A Feasibility Study of Rural Radio Communications

Study performed for
Rural Communications Program Branch
Department of Communications
Government of Canada

by Comdat Telecommunications Inc.
formerly L. Lee Associates
Ottawa Canada.

March 1979

Volume 1

Executive Summary

Volume 1	Executive Summary	Management and executive summary volume containing an introduction to the feasibility study, the terms of reference of the contract, as well as an overall summary of the highlights and major recommendations of the project.
Volume 2	Existing Services and Available Alternatives	This volume contains a discussion on the use and value of existing radio services in Canada and the United States, as well as an assessment of available alternatives. In addition to a section of conclusions and recommendations, Volume 2 contains appendices on suppliers and products, related study results as well as present spectrum use and rural considerations.
Volume 3	A High Technology Solution	This final volume of the feasibility study proposes a high technology solution to the communication needs of rural Canadians. The volume examines a new approach to rural communications, and develops a blueprint as well as spectrum needs and alternatives.

1.0 Terms of Reference

1.1 Authorization and Working Relationships

The study was performed at the request of the Rural Communications Program Group (RCPG) of the Department of Communications, and authorized by contractual agreement with the Science Procurement Branch of Supply and Services Canada. The scientific and technological content of this work is the responsibility of Mr. A.T. Schindler of the RCPG of the Department of Communications.

The study is an integral part of the overall rural communications program which has been a team effort with close interaction between its members and groups. The consultant has worked closely with the team members throughout the period of the contract, and acknowledges with thanks the considerable benefit received through their generous cooperation.

Other assistance of considerable value in the carrying out of the work of this study was received from various branches within the DOC, particularly the Spectrum Engineering, National Policy, and Radio Regulations groups. We also acknowledge the valuable interaction and assistance received from numerous personnel in the manufacturing and service industries.

During the study, discussions were held on the subject of radio services in rural areas with technical and marketing people in all the major telephone companies across Canada. There were also informal discussions with Canadian Telecommunications Carriers Association and TransCanada Telephone System personnel as well as a formal presentation to the technical committee of the CTCA in September 1978.

1.2 Purpose of Feasibility Study

The purpose of the study as outlined in the statement of work, was to examine the "Feasibility of Radio Facilities in Rural Parts of Canada" or more specifically:

a) To undertake general studies related to the application of radio technologies to rural communications.

b) To devise and coordinate a plan for feasibility for selected areas.

c) To organize a pilot project at a selected location to demonstrate feasibility and acceptability by the public.

1.3 Study Approach

It became clear early in the study that none of the existing radio services held the key to significant improvements in rural communications. A review of fixed subscriber and mobile radio services revealed that the various categories were serving the users well within their limitations, but that no amount of modifying or patching would lead to a dramatic improvement in rural communication standards.

On the other hand, it was evident in looking at new developments in radio system technology that much more effective services could be developed with the potential of delivering high standard of communication capability to the rural user at reasonable cost.

It seemed important, therefore, to assess these developments and to evaluate the possibility of applying the most advanced technology available to rural communications needs. Much of the effort of the study, therefore, has been devoted to developing an appreciation for what is happening in technology...reporting on these developments, assessing people's observations and conclusions, and placing this all into the rural communications perspective so that it becomes evident in what direction any future effort should be placed.

We did not, as part of this study, conduct any grassroot surveys. However, many surveys, demand studies, market studies, etc. have been reviewed and assessed for valid content for incorporation in this report. This is not to say that an attempt to address the marketplace to test some of our recommendations is not necessary. However, unless carefully designed, the questionnaire approach can be very unproductive as well as time consuming. Market predictions are unreliable even for existing products. It has been concluded that a sufficient understanding of the situation in rural radio communications has been obtained from existing documentation in order to make valid observations and recommendations.

A study of this kind would not be possible without an understanding of the status and future developments in the use of radio spectrum. Because the allocation of spectrum is complicated by many factors (such as the various lobby groups, regional differences, international agreements, changing needs, and new technologies), one can only hope to have a feel for the direction allocation policies should take. We have,in this feasibility study, attempted to assess this question as objectively as possible, recognizing the need for international cooperation, while at the same time noting our right as Canadians to satisfy our unique requirements.

On reporting on this study, we have attempted to keep the volume of information to a reasonable level, and yet cover all relevant subjects.

This report "A Feasibility Study of Rural Radio Communications", is organized into three volumes.

Volume 1 (this volume), is an Executive Summary presenting an overview of the study's major recommendations and conclusions. Volume 2, "Existing Services and Available Alternatives", contains a discussion as well as the arguments for a new approach to Rural Radio Communications in Canada. Volume 3 "A High Technology Solution", outlines the role high technology will play in bringing the new approaches to a feasible reality.

Each volume is a stand-alone document, with its own set of section numbers, pages, figure and table designations,as well as supporting appendices and illustrations.

A number of useful aids have been provided throughout the reports to assist readers and others who will be reviewing the contents of these three documents. Each volume has, as part of its introductory pages, a comprehensive table of contents and an index of figures and tables, so that virtually any content can be quickly and easily referred by section page number. Each section is divided with a colored index paper, also containing the major subheadings of that section. All pages carry the sub-heading title at the top of each page.

Throughout the report, a number of summary paragraphs (typed in italics) have been included to assist the reader in capturing the major thrusts of the individual sections.

Figures and tables, wherever possible, are built into the text of the report for quick and easy reference.

Volume 2 and 3 also contain their own observations, conclusions and recommendations as well as a complete set of references, supporting nomenclature and definitions.

2.0 Introduction to the Study

This report is about rural radio communications in general and the feasibility of a sophisticated rural radio distribution service in particular. Rural, for the purpose of this report, is defined as "The areas of continuous settlement with population groupings of less than 1000 people or with a population density of less than 1000 people per square mile. The definition excludes (1) incorporated settlements of greater than 2500 people (2) the remote areas". Rural areas of Canada, based on 1976 data is illustrated in FIGURE 2-1.

As indicated in the terms of reference, the study was to evaluate radio in all its different forms, to single out one or more specific services as being most significant in rural areas, to recommend solutions and to organize a field trial to demonstrate their feasibility.

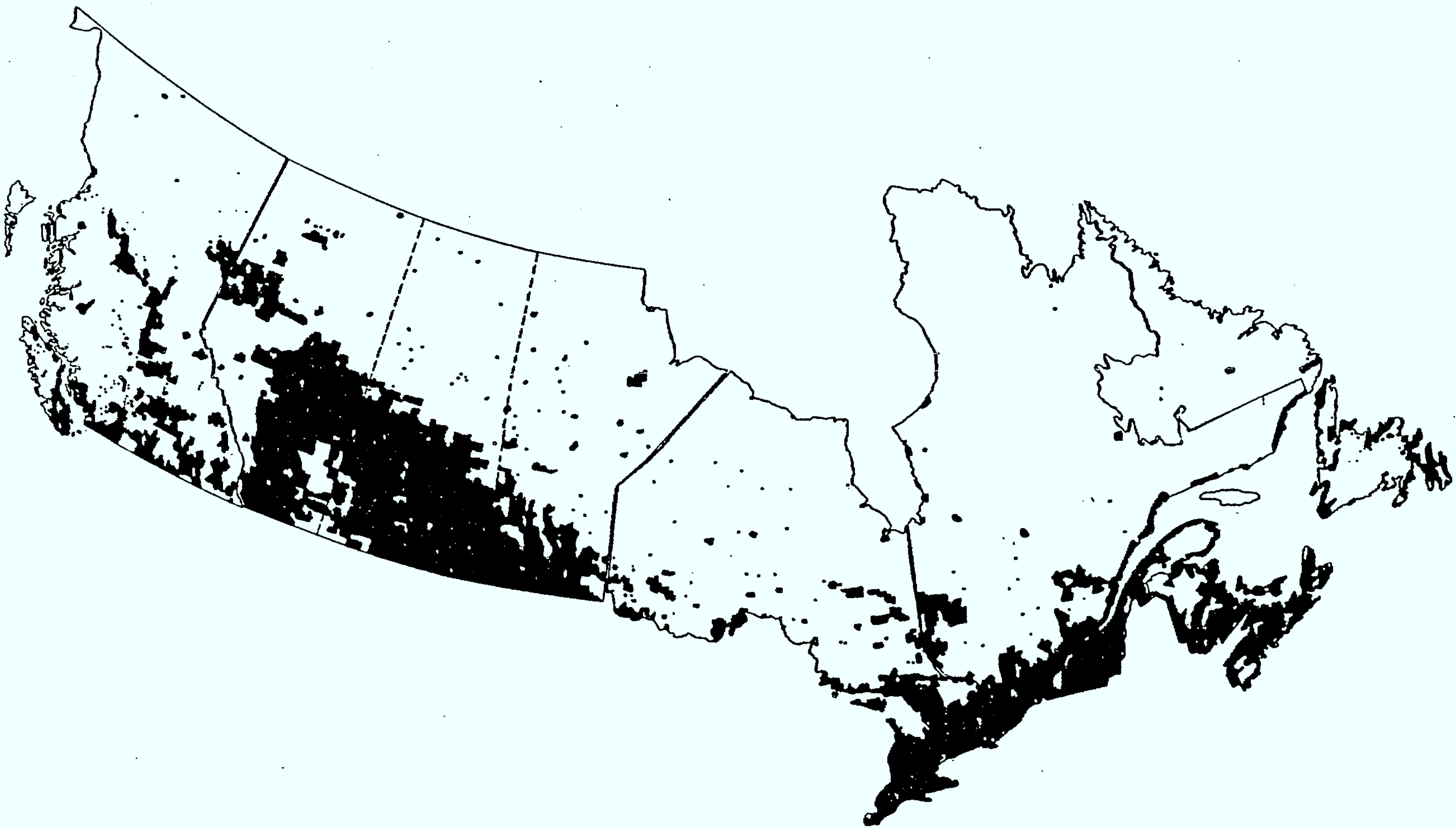
In doing this, we have concluded that the most significant contribution to rural communications would be a new type of radio service developed around the needs of mobile radio users and capable of serving a variety of other communication needs as well. Thus, a specific type of service has been proposed, which we refer to as a rural radio service or RRS.

This conclusion was not obvious at the beginning of the study, and to many it still may not be obvious. The application for radio which seemed most promising initially was the serving of fixed telephone subscribers who had inferior service from conventional network facilities. So, we reviewed the experience of users and suppliers of subscriber radio systems, alternately referred to as "fringe" radio, "rural" radio or "subscriber" radio systems. It was obvious that radio had a role to play in this application but that it was not performing very well from the point of view of penetration.

We then looked at mobile radio communications and discovered that it was serving a basic need in rural areas, that the penetration was high, but that the existing services were deficient in many respects. In fact, it was observed that if mobile systems could be configured to fully satisfy user requirements, the same systems could serve other users as well including fixed telephone subscribers.

FIGURE 2-1

Rural Areas of Canada



There are basically three communication categories capable of being used as distribution systems, i.e. wire line, terrestrial radio, and satellite. All three have applications in rural areas but they also have limitations. Wire line or cable systems are, at present, serving the majority of the rural population to one degree or another but become uneconomical in low density areas. And, of course, they are incapable of serving mobile users.

Satellites are potentially capable of serving all types of communication distribution needs (both fixed and mobile). However, it has not been demonstrated that they can be competitive. These two categories, wire line network and satellite are being given adequate attention by government and industry alike, with considerable amounts of money being spent in field trials (e.g. Elie, Manitoba fibre optics) and satellite development programs (e.g. MUSAT).

This report, therefore is concentrated on the mobile radio communications requirements, and more broadly an integrated terrestrial radio service. This does not mean that we consider all other types of radio service redundant. For those who wish to assert their individuality, there are many services to choose from. However, we don't feel these latter services satisfy the universal need for rural communications.

Paging systems, for example, provide a valuable service, but we have chosen not to discuss them in detail in the report. The reasons for this are simple when considering rural coverage. A paging receiver is about 25 dB less sensitive than a mobile receiver using a roof mounted antenna which means that higher powers and more transmitters are needed to obtain coverage in a paging system. A paging service has limited value to the person in an isolated location with no access to a telephone. In such cases as common in rural areas, there is a need to acknowledge the page and to know the urgency of the message. The proposed Rural Radio Service would, in an case, include a paging capability.

Portable radios are not discussed in detail in this report. This is with the understanding that there is not essential difference between a portable and a mobile radio, except for the lower antenna efficiency and the usually lower power inherent in a portable transceiver. We conclude that portables can be built to be compatible with any radio system design with the understanding that the quality of communications at times will be poorer than for a radio installed in a vehicle.

We have taken a brief look at cordless telephones and rejected this type of system as a non-contender for universal communication service.

Two specific types of rural microwave radio systems have been examined (i.e. the Farinon SR subscriber radio and the Bell Northern Pole Line Microwave Radio). Both are very fine products of Canadian design and should do well. We see the pole line radio, for example, forming part of a new radio distribution network. Its relatively low cost and simplicity make it ideal for such applications. However, it was not considered necessary or desirable to discuss these systems in detail in our report.

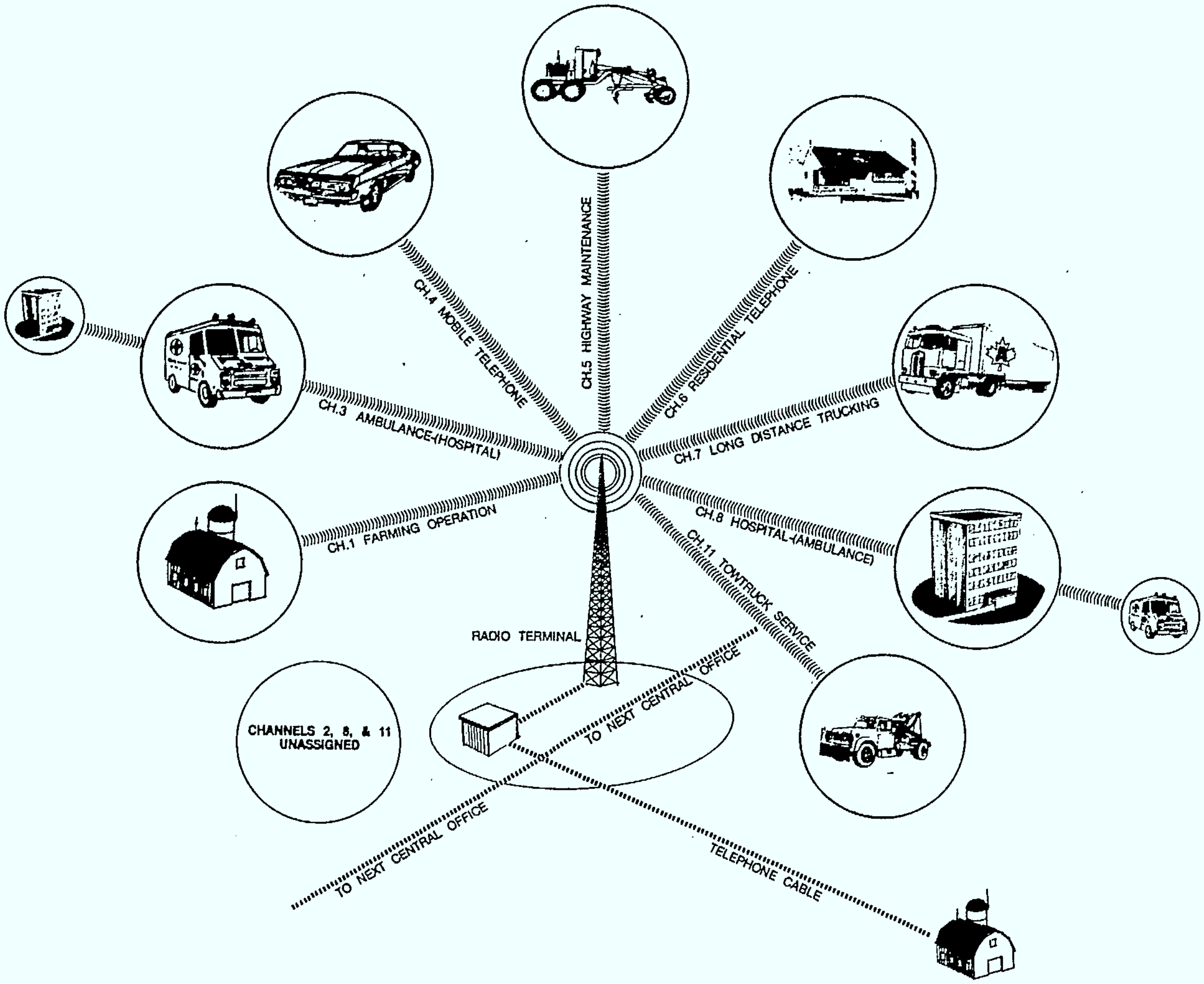
Thus, we have narrowed the scope of our report mainly to the field of mobile radio communication, which in itself is a very large field. It includes the various land mobile services, General Radio Service, and the emerging cellular services. These are all discussed in detail in the report with significant observations and conclusions summarized in each section, and embodied in the executive summary that follows.

Referring again to the terms of reference of our contract, we have made every effort possible to satisfy them. The detailed definition of a field trial, however, could not have been done satisfactorily within the time frame of the study, since it depended on other developments of considerable importance to the project, which for various reasons have taken longer than anticipated originally. These included, for example the resolution of spectrum issues, the commitment of users and manufacturers to the project, the detailed design of the system and availability of demographic information.

As a result of this, and because of the complexity of the proposed service, it has been concluded that, indeed, a great deal more effort is needed before a field trial can be defined and implemented, and that further feasibility studies are needed before the reality of an effective farm community Rural Radio System such as suggested in the illustration of FIGURE 2-2, can become an operating reality in Canada.

FIGURE 2-2

Rural Radio System for the Farm Community



3.0 Executive Summary

3.1 Major Recommendations of the Feasibility Study

3.1.1 We recommend that a program be started for the development of a Rural Radio Service in Canada, employing the most advanced technology available and capable of serving mobile and fixed users for the transmission of voice and data messages.

3.1.2 We further Recommend that:

1. Spectrum allocation techniques be developed, taking into account rural conditions in the aspects of user density, propagation, interference and compatibility.

2. The telephone network alternatives be evaluated to determine the most effective solution, taking into account the various data formats, transmission and switching techniques, and that design parameters be specified.

3. The Rural Radio System be designed, incorporating the proposed service requirements.

4. A study be initiated for the development of high technology radio equipment.

3.1.3 We recommend that the federal government through its Department of Communications can give greater emphasis to the mobile radio industry, and energize its growth through the development of a new Rural Radio Service in Canada.

3.2 Major Conclusions of the Feasibility Study

The previous recommendations are based on the following conclusions:

3.2.1 With regard to the need for improved communication services in rural areas, we conclude that radio systems currently available for rural telephone subscriber services are not cost-effective, and will not significantly contribute to the overall improvement of rural communications services in Canada.

3.2.2 With regard to the unique role of mobile radio in rural areas of Canada, we conclude that:

1. Existing services are deficient when evaluated against the basic criteria for mobile communications.

2. Alternative communication concepts proposed to date would not, significantly alter the present situation in rural Canada.

3. More suitable alternative solutions are needed to serve rural areas.

4. A universal radio service to serve many types of users is feasible with today's technology, and could contribute significantly more towards upgrading rural telecommunications than any other approach. It could achieve this by making single party telephone service universally available, by making the future implementation of home data services possible, and by making mobile communications accessible throughout rural Canada.

5. This universal radio approach is very appropriate for low density areas since it increases the user population and provides better utilization of fixed facilities with a very significant reduction in user cost.

3.2.3 With regard to the role of technology in the development of a Rural Radio Service for Canada, we conclude that:

1. Considerable development effort is needed in the areas of propagation, spectrum usage, transmission requirements, signalling and control requirements, system configurations, etc.

2. Canadian development and manufacturing capabilities, although fragmented in the kinds of technology required, could, through a coordinated effort, successfully carry out a program to develop a Rural Radio Service.

3.2.4 With regard to the potential market for a Rural Radio Service, we have concluded that:

1. A large market exists for the right type of Rural Radio Service in Canada and elsewhere.

2. The tariff barriers on imported mobile radio products have only served to increase costs in Canada, without contributing significantly to the development of Canadian industry or technical expertise in this area.

3.2.5 With regard to the use of spectrum in rural areas, we conclude that:

1. The growth of large area systems, such as public mobile and province-wide mobile systems, has been impeded by the congestion in urban areas and by the lack of spectrum policy coordination from province to province.

2. A sizable band of frequencies, coordinated throughout the country, will be needed in order to implement an effective Rural Radio Service.

3. The cellular approach to spectrum allocation is desirable in rural areas, but more effective utilization of spectrum may be desirable to achieve the most cost effective service.

3.2.6 With regard to propagation, we conclude that:

1. The 400 MHz band is generally optimum in rural areas of Canada, would result in a more economical system, and is feasible in spite of some geographic differences in availability.

2. A radius of coverage of 20 to 24 kilometres is optimum in rural areas, would be sufficient to ensure satisfactory loading in most rural areas, but may have to be reduced in high density rural areas.

3.2.7 With regard to the manufacturing of mobile radio equipment in Canada, we conclude that:

1. Most manufacturers are foreign-owned and import the bulk of the more sophisticated system components.

2. A large market needs to be developed in Canada as a base for increased production in this area.

3. Canadians need to take the lead in developing equipment to serve our interests and in order to be competitive on the world market.

3.2.8 With regard to telephone network facilities, we conclude that:

1. Existing switching and transmission methods restrict the kind of mobile users who can be served in an interconnected radio system, because of the variety of equipment, slow switching speeds, high trunking costs and other variables.

2. To enable a high technology radio system to function over a wide area, an overlay network is needed with switching, trunking and control equipment dedicated to the system.

3. The increased loading of network facilities may justify an overlay digital network in the higher density rural areas.

A Feasibility Study of Rural Radio Communications

Volume 2

Existing Services and Available Alternatives

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Section 1

The Use and Value of Mobile Communications

Section 2

Assessment of Existing Radio Services and Available Alternatives

Appendix 1

Suppliers and Products

Appendix 4

Spectrum: Present Use and Rural Considerations

1.0 Use and Value of Mobile Communications

1.1 Overview

It is generally acknowledged that there is an increasing interdependence between rural and urban societies, resulting in a closer identification of mutual needs. It is also acknowledged that "it is very well possible that, in fact, the lifestyle of nearly the entire Canadian population is essentially urban in character" (1).

The rural dweller has the same basic needs as his urban counterpart for telephone, broadcasting, mobile radio and data communications.

The gap in the quality of service evident between rural and urban areas is a direct result of the lower population density and the corresponding higher cost of delivering communication services to these areas. There are also other inherent differences (2). Rural residents are more isolated and the greater distances between households, and therefore, the greater travel distances influence the approach to the delivery of communication services. This also places a greater demand for such services. Furthermore, the usage patterns are different. Mobile communications is more of a necessity for the farmer who must drive ten miles to town for provisions than for the urbanite who can shop next door. Mobile radio can serve the farmers need to communicate for business, social or emergency purposes, in much the same way as the telephone serves these purposes for residents in more densely populated areas.

Accordingly, although the rural and urban communication needs are very similar if not identical, nevertheless because of isolation, different techniques are needed in rural areas in order to deliver communication services economically. There is a tendency to rely more on telecommunication to compensate for lack of direct social contact. Mobile radio provides a bridge in time and space between people living and working in relative isolation and the rest of the community.

1.2.1 General

Communications has become a basic need in our society. How is this need being met, particularly in rural areas? Are present alternatives adequate or are new concepts needed? To answer these questions, a means of measuring the value of communications is needed. Telecommunications serves both a social and an economic need which will be discussed. A user justifies the purchase of a mobile radio or telephone service for economic or social reasons, or both. How much value the user receives for the money is another question. By providing some criteria for comparing the relative user value of different services, enables us to better understand the market potential for these and possibly even newer services.

1.2.2 Economic Value

Businesses save money by using mobile radio. According to a report from the United States Department of Commerce "vehicles equipped with mobile radios properly managed can effect a fuel saving of about 40% compared to non-mobile equipped vehicles serving similar functions"(3). A corresponding saving in other vehicular operating costs, man hours, wear and tear on highways is also realized. Thus, the benefit from equipping vehicles with radios is felt not only be the user but by the taxpayer. Future generations benefit by the conservation in energy and material resources.

The reduced operating cost is a primary reason for equipping vehicles with radio, according to the Institute for Northern Studies survey of rural users in the prairie provinces" GRS and private radio users liked the time and money savings... that these services fostered" (4).

The rapid growth in the use of this form of communications is largely a result of cost savings particularly in competitive business situations to which mobile radio makes a unique contribution.

1.2.3 Social Value

Frequently, the need for mobile radio is social rather than an economic consideration, although there is usually an indirect cost saving attached. Social reasons for using mobile radio include such considerations as convenience, entertainment, prestige, emergency and most importantly, public safety. The significance of radio in public safety applications, such as police, fire and ambulance is in reducing the time required in responding to a call for assistance or in the time to complete assignment.

Referring to the response loop illustrated in (FIGURE 1-1) the dispatcher can, with radio, reroute a vehicle at any time to a more important assignment, reducing or eliminating time intervals T2, T3, and T4.

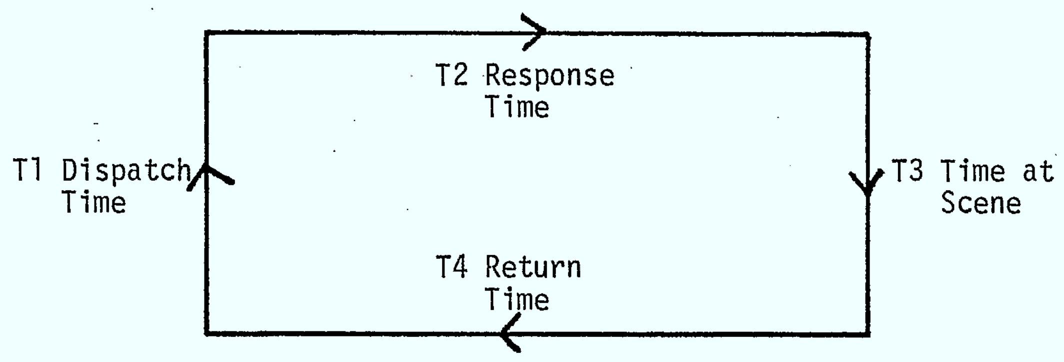


FIGURE 1-1
Mobile Radio Response Loop

The value of radio in this sense is greater in rural areas where an emergency or police service has a large territory to cover and where radio facilitates locating and assigning the nearest vehicle to the scene. The benefit of time saved may not always be measureable in dollars, but sometimes in the saving of lives (5).

A person subscribing to the General Land Mobile Radio Service (GLMRS) is more likely to measure the usefulness of radio telephone in terms of convenience rather than in dollars (4). A person who travels relatively long distances enjoys the freedom of being able to access the telephone network from his car and be connected to telephone subscribers anywhere. More recently many people have learned the value of mobile radio as a source of entertainment while travelling along the highway. Citizens band radio or General Radio Service (GRS) has made this possible because of the community nature of the service and its relative low cost.

In the social sense, mobile radio makes a unique contribution to society because of our dependency on mobility on the one hand, and our dependency on communication on the other.

1.2.4 Spectrum Allocations and the Value of Mobile Radio

The rapid increase in the use of mobile radio bands particularly in Canada and the United States, has caused the spectrum to become congested in many urban areas. This has resulted in the necessity for the users to time share frequencies and for the licensing people to develop equitable means of rationing this limited resource. Rostow has suggested (6) that the individual's right to the spectrum be measured in terms of the "marginal" or incremental value he derives from adding more radios to his system, compared to some universal standard. By his method, the user with the highest priority need (say a police system) would have first choice of the first available frequency. However his need for a second frequency may then be placed at a lower priority to that of some other users, i.e. highest priority for the initial allocation does not ensure prior right to subsequent allocations. Rostow further pointed out that any user will forego his claim on spectrum at some price. Accordingly, a shortage of spectrum will force users to employ other and more expensive forms of communication to satisfy some of their needs.

How does this affect the user of mobile communications in rural Canada, where there is no apparent spectrum shortage in most rural areas? In fact, to the majority of present rural users, this resource is in a practical sense in short supply. Consider the following:

- GRS users share a limited spectrum which in periods of high sunspot activity becomes increasingly crowded and ineffective in rural areas.
- Rural users of the General Land Mobile Service share the same limited spectrum with urban users and congestion is felt even in some rural areas.
- Large private systems requiring province-wide frequency coordination find it increasingly difficult to obtain enough free channels to operate their systems efficiently.

Small private systems, where frequency allocations are no problem in rural areas, comprise a small percentage of the total number of users at present. The result of this congestion is the trend toward alternate radio services which meet people's needs better, but are more expensive (4).

Spectrum limitation, therefore, is a factor even in rural areas and forces users to either make more efficient use of what is available or to resort to other more expensive or less efficient forms of communication.

1.2.5 Value of Mobile Radio as a Function of Various Service Characteristics

The purpose of a mobile or portable radio service is to enable the user to communicate over a distance while in motion or when other forms of communication are unavailable. To define the ideal system, the user should be able to contact anyone from any location, without delay, to converse freely without interference or fear of being overheard and without degradation in the quality of transmission. All mobile radio services are compromises in some or all of these requirements of the ideal service, and are constrained by design limitations and policy barriers.

The usefulness of the radio service to the user can be measured by the characteristics implied in the above definition, and comparing them to the following five criteria:

1. Communications range - how far does the system allow him to communicate?
2. Scope - who can he communicate with?
3. Speed of access - what is the blocking probability? How long does it take to signal the other party? Is queuing provided when channels are loaded? Is there provision for emergency access to the system?
4. Quality of communications - what will be the frequency of and severity of noise on the channel due to interference, signal degradation? Is the system essentially free from audio degradation?
5. Privacy - does the system provide the needed level of protection against unauthorized monitoring?

By examing these characteristics as they apply to existing radio services, and by weighing our assessment against what is required of them, as well as against the ideal system, we will be better able to see what the limitations are and where improvements can be made. This will also permit a comparison with some proposed services.

Accordingly, mobile radio has a unique social and economic value to the user and to society as a whole. Nevertheless it must be evaluated in relation to the need to allocate radio spectrum among the many services which are dependent upon it. Within this constraint, the user can assess the value he receives from his system by measuring basic characteristics common to mobile radio systems, the most important of which we consider to be; coverage distance or area, scope or flexibility, ease of access to the system, accuracy of interpreting the transmitted intelligence, and privacy. By comparing these factors, the user can choose the system which gives the best value for money, and the designer can develop the most universally acceptable types of communication services.

1.3 Existing Radio Services in Rural Canada

1.3.1 General

Mobile radio communication for public use falls into two broad divisions, one referred to as Land Mobile services and the other the General Radio Service. Land Mobile Services are at present available in three parts of the spectrum centered around 40 MHz, 150 MHz and 450 MHz (see Appendix 4). Frequencies in these bands are regarded as a scarce resource and are allocated on the basis of a justified need and efficient use. All radio equipment must be licensed and must meet appropriate radio standard specifications.

Use of these bands is strictly controlled by Department of Communications (DOC) regulations. Many of the frequencies are allocated for special use, either on a regional, provincial or national basis. Of these, two groups are of particular interest in this feasibility study; that is those allocated for the use of the telephone common carriers in the General Land Mobile Service and those allocated for use in the Restricted Common Carrier Service. These two services comprise a very small portion of the total land mobile spectrum, but are used more efficiently than the bulk of the remaining land mobile spectrum allocated to private systems.

The traditional approach of allocating frequencies to individuals or groups rather than on shared basis today appears inefficient. Alternate approaches to frequency allocations are being evaluated by the Spectrum Policy Management Groups in Canada and the United States to make more efficient use of them. Cellular techniques, for example, enable a limited spectrum to serve a much larger number of users. Other sharing approaches are also being evaluated.

The GRS band is an excellent example with 40 channels serving four times as many users as the Land Mobile Services which share over 3000 channels.

Conventional land mobile radio as a licensed form of communication in the public sector is little more than a quarter century old. During this time it has become an important communications medium. Numerically, there were approximately 10,000 licensed radios throughout Canada in 1959 while at the end of 1978, the number had risen to 315,000 licensed radios. Technically during this period mobile radio communications has developed rapidly now attracting many highly trained professional people with specializations in microprocessor control, cellular systems, packet radio, data transmission, personal portables and computerized allocation schemes (7).

The land mobile services are divided into three categories, i.e.:

1. General Land Mobile Service offered to the public on a leased basis by the telephone companies.
2. Private Services.
3. Restricted Common Carrier Services which are privately owned but leased on a shared basis to the user.

Of these categories, the largest number of users is in the private sector. However each category has a particular significance.

The impact of these services on rural life has been much less significant than GRS, which in less than 10 years has exceeded the penetration of land mobile radio in Canada by a ratio of 3 or 4 to 1, and in some rural areas by a ratio approaching 10 to 1.

Accordingly the traditional approach to allocating spectrum is out of date and inefficient in the Land Mobile Services suggesting the need for a complete revision of allocation policy to encourage the development of systems employing modern communications techniques.

1.3.2 General Land Mobile Radio Service (GLMRS)

GLMRS, which is also called Public Mobile, is a mobile radio service available on a leased basis from telephone carriers. In some areas the equipment can be purchased, but the user must pay an interconnect fee and toll charges. Most systems available in Canada have evolved from the Mobile Telephone Service (MTS) in the United States, which requires operator supervision and employs one-way signalling from base to vehicle. Improved Mobile Telephone Service (IMTS), with two-way dialling and various features required to enable the user's radio to appear more like a telephone, were introduced in the United States in 1964. The control terminal concept for IMTS was patented in 1965 (8) and has formed the basis for the automatic Public Mobile Service.

GLMRS has had limited penetration in Canada when compared to the United States for reasons of insufficient spectrum and high cost. The carriers claim there is a very large potential market and have put forth various proposals for new automated services. To implement these services, additional spectrum is required.

The purpose of the following section is to explore the value of GLMRS to the rural user, and therefore its potential for satisfying the communication needs of rural residents. The concept will be evaluated according to the parameters listed in the previous section, with reference to the results of previous studies.

How well does the GLMRS satisfy the five basic criteria proposed in section 1.2.5?

1. Communication Range

   In the prairie provinces and British Columbia, area coverage is considerable (4) in relation to so-called "rural" areas. A mobile within a coverage contour can talk to another mobile throughout the indicated coverage area or to anyone connected to the switched network. Coverage in some provinces is less complete (i.e. Nova Scotia and New Brunswick) while in Prince Edward Island, coverage is essentially total.

2. Scope

   The GLMRS user can be connected to anyone interfaced with the switched telephone network, i.e. fixed subscribers and other GLMRS mobile telephones. There is no provision for interconnection with other types of users, for example with private mobile or GRS radios, a result of telephone company policy to limit this capability to primarily emergency services.

3. Speed of Access

   The blocking probability in most services approaches 50% during peak loading conditions because of channel limitations. In most existing services, queuing is not provided, and call attempts are blocked when the channels are loaded. Access is also limited due to lack of compatibility between systems, i.e. from province to province or even within the same service where both VHF and UHF systems coexist. No provision is made for emergency access.

4. Quality of Communications

Carriers are understandably very much concerned about the degree of degradation in transmission quality caused by the mobile environment. Some degradation is to be expected part of the time. Quality is expressed in terms of circuit merit (9)(10), a measure of probability of receiving an acceptable voice transmission as determined by subjective listening tests. The minimum objective of most existing systems is circuit merit 3. That is where there is a 90% probability that speech is understandable with a slight effort, to 90% of users. This emphasis on quality is to protect the overall network integrity. and is one reason for the strong objections the carriers have against interconnection with other services that cannot maintain minimum quality standard.

5. Privacy

There is no guarantee of privacy in this type of service. Some privacy protection is provided by the mobile receiver design in the form of lock-out on occupied channels. However since standard channels are use, it is a simple matter to modify any standard receiver to monitor the GLMRS channels.

GLMRS, even though available in a large part of Canada and through its access to the telephone network has countrywide coverage, could not replace other mobile services, not even with the addition of unlimited spectrum and a substantial cost reduction. Its present design limits its appeal to the individual who wants a conventional telephone in his vehicle.

The possibility of making GLMRS or its replacement available to other categories of mobile users in future is limited both by design and policy constraint. In its present and proposed configurations the service is not suitable for the kind of applications currently filled by private systems. And both carrier and government regulations restrict its application in these areas.

The basic purpose of General Land Mobile Service is to provide the mobile subcriber with telephone service and which offers a wide range of coverage. Unfortunately GMLRS has a limited growth potential because of 1/spectrum shortage therefore high blocking rate 2/inflexibility of design and service capability determined by carrier policy and government restrictions 3/geographic incompatibility due to spectrum and design differences and 4/is expensive to the end user. To appeal to the bulk of mobile users, new features and options are needed along with a considerable reduction in overall cost.

1.3.3 User Owned or Private Mobile Systems

The private Mobile category includes all those land mobile users who employ mobile radio systems to serve their specific business or function. It includes public safety systems, government radio systems such as highway maintenance, forestry, etc, systems used for the dispatching of taxis, delivery vehicles, construction vehicles, and mining vehicles to name only a few. The systems are custom designed to the user's specifications taking into account particular needs and design considerations such as:

- Frequency band and number of channels
- Area of coverage
- Control function
- Trunking requirements
- Equipment parameters
- Standby and alarm functions
- Site planning

The simplest system comprises a fixed base station and one mobile unit. It occupies one radio channel and has a coverage area with a radius of up to about 65 kilometres. A complex system usually has many base stations; up to 30 radio channels and may cover the entire rural area of a province. Its control system may include several control consoles, with digital signalling and data transmission, and computer-aided dispatch.

The most sophisticated private mobile systems are operated by police services more commonly in metropolitan areas (e.g. Toronto Metropolitan Police and the Lower Fraser Valley RCMP systems). Other systems in this category are in various stages of planning and implementation throughout Canada (e.g. the Montreal Urban Community Police, Ottawa Police and the City of Winnipeg).

The large majority of mobile radios operate as private systems custom designed to the user's requirements. In this way, the system operator feels as though he gets precisely what he needs and only what he is paying for. Other available services do not offer this flexibility of choice and any new service directed to this market must adequately satisfy the user's individual needs. Most private systems, however even those which are designed with a great deal of care outgrow their usefulness fairly quickly because of changing needs. They must be replaced or modified at considerable expense within the lifespan of the equipment.

With reference to the criteria for measuring the value of mobile systems, how well do the private systems satisfy the requirements?

1. <u>Communications Range</u>
   The range of private systems is limited to the area in the immediate vicinity of one or more radio base stations. This usually satisfied the users at the time of the initial installation. However time usually changes the required range and there is always a percentage of locations where coverage is inadequate. Therefore, coverage is limited to begin with, and becomes increasingly inadequate over a period of time.

2. Scope

The system operation of private systems is determined by the initial design, and there is often no flexibility if new requirements come along. The scope of a private system is therefore measured by the flexibility of its design.

3. Speed of Access

User access to most private systems in rural areas is usually no problem. The radio channels are seldom busy so that channel access is usually successful. In province-wide systems, this is not always the case (5).

4. Quality of Communications

Radio equipment designed to meet the current DOC specifications provides good quality audio. The main limitation is noise due to marginal signal strength. In rural areas, this limitation is primarily experienced in fringe areas and gradually increases with distance.

5. Privacy

In most private systems, it is intended that the system operate in a conference mode since it is often valuable or necessary for the workers to know what is happening elsewhere in the system. Privacy is required in some systems as an alternate mode under dispatcher control. In another sense, private systems are free from interference or monotoring from other systems because of different channel allocations.

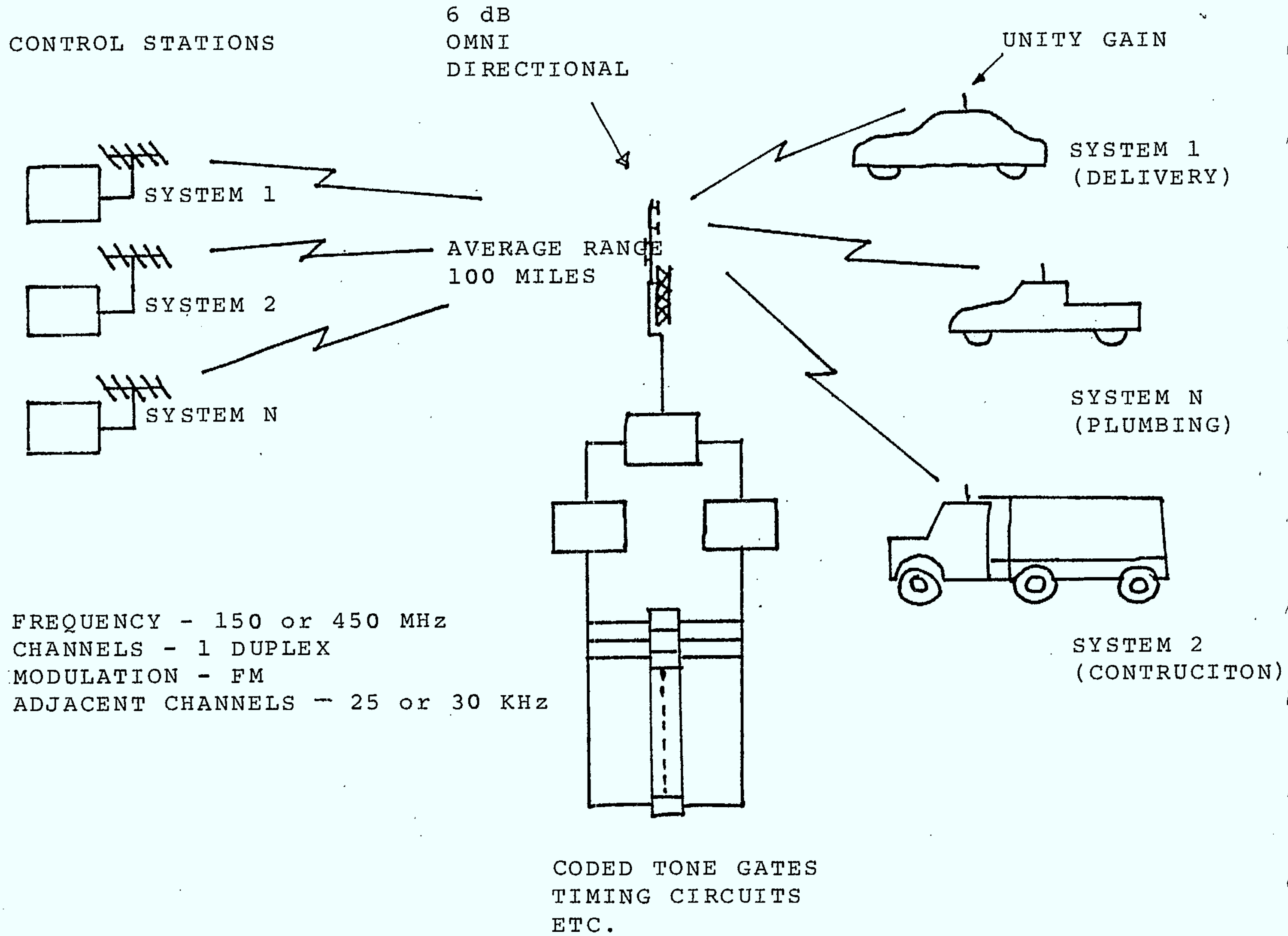
Accordingly, private mobile radios are in the majority in the Land Mobile Radio category because of their high initial value in meeting the user's specific requirements. They vary widely in size and complexity, although advanced technological features are limited to the large systems. Small users including most rural systems, are unable to benefit from such innovation. Although essentially meeting the user's requirements for range, operational features, loading, quality and privacy when first placed into service, users find that changing needs result in a reduction in system value with time, requiring costly modifications or premature replacement.

1.3.4 Restricted Common Carrier Mobile Radio Services (RCCMRS)

RCCMRS is, in a sense, a compromise between large and small private systems. An RCC station is privately owned, and its facilities leased to various users. The users may either purchase the mobile and control equipment or lease it from the system supplier. Theoretically anyone can set up an RCC system providing they meet the minimum requirements as set forth in the Radio Regulations Act. Most systems in large urban areas are owned and operated by large companies.

In its basic form, an RCC system consists of a simplex repeater shared by several groups of users (FIGURE 1-2) allowing subscribers to communicate with each other over a relatively large area. By this means, a business with only a few vehicles can equip them with mobile radios without having to spend a great amount of money on fixed equipment and telephone control lines.

Most RCC base stations are located at points of high elevation above surrounding terrain in order to give a wide area of coverage, thus attracting more potential subscribers. Often an RCC station will be located on a mountain top or the highest elevation in the area, frequently providing a coverage range in excess of 160 kilometres.



TYPICAL RCCMRS SYSTEM

FIGURE 1-2

An RCC station can accommodate 50 or more mobile radios. Where there are two or more unrelated groups of users which is the usual case, it is preferable to provide a degree of privacy between the groups. As well as eliminating the annoyance factor, this facility provides a degree of security between groups who may have competitive interests. From the RCC owner's point of view, there is a need to have control of who uses the station and for what percentage of the total time. By introducing a sub-system for isolating the groups of users, the owner can take a particular group off the air (e.g. for not keeping up payments) and can total each group's access time and charge accordingly. Thus access to an RCC station is carefully controlled by the owner.

An additional benefit of the RCC system is that a new subscriber can be accommodated very quickly because there is no waiting time for licenses as in the case with private systems. RCC services therefore are convenient for seasonal users or for those who have applied for a private license but need immediate service.

Loading of an RCC channel and access waiting time are dependent on many factors. Where there is one large group on the channel along with several smaller groups, the large group often dominates the channel at peak periods, preventing the small users from gaining access. Various techniques have been devised for minimizing this limitation. However, it remains a problem when only one RCC channel is available to the user in the particular area.

For rural applications, the RCC approach has some useful features. The main attraction is being able to offer users a large area coverage at a reasonable cost. However, although the station is located to serve the largest number of potential users, each user has somewhat different coverage requirements. There is a good chance that the station coverage doesn't fit the users needs too well. Where there are RCC systems in adjacent areas, a user can normally subscribe to these as well. However, in rural areas, there are relatively few RCC stations set up in continuing areas because of the low user density.

Some users may require a wider radius of coverage than provided by the station; or it may only cover a portion of the area of interest to the user. Also it could provide a much larger area of coverage than needed by some; a condition which is undesirable since the total inteference potential is unnecessarily high.

Therefore, the advantages of RCCMRS to rural users are:

1. Good coverage at reasonable cost to small users.
2. No licensing delay to gain access to the system.
3. No need for leasing telephone control lines.
4. Cost of the base station service usually determined by the amount of use.

The Disadvantages of RCCMRS to rural user are:

1. The one RCC station in the area may cover only a part of the area of interest to many potential subscribers. Once out of range, the user cannot communicate with anyone.
2. There is a large probability that once the channel is loaded, its use will be dominated by one or more large users to the detriment of the smaller users.
3. An RCC Station by definition is restricted to local coverage and cannot be interfaced with the telephone network.

The RCC approach has a greater potential for rural areas which is not being exploited. High blocking probability and extended coverage are the main limitations of present systems. By installing a network of RCC stations with overlapping coverage and interconnected by land line or radio link, and also by making several channels available in each area, both of problems would become insignificant. The obstacles to this approach are low user density, government imposed limitations on the number of channels in a given area, and spectrum availability. Furthermore a higher degree of technology would be needed to allow such a system to function effectively.

The potential for developing this concept further should not be overlooked by spectrum people or by entrepreneurs. There is a large enough user population to provide the needed loading in many rural areas, not to mention the urban areas.

The technology for providing the RCC service is available and at reasonable cost if exploited on a large enough scale. A group of radio common carriers in the United States have proposed that such a concept be developed in the 800-900 MHz band and implemented on a country-wide basis (11). There is scope for a similar proposal in Canada.

The value of an RCCMRS system is that, the user has access to a larger area of coverage than be could normally afford in a private system. Otherwise he has no flexibility in choice of features and is often faced with a problem of overloading, since there is no sharing of channel resources. Limited privacy is available but it affords very little security in the sense that privacy features can be bypassed fairly easily.

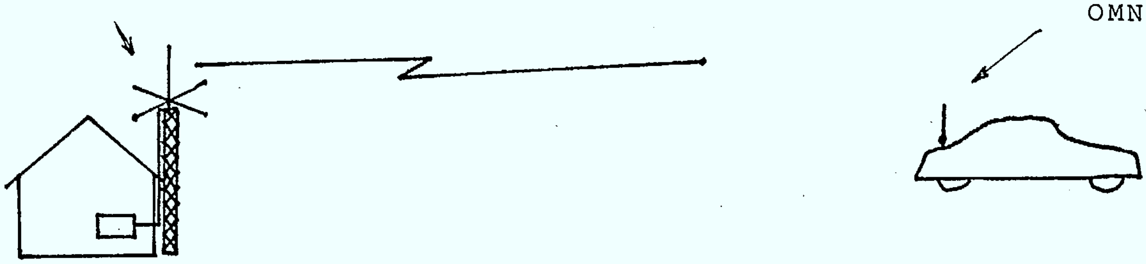
Accordingly, the value of RCCMRS to a user is measured by the large coverage area usually provided (although not always compatible with the coverage he requires), and by the short delay time in obtaining service and by the reasonable cost. The value is diminished by the lack of system flexibility or choice of options, difficulty of access at peak periods and limited security. Considerable improvement would result if several channels were provided in a given area in such a way that the user was automatically assigned the next available channel.

1.3.5 General Radio Service

Roger Schindelka in his report "Man on the Move" stated that GRS is the "business radio of today" in the prairies (4). His findings have indicated that 75% of owners use their radio primarily for business purposes, and that the penetration of General Radio Service (GRS) radios is several times that of the land mobile services. In the United States on the other hand Citizens Band (CB) radio is regarded primarily as a form of entertainment, allowing the user to enter a "state of consciousness that is a form of repression from daily activities" (12) and although its value in other respects is acknowledged (emergency, etc) for the majority, these are secondary in importance to the emotional satisfaction.

A complete understanding of the social significance of citizens band is not clear. Those studies which have been carried out to date tend to provide a confusing picture (4,7-p 281, 12,13). What has become clear is the universal interest in mobile communications which has suddenly been created through the use of CB. CB was originally intended for business use, but this function has been largely replaced by other uses. Meanwhile people who have become dependent on radio through CB tend to look for alternatives which are more reliable. This group may form the major market for future mobile radio services. An understanding of their needs is fundamental in new system designs. Thus, a great deal of significance is given in this study to the CB user group.

The General Radio Service occupies 40 AM channels (80 SSB) centered around 27 MHz. A user may obtain a license to operate a CB radio without qualification or delay, but must follow minimum requirements on antenna gain and height of a base station antenna installation. The user has complete freedom under present rules to operate on any channel. However, it is against DOC regulations to communicate beyond local range, such as by skip, but users pay very little attention to the rules and little is done to enforce them. CB radio equipment must meet minimum specifications before it can be offered for sale in Canada.

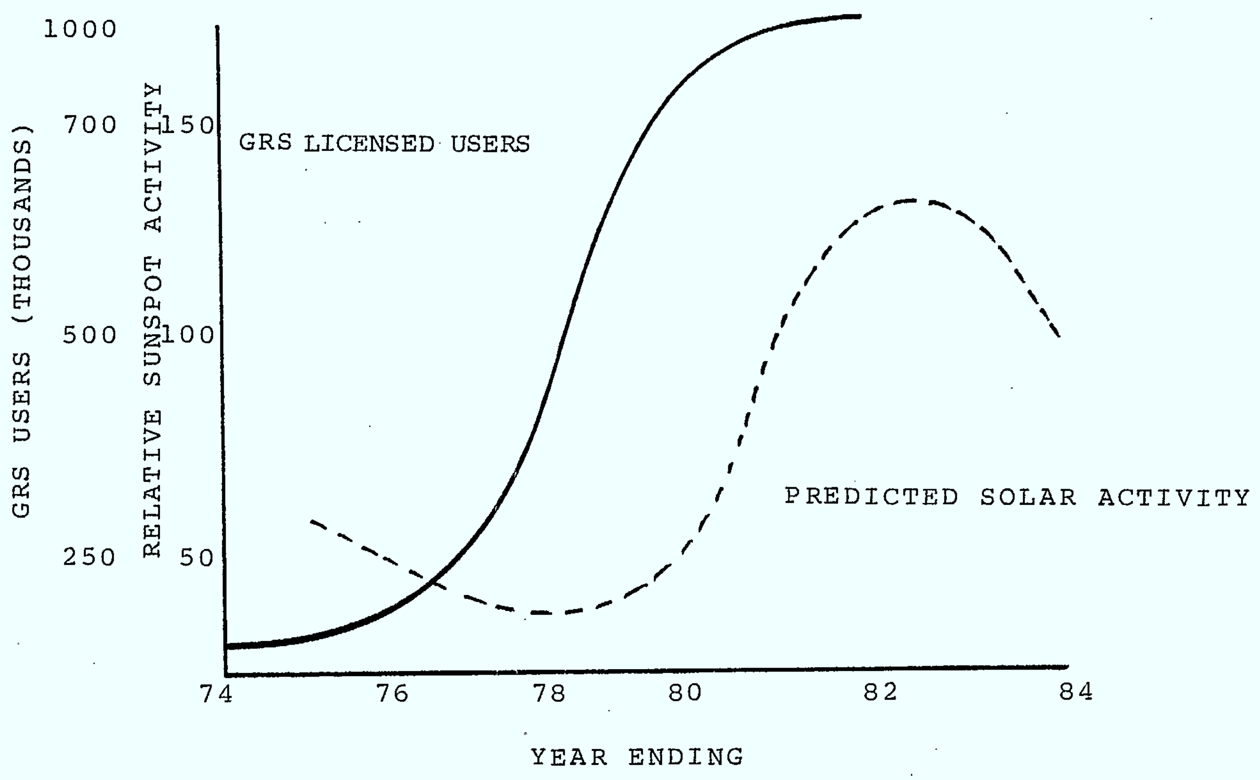


BASIC GRS SYSTEM

FIGURE 1-3

The local communication range of a CB system is from 8 to 50 kilometres depending on a number of variables (14). Because amplitude modulation is used, the reception is severely affected by ambient noise and also is more susceptible to co-channel interference than a frequency modulated system. These two factors limit effective range in densely populated areas. In rural areas, on the other hand, range is more frequently limited by the effects of skip interference. These effects vary on a diurnal, seasonal and 11-year cyclical basis and are most severe during the daytime at sunspot maximum. For the category of users who regard CB as a source of entertainment, this phenomenon enhances its value. The lack of privacy, the uncertainty as to who may respond to a call, the prospect of establishing long-range contacts; all are the elements which make CB an entertaining medium to many users.

The problem is that these characteristics inhibit reliable communications and create a dilemma for those who want to use their radios for serious applications, such as managing a small business or farm. In the more isolated rural areas where the local user density is low, interference is not a serious problem except during high sunspot activity. This is evident from the results of the INS study (4). The rapid growth of CB sales began during low sunspot activity and is reaching saturation during sunspot maximum (see FIGURE 1-4). This will greatly limit the usefulness of these radios during the period of 1978 to 1982 by reducing effective range as much as 1/6 of the normal range (7,14).



GRS USERS AND THE SOLAR CYCLE

FIGURE 1-4

The loading in a congested area tends to be spread evenly over all channels because a user can access any available channel. Only because of this is it remotely possible to accommodate the very high user population. Thus, this form of communications has demonstrated the effectiveness of sharing a limited spectrum, a necessary concept in future services.

However no matter what the technique or how patient the users, there is a limit to the amount of information one can squeeze into a given band width. In the United States this limit has been reached in many parts of the country. The problem is less severe in Canada, but is expected to reach serious proportions by 1981 (13).

Accordingly, CB radio, which in a short interval of time has become a preoccupation for 40 to 50 million people in Canada and the United States as both an entertainment medium and a business tool, appears to be outgrowing its usefulness. Simultaneously, it has paved the way for other alternative communication concepts by illuminating some interesting social and technical phenomena, such as:

- Mobile radio satisfies a universal need for communications which cannot be satisfied by any other medium.
- This large body of users is in fact the market for new, more effective forms of radio communications unencumbered by the limitations of the CB service.
- It is possible even with a primitive form of channel sharing to accommodate a very high user population on a very limited spectrum.

From the viewpoint of our value and usefulness criteria, General Radio Services or CB has little to offer to the serious user other than low cost. Range is unpredictable; the user has some choice of options but cannot design a system to meet his particular requirements; interference is often overpowering, limiting access to the channels; noise is a frequent source of degradation; audio quality varies from one make of radio to another; and the service offers no privacy.

Further details on the GRS or Citizens Band are contained in Appendix 4.

1.3.6 Radio and Rural Subscriber Services

Conventional telephone distribution techniques are expensive in low density rural areas. Estimates of average costs for installing new cable to upgrade existing services or for new services vary widely (e.g. cable installation $1,000 to $5,000 per mile). Typically to upgrade a multi-party to a maximum 4-party service cost $2,500 per subscriber in 1975 (15). Present plans by Canadian telephone carriers are to provide a maximum of four subscribers per loop. The Newfoundland Telephone Co. is the exception, and is aiming for universal single party service. Nevertheless, there remains a large number of rural Canadians without the option of having private service and a significant number (approximately 600,000) with no service at all. Many of these people would opt for an upgraded service if it were available at a reasonable cost.

This situation has been the concern of the Department of Communications for some time, and pressure has been placed on telephone companies to improve rural services. As a result, funding has been provided to industry to find techniques which will reduce the cost of improving rural telephone services. The DOC rural communications program is dedicated to this purpose.

The alternative to providing subscriber distribution service by cable is to use radio. Note the distinction between radio distribution systems, which are discussed here, and microwave trunking systems, used for inter-office or long haul links.

At present, radio is used primarily to extend telephone services into fringe areas where the cost of installing cable would be prohibitive. Radio systems designed for such application are logically referred to as fringe radio or rural radio. Many companies around the world produce these radio systems:

- Canadian Marconi
- Motorola
- OKI
- Plessey
- Pye Electronics
- SIAE Italy
- Siemens
- Storno

These systems are adaptations of mobile radio equipment and operate in the VHF and UHF mobile bands. In the remote areas where these systems are installed, there is no shortage of radio spectrum in these bands. Also, the General Land Mobile Service is readily adapted to serve fixed subscriber use and is sometimes used for this purpose. For a number of reasons such as high cost, limited spectrum and CRTC regulations on leasing rates, this approach has not been implemented on a wide scale.

In the past four or five years, a number of developments have taken place in different countries in recognition of the possibility of using radio for distribution systems in a more organized way and in more densely populated rural areas.

In Canada for example, Farinon developed a time division multiplex system with 15 digitized voice channels operating at 1.5 GHz. The system provides both trunking and local distribution interface facilities for up to 90 single party subscribers, and can accommodate 15 radio substations. A dozen systems have been installed in Canada, and are reported to be giving very satisfactory service. Indications are that, although the systems may be too costly to prove-in as a general alternative in rural areas, they are well suited to serving small communities and applications such as hydro stations where voice and data are used.

In Japan: NTT has developed a subscriber radio telephone system for rural areas. This system operates at 250 MHz (marine band in Japan) and employs six separate FM radio channels capable of serving 50 subscribers on the basis of individual calling rate of 0.04 erlangs. The system is similar in operation to an automatic General Land Mobile Service (16).

In Italy: ITATEL-SIT have a multiaccess VHF/UHF radio (17). This system serves fixed rural subscribers and may be operated in the VHF or UHF bands. The system comprises a radio concentrator and telephone exchange interface unit, multiple radio base stations and subscriber radio terminals. The system is intended to be implemented universally employing a spectrum allocation plan devised in the "cellular" concept.

Accordingly, there are many radio systems developed to serve telephone subscribers in low density rural areas. Most are adaptations of equipment used for other applications and are not compatible in the true sense with telephone exchange interface parameters. Others, such as the Farinon SR system, are fully compatible, but are only competitive in the more remote areas of the country.

1.4 Users of Mobile Radio Services

1.4.1 Introduction

A number of studies and reports have been prepared on the use and demand for mobile radio services. This section will summarize these findings from the point of view of user trends, spectrum needs and future markets with emphasis on rural Canada. In a later section, the conclusions and results of these reports will be examined in relation to trends in technology and the development of user expectations.

The amount of detail which has been reported on mobile radio is such that it is necessary to narrow our scope to the area of mobile radio excluding other products and services associated with mobile radio communications systems. The two relevant general categories of mobile radio are Land Mobile Services and the General Radio Service or Citizens Band.

1.4.2 Mobile Radio Usage in the United States

(i) Private Mobile

The private mobile services as we define them in this report are divided into three main categories in the United States - public safety, industrial, and land transportation. This includes the bulk of all the land mobile radio systems. The total number of mobile radios in these categories in 1975 was 6.8 million radios as compared to 60,000 RCC radios and a similar number of public mobile radios. At the 1975 rate of growth, the total number of land mobile radios would have reached 10 million radios by 1978. In comparison, there were estimated to be 22 million licensed CB radios in use in the United States in 1977 (28 million including non-licensed users).

As illustrated in TABLE 1-1 the most important single group of land mobile users are the police who accounted for about 1.7 million (25% of the total) mobile radios in 1975. This group also accounts for the most sophisticated systems and accordingly a disproportionate share of the monetary value of all mobile radios (36%). Other major users in descending order are business mobile, local government, power, fire and highway maintenance. Almost one-half of the total are government-related activities (3 million out of 6.8 million) and this category continues to have the highest growth rate. All others are related to large business, except for the business mobile category (1.16 million users in 1975 or 17% of the total) and this category includes a wide range of small business users (11). This group most closely resembles the CB business user in character.

Also of particular interest in the data of TABLE 1-1 is the very small number of users in the public mobile sector, which we refer to in this report as the General Land Mobile Service. Although we have no exact figure, it is estimated that this group totals about 50,000 or 7% of the total. Growth in this band has been limited by insufficient spectrum. Growth of the RCC service is also spectrum limited. Both of these groups have high hopes for the new 800 MHz band to be discussed later.

(ii) Citizens Band Radio

Prior to the CB explosion which began about 1970 in the United States, a large percentage of users were small businessmen and farmers. The latter group accounted for about 1/3 of the total, or about 600,000 CB radios in 1970. This user picture has changed entirely since then. CB is no longer a businessman's radio in the United States, but has emerged as a personal radio in the sense that it is used primarily for entertainment or for casual communication. As a useful service apart from entertainment, CB plays a significant role for helping travellers obtain assistance in an emergency or for exchanging information about highway conditions, such as for platform and combination trucks (see TABLE 1-2).

TABLE 1-1

Major Trends Affecting the Market (12)

User Category	Number of Mobile Licences 1975	Mobile/ Base Ratio	Annual Growth Rate (1973-5) in %
Public Safety	3,042,782	11.5	19
Fire	364,230	11.4	4
Forestry Construction	197,986	4	38
Highway Maintenance	230,637	8.3	
Local Government	448,334	10	20
Police Radio	1,694,253	21	24
Special Emergency	105,828	6.5	30
Industrial Radio	2,390,038	7	14
Business Mobile	1,164,343	7.8	15
Forest Products	54,218	12	8
Manufacturers	82,498	18	18
Petroleum	116,945	9.4	8.5
Power	447,107	20	17
Special Industrial	427,961	10	7
Transportation	1,362,990	19	-ve
Railroad	1,058,356	60	-ve
Taxicab	133,936	33	3
Other Transport	170,704	15	6.5
Others			
RCC	60,690		9.5 to 1980
			4 to 1985
Public Mobile	50,000		50 to 1980
			26 to 1985
CB	22M (1977)		15% of households 1977

TABLE 1-2

Number of Mobile CB Licenses in the U.S.A. by Type of Vehicle - 1977

Type of Vehicle	No. of Licenses
Passenger (Auto)	12,215,000
(Truck)	2,000,000
Pickup Truck	1,503,000
Public Auto	100,000
Platform Truck	1,400,000
Van	600,000
Comb. Trucks	800,000
Dump Trucks	250,000
Utility Trucks	100,000
Police Cars	25,000
TOTAL	18,993,000

Accordingly, of the approximately 9 million mobile radios in the land mobile service in the United States, over 83% are used for government, major business activity and transportation, while only 17% are used for small business purposes and less than 7% are used for public mobile users. On the other hand, there are around 28 million CB radios in use in the United States. Their application to small business has rapidly diminished in place of personal communications. Future growth in existing land mobile and CB bands is greatly restricted because of congestion, and in both areas, the small businessman has been the main loser.

1.4.3 Mobile Radio Users in Canada

(i) Land Mobile Radio Users in Urban Areas

An accurate assessment of the utilization of land mobile radio in Canada, although not available at the time of this report, is being prepared by the spectrum engineering division of the DOC. The DOC maintains a data base comprising the information on all land mobile licensees as included on the DOC License Requisition form (see Appendix 3). Information is thus available by geographic area, frequency, SIC code, etc.

For the purpose of this report, earlier land mobile studies for the DOC (4,18,19) were used to develop a perspective of utilization by industrial sector. The data base file was used to develop growth trends in the various spectrum bands.

This section of the report will present a snapshot of user situation in Canada as a whole, and more specifically, in urban Canada in 1977. Trends and the future market are discussed later .

The number of mobiles in major urban areas of Canada representing approximately 90% of the mobiles in use are listed in TABLE 1-3. A further breakdown by user category for the cities of Montreal and Toronto is shown in TABLE 1-4.

The different growth rates for the various sectors in the period 1963-73 is of interest, and is explained to some extent by the trends in the Montreal and Toronto areas. Transportation (which includes taxis, urban transit, truck transport, and rail) and public administration (which includes police, fire, and other local government systems) comprised 80% of the urban total in 1963, but only 56% in 1973, a decrease of 24% over 10 years. Very little growth took place in taxi and police systems during this period in major urban centres, suggesting that the market was saturated rather quickly in these areas. The use of radio for police activity was justified on the basis of its benefit to the public, and cost was a secondary consideration. In the taxi business on the other hand, radios provided a direct cost benefit by reducing deadhead trips. As a result, a large percentage of taxis were equipped with radio in the early 50's. Benefits to other sectors were not as easy to justify, and growth took place more slowly. After 1973, the share of the total market by sector was not expected to fluctuate to any great extent (18) although growth rates of groups within these sectors still showed considerable variation within specific urban areas (TABLE 1-4).

The tables do not show General Land Mobile or RCC users separately. This information is not readily available. The number of GLMRS users in Canada is estimated at approximately 25,000 or between 8 and 9% of the total and, as in the United States, has been limited in growth by the lack of spectrum. Alberta has 12,000 radios in this category and can attribute the relatively large penetration to the greater dispersion of their system throughout the province (as a direct or indirect result of the oil business).

The total number of RCC radios in Canada is not known with any degree of accuracy, but is probably in the order of 40,000. However, the RCC subscribers are divided among a cross-section of a number of the sectors listed in TABLE 1-3, such as construction, manufacturing, trade, and services. As a group, they are not a very significant percentage of the total, perhaps 10%.

TABLE 1-3
Urban Utilization of Land Mobile Radio (20)

Sector	1963	1973	1977*
Transportation	11,506	67,309	94,232
Public Administration	11,893	35,907	50,269
Construction	888	17,897	25,055
Manufacturing	1,309	12,760	17,872
Services	381	11,927	16,700
Trade	780	8,308	11,631
Others	2,704	28,020	39,228
TOTALS	29,461	182,128	256,500

*The quantities by sector are extrapolated from the 1973 values. The grand total is obtained form the computer files.

TABLE 1-4

Land Mobile Users - Montreal and Toronto (20)

User Category	Predicted Mobiles 1977 Montreal	Predicted Mobiles 1977 Toronto	Annual Growth Rate Montreal	Annual Growth Rate Toronto
Public Safety				
Police	1,520	1,120	1	2.8
Fire	344	350		5.5
Other Government	1,100	3,700	2	3.5
Industrial				
Utilities	3,300	3,100	3.8	5.5
Construction	2,300	2,700	11.6	13.1
Trade	2,700	1,900	15.5	10.7
Manufacturing	1,550	7,400	7.1	7.8
Communications	1,900	3,000	13.3	9.2
Community, Business and Personal	2,500	2,200	17.8	12.1
Mining	300			
Transportation				
Taxicab	4,100	2,300	1.8	2.4
Other	10,000	7,700	10.9	11.3
TOTALS	31,614	31,370		

As assessment of user needs for Canada as a whole was made through a survey done in 1975 by Harry Dulmage Associates (21). For this survey, a sampling of users and non-users was made to determine the present applications and future expectations in the land mobile field. The report made no attempt to distinguish between urban and rural users. However, in view of the high percentage of the total radio systems centered in urban areas (approximately 90%), the observations and conclusions can be considered as representing primarily the urban rather than rural needs. Many of the conclusions of the report, nevertheless, can be considered applicable to rural areas and will be further assessed in Section 2.4.

The Dulmage study divided the users into "business and commercial", "federal and provincial", and "municipal". It was concerned with historical development, uses, growth, system sizes, frequency bands, air time, range, adequacy of systems, technical facilities, costs, DOC policy, need for an emergency channel, telephone interconnection, satellite future needs, system sharing, and miscellaneous other topics. A brief summary of the report is included in Appendix 2. No attempt has been made to assess the original materials and summary results included with the report. However, it is recommended that a review of this information be made before planning large-scale systems.

Some observations from the Dulmage report which were of particular interest are as follows:

1. System usage - (taken as a whole the majority of users employ their radios for mobile to mobile communications) while less than 25% of activity is between mobile and base.

2. Use of portable radios is gaining rapidly in many sectors because of their flexibility in job sitations. This applies more to government systems, particularly police and fire.

3. Range - the majority of systems achieve in excess of 36 kilometres range while 24% exceed 72 kilometres. Half the users would require expanded range within the next five years.

4. System adequacy - main concerns were insufficient range (12%), delays in accessing the system or contacting the dispatcher or GLMRS operator (22%) and insufficient privacy (28%).

5. Paging - 10% of business users employ paging in one form or another.

6. Future needs - although coded signalling had little penetration at the time 10 - 20% were planning to incorporate vehicle identification, 24% were planning to incorporate selective calling. Others would like to incorporate automatic vehicle location (AVL). This applies to business and commercial users, not federal and provincial governments. Varying numbers of federal and provincial government users indicate future requirements for teletype, data terminals, CAD, AVI, and AVL, and other forms of data transmission.

7. Emergency channel - approximately 80% of all users would favour the establishment of a mandatory emergency channel.

8. Telephone interconnection - 2/3 of businesses stated that access to the telephone networks by some or all of their radios would be of value. The attitude of government users was not reported.

9. Non-users - 55% expect mobiles to be employed in their businesses in the future.

Conclusions

The Dulmage report concluded that: "Long distances, in excess of 70 kilometres radius, are being achieved now by most systems, and more users are forecasting the need for greater distances in the next five years. This may well suggest the need for some other form of regional or nation-wide service embodying the traditional fast access features of private dispatch, but having roaming characteristics more like MTS with emphasis on most main roads, as well as into more sparsely populated regions."

(ii) Land Mobile Radio Users in Rural Canada

An excellent source of information on mobile radio uses in rural areas is the INS study report Man on the Move (4). This report confirms the fact that private mobile services have an urban orientation (TABLE 1-5). However, the study did not include government users which constituted almost 43% of the total number of users in the prairie provinces. The assessment therefore is valid only for the business sector.

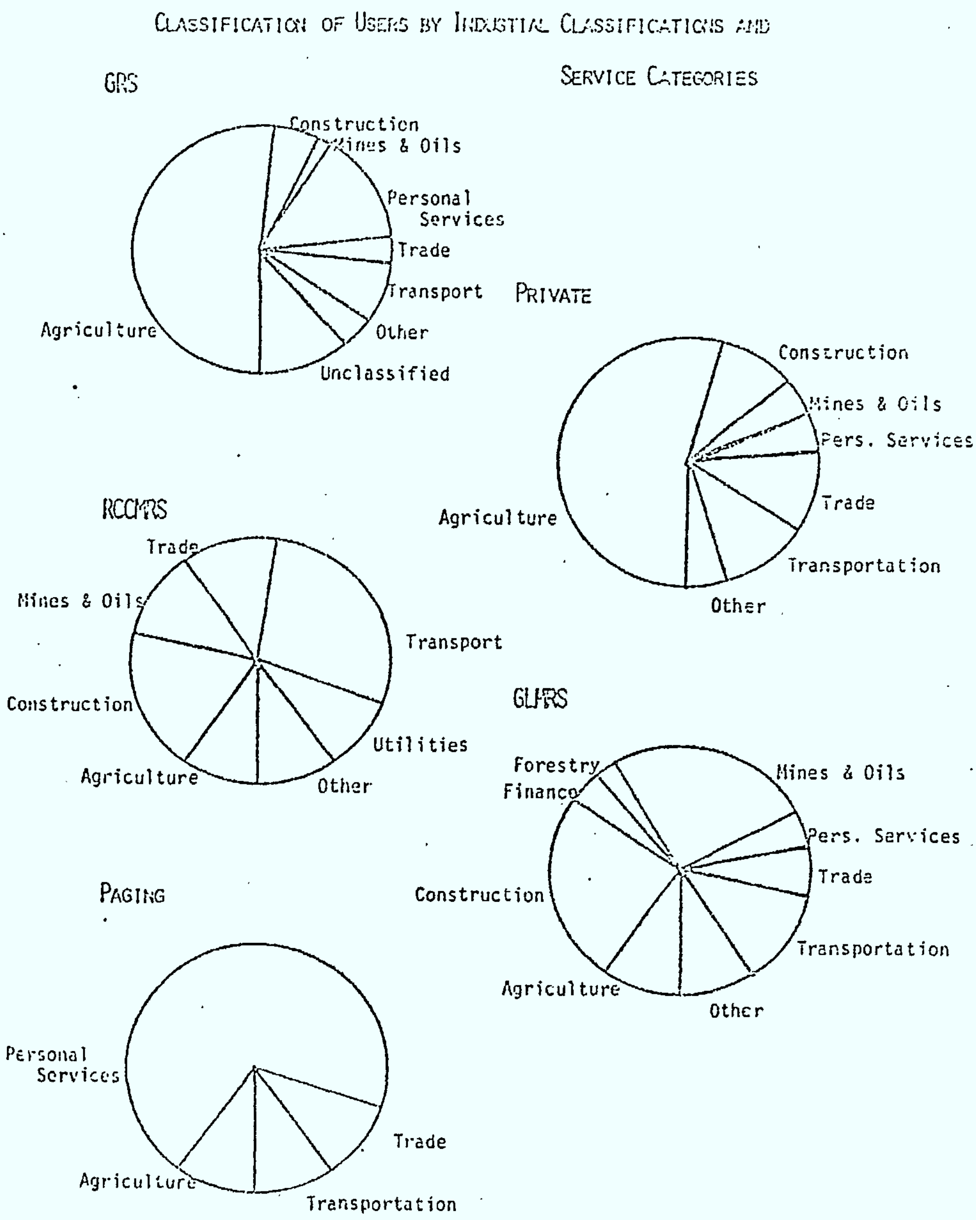
TABLE 1-5

Penetration of Land Mobile Users/1,000 of Workforce in the Prairie Provinces (Government Excluded) in 1976 (4)

	Private and RCC	GLMRS	Total
Overall	10.9	5.9	15.9
Centres over 100,000	40.9	6.8	27.7
Centres 10,000 - 99,000	21.0	7.4	28.4
Centres 5,000 - 9,999	18.7	8.7	27.4
Centres under 5,000	27.1	13.4	40.5
Rural	3.6	1.58	5.2

There are large variations from province to province which these figures don't show, but which are discussed in the INS study. For example, Alberta had the lion's share of GLMRS radios in the prairies in 1975 (88%) leaving very low penetration in all population ranges in Manitoba and Saskatchewan. Alberta also had the highest penetration of private mobiles fairly evenly distributed throughout the urban population categories, but with a lower penetration in rural areas than the other two provinces. The report (4) does not clearly distinguish between centres under 5,000 and rural, which we assume to mean the Statistics Canada definition (22).

Distribution of users by industry category in shown in FIGURE 1-5 for the different mobile services. Agriculture predominates for private systems, but comprises only a small percentage of the total GLMRS users. Cost is an important factor in this difference, but private systems are more suited to the farmers' needs for local communications.



(FROM THE INS STUDY (4)) FIGURE 1-5

The type of users of land mobile equipment which the INS study dealt with are an important group to consider in evaluating user needs. This group employs mobile radio in a relatively simple configuration, consisting essentially of a base station and tower located on the user's property and providing coverage to mobiles in the immediate vicinity which encompasses most of the territory within which the business is conducted. The average radius of reliable coverage is around 48 kilometres and the systems are relatively simple. Dispatching is accomplished with a basic radio control station equipped with microphone and loudspeaker with press-to-talk facility. This is the basic kind of service which most small businesses would benefit from.

At present, there are relatively few of these systems in the rural areas of the prairie provinces (about 1,000 systems with an average of two to three mobiles per system in 1976 comprises only a small percentage of the total business market). The number of users of private systems is limited by cost. A significantly larger number of these users, as indicated earlier, were being served by GRS radio at the time of the INS survey.

The INS study did not deal with radio systems according to size and complexity. Many private and government organizations operate large, and in many cases, complex systems. These systems are custom-designed, unique and include such examples in rural Canada as:

- McMillan Blodell logging in British Columbia
- Saskatchewan Power Corp., operated by Sask Tel.
- Trans-Canada Pipe Lines
- Ambulance services in Ontario, British Columbia and Manitoba
- Ontario Provincial Police
- RCMP in various provinces
- New Brunswick Power Commission
- Various forestry services
- Department of Transportation and Communications in Ontario

Although different in design, there are certain common factors to these systems which are significant in the designing of future services, i.e.

1. The service areas are large, and in many cases, cover the entire populated area of a province.
2. Multiple frequencies are employed which must be coordinated throughout the service area.
3. Some degree of coordination is needed between segments of the systems, necessitating a centralized control system.
4. The systems depend to a large extent on telephone companies for the provision of control lines for the interconnection of control stations and base stations.

Since vehicles must have the capability of operating anywhere within the service area, their radios are built to a standard configuration equipped with all frequencies. As noted earlier, it is difficult to locate frequencies in existing mobile bands which can be cleared over a large area. This includes urban centres already faced with spectrum limitations.

In many cases, the need for centralized control leads to complex control systems and high control line costs. In some such applications, several hundreds of kilometres of dedicated control lines are used, at a cost in the vicinity of $2.50 per month/kilometre (23). Other factors which lead to high costs for these systems include custom engineering, custom-built mobile radios, expensive control systems and site development.

As a result, the cost per mobile for a large, complex system is often $5,000 or more, with additional high operating costs for line leasing and maintenance. Systems employing a minimum of centralized control, (e.g. forestry, and most ambulance systems), are correspondingly less costly to install and operate.

The New Brunswich Electric Power Commission mobile radio system is an example of a province-wide system with centralized control (23). All vehicles in the province are accessible from the Fredericton control centre over dedicated telco-provided control lines and a network of base stations. A total of 14 VHF frequencies are employed. The system includes selective calling, an alarm system, standby facilities, and is controlled primarily from three elaborate control consoles in Fredericton, with auxiliary control in district offices. Vehicles are equipped to operate on any of the assigned frequency pairs and use tone signalling to alert the operator.

In rural areas, systems tend to be either small (average 3 mobiles per system) and limited in coverage to the one base station area, or they are large, employing perhaps several hundred radios. Intermediate between the simple and complex private systems are the RCCMRS systems which we have already discussed. RCC systems are not in common use in rural areas. However there is an increasing number of farmer groups setting up RCC systems on a cooperative basis. The sharing of the RCC base station results in more coverage than from a system of similar cost to the individual user.

Accordingly, the users of land mobile radio in Canada and the United States are usually divided into three main sectors (as shown below) but with significant differences in breakdown among the sectors in the two countries.

Geographic Area	Total (LM) Radios in 1977	Percentage of Total by User Sector: Government & public safety	Industrial	Transportation	Radios per 1,000 people
			Industrial	Transportation	
U.S.A	8.9 M	45%	35%	20%	44.5
Canada	256 K	19%	45%	36%	12.3
Toronto	31 K	16%	52%	32%	15.5
Rural Canada (Approx)		(45%)	(43%)	(12%)	

The noticeably greater percentage of mobiles in the United States in the government and public safety sector is largely in police systems. There is a correspondingly greater emphasis on sophistication in the United States land mobile systems. Surveys in Canada show a trend toward more features in radio systems in the near future but Canada lags far behind the United States in both sophistication and penetration. This trend is even more pronounced in rural areas.

The majority of land mobile radios in both countries are in private systems. Only 8% of the total in Canada are in the public mobile catefory (GLMRS) and 12 to 15% in RCC systems.

(iii) GRS Users in Canada

The number of licensed GRS users increased from 60,000 in 1974 to 800,000 in 1978. The number of unlicensed users is not known, but may be as high as 400,000. Woods Gordon (13) predicts a doubling of the number of radios by 1983 (Possibly reaching 2.4 million when unlicensed users are included). The total value of equipment at present is about $372 million.

According to the Woods Gordon survey in the Montreal-Toronto area, the primary uses made of GRS radio are illustrated in TABLE 1-6

TABLE 1-6
Primary Users of GRS Radio (13)

Primary Use	Percentage of User	
	Toronto	Montreal
Check travelling conditions	43.8	27.4
Listening only	29.5	28.2
Personal	15.1	19
Emergency monitoring	14.7	12.4
Emergency calling	3.9	8.4
Hobby and Recreational	9.9	14.5
Business	4.9	4.4
Other	2.5	4.9

The most frequent use of GRS radio in Canada is to obtain information about travelling conditions (average 36%). However if we combine those who use their radios for listening only, for hobby and recreational and for personal use into one category, called personal and recreational, this group accounts for 58% of primary use. Business users account for only 4.7% of primary usage in these urban areas.

This pattern is similar to that in the United States, but is quite different from the use pattern in rural Canada.

(iv) GRS Users in Rural Canada

In the prairie provinces, there was a 50% higher penetration of GRS users in rural areas (communities of 5,000 people or less) than in urban areas in November 1976, accounting for 56% of the total number of units in service. Up to 75% of users employed their radios for business purposes, with an average system size of 2.8 radios (compared to 1.7 in rural areas). The largest use sector understandably is agriculture as illustrated previously in FIGURE 1.5.

The primary uses reported in order of importance by GRS operators were for the realization of time and money saving, the separation of work areas, and the ability to contact personnel and vehicles. No qualification of the value of the radios in these general benefits was provided, however, an overall satisfaction was expressed by the majority of users in the ability of their radio systems to meet their needs. Nevertheless, a significant number were critical of performance for various reasons and would like to see improvements. The improvements most often mentioned in the responses:

- Better area coverage (34%)
- Better quality of equipment (22%)
- More privacy (10%)
- Telephone interconnect (10%)
- Less congestion (70%)

A conclusion of the INS study is that there is a marked orientation of GRS to rural business use, corresponding with the urban use of the land mobile services. The reasons for this seems to be closely related to the differences in rural and urban income levels. However, the greater congestion in urban areas is a limiting factor, and greatly reduces its effectiveness for managing a business and would also contribute to the lower urban penetration.

The Institute of Northern Studies (INS) study also addressed the question of user satisfaction and expectations. It is necessary to consider that since the survey was conducted in 1976, significant changes have been taking place. The GRS user population has more than doubled, a development which could change the picture appearing at that time. Adding to the increased congestion as a result of this growth is the rise in noise and skip interferences caused by increased ionospheric activity (FIGURE 1-4).

It has been predicted that in the United States the average range of CB radios will be reduced to 1/6 of their range at sunspot minimum (7) and the amount of co-channel interference will multiply tremendously. The user satisfaction index is found to change as a result of the degradation in system performance. Local congestion will also increase as a result of people making long distance contact.

As we see, range of communication can be regarded as the most serious limitation of GRS radio systems. Improvements in range by increasing power, or by increasing antenna gain by height (which are illegal) would only be marginal. It would not alter the inherent variation which occurs in signal conditions on a daily, seasonal or long-term basis, contributing to the poor reliability of this service. Alternatives have been proposed but these are not satisfactory solutions to the need for coverage which must eventually be met by an interconnected network of radio stations.

In the United States, CB radio is being increasingly replaced by private radio systems because of less congestion in the land mobile bands (38).

Accordingly, the GRS or CB users in both Canada and the United States are primarily private citizens or truckers who use their radios for personal reasons rather than for business. The exception is in rural Canada where CB is still a useful business tool.

The number of users in both Canada and the United States is approximately triple the number of land mobile users, i.e. 140 radios per 1,000 people in the United States and 60 radios per 1,000 people in Canada. Congestion is a severe limitation to serious use of this band in Canada and the United States, with Canadians experiencing co-channel interference from the United States during high sunspot activity.

1.5 Deployment of Mobile Radio by the User

1.5.1 General

In section 1.2, the value of radio and some criteria that could be used to compare the relative value of various system configurations was presented. Two underlying reasons for using mobile radio are economic and social. The INS study divides these into three categories: safety, efficiency, and convenience. Greater efficiency leads to direct cost benefit, while safety and convenience are primarily of social benefit. By examining system utilization, we can gain a better appreciation of value (social and economic) and of the meaning of spectrum utilization. This is needed when considering new system solutions.

1.5.2 Coordination of Activity

The main purpose for the vast majority of land mobile radio systems is to provide coordination of activity in what the INS report refers to as the "separation of work areas". This leads to improved efficiency and reduced labour and expenses (cost benefit) and faster completion of assignments (social benefit).

In the overall picture, convenience is of least importance at the present time. In some systems the major coordination is by centralized control where a dispatcher makes the job assignments and has the responsibility for the efficient allocation of field resources. Examples are police, ambulance, taxi, delivery, and maintenance services. In these services, although there is little need for direct interaction between field personnel except in special tactical exercises (e.g. police stake-outs), it is often desirable for personnel to monitor what is going on in the rest of the system, large taxi systems excepted (24). Where this is not a need, or where it is undesirable, selective calling is used and personnel may be addressed individually or in groups.

In other applications there is more interaction between field personnel than between the dispatcher and mobiles. In these situations a group is assigned to a common task (such as fighting a forest fire or repairing a power line) and must be in contact with each other at all times. The Dulmage report refers to this as inter-worker communication and claims that around 75% of system activity in in this mode rather than the dispatch or command and control mode. This conclusion conflicts with the INS results which showed that mobile to base ranked highest in frequency of call initiation (GRS 62%, private 47%). Mobile to mobile ranked second by GRS users and 3rd by private users. It is possible that the Dulmage results may have been overly influenced by a few very large systems users who responded (such as forestry and transportation). We estimate a 50-50 split between base-mobile and mobile-mobile communications.

This discussion has a bearing on future system design considerations and on channel loading requirements. Most systems must accommodate mobile-to-mobile communications over varying distances determined by the nature of the activity. More often than not, the required range is beyond direct vehicle-to-vehicle communications range, and must be achieved by converting the base into a repeater (see for example FIGURE 1-2). As to loading, characteristically dispatcher to mobile communications are short and concise in contrast to mobile to mobile which tend to be chatty.

Message lengths vary widely from one system to another, depending on the nature of the business, the communication mode, and the category of service. Quantification of this information is incomplete, but a consensus can be obtained by evaluating information from various sources (4,5,7). Reference 4 provides a rough indication of average message lengths for the various services:

- GRS 3 minutes
- Private 1 minute
- GLMRS 2 minutes

Average message length in a taxi system is typically 10 seconds, reduced to 6 seconds with computer-aided dispatch (24). In a dispatch system, the air time to complete an assignment, a regular sequence of events, is a convenient measure as used in the above example. Message length is a function of many factors, such as channel activity, voice vs. data information, repetition due to noise and interference and message content. Message length can be greatly reduced through the use of data. On the other hand, shorter verbal message lengths are found in urban rather than in rural systems because channels are less busy and the personnel under less pressure. We estimate, however, that an average message length for voice systems of 20 seconds for dispatch services is easily realizable. Mobile-mobile conversations will have longer messages, averaging one minute.

It should be apparent that channel access time and time to contact the vehicles are important parameters to be considered in designing a dispatch system. They add to the message length and therefore should be kept to a minimum. This point will be discussed in greater detail in subsequent sections.

In GLMRS systems, message lengths are characteristically longer than in private systems. Access and signalling time as a fraction of the total message length are therefore less significant in the GLMRS than in private systems. Earlier mobile and improved mobile telephone systems, for example, employed rotary dials while more recently designed systems employ DTMF. Automated systems, on the other hand, employ faster signalling techniques.

Accordingly, in the manner in which private radio systems are employed approximately one-half of the communicating is between a dispatcher and the fleet for coordination purposes while the other half is mobile to mobile or for "inter-worker communication". This applies also to the GRS users in rural Canada where system utilization is very similar to that of small private radio systems. Message lengths are considerably shorter in private systems than for GLMRS users by a ratio falling between 5 to 1 and 10 to 1 on the average. In designing new systems, it is important to know the approximate mix of the various types of users and utilization, since the channel capacity needed varies accordingly.

2.0 Assessment of Existing Radio Services and Available Alternatives

People use mobile radio to satisfy a variety of needs as discussed in Section 1. For the rural user, the saving of time and money is predominant, while emergency, convenience, and personal uses are secondary. This applies to CB radio as well as to the land mobile services. Urban users also regard mobile radio as necessary to the efficiency of their business activities with competition playing a major role. To the urban user, however, CB radio is primarily for convenience and plays a minor role in business activity.

When making a choice, the prospective user is concerned with the usual questions - which alternative will serve my purpose best? And how much will it cost? We have discussed existing services from the viewpoint of usefulness and value, and have provided some criteria for assessing the value of different services. The main concerns in this study are what choices are there for the user, and given the alternatives, which would the user choose? These questions will be discussed in this section, firstly by projecting the existing service trends, evaluating various new service alternatives, and finally by recommending a solution most appropriate to the rural user.

2.1 The Evolution of Existing Services

2.1.1 Private and RCC Systems

The nature of small private radio systems has not changed in any significant way in the three decades since mobile radio has been in common use in Canada. The earlier systems will have been upgraded with new equipment or expanded along with growth of the business, but remain in a simple, basic configuration. With large systems, the picture is entirely different. In the one case, such as a large urban taxi or police system, when it comes time to update (every 10 to 15 years) not only is the old radio and control equipment replaced by new, but advantage is taken of the latest technology as a means of improving efficiency and of reducing personnel. Some form of digital control scheme with or without the aid of computers is usually incorporated. Otherwise, a large system comprises a number of basic systems over a large area, serving a specific function (e.g. rural police, highways, forestry, etc). A changeover often leads to increased centralization of control and information storage, and a corresponding increase in complexity.

In either case, the trend is to add a number of additional features selected from a long list of available options such as:

- selective calling
- status reporting
- automatic identification
- facsimile
- teletype
- mobile terminal
- computer-aided dispatch

It has been indicated that 50% of private users have some intention of adding new facilities by 1980 (21). A cost premium is paid for these improvements and the technological gap between the large system which can afford the frills and the small systems which cannot becomes wider. The large system is still limited by design and becomes outdated.

The small private users could benefit by sharing in a common system configuration. One alternative is to share an RCC channel, where available, and benefit from the increased coverage. However, it is difficult and costly at present for the small private system user to extend his coverage progressively as his needs change. Once out of range of his base station, for example, or during off hours, his radio is useless to him. To compensate for this limitation, the user will often employ an alternative mobile radio such as CB or GLMRS (21). The potential for expanding the RCC concept to better serve small businesses is limited unless it is promoted on a large scale with full government support. Present licensing regulations and spectrum policies are immediate obstacles. To show the feasibility of a large scale service of this type would need substantial evidence of feasibility from a market and user cost point of view as well as technically.

2.1.2 GLMRS Evolution

Spectrum shortage in urban areas and cost in rural have been the deterrents to evolution in GLMRS services, which in Canada have changed only slightly over the years since it was first introduced in the early 50's. IMTS has been implemented in Canada to a very limited degree (e.g. in Manitoba) and is likely to go no further in the light of new techniques now available.

Alberta has had the largest demand for public mobile radios and has enlarged its system capacity by splitting the channel assignments (15 KHz channel spacing) which has allowed AGT to meet the demand until 1981.

The automatic mobile telephone system (or Access 450) which Bell Canada planned to implement has been delayed by the Challenge Communications case (25). Spectrum is also a major deterrent to proceeding with this scheme.

The telcos have still not produced a solution which would result in a large cost reduction, or which has an appeal to the many mobile radio users in the private and GRS categories who are dissatisfied. It is doubtful if the full potential of automatic systems will be realized until a more suitable approach is adopted. This will be discussed further in section 2.4.

2.1.3 GRS Evolution

The use of the General Radio Service band has developed into a state of disorganization, which is characterized by poor user behaviour, little discipline or policing by DOC, the lack of channel priority use and congestion in urban areas. To correct these problems, the DOC plans to introduce improved techniques for managing the band. Meanwhile, the impact of increasing the number of AM channels to 40 (SSB to 80) will never be fully felt because of the continuing increase in users and increased interference from the United States.

Proposed changes as recommended by Woods, Gordon are not likely to make the band more appealing to the business user. It is likely to remain essentially, what it has become in urban areas, a device for monitoring highway conditions, for tribal communications, a useful aid in emergency situations, etc. It will become less and less useful for business users even in rural Canada. Other alternatives are being proposed for serious mobile users who want low cost radio, which will be discussed further on.

Accordingly of the traditional mobile services there is little indication of any significant changes which would benefit the small system user. Many users find it necessary to employ radios in two or more types of service in order to get adequate benefit from mobile communications. Trends in the general land mobile service are towards streamlining, (i.e. greater automation) but new designs do not recognize the need for a universal service. It is still too soon to predict the long-term effects of proposed new bands for personal radio services in the United States (new CB and advanced new CB), however it is possible these services will adopt many cellular system concepts. Canada is likely to follow the United States trend in this regard. There is no really new alternative to the traditional services in Canada.

Some people have proposed the cordless telephone as a solution to the mobile telephone interconnect requirement if the range could be extended to include the area of a farm or business complex. We do not see this as being either probable or desirable. A cordless telephone is intended as an extension to the user's regular telephone, providing the convenience of being able to communicate from anywhere in immediate vicinity of his home or office without the encumbrance of a long cord. The transmitter power is below that for which licensing is necessary (i.e. in the order or 100 microwatts) and the range is very limited. A complementary fixed transceiver is interconnected with the subscriber's telephone line. The system operates in a duplex mode and provides all the normal functions of a telephone (dialling, ringing, etc). Telephone interconnection of cordless telephones is not yet permitted either in the United States or Canada.

The question of telephone interconnection from various types of mobile systems is one which has found a great deal of opposition from the telephone companies. Theoretically, any mobile system can be interconnected and can provide a cordless telephone type of service. However, preferential treatment in this regard in Canada is given to emergency services such as police and ambulance services. Many other systems are interconnected illegally. The resistance of the telcos is breaking down gradually on this issue, and they face the prospect of eventually allowing system interconnect, providing specified conditions are met.

Until recently, Bell Canada would not even allow customer owned mobile telephones to access the GLMRS terminals. However, the recent court decision in favour of Challenge Communications has overruled Bell's position (25). This is still a long way from opening the door for mobile systems in general to be interconnected.

In the United States according to International Research Development (IRD) (12) "... there is no doubt that AT&T has lost the interconnect battle resoundingly. Even AT&T has as much as conceded this point. Chairman John de Butts in recent speeches has drawn the interconnect line at one AT&T telephone handset that must reside in the home. Frankly, even this line is drawn arbitrarily and is not likely to remain".

Nevertheless, the ability to interconnect one's mobile system to the switched network would limit the user's access to within the coverage area of his base station. In the long run, the ability to access the network from any location would be the best answer, but will only be possible when universal standardized systems are available.

2.3 New CB and Canadian Alternatives

A number of studies have been carried out in Canada and the United States to evaluate the significance of the CB/GRS phenomenon, and to predict future needs and to recommend alternate solutions (12,13,14,26). The conceptual aspects of the proposed systems, as well as their technical parameters, are discussed below in relation to Canadian rural needs. Anticipated markets and prices are discussed in Section 6 of Volume 3.

2.3.1 New CB

The Federal Communications Commission (FCC) study report "Alternatives for Future Personal Radio Services" (14), and the IRD report "Citizen Band and the Future Portable Telephone" (12), provide a good indication of the thinking in the United States on this subject. The FCC's concern was mainly in the consideration of spectrum alternatives and technical parameters. Two alternatives were considered (see TABLE 2-1), one in the 220-220 - 225 MHz band and the other in the 894 - 947 MHz band. Indications are that the 900 MHz approach will be recommended officially, in which case up to 5 MHz will be allocated, FM modulation will be employed, and other RF parameters will be similar to those in the present 27 MHz band.

Some important proposals in system facilities were considered, such as automatic transmitter identification (ATIS), telephone interconnect, selective calling, the use of repeaters for extended range in rural areas, and even the possibility of integrating those services eventually into a cellular type of service. It is expected that microprocessors will be employed in the radios in the so-called advanced CB concept.

It will take two years after official rule making is completed in 1979 before equipment will be available on the market. IRD have looked more closely at their crystal ball and predict that as early as 1985 there will be a merging of CB and radio telephone in the cellular concept.

TABLE 2-1

New CB in the U.S. FCC Study/May 1978

Evaluation Criteria		Prediction	
		Alternative I	Alternative 2
		220 - 225 MHz	894 - 947 MHz
Spectrum Needed		1 - 5 MHz	2.5 - 5 MHz
Transmitter Power		4 watts	4 watts
Relative Range (Flat Rural Areas)		31 miles	23 miles
Modulation		FM	FM
Cost (Low Quality)	Basic	\$250 - \$350	\$312 - \$437
	Advanced	+ \$80	+ \$80
Time to Implement		6 months	2 years
User Compliance		Better than 27 MHz	Better than 220 MHz
Advanced Features		Special channels, repeater, Sel, calling, ATIS, Time limiting, possible cellular, TEL INT/CON, microprocessor	

It is quite evident from these predictions that the new CB will not be a carbon copy of the present CB service. In fact, it may become the personal telephone service. The IRD report does not discuss how this will come about, or how it will interact with the telco-offered public mobile services.

2.3.2 New GRS and Other Canadian Alternatives

Woods, Gordon expect urban congestion in the General Radio Service band to reach serious proportions in the 1980's, and that new spectrum will be required "in the 1983-90 time frame". With the kind of users studied by Woods, Gordon, congestion is not as serious a problem as it is in rural areas, where the effects of increasing skip interference will seriously limit the usefulness of GRS radio before that.

SED Systems in their study anticipate serious problems in the prairie regions and have studied alternatives suggesting that from a propagation point of view the 220 - 225 MHz band would be most appropriate (26). They propose two services in this band, one called New Mobile Service (NMS) for the general public, and the other Business Mobile Service (BMS) for business users (TABLE 2-2), in which the BMS would be allowed more transmitter power. Both reports recommend better management techniques, and the incorporation of ATIS.

The DOC reaction to the FCC proposal was a preference for the 220 MHz band as being more appropriate to the Canadian conditions because of lower population density distribution. However it is probable that the DOC will go along with the FCC decision. Meanwhile, the DOC is placing more emphasis on the managing of the present band, in accordance with the Woods, Gordon recommendations.

TABLE 2-2

New Service Characteristics - Citizens Band

	NMS	BMS
Transmitter Power	5	10
Licensing	General Public	Business Users Only
Frequency Band	220 MHz	220 MHz
Range (miles)		
M-M	3	5
M-B	8	18
B-B	21	63
Cost (Base and Mobile)		$1200-$1800

2.3.3 New CB/GRS Implications for Rural Canada

There is no doubt that there are better ways of meeting the need for effective mobile communication than the CB/GRS approach, although it has satisfied the needs of many small businessmen and farmers very well (4). The new service facilities predicted for the proposed new CB services (e.g. telephone interconnect and selective calling), would be helpful to present users, and would provide better value in improved flexibility and reduced interference. However, there are many limitations to this kind of service which could only be resolved through greater sophistication in system design. Limitations like full utilization of the spectrum, the elimination of harmful interference, minimal waiting times and wide area coverage. As pointed out earlier, these features are not available to the small user and won't be in any new GRS band unless provided through some form of central control.

Accordingly alternatives have been suggested as means of better serving present GRS users in rural Canada (i.e. New Mobile Service similar to New CB in the United States), or simply more management of the 27 MHz band. However, these only appear to be halfway measures which are not addressed to the specific needs of rural mobile users. They also make no innovative use of new equipment and system technology.

2.4 New Public Mobile System Alternatives

The limited growth of GLMR services in both Canada and the United States has been attributed primarily to spectrum limitations. To alleviate this problem the Canadian Telecommunications Carriers Association (CTCA), on behalf of the Canadian telcos, submitted a request to the DOC in 1975 for an additional 120 channels operating in the 406-430 MHz band (56) and this request has been included in the DOC consideration for spectrum revision in preparation for 1979 WARC conference.

Meanwhile, several telephone companies have been studying the alternatives for potential use of this spectrum should it become available and have developed plans for system implementation in anticipation of DOC approval. In general, the proposed systems are intermediate between the high capacity cellular concepts proposed by AT&T and others, and the automatic telephone systems such as IMTS and AMTS.

These new automatic mobile telephone systems are intended to serve the high congestion areas primarily, and those users who are prepared to pay a high price for the wide area telephone interconnect capability. Even the existing services provide coverage over a large percentage of rural areas in most provinces. However, very few subscribers are in rural areas because the service is too costly and because other mobile services are more suitable to their basic need for local communications.

The new proposals, if implemented, are not likely to alter this situation very significantly if the two primary limitations are not changed (i.e. if a signigicant cost reduction is not achieved and if the systems are not configured to serve the small system user). It is unlikely that this will happen. Thus the new services will not signigicantly improve rural communications.

Accordingly new public mobile proposals are aimed at serving the mobile telephone users more efficiently. This group will remain only a fraction of the total mobile market which, if included in these plans, could greatly increase the system utilization and spectrum efficiency. The various plans, in fact, do not even appear to have universal appeal among the common carriers.

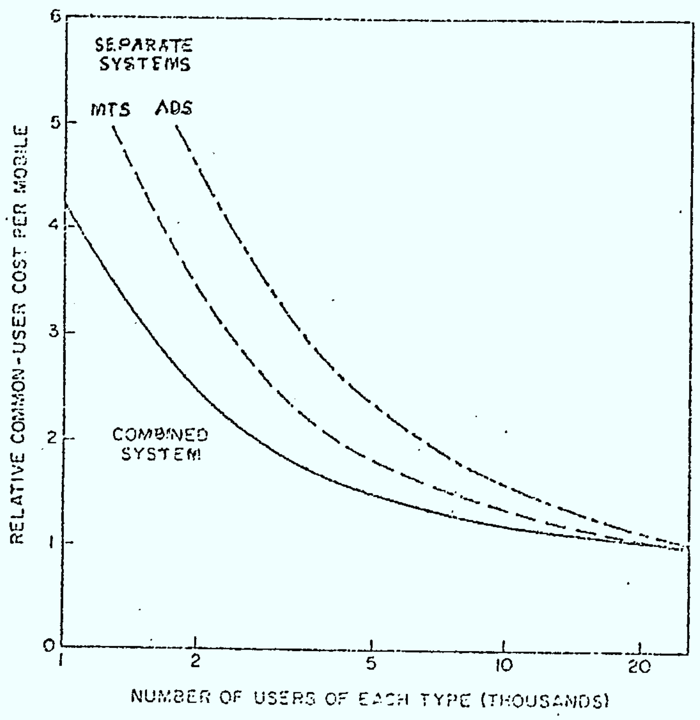


FIGURE 2-1

RELATIVE COST PER MOBILE
VS.
NUMBER OF USERS

2.5 Cellular Systems as Alternatives for Rural Communications

The possibility of extending cellular systems into rural areas is a long-term plan of the FCC and of industry in the United States. In its technical report on high capacity mobile radio communication systems filed with the FCC in 1971, AT&T recognized the need for small-scale systems serving 300 to 3,000 users (10) for the following reasons:

1. "Large-scale production of mobile units and other basic components will make a system compatible with the high-capacity system cheaper than either the MJ or MK system.
2. The large-city MTS customer will expect coverage when he leaves the city; the rural customer will expect service when he goes to the city.
3. The obsolescent MJ/MK system components will become more expensive to repair and to stock as time passes.
4. The 150 and 450 MHz bands may become crowded even in the more rural areas, if mobile service is more popular (on a per-capita basis) in rural areas than in cities.
5. The expected small size and modern design of the high-capacity mobile unit (as compared to MJ/MK) would prove universally acceptable to the customers."

The report discussed the increased cost per user as a function of the user density, showing that an exponential increase in shared cost would occur by extending the high density urban design into lower density areas (FIGURE 2-1) and proposed certain variations in system design to reduce these costs. Some of these changes included simplified control processor, deletion of hand-off capability, the pooling of all channels into a single access group and the use of directional antennas, higher powers, and greater antenna heights.

Nevertheless there is a cost penalty for low density systems even when simplification is applied. The most recent estimates of the rates for the AMPS system in high density areas indicate that subscribers will pay around $60/month for this service. Clearly, although high utilization may lead to a reduction in cost eventually, the rural subscriber could expect to pay around $100/month, which would rule out the possibility of serving any but the premium users as at present.

On this basis a direct application of high capacity systems in low density areas would not appear feasible without a great deal of simplification or without a complete modification to the basic design and the use of lower cost techniques in telephone network interface and radio terminal design.

In a study by Cornell University of users of conventional land mobile systems regarding the relative advantages of business radio in the United States versus those of cellular systems (27), the authors concluded:

"In general... management personnel did not view the Cellular system as an attractive and viable replacement for their present mobile communication system. The respondents indicated the service improvements obtainable with cellular systems were not sufficiently attractive to merit higher costs of the new system. It would appear that the developers of the cellular systems will have to either decrease the projected user cost or increase the benefits derived from the system if this group of current mobile communications users are to be considered a viable market."

Nevertheless many conventional mobile users liked some features of cellular systems presumably if available without reducing present benefits (e.g. the direct dialling capability), while the ability to reach a mobile employee without knowing his location was of least importance (TABLE 2-1).

AT&T in their original plans included a capability for automatic dispatch (ADS) and still anticipate this type of user to provide loading to their system. However, the original concept has been modified and no longer includes the conference capability because the FCC will not allow simultaneous broadcasting of voice transmissions to a group of mobiles in these systems.

Accordingly, current approaches to cellular systems design result in high cost to the user, and furthermore, are not likely to appeal to the major mobile user market. Since low cost and versatility of shared systems are particularly essential in rural areas, a more appropriate alternative is needed.

TABLE 2-3
Most Important and Least Important Feature of the Proposed Cellular System

Feature	Most Important	Least Important
Direct dial from all telephones	41.0	7.4
Adequate channels	18.1	11.7
Privacy	16.5	29.1
Vehicular and portable capacility	13.3	17.4
Ability to reach party without knowing his/her location	8.0	34.3

(i) ARCH Joint Venture

As an alternative to the high capacity cellular systems a consortium of United States common carriers submitted an application to the FCC for license to evaluate a high capacity digital system concept developed by Harris Corporation. The brief was ruled "defective" by the FCC on the grounds that it did not comply with FCC guidelines on developmental high capacity systems (see Section 4 - Volume 3).

ARCH proposed the use of high powered frontend base transmitters with digital modulation to provide 48 to 80 kilometres coverage to mobiles which would in turn employ narrow band transmitters equipped with 96 or more channels assigned by central control. FCC rejected the proposal for a number of reasons, e.g.

- not truly cellular
- not capable of evolution by cell division
- not suitable for nationwide service
- does not use narrow band (40 KHz) discrete channels
- employs a network of radio links to interconnect the base stations.

(ii) RYDAX Inc. Rural Telephone Service

The Rydax system was designed initially for rural subscriber use and employs discrete FM modulated channel trunking, interoffice trunk interface, recording of all transactions, and local interconnections of subscribers (28). The system has been evaluated by some Canadian telephone companies for use in their automatic mobile telephone systems, and in fact, is under evaluation by B.C. Tel for their medium capacity radio telephone system.

Mr. C. Rypinski of Rydax, who is one of the pioneers of mobile telephone systems and remains a leading authority in the field, has stated with regard to the state-of-the-art on radio telephone systems, "there are many common features between a rural and a mobile automatic radio telephone system. One gateway could serve for both functions."

"Many existing rural radio telephone systems would not be suitable for mobile services because of insufficient logic function in the remote subscriber station. With the availability of microprocessor logic, there is no longer any significant economy from the omission of any useful telephone functions. There is more economy from deferring obsolescense (28).

The Rydax approach, which is more advanced than other rural or subscriber systems, emphasizes decentralized control and is designed to serve a community of interest as its primary function with network interconnect secondary. For rural applications, this concept has a lot of merit and is an inexpensive approach. A large portion of the realistic thinking that has gone into this system is applicable to rural shared radio systems and should be considered carefully before launching into highly sophisticated but possibly overrated high capacity cellular systems.

(iii) Farinon SR System (App. II)

Although not applicable to mobile communications in its present form, the Farinon subscriber radio system is of interest because its main purpose is to serve small clusters of telephone subscribers in rural areas. The system proves-in for some of the more isolated communities in Canada, and shows promise in serving remote hydro stations and similar applications. It has not been found an economic alternative in serving dispersed households in low or medium density rural areas within the terms of reference of this study.

Accordingly, apart from the cellular concept and some aspects of new CB for personal communications, none of the other proposals have the potential for meeting a universal communication need.

3.0 Conclusions and Recommendations

3.1 The Need for Improved Communication Services in Rural Areas

In regard for the need for improved communication services in the rural areas of Canada, we have noted that:

1. All basic services are substantially inferior in rural parts of Canada. That is telephone, broadcasting, and mobile.
2. The rural population has the same basic need for telecommunications facilities as the urban population, and in many cases is more reliant on it.
3. Different techniques are needed in rural areas to compensate for distance and high cost.
4. Radio has a particularly signigicant role to play because its cost is relatively independent of coverage distance.

With regard to telephone subscriber service, we have concluded that radio systems currently available for rural telephone subscriber services are not cost-effective, except in special applicatons, and will not significantly contribute to the overall improvement of rural communications services in Canada.

3.2 The Unique Role of Mobile Radio in Rural Areas

In regard to the special and unique role of mobile radio in rural areas of Canada, we have noted that:

1. The greater travel distances and isolation encountered in rural areas give mobile radio a unique importance in the telecommunications scale of user benefits.
2. This overall importance has been demonstrated by the large demand throughout rural Canada.
3. The majority of Land Mobile Radio users are in the private category with less than 10% in the public mobile category (GLMRS).

We have also concluded that:

1. *Existing services are deficient when evaluated against the basic criteria for mobile communications.*
2. *Alternative communication concepts proposed to date would not, significantly alter the present situation in rural Canada.*
3. *More suitable alternative solutions are needed to serve rural areas.*
4. *A universal radio service to serve many types of users is feasible with today's technology, and could contribute significantly more towards upgrading rural telecommunications than any other approach. It could achieve this by making single party telephone service universally available, by making the future implementation of home data services possible, and by making mobile communications accessible throughout rural Canada.*
5. *This universal radio approach is very appropriate for low density areas, since it increases the user population and provices better utilization of fixed facilities with a very significant reduction in user cost. We therefore recommend: that a program be started for the development of a rural radio service employing the most advanced technology available and capable of serving mobile and fixed users for the transmission of voice and data messages.*

4.0 Nomenclature and Definitions

ADS	Automatic Dispatch Service
AMPS	Automatic Mobile Phone System
AMTS	Automatic Mobile Telephone Service
ATIS	Automatic Transmitter Identification System
AT&T	American Telephone and Telegraph Company
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
BCH	Binary Coded Hexidecimal
BER	Bit Error Rate
CAD	Computer Aided Dispatch
CMDS	Complementary Metal Oxide Semiconductor
COI	Community or Interest
CRC	Communications Research Centre
CRTC	Canadian Radio-Television and Telecommunications Commission
CTCA	Canadian Telephone Carriers Association
CTCSS	Continuous Tone Coded Squelch System
DMS	Digital Multiplex System
DOC	Department of Communications
DTMF	Dual Tone Multi Frequency
EIA	Electronic Industries Association
FCC	Federal Communications Commission
FFSK	Fast Forward Frequency Shift Keying

GLMRS	General Land Mobile Radio Service
GRS	General Radio Service (also known as CB)
ID	Identification
IMTS	Improved Mobile Telephone Service
INS	Institute for Northern Studies
LSI	Large Scale Integration
MTS	Mobile Telephone Service
MUSAT	Multi-purpose UHF Satellite
NTT	Nipon Telephone and Telegraph
RCCMRS	Restricted Common Carrier Mobile Radio Service
RCPG	Rural Communications Program Group
RID	Rural Interface Device
ROM	Read Only Memory
RRS	Rural Radio Service
SIC	Standard Industrial Code
SINAD	Ratio of Signal to Noise and Distortion
TTL	Transistor Transistor Logic
WARC	World Administrative Radio Conference

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A list of suppliers of radio and accessory equipment particularly related to mobile communication systems was compiled by SED Systems Ltd (26) and is shown in a condensed form in this Appendix. Suppliers of particular interest as potential contributors to new services include the following:

A1.1 Motorola Canada Ltd

Motorola is presently the largest supplier of land mobile radio equipment in Canada and the United States. Included in their product line is a complete list of radio and accessory products enabling them to supply every type of system including cellular systems, paging systems, PREP systems, CAD, mobile data, antennas accessories, GLMRS, GRS, and rural radio subscriber systems.

A1.2 Canadian General Electric

The mobile radio department of CGE has an extensive range of products, and is the second largest supplier of systems in Canada. Although the product line is not as complete as Motorola, General Electric is competitive with Motorola on most complex systems.

A1.3 International Systcoms Ltd

ISL is a Canadian-owned company which has specialized in rural radio and the general land mobile market. Their major customers are the telephone carriers with whom they enjoy good relations. They also have a significant off shore market.

A1.4 Pye Electronics Ltd

Pye is a subsidiary of Pye Telecommunications of England, and has a world-wide reputation in the mobile communications field. The company has extensive system capability, and is able to supply complex mobile radio systems. It has traditionally been strong in the Maritime provinces, and is probably the major supplier in that area. Pye Telecommunications have a line of rural radio subscriber equipment but has not been active in promoting it in Canada. Pye aslo supplies paging systems, community repeaters and point-to-point links.

A1.5 Canadian Marconi Co Ltd

Marconi has been in the mobile business in Canada since the early 1950's and has traditionally supplied the small system user but has occasionally entered into the more complex system field. However, Marconi's accessory products are limited, making it difficult for them to compete with the larger suppliers in this area.

A1.6 Mobile Data Incorporated

MDI is a new company which specializes in products in keeping with the trend to digital transmission in the mobile environment. Its progressive approach to data terminal design promises to place them into a leading position in this field as the importance of digital techniques in mobile applications increases.

A1.7 Farinon Sr Systems

This company was formed in order to develop and market a new 1.5 GHz subscriber radio system based on time division multiplex techniques. Although growth in Canada has been slow, the product has proven technically very acceptable and shows good promise on the international market.

A1.8 Other Companies

Other companies which have appeared in the Canadian market and which manufacture products in the nobile radio, subscriber radio, or mobile accessory fields are:

- Harris
- Glenayre
- Rydax
- E.F. Johnson

These companies can be expected to increase their marketing efforts and to be contenders for the market in future.

A1.9 GRS Suppliers

There are at present no manufacturers of GRS or CB equipment in Canada. This equipment is supplied through outlets of which Radio Shack and Canadian Tire are the leading representatives.

A complete list of suppliers and products of telephone equipment was compiled by K. Logan Associates, but is not reviewed here (29).

Special Systems Signalling Suppliers TABLE A1-1

Supplier Manufacturer	CTCSS	Tone Burst	Fixed	Mobile	AN I	Digital Address	Status Eqt	DTMF	MUX	Other Accessories
AVCOM INC	x	x	x	x						
BRAMCO		x			x	x	x	x		Printer, calling
CARDION (TRS)									x	MUX Accessories, alm
CHALLENGER	x		x	x						Dial
CODEP COMS.			x	x		x	x			Printer, Keybd
COMEX SYSTS INC										Paging Encoders rtmls Voice storage units (digital)
COM. P 1200										Tone dial, Phone Patch
COMS. Specialists	x									
COMS. Transp. Inc										Tone dial
Data Signal INc.			x	x	x			x		Keyboard control, Console Mobile TMLS, CAD
ELECTRONETICS										Switching, Port-a-tone
FARGO										Scrambling
Territronics	x							x		Filters, VEH Status
GEN (IM) Inc										Encoders, etc.
GLENAYRE	x									Tone dial, Railway Syst.
HARRIS										Paging Systems
IEC										Paging Systems
KUSTOM										Command Central Systs
PHILLIPS										Paging Systems
RYDAX						x	x			Mobile Status Systs
SECODE			x	x	x					2-tone dial, MTS TML, Systems status
SPECTRO CAB										Solar Panels
U.S. COMS CORP										2-tone dial
VEGA	x		x	x						Tone Eqt?

Suppliers of Radio - VHF, UHF, Microwave Equipment (SED Ltd) TABLE A1-2

Supplier or Manufacturer	Antenna Syst		Fixed and Mobile Radio		Paging		Hand Held Radio	Micro wave Radio	Sub-scriber Radio	ALN		Ampli-fiers	System Accessories
	ANT	Duplexers	VHF	UHF	RX	Access				RX	TX		
Bell-Howel (COMTAC)			x	x	x	x	x			x	x	x	MTS
CGE			x		x								
Capitol Coms													
CARDION (TRS)								x					Single & MUX
G.R. Electronics (CIC)		x	x									x	
E-Systems			Fx	Fx						x	x		Mobile Location Digital Alm
FARINON								x	x				
Genave Int'l	x		x	x									Inverters Enc-Dec
Harris			x	x									Community Rep Scrambling
Hoffman			x										AVM
IEC Electronics Corp			x	x	x		x						Signalling
Johnson			x	x									
Microwave Assoc													Accessories
Monitronics			x				x						Signalling Porta Peater
Motorola			x	x	x	x	x		x				MUX, Voting, Motorcycle
NEC America			x	x	x		x	x					MUX
MULTITONE					x	x	x						Signalling
PATHCOM	x		x	x	x		x						
PHILLIPS	x		x		x		x						
PYE			x	x	x		x						Digital Tx
RACAL			x										
RCA			x	x			x						
REPCO			x	x			x						
SDE			x	x			x						
SCALA	x		x	x									Scanning RX
FLEET COM													
ULTRACOM (AcScm)			x										
SINCLAIR	x	x											
S&T			x				x						

Suppliers of Radio - VHF, UHF, Microwave Equipment (SED Ltd) TABLE A1-3

	Antenna Syst		Fixed and Mobile Radio		Paging		Hand Held Radio	Micro wave Radio	Sub-scriber Radio	ALN		Ampli-fiers	System Accessories
	ANT	Duplexers	VHF	UHF	RX	Access				RX	TX		
SKYTRONICS													Attache case RT
SYST COMS			x	x	x		x						Duplex Portable
Thomson-CSF			x	x					x				
Toyo Radio Cd			x	x			x						
TPL			x										Power Amplifiers
VHE Engineering			x										Power Amplifiers
WABCO			x				x						Vehicle Control Syst Railway, Signalling
Wilson							x						
LOGAN INFO-RADIO													
Collins								x Digital					
FARINON									x				
Lorain Products								x Digital					Mobile Inverter
CMC													
Motorola													
Bayley Eng.													
Int. Systcoms									x				
Martin Marietta													
Avante								x Digital					
Telephone Products													Cordless Port-a-Phone
SED													Satellite Products

Previous related studies which have been carried out under the direction of the Department of Communications are described below with comments on their relevance to rural radio communications and this present study.

A2.1 "A Study of Rural Mobile Radio in the Prairie Provinces" by SED Systems Ltd, May, 1978 (26)

This study was a sequel to the INS study and examined some alternative to present services with the following specific recommendations:

1. The use of RCCMRS should be encouraged in place of private systems to permit better spectrum utilization and to reduce user costs.
2. Greater automation of GLMRS is needed with increased coverage and reduced costs.
3. The development of a new service to replace GRS is needed in order to provide users with more reliable communications while retaining the basic characteristics and low cost of GRS.

A2.2 "A Users Survey of Mobile Radio Services in Rural Areas of the Prairie Provinces" by the Institute of Northern Studies, University of Saskatchewan, August 1977 (4).

The use of mobile communications in the Prairie provinces was surveyed and evaluated from the point of view of socio-economic characteristics of users, complaints and frequencies, use patterns and future needs. The main conclusions were:

1. Most GRS systems are used for business purposes.
2. Costs are justified by the benefits in terms of monitory savings, social value and emergency value.
3. The low penetration of private and GLMRS services is correlated with their higher costs compared to GRS.
4. There is a need for a new and unidentified type of business radio system since none of the existing services are totally satisfactory.

A2.3 "A Study of User Needs in Mobile Radio" by Harry Dulmage Associates Ltd June, 1976 (21)

The study dealt with mobile radio as it is used throughout Canada. Users were divided into three categories, business and commercial, federal and provincial, and municipal. The main conclusions of this study were:

1. For business and commercial users

- a tendency for users to adopt a second type of service in order to better satisfy their needs.
- heightened interest in GRS expected to continue.
- Most users expect to need greater radius of coverage within the next five years. Possibly a nationwide service employing both dispatch and MTS features.
- need for reduced cost to stimulate growth.
- greater sophistication expected by most users.
- need for telephone interconnect.

2. For federal and provincial users

- private systems most prevalent.
- interworker communication exceed the mobile to dispatcher mode.
- average mobile system has 20 to 100 mobiles.
- increase in portable radios expected.
- large interest in an emergency channel.
- little use of other than voice communications.

3. For municipal users
   - private systems predominate.
   - dispatch and interworker communications both important modes.
   - selective calling more common in this group.
   - interest shown by police departments in CAD.
   - large interest in an emergency channel.

A2.4 "The General Radio Service - Prospects and Band Management Strategy" by Woods, Gordon & Co, May 1978 (13)

This study on uses and future of the General Radio Service band centered around the Toronto-Montreal areas, and dealt with growth, social significance and management policy. Main conclusions were:

1. Number of licenses issued each year is stabilizing and will remain fairly constant.
2. The license population will double by 1982/83.
3. GRS use exhibits a general trend toward a more communication-oriented society.
4. GRS is the major cause of interference toward FM and non-radio equipment.
5. GRS users were typically male, younger than average, married and had higher than average incomes.
6. Most users employed their radios for instrumental purposes rather than expressive purposes.
7. There was no clear explanation for the social value of GRS.
8. There is no simple enforcement policy which would satisfy all users.
9. Enforcement of discipline has been minimal due to inadequate resources and unclear regulations, etc.
10. Disbanding of GRS is out of the question.

11. A new band at 200 or 900 MHz is desirable with more sophisticated control mechanisms (i.e. ATIS).
12. More control at source is needed.
13. Recommendations of specific changes to the Radio Regulations Act were beyond the scope of the study however generally
    - new technical standards needed
    - changes in regulations needed on use of the band
    - more effort needed to enforce realistic regulations
    - etc.

A2.5 Other Land Mobile Equipment Studies

Several studies on the demand for land mobile equipment are listed below. Relevant parts of those studies are referred to in this report. In general, however, the studies represent trend analysis based on historic data and do not attempt to analyze future trends based on technological change. In our opinion, therefore, these reports are of interest only to the extent to which they describe the past and present situation.

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Government of Canada
Department of Communications

Gouvernement du Canada
Ministère des Communications

LICENCE REQUISITION

COMMANDE DE LICENCES

3	Land/Coast/Earth Station *Station terrestre/côtière/terrienne*	4	Mobile/Space Station *Station mobile/spatiale*	5	Aircraft Station *Station d'aéronef*	6	Ship Station *Station de navire*

T.C. T.		Company Code *Code de Compagnie*	Pref. - *Préf.* Reg. Adm. Off. *Bur. adm. rég.*	Licence Number *Numéro de licence*	To À	Licence Number *Numéro de licence*	No. of Licences *Nombre de licences*
	2 ☐ New Licence *Nouvelle licence* 6 ☐ Amendment *Modification* 1 ☐ Cancellation *Annulation* 3 ☐ Re-Issue *Redélivrance*	03	10	13		13	

Enter Name here if not to be keypunched
Inscrire le nom ici s'il ne doit pas être perforé

Enter a change of Company Code, Prefix or Licence Number below
Inscrire un changement de code de Cie, de préfixe ou de no de licence ci-dessous

Line - *Ligne*	22	29	32
19 C1			

Line Code *Ligne*					
M1 (19)	Name of Licensee - *Titulaire de la licence* (35) 22	1 ☐ Individual *Particulier* 2 ☐ Other *Autre* (57)	1 ☐ 2 ☐ (58)	Holder - *Détenteur* (22) 59	
M2 (19, 21)	Licensee (Cont.) - *Titulaire (suite)* (Optional - *Facultatif*) (35) 22				
M3 (19, 21)	Address (Street, P.O. Box, etc.) - *Adresse (Rue, C.P., etc.)* (Optional-*Facultatif*) (35) 22	Postal Code *Code postal*	Language *Langue*	Nationality Status *Statut de nationalité*	
M4 (19)	City, Town, etc. - *Ville* (26) 22	57	63 1 ☐ English *Anglais* 2 ☐ French *Français*	64	

M5 (19)	Station Location - *Emplacement de la station* (35) 22	Service Category *Catégorie de service* 57	Fee - *Taxe* If no fee enter "NIL" *Si sans taxe inscrire* 61	If Municipal SVC., enter NO. of STNS. *Si serv. munic., indiquer nombre de stations* 67	Vessel - *Navire* Type *Genre* 67	Tons *Jauge* 68	Std. Ind. Code (S.I.C.) *Code indus. rég.* 70

M6 (19)	Call Sign *Indicatif d'appel* 22	Coordinates - *Coordonnées* Latitude N 30 ° ′ ″	Longitude W ° ′ ″	If no coords., enter *Si sans coord.,* "NIL" *inscrire* 43	Antenna structures - *Bâtis d'antenne* Paint - *Peints (X)* 46	Light - *Eclaires (X)* 47

Additional Equipment (indicate with 'X') - *Equipement supplémentaire (indiquer d'un 'X')*

M6	Aircraft Markings *Marques sur aéronef* Ident.	A/C Class *Classe d'aéronef*	VHF	High Freq. *Haute fréq.*	SSB *BLU*	ADF *GONIO*	DME *EMD*	WEA Radar *Radar météo*	ATC Trans. *Trans. de CCA*	Doppler	Radio *Alt.*	Misc. *Divers*
	22	27	28	29	30	31	32	33	34	35	36	37

M6 (19)	Call Sign *Indicatif d'appel*	Power - *Puissance* kW Med. freq.-*Fréq. moy.*	VHF	Min. Equip. Std. *Normes min. d'équip.* (Code)	Equipment carried *Equipement à bord* Main *Princ.*	VHF	SSB *BLU*	Additional Authorized Eqpt. *Equip. supplément. autorisé* Auto Alarm	DF *GONIO*	RADAR	LORAN	DECCA	Place an "X" *inscrire un* Lifeboat *Embarc. de sauv.*
	22	30	34	38	39	40	41	42	43	44	45	46	47

M6	Continued *Suite*	Amendment Charge *Frais de modification*	Application Date *Date de la demande* Day - *Jr*	Mo. - *Mo.*	Yr. - *An.*	Issue Date *Date de délivrance* Day - *Jr*	Mo. - *Mo.*	Yr. - *An.*	Appendices to Licence *Annexes à la lic.*		Expiry Year *Année d'expiration*
		51	55			61			67		

Line *Ligne* No (19)	◆ (21)	Frequencies *Fréquences* HZ (22)	K M G	Necessary Band Width & Class of Emission *Largeur de bande nécessaire et classe de l'émission* (9) (32)	Power *Puissance* kW (41)	Authorized Communications/Conditions *Communications autorisées/Conditions* (33) (48)
01						
02						
03						
04						
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Originator - *Auteur*	Originating Section - *Section d'origine*	Actioned by - *Mesures prises par*	Page of *de*

A4.1 Introduction

The use of spectrum for communications purposes is an evolutionary one which is changing constantly in response to needs and technological advances. Here we examine the use of spectrum from the point of view of rural users to assist in forming a policy for rural mobile and subscriber communications.

A4.2 Present Use of Spectrum

The bands specifically allocated for non-military mobile communications in Canada are listed in TABLE A4-1 along with proposed additions (30). Allocation in the LF and HF bands (330 KHz to 27 MHz) are not of interest in this study and were not included in the table. Other frequencies used for mobile communications such as amateur and marine frequencies are not considered.

The number of mobile radios licensed for use in Canada is a partial measure of the utilization of the various frequency bands. These figures are plotted on a province by province basis in FIGURES A4-1 to A4-5 inclusive for the following bands:

FIGURE	BAND	FREQUENCY RANGE
1	1	27.225 to 50 MHz
2	2	138 to 150 MHz
3	3	150 to 174 MHz
4	4	410 to 421 MHz
5	5	450 to 470 MHz

Utilization of the GRS band on a regional basis is shown in FIGURE A4-6, indicating the increase in licenses over the calendar year of 1977. The increase over the period 1972 to 1978 is plotted in FIGURE A4-7. It is estimated that these figures only represent about 70% of the total number of radios active in the band. In all cases, the information is plotted as

TABLE A4-1

Land Mobile Frequency Allocations

Mobile Band	Frequency Band (MHz)	Channel Spacing	Approx Number of Channels	Modulation Technique	Regulated By
GRS	26.920-27.410	10 KHz	40	AM, SSB	RSS 136
Lo Band VHF	27.23-50	20 KHz	1120	FM, PM	RSS 120, 121, 119 139
Hi Band VHF	138-144 150.8-174	30 KHz	200 770	FM, PM FM, PM	RSS 120, 121 119 , 126
UHF (Existing)	410-420	25 KHz	400	FM, PM	RSS 105, 119 , 120,121
UHF (Proposed) to be shared with radio astronomy & mobile satellite	406.1-410		156 (assuming 25 KHz spacing)		
UHF (Proposed)	420-430		400 (assuming 25 KHz spacing)		
UHF (Existing)	450-470	25 KHz	800	FM, PM	RSS 119 , 105 120,121
Microwave - to be shared with broadcasting	806-890				

a log/linear relationship enabling comparison of the trends with a constant rate of increase (or decrease) and extended to the end of 1979.

With reference to the various bands, we observe the following:

1. GRS band (FIGURE A4-7) has a high rate of increase levelling off in 1977-78. Maximum increase of 140% occurred in 1976.
2. Band 1 (27 - 50 MHz) has a fairly high growth rate (10 - 20 %) and remaining constant.
3. Band 2 (130 - 150 MHz) has a high increase prior to 1974, reflecting the recent availability of the band. It then tapers off to a modest but steady increase in most provinces.
4. Band 3 (150 - 174 MHz) constant or increasing growth rate in most provinces (diminishing in Ontario).
5. Band 4 (410 - 421 Mhz) high rate of increase in 1974 and 75, diminishing in 1976. However, there is too little data to predict a trend.
6. Band 5 (450 - 470 Mhz) showing a high but diminishing rate of increase in all provinces.

Surprisingly the band which shows a consistent rate of increase is the VHF low band. The general preference for VHF high band is evident in FIGURE A4-3 where we see a constant or rising rate of increase except in the provinces of Quebec, Ontario and British Columbia, where the reduced rate is due to the congestion in the major urban areas of Montreal, Toronto and Vancouver. The high rate of increase in band 5 (in excess of 20%) between 1974 and 1976) compensates for this trend.

A4.3 Application of Mobile Frequency Bands in Rural Areas

The VHF hi band has been found to be the most useful band for mobile communication in the past as can be seen from the relative quantities in use (FIGURES A4-1,3,5). For example, in Ontario in 1976, there were 50,000 hi band mobile radios licensed compared to 11,000 low band and 10,000 UHF. The primary reason for this preference for the 150 MHz band is that it consistently provides the best coverage in the majority of applications.

The VHF low band provides better coverage in rural areas where it finds its largest application, particularly in areas where coverage is limited by distance rather than by terrain variations. Low band is more popular in the Prairies than in British Columbia, for example, as can be seen from FIGURE A4-4. However, many users prefer hi band VHF in rural areas in spite of its coverage limitations for a number of reasons, e.g.

- less sensitive to noise and skip interference
- less compatible with urban systems
- more consistent and predictable in performance.

These large province-wide systems tend to employ VHF hi band in rural areas (e.g. police forces, highway departments, common carriers, etc). There are exceptions, such as the Ontario Provincial Police, who still use low band VHF.

The UHF band (450 - 470 MHz) is rapidly gaining in use as can be seen by the large rate of increase in the last five years (FIGURE A4-5. This is mainly a result of the congestion in urban areas in the 150 MHz band. The UHF band is as satisfactory for communications in urban areas as the VHF hi band even though propagation losses are greater. The following factors offset the higher propagation loss:

1. Better effective receiver sensitivity due to lower noise levels in the UHF band.

2. Better penetration around large buildings due to higher reflectivity (and less absorption) in the UHF band.

In rural areas, system performance in the UHF band is definitely inferior to that in the VHF hi band since the above factors are not generally present and coverage is limited mainly by propagation conditions. Typically, the area covered by a UHF base station would be one half of that of a VHF base station with the same system parameters.

The microwave band (906 - 890 MHz) will not be available in Canada until a policy has been established based on negotiations with the FCC and the broadcasters. The band is allocated to television broadcasting (channels 70 - 83) at present. However, as in the case of 450 MHz it is more suited to urban communications than to rural and is particularly well suited to small cell, high capacity systems.

The GRS or citizen's band (27 MHz) is the least desirable for serious system applications because of the limitations of noise, skip interference, low power and congestion. Nevertheless, it is the most heavily loaded band, as seen from FIGURES A4-1 to A4-6 (i.e. 1.4 million estimated users share 40 channels compared to 250,000 users on 3290 channels). Skip interference and ionospheric noise increase dramatically during peaks in the sunspot count with a net reduction in the effective range of this equipment.

A4.4 Rural Radio Spectrum Needs

We will discuss in Volume 3 the spectrum needs for an integrated rural radio service serving fixed and mobile telephone subscribers and private mobile system users.

To serve this market adequately, a network of radio stations interfaced with the telephone network will be needed. A substantial band of frequencies will be required. The 6 MHz or so of bandwidth to fill this need would have to be available and compatible on a country-wide basis.

The band most suited for this purpose must be high enough in frequency to be free from noise and long-range interference and low enough in frequency to provide the needed coverage economically. For a strictly rural system, any frequency above about 100 MHz would meet the noise criteria (FIGURE A4-9). However, noise levels vary and can be a problem even in rural areas at much higher frequencies depending on local conditions, for example new high voltage transmission lines or heavily travelled highways. A more appropriate design guide would be the noise levels experienced in suburban areas (FIGURE A4-9). In practice, any of the present or proposed mobile bands from 138 MHz and up would satisfy the rural system from a noise standpoint.

Other frequency dependent factors are long-range skip and atmospheric effects (e.g. ducting). These effects become less significant from the point of view of co-channel interference with increasing frequency and at 400 MHz are totally unimportant.

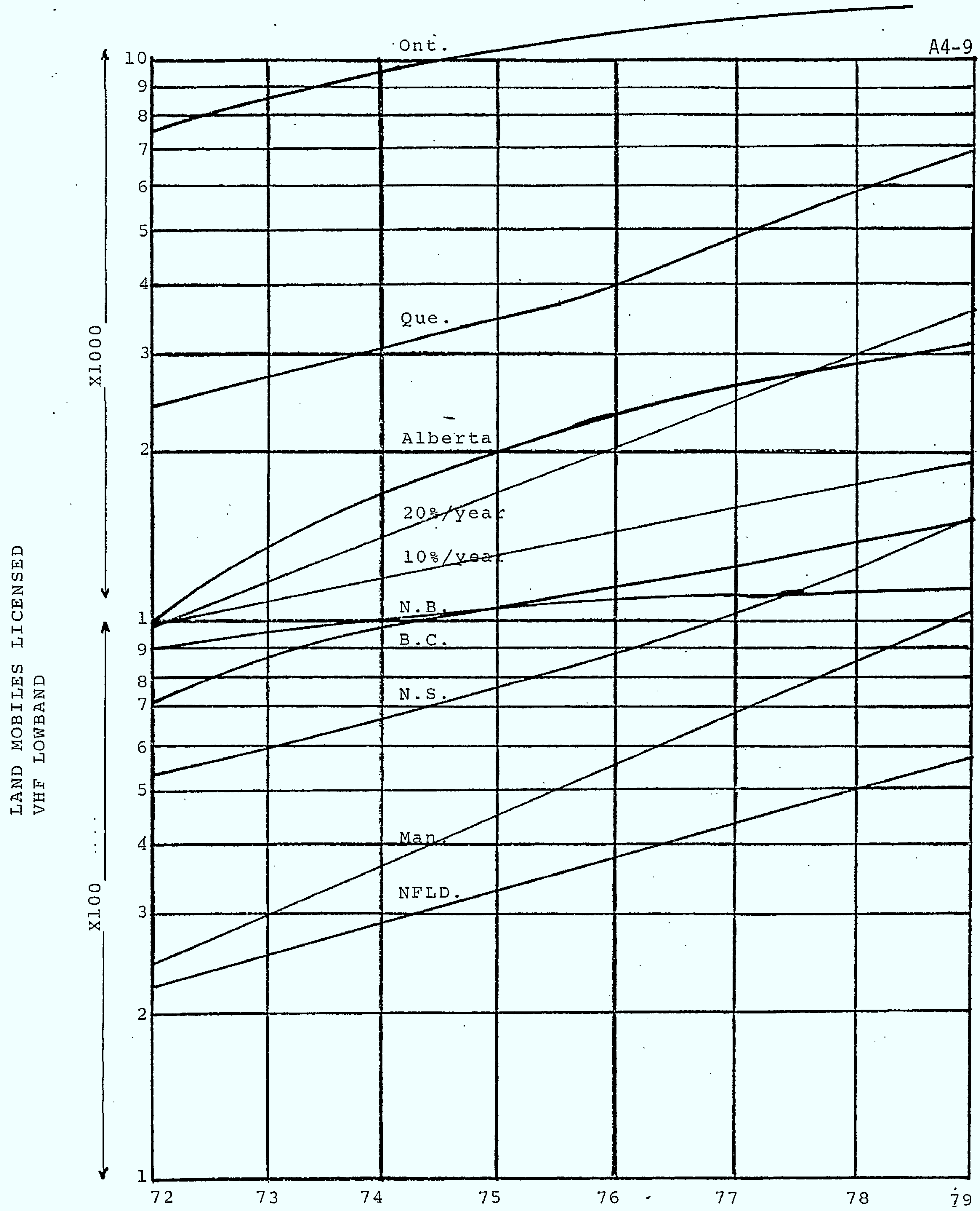
The availability of frequencies in the existing mobile bands is a function of geographic location and the method of utilization. In the major metropolitan areas of Montreal, Toronto and Vancouver, virtually all frequencies in the VHF hi band and UHF band are in use by Canadian or United States users and there is no possibility in the near future of freeing a sizeable portion of spectrum in these bands for any new service even though a more efficient utilization could be achieved by improved system techniques. Even in the smaller cities and towns any move to carve out a portion of these bands would result in a great deal of expense in relocating existing systems.

The only frequency band that is potentially available is 406 to 430 MHz as proposed in the "Discussion Paper on Spectrum Allocations". Occupancy of the 410 - 420 MHz portion of this band is shown if FIGURE A4-4. Only in Quebec and Ontario was there a signigicant number of allocations in this band, and although numbers are small in comparison to the other bands, the allocations are spread out so that no significant portion is free for a particular application.

Of the proposed extensions to the band, 406.1 to 410 MHz would be shared with radio astronomy on a secondary basis and 410 to 420 MHz with field services on a primary basis. The two radio astronomy sites are located in Algonquin Park and near Penticton, British Columbia and must be protected. A radius of 320 to 640 kilometres has been suggested as the minimum protection distances. However, this should be further evaluated on the basis of the proposed utilization of these frequencies before any rigid rule is established.

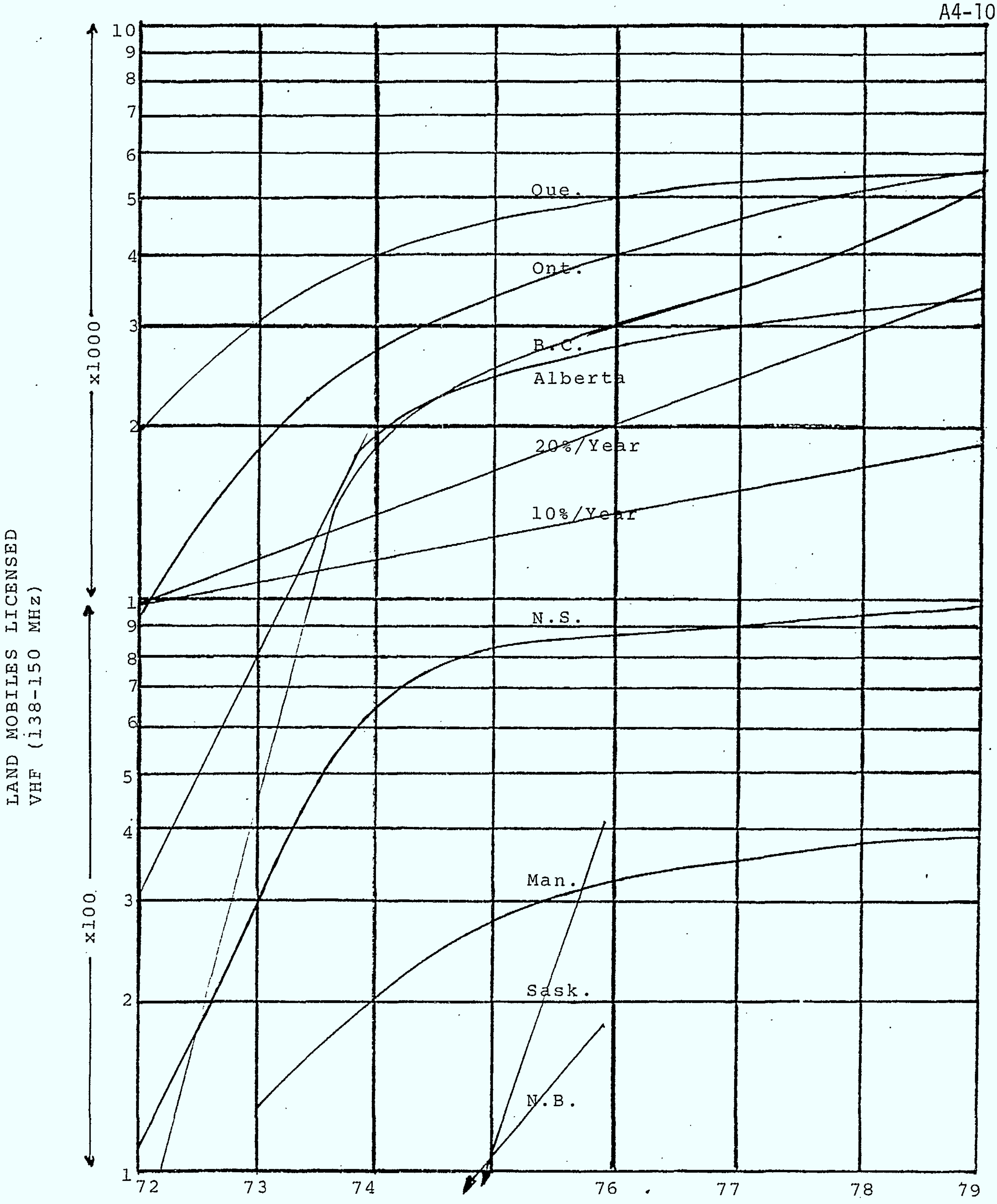
The 420 to 430 MHz band is presently assigned to radio location and amateur radio and under the new proposal would be primarily used for mobile applications. However, the band is used by the United States for high power surveillance radar and the degree of interference this may cause to systems operating in the band is unknown.

From the point of view of the proposed rural program, 406 - 430 MHz would be the most suitable band in which to carry out a field trial. The suitability of this band has been discussed and there is no question that it would be available in most of rural Canada. From a practical point of view, it would cost much less to implement a system at 400 MHz than at 800 MHz. It should also be considered that the telcos, specifically MTS, AGT and B.C. Tel have already devoted much time and expense in evaluating alternatives and designing systems for proposed new public mobile service to operate in this portion of the spectrum. This work would be valuable in the proposed field trial.



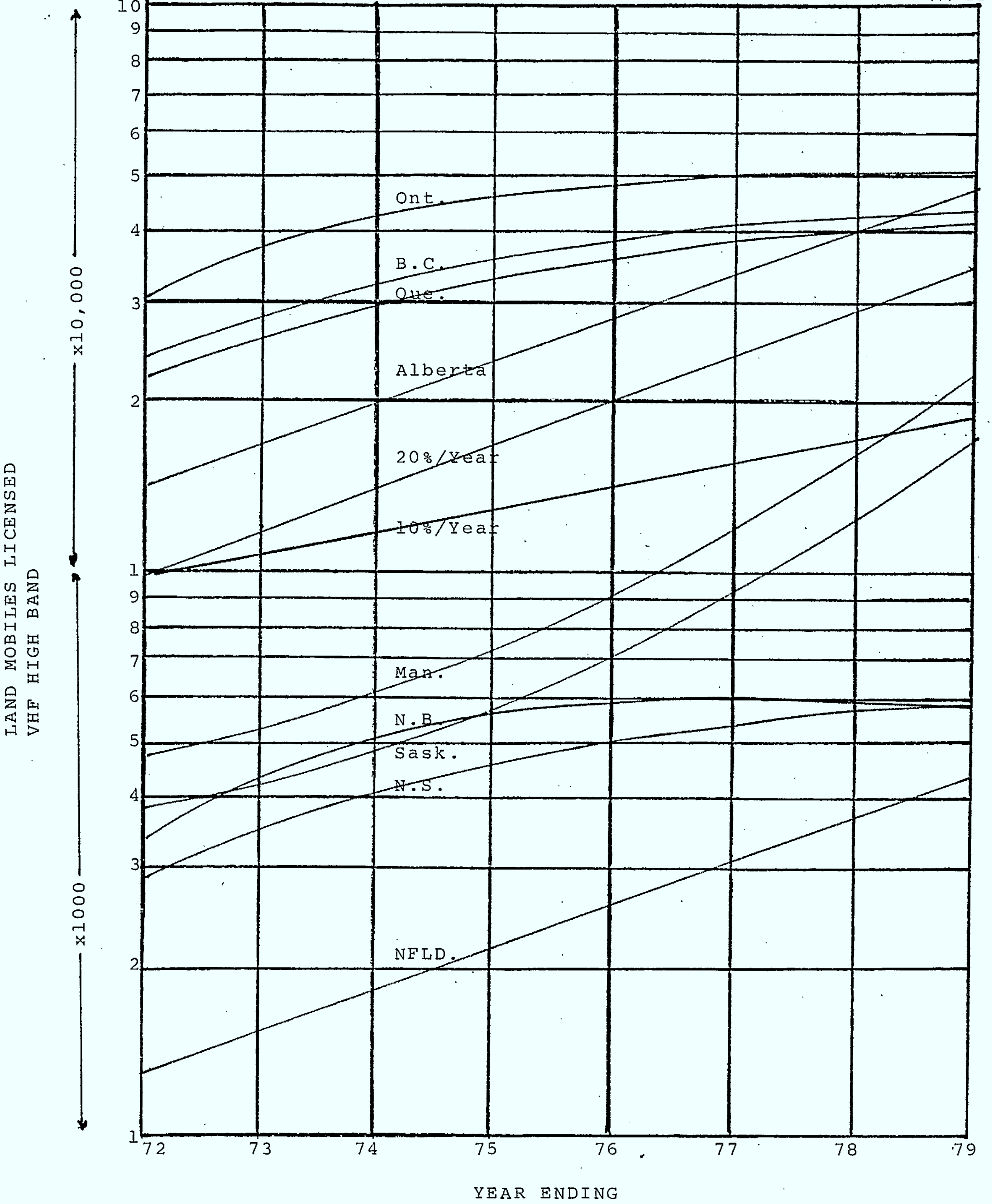
LAND MOBILES IN THE 27.225 to 50 MHz BAND 1

FIGURE A4-1



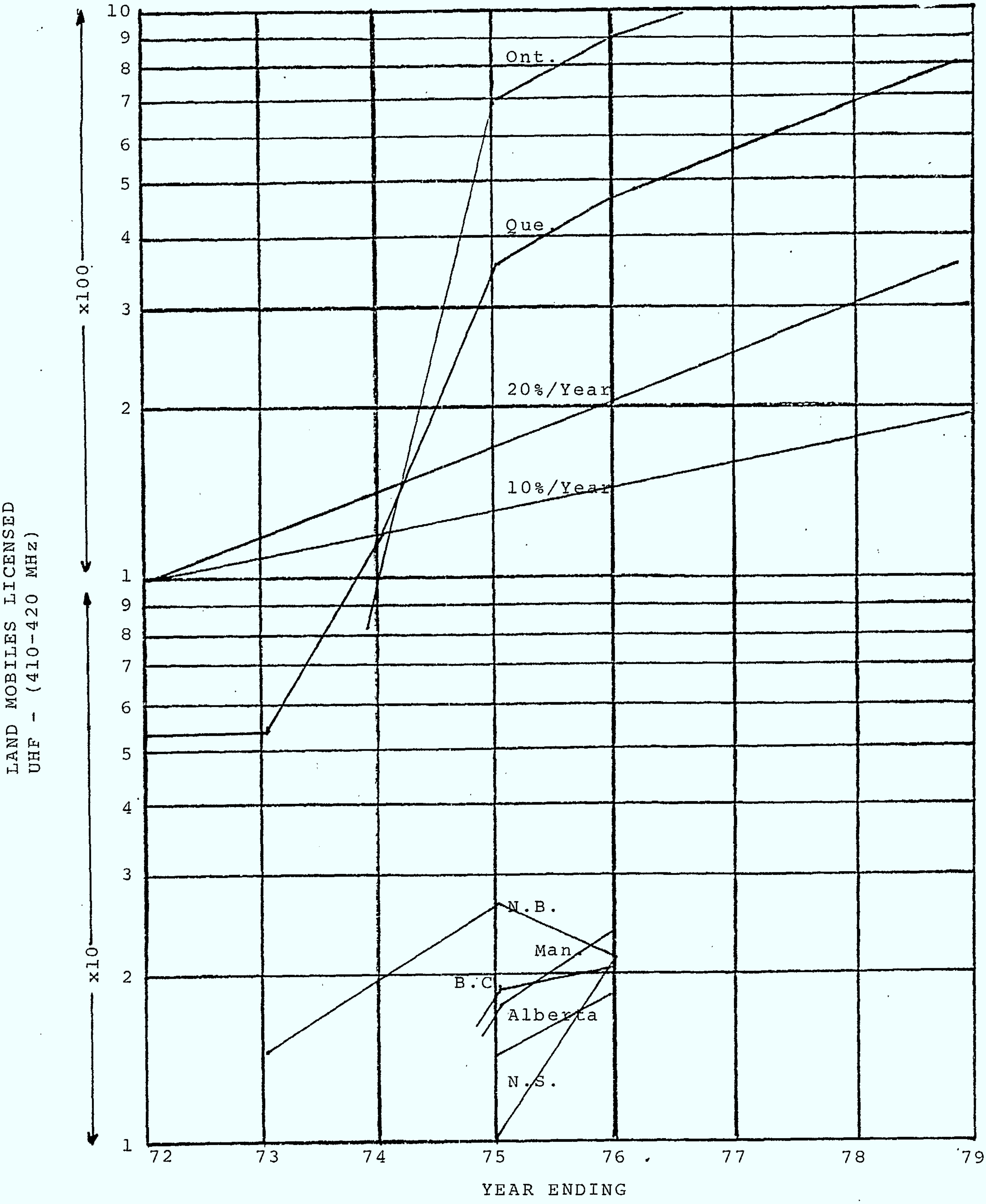
LAND MOBILES 138-150 MHz BAND 2

FIGURE A4-2



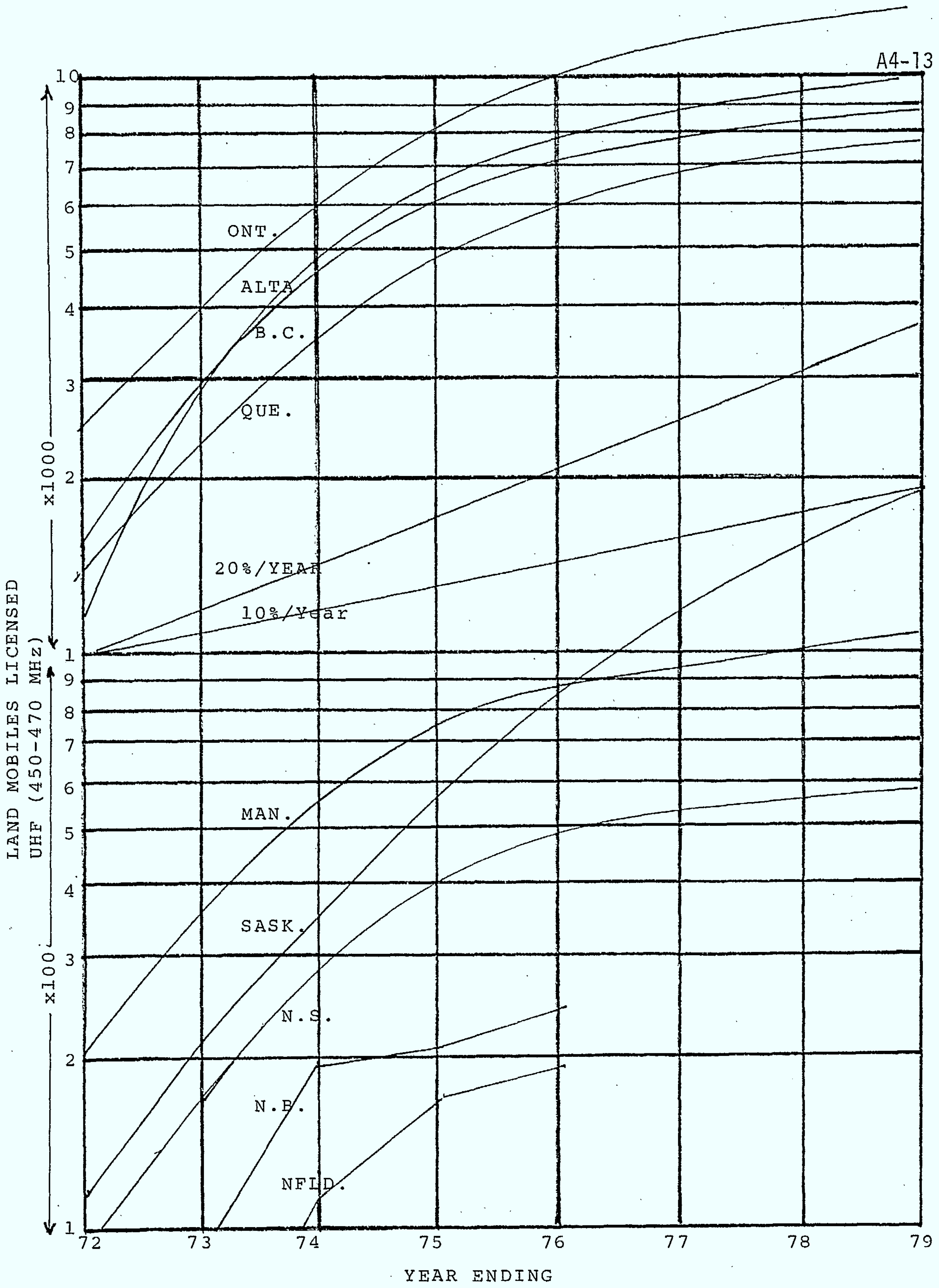
LAND MOBILES 150-174 MHz BAND 3

FIGURE A4-3



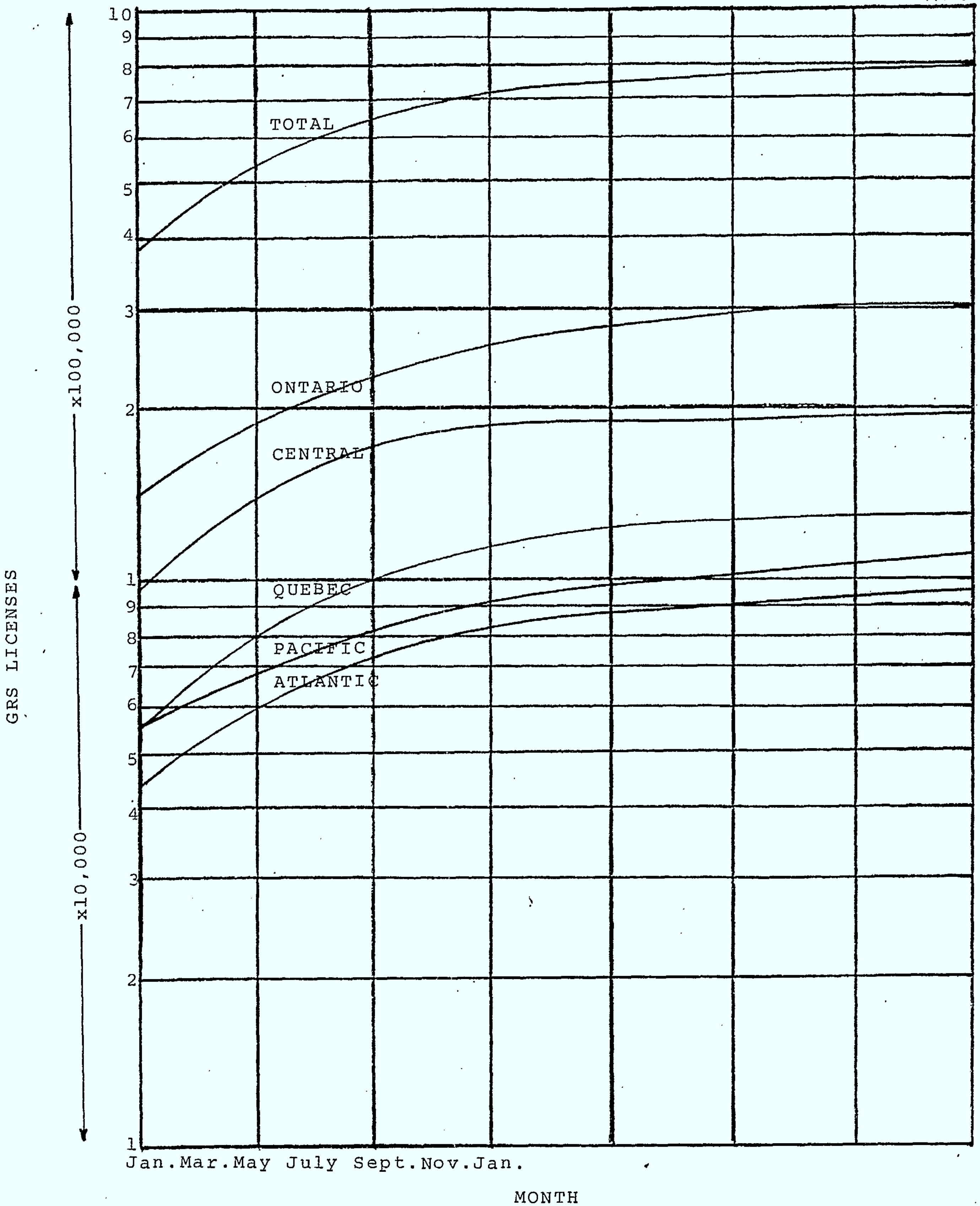
LAND MOBILES 410 to 420 MHz BAND 4

FIGURE A4-4



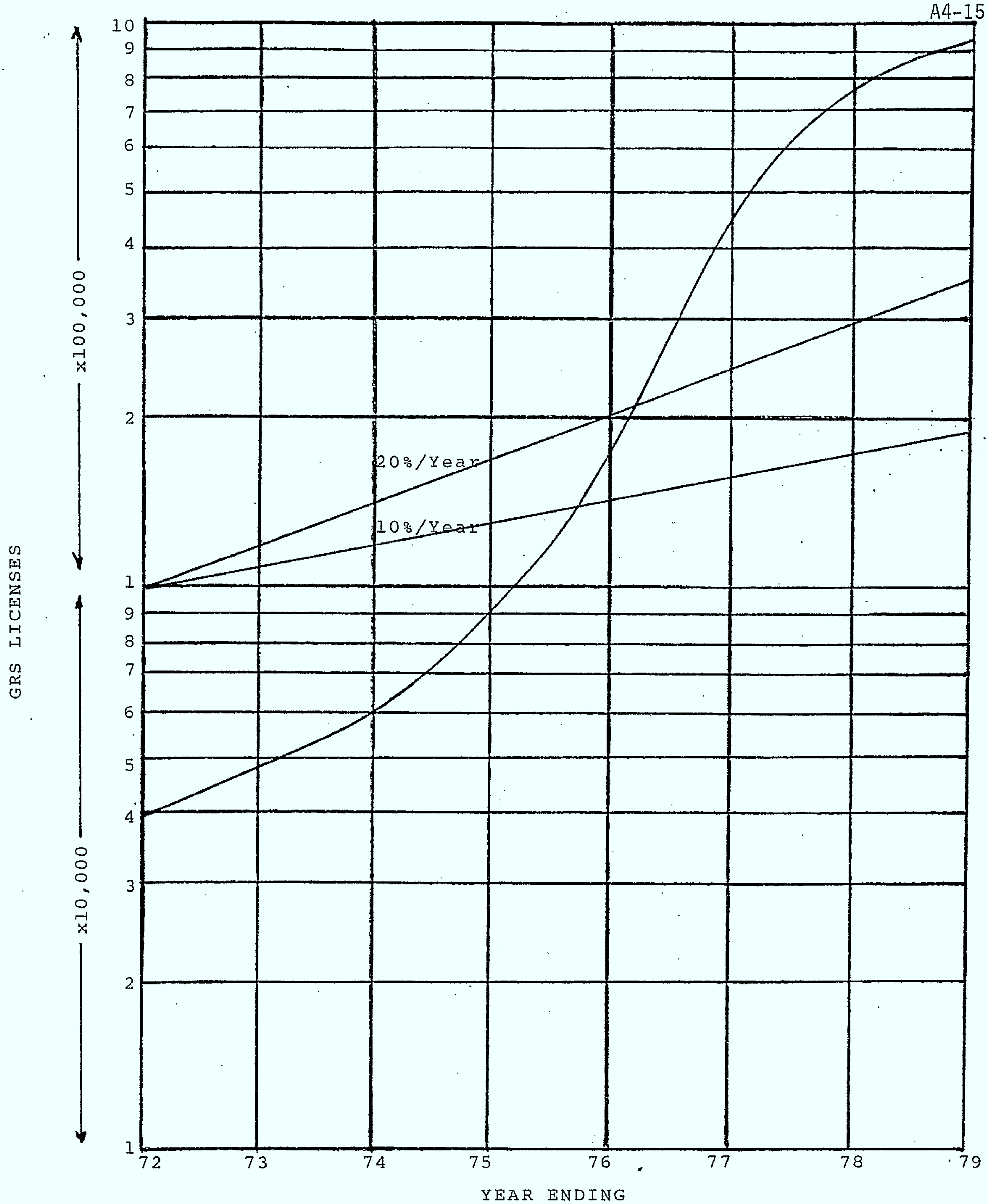
LAND MOBILE IN THE 450-470
MHz BAND 5

FIGURE A4-5



RADIO LICENSES BY REGION GENERAL RADIO SERVICE BAND
27 to 27.225 MHz 1977-78

FIGURE A4-6



RADIO LICENSES GENERAL RADIO SERVICES
BAND 27-27.225 MHz

FIGURE A4-7

2-1

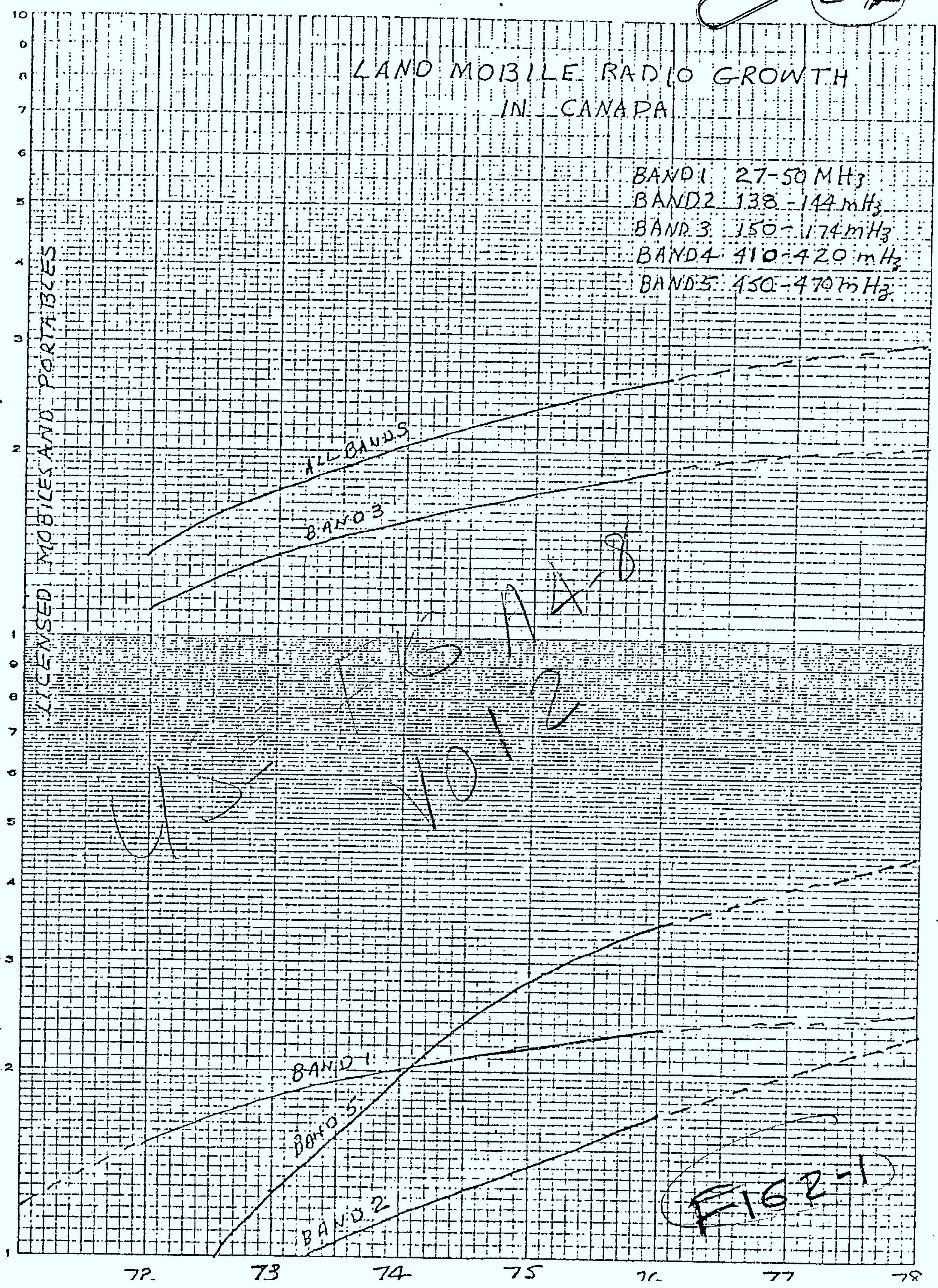
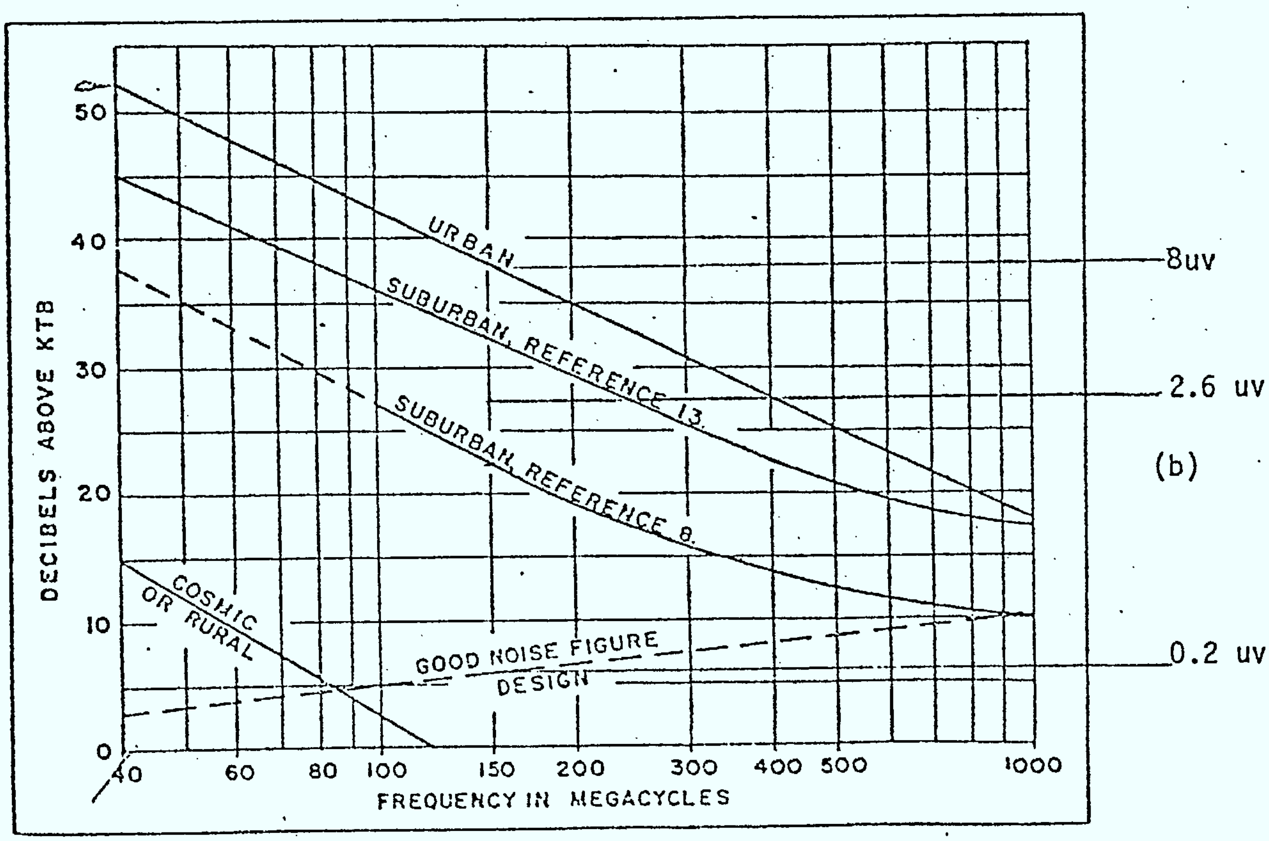

LAND MOBILE RADIO GROWTH
IN CANADA
BAND 1 27-50 MHz
BAND 2 138-144 mHz
BAND 3 150-174 mHz
BAND 4 410-420 mHz
BAND 5 450-470 mHz
X 100,000
X 10,000
LICENSED MOBILES AND PORTABLES
ALL BANDS
BAND 3
BAND 1
BAND 5
BAND 2
73
74
75
77
78

FIG 2-1



MEDIAN INDIGENOUS NOISE

Median indigenous noise.

vs.
FREQUENCY

FIGURE 4-9

A Feasibility Study of Rural Radio Communications

Volume 3

A High Technology Solution

Study performed for
Rural Communications Program Branch
Department of Communications
Government of Canada

by Comdat Telecommunications Inc.
formerly L. Lee Associates
Ottawa Canada

March 1979

Section 2

Blueprint for Developing a Rural Radio Service

Section 3

Spectrum Needs and Alternatives

Section 4

New Technology And Rural Communications

Section 5

Alternatives for Implementing a Rural Radio Service

Appendix 2

Propagation Models

1.0 A New Approach to Rural Communications

1.1 General

In spite of the fact that the existing mobile services are far less than satisfactory to the rural user, there is widespread use of mobile communications with an overwhelming emphasis on the general radio service band because of its low cost. Mobile radio is obviously essential in rural areas. Why not, therefore, design a service which fully addresses the rural needs? Is there any valid reason why a service cannot be provided which would enable a person to communicate from almost any rural location and not be prevented by the inherent limitations of one of the existing services?

The need for alternatives has been stated in various other reports without offering any significant solutions. The possibility of applying high technology to the solution of rural communication problems has been passed over as impractical. The usual comment is that they must be applied first in high density (urban) areas. We take the opposite view in this study - that is the new technology is the answer to rural communication needs where conventional (urban) solutions have failed.

The question was raised earlier as to how the small private user can benefit from the technological revolution. Large systems (i.e. those operated by governments and large industry and large urban systems) can benefit because they have the financial resources to incorporate new concepts and economy of scale justify the adaptation of complex control systems to improve the efficiency of their operations. Owners of small businesses cannot benefit from advanced technology as long as their options are limited to presently available services. A new alternative is needed for these users.

Accordingly there is a need for a new radio service for rural areas which will enable people to benefit from new technology. This will make better use of their resources by increasing productivity, by reducing lost time and travel costs, and placing them in a more competitive position with their counterparts in the urban areas.

Since individuals or small businesses cannot readily benefit from new technology through their own separate resources, the alternative is for society in general to provide the service which they can share, as in the case with the telephone systems, electric power distribution, and the highway system. A universal radio distribution system would serve a similar function, and meet an important need.

The General Land Mobile Services, provided by some carriers, partly, fulfills this function. Improved services which are in the planning stages may alleviate the present situation somewhat. However, the kind of service provided by the telcos does not perform the main function for which mobile radio is used, and is not the complete answer.

It is proposed, therefore, that a new type of radio service be developed: one which can serve the majority of rural residents in the most effective way. The service should incorporate a high level of technology to be fully effective, and should provide the following capabilities:

1. Capability of expanding the user's coverage area as needed to keep pace with his changing needs.
2. Consistent reliability in range and quality of communications.
3. Low blocking probability for fast access to the system a large percentage of the time.
4. Capability of communicating instantaneously with a fleet of vehicles involved in a common activity.
5. Capability of communicating via the standard telephone network with any telephone subscriber or other mobile radio user.
6. Capability of accessing available data services to meet the user's particular need.

7. An emergency facility which would enable the user to quickly obtain help when stranded or in an accident at an isolated spot.

8. The possibility of using the radio service for the coordination of fleets of mobile vehicles and personnel over a large area.

It is recommended that a versatile rural radio service be developed, having all these capabilities, and be available to any person who wishes to subscribe to the service. A proposal for such a service is included as the Section 2 of this volume.

Accordingly, it is recommended that a new radio service to serve a variety of rural users and some categories of urban users should be developed. One approach is outlined in the next section of this study. Other approaches may be more appropriate. Nevertheless here is a large opportunity to apply new technology using Canadian talent and other Canadian resources.

2.0 Blueprint for Developing a Rural Communication Service

2.1 Introduction

We discussed in Volume 2 the unique role which radio plays in telecommunications when applied to mobile communications. There is simply no other practical way of maintaining communications with persons or vehicles in motion. The importance of this fact, relative to the needs of the individual, can be measured by the benefits he receives in the form of cost savings, convenience and social value.

Attempts to quantify these benefits are continually being made by radio equipment manufacturers, user groups and in independent studies. Fleet owners, for example, measure the value of radio in terms of the reduced number of trips, with resultant savings in man hours and vehicles required to do a given volume of work. They also frequently refer to the improved work performance by workers who feel more closely identified with the organization because of having radios in their vehicles. Ambulance service operators measure the value of radio by the reduced response time required to deliver an accident victim to hospital and by the improved care given to the victim en route.

Thus each user measures the value of the radio system by a different criteria which nevertheless must translate into a cost benefit.

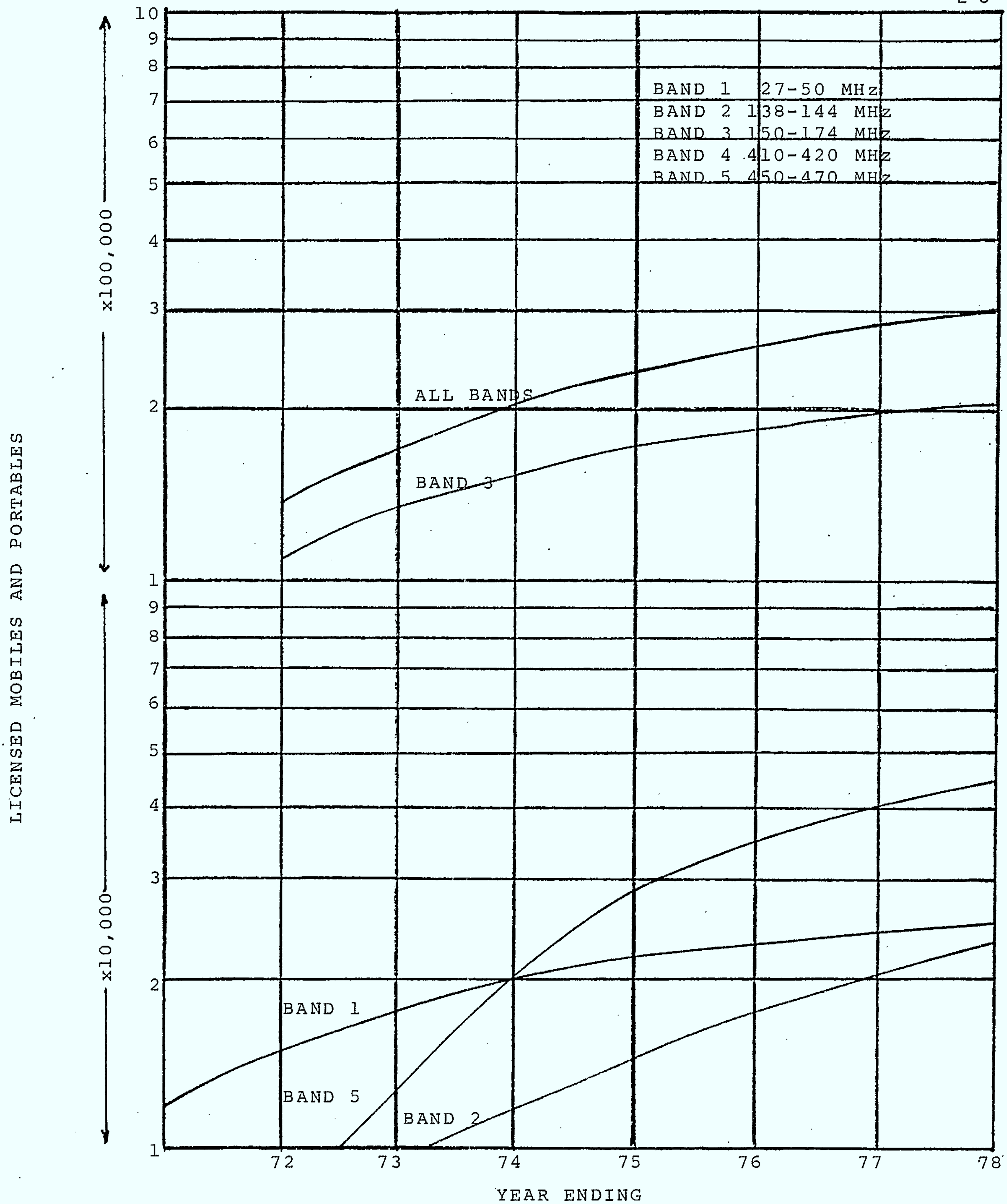
A more objective measure of value is applied by the spectrum policy maker who, although concerned about the user's need, is also aware of the limited spectrum and the need for an equitable distribution of this resource. One approach is that suggested by Eugene Rostow that the right to use spectrum should be determined by the marginal theory of value (6). However, traditional usage of spectrum is inefficient, and new concepts are being developed which allow a larger user density for a given portion of spectrum. The larger market possible will lead to lower costs to users - even lower if a high degree of system standardization can be achieved.

Until recently, only organized businesses or government funded organizations plus a relatively few individuals could afford mobile radio systems.

Accordingly, the increase in the use of radio, although significant has been steady and predictable (FIGURE 2-1), but the penetration has been limited by cost.

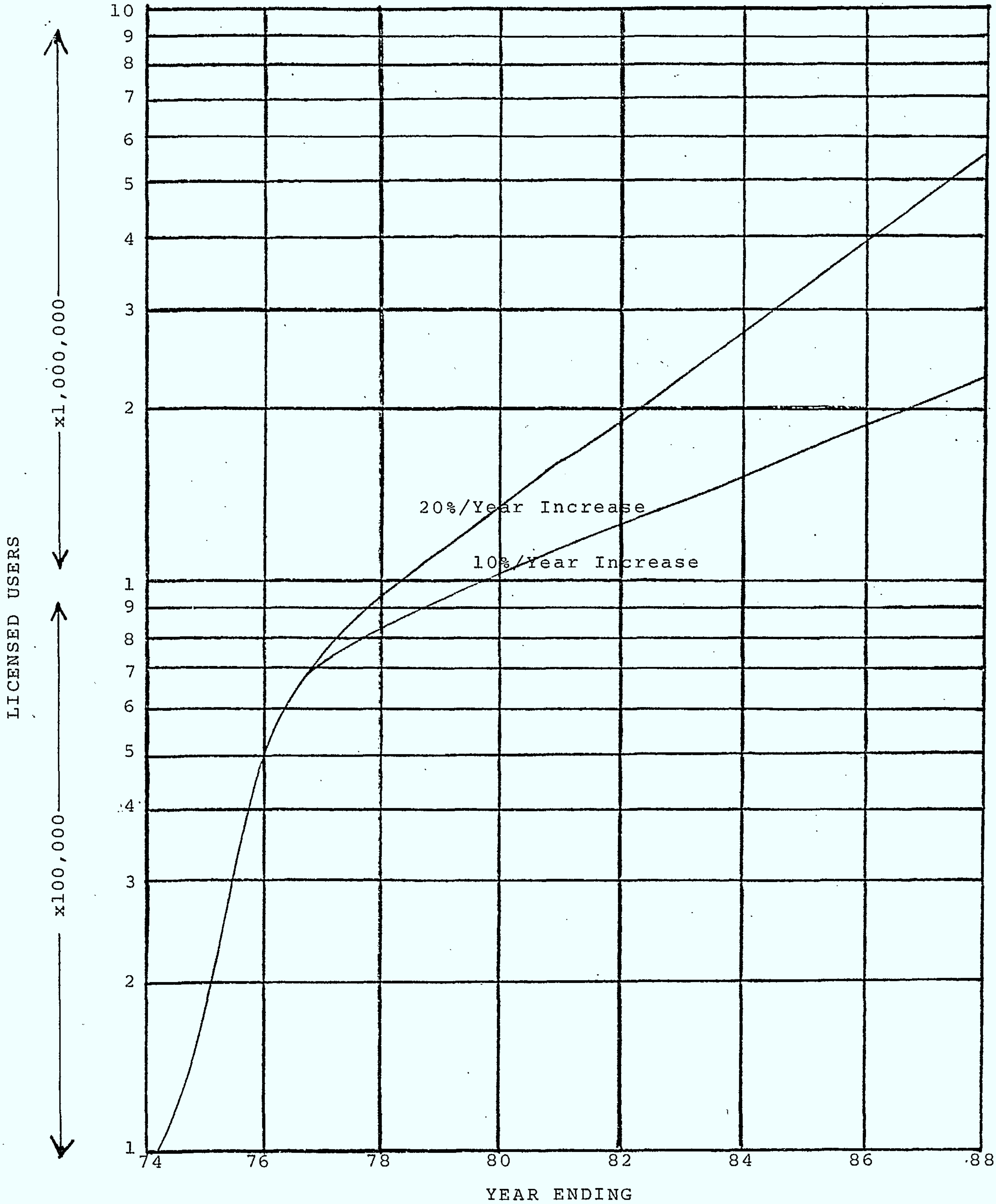
This picture has changed radically in the past three for four years with the rapid growth of citizens band radio and the introduction of low-cost, two-way radios which could be used by anyone, with no justification for the use of spectrum and no hastle over obtaining licenses. In this short space of time, the number of users rose from an insignificant number in 1974 to nearly a million licensed users now in Canada (see FIGURE 2-2) plus a significant number of unlicensed users for a total which is nearly five times the number of users in the land mobile bands. Although many of these use their radio primarily for entertainment, a majority in rural Canada appear to use them for business purposes (4). Thus, CB radio, primarily because of its low cost, has allowed the small businessman and farmer to have mobile communications, and thus reap some of the benefits previously mentioned as being the exlusive domain of larger business and government.

Accordingly, the penetration of citizens band radio has been limited primarily by the user's need for communication, rather than by cost.



LAND MOBILE RADIO GROWTH

FIGURE 2-1



GENERAL RADIO SERVICE GROWTH

FIGURE 2-2

Unfortunately, citizens band radio is not the panacea many people expected, and its effectiveness is declining due to inherent limitations in the band (i.e. congestion, skip, interference and noise) (7). Furthermore, for serious users, citizens band does not offer the kind of communications services needed (i.e. features which are characteristic of one or another of the systems operating in the land mobile bands). These developments in the use of citizens band radio have caused a dilemma which both the FCC (14) and the DOC are trying to resolve (13).

The huge demand for mobile communications particularly in the United States, coupled with the inadequacy of the existing frequency bands and allocation procedures, has generated a great deal of activity in government and industry. In the United States the development of new mobile bands and new techniques to enable a more orderly growth of mobile communications is taking place.

2.2 Mobile Communications Needs in Rural Canada

A general discussion of the radio needs in Canada can be found in various study reports (21). Briefly restated, the need for mobile communications is greater in rural areas than in urban because of the greater distances people must travel without alternate forms of communications. Therefore, the rural user benefits more in time and vehicle cost savings than the urban user. On the other hand, costs are generally higher in rural areas. Generally speaking, the rural user who has a lower income than his urban counterpart, and must pay more for a conventional radio system must often resort to an inferior form of communications service (e.g. Citizens Band).

Accordingly, in attempting to answer the question of how mobile can best serve rural residents, the fundamental factor appears to be one of how to provide needed services at a reasonable cost.

TABLE 2-1

Comparison of Rural Radio Service Features

SERVICE CATEGORY	TEL INT CONNECT	TEL. SUB. SERVICE	WIDE AREA COVERAGE	DISPATCH SERVICE	FREQUENCY SHARING	PRIVACY	LOW BLOCKING	QUEUEING	LOW COST	AUTOMATED
PRIVATE	NO	NO	NO	YES	NO	NO	YES	NO	NO	NO
GLMRS	YES	YES	YES	NO	YES	NO	NO	NO	NO	NOTE 1
RCCMRS	NO	NO	NO	YES	NO	NO	NO	NO	NO	NO
GRS	NO	NO	NO	YES	YES	NO	NO	NO	YES	NO
SR	NOTE 2	NO	NO	YES	YES	NO	NO	NO	YES	NO
NEW GRS	N/A	YES	NO	NO	NOTE 1	YES	YES	NO	NO	YES
SATELLITE	YES	YES	YES	NOTE 2	YES	NOTE 3	NOTE 2	NOTE 2	NOTE 2	YES
RRS	YES	YES	YES	YES	YES	NOTE 3	YES	YES	NOTE 2	YES

NOTE 1 The features shown (YES) are inherent in the system concepts or typical of existing services.

NOTE 2 The features shown are proposed as standard or optional in these new services.

NOTE 3 Privacy means a reasonable assurance against unauthorized monitoring.

The main service categories employing radio in rural Canada are:

1. Land Mobile Services
   - GLMRS (General Land Mobile Radio Service)
   - Private
   - RCCMRS (Restricted Common Carrier Mobile Radio Service)
2. General Radio Service (GRS or Citizens Band)
3. Rural Radio and Subscriber Radio

The characteristics of these services are described in volume 2. In this section, the limitations of such services for rural communications are discussed and a need for another alternative suggested.

2.3.1 Limitations of the Land Mobile Service

The penetration of land mobile services in rural areas is limited by cost. Penetration of land mobiles in rural areas is about 1% (1 radio per 100 people). The number of users, however, is also limited by the ability of any particular service to satisfy the varied communication needs (TABLE 2-1). In other words, a more versatile service would attract more users.

2.3.2 Limitations of General Radio Service

The penetration of GRS is very high and approaching 10 per 100 population if one includes both licensed and unlicensed users. At the present rate of growth, the penetration could double in five years time (FIGURE 2-3) and reference 13).

The effectiveness of GRS, however, is diminishing for any serious use due to inherent limitations in the service, such as noise, congestion, skip, lack of privacy and range. The effect of the increasing sun spot activity over the next few years will multiply the present problems significantly, particularly for rural users (7). Many CB users would like additional features to make their radios more useful and satisfactory. Telephone interconnect, selective calling, a means of disciplining users are frequently indicated needs (12,33,13).

Accordingly, as in the case of land mobile service, a more versatile service would appear to the many CB users who are looking at alternatives.

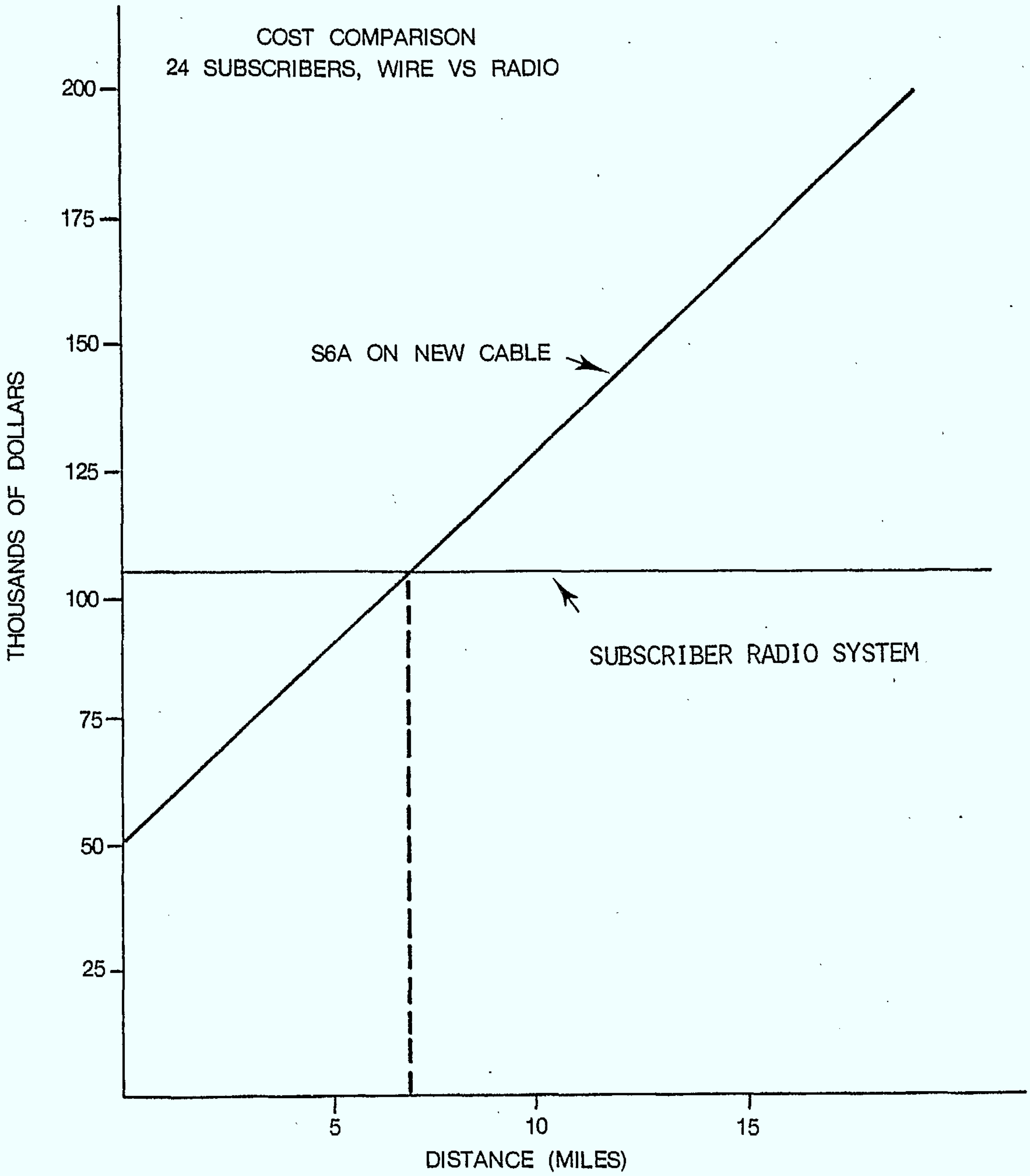
2.3.3 Limitations of Subscriber Radio

At present subscriber radio and rural radio are used primarily in remote areas of Canada where the installation of cable presents special difficulties (e.g. in rocky regions - Manitoba White-shell or over water - Magdeleine Islands). The telcos do not consider such equipment competitive in most rural areas for such reasons as initial high cost (FIGURE 2-3), custom engineering and lack of in-plant standards. The serving of fixed subscribers from the public mobile service is common practice in western Canada. However, in those regions under Canadian Radio-Television and Telecommunications Commission (CRTC) jurisdiction, the high rates used in the GLMR service must be charged to the fixed subscriber, thus limiting the potential of this approach. Rural radio cannot be cross subsidized from the toll network as is commonly the case in rural telephone installations.

Accordingly, the penetration of land mobile and rural radio services in rural Canada is quite low mainly because of cost, while the penetration of GRS is high but has inherent deficiencies which are progressively reducing its effectiveness. In either case, a service which offered the user versatility at a reasonable cost would be a desirable alternative.

FIGURE 2-3

Typical Cost of Subscriber Services - Wire vs Radio



2.3.4 Comparison of Existing and Proposed Services

The inherent features of existing and various proposed radio services are compared in TABLE 2-1. As can be seen, all existing mobile services are rather limited in their service capabilities.

The main alternatives to existing services proposed for future implementation are:

- New GRS (in the United States new CB and advanced CB)
- Satellite
- High capacity cellular

The new GRS would eliminate many problems of the existing band but from a functional standpoint, may be only marginally better than the present service. Direct mobile-satellite communications is feasible and could provide a solution at some future date. A high capacity cellular system could satisfy the basic system requirements but is not the most suitable alternative for rural use. However, an adaptation of cellular technology to rural conditions is more appropriate and would lead to a service we will call a "Rural Radio Service" or RRS.

Accordingly, a single radio service, satisfying a variety of needs, would be desirable. Existing services have inherent limitations while of the proposed future services, an adaptation of the cellular approach to rural conditions, is recommended.

TABLE 2-2

Potential Rural Radio Service Market in Canada

Type of User	Total 1978	Total 1983 (est)	Potential New Service User	Estimated New Service Users In Percent(%)	Estimated New Service Users Actual Number
Rural					
Multi-party tel. subscriber 4-party or more	500,000	500,000	500,000	30%	150,000
Non serviced households	94,000	94,000	94,000	50%	47,000
Citizen's Band	500,000	1,234,000	1,347,000	20%	274,000
Land Mobile	70,000	113,000			
Subtotal					471,000
Urban					
Citizen's Band	780,000	1,872,000	2,162,000	10%	216,000
Land Mobile	180,000	290,000			
Total					697,000

2.4 Rural Radio Service

Why not a new rural radio service to satisfy all the basic rural radio needs? Needs like local and wide area dispatching, local personal communications and those of telephone subscribers. The resulting cost reduction achieved through the efficient sharing of facilities and through standardization could be very substantial.

In the sections to follow we discuss an approach to the design of a rural radio service highlighting the kinds of questions which need to be answered. It is not presented as the only solution but as a framework to be used in developing the best answer.

2.4.1 Who Would Use This RRS Service

In defining such a service, it is suggested that all types of potential user needs be considered, including the following:

1. Local dispatch of vehicles and personnel within a community of interest. Potentially this would include those groups who traditionally use private radio systems or radio common carrier systems, i.e.
   - veterinary services
   - ambulance services
   - garages
   - real estate personnel
   - delivery services
   - sales personnel
   - municipal workers
   - school buses
   - construction workers
   - any local business which employs field personnel

2. Wide area dispatch of vehicles and personnel which use large private systems, i.e.

- highway maintenance
- provincial police forces
- travelling salesmen
- trucking companies
- power distribution and maintenance services

3. Local personal communications within a community of interest who presently use general radio service

- farmers
- many of those listed in 1 & 2 above

4. Fixed telephone subscribers who are too remote for single-party service.

2.4.2 The Market For RSS

An indication of the potential market for this service was given in TABLE 2-2. An Estimated 470,000 rural users or potential users of communications equipment may, in 1983, be prepared to choose a more appropriate service. Assuming the service was available in urban areas as well, the potential market would be considerably greater.

Accordingly, the market potential for a rural radio service is quite large in Canada when one considers the various user categories.

2.4.3 How to Achieve a Rural Radio Service?

Is it feasible to firstly develop a highly sophisticated and versatile radio system and secondly to offer the service at a reasonable cost? The answer to the first question is an unqualified yes, by employing high technology and appropriate production and implementation techniques. The second question depends on the amount of effort invested in the equipment and system design, especially the mobile unit. Recognition of this service in the frequency allocation policy and a radio standard specification would also be needed. These factors are discussed below.

1) Automated System Technology

By using computer-aided dispatch and cellular techniques, the following system features can be provided:

- a frequency allocation plan
- dynamic channel assignment
- channel trunking
- unit identification and addressing
- microprocessor switching

Techniques used in telephone traffic analysis to evaluate grade of service and blocking are readily adapted to mobile communications and would be employed in the system design.

2) The Production of a Low Cost Radio Telephone

The major expense in an extensive system is the end user radio since the quantity is large compared to the terminal equipment. To reduce the cost of the radio to an affordable level, a considerable design effort would be needed in order to incorporate as much of the circuitry as possible into chips reproducible in large quantity at low cost. For example:

- frequency synthesizer
- data modems
- audio and switching circuits
- signalling and display packages

Other factors affecting cost of the radio would require a corresponding degree of attention. The duplexer, for example, where cost varies inversely with frequency spread as well as the ruggedness and environmental considerations would also be important.

3) Spectrum Policy and Radio Standards

Present spectrum allocation policies employ to the traditional approach by responding to the greatest need in partitioning a limited resource. Recent technological advances have made it possible to consider structuring systems so that a given band of spectrum can be reused much more efficiently in a limited area serving many more users than is practical with present allocation procedures.

This concept would have to be applied to the proposed rural radio service if the anticipated market in rural Canada is to be served adequately. DOC regulations, therefore, would have to recognize this need and respond accordingly (i.e. by allocating a block of frequencies to rural Canada which would allow orderly growth to take place.

On the other hand, the minimum standards for equipment to be used in this service should be assessed in proper perspective (i.e. in recognition of the most appropriate power levels, station locations, system design features, modulation techniques, etc), all of which would be controlled by a master plan. This could result in a self-regulating service where an acceptable level of interference is determined in advance and maintained as the system develops. It is felt that the cost of the radio RF packages can be reduced appreciably by this approach.

4) Rate Structure for Rural Subscribers

In order to make existing telephone service available to rural subscribers at an acceptable cost, the carriers must often cross subsidize these services from the toll network revenues. Subsidization of rural services is common policy by governments, as indeed it should be. A review of this policy with regard to services provided by radio would be needed, recognizing that radio is an increasingly important element in rural business and social development.

Accordingly, with the application of high technology to system and equipment design and standardization to production and implementation, a low cost Rural Radio Service (RRS) can be achieved.

2.5 The Design of a Rural Radio Service

The radio system would be mapped out in typical areas (as determined from topographical maps and the demograhic studies) to establish local coverage areas based on community of interest and to develop the RF system design models. Each zone would be configured as shown in FIGURE 2-4. The geographic layout and RF design parameters have a bearing on the functional design.

These three factors, community of interest, RF design and functional design form the basis for the proposed system concept and are discussed in detail in the following sections.

2.5.1 The Community of Interest

It has been observed (55) that the prairie regions consist of a series of community systems dominated by a farm city (FIGURE 2-5). This indicates that the major activity of residents (including communications) takes place within this community of interest. That being the case, a local radio service which is designed to provide function could handle a large percentage of the traffic within that area. It is proposed, therefore, that the community of interest geographic area form the basis for the primary radio coverage.

A cursory look at other kinds of rural areas suggests that the community of interest principle applies in these areas as well. The validity of this point is important and has considerable bearing on the system design as will be discussed in the following section.

A rural service would not be restricted to serving local residents and would have to accommodate users having community of interests beyond the local community boundaries. Thus, a community of interest may encompass several communities or perhaps the entire rural area of a given province. The design must allow for such alternatives.

FIGURE 2-4

Rural Radio System Configuration

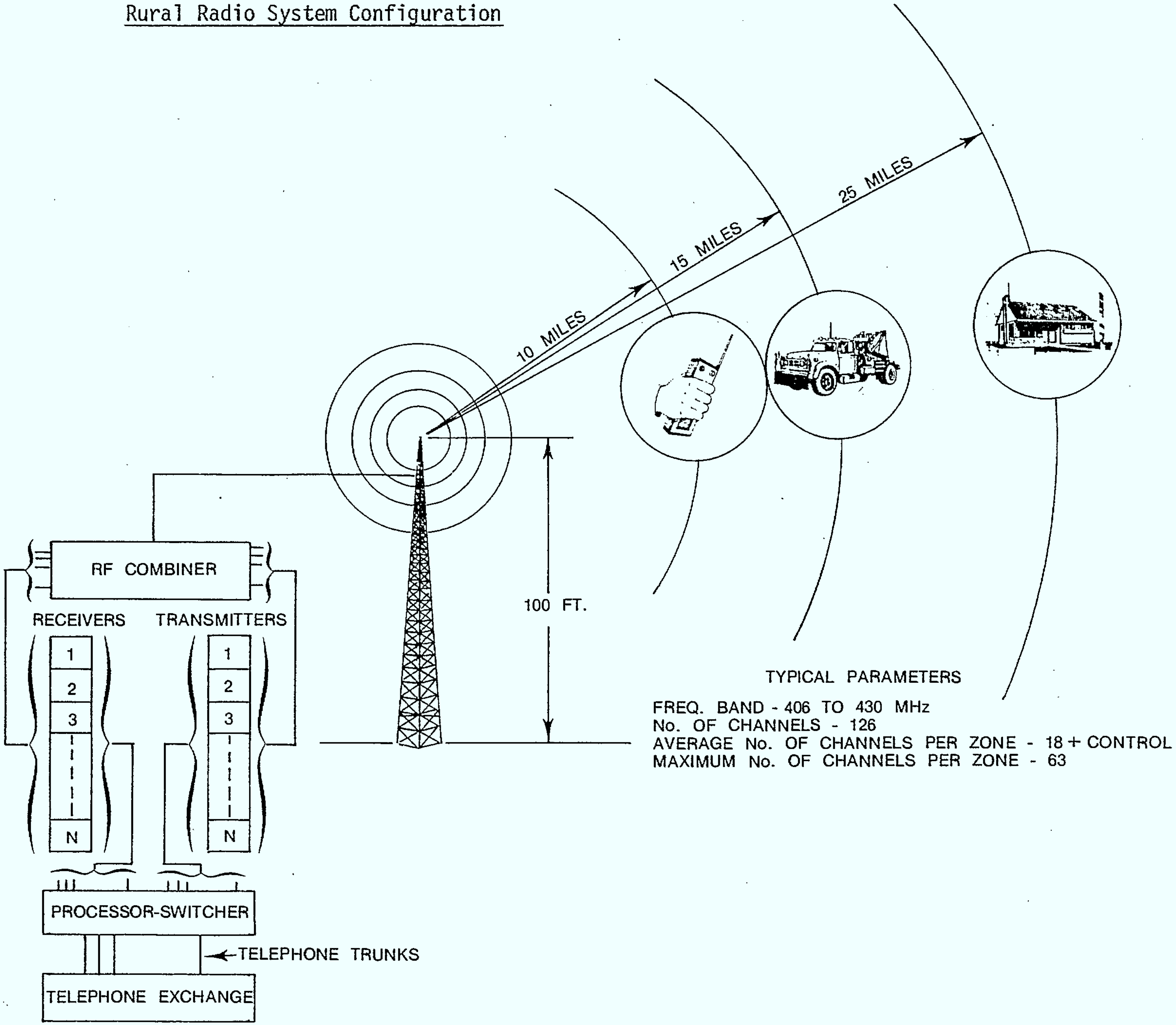
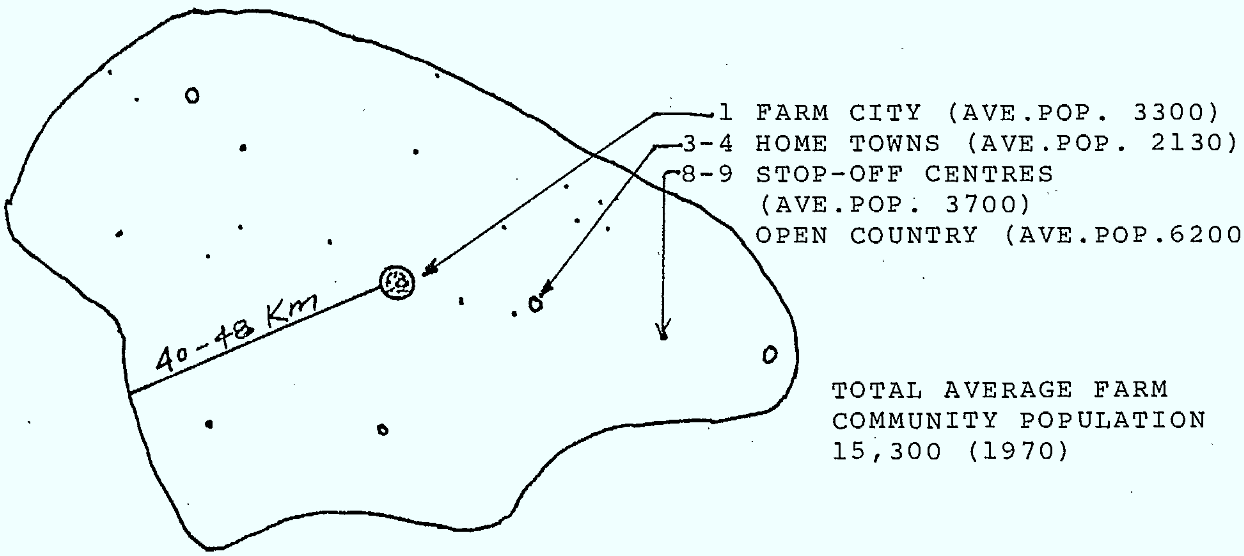


FIGURE 2-5

Rural Community of Interest - Farm City (55)



For an illustration of this point, refer to FIGURE 2-6. The solid circles roughly represent mobile radio coverage from terminals centred in these areas. The dotted circles represent coverage to fixed locations (residential radio telephones). If it can be assumed that residents tend to do most of their business in the nearest town, then placing the radio terminal in the town site would provide the nearest neighbours with most of their mobile communications needs. On the other hand, residents near the coverage limits would have the option of being assigned to one, two or more areas. For example, a person in Malbank would be within mobile range of Madoc, Kaladar and Napanee and could be given access through any one or all of the terminals.

So far as fixed subscribers are concerned, they would always access the particular terminal to which they are assigned (usually the nearest one). The greater coverage radius for fixed users (FIGURE 2-6) provides an option to many subscribers as to which exchange area they wish to be attached or to the telephone company in distributing facilities which may be overloaded in a particular area.

A highly effective tool for determining rural community boundaries and to aid in the design of the rural radio service is to be found in the demographic reports recently prepared by the RCPG. We refer to references 22 and 54.

2.5.2 RF Design

The frequency allocation plan would be determined by selecting from various cellular allocation plans, the most appropriate procedure for the particular rural conditions. In areas of evenly dispersed populations, an adaptation of a hexagonal plan as used by AT&T (10) may be appropriate (FIGURE 2-7). For example, a large cell system using 4 cells/block may suit most rural conditions. A combination of area and linear distributions would be used (FIGURES 2-7,8,9).

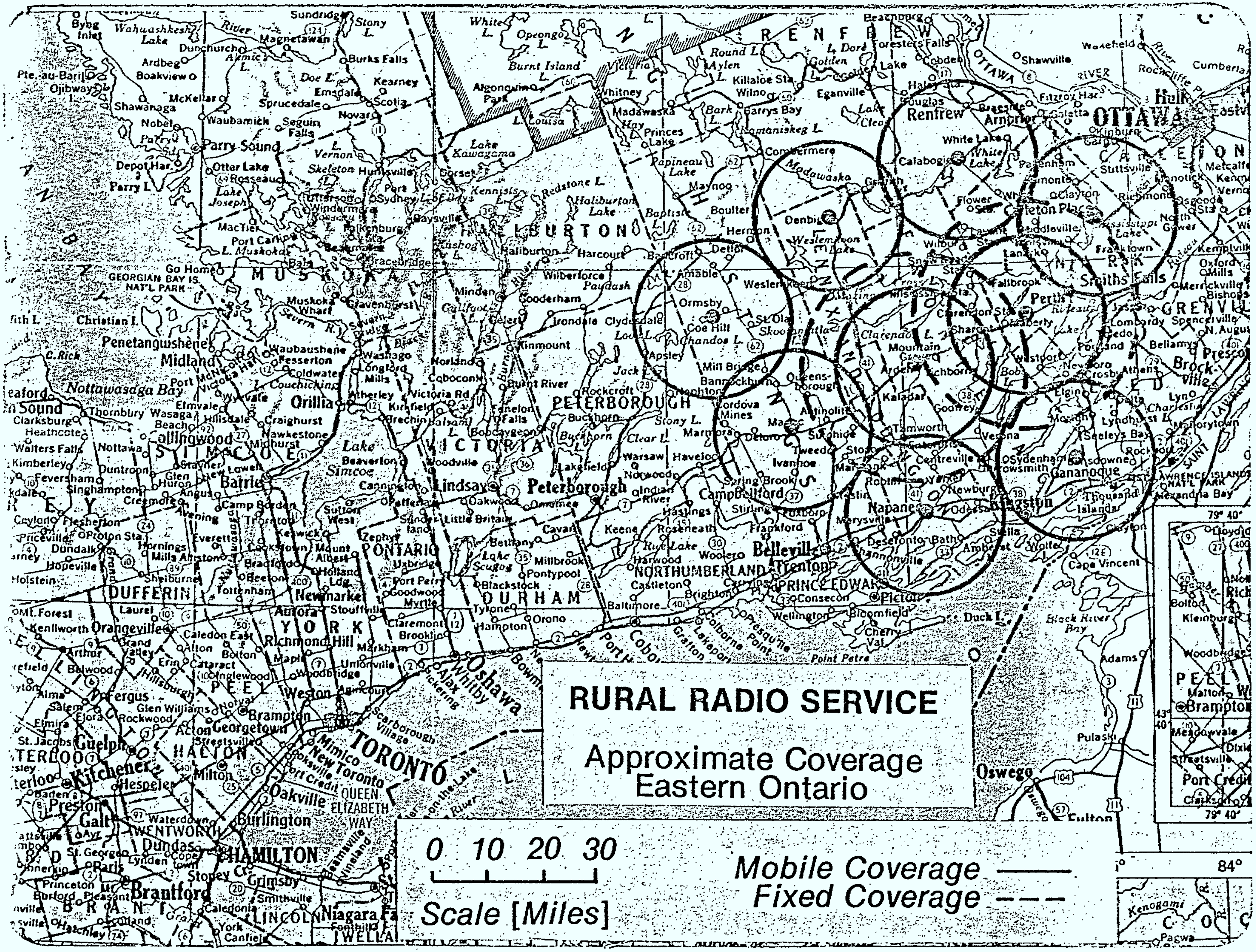
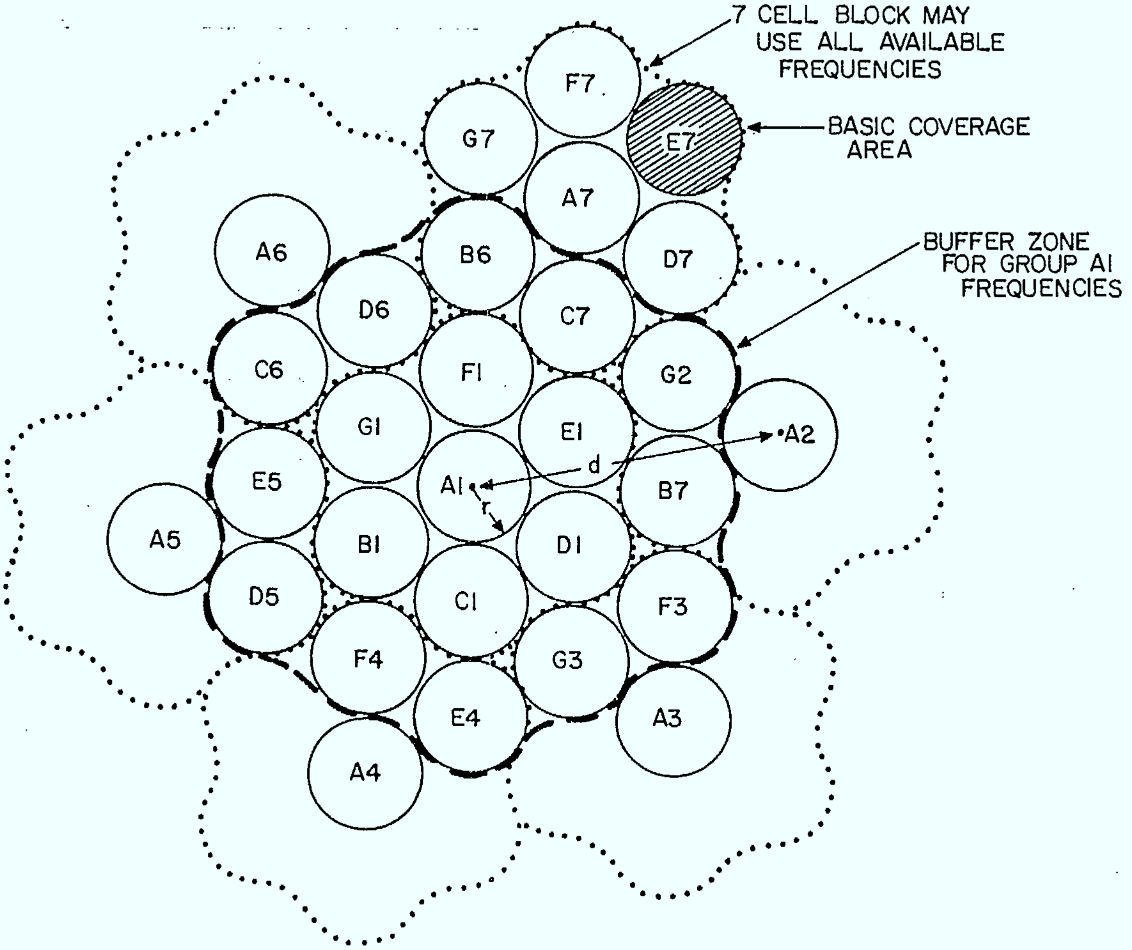

RURAL RADIO SERVICE
Approximate Coverage
Eastern Ontario
0 10 20 30
Scale [Miles]
Mobile Coverage
Fixed Coverage

FIGURE 2-7

Frequency Allocation for Hexagonal Cells (7 cells per block)



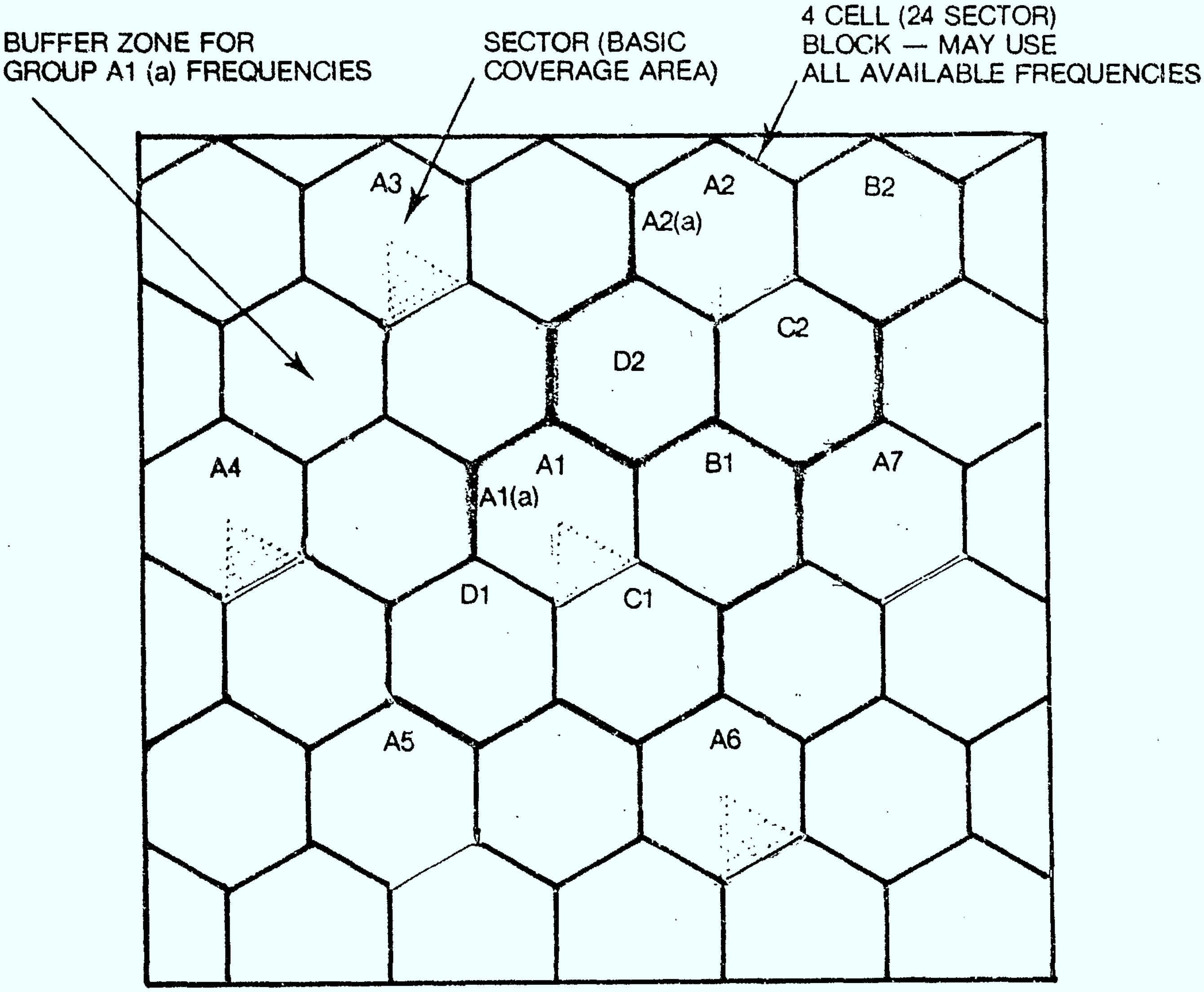
AI TO A7 - CELL IN WHICH GROUP A FREQUENCIES MAY BE USED.

r - CELL RADIUS ≅ 15 MILES IN PROPOSED SYSTEM

d - MINIMUM CO CHANNEL SEPARATION ≅ 70 MILES IN PROPOSED SYSTEM.

FIGURE 2-8

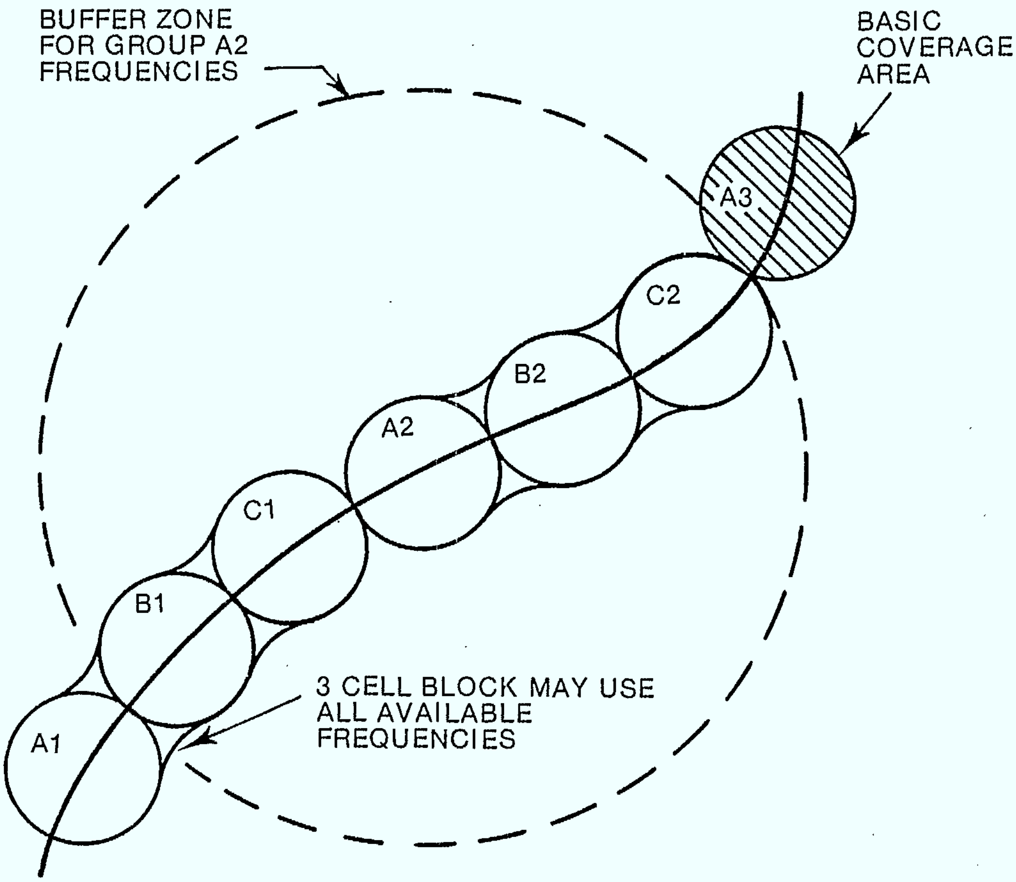
Frequency Allocation For Hexagonal Cells (4 cells per block)



A1(a) TO A7(a) — SECTORS IN WHICH FREQUENCY SUBGROUP (a) MAY BE USED

FIGURE 2-9

Frequency Allocation for Linear Cell Distribution



The design criteria from a coverage point of view would be to place the radio terminals in locations providing optimum coverage within the community of interest. In general, towers would be located so as to minimize the interference to other zones (i.e. the highest hill or mountain in the area would not normally be the best choice). Where possible, the towers would be adjacent to central office exchanges to minimize trunking costs (FIGURE 2-6).

The choice of frequency band is not discussed in detail here. However, the most appropriate and potentially available band for a rural system, all factors considered, is the 406-430 MHz band.

If current technology is used, typically the Rural Radio Services system would have the following parameters:

- Frequency band	406-430
- RF channels	150 or more
- Frequency spacing	25 to 30 KHz
- Modulation	FM
- Base ERP	40 W
- Mobile ERP	20 W
- Coverage radius	24 Km
- Tower height	30 M
- Base antenna gain	9 db
- Mobile ant gain	3 db

2.5.3 Functional Design

As mentioned earlier, the functional design of the system is dependent not only on the user needs, but also on demographic factors, and other considerations. In fact, user needs, communities of interest, choice of frequency band and number of channels available are basic in determining the system functional design. The functioning of the system is discussed in relation to the system layout FIGURE 2-10 and the radio terminal and mobile control flow diagrams of FIGURE 2-11.

The selection of the 400 MHz band instead of 800 MHz for a rural service would enable the community of interest for a majority of users to be served through a single radio terminal with modest tower heights and power levels. This could reduce system complexity and cost and (34,10) influence questions such as:

1. The need for automatic hand-off; a requirement in small cell systems (10,34.) At 400 MHz, the possibility of providing coverage within the community of interest is greater than at 800 MHz assuming other RF parameters remain the same. The need for automatic hand-off for a roaming vehicle would be reduced due to larger cell sizes thus reflecting on the fixed system costs (AVL, network architecture, central control, etc).

2. The total number of radio terminals required to serve an area. Again for the same RF parameters more terminals would be needed to provide total coverage at 800 MHz.

3. The cost of trunking facilities between terminals or between the terminals and the central office. A greater percentage of terminals would be co-located with central office exchange equipment in a 400 MHz system with a resultant reduction in line costs.

2.5.3.1 Radio Terminal Functions

The functions performed by the terminal processor are illustrated in FIGURE 2-10. Four basic modes are suggested:

1. Local dispatch
2. Extended area dispatch
3. Local dialling
4. Remote dialling

FIGURE 2-10

Terminal Control Flow Diagram

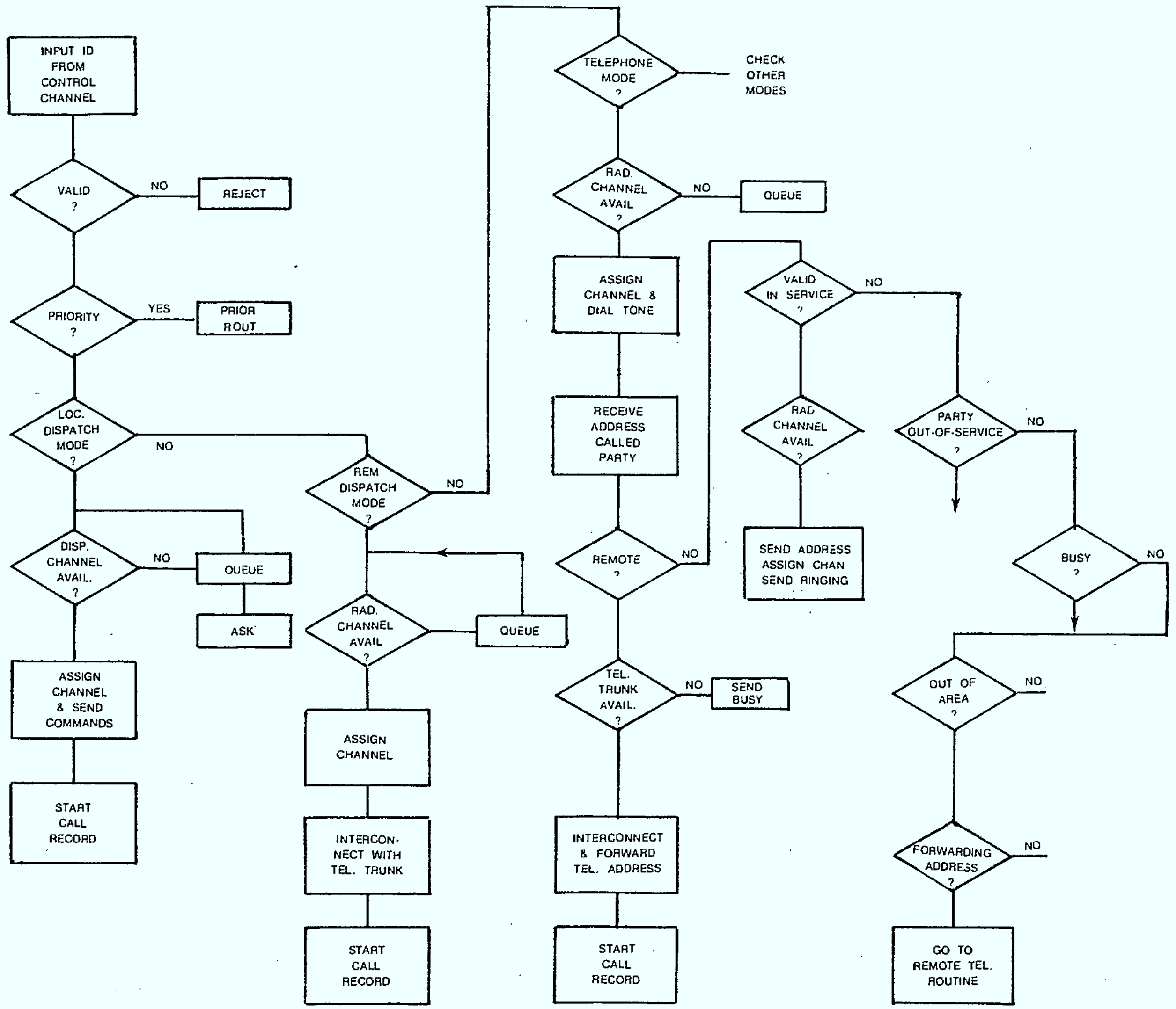
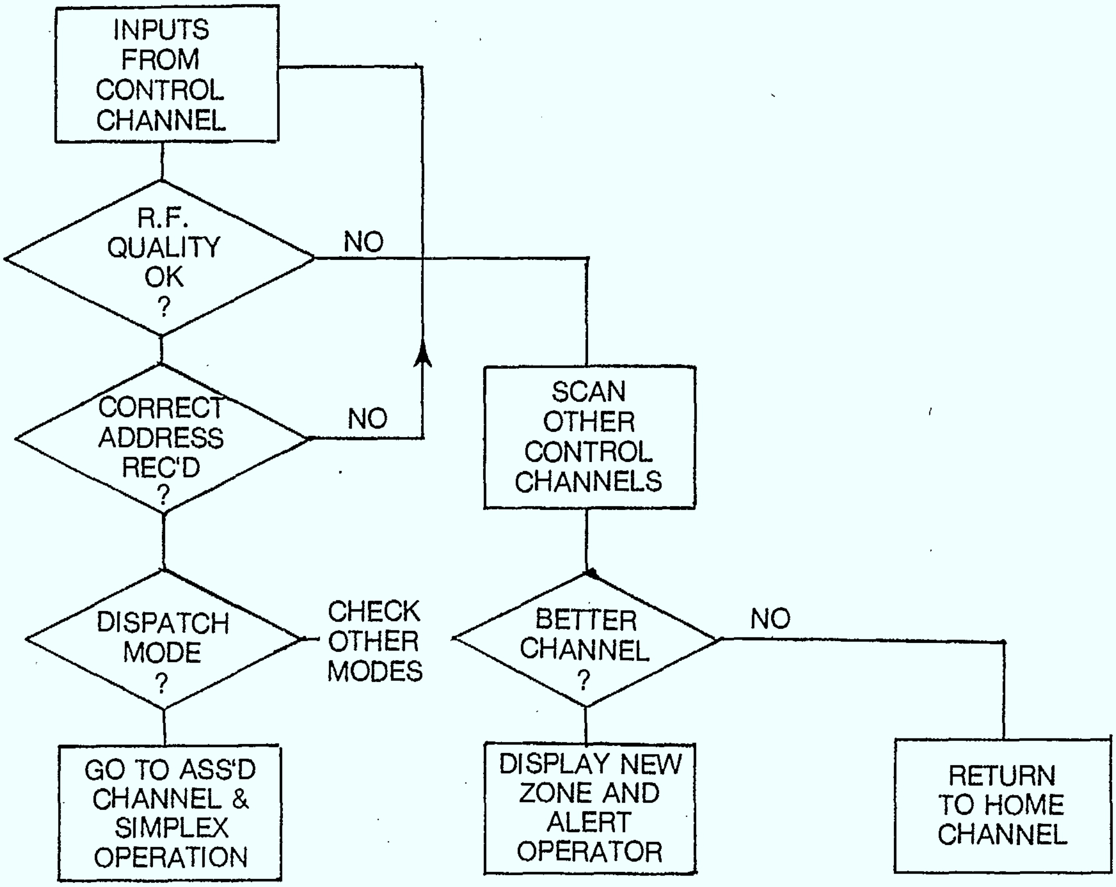


FIGURE 2-11

Typical Routine in User Radio



The routine to be employed by the processor would be determined by the originator's identification code, which would contain the information necessary for the processor to make a decision. The user's ID code would be stored in computer memory according to the valid modes for that user. Where the user has options, a mode switch would be incorporated in his radio which would insert the necessary data into the code format for recognition by the processor. Some options may include priority, dispatch and dialling.

The priority option would be available to emergency services and would place them at the front of the queue for channel assignments etc. In the dispatch mode, the processor could assign a common channel to a group of vehicles and signal them into a simlex, open speaker operation. In the case of extended area dispatching, where a subscriber wishes to address a remote dispatcher, the processor would interconnect the assigned radio channel with a dedicated trunk circuit to the dispatch centre.

In the dialling mode, the processor would select either the local or remote routine, depending on whether the addressee was in the local coverage area or was a subscriber in another coverage area or connected to the standard network facilities.

2.5.3.2 Radio Telephone Functions

Two basic variations of the subscriber equipment are suggested for standard telephone operations and dispatch operation. Either or both functions could be incorporated in the same unit. If the dispatch option was included, the radio would operate in the press-to-talk mode and may have a loudspeaker.

A simplified flow diagram of the user's equipment functions is shown in FIGURE 2-11. (See previous page)

2.5.3.3 Roaming Function

In the proposed system, the onus is on the mobile to indicate its location. To simplify the procedure it is proposed that the user radio be equipped with circuitry for assessing the RF quality of the control channels. By means of a scanning circuit which samples the control channels, the operator could be alerted when outside his home coverage area or the vehicle could report back automatically. A procedure analogous to the call forwarding option, presently available to telephone subscribers, could be employed.

In order to effect this procedure, it would be necessary to transmit a terminal identification code on each of the zone control channels. A corresponding numerical code could be displayed on the subscriber's equipment with an alerting feature to draw his attention to the change.

Other alternatives to accomplish this function should be evaluated taking into account questions such as available network facilities, central versus local control, urban system requirements and available technology (e.g. AVL).

Accordingly, the design of the rural radio service comprises three main factors:

1. *Community of interest*
2. *RF design*
3. *Functional design*

Careful consideration of these factors in relation to the rural situation can result in an effective system at a realistic cost.

2.6 The Cost of Providing a Rural Radio Service

The proposed rural radio service will only be possible if it can be supplied at cost which can be justified by the subscriber. On the other hand, a low cost service is only possible if a large market exists. The potential market has been discussed and a number of elements identified as factors in reducing cost, such as system standardization, high technology and large scale production methods. The implication is that with a large enough development effort, the objectives of low cost equipment can be achieved. With present technology, we believe it is realistic to predict that the subscriber radio could be produced at a user cost of about $600.

Estimates of comparative user costs are shown in TABLE 2-3 indicating a capital cost of about $1000/user by applying the factors suggested above. The corresponding design effort needed is estimated in the activity plan, FIGURE 2-12. The cost of R & D and the level of support by industry and the DOC is shown in TABLE 2-4 for vaious penetrations based on a five-year plan with service starting in 1983.

By extrapolation of the cell arrangement shown in FIGURE 2-6 and applying the costs suggested in TABLES 2-3, the entire rural area of Canada could be given radio coverage to a limited number of users (100,000) for a cost in the order of $100 million (FIGURE 2-13).

The development effort in order to achieve the level of technology needed and the system standardization proposed would comprise a concentrated effort in such areas as system definition and design, transmission planning as well as equipment design. It could require two phases of field experience and initial demonstration system employing a modified form of existing equipment followed by a pilot project to prove the performance of the final equipment and system design. In total a development cost of $8.5 million is anticipated before a regular service could be offered to the public in 1983 (TABLE 2-4).

TABLE 2-3

COMPARATIVE USER COST OF RURAL RADIO SERVICE

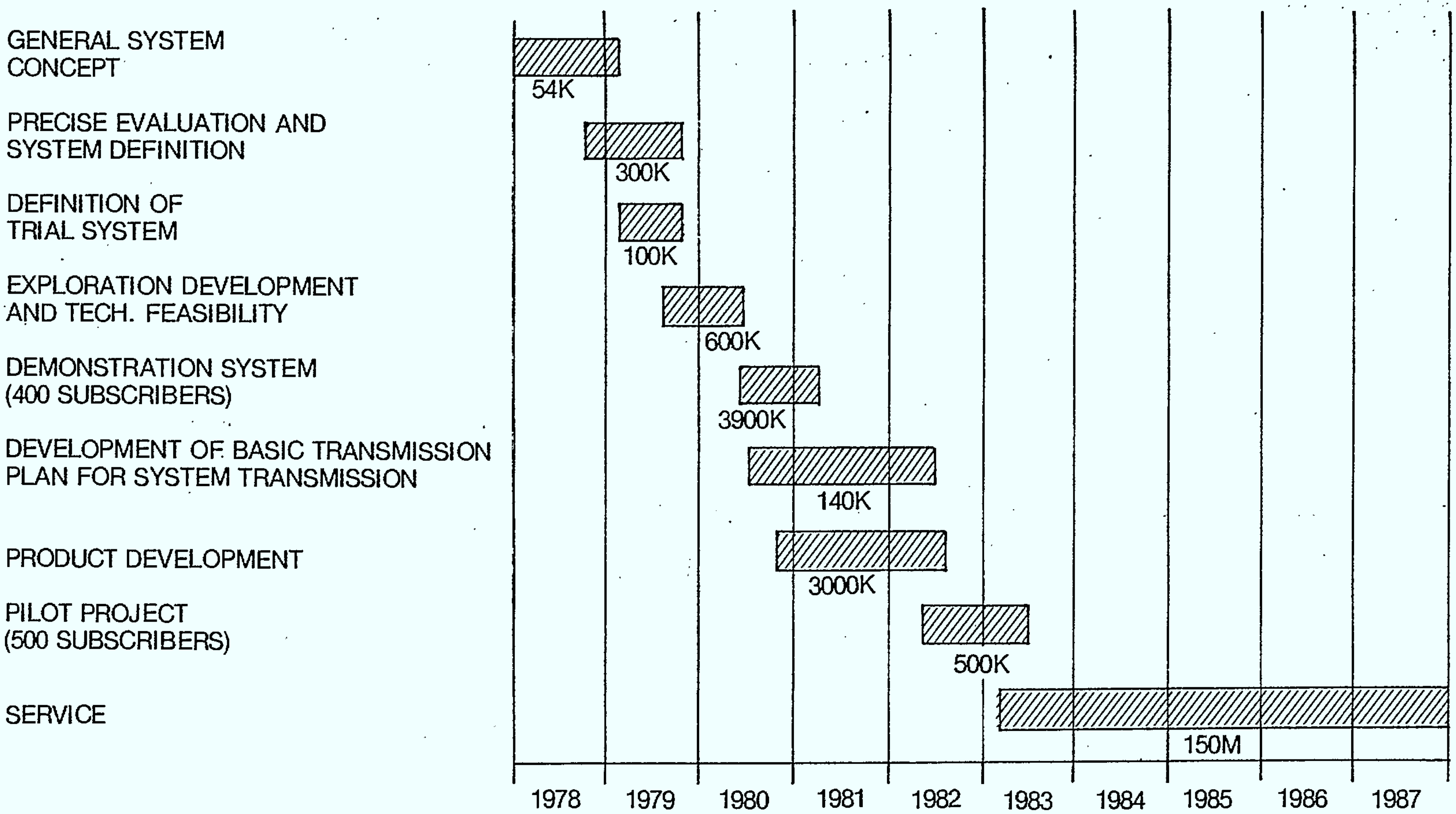
	TELEPHONE PLANT	BASE STATION (15 CHANNELS)	SITE PREPARATION	MOBILE	COST/ USER
TELEPHONE *SINGLE PARTY FIXED SUBSCRIBER [20K FT. OR MORE]*	>5,000				>5,000
RADIO SYSTEM *USING PRESENT RADIO EQUIPMENT SUITABLY MODIFIED*	NOTE 1	$100,000	25,000	2,500	3,300
RADIO SYSTEM *USING LARGE-QUANTITY MANUFACTURING TECHNIQUE*	NOTE 1	75,000	20,000	600	1,075 (NOTE 2)

NOTE 1: IF LOCATED AT EXISTING CO REQUIRING NO ADDITIONAL FACILITIES, THE COST IS MINIMAL.

NOTE 2: BASED ON 200 USERS PER ZONE

FIGURE 2-12

Activity Plan



TOTAL FRONT END COST: $8.5M
TOTAL SYSTEM COST (140K SUBSCRIBERS): $150M

TABLE 2-4

Development Costs for a Rural Radio Service

ESTIMATED NUMBER OF SUBSCRIBERS:

RURAL	471,000
URBAN	216,000
TOTAL	697,000

ASSUME SERVICE INTRODUCTION: 1983

MARKET INTRODUCTION FIRST 5 YEARS		INVESTMENT IN PLANT		INDUSTRY 5% R&D	TOTAL R&D	GOV'T SUPPORT REQ'D
%	TOTAL	TOTAL	HIGH TECHNOL.			
10	70,000	$75M	$68M	$3.4M	$8.5M	$5.1M
20	140,000	$150M	$136M	$6.8M	$8.5M	$1.7M

FIGURE 2-13

Minimum Rural System Cost

A Basic Radio System Covering Rural Canada Serving 100,000 Users for $100,000,000

Rural Area	1,165,000
Coverage Per Location	2,330
Number of Sites	500
Number of Users Per Site	200
Average Cost Per Zone	
Terminal Facilities	$ 95,000
Radio Telephones	$120,000
Total Cost	500 x 215,000 = $107,500,000.00

Accordingly, a basic system covering the entire area of rural Canada and capable of serving 100,000 users could be provided at a cost of $100 million but would require an initial development expenditure of about $8.5 million.

2.7 Steps Needed to Achieve Rural Radio Service

For this program to proceed, a definition of the division of responsibility is needed. In this regard, a cooperative effort between the DOC and the telcos is essential since the service could not be implemented without both the technical input of the telephone companies and integration with the network facilities.

Other necessary steps have been discussed in previous sections of this project, and are listed below.

1. Selection and survey of a particular field trial location.
2. Feasibility study of the $600 radio.
3. Detailed system design.
4. Allocation of a block of frequencies.
5. DOC policy revisions (spectrum & equipment standards).
6. Clarification of the interconnect question.
7. Review of the rural subscriber rate structure.
8. Developmental and field trial activity.

One factor not previously mentioned is the important role of Canadian industry in this proposed program. A service of this magnitude with full government backing would provide an opportunity to develop a truly significant Canadian radio industry. It should be a major objective, therefore, to involve Canadian industry in all stages of the program as outlined in Section 4.

Accordingly, a number of necessary steps are needed to achieve Rural Radio Services. Starting with a definition of responsiblities the program will lead into feasibility studies, detailed system design, policy issues, rates, and finally field trial activities.

3.1 General

Rural users of mobile radio face a different set of problems with regard to spectrum than urban users. Briefly stated, in the land mobile services, two problems are encountered when trying to coordinate a band of frequencies on a province-wide or country-wide basis. Firstly, existing bands are almost fully allocated in the heavily populated areas, particularly along sections of the United States border. Secondly, there is little coordination between regions with regard to allocation policy. So, for province-wide services, the shortage of frequencies in the urban areas limits the freedom of designing integrated urban/rural systems. The General Land Mobile Service, for example, cannot expand significantly even in rural areas. Large private systems have similar limitations, and it is becoming increasingly difficult for any new wide area systems to develop.

In the General Radio Service, the spectrum is congested in and around large cities and the use of the band is inhibited in rural areas due mainly to skip interference which effectively limits its range. In any case, the GRS band is unavailable for a structured radio service and therefore is of no importance in this discussion.

A radio service, such as that proposed in the previous section, requires a large band of frequencies which would have to be coordinated in both rural and urban areas throughout the country for reasons of congestion and standardization. The purpose of this section is to examine the spectrum needs and alternatiges and various scenarios for future utilization.

The proposed system would serve two main catetories of users 1) those who require telephone communications primarily (mobile or fixed) and 2) those who require a form of local conference communication (e.g. dipatch service). The spectrum requirements for rural are based on serving both of these categories with an integrated communication network. It is then more possible to achieve the loading required to reduce the shared user costs and to provide a flexible service to the user which an inter-conncecting network can provide. These constraints do not necessarily apply in urban areas since sufficient potential user density exists to develop such a service economically from either user category.

An estimate of spectrum needs can be made from assumptions such as the following:

1. Average channel loading for radio telephone service with P.01 blocking is 10 users per channel.
2. Average channel loading for dispatch service is 50 users per channel.
3. Maximum combined user density anticipated for the type of service offered based on population is one user per 10 people.
4. Average population density in rural areas is 26 square kilometres.
5. Ratio of mobile dispatch to mobile telephone radios -
   - Low Density Rural 10/1
   - High Density Rural 5/1
6. Average coverage area for a 400 MHz system is 1800 square kilometres. (24 kilometre radius).
7. Average coverage area for a 800 MHz system is 900 square kilometres (17 kilometre radius).

Thus the maximum average user density is 2.6 users/square kilometre, or 2.6 x 1800 = 4680 users/cell in a 400 MHz system. At a ratio of 10 mobile users to one telephone user, these would require a total of 128 channels in all to accommodate them. In a hexagonal configuration (7 cells/block) 896 channels would eventually be needed to handle the traffic. It is clear that even some in rural areas, smaller cells will eventually be needed if only 150 to 200 channels will be available.

Present assumptions with regard to users for channel and ratio of mobile to fixed users are debatable in view of possible future changes in transmission methods.

The spectrum is capable of being used much more efficiently than at present, and the above example stresses the need to evaluate alternate approaches. If the problems inherent in SSB modulation, for example, can be overcome, a 10 to 1 improvement in utilization may be possible. When more efficient methods of transmitting void information are achieved, even greater economies will be possible. Additional spectrum economies are possible through the use of companding methods, etc.

There are essentially two spectrum alternatives, 406 to 430 and 806 to 890 MHz, with 156 channels potentially available in the 400 MHz band and around 600 channels at 800 MHz. (The other mobile bands are at present too committed to be considered practical alternatives in the near future, although it is quite probable that the success of new system approached will result in revised usage of these bands, as well, even though it will take many years to make the transition). The 400 MHz band is preferred in rural areas for propagation reasons. The improvement is the sum of differences in diffraction loss, shadow loss and terrain factor and varies from 5 to 9 db depending on the terrain conditions (Appendix A2). The least difference occurs in the Prairies, the greatest difference in hilly, wooded areas. For the same RF parameters (and it is assumed here that the same transmitter powers, antenna gains, receiver noise figures, i.e. system gains, are achieveable in the two bands), an 800 MHz system could cover approximately half the area of a 400 MHz system, and would cost twice as much in base station equipment.

It is clear that 400 MHz is preferable provided the spectrum is sufficient for the intended use. The intended use is to provide for private mobile needs and public subscriber needs in rural areas and to provide for either public or private mobile needs in urban areas. What about long-term developments? If, for example, a decision is made in favour of adopting the 800 MHz high capacity cellular system for public mobile service in Canada (quite probable), a 400 MHz service will still be viable to serve private users and fixed rural subscribers, as well as initially serving public mobile subscribers on an interim basis.

Accordingly, the development of a 400 MHz system is very practical, since it would initially be employed to serve a variety of users and could eventually revert to serve primarily private users and rural fixed subscribers, allowing for a gradual evolution.

TABLE 3-1

Proposed Scenario

Year	400 Mixed Mode Service	800 MHz Public Mobile Service
1983	Introduced in Canada for: . Rural Fixed Subscriber . Rural Public Mobile . Rural Private Mobile . Urban Public Mobile (or private) . Digital Communications	
1987	Reverts Gradually to: . Rural and Urban Private Mobile . Rural Fixed Subscriber Also in this Period: . Increasing use of Digital . Gradual Transition of Other Mobile Bands to High Technology Usage	Introduced in Canada for: . Urban Public Mobile Service
1995		Personal Portable Service Introduced in Canada for - Urban Use - Extends Gradually Into Rural (Alternately Satellite Service Introduced for Personal Radio)

3.4 A 400 MHz Scenario

With reference to our proposed scenario of TABLE 3-1, the 400 MHz system would eventually serve private users in rural and urban areas, and fixed telephone subscribers in low density rural areas. Utilization by private users will be increasingly in the digital mode, so that channel loadings will increase from a conservative 50 users per channel, to 100 or more users per channel, employing packet or other digital techniques.

The number of users served in a 400 MHz system could then be in excess of the numbers shown in TABLE 3-2.

TABLE 3-2
Users Accommodated in a Cellular System
Serving Private User Groups in a Digital Mode
156 Channels at 400 MHz

Cell Organization	Type of Area	Average Usable Channels per Cell	Number of Users/Cell
7 cells/block	Urban and High Density Rural	21	2,100
4 cells/block	Low & Medium Density Rural	38	3,800
3 cells/block	Linear Areas (Coastal, Valley, Highway, etc)	51	5,100

To approach the high potential utilization of the available radio channels in rural areas, it is desirable to have the cells as large as possible within the limits of propogation conditions. At 400 MHz, 24 Km average radius is realistic (increasing in flat, open areas and decreasing in hilly, wooded areas). In some areas, it will be desirable to skew antenna patterns for optimum design. However, the average user population for low and medium density areas will rarely be reached. In high rural and urban areas, the indicated cell user population will be exceeded, and it will be necessary to reduce cell size to accommodate the demand.

Other scenarios are possible. For example, the ratio of public to private users could increase, then the user population, which could be accommodated, would be reduced accordingly. In fact if only public users are accommodated, the average number per cell will be reduced by a factor of 10, and a 4-cell block in low to medium density areas would only accommodate 380 users per cell, and the probability of having to reduce cell size would increase or would occur sooner.

Accordingly, present mobile bands are congested even in rural areas partly as a result of spectrum limitations in some categories (GRS, GLMRS and RCC) and partly as a result of allocation policies in private systems which inhibit the coordination of frequencies on a large area basis. A fresh start is needed, not necessarily by taking the easy road offered by new spectrum at 800 to 900 MHz, but by beginning in existing bands, more particularly in the 406 to 430 MHz band, which is more suitable in rural areas than 800 MHz. The development of a radio service at 400 MHz, employing high technology and mixes user modes, would serve most rural needs for private voice and data dispatching activity with large cells, but may require reduced cell size and eventually cell division in high density rural and urban areas. On the other hand, if used primarily for public mobile service, the system may require smaller cells initially, and cell division much sooner (and in lower density areas) than in the first case.

3.5 Frequency Allocations for a 400 MHz Cellular Type System

3.5.1 Dynamic Channel Assignment

The concept of dynamic channel assignment to achieve maximum usage of available spectrum is a basic feature of cellular systems proposed for public mobile service. This concept is also applicable to other categories of mobile service and , in fact, would have to eventually be applied to existing mobile bands in order to fully utilize them.

The concept is proposed for a rural communication service in which a variety of user categories would be accommodated. The same service would logically extend into urban areas to accommodate certain categories oof users.

3.5.2 Preferred Frequency Band

The 406 - 430 MHz band is near optimum for such a service in rural areas as illustrated in FIGURE 3-1. Let's assume that 406.1 to 410 MHz is available in most of rural Canada for mobile transmitting, this would provide 156 channels at 25 KHz band would give best results for this purpose (thus allowing a channel transmit-receive separation of 10 - 20 MHz). Certain taboos would have to be accommodated, i.e.

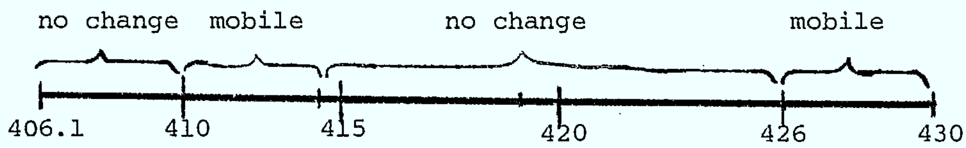
1. Protection to the radio astronomy receiving stations in Algonquin Park, Ont. and Penticton, British Columbia. In these areas mobile transmit frequencies would have to be assigned in another part of the band preferably 410 - 414 MHz. Since the area is primary rural, this would not create too many relocation problems.

2. Protection to United States radio location operating at 420 - 430 MHz.

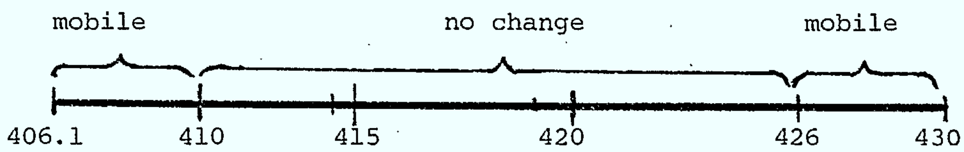
3. Protection to fixed services operating at 415 and 420 MHz. These are 1 MHz slots which are assigned on a primary basis to fixed services.

FIGURE 3-1 Possible Spectrum Allocations in Rural Areas

Proposed Rural Radio Near RA Stations



Other Rural Areas



Accordingly, although the available spectrum in the 406 - 430 band is limited to possibly 6 MHz and is subject to geographic variations, nevertheless it is feasible to plan a standardized country-wide service in this frequency band.

4.0 New Technology and Rural Communications

4.1 General

One aspect of this study has been to examine present and developing technology, and to evaluate it with reference to the type of radio communications systems which would be suitable for serving the rural areas of Canada. The following subsections provide a summary of these findings, with references to some of the source material. The subject is divided into telephone, radio, coding, propagation, integration, cellular and spectrum. Additional detailed information is provided in Appendix 2 on propagation models.

The information on telephone technology and integrated services was obtained mainly from personnel within the Rural Communications Program Group of the Department of Communications, who have devoted a considerable amount of time in the study of these service areas. Information for the remaining sections stem from a review of recent literature, technical studies, people in industry, course materials, etc, which were considered pertinent to the subject of new rural communications technology.

Our discussion concentrates on system application aspects of technology, particularly in relation to parameters, techniques and trends.

Accordingly, in discussing radio equipment, for example, we are interested in devices such as digital filters, synthesizers, and microprocessors inasfar as they affect the overall performance of the radio in the system and its production cost. However, no attempt is made to explore the detailed problems of designing these components.

"The design of new transmission systems is constrained by the fact that they must be compatible with an existing multi billion dollar plant, and by the fact they must perform a number of functions, such as transmission of various messages, e.g. telephone, narrow band and wide band data, telephoto, or television." (35)

This explains, in part, the conservative attitude adopted by telephone companies toward new concepts, and the implementation of innovative ideas, and their rigid opposition to interference in their network operations, (i.e. to interconnect). It also explains the part the large variety of switching equipment etc and the high cost of designing new switching machines. Northern Telecom's DMS* machines (36), for example, are relatively inexpensive from a hardware point of view, but were costly to design and to program due to the large variety of interface requirements.

Network switching in Canada and the United States is done at five levels, is classified in TABLE 1-4 and also illustrated in FIGURE 4-1.

TABLE 4-1
Classes of Network Switching

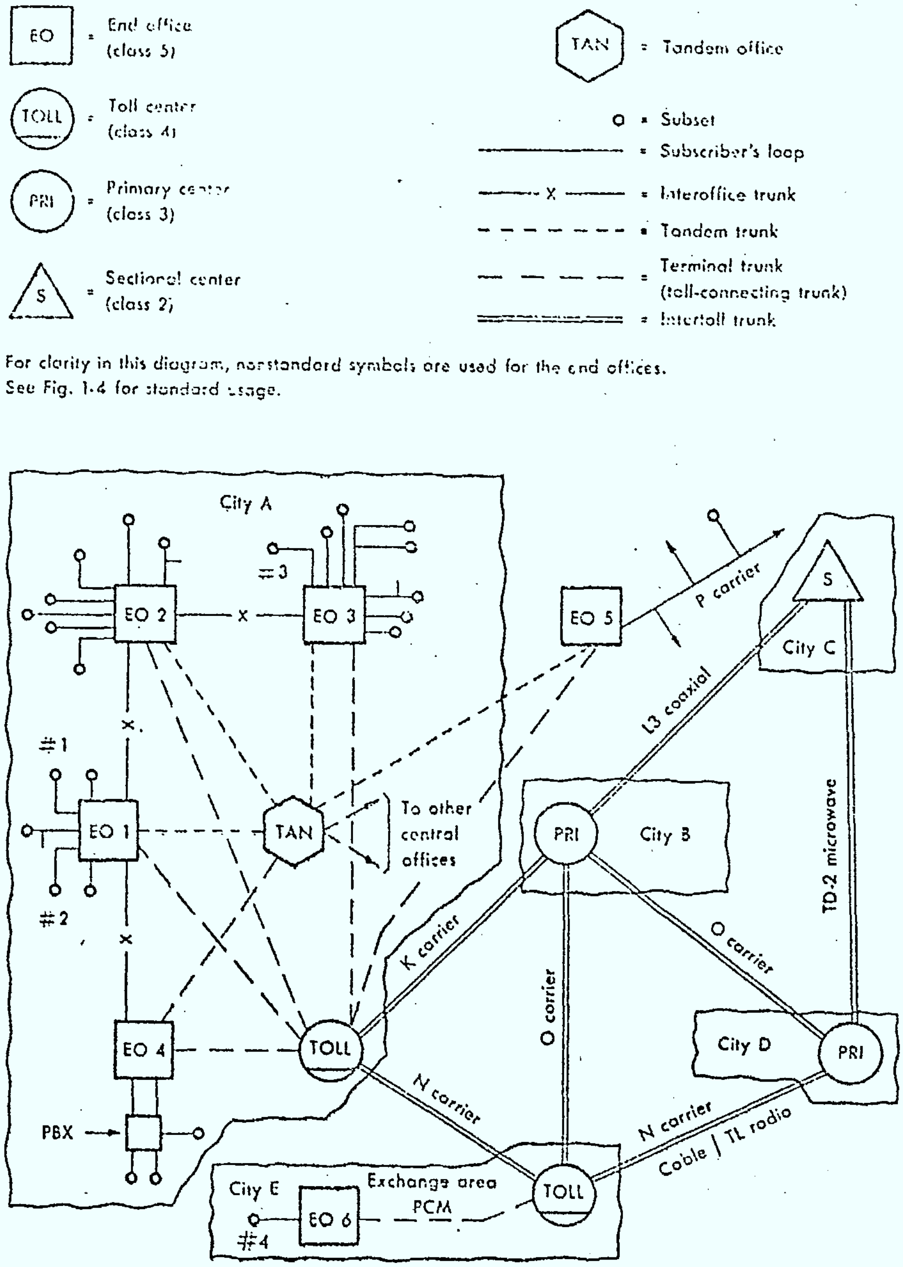
			Approximate Number of Offices in Canada
Class I	-	Regional	2
Class II	-	Sectional	7
Class III	-	Primary	9
Class IV	-	Toll	200
Class V	-	End Office	3,000

In addition, tandem offices are employed to interconnect end offices within the free calling area (see FIGURE 4-1). Of the 3,000 end offices, about 2,200 are in rural areas.

*Trademark of Northern Telecom Limited

FIGURE 4-1

A Simplified Telephone System (from Reference 35)



There are 14 million telephones in Canada, of which 7.6 million are connected to step-by-step switches, 4.6 million to cross bar, 1.5 million to electronic switches (SP-1 or EAX), and the balance to miscellaneous types. All electronic switches are in urban areas.

Digital concentrators are used in some rural areas where the population has a clustered distribution, as in the Maritimes or in British Columbia. However, the design of existing digital concentrators is not suitable for small cluster or dispersed distribution, so they have not found a significant application in the prairie regions. The Farinon SR system (Appendix 1 Volume 2) was designed around prairie conditions, (i.e. to perform as a concentrator extending over microwave radio the end office facilities into scattered clusters of households).

The use of digital transmission systems is increasing because of their better utilization of existing trunking circuits. An existing trunk (copper pair) can be conditioned to carry 1.544 Mb/s (Tl line), or the equivalent of 24 voice channels, and much of the urban interoffice traffic is in this form. The extension of digital transmission into rural areas is limited to those situations mentioned above, where there are appropriate clusters to justify the conversion . . Digital or even electronic switching appears still a remote development in most of rural Canada, on the basis of present growth trends.

The introduction of new services into rural areas could provide the justification for an overlay digital network and the eventual conversion of rural exchanges to digital. Wide area mobile communications, for example, cannot be handled adequately with existing network and switching systems, and present trunking methods are too expensive for complete centralized control of these services. Other data services which are being proposed for home use on a wide scale use digital message formats, and can be handled most economically by means of packet switching and transmission techniques. These various new services which could place a large demand on network capacity, along with normal growth of demand in rural areas, may result in an acceleration of the introduction of digital data transmission systems in rural Canada.

The main problem which has confronted the carriers in rural areas is the provision of telephone service to low density areas with dispersed household distribution. Historically, this has been resolved by means of multiparty lines with the inherent drawback of poor access and lack of privacy. A compromise solution has been to strive for a maximum of 4 subscribers per line in rural areas, a program which is well advanced in most of rural Canada.

Various techniques are used in rural areas in an attempt to reduce the cost of distribution without penalizing the subscriber in terms of blocking probability. One method is to use low capacity subscriber carrier systems designed specifically for small subscriber groups.

Recent approaches allow analog subscriber carrier to be adapted to existing multi-party circuits to increase the capacity from one to six or eight simultaneous voice channels (31). Another technique employed by the carriers is to use radio to provide direct links to subscriber homes. The three basic methods employed are:

1. Single channel link with dedicated radio frequencies.
2. Multiple links forming a group of trunks with frequency agile subscriber terminals with the radio system acting as a line concentrator.
3. Broad band microwave links with time division multiplexing and digital voice sampling (e.g. Farinon SR). Examples of these systems are described in the manufacturer's data contained in Appendix 1 of Volume 2.

An inexpensive means of providing privacy to the user on a multi-party circuit is currently under evaluation by Alberta Government Telephones. This is the Rural Interface Device (RID) which senses if the circuit is busy and locks out all but the particular subscriber using the circuit. The RID does not, of course, reduce the blocking rate, but prevents other users from monitoring conversations in progress.

Accordingly, in considering new services, the telephone companies are faced with the dilemma of what to do with existing plant in which billions of dollars have been invested and which continue to serve its function. Nevertheless, considerable progress is being made toward the introduction of digital transmission and switching techniques because of its better utilization of existing trunking facilities and in response to demands for new types of data services. The introduction of new services in rural areas, such as the Rural Radio Service, could accelerate this trend at the same time helping to improve conventional services and paving the way to new data services for the home. This would be consistent with informal proposals and objectives expressed in many countries (58).

4.3 Radio Technology

4.3.1 Mobile Radio Technology

Mobile radio technology advanced very little in the 1950's and 1960's, other than following the lead of the electronic industry as a whole in the transition from vacuum tube technology to printed circuitry, transistors, and medium-scale integration. Current models still contain a large number of discrete components, require custom assembly and testing methods, and are therefore expensive. Both the labour and material content is high. The top of the line Motorola Micor (FIGURE 4-2) illustrates this point, with tuneable RF amplifiers, discrete channel crystals many optional boards and components all carefully packaged in a cast metal case. These radios were large and heavy (20 to 30 kilograms), but typical of the construction of high quality radios during the early 1970's. In contrast is Motorola's Dynatac portable radio telephone designed for cellular system use, a product of high technology since then.

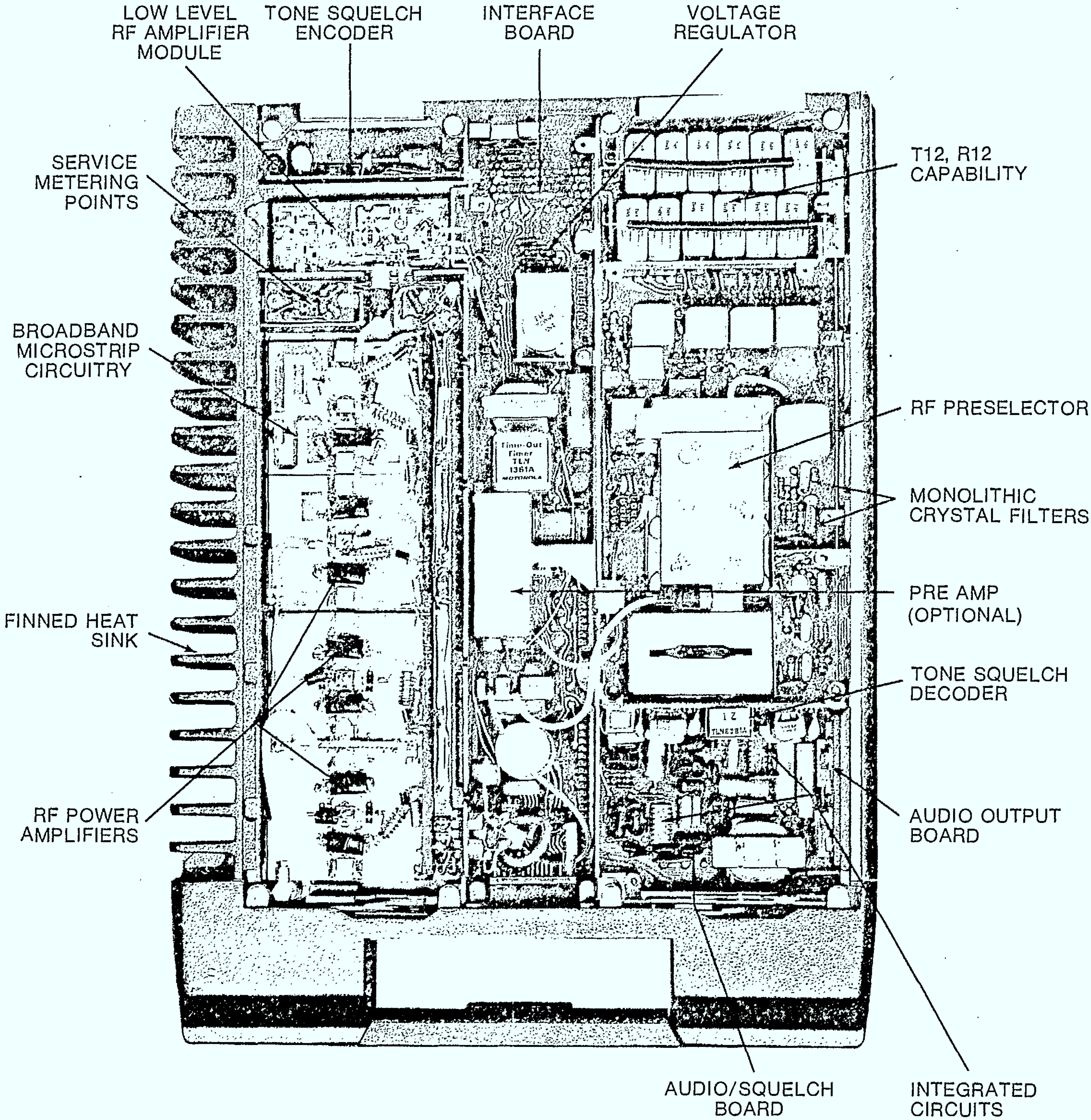
Much of the complexity and precision resulting in high cost of radio circuitry during this period was to compensate for the high level of congestion and interference in densely populated areas, particularly in the United States, resulting in the need for improved RF specifications, channel-sharing devices, and other ancilliary devices. Another factor was the large number of custom systems which were being constructed to meet customer needs, and therefore the use of many options which were often designed to the customer's specifications. Nevertheless, the demand for mobile radio has continued to increase.

Today a major revolution in the design of mobile radios is taking place, primarily as a result of:

- New spectrum allocations, i.e. the allocation of 117 MHz of virgin spectrum by the FCC (866 to 923 MHz) for mobile services.
- The development of new system techniques such as the cellular concept to allow more efficient spectrum usage.
- The development of large scale integration (LSI).

FIGURE 4-2

Motorola - Micor Radio Construction



4.3.2 Present Status of Mobile Radio Technology

With certain exceptions, mobile radio systems are designed to serve vehicular radio installations from the point of view of coverage and operating requirements. Hand-held portables are often used as accessories to the system, but are more limited in communications range, channel capacity, environmental range, and specifications in general. The performance of pack sets or transportable radios falls in between mobile and hand-held portable radios in such systems.

i) Channel Capacity

Vehicular radios were not manufactured with channel capacities greater than 12 until fairly recently. In fact, the majority of radios are still supplied with under six manually selectable channels. More recently, radios have become available with 24 and 36 channel capacity, usually employing frequency synthesizing techniques. With the introduction of high capacity cellular radio systems, some manufacturers are now producing radios with virtually unlimited channel capacity, since frequency agility is an essential feature of these systems. There are 666 channels available in the band allocated by FCC for cellular mobile use.

ii) Radio Specificaitons

Performance specifications have improved in response to the increase in interference potential, and due to improvements in solid state techniques and components. Some of the more important parameters are listed in TABLE 4-2. These and other specifications must hold over the temperature range of -30 to +60 C, according to standard North American specifications and over a primary voltage variation of ± 10%, with some degradation allowed in certain specifications, e.g. transmitter power output.

TABLE 4-2

Mobile Radio Typical Specifications and Minimum Standards (UHF)

Parameter	Typical Industry Range	Minimum Standards RSS 105	RSS 119 (Draft)
Frequency	±.0005%	±.0005%	±.00025%
Stability	±.0002%		
Adjacent Channel Selectivity	-80 to -90 dB	-66 dB	-70 dB
Receiver Sens. 12 dB Sinad	0.2 to 0.5μ v	0.75 μ v	0.75 μ v
Intermodulation Response	-70 to -85 dB	-45 dB	-70 dB
Spurious Response Attenuation	-85 to 100 dB	-85 dB	-85 dB
Spurious Output	-70 to -85 dB	-60 dB	-60 dB
FM Hum and Noise	-45 to -60 dB	-37 dB	-37 dB

Radios sold in Canada must meet DOC specifications before they can be licensed. These specifications tend to reflect the state-of-the-art and are tightened periodically in response to improvements in technology and increasing congestion in the mobile bands. This process rules out the possibility of many offshore suppliers selling on the Canadian market and, to some extent, inflates the cost of mobile radio equipment. For example, the differences between Radio Standard Specification (RSS) 105 and RSS 119 with regard to frequency stability and intermodulation response, as applied to the 450 to 470 MHz band (TABLE 4-2). Nevertheless, there has been little change in specifications or the standards format since RSS 126 for VHF highband equipment was issued in 1962. The new specifications do not reflect the developments currently taking place in mobile technology, nor the innovative techniques which have been implemented in some major systems over the past 10 years (i.e. employing digital addressing and message transmission).

We conclude that the Radio Standard Specifications should not only reflect past history, but also new trends in technology in ways which encourage the adoption of system designs for better spectrum utilization.

4.3.3 Current Trends in Mobile Technology

The most important trend in mobile communications affecting cost is that which could lead to standardization in system configurations, and the corresponding standardization in mobile radio equipment. The cellular system developments or any other systems which share a network of base stations with standard coding and control schemes, and spectrum organization, depend for their success on a correct interpretation of the needs of a large user population. This should provide the blueprint for large quantity production, close competition, and lower costs, made even more possible through the use of new LSI and microprocessor technology.

The state-of-the-art in mobile radio design is in transition from the conventional technology described in the preceeding section to a technology which will eventually see common use of the pocket portable telephone. This transition is, nevertheless, evolutionary, with stages determined not so much by technical feasibility, but by the development of user need patterns and by economics. In rural areas, for example, it will take longer to justify the personal pocket telephone using conventional means than in urban areas because of cost, and it may in fact be the mobile satellite approach which is the most practical in the long run.

However, the widespread use of mobile radio in rural areas, already an established fact, will be best served in the near future by increasing its versatility, range and reliability. A new service of the kind proposed would be a logical transition stage in the evolution if it can be provided at reasonable cost.

4.3.4 Major Factors Affecting Mobile Radio Costs

New generations of mobile radios will be very sophisticated and will include as standard equipment many features which are optional, at best, in most existing radios, e.g.

- selective calling
- automatic identification
- large channel capacity
- status reporting and dispaly
- remote channel allocation
- duplex operation

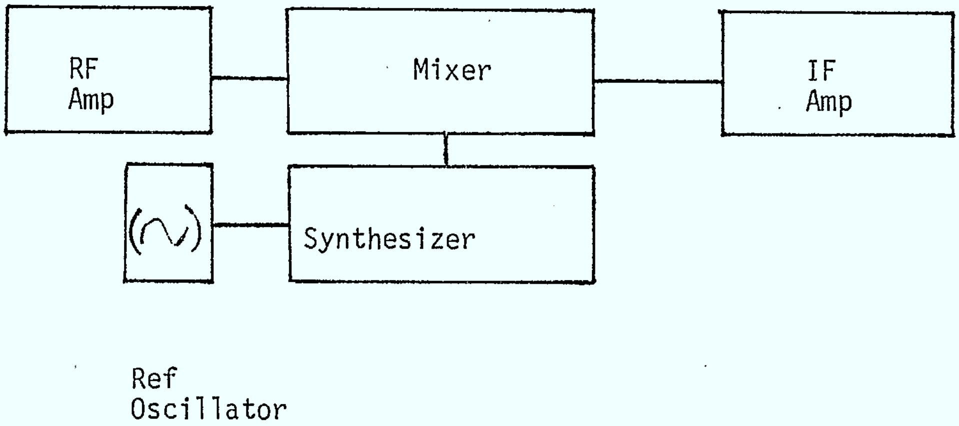
The possibility of producing radios with this degree of sophistication, and at low cost, depends on maximum standardization of design, extensive use of LSI, and considerable development effort, as discussed in the following examples.

i) Frequency Synthesizer

Synthesizers are coming into more common use in multichannel mobile radios, since it is a more economical approach than providing separate channel elements for radios equipped with six or more RF frequencies. The production cost for a synthesizer is quite high, in the order of $200 at present (adding around $400 to the user price). The reason for the high cost is the need to control the noise and spurious outputs, and this is done at present by generating a highly stable reference frequency at or near the RF frequency, and dividing down to the mixer frequency. A true synthesizer as illustrated in (FIGURE 4-3) in which "the output frequency is produced directly by mathematical operations on the input reference frequency without internal locked oscillators or feedback loops" (38 P. 42) in not practical for this application at present for several reasons.

FIGURE 4-3

Block Diagram of a True Synthesizer



In analog synthesizers the noise output is increased by 6 dB with each doubling of the frequency. In digital synthesizers the output frequency is limited by the processing speed. Practical limits are a few megahertz since large memories are needed with access times measured in nanoseconds (38 P. 43).

Present day phase lock loop synthesizers can be cost reduced by making maximum use of LSI (i.e. for frequency division programming and for phase detection). Whether this will result in sufficient cost reduction, or whether some other technique will be found remains to be seen. However many experts in the field are of the opinion that all mobile radios (even single channel) will use synthesizers at some future date, a desirable goal in order to eliminate custom crystal manufacturing with the resulting delays in production and delivery.

Other alternatives are worth evaluating. One approach is to use the base station frequency to synchronize the mobile oscillator. Where a duplex arrangement is standard or the mobile frequency generator is synchronized at regular time intervals, this may be the least costly approach. This is an area requiring development work in order to further cost reduce the radio RF circuitry.

ii) Signalling and Control

Programmable ROMS are appropriate for use in these sophisticated radios. There are many functions which can be best handled in the digital mode, including address generation and detection, information display, frequency selection, handshake routines, gate control, etc. In existing automatic systems, these functions are still largely performed by TTL logic with varying levels of LSI where the data packages are added to standard mobile radios and adding cost equal to that of the basic radio. Once the signalling and control functions are fully defined, most of the refined circuitry can be supplied in the form of LSI chips at a fraction of the cost of present equipment.

Advances in microprocessing techniques and applications has been such that almost any function which can be transformed in to the digital mode can be performed more economically and more reliably using LSI. The growth between 1970 and 75 (FIGURE 4-4) has led to widespread use of CMOS, always at a fraction of the cost of circuits employing TTL (FIGURE 4-5) (37).

FIGURE 4-4

Approximate Component Count for Complex Integrated Circuits (37)

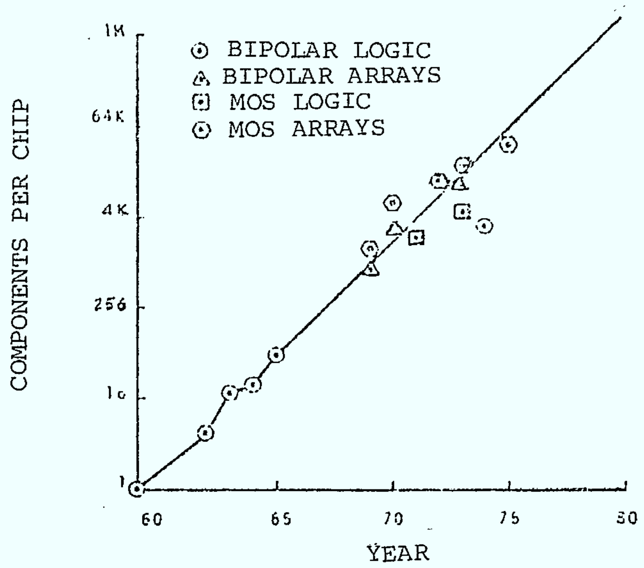
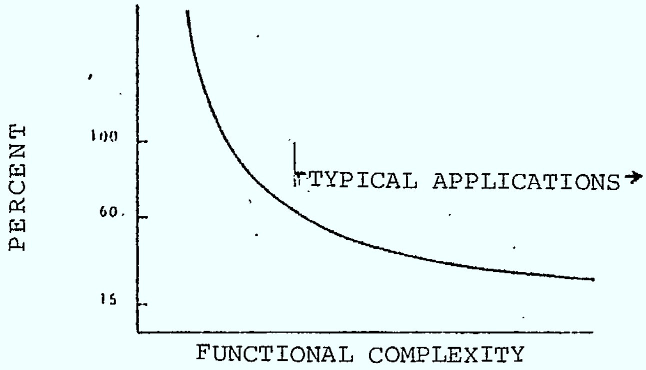


FIGURE 4-5

Cost of Microprocessor-based System as a Percentage of the Cost of its TTL Equivalent (37)



According to Nichol's (37), "Considering current applications and recent events, a number of future trends are clear."

1. As new microprocessor-based products come into being, there will be a rapid tendency to add increasing sophistication to the initial product.
2. The number of analytical instruments based on micro-computer technology will increase tremendously while at the same time simplifying their operator control.
3. There will certainly be microprocessors in the home. They will control many aspects of our lives such as appliances, temperature, lighting, and security.
4. Entertainment will become a major area for microprocessors, with sophisticated real-time participation games moving into the livingroom.
5. Significant inroads will be made into the area of transportation. Microprocessor control will appear in most transportation units such as automobiles, trains, airplanes, and boats. In addition control of the flow of units in traffic control and freight car identification will come to rely more and more on this new technology.
6. A signigicant revolution will take place in process control, as well as in other manufacturing functions such as inventory management and data collection.
7. The use of microcomputers in communication modules will continue to increase. They will make possible more sophisticated switching systems, multiplexers, error detection and correction circuits and encryption equipment.

iii) Radio Frequency Components

Cost reduction in the RF portion of the mobile radio cannot be achieved as dramatically as for those circuits which can be handled digitally. FR technology and components continue to improve, but the use of discrete components, custom assembly and testing continues to be normal practice. With a standard radio, however, less time will be required in tuning and testing, a process which could be largely automated. Further significant reductions are possible due to economy of scale.

We assume a continuation of traditional RF parameters such as band width, spacing, modulation techniques. In fact these assumptions should be reviewed in the light of new technological advances and spectrum.

4.3.5 Cellular System Specifications

A relaxation in the specifications for radios used in cellular type systems should be possible. There is a direct relationship between specification values and radio costs. We do not suggest any specification changes which would significantly degrade system performance. However, in the structured system, some problems experienced in present congested areas largely disappear. For example:

i) Third Order Intermodulation Products

This most common source of interference in conventional systems would be eliminated with a controlled frequency allocation approach.

ii) Adjacent Channel Interference

If adjacent channels allocations are avoided in a given cell, there is small probability of receiving a strong enough signal from a neighbouring cell to cause interference.

iii) Co-channel Signals

Co-channel signals from other cells will be received occasionally, but will seldom cause interference with the local transmission due to the capture effect and will be of no consequence when the radio is muted.

Accordingly, mobile radios employed in the land mobile service are still largely produced using traditional manufacturing techniques and the cost remains high particularly for radios being built for sophisticated or automated systems. Nevertheless, the revolution in the development of electronic devices is now being applied to many aspects of the mobile radio and will eventually reduce its cost very considerably. A new look at radio specifications which have been developed in response to the traditional spectrum allocation procedures and interference patterns could result in some revolutionary changes in the design of the RF portions of mobile equipment. This step is essential to the production of a low cost radio service.

4.4 Use of Coding Techniques in Mobile Communications

4.4.1 Introduction

Coding and code transmission here refer to the generation, transmission and detection of information other than analog voice in mobile communication systems. Coding is used for the following purposes:

- selective addressing
- individual identification
- group calling
- status message transmission (canned messages)
- text transmission (facsimile, teletype, video, text, etc)
- control
- interactive data communications
- packet data communications
- digital voice communications

The radio channel is frequently shared in existing systems between voice and data transmission or for simultaneous code signalling and voice transmission. The most standard form of coding used is the continuous tone controlled signal system (CTCSS) which is specified by the Electronic Industries Association (EIA) for group signalling or for channel interference protection. In the CTCS system a subaudible tone modulates the transmitter output continously, gating the audio circuits in a particular group of receivers. It is sometimes used for selective calling or status message transmission control.

In-band tones are most frequently used for selective signalling and control purposes. There are many different tone systems used, some of which have achieved some degree of standardization. More recently, the dual tone multifrequency system (DTMF), of which TOUCHTONE * is a particular example, has been widely used in radio systems.

* Trademark of AT&T

In the more sophisticated systems, digital techniques are used more commonly, employing frequency shift tone keying or direct carrier shift methods. Examples of systems employing these techniques are paging (Bell system), packet data, status systems, teletype, etc.

In rural areas, the use of coding techniques has been nonexistent in small systems (other than for paging), but it is employed in one form or another increasingly in major systems (e.g. power distribution maintenance systems). In urban areas, CTCSS is used extensively to reduce the amount of noise and co-channel interference, while digital techniques are used in recent or proposed system designs for major systems employing computer-aided dispatch. Facsimile and teletype are used in isolated cases, mostly in remote areas. Packet radio communications systems are not used in the land mobile bands in Canada, but have been suggested as a useful alternative to conventional land line technique for shared computer access.

Although only 8% of mobiles in the business sector (23% in government) included any coding technique (other than CTCSS) in Canada in 1976 (21) 50% to 75% indicated a need for some form of coding system by 1981. Any major user of land mobile equipment who is planning a new system or to revamp an existing system will almost certainly employ coding in one form or another. Digital techniques are essential in high capacity radio systems which are going to absorb much of the mobile market in future years. It is clear that coding techniques will be used in most mobile systems in a few years' time.

Significantly, in most current applications of coding techniques, the coded information is superimposed on the RF voice channel and performs a convenience function rather than an essential system function. The cost of this convenience is usually high, which accounts for their low penetration and for the fact that government systems where cost is less important reported three times as many systems employing coding systems than commercial users. This situation could change very quickly once the economic advantages of digital techniques are available to the user. These benefits are in two areas:

1. Reduced share in the cost of fixed facilities which will be possible when the user is charged on time used basis for a facility he shares with a large number of other users.

2. Increased efficiency brought about through digital message transmission (i.e. in reduced labour, faster service, etc).

4.4.2 Present and Future Uses of Coding Systems

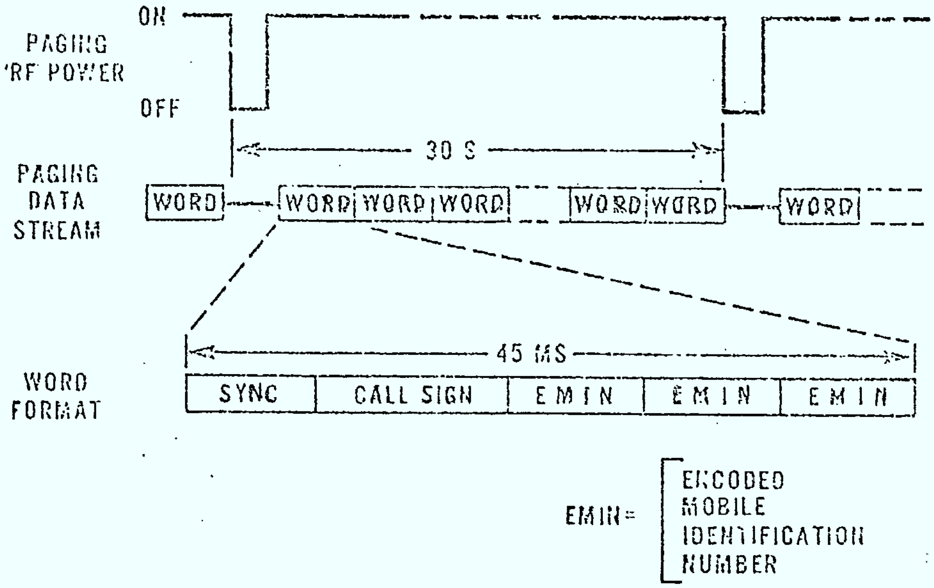
The earlier coding systems and those still most common in the land mobile services were the CTCSS system and various in-band tone systems for selective calling and control mentioned in the introduction. Digital coding, because of its greater versatility (i.e. large address capability, etc) is able to perform these and other functions more effectively in large systems and will eventually replace all other coding techniques in major systems. Examples of coding and code formats in such systems are discussed below, while in the next subsection, the problems faced by the designer due to the mobile environment are discussed.

i) Status Reporting

In systems used for status reporting, the mobile is equipped with a mobile data unit or module containing buttons for reporting changes in status (e.g. arrival at scene, out of service, etc). Each data unit has a unique identification and address code and is capable of generating several status codes which are transmitted along with the ID code when the appropriate status buttons are depressed. In some systems the code is transmitted as soon as the button is pressed (FIGURE 4-7) while in others the vehicles are polled and transmit status when interrupted (FIGURE 4-6).

FIGURE 4-6

Paging Data (Format and Rate) (10)

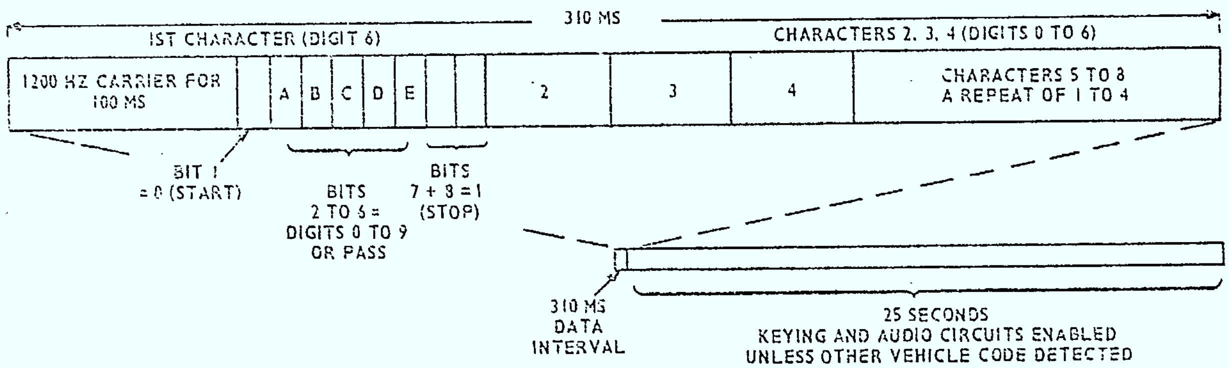


SYNC	11 BITS
CALL SIGN	15 BITS
(E M I N) X3	108 BITS
	134 BITS

134 BITS/.045 SEC.=3.6K BITS/S

FIGURE 4-7

Code Format for a Simple Digital Status System (24)



The data unit may also be capable of receiving several different instruction codes which when detected provide an audible alarm and a visual indication of the instruction.

Simple status reporting systems are most appropriate for radio dispatch systems, in which the vehicles perform a regular sequence of actions during an assignment (e.g. police and ambulance services or concrete delivery systems).

Two examples of coding techniques used are as follows:

1. Motorola Modat Status System - employs an older version of standard CCIR code in which 11 tones are transmitted in sequence, each tone having a duration of 20 ms (total duration 220 ms). The function of each tone is determined by its position in the tone sequence (i.e. several locations are assigned to individual identification, others to status function, etc).

2. Rydax Corporation Status System - an FSK code at 900 baud (see FIGURE 4-7). More sophistication is found in status systems which provide a numeric read-out in the vehicles on a LED or CRT display. Most of those systems employ FSK at from 800 to 3000 bits/second and require message repetition to achieve an acceptable level of reliability. Among the companies which offer these systems are Motorola, Kustom Electronics and MDI.

ii) Mobile Terminal

Another level of sophistication is reached in the mobile terminal which contains a keyboard in addition to a display, and may also contain a set of status buttons. Kustom NCT (FIGURE 4-8) or MDITMDT (FIGURE 4-9)

iii) Digital Voice Transmission Techniques and Codes

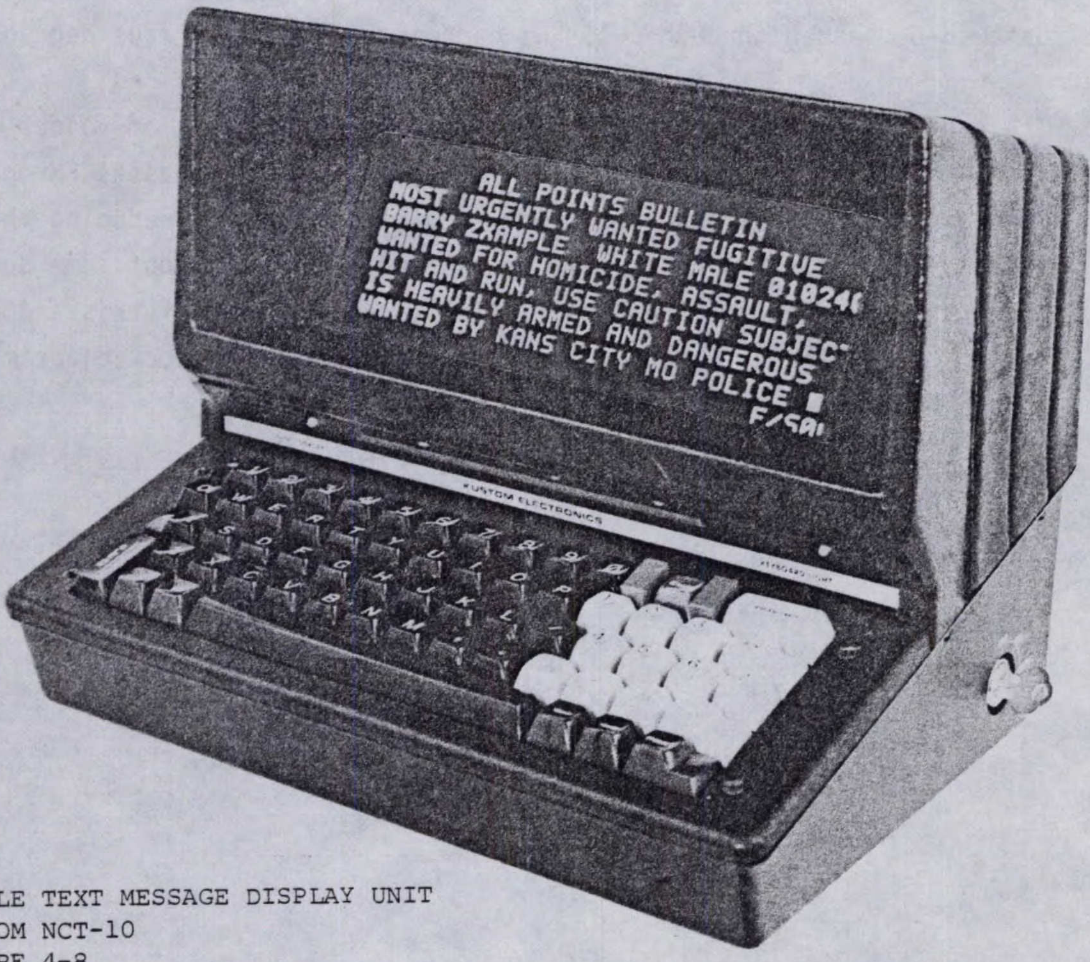
The need for voice privacy has led to considerable development of digital voice transmission techniques for mobile applications. A more recent example is a joint effort of Communications Research Centre and Canadian General Electric, results of which are described in a paper given recently to the NTC (39). The system is designed for compatibility with existing mobile systems which places a strict data rate limitation on the design. The most appropriate approach was found to be an FFSK modem operating at 16Kbits/s using an adaptive delta modulation codec which enables the data to be passed through a 13 KHz bandwidth without serious degradation.

The system is claimed to perform "as well as FM in terms of voice intelligibility on average while in fringe areas it surpasses FM operation". However there is some loss in fidelity and naturalness by reducing the data rate to 16Kbits/s (24 Kbits/s is considered minimum without some degradation), which somewhat limits the potential application areas of this and other systems developed to date. The operation is shown in block diagrams FIGURE 4-10).

KUSTOM MCT-10 MOBILE COMMUNICATIONS TERMINAL

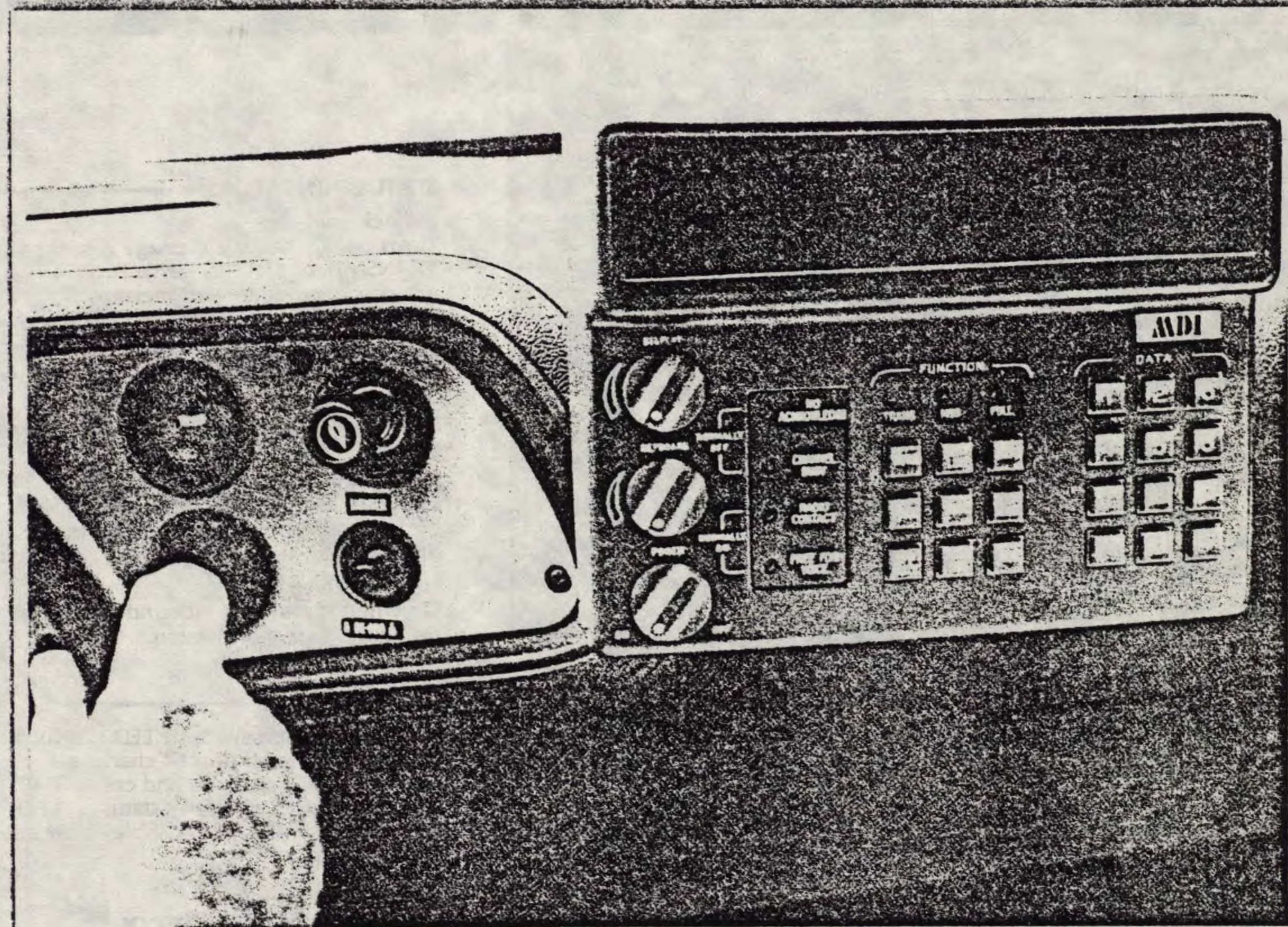
The Kustom Mobile Communications Terminal (MCT-10) is a safety engineered terminal especially designed to meet the need for faster, more accurate and more flexible two-way communications.

The mobile terminal consists of a keyboard, a solid-state display (not a CRT), and internal power supply and a special design modem. The keyboard has full alphanumeric capability including special function keys (status, 10-xx, emergency, canned messages, etc.). The transmit key initiates all mobile-to-base transmissions of composed messages. The display is a low-voltage, solid-state, dot-matrix panel. Since the display is not a Cathode Ray Tube, it does not have the hazards of the CRT, such as implosion due to impact or the possibility of high voltage shock. The display has large, easy-to-read characters and a full **224**-character capacity. The modem is a high-speed synchronous audio phase-shift-keyed system with exceptional noise immunity.



MOBILE TEXT MESSAGE DISPLAY UNIT
KUSTOM NCT-10
FIGURE 4-8

INTERNATIONAL
MOBILE
DATA INC.



TRANSPORTATION MOBILE DATA TERMINAL (TMDT)

The TMDT is an intelligent mobile terminal designed for rugged vehicular environments and with broad capability in improving the management of field resources, particularly in the following areas:

- Police
- Fire
- Emergency Medical
- Utility
- Service
- Transportation

The TMDT can provide data entry and retrieval as well as automated command and control including automatic vehicle monitoring (AVM) and automatic vehicle location (AVL). It enables:

- Reliable and private digital dispatch.
- Status reporting and other "formatted message" capability.
- Data entry in both free form and "fill in the blank" mode using protected forms with editing.
- Data retrieval with visual display, multi-line memory and optional printer.

The TMDT can share an existing voice radio channel or use a dedicated radio channel. The unit is designed to interface with any 2 way FM mobile radio. All common channel control modes (such as simplex and half duplex in controlled contention or polling configurations) are incorporated as well as other strapping options.

FIGURE 4-9

Features

The TMDT offers features available only through modern design using the latest in technology.

UNPRECEDENTED THROUGHPUT: Using a combination of the highest possible bit rate (4800 bits per second), powerful error correction, and fast channel protocol, a single radio channel can support hundreds of terminals. The massive error correction also means that data range is equal to or better than voice.

FAST ACCESS TIME: With hundreds of terminals on one channel the access time will be one second or less.

HIGH DISPLAY VISIBILITY: Using special high intensity LED's as indicators and LED's with directional filters as display, the unit offers high visibility (even in sunlight) plus the reliability of all-solid-state technology.

A COMPACT, TOTALLY ENCLOSED UNIT: The use of solid state displays and indicators means no consumable parts to wear out (even the keyboard illumination is solid state!). This enables the unit to be totally enclosed and sealed.

ADVANCED TECHNOLOGY: Use of the most advanced microprocessor available (Z80) plus other state-of-the-art components assures that the unit will be flexible in use and will not be obsolete in coming years.

PROGRAMMABLE KEYBOARD: The user may choose from the standard keyboards or select key placement and originate nomenclature for his application.

EASE OF USE: The unit is fully prompting for the operator. When the wrong keys are depressed a buzzer sounds but no other operation takes place. System and unit status are clearly displayed, including indicators for radio channel busy, radio contact with base RF signal and messages in memory.

HIGH PERFORMANCE: The TMDT meets or exceeds all industry specifications for mobile data terminals.

SYSTEM INTERFACES: Complementary base station and computer communications controllers are provided on a system basis to match any computer.

SOFTWARE: Standard software and implemented firmware are included in every terminal package. Custom software and expansion memory are available.

STATUS INDICATORS

No Acknowledge
Turns on whenever a message is sent (via TRANSMIT or STATUS keys). Turns off when acknowledgement message received or when cleared by CLEAR key.

Channel Busy
On whenever channel is busy with voice or data from other mobiles. Data transmission is inhibited as long as channel is busy.

Radio Contact
On when mobile is in radio contact with base for reception of data messages. Is not used for voice.

Free For Voice
On when there is no inbound or outbound data transmission.

DISPLAY
32 characters alphanumeric LED display. Character set consists of 64 characters. Used to display received and composed messages as well as display status and I.D. Returns to status and I.D. display after one minute of no activity.

DISPLAY INTENSITY CONTROL
Dims display and indicators simultaneously for night use.

KEYBOARD ILLUMINATION CONTROL
Dims keyboard illumination.

POWER ON/OFF SWITCH
Connects power to terminal.

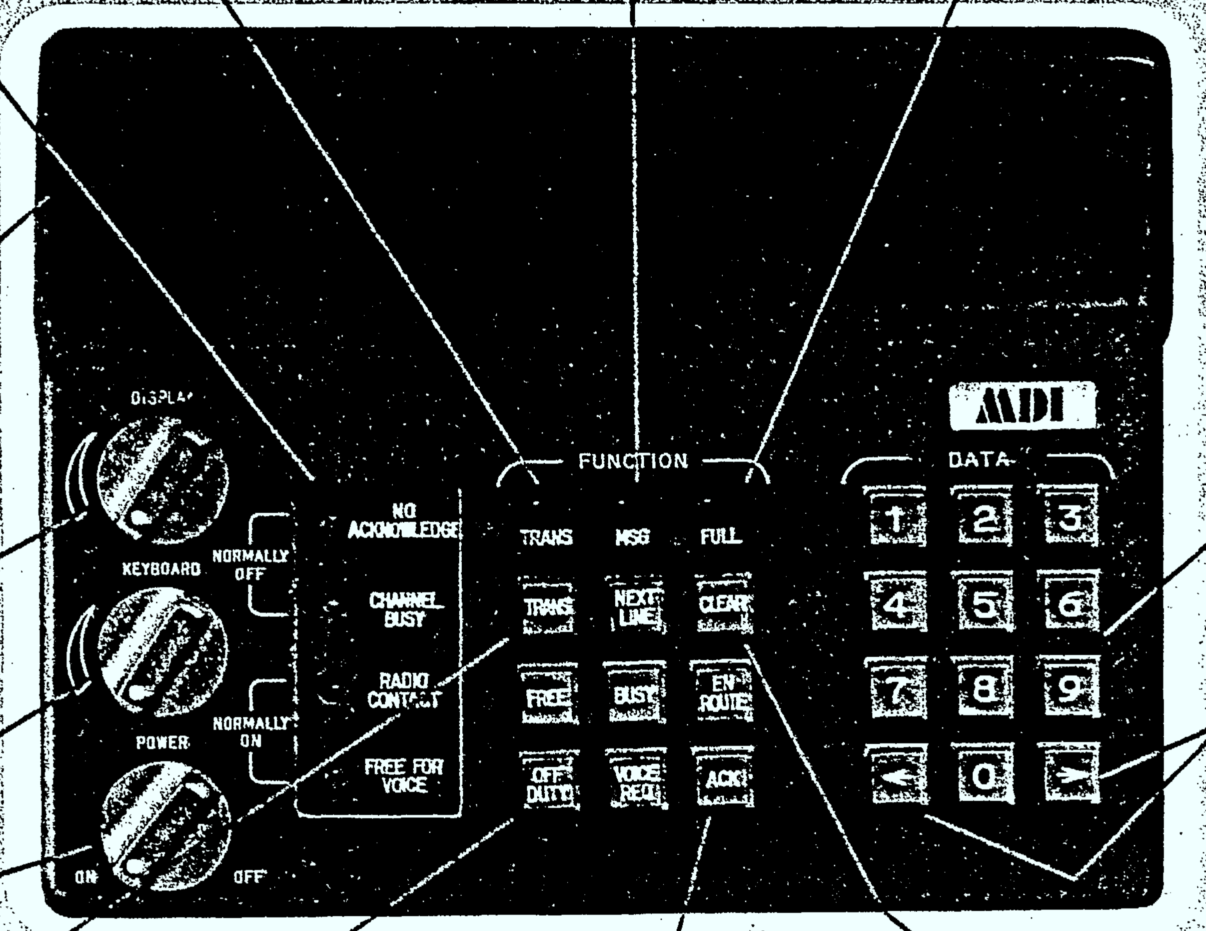
TRANSMIT KEY
Depressing key transmits the displayed line. If no acknowledgement is received after 5 attempts the NACK indicator stays on and the buzzer sounds.

Model MD7781 Mobile Data Terminal

MESSAGE INDICATOR
On when one or more messages in the buffer have not been displayed yet. Use NEXT key to view messages.

BUFFERS FULL INDICATOR
On when all six buffers are full (due to received or composed messages). When on operator should examine buffers and clear at least one to make room for incoming messages.

TRANSMIT INDICATOR
On when transmitter keyed.



NUMERIC DATA ENTRY
Used to enter I.D. number and for filling out forms received by the terminal.

EDITING KEYS
Depressing key moves cursor. Cursor starts running when key held down continuously.

STATUS & FORMATTED MESSAGE KEYS
User specified messages are programmed into the system.

MANUAL ACKNOWLEDGE KEY FORMATTED MESSAGE
Causes transmission. Does not affect the status of the terminal. Used only when requested.

CLEAR KEY
Clears current function. When operated on a form, first activation clears the data and saves the form; second activation clears the form.

TMDT Specifications

FUNCTIONAL

MESSAGE RECEPTION: Up to 6 alpha-numeric messages of 32 characters each or any combination of messages with a total length of 6 lines. Forms with protected fields can be received and stored in memory for easy entry and transmission of data.

MESSAGE TRANSMISSION: 6 "canned message" plus free format or "fill in the blanks" entered data of up to 6 lines of 32 characters depending upon model.

DISPLAY: 32 character LED, character height is 4 mm. (0.16"), character set is 64 characters. Clearly visible in sunlight. Adjustable intensity for night use.

INDICATORS: 7 indicators using sunlight visible LED. Variable dimming provided for night-time use.

KEYBOARD: Up to 28 non-glare keys with adjustable night-time illumination.

CONTROLS: Power on/off, display intensity and keyboard illumination. Screwdriver adjustments for deviation and input sensitivity.

TRANSMISSION METHOD: A proprietary modem (patent applied for) operating at 4800 bits per second. The data transmission envelope meets Canadian (DOC RSS119) and EIA (RS152B) specifications. Bit rate conversion at land line interface is optional.

ERROR CORRECTION: Any burst or combination of errors up to 25 ms long minimum will be corrected without retransmission.

RETRANSMISSION AND ACKNOWLEDGEMENT: Automatic (up to 4 retries) plus manual acknowledgement when desired.

UNDETECTED ERROR RATE: Less than one in 10 million characters.

NOISE FALSING: Unmeasurable

SYSTEM CAPACITY: Typically 6000 transactions/hour on a single radio channel with a controlled contention access time of one second or less. Up to 75000 transactions per hour in a short message polling system.

RF SIGNAL STRENGTH REQUIRED: Static test: 6 db above the 12 db Sinad level for 5% retransmission. Fading channel: 12 db above the 12 db Sinad point for 5% retransmission.

SELECTIVE CALL: Individually addressed, group call or all call modes.

VOICE I.D.: The terminal can provide I.D. message for voice whenever the PTT switch is activated.

PERIPHERALS: The terminal will support an external printer for hard copy, or an external multiplexer for automatic vehicle monitoring, passenger counting and vehicle location sensors.

EXTERNAL INPUTS: Two contact closure inputs are encoded into the message header and transmitted with each message. Any change in the state of these inputs generates a message.

EXTERNAL OUTPUTS: Two control outputs capable of switching remote devices such as horn, light, etc. can be controlled from base station.

ELECTRICAL

INPUT VOLTAGE: 13.8 v ± 20% for 12V Systems positive or negative ground. 24 VDC operation available.

CURRENT DRAIN: 1.5A max. at 13.8 VDC.

INPUT: From radio receiver discriminator, internally adjustable to accept 0.5 to 5 V p-p. Input impedance 110 Kilohms AC coupled.

OUTPUT: To radio modulator, internally adjustable to 2 V p-p, Z^o=1 kilohm or less, AC coupled. 0 to 4 V p-p optional.

CONTROLS: (2) Solid state (open collector transistor) to switch 1 amp d.c., continuous.

ALARMS: (2) Dry contact closures.

UNIVERSAL INTERFACE: (optional). Fully programmable. Bi-directional 3 port 8 bit parallel.

PHYSICAL

SIZE: 18 x 23 x 6.5 cm. (7.2" x 9" x 2.5")

WEIGHT: Approximately 2 kg. (4.4 lb.) including mount. 1.75 kg. (3.8 lb.) without mount.

MOUNT: Spherical mount. Allows swivel and tilt of up to 30° in all planes plus full rotation.

TEMPERATURE RANGE: -30 C to +60 C operational; -50 to +75 C storage.

HUMIDITY: 0% to 95% RH non-condensing. Occasional condensation allowed.

SHOCK & VIBRATION: Meets EIA RS 374A specifications.

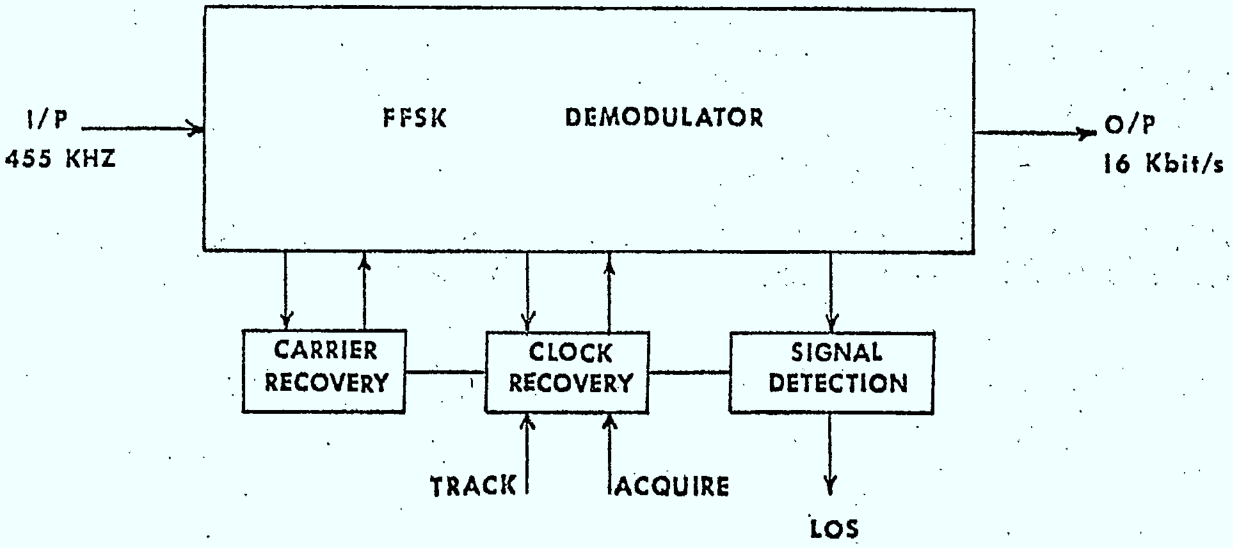
MDI

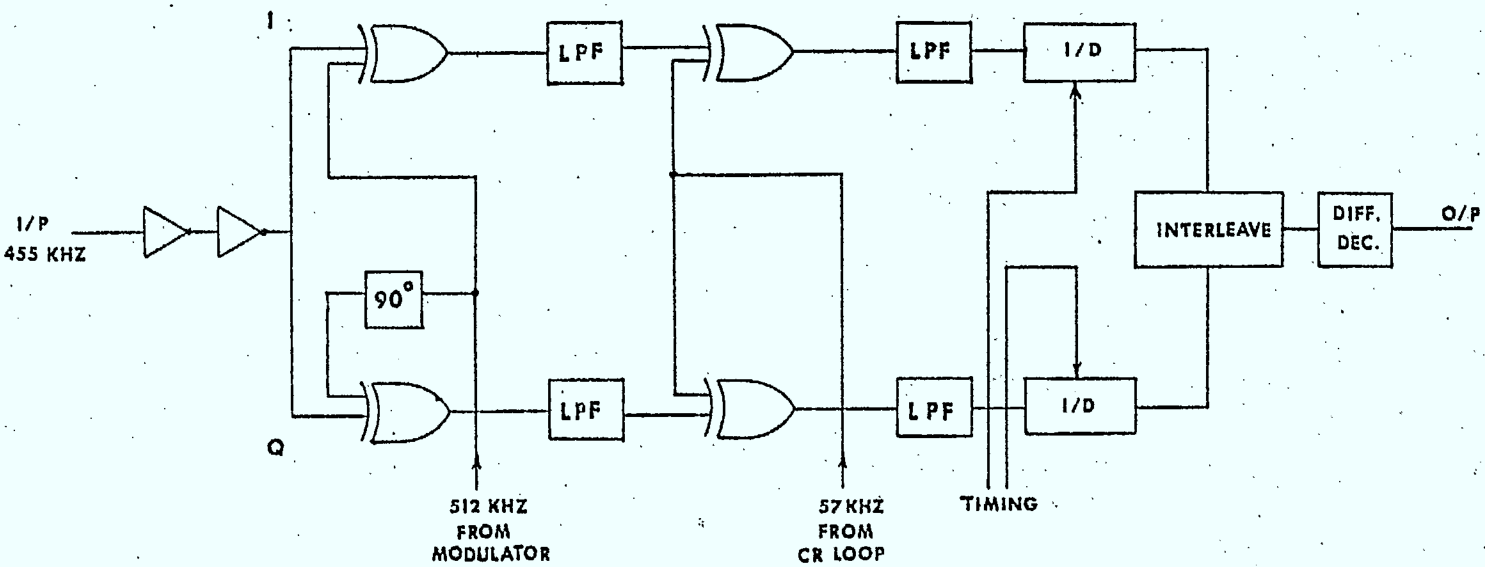
For further information contact

INTERNATIONAL
MOBILE DATA INC.

10110 Shellbridge Way, Richmond, British Columbia
Canada V6X 2W7 Telephone (604) 278-3556

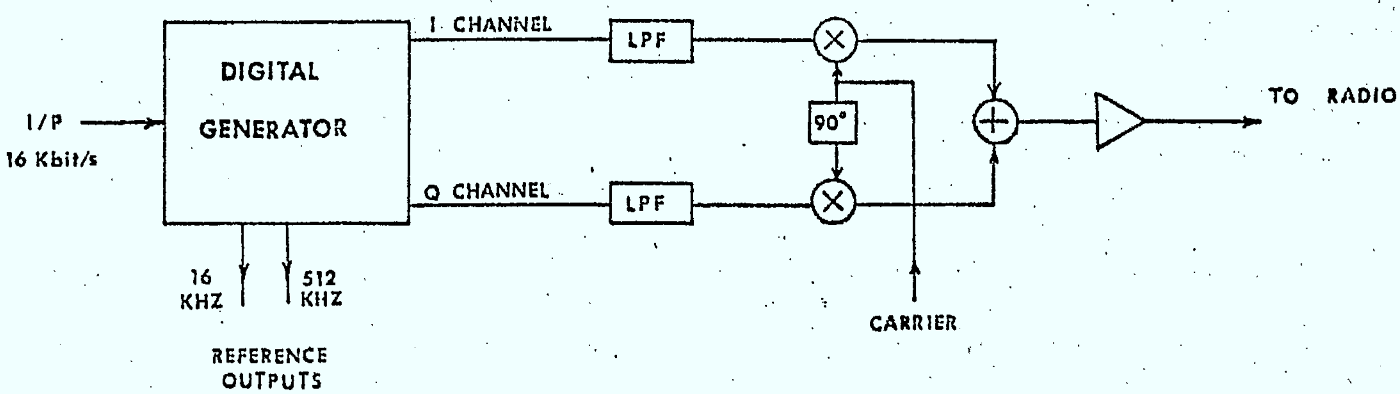
Printed in Canada





FFSK DEMODULATOR AND DEMODULATION PROCESS (39)

FIGURE 4 - 10A



FFSK MODULATOR (39)

FIGURE 4-10B

Digital voice systems designed for mobile applications normally incorporate voice privacy employing encryption techniques of a highly proprietary nature. The user cost for adding this feature to his radio system is around $1000 per radio and will remain high in cost until a standard approach is adopted, which can be incorporated in the original radio design. This will not happen until a fully satisfactory design has been developed and adopted.

There are varying levels of privacy. Radiotelephone systems with dynamic channel assignment and normal voice modulation techniques provide a low degree of privacy which may be satisfactory to the majority of users. However, those subscribers requiring a higher level of security would need an option such as provided by digital voice privacy systems. For these users, the concept just described may be satisfactory.

iv) Signalling Technique in High Capacity Systems

Various schemes for providing the control and supervisory functions in high capacity systems have been suggested. The system proposed by AT&T employs a control and answering channel in each cell which controls all vehicles in the cell area. A more efficient scheme for a system with relatively few channels per cell would signal on any available channel as in the IMTS system (channels are scanned by the radio receivers) until all channels are loaded, in which case any new call initiated would be blocked. It is also possible to interleave the control data with voice data on active channels employing packet techniques, thus making maximum use of the cahnnel capacity.

A proposed scheme for use in medium capacity systems based on the AT&T approach would employ a BCH (60,42) code (FIGURE 4-11). The mobile signal contains the mobile ID, control information, dialled number, plus the parity information. The base-oriented control signal contains mobile

ID, control, area code, and first three digits of the mobile address, message data and parity information. All transmissions to or from the radiotelephone set include the four digit ID. Other transmissions contain control or message information such as channel assignment, operating mode and station ID. It is probably that a standard code format and signalling procedure for systems interconnected with the telephone network will be adopted in the United States as a result of the cellular system trials, and pressure will be applied on Canada to adopt the same standard. The final format has yet to be determined but a fairly high data rate is needed to handle the traffic in heavily-loaded cells (up to 3600 bits/s originally proposed by AT&T).

FIGURE 4-11

Signalling Formats, BCH (60, 42) Coding (40)

MOBILE ID XXXX 14 BITS	CONTROL 4 BITS	MOBILE ID NPA + NXX 14 BITS	MESSAGE 10 BITS	BCH PARITY CHECK 18 BITS

TYPE 1

MOBILE ID XXXX 14 BITS	CONTROL 4 BITS	7 DIALED DIGITS 24 BITS	BCH PARITY CHECK 18 BITS

TYPE 2

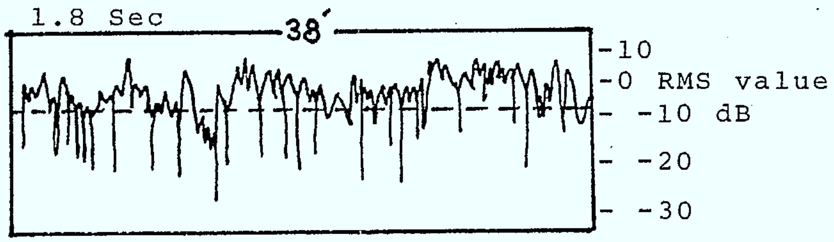
4.4.3 Digital Techniques and the Mobile Environment

Designers have had considerable difficulty in trying to design successful signalling equipment for mobile radio use. Signal levels and noise conditions vary continuously with a combination of fast and slow changes as the vehicle moves. Noise, which is most severe in urban areas, is rrelatively unimportant in rural at frequencies above 400 MHz, and can be disregarded in designing rural systems.

The objective in designing signalling systems for mobile use is usually to achieve reliable signal operation at S/N threshold, usually considered to be in the 6 to 12 dB SINAD region. Gradual variations in signal level occur locally and more gradually in accordance with the normal laws of propagation, and these present no problem according to the above criteria. However, in addition to this slow change, rapid fluctuation resulting from multipath interference between direct and reflected signals occur (FIGURE 4-12). The effect on bit error rate is seen in FIGURE 4-13 for a 4800 b/s signal. As seen, the average signal level required in the presence of Raleigh fading is 17 dB more than with no fading at BER of 10^{-3}. At threshold the BER in the presence of fading in close to 10^{-1}.

For short duration signals such as an address the reliability can be increased to a satisfactory level by message repetition (in close sequence or if no acknowledgement is received). However with long bit streams, (e.g. for transmitting text messages), simple repetition will not increase the reliability enough except at fairly high signal levels. Typically, such systems have required average signal margins 20 dB above threshold to operate reliably. Improved techniques have reduced the required margin according to MDI aby 10 dB or more.

FIGURE 4-12
Typical Received Signal Variations at 836 MHz Measured at Mobile Speed of 24Km/H (41)



4.4.4 Data Messages and Spectrum Use

The advantage of data over voice for message transmission can be appreciated by comparing the average time taken to transmit the same message by both means. To transmit a simple instruction by voice requires the following sequence.

1. Key the transmitter and call the vehicle operator.
2. Wait for acknowledgement.
3. Key again and transmit the information.
4. Wait for acknowledgment.

FIGURE 13A

Predicted Error Performance With Fading and Shadowing (42)

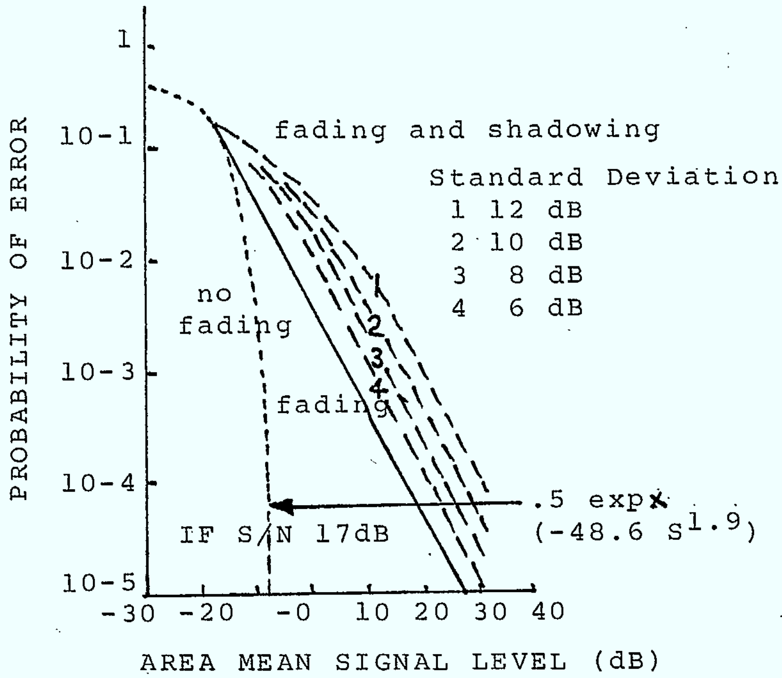
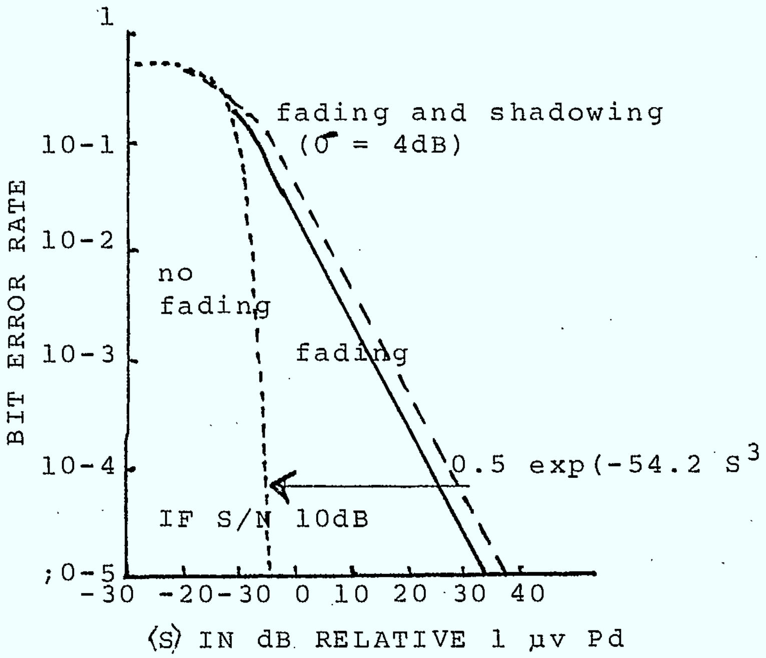


FIGURE 13B

Error Performance in London at 462 MHz 1200/s PSK Subcarrier



This sequency takes about 10 seconds of air time on the average. To transmit the same information by digital means assuming a 32 character message, 2400 b/s, 10 bits per character repeated 3 times, takes less than ½ second of air time, including acknowledgement.

Accordingly, coding techniques are being used increasingly in mobile radio systems with two major changes occurring:

1. *The trend from simple tone systems of low capacity to high capacity digital systems.*
2. *The trend from the use of coding as an add-on feature for the convenience of the user to its use as an integral and essential component of major complex systems.*

Significant progress is also being made toward the eventual universal employment of digital voice in mobile and satellite systems (43,44,45,59).

In high capacity mobile systems, digital signalling techniques are essential to the proper functioning of the systems and are an integral part of the control process which includes computer management both at the base stations and in the mobile radios themselves. The signalling formats must be designed specifically for the mobile environment and much effort has gone into finding techniques for increasing the through-put of data under conditions of low median signal levels. Packet data techniques have considerable promise in the mobile environment both for voice and data message transmission because they allow error detection with a minimum of delay and without having to repeat the entire message. They also present the possibility of developing systems which interleave information from different sources or to different destinations with resulting further economy in spectrum employment. Spread spectrum is one such development of considerable interest (46,47).

4.5.1 There is a lot of uncertainty in predicting the performance of mobile radio communications due to the large variations which take place in the received field strength as the vehicle moves about. Over a relatively short distance the received power can vary as much as 60dB from the effects of reflection and obstructions. In fact, most mobile communications take place under obstructed conditions. For this reason communication performance must be expressed in statistical terms, (e.g. the percentage of locations within a given contour to receive a minimum acceptable signal power).

Prediction methods, therefore, are suitable only as a guide giving approximate results, which in the end have to be verified by field measurements. There are few mobile engineers who have not been dismayed from time to time by the discrepancy between predicted and actual performance of their systems.

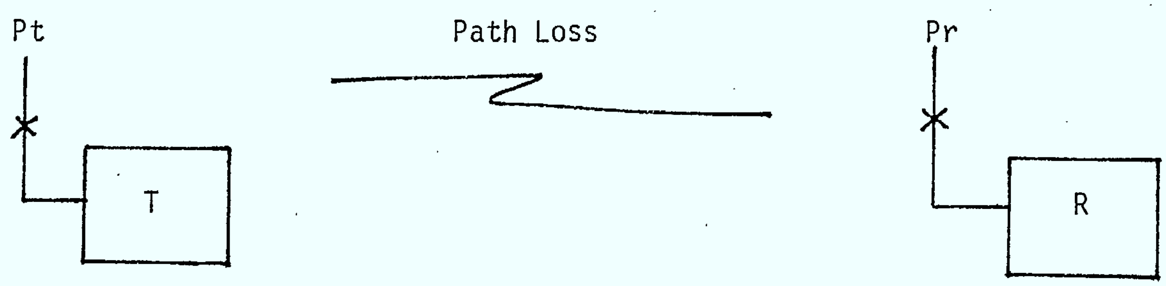
In this discussion, we will examine some of the methods used to predict performance and suggest the method most suitable for rural use in the 400 to 1,000 MHz range.

4.5.2 Propagation Characteristics

For our purpose, the signal path loss is expressed in dB as a transmission ratio or 10 log $\frac{Pr}{Pt}$ (FIGURE 4-14) where Pr and Pt are the received and transmitted powers in watts. The minimum required received power equal to the receiver sensitivity expressed here in dBw. Typically, a receiver has a sensitivity of 0.5 μv which for a 50 ohm receiver input is equivalent to -146 dBw. This figure is also the maximum allowable transmission ratio between isotropic radiators for one watt of radiated power.

FIGURE 4-14

Propagation Path Loss



Transmission Radio = Path Loss = $10 \log \frac{Pr}{Pt}$

Earlier mobile propagation predictions were based on Bullington's analysis (48) which provided a method of predicting point-to-point attenuation over obstructed paths. John Egli provided additional information (49) which took into account the effects of the vehicle's motion and local terrain variations. Other researchers have explored the effects of foliage, variations in refraction, noise, knife-edge diffraction, etc, and have proposed methods of quantifying them.

In 1968, Okumura (50) conducted an extensive series of measurements and provided a more accurate assessment of propagation effects for mobile communications than previously recorded. His results revealed some inaccuracies in earlier methods, appear to be more reliable, and are more comprehensive. Some propagation characteristics are discussed below with reference to various models. From Egli one can derive the following equation:

$$Pr\ (dBw) = 20 \log Ht + 20 \log Hr - 40 \log d - 20 \log \frac{40}{f}$$

$$- 10 \log L + 10 \log Pt$$

$$+ 10 \log GT + 10 \log Gr$$

$$- 10 (\log H + \log L)$$

Which simply states the following:

The mediam received power (Pr)

increases 6dB per octave with antenna heights (Ft, Hr)

increases 3dB per octave with antenna gains (Gt, Gr)

and transmitter power (Pt)

decreases 12dB per octave with distance (d)

decreases 6 dB per octave with frequency above 40 MHz

decreases 3dB per octave with noise (N)

and line losses (L)

Various monographs developed by Bullington and Egli (Appendix 2 of this Volume) can be used to determine the losses due to terrain along discrete radials and then be including margins to allow for Raleigh fading and required grade of service the coverage area can be determined and charted in the form of coverage contours.

Okumura has shown that the Egli model is inaccurate in some respects. The two methods are compared in TABLE 4-3. For example, the relationships between received power and frequency, distance and antenna height change according to Okumura. Also, Okumura's measurements took into account various degrees of terrain irregularity which Egli did not consider.

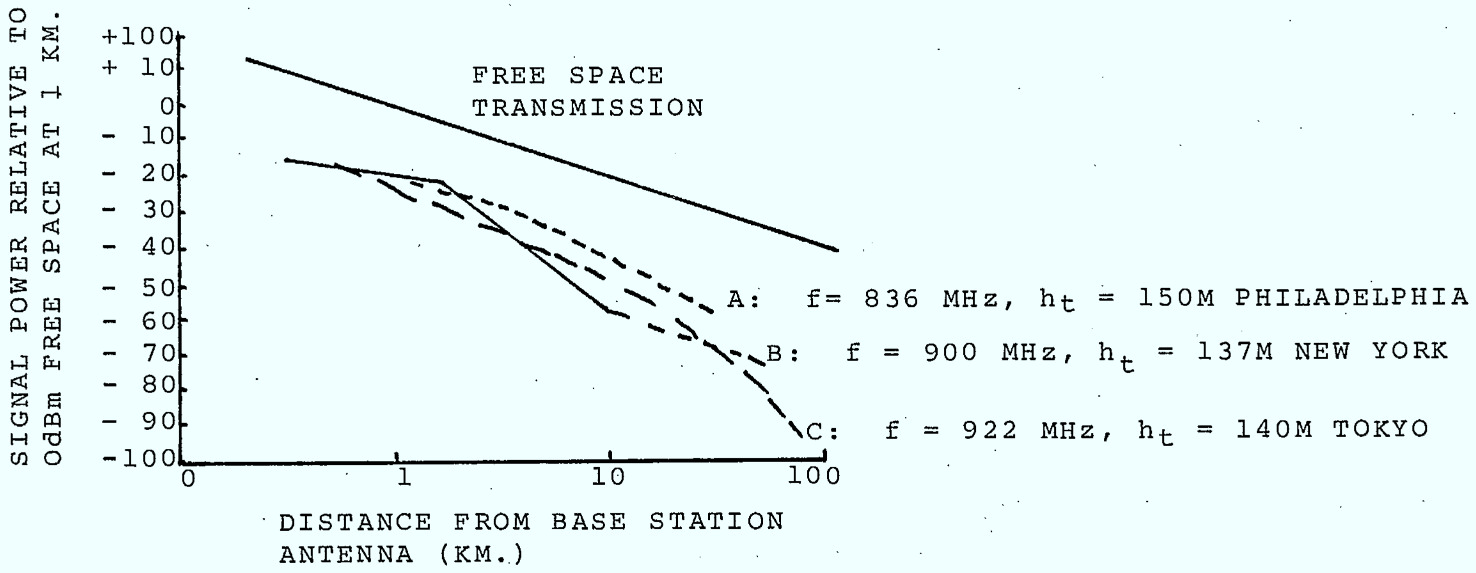
TABLE 4-3

Median Received Power as a Function of Frequency, Distance, and Antenna Height

Prediction Method	Change in Pr With Frequency		Change in Pr With Distance		Change in Pr With Antenna Height: Base		Change in Pr With Antenna Height: Mobile	
	Condition	Change	Condition	Change	Condition	Change	Condition	Chg
	Regular Flat Terrain	0	All Distances	-12dB per octave	All Heights	+6Db Per Octave	All Heights	+6dB per Octav
Egli	Terrain Approx. +500 Ft Irregula-rities	-6dB Per Octave						
Okumura	Equal to Free Space Loss at 100 MHz and Short Dis-tance (Increas-ing with Freq. and Distance	-6dB Per Octave to	1 to 15Km	-3dB Per Octave to	Short Distances	+6dB Per Octave	Height Under	+3dB Per Octa
	At 1000MHz 100 Km	-9dB Per Octave	Over 40Km	-14dB Per Octave	Longer Distances And Heights Over 200M	+9dB Per Octave		

Reudink (41) has simplified Okumura's results in an attempt to provide a practical method for predicting mobile coverage for urban areas (see Appendix 2 in this Volume), and has compared Okumura's results for Tokyo with measurements made in Philadelphia and New York (FIGURE 4-15), indicating a close correspondence between the different results and with predicted performance.

FIGURE 4-15 Examples of Transmission Loss With Distance (50)



An adoption of Okumura's results to cover calculations in rural areas is proposed in Appendix 2, and a comparison of this approach with Egli's had been made in order to illustrate the differences.

All of the methods discussed provide a means of calculating the median value of received signal power at some distance adding corrections for terrain variations and local conditions. A margin for probability is then added and an allowance for Raleigh fading.

Raleigh fading occurs as a result of random arrivals of numerous reflections resulting in an envelope distribution as previously shown in FIGURE 4-12, which is essentially independent of frequency and distance in beyond line-of-site paths. As shown, the maximum excursions are as much as 30dB below median envelope amplitude, occur rapidly, and result in audible noise bursts when below a certain receiver threshold. It is usual to allow 10 to 20 dB margin in the calculations for this effect.

Cellular System Design Factors

Some factors of particular interest to the designer of cellular systems are the following:

i) There is significant increase in rate of transmission loss beyond 15 to 20 Km (TABLE 4-3). Although the increase in open areas is less than in urban areas, the increase should be effective in reducing co-channel interference in large cell systems, i.e. with cell radii of 20 to 24 kilometres, and help reduce the number of cells per block needed in a rural cellular system.

ii) The base station height gain also varies with distance (6dB/octave at 40 Km and 5dB/octave at 10 Km), which is also an advantage in cellular systems when antenna heights are kept as low as possible.

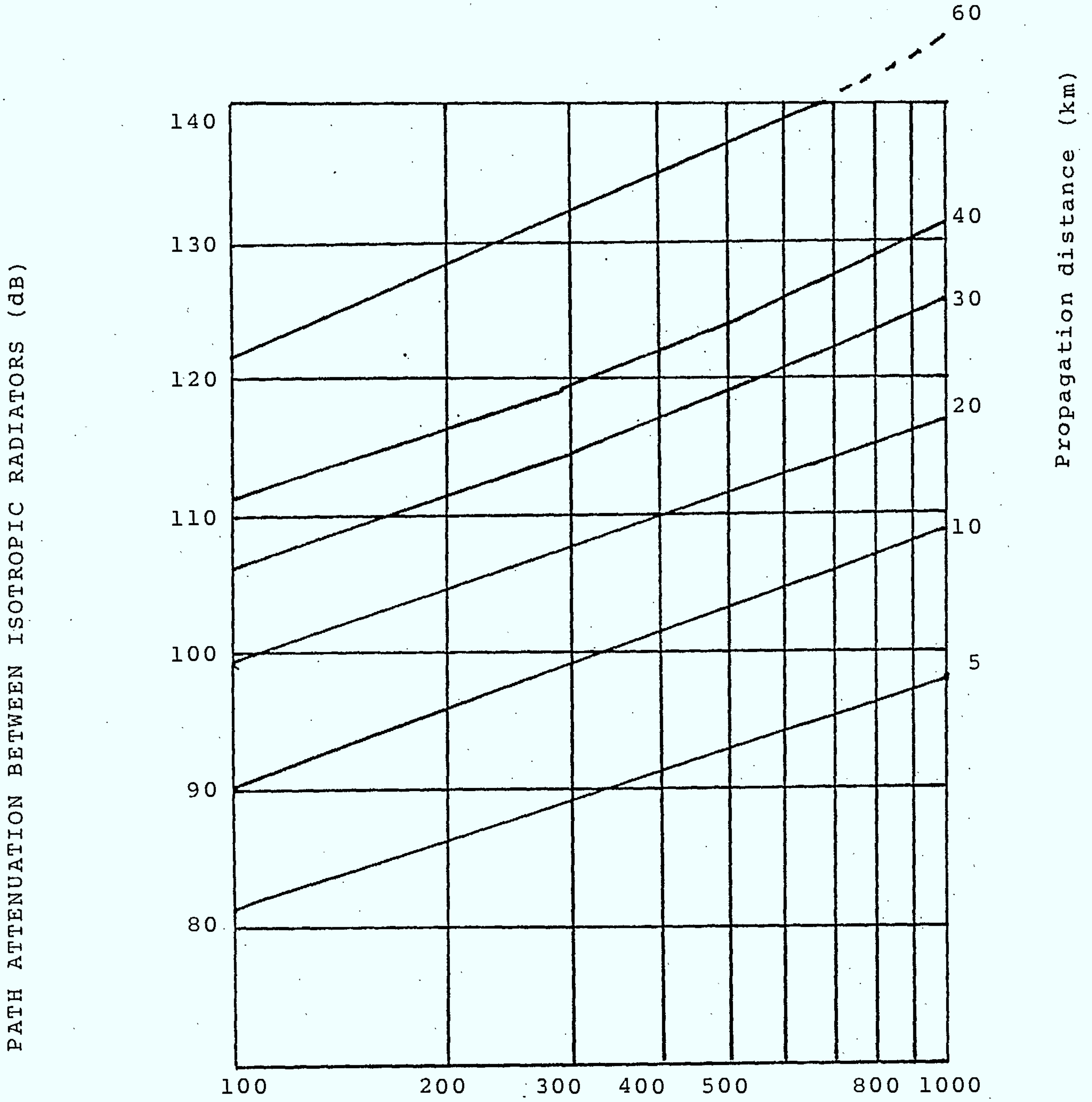
iii) A fairly constant increase in median transmission attenuation of 5 to 6 dB/octave occurs with increasing frequency in open areas (FIGURE 4-16).

iv) Additional losses for general obstruction can be expected to be frequency-dependent according to Bullington, (Appendix 2, FIGURE A3). A 2 to 3 dB per octave increase with frequency is typical.

The results and the examples given in Appendix 2 confirm the proposition that:

1. Cell sizes in rural areas of up to 20 Km radius will be aided by the increased rate of attenuation occurring beyond this distance, but that increasing the radius further will result in more rapid degradation of signal which would be undesirable in such systems.

2. A system operating in the 400 MHz band will have 5 to 8 dB greater margin than a system operating in the 800 MHz band when all system parameters are equal. Thus for the same power, antenna gains, and heights, receiver sensitivities, noise conditions, etc, a 400 MHz



PATH ATTENUATION OVER SMOOTH EARTH AS A FUNCTION OF FREQUENCY AND DISTANCE

FIGURE A2-11

base station will cover, on the average, about twice the area. The cost of compensating for this difference by increasing power, antenna heights, and antenna gains should be weighed against the advantage of using available spectrum at 800 - 900 MHz.

Accordingly, the prediction of the performance of a mobile radio system is a definite art when considering the complexity of propagation effects. Various models have been developed over the past three decades, all of which give results in the form of the probability of receiving a signal of a given intensity (usually the minimum median signal level required to ensure satisfactory communications). The method adopted here is a composite of other methods and is easily applied to rural conditions. It is noted that average signal levels at 800 MHz are 5 to 6 dB lower than at 400 MHz over flat terrain but that this difference increased with obstruction.

4.6 Integrated Services

The standard of communications services available in Canada varies widely, and in rural Canada is generally much lower than in major Canadian cities. The rural status with regard to telephone communications and broadcasting as discussed in the DOC green paper (1) provided statistics indicating the following services to rural households.

Telephone	- 60% of telephone subscribers were on lines of 4 parties or more.
Monaural Broadcasting	- Approximately 4% were without Canadian broadcasting services during the day and about 40% at night.
Stereo Broadcasting	- Approximately 60% were without FM stereo broadcasting.
TV Broadcasting	- Almost all rural areas were considered situated in the "B" coverage area of CBC stations.
Cable TV	- 72% of rural households had no access to cable TV.

These statistics have improved since the survey was made; however, the fact remains that the majority of rural Canadians have second-rate service and many have no consistent service. Futhermore, with broadcasting the choices are fewer and a majority of those reported as having some radio or TV coverage have no alternate choice in their own language. Thus the basic services which those in the more densely populated areas take for granted are largely inferior in rural Canada.

There is considerable discussion about the introduction of more sophisticated data services into Canadian homes (i.e. Videotex or Telidon as DOC has named it) with access to potentially unlimited information sources. Assuming this program is successful, how will the service be made available to rural households? In fact, such services could play a much more useful role to rural residents than to those in population centres where librairies, schools, shopping centres, etc are readily at hand.

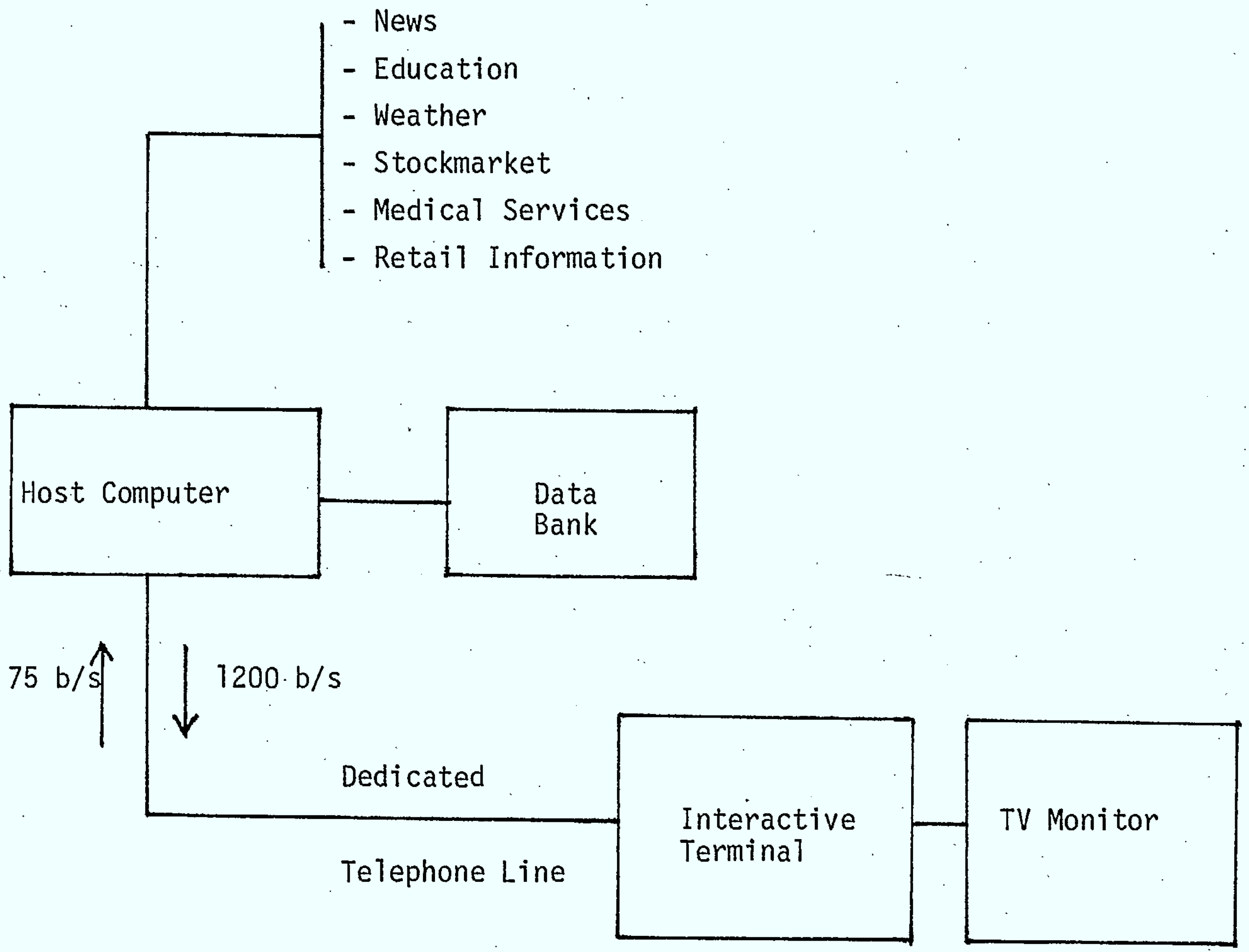
A partial answer to this question is integration, which in this context means sharing of facilities such as transmission media, housing and radio sites. When planning any new service offerings for rural Canada, this must be considered as a means of minimizing cost, which is the primary restraint at present.
Some factors which can be taken into account are:

1. The integration of home data services with a radio distribution system.
2. The sharing of radio site costs between TV broadband transmitters and radio distribution terminals.
3. The integration of radio telephone subscribers and land mobile radio users, which we have discussed previously.

Present plans for the application of Telidon are tentative. Initially for demonstration purposes, the system will be in the form shown in FIGURE 4-17.

FIGURE 4-17

Telidon Interactive TV System



A host computer will store information from various sources. The subscriber's terminal will have a means of accessing this information and displaying it on the subscriber's TV screen. Interconnection will be by means of a dedicated telephone circuit of voice quality.

To integrate this type of service with a rural radio distribution system, a more sophisticated arrangement would be needed. Ideally the subscriber would have dial access to the host computer via the radio channel and telephone network facilities. The subscriber's terminal would time-share the radio link with the subscriber telephone. For this purpose, the radio link appears like a four-wire circuit and the interface would be accomplished rather easily. Other data facilities could be accommodated in a similar fashion (e.g. fire alarm, burglar alarm, meter reading, etc), where a priority code would accompany an alarm signal to prevent blocking. Thus the use of a radio distribution system by providing the subscriber with the equivalent of a single party telephone line, makes integration with data services a straightforward task.

There is no obvious way of combining TV services with other services, other than by sharing site services and antenna towers. It is not known yet in what direction the provision of broadband services will go in rural areas. However, various possibilities include terrestrial distribution with relays, satellite-to-earth stations with translators, or direct broadcast satellite. Some form of site sharing is feasible when considering the first two alternatives.

Accordingly, although plans for the introduction of home data services and for the distribution of improved TV broadcasting services are tentative, the need for integration to minimize distribution costs should be considered when designing any new rural service. Rural radio has a particularly significant role to play in integration and could accelerate some of these services more quickly than other methods.

5.0 Alternatives for Implementating a Rural Radio Service

The radio service proposed in this report combines the operational needs of users who are at present divided into several differerent services (i.e. private, RCCMRS and GLMRS - also GRS which is however, not relevant to this discussion). It has been shown that access to the telephone network would considerably increase the value of rural radio to the private and RCC user, while by combining these various services into a common service would very significantly reduce the shared cost of the common equipment.

The common carriers should inevitably be involved in such a system, in providing network and interface facilities, and helping to set performance standards. They are also a logical choice to implement the service. Nevertheless, we anticipate many obstacles to this approach. First there is no guarantee the carriers will agree to a new rural radio service. Second is the question of the carriers monopolizing the mobile radio field which will be the concern of the independent operators and the CRTC.

What are the alternatives? One is to have the service provided by private operators. The other is for the federal or provincial government to provide the service, the most unlikely and perhaps least desirable approach. Nevertheless governments spend a great deal of money on mobile systems, and would benefit from an integrated service. In Ontario, there are at least four main government agencies who operate independent mobile systems across the province (i.e. ambulance, provincial police, highways, and forestry). Some sharing of facilities takes place, but there is no overall coordination between ministries. This appears to be typical of most provinces. A sharing of facilities would significantly reduce costs but these systems could benefit in other tangible ways by participating in a standard province-wide network. The Nova Scotia government has moved in this direction and is installing a $4 million backbone system across the province, to be shared by various government departments. However, the system will lack the universal appeal and flexibility we propose in a new rural radio service.

The implementation of this service, we feel, lies with the telcos or the private operators or, preferably, both. The advantages and disadvantages from the telcos and RCC operators are presented in TABLE 5-1. The main argument in favour of the carriers is the inherent need for network facilities which no other organization can provide at the present time. The main obstacle would be the concern by other private groups that the carriers would be in a position to monopolize the mobile industry. A compromise solution in which RCC or other groups would have an opportunity to participate in the program may be desirable, and should be explored.

For example, the carriers could install the terminal and network facilities, providing the interface and channel capacity to the RCC operators on a leased basis. The RCC's in turn, would market the mobile service, including the leasing of the common facility, and the selling or leasing of mobile equipment. This would allow the carriers to retain control of the radio telephone (fixed) subscribers as part of their total subscriber service without monopolizing the main mobile market. RCC's or other private operators are likely to be more aggressive in selling the service, and would tend to be more responsive to the mobile customer's needs.

Accordingly, in order to implement a new nationwide radio service, both the common carriers and private operators could be involved. The former because of the network facilities they can offer, and the latter to prevent complete monopoly of this important communication medium and to help ensure its growth through aggressive marketing talent.

TABLE 5-1

Implementation of Rural Radio Service
Telephone Carriers Vs. RCC Operators

System Operator	Advantages	Disadvantages
Telephone Carrier	1. Interconnection with the telephone network system requirement.	1. Difficulties anticipated in obtaining a common commitment to the system concept.
	2. Telcos have the technical resources to support system development.	2. Danger of carriers monopolizing mobile services.
	3. Long-term changes in network architecture may be needed to fully exploit the system concept.	
	4. Regular telephone subscribers could be served by the new system.	
RCC's	1. Would be aggressive in looking for most economic solutions and in selling the service.	1. Need to set up a body representative of RCC's in Canada to set standards, etc.
	2. More representative of industry.	2. Problem of cooperation with carriers over interconnect.
	3. More flexible.	3. Would compete with carriers in providing telephone service.

6.0 The Future Market for Radio Services in Canada

6.1 General

In this section, we will present a perspective on the future market for rural radio services in Canada. Numerous studies have analyzed the status of mobile communications in Canada (20,51,19,21,13,4,26). We know generally who uses radio, how they use it, the growth rates in various sectors, features which users like about mobile radio, and other features they would like to have.

There is general agreement that the market will continue to grow at 10% per year based on linear projections of trends in existing services. It is also known that mobile radios and systems wear out or become outdated, and must be replaced. A reasonable estimate is that 90% of radios are replaced after 12 years service, which in itself is almost enough to maintain the present rate of sales. The predicted growth rate of 10% is modest, under the circumstances.

What the studies have not attempted to do is predict the potential market if conditions were to change dramatically (e.g. if radio services were designed differently to better serve the user and if the user could obtain a more efficient service for less money).

6.2 Present Mobile Market in Canada

The penetration of mobile radios in Canada (both land mobile and Citizens Band) is approximately one-third that in the United States. There are many reasons for this, on which to speculate. For example:

1. Higher Cost Canadians pay about 50% more for mobile equipment than Americans due to a smaller, more fragmented market, high import duties, a large variety of products, tighter specifications on equipment parameters, etc.

2. Lack of Technical Innovation We depend largely on the United States and others for sophisticated products used in radio systems. Most control equipment, data systems, base station equipment, and portable equipment are designed and produced outside of Canada. This places us in the position of followers rather than innovators. As a result there are few sophisticated systems in Canada and relatively little expertise in this field. This factor also limits our capability as an exporter of mobile products.

3. Other Factors Other factors which have more or less of an influence on the penetration of mobile radio into the Canadian market include:

   - Long delays in obtaining licenses to operate private systems due to border coordination and border congestion.
   - A more conservative attitude in Canada towards the purchase of nonessential equipment.
   - Less money allocated by governments at various levels to the purchase of mobile systems (emergency services).

6.3 Potential Mobile Market in Canada

We believe there is a much larger potential market for mobile radio than indicated by the various surveys and studies, and that radio services could play a more important role in Canada then they do at present. As we have suggested elsewhere in this report, this situation can only be changed by developing more appropriate radio services and by reducing the end user costs. Alberta Government Telephones and ISL have recognized this fact by setting up Westech Systems Ltd. to develop a new service to meet the demand for radio telephones in Alberta and elsewhere.

We have identified a large potential market in rural Canada, partly satisfied at present by GRS radio and miscellaneous other services. To exploit this market will require a fresh approach which specifically addresses its needs.

Accordingly, the approach we have suggested would lead to the introduction of a standard radio service with a large enough market to justify the cost of development in Canada and to support a much more efficient industry. The potential market in rural Canada alone is several times the present total of mobile radio services and subscriber radio services now existing.

7.0 Conclusions and Recommendations

7.1 Role of Technology in the Development of Rural Radio Communications

Regarding the role of technology in the development of rural radio, we have concluded that:

1. Conditions in rural areas are fundamentally different from those in urban areas vis-a-vis propagation, spectrum usage and control and transmission requirements.

2. Telephone network facilities in their present configuration cannot handle the signalling and control requirements of a high technology mobile communications network.

3. System configurations in planned high capacity mobile radio services are not appropriate to be employed in a mixed user situation.

4. Mobile radios designed for planned high capacity systems would not satisfy the system requirements of a mixed user service, and would be unsuitable in certain other respects.

As a result of these observations, we have concluded that:

1. Considerable development effort is needed in each of these areas.

2. Canadian development and manufacturing capabilities, although fragmented in the kinds of technology required, could, through a coordinated effort, successfully carry out this program.

We therefore recommend that:

1. *Spectrum allocation techniques be developed, taking into account rural conditions in the aspects of user density, propagation, interference and compatibility.*

2. *The telephone network alternatives be evaluated to determine the most effective solution, taking into account the various data formats and transmission and switching techniques, and that design parameters be specified.*

3. *The radio system be designed, incorporating the proposed service requirements.*

4. *A study be initiated for the development of high technology radio equipment.*

7.2 The Market for a Rural Radio Service

With regard to the potential market for a Rural Radio Service, we have noted that:

1. There is a large market for mobile communications as demonstrated by the rapid growth particularly in the GRS band.

2. Mobile radio (GRS and Land Mobile) has only one-third the penetration in Canada as that in the United States.

3. A very small number of Canadian users employ advanced technology in their systems.

4. The cost of land mobile radio is about 50% higher in Canada than in the United States.

5. Existing radio services have a very limited growth potential in comparison to an appropriate service employing higher technology.

As a result of these observations we have concluded that:

1. The tariff barriers on imported mobile radio products have only served to increase costs in Canada without contributing significantly to the development of Canadian industry or technical expertise in this area.

2. A large market exists for the right type of service in Canada and elsewhere.

We therefore recommend that the federal government, through its Department of Communications, give greater emphasis to the mobile radio industry and encourage its growth through support of approaches such as we have proposed.

7.3 Implementation of a Rural Radio Service

With regard to the implementation of a Rural Radio Service, we have noted that:

1. A universal radio service could lead to monopolization of mobile communications.

2. Telephone network facilities are nevertheless needed in the proposed service and that common carrier participation is inevitable.

3. Private system operators are probably more sensitive to the small user needs than are the large telephone companies.

We therefore recommend that a formula be developed which would enable both the carriers and private system operators to participate, the most logical division being between the provision of the distribution facilities on the one hand, and the provision of the interconnecting and network transmission facilities on the other.

8.0 Nomenclature and Definitions

ADS	Automatic Dispatch Service
AMPS	Automatic Mobile Phone System
AMTS	Automatic Mobile Telephone Service
ATIS	Automatic Transmitter Identification System
AT&T	American Telephone and Telegraph Company
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
BCH	Binary Coded Hexidecimal
BER	Bit Error Rate
CAD	Computer Aided Dispatch
CMOS	Complementary Metal Oxide Semiconductor
COI	Community or Interest
CRC	Communications Research Centre
CRTC	Canadian Radio-Television and Telecommunications Commission
CTCA	Canadian Telephone Carriers Association
CTCSS	Continuous Tone Coded Squelch System
DMS	Digital Multiplex System
DOC	Department of Communications
DTMF	Dual Tone Multi Frequency
EIA	Electronic Industries Association
FCC	Federal Communications Commission
FFSK	Fast Forward Frequency Shift Keying

GLMRS	General Land Mobile Radio Service
GRS	General Radio Service (also known as CB)
ID	Identification
IMTS	Improved Mobile Telephone Service
INS	Institute for Northern Studies
LSI	Large Scale Integration
MTS	Mobile Telephone Service
MUSAT	Multi-purpose UHF Satellite
NTT	Nipon Telephone and Telegraph
RCCMRS	Restricted Common Carrier Mobile Radio Service
RCPG	Rural Communications Program Group
RID	Rural Interface Device
ROM	Read Only Memory
RRS	Rural Radio Service
SIC	Standard Industrial Code
SINAD	Ratio of Signal to Noise and Distortion
TTL	Transistor Transistor Logic
WARC	World Administrative Radio Conference

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A1.1 Introduction

A complete assessment of the activity leading to the present status of mobile cellular systems is beyond the scope of this feasibility study report. However, it is consistent with the terms of reference of the study to briefly outline the design considerations and market objectives as well as to indicate the attitude being taken in Canada by interested companies and by the DOC.

A cellular system as defined by the FCC (Memorandum of Opinion and Order, March 1975) may be summarized as follows: (34)

One which utilizes a cellular configuration of base station transmitters and receivers to cover the proposed area with the stipulations that:

- Base transmitters must radiate no more radio frequency power than required to adequately cover each cell.
- Base sites must be connected together through a common switching and control point using wire lines.
- The radio system must be fully interconnected with the public land line telephone network and be capable of providing a grade of service comparable to that of the land line system.
- Narrow band frequency modulation must be employed for all voice channels in the radio system and each radio must not exceed 40 KHz of authorized bandwidth.
- Radio frequency channels employed within each cell must be trunked for greater spectrum efficiency.

- In major metropolitan areas, the developmental system must have the potential for orderly evolution into a highly efficient small-cell configuration.

A further stipulation by the FCC is that the system may not be configured to allow simultaneous transmissions to several vehicles, originally referred to as Automatic Dispatch Service (ADS) by AT&T (8). AT&T and the American Radio Telephone Company in the United States have developmental system under evaluation (52,34,10) as also has the NTT in Japan.

A1.2 Design Considerations

Cellular systems by definition are highly structured and require a higher degree of system standardization than the approach which the development of mobile communications has taken in the past. Thus the form of modulation, the system deviation, channel spacing, etc. are specified. However, the designer must also start with some assumptions with regard to:

- Traffic characteristics
- Allowable interference
- Minimum distance between co-channel base stations
- Signal quality (circuit merit)
- Effects of fading
- Minimum signal probability
- Frequency re use plans
- Antenna configurations
- User density

The constraints, although presenting a complex design problem initially, greatly simplify future growth and additions of subscribers to the system.

In addition, because the vehicles will cross the boundary between one cell coverage area and another while a call is in progress, a means of tracking the vehicles motion and re-assigning channels is considered necessary. This implies a form of AVL system and a procedure in the system control for automatically terminating the connection in one cell and re-initiating it in the next. The user's address and identification must therefore be kept on file with an update on his location.

It follows from these constraints that a cellular system constructed according to the FCC definition must employ a highly sophisticated computer program and switching system and that the user's radio must be more complex than that used in conventional mobile systems, employing micro processors and LSI techniques. Because of the multiple transmitters and receivers sharing a common site RF interference becomes a major problem.

A1.3 Canadian Activity

The high cost of developing cellular systems as defined, is a strain on the resources of even large companies such as AT&T and Motorola. The tendency in Canada, therefore, has been to keep an eye on developments elsewhere while evaluating the feasibility of compromise solutions.

A number of telephone companies and universities have been studying cellular systems and some alternatives have been proposed, such as that by B.C. Tel (40). More recently, a new company has been set up in Alberta called Westech System Ltd to develop a new system for AGT employing some cellular principles. Bell Canada and Bell-Northern Research have also been studying the alternatives.

The Department of Communications has not committed itself to the FCC frequency allocation plan as yet, and are still evaluating spectrum alternatives as well as usage of the 800 - 900 MHz band. It appears probable, however, that Canada will adopt the frequency plan proposed by the FCC (Appendix 4, Volume 2, Table 1).

A1.4 Assessment of Cellular Systems

The DOC has been studying the cellular radio concept, and as part of its program, has initiated independent studies such as that performed by Dr. R.W. Donaldson of the University of British Columbia (53). In his report, Dr. Donaldson has proposed a general method of evaluating cellular systems with fixed channel assignments (as opposed to systems in which the number of channels available in a cell may be varied according to instantaneous loading requirements). Other stipulations made by Donaldson were:

1. Use of diversity reception.
2. Automatic hand off not used (No AVL).
3. Call arrivals are POISSON distributed.
4. Waiting time has an exponential distribution.

The performance of cellular systems with fixed channel assignments was assessed on the basis of throughput - a function of the number of calls per cell, and fixed and variable cost of base station equipment as dependent on system requirements such as carrier to noise ratio, channels per cell and various system constants like blocking probability.

A major variable in the signal to noise ratio in Donaldson's analysis is the modulation index which he considers an important parameter to determine as part of the system design since the interfering effect of co-channel signals and steady state-noise vary exponentially with this factor.

Dr. Donaldson has adopted the basic definition of cellular radio and made assumptions regarding the system configuration and the variables in the system design. The analysis, although oversimplified, can be used as a model for assessing a particular design. However, there are major areas which must be examined in greater depth (e.g. the user radio, the telephone networks structure and the unique requirements of specific service areas).

The design criteria the FCC provide for an extension of telephone service on a nationwide basis relies heavily on existing telephone network structure and the expectation of a large subscriber density in urban areas. Subscriber rates for this type of service are expected to be comparable with those charged for existing mobile telephone services even with the much larger user population. This is a reflection of the system complexity and associated high cost per user for the grade of service to be provided. As such, this type of service would be too costly to appeal to the average user of mobile equipment in Canada particularly in rural areas.

An alternative solution is needed if the cellular concept is to be applied in Canada and it is suggested that the problem be reassessed from the point of view of Canadian socio-economic and demographic conditions. Among the factors to be assessed are the following:

1. The feasibility of configuring the service to appeal not only to the radio telephone user but also to the larger mass of mobile users who employ mobile communications for running their day-to-day business activity. This would increase the user population in a given area but more importantly would increase the number of users sharing the cost of the fixed radio base and telephone network facilities dedicated to the service.

2. The feasibility of restructuring the network portion of the system to reduce trunking costs and to accommodate other forms of information transmission potentially needed in rural areas. An overlay digital network is possible whereby all voice and data are converted at the ratio-telephone interface points into a standard digital format (i.e. packet data) for processing at common routing centres. This approach would allow the new service to bypass some of the complexity of existing network facilities brought about as a result of the historical growth and large variety of network protocols.

3. The system parameters and signalling facilities would be evaluated in the perspective of a new structure to determine the most effective design of the radio system. The methods of determining vehicle location, providing hand-off, switching local calls, dealing with conference communications, handling data messages, etc need to be reviewed in the light of specific conditions and needs and by assessing the experience others have gained in the various trial systems.

4. The demographic and topographical conditions of Canada are well documented (22,54) and can furnish the designer with typical areas categorized by household distribution patterns, transport routes and terrain characteristics.

A2.1 General

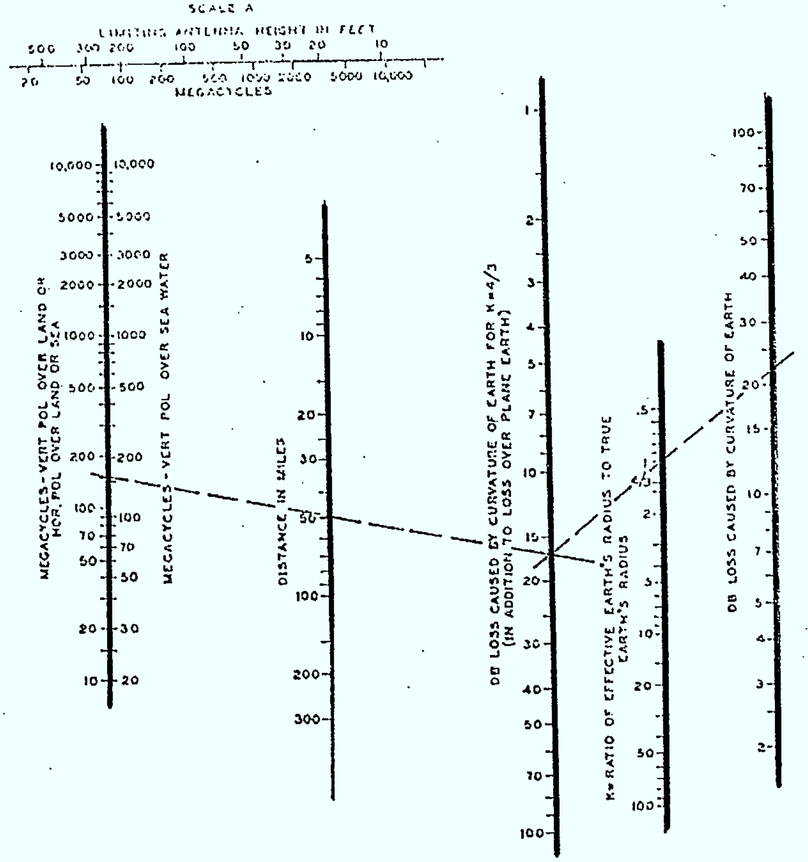
Three models are compared and the methods of their applications to mobile coverage prodiction are discussed. It has been observed that the applications of the various methods are open to interpretation and one finds a number of variations of procedure used by the different companies which are based on the Bullington approach.

This assessment is not intended to provide a complete analysis of the methods discussed, but rather to examine the credibility of the results and account for some of the differences.

A2.2 Bullington Model (48)

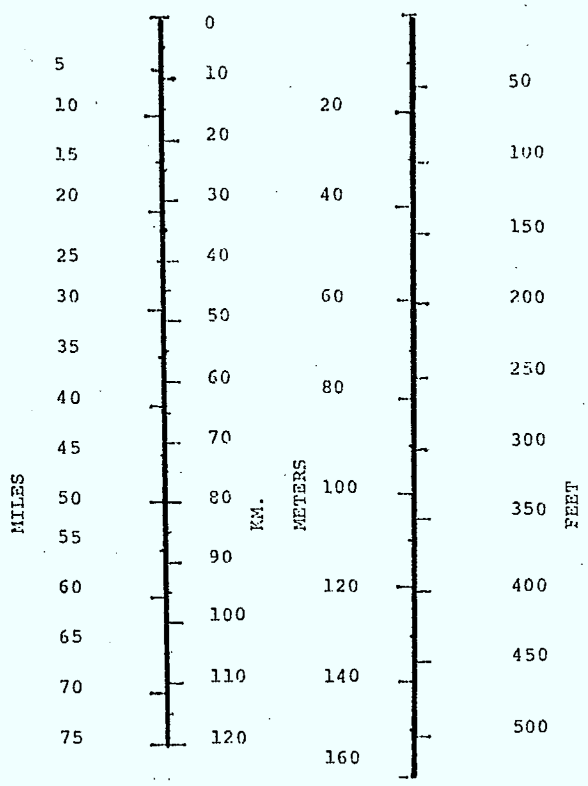
Bullington provided two methods of calculating point-to-point path losses using plane earth attenuation as the basic median loss on the one hand and free space loss on the other. The plane earth approach is the one most applicable to most mobile systems and is the one discussed here. It is derived theoretically from optical theory and wave analysis.

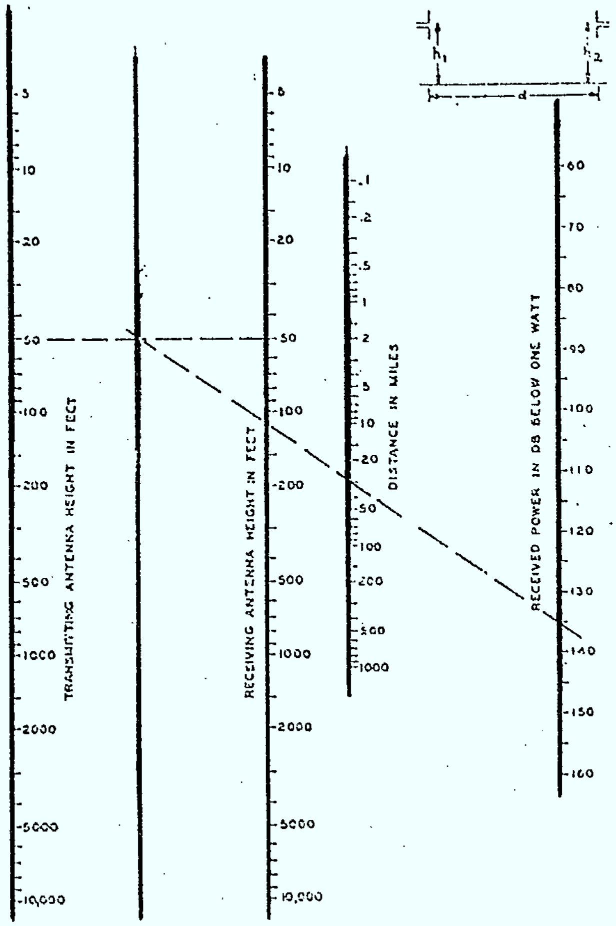
Basic plane earth loss is obtained from FIGURE A2-2 and is the attenuation over smooth earth between fixed dipoles of specified heights above terrain. The plane earth attenuation varies at 6 dB per octave with distance and is frequency independent. Added to this is the diffraction loss FIGURE A2-1 resulting from earth curvature and which as indicated is frequency dependent and increasing exponentially with distances. The third main path loss factor is the shadow loss which is determined from the geometry of the path profile. This factor is also frequency dependent showing about 3 dB per octave change with frequency (FIGURE A2-3).



DIFFRACTION LOSS CAUSED BY CURVATURE OF THE EARTH (48)

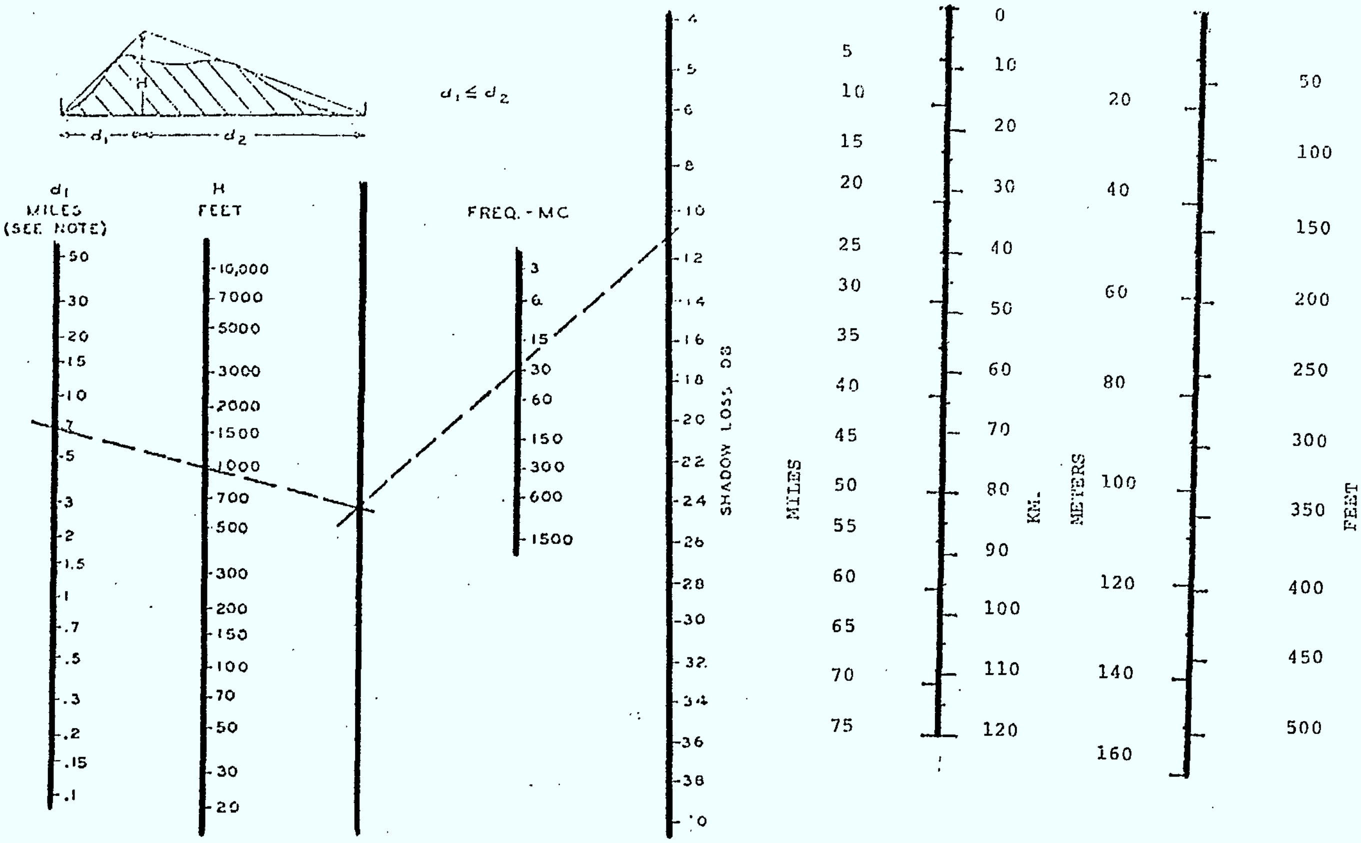
FIGURE A2-1





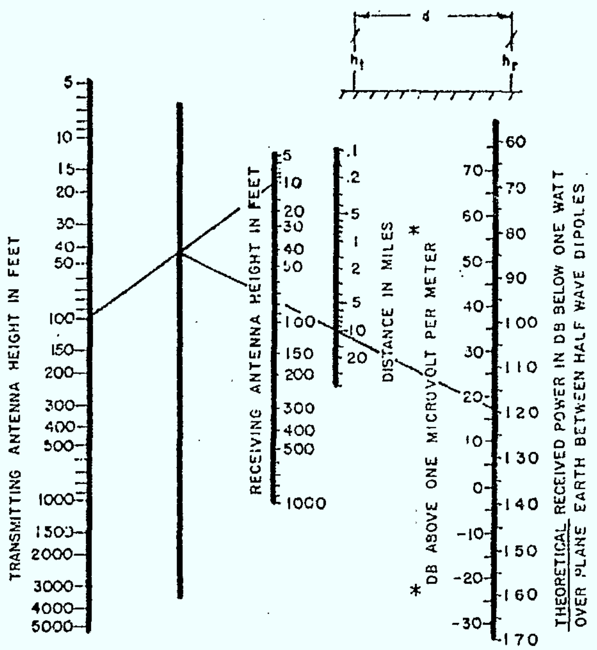
RECEIVED POWER OVER PLANE EARTH BETWEEN HALF-WAVE DIPOLES, 1 WATT RADIATED (48)

FIGURE A2-2



SHADOW LOSS RELATIVE TO SMOOTH EARTH (48)

FIGURE A2-3



*50 PERCENTILE LOCATION MEDIAN FIELD STRENGTH.

RECEIVED POWER OVER PLANE EARTH AND 50 PERCENT LOCATION MEDIAN FIELD STRENGTH ONE WATT RADIATED (49)

FIGURE A2-4

Adjustments are made necessary for variations in refractive index, knife edge obstacles, etc.

Since the Bullington method was developed for fixed points there is no allowance for local terrain variations and small sector variation (Raleigh finding) due to vehicular motion.

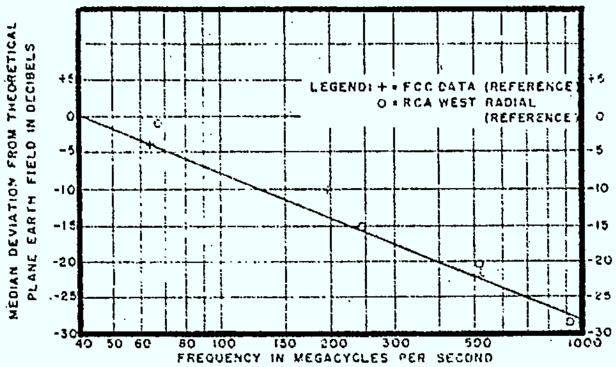
Another factor not considered by Bullington is the change in height gain which occurs from antennas close to ground level. This provides an error in results using this method of approximately 7 dB according to Egli.

In order to apply the Bullington method to mobile coverage calculations, one must include margins for terrain undulations and Raleigh fading. The values given by Okumura are included in the comparison in TABLE A2-1. (Section A2-5)

A2-3 Egli Model (58) A2-6

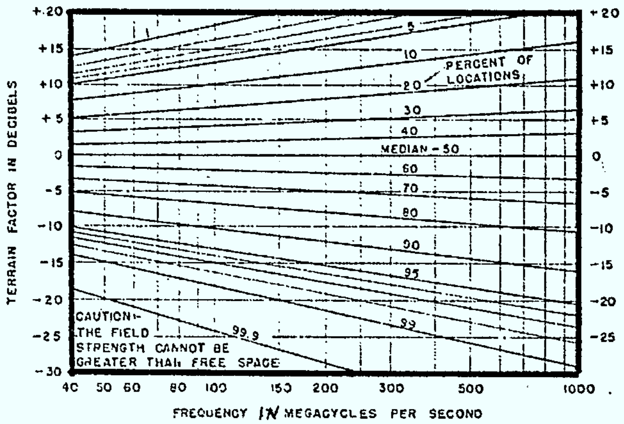
Egli adopted Bullington's plane earth approach to explain measurements made by him and others but altered the plane earth nomograph to allow for the mobile height-gain factor (FIGURE A2-4) to this basic attenuation Egli added a terrain factor (FIGURE A2-5) and a probability factor (FIGURE A2-6) both of which are frequency dependent. FIGURE A2-5 and FIGURE A2-6 are combined to produce FIGURE A2-7.

The additional loss due to terrain irregularities given by Egli theoretically corresponds to hills with depths of about 500 feet. Egli does not discuss variations due to obstruction or diffraction nor does he deal with terrain irregularities of varying depth. Therefore the Egli approach must be combined with other methods in order to obtain a complete analysis. Egli discusses Raleigh fading and provides an approximate indication of its effect. On the whole, however, this method is over-simplified and incomplete.



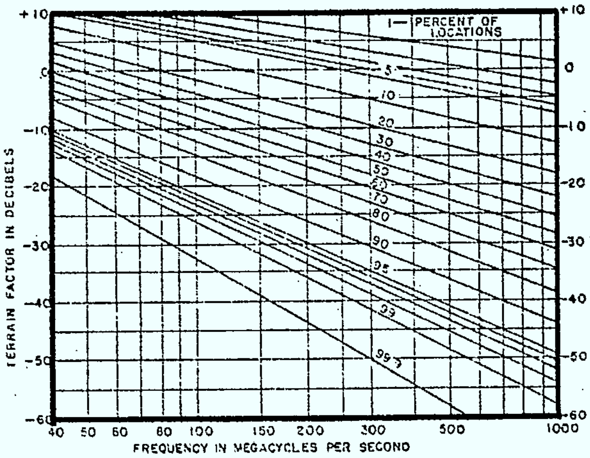
MEDIAN TERRAIN FACTOR FOR
FIXED-TO-VEHICULAR, OR MOBILE SERVICE (49)

FIGURE A2 - 5



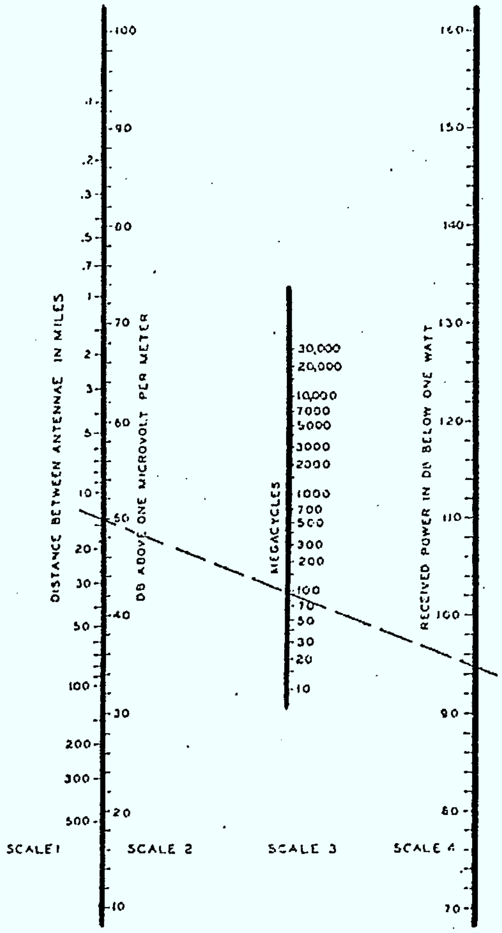
FIXED-TO-VEHICULAR
OR MOBILE SERVICE
FIELD STRENGTH TERRAIN FACTOR (49)

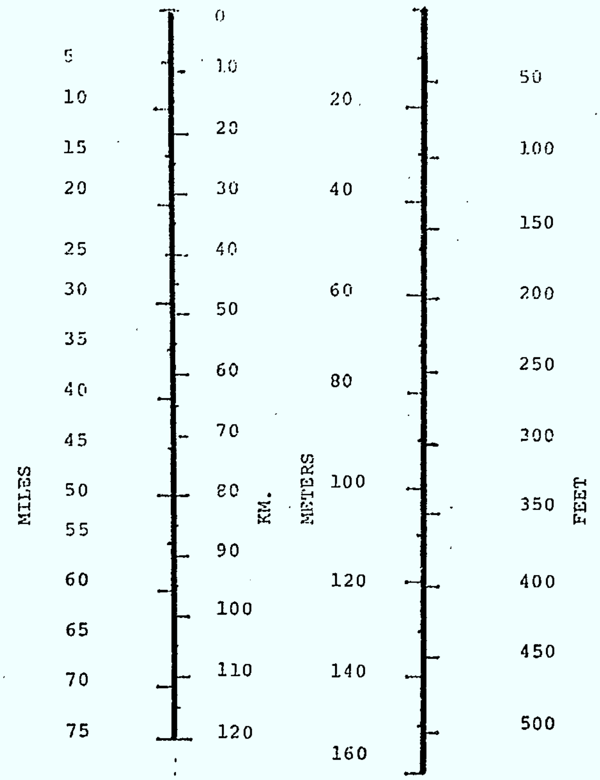
FIGURE A2 - 6



RECEIVED POWER TERRAIN FACTOR FOR
FIXED-TO-VEHICULAR OR MOBILE SERVICE (49)

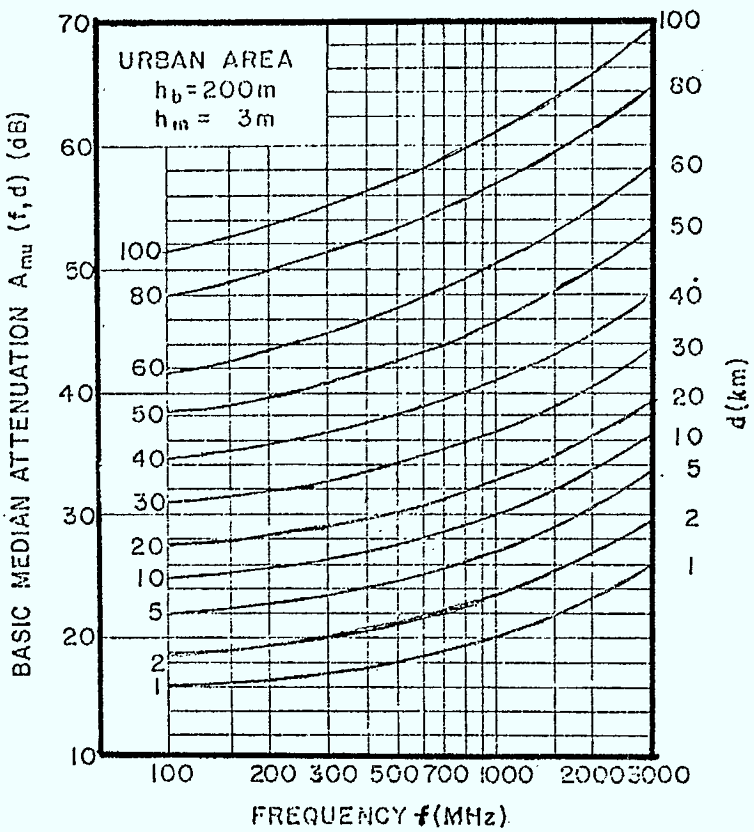
FIGURE A2 - 7





Free space field intensity and received power between half-wave dipoles, 1 watt radiated (48)

FIGURE A2 -8



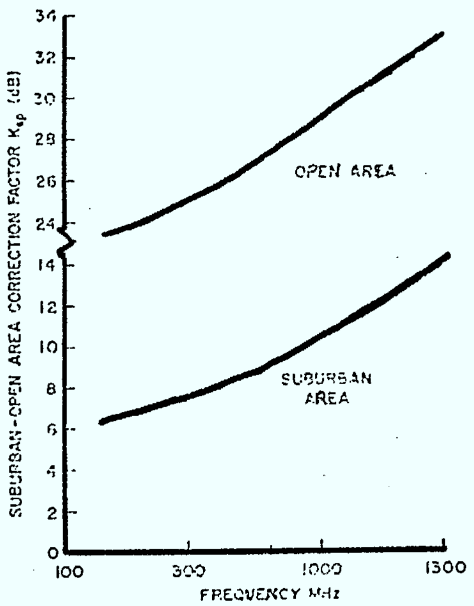
Prediction curve for basic median attenuation relative to free space in urban area over quasi-smooth terrain referred to h_b=200M, h_m=3M (41)

FIGURE A2-9

A2.4 Okumura/Ruadink Model

Okumura uses free space loss as the starting point and adds corrections for urban, suburban and open areas as well as for antenna heights (normalized at 200 meter base antenna height and 10 meter mobile antenna height), undulations and gradual terrain slope. Margins are then added for probability and Raleigh fading.

For our purpose, we have combined Okumura's median attenuation for quasi-smooth terrain (FIGURE A2-9) with the correction for open area (FIGURE A2-10) with free space loss to produce (FIGURE A2-11) which represents the median loss for open areas (rural). To this we add corrections for slope (FIGURE A2-12), hilly terrain (FIGURE A2-13) probability correction (FIGURE A2-14) and height-gain (FIGURES A2-15, A2-16). To this is added an allowance for Raleigh fading.



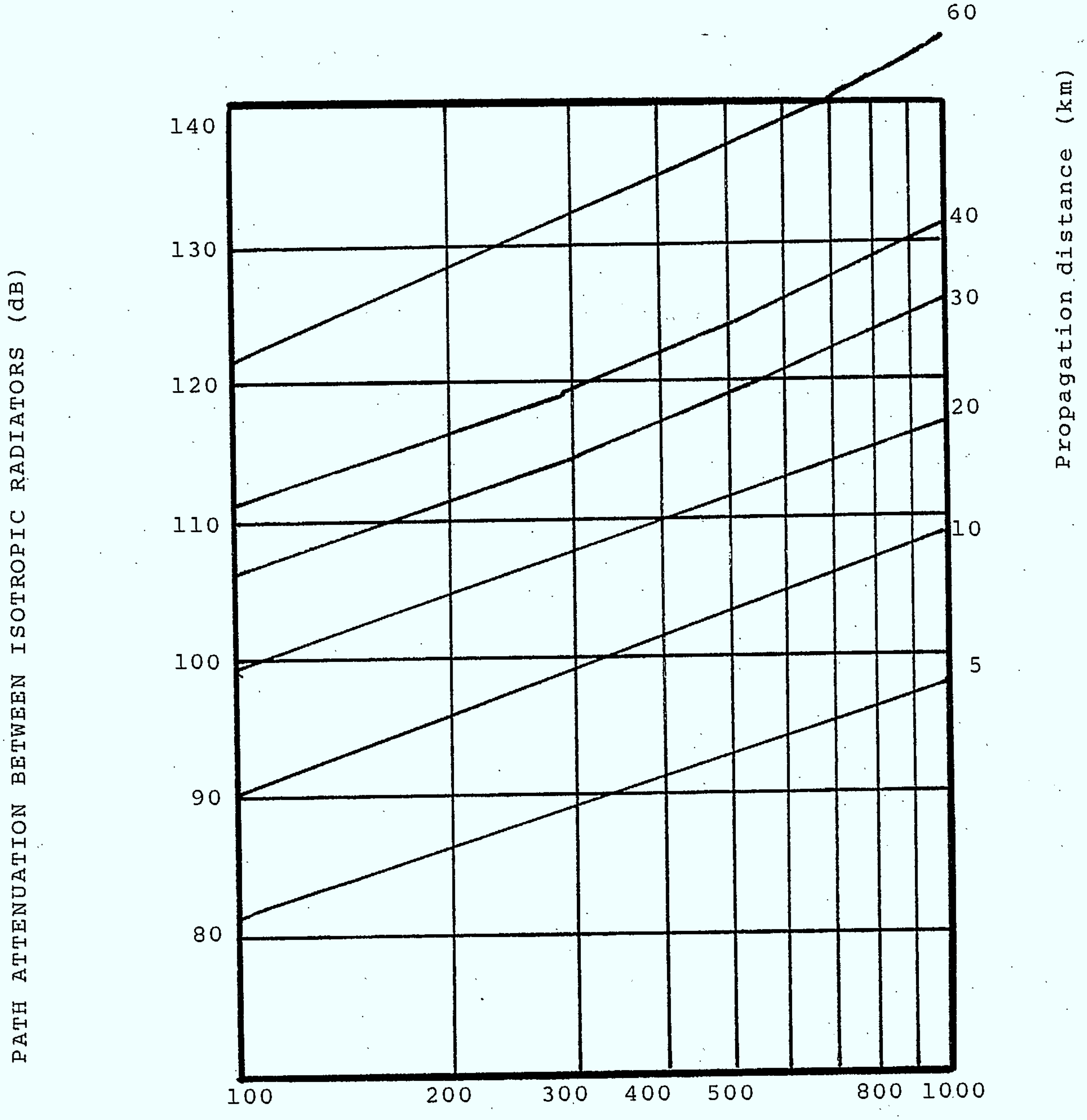
PREDICTION CURVES FOR SUBURBAN AND OPEN AREA CORRECTION FACTOR K_{sp} (41)

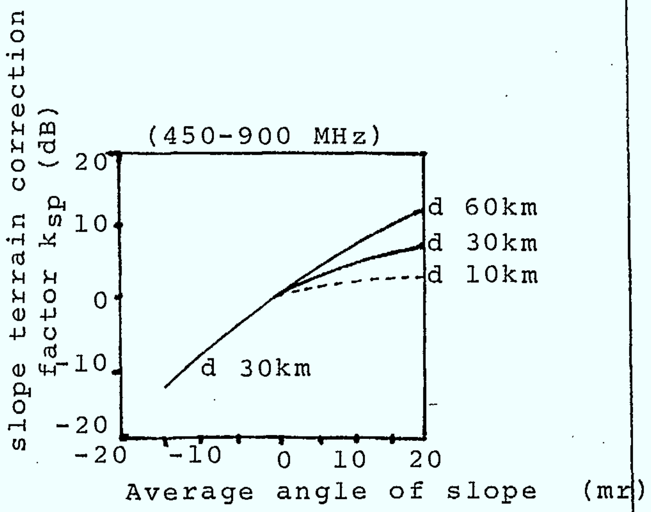
FIGURE A2 -10

FIGURE A2-11

Path Attenuation Over Smooth Earth

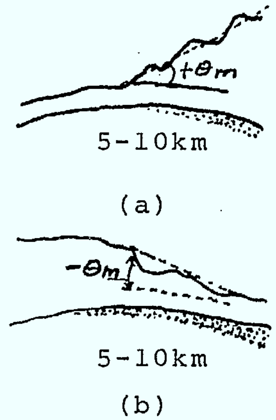
as a Function of Frequency and Distance





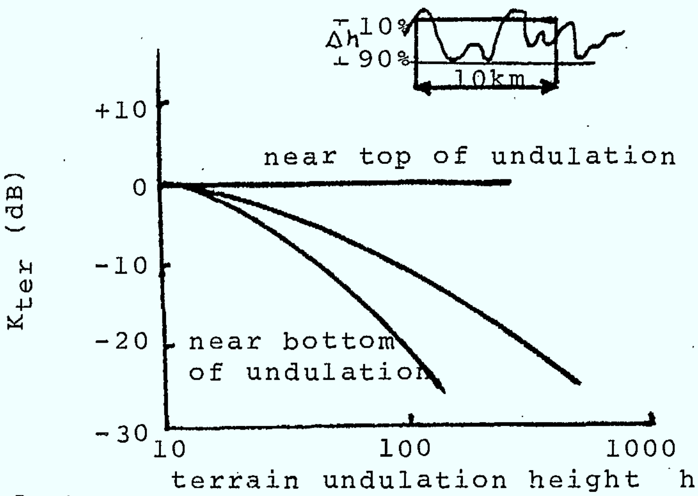
Measured value and predicition curves for "slope terrain correction factor" (41)

FIGURE A2 12-A



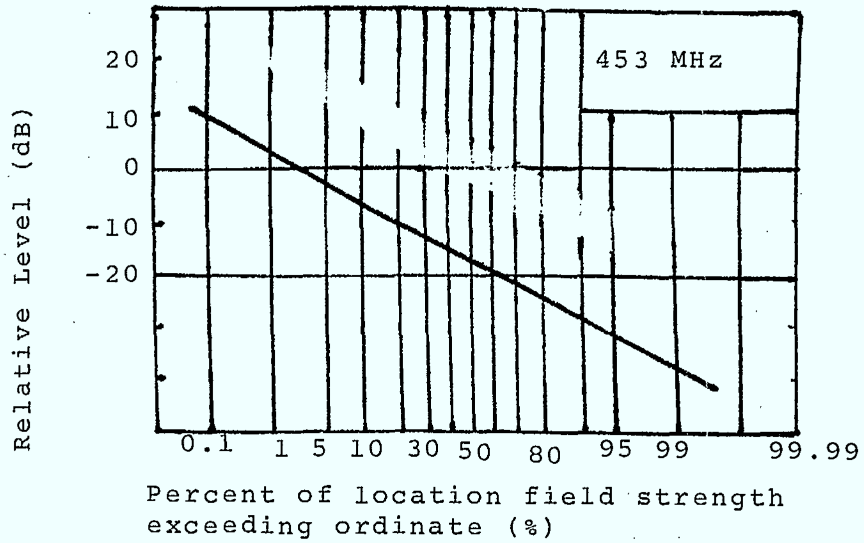
Definition of average angle of general terrain slope
(a) positive slope (+θM)
(b) negative slope (-θM) (41)

FIGURE A2 -12B



Rolling Hilly Terrain Correction Factor (k_{ter}) (41)

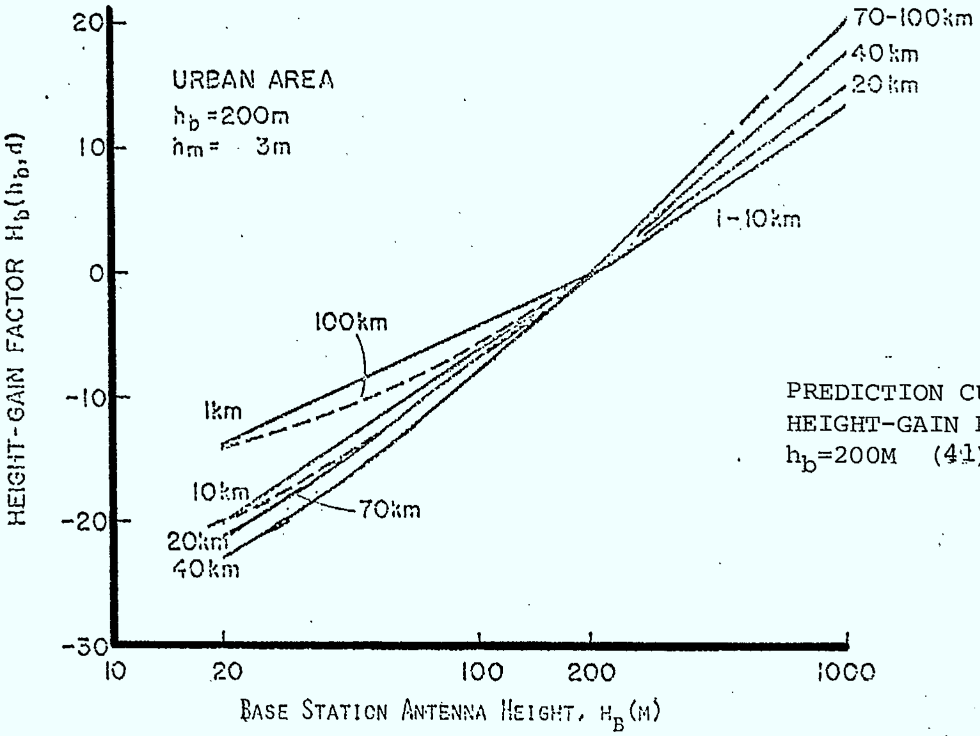
FIGURE A2 - 13



In suburban area (h_{tb}=60m, h_{tr}=3m)

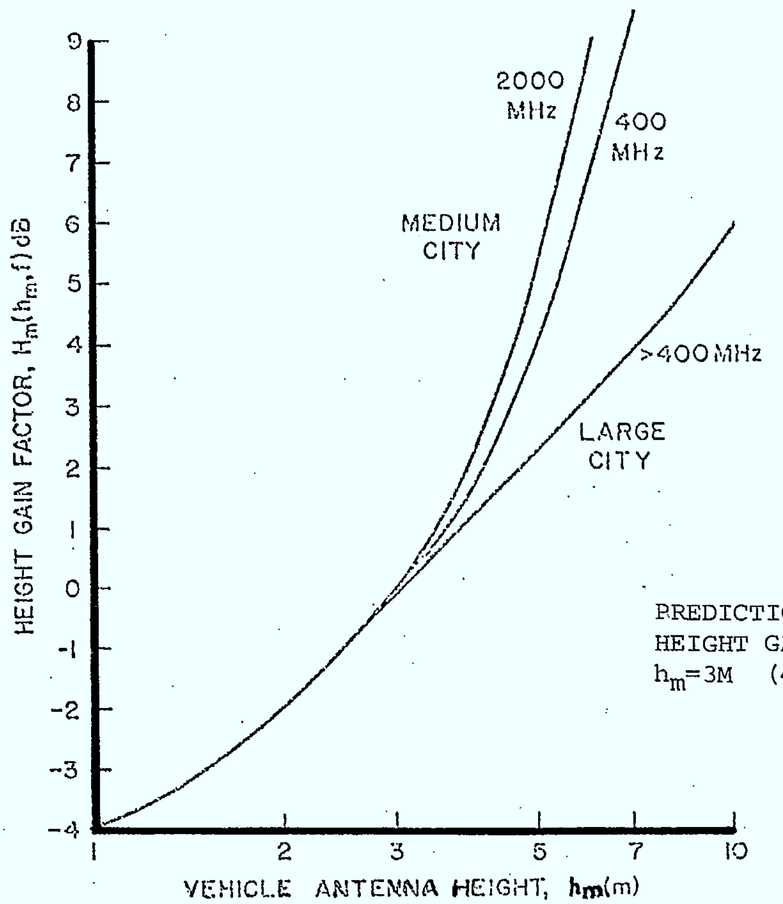
Distribution of Small-sector Median Field in Sampling Interval (1-1.5 KM) (41)

FIGURE A2 - 14



PREDICTION CURVES FOR BASE STATION HEIGHT-GAIN FACTOR REFERRED TO h_b=200M (41)

FIGURE A2-15



PREDICTION CURVE FOR VEHICULAR HEIGHT GAIN FACTOR REFERRED TO h_m=3M (41)

FIGURE A2-16

A2-5 Sample Calculation

To illustrate the basic methods, the three procedures are applied to a simple path profile (FIGURE A2-17). The path is 20 Km long with undulations having a 90% depth of 120 meters.

The following parameters are specified

Base antenna height	50 meters
Mobile antenna height	1.5 meters
Transmitter power into the antenna	20 watts
Base antenna gain	10 dB
Mobile antenna gain	3 dB

The calculation is made at 500 MHz and 1000 MHz.

The results of the calculations are listed in TABLE A2-1. As can be seen, the results vary considerably as follows:

		500 MHz	1000 MHz	ΔdB
Non sloping terrain	Bullington	147 (140)	151 (144)	4
	Egli	143	150	7
	Okumura	134	140	6
Partly sloping terrain	Bullington	151 (144)	155 (148)	4
	Egli	143	150	7
	Okumura	144	150	6

Calculation of Received Signal Power (dBw) (Refer to Figure A2-17) TABLE A2-1

Apply to	Factor	500 MHz (1) Bullington −	+	(2) EGLI −	+	(3) Okumura −	+	1000 MHz (1) Bullington −	+	(2) EGLI −	+	(3) Okumura −	+
(1),(2)	Plane earth loss	128(121)		121				128(121)		121			
(2)	Terrain factor (90%)			37						44			
(1)	Shadow loss	9(13)						11.5(15)					
(1)	Diffraction loss	4						5.5					
(3)	Median loss					111						117	
(3)	Slope correction					(10)						(10)	
(1),(3)	Hilly correction	11				11		11				11	
(3)	Base HT-gain corr					14						14	
(3)	Mobile HT-gain corr					3						3	
(1),(3)	90% correction	10				10		10				10	
All	Raliegh Fading Allowance	10		10		10		10		10		10	
All	Transmit power		13		13		13		13		13		13
All	Base Ant Gain		9		9		9		9		9		9
All	Mob Ant Gain		3		3		3		3		3		3
	TOTALS	172	25	168	25	159	25	176	25	175	25	165	25
		(176)				(169)		(180)				(175)	
	NET LOSS (20Km)	147		143		134		151		150		140	
		(151)		(143)		(144)		(155)		(150)		(150)	

Numbers in brackets refer to sloping terrain condition Figure A2-17 (b)

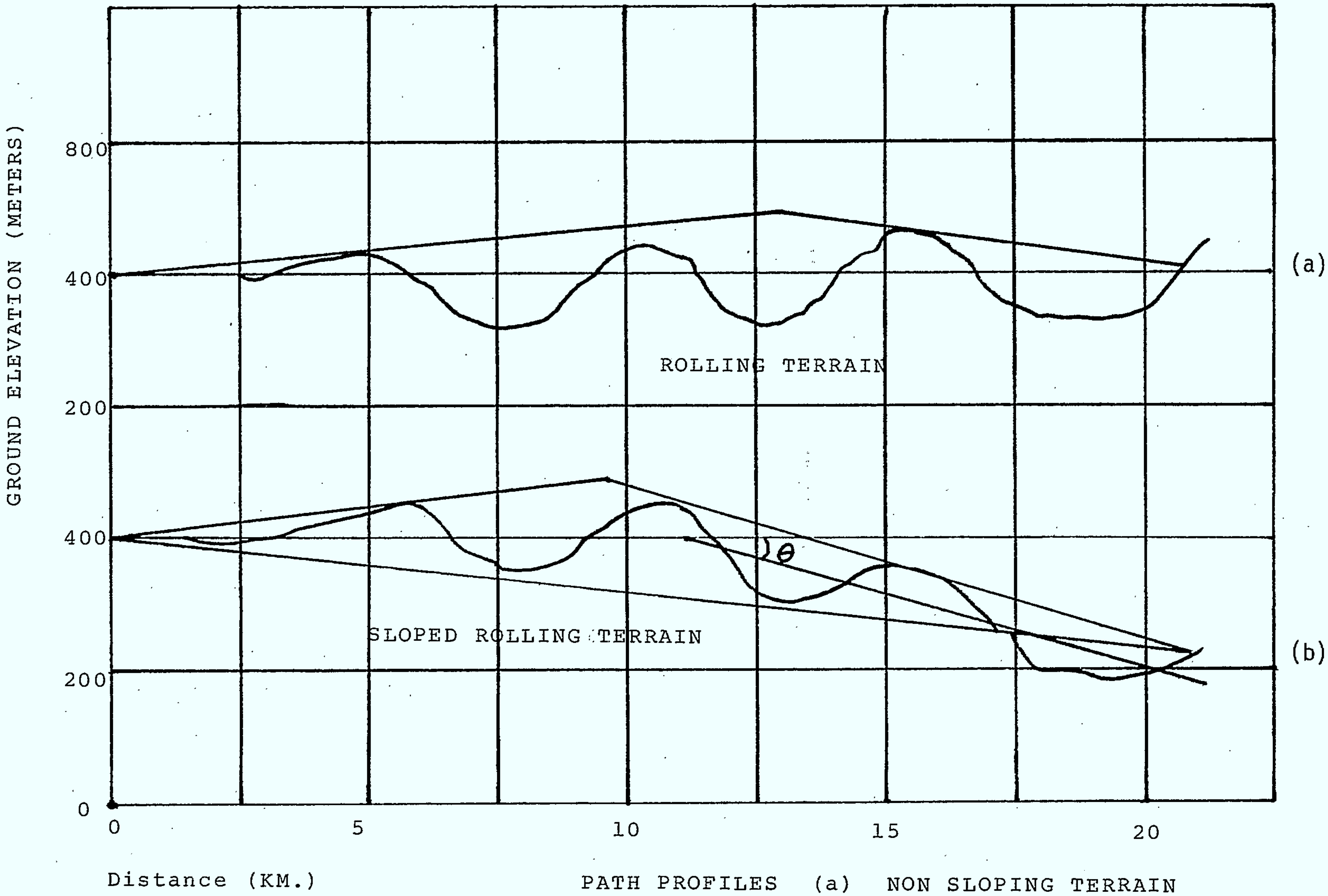
For the case where the terrain is non-sloping, the Egli and Bullington results are very similar, and Okumura's are about 10 dB less. However, as was pointed out, the Bullington plane earth nomograph has a discrepancy amounting to 7 dB if compared to Egli (FIGURE A2-6). When this correction is made the Bullington prediction falls in between Egli and Okumura for the non-sloping case.

For the second case where the average terrain is gently sloping (angle of slope 20 milliradians), all three results are more or less identical once the correction is made to the Bullington results. However as stated earlier the Egli results for sloping terrain is questionable, and there is an uncertainty in the Bullington analysis, since the shadow loss is a function of how one estimates the shadow triangle.

This very simple calculation demonstrates the uncertainty of earlier methods which nevertheless are close enough to Okumura's results to suggest a reasonable degree of correspondence. Because Okumura's method is more sensitive to the major factors affecting propagation loss and show a greater consistency one can place greater confidence in his results. The major advantage however is the fact that there is less uncertainty in applying Okumura and the results are likely to be more consistent.

Path Profiles (a) Non-sloping Terrain
(b) Gently Sloping Terrain

FIGURE A2-17



PATH PROFILES (a) NON SLOPING TERRAIN
(b) GENTLY SLOPING TERRAIN

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