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MICROCOMPUTERS

FOR

SPECTRUM MANAGEMENT /

BY

Dr. J. deMercado

Dr. J. daSilva

Dr. S. Mahmoud

Mr. G. Overtveld

TELECOMMUNICATION REGULATORY SERVICE

MINISTRY OF COMMUNICATIONS

CANADA

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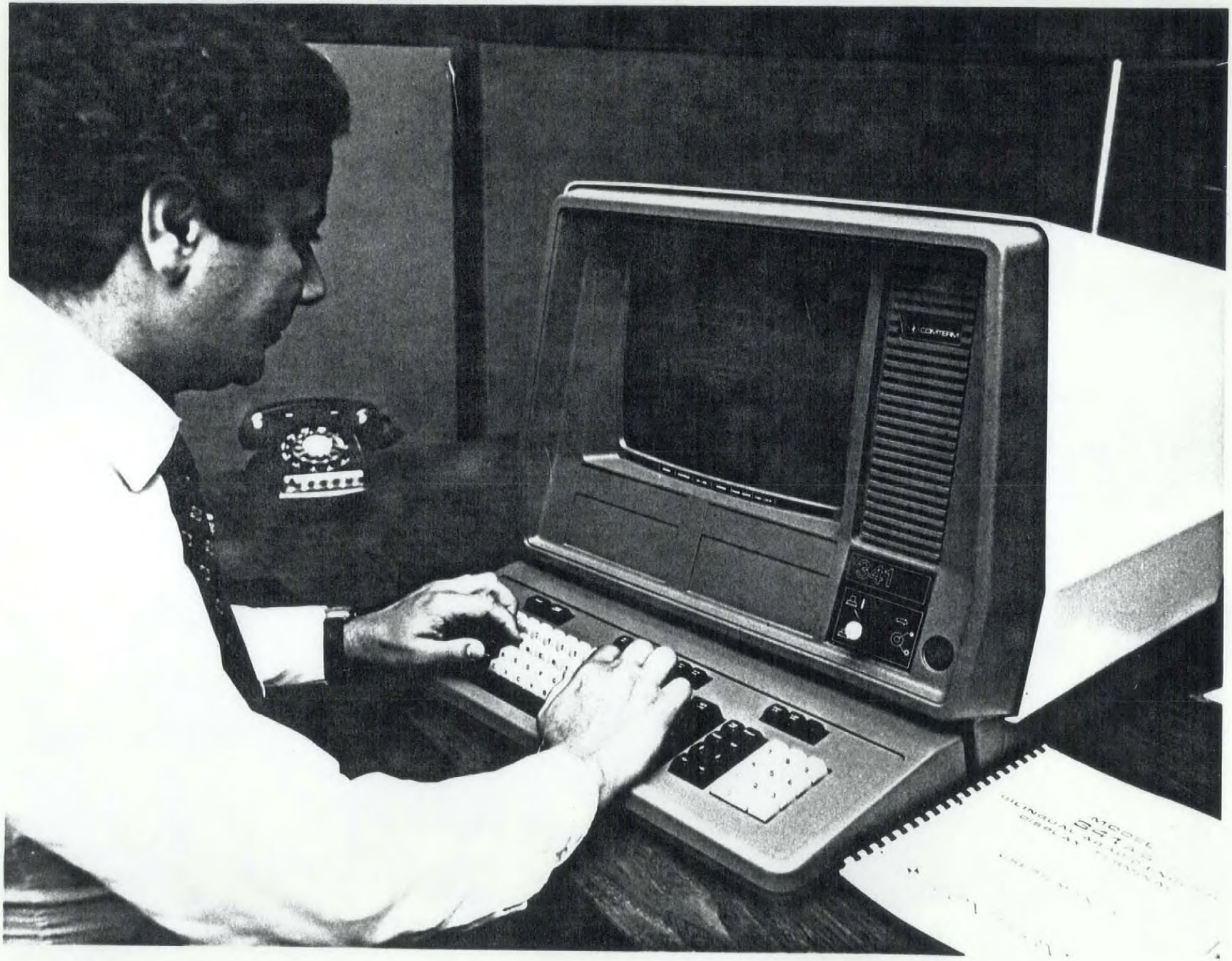
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1. INTRODUCTION

Over the last 20 years there has been a rapid growth in the demand for radio communication services. This in turn has created an urgent need for Administrations to find adequate methods and tools for meeting this demand and for ensuring efficient utilization of the spectrum .

In general this demand has been met by the opening up of new frequency bands and by applying new engineering methodologies and innovations in the technology that guarantee better sharing and use of frequency assignments.

The growing demand along with the constant search for improved methods of satisfying it, has transformed the management of the spectrum into an increasingly complex field, both technically and administratively which is progressively becoming more dependent on the use of computers.

On an international level to assist the various National Administrations in solving these complex problems ,the CCIR was given the task of describing the application of computer aided techniques in spectrum management. Several spectrum management tasks which can be considerably aided by the use of computers have been identified by the CCIR and include ;

- Resolving potential interference problems between users,

- Providing administrative assistance through licence record keeping and the processing of frequency applications,

- Frequency analysis to accommodate new radio systems or techniques,

- Frequency assignment to individual units, systems or class of systems to minimize potential interference,

- Evaluation of technical specifications of equipment and their spectrum use methodologies,

- Development of tabular and graphic engineering aids (such as frequency-distance separation curves) to assist spectrum planning.

Some Administrations are using computer based procedures to aid in performing the above mentioned tasks. However the majority of Administrations are still at least at present studying and planning the introduction of computer systems for spectrum management.

The successful introduction of computers to aid spectrum management functions is extremely dependent on the computer hardware and software to be used. The methodology for selecting and introducing computer facilities in the ongoing operations of

Administrations , requires a phased approach and is based on obtaining or developping computer programs (software) to perform the required tasks, as well as the training of personnel who will man the new facilities.

This paper reviews the above mentioned issues in light of the plans and programs beeing made in the Department of Communications , to select and deploy microcomputers to assist in performing the various tasks associated with spectrum management in Canada.

Specifically this paper describes the Program currently under way in the Department of Communications (Canada) to use microcomputers to support the engineering and administrative functions of spectrum management. From the many excellent microcomputers available , the Department has selected two configurations . The first which is based on the Digital Equipment Corporation DEC-LSI-11/23 microcomputer is shown in Photograph 1 . The second which is based on the CROMENCO SYSTEM III microcomputer is shown in Photograph 2 . There are undoubtedly other microcomputers which could be used, however the Department has not to date explored any other equipment than the ones depicted in this paper . The experience to date, indicates , that many nations , could readily use these microcomputers to meet many of their spectrum management computing needs; with the added benefits of low cost , portability and serviceability plus access to proven software from Canada .

Section 2 of this paper summarizes the advances made in software and hardware technology which led to the availability of

these powerful low cost microcomputers. The section also summarizes some of the advantages of using these microcomputers in spectrum management. Section 3 provides two examples of complex spectrum management programs that have been developed in partnership with Canadian Industry and which are currently running on the microcomputers shown in photographs 1 and 2 in the Department of Communications . Section 4 elaborates on the issues related to the technology transfer process. Finally some future directions that these developments are likely to take are outlined in Section 5. Appendices A and B contain further information on microcomputers and their associated software in use in the Department of Communications in Canada .


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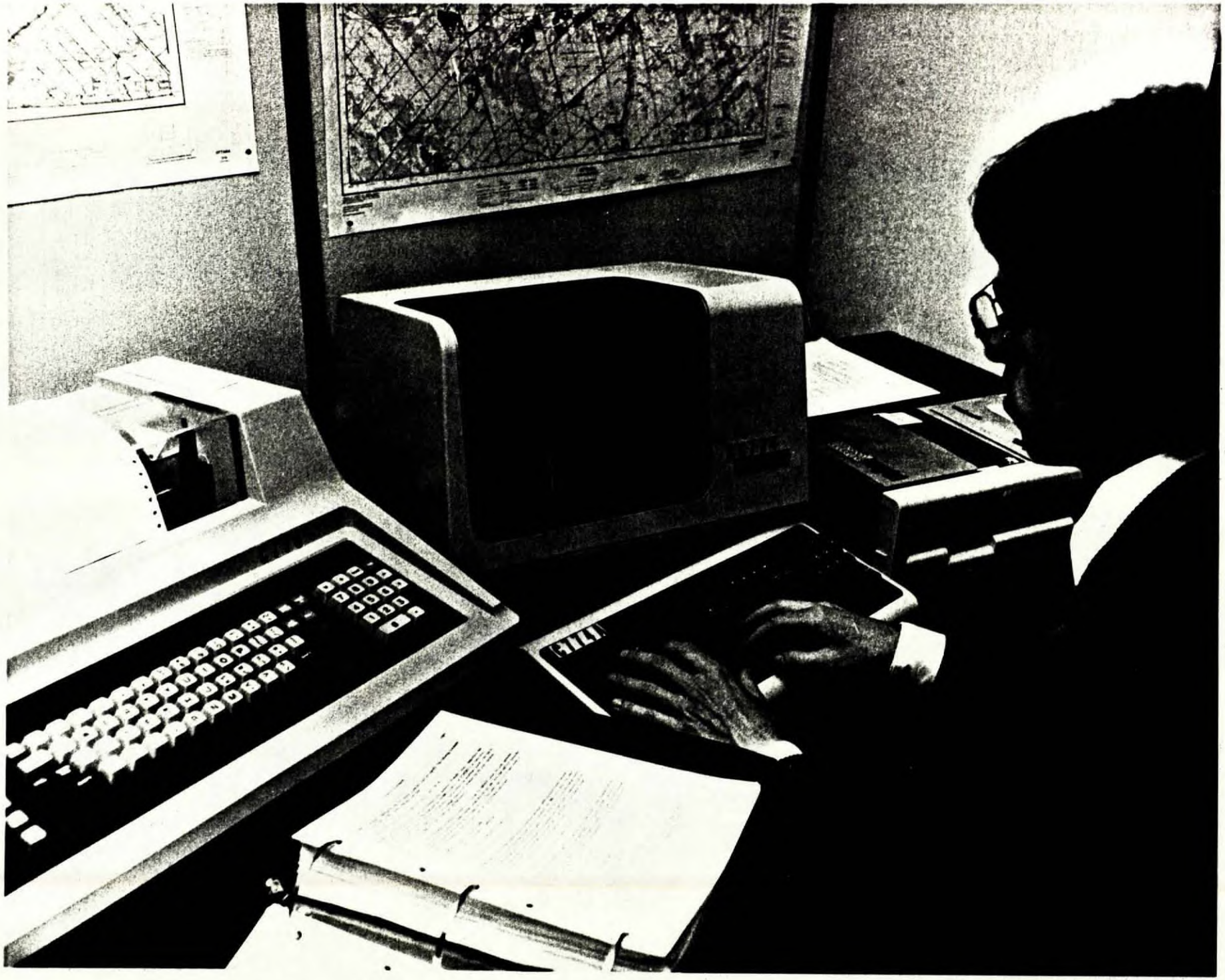


System
Three
Computer

2. ADVANCES IN MICROCOMPUTERS

The use of microcomputers , has until very recently been confined to small control and communications applications. This was because , until 1978/1979 , microcomputers had very limited processing capabilities , small memories and restricted peripheral storage capabilities .

Technological advances in large scale integrated circuits and memory technologies have led , however , to the emergence of a new generation of powerful microcomputers . These microcomputers are extremely reliable and of very low cost, offering speed and ease of programming along with memory capacity which until recently had been found only on much more expensive full sized computers . The improvement in cost/performance ratio over the last two years has been simply breathtaking and the future promises to be even more spectacular.

With advances in microcomputer equipment and technology have come an ever increasing availability of high level programming languages (FORTRAN IV, COBOL , PASCAL , APL etc.), transportable software packages, operating systems, application programs and perhaps most significant of all , highly versatile Data Base Management Systems. Efforts are already well underway to standardize the most commonly used operating systems, interface hardware and software and programming languages so as to ensure a high degree of program portability between various microcomputer systems .

Examples of the most commonly used operating systems are the CPM system for microcomputers that is based on the Z-80 microprocessor and the RT11/RSX11 operating system for the DEC LSI-11/23 microcomputer.

Appendix A presents a summary of the most important characteristics of microcomputers , their secondary storage devices, operating systems and programming languages. Appendix B presents a brief summary of the two microcomputer architectures being used by the Department of Commnunications in Canada , along with the hardware and software capabilities currently resident on these machines.

These microcomputers are demonstrating that they hold a real promise for allowing cheap and efficient transfer of spectrum management computer programs between Administrations . Specifically, these microcomputers offer the following features to spectrum managers :

1. Low cost: Administrations will be able to introduce powerfull microcomputers into spectrum management with a relatively low initial capital investment. As the requirements for increasing computing capability grow , these microcomputers can also be expanded again at very low cost relative to what would have been the cost of expanding large computer systems only a few years ago.

2. Expandability: microcomputer systems can be expanded in two basic

ways. These are: (1) each microcomputer system unit can be expanded in memory, secondary storage and numbers of user terminals ; and (2) several microcomputers can be interconnected into a network configuration accessing a centralized mass storage memory system to accommodate almost unlimited growth in data base and program size.

3. Ease of Operation: the managed and controlled growth and operation of these systems is more straightforward and simpler than what is involved for large computers , and can usually be accomplished by a very small team of professionals . This feature is extremely important for applications involving low computer utilization and where large numbers of skilled computer personnel are not readily available.

4. Reliability: the relatively low cost and high reliability of microcomputers is now proven . In addition it is easy to build into these installations spare capacity in the form of extra microcomputers . This feature is extremely important in locations where maintenance and servicing may not be readily available .

5. Software Transportability: the widespread use of certain types of computers (e.g. DEC's PDP11 line, Z-80 CROMENCO and other microcomputers, etc.) will make it possible to easily exchange and transfer software programs among users. This will have the advantage or reducing or minimizing the time and costs associated with the development of software and will prove to be a real benefit to Administrations who do not wish to go to the expense of writing their own programs in their entirety.

3. SPECTRUM MANAGEMENT APPLICATIONS

In the Department of Communications , the following two examples illustrate the use of microcomputers to solve spectrum management problems that had previously only been possible by the use of a large computer . The first of these applications involves propagation prediction using a computer program which is now resident on the DEC microcomputer system (photograph 1) . This program runs with a topographical data base which makes it useful for performing calculations for radio systemes operating in different terrains .

The second application involves the use of a CROMENCO computer (photograph 2) to house a frequency record data base that is used for administrative purposes and for conducting Electromagnetic Compatibility Analysis (EMC). This program is in the prototype stage , but it already is demonstrating the power and facilities of the Database Management System (DBASE II) . Additional details are as follows.

3.1 The Propagation Prediction Computer Program

An existing [5] comprehensive propagation program originally developed and running on a main frame computer system at the Communications Research Center of the Department was modified and implemented on the DEC minicomputer system. This program incorporates several propagation models that cover the VHF/UHF band from 30 MHz to 1 GHz. The

models included in the program cover a wide range of propagation conditions, terrain types and clutter features in the vicinity of the transmit and receive antennas. The program is further enhanced by a topographical data base that resides in the microcomputer and which permits detailed propagation analyses to be made.

The program is designed so that it can be used by engineers who are not familiar with programming techniques or details of the operation of the DEC system. The program's overall capabilities are that it contains ;

(1) A conversational (interactive) subroutine called "Predict", which acts as an interface between the user and the computer. "Predict" constructs a data input file based on user responses to questions set by the computer, and sets a series of flags that identify the specific types of calculations to be carried out.

(2) A topographical data base called "Topo", which contains previously stored information about the terrain. For instance, a rectangular area of M by N km square may be scaled in the form of a grid with a resolution of 1 or .5 km. Each of the points in the M*N grid of "Topo" will consist of the coordinates of the grid point as well as the average terrain elevation within the 1 km square cell centered on that point.

(3) A computational subroutine called "Run", which contains the propagation equations and computational algorithms.

Figure 1 illustrates the general structure of the propagation prediction program. The user enters all input parameters and selects one of four terrain options:

Option 1 is selected when terrain features are not known. A "smooth-earth" model is automatically assumed by the program for this case. In option 2, the user selects to specify the terrain features from a given stored list. In option 3, the user enters the profile of the terrain point by point. Finally, option 4 can be selected if the terrain in question falls within the boundaries of a previously stored topographic data base.

Once the terrain option is selected and completed, the program goes into execution mode, produces the results and displays them to the user. The main memory storage requirement for this program is approximately 128 K.bytes. The storage requirement for the topographic data base is such that 5 bytes are required for each square kilometer. Thus assuming the existence of 100 maps, each covering an area of 10,000 square km, the secondary storage currently on a hard disk is :

$$100 \times 5 \times 10{,}000 = 5 \text{ Megabytes}$$

The above storage requirements indicate that the program can be fully supported by the processor configuration shown in Photograph 1.

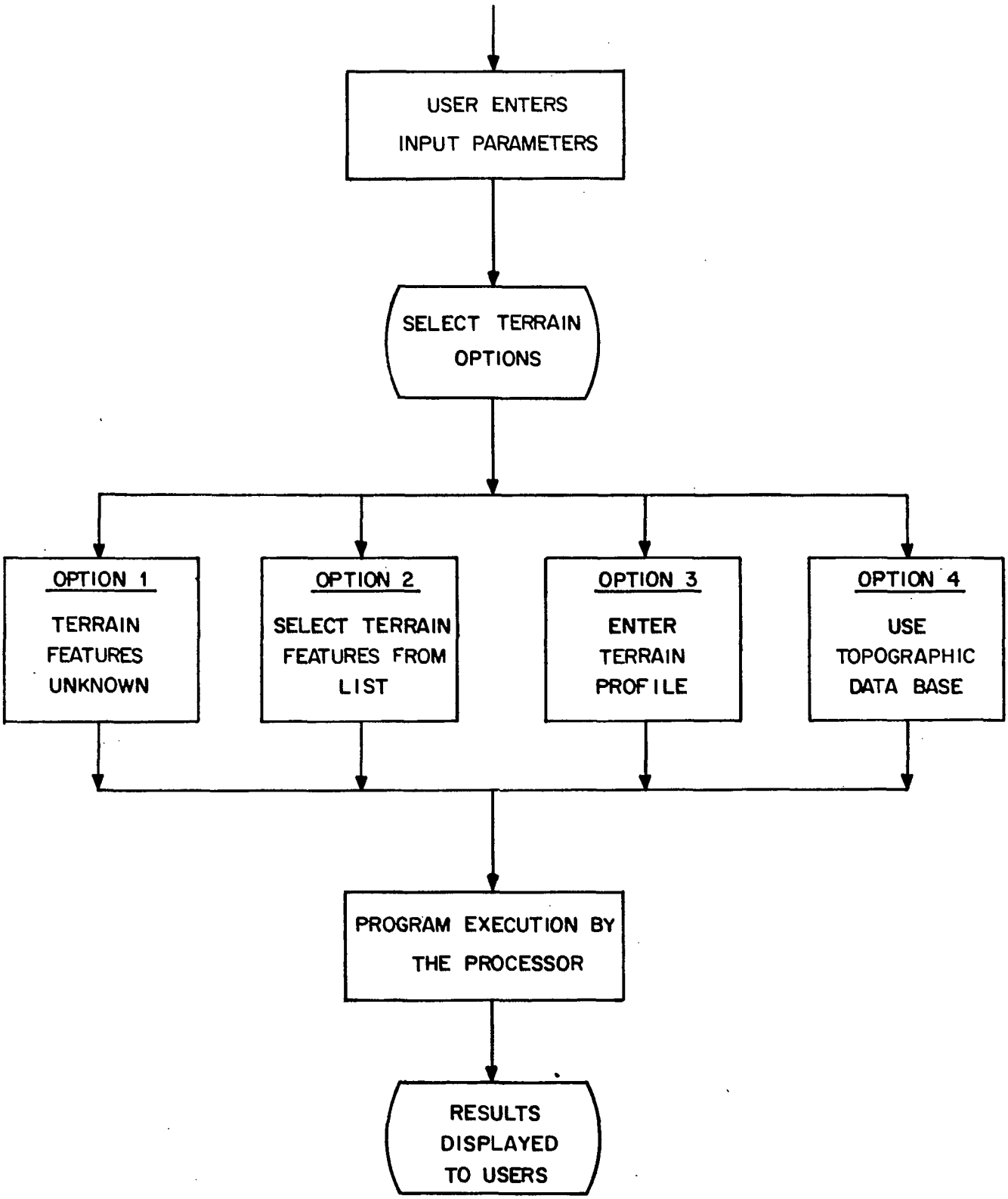

Figure 1

GENERAL STRUCTURE OF THE PROPAGATION PREDICTION PROGRAM

3.2 Electromagnetic Compatibility Test (EMC)

An EMC program which accesses a stored frequency data base is described in this section. The program which was developed in collaboration with Intellitech Canada Ltd. and its data base has been implemented on the CROMENCO microcomputer (Photograph 2). The program which is still under exploration has at present, the following capabilities.

(1) A screen oriented data entry and editing facility to allow the user to enter the data on the proposed new radio station which is to be evaluated against existing stations.

(2) A data base which containing the records of existing stations and all their related data,

(3) A Frequency Analysis program which permits (i) Co-channel analysis, (ii) Interstitial analysis, and (iii) Adjacent channel analysis,

(4) A natural "plain english" language retrieval feature that allows users to retrieve records and produce reports on the basis of one or more simple "plain english" requests. This is an extremely powerful feature and underlines the usefulness of the DBASE II Data Base Management System .

From the user viewpoint the system functions as follows:

Step 1: record entry

The user enters the data of the proposed station so that frequency analysis can be performed .Specifically the following data items are entered:

Licence number	7 numeric	(optional)
Name of Licensee	35 characters	(optional)
Call Sign	8 characters	(optional)
Address of Licensee	35 characters	(optional)
District Office	2 numeric	(optional)
Name of Station	35 characters	(optional)
Company Code	9 numeric	(optional)
Record ID	9 numeric	(optional)
Frequency (MHz)	7 real number	(compulsory)
Latitude (degree,minute,sec)	9 real number	(compulsory)
Longitude (degree,minute,sec)	9 real number	(compulsory)
Antenna AMSL (m)	4 numeric	(optional)
Ground Elevation AMSL (m)	4 numeric	(optional)
Antenna Gain (dB)	3 real number	(compulsory)
Total Losses (dB)	3 real number	(compulsory)
Effect. Rad.Power (dBW)	3 real number	(compulsory)
Station Mode (TX or RX)	1 character	(compulsory)

If any of the (compulsory) fields is not entered, the system will request the user to enter the missing field value before moving to the next step.

Step 2 Entering Parameter Values

The user on request of the system enters the values of the following parameters :

(i) Receiver noise code : This is entered as a 1,2 or 3

(ii) Interstitial channel rejection ratio called IC in units of dB .In this instance if no value is entered for IC, the following default values are automatically used by the system depending on the frequency band under consideration :

FREQUENCY BAND (MHZ)	IC (dB)
27-50	-
138-174	15
410-470	12.5

(iii) Adjacent channel rejection ratio, AC, in dB units. Here if no value is entered for AC, the following default values are automatically used by the system :

FREQUENCY BAND (MHZ)	AC (dB)
27-50	75
138-174	74
410-470	72

(iv) Value for the receiver threshold power, Pmin, in dBw.Here if no value is entered for Pmin, the following default values are automatically used by the system :

FREQUENCY BAND (MHZ)	NOISE CODE (dB)		
	1	2	3
27-50	-143	-139	-131
138-174	-148	-139	-131
410-470	-146	-145	-138

Step 3: Analysis

The system allows the user to select one of the following five analysis options:

1. Co-channel Analysis : This option displays all of the records satisfying the co-channel interference criterion.

2. Interstitial Analysis: This option displays all of the records satisfying the interstitial channel interference criterion.

3. Adjacent Analysis : This option displays all of the records satisfying the adjacent channel interference criterion.

4. Enter Station : The proposed station record can be entered into the data base containing existing station records.

5. Quit : The system will give the user the option of entering another station record or terminate the session.

The program for carrying out all of the above, requires a main memory of only 32 kbytes , which means it easily runs on an 8-bit

or a 16-bit microcomputer such as the CROMENCO or the DEC microcomputer. Each data base record has a maximum size of 200 bytes. Thus, a 10 Megabyte disk space would accommodate a data base with a total volume of 50,000 frequency records. In addition to being able to study the potential interference impact of a proposed radio station , the user is also allowed to exploit the capabilities of the data base management system. Using the natural language features of a data base management system , record retrieval and report preparation can be accomplished in a very simple and straightforward manner. For example if a user wished to retrieve the licensee name (LNA) and address (LAD) for all radio stations whose frequencies (FREQ) exceed 150 MHz and whose latitude (LAT) is between 45(d),30(m),25(s) and 45(d),30(m),35(s) this could be accomplished by typing the following "plain english" statement :

```
DISP LNA,LAD FOR FREQ>=150 AND (LAT>=45.30.25).AND.(LAT<=45.30.35)
```

Alternatively as another example a user might want to have a listing of all call signs (CALL.SIGN) corresponding to radio stations whose antenna heights (ANT.HEIGHT) are greater than 30 m and whose location is within the administrative boundaries of district office (DIST.OFF) 35 . In this case the user would enter the following statement:

```
DISP CALL.SIGN FOR ANT.HEIGHT)=30 AND DIST.OFF="35"
```

The retrieval capabilities provided by the CROMENCO microcomputer and the data base management system DBASE II are however not limited to the two examples given above. Various other "simple english" retrieval capabilities can be readily generated including ,for instance, the calculation of averages of antenna heights, effective radiated power, etc.

4. THE ACQUISITION OF MICROCOMPUTER TECHNOLOGY

Many Administrations are countinuously facing the problem of deciding which specific spectrum management technology is more appropriate to their environment . The technology (hardware, software) and know-how (brainware) continue to be developed at phenomenal rates that reduce the existing technology to obsolescence within 3 to 7 years . Hence decisions concerning the acquisition of computers to support spectrum management are increasingly difficult to make. Costly and difficult to rectify mistakes will most likely result if the most cost/effective computer technology and software is not selected from the outset.

Canada is convinced that the transfer of technology and know how in the area of spectrum management must be undertaken so as to allow Administrations to progressively acquire and build their own skills and generate applications actually tailored to their own environment . Administrations who wish to ensure the flow of technology in harmony with their local cultural realities have always to underline the scarcity of human and financial resources . Indeed the mere fact that the hardware and software to support spectrum management is available in one Administration, is no guarantee that it can be effectively transferred to another Administration without careful attention being given to human factors and local cultural realities . There must be a commitment from Administrations wishing to successfully deploy spectrum management technology to develop to the extent required the

necessary skills (brainware) through comprehensive training programs .

Transfering technology to a milieu where resistance to change is built-in often leads to problems of a non-technical nature. In such circumstances the failure of technology is not only measurable in terms of quantifiable costs such as equipment but also as well in terms of socio-economic and cultural ones . However if the strategy of modernization through technology transfer is both limited and regulated, the risk of it failing will be minimized. This implies that a pragmatic approach of progressive deployment of human, technical and financial resources has to be instituted. In the particular case of microcomputer technology as applied to spectrum management it is important that the program of technology transfer be structured according to the following phases:

1. TECHNOLOGICAL ABSORPTION: During this phase an Administration would as a first step acquire a minimum configuration system consisting of a microcomputer, visual display terminal, printer and floppy disk secondary storage. Software wise the microcomputer would have a single user operating system capable of supporting three computer languages Basic, Pascal and Fortran, together with a set of demonstration programs. These demonstration programs would allow users; to experiment with creating and retrieving records of information pertinent to a limited set of radio stations via a file management system; to use the system in the word processor mode; and to run some simple

programs providing for instance calculations of the coverage area of a land mobile base station. This experience would allow users to rapidly become familiar with both the hardware and software capabilities of a microcomputer.

2. EXPANSION OF TECHNOLOGICAL ABSORPTION: In this phase hardware and software capabilities are expanded to include a number of visual display terminals, printers and a hard disk drives with a minimum of 20 M.bytes of storage. A time-shared operating system would also be installed along with a Data Base Management System. An additional option would be a plotter and corresponding graphics package that would allow the displaying of path profiles using stored terrain data or the drawing of coverage contours of for example, broadcasting stations . The Data Base Management System would allow users to gain experience in the retrieval of administrative or technical data elements from a spectrum management data base using "simple english " instructions . Demonstration packages would to allow the user to study the frequency assignment problem in a congested radio environment and gain a feel for the overall operation of the system .

During this phase the users will interact closely with and become thoroughly familiar with the equipment learning how to best configure it and utilize it for the various applications . User skills and familiarity with software are expanded in parallel and by the end of this phase users should be able to write programs in BASIC or FORTRAN IV.

3. CREATIVE DEVELOPMENT: At the end of the first two phases the capabilities of microcomputers to aid spectrum management will have been fully demonstrated. In this third phase users begin creative development and customizing of programs by exploring new applications and tailoring the existing programs to their own specific needs. In this phase, the capabilities of hardware and software are stretched to their limits and users gain experience with generating documentation while undertaking limited software and hardware maintenance . A methodology for human resource development is established during this phase to qualify and train personnel particularly in the areas of software design and hardware maintenance. More efficient operating systems, other languages (COBOL, C, etc.) and a library of mathematical subroutines are then installed. At the end of this phase the spectrum management microcomputer system would have the capability to study ,propagation models, antenna models, frequency allocation plans, and provide licensing .

4. CONSOLIDATION OF CREATIVITY: During this phase the user is expected to achieve a limited technological autonomy particularly in the software sense. The user would now be in full control of the microcomputer based spectrum management system and all of its programs . The need might arise to extend the intelligence of the spectrum management system to other offices of the Administration located in other parts of the country, in which case access to telecommunication channels will have to be provided. This however will not modify to any substantial degree the technical characteristics of the spectrum management system

but rather will impact on its operational and administrative aspects.

The capacity for innovation is stimulated by an appropriate training program that will emphasize the brainware aspects of spectrum management. To be able to perform a full scale maintenance program it will be necessary to train personnel in the use and understanding of technical service data and drawings as well as automated trouble shooting and diagnostics programs including the replacement of printed circuit boards.

In the past, the cost of technology transfer involving large scale computers has been very high. However in the future, spectrum management technology based on microcomputers can be transferred to Administrations at relatively low cost. This will ensure that the financial burden is kept at a very modest level while allowing the recipient Administrations to carry on their national and international spectrum management obligations in a framework of creativity and innovation.

Canada looks forward to working with interested Administrations in this vitally important area.

5. CONCLUSION

Meeting the growing demand for radio communications continues to be a principal preoccupation of Administrations. As radio waves do not respect international boundaries, the increasing and diversified use of radiocommunication has led, in recent years, to a realization of the necessity of properly managing the spectrum. Most Administrations are therefore planning to, or have introduced modern and sophisticated computer tools and associated engineering techniques . Such a trend is typified by the increasing involvement of the ITU and its organs in spectrum management related projects and programs.

Canada has realized that, in the future , spectrum management will be based extensively on the use of microcomputers. In the past large scale computers were utilized at great cost as these were the only ones available . With the advances in technology however , it has been clear that spectrum managers can utilize microcomputers which have now attained capabilities that in many instances exceed that of the large scale computer of a few years ago. Administrations can now avail themselves of these new Canadian innovations and experience gained by working closely with Canada therefore minimizing the financial and human resources that would otherwise be required to develop and maintain effective Spectrum Management facilities. Canada in collaboration with its Industry would be pleased to assist national Administrations develop a program in this vitally important and dynamic area .

APPENDIX A

ESSENTIAL FEATURES AND CHARACTERISTICS OF MICROCOMPUTERS

The main features used to determine and evaluate the capabilities of microcomputers are:

(0) Cost

(1) Word Length

(2) Main Memory Size

(3) Central Processing Unit (CPU) Capabilities

(4) Input/Output Support

(5) Secondary Storage Devices

(6) Number of Users that can be supported

(7) Communications Interfaces

(8) Software (applications and operating system)

(9) Price and Delivery time (Including Service)

(10) Continuity of Compatibility

A description of each of the above categories is presented below. More details of commercially offered microcomputers, and available software is given in references [1] and [2]. Additional information can also be found in various trade journals and magazines [3],[4].

0. Cost

All microcomputers with fully expanded main memory but, exclusive of software and peripherals such as disc drives printers and CRTS, currently cost less than $10,000 at the retail level in single quantities. Complete systems of high quality have hardware costs of between $15,000 and $100,000 depending on the amount and type of the peripheral devices utilized.

1. Word Length

The word length refers to the number of bits (binary digits) that can be retrieved or stored from memory during a single cycle. Microcomputers with longer word length tend to be, in general, more efficient and accurate. All existing microcomputers have an 8-bit word length or 16-bit word length.

2. Main Memory Size

The storage type can be either magnetic core (as in early computers) or semiconductor memory (as in modern computers). The demand for higher performance at lower cost, coupled with continuing improvements in semiconductor technology have accelerated the trend toward the use of semiconductor memories. The maximum memory size of 8 bit microcomputers is 64Kb and of 16 bit microcomputers is 256Kb.

3. Central Processing Unit (CPU) Capabilities

The majority of currently available microcomputers are parallel, binary processors with single address instructions and fixed word lengths of 8,12,16 bits.. It is now expected that 32 bit microcomputers will be on the market by 1985. The important factors to be considered when evaluating the central processing units' capabilities are:

3.1 Address space, or the maximum size of directly addressable main memory. The shorter the word length, the smaller the size of the directly addressable main memory. This in turn places constraints on the size and number of data records and size of application programs. The most common techniques used to minimize the restrictions of word length in 8 bit and 16 bit microcomputers are based on techniques such as multiword instructions, indexing or indirect addressing.

3.2 Hardware multiply/divide logic. When this hardware is not specifically a part of the CPU, operations of multiplication and division must be performed by programmed routines. This leads to a reduction in the speed at which these operations can be performed. Thus it is always desirable to have all arithmetic as well as many as possible mathematical operators realized directly as part of the hardware of the Central Processing Unit.

3.3 Microprogrammability. In place of conventional hardwired logic, a microprogrammed computer uses sequences of microinstructions stored in a special read-only-memory to define the effects of each instruction in its repertoire. Microprogrammability increases the flexibility of the computer by allowing the user or the vendor to alter the microprograms. However, this feature usually reduces the speed and/or increases the cost, and the added flexibility may not be sufficient, to justify its use.

3.4 Hardware Floating Point Facilities. These facilities are needed in most scientific applications and are useful in reducing the execution times of certain programs which would otherwise use time consuming floating point subroutines. Many microcomputers offer a small "chip" called a Floating Point Processor, which can be plugged in directly on the Main CPU board. The cost of this chip is typically of the order of $300.

3.5 Battery back-up. This is essential to preserve the contents of the solid state memory in the event of a power failure.

4. Input/Output Support

The transfer of data from a peripheral device, such as a disc unit, to the main storage may take place either under program

control or via a direct memory access channel (DMA). Generally speaking, DMA has two significant advantages over program controlled I/O: (1) it can accommodate higher I/O data rates and (2) it causes less interference with internal processing operations.

For applications of a real-time nature, an effective "program interrupt" facility is an essential requirement. An interrupt is a signal that causes a temporary suspension of normal program execution so that the specific condition that caused the interrupt can be dealt with. In real-time applications, an external interrupt usually indicate that a particular peripheral device requires attention. The number of external interrupt levels provides a reasonable indication of the power of the computer's interrupt system. It indicates the number of different external devices the computer can support.

5. Secondary Storage Devices

The most commonly available secondary storage devices for microcomputers are:

- Floppy disc drives with storage capacity of 1 to 3 Megabytes per drive, at a cost of $3,000. to $6,000. for a high quality double drive system.

- Disk pack/cartridge drives with storage capacity of 3 to

10 Megabytes per disk. A typical high quality 5 Mb hard disc system for the DEC LSI11/23 system costs under $10,000.

- Drum/fixed-head disk with storage capacity similar to cartridge drives.

- Magnetic tape cassettes

6. Number of Users that can supported

Users refer to the number of individual data processing devices or terminals that can be connected to the microcomputer. An important factor to consider in an applications environment is the number of such devices or terminals which can be concurrently supported by the microcomputer in a time-shared mode. If the microcomputer system is being used in "time-sharing" environment, it must be capable of interfacing to and serving several users who may share the same set of applications or may alternatively run their own special programs. The computer will appear to each user as if it is dedicated to running his individual job despite the fact that it is serving several other users at the same time. This "time-sharing" feature, in the past an exclusive preserve of the large computer, is now readily implementable on microcomputers.

7. Communications Interfaces

A special interface is usually employed to enable the microcomputer to send and receive data over a telephone channel. Three main factors define this communications interface, these are;

- The maximum number of communications lines that can be handled by the microcomputer system

- the type of interface (synchronous and asynchronous) and the transmission speed in bits/second that it supports

- the type of communications protocol supported by the computer in the form of a software or a hardware facility.

8. Software

The software is defined as the programming packages and languages used to program the computer. The availability of software for any given microcomputer is a very important factor to be considered when evaluating the usefulness of that microcomputer for the applications under consideration. It is possible to classify software into the following three categories:

(i) The operating system: forms the core of the computer's software and handles functions such as scheduling, loading, initiating and controlling I/O operations and devices,

supervising the execution of programs, dealing with errors, handling all interfaces to human operators and organizing multiprogramming or time-sharing operations. Operating systems are usually licenced for use with a given microcomputer and costs range from a few hundred to several thousand dollars.

(ii) Programming Languages and Compilers: the programming language (eg: BASIC, FORTRAN IV, COBOL) allows users to write complex programs in a straightforward fashion. The compiler of the language converts the program into executable machine language code. The compiler thus shifts part of the program preparation task from the user to the computer itself. Examples of programming languages include FORTRAN IV, BASIC, APL, COBOL, PASCAL and C and their associated compilers are now available for microcomputers. The costs of these compilers, usually licenced for a given system run from a few hundred to several thousand dollars.

(iii) Data Base Management Systems: these software packages are the wave of the future, and allow the user to specify a logical structure for the data he wishes to store and then retrieve later. The user is also provided with facilities for updating or modifying the data. The user can specify, retrieve and manipulate his data using a high level procedure. The data base system translates the logical structure into a physical layout, stores it on secondary storage devices and controls all access operations to the stored data. Data Base

Management Systems for a 16 bit microcomputer can easily cost as much as $50,000. Such a system would have its own high level programming language.

9. Price and Delivery Time (Including Service)

Four important factors must be considered in the price and availability issue:

i. The price of CPU, power supply, minimum memory (and memory increements), secondary storage, I/O devices, hardware options like floating point processor. The price of various software packages must also be considered.

ii. Delivery date - the time lies between issuing a purchased order and the installation of the facility. Typical delivery dates and installation times should be kept within 6 months.

iii. Availability of field support and maintenance for the hardware and the software components. In this regard a parallel "back-up" system will minimize down time between repairs in any location.

iv. Costs of software, tailored to given applications is always expensive, however the widespread use of Data Base Management promises to minimize the costs of developing and transporting software between microcomputers.

10. Continuity of Compatibility

This factor, refers to how long a given microcomputer will be produced and whether or not successive generations of improved microcomputers will "run" the software of earlier generations without major modifications. In this regard the performance of the DEC microcomputer line will be excellent ensuring compatibility with successive generations of equipment and full transportability of all software.

APPENDIX B

SUMMARY OF MICROCOMPUTERS IN USE

IN THE DEPARTMENT OF COMMUNICATIONS

FOR SPECTRUM MANAGEMENT

INTRODUCTION

The microcomputers installed in the Telecommunication Regulatory Service of the Department of Communications , Canada , take advantage of the most recent developments in miniaturized hardware and software including Data Base Management Systems .

The "Digital Equipment Corporation" (DEC) 16 bit LSI-11/23 microcomputer (Photograph 1) has been chosen . This microcomputer is a direct descendent of the DEC minicomputer line ;and is much smaller and cheaper then the original minicomputer , yet all the major software written over the years for the larger PDP-11 minicomputer will run on the micro version , once sufficient provisions for storage have been made .

The CROMENCO SYSTEM III has been chosen as the 8 bit microcomputer that will be used . This computer is based on the Z-80 microprocessor which has been produced in quantities of hundreds of thousands . The advantage here is, the large and rapidly increasing group of users, which at the latest estimate number more than 500000 installations in North American . A variety of software houses cater to this group with application software. Although some of this is still of the "hobby" variety, some excellent packages have been made available lately, which offer features that rival those previously only available for large computers . This software stands out by its ease

of installation, its lucid clarity to non computer operating personnel and its ability to adapt to new uses. The 8 bit microcomputer is thus an excellent choice to gain an appreciation of the large and growing market of application software .

HARDWARE CONFIGURATIONS FOR THE DEC-LSI 16 BIT MACHINE.

The configuration (Photograph 1) of the DEC-LSI machines was selected from a number of possibilities. For the processor a choice of LSI-11/2 or LSI-11/23 is possible. The LSI-11/23 was chosen for its ability to address a larger memory with the attending capability of memory management. The largest possible memory of 256 KB (KiloBytes), is being utilized and this memory is on a single small printed board . For long term storage, a dual 8 inch floppy disk drive with single or double density capabilities is used and two hard disk systems each of 10 MB (MegaBytes) is also used . 5 MB of this hard disk storage is removable as a disk pack thus allowing easy transportation of large programs between these minicomputers . Communication with peripherals and the outside world is accomplished via six serial I/O ports.One for the Video Terminal, one for a printer and four that can be dedicated to other terminals, printers, modems and so on. Peripherals such as a high quality printer are shared among several of these installations helping to keep acquisition costs down. One of the most interesting features of this configuration is, that the Console Terminal which is a high speed DEC VT103 CRT, houses all the computer printed circuit boards i.e. the processor,two disk

controllers,the memory and the I/O ports. The computer thus resembles the appearance of the terminals used with large time shared machines. However, the screen accessing is in the 19000 Baud range whereas over the telephone, 300 Baud is normal and 1200 Baud is available. To the user this means lightning-fast screen addressing with its attending ability to simplify and speed up data entry. The whole installation easily fits on a standard desk, which if equipped with casters could be located in a number of areas as sharing becomes desirable . The Department of Communications currently has four of these installations and their internetworking will begin shortly .

OPERATING SYSTEMS FOR THE DEC 16 BIT MICROCOMPUTERS

This microcomputer runs the operating systems of the DEC minicomputers retaining nearly all the essential features, that made the DEC computers so versatile. These operating systems include the DEC RT-11 of which the current version is IV, which permits extended memory addressing, file handling including floppy and hard disk drives and if need be, magnetic tape and modems. For daily use an RT-11 Operating System was generated for the above described configuration. This was done only once, after which each system user was given a personalized disk, which also has his application programs on it. The system can be configured, so that each user,if he wished could use a high quality printer instead of a dot matrix for wordprocessing.

The second Operating System being used is the DEC time sharing RSX-11M system . This is a much more complicated system than the RT-11 and permits multi-user and & multi-tasking, very similar to what big time-shared computers support. Once a large number of RT-11 users begin to develop on the micro system the decision to provide time sharing using RSX-11M was implemented to allow more sharing of hardware and to minimize the acquisition of more hardware . This decision in general will always depend on the applications and usage and is not easy to arrive at from a logistic point of view.But at least this upward capability option exists in the DEC-LSI family of computers.

In addition to these two Operating Systems, which support a large variety of languages, some application systems provide their own Operating System. One of these is UCSD Pascal, which runs with its own operating system. UNIX is an Operating System, which supports the language "C", widely used at the Bell Laboratories. A variant of UNIX, named IDRIS, has its own Operating System, akin to RSX and supports both "C" and "Pascal" high level languages. The latter has been installed on the Department's microcomputer (Photograph 1) . described configuration.

APPLICATION LANGUAGES AND PROGRAMS FOR DEC 16 BIT MICROCOMPUTER

For the case of the operating system RT-11, the conventional languages such as FORTRAN IV Plus and BASIC are installed. OMSI

PASCAL is also available for the more advanced engineering programmers. Many spectrum managemeent application programs, originally in use on the Departments large time-shared machine, are now connected to and running on these microcomputers. In general, if a program is written in FORTRAN IV, it is quite feasible to convert it for operation on a microcomputer. Small programs can simply be "typed in" from their paper listing. Larger ones can be transported from a large computer installation to the microcomputer and via floppy disks and still larger ones via the magnetic tape drive. An easy to use word processor has also provided and has proven to be one of the most popular application programs. A variety of powerful Data Base Management Systems are currently being installed to permit access to large data files used in the licencing process of Spectrum Management.

HARDWARE CONFIGURATIONS FOR THE 8 BIT CROMENCO SYSTEM III MICROCOMPUTER (Photograph 2)

The CROMENCO SYSTEM III is equipped with 8 inch dual drive using two double side, double density diskettes with a total storage capacity of 2 Mb. Adressable memory is 64 KB, the I/O has a Console CRT port and a printer port. This is, at present, the minimum configuration. However, there is room for another sixteen boards and another dual drive. Hard disk storage and modem access is planned in the near future. The console is a screen oriented video terminal, made by Zenith Data Systems. The printer is a 1200 Baud dot matrix printer made by Texas Instruments. These peripherals were purposely chosen to

be also compatible with the LSI 16 Bit machines. It is even possible, to achieve compatibility with the hard disk drives used on the LSI-11, thus a large amount of hardware interchangability is inherent, even among different machines. At all times, this was taken into consideration when acquiring the various components for the microcomputer installation.

OPERATING SYSTEMS FOR CROMENCO MICROCOMPUTER

There are many operating systems available for the eight bit computer, however one most widely used is the CP/M, which is used under licence from Digital Research. This Operating System supports nearly every programming language and affluation program for the CROMENCO and is easily as oustomized to different peripherals. CP/M also supports hard disk drives and multi-user, multi-task applications. However, UCSD pascal has its own Operating System similar to the 16 Bit machine. A UNIX like Operating System has also been installed and is under evaluation. The system will also run under CDOS, the Operating System supplied by the manufacturer. Because of the need for access to the largest software market, it was decided to concentrate on CP/M as the main operating System. A total of two CROMENCO microcomputers are being used for Spectrum Management and a third will be added shortly.

Several versions of compiled or interpretive BASIC languages are available, a FORTRAN & COBOL compiler, a native code and P- code Compiler for PASCAL, a subset Compiler for the Language "C" as well as a fully standardized Compiler. A PL/I subset "G", standardized to International Standards is installed as well as such threaded languages as FORTH.

Application packages range from a wordprocessor to a relational Data Base Management System (DBASE-II). A development package is installed which will generate source code in the language CBASIC upon entering system specifications. (Tradename "PEARL"). In all, some twenty application packages are available for mathematical calculations and file or record management tasks. These are all being adapted to specific requirements associated with Spectrum Management. The low cost of these packages permits acquisition for evaluation, retaining the most suitable, without any large financial outlay.

INTERCHANGEABILITY BETWEEN 8 & 16 BIT MACHINES.

Considerable effort is being expended to make both systems compatible . For example, software is available which permits the CROMENCO to create a diskette for the 16 bit DEC microcomputer. Under UCSD Pascal source programs are completely transportable, between these microcomputers and each machine will read the diskette generated by another. The same is true for source programs written in "C". The IDRIS system will cross compile from the DEC to the CROMENCO . The previous hardware examples of matching peripheries and hard disk drives serve as further examples of the emphasis given to this area.

SUMMARY.

The following is a summary of the microcomputer system configurations and software currently in the Telecommunication Regulatory Service of the Department of Communications and being used for spectrum management applications .

16 BIT DEC LSI-11/23 (Photograph 1)

*Processor: LSI 11/23 - Hardware Floating Point

*Memory : 256 Kilo Bytes Dynamic Memory

*Storage :	a) Floppy Disks Single & Double Density
	b) Hard disk cartridge 20 MB, 10 Mbytes removable
	c) 9 Track Magnetic Tape Drive
*I/O :	8 Serial ports, Video Console, Printer and four other ports.
*Printers :	Dot Matrix ; Spin Wheel -low,high speed
*Oper.Sys.:	RT-11-IV, RSX-11M, UCSD PASCAL, IDRIS
*Languages:	BASIC,PASCAL,FORTRAN,COBOL,FORTH,"C"
*Appl.Pack:	EZEDIT Wordprocessor, MCBA filemanagement, PIRAT DataBase

8 BIT CHROMENCO SYSTEM III (Photograph 2)

*Processor:	Z80 - No hardware floating point.
*Memory :	64 Kilo Bytes Dynamic Memory
*Storage :	Floppy Disks, dual side,double density, 2 Mega Bytes storage.
*I/O :	2 Serial ports, Console and Printer
*Printers :	Same as above
*Oper.Sys.:	CP/M 2.2,CDOS,CHROMIX
*Languages:	CBASIC,MBASIC,FORTRAN,COBOL,UCSD PASCAL,PASCAL/Z,PASCAL/MT,"C",FORTH
*Appl.Pack:	PEARL,HDBS,T/MAKER,DBASE-II,WORDSTAR DATASTAR

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THIS PAPER WAS PREPARED ON A DEC-LSI-11/23

MICROCOMPUTER