SYSTEMS STUDY AND EXPLORATORY DEVELOPMENT OF A SUBSCRIBER CARRIER SYSTEM TO SERVE LOW DENSITY RURAL AREAS

VOLUME 1 - EXECUTIVE SUMMARY

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OVERALL INDEX OF

A SYSTEMS STUDY AND EXPLORATORY DEVELOPMENT

OF A SUBSCRIBER CARRIER SYSTEM TO SERVE LOW

DENSITY RURAL AREAS

VOLUME 1: EXECUTIVE SUMMARY

A summary of the study including the background to the study, the terms of reference of the contract, an overview of the work performed, and the resulting recommendation.

VOLUME 2: FINAL REPORT

The findings of the study are discussed in this volume. The background to the study and the methodology are also explained. Theoretical and factual background information for both technical and marketing analyses is detailed in several appendices.

VOLUME 3: SYSTEM DOCUMENT

The system concept which resulted directly from the work done during the study is described in this volume. In addition to the functional requirements, circuit details of a breadboard system are also given.

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PREFACE

The study was initiated by the Rural Communications Program of the Department of Communications and performed under a contractual agreement with the Science Procurement Branch of the Department of Supply and Services.

The main purpose of the study was to identify whether an opportunity exists to develop a low cost, low capacity, subscriber carrier system for low density areas, and to accelerate its development by reducing R & D investment to a Canadian manufacturer.

SED Systems Inc., with major subcontractors Systems Approach Consultants Limited and Saskatchewan Telecommunications, carried out the work over a 19 month period, during which numerous discussions were held with Canadian and independent U.S. telcos, the Rural Electrification Administration of the U.S. Federal Government and manufacturers.

1.0 TERMS OF REFERENCE

1.1 BACKGROUND TO THE STUDY

Providing telephone service to rural areas is very expensive, due to the small number of telephones and the long distances between subscribers. Cable prices are rising rapidly, as is the cost of installing them, which is a very labor intensive activity. Cable system costs are also directly proportional to the number of pairs and the wire size used, making the price tag for a typical rural ILS installation ($2000 or more) very unattractive. In order to minimize these costs, telcos provide multiparty line service, where a number of subscribers share the same line, and its cost. However with communication services continually improving in virtually all aspects, multiparty line service is now being viewed as substandard by the majority of subscribers, many of whom have relocated from urban areas and tend to expect city-like service. Telcos are striving to satisfy the demands for improved service, but within economic limits, thus creating a strong need for technical innovation to reduce the costs of telephone services in rural areas.

The Rural Communications Program has two prime objectives: to determine cost effective ways to improve telecommunciations services in rural Canada and to identify opportunities for industrial electronics development. Accordingly, the Rural Communications Program is studying existing and new technologies and systems that could be used to provide these improved services, including microwave and HF radio, satellite, and fibre optics systems.

This continuing work has resulted in the identification of an opportunity for the development of a low capacity, low cost cable carrier system to serve low density rural areas. Discussions with Canadian telcos, the Rural Electrification Administration of the United States, and manufacturers revealed that existing carrier systems are either too large or too small, and generally lack a multiple drop capacity required for distributed systems.

A draft proposal for the development of a small distributed subscriber carrier system was presented to the Canadian telcos and interested Canadian manufacturers to obtain their reactions. It was indicated at that time that the Rural Communications Program was interested in funding a systems study and exploratory development of such a low cost, low capacity system. The aim was to reduce the R & D investment to a Canadian manufacturer, thereby reducing the system cost and accelerating its development. Considerable interest was shown by the manufacturers, and the study contract was subsequently awarded to SED Systems Inc.

1.2 STUDY REQUIREMENTS

The final output of the study was to be a well defined system concept with preliminary designs, and an analysis of its marketability. Several iterations of concept development, refinement, market studies, and telco consultation were deemed necessary to achieve these goals.

Deliverable items included two interim reports on the progress of the work and arising recommendations for subsequent activities, and breadboard circuits to verify the concepts and technologies.

The final report was to provide information on all work activities undertaken during the study. It also was to include a product specification defining the system concept in sufficient detail to allow a development team to develop it to standardization for manufacturing. Circuit drawings and detailed technical information were also to be included. The report was also required to contain a discussion on the feasibility of the system and a recommendation on a course of action to follow.

1.3 CONDUCT OF STUDY

The study was divided into three phases, each terminating with a more refined definition of the system concept, concluding with this report. The work activities within those phases were also divided into three major categories: systems engineering and concept development, economic analysis, and market analysis.

The study commenced in May 1978, at which time some work towards the concept development had already been done by the DOC and SED through proposal work. During the first phase two concepts, a 7 channel concentrator operating at a bit rate of 320 kbit/s and a 24 channel unconcentrated T1 carrier system, were evaluated for their respective merits.

At the completion of Phase 1 in January 1979, a recommendation to pursue a somewhat modified T1 carrier concept was made. (Work on developing the 7 channel concentrated system has continued independently at SED).

This concept, which was further defined and breadboarded during Phase 2, required a flexible design to allow distributed installations, concentration, subscriber supplied talk battery and ringing power, a choice of coding (modulation) techniques, including 32 kbig/s ADM, and various maintenance features. Concurrently with the design activity, the concept was presented to the telcos for their reaction and input. As a result modifications were made to the specifications and functional design. The breadboard showed the system's feasibility, along with areas requiring further development. Cost estimates were made based on the breadboard design with due allowances for upgrading to production standards. A recommendation to adopt this design was made at the end of Phase 2 in August 1979.

Phase 3 consisted of one more iteration of the development cycle, with equipment prices and installed costs being presented to the telcos for their reactions. Detailed market size calculations were carried out, and a final system design was formulated.

1.4 PARTICIPANTS

Instrumental in the origination of the concept and its early development was the Rural Communications Program of the Department of Communications. SED Systems Inc. was the prime contractor responsible for the management of the study, and also assumed all systems engineering work, including continued concept development and refinement. The Department of Communications provided continuous assistance and critiques. Economic analyses based on the SED manufacturing cost estimates were carried out by the Planning Department of major subcontractor Saskatchewan Telecommunications.

The market analysis was performed by major subcontractor Systems Approach Consultants Ltd. with extensive input from the participating Canadian telcos -

- The New Brunswick Telephone Co. Ltd.
- the Manitoba Telephone System
- Saskatchewan Telecommunications
- Alberta Government Telephones

Input through interviews was also received from -

- the Rural Electrification Administration
- the Commonwealth Telephone Company
- Bell Canada
- British Post Office
- Austrian Telephone Authority

Finally some insight into the manufacturing industry, specifically relating to competing technologies, future trends, and standards, was obtained from Logan Telecom Inc.

1.5 ORGANIZATION OF THE REPORT

VOLUME 1 (this volume) is the executive summary, which includes the background to the study, an overview of the work performed, and the conclusions and recommendations.

VOLUME 2 is divided into two parts, the main body and the appendices. Discussions about the study, its findings and the proposed carrier system make up the bulk of the main body, whereas detailed factual information, both of a technical and marketing nature, is given in the appendices.

The sections of the main body of the report are structured to provide a logical progression from the problem to the solution. Sections 3 and 4 discuss the market and technical requirements respectively, providing the basis for the formulation of the proposed system concept discussed in Section 5. The market and sales potential for the system is derived in Section 6. The study conclusions are summarized in Section 7, and recommendations for a course of action to follow are given in Section 8. An overview of the study and the methodologies used to arrive at these findings is provided in Section 2.

The first four appendices are technical in nature, and provide some theoretical background to the major issues encountered in developing a suitable system concept. These include T1 transmission on small cable, requirements for interfacing directly to digital switches, modulation techniques, and system powering methods. Appendices E and F deal with surveys performed of Canadian and U.S. telcos and the REA; general profiles of each telco are presented in Appendix F, and engineering practices and reactions to the proposed system are detailed in Appendix E. Appendix G shows the calculations used in the market projections and trends analyses. Finally, installed system costs of various telcos are tabulated in Appendix H.

VOLUME 3 is the System Document and provides all the technical information about the proposed subscriber carrier system concept. A system overview is presented, followed by a functional description with desired performance specifications. Detailed circuit descriptions of the resulting breadboard system are also included. A discussion on the data format, as well as block and circuit diagrams are provided in the appendices.

2.0 OVERVIEW OF THE REPORT

2.1 PRODUCT AND SERVICE REQUIREMENTS

A thorough knowledge of the purchaser of the new system is necessary to maximize the realizable sales potential. The primary market for which this subscriber carrier system is to be designed consists of the operating telephone companies in Canada and the U.S. To a lesser extent markets outside North America are also examined.

The analysis of telco purchasing decisions suggests that the major determinant of demand for outside plant is the tendency of the telco to think in terms of service improvement programs which tend to be long-term and involve heavy expenditures.

This approach by the telcos is dictated by economic and technological factors. Since they find that rural service does not pay for itself, decisions on improving service are taken in response to the telco's perceived mandate to provide equitable service across the system than in response to revenue-generating opportunities. Incremental cost-reductions due to improving technology will not alter this basic fact nor, therefore, the demand function for outside plant.

There are also technological factors behind the existence of long-term trends in the telephone industry. First, true break-throughs are rare. Second, the lead time for major advances is such that the capabilities of the technology are foreseen, and can be anticipated in improvement programs, a decade or more before they are commercially viable, and third, investment in existing plant is so heavy that new technologies can only be incorporated into the system slowly.

Service improvement programs will therefore continue to be formulated and proceed on the basis of ballpark costs which are largely independent of the technology employed in specific installations. Specifically, upgrading to 4PL will proceed with a mixture of technologies based on the existing plant and local conditions. Further, the existence of a small digital carrier system will not of itself induce the telcos to commit themselves to providing universal ILS in the next decade. Thus a low capacity system must be capable of supporting 4-party service for the foreseeable future. Finally, market estimates for the requirements for new lines in rural areas can reasonably be derived from the past behaviour of the telcos.

Aside from these general requirements, some specific ones can be defined. A product gap has been identified between the existing small analog and the larger digital carrier systems, specifically for distributed configurations (See Figure 1). The need for a small digital carrier system has been expressed by all of the participating telcos for various reasons, specifically economics and a trend away from analog. Target installed costs specified by these telcos ranged from $550 to $1300/line, the variance resulting mainly from different experiences with installation costs of existing systems.

2.2 TECHNICAL REQUIREMENTS

The basic requirement for any new subscriber carrier system must fall in the following broad categories:

- It must be compatible with the existing outside plant, end equipment, and switch gear.
- It must meet the needs of the various rural demographies which it is to serve, which range from widely scattered populations on the prairies to more densely grouped settlements along roads in the coastal regions, and,
- It must be developed sufficiently early to claim its share of the market, yet it must be developed with existing technology which continuously improves with time.

Within these requirements, many technical constraints became apparent. Most of these, such as VF Performance, maintenance requirements, capacity, etc. are common to any carrier system. It was found, however, that the transmission plant posed the most severe constraint, particularily with respect to crosstalk.

2.3 PROPOSED SYSTEM

As the study progressed through its iterations of the development cycle, a system definition emerged which satisfies most of the market and technical requirements. This system has the following attributes:

- digital T1 subscriber carrier system
- optimized for less than 64 subscribers
- distributed configuration
- clustered configuration also possible
- low power consumption
- individual and party line service
- PCM, alternatively ADM
- concentration optionally available as add-on to central office terminal only

Figures 1 to 3 illustrate this concept graphically. Traditionally, carrier systems serve only point to point applications and those that do support more than one remote terminal, do not allow cable branching. In a distributed design (Figure 1), these restrictions are removed. Single and four drop remote terminals bring subscriber lines to widely separated dwellings. The technical implementation does not, however, exclude its use for a clustered

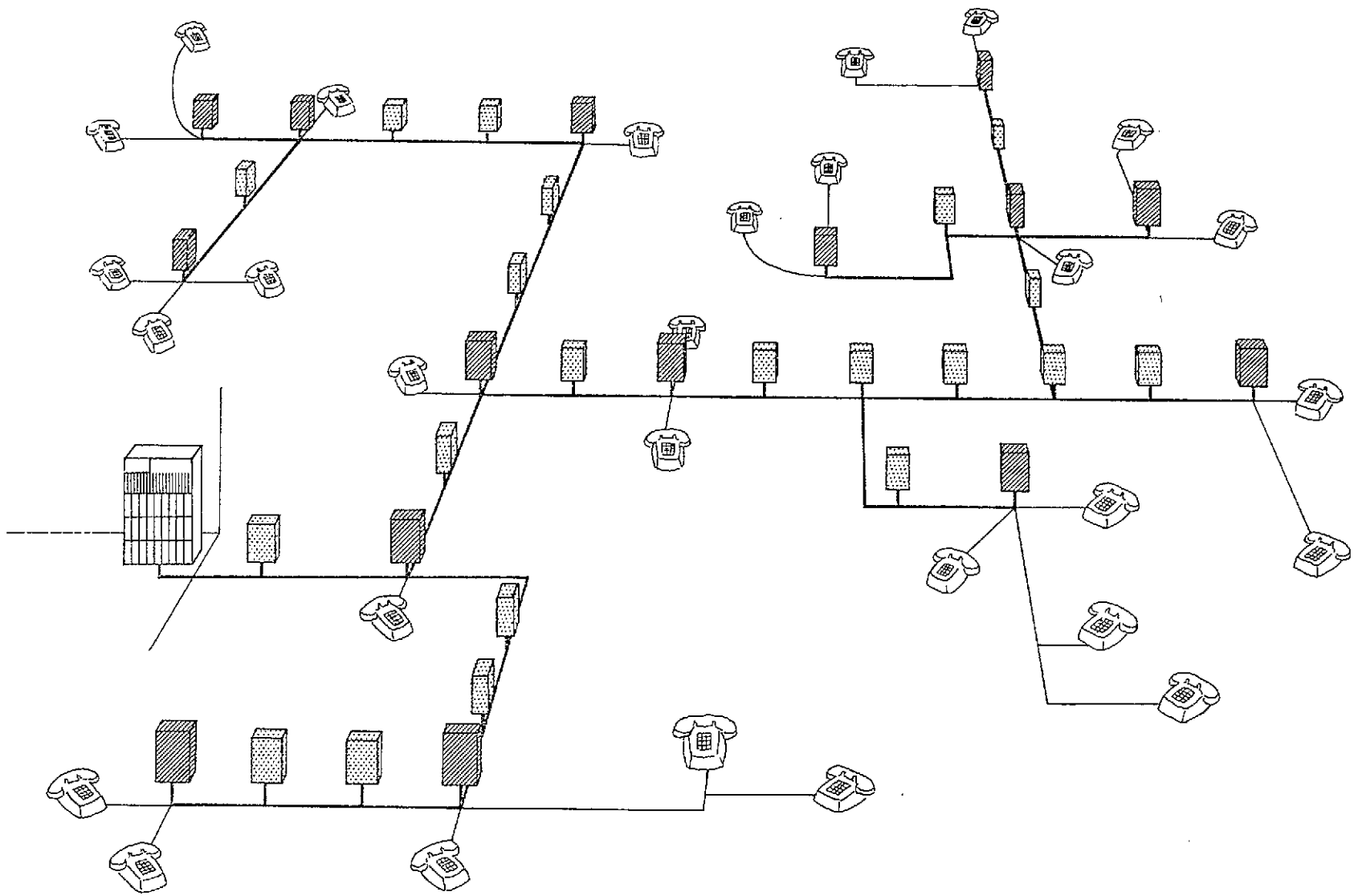

FIGURE 1 DISTRIBUTED SUBSCRIBER CARRIER SYSTEM

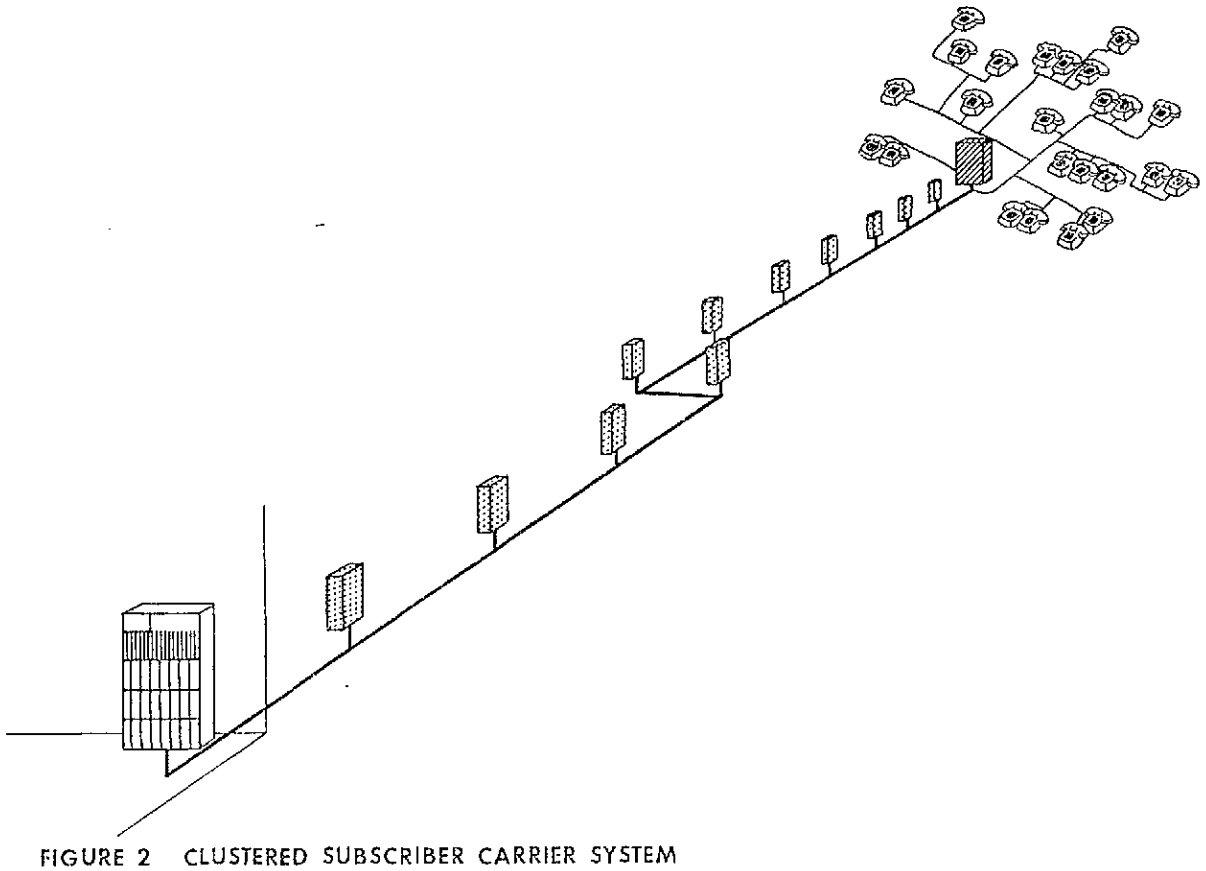

FIGURE 2 CLUSTERED SUBSCRIBER CARRIER SYSTEM

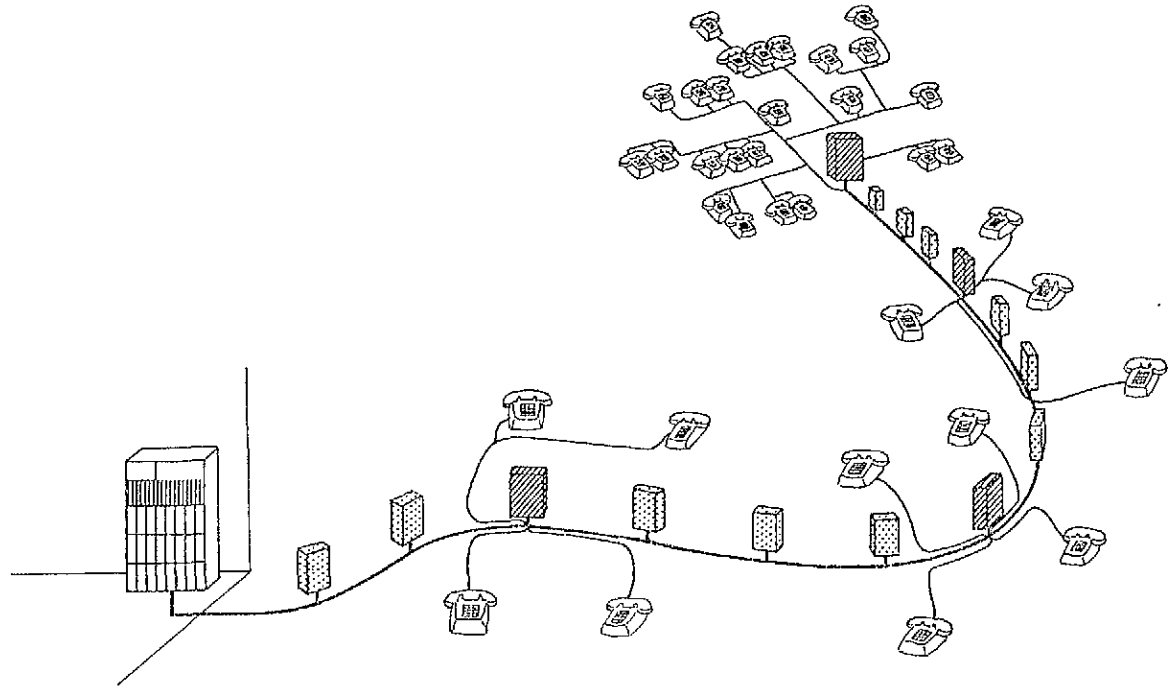

FIGURE 3 COMBINED DISTRIBUTED/CLUSTERED SYSTEM

system with a single large remote terminal (Figure 2) or even a combination of both (Figure 3).

As the system definition progressed, various economic analyses were carried out which showed that while it is generally possible to meet the telcos' target installed cost figures, it is difficult to significantly reduce the manufacturing costs much below these levels with low production volumes (200 units over one to two years), and existing technologies. One dilemma facing the manufacturer is the varying requirement for system features and reliability along with the conflicting requirement for low costs. Clearly, some tradeoff decisions must be made. A modular design with add-on options will make this task much simpler.

A system conforming to the above concept and requirements could be manufactured and sold in quantities of 200 for $464 to $1628 per line (Canadian 1979 dollars) depending on the configuration, with an average of approximately $580 per line. Installed costs to the telcos would start at $650 per line, with an average of approximately $750 to $800 per line. Total research and development costs are estimated at $650,000. (See also Section 3, Conclusions).

2.4 SALES POTENTIAL

The total number of subscriber lines which can potentially be accommodated by the described small digital carrier system is calculated as a function of the growth in the total number of lines of specific telcos.

This growth figure is based on historical trends over the last twenty years, with the assumption that the growth rate will not change during the 1980's. This total market sector is then subdivided to remove those lines from consideration which will be placed on spare capacity plant, VF cable, large digital carrier, and small analog carrier systems. Finally a dollar value is assigned to the remaining market using the average selling price of $580 per line. The gross market potential is thus found to be approximately $1.4 million per year for the four participating telcos (AGT, Sask Tel, MTS, NBTel) and $12.5 million for the U.S. independent telcos.

A further independent analysis is performed on data received through interviews with the participating telcos. Emphasis is placed on specific planned requirements as opposed to continuance of historic trends. The results largely substantiate the above estimates and confirm the conservative nature of the assumptions used.

Another important observation is that although the market potential exists today, sales of a new system will be slow for two years at least. This allows a system which is introduced later but clearly superior to obtain part of the market before the leader is well established.

3.0 CONCLUSIONS

The primary objective of this study was to identify whether an opportunity exists to develop a low cost, low capacity, subscriber carrier system for low density rural areas. This objective has been met and such an opportunity has been identified.

A subscriber carrier system design which is believed to best meet the requirements has been defined functionally and has the following attributes:

- It is a low capacity T1 carrier system optimized for distributed installations with optional add-on concentration.
- The design is based on a data ring concept which provides a simple solution for cable branching and reduces the circuit complexity.
- The basic channel capacity is 24 and may be increased by using adaptive delta modulation as an alternate coding technique.
- No specific upper limit for the total system line capacity is suggested, except that it be no less than 128 to serve as wide a market as possible.
- The number of remote terminals per installation is virtually unrestricted.
- Compatibility with existing T1 carrier lines is maintained by the use of simplex power feed.
- Power is injected as required with inexpensive remote power packs.
- Maintenance of the system is simplified with the use of a comprehensive diagnostic package including automatic fault location.
- The VF performance of the proposed carrier system is comparable to that of existing equipment, with certain compromises in the interest of lower costs.
- The remote terminal and repeater electronics and housings are designed towards compliance with the REA environmental specifications.

The cost for this system has been found to be very competitive with existing technologies at the desired low capacities. The following estimates are based on the preliminary design and are subject to revision as technologies change. They are given in 1979 dollars:

- Continued R & D costs including initial production engineering are $650,000 over an 18 month period. This figure can be further divided into $450,000 for the development of a basic unconcentrated system, and $200,000 for the concentrator. A manufacturer who has existing designs to draw from will be able to reduce these costs substantially.
- A basic unconcentrated system can be produced for as low as $300 per line in quantities of 200 with 46 lines per remote terminal. The manufacturing costs for an unconcentrated distributed system range from $500 to $1100 per line.

- Equipment selling prices range from $460 per line to $1700 per line for the above configurations based on a 55% markup for full development cost recovery.

There is a definite market for small carrier systems with a capacity up to 50 or 60 lines. This market has been quantified in terms of dollars and lines per year as follows:

Region	Lines per year	$000,000
All of Canada	12,400	7.2
Participating Telcos (NBTel, MTS, Sask Tel, AGT)	2,400	1.4
U.S. Independents	21,600	12.5
REA Borrowers	9,000	5.2
Overseas	limited	

The estimates should be regarded as minimum potentials. They are, however, for small carrier systems in general, not just for the proposed system in specific. The exact extent to which a new distributed system will capture part of this market will depend on its superiority over the competition, the time of its introduction, and technological trends. One notable finding is that a number of telcos have stopped purchasing analog carrier systems in favor of digital, and this trend is expected to continue.

The realizable sales potential also depends on a number of significant technical issues:

- Cost versus performance tradeoffs. A proper compromise, which is influenced by the performance of competing systems and telco service standards, is necessary to avoid unacceptably high costs or, conversely, low performance levels.

- A direct digital interface to the new electronic class 5 central office switches will be a requirement within a few years. (A consensus on the exact time, which will vary with the rate of introduction of digital switches in rural areas, could not be found). Such an interface will have a significant, favourable impact on the cost and performance of the subscriber carrier system.

- The technology required to manufacture a low cost system with the potential to significantly alter telco purchasing patterns is not yet commercially available. The general feeling is that a breakthrough towards a low cost transmission medium is needed before this can take place. Most companies are looking towards fibre optics as the medium of the future. The impact of this type of thinking on the total market is not very clear, except that it tends to restrict the life expectancy of conventional subscriber carrier.

4.0 RECOMMENDATIONS

The final requirement for the study was to recommend a course of action to follow. Considering the stated market size, and that the R & D costs were assumed to be fully recovered with gross sales of $6,000,000 (which is equivalent to approximately one half the total participating telco market over 8 years), it is recommended that the proposed carrier system be developed and manufactured.

It is also recommended that:

- the expensive features such as concentration and full diagnostics be offered as options to allow for individual telco preferences.
- the initial version of the carrier system be based on PCM, and that the use of ADM be re-examined once the system is introduced.
- the system be designed sufficiently flexible to allow its modification for data services and alternate speech coding techniques.
- the feasibility of designing the remote terminals such that no field modifications and/or additions are required when adding concentration to an existing installation be examined.

Although a decision of whether or not to follow this course of action is not required immediately from a marketing standpoint, it is recommended that it be made within one year to prevent the gradual erosion of the realizable sales potential through the establishment of competitive systems in the market place and/or the provision of the required services by the telcos with alternate technologies.

Attempts to resolve the various technical problems and issues resulted, in a number of cases, in the identification of areas where additional work is required before the stated sales potential can be fully realized. It is therefore further recommended that:

- standards for the direct digital interfacing of subscriber carrier systems to digital switches be defined, or that, in lieu of the above, manufacturers of digital switches be required to publish interfacing information for use by independent subscriber carrier manufacturers.
- an examination be made of the feasibility of using alternate, bandwidth efficient speech coding techniques for carrier systems.
- the limitations of using T1 on low pair count cable be studied in more detail to obtain a definitive specification.