

SED #080700-TR-101

A STUDY OF
RURAL MOBILE RADIOS
IN THE
PRAIRIE PROVINCES
(ISSUE 2)

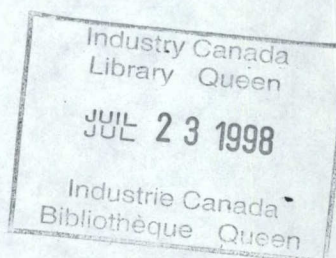
SED SYSTEMS

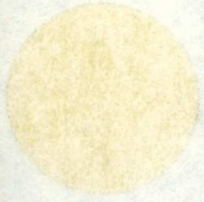
QUEEN
P 92
92 C2
.C2 843
B45
1978

Queen
P
92
C2
B45
ATB

SED #080700-TR-101

A STUDY OF
RURAL MOBILE RADIOS
IN THE
PRAIRIE PROVINCES
(ISSUE 2)





RECEIVED
JAN 10 1963
U.S. AIR FORCE
HEADQUARTERS
WASHINGTON, D.C.

RECEIVED
JAN 10 1963
U.S. AIR FORCE
HEADQUARTERS
WASHINGTON, D.C.

P
92
CE
B45

SED SYSTEMS LTD.
AEROSPACE PRODUCTS DIVISION

Saskatoon

Canada

A STUDY OF
RURAL MOBILE RADIOS
IN THE
PRAIRIE PROVINCES

SED Project #

080700-TR-101

Issue #

2

Date of Issue:

May 8, 1978

Prepared by:

A.R. Bens

A.R. Bens

Approved by:

D.W. Johnson

D.W. Johnson

TABLE OF CONTENTS

	<u>Page</u>
1.0 GENERAL	1
1.1 Introduction	1
1.2 Background	1
1.3 Project Approach	1
1.4 Summary of the Results of the Parallel Study Carried Out by the Institute for Northern Studies (INS)	4
1.5 Mobile Radio Systems Currently in Use	12
2.0 TECHNICAL SURVEY	21
2.1 Introduction	21
2.2 Spectrum Considerations	21
2.3 Mobile Services Provided by the Telephone Companies	25
2.4 Equipment Survey	28
2.5 Meetings with Manufacturers	32
2.6 Conference Report	37
2.7 Technological Trends	39
2.8 Current Systems Concepts	41
2.8.1 General	41
2.8.2 Basic Radio Links	42
2.8.3 Selection of Frequencies	43
2.8.4 Site Selection: Base Stations and Relay Stations	43
2.8.5 Conservation of Frequency	47

	<u>Page</u>
2.9 Discussion	48
3.0 MOBILE RADIO SYSTEMS FOR RURAL APPLICATION	53
3.1 Introduction	53
3.2 A Model for Estimating the Range of Mobile Radio Systems	53
3.3 Assessment of Present GRS Usage	58
3.4 System Concepts of New Mobile Systems	65
3.5 Rural Mobile Systems: The Long Term	83
4.0 CONCLUSIONS AND RECOMMENDATIONS	90
4.1 Conclusions	90
4.2 Recommendations	92

APPENDICES:

- APPENDIX A - LIST OF SUPPLIERS POLLED
- APPENDIX B - SYSTEMS DESIGN CONSIDERATIONS
FOR MOBILE RADIO SYSTEMS

FIGURES:

		<u>Page</u>
FIGURE 2/2	BASIC RADIO LINKS	44
FIGURE 2/3	RELAY SYSTEMS A & B	45
FIGURE 2/4	RELAY SYSTEMS C & D	46
FIGURE 2/5	FREQUENCY REUSE ARRANGEMENT FOR TYPICAL CELLULAR SYSTEMS	49
FIGURE 3/1	SCENARIO FOR RURAL BUSINESS- ORIENTED SYSTEMS	87

TABLES:

TABLE 1/1	MOBILE RADIO INFORMATION SHEET	6a
TABLE 3/1	DEFINITION OF MODEL PARAMETERS	57
TABLE 3/2	PARAMETERS OF TYPICAL GRS SYSTEM (27 MHz)	60
TABLE 3/3 a	MOBILE ↔ MOBILE INTERFERENCE (GRS)	61
TABLE 3/3 b	MOBILE ↔ BASE INTERFERENCE (GRS)	62
TABLE 3/3 c	BASE ↔ BASE INTERFERENCE (GRS)	
TABLE 3/4	PARAMETERS OF PROPOSED BUSINESS MOBILE SYSTEM, RURAL APPLICATION (220 MHz)	71
TABLE 3/5 a	MOBILE ↔ MOBILE INTERFERORS (220 MHz)	72
TABLE 3/5 b	MOBILE ↔ BASE INTERFERORS (220 MHz)	73
TABLE 3/5 c	BASE ↔ BASE INTERFERORS (220 MHz)	74
TABLE 3/5 d	ESTIMATED COST OF A BMS SYSTEM	79
TABLE 3/8	MOBILE RADIO CHOICES WITH THE ADDITION OF NMS/BMS	81

EXECUTIVE SUMMARY

The objective of this study has been to investigate the applicability of mobile radio techniques to rural communications in the provinces of Manitoba, Saskatchewan and Alberta, to develop conceptual systems to satisfy selected rural communications requirements in these provinces, and to assess these conceptual systems from the technical, cost and marketing aspects.

The project was carried out in parallel with a complementary project undertaken by the Institute for Northern Studies (INS) at the University of Saskatchewan. The INS project was concerned with the social, economic and geographical aspects of the study, surveying the rural areas of the three provinces regarding the use of mobile radio for communications, and consolidating the results of the survey.

The project was divided into two phases:

- 1) A fact finding/assessment phase, which covered existing systems and technology,
- 2) A conceptual model development phase, where a model for a proposed new mobile system was assessed for its applicability to the rural prairies.

Present mobile radio technology exhibits several major trends:

- 1) Increasing use of digital circuit techniques - such as digital frequency synthesis, microprocessor switching and control, etc.,
- 2) Increasing modularization of design, providing the system designer with more design options.
- 3) Increasing miniaturization and reduced power consumption,

4) Decreasing hardware costs.

These trends are leading directly to personal, pocket sized, automated, and inexpensive two-way radio systems.

Mobile systems which are significantly used in the rural areas of the prairies are:

- 1) The General Radio Service (GRS),
- 2) Private Systems,
- 3) The General Land Mobile Radio Services (GLMRS)
offered by the telephone companies.

The GRS is the most utilized service (by a wide margin) and about 75% of the users utilize the service for legitimate business purposes, according to the INS survey. Most users of all three systems were generally satisfied with their systems, although GRS users had some complaints regarding the manner in which non-business users utilize GRS. A sizable portion of GRS users plan to adopt Private systems in the near future.

An interference analysis established that GRS usage in certain rural areas of the prairies may be close to saturation during periods of peak usage; this will no doubt increase the move of GRS users to other systems.

The type of communications service provided by GRS appears well suited to satisfying the needs of the majority of rural business users.

The major recommendation of the report was the establishment of a pair of new mobile services, one serving the general public, the others available to business users only. It is suggested that these occupy adjacent areas

of the spectrum, that users be required to pass an examination, and that each radio unit transmit a unique identification code which is assigned to the user with his licence. This unique identifier code is included to facilitate the enforcement of the regulations, ensuring a viable service.

Representative calculations for the business oriented service were performed for a frequency of operation of 220 MHz, where a little-used amateur band could possibly be partially re-assigned for mobile use.

A secondary recommendation of the report was that the Department of Communications encourage the establishment and use of Restricted Common Carrier (RCC) systems for rural applications.

A ten-year scenario postulates the continued growth of GRS-based business systems until such a time as a new business oriented mobile service can be introduced (assumed to be the end of 1981). After this date, business use of GRS declines.

A significant number of business systems are postulated to be based on RCC systems (assuming that RCC systems are established in about one half of the small farm cities servicing agricultural communities, commencing in 1980.)

The scenario postulates moderate growth to Private systems and GLMRS.

1.0 GENERAL

1.1 Introduction

The objective of this study has been to investigate the applicability of mobile radio techniques to rural communications in the provinces of Manitoba, Saskatchewan and Alberta, to develop conceptual systems to satisfy selected rural communications requirements in these provinces, and to assess these conceptual systems from the technical, cost and marketing aspects.

The project was carried out in parallel with a complementary project undertaken by the Institute for Northern Studies (INS) at the University of Saskatchewan. The INS project was concerned with the social, economic and geographical aspects of the study, surveying the rural areas of the three provinces regarding the use of mobile radio for communications, and consolidating the results of the survey.

1.2 Background

Generally speaking, rural households do not have access to the same level of communications as do urban households. For example, about 2/3 of rural households share their telephones with three or more other parties, while only about 10% of urban households share their telephones with one other party only. About 7% of rural households have no telephones, compared to under 3% for urban households. Access to data services is extremely limited in rural areas; such access is much more readily accomplished in urban areas.

In addition, radio and television programming is restricted, and in some cases, unavailable in some rural areas.

Taking these facts into account, and recognizing that rural residents have a legitimate requirement for acceptable communications, the Department of Communications is undertaking a project which will investigate rural communications in depth. Major objectives of the project are:

- 1) To provide an engineering and economic framework for the development of Federal policies,
- 2) To foster Federal/Provincial co-operation,
- 3) To provide a basis for a domestic market for equipment.

SED's study of rural mobile radio on which this document reports, is part of this overall program.

1.3

Project Approach

The project was split into two phases, namely:

- fact finding/assessment
- conceptual model development

Fact Finding/Assessment

During this first phase, telephone and mail contact was made with suppliers of mobile-radio oriented communications equipment. The objective was two-fold:

- 1) To establish a data-file on existing equipment,
- 2) To establish the nature of new and projected technological developments.

Canadian suppliers, other North American and certain well established non-North American suppliers were contacted. Personal meetings were held with some major Canadian Suppliers; and an equipment display was attended in the U.S.

Contact with provincial telephone companies (Manitoba and Saskatchewan) was also established, with the assistance of DOC; these contacts were followed by personal visits to each company. The objective was multi-fold:

- 1) To review existing systems based on mobile radio concepts,
- 2) To determine the telephone companies plans for expansion in this area,
- 3) To obtain information on present radio-telephone subscribers,
- 4) To determine the type, quantity and manufacture of equipment presently in use,
- 5) To ascertain specific communications requirements where mobile radio techniques may be applicable in the future.

Conceptual Model Development

Based on the results of the fact-finding task and the results of the INS survey, a system to supplement the existing systems in an effort to satisfy the anticipated mobile communications requirements was conceptualized.

This model, a shared multi-channel service was analyzed from the viewpoint of:

- 1) Technical feasibility,
- 2) System costs,
- 3) Potential markets.

The use of shared community repeaters (via RCCMRS Systems), for those requiring better communications than can be provided by a shared multi-channel service, is also assessed as a feasible means of mobile communications suitable for widespread rural use.

1.4 Summary of the Results of the Parallel Study Carried Out by the Institute for Northern Studies (INS)

The Institute for Northern Studies carried out a users survey of mobile radio sources in the rural areas of the prairie provinces. The study had a fourfold objective:

- 1) To identify the socio-economic-geographic characteristics of users,

- 2) To identify user complaints and preferences.
- 3) To analyze communications patterns of users.
- 4) To estimate future needs.

Results of the study are documented in Reference 1/1.
A brief summary of the results appear below.

The present population of the rural areas is generally mobile in its activities, and the future population is generally characterized as becoming increasingly mobile. At present, mobile radio is meeting needs in the areas of:

- safety
- efficiency
- convenience

Factors which will play a role in determining future developments are:

- needs
- technical possibilities and barriers
- economic constraints
- legal or organizational barriers

(Chapter 2)

The individuals who use mobile radio services are generally engaged in the production and distribution of goods and services (as opposed to the consumption of goods and services). While engaged in these production and distribution activities, it is necessary for interaction between individuals to take place, and mobile communications facilitates this. It is anticipated that the primary industries will continue to be the major employer of the rural labour force (Chapter 3).

In discussing the manner in which the population is spread over the prairie provinces, the concept of "ecumene" was introduced. The ecumene is defined as "land upon which man has made his permanent home and to all occupied work areas which are utilized for agricultural or any other economic purpose". On the prairies, the figure for population density of the ecumene is less than one-half of the figure for Canada as a whole. The "thin but continuous" nature of the population of the inhabited areas of the prairies is thus illustrated. A model for the prairie community system was also presented. This model considers an agricultural community to be dominated by a farm city - a small urban centre which provides services to a surrounding agricultural area. Within this community, a symbiotic relationship exists between different segments of the population, implying interaction at the business and social level. The total community including the farm city comprises about 15,000 people, and covers an area of about 2,500 square miles (Chapter 4).

The data used in the survey was obtained from rural users only. (For the purposes of this study, the term "rural" included urban centres of up to 5,000 population). People who received the questionnaire were selected from lists of license holders from the records of the Department of Communications, in sufficient numbers to present a representative sample. Data was solicited for all categories of mobile radio service (see Table 1/1). The numbers sampled and the responses received are illustrated below:

	<u>No. of Questionnaire</u>	<u>Sample Size</u>	<u>No. of Responses</u>
GRS	1201	≈ 2% (1)	571
Private		100%	580
RCCMRS	1381	100%	42
Paging		100%	10
GLMRS	1148	100% (2)	229

Notes: 1) Except Grande Prairie - 5%, and Yellowknife, Fort Smith and Thompson - 15%

2) Except Alberta - 50%

TABLE 1/1

MOBILE RADIO INFORMATION SHEET

Definitions of the Categories of Mobile Radio Service

System: A mobile radio system consists of at least one fixed base station and at least one mobile radio unit capable of communicating with each other. Radios on different systems do not communicate with each other.

GRS: General Radio Service. GRS is the Canadian version of the American CB or Citizen's Band category. The user owns and operates his system on one or more of the channels allotted to this service.

Private: A private system is one in which the equipment is owned by a business enterprise and operated by its employees. It is licensed for operation on a specific channel(s) in the mobile radio band.

GLMRS: General Land Mobile Radio Service. This is a service offered by the telephone companies as an extension of their normal telephone service. It consists of a radio-telephone installed in a vehicle which can operate on one or more channels in a specific area. The terms General Mobile, Public Mobile, Radio-telephone and Mobile Telephone are all used to describe this type of service.

RCCMRS: Radio Common Carrier Mobile Radio Service. This service is distinguished by the rental of a repeater station operating on two frequencies - one sending and one receiving - to many users. The users may either own or lease their mobile equipment.

Paging: Paging is considered a "one-way" system and involve the transmitting of tone or tone and voice messages to pocket receivers. A paging system can accommodate many users.

Selected Characteristics of the Service Categories

	GRS	PRIVATE	GLMRS	RCCMRS	PAGING
Principal Feature	Low Cost	Privacy	Telephone Access	Rental of Equipment	Very Mobile
Typical User	Individual	Taxi Company	Business	Business	Doctor
User Owns or Leases	Owns	Usually Owns	Owns or Leases	Usually Leases	Usually Leases
Initial Cost per Mobile	\$200 Average	\$1000 Average	\$1200 Average	\$1200 Average	\$350 Average
Monthly Cost (average)	None	None	\$30; if owned \$75; if leased	\$10; if owned \$40; if leased	\$12; if owned \$25; if leased
Telephone Access	NO	NO	YES	NO	NO
Type of Communication	Multi-Way Voice	Two-Way or Multi-Way	Two-Way Voice	Two-Way or Multi-Way	One-Way Paging

Responses for GRS, Private and GLMRS were analyzed in depth. Because of the relatively few users of RCCMRS and Paging services, these services were not analyzed to the same degree (Chapter 5).

The following table illustrates the distribution of users at the time of the INS survey (early 1977). (The information in the table is derived from the INS report, which in turn was derived from Department of Communications records). The rural popularity of GRS, and the urban orientation of both Private systems and GLMRS systems is evident.

		RURAL (<5000 POP)		URBAN (>5000 POP)	
		<u>No. of Mobiles</u>	<u>Mobiles/1000 Work Force</u>	<u>No. of Mobiles</u>	<u>Mobiles/1000 Work Force</u>
GRS	Alberta	8,360	31.9	10,287	20.8
	Saskatchewan	9,378	41.5	4,454	24.2
	Manitoba	3,632	24.3	3,777	12.2
	Prairies	21,370	33.5	18,518	18.9
Private	Alberta	2,973	11.2	14,690	29.7
	Saskatchewan	940	4.2	2,061	11.1
	Manitoba	1,585	10.6	3,811	12.3
	Prairies	5,498	8.6	20,562	20.8
GLMRS	Alberta	2,279	8.7	5,136	12.4
	Saskatchewan	247	1.1	429	2.3
	Manitoba	75	0.5	339	1.1
	Prairies	2,601	4.1	6,904	7.0

The total number of rural systems were GRS-7632, Private - 1353, GLMRS - 1622.

(Chapter 6)

Concerning the manner in which the mobile radio systems are utilized, GRS has a high utilization by the agriculturally-based rural populations, whereas Private and GLMRS were more oriented to urban based activities, as to be expected from the distribution of these systems. It was noted that significantly higher penetration of mobile communications exists in areas containing a high concentration of economic activity or in which there is a much greater adoption of mobile communications by activities other than conventional ones. It was also noted that a significant factor inhibiting the adoption of mobile communications in rural areas is the cost factor (Chapter 7).

Regarding user characteristics, 75% of the GRS users use their system for business purposes. Types of business operations are primarily agriculture, followed by construction and transportation. Private systems were used for the same business purposes as GRS (that is to say, agriculture, construction and transportation). GLMRS showed a markedly different usage pattern, being used primarily in construction, mining and oil operations, with transportation and agriculture being secondary. (Chapter 8).

It was determined that for GRS, calls originating from mobile units were more important than those originating from base stations, and mobile to mobile calls were of considerable importance. Private systems were similar, with mobile to mobile calls being of somewhat less significance. For GLMRS, calls from the mobile to the telephone system were the most important. Mobile to mobile calls were of little importance for GLMRS users. The average length of calls was greatest for GRS systems, likely due to the dual business/personal nature of GRS usage. The average number of calls per working day is 31 for GRS, 29 for Private systems, and 7 for GLMRS (Chapter 9).

Reasons for using mobile communications were, for GRS and Private systems, a realization of time and money savings, and the ability to contact personnel and vehicles in separate work areas. GLMRS users apparently use their systems primarily because no other communications facilities are available. GRS users felt, on the average, that their systems were of "considerable importance", while Private and GLMRS users were inclined to view their services as "absolutely necessary". Users of all three systems felt their frequency of use to be increasing (Chapter 10).

Possible improvements recommended for GRS were better area coverage and higher quality equipment. Private system users primarily recommended better area coverage, with lower cost and connection to the telephone system as secondary suggestions. GLMRS users also recommended better area coverage as a primary suggestion; their secondary suggestions were less congestion and lower cost equipment. About 8% of GRS users indicated they planned to adopt either a Private system or GLMRS within the next five years. (Most of these users planned to adopt a Private system rather than GLMRS). More than 1000 new Private systems will appear within the rural prairie population if these individuals follow through as they have indicated - this is almost as many Private systems as there are now (Chapter 11).

Significant socio-economic findings for GRS users were that areas with larger farms and larger populations of young farm operators tended to have larger systems, and that larger systems were primarily business oriented (Chapter 12).

Results of a series of personal interviews carried out in a typical agricultural community revealed some helpful insights:

GRS

- Most GRS users were farmers,
- For GRS users, there was an indication that there was a network of GRS "communities" in the area - each community consisting of closely grouped farmers who pooled labour for certain tasks,
- GRS communications for small family farm operations was found to be important, often serving for a means of communications between a farmer and his wife, for example.

Private

- Half (6) of the Private systems were agriculture based, and a further one quarter (3) were agriculture-oriented services. The remainder were used by an ambulance service, a funeral home, and a mobile sales and service business.

GLMRS

- Of 7 GLMRS users in the area, 2 were farm operators, 1 was a farm equipment dealership, 2 were auctioneers, and 2 were involved in road construction,
- No general conclusions were evident from GLMRS users.

General conclusions drawn from the study are as follows:

- GRS is primarily used as a "business radio" system for the population surveyed, and has a strong rural agriculture orientation. Signs of friction between business and non-business users of GRS is evident,
- Private systems are mainly used by services typically associated with farm cities, and the higher income farm population,
- GLMRS users are concentrated in Alberta. This service has a strong urban orientation,
- The following paragraph is particularly significant for the planning of new systems.

"Users in all three of the major service categories have demonstrated a desire for better area coverage. This may be the key element upon which future improvements should be concentrated. Generally, all rural residents are within forty miles of a farm city. In addition, agricultural units do not typically have contiguous parts but may be spread out over thirty miles or more. The ultimate communications system would be able to provide communications both within the sphere of operations and from that sphere to the service center locations".

(Chapter 14)

1.5

Mobile Radio Systems Currently in Use

This section presents a description of each of the categories of mobile radio service.

General Radio Service (GRS)

GRS is the Canadian version of the service known as Citizen's Band (CB) in the United States. In this service, users have common access to 40 communications channels at 27 MHz in the H.F. region of the frequency spectrum. Transmitter powers are 4 watts for AM transmissions and 10 watts for SSB transmissions.

Licenses are routinely granted by the Department of Communications to potential users of type-approved equipment.

A typical sequence of operation a GRS system is as follows: A user pages the party he wishes to call on the channel reserved for calling purposes; if he is successful in contacting his party (that is to say, the party he wishes to call has been monitoring the calling channel and transmits an acknowledgment) the two parties then carry out their conversation on another channel which is free at the time. The same channel is shared for both transmitting and receiving. Units are normally in "the receive mode"; when a user wishes to transmit, he pushes a "transmit" button (this "push to talk - release to listen" mode is commonly referred to as the simplex mode of operation).

Because of the "open party line" nature of the system, multi-way conversations with several individuals participating are possible. Because of the "fully shared" nature of GRS, use of the equipment is not restricted to any geographical area.

In the rural prairie environment, good communications is possible up to a range of about 3 miles between two mobiles, and up to a range of about 8 miles between a mobile and a base station, assuming relatively flat terrain. These are average numbers; they can be less or greater, depending on system configuration, nature of the terrain and propagation conditions.

Typical system cost for a good quality system for rural use, consisting of a base station and one mobile, is in the vicinity of \$500 - \$1000, with costs of additional mobiles running in the vicinity of \$250. License fees are \$13.50 per radio unit for a 3 year license.

Private Systems

In a Private System, a particular frequency (or frequencies) is assigned to a user for his exclusive use in a particular geographic area (the same frequency will be re-used in other systems in non-contiguous geographic areas which are far enough away to make interference between systems unlikely).

The frequency of operation of a system could be at any of the available business bands across the spectrum, but will most probably be in the lower VHF band around 150 MHz. Transmit powers around 10-15 watts are typical, and the modulation used is generally FM.

Systems configurations can vary according to various user requirements. System configurations are approved by the Department of Communications prior to issuing a license.

A typical system for rural applications consists of a base station and a number of mobiles, all operating on a single frequency. Communications between the base station and mobile, and between the mobiles themselves, takes place utilizing the single frequency in the simplex mode.

A feature that may be considered as an advantage which Private Systems have over other types of systems is the privacy obtained due to the exclusive use of the channel by the license holder.

The same feature may also be considered a drawback in certain cases as it is not possible to communicate with units which are not part of the same system; it is also not possible for a mobile to communicate with anyone when the mobile is beyond its normal area of operations.

Typical ranges for good quality communications for this type of system in rural areas is 5 or 6 miles between mobiles and 20 to 25 miles between a mobile and a base station, assuming relatively flat terrain. These are average numbers dependent on system configuration, nature of the terrain, and propagation conditions.

Typical costs of a good quality Private System run in the vicinity of \$2500 - \$3000 for a system consisting of a base station and one mobile, with costs of additional mobiles running in the vicinity of \$1000. License fees are \$10.00 per mobile per year and \$26.00 per year per base station.

Restricted Common Carrier Mobile
Radio Service (RCCMRS)

This service, which is basically a shared Private system, is characterized by a number of users sharing a central repeater station. The license for the system is issued to the party providing the service; use of the service is then rented to subscribers in the area.

Frequencies of operation and equipment are similar to those used in the Private systems.

A typical RCC system utilizes a pair of frequencies. The base station transmits on the first frequency and receives on the second; the mobiles transmit on the second frequency and receive on the first. Direct mobile-to-mobile communication is thus not possible - mobile-to-mobile transmissions all take place through the base station, using it as a relay.

Typical ranges for good quality communications for this type of system in rural areas is 20 to 40 miles between a mobile and a base station, assuming relatively flat terrain. Because mobile to mobile communication is relayed through the base station, the range of mobile-to-mobile communications can be up to twice these distances (as will be the case if the two mobiles are on opposite sides of the base station). These range numbers are considered typical for a rural oriented system; they could be higher or lower depending on the system design and terrain and propagation conditions in the area.

Privacy from other users of the same system is normally not achieved, and communications with other systems is not possible. Communications beyond the geographical area of the system is also not possible.

Cost of using an RCC system are about \$40 per month per mobile if the mobile is leased, and about \$10 per month per mobile if the subscriber owns his own mobile. Purchase cost of a mobile unit is about \$1200. License costs are \$10.00 per mobile per year, \$26.00 per fixed station per year, and \$13.00 per repeater per year. The main RCC base terminal license fee is \$130.00/year.

Paging Systems

Paging services involve the one-way transmission of messages to pocket receivers on a one way basis. These systems are often an adjunct to RCC systems.

The principle of operation of an efficient paging system is typically as follows: A subscriber's office or base of operations wishes to contact a particular individual of the organization. Using his telephone, the base station of the paging service is dialled; upon acquiring the base station the address of the individual's pager is then dialled. The equipment of the base station records the address and then transmits the page, usually within a few minutes. The paging receiver, upon recognizing its own address, emits a tone, thus alerting the user that he must contact his office or base of operations. Some systems actually transmit a voice message, in which case it may be unnecessary for him to contact his base.

Paging systems generally serve customers over a range of 5 to 10 miles from a repeater site, which is normally situated in an urban area.

Typical costs of renting a paging service are about \$25 per month per pager if the pager is leased, and about \$12 per month per pager if the subscriber owns his own pagers. Purchase cost of a pager is in the vicinity of \$350. License costs are \$26 per paging station per year. The mobile pagers must be type approved but are not required to be licensed.

General Land Mobile Radio Service (GLMRS)

This service is offered by telephone companies as an extension of their normal telephone service. Through the use of mobile radio telephone installed in a vehicle, the subscriber can access the regular telephone network, and can thus contact any telephone subscriber, including other mobile telephone subscribers.

This service normally uses channels in the 150 MHz region reserved for mobile use, and operates using FM. Transmit powers in the range of 15 to 25 watts are typical.

A number of channels, sufficient to accommodate the local requirements, are assigned to a particular geographical area. (the same frequencies are re-used in other non-contiguous geographic areas which are sufficiently distant to avoid interference).

Subscribers are required to obtain a license for units assigned to them. The cost of the license is \$10.00 per mobile per year.

To use a mobile telephone, a subscriber selects a clear channel serving his area, signals the operator, identifies himself,

and advises the mobile operator of the number he wishes to call. The operator then completes the call. In the receiving mode of operation, the mobile telephone responds to incoming calls with an audible signal. Conversations are carried out on a "push to talk" and "release to listen" basis.

The communications range of a mobile telephone to the "base" (that is to say, the mobile tower) is typically in the order of 25 to 50 miles for relatively flat terrain. Communications are possible if the mobile is within range of any mobile telephone tower. If the mobile is within the range of a mobile tower, he can communicate with any telephone subscriber, including other mobile telephone subscribers. Direct mobile-to-mobile communications is not possible on these systems, as all calls must be established through the telephone network facilities.

Costs of subscribing to a GLMRS service are about \$75 per month per mobile if the equipment is leased, and about \$30 if the mobile is owned by the subscriber (each telephone company has slightly different fee schedules). Purchase costs of a mobile unit will be in the order of \$1500 to \$2000.

Reference:

- 1/1 "Man on the Move: A Users Survey of Mobile Radio Services in Rural Areas of the Prairie Provinces", by C. Roger Schindelka, Institute for Northern Studies, University of Saskatchewan, 1977.

2.0 TECHNICAL SURVEY

2.1 Introduction

This section presents a summary of the information gathered during the fact finding phase. Items covered are:

- spectrum considerations
- summary of services provided by the telephone companies
- results of equipment survey
- results of meetings with manufacturers
- conference report
- summary of technological trends
- current systems concepts
- discussion of facts and opinions

2.2 Spectrum Considerations

Frequency allocations for mobile and point to point rural communication are controlled by the Department of Communications. International agreements also help to coordinate allocations between nations, and to encourage common allocations for similar purposes in different countries. Many of the spectrum allocations have evolved with specific requirements. Changes to current allocations are rather difficult to arrange, due to extensive use of the spectrum by existing installations. Large bands of frequencies are devoted to commercial radio and television broadcasting, and to military and commercial air, sea and land use. Other bands which are particularly dedicated are amateur radio bands and scientific research bands, including radio astronomy. Private business communication is a relative newcomer to the spectrum, and Citizen's Band or General Radio Service is even more recent. These users have been assigned bands between, or in some cases overlapping adjacent pre-allocated

spectrum. The current popularity of General Radio Service equipment, especially in rural areas for communication among agricultural units, has demonstrated to many thousands of users the utility of radio communication for private business purposes, and makes continuity of service rather essential.

This section does not intend to be an exhaustive compilation of frequency allocations for different purposes. These are readily available from the Department of Communications. This summary is intended only as an outline of bands used for rural mobile communication, together with some advantages and disadvantages. Note that reference to a band of frequencies does not imply that all frequencies in that range are available for mobile communication. Briefly, mobile radio generally utilizes frequencies in bands at 27 MHz in the HF band, from 30 to 50 MHz, and from 138 to 174 MHz in the VHF band, from 450 to 470 MHz in the UHF band, and some initial work is being done in the UHF band near 900 MHz. To determine the suitability of various frequency bands for mobile use, several factors including propagation loss, multipath reflections, noise, terrain and obstructions and equipment availability, characteristics and costs must be considered.

Statistical techniques are often applied in propagation studies to determine median values and standard deviations for the signal strength at a given distance from a transmitter. For land mobile services, free space propagation exists only for very short paths with modifications due to earth curvature and surface conditions. Ionospheric propagation is generally absent except for frequencies below 50 MHz where skip effects may produce serious interference from stations far away. Multipath reflections set up standing waves in the received signal, leading to fading and flutter effects as the mobile unit moves. For rural situations

this effect is primarily evident for UHF operations, and can be serious especially if a mobile stops in the null position.

Various sources of noise are known to affect mobile communications, from electrical noise generated in spark producing equipment, to atmospheric noise, which is of little effect to mobile bands, to man made noise such as occurs near high voltage power lines, and noise of cosmic origin. Noise degradation can be quite serious for the lower frequency bands considered (50 MHz, 150 MHz) and compensates considerably for the propagation effects which tend to degrade the higher frequency bands to a greater extent than the lower bands.

Terrain effects, including hills and valley, and the presence of vegetation, as well as ground conductivity and dielectric constants are important in selecting frequencies and systems appropriate to a given service requirement. The soil effects are most noticeable for lower frequency use, while hills and valleys and vegetation are more important at higher frequencies, where wave bending around obstacles is less pronounced. Where a large number of obstructions are present, such as in a city, higher frequencies tend to utilize more multiple reflections and achieve fill-in better than lower frequencies. The use of only two multipath signals, however, can cause cancellations due to the phase shift of one signal, and space diversity reception at the base station may be required at the 900 MHz region of the UHF spectrum to avoid the problem.

As far as equipment availability and cost are concerned, higher frequency equipment tends to be more expensive, and limited in transmitter power and receiver sensitivity. Antenna gains, however, increase with frequency and offset the equipment deficiencies to some extent. Typical costs for base stations

increase with frequency being approximately 30 to 50 percent higher at 900 MHz than at low band VHF. Similarly with mobile units, which tend to be the primary economic factor affecting the frequency range chosen, cost increases by 10% to 20% from VHF to UHF 400 MHz band, and increases again into the 900 MHz band. Portable units show the same price trends as the mobiles.

Due to coverage, and to cost and manufacturing obstacles, most mobile equipment is supplied in the lower frequency ranges (27 MHz, 30 to 50 MHz and 138 to 174 MHz) and considerable congestion is now occurring in these bands in urban areas. Some applicants for licences are now being encouraged to switch to UHF equipment where possible, and manufacturers are responding to this demand (this congestion is not generally in evidence in the rural prairie areas).

Already in the consideration of available equipment, spectrum, and the user requirements, two major problems impacting on spectrum allocation have arisen. The first feature is the large amount of spectrum allocated to UHF television broadcasting in the 800 MHz band. Approximately 83 TV channels exist in this band, although adjacent bands cannot be used for TV broadcasting. It is distinctly possible that a significant reduction in the number of channels available for broadcast. TV use could well be restricted to cable for applications requiring a multitude of channels. Mobile communications could then be assigned a much more extensive band of frequencies in the 800 - 900 MHz region. Significantly, some moves in this direction have occurred in the U.S. where two upper TV channels have been switched to mobile use.

Another problem occurs in the General Radio Service bands around 27 MHz. As has been determined in the INS study, these are being extensively used for serious business purposes in the rural areas, and are popular with users. When ionospheric conditions change in response to sunspot influences (within 2 years when the sunspot cycle reaches its peak) severe problems are anticipated due to skip interference, with local communications being overwhelmed by transmitters thousands of miles away. The problem will reoccur every eleven years coinciding with maximum sunspot activity. One solution proposed is to establish a new service somewhere in the VHF band at 50 MHz or higher, possibly at a VHF band around 220 MHz, where an infrequently used amateur band now exists. This would avoid the ionospheric disturbance affecting GRS with minimal disruption of established service. With mass production techniques, it can be expected that mobile unit costs of 220 MHz units, now in the \$1000 range, could be reduced to the \$400 to \$500 range within a short time, and the rural user would be able to afford service.

2.3 Mobile Services Provided by the Telephone Companies

Of all the present mobile radio-based services, the general land mobile radio service (GLMRS) or radio telephone service has the greatest communications potential, as it allows the subscriber access to the telephone network.

At this time, service is primarily used by travelling business men and public servants across all three provinces. Individual provincial telephone companies provide service tailored to regional demands, and so considerable differences exist between provinces. The Manitoba system is based in Winnipeg and has recently expanded to cover major east-west and north-south highway routes with a VHF network. Expansion

in large metropolitan areas is restricted by spectrum allocations, and new bands are required to provide continuing service. In Alberta, service has expanded to cover provincial highway routes and intensively cover the oil producing areas, where day-to-day business operations have required radio-telephone service for many years. New techniques to permit expansion of service to more subscribers, either within the bands now allocated, or with new bands yet to be allocated, are being investigated (AGT's recent adoption of its tertiary scheme, effectively doubling the number of channels that can be supported in a spectral band, is one solution).

The Saskatchewan situation is somewhat different than in its neighboring provinces, since no large metropolitan areas exist, and the population is spread over a larger area, with smaller concentrations of people in small towns and cities. More comprehensive information was obtained from the Saskatchewan Telecommunications office, and this system will be used to exemplify service now existing in the prairie region.

General mobile radio service in Saskatchewan began in 1955 to serve oil operations in the province. Single channel, 15 watt equipment was leased to the customer with a monthly charge plus a flat rate per call. Current equipment, a 25 watt model with a capacity for 13 channels, is used in Saskatchewan with 8 channels operational. A flat rate of \$70 per month regardless of the number of calls made is charged to the subscriber, and person to person day rates are charged for long distance calls. Units are installed for \$50, and optional accessories such as a high gain antenna and car horn relay to signal an incoming call are available at extra cost.

Equipment is supplied primarily by Sask. Tel. but can be independently bought from private suppliers in the province for approximately \$2000. Service is supplied by Sask. Tel. for approximately \$30 per month, although no free maintenance is supplied for privately owned units.

In order to place a call within a General Mobile Radio coverage area, most of which are based in population centers across the province, a user selects a frequency appropriate to that area, verbally signals the operator with his identification number and gives the operator the number he wishes to call. When the subscriber is being called, his equipment signals him after scanning all available channels and finding a call signal. Sask. Tel. maintains 28 mobile terminals in Saskatchewan and uses a total of 8 channels with ranges between 35 and 50 miles radius (depending on terrain). High gain antennas are supplied for better fringe area reception.

Agreements have been made to allow Saskatchewan registered subscribers to use Manitoba and British Columbia services with no extra charges other than long distance rates.

Future development of mobile telephone service will necessitate some standardization of equipment, frequency channels, type of dial signals, and billing policies among the provinces, and with national and international agencies.

Some difficulties faced by mobile users include delays encountered in finding a clear channel and having a call placed, the necessity to go through an operator for each call, the lack of privacy for some situations of business or personal use, and the lack of answering service for mobile users. For business use, the rates are generally acceptable for frequent users, however for occasional users and for private subscribers, the cost of

mobile service is significantly high, especially compared to normal residential rates.

For these systems to find more rural application, the major improvements would have to be the reduction of cost per subscriber and the expansion of areas covered, and possibly the provision of automatic dialling features.

2.4

Equipment Survey

At the outset of this work, a form letter outlining the goals of this study, and containing a request for information, was prepared (Figure 2/1). It was sent to 180 companies representing a cross-section of capabilities, from small specialty-item houses to large companies offering a full range of equipment. The response rate was about 50%.

The intent of the survey was to establish a representative current equipment file, enabling system designers to become cognizant of the available equipment and the current technological trends. The resulting file was a "working file", which was used throughout the project (this equipment file is delivered as a separate item).

Information that was received was scanned briefly and types of equipment described were noted. Two general types of equipment, RF equipment and ancillary non-RF equipment were classified. Over 1000 individual items were then reviewed in detail.

Of the suppliers having RF equipment, the majority offer equipment in the VHF (30-300 MHz) region; HF (3-30 MHz) and UHF (300-3000 MHz) equipment was evident to a lesser extent. (A somewhat surprising result of the survey was the lack of information on GRS equipment - although sufficient information for the purposes of this study was received).

In the non-RF ancillary equipment, a great deal of information was received. This is particularly satisfying since these are the devices enabling the synthesis of sophisticated systems.

A number of manufacturers included price information with their submission; this information was sufficient to establish general pricing levels for each equipment category, and is included in the equipment file.

FIGURE 2/1

Dear Sirs:

SED Systems Ltd. has recently received a contract from the Department of Communications, Government of Canada to carry out a study on rural mobile radio in the prairie provinces of Alberta, Saskatchewan and Manitoba. The survey will investigate the applicability of mobile radio techniques to rural communications in the three provinces, and develop conceptual systems to satisfy selected rural communications requirements in these provinces using existing and projected mobile radio equipment. This work includes a complete survey of available equipment, and close liaison with the Manitoba Telephone System, Saskatchewan Telecommunications, and Alberta Government Telephones.

The survey will include:

- mobile radio telephone systems
- private mobile radio systems including base stations and associated equipment
- general radio service (citizen's band) equipment
- paging systems

Subscriber radio systems, while not strictly "mobile", are also within the scope of the study.

I am requesting your assistance in the form of technical information (brochures, specifications, etc.) on the equipment and systems which can be supplied by your company.

Information received will be assessed, collated and delivered to the Department of Communications. This information, along with engineering reports prepared by systems engineers at SED, will be among the items which provide the framework for the development of Federal policy on rural communications.

(I understand that this type of study will eventually be extended to all of Canada and that Federal policies will cover the entire country).

Following the receipt and assessment of the information, I will be making personal visits to selected manufacturers. During these visits, we can discuss the communications requirements special to the rural areas of the prairie provinces, and consider the equipment and systems which can be used to satisfy these requirements.

Thank you for your consideration.

Yours truly,

A.R. Bens, P. Eng.

ARB/dp

Appendix A presents a list of suppliers who received the letter requesting information, it also indicates those suppliers who responded. All information received as a result of these responses is filed according to manufacturer in the equipment file.

In addition to the very specific information in the equipment file, a number of "buyers' guide" publications are available from various publishers of trade magazines and other sources. The Business Radio Buyers' Guide published by Communications Publishing Corporation of Denver, Colorado, which has been included in the equipment file, is typical of these types of publications. It includes information presented under the following headings:

- manufacturers/suppliers, including name, address, company officers, and identification of major equipment lines
- government agencies (U.S.)
- land mobile associations (U.S.)
- antennas
- auxiliary equipment
- batteries/battery chargers
- consoles
- crystals
- emergency medical services equipment
- land mobile transceivers
- marine transceivers
- message recorders/loggers

- microphones/headsets
- microwave products
- mobile telephone equipment
- monitor receivers and scanning monitors
- paging equipment
- specialized services
- test equipment
- tone encoders/decoders
- towers
- manufacturers representatives

Representative prices for equipment is included in the information presented.

2.5

Meetings with Manufacturers

Personal meetings with five Canadian suppliers took place in late March 1977. The intent of these meetings was threefold:

- to brief major Canadian suppliers on the nature and scope of the study
- to discuss the types of systems these companies have sold or have available
- to discuss technological trends

Meetings occurred with the following companies:

- Motorola
- Canadian General Electric
- International Systcoms
- Canadian Marconi
- Pye Electronics

It was felt that this group was representative of Canadian suppliers.

Motorola

Discussions were held with Peter Aimone, P. Eng. Area Systems Engineer, and Les Taylor, P. Eng. Mobile and Fixed Products.

Motorola commenced by describing a basic system, a full duplex radio system which interfaces to a telephone central office, and apparently looks and acts like a normal dial telephone. This system can operate on either single frequency or on multiple frequencies with up to eight base stations using RF channels (16 selected frequencies in the VHF region from 136-174 MHz).

At the base station interface, an incoming trunk call initiates a search for an unused RF channel and sends out a subscriber identification code which is unique for that user. The subscriber unit is continuously scanning all RF channels looking for its ID code and upon finding the proper code, sends its ID code to the base. Ringing then starts under command from the central office; conversation can begin when the unit goes off-hook.

To initiate a subscriber call through the exchange, the subscriber goes off-hook, the remote unit searches for a clear channel, then sends out its ID code and looks for the return of the ID from the central office. Ringing can go through to the central office upon establishment of the dial tone.

Motorola also manufactures a single channel system with coded rings for up to five users. None of these systems have been installed in Canada, however, they have been installed in several South American regions where a trunk line ends in a community and no lines exist to the outlying rural area. Portions of these systems have been installed in Canada in conjunction with other manufacturers equipment.

The system can also be used to bridge exchanges where trunk lines are inadequate.

Regarding a comprehensive wide-area coverage installation, Motorola would be concerned with channel interference problems and problems associated with interfacing to existing telephone equipment.

Canadian General Electric

A discussion was held with Harvey N. Marchand, Product Manager, Government and Utility Market.

Mr. Marchand has had several years field experience and has considerable familiarity with the wide range of radio systems serving different agencies in Saskatchewan.

Mr. Marchand described at some length an RCC system of base stations and mobiles installed by CGE in a rural area of southern Saskatchewan. It serves subscribers within a 50-60 mile radius of the base station. It is a full duplex system on 5 channels and utilizes automatic repeater stations. There are approximately 80 mobiles per channel; mobiles can communicate with each other via central. This system was installed by an agricultural machinery dealer.

An important CGE development with regard to some rural applications, is a mobile repeater which permits individuals to communicate using small hand-held units within working distance of the mobile repeater. This equipment has a significant export market, complete systems have been installed, for example, in Iran.

Much of this equipment finds use in rural environments, including voice, data, rural hospital and emergency medical application.

International Systcoms

Discussions were held with Igor Kossatkine, Marketing Manager and Robert Duchamp, Chief Engineer.

International Systcoms have supplied mobile radio systems to the Canadian market since the early 1960's.

The company manufactures and distributes mobile radio telephones, point to point rural telephones, and two way radio systems. Sales are to telephone companies, communications companies, utilities and private consumers.

The company is a major supplier of mobile equipment to the Canadian market, mostly to the telephone companies, with Alberta Government telephones being a major customer.

The company also has significant export market - a system of mobiles and the associated base station recently installed in Iran was cited as an example.

Canadian Marconi

Discussions were held with Paul Lachapelle and Miles Kermode of the Marine and Land Division.

This company is a major supplier of equipment and systems, and has supplied a number of systems to satisfy special requirements. One such system supplies a party line service to residents of 3 islands of the Grand Camores off the coast of Africa. These islands are separated by distances up to 65 miles. Another system supplies three channels of voice communication to construction sites in Northern Quebec.

Other systems of interest are:

- an installation along the Winnipeg River in Manitoba. It has 120 channels arranged in groups of 24, and has voice and data capabilities
- a system serving a mining company, providing service from Uranium City to Cluff Lake, Saskatchewan
- an RCC system serving the oil industry north of Edmonton, Alberta. This system has been in service for about 10 years.

In the field of wide area communications - the initial civil defence communication systems were installed by Canadian Marconi.

A company specialty at the present time is a single-sideband equipment in the 10-20 watt power category for 2-18 MHz, with a 100 watt model available for HF service up to 200 miles. This type of equipment is oriented to supply communications requirements of remote sites.

Pye Electronics

Discussions were held with Bill Bitcon, Manager, Marketing and Malcolm Golding, Manager, Engineering and Technical Services.

Most of Pye's Canadian business is in supplying private radio and telephone-mobile units to domestic telephone companies.

They described some of their mobile models including a multi-channel simplex unit and their new equipment incorporating frequency synthesis for 32-channels, and a "marked-idle" scheme with ringback suitable for use on the tertiary system now being implemented by some telephone companies.

This company appears to have considerable experience in the area of rural mobile communications.

2.6

Conference Report

The National Business Radio Dealers Conference, held in Denver on April 27, 28 and 29, 1977 was attended primarily for the associated exhibitions, and the opportunity to meet with representatives of a large number of firms acting in the radio communications business. A list of exhibitors appears overleaf.

The purpose of our attendance was to be able to have a hands-on inspection of a large variety of equipment, and to talk to technical representatives in order to gain information and to attempt to assess current technological trends. Discussions were held with all exhibitors.

Exhibitors Coming As of 3/17/77

Aerotron

Sales Mgr. — Joe Tryzenski
(919) 876-4620

Antenna Specialists

Sales Mgr. — Bill Randall
(216) 791-7878

Athans Comm.

Sales Mgr. — Tom Athans
(817) 573-0404

A.I.E.

Sales Mgr. — Tony Crady
(803) 532-5964

Bramco

Sales Mgr. — Ed Eidemiller
(513) 773-8271

CSI

Sales Mgr. — Jim Kennedy
(213) 980-5414

CTI

Sales Mgr. — Jim Tucker
(601) 287-2449

Cushman

Sales Mgr. — E.M. Thompson
(408) 739-6760

Coded Communications

Sales Mgr. — David Robison
(714) 438-2800

Comex

Sales Mgr. — David Mackey
(603) 889-8564

Comm. Products

Sales Mgr. — Perry Easterling
(214) 238-9596

Custom Devices

Sales Mgr. — Paul Cantrell
(602) 268-1371

Dynatron

Sales Mgr. — Mike Robbins
(213) 933-9638

Decibel

Sales Mgr. — Ed Rhinehart
(214) 631-0310

E.F. Johnson

Sales Mgr. — Dave Farrell
(507) 835-6222

Ferritronics

Sales Mgr. — Ray Hogue
(416) 889-7313

Genave

Sales Mgr. — Pat Temby
(317) 546-1111

Glenayre

Sales Mgr. — John Morgan
(206) 633-4500

Harris RF

Sales Mgr. — Mark Bolin
(716) 244-5830

IEC

Sales Mgr. — Burch Falkner
(315) 331-7742

IFR

Sales Mgr. — Joe Barnhill
(316) 685-9271

I.S.T.

Sales Mgr. — Terry M. Burney
(214) 271-2661

Kokusai

Sales Mgr. — Fred Deeg
(213) 679-8233

Larsen

Sales Mgr. — John Beaman
(206) 572-2722

McCloud & Raymond

Sales Mgr. — Irvin Zwick
(303) 756-1589

Motorola Inc.

Sales Mgr. — Jim Hitchcock
(312) 451-1000

Motorola C & E

Sales Mgr. — Jack Wilson
(312) 397-1000

Minute Man

Sales Mgr. — Richard Ryker
(308) 324-2191

Microwave Assoc.

Sales Mgr. — Lyle Sherburne
(408) 736-9330

M.T.I.

Sales Mgr. — Don Wallower
(717) 732-3636

Mobile Comm.

Sales Mgr. — Gary Holt
(806) 792-2393

Path Com

Sales Mgr. — Fred Hamer
(213) 325-1290

Phelps Dodge

Sales Mgr. — C.H. Davison
(201) 462-1880

Quintron

Sales Mgr. — Al Goosens
(217) 223-3211

Reach Electronics

Sales Mgr. — Bill West
(308) 324-4607

RCA

Sales Mgr. — D.O. Reinert
(412) 222-1100

Regency

Sales Mgr. — Reno Kobold
(305) 777-1414

Repco

Sales Mgr. — Bill Scott
(305) 843-8484

Standard

Sales Mgr. — Don Welch
(213) 532-5300

SBE

Sales Mgr. — Gordon West
(408) 722-4177

Sinclair Radio

Sales Mgr. — Bob Corwin
(716) 874-3682

Singer

Sales Mgr. — Glenn Whiting
(213) 822-3061

Tektronix

Sales Mgr. — Frank Hahn
(303) 773-1011

Texscan

Sales Mgr. — Jim Connors
(317) 357-8781

3M Mincom

Sales Mgr. — Dave Bixler
(612) 733-7914

TXRX

Sales Mgr. — Elliott Johnson
(716) 549-4700

Wilson Elect.

Sales Mgr. — Mike Krohn
(702) 739-1931

Solid State

Sales Mgr. — Perry Seal
(415) 785-4610

April 27, 28, 29, 1977

Denver, Colorado

Communications

THE PROFESSIONAL JOURNAL OF BUSINESS COMMUNICATIONS
1900 WEST YALE STREET, ENGLEWOOD, COLORADO 80110 • 303-781-3770

A considerable amount of technical information was acquired and individual requests for detailed information made at the meeting were received by mail. Personal contacts were pursued to obtain information on equipment of particular interest to our application. This information was added to the equipment file described earlier.

2.7 Technological Trends

As a result of the equipment survey, meetings with manufacturers, and attendance at the conference, a number of technological trends are evident, namely:

- continuing development of reliable, "secure" communications systems for public safety, building security and special control system applications,
- continuing trend towards "digitization" - digital frequency synthesis, microprocessor switching and control, etc.
- evidence of increasing "modularization", providing the system designer with more options in design
- a continuing trend toward miniaturization and reduced power consumption leading directly to personal, pocket sized, automated, inexpensive two way radios.

Some details of these trends for the major classes of radio systems are presented on the following page. Each of the items listed is either available or under development.

GRS Equipment

- channel selection from keyboards with LED or LCD readouts
- memory stored digital selective calling
- modulation compression devices
- sophisticated clarifier devices (for SSB)
- automatic antenna sampling and noise blanking
- general improvements such as better frequency stability, improved audio

Private/RCC Equipment

- selective calling to a unit or group of units
- "digital" information transmission (status, location, identification, etc.)
- "lock-out" features which disable all transmitters except the one occupying the channel
- "busy light" indicating that a channel is occupied
- repeater "time-out" - RCC repeater terminates the relaying of a transmission after a pre-set time
- general improvements such as greater frequency stability, improved audio, etc.

GLMRS Equipment

- preprogramming of numbers for abbreviated dialing
- on-hook call processing
- automatic re-entry of last number dialed
- LED seven digit telephone number display
- preprogrammed channel selection
- automatic error checking

- call acknowledgement and verification
- automatic dial tone detection
- general trend toward completely automatic two way dial access capability for personal (portable) radio telephones

2.8 Current Systems Concepts

2.8.1 General

The manufacturers' emphasis tends to be placed on "equipment" rather than "systems". Nevertheless, all major manufacturers have extensive in-house systems design capability. Systems designs produced by manufacturers feature the manufacturer's standard hardware, modified if necessary; some specialized items from other sources are often incorporated. Thus, a large number of potential systems are available.

A drawback to this approach is that there is usually a one-time engineering cost associated with a system. A number of manufacturers have mentioned this as a problem - users may want similar but not identical systems - as a result, systems cost to users are higher than they would be if some form of system standardization could be agreed upon.

Synthesis of a system can commence upon the establishment of user requirements, and consists of:

- selection of the type, number, combination and operation of the radio links
- selection of frequencies
- site selection for base stations and relay stations

This selection must be made so that the system adequately serves the users' needs. Other considerations which must be taken into account are:

The items listed above imply "intra-system" optimization which must take place within acceptable cost constraints.

- geographic and frequency isolation from other systems
- conservation of the frequency spectrum
- conservation of "space", i.e. limiting the transmission of RF energy to the areas where it is required.

Of equal importance is "intersystem" optimization, i.e. the necessity to achieve the best use of frequency and "space" over a wide geographical area, also within acceptable cost constraints.

2.8.2

Basic Radio Links

The basic types of radio links can be characterized as follows:

Single Channel One-Way Link

Allows a base station to transmit to (i.e. "page") remote units.

Single Channel Two-Way Link

Allows a base station and remote units to share a channel on a simplex basis.

Dual Channel Two-Way Link

Allows communication from base station to remote units, and from remote units to base station, on a simplex or duplex basis,

according to design. Communication between remote units must take place via the base station.

Refer to Figure 2/2.

2.8.3 Selection of Frequencies

This selection must be carried out in accordance with:

- the basic type of links selected
- propagation considerations
- inter-system and intra-system interference avoidance

The selection must be carried out in consultation with officials of the Department of Communications, which regulates and licences the available frequencies.

2.8.4 Site Selection: Base Stations and Relay Stations

A system designer may tend to solve his problems by placing a high antenna on the highest hill in the neighborhood and by using high-powered transmitters throughout the system. Such an approach may pre-empt frequencies over wide areas, often well outside the nominal geographic boundaries of the system.

Use of relay stations may obviate the need for the high antenna/high hill/high power approach, also generally ensures better area coverage, and reduces frequency and "space" pollution considerably.

A number of types of relay systems are illustrated in Figure 2/3. System A illustrates a situation where mobiles can communicate with central either directly or through relays; mobiles can also

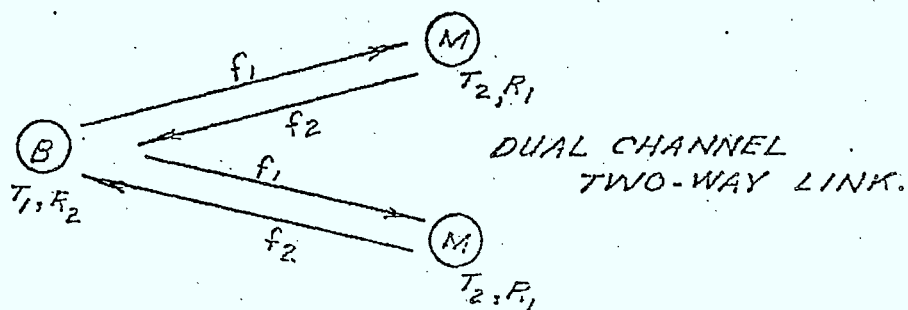
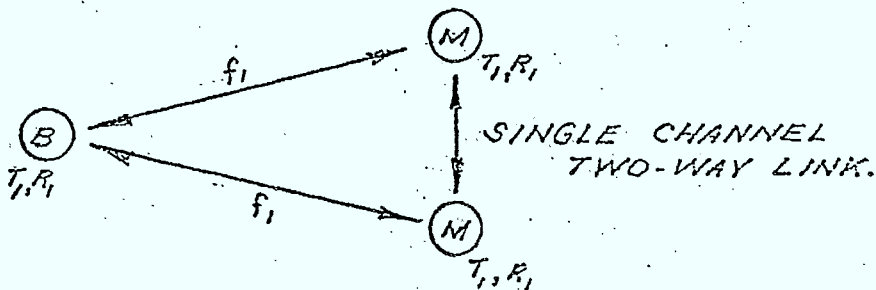
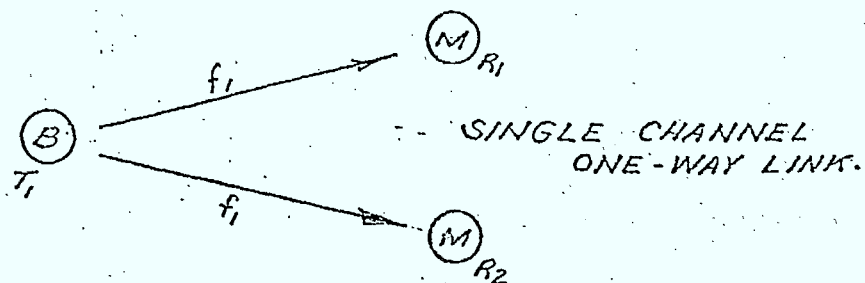
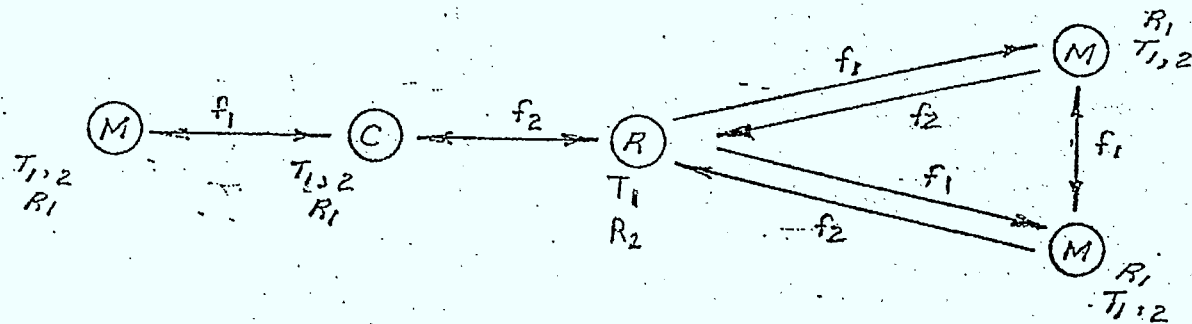
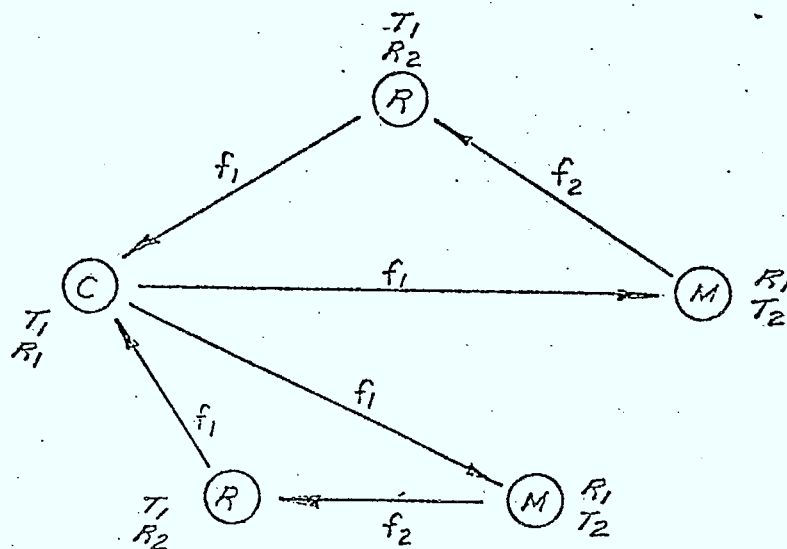


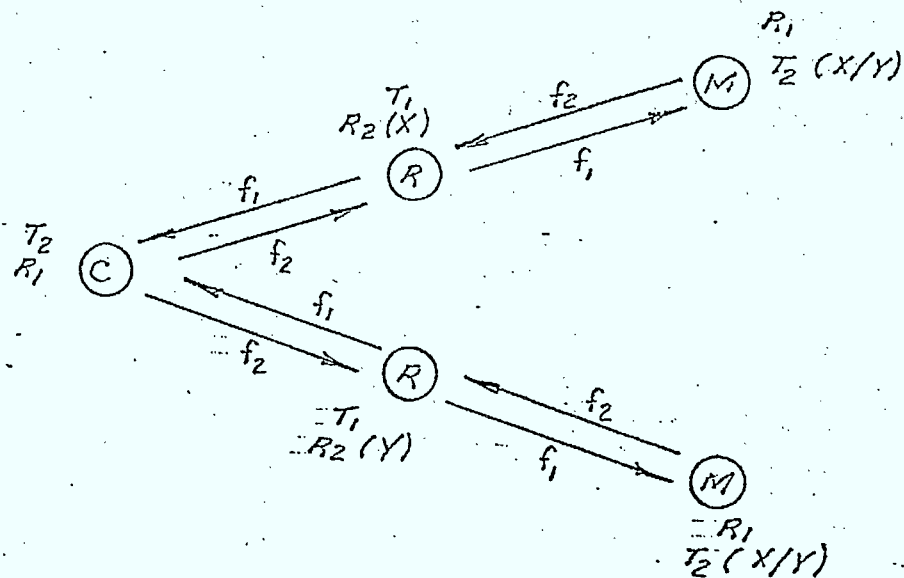
FIG. 2/2 BASIC RADIO LINKS



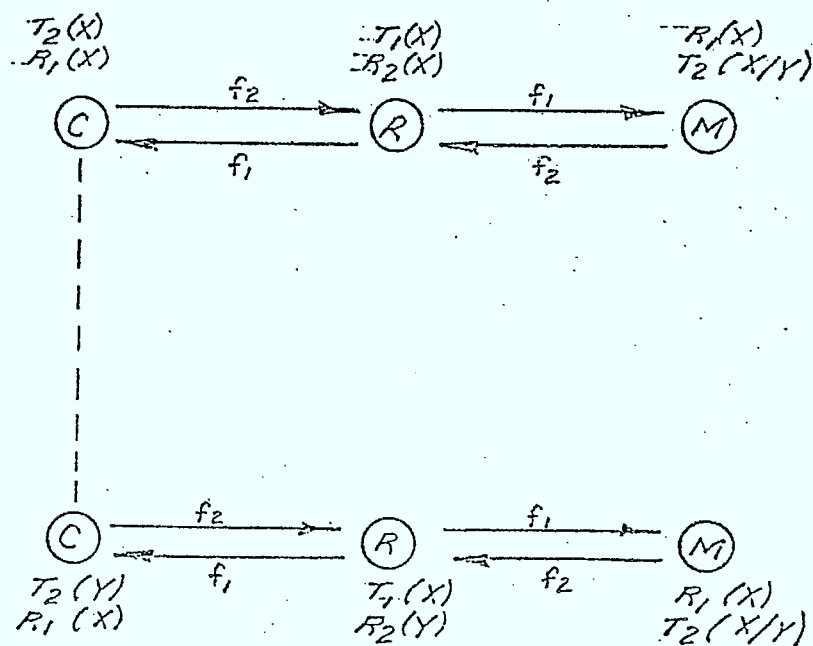
RELAY SYSTEM A



RELAY SYSTEM B



RELAY SYSTEM C



RELAY SYSTEM D

communicate with each other. System B illustrates a situation where central transmits directly to mobiles, and mobiles transmit to central via a relay. The relays are actuated by an identification code (X/Y), which in the simplest case can be manually set by the operator of the mobile unit. System C is similar to System B - the difference being that transmissions from central to mobiles also take place via relays. System D illustrates the concept of the "zoned" systems; the dotted line indicates the possibility of the land line (hardwire or microwave) linking the zone centrals, allowing inter-zone communication.

Other relay systems are conceivable; and a given system could conceivably incorporate many permutations and combinations of all types.

2.8.5

Conservation of Frequency

Conservation of the spectrum can be achieved by two methods:

- frequency sharing
- frequency reuse

The first can be achieved by the time sharing, by users, of the links of a system - the user claims a link from the available pool as needed. This is analogous to the "trunking" schemes of telephone systems. The second is achieved by reusing the same frequency in a nearby geographical area that is sufficiently isolated to make this possible.

An approach which is very efficient in accomplishing conservation of frequency is the "cellular" system, where an area is divided into a series of zones or "cells", and given frequencies are assigned to each cell. Frequencies are reused throughout

the area in the manner similar to the scheme shown in the sketch of Figure 2/5. Connection of cell base stations via land lines (hardware or microwave) is implied; this ensures coverage of the entire area.

Full adoption of cellular concepts for mobile system accomplishes the automatic change of frequency as a mobile passes through a cell boundary, without the user's conversation being interrupted (and without the user being aware of the switches). Such systems, while sophisticated, are within the scope of current technology - but the complexity of such systems can be substantial - computerized central switching, and a mobile location find system is required.

For Private systems, the Department of Communications assigns frequencies for re-use on a cellular basis. In the GLMRS services of the telephone companies, the cellular concept of frequency assignment is also utilized.

2.9

Discussion

This section presents a consolidation of fact and opinion garnered during the fact finding phase.

Most rural areas are served by the existing rural telephone system, and a mobile telephone system is available generally near urban concentrations and major highways on an operator assisted basis. Automatic signalling is foreseen as a potential improvement to the mobile telephone system.

Communications in sparsely settled rural areas and especially in the northern regions of the provinces is less well developed and relies in many cases on single sideband (SSB) HF communication although VHF point-to-point systems are available to provide extended trunk service from a central office to small communities.

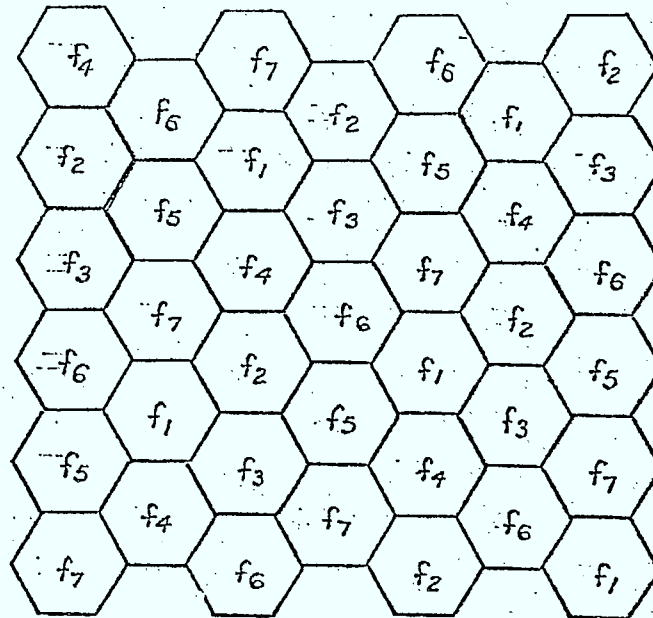


FIG: 2/5 FREQUENCY REUSE ARRANGEMENT
FOR TYPICAL CELLULAR SYSTEMS.

The mobile telephone service is provided exclusively by the Telephone Companies, where basic 12 and 13 channel (optionally 8 in Saskatchewan) VHF equipment has been used in all provinces with 30 KHz channel spacing. In urban areas, channel congestion is occurring and methods are being sought to expand the service either within the spectrum currently allocated, or in other potentially usable frequencies.

For example, the Alberta Government Telephone (AGT) "tertiary" solution increases the nominal 12 channels to 24 by reducing the current channel spacing to 15 KHz.

The British Columbia Telephone System (B.C. Tel.) on the other hand, appears to be maintaining an operator-based telephone system on the existing 13 channels and implementing Rydax automatic dialing (to achieve an automatic mobile telephone system) on the tertiary channels.

At the same time, the Manitoba Telephone System have been planning to switch to UHF channels (450 MHz region) with many more channels available.

Because of the population distribution in Saskatchewan, Saskatchewan Telecommunications (Sask. Tel.) does not face an urban congestion problem. The present system, with appropriate expansion, is expected to be adequate for some time.

Manufacturers view these apparent divergencies in mobile telephone systems with some concern, since the necessity of manufacturing several types of equipment for specialized markets tends to increase the unit cost, and therefore reduces sales. They would be in favour of province to province compatibility,

especially in signalling and dialling patterns. They realize that compatible systems could imply a delay while agreement is being reached, and that compatibility may mean selecting a single supplier for terminal equipment.

From the radio manufacturers' point of view, the radio telephone is probably not the answer for the agricultural user, whose principal requirement is for mobile-to-mobile in a restricted area (as has been indicated by the INS survey). A suggestion was received that a low price mobile unit with a community repeater may be the answer, rather than private systems. The consensus of opinion seemed to be that privacy, while it can be provided at a price, is probably not a necessary feature for the majority of rural communications. Examples were described where a decoder was supplied but was disabled in actual use. The principle appears to be "radio is not a private medium", although various manufacturers supply encoders/decoders where essential for business purposes.

Significant problems are encountered by manufacturers supplying low cost equipment to rural users that must meet the high level specifications necessary to control interference in densely populated areas. (For example, the FCC has a 200 μ V receiver conductive radiation requirement which is felt to be unrealistic by some manufacturers). The DOC has transmitter and receiver specifications defined primarily for urban areas which could possibly be relaxed in rural areas. X

To solve some spectrum congestion problems, some manufacturers suggested that current wide-band users such as television broadcast, should be reduced and transferred to cable where possible and that point-to-point communication should be wired wherever possible. (In the U.S. and Canada, rulings already exist to prevent the use of radio links to bypass existing hard-wire installations, due to limited spectrum availability).

Manufacturers are putting a significant development effort into personal mobile communication, with experimental high channel capacity urban cellular systems proposed for New York and Chicago, and the Washington-Baltimore area.

Currently, some duplication of mobile services seems to have occurred. In retrospect it is conceivable that duplication might have been avoided and that a similar investment could have achieved almost universal service for the population.

It is important that needless duplication be avoided and that reliable service be provided to a large number of rural residents at an affordable cost. Such a service can be foreseen within the scope of current technology and it is necessary that all those who plan, provide, and regulate communication services co-ordinate their efforts.

3.0 MOBILE RADIO SYSTEMS FOR RURAL APPLICATION

3.1 Introduction

This section presents a simple model for estimating the range of mobile radio systems, assesses the present capacity of GRS and proposes systems to meet rural users requirements in the future.

3.2 A Model for Estimating the Range of Mobile Radio Systems

In this section, a simple model for estimating the communications range of a mobile radio system is presented. The model is based on the Egli model according to the detailed design considerations of Appendix B.

The relation used to estimate the communication range is:

$$d = 10^{\left\{ \frac{1}{40} \left[P_T - A_T + G_T + T_F - 117 - 20 \log f + 20 \log h_t \cdot h_r + G_R - A_R - P_R \right] \right\}} \text{ (miles)}$$

where:

d = communications distance (miles)

P_T = transmit power (dbm)

A_T = transmit antenna cable loss (db)

G_T = gain of transmit antenna (db)

T_F = "terrain factor" (db)

f = frequency (MHz)

h_t = height of transmit antenna (ft)

h_r = height of receive antenna (ft)

G_R = gain of receive antenna (db)

A_R = receive antenna cable loss (db)

P_R = power available at the receiver (dbm)

The "terrain factor", TF is a function of frequency and hill height, and is approximated as follows:

$$TF = (-.00009880 f - .03028) h_H + (-.004940 f + 1.514) \quad (\text{db})$$

where:

h_H = average hill height (ft)

The relation was obtained by a curve fit to the data in Figure B/5 of Appendix B. (Note that $TF = 0$ db when $h_H = 50$ ft).

The power required at the receiver is

$$P_R = P_{MUS} + PM \quad (\text{dbm})$$

where

P_{MUS} = minimum usable signal (dbm)

PM = performance margin (db) required to achieve the desired performance.

Following accepted standards the minimum usable signal is taken to be 12 db above the noise level at the receiver:

$$P_{MUS} = N_R + 12 \quad (\text{dbm})$$

where

N_R = the total noise power in the signal bandwidth at the receiver (dbm)

N_R is comprised of three components, as follows:

$$N_R = 10 \log \left\{ n_{rx} + n_{cos} + n_{mm} \right\} + 12 \quad (\text{dbm})$$

where

n_{rx} = inherent noise power of the receiver (mw)

n_{COS} = cosmic noise power accepted by the receiver (mw)

n_{MM} = man made noise accepted by the receiver (mw)

These noise components are given by the following relations:

$$N_{\text{RX}} = 20 \log S - 119 \quad (\text{dbm})$$

$$N_{\text{COS}} = P_{\text{COS}} + 38.55 - 20 \log f + 10 \log B \quad (\text{dbm})$$

$$N_{\text{MM}} = P_{\text{MM}} + 38.55 - 20 \log F + 10 \log B \quad (\text{dbm})$$

where

S = the receiver sensitivity (μV)

P_{COS} = cosmic noise flux ($\text{dbm}/\text{m}^2/\text{kHz}$)

P_{MM} = man made noise flux ($\text{dbm}/\text{m}^2/\text{kHz}$)

B = receiver bandwidth in kHz

The cosmic noise flux is estimated from the relation

$$P_{\text{COS}} = -3 \log f - 119.6 \quad (\text{dbm}/\text{m}^2/\text{kHz})$$

This relation was obtained from a curve fit to the cosmic noise curve of Figure B/2 and represents a worst case.

The man made flux is dependent upon receiver location, its values being typically:

$$P_{\text{MM}} = \begin{cases} -132 \text{ dbm}/\text{m}^2/\text{kHz} & (\text{rural}) \\ -116 \text{ dbm}/\text{m}^2/\text{kHz} & (\text{suburban}) \\ -104 \text{ dbm}/\text{m}^2/\text{kHz} & (\text{urban}) \end{cases}$$

according to Figure B/7 of Appendix B.

The performance margin (PM), the amount by which the received signal (PR) exceeds minimum usable signal, is defined so that a value of 0 db corresponds to a 50% probability of achieving communications at a given distance.

(If other probabilities are to be considered, the required performance margin is determined by the curves of Figure B/1).

Table 3/1 shows the important parameters of a mobile radio system. It also indicates those parameters which are inputs to the model and those which are outputs.

In the next sections, the model will be used to assess a number of systems.

inputs	P_T	dbm	transmitter power
	A_T	db	transmit antenna cable loss
	G_T	db	gain of transmit antenna
	h_H	ft	average hill height
	f	MHz	frequency
	h_T	ft	height of transmit antenna
	h_R	ft	height of receive antenna
	G_R	db	gain of receive antenna
	A_R	db	receive antenna cable loss
	S	MV	sensitivity of receiver
	B	kHz	bandwidth of receiver
	R_x	LOC.	location of receiver (Rural/Suburban/Urban)
outputs	P	%	probability of communicating
	T.F.	db	terrain factor
	N_{RX}	dbm	receiver noise (inherent)
	N_{COS}	dbm	cosmic noise accepted by receiver
	N_{MM}	dbm	man made noise accepted by receiver
	N_R	dbm	total receiver noise ($N_{RX} + N_{COS} + N_{MM}$)
	P_{MUS}	dbm	minimum usable signal ($N_R + 12$ db)
	PM	db	performance margin required to achieve probability P %
	PR	db	received power required to achieve probability P %

TABLE 3/1: Definition of Model Parameters

3.3 Assessment of Present GRS Usage

It is instructive to estimate the present degree of saturation of GRS in rural environments, prior to suggesting new systems for consideration. Table 3/2 presents parameters for a fairly representative GRS system in a rural environment. The table shows that communications are possible for the following separation distances:

mobile ↔ mobile	3.0 miles
mobile ↔ base	7.5 miles
base ↔ base	21.2 miles

In computing these ranges a probability of communicating of 50% is used--this implies that one-half of the possible locations on circles of these radii will experience good communications.

Communications are possible over greater distances, but the reliability of these communications will deteriorate as distance increases.

By the same token, interference (which can be considered as "communication" from an unwanted source) can take place over much greater distances, with a certain statistical probability. To produce an estimate of this interference, the following procedure was adopted:
(Refer to Tables 3/3 and 3/4)

- the performance margin of a potential interference at successively increasing separation distances was determined.

- the "probability of communicating" was determined according to the curves of Figure B/1 (for performance margins less than - 18 db the probability was assumed zero).
- the area of the annulus for each radius (separation distance) was determined.
- the product (probability x annulus area) was formed. This is the number of "interfering" mobiles at distance R, for "unit density" of interferors (i.e.: - one interferor per square mile).

Now, if one knew the "density" of mobiles in the area, it would be possible to estimate the actual number of units which cause interference.

The INS report has indicated that the density of mobile units is the order of 60 units per 1,000 population in certain rural areas. If one adopts the typical farm community model presented in the report -- 15,300 people in an area of 2,000 - 2,800 square miles, a population density of about 6.4 people per square mile is obtained.

Now, if one assumes that a mobile system contains 2 mobiles and one base, based on an average system size of ~3 (2.8 in the INS study) the density of mobiles is:

$$\frac{40 \text{ units}}{1,000 \text{ pop.}} \times \frac{6.4 \text{ people}}{\text{sq. mile}} = 0.26 \frac{\text{mobiles}}{\text{sq. mile}}$$

TABLE 3/2

PARAMETERS OF TYPICAL GRS SYSTEM (27 MHz)

		Mobile →		Base →	
		<u>Mobile</u>	<u>Base</u>	<u>Mobile</u>	<u>Base</u>
P _T	dbm	36	36	36	36
A _T	db	0	0	1	1
G _T	db	0	0	2	2
h _H	ft	50	50	50	50
f	MHz	27	27	27	27
h _T	ft	8	8	50	50
h _R	ft	8	50	8	50
G _R	db	0	2	0	2
A _R	db	0	1	0	1
S	μV	.5	.5	.5	.5
B	KHz	6	6	6	6
R _X	Loc.	Rural	Rural	Rural	Rural
p	%	50%	50%	50%	50%
T.F	db	0	0	0	0
N _{RX}	dbm	-125.02	-125.02	-125.02	-125.02
N _{COS}	dbm	-105.27	-105.27	-105.27	-105.27
N _{MM}	dbm	-114.25	-114.25	-114.25	-114.25
N _R	dbm	-104.71	-104.71	-104.71	-104.71
P _{MUS}	dbm	- 92.71	- 92.71	- 92.71	- 92.71
PM	db	0	0	0	0
PR	dbm	- 92.71	- 92.71	- 92.71	- 92.71
d	mi	3.0	7.5	7.5	21.2

TABLE 3/3a

MOBILE ↔ MOBILE INTERFERENCE

- A - Separation distance d (miles)	- B - Performance Margin (db)	- C - Probability of Communicating	- D - Area of annulus at distance d	- E - C x D
.5	31.25	.99	3.14	3.09
1.5	12.17	.80	9.42	7.56
2.5	3.29	.59	15.71	9.28
3.5	- 2.55	.43	22.0	9.44
4.5	- 6.92	.31	28.27	8.88
5.5	-10.41	.23	34.56	8.06
6.5	-13.31	.18	40.84	7.32
7.5	-15.79	.13	47.12	6.35
8.5	-17.97	.10	53.41	<u>5.58</u>

66

Total number of interferors = 66 x density of interferors

TABLE 3/3b

MOBILE ↔ BASE INTERFERENCE

<u>- A -</u> <u>Separation</u> <u>distance d</u> <u>(miles)</u>	<u>- B -</u> <u>Performance</u> <u>Margin</u> <u>(db)</u>	<u>- C -</u> <u>Probability</u> <u>of</u> <u>Communicating</u>	<u>- D -</u> <u>Area of</u> <u>annulus at</u> <u>distance d</u>	<u>- E -</u> <u>C x D</u>
1	36.13	.99	12.57	12.5
3	17.04	.88	37.70	33.3
5	8.17	.72	62.83	45.0
7	2.32	.56	87.96	49.6
9	- 2.04	.44	113.10	50.1
11	- 5.53	.35	138.23	48.3
13	- 8.43	.28	163.36	45.4
15	-10.92	.22	188.50	42.0
17	-13.09	.18	213.63	38.4
19	-15.02	.15	238.76	35.0
21	-16.76	.12	263.89	31.8
23	-18.43	.10	289.03	28.8
				<u>460</u>

Total number of interferors = 460 x density of interferors

TABLE 3/3c

BASE ↔ BASE INTERFERENCE

- A - Separation distance d (miles)	- B - Performance Margin (db)	- C - Probability of Communicating	- D - Area of annulus at distance d	- E - C x D
2.5	37.13	1.00	78.5	78.5
7.5	18.04	.90	236	211.6
12.5	9.17	.74	393	290.6
17.5	3.32	.59	550	325.5
22.5	- 1.04	.47	707	333.0
27.5	- 4.53	.38	864	324.6
32.5	- 7.43	.30	1,021	308.0
37.5	- 9.92	.24	1,178	287.4
42.5	-12.09	.20	1,335	265.6
47.5	-14.02	.16	1,492	243.8
52.5	-15.76	.14	1,649	223.0
57.5	-17.34	.11	1,806	203.4
62.5	-18.79	.10	1,963	<u>185.4</u>
				3741

Total number of interferors = 3,741 x density of interferors

The density of bases is:

$$\frac{20 \text{ units}}{1,000 \text{ pop.}} \times \frac{6.4 \text{ people}}{\text{sq. mile}} = 0.13 \frac{\text{bases}}{\text{sq. mile}}$$

It is now possible to estimate the number of units which compete for the available spectrum in an area.

A mobile unit will compete with:

$$66 \times .26 = 17 \text{ mobiles}$$

$$460 \times .13 = \underline{60} \text{ bases}$$

$$77 \text{ units}$$

A base unit will compete with:

$$460 \times .26 = 120 \text{ mobiles}$$

$$3,741 \times .13 = \underline{486} \text{ bases}$$

$$606 \text{ units}$$

Now, the INS report indicates that for the GRS, the average call is the order of 3 minutes, with the average number of calls in the busy afternoon period is 1.2 calls per hour for each user. Thus the "traffic" associated with one user will be 3.6 call-minutes per hour, or .06 call-hours per hour.

For a base to establish a call, it competes with 606 other units, and if each of these units has a demand of .06 call-hours per hour, a total traffic of 36.4 call-hours per hour can be expected. This is very close to the capacity of the 40 channels of GRS.

This calculation indicates, surprisingly, that GRS may be approaching saturation in certain rural areas.

Admittedly the calculation is of an approximate nature, but it is nevertheless sufficiently realistic to give cause for concern, as the effect will be, as the number of GRS units increases, for certain GRS users to seek other types of systems to provide the type and quality of services that they need.

This tendency to move to other types of systems is already evident, according to the INS survey.

This fact, coupled with the explosive growth rate of GRS and the urban saturation of GRS, leaves little doubt that the demand for other types of services will increase in all areas, both urban and rural.

3.4 System Concepts of New Mobile Systems

In producing the system concepts outlined in this chapter, the following facts gleaned from the INS report concerning rural users are taken into account:

- users are mainly engaged in the primary industries (production and distribution of goods and services)
- the population density is "thin but continuous"
- the type of service provided by GRS is the most popular in the rural areas
- 75% of GRS users use the system for business purposes
- complaints of GRS users are generally directed at non-business users

- calls originating from mobile units are of major importance
- mobile-to-mobile calls are of considerable importance, especially for GRS business oriented users
- users view their systems as being of "considerable importance" or "absolutely necessary"
- better area coverage was identified by the users as a major requirement for new services
- the popularity of GRS may be partly due to the low cost of this service

Basically, the GRS is the major rural business service at the present time, and user dissatisfactions are due to:

- undisciplined use by non-business users
- limited range

Considering the above facts, and noting that saturation of the GRS may be imminent even in rural areas at the present explosive growth rate of GRS and that the skip interference problems prevalent at sunspot maxima will cause further dissatisfactions, it is concluded that a simple service similar to GRS, but lacking its major shortcomings, is required in the near term future to serve the rural mobile radio user.

This section considers the establishment of two new systems of mobile service, for implementation in the near future.

- a "new mobile service" ("NMS") of the shared multi-channel type, available to the general public
- a "business mobile service" ("BMS"), associated with the NMS, for legitimate business use only

The present services can be ranked according to sophistication and cost in the following order:

- GRS
- Private/RCC
- GLMRS

With the addition of two new services, the ranking according to sophistication/cost would then logically be:

- GRS
- NMS/BMS
- Private/RCC
- GLMRS

The intention here is not to replace GRS with the NMS/BMS combination, but to offer the NMS/BMS combination as an attractive alternative to serious users (who might otherwise be dissatisfied GRS users, or individuals who might use private systems as the only alternative to GRS).

In addition to an assessment of the potential of the BMS for rural application, the future potential of Private/RCC and GLMRS to serve rural needs is also assessed, in particular the potential of more widespread use of RCC systems to satisfy rural communications requirements is addressed.

New Mobile Service (NMS)

For the purposes of this study, it is assumed that a new mobile service would be of the open party line type with all channel frequencies available to all users irrespective of geographical location. The mode of operation

is the simplex mode. The NMS mode of operation would thus be similar to GRS. In addition, the transmitter power is assumed to be slightly greater than the power level of GRS (say 5 watts). Important differences between GRS and the "NMS" would be:

- potential users would be required to pass an examination covering the operation of equipment
- the Department of Communications would enforce regulations stringently

To facilitate enforcement of regulations, it is suggested that a unique users identifier code be incorporated, via sub-audible tone or other means, on every transmitted carrier. This code would be assigned to a user with his license.

One way to facilitate the adoption of this identifier code scheme would be to design units so that they require the insertion of a read only memory (ROM) device to become operative. The ROM, programmed with the users identifier code, would be issued to the user by the regulatory agency. Upon insertion of the ROM, the users equipment would become operative. (The logistics associated with this scheme would obviously have to be established prior to the implementation of the service in consultations with manufacturers.)

An added advantage associated with this unique identification code is that selective calling of units would be facilitated.

It is assumed that this service would be implemented throughout the U.S. and Canada. Mass production of equipment for this large market would then, of course, tend to make equipment relatively inexpensive. Costs could be expected to stabilize at a level somewhat higher than GRS.

Business Mobile Service (BMS)

It is proposed that this service be associated with the NMS, occupying spectrum immediately adjacent to the NMS.

It is suggested that this service be characterized by a higher transmitter power (\approx 10 watts).

Licenses for this service would only be granted to legitimate business operations, for use in conducting the affairs of the business.

Apart from the higher transmission power and the licensing restrictions, this service could be essentially identical to the NMS. (That is to say open channel simplex operation)

It is further suggested that a BMS license automatically authorize the user to operate on NMS channels (at the NMS power level). Conceivably, manufacturers might offer BMS and NMS sets in a common chassis, allowing the user to use either service.

Representative calculations for a NMS at 220 MHz have been performed in keeping with the suggestion made in

Section 2.2. Such a new service could, of course, be located elsewhere in the spectrum. The following analysis of a system based in the 220 MHz region is used as a baseline in this report, and the impact of locating the service at another region of the spectrum is considered later.

Parameters of a BMS system for rural application are presented in Table 3/5.

Typical ranges over which communication is possible are:

Mobile ↔ Mobile	4.9 Miles
Mobile ↔ Base	18.0 miles
Base ↔ Base	65.3 miles

It should be noted that these ranges correspond to a probability of communicating of 50%--this implies that one-half of the possible locations and circles of these radii will experience good communications.

Performance over larger distances is possible, with the quality of the communication dropping with increased distance.

An assessment of the interference problems associated with such systems will now be made, in a manner similar to the assessment carried out for GRS.

Tables 3/5 a, b, and c show performance margins of a potential interferor at various distances, and the associated probability of communicating. The number of interfering

TABLE 3/4

Parameters of Proposed Business
Mobile System, Rural Application (220 MHz)

		Mobile →		Base →	
		<u>Mobile</u>	<u>Base</u>	<u>Mobile</u>	<u>Base</u>
P _T	dbm	40	40	40	40
A _T	db	0	0	1	1
G _T	db	2	2	6	6
h _H	ft	50	50	50	50
f	MHz	220	220	220	220
h _T	ft	8	8	75	75
h _R	ft	8	75	8	75
G _R	db	2	6	2	6
A _R	db	0	1	0	1
S	μv	.4	.4	.4	.4
B	KHz	6	6	6	6
R _X	Loc	Rural	Rural	Rural	Rural
p	%	50%	50%	50%	50%
T.F.	db	0	0	0	0
N _{RX}	dbm	-126.96	-126.96	-126.96	-126.96
N _{COS}	dbm	-127.14	-127.14	-127.14	-127.14
N _{MM}	dbm	-132.47	-132.47	-132.47	-132.47
N _R	dbm	-123.45	-123.45	-123.45	-123.45
P _{MUS}	dbm	-111.42	-111.42	-111.42	-111.42
PM	db	0	0	0	0
PR	dbm	-111.42	-111.42	-111.42	-111.42
d		4.9	18.0	18.0	65.3

TABLE 3/ 5a

<u>Mobile Mobile interferors</u>				
<u>-A- Separation Distance d (Miles)</u>	<u>-B- Performance Margin (db)</u>	<u>-C- Probability of Communicating</u>	<u>-D- Area of Annulus at Distance d</u>	<u>-E- CXD</u>
1	27.73	.97	12.57	12.24
3	8.64	.73	37.70	27.41
5	- .29	.49	62.83	30.91
7	- 6.07	.34	87.96	29.52
9	-10.44	.23	113.10	26.32
11	-13.93	.16	138.23	22.81
13	-16.83	.12	163.36	19.64
15	-19.31	.09	188.50	16.67

186

Total number of interferors = 186 x density of interferors

TABLE 3/5b
Mobile Base Interferors

<u>-A- Separation Distance d (Miles)</u>	<u>-B- Performance Margin (db)</u>	<u>-C- Probability of Communicating</u>	<u>-D- Area of Annulus at Distance d</u>	<u>-E- CXD</u>
2.5	34.25	.99	78.5	77
7.5	15.17	.85	236	202
12.5	6.29	.67	393	263
17.5	.45	.51	550	281
22.5	- 3.92	.39	707	275
27.5	- 7.40	.30	864	259
32.5	-10.31	.23	1021	239
37.5	-12.79	.18	1178	217
42.5	-14.97	.15	1335	195
47.5	-16.90	.12	1492	175
52.5	-18.64	.10	1649	157
				<u>2340</u>

Total number of interferors = 2340 x density of interferors

TABLE 3/5c

Base Interferors				
-A- Separation Distance d (Miles)	-B- Performance Margin (db)	-C- Probability of Communicating	-D- Area of Annulus at Distance d	-E- CXD
5	44.65	1.00	314	314
15	25.56	.96	943	908
25	16.69	.88	1571	1380
35	10.85	.78	2199	1706
45	6.48	.67	2827	1907
55	2.99	.58	3454	2013
65	.09	.50	4084	2052
75	- 2.39	.43	4713	2044
85	- 4.57	.37	5341	2001
95	- 6.50	.32	5968	1938
105	- 8.24	.28	6597	1862
115	- 9.82	.25	7226	1776
125	-11.27	.22	7854	1691
135	-12.61	.19	8482	1603
145	-13.85	.17	9111	1516
155	-15.01	.15	9739	1431
165	-16.09	.13	10367	1350
175	-17.11	.12	10996	1273
185	-18.08	.10	11624	1197
				29962

Total number of interferors = 29,962 x density of interferors.

mobiles at a distance R for unit density of interferors is also shown.

In order to estimate the density of these systems, it is desirable to once again look at a typical prairie community model, similar to that presented in the INS report. This model community, of approximately 2,400 sq. mi. in size, contains the following rural businesses:

1,650 farms
228 farm services
<hr/>
1,878 businesses

which is a "business density" of 0.78 businesses/sq. mi. on the average.

If we make the assumption that 5% of these businesses would make use of the BMS (bearing in mind that GRS, NMS, Private, RCC and GLMRS are all available as choices) the density of systems will be

$$0.78 \times 0.05 = 0.039 \text{ systems/sq. mi.}$$

Assuming that the average system contains four mobiles and one base, we then have:

$$\begin{aligned} \text{density of mobiles} &= 0.156/\text{sq. mi.} \\ \text{density of bases} &= 0.039/\text{sq. mi.} \end{aligned}$$

Using the tabulations of Table 3/5, an estimate of the number of units competing for channels can now be made.

A mobile unit will compete with

$$\begin{aligned} 186 \times .156 &= 29 \text{ mobiles} \\ 2340 \times .039 &= \underline{91} \text{ bases} \\ &120 \text{ units} \end{aligned}$$

A base unit will compete with

$$\begin{aligned} 2,340 \times .156 &= 365 \text{ mobiles} \\ 29,962 \times .039 &= \underline{1169} \text{ bases} \\ &1533 \text{ units} \end{aligned}$$

If a base unit makes an average of, say, 1.5 calls of one minute duration during the "busy hour", and competes with 1533 other units for channel space, then the total traffic will be

$$\frac{1.5 \times 1}{60} \times 1533 = 38 \text{ call hours/hour}$$

From this analysis, a 40 channel BMS would provide a viable rural service, under the assumed conditions.

The level of interference experienced can be reduced by duplex operation (in the simplest case, the base transmits on frequency A, receives on frequency B, mobiles transmit on channel B, receive on channel A). Because of the significant requirement for mobile-to-mobile communications, it would be convenient for the mobiles to transmit on channel A as well, allowing direct mobile-to-mobile communication. (This feature is particularly important when mobiles are beyond communications range with the base.) If base-to-base communications were required (and in rural areas this may be likely on occasion) the base would then have to have the capability to transmit on channel B as well-this is probably a necessary feature even though base-to-base calls would probably be limited.

If this type of system were adopted, the base-to-base type interference would be largely eliminated, reducing the interference to about $\frac{1}{4}$ of that in the above analysis, reducing the total communication channels requirement from forty to ten. Since the ten channels are dual, twenty frequencies would be required to serve the same number of users. Alternatively, if forty channels were used, then twice the number of users could be accommodated.

If the system were implemented at 450 MHz rather than 220 MHz, the conclusions would be similar. If the system parameters of a 450 MHz system were identical to the 220 MHz system parameter of Table 3/4 with the exception of frequency, the communication range would be:

mobile ↔ mobile	4.0 miles
mobile ↔ base	14.6 miles
base ↔ base	53 miles

These ranges are the order of 20-25% less than for the system with identical parameters at 220 MHz. As a result of this, the interference problem is lessened and the system could support a higher density of users. On the other hand, if the ranges of the two systems were made equal (through the use of higher gain antennas and higher antennas, for example), the allowable user density would be similar.

Costs associated with implementing a BMS system for rural application would be comparable to an NMS system, but possibly somewhat higher. Note that this assumes a BMS service adjacent in the spectrum to an NMS service, and commonality of equipment.

The estimated cost, in today's dollars, of a BMS system similar to the one described, appears in Table 3/5.

These estimates were arrived at by considering the present quality and costs of equipment produced for private systems, and the quality and costs of the higher quality GRS equipment. By assuming the complexity and sales volume of NMS/BMS to be between these two, the estimates in the table were produced.

It will be noted that the cost of the radio equipment is about double that of good quality GRS units, and about one half the cost of VHF equipment used in Private/RCC systems.

The table indicates that the cost of a base plus one mobile is the order of \$1,500, a GRS system (base plus one

TABLE 3/5d

Estimated Cost of a BMS System

Mobile Unit	\$400-500
Mobile Antenna	25- 50
Base Unit	500-600
Antenna Tower (installed)	200-450
Base Antenna	<u>75-200</u>
Cost of Base plus One	
Mobile	\$1200-1800

mobile) with similar antenna tower, would cost in the vicinity of \$750, assuming quality equipment. On the other hand, the cost of a private system, (base plus one mobile) again assuming the same antenna tower, would be about \$2,800.

Based on these estimates, a BMS service would be an attractive option for the user.

It is proposed that the new services, (NMS/BMS) supplement the existing services (GRS, Private/RCC and GLMRS). The options available to the user would then be as shown in Table 3/6.

Use of Existing Services

At the present time mobile communications needs in rural areas are satisfied by existing services (GRS, Private/RCC and GLMRS), and until new services are introduced, these services will have to satisfy all rural mobile communication needs.

As demand for mobile services continues to grow, the pattern of usage of these services can be expected to change. Users dissatisfied with GRS can be expected to have the largest impact, as they move to upgrade their service.

A number of suggestions regarding these services are presented:

- GRS--an attempt to keep this service viable in rural areas should be undertaken. This could consist of an educational program coupled with a more stringent enforcement program

TABLE 3/8: MOBILE RADIO CHOICES WITH THE ADDITION OF NMS/BMS

	<u>RANGE (miles)</u>			<u>COST (typical)</u>
	Mobile ↔ Mobile	Mobile ↔ Base	Base ↔ Base	(base or use of base plus one mobile)
GRS	3	8	21	\$ 500 - \$1,000
NMS (1)	3	8	21	\$1,000 - \$1,600
BMS	5	18	63	\$1,200 - \$1,800
PRIVATE	5-6	20-25	N/A	\$2,500 - \$3,000
RCC	40-80 (2)	20-40	N/A	\$1,200 & \$10/month (or \$40/month)
GLMRS	unlimited (3)	25-50	unlimited (3)	\$1,800 & \$30/month (or \$75/month)

Notes:

1. NMS ranges are assumed to be similar to GRS.
2. Mobile-to-mobile range for RCC based on using base as a relay station.
3. Mobile-to-mobile and base-to-base ranges for GLMRS are considered to be unlimited as the connection is established through the land-line telephone network.

- Private/RCC systems--encourage the establishment and use of RCC systems over private systems (to conserve spectrum)
- GLMRS--continue to expand these services

A typical RCC system--where a community repeater is shared by the subscribers, and is used as a relay for mobile-to-mobile or base-to-mobile communications--is a realistic and cost-effective option for providing rural mobile service, especially where long ranges (20 to 40 miles) are involved.

The current technology of RCC equipment allows for a reasonable degree of service to be provided. For example, selective calling to all units of one subscriber is in effect in some systems, and a "lock-out" feature which disables all transmitters except the one occupying the channel can also be incorporated. Other features, such as a "busy light" (indicating that a channel is occupied) and a repeater "time-out" (relay of transmission is terminated after a pre-set time) can add to the attraction of RCC systems.

In spite of the apparent potential of RCC systems, they are not, at present, in wide use in the prairies. The reason for this is not known, although it is speculated that it is because present RCC systems tend to cater to dispatch-oriented services.

If future RCC systems have a capability of direct mobile-to-mobile communications, they would likely have considerable appeal to the rural user.

It is suggested that the Department of Communications continue to recommend the use of RCC systems over Private

systems, where possible, and that the establishment of new RCC systems be encouraged.

Because assignments of frequencies are under control of the DOC an RCC system provides a more controlled type of service than the open party line systems of GRS (or the proposed NMS and BMS); and if their use is encouraged, RCC systems could be expected to play a very significant role both before and after the introduction of any new services, especially where long range communications are required.

It is conceivable that effort to encourage the use of RCC systems could result in further development of equipment by manufacturers, resulting in better services for the user.

3.5

Rural Mobile Systems: The Long Term

The previous section suggested ways to provide needed mobile radio services for rural areas in the near future, taking into account user needs and technical and cost factors.

The INS report established that the existing types of services are generally satisfactory, and that a need for more sophisticated service is not evident.

It would, however, be unwise to assume that users requirements will remain static, so, a brief look at the future of rural mobile systems will be made.

Development work on sophisticated mobile radio-telephone systems in the United States is nearing the point where pilot systems are being proposed. These systems are

designed for heavily populated urban areas, and use sophisticated cellular concepts, and complex central switching techniques to accomplish such items as automatic channel switching of mobiles when cell boundaries are crossed.

These developmental systems may prove to be prototypes of an eventual continental network, which provides affordable land-mobile communications for the general public. These systems, allowing an individual access to a continental network from a mobile unit or even a portable unit can be expected to be generally available at or near the end of the century. These systems, to be continental in nature, will have to interface to land-line networks; hence, it is conceivable that the telephone utilities will offer these services. Existing GLMRS systems can thus be expected to ultimately evolve to this capability.

It is likely that such systems will incorporate techniques not now prevalent in mobile systems, namely:

- unique number addresses for mobile units
- digital signaling techniques for selective calling
- digital voice encoding techniques
- digital modulation techniques
- possibly use of communications satellites in a relay capacity

One more item, somewhat more speculative than those just mentioned, deserves further discussion. This item is the use of the "spread spectrum" modulation technique.

Spread spectrum, applied to mobile systems (Reference 3/1), would consist of the encoding of a voice according to some encoding law, and the transmission over a very wide bandwidth. Many transmitters share the same spectrum, but they would not interfere with one another if each transmitter uses a different encoding law, because a receiver tuned to a specific encoding law will see all other transmissions as noise. (Spread spectrum modulation yields a low-power density signal which is statistically similar to random noise). (See Reference 3/2)

Use of spread spectrum results in relatively easy implementation of:

- multiple access capability
- selective calling
- transmitter identification
- message privacy

Such systems have been implemented for military usage, so the system is not purely speculative. Recent developments in surface acoustic wave (Reference 3/3) devices for modulators and demodulators indicate potential for eventual low-cost volume production--if this occurs, cost of spread spectrum mobile units should approach that of conventional units.

An intriguing feature of a spread spectrum system, is that an experimental system could use the same spectrum already used by existing services. This would allow a pilot system to be introduced without a special frequency assignment.

The references indicate that spread spectrum has considerable potential for mobile application and deserves to be investigated.

A conjectured scenario of the near term future of business-oriented systems in the rural areas of the prairies is presented in Figure 3/1. Key assumptions in this scenario are:

- the number of business-oriented systems will triple over the course of the next ten years
- incentives for the establishment and use of RCC systems will result in their installation in about one-half of the 107 farm-cities on the prairies, and such RCC systems will accomodate about fifty business subscribers.
- a Business Mobile Service (BMS) similar to the one discussed in this report will be introduced by the end of 1981
- the number of Private systems will grow at a slow but steady rate
- GLMRS will show slow but steadily increasing growth
- use of GRS for business purposes will increase until the introduction of the BMS; thereafter, its use for business purposes will decline.

The scenario essentially postulates a major shift of rural business users from GRS to BMS, and that this will occur because it is the most cost-effective means of attaining a true business radio service, which retains the utility of the GRS, but without its major shortcomings.

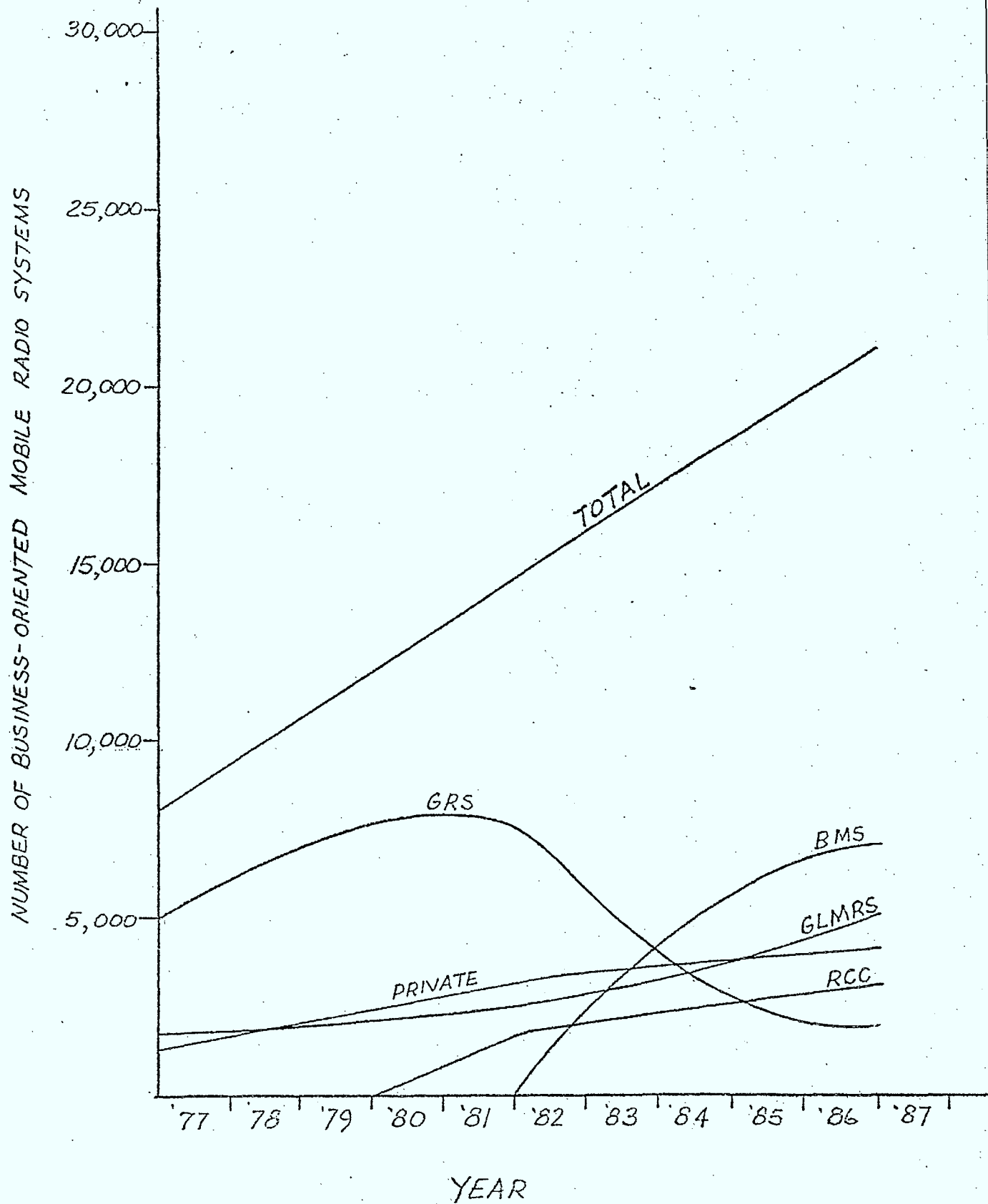


FIGURE 3/1: SCENARIO FOR RURAL BUSINESS-ORIENTED SYSTEMS

The scenario also postulates a shift of some users to RCC systems--these users would tend to be those requiring long-range base-to-mobile and mobile-to-mobile communications. This increased use of RCC systems will require some initiative by DOC in the form of an educational program, encouragement of companies, organizations, and individuals to establish the systems, and some incentive to users to subscribe to these systems.

The scenario postulates moderate growth to Private systems and GLMRS, as a result of the introduction of the BMS and the encouragement of the use of RCC systems.

REFERENCES

- 3/1 Eckert & Kelly, "Implementing Spread Spectrum Technology in the Land Mobile Radio Services", IEEE Transactions on Communications, vo. COM-25, No. 8, August 1977.
- 3/2 Davies, "Performance and Synchronization Considerations", AGARD Lecture Series No. 58 on Spread Spectrum Communications, AGARD-LS-58, June 1973.
- 3/3 Bell, Holmes and Ridings, "Application of Acoustic Surface Wave Technology to Spread Spectrum Communications", IEEE Transactions on Sonics and Ultrasonics, Vol. SA-20, No. 2, 1977.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

As a background to the presentation of the conclusions of this report, the general conclusions of the INS study are first presented:

"Perhaps the most obvious, and illuminating, results pertain to the status of GRS communications. It has been demonstrated that this communications technique stands up quite well when scrutinized from a 'business radio' point of view. Admittedly, there are elements within the service category which are non-business. But the indications are that these elements are concentrated in urban places. There is also an indication of friction between business and non-business users. The popularity of GRS communications in rural areas is unquestionable and it is tempting to conclude that the major reason for this popularity is the lower cost factor. Nevertheless, the recent growth of GRS has resulted in greater number of mobile radio users than ever before.

The status of private radio systems in rural areas is not on the same level as that of GRS. The attraction of this type of communications system is greatest for services typically associated with farm cities and for the higher income farm population. The higher cost of this communications technique demands that greater benefits be realized.

Radio-telephone communications in rural areas has been shown to be concentrated in Alberta. But, like private radio communications, this service presents an urban orientation. The higher cost of this service is also seen to hamper its popularity.

Users in all three of the major service categories have demonstrated a desire for better area coverage. This may be the key element upon which future improvements should be concentrated. Generally, all rural residents are within forty miles of a farm city. In addition, agricultural units do not typically have contiguous parts but may be spread out over thirty miles or more. The ultimate communications system would be able to provide communications both within the sphere of operations and from that sphere to the service center locations.

Never before has mobile communications been within the reach of so many rural residents. The popularity of GRS at present is sure to reflect upon the alternative communications techniques in the future. The friction between responsible and non-responsible users will promote the adoption of these other services. But it is also possible that many users will be forced, from an economic viewpoint, to continue using this service even though it is not considered to be optimal."

General conclusions of this present study are based on these INS conclusions, and on the considerations just presented:

The conclusions are:

- 1) The present mix of mobile radio services (GRS/Private/GLMRS) used in the rural areas of the prairies appears to be generally satisfactory to the users.

- 2) During peaks of activity in rural areas, GRS may be approaching saturation in areas where it is used extensively,
- 3) The present growth rate of GRS will result in more and more users and potential users of GRS seeking to adopt other systems,
- 4) A Business Mobile Service (BMS) associated with a New Mobile Service (NMS) operating in a manner similar to GRS, but licenced only for legitimate business use and efficiently policed, would be a viable rural mobile system and a desirable alternative to GRS,
- 5) Establishment of RCC systems oriented toward the rural user would provide a reasonable alternative to the establishment of numerous private systems.
- 6) The long term trend of mobile communications technology appears to be toward automatic mobile and portable telephones which access the national and international networks. Estimates vary on the time when this will occur, but the end of the century is a typical estimate.

4.2

Recommendations

General recommendations generated as a result of this study are presented:

1) Immediate

- GRS - carry out sufficient enforcement procedures to preserve GRS as a viable business service for rural areas

- RCC - encourage the installation of RCC systems to service the rural user

2) Near Future

- Establish a "quality" mobile service for the general public. Main features of this system would be:
 - . identification code modulated on transmitted carriers
 - . selective call capability
 - . examination prior to licensing
- Establish a business mobile service adjacent in the spectrum to the above service. Features distinguishing this service from the above service would be:
 - . higher transmit power
 - . restricted licencing (businesses, farmers, ranchers, services, etc.)
- Encourage further development of RCC systems for rural application and continue to encourage the use of these systems.

3) Long Term

- Ensure that rural needs are taken into account in the design and implementation of future mobile systems, so that systems now under development can be applied in rural situations.

APPENDIX A

List of Suppliers Polled

ADT/COOK'S COMMUNICATIONS
160 N. Broadway
Fresno, California 93701

AEROTRON, INC.
U. S. Highway One North
P. O. Box 6527
Raleigh, North Carolina 27628

Yes

ALBAR INDUSTRIES LTD.
1698 W 3rd Avenue
Vancouver, British Columbia V7M 2H4

LOUIS ALBERT ASSOC. INC.
2264 Stevnage Dr.
Ottawa, Ontario K1G 3N4

ALDEN ELECTRONIC & IMPULSE RECORDING EQUIP. CO. INC.
Washington Street
Westboro, Mass. 01581

Yes

Alexander Manufacturing Company
P.O. Box 1645
Mason City, I.A. 50401

Yes

AMERICAN DISTRICT TELEGRAPH CO.
1 World Trade Center
New York, New York 10048

ANDREW CORP.
10500 W. 153 St.
Orland Park, Il. 60462

Yes

ANTENNA, INC.
23850 Commerce Park Road
Cleveland, Oh. 44122

Yes

THE ANTENNA SPECIALISTS CO.
12435 Euclid Avenue
Cleveland, Oh. 44106

Yes

ASTRONAUTICS CORP. OF AMERICA
907 South First Street
Milwaukee, WI. 53204

AVCOM INC.
P. O. Box 29153
Columbus, Ohio 43229

Yes

BAYLY ENGINEERING LTD.
167 Hunt Street
Ajax, Ontario L1S 1P6

BELL & HOWELL COMMUNICATIONS CO.
78 Blanchard Rd.
Burlington, MA. 01803

Yes

BIDCOM, INC.
9522 W. Jefferson Blvd.
Culver City, CA 90230

BOGEN (LEAR SIEGLER)
P.O. Box 500
Paramus, NJ 07652

Yes

BRAMCO CONTROLS DIV., LEDEX INC.
540 College Street
Piqua, OHIO 45356

Yes

C & D ELECTRONICS INC.
8305 Nicholson Court
New Carrollton, MD 20784

CALDWELL A/V EQUIPMENT CO. LTD.
1080 Bellamy Rd. N.
Scarborough, Ontario M1H 1H2

CANADIAN GENERAL ELECTRIC
COMMUNICATIONS SYSTEMS & SERVICE DEPARTMENT
189 Dufferin Street
Toronto, Ontario M6K 1Y9

Yes

CANADIAN LARSEN ELECTRONICS LTD.
1340 Clark Drive
Vancouver, British Columbia V5L 3K9

CANADIAN MARCONI CO.
MARINE & LAND COMMUNICATIONS DIV.
2442 Trenton Avenue
Montreal, Quebec H3P 1Y9

Yes

CANADIAN MOTOROLA ELECTRONICS CO.
3125 Steeles Avenue E.
Willowdale, Ontario M2H 2H6

CAPITOL COMMUNICATIONS, INC.
2817 East Fifth Street
Austin, Texas 78702

Yes

CARDION ELECTRONICS DIV.
GENERAL SIGNAL CORP.
Woodbury, NY 11797

Yes

CARRILL INTERNATIONAL CORPORATION
P.O. Box 4039
Foster City, CA 94404

Yes

CASCADE ELECTRONICS
1931 Greenspring Dr.
Timonium, MD 21093

CEI Div.
WATKINS-JOHNSON CO.
700 Quince Orchard Rd.
Gaithersburg, MD 20760

CEPCO INC.
COMMUNICATIONS & ELECTRONICS PRODUCTS
4563 S. Westmoreland
Dallas, Texas 75237

CERRO COMMUNICATIONS PRODUCTS
DIVISION OF CERRO MARMON CORP.
Halls Mill Road
Freehold, NJ 07729

CHALLENGER ELECTRONICS INC.
6800 N. E. Durham
Portland, OR 97211

Yes

CHATTRONIX COMMUNICATIONS INC.
5375 NW 74 Avenue
Miami, FL 33166

CODED COMMUNICATIONS CORP.
6241 Yarrow Drive
Carlsbad, CA 92008

Yes

COMCENTER CORP.
6747 Valjean Avenue
Van Nuys, CA 91406

Yes

COMEX SYSTEMS INC.
P. O. Box 278
Executive Drive
Hudson, NH 03051

Yes

COMMUNICATIONS ASSOCIATES INC.
200 McKay Rd.
Huntington Station, NY 11746

Yes

COMMUNICATIONS CO.
300 Greco Ave.
Coral Gables, FLA 33134

Yes

COMMUNICATIONS CONTROL CENTRES, INC.
4312 Black Rock Rd.
Hampstead, MD 21074

Yes

COMMUNICATIONS PRODUCTS INC.
1401-B South Floyd Rd.
Richardson, TX 75081

Yes

COMMUNICATIONS SPECIALISTS
P. O. Box 153
Brea, CA 92621

Yes

COMMUNICATIONS TRANSPORTATION INC.
Cardinal Drive
P. O. Box 1422
Corinth, MS 38834

Yes

COMPUTING DEVICES OF CANADA LTD.
P. O. Box 8508
Ottawa, Ontario K1G 3M9

CONTROLONICS CORP.
One Adams Street
Littleton, MA 01460

CONTROL SIGNAL CO.
5964 W. Columbia Place
Denver, CO 80227

Yes

CONWAY ELECTRONIC ENTERPRISES LTD.
88-90 Arrow Rd.
Weston, Ontario M9M 2L8

COURIER PRODUCTS FANON, COURIER CORP.
990 S. Fair Oaks
Pasadena, CA 91105

CR ELECTRONICS
1155 Triton Dr.
Suite D
Foster City, CA 94404

CUSTOM RADIO AND COMMUNICATIONS
3234 W. Shangri-la Rd.
Phoenix, AZ 85029

CYGNED INC.
168 Lawrence Rd.
Salem, NH 03079

DATA SIGNAL INC.
2403 Commerce Lane
Albany, GA 31707

Yes

DECIBEL PRODUCTS, INC.
3184 Quebec St.
Dallas, TX 75247

Yes

DYNASCAN CORP.
1801 W. Belle Plaine
Chicago, ILL 60613

ELECTROMECHANICAL PRODUCTS
6087 Kingston Rd.
West Hill, Ontario M1C 1K5

ELECTROSPACE SYSTEMS INC.
320 Terrace Village
Box 1359
Richardson, TX 75080

ELKAY ELECTRONICS LTD.
60 Nugget Avenue
Aincourt, Ont. M1S 3A9

EMERGENCY BEACON CORP.
15 River Street
New Rochelle, NY 10801

E-SYSTEM INC. GARLAND DIV.
Box 6118
Dallas, TX 75222

Yes

FANON ELECTRONICS OF CANADA LTD.
25 Bathurst Street
Toronto, Ontario M5V 2P1

Yes

FARGO
1162 Bryant Street
San Francisco, CA 94103

Yes

FEDERAL SIGNAL CORP.
136 and Western Avenue
Blue Island, IL 60406

FERRANTI LTD.
hollinwood OL9 7JS
Lancashire, England

FERRITRONICS
222 New Kirk Rd.
Richmond Hill, Ontario L4C 3G7

Yes

FORT WORTH TOWER CO. INC.
1901 E. Loop 820S
P. O. Box 8597
Fort Worth, TX 76112

Yes

FRONTIER COMMUNICATIONS CO. LTD.
236 Catharine N.
Hamilton, Ontario L8L 4S6

GENERAL AVIATION ELECTRONICS INC.
414 Kingman Dr.
Indianapolis, Ind. 46226

Yes

GENERAL COMMUNICATIONS
827 S. 20th
Omaha, NE 68108

Yes

GENERAL ELECTRIC CO.
COMMUNICATION SYSTEMS DIV.
Box 4197
Lynchburg, VA 24502

Yes

GLENAYRE ELECTRONICS, INC.
1551 Columbia Street
North Vancouver, British Columbia
Canada V7J 1A3

Yes

GTE SYLVANIA CANADA LTD.
8750 Cote de Liesse Rd
Montreal, Quebec H4T 1H3

GTE SYLVANIA INC.
ELECTRONIC SYSTEM GROUP
100 2nd Avenue
Waltham, Mass 02194

E. S. GOULD MARKETING CO. LTD.
109 Montee de Liesse
Montreal, Que. H4T 1S9

HACKBUSCH SALES LTD.
395 Ormont Dr.
Weston, Ontario M9L 1N8

HARRIS CORP.
55 Public Square
Cleveland, OHIO 44113

Yes

HARRIS-WEINER & ASSOC.
77 Steelcase Rd.
Unit C
Markham, Ontario L3R 2M4

HENRY RADIO
11240 W. Olympic Blvd.
Los Angeles, CA 90064

Yes

HERMES ELECTRONICS LTD.
Box 1005
Dartmouth, Nova Scotia

HOFFMAN ELECTRONICS CORP.
4323 Arden Drive
El Monte, CA 91734

Yes

IEC ELECTRONICS CORP.
319 E. Chestnut St.
East Rochester, NY 14445

Yes

INSTRONICS LTD.
171 Neil Avenue
Stittsville, Ontario KOA 3G0

Yes

INTEGRATED SYSTEMS TECHNOLOGY, INC.
2701 National Dr.
P. O. Box 2585
Garland, TX 75041

INTERNATIONAL AERADIO (NORTH AMERICA) LTD.
70 Don Park Rd.
Unit 15
Markham, Ontario L3R 1G4

INTERNATIONAL MOBILE TELEPHONE SYSTEMS, INC.
NATIONAL MARKETING DIVISION
P. O. Box 3634
New Haven, CT 06525

INTERNATIONAL SYSTCOMS LTD.
4900 Fisher St.
Montreal, Quebec H4T 1J6

Yes

ITT DEFENSE COMMUNICATIONS DIV.
492 River Rd.
Nutley, NJ 07110

JMD ELECTRONICS
P. O. Box 346
West Hempstead, NY 11552

E. F. JOHNSON CO.
299 10th Avenue SW
Waseca, Minn. 56093

Yes

KAAR ELECTRONICS CORP.
232 Wescott Dr.
Rahway, NJ 07065

KOKUSAI ELECTRIC CO. OF AMERICA
5422 West Rosecrans Avenue
Lawndale, CA 90260

KUSTOM DATA COMMUNICATIONS INC.
1010 W. Chestnut
Chanute, Kansas 66720

Yes

KW MANUFACTURING CO.
P.O. Box 508
Progue, OK 74864

Yes

KUSTOM DATA COMMUNICATIONS INC.
1010 W. Chestnut
Chanute, Kansas 66720

Yes

LAKE SYSTEMS CORP.
55 Chapel St.
Box 65
Newton, Mass. 02160

LARSEN ELECTRONICS INC.
11611 N.E. 50th Avenue
P. O. Box 1686
Vancouver, WA 98663

LEAR SIEGLER, BOGEN DIVISION
P. O. Box 500
Paramus, NJ 07652

ARTHUR D. LITTLE INC.
25 Acord Park
Cambridge, Mass. 02140

LIVERMORE
2050 Research Drive
Livermore, California
94550

Yes

LOCATOR TEL-COM
South Country Industrial Park
Drawer 10609
Saint Louis, MO 63129

MARTIN MARIETTA
P.O. Box 5837
Orlando, Florida 32805

Yes

MEMCOR DIV., E-SYSTEMS INC.
41 E. Park Drive.
Huntington IND 46750

Yes

MICROFLECT CO. INC.
3575 25th Street S.E.
Salem, OR 97302

Yes

MICROWAVE ASSOCIATES INC.
Land Mobile Communications Division
850 A. Steward Dr.
Sunnyvale, CA 94086

Yes

MICROWAVE ASSOCIATES INTL. INC.
P. O. Box 22
Waterloo, Ontario N2J 3Z5

MIECO, DIVISION OF POLARAD ELECTRONICS CORP.
109 Beaver Ct.
Cockeysville, MD 21030

Yes

MILES ASSOCIATES DIV. - MILES ADR PRODUCTS LTD.
240 Birmingham St.
Toronto, Ontario M8V 2C8

MISCOE DATA COMMUNICATION EQPT. SERVICES LTD.
6358 Viscount Rd.
Mississauga, Ontario L4V 1H3

MOBIL ELECTRONICS INC.
Box 1132
Anderson, IND 46015

MONITRONICS
60 Nugget Ave., Unit 10
Agincourt, Ontario
M1S 3A9

Yes

MOSELEY ASSOCIATES INC.
111 Castilian Dr.
Goleta, CA 93017

MOTOROLA, COMMUNICATIONS DIVISION
1301 E. Algonquin Rd.
Schaumburg, ILL 60172

Yes

MUIRHEAD INC.
1101 Bristol Rd.
Mountainside, NJ 07092

Yes

MULTITONE ELECTRONIC INC.
One Cornell Pkwy.
Springfield, NJ 07081

Yes

MULTITONE ELECTRONICS LTD.
90 Oakdale Rd.
Downsview, Ont. M3N 1V9

Yes

MOSCAN INTERNATIONAL LTD.
85 South Service Rd.
Plainview, NY 11803

NEC AMERICA INC.
Mobile Radio Division
4940 West 147th Street
Hawthorne, CA 90250

Yes

NYTEK ELECTRONICS
800 San Antonio Rd.
Palo Alto, CA 94306

OMEGA-T SYSTEMS INC.
Richardson, TX

OSITIS ELECTRONICS
Box 426
Orinda, CA 94563

PACE LANDMASTER
24049 S. Frampton Avenue
Harbor City, CA 90710

PATHCOM, INC.
24049 S. Frampton Avenue
Harbour City, CA 90710

Yes

PAYETTE RADIO LTD.
730 St. Jacques
Montreal, Quebec H3C 1G2

Yes

PHELPS DODGE COMMUNICATIONS CO.
Route 79
Marlboro, NJ 07746

Yes

PHILLIPS
6 Leswyn Road
Toronto, Ontario M6A 1K2

PLECTRON
Overton, Nebraska 68863

Yes

PIONEER MEDICAL DIVISION
AQUONICS, INC.
10 Rockdale, St.
Worcester, MA 01606

POSITRON INDUSTRIES INC.
5473 Royalmount Avenue
Montreal, Quebec H4P 1J3

Yes

PYE ELECTRONICS LTD.
8580 Darnley Rd.
Montreal, Quebec H4T 1M6

Yes

QUINTRON CORPORATION
13 B Commercial Drive
Quincy, ILL 62301

Yes

RCA GOVERNMENT & COMMERCIAL SYSTEMS
Marne Hwy & Borton Landing Rd.
Moorestown, NJ 08057

RCA LTD.
21001 North Service Rd.
Ste. Anne de Bellevue, Quebec

Yes

RACAL (CANADA) LTD.
1806 Woodward Dr.
Ottawa, Ontario K2C 0P7

Yes

REACH ELECTRONICS INC.
Box 308A
Lexington, Nebraska 68850

Yes

REGENCY ELECTRONICS INC.
7707 Records St.
Indianapolis, IND 46226

REPCO, INC.
1940 Lockwood Way
Orlando, FL 32804

Yes

RESDEL
90D South Fair Oaks Avenue
Pasadena, CA 91105

RF COMMUNICATIONS DIV.
Harris Intertype Corp.
1680 University Avenue
Rochester, NY

RONTEL
465 St. Jean
Suite 702
Montreal, Quebec
H2Y 2R6

Yes

RYDAX CO.
76 Belvedere
San Rafael, CA 94902

Yes

SABER LABORATORIES INC.
1150 Bryant St.
San Francisco, CA 94103

SANDERS ASSOC. INC.
Bedford Division
24 Simon Street
Nashua, NH 03060

SBE INC.
220 Airport Blvd.
Watsonville, CA 95076

Yes

SCIENTIFIC RADIO SYSTEMS INC.
367 Orchard St.
Rochester, NY 14606

SEARCH & SUPPLY - PRAIRIE AGENCIES (CANADA) LTD.
206 - 138 Portage Avenue
Winnipeg, Manitoba R3C 0A1

SECODE
908 Dragon Street
Dallas, TX 75207

Yes

SERVISONIC LTD.
820 Eglinton Avenue E
Toronto, Ontario M4G 2L1

Yes

SIGNAL DIVISION
FEDERAL SIGNAL CORPORATION
136th & Western Avenue
Blue Island, Illinois 60406

A.C. SIMMONDS AND SONS LTD.
285 Yorkland Blvd.
Willowdale, Ontario M2J 1S8

Yes

SIMPSON ELECTRONICS INC.
2295 NW 14th Street
Miami, FL 33125

SINCLAIR RADIO LABORATORIES LTD.
122 Rayette Rd.
Concord, Ontario L4K 1G6

Yes

SINGER INSTRUMENTATION
Los Angeles Operation
5340 Alla Rd.
Los Angeles, CA 90066

SKYTRONICS
227 Oregon Street
El Segundo, CA 90245

Yes

SOLID-STATE COMMUNICATIONS INC.
21060 Corsair Blvd.
Hayward, CA 94545

SONAR RADIO CORPORATION
73 Wartman Avenue
Brooklyn, NY 11207

SPILSBURY & TINDALL LTD.
120 E. Cordova St.
Vancouver, British Columbia V6A 1L1

Yes

STANDARD COMMUNICATIONS
P. O. Box 92151
Los Angeles, CA 90009

STONER COMMUNICATIONS CORP.
108 W. Victoria
Carson, CA 90746

SUNAIR ELECTRONICS INC.
3101 SW 3rd Avenue
Ft. Lauderdale, FLA 33315

Yes

SUPERIOR ELECTRONICS INC.
1330 Trans Canada Hwy S.

Yes

SYMETRICS COMMUNICATIONS INC.
1227 S. Patrick Dr.
Satellite Beach, FLA 32937

SYT CORPORATION
2208 Texas
El Paso, TX 79901

Yes

TECHNEX INTERNATIONAL LTD.
2600 Brabant Marineau
St. Laurent, Quebec H4S 1L1

Yes

TECHNICAL COMMUNICATIONS CORP.
56 Winthrop St.
P. O. Box St. 1
Concord, MA 01742

TELECOMM COMMUNICATIONS EQPT.
P. O. Box 3232
Margate, NJ 08402

TELE-RADIO SYSTEMS LTD.
301 Supertest Rd.
Toronto, Ontario

Yes

THERMO-ENERGY CONVERTERS CORP.
607 Kent Avenue
Brooklyn, NY 11217

THOMSON CSF INC.
BP 9608/75362
Paris, CEDEX 08
FRANCE

Yes

THOMSON CSF INC.
75 Rockefeller Plaza
New York, NY 10019

TMC (CANADA) LTD.
R. R. 5
Ottawa, Ontario

TOPPING ELECTRONICS LTD.
1320 Ellesmere
Scarborough, Ontario M1P 2X9

TOYO
No. 9-17 3- Chome
Nishi-Gotanda
Shinaguna-Ku
Tokyo 141, Japan

Yes

TPL COMMUNICATIONS
1324 W. 135th
Gardena, CA 90247

Yes

TRANSCOM ELECTRONICS INC.
Box 9
La Mesa, CA 92041

TRW SYSTEMS GROUP
Box CR1 Space Park
Redondo Beach, CA 90278

U. S. COMMUNICATIONS CORP.
1819 S. Central #46
Kent, WA 98031

Yes

VEGA, DIVISION OF CETEC CORP.
9900 Baldwin Pl.
El Monte, CA 91731

Yes

VHF ENGINEERING
320 Water St.
Binghamton, NY 13901

Yes

WABCO-UNION SWITCH AND SIGNAL DIVISION
Braddock Avenue
Swissvale, PA 15218

Yes

WATKINS-JOHNSON COMPANY
700 Quince Orchard Road
Gaithersbury, MD 20760

WESTERN RADIO SERVICES, INC.
1165 Harrison St.
Seattle, WA 98109

K. W. WILK ASSOCIATES LTD.
34 Capital Dr.
Ottawa, Ontario

WILSON ELECTRONICS CORP.
4288 South Polaris Avenue
Las Vegas, NEVADA 89103

Yes

APPENDIX B

SYSTEMS DESIGN CONSIDERATIONS

FOR MOBILE RADIO SYSTEMS

B.1

INTRODUCTION

This appendix presents a detailed discussion of the following:

- design considerations
- propagation loss model
- minimum usable signal required for acceptable communications
- system design trade-offs

B.2

DESIGN CONSIDERATIONS

In this section, the basic design considerations for a rural mobile-radio communications system are considered. Among the factors that must be considered in the design of a communications system are:

- quality of service, i.e. probability of communication
- required range and antenna heights
- environmental limitations such as terrain, noise, etc.
- operational and cost constraints
- regulatory constraints, including available frequencies, and maximum permissible transmitter power

A measure of the performance of a mobile communications system is the "performance margin", defined as:

$$PM \text{ (dB)} = P_{RX} + P_{MUS} \text{ (dBm)}$$

(1)

where P_{RX} is the received power (in dBm) and P_{MUS} is the receiver's minimum usable signal power (also in dBm). The minimum usable signal power is the signal power for which good communications can be obtained with only slight degradation in quality due to environmental and equipment noise. Typical minimum usable signal levels for various noise environments will be discussed later.

When the performance margin is zero dB, 50% coverage of locations on a circle of a given radius is possible, i.e. the median received power at all points on the circle is at least equal to the minimum usable signal. The performance margin is often related to the probability of communications over a given area (Reference B/1). The probability of communications can be considered in two ways. First, it represents, for an arbitrary path, the probability of communicating over a specified distance. Secondly, it may be used to represent the fraction of sites on the circle with which communications is possible. A 50% probability of communications corresponds to a performance margin of 0 dB.

The received signal power is dependant on a number of factors, including frequency, antenna heights, separation distance and terrain. These are time independent for a given path in general. Several time dependent factors also affect the received power, including the amount of foliage along the path, the moisture content of the ground, temperature, humidity, and wind velocity (these affect the refractive index along the path). The effect of terrain is usually modelled in systems applications by specifying the average hill height for typical terrain and applying a correction factor to the calculated propagation loss. The effect of the time dependent factors, and of time independent factors such as surface roughness and local environment of the antennas, are difficult to account for in most circumstances. It is possible however to model

the path loss (and hence the performance margin) as a random variable and estimate the variance due to these effects. In most applications, the propagation loss is assumed to be a normally distributed random variable (Reference B/1, Chapter 2). As such, it can be characterized by the mean and the standard deviation for a given type of terrain. A deviation of 9 dB is typical for the 30 to 300 MHz range (Reference B/1, Chapter 2) although it does vary slightly with frequency. The probability of communications can be related to the performance margin using Figure B/1. It should be noted that between 30 to 500 MHz, the variation in median signal strength throughout gently rolling terrain due to terrain effects is far in excess of the time dependent fading between two fixed stations separated by the same distance (Reference B/4). As a result, mobile-radio equipment is usually designed for vehicular operation based on signal strength variation due to terrain, rather than for time fading due to tropospheric refractive index variations.

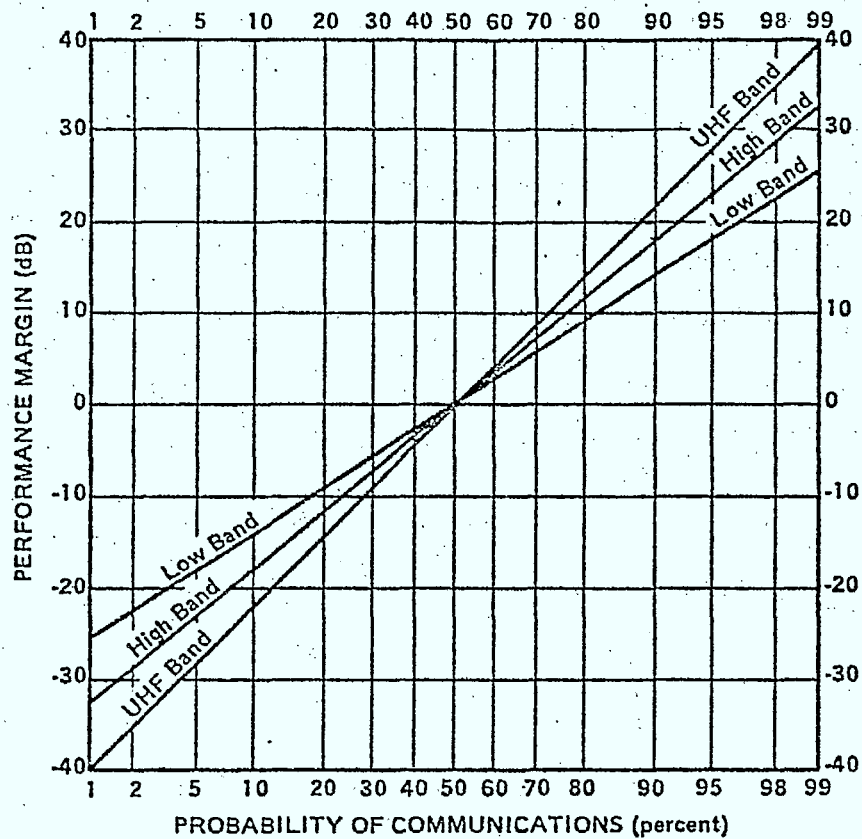
From Figure B/1, it can be seen that 90% and 10% probabilities of communication will typically occur when the received signal power is approximately 15 to 22 dB above or below the minimum usable signal level respectively. The 90% level represents a high quality, reliable signal while the 10% level represents a system with an unacceptably poor performance. The 10% level generally occurs in fringe areas of a mobile system's coverage area, and should be of concern in interference analysis, rather than in a link performance analysis.

The mean received signal, P_{RX} , is a function of the transmitter power, P_T the gains of the transmitting and receiving antennas (G_T and G_R respectively), and the basic transmission loss, L , i.e.:

$$P_{RX} \text{ (dBm)} = P_T \text{ (dBm)} + G_T \text{ (dB)} + G_R \text{ (dB)} - L \text{ (dB)} \quad (2)$$

Typical transmitter powers can range from 30 to 56 dBm for base stations, depending on the desired coverage area and system parameters, while mobile transmitter powers would not likely exceed 50 dBm (100 watts). Antennas used in most mobile applications are generally designed to radiate and receive uniformly from all horizontal directions surrounding the antenna, and are thus relatively low gain antennas, i.e., less than 10 dB relative to isotropic. Vertically polarized antennas are usually used. For mobile transceivers, directional antennas are not feasible in general, limiting their useful gain to approximately 2.5 dB. For base stations, directive antennas are feasible. In this case, gains up to 15 dB can be obtained (Reference B/1) using multi-element yagi or rhombic antennas, but only by sacrificing omnidirectional coverage. This may be desirable however for some users, particularly when long distance (30 - 50 mile) paths are involved.

Basically, the transmission loss L , is dependent on the antenna heights, separation distance, frequency, and terrain (i.e. average hill height). The model chosen, (the Egli model, Reference B/4) is particularly appropriate to an analysis of this type since it was developed for applications involving gently varying irregular terrain, such as found in Western Canada. Although other models exist, none seem as appropriate as the Egli model for estimating the transmission loss in rural areas.



(From Reference 8/1)

LOW BAND = 30 MHz

HIGH BAND = 150 MHz

UHF BAND = 450 MHz

Figure B.1 Probability of Communications versus performance margin, for several frequencies for gently rolling terrain.

Equations 1 and 2 can be used to estimate the coverage area of a mobile-radio communications system for a specified probability of communications. In this study, the coverage area is taken to be the area where the probability of communications is 50% or better. This is the area where the performance margin (PM) is 0 db or better. The basic approach is to determine the minimum usable signal, P_{MUS} for the receiver, assume a performance margin of 0 db, and calculate the median transmission loss, L , for which these conditions hold, i.e.,

$$L = P_T + G_T + G_R - P_{MUS}, \text{ dB} \quad (3)$$

The distance at which this loss occurs can be calculated (see Section B.3). Although this procedure can be applied on base-to-mobile, mobile-to-base, mobile-to-mobile, and base-to-base links for arbitrary transmitter power, receiver sensitivities, antenna heights and gains, it is desirable to make the following assumptions:

- The performance margin and median distance should be maximized for base-mobile links, and be equal for the talk-out and talk-back directions,
- Although it is feasible to use transmitters with different powers for the base and mobile stations, many existing systems use the same transmitter output power for both. This assumption will be adopted in this report,
- The median distance between mobile stations for which 0 db performance margin can be maintained should be maximized, subject to the above constraints,

- The median distance between base stations, over which interference is possible, should be minimized, subject to the above constraints.

These considerations are discussed in more detail in subsequent sections.

B.3

PROPAGATION LOSS MODEL

Various propagation modes may be encountered on paths between the receivers and transmitters in a mobile communications system depending on a number of factors, including frequency, separation distance, terrain, polarization, etc. In the prime coverage area of a mobile transmitter or receiver, the main line-of-sight propagation mode will be via a ground wave consisting of three components (Reference B/1, B/2):

- Surface Wave - usually only important below 30 MHz. The vertically polarized surface wave is the most significant mode. For this mode to apply, antenna heights must be small compared to the wavelength since the surface wave is limited to heights of about one wavelength over ground, and slightly higher over seawater,
- Direct Wave - propagates directly from the transmitter to the receiver,
- Ground-Reflected Wave - this wave reflects off the earth's surface between the transmitter and receiver.

The direct wave and ground-reflected wave predominate above 30 MHz. This propagation mode is very dependent on surface conditions (i.e. roughness, conductivity) and is usually treated empirically in systems calculations. The Egli model, to be discussed later, is one such empirical model, and can be used to obtain an overall estimate of the propagation loss without the need for actual terrain profiles. For line-of-site conditions over smooth flat terrain, the propagation loss between a base station and mobile unit may be estimated using the theoretical "plane earth" (References B/1, B/2, B/3).

At distances just beyond the radio horizon, the propagation mode becomes one of ground-wave diffraction. For frequencies in the 20 to 500 MHz range, this mode may exist up to several hundred miles from the transmitter. The diffraction losses increase quite rapidly with increasing distance until tropo-scatter and ionospheric scattering become the significant mode. Since large losses are associated with scatter propagation, this mode cannot be reliably used as a propagation mode for mobile-communications links, but can be a source of unwanted interference from distant transmitters.

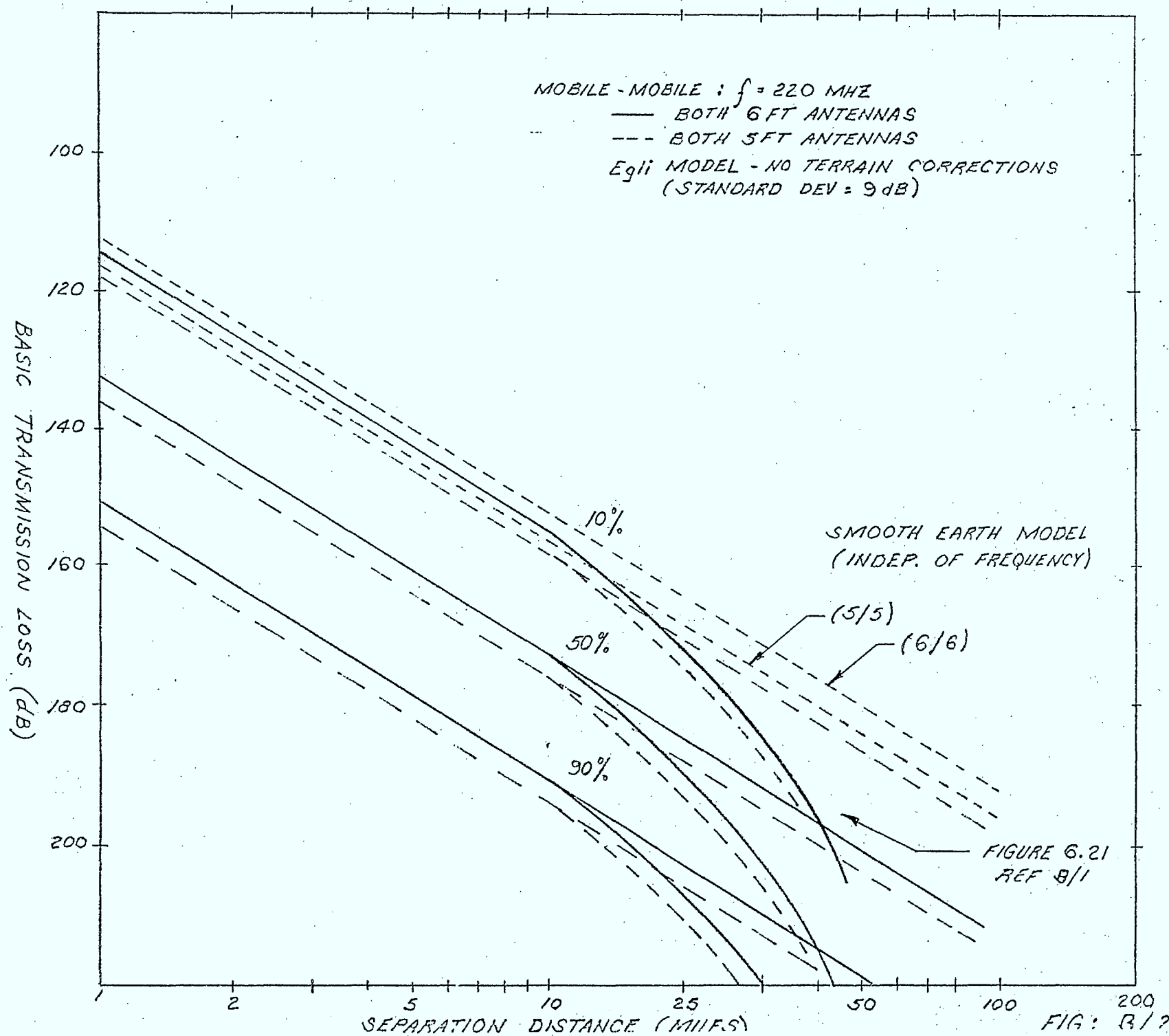
As mentioned previously, the Egli model (Reference B/4) is an empirical model used to estimate the propagation loss in the "reflection" region where the ground-wave propagation mode dominates. The model is based on measured data using ground-based antennas with frequencies in the range 40 to 400 MHz and separation distances less than 40 miles. The transmission loss given by this model is:

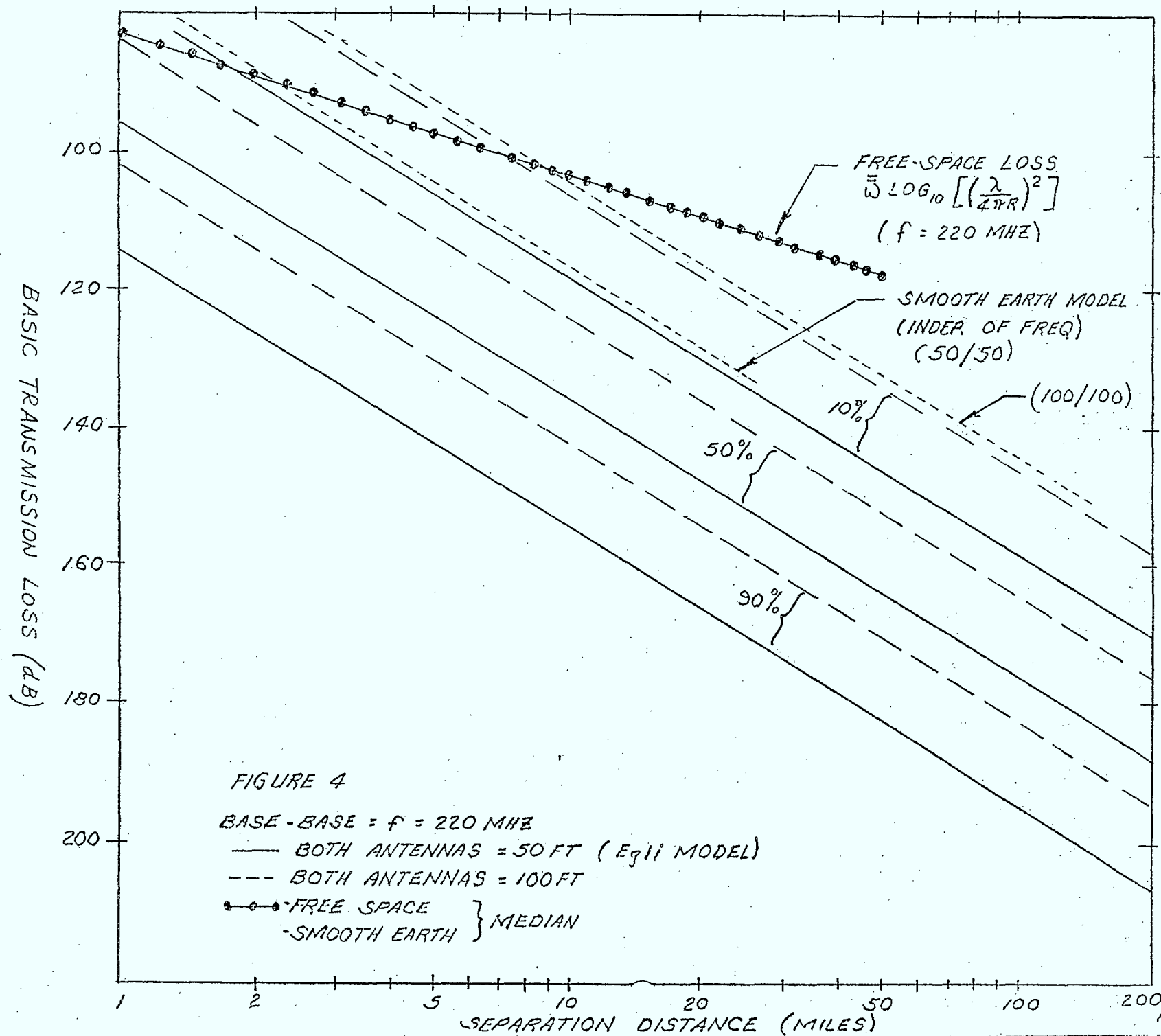
$$L = 117 + 20 \log_{10} f_{\text{MHz}} - 20 \log_{10} h_T h_R + 40 \log_{10} d_{\text{mi}}, \text{ dB} \quad (4)$$

where f_{MHz} is the frequency in MHz, h_T is the height of the transmitting antenna (in feet), h_R is the height of the RX antenna and d_{mi} is the separation distance in miles. This transmission loss is plotted in Figures B/2, B/3, and B/4 for a frequency of 200 MHz, for typical base-mobile, mobile-mobile and base-base paths. Also shown on the figures are the transmission losses corresponding to the 10% and 90% probabilities of communications (based on Figure B/1). The mean "smooth earth" model (Reference B/1, B/3) is also shown. Since the Egli model corresponds to propagation over irregular terrain, the "smooth earth" model predicts lower transmission losses. Since "smooth earth" conditions are rarely met in practice, the Egli model will provide a more realistic estimate of the expected transmission loss over a given path.

It is possible to modify the Egli model slightly to include a factor to allow for terrain. This "terrain correction factor" is shown in Figure B/5, and represents the amount the transmission loss should be adjusted to include the effect of hill height. The terrain correction factor increases with frequency above approximately 100 MHz due to the decreasing wavelength.

The Egli model applies to gently rolling terrain. In areas where deep ridges and cliffs are found, or in the downtown areas of cities, obstruction losses (also called shadow losses) and multipath losses of 20 to 30 dB should be added to the median transmission loss (Reference B/1). These additional losses can be ignored when estimating the performance of mobile-radio system designed for operation in most rural areas of Western Canada.





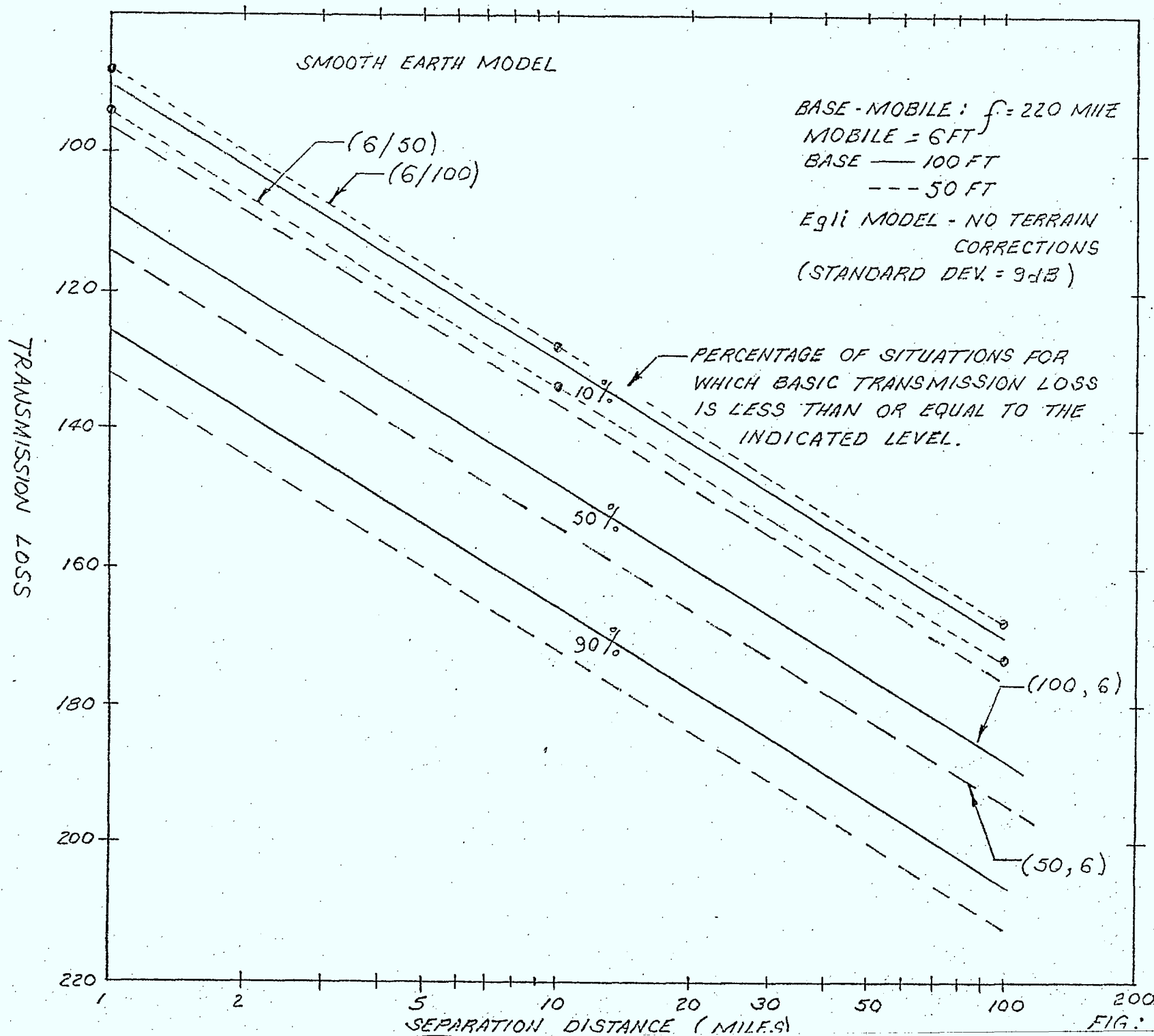
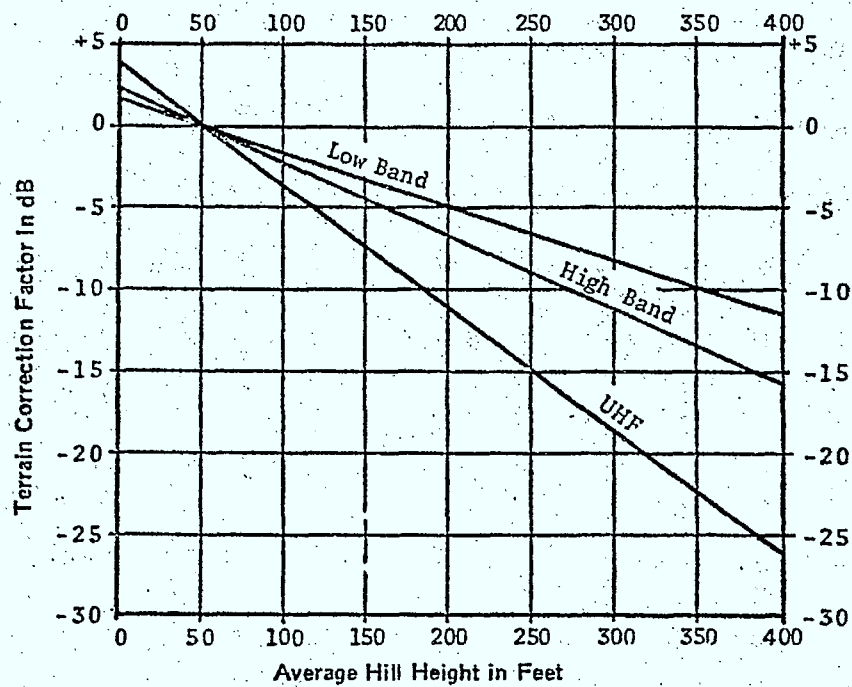


FIG: R/4



(From Reference B/1)

Figure B/5 Terrain Correction Factor

B.4

Minimum Usable Signal

The minimum usable signal, P_{MUS} , is the minimum received power that will permit successful operation of the receiver, with only slight degradation in communications due to noise. This condition occurs when the received signal power is at least 6 to 12 dB higher than the typical ambient noise (due to receiving equipment, atmospheric and extra terrestrial noise sources, and man-made noise). At 12 dB SINAD (signal-to-noise and distortion), good communications are possible, with only slight degradation in quality due to environmental noise. Trained operators working with a limited vocabulary can communicate at 6 dB SINAD (Reference B/1) but the quality is poor and some repetition of messages is required.

The major sources of electromagnetic noise in the 30 to 500 MHz region are:

- man-made noise, caused by spark-producing electrical equipment (i.e., motors, generators, automotive ignition systems, etc.) and power transmission lines.
- man-made EMI sources, such as unintentional out-of-band emissions from radars and telecommunications transmitters, as well as in-band sources such as other mobile-radio transmitters within a receiver's coverage area.
- naturally occurring noise sources such as cosmic noise, solar radio noise, and atmospheric noise.
- inherent receiver noise (i.e., as characterized by the receiver sensitivity).

Typical noise levels are shown in Figure B/6.

For urban and suburban areas, man-made noise is the most severe of the noise sources affecting mobile-radio system performance in the 30 to 400 MHz range. It is also the most difficult to accurately predict and so typical levels expected in urban, suburban, and rural areas are usually used. Representative values, from Reference B/2 are shown in Table B/1 and Figure B/7.

The noise power accepted by the receiver is proportional to the mean antenna aperture area and the bandwidth, i.e.,

$$\begin{aligned} N_{MM} \text{ (dBm)} &= \rho_{MM} + 10 \log \frac{\lambda^2}{4\pi} + 10 \log B \\ &= \rho_{MM} + 38.55 - 20 \log f_{\text{MHz}} + 10 \log B, \text{ dBm} \end{aligned} \quad (5)$$

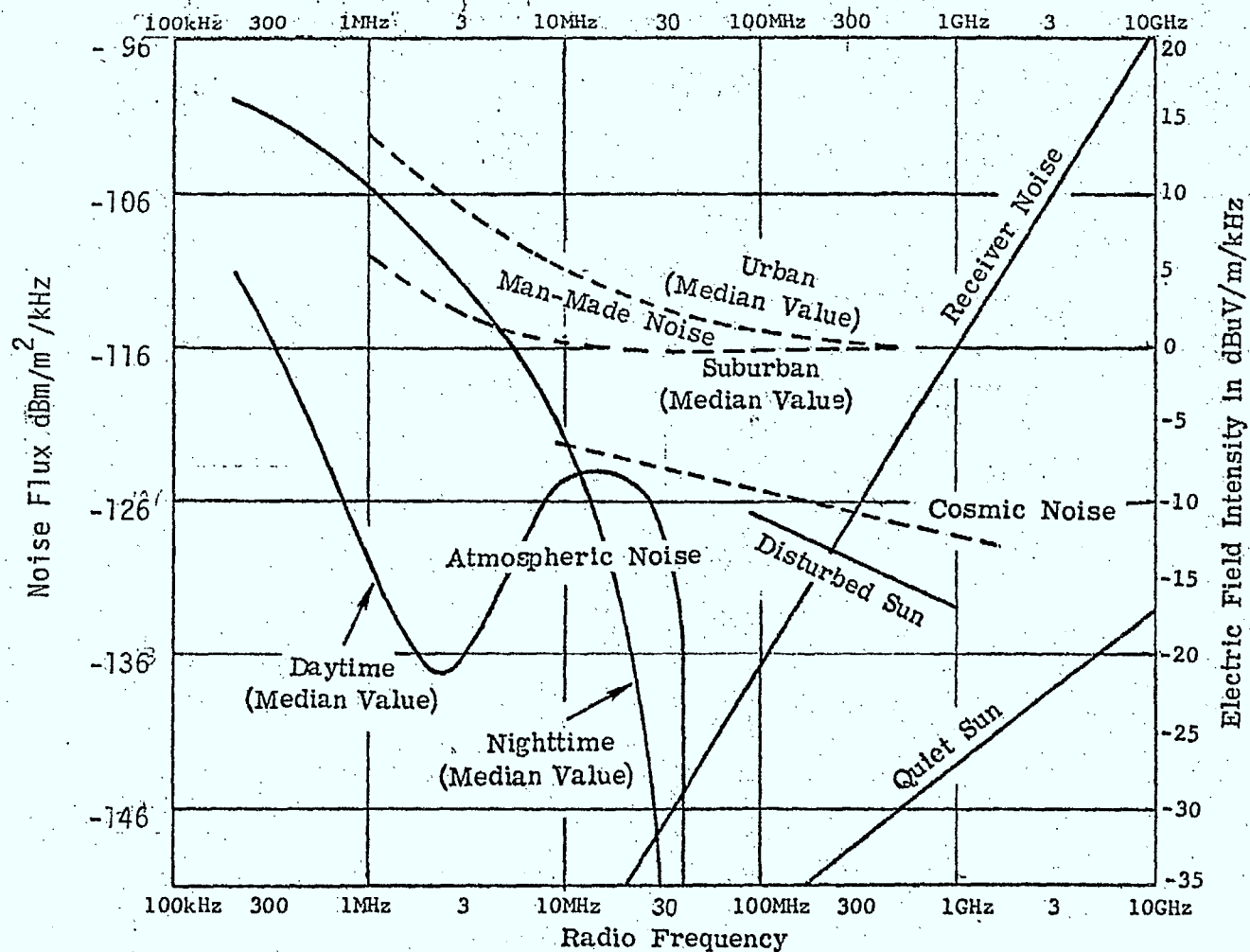
where ρ_{MM} is the flux level of the manmade noise in dBm/m²/kHz, B is the bandwidth in kHz, and f is the frequency in MHz. Although the power accepted by the antenna depends on the distribution of noise sources around the antenna, and hence the antenna pattern, equation 5 will be used for all low gain antennas in this report since actual noise distributions are not known. If the noise brightness were known, the power accepted by the antenna would depend on the antenna gain, i.e.:

$$P = B \int_{4\pi} F(\Omega) \frac{G_R(\Omega) \lambda^2}{4\pi} d\Omega,$$

where Ω is the solid angle and $F(\Omega)$ is the brightness. The electric field intensity, ρ , is given by

$$\rho = \int_{4\pi} F(\Omega) d\Omega$$

Thus since the electric field intensity is proportional to the



(From Reference B/2)

Figure B/6 Electromagnetic Noise Sources

mean brightness of the noise sources surrounding the antenna, the mean antenna aperture area should be used in calculating the power since the aperture area is given by

$$A_p = \frac{G_{R\lambda}^2}{4\pi}$$

and the mean gain of any antenna is 1, equation 5 follows.

Sky-background, or cosmic noise also contributes to the received noise power. This noise is generated by both discrete and distributed sources scattered about the galaxy in an approximately continuous distribution, with some concentration near the galactic center. This results in a diurnal variation in the level of this noise, as determined by the receiving antenna orientation and the position of the galactic center. Typical levels of the received cosmic noise level are shown in Table B/1. If the flux level, p_{cos} , is given in $\text{dBm/m}^2/\text{kHz}$, then the received noise power due to cosmic noise is given by

$$N_{\text{COS}} (\text{dBm}) = p_{\text{COS}} + 38.55 - 20 \log f_{\text{MHz}} + 10 \log B, \text{ dBm} \quad (6)$$

In the 30 to 500 MHz range, quiet sun (i.e., low sunspot activity) radio noise is below the cosmic background noise level and can be neglected. During periods of high sunspot activity, solar flare noise can be important in this frequency range. The most severe noise, associated with Type-IV flares (Reference B/1), is broadband noise and may endure for several days. The power density of this noise may reach $-122 \text{ dBm/m}^2/\text{kHz}$, exceeding sky-background noise. Since it is a transitory noise source, it will not be included in calculating the minimum usable signal level for the mobile-radio systems considered in this appendix. It should be remembered though, that this noise source could compromise system performance in electrically quiet

rural areas during periods of high solar activity, since it can exceed the other noise levels for which the radio system is designed to operate.

Inherent receiver noise is usually specified by the "receiver sensitivity", S . The sensitivity represents the signal level that is required in the absence of external noise to produce a 12 dB signal-to-noise and distortion (SINAD) at the receiver input. The noise level in dBm corresponding to the sensitivity (in μV at 12 dB SINAD), is given by:

$$N_{RX}(\text{dBm}) = 20 \log S - 119.0, \text{ dBm.} \quad (7)$$

Typical receiver sensitivities vary from 0.2 to 2.5 μV for both base and mobile receivers depending on receiver quality. A value of 0.30 μV , typical of current 150 MHz equipment, is easily obtainable for mobile equipment in the frequency range considered in this study. As a result, inherent receiver noise will rarely be the limiting factor in a mobile-radio communications system, since it is usually below cosmic and manmade noise.

The minimum usable signal, P_{MUS} , can now be determined by adding the noise powers due to cosmic, manmade, and receiver noise sources, and increasing the result by 12 dB (i.e., to obtain a 12 dB SINAD in the noise environment), i.e.:

$$P_{MUS}(\text{dBm}) = 10 \log \left\{ N_{RX}(\text{mW}) + N_{COS}(\text{mW}) + N_{MM}(\text{mW}) \right\} + 12, \text{ dBm.} \quad (8)$$

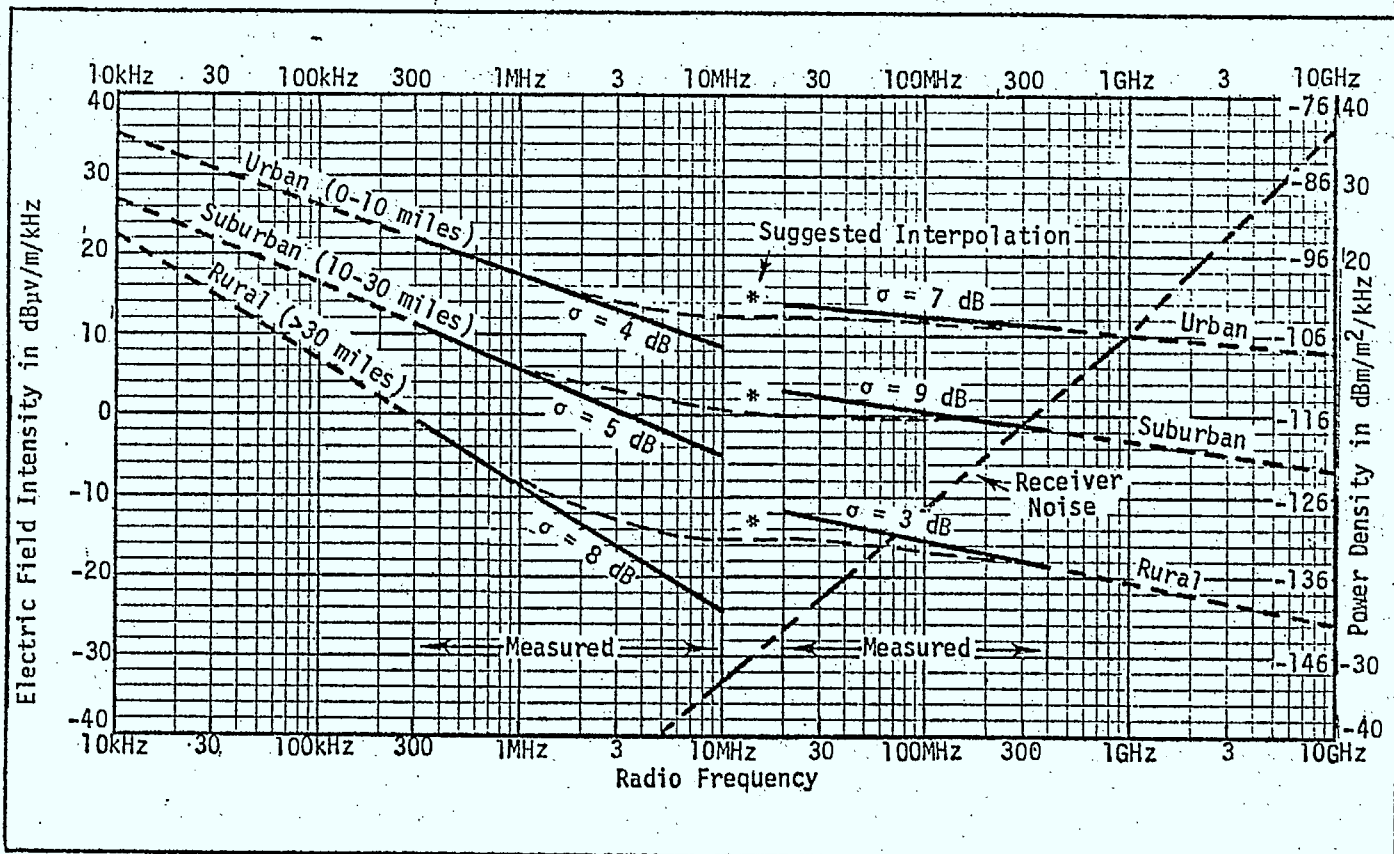
Typical values are shown in Table B/1 for receiver sensitivities of 0.3 and 1.0 μV , for a 10 kHz receiver bandwidth.

TABLE B/1 MINIMUM USABLE SIGNAL (dBm)

FREQ (MHz)	RX sensitivity 0.3 μ V 12dB SINAD NOISE = -129.4 dBm			RX sensitivity = 1 μ V at 12dB SINAD NOISE = -118.0 dBm		
	RURAL	SUBURBAN	URBAN	RURAL	SUBURBAN	URBAN
30	-91.53	-81.7	-73.9	-91.4	-81.6	-73.9
150	-106.6	-98.4	-88.9	-103.9	-97.88	-88.8
220	-110.5	-102.6	-93.2	-105.7	-101.4	-93.1
300	-113.3	-106.1	-95.9	-106.4	-103.7	-95.6
450	-115.5	-110.8	-101.4	-106.8	-105.8	-100.4

NOISE FLUX (dBmW/m²/kHz)

FREQ (MHz)	COSMIC NOISE	MAN-MADE		
		RURAL	SUBURBAN	URBAN
30	-124	-128	-113	-105
150	-125	-131	-116	-106
220	-126	-133	-117	-107
300	-127	-135	-118	-107
450	-128	-137	-120	-109



Models of Median Incidental Man-Made Noise Based on Lossless Omni-directional Antenna Near Surface

(From Reference B/2)

Figure B/7 Models of Median Incidental Man-made Noise Based on Lossless Omni-directional Antenna Near Surface

B.5

System Design Tradeoffs

Using the basic design equations (1, 2, 3) and the information presented in the preceding sections, it is possible to determine some of the tradeoffs available to designers of mobile-radio systems used in the rural areas of Western Canada. A baseline system will first be considered, that is representative of the technology available for a moderate-to-low cost communications system.

<u>BASELINE SYSTEM PARAMETERS</u>			
Frequency	=	220 MHz	
Bandwidth	=	10 Hz	
		<u>BASE</u>	<u>MOBILE</u>
Antenna Height		100 ft.	8 ft.
Antenna Gain		6 dB	2.5 dB
Sensitivity		.3 μ V	.3 μ V
P _{MUS}	RURAL	-110.5	-110.5 dBm
	SUBURBAN	-102.6	-102.6 dBm
	URBAN	-93.2	-93.2 dBm
Transmitter Power (watts)		1 to 100	same as base

The performance of this communications system will first be determined in terms of median coverage distances for base-mobile and mobile-to-base links, for various transmitter power levels. Assuming terrain with average hill heights of 50 ft., the median transmission loss is given by:

$$L = 117 + 20 \log f_{\text{MHz}} - 20 \log h_B h_M + 40 \log d, \quad \text{dB} \quad (9)$$

where h_B and h_M are the base and mobile antenna heights in feet respectively, and d is the median base mobile distance in miles.

If average hill heights other than 50 ft. are of interest, equation 9 (and 12) should be modified by the inclusion of the appropriate terrain factor from Figure B/5. For hill heights of 0 and 100 ft., this modifies the transmission loss given by eq. 10 by ± 2.7 dB, and can influence the median distance (equation 12) by $\sim 16\%$ at 220 MHz. For lower frequencies, the effect of terrain (i.e., average hill height) is smaller (i.e., ± 2 dB in loss, or 12% in distance at 30 MHz), while at 450 MHz, the loss can vary by ± 4 dB or 25% in distance.

From equation 3, the maximum loss for which 0dB performance margin can be maintained over the distance d , is

$$L = P_B + G_B + G_M - P_{MUS,M} \quad \text{dB} \quad (10)$$

for base-to-mobile paths, where P_B is the base transmitter power (dBm), G_B is the base station antenna gain (dB), G_M is the mobile antenna gain (dB), and $P_{MUS,M}$ is the mobile receiver's minimum usable signal in dBm. For mobile-to-base paths, the maximum loss is

$$L = P_M + G_B + G_M - P_{MUS,B} \quad \text{dB} \quad (11)$$

In general, this will be different than for base-to-mobile paths if the noise environment of the base differs from that of the mobile. Assuming that $P_{MUS,M} = P_{MUS,B}$, and $P_M = P_B$, then the same performance margin is obtained on the talk-out and talk-back directions.

Equating equation 9 and 10 or 9 and 11, and solving for the median base-mobile distance, d , gives:

$$\log d = \frac{1}{40} \left[P_B + G_B + G_M - P_{MUS} + 20 \log h_B h_M - 20 \log f_{\text{MHz}} - 117 \right] \quad (12)$$

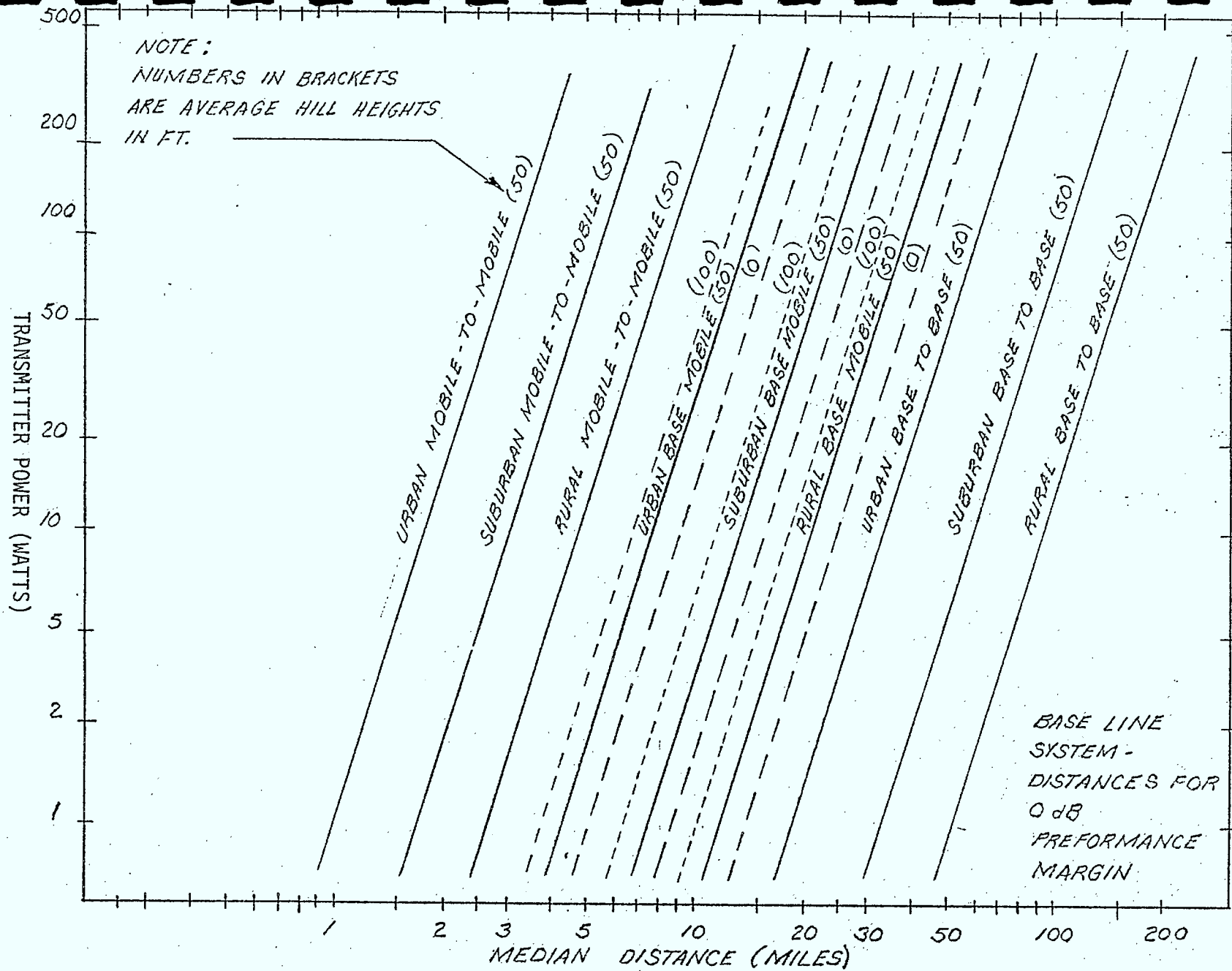
This distance is plotted in Figure B/8 for urban (high noise), suburban, and rural (low noise) receiver environments. This is the distance at which 50% probability of communication between base-mobile stations occurs. From Figure B/1 the path loss change corresponding to 10% and 90% probabilities of communication can be obtained. For a given transmitter power, the distances at which these probabilities occur can be determined, relative to the median distance using the scale factors shown below, since the 4th power of the median distance is proportional to the loss.

FREQUENCY	<u>DISTANCE SCALE FACTOR</u>		
	PROBABILITY OF COMMUNICATIONS		
	10%	50%	90%
30	2.24	1	0.446
150	2.82	1	0.355
220	2.90	1	0.345
300	3.10	1	0.323
450	3.55	1	0.282

These factors are based on an average hill height of 50 feet.

The effect of base station antenna height on the median base-mobile distance is easily seen from equation 12, i.e., the distance is proportional to the square root of the antenna height. In some system designs it may be desirable to trade-off antenna height for gain, since towers generally increase in cost very rapidly with height.

If it is assumed that the same antenna is used for receiving and transmitting, then the median distance over which mobile-to-mobile communications can be maintained, d_m , can be related to the mobile-to-base distance, d , by:



$$\begin{aligned}
 \log d_m - \log d &= \frac{1}{40} \left(P_M + 2G_M - P_{MUS} + 20 \log h_M^2 - 20 \log f_{MHz} - 117 \right) \\
 &\quad - \frac{1}{40} \left(P_B + G_B + G_M - P_{MUS} + 20 \log h_B h_M - 20 \log f_{MHz} - 112 \right) \\
 &= \frac{1}{40} \left[G_M - G_B + 20 \log \left(h_M/h_B \right) \right] \quad (13)
 \end{aligned}$$

assuming $P_M = P_B$. Typical values of (d_m/d) are shown in Table B/2. For base-to-base links, an equation similar to equation (13) can be derived for the median base-to-base distance, d_B , i.e.:

$$\log d_B - \log d = \frac{1}{40} \left[G_B - G_M + 20 \log \left(\frac{h_B}{h_M} \right) \right] \quad (14)$$

The factor d_B/d is also shown in Table B/2, for various base station antenna heights and gains.

The distances ratios shown in Table B/2 apply for the median, 50% (0 dB performance margin) situation. For mobile-to-mobile paths, the range applicable for other probabilities of communication will in general be different than those shown in the table for base-mobile paths, due to larger changes in the transmission loss for the 10 and 90% cases. The factors given in the table for 10% probability can be increased by ~1.5 to estimate the ratio $[d_m(10\%)/d_m(50\%)]$ for 10% probability of communications. For 90% probability, decrease the factor by 0.5.

For base-base paths, it is difficult to estimate the link performance for non-median conditions, since time-fading will predominate. However, the standard deviation of the path loss (or performance margin) will generally be lower than for mobile-base paths.

To estimate the coverage distances at different frequencies, let $d(f)$ be the median base-mobile distance at frequency f , and d_0 be the distance at f_0 . Equation 12 can be used to give:

$$\log \left[\frac{d(f)}{d_0} \right] = \frac{1}{40} \left[P_{\text{MUS}}(f_0) - P_{\text{MUS}}(f) + 20 \log \left(\frac{f_0}{f} \right) \right]. \quad (15)$$

This assumes equal transmitter powers and antenna heights and gains for the two frequencies. Receiver sensitivities and noise levels determine P_{MUS} and in general are different at the two frequencies. Using the minimum usable signal levels from Table B/2, the ratios $d(f)/d_0$ are given in Table B/3 for $f_0=220$ MHz, indicating that the performance of similar systems at different frequencies will be comparable.

TABLE B/2

MOBILE-TO-MOBILE AND BASE-TO-BASE DISTANCE FACTORS

- ASSUMPTIONS:
- $P_{MUS,B} = P_{MUS,M}$
 - $P_B = P_M$
 - $G_M = 2.5 \text{ dB}$
 - $h_M = 8 \text{ ft.}$

BASE HEIGHT (ft.)	BASE GAIN (dB)	dm/d	MEDIAN d_B/d
50	3	.389	2.57
50	6	.327	3.06
50	9	.275	3.63
100	3	.275	3.64
100	6	.231	4.32
100	9	.195	5.14
150	3	.224	4.46
150	6	.189	5.296
150	9	.159	6.295

$$dm/d = \frac{\text{median mobile-mobile distance}}{\text{median base-mobile distance}}$$

$$d_B/d = \frac{\text{median base-base distance}}{\text{median base-mobile distance}}$$

TABLE B/3

RATIO OF MEDIAN BASE MOBILE DISTANCE AT DIFFERENT FREQUENCIESRECEIVER SENSITIVITY = $0.3\mu\text{V}$

FREQUENCY	RURAL	SUBURBAN	URBAN
30	.908	.81	.89
150	.967	.95	.95
220	1	1	1
300	1.006	1.05	1.0
450	.932	1.12	1.12

RECEIVER SENSITIVITY = $1\mu\text{V}$

FREQUENCY	RURAL	SUBURBAN	URBAN
30	1.19	.87	.897
150	1.09	.99	.95
220	1	1	1
300	.89	.978	.989
450	.74	.90	1.064

Assumptions: . Same transmitter power at all frequencies

. Same antenna gains and heights at all frequencies

REFERENCES

- B/1 "Mobile Communications", W.G. Duff Publ. Don White Consultants Inc., 1965.
- B/2 "Electromagnetic Interference and Compatibility", Vol. 5, W.G. Duff and D.R. White, Publ. Don White Consultants, Inc., 1972.
- B/3 K. Bullington, "Radio Propagation at Frequencies Above 30 MHz", Proc. IRE, Vol. 35, pp. 1122-1136, Oct. 1947.
- B/4 J.J. Egli, "Radio Propagation Above 40 MHz Over Irregular Terrain", Proc. IRE, Vol. 45, Oct. 1957.

QUEEN P 92 .C2 B45 1978
Bens, A. R.
A study of rural mobile radi



84612

BENS, A.R.
-- A STUDY OF RURAL
MOBILE RADIOS IN THE
PRAIRIE PROVINCES.

P
:92
C2
B45

Date Due

NOV 12 1979

MAR 4 1980

MAR 25 1980

APR 29 1980

JAN - 3 1992

JUN 23 1992

