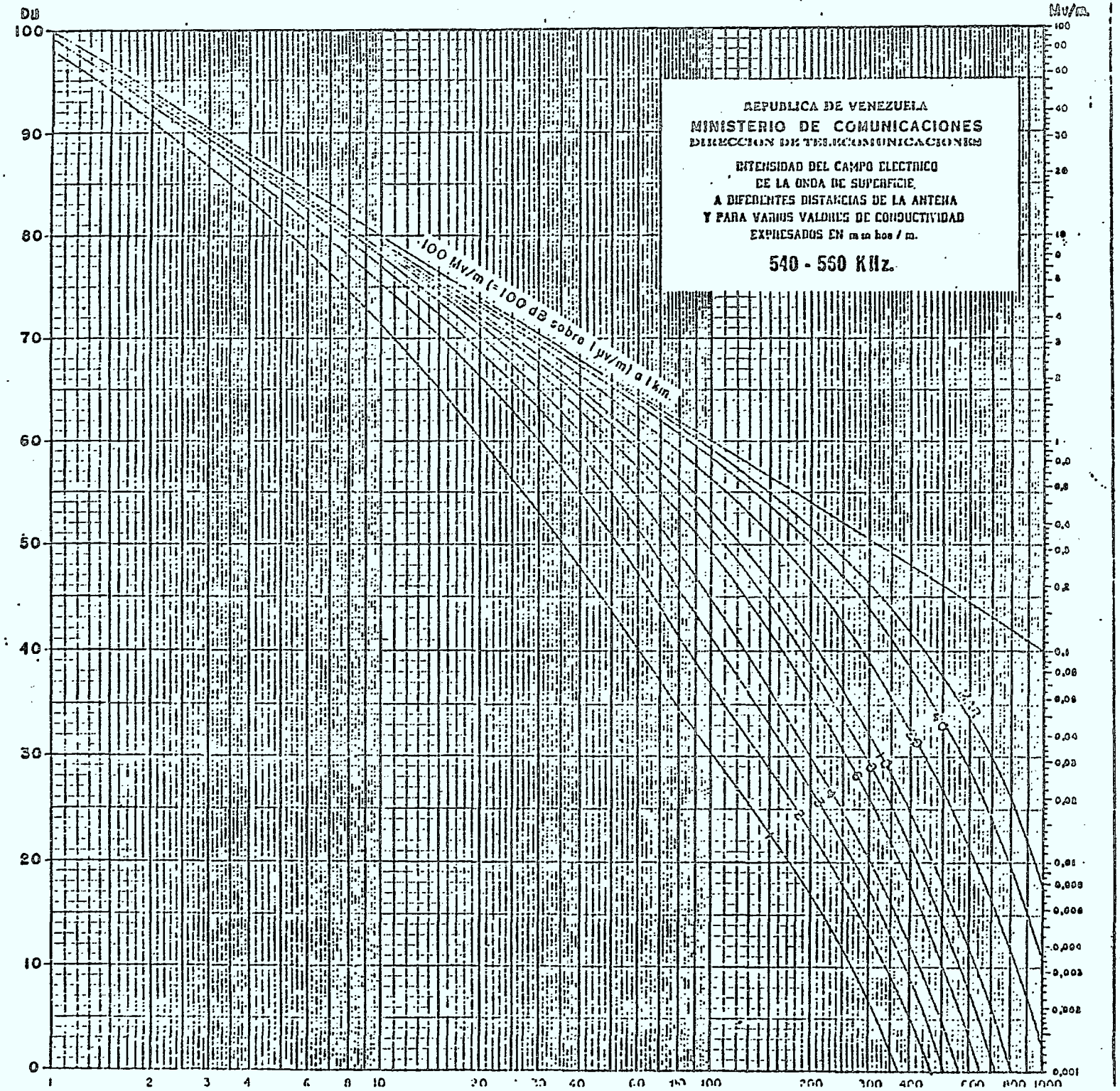
Following the 2 mS/m curve, we find the 100 uV/m (40 dBu) contour at 48 km, giving us the "equivalent distance". The true distance is 48 + (30 - 10) km = 68 km.

9.4 Estimated Conductivity Values

When no soil conductivity values are available, estimated values given in the following table can be used for each type of soil. This is in accordance with figure 1 of CCIR recommendation 527.

TYPE OF TERRAIN	mS/m
Sea water (average salinity) 20°C	5000
Humid soil	10
Fresh water 20°C	3
Relatively dry soil	1
Very dry soil	0.1

NOTE: Canada is of the opinion that the fresh water conductivity is 10.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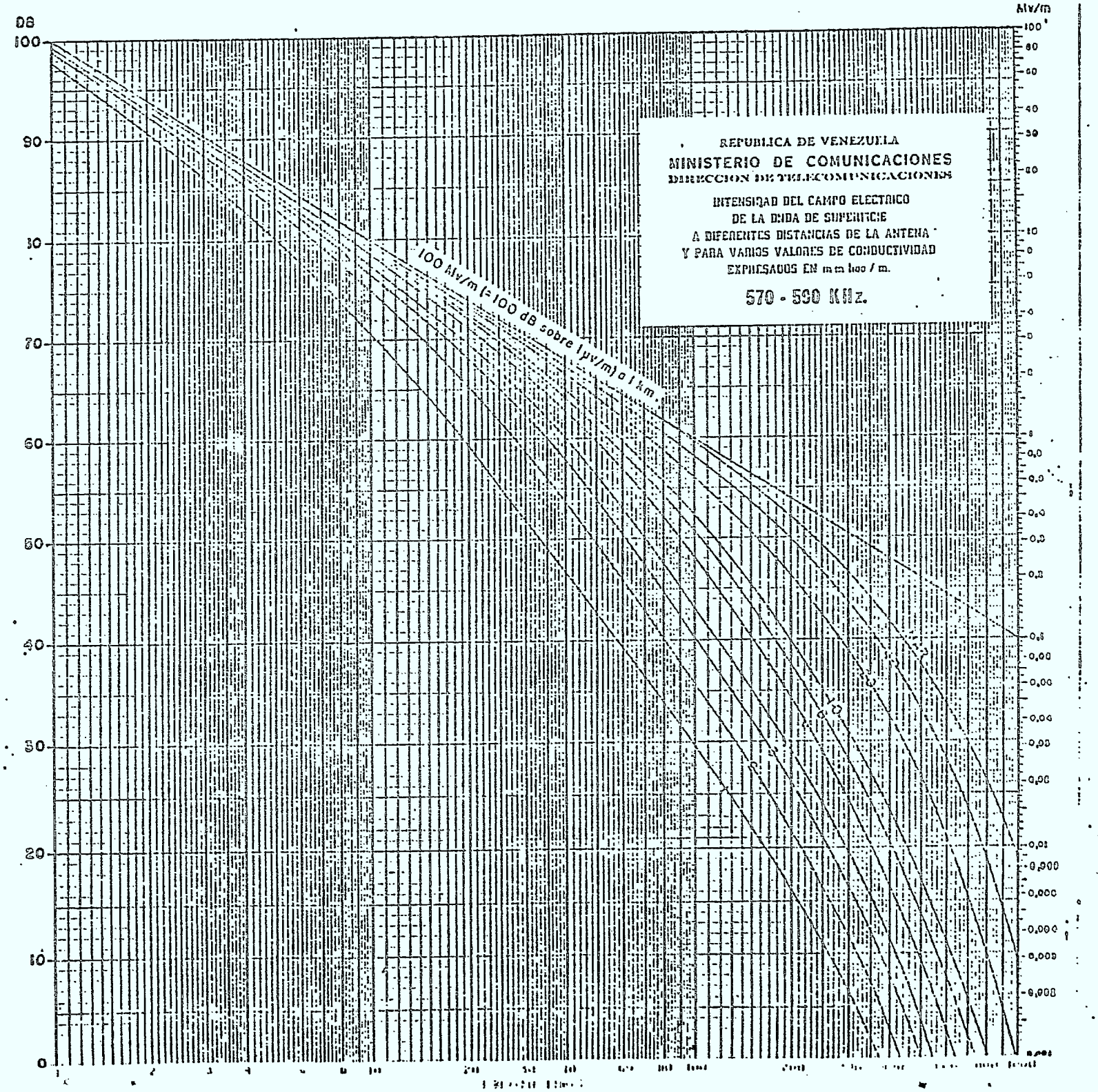
DIRECCION DE TELECOMUNICACIONES
INTENSIDAD DEL CAMPO ELECTRICO
DE LA ONDA DE SUPERFICIE,
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m hos / m.
540 - 550 KHz.
100 Mv/m (= 100 dB sobre 1 µv/m) a 1 km.
DB
Mv/m

FIG. 9.1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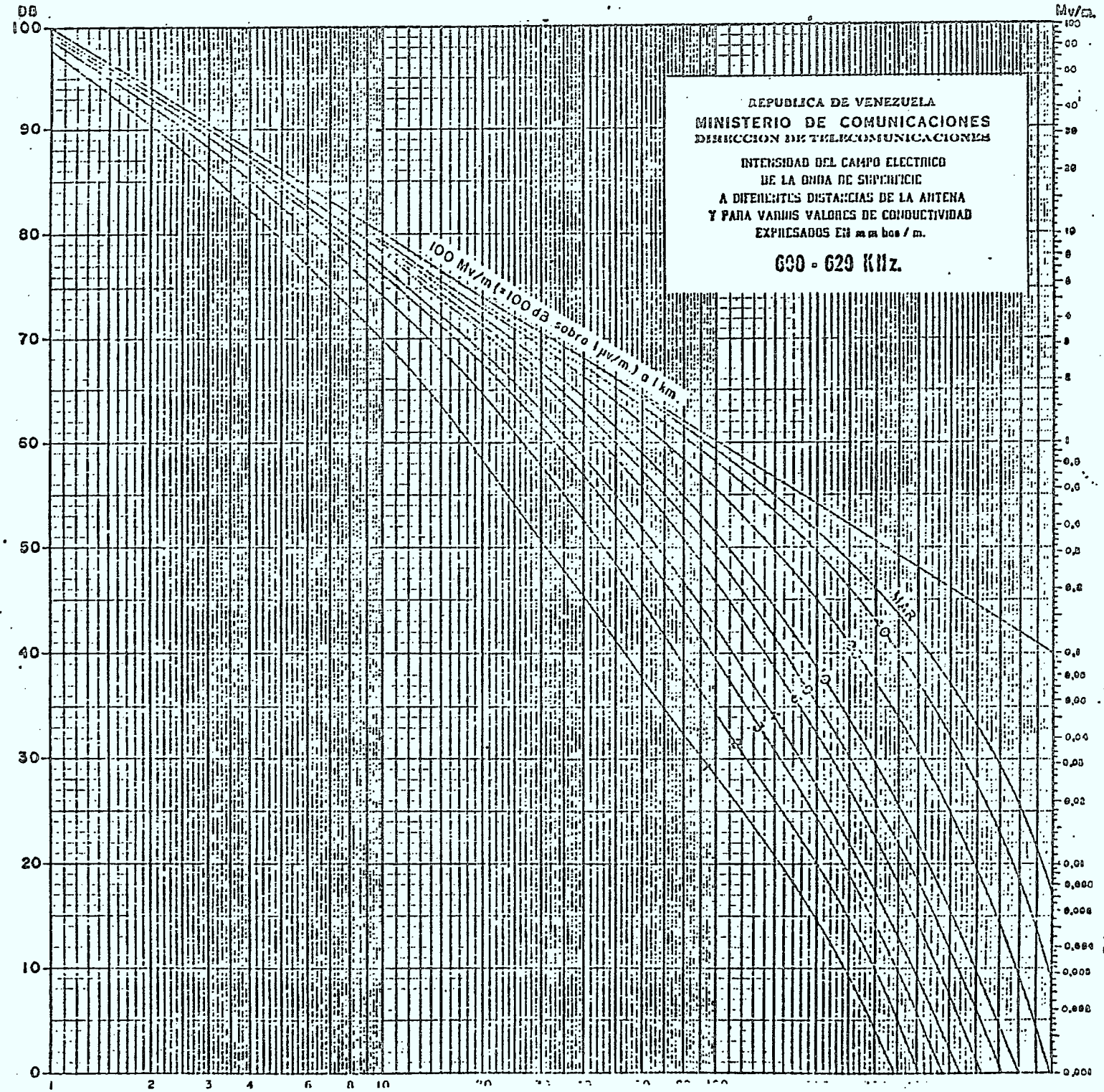
INTENSIDAD DEL CAMPO ELECTRICO
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m ho / m.
570 - 590 KHz.
100 Mv/m (= 100 dB sobre 1 μv/m) a 1 km.
dB
Mv/m

Fig. 9.2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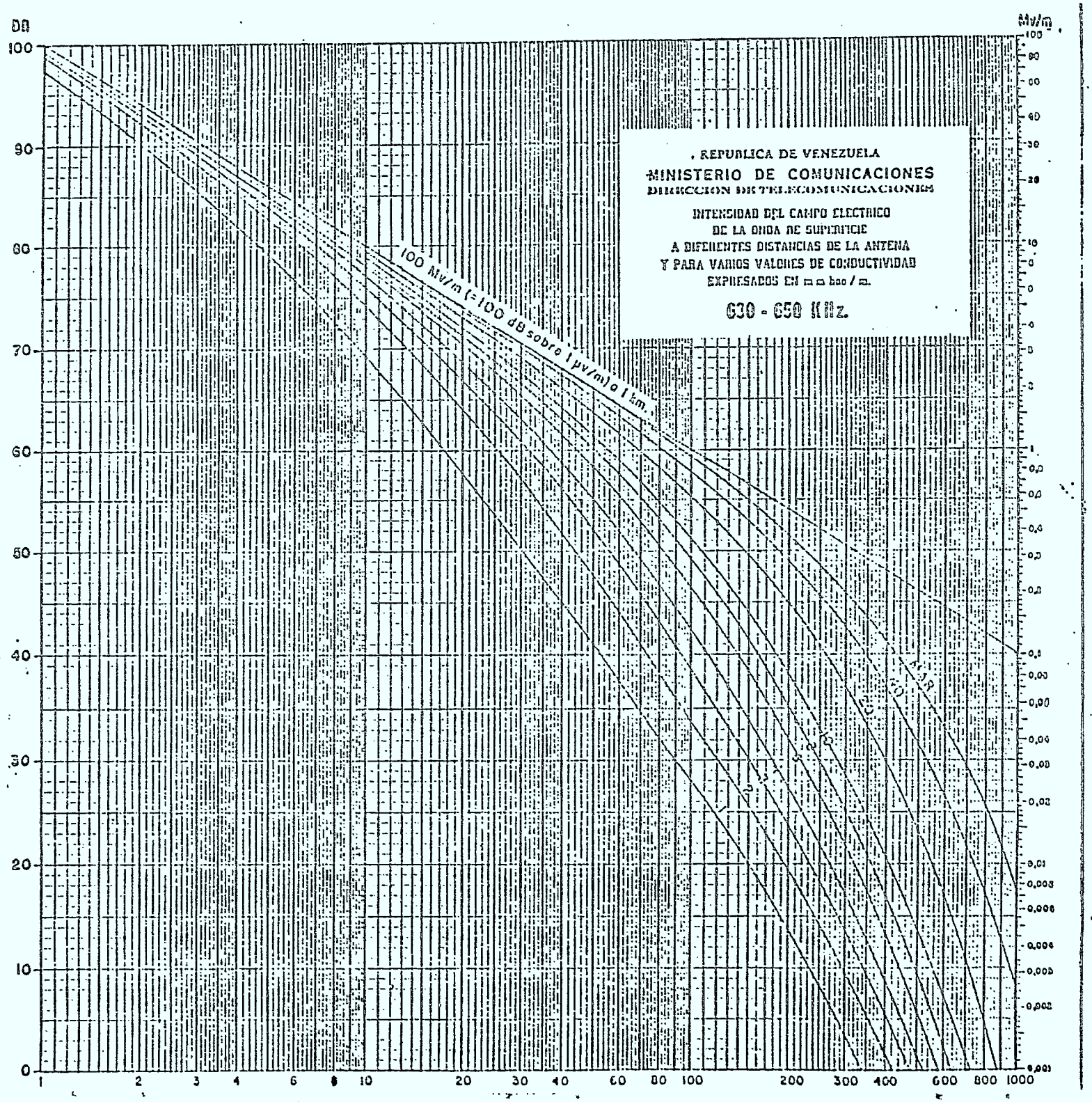
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN mm hos / m.
600 - 629 KHz.
100 Mv/m (=100 dB sobre 1 µv/m) a 1 km.
DB
Mv/m.

Fig. 9.3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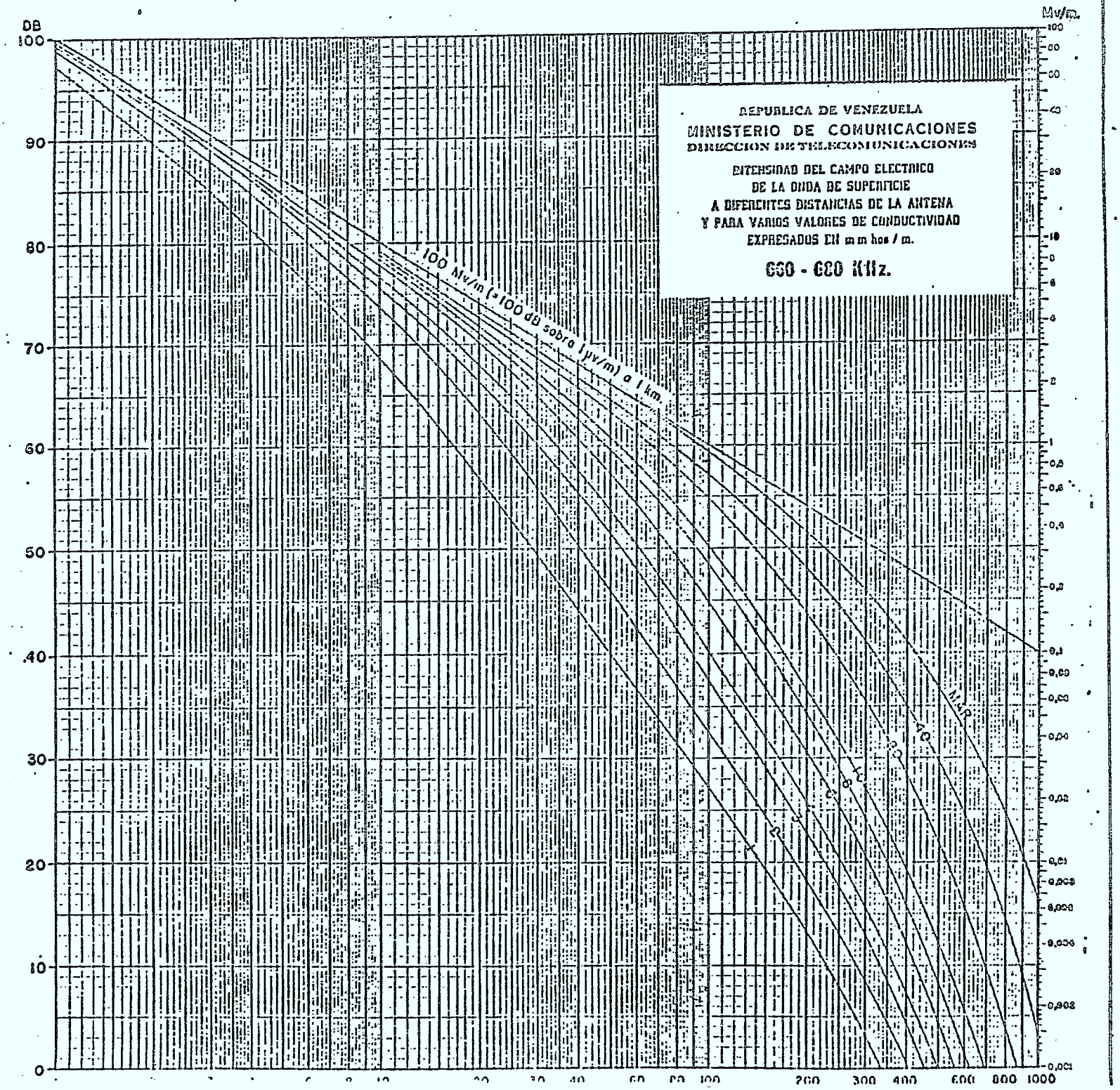
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m ho / m.
630 - 650 KHz.
100 Mv/m (=100 dB sobre 1 µv/m) a 1 km.
DB
Mv/m

Fig. 9.4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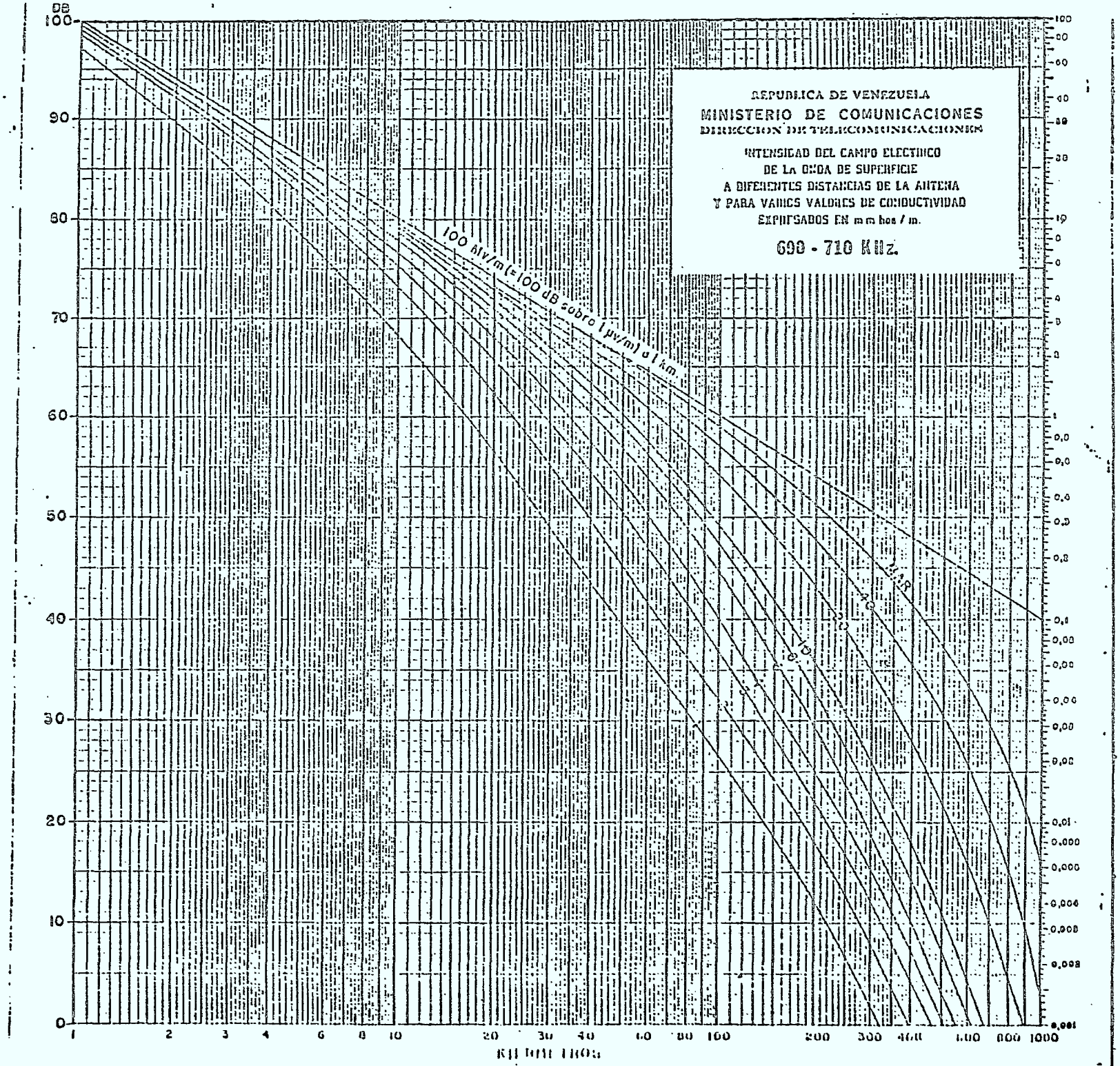
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m hos / m.
600 - 680 KHz.
100 Mv/m (=100 dB sobre 1 µv/m) a 1 km.
DB
Mv/m.
MAR
40
20
10
5
2
1
0,5
0,2
0,1
0,05
0,02
0,01
0,005
0,002
0,001
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
60
80
100
200
300
400
600
800
1000

Fig. 9.5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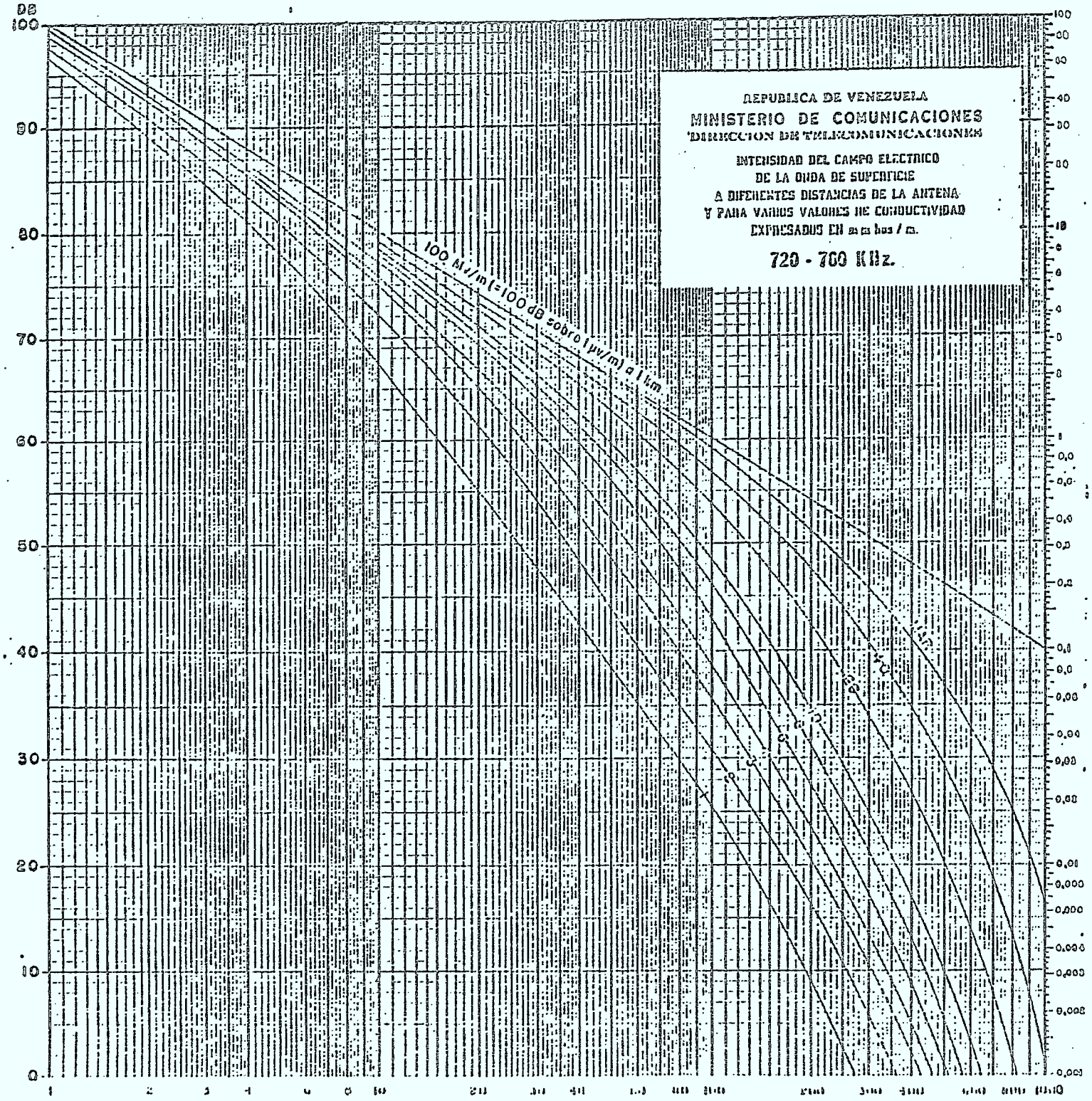
INTENSIDAD DEL CAMPO ELECTRICO
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m hos / m.
690 - 710 KHz.
100 mv/m (=100 dB sobre 1 µv/m) a 1 km.
DB
KILOMETROS

Fig. 9.6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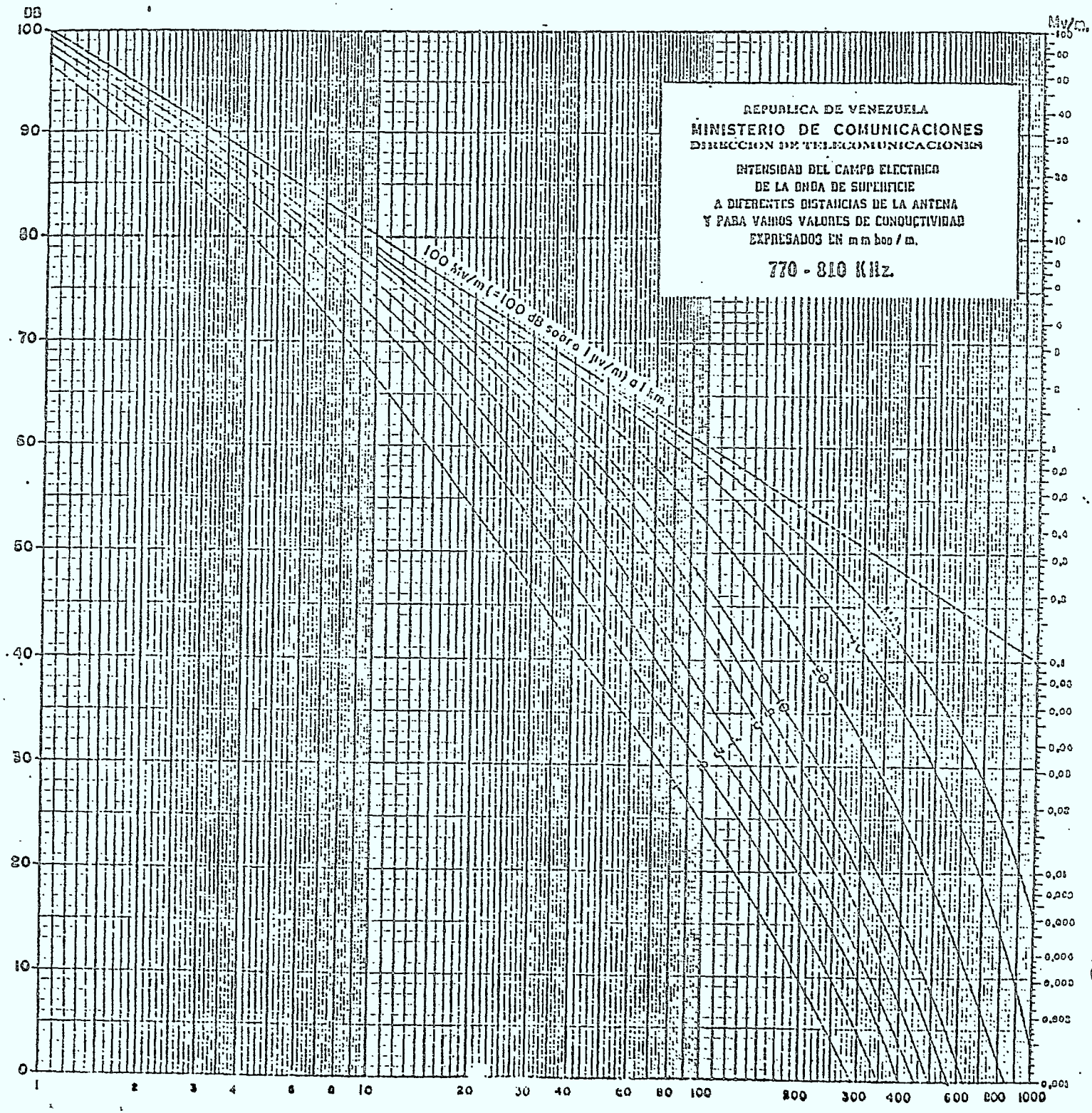
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN mili mhos / m.
720 - 760 KHz.
100 M.V/m (=100 dB sobre 1 µv/m) a 1 km
DB
100
90
80
70
60
50
40
30
20
10
0

Fig. 9.7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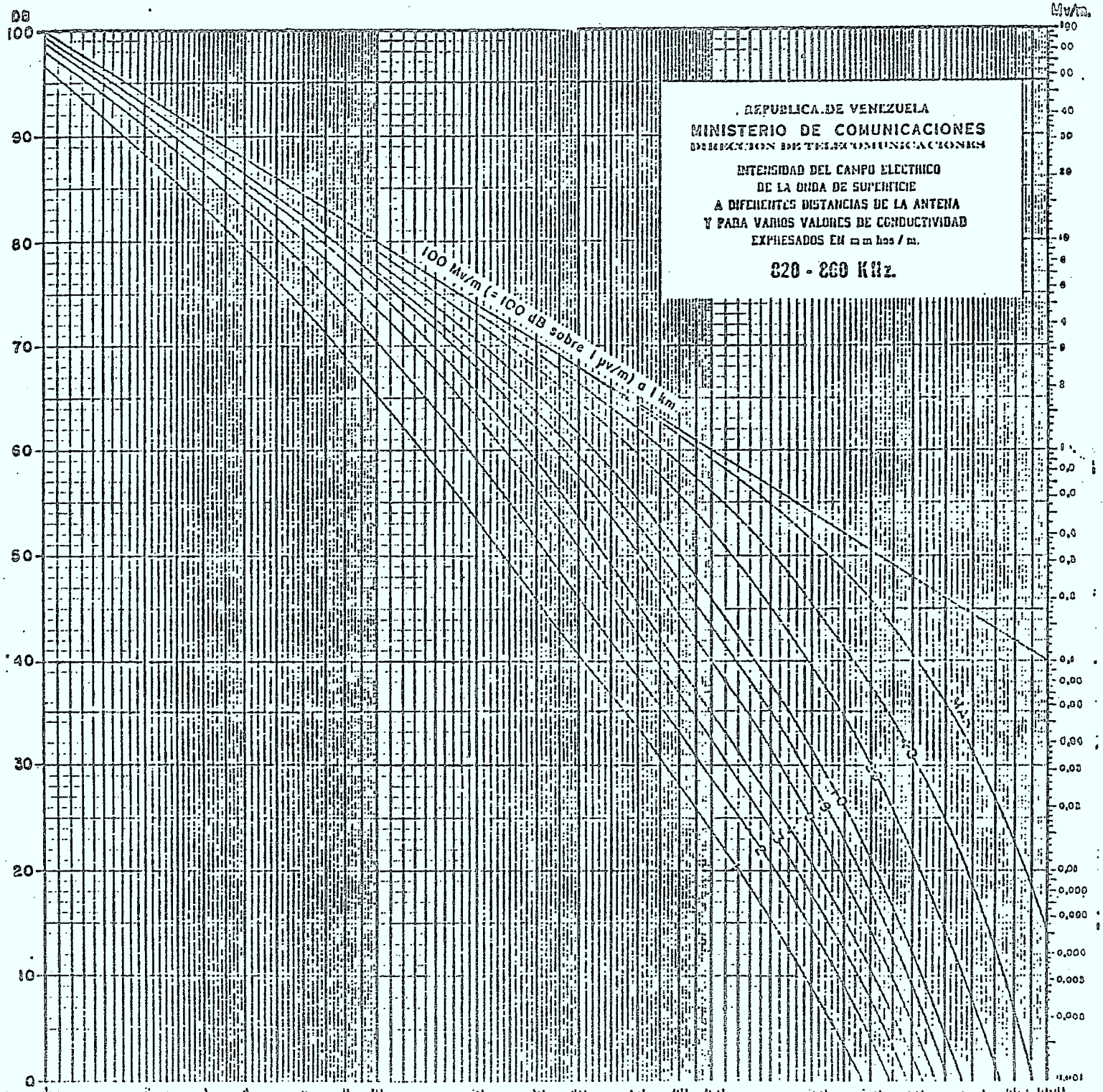
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m bob / m.
770 - 810 KHz.
100 µv/m (=100 dB sobre 1 µv/m) a 1 km
dB
Mv/m
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
6
8
10
20
30
40
60
80
100
200
300
400
600
800
1000

Fig. 9.8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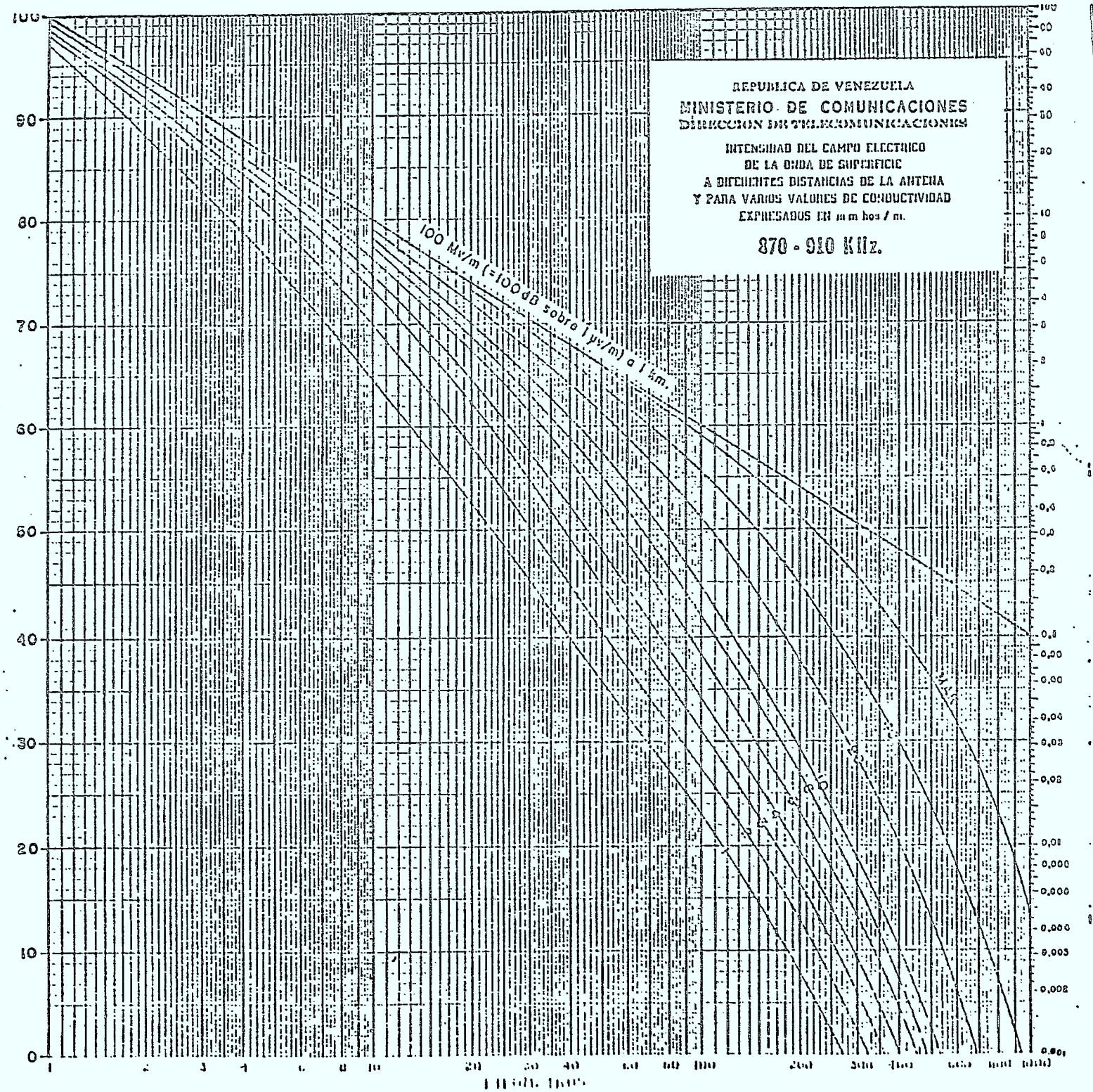
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m hos / m.
820 - 860 KHz.
100 Mv/m (= 100 dB sobre 1 µv/m) a 1 km.
dB
Mv/m.
100
90
80
70
60
50
40
30
20
10
0

Fig. 9.9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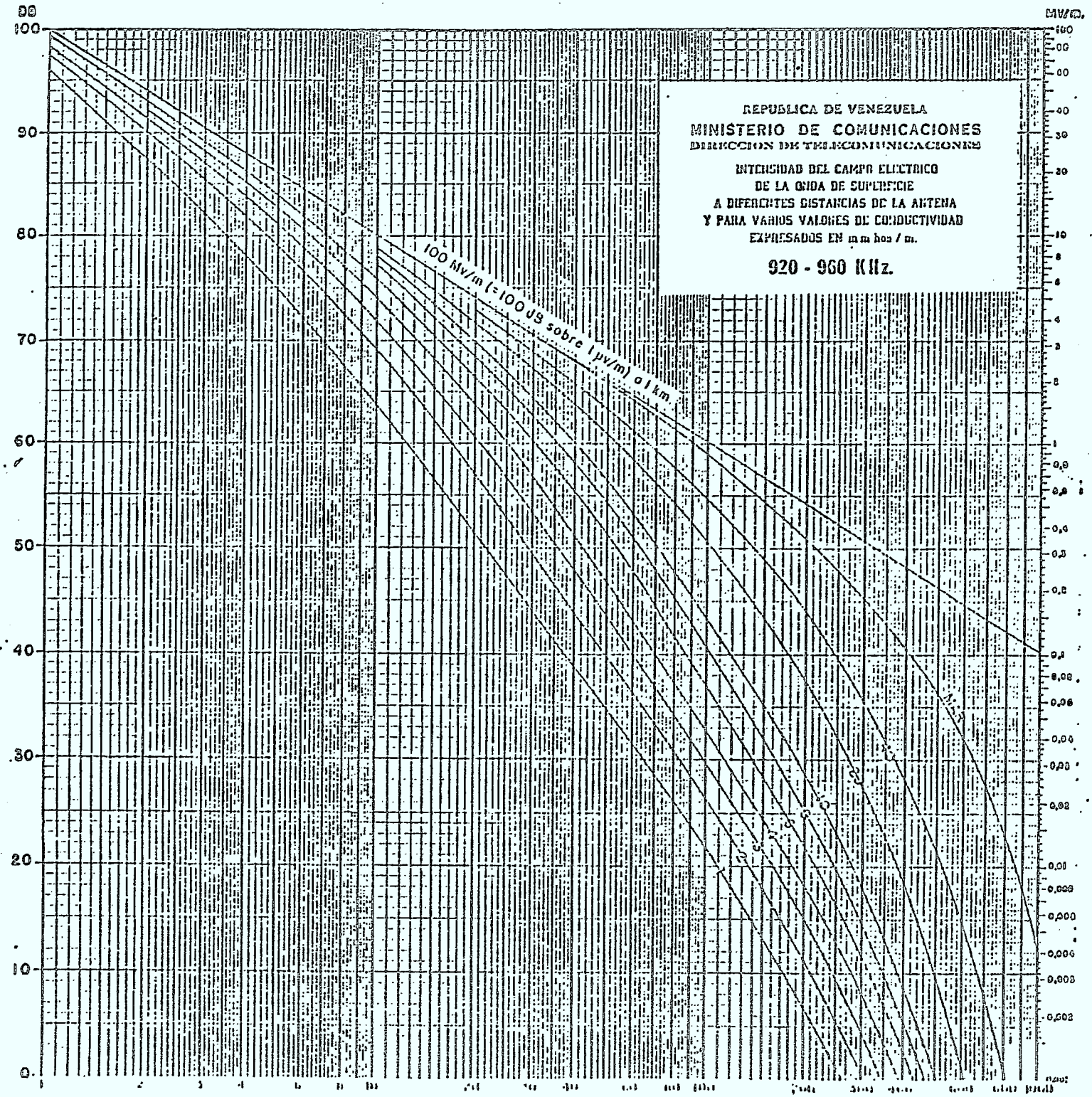
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m hos / m.
870 - 910 KHz.
100 Mv/m (=100dB sobre 1 µv/m) a 1 km.

Fig. 9.10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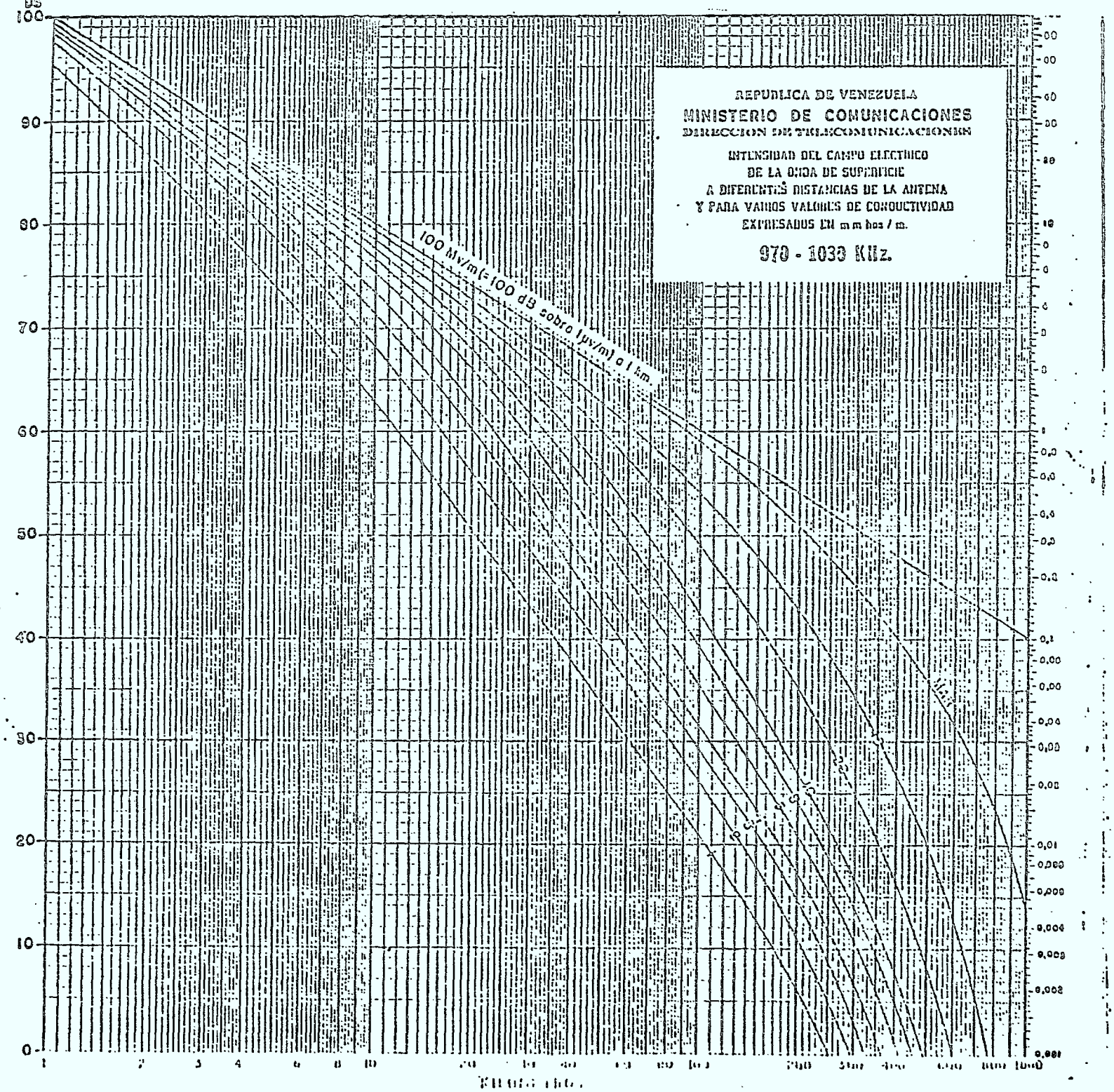
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m hos / m.
920 - 960 KHz.
100 Mv/m (=100 US sobre 1 μv/m) a 1 km.
DB
MV/M.

Fig. 9.11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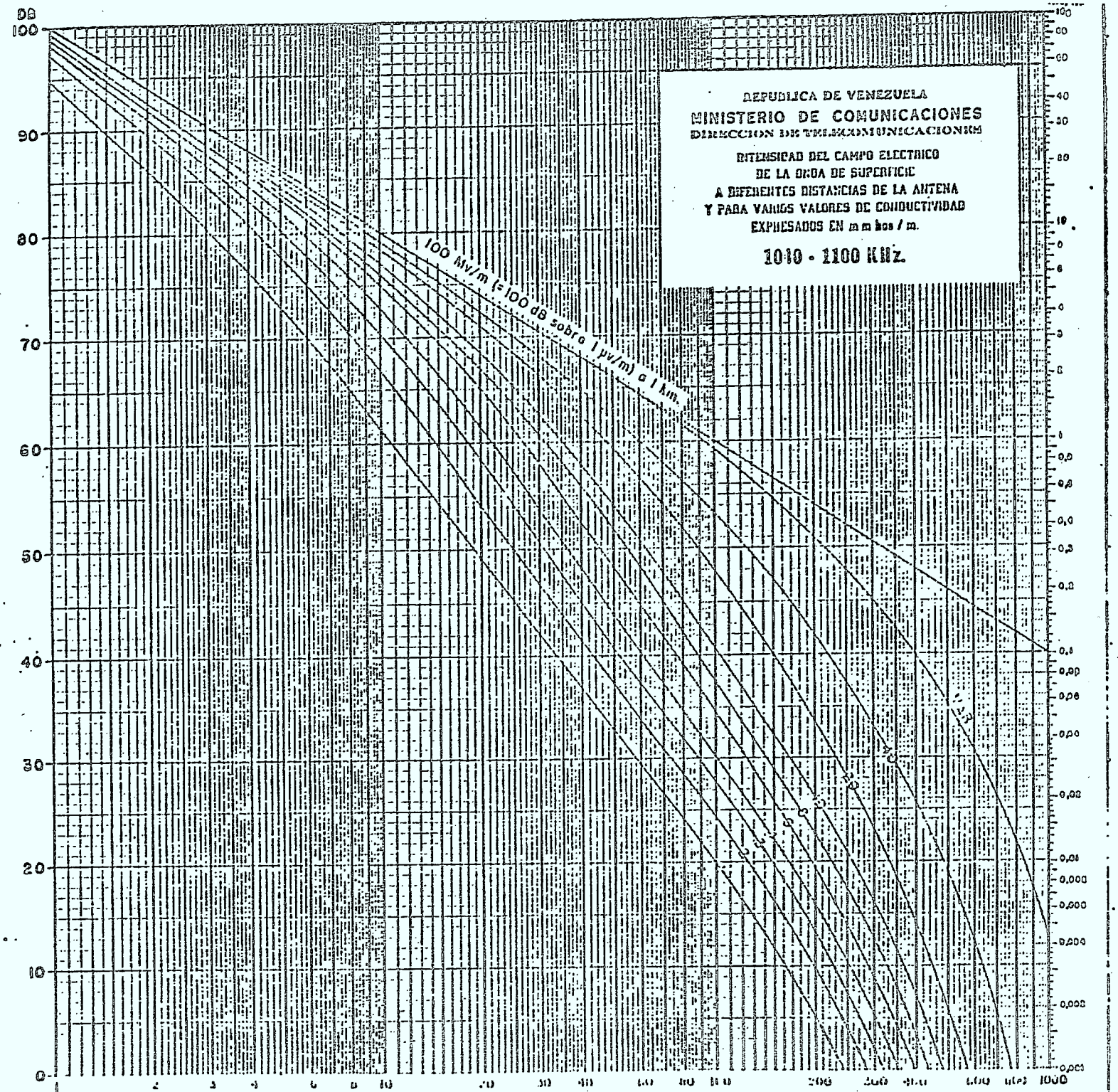
INTENSIDAD DEL CAMPO ELECTRICO
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m hos / m.
970 - 1030 KHz.
100 Mv/m (= 100 dB sobre 1µv/m) a 1 km.
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
6
8
10
20
30
40
50
60
70
80
90
100

Fig. 9.12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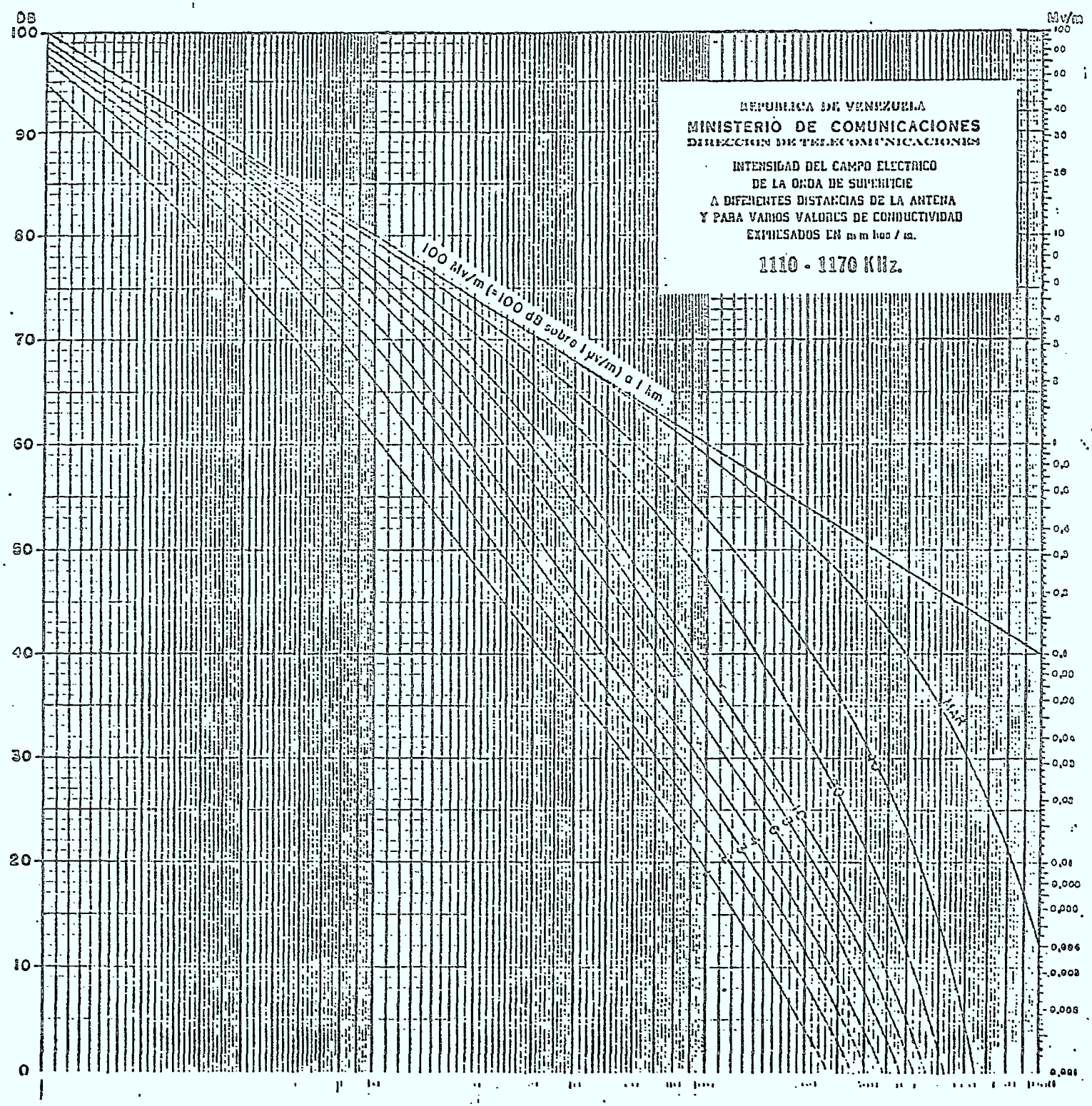
INTENSIDAD DEL CAMPO ELECTRICO
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN mmhos / m.
1010 - 1100 KHz.
100 Mv/m (= 100 dB sobre 1 µv/m) a 1 km.
dB
100
90
80
70
60
50
40
30
20
10
0
1000

Fig. 9.13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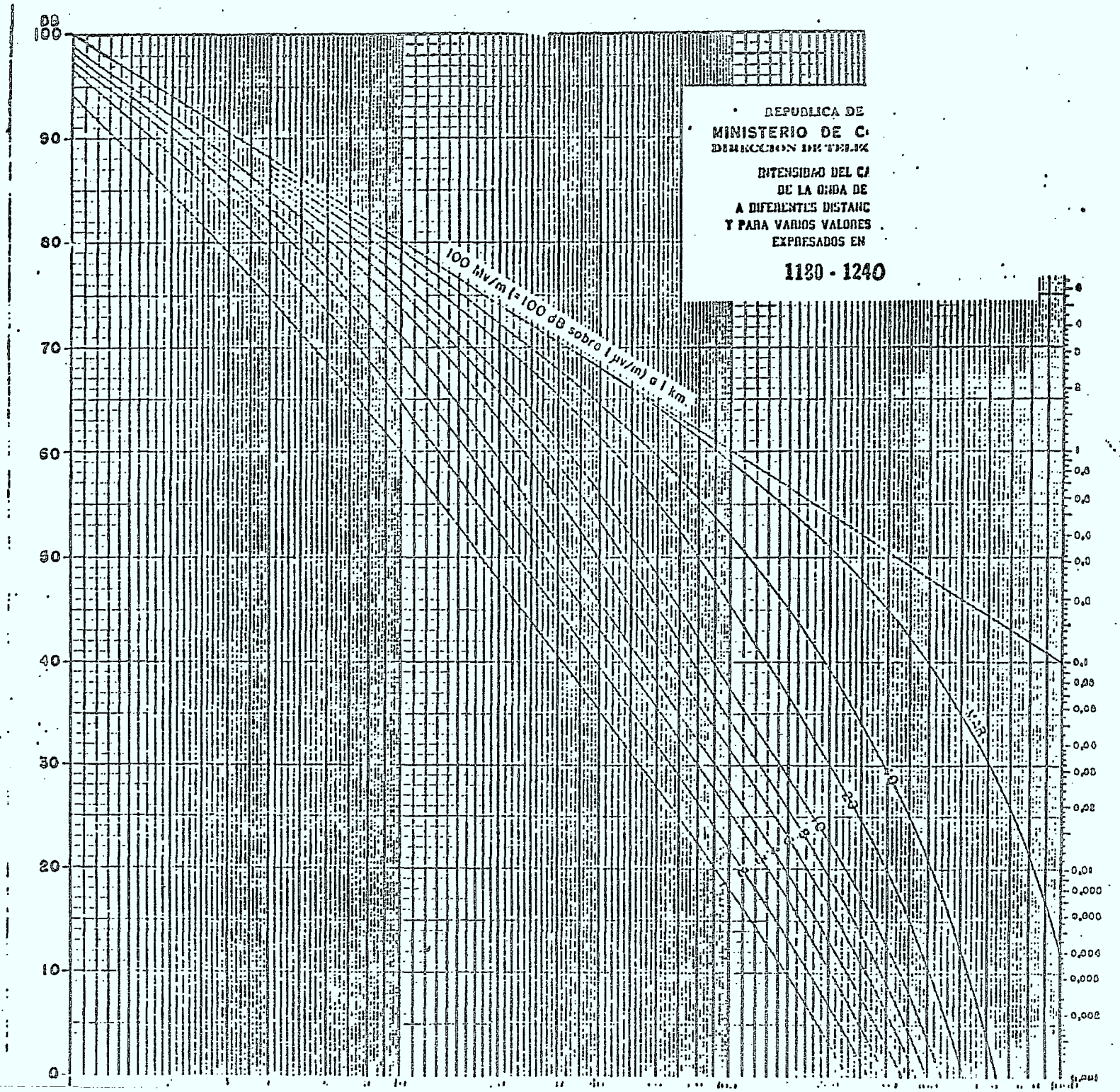
INTENSIDAD DEL CAMPO ELECTRICO
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m hoo / m.
1110 - 1170 KHz.
100 mV/m (=100 dB sobre 1 μv/m) a 1 km.
DB
Mv/m

Fig. 9.14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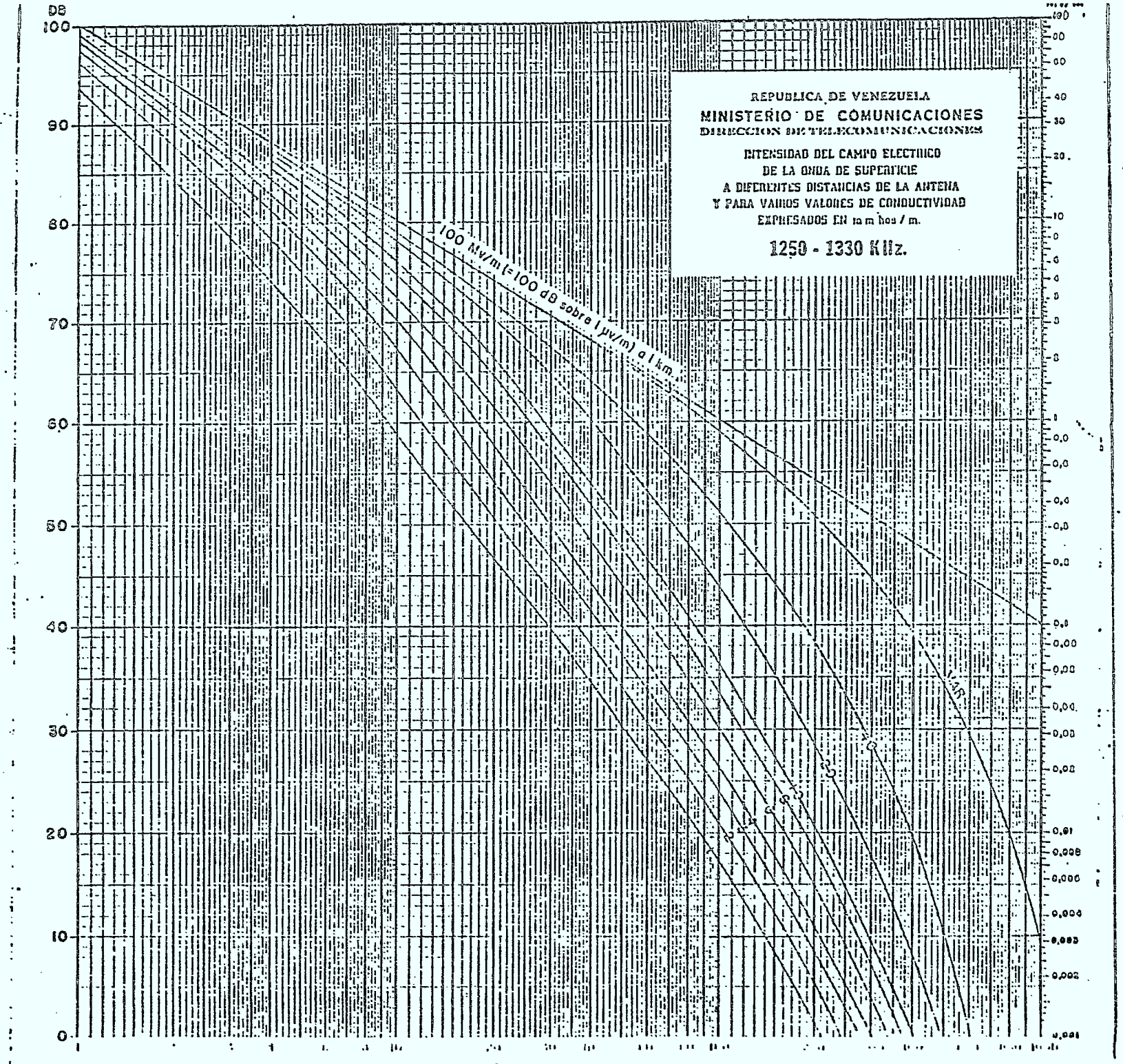
INTENSIDAD DEL CA
DE LA ONDA DE
A DIFERENTES DISTANC
Y PARA VARIOS VALORES
EXPRESADOS EN
1180 - 1240
100 mv/m (=100 dB sobre 1 µv/m) a 1 km.
dB
100
90
80
70
60
50
40
30
20
10
0

Fig. 9.15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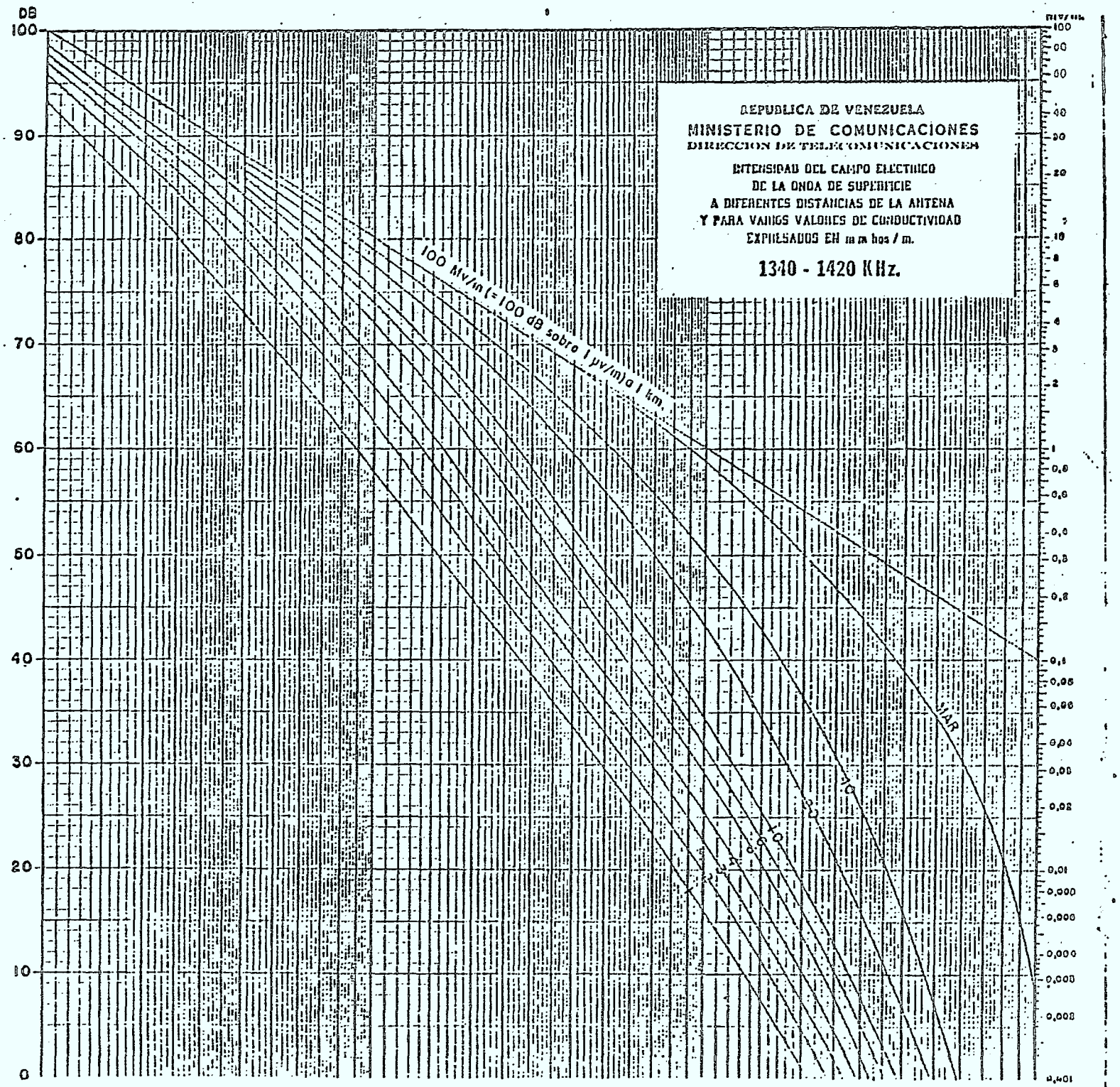
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m mhos / m.
1250 - 1330 KHz.
100 Mv/m (= 100 dB sobre 1 µv/m) a 1 km.
DB
100
90
80
70
60
50
40
30
20
10
0

Fig. 9.16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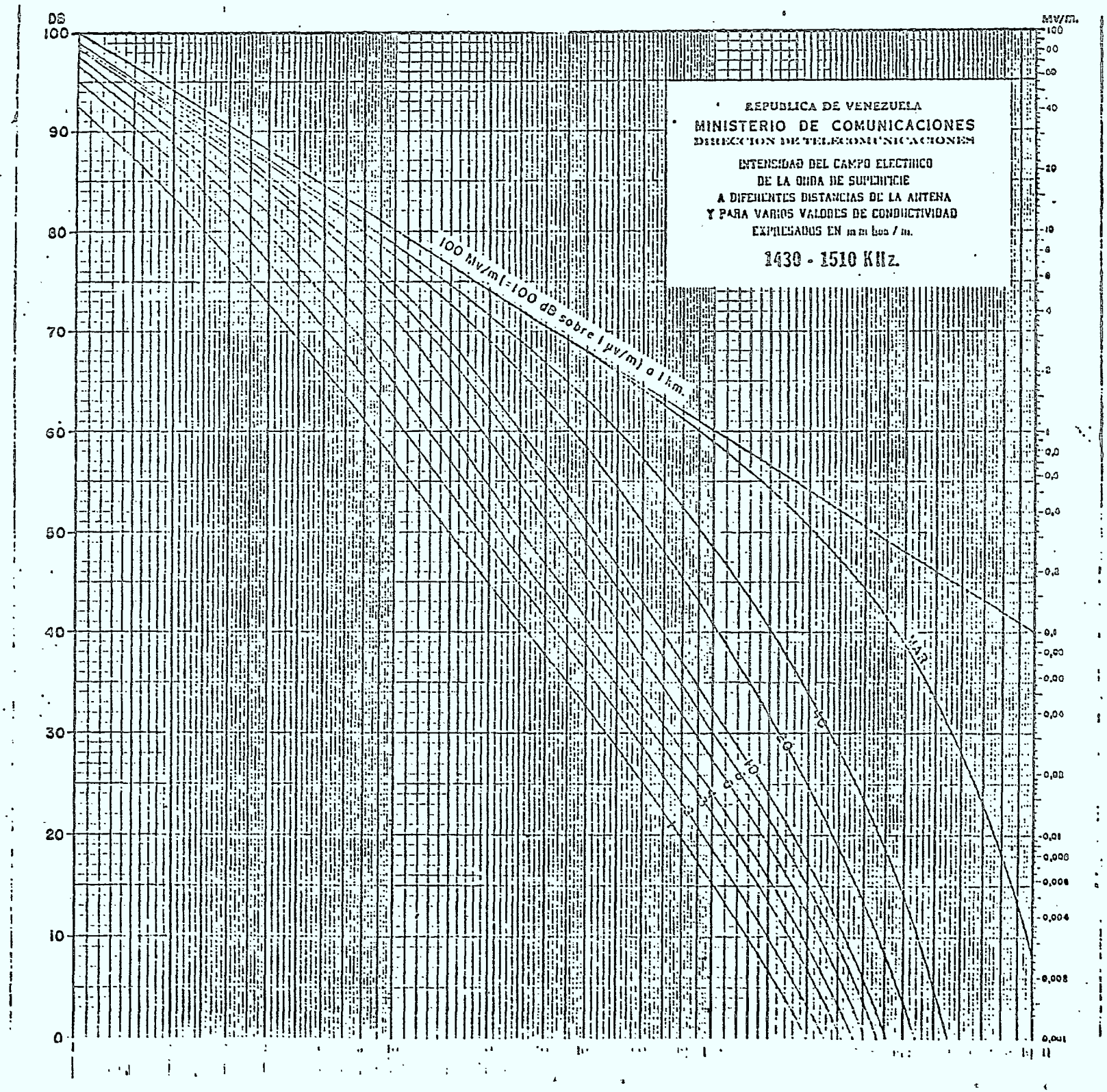
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m hos / m.
1340 - 1420 KHz.
100 Mv/m (= 100 dB sobre 1 µv/m) a 1 km.
DB
MV/M

Fig. 9.17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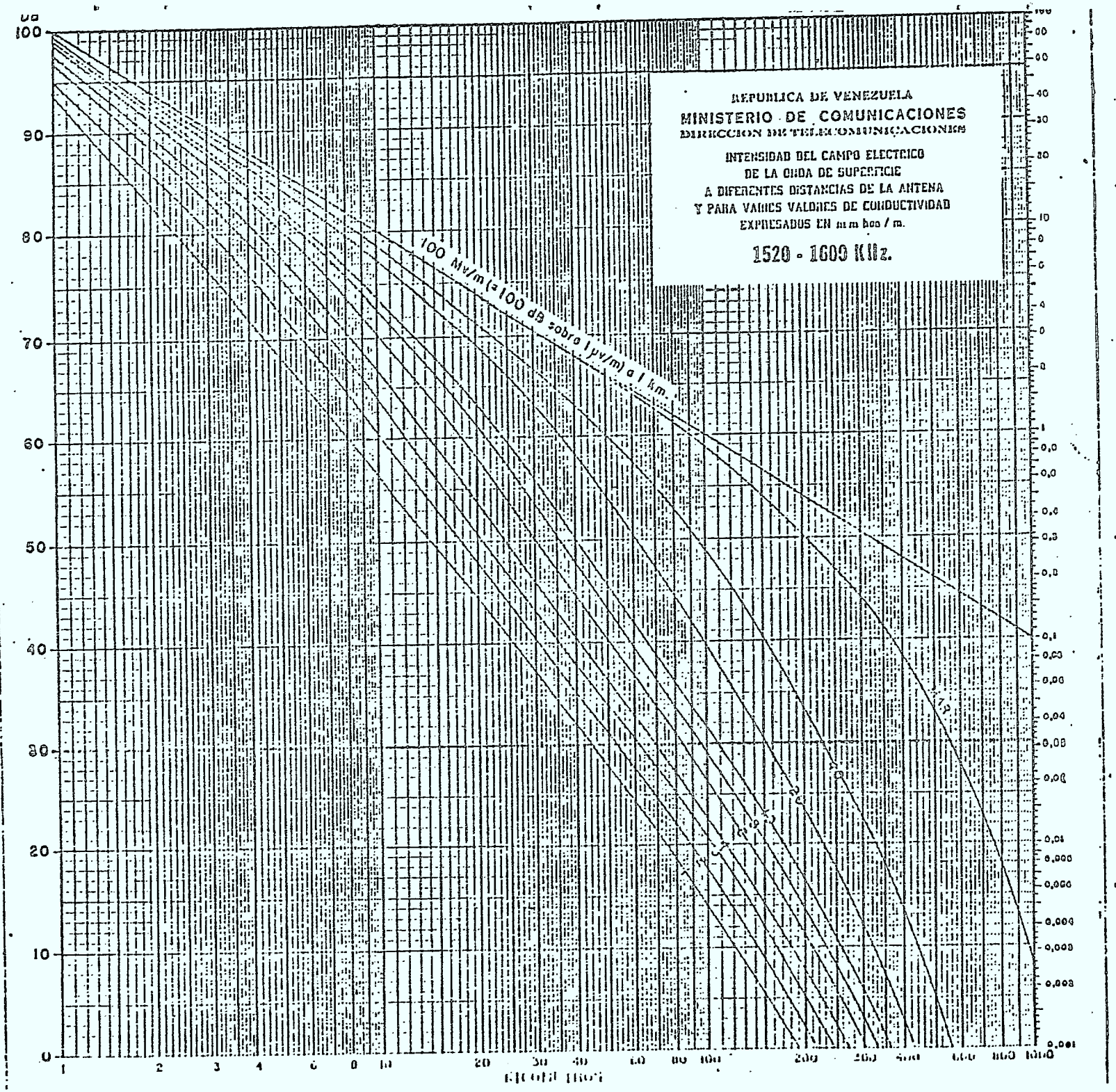
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m hos / m.
1430 - 1510 KHz.
100 MV/m (=100 dB sobre 1 μv/m) a 1 km.
DB
MV/m.

Fig. 9.18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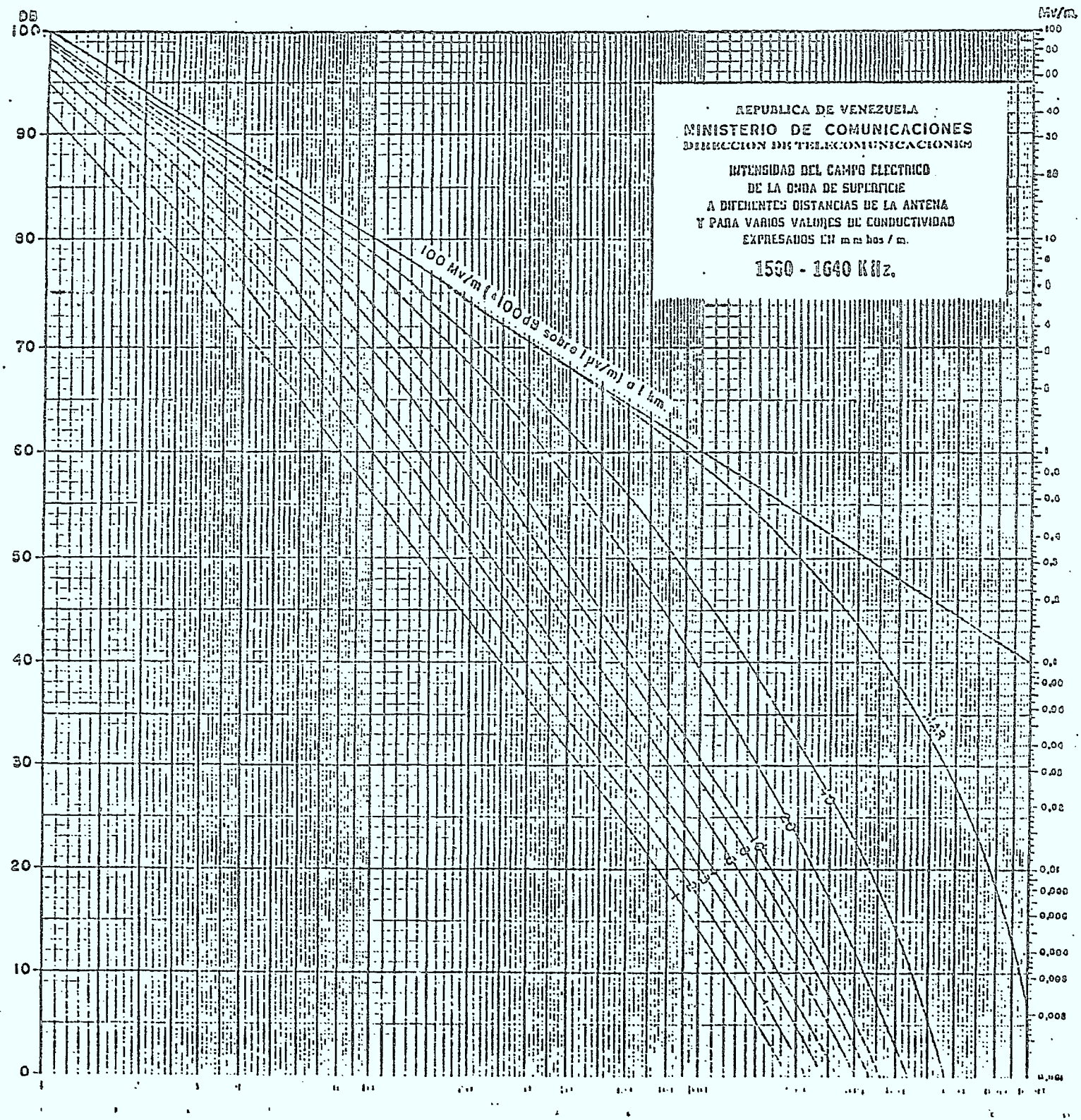
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m m ho o / m.
1520 - 1600 KHz.
100 Mv/m (=100 dB sobre 1 µv/m) a 1 Km.
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
6
8
10
20
30
40
60
80
100
200
300
400
600
800
1000

Fig. 9.19


DB
Mv/m
REPUBLICA DE VENEZUELA
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INTENSIDAD DEL CAMPO ELECTRICO
DE LA ONDA DE SUPERFICIE
A DIFERENTES DISTANCIAS DE LA ANTENA
Y PARA VARIOS VALORES DE CONDUCTIVIDAD
EXPRESADOS EN m ms hos / m.
1530 - 1640 KHz.
100 Mv/m (100dB sobre 1 μv/m) a 1 km.

Fig. 9.20

10. CALCULATION OF REFLECTED WAVE FIELD STRENGTH

~~10.1--Introduction~~

~~Several methods are available for estimating the MF reflected wave signal strength.--These include the FCC method; the CCIR methods in their original form and as modified in Doc. RADIF/3/79, Brasilia.--There are also the Gaire curves.--A discussion of these methods is given in Appendix 10.1.~~

~~For reasons of administrative convenience such as familiarity with the method and its simplicity, the Working Group recommends that the FCC method be adopted for use in Region 2 for distances less than approximately 4300 km.~~

~~The Working Group recommends that, for greater distances the FCC median signal level curve be extended by a line drawn parallel to the Gaire N-S curve and joining the FCC curve at 4300 km (fig. 10.1).~~

10.1 Charts used

The pertinent angle of departure for the reflected wave to a particular distance is obtained from Table 10.1. Linear interpolation shall be used for other than listed distances.

The reflected wave electric field strength is obtained from the curves in Figure 10.2 for distances up to 4000 km. For distances between 4000 and 10,000 km, Figure 10.2A or table 10.2, both of which are derived from the following equations, may be used:

10% curve: $E\ (\text{dBu}) = -37.7 \log \left(1.791 \times \frac{d}{10000}\right)$

50% curve: $E\ (\text{dBu}) = -37.7 \log \left(2.92 \times \frac{d}{10000}\right)$

where d is in kilometres.

Reason: Canada supports the Working Group recommendation that the method described in Section 10.2 be adopted. The extension of the curves of Figure 10.2 proposed by the Working Group is given in new Figure 10.2A and Table 10.2. Section 10.1 as well as Appendix 10.1 and Figure 10.1 become redundant.

Note: Canada recommends that the curves of Figure 10.2 be extrapolated to a distance of 80 km.

10.2 General Description of Method

a) Figs. 10.2 and 10.2A, show the reflected wave signal intensity as a function of distance from a transmitting antenna with a radiated field of 100 mV/m at the pertinent angle for the distance. The pertinent angle θ is the angle described by ~~curves of figures 10.3~~ table 10.1. To determine the field at any distance requires, therefore, determination of the radiation at the pertinent angle θ.

b) ~~To determine the field at any distance requires, therefore, determination of the radiation at the pertinent angle θ.~~ For Class A station the pertinent angle θ for coverage calculation is taken from ~~curve 1 of figure 10.3~~ column C1 of Table 10.1. The ratio of the value of radiated field at that value of angle θ to 100 mV/m then is used as the multiplying factor for the value of the field read from the ~~pertinent~~ 50% curve of figure 10.2 or 10.2A.

c) For all Classes, Columns I2 and I3 of Table 10.1 ~~curves 2 and 3 of Figure 10.3~~ are used in connection with the determination of interfering reflected wave signal and describe the limits of the pertinent angle for this field. The radiation within these pertinent angles is determined and the highest value indicated is used in computing interference. The ratio of this value to 100 mV/m then is used as the multiplying factor for the value of the field read from the 10% curve of Fig. 10.2 or 10.2A.

Reason: The use of Table 10.1 and the associated computer program will remove subjective discrepancies that would occur by reading the set of curves of Fig. 10.3 which become redundant. This approach was favored at the fifth meeting of the Working Group. The revised text specifies Canada's position for the use of 10% or 50% curves from Figures 10.2 or 10.2A (Table 10.2). It is our opinion that the 10% reflected-wave curve gives a more realistic value to protect service areas from objectionable interference.

NEW CHART - REASON: SEE SECTION 10.1

TABLE 10.1

ANGLE OF DEPARTURE VS DISTANCE

DISTANCE (km)	I3 (Deg)	C1 (Deg)	I2 (Deg)
50	71.1	75.3	81.8
100	55.6	62.2	70.1
150	44.1	51.6	59.9
200	35.9	43.3	51.4
250	29.9	36.9	44.5
300	25.4	31.9	38.9
350	22.0	27.9	34.2
400	19.3	24.7	30.4
450	17.1	22.0	27.1
500	15.3	19.8	24.4
550	13.7	18.0	22.1
600	12.4	16.3	20.1
650	11.3	14.9	18.4
700	10.3	13.7	16.9
750	9.4	12.6	15.6
800	8.6	11.7	14.5
850	7.9	10.8	13.5
900	7.3	10.0	12.5
950	6.7	9.3	11.7
1000	6.1	8.6	10.9
1050	5.6	8.0	10.2
1100	5.1	7.4	9.5
1150	4.7	6.9	8.9
1200	4.3	6.4	8.3
1250	3.9	5.9	7.8
1300	3.5	5.4	7.3
1350	3.2	5.0	6.8
1400	2.8	4.6	6.3
1450	2.5	4.3	5.9
1500	2.2	3.9	5.5
1550	1.9	3.5	5.1
1600	1.6	3.2	4.7
1650	1.4	2.9	4.3
1700	1.1	2.6	4.0
1750	.9	2.3	3.7
1800	.6	2.0	3.3
1850	.4	1.7	3.0
1900	.0	1.5	2.7
1950	.0	1.2	2.4
2000	.0	1.0	2.2
2050	.0	.7	1.9
2100	.0	.5	1.6
2150	.0	.2	1.4
2200	.0	.0	1.1
2250	.0	.0	.9
2300	.0	.0	.6
2350	.0	.0	.4
2400	.0	.0	.0

d) The radiation at a pertinent vertical angle can be determined from actual design data or from the table in Appendix 10.2. Radiation in the horizontal plane (characteristic field strength) either is known from the actual design data, or, if the actual design data is not available, from Figure 10.8. The reflected wave signal intensity is calculated as follows:

$$E_r = E_o \times \frac{E_c\sqrt{P}}{100} \times F(\theta)$$

where E_r = reflected wave signal intensity in mV/m

E_o = reflected wave propagation value in mV/m as determined ~~in~~ from Figure 10.2 or 10.2A.

E_c = characteristic field strength in mV/m at 1 km as determined from actual design data or from Figure 10.8, ~~(converted to 1 km)~~ - multiplied by 1.609..

Reason: Figure 10.8 is referenced to 1.609 km (one mile)

P = station power in kW ~~km~~

Reason: Typographical error

$F(\theta)$ = vertical radiation factor at pertinent angle θ as determined from actual design data or from the table in Appendix 10.2

e) The reflected wave interference to a broadcasting station from broadcasting stations in synchronous operation shall be calculated as if the synchronous stations were in independent operation.

~~f)~~ ~~Sea Gain~~

~~G_s is the additional signal gain when one or both terminals is situated near the sea. G_s for a single terminal is given by:~~

~~$$G_s = G_o - 10^{-3} \frac{Qsf}{\theta_0} \text{ (dB)} \qquad (1)$$~~

~~where G_o is the gain when the terminal is on the coast, f is the frequency in kHz and s is the distance in km of the terminal from the sea, measured along the great circle path. Q = 1.75 in the MF band. G_o is given in Figure 10.4 as a function of d for the above mentioned bands. In the MF band, G_o = 10 dB when d = 6,500 km. Equation (1) applies for values of s such that G_s = 0. For larger values of s, G_s = 0. If both terminals are near the sea, G_s is the sum of the values of G_s for the individual terminals. The term d is the great circle path length in kilometres.~~

~~The net sum of Equation (1) is to be added to the value obtained in paragraphs 10.2 b) and c)~~

f) Sea Gain

Sea gain is the additional signal gain when one or both terminals is situated near the sea. Sea gain for each terminal is given by:

$$G_s = G_o - \frac{1.75 \times s \times f}{G_o \times 10^3}$$

where G_s = sea gain for a single terminal in dB. (G_s is never negative. For values of s such that the equation above gives a negative value, use $G_s = 0$). If both terminals are near the sea, G_s is the sum of the values of G_s for the individual terminals.

G_o = sea gain in dB when the terminal is on the coast. G_o is shown in Figure 10.4 as a function of d, the great circle path length in km. ($G_o = 10$ dB when $d > 6{,}500$ km).

s = distance in km of the terminal from the sea, measured along a great-circle path.

f = frequency in kHz.

The value of G_s should be converted to a multiplying factor and used to multiply the value of field strength determined in Section 10.2b or 10.2c.

Reason: Editorial

~~g) Excess Polarization Coupling Loss~~

~~L_p is the excess polarization coupling loss. In the MF band, at low latitudes, for $|I| \leq 45^o$, the following formula applies for each terminal:~~

$$\cancel{L_p = 180 (36 + \theta^2 + I^2)^{-\frac{1}{2}} - 2 \text{ (dB)}} \qquad \cancel{(2)}$$

~~(see Figure 10.5).~~

~~where I is the magnetic dip in degrees at the terminal and θ is the path azimuth measured in degrees from the magnetic E-W direction, such that $|\theta| \leq 90^o$. For $|I| > 45^o$, L_p should be evaluated separately for the two terminals, because of the different θ and I that may apply, and the two L_p values added. The most accurate available values of magnetic dip and declination should be used in determining θ and I (see Figures 10.6 and 10.7).~~

~~The net sum of Equation (2) is to be substracted from the value obtained in paragraphs 10.2 b) and c).~~

g) Excess Polarization Coupling Loss

At higher latitudes, such that the magnetic dip at the terminal is greater than 45°, the excess polarization coupling loss is zero. At lower latitudes, such that the magnetic dip at the terminal is equal to, or less than, 45° the following equation applies for each terminal separately:

$$L_p = \frac{180}{(36 + \theta^2 + I^2)^{\frac{1}{2}}} - 2$$

where L_p = the excess polarization coupling loss in dB.

θ = the path azimuth in degrees measured from the magnetic east-west direction such that $|\theta|$ is $\leq 90^o$.

I = the magnetic dip in degrees at the terminal.

L_p may also be read from Figure 10.5. For $|I| > 45^o$, L_p should be evaluated separately for the two terminals, because of the different values of θ and I that may apply, and the two L_p values added. The most accurate available values of magnetic dip and declination should be used in determining θ and I (see Figures 10.6 and 10.7).

The net sum of the two values of L_p should be converted to a multiplying factor and used to multiply the value of field strength determined in Section 10.2b or 10.2c.

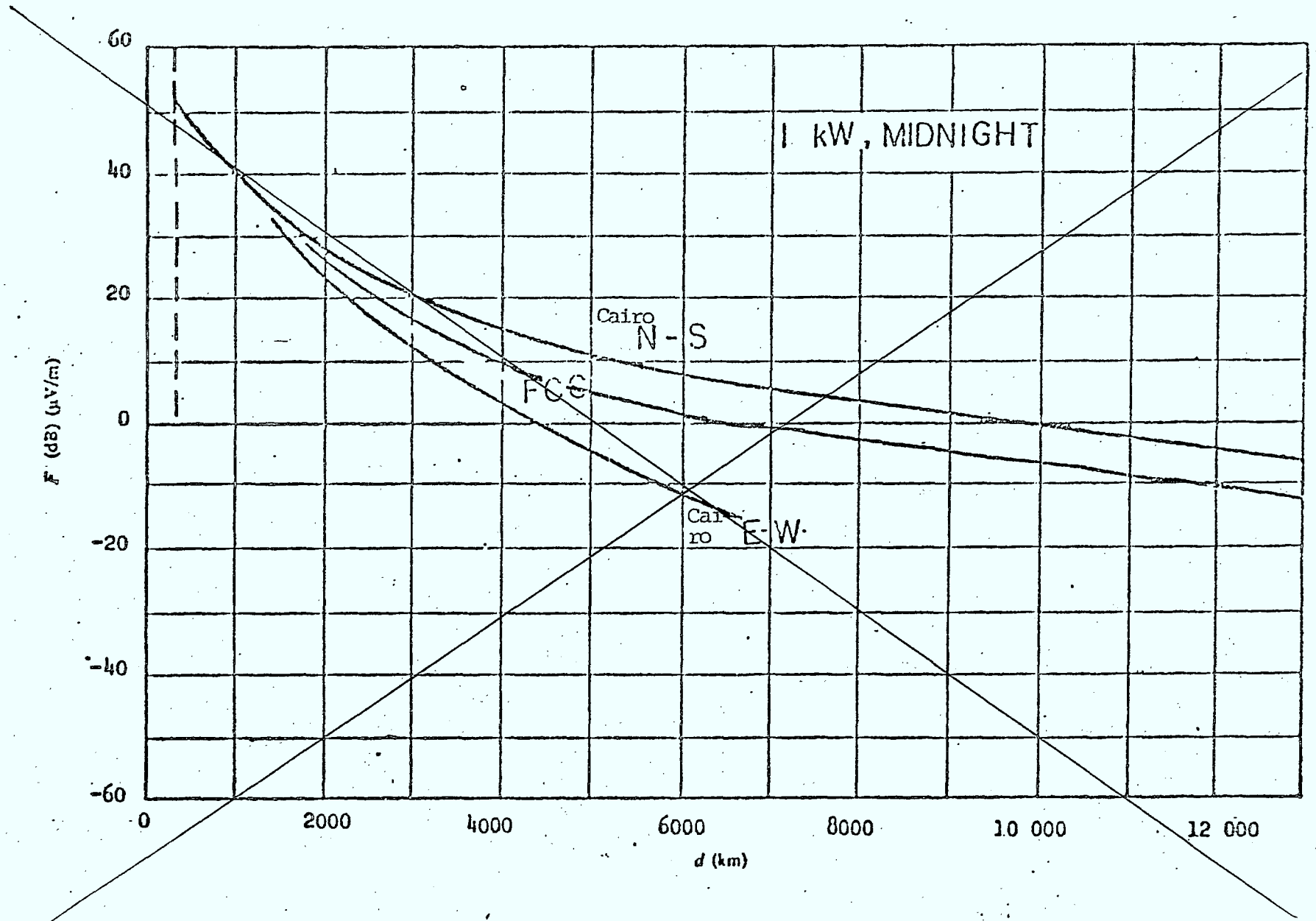
Reason: Editorial

10.3 METHODS OF CALCULATION OF ROOT SUM SQUARE (RSS) NIGHT-TIME LIMITATION OF A CLASS B OR A CLASS C STATION

The interference from two or more reflected wave signals to a desired signal is taken to be the root sum square (RSS) value of such interfering field intensities, as calculated from the 10% curve of Fig. 10.2 or 10.2A or Table 10.2. Calculation is accomplished by considering the signals, in order of decreasing magnitude, adding the squares of the values and extracting the square root of the sum, excluding those signals which are less than 50% of the RSS value of the higher signals already included. The RSS value will not be considered to be increased when a new interfering signal is added which is less than 50% of the RSS value of interference from existing stations and which is, at the same time, less than the smallest signal included in the RSS value of interference from existing stations. However, when the existing RSS value is less than the value of the nominal usable field strength, the incoming station's signal may be included in the RSS calculation, provided that the night-time limitation is not increased above the nominal usable field strength for the class of station concerned.

~~Note: For Class A stations,~~ ~~t~~The above calculations of the interfering signal will be based ~~on the site-to-be-protected contour separation, and, for Class B and C stations, it will be based~~ on site-to-site separation.

Reason: It is Canada's opinion that the 10% reflected-wave curve gives a more realistic value to protect service areas from objectionable interference. It is also necessary to define the means of applying this method when the night-time limitation is less than the nominal usable field strength for Class B and Class C stations.



~~FIGURE 10.1 MEDIAN (50%) PROPAGATION CURVES (UPPER DECILE CURVES TO BE ADDED.)~~

DELETE - (SEE REASON, PAGE 32 SECTION 10.1)

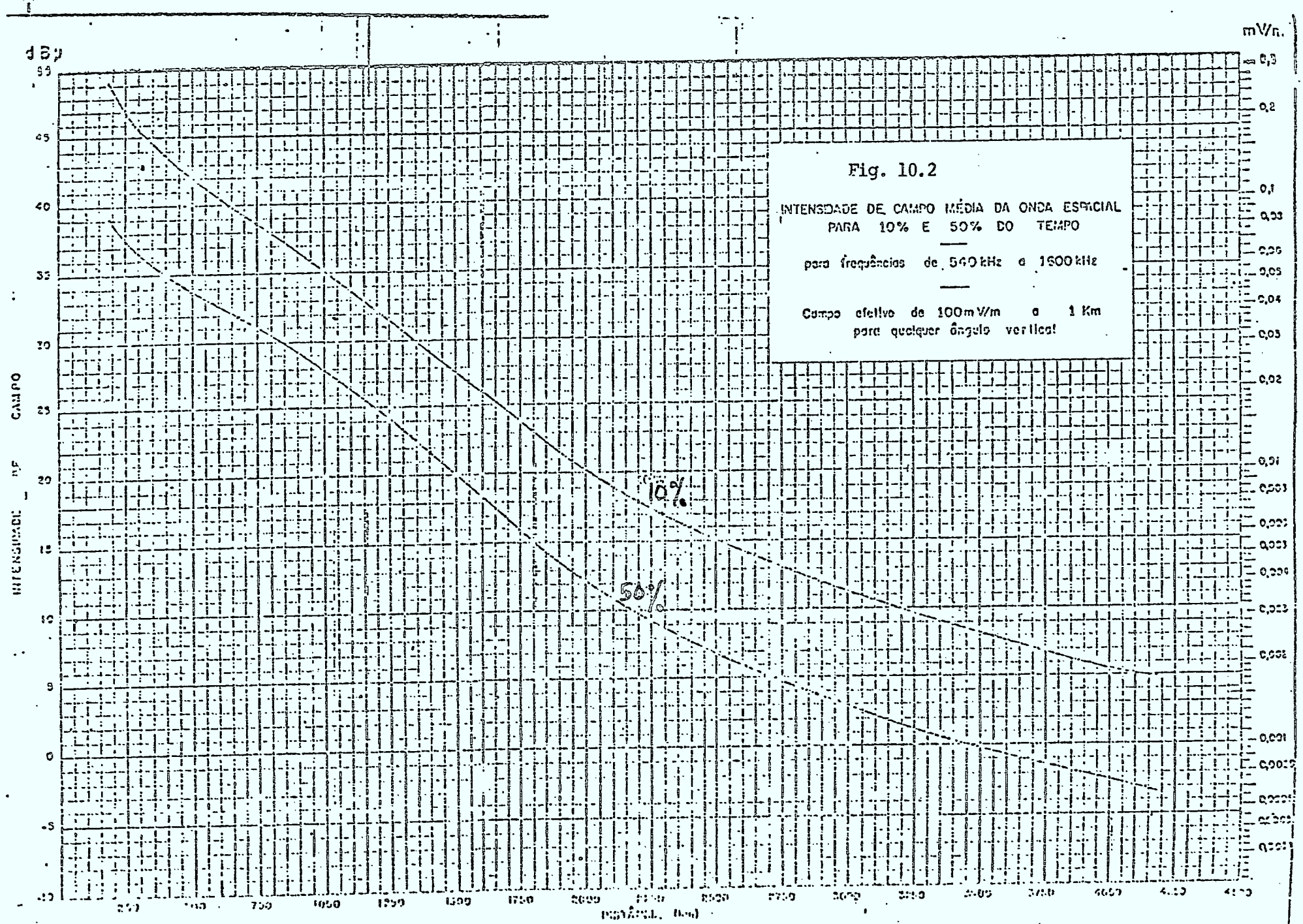


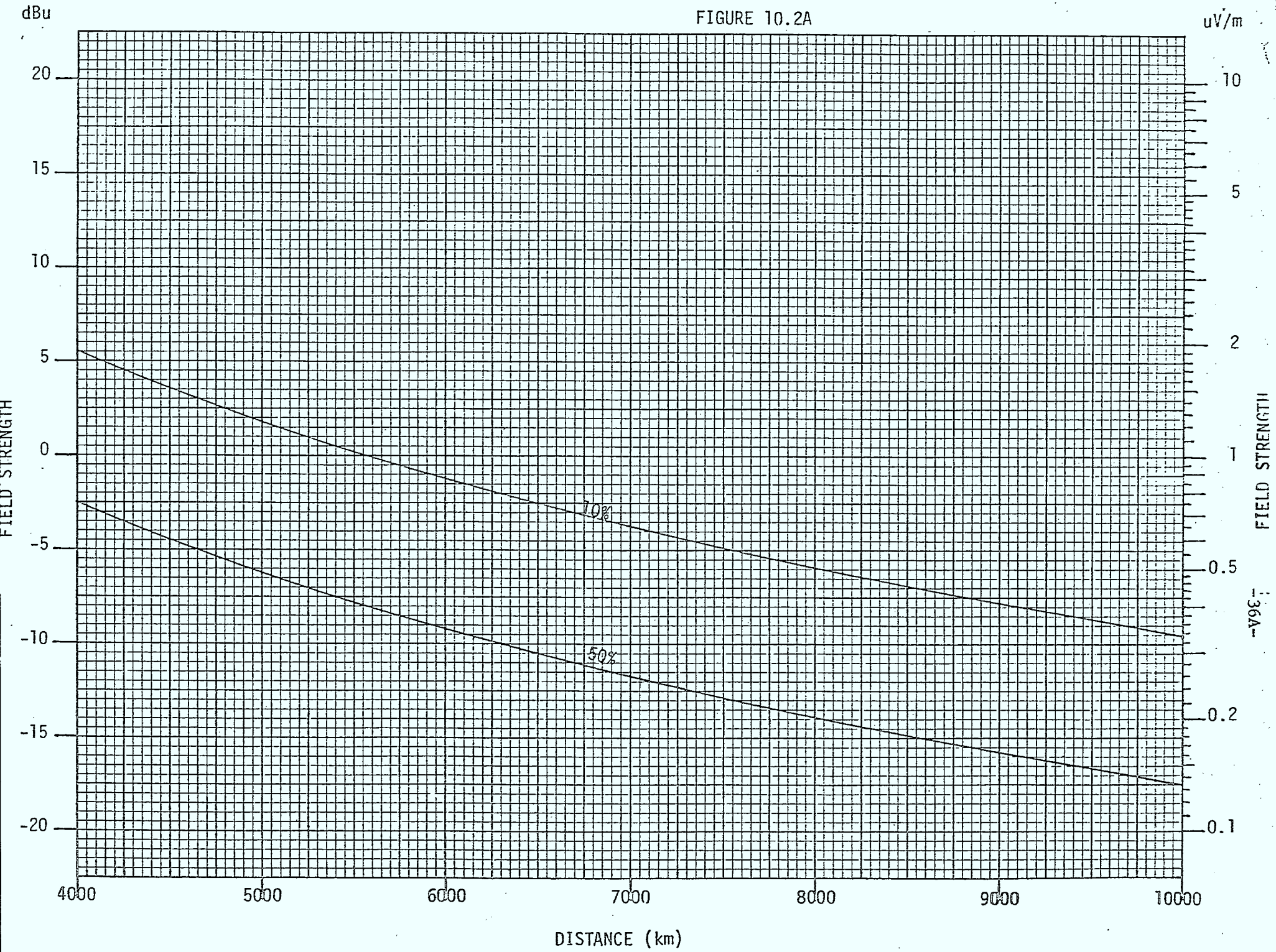
Fig. 10.2

INTENSIDADE DE CAMPO MÉDIA DA ONDA ESPACIAL PARA 10% E 50% DO TEMPO

para frequências de 540 kHz a 1600 kHz

Campo efetivo de 100 mV/m a 1 Km para qualquer ângulo vertical

FIGURE 10.2A


dBu
uV/m
20
15
10
5
0
-5
-10
-15
-20
10
5
2
1
0.5
0.2
0.1
FIELD STRENGTH
FIELD STRENGTH
10%
50%
4000
5000
6000
7000
8000
9000
10000
DISTANCE (km)

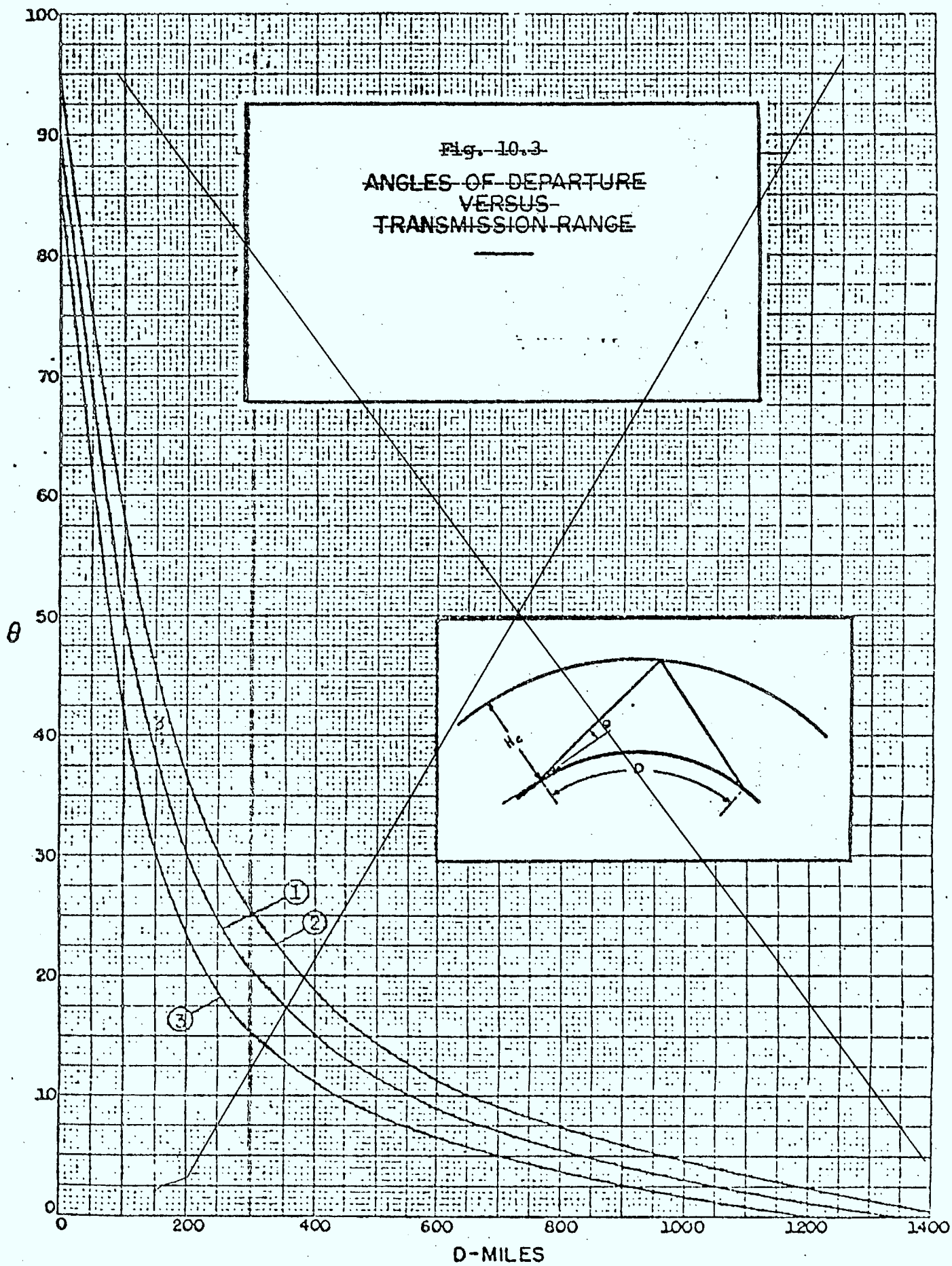
NEW CHART - REASON: SEE SECTION 10.1

TABLE 10.2

Reflected Wave Field Strength
for distances from 4000 to 10000 km

d (km)	E (dBu)		e (uV/m)	
	10%	50%	10%	50%
4000	5.46	-2.54	1.87	0.75
4100	5.06	-2.95	1.79	0.71
4200	4.66	-3.34	1.71	0.68
4300	4.28	-3.73	1.64	0.65
4400	3.90	-4.10	1.57	0.62
4500	3.53	-4.47	1.50	0.60
4600	3.17	-4.83	1.44	0.57
4700	2.82	-5.18	1.38	0.55
4800	2.48	-5.53	1.33	0.53
4900	2.14	-5.87	1.28	0.51
5000	1.81	-6.20	1.23	0.49
5100	1.48	-6.52	1.19	0.47
5200	1.16	-6.84	1.14	0.45
5300	0.85	-7.15	1.10	0.44
5400	0.55	-7.46	1.06	0.42
5500	0.25	-7.76	1.03	0.41
5600	-0.05	-8.05	0.99	0.40
5700	-0.34	-8.34	0.96	0.38
5800	-0.62	-8.63	0.93	0.37
5900	-0.90	-8.91	0.90	0.36
6000	-1.18	-9.18	0.87	0.35
6200	-1.71	-9.72	0.82	0.33
6400	-2.23	-10.24	0.77	0.31
6600	-2.74	-10.74	0.73	0.29
6800	-3.23	-11.23	0.69	0.27
7000	-3.70	-11.71	0.65	0.26
7200	-4.16	-12.17	0.62	0.25
7400	-4.61	-12.61	0.59	0.23
7600	-5.05	-13.05	0.56	0.22
7800	-5.47	-13.48	0.53	0.21
8000	-5.89	-13.89	0.51	0.20
8200	-6.29	-14.30	0.48	0.19
8400	-6.69	-14.69	0.46	0.18
8600	-7.07	-15.08	0.44	0.18
8800	-7.45	-15.45	0.42	0.17
9000	-7.82	-15.82	0.41	0.16
9200	-8.18	-16.18	0.39	0.16
9400	-8.53	-16.53	0.37	0.15
9600	-8.87	-16.88	0.36	0.14
9800	-9.21	-17.21	0.35	0.14
10000	-9.54	-17.54	0.33	0.13

DELETE - replace by Table 10.1



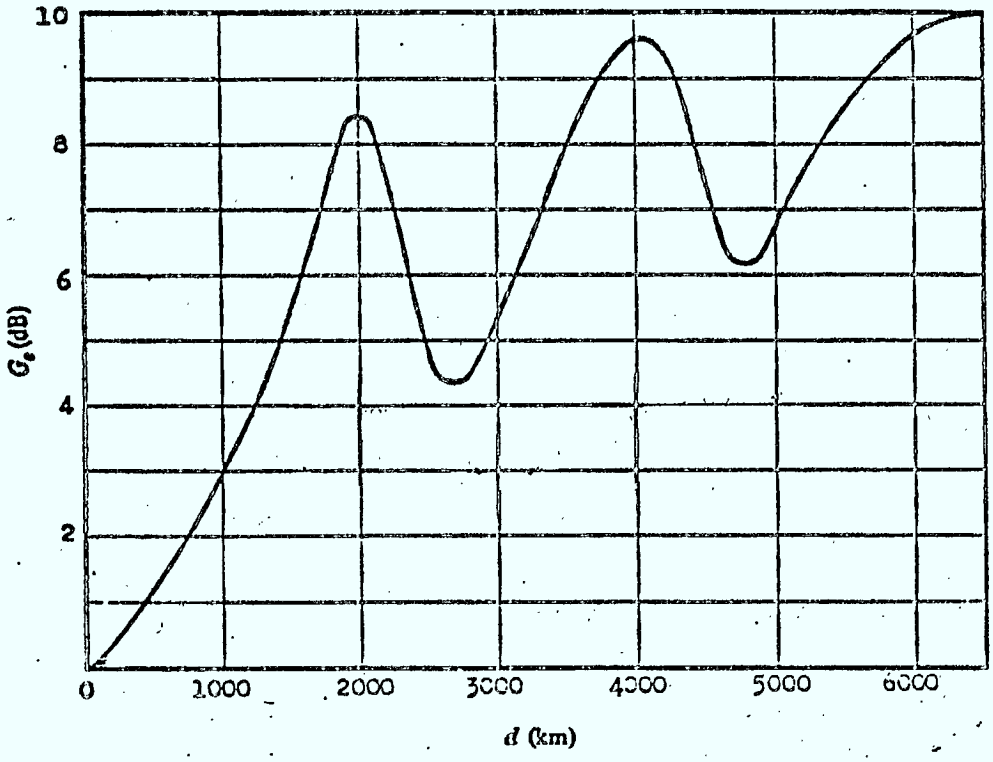


FIGURE 10.4

Sea Gain for a single Terminal on the Coast

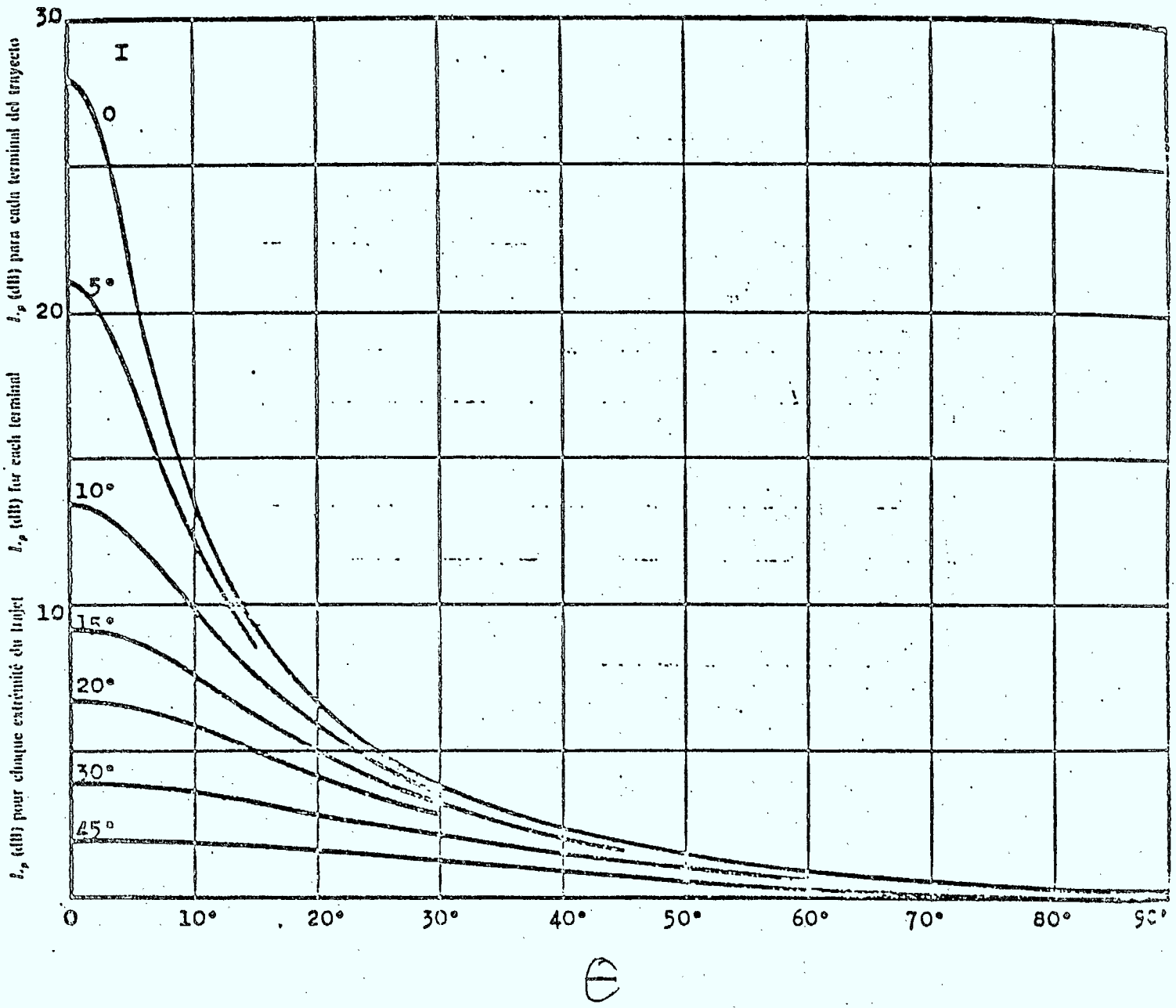


FIGURE 10.5

Excess Polarization Coupling Loss L_p

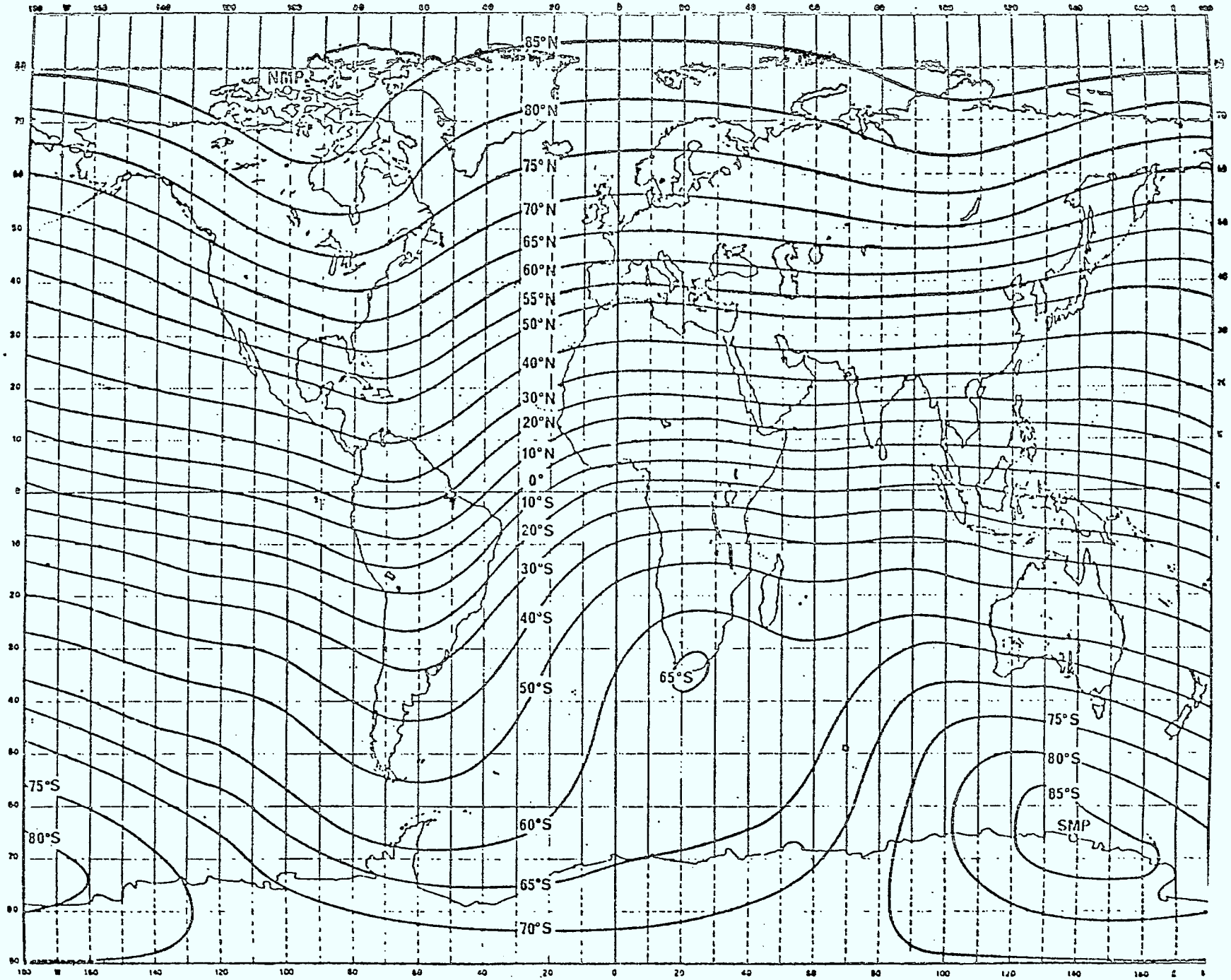


FIGURE 14 -- FIGURA 10.6

-- Map of magnetic Dip -

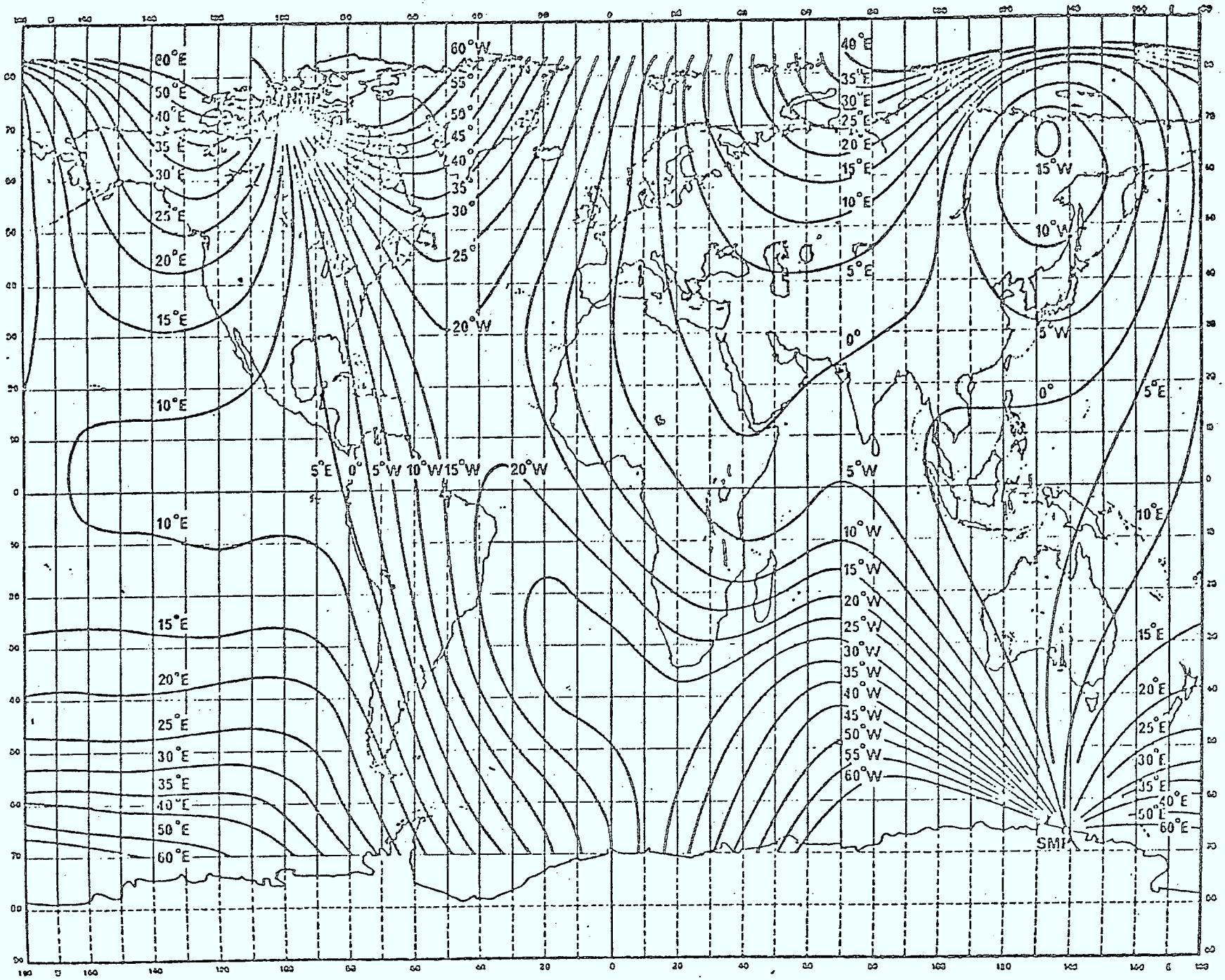

60°E
50°E
40°E
35°E
30°E
25°E
20°E
15°E
10°E
60°W
55°
50°
45°
40°
35°
30°
25°
20°W
40°E
35°E
30°E
25°E
20°E
15°E
10°E
5°E
0°
15°W
10°W
5°W
0°
5°E
5°E 0° 5°W 10°W 15°W 20°W
5°W
10°W
15°W
20°W
25°W
30°W
35°W
40°W
45°W
50°W
55°W
60°W
10°E
15°E
20°E
25°E
30°E
35°E
40°E
50°E
60°E
SMI

FIGURE 10.7

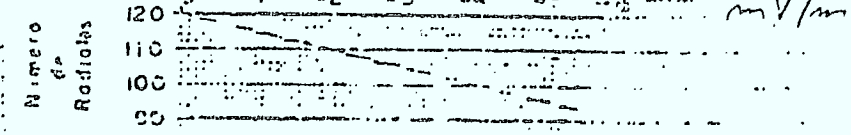
Fig. 10.8

CAMPOS CARACTERISTICOS DE ANTENAS VERTICALES

A 1.609 KILOMETROS (UNA MILLA)
PARA UN KILOWATT

Usar para antenas verticales omnidireccionales simples con sistema de tierra ó al menos 120 radiales de la longitud indicada.

Para sistemas de tierra que tengan menos de 120 radiales, restar:



~~APPENDIX 10.1~~

(DELETE - SEE REASON PAGE 32, SECTION 10.1)

Several methods are available for estimating the MF reflected wave signal strength. These included the FCC method, the CCIR methods in their original form and as modified in Doc. RADIF/3/79, Brasilia. In addition, there are the Cairo curves.

The FCC method has the advantage of being widely used in North America over a considerable period of time with apparent satisfactory results. It has the disadvantage that it is completely empirical and was developed on the basis of measurements within the U.S. and does not include factors for magnetic effects. It applies primarily to a frequency of 1 MHz and is independent of both frequency and sunspot number. It is intended only for use at distances of less than 4,300 km.

The CCIR method is stated to be usable for distances up to 10,000 km. It includes factors allowing frequency, magnetic latitude, direction of propagation, polarisation coupling loss, solar activity in certain geographical regions, and sea gain to be considered. This method was recommended by the CCIR for provisional use in 1978 and appears to have received wide international use, exemplified by its selection as the basis for propagation calculations associated with Regions 1 and 3. Improvements to this model have been proposed by Wang (Doc. RADIF/3/79, Brasilia).

The Cairo N-S curve is also purely empirical and is based essentially on measurements made on long paths between South America, Europe and North America, during a period of high sunspot activity. It is drawn for distances of up to 12,000 km, and is independent of frequency and path orientation. Measurements in Asia and the Pacific fit this curve very well.

Comparisons have been made by Wang between measurements over several paths, and the predictions made by the FCC, Cairo N-S, and the original and modified CCIR methods. These comparisons show that in low-latitude areas of Region 2 measured field strengths are consistently higher than predicted values for all methods studied. When compared to measured low-latitude data, the FCC method, the Cairo N-S curve, the CCIR method and the modified CCIR method have an RMS deviation of 8.8 dB, 5.1 dB, 10.3 dB and 5.8 dB, respectively.

APPENDIX 10.2

The antenna gain may be calculated as a function of the vertical angle by means of ~~the following~~ table 10.3.

When the negative sign (-) appears in the table, it signifies only the existence of a secondary lobe, having the opposite electrical phase from the principal lobe, in the vertical radiation pattern. In order to perform the calculation, ignore the negative (-) and use only the absolute value of $f(\theta)$ from the table.

Reason: Editorial

TABLE 10.3

F (θ) Values for Vertical Monopoles

ANGLE OF DEPARTURE (degrees)	F(θ)					
	0,11λ	0,13λ	0,15λ	0,17λ	0,19λ	0,21λ
0	1,000	1,000	1,000	1,000	1,000	1,000
1	1,000	1,000	1,000	1,000	1,000	1,000
2	0,999	0,999	0,999	0,999	0,999	0,999
3	0,999	0,998	0,998	0,998	0,998	0,998
4	0,997	0,997	0,997	0,997	0,997	0,997
5	0,996	0,996	0,996	0,995	0,995	0,995
6	0,994	0,994	0,994	0,993	0,993	0,993
7	0,992	0,992	0,991	0,991	0,991	0,990
8	0,989	0,989	0,989	0,988	0,988	0,987
9	0,987	0,986	0,986	0,985	0,985	0,984
10	0,984	0,983	0,983	0,982	0,981	0,980
11	0,980	0,980	0,979	0,978	0,977	0,976
12	0,976	0,976	0,975	0,974	0,973	0,971
13	0,972	0,972	0,971	0,969	0,968	0,967
14	0,968	0,967	0,966	0,965	0,963	0,961
15	0,963	0,962	0,961	0,959	0,958	0,956
16	0,958	0,957	0,956	0,954	0,952	0,950
17	0,953	0,952	0,950	0,948	0,946	0,943
18	0,947	0,946	0,944	0,942	0,940	0,937
19	0,941	0,940	0,938	0,935	0,933	0,930
20	0,935	0,933	0,931	0,929	0,926	0,922
22	0,922	0,920	0,917	0,914	0,911	0,907
24	0,907	0,905	0,902	0,898	0,894	0,890
26	0,892	0,889	0,885	0,882	0,877	0,872
28	0,875	0,872	0,868	0,864	0,858	0,852
30	0,857	0,854	0,849	0,844	0,839	0,832
32	0,838	0,834	0,830	0,824	0,818	0,811
34	0,819	0,814	0,809	0,803	0,796	0,789
36	0,798	0,793	0,788	0,781	0,774	0,766
38	0,776	0,771	0,765	0,758	0,751	0,742
40	0,753	0,748	0,742	0,735	0,726	0,717
42	0,730	0,724	0,718	0,710	0,702	0,692
44	0,705	0,700	0,693	0,685	0,676	0,666
46	0,680	0,674	0,667	0,659	0,650	0,639
48	0,654	0,648	0,641	0,633	0,623	0,612
50	0,628	0,621	0,614	0,606	0,596	0,585
52	0,600	0,594	0,587	0,578	0,568	0,557
54	0,572	0,566	0,559	0,550	0,540	0,529
56	0,544	0,537	0,530	0,521	0,512	0,501
58	0,515	0,508	0,501	0,493	0,483	0,472
60	0,485	0,479	0,472	0,463	0,454	0,443

TABLE 10.3

F (θ) Values for Vertical Monopoles

ANGLE OF DEPARTURE (degrees)	F(θ)					
	0,23λ	0,25λ	0,27λ	0,29λ	0,311λ	0,35λ
0	1,000	1,000	1,000	1,000	1,000	1,000
1	1,000	1,000	1,000	1,000	1,000	1,000
2	0,999	0,999	0,999	0,999	0,999	0,999
3	0,998	0,998	0,998	0,998	0,998	0,997
4	0,997	0,996	0,996	0,996	0,996	0,995
5	0,995	0,994	0,994	0,994	0,993	0,992
6	0,992	0,992	0,991	0,991	0,990	0,989
7	0,990	0,989	0,988	0,988	0,987	0,985
8	0,987	0,986	0,985	0,984	0,983	0,980
9	0,983	0,982	0,981	0,980	0,978	0,975
10	0,979	0,978	0,977	0,975	0,973	0,969
11	0,975	0,973	0,972	0,970	0,968	0,963
12	0,970	0,968	0,966	0,964	0,962	0,956
13	0,965	0,963	0,961	0,958	0,955	0,949
14	0,959	0,957	0,955	0,952	0,948	0,941
15	0,953	0,951	0,948	0,945	0,941	0,932
16	0,947	0,944	0,941	0,937	0,933	0,924
17	0,941	0,937	0,934	0,930	0,925	0,914
18	0,934	0,930	0,926	0,921	0,916	0,904
19	0,926	0,922	0,918	0,913	0,907	0,894
20	0,919	0,914	0,909	0,904	0,898	0,883
22	0,902	0,897	0,891	0,885	0,877	0,861
24	0,885	0,879	0,872	0,865	0,856	0,837
26	0,866	0,859	0,852	0,843	0,833	0,811
28	0,846	0,838	0,830	0,820	0,809	0,785
30	0,825	0,816	0,807	0,797	0,784	0,758
32	0,803	0,794	0,784	0,772	0,759	0,729
34	0,780	0,770	0,759	0,747	0,732	0,701
36	0,756	0,746	0,734	0,721	0,705	0,671
38	0,732	0,720	0,708	0,694	0,677	0,642
40	0,706	0,695	0,681	0,667	0,649	0,612
42	0,681	0,668	0,654	0,639	0,621	0,582
44	0,654	0,641	0,627	0,611	0,593	0,552
46	0,628	0,614	0,600	0,583	0,564	0,523
48	0,600	0,587	0,572	0,555	0,536	0,494
50	0,573	0,559	0,544	0,527	0,507	0,465
52	0,545	0,531	0,516	0,498	0,479	0,436
54	0,517	0,503	0,487	0,470	0,451	0,408
56	0,488	0,474	0,459	0,442	0,423	0,331
58	0,460	0,446	0,431	0,414	0,395	0,354
60	0,431	0,418	0,403	0,387	0,368	0,328

TABLE 10.3

F (θ) Values for Vertical Monopoles

ANGLE OF DEPARTURE (degrees)	F(θ)					
	0,40λ	0,45λ	0,50λ	0,528λ	0,55λ	0,625λ
0	1,000	1,000	1,000	1,000	1,000	1,000
1	1,000	1,000	0,999	0,999	0,999	0,999
2	0,998	0,998	0,998	0,997	0,997	0,995
3	0,997	0,996	0,995	0,994	0,993	0,989
4	0,994	0,992	0,990	0,989	0,988	0,981
5	0,991	0,988	0,985	0,983	0,981	0,970
6	0,986	0,983	0,979	0,975	0,972	0,957
7	0,982	0,977	0,971	0,967	0,962	0,941
8	0,976	0,970	0,962	0,957	0,951	0,924
9	0,970	0,963	0,953	0,945	0,938	0,904
10	0,963	0,954	0,942	0,933	0,924	0,882
11	0,955	0,945	0,930	0,919	0,909	0,859
12	0,947	0,934	0,917	0,905	0,893	0,834
13	0,938	0,923	0,903	0,889	0,875	0,807
14	0,929	0,912	0,889	0,872	0,857	0,778
15	0,918	0,899	0,873	0,855	0,837	0,748
16	0,908	0,886	0,857	0,836	0,816	0,717
17	0,897	0,873	0,840	0,817	0,795	0,684
18	0,885	0,859	0,823	0,797	0,772	0,651
19	0,873	0,844	0,804	0,776	0,749	0,617
20	0,860	0,828	0,785	0,755	0,726	0,582
22	0,833	0,796	0,746	0,710	0,677	0,510
24	0,805	0,763	0,705	0,665	0,626	0,436
26	0,776	0,728	0,663	0,618	0,574	0,363
28	0,745	0,692	0,621	0,570	0,522	0,290
30	0,714	0,655	0,577	0,522	0,470	0,219
32	0,682	0,619	0,534	0,475	0,419	0,151
34	0,649	0,582	0,492	0,428	0,369	0,086
36	0,617	0,545	0,450	0,383	0,321	0,025
38	0,584	0,509	0,409	0,340	0,275	-0,031
40	0,552	0,473	0,370	0,298	0,231	-0,083
42	0,519	0,438	0,332	0,258	0,190	-0,129
44	0,488	0,405	0,296	0,221	0,152	-0,170
46	0,457	0,372	0,262	0,187	0,117	-0,205
48	0,427	0,341	0,230	0,155	0,085	-0,235
50	0,397	0,311	0,201	0,126	0,056	-0,259
52	0,369	0,283	0,174	0,099	0,031	-0,278
54	0,341	0,257	0,149	0,076	0,009	-0,291
56	0,315	0,232	0,126	0,055	-0,010	-0,300
58	0,289	0,208	0,105	0,037	-0,026	-0,304
60	0,265	0,186	0,087	0,021	-0,039	-0,304
62				0,008	-0,049	-0,300
64				-0,003	-0,056	-0,292
66				-0,011	-0,062	-0,281
68				-0,017	-0,064	-0,267
70				-0,022	-0,065	-0,250
72				-0,025	-0,064	-0,231
74				-0,026	-0,061	-0,210
76				-0,026	-0,056	-0,188
78				-0,024	-0,051	-0,163
80				-0,022	-0,044	-0,138

III. FORMAT FOR NOTIFYING MF BROADCASTING STATIONS

1. Standardized Form

Complete physical and technical specifications of antenna design shall be provided when available (see attached form and instructions).

Note: Canada continues to support this format. However, due to the lack of time available to submit its inventory, Canada decided to abide by the IFRB recommendation (circular letter 441 Aug. 24, 1979) with the following modifications:

1) Add the theoretical RMS radiation in Part 2.

Reason: to define the radiation pattern size.

2) Add the Expanded Pattern RMS Radiation and the Q factor.

Reason: to provide the same information presently exchanged between U.S. and Canada.

3) The use of greater precision in the description of directional antenna.

Reason: to avoid inaccuracies in the calculation of pattern nulls.

4) Add the RSS night-time limitation for Class B and C stations as described in Section 10.3

Reason: To ensure consistency in the calculation of night-time interference

1.1

FORM FOR NOTIFYING BROADCASTING STATIONS IN MEDIUM FREQUENCY BAND (535 - 1605 kHz)

Administration

Date
No.

	Assigned frequency (kHz)	1	
Transmitting Station	Name of the transmitting station	2a	
	Call sign	2b	
	Additional Identification	2c	
	Class of Station	2d	
	Operational Status	2e	
	Country Symbol	3	
Geographical Coordinates	Longitude	4a	
	Latitude	4b	
	Degree of Compression and necessary bandwidth	5	
Carrier Power (kW)	for daytime operation	6a	
	for nighttime operation	6b	
Radiation Characteristics of the Transmitting Station – Day	Maximum radiation (dB)	7a	
	Azimuth of maximum radiation	8a	
	Sectors of limited radiation	9a	
	Maximum radiation in the limiting sector	10a	
Radiation Characteristics of the Transmitting Station – Night	Maximum radiation (dB)	7b	
	Azimuth of maximum adiation	8b	
	Sectors of limited radiation	9b	
	Maximum radiation in the limiting sector	10b	
Antenna – Day	Type	11a	
	Height	12a	
Antenna – Night	Type	11b	
	Height	12b	
	Ground Conductivity (mS/m)	13	
	Hours of Operation (GMT)	14	
	Remarks	15	

Hours of Operations (GMT)	16	
Theoretical RMS Radiation (dBu)	17	
Expanded Pattern RMS Radiation (dBu)	18	
Q (dBu)	19	
Total Number of Towers	20	

(21) TOWER NUMBER	(22) FIELD RATIO	(23) PHASE ANGLE (DEG)	(24) TOWER SPACING (DEG)	(25) TOWER ORIENTATION (DEG)	(26) TWR REF IND	(27) ELECTR HGT (DEG)	(28) TOP LOAD

Column 1	Assigned frequency (kHz).
Column 2 a	Name of the transmitting station. Indicate the name of the locality by which the station is known. Limit the number of letters and numerals to a total of 14.
Column 2 b	Call sign. This information is optional. Limit the number of letters and numerals to a total of 7.
Column 2 c	Additional identification. Give any additional information which may be considered as essential for completion of identification. In case no such information is essential, this column may be left blank.
Column 2 d	Class of Stations A, B or C as defined in this Agreement
Column 2 e	O or P. Operational or proposed
Column 3	Country. Indicate the country in which the station is located. Use the symbols in Table 1 of the Preface to the International Frequency List.
Column 4	Geographical coordinates of the transmitting station.
Column 4 a	Indicate the longitude of the site of transmitting antenna in degrees and minutes.
Column 4 b	Indicate the latitude of the site of the transmitting antenna in degrees and minutes.
Column 5	Necessary bandwidth (kHz). Indicate the necessary bandwidth of the emission, as defined in No. 91 of the Radio Regulation preceded by symbols A, B, C or D having the meaning given in C.C.I.R. Recommendation 449-2.
Column 6	Carrier power (kW).
Column 6 a	Indicate the power supplied to the antenna transmission line by the transmitter, accurate to one decimal position, for daytime operation.
Column 6 b	Indicate the power supplied to the antenna transmission line by the transmitter, accurate to one decimal position, for nighttime operation.
Column 7	Transmitter radiation characteristics.
Column 7 a	Indicate maximum radiation in dB relative to effective monopole radiated power (e.m.r.p.) of 1 kW, for daytime operation. This value is obtained by adding the nominal power of the transmitter (in dB) to the theoretical gain of the antenna in dB without allowing for miscellaneous losses.
Column 7 b	Indicate the maximum radiation in dB relative to e.m.r.p. of kW, for nighttime operation. This value is obtained by adding the nominal power of the transmitter for nighttime operation, to the theoretical gain of the antenna without allowing for miscellaneous losses.
Column 8	Azimuth of maximum radiation.

Column 8 a	Indicate the azimuth of maximum radiation in the horizontal plane, in degrees (clockwise) from True North, for daytime operation. In the case of a simple vertical antenna, this column may be left blank.
Column 8 b	Indicate the azimuth of maximum radiation, in the horizontal plane, in degrees (clockwise) from True North, for nighttime operation. In case of a simple vertical antenna, this column may be left blank.
Column 9 a	Indicate here the azimuths defining the sector of limited radiation, for daytime operation. The intent of this information is to indicate the directions in which the radiation is significantly below the maximum radiation.
Column 9 b	Indicate here the azimuths defining the sector of limited radiation, for nighttime operation. The intent of this information is to indicate the directions in which the radiation is significantly below the maximum radiation.
Column 10 a	Indicate here the maximum radiation, in dB, in the sector defined in 9 a.
Column 10 b	Indicate here the maximum radiation, in dB, in the sector defined in 9 b.
Column 11	Antenna.
Column 11 a	Indicate here the type of antenna used for daytime operation. In case of a simple vertical antenna insert here the symbol A. In case of an antenna other than a simple vertical antenna, insert here the symbol B.
Column 11 b	Indicate here the type of antenna used for nighttime operation. In case of a simple vertical antenna insert here symbol A. In case of an antenna other than a simple vertical antenna, insert here symbol B.
Column 12 a	Indicate here the electrical height, in degrees, for a simple vertical antenna in use during daytime operation. In case of a B type antenna this column should be left blank.
Column 12 b	Indicate here the electrical height, in degrees, for a simple vertical antenna in use during nighttime operation. In case of a B type antenna this column should be left blank.
Columns 13	Indicate here the average value of ground conductivity (mS/m) in the service area.
Column 14	Hours of operation (GMT). Indicate the daily hours of operation in GMT, to the nearest hour. Or, alternatively: for daytime operation insert HJ; for nighttime operation insert HN.
Column 15	Remarks

Column 16	Hours of operation for the pattern under considerations (GMT).
Column 17	Theoretical root-mean-square (RMS) Radiation (dBu).
Column 18	Expanded pattern root-mean-square (RMS) radiation (dBu).Calculated RMS value of the expanded pattern due to null fill.
Column 19	Q (dBu). Value associated with column 18.
Column 20	Total number of towers which constitute the array.
Column 21	Tower number within the array.
Column 22	Ratio of the tower current to the current of a reference tower (Tower nº 1) in the antenna system. (Leave blank for passive tower).
Column 23	Difference in phase angle (degrees) of the current in the tower with respect to the current in a reference tower (Tower nº 1) in the antenna system (Leave blank for passive tower).
Column 24	Spacing (electrical degrees) of the tower from tower number 1 or the previous tower. Used with the tower reference indicator in column 26.
Column 25	Orientation (degrees) of the tower from tower 1 or the previous tower. Used with the tower reference indicator in column 26.
Column 26	Tower reference indicator. 0 = spacing (Column 24) and orientation (Column 25) of the tower with respect to tower number 1. 1 = spacing and orientation of the tower with respect to the previous tower.
Column 27	Electrical height (degrees) of the vertical radiator under consideration.
Column 28	Top loading or sectionalized indicator (0=simple vertical monopole, 1 = top loated, 2= sectionalized).

Note 1 For items 6 b through 12 b, if radiation characteristics of the transmitting station are identical for daytime and nighttime operations, enter "ditto" in nighttime description.

Note 2 For items 7 a through 10 b, a maximum of four sets of radiation characteristics of the transmitting station may be entered each for daytime and nighttime.

2. Radiation Characteristics of Transmitting Antennae

a) The radiation pattern of an antenna array can be calculated using the formulae provided in the attached pages taken from the C.C.I.R. Handbook Antenna Diagrams, Geneva, 1978. However, the formula (3) should be corrected to read:

$$f(\theta) = \frac{\cos(\beta . h . \sin\theta) - \cos(\beta . h)}{(1 - \cos\beta . h)\ \cos(\theta)}$$

Note: The text book "Theory and Design of Directional Antennas" by Carl E. Smith, 1959, has been used extensively in Region 2. It contains many examples to illustrate the theory.

b) In those cases where the information required is not available for 1... above, full particulars relating to the gain (dBu) for different azimuths and angles of elevation should be provided by the responsible administration. The intervals in the azimuths and the elevation angles, for which the information shall be provided may be determined by the notifying administration. The accuracy with which the protected contour for a station with a highly directional antenna system shall be calculated may sometimes require that the antenna gain be known for intervals of five degrees or less in the horizontal plane, with a corresponding precision in the vertical plane.

c) When the administrations are not able to provide the data on the radiation characteristics as proposed in 2 b), the same information may be provided in the form of graphs on which the antenna gain is shown as a function of the azimuth and the angle of elevation. In this event care should be taken to mention, unambiguously, the value used as reference for drawing the graph.

ANTENNA DIAGRAMS

1. Introduction

The antenna diagrams represent the spatial radiation distribution of an antenna or an array of antennae. They indicate the values of cymomotive force* (c.m.f.) on a half-sphere above the ground centred at the antenna and of radius which is large compared to the physical and electrical dimensions of the antenna.

The c.m.f. at a point on the sphere is indicated in dB below the maximum c.m.f., which is labelled 0 dB. The curves are equipotential contours corresponding to the following values in dB:

0, 1, 2, 3, 4, 6, 8, 10, 13, 16, 20, 25, 30, 40 and ∞,

according to C.C.I.R. Recommendation 414.

C.m.f. contours of –20 dB and less are plotted in dot-dash lines, whereas the contours corresponding to $-\infty$ are traced in dashed lines.

All minor lobe maxima are indicated, and labelled with the corresponding value of c.m.f.

To calculate the c.m.f., the hemisphere is divided in steps of 0.25° and the normalized radiation pattern function $F(\varphi, \theta)$ is determined at each of these points. If this function is integrated over the half-space above the ground, the value of the specific cymomotive force* (F_{cs}) in the direction of maximum radiation can be calculated using the following formula:

$$F_{cs}\,(\max) = \frac{200 \cdot \sqrt{3\pi}}{\sqrt{\int_0^{2\pi} \int_0^{\pi/2} F^2\,(\varphi,\theta) \cdot \cos\,\theta \cdot d\theta \cdot d\varphi}} \quad \text{in volts} \qquad (1)$$

The electric field strength E in mV/m at a distance of 1 km for 1 kW radiated power is numerically equal to F_{cs} (see footnote below).

The curves are calculated and plotted using a digital computer system with plotting peripherals.

A sinusoidal projection, also called "Sanson-Flamstead projection" is used to represent the hemisphere and the contours in the plane of the paper.

The parallels of the hemisphere are straight lines spaced in proportion to the elevation angle θ. The meridians are portions of cosine waves passing through the pole of the hemisphere and spaced in proportion to the azimuth angle φ, at an elevation angle of 0°.

One of the properties of this projection is that equal areas on the hemisphere remain equal in the plane of the paper.

The reference axis 0° to 180° is usually an axis of symmetry of the antenna. To represent the whole hemisphere, two diagrams are needed: the forward radiation pattern (grid printed in brown) and the backward radiation pattern (blue grid). The first of these represents the radiation in the quarter sphere between the azimuth angles –90°, 0°, +90°, while the second contains the radiation in the other quarter sphere above the ground (+90°, 180°, –90°). Both of these patterns have the same figure number, that of the backward radiation pattern being followed by an apostrophe. In the cases where these patterns are identical, only one is included, and carries a double number.

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* Definitions of cymomotive force and specific cymomotive force (see C.C.I.R. Report 618).

The cymomotive force at a given point in space is the product of the electric field strength at that point produced by the antenna, and the distance from that point to the antenna. This distance must be large enough for the reactive components of the field to be negligible. The c.m.f. is a vector, only its amplitude being considered in the diagrams.

The c.m.f. in volts is numerically equal to the electric field strength in mV/m at a distance of 1 km.

The specific cymomotive force at a point in space is the c.m.f. at that point when the power fed to the antenna is 1 kW.

2. Vertical antennae over flat and perfectly conducting ground

These antennae consist of one or more vertical conductors close to the ground, fed between their base and the ground. The radiation is vertically polarized everywhere.

Fig. 1 gives polar radiation patterns for single-element antennae of different heights. The actual three-dimensional radiation pattern is a figure of revolution around the antenna. The maximum s.c.m.f. in volts is indicated on each curve.

Fig. 2 is a graph of the maximum s.c.m.f. as a function of the height of a single-element antenna.

Fig. 3 gives normalized horizontal radiation patterns for arrays of two elements. The current in the two elements is assumed to be equal in amplitude, with a phase difference of α°. The spacing d between the elements is indicated in fractions of a wavelength. The azimuth angle of all the nulls is indicated.

There are innumerable different radiation patterns that can be obtained with arrays of two or more elements, even though they are identical. They vary according to the elements, their geometrical layout and the feed characteristics of each element. Only a limited number of cases are considered in Figs. 4 to 23, with a maximum of four radiating elements. Most of these have one or two major lobes, with very little radiation in a relatively large section of the diagrams (both in azimuth and in elevation). These diagrams are included as examples to facilitate the task of finding the most appropriate diagram for each particular case.

Each diagram gives:

- the radiation pattern;
- a drawing to the right of the radiation pattern, indicating the number of radiating elements, the spacing between the elements (d) in wavelengths, their height (h) in wavelengths, the relative amplitude of the currents (I) and their phase angles (α). The arrow through the symmetry line points to 0° for the forward radiation pattern, or to 180° in the case of the backward radiation pattern. Two heights are considered, and the figures are numbered accordingly: (A) for $h = 0.25\lambda$, and (B) for $h = 0.50\lambda$;
- a horizontal radiation pattern to the left;
- the s.c.m.f. in volts in the direction of maximum radiation (F_{cs} rounded off to the nearest multiple of 5 volts) and the gain in dB relative to a short vertical element (G_v to within 0.1 dB).

The normalized radiation pattern function $F(\varphi, \theta)$ is given by the following expression:

$$F(\varphi, \theta) = k_1 \cdot f(\theta) \cdot S_x \cdot S_y \qquad (2)$$

where

$$f(\theta) = \frac{\cos(\beta \cdot h \cdot \sin\theta) - \cos(\beta \cdot h)}{\cos\theta}$$ is the vertical element pattern function; (3)

$$S_x = \sum_{m=1}^{N_x} I_m \exp\left[j(\beta \cdot x_m \cdot \cos\varphi \cdot \cos\theta + \alpha_m)\right] \qquad (4)$$

and

$$S_y = \sum_{n=1}^{N_y} I_n \exp\left[j(\beta \cdot y_n \cdot \sin\varphi \cdot \cos\theta + \alpha_n)\right] \qquad (5)$$

are the array factors for the x and y directions;

k_1 : normalizing factor to set $|F(\varphi, \theta)_{max}| = 1$, i.e. 0 dB;
$\beta = 2\pi/\lambda$;
λ : wavelength;
φ : azimuth angle;
θ : elevation angle;
h : height of the elements;
N_x : number of elements in the x-direction;
N_y : number of elements in the y-direction;
I_m : amplitude of the current in the mth element;
I_n : amplitude of the current in the nth element;
x_m : x-coordinate of the mth element;
y_n : y-coordinate of the nth element;
α_m : phase angle of the current in the mth element;
α_n : phase angle of the current in the nth element.

This formula is used with the following assumptions:

– all radiating elements are identical and fed at their base;
– the current fed to the elements is a pure sine wave;
– the current distribution in the elements is sinusoidal;
– there are no losses, either in the elements or in the ground;
– the array stands on plane ground.

The gain relative to a short vertical antenna is given by the following expression:

$$G_v = 20 \log \left(\frac{F_{cs}\ (\max)}{300} \right) \tag{6}$$

3. Arrays of horizontal half-wave dipoles over flat and perfectly conducting ground

Figs. 24 to 27 give curves relating the value of the specific cymomotive force F_{cs} in the direction of maximum radiation to the height h of the antenna above the ground. The height of the antenna is given in terms of the height of the lowest dipole or row of dipoles above the ground. The angle of elevation θ_{max} at which this maximum occurs is also given. The different curves in Fig. 24 apply to arrays with one horizontal row of dipoles and one, two, four or eight half-wave dipoles wide. Figs. 25 to 27 give similar information for arrays with two, three or four rows. The configuration of the arrays is shown to the right of the diagrams. The angle, θ_{max}, of maximum radiation should be read on the right-hand ordinate scale, whereas the maximum amplitude of the main lobe should be read on the left-hand ordinate scale of Figs. 24 to 27.

Figs. 28 to 63 are radiation diagrams for different horizontal dipole arrays. The designation of each array is of the form HR $m/n/h$ where "HR" means "horizontal with reflector curtain", m is the number of half-wave dipoles in each row, n is the number of rows spaced half a wavelength apart and h is the height above the ground in full wavelengths of the bottom row of dipoles, e.g. HR 4/2/1.0 indicates an antenna of horizontal dipoles with a reflector curtain, four half-waves wide, with two horizontal rows one above the other, the lowest row of elements being one wavelength above the ground.

The antennae of which the radiation diagrams are given in Figs. 28 to 63 are all used with a reflector curtain, which is geometrically identical to the main or driven array and spaced from it at a distance of $\lambda/4$. If the current in the reflector is equal in amplitude and leads in phase by $\pi/2$ that in the driven array, the major lobe in the unwanted direction will be suppressed, and in the wanted direction will be augmented.

Two diagrams are needed to represent the hemisphere above the ground plane: the forward radiation pattern, centred at $\varphi = 0°$ (grid printed in brown), and the backward radiation pattern, centred at $\varphi = 180°$ (blue grid). They have the same figure number, followed by an apostrophe in the case of the backward radiation pattern.

The formula used in calculating these diagrams is given below. It is assumed that the antenna is situated above a flat, horizontal and perfectly conducting ground.

$$F(\varphi, \theta) = k_2 \cdot f(\varphi, \theta) \cdot S_x \cdot S_y \cdot S_z \tag{7}$$

where

$$f(\varphi, \theta) = \frac{\cos\left[\frac{\pi}{2} \cdot \sin\varphi \cdot \cos\theta\right]}{[1 - \sin^2\varphi \cdot \cos^2\theta]^{\frac{1}{2}}}$$ is the horizontal element pattern function; (8)

$$S_x = \cos\left[\frac{\pi}{4} \cdot (\cos\varphi \cdot \cos\theta - 1)\right]$$ is the array factor due to the reflector curtain; (9)

$$S_y = \sum_{r=0}^{m-1} \exp\left[j \cdot \pi \cdot r \cdot \sin\varphi \cdot \cos\theta\right]$$ is the array factor for the elements in a horizontal row of dipoles; (10)

$$S_z = \sum_{r=0}^{n-1} \exp\left[2\pi j\left(\frac{h}{\lambda} + \frac{r}{2}\right) \cdot \sin\theta\right] \cdot \left\{1 - \exp\left[-4\pi j\left(\frac{h}{\lambda} + \frac{r}{2}\right) \cdot \sin\theta\right]\right\} \tag{11}$$

S_z is the array factor for the elements in a stack placed at a height h;
k_2: normalizing factor to set $|F(\varphi, \theta)_{max}| = 1$, i.e. 0 dB;
h : height of the lowest dipole or row of dipoles above the ground;
m : number of dipoles in each row;
n : number of dipoles in each stack.

4. Arrays over ground of finite conductivity

Figs. 64 to 90 are to be used in conjunction with the radiation patterns of § § 2 and 3. They indicate the amount by which the radiation patterns are changed when the ground constants are taken into account. For any angle of elevation θ between 0° and 90°, they give a correction factor δ in dB to be added to the curves in the radiation patterns. The value of δ is such that the radiation patterns are still normalized, when the ground losses are taken into account, i.e. the direction of maximum radiation still has a value of 0 dB associated with it. The corresponding values of s.c.m.f. can be found in Tables I to IV, which give the radiation characteristics of the arrays of § § 2 and 3, when placed over various types of ground. For each type of ground, the Tables give the following information:

– the specific cymomotive force F_{cs} in volts in the direction of maximum radiation;

– the elevation angle θ_{max} in degrees of the main lobe.

4.1 Arrays of vertical elements

Figs. 64 to 66 should be used to obtain the correction factor δ for arrays of vertical elements of heights 0.25λ to 0.5λ.

Three types of soil are considered which have the following characteristics at 1 MHz*: "poor" ground ($\sigma = 10^{-4}$ S/m, $\varepsilon = 3$), "average" ground ($\sigma = 10^{-3}$ S/m, $\varepsilon = 15$) and "good" ground ($\sigma = 10^{-2}$ S/m, $\varepsilon = 30$). Each figure gives information concerning one type of ground for two antenna heights.

δ is defined as follows:

$$\delta = 20 \log \frac{|F'(\varphi, \theta)|}{|F(\varphi, \theta)|} \quad \text{in dB} \tag{12}$$

where $F(\varphi, \theta)$ is the normalized radiation pattern function given by equation (2), and $F'(\varphi, \theta)$ is a similar expression for the case of imperfect ground:

$$F'(\varphi, \theta) = k_3 \cdot f'(\theta) \cdot S_x \cdot S_y \tag{13}$$

where

$$f'(\theta) = A_1 + j \cdot B_1 + R_v \cdot (A_1 - j \cdot B_1) ; \tag{14}$$

$$A_1 = \cos(\beta \cdot h \cdot \sin\theta) - \cos(\beta \cdot h) ; \tag{15}$$

$$B_1 = \sin(\beta \cdot h \cdot \sin\theta) - \sin(\beta \cdot h) \cdot \sin\theta ; \tag{16}$$

$$R_v = \frac{\left[\varepsilon - j \cdot \frac{18 \cdot 10^3 \cdot \sigma}{f_{\text{MHz}}}\right] \cdot \sin\theta - \left[\varepsilon - \cos^2\theta - j \cdot \frac{18 \cdot 10^3 \cdot \sigma}{f_{\text{MHz}}}\right]^{\frac{1}{2}}}{\left[\varepsilon - j \cdot \frac{18 \cdot 10^3 \cdot \sigma}{f_{\text{MHz}}}\right] \cdot \sin\theta + \left[\varepsilon - \cos^2\theta - j \cdot \frac{18 \cdot 10^3 \cdot \sigma}{f_{\text{MHz}}}\right]^{\frac{1}{2}}} \tag{17}$$

R_v is the complex reflection coefficient for vertically polarized waves;

k_3: normalizing factor to set $|F'(\varphi, \theta)_{max}| = 1$, i.e. 0 dB;

S_x and S_y are the same as for perfect ground (equations (4) and (5)).

The first type of antenna to be considered in Table I is a single vertical element, of heights 0.25λ (A) and 0.5λ (B). Then follow the arrays identified by their figure number (4A, 4B, etc.). The frequency of operation is 1 MHz, and four types of ground are considered: "perfect", "good", "average" and "poor". In the case of "perfect" ground, θ_{max} is always 0°, while for the other types of ground it can be as high as 30°.

4.2 Arrays of horizontal half-wave dipoles

Figs. 67 to 78 refer to arrays containing only one horizontal row of dipoles, while Figs. 79 to 90 give similar information for arrays with 2 rows.

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* See C.C.I.R. Report 229-2.

Two types of soil are considered – "poor" ground and "good" ground – at three different frequencies: 1 MHz, 10 MHz and 20 MHz.

The expression used for calculating δ is given below:

$$\delta = 20 \log \frac{|F'(\varphi, \theta)|}{|F(\varphi, \theta)|} \tag{18}$$

where $F(\varphi, \theta)$ is given by equation (7) and $F'(\varphi, \theta)$ is a similar expression:

$$F'(\varphi, \theta) = k_4 \cdot f(\varphi, \theta) \cdot S_x \cdot S_y \cdot S'_z \tag{19}$$

where

$$S'_z = \left[\frac{|A_2|^2 + |B_2|^2}{1 - \sin^2 \varphi \cdot \cos^2 \theta}\right]^{\frac{1}{2}} \tag{20}$$

$$A_2 = \sin \varphi \cdot \sin \theta \cdot \sum_{r=0}^{r=n-1} \exp\left[2\pi j \left(\frac{h}{\lambda} + \frac{r}{2}\right) \cdot \sin \theta\right] \cdot \left\{1 - R_v \cdot \exp\left[-4\pi j \left(\frac{h}{\lambda} + \frac{r}{2}\right) \cdot \sin \theta\right]\right\} \tag{21}$$

$$B_2 = \cos \varphi \cdot \sum_{r=0}^{r=n-1} \exp\left[2\pi j \left(\frac{h}{\lambda} + \frac{r}{2}\right) \cdot \sin \theta\right] \cdot \left\{1 + R_h \cdot \exp\left[-4\pi j \left(\frac{h}{\lambda} + \frac{r}{2}\right) \cdot \sin \theta\right]\right\} \tag{22}$$

$$R_h = \frac{\sin \theta - \left[(\varepsilon - \cos^2 \theta) - j \dfrac{18000\,\sigma}{f_{\mathrm{MHz}}}\right]^{\frac{1}{2}}}{\sin \theta + \left[(\varepsilon - \cos^2 \theta) - j \dfrac{18000\,\sigma}{f_{\mathrm{MHz}}}\right]^{\frac{1}{2}}} \tag{23}$$

R_h is the complex reflection coefficient for horizontally polarized waves;

R_v is given by equation (17):

$f(\varphi, \theta)$, S_x and S_y are the same as for the case of perfect ground (equations (8), (9) and (10)):

k_4: normalizing factor to set $|F'(\varphi, \theta)_{max}| = 1$, i.e. 0 dB.

Tables II to IV refer to the curtain arrays of § 3. Here, three types of ground are considered: "perfect", "good" and "poor". The frequencies in Tables II, III and IV are 1 MHz, 10 MHz and 20 MHz respectively.

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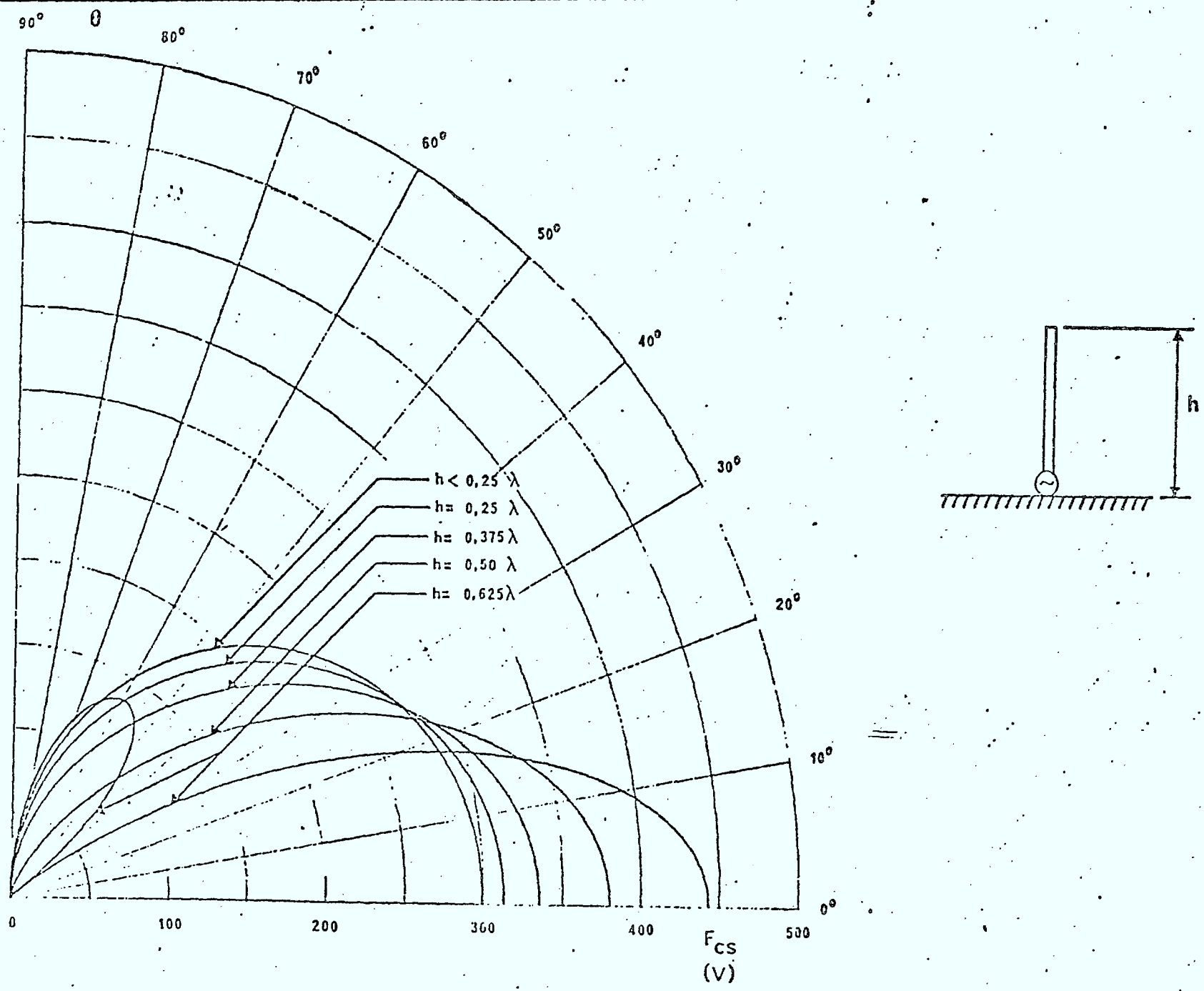
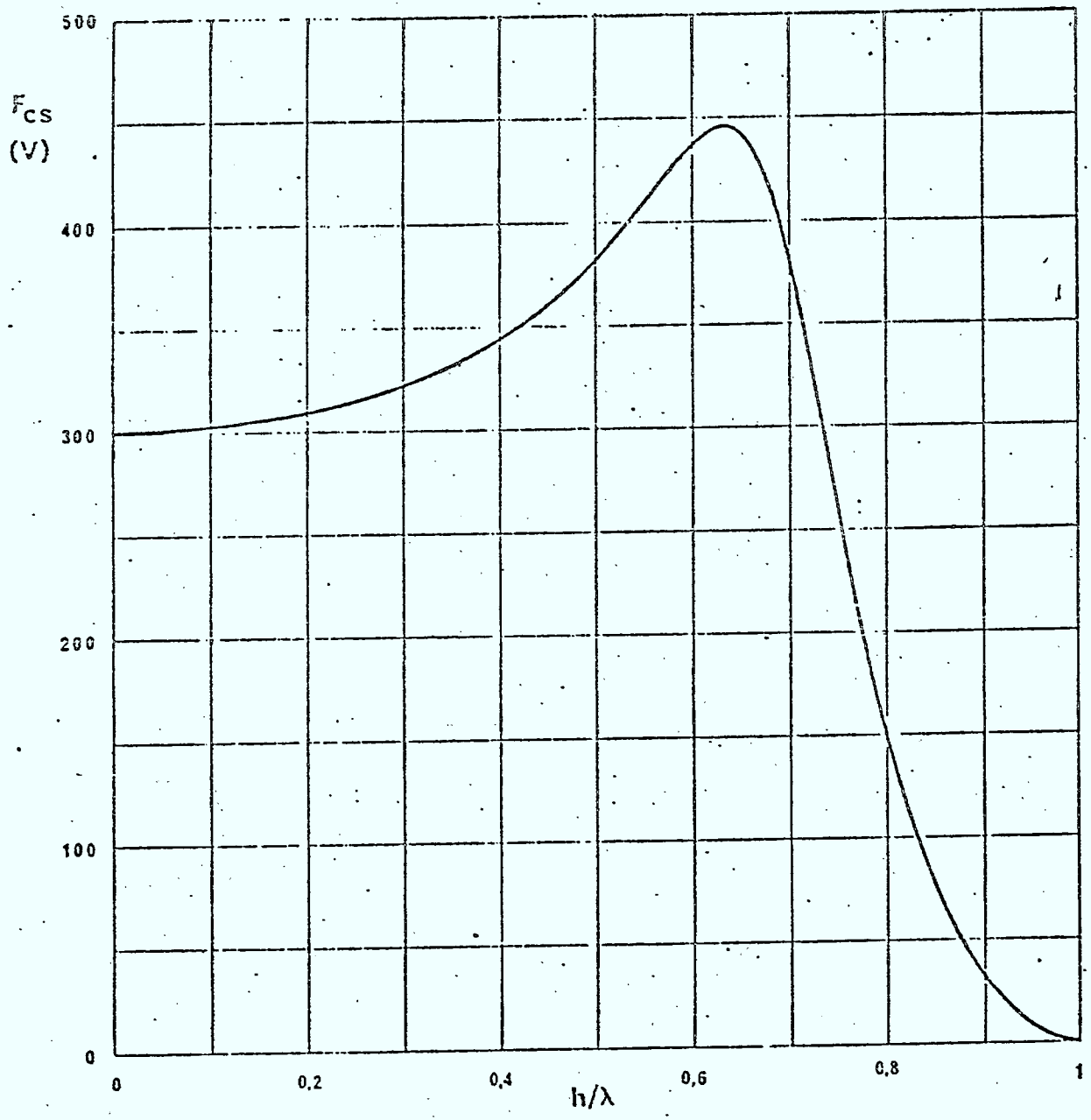

θ
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
h < 0,25 λ
h= 0,25 λ
h= 0,375 λ
h= 0,50 λ
h= 0,625 λ
0
100
200
300
400
500
F_{CS}
(V)
h

Fig. 1



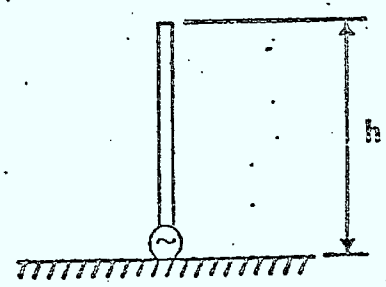


Fig. 2

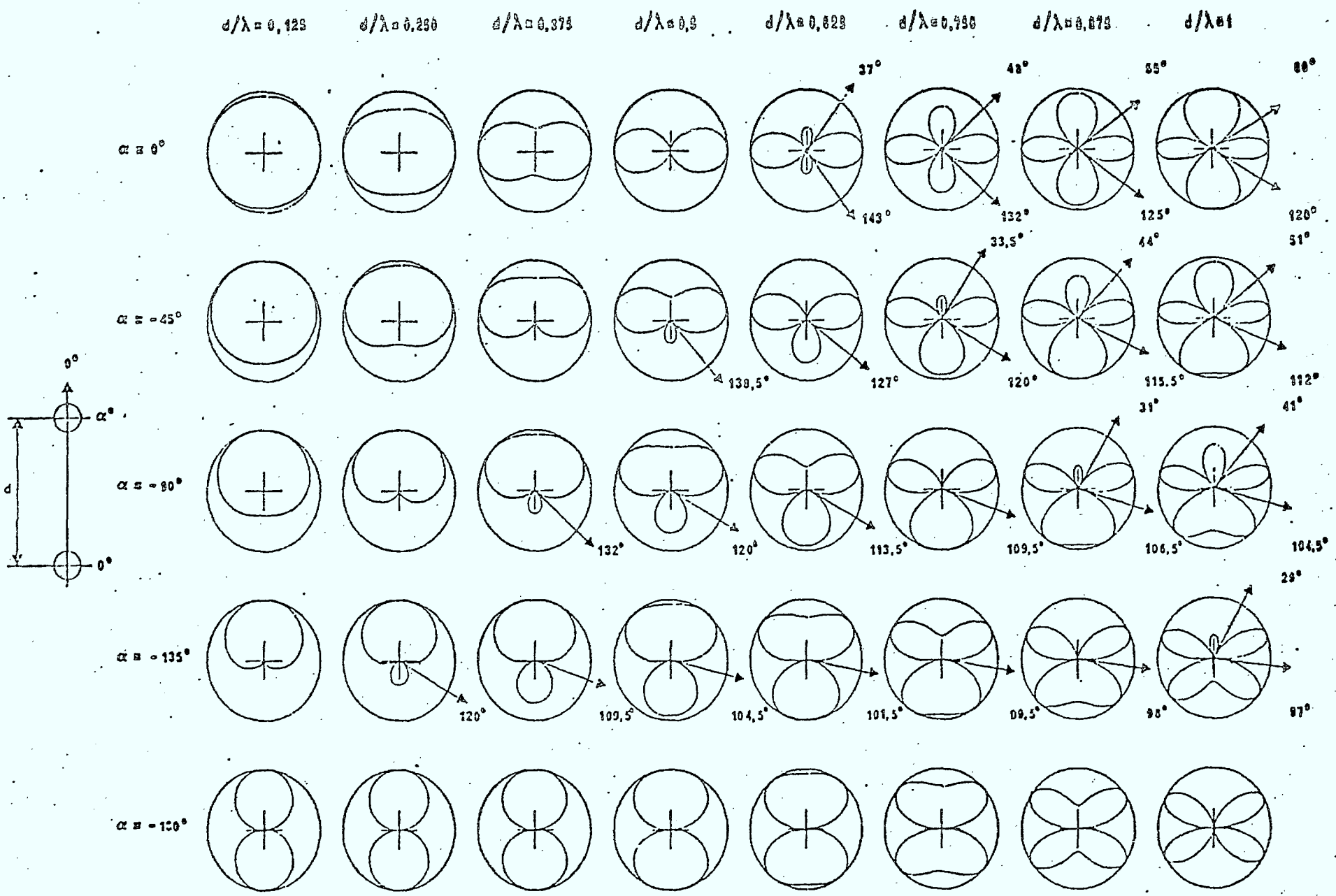

d/λ = 0,125
d/λ = 0,250
d/λ = 0,375
d/λ = 0,5
d/λ = 0,625
d/λ = 0,750
d/λ = 0,875
d/λ = 1
α = 0°
α = -45°
α = -90°
α = -135°
α = -180°
0°
α°
d
0°
37°
48°
55°
60°
143°
132°
125°
120°
33,5°
44°
51°
138,5°
127°
120°
115,5°
112°
31°
41°
132°
120°
113,5°
109,5°
106,5°
104,5°
29°
120°
109,5°
104,5°
101,5°
99,5°
98°
97°

Fig.3.

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Canadian proposals : propose

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