AN EVOLUTIONARY CONCEPT OF SPECTRUM MANAGEMENT

DEPARTMENT OF COMMUNICATIONS

AN

EVOLUTIONARY CONCEPT

OF

SPECTRUM MANAGEMENT

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AN EVOLUTIONARY CONCEPT OF SPECTRUM MANAGEMENT

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INTRODUCTION AND BACKGROUND

At this time Canada has 250,000 radio stations. The rate of growth over the past 10 years has been about 17% per year on the average. Based on experience of the past decade, it is almost mandatory that we think in terms of 1,000,000 radio stations in ten years' time. Congestion has already begun in some specific frequency bands and geographical areas, particularly in the land mobile service.

About 4 years ago, in high density utilization areas, it became necessary to improve our capabilities for analysing and assessing spectrum occupancy and utilization. Spectrum observation centres were established in these areas on a limited basis and proved to provide significant information for decision-making. These centres having demonstrated an essential role in the management of the radio frequency spectrum it is, therefore, deemed necessary to expand some efforts in that direction.

Taking advantage of available technology, it should be possible to maintain a personnel growth to a relatively low level while increasing the flow of input data necessary for an improved planning of spectrum utilization.

LIMITATION OF REPORT

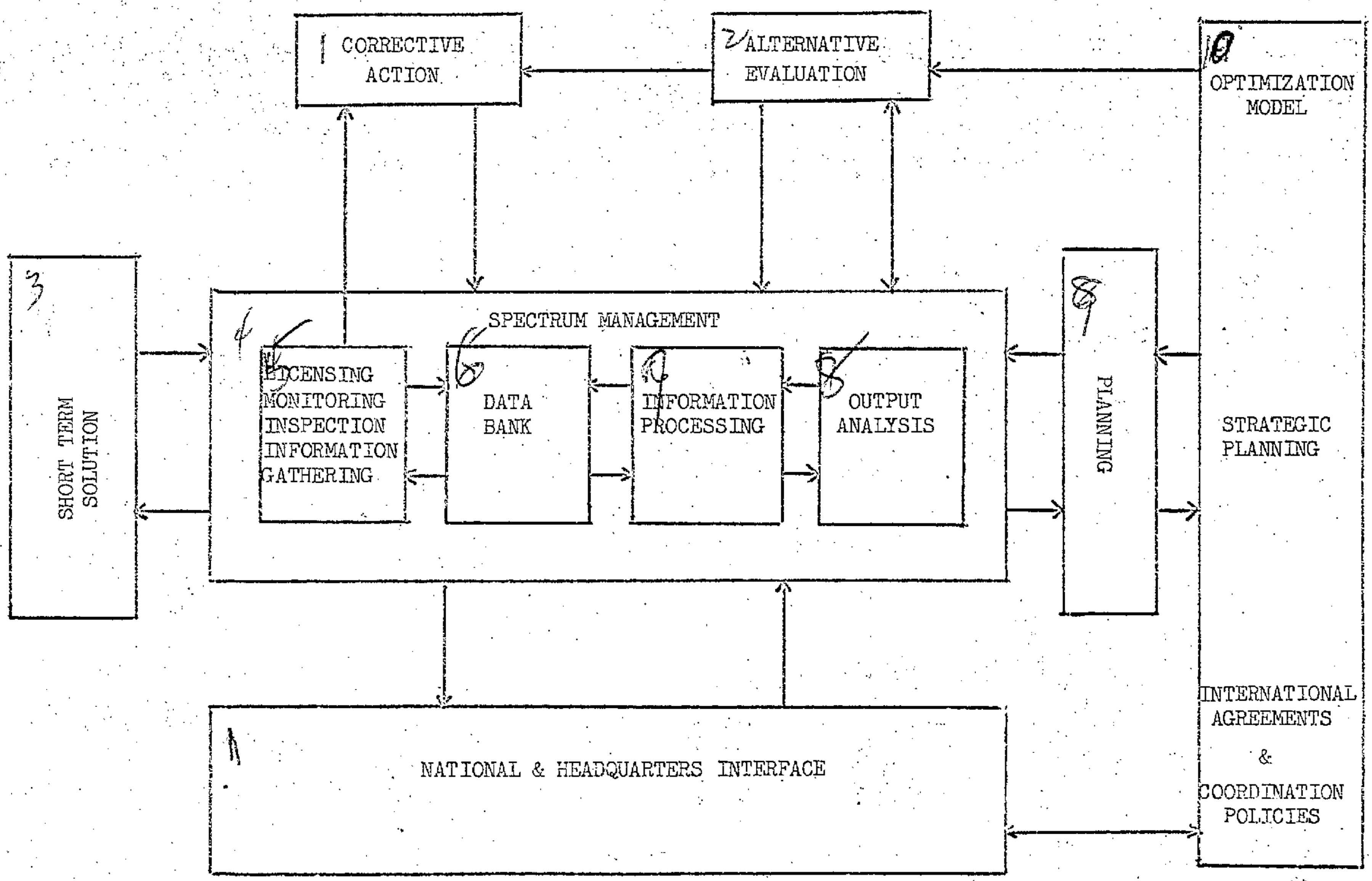
This is a preliminary report and is conceptual in its original plan. Details are limited to the level appropriate to give a clear view and understanding of the concept. System details will be developed for the implementation phase which could commence immediately following basic decisions.

OBJECTIVES

The objective of this report is to develop a concept of improved management of the radio frequency spectrum and provide a plan of action for its implementation with a sub-objective to integrate an improved monitoring/inspection service as a short term benefit.

The development of the proposed concept is the result of an initial work (Annex "A") which was set up to study the collection of spectrum utilization data and integrate the monitoring/inspection services. The relationship and interdependence of all sub-systems of spectrum management could not be overlooked and brought to light the need to approach the problem on a conceptual basis.

AN EVOLUTIONARY CONCEPT OF SPECTRUM MANAGEMENT



C O N C E P T

This concept, shown opposite, embodies the application of technical and scientific methods for the collection of information essential to the control and planning of spectrum utilization.

The primary advantage of developing an evolutionary concept of management of the radio frequency spectrum is that the results of the overall interdependence of sub-systems are recognized and appreciated.

This concept presents all of the essential functions of sub-systems required to achieve the objective of efficient and optimum utilization of the spectrum.

This evolutionary concept approach has been used in order to:

1) use present resources more effectively and to provide for an improved relationship between the collection of information and corrective action on a short term basis;

2) provide the basis for system development capable of satisfying an increasing need for rationalized decision-making;

3) provide for the establishment of a data bank interfacing with an information and analytical capability for longer term alternative evaluation, strategic planning and policy formulation on spectrum utilization.

APPLICATIONS

The combination of basic data collection with analytical capability for the longer term objective makes feasible a broad range of spectrum evaluation applications that were previously impossible for technical and economical reasons. The number of users anticipated could be very large and can range from day-to-day adjustment and action to national spectrum strategic planning and policy making. It is not intended to cover them all; however, a partial list of applications may be grouped under headings such as:-

1) Frequency selection and assignments.

2) Electromagnetic compatibility studies.

3) Determination of channel overloading.

4) Frequency assignment and allocation studies.

5) Anticipation and resolution of interference problems.

6) Continuous inventory of spectrum utilization and prediction of future demand for spectrum space.

7) Anticipation of improved requirements for equipment performance and operational standards.

8) Acquire knowledge and develop potential control to prevent and mitigate spectrum pollution.

9) Anticipate new technology and promote improved equipment design.

NATIONAL PROGRAM

The advent of fully developed systems of spectrum management will have economical and social consequences insofar as influencing the reliability of radio communications and the introduction of new technology and equipment and their application for communications. The size and complexity of the task the Telecommunications Regulation Branch faces, if Canadians are to benefit fully from the achievement promised by the communication utilities and the natural resource of radio frequency spectrum, require creativity and capital into a coordinated effort. Working within the context of a national objective makes the task realization beyond the reach of any existing single segment or group. This can be achieved by the encouragement of appropriate programs, information sampling, data accumulation, analytical capability, spectrum management optimization model, formulation of strategy and policy and their verification against predicted demand, i.e., utilization.

A major program approach is also called for by the increasing degree of technological advancement in the field of spectrum management information data bank, computer and data transmission interface. In the past, problem solving could be piecemeal, the spectrum loading was limited only to the ability to select other frequencies since there was abundance of the resource. However, with the advances of technology and the grouping of people into urban concentration and the accessibility of communications equipment, it is becoming imperative to accelerate the implementation of management cycle that will create the momentum for an effective and optimum utilization of the spectrum for the present and future generation.

OPTIONS AND CONSEQUENCES

1 - Continue on present basis which does not provide analytical means for accurate and effective forecasting and planning of spectrum utilization and, therefore, fostering unplanned and/or uneconomical shifts in spectrum space utilization.

2 - Begin collection of data concurrently with the development of an analytical system which will provide experience. This is the recommended first option on which more informed decisions can be made on spectrum allocation, equipment selection, sampling techniques to be implemented as well as determining manpower and financial resources required including assessment of alternatives.

3 - Await development of new spectrum planning capabilities underway in the U.S.A. and follow their lead. This approach could lead to the jeopardization of Canadian electronic manufacturing and marketing contributory participation to the spectrum resource.

4 - Acceptance of the proposed management concept which places each element into proper perspective focusing on a national plan. This evolutionary approach will provide the means whereby the Telecommunications Regulation Branch objectives can be achieved.

ECONOMIC CONSIDERATIONS

As a resource, the spectrum is wasted and kept from public contribution when not being used or when not used as effectively as it should. On that basis our prime objective should be to promote its use to the maximum to enhance its contributory value for the benefit of Canadians.

The economic dimensions of this resource for Canada alone, to say nothing of its social implications which are considered as having an annual impact in the order of 5 billion dollars, would seem to amply justify the limited financial consideration anticipated as a result of this study.

CO-ORDINATION COMMITTEE

To ensure effective arrangements for the project co-ordination policy definition and plan of action, it is recommended to establish a co-ordinating committee directed by a chairman with representation as required from all branches of the Department.

The organizational relationship broad duties and responsibilities of the Committee are shown below. Recommendations will be referred to the Director, Telecommunications Branch.

DUTIES & RESPONSIBILITIES

- Determine long and short term accomplishment goals.
- Develop an action plan.
- Set up working groups and determine their respective terms of reference for specific studies.
- Outline financial requirements current and future.
- Keep management informed of progress, alternatives and commitments.

RELATED STUDIES TO THIS PROJECT

1 - Radio station data bank system including licensing and accounts receivable information.

2 - Telecommission Task Force studies on a range of frequencies.

3 - Long term demand potential on spectrum.

4 - Policy formulation - arrangement for the optimum development and use of spectrum resources in the public interest.

POSSIBLE CONSTRAINTS IN IMPLEMENTATION

POTENTIAL PROBLEM AREAS	AN ACTION PLAN
Conflicts between ongoing program with proposed resource commitments for study.	Determine the extent of the study and establish priorities and allocate resources.
Inexperience and resistance of a multi-disciplinary approach in the conduct of the study.	Establish a co-ordination committee.
Status of study group.	Co-ordination committee accountable only to the Director, Telecommunications Regulation Branch.
Natural inertia for immediate decision-making to solve anticipated problems.	Improved visibility on spectrum management by setting up working groups, doing research.

POTENTIAL IMPLEMENTATION PROBLEMS

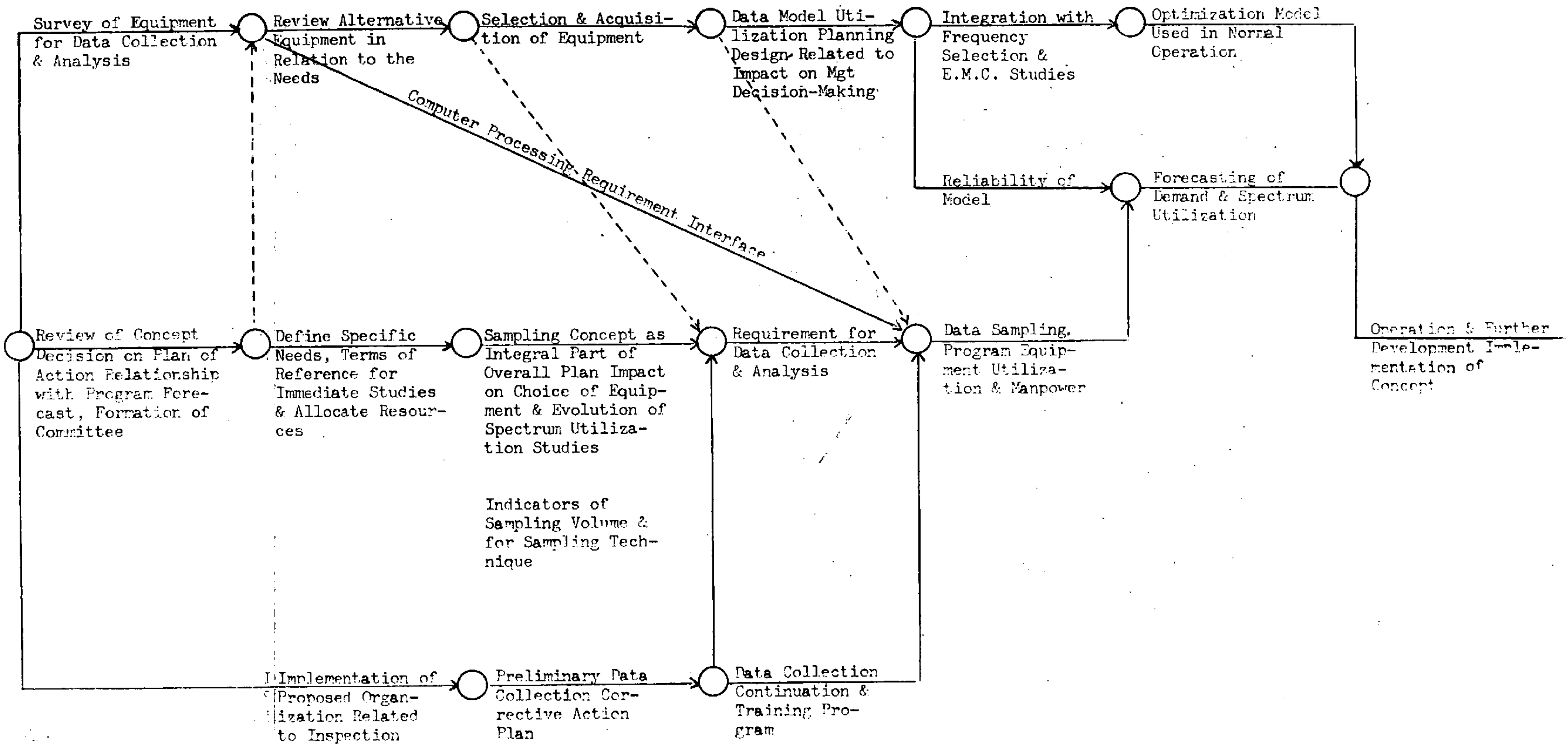
There are a number of problems which may arise in implementing this study which require immediate action as shown above. Others will require a period of planning in order to develop workable solutions.

To ensure maximum contribution to the study, management should establish priorities for recommended program activities, as shown ~~opposite~~ above, for co-ordinating this with ongoing branch activities. A statement issued by the Branch Director should clearly establish the priorities for the various studies and the allocation of resources.

To define present and future status of study groups management must clearly define their role and identify the organizational relationship and accessibility to information and resources to the successful completion of the study.

Positive action will have to be taken to ensure immediate resolution of potential problems lest they have detrimental effects on the success of this study.

PROGRAM ACTIVITIES NETWORK



IMPLEMENTATION PLAN

The concept, as previously presented, is far reaching and probably the ultimate goal if viewed from a long term objective. In order to preserve our position and eliminate or at least alleviate the forthcoming problem of spectrum congestion, immediate action for its implementation should be undertaken. In discussion at the last Superintendents Conference, a preliminary plan of action was agreed in order to develop a plan for the study and implementation of a management program for spectrum utilization optimization.

During the course of their study, the working group recognized the interdependence and interfacing of the several activities and sub-systems of spectrum management. It was felt that an implementation plan could only be developed taking into account these many facets of the problem. The program activities network, as shown opposite, is an attempt in this direction as is recommended for the implementation of this proposed evolutionary concept of spectrum management.

It should be agreed that the plan can be implemented by utilizing the professional and technical expertise of the Telecommunications Regulation personnel extensively where abilities are proven and performance pre-determined and agreed target is assured.

We now describe a phased approach to implement the concept. The plan of action, as shown opposite, should be consulted so that a logical sequence of implementation evolves. We recommend the immediate appointment of a co-ordination committee to co-ordinate, review and assess results. Studies with terms of reference must be assigned to the appropriate expertise for each activity or sub-activity as outlined in the implementation plan.

IMPLEMENTATION

PHASE I

This phase which is setting the basic pattern for further development can be accomplished in two major activities:

a) Taking the decision on the implementation plan and setting up the coordination committee, working group and define role for each.

b) Establish priorities and commit resources with terms of reference. In parallel with this, the work already underway on equipment investigation should be completed as well as the integration of the monitoring/inspection services as recommended on the proposed Regional organization. This work is underway and explained in Annex A.

This phase should be completed by September in accordance with previously established target, in order to provide the necessary support and an outline of the forecasted results, accomplishments and benefits for justification of programs.

PHASE II

In this phase three types of results are sought:

a) Definition of specific needs for acquisition of knowledge on spectrum utilization.

b) Indication of sampling methods to be used as well as relevant data to be provided for decision on the scope of volume of data to be collected, sampling techniques to be used in order to plan and allocate appropriate resources for this function.

c) The choice of equipment that would best meet the data sampling analysis requirement as well as being capable of interfacing with data processing computer equipment.

This phase should be completed during the current fiscal year in order to be in phase with program budgetary authorization as well as ensuring that the development action takes place within the time frame which is believed to be fast becoming critical.

PHASE III

Expand the system on a national basis and develop tools to be of greater assistance in the decision-making and formulation of spectrum utilization national and regional policies.

This phase would complete the implementation of the concept and make its contributory impact on the spectrum management as well as providing for scientific alternative evaluation and assessment of consequences.

ANNEX "A"

STUDY - MONITORING INSPECTION SERVICE

The attached report summarizes the findings and/or recommendations of working groups to which participated the members listed hereunder:

Chairman	-	T. Foucault
		D.T. Black
		L. Greenwood
		E.W. Groves/D. Gifford
		V. Lee Chong
		A.P. Stark
Secretary	-	R.O. Hewitt

STUDY - MONITORING & INSPECTION SERVICE

TERMS OF REFERENCE

The objectives of this study are:-

To review, develop and make recommendations to improve and integrate monitoring and inspection activities to increase the effectiveness of the radio frequency spectrum management.

> "Integration of monitoring and inspection services means close coordination of three specialized complementary activities, i.e., inspection, mobile monitoring and fixed monitoring. The work carried out involves monitoring, on-site and off-air inspections, inter/intra system interference investigation and the collection of spectrum occupancy and utilization data."

The scope of the work is:-

A) to determine what we want from an integrated monitoring and inspection service -

B) to determine what we are achieving now and what are the shortcomings -

C) to make recommendations for a more efficient use of existing personnel and equipment -

D) to make recommendations for present and future staff and equipment requirements -

E) to study cost consideration -

F) to develop organizational plans for functional and career integration of inspection and monitoring activities -

G) to develop plans for providing a spectrum utilization information system.

A) to determine what we want from an integrated monitoring and inspection service -

1. a good reporting system providing information on the use being made of the spectrum, i.e., an up-to-date and continuous inventory of frequency assignments, channel loading, etc. -

2. assessment of users' operating procedures -

3. assessment of users' operational needs -

4. data on station equipment performance, i.e., transmitter power, radiated power, frequency, modulation percentage on FM deviation as applicable, radiation coverage patterns, harmonics, spurious and inter-modulation levels -

5. the uncovering of unlicensed and improper operation -

6. data on antenna farm systems -

7. the most efficient and flexible utilization of staff and equipment.

B) to determine what we are achieving now and what are the shortcomings -

1. off-air inspection carried out by certain inspection offices, fixed monitoring and mobile monitoring which involves:

   i) technical measurements - frequency and deviation,

   ii) operational procedures,

   iii) operational needs,

   iv) limited occupancy studies,

   v) special projects.

2. on-site inspection carried out by field office personnel only which involves:

   i) determination of compliance with installation standards and regulations,

   ii) antenna characteristics patterns,

   iii) ascertain that base stations are actually located at authorized sites,

   iv) establish number of mobile units versus licences,

   v) special projects - harmonics, spurious radiation, intermodulation, etc.

Advantages of off-air inspection:-

   i) saves time in that it is physically impossible to inspect all stations,

   ii) it is being done without the knowledge of licensee,

   iii) allows time to properly assess operational procedures or users' needs.

Advantages of on-site inspection:-

   i) provides personal contact with licensee for discussion and resolution of mutual problems,

   ii) reminds licensees of existence of regulatory authority,

iii) acts as a deterrent to breach of regulations,

iv) permits determination of some operating and technical features which cannot be determined by off-air inspection.

Shortcomings of existing procedures and equipment:-

1) number of stations too large to carry out adequate physical inspection without the assistance of off-air monitoring -

2) lack of adequate complement of measuring equipment at some field offices hampers off-air inspection -

3) inspection tours by field offices are not co-ordinated with monitoring activities. -

4) lack of integration does not permit full use to be made of off-air inspections (monitoring) -

5) lack of direction-finding for the location and identification of sources of interference and/or unauthorized operations -

6) lack of equipment capable of gathering information on spectrum usage -

7) lack of geographical coverage by monitoring facilities particularly insofar as concerns VHF/UHF frequency bands -

8) lack of adequate staff for fixed and mobile monitoring facilities -

9) lack of interchangeability of personnel between monitoring and inspection services -

10) lack of career opportunity for monitoring personnel (recent BCR conversion).

Some of these shortcomings can be overcome by a better utilization of existing staff and equipment; others can only be rectified by the addition of staff and/or equipment as a result from a change in organizational structure. This latter aspect will be dealt with under Item [illegible].D

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C) to make recommendations for a more efficient use of existing personnel and equipment -

1. greater use should be made of off-air inspection which would result in saving of man-hours while ensuring a greater number of stations being inspected at closer regular intervals -

2. implement a system of improved co-ordination between inspection and monitoring personnel. Field offices inspection work program could begin with off-air inspections by fixed or mobile monitoring stations or both and followed by on-site inspection as the need arises -

3. on-site physical inspection to be carried out; where required by law or regulations; where deficiencies are reported as a result of off-air inspection; on a spot-check basis.-

4. proceed immediately with reclassification of monitoring positions to the Radio Inspector level (EL 4 - working) with inherent delegated authority and responsibilities. It should be noted that monitoring personnel are recruited from graduates of technological schools, are given the same regulatory and technical basic training and use identical electronic measuring instruments as those used by Radio Inspectors.

D) to make recommendations for present and future staff and equipment requirements noting that:

the basic elements of responsibility of the inspection service will change little in the foreseeable future except for a high growth rate in the number of stations and increasing technical complexity; the sucess of spectrum management is dependent of the quality of monitoring and the service should be expanded to provide as follows:

a) identifying and locating the sources of electromagnetic radiation;

b) measuring pertinent parameters of electromagnetic energy;

c) determining spectrum occupancy in specific frequency bands and geographical areas.

1) <u>Equipment recommendation</u>:

Continuing studies should be undertaken with a view to providing monitoring facilities with up-to-date spectrum analysis and measuring instruments in keeping with the state of the art.

To our knowledge, Canada is the only modern country that does not possess direction-finding capabilities at its monitoring stations. The Committee considers such equipment as mandatory from a national security standpoint as well as for spectrum pollution control.

2) <u>Staffing recommendation</u>:

Existing monitoring facilities should be staffed at full established complement. In some regions monitoring stations have an establishment of 6 members, i.e., 5 EL-3 and 1 EL-4. However, most regions have 5-member establishments, i.e., 4 EL-3 and 1 EL-4. It is recommended, as an initial step, that all monitoring fixed stations be staffed with 6 members having job classification as follows: 5 EL-4 and 1 EL-5.

A mobile monitoring station should also be staffed with a minimum of 1 EL-4.

3) Additional personnel will be required as follows:

The present monitoring system has been established primarily to meet our HF spectrum requirements. The rapid growth of the land mobile services requires expanded VHF and UHF facilities and it is recommended that monitoring establishments be expanded to provide for 24-hour coverage by two operating positions. Each fixed station should have a staff of 10 which would include one clerical support position.

4) General recommendations:

a) greater use should be made of mobile monitoring units for spectrum surveys and off-air inspections;

b) determination of present site location of fixed monitoring stations was based on HF requirements; however, future site selection should take into account VHF and UHF requirements, particularly with respect to frequency congested areas such as Vancouver, Toronto and Montreal;

c) full integration of monitoring capabilities into each element of the spectrum management function;

e) equipment designs should be standardized to keep cost down;

f) equipment should have an anticipated useful life of 5 to 10 years and have uniformity of calibration, maintenance and operating procedures.

E) to assess cost benefit factors -

The present organizational structure does not permit interchangeability between monitoring and radio inspection personnel. Bearing in mind the fact that monitoring and radio inspection personnel are recruited from the same technological institutes, receive identical basic training and use essentially the same type of electronic and measuring equipment, the Committee is of the opinion that the working levels for the two services should be identical so as to permit a better utilization of manpower, particularly with respect to our enforcement activities.

The cost effectiveness of the enforcement activity should be substantially accrued, particularly insofar as concerns the utilization of mobile monitoring facilities. Also, in certain areas such as P.E.I. and others, where we have fixed monitoring facilities but no inspection office, the personnel at the former station could just as well carry out interference investigations, inspections and take corrective action, thereby improving effectively our service to the public at a much reduced cost.

F) to develop organizational plans for functional and career integration of inspection and monitoring activities -

a) assess advantages and disadvantages of present organization versus an integrated organization:

Disadvantages present organization

1 - lack of interchangeability of staff -

2 - lack of uniformity of training (formal or on-the-job) -

3 - lack of uniformity of equipment utilization -

4 - problems in dual purpose utilization of mobile monitoring units (monitoring and inspection) -

5 - career limitations on monitoring personnel.

Disadvantages integrated organization

1 - problems in integrated operating versus non-operating functions -

2 - problems of shift work assignment for established radio inspectors -

3 - problems in retaining fully trained monitoring personnel -

Advantages present organization

1 - convenient separation of operating and non-operating functions -

2 - creates no problems concerning shift assignment for radio inspectors-

3 - develops a high degree of specialized skills of monitoring and inspection staffs.

Advantages integrated organization

1 - better interchangeability of staff -

2 - more uniformity of experience and training -

3 - better familiarity with all types of equipment -

4 - more efficient utilization of mobile monitoring units -

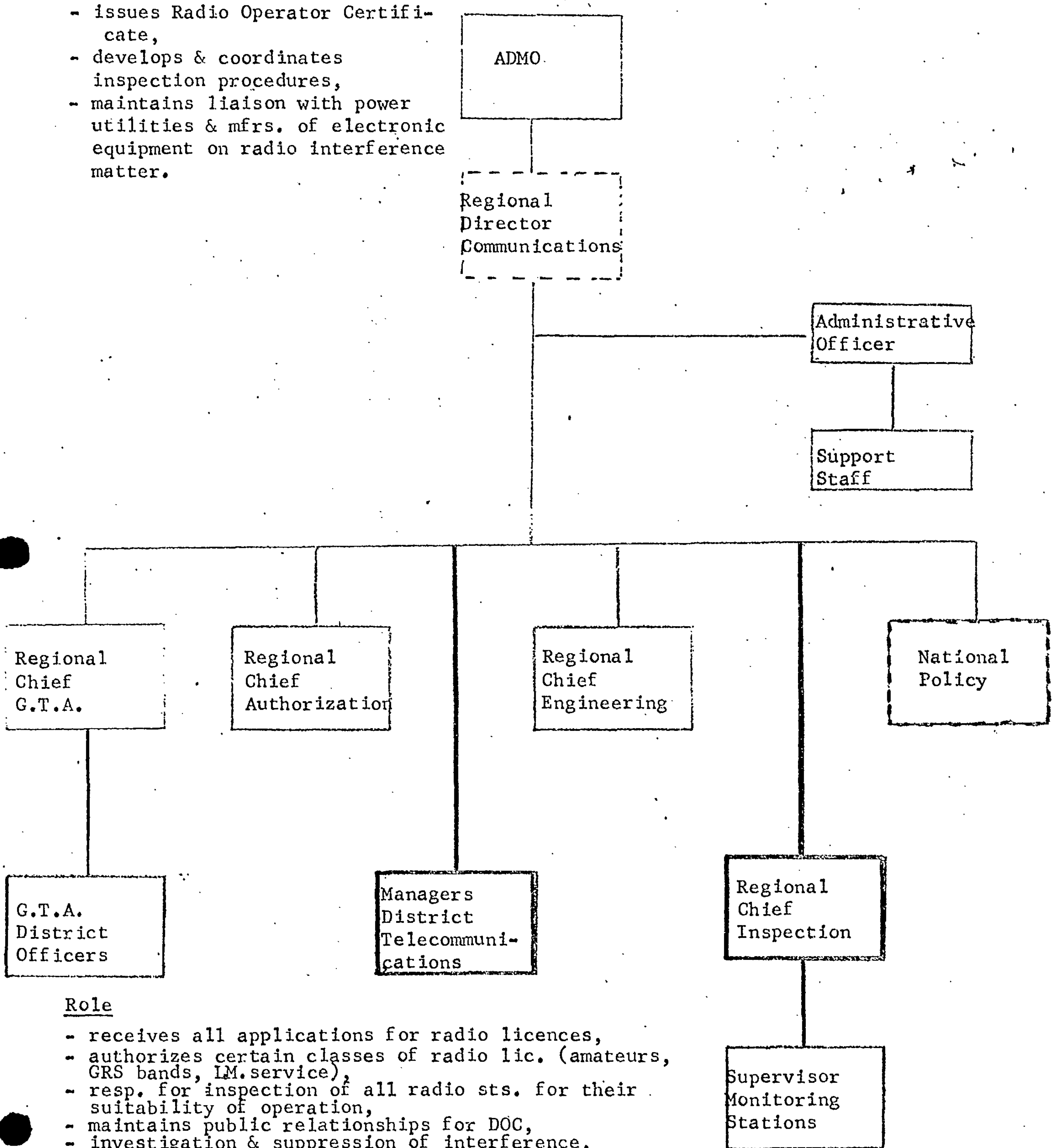
5 - expanded career opportunities for monitoring staff and improved morale.

b) organization chart:

(see next page)

Role: Chief Inspection

- inspects all clas's of radio stations,
- responsible for investigation & suppression of radio interference,
- coordinates the inspection and application of legislation,
- manages functions of monitoring stations,
- recommends legal action,
- responsible for examination of candidates,
- issues Radio Operator Certificate,
- develops & coordinates inspection procedures,
- maintains liaison with power utilities & mfrs. of electronic equipment on radio interference matter.



Role

- receives all applications for radio licences,
- authorizes certain classes of radio lic. (amateurs, GRS bands, LM.service),
- resp. for inspection of all radio sts. for their suitability of operation,
- maintains public relationships for DOC,
- investigation & suppression of interference,
- examines candidates & authorizes Radio Operator Certificate,
- enforces Radio Act,
- takes evidence & acts as expert in court,
- operates a mobile monitoring station.

PART "G"

DEPARTMENT OF COMMUNICATIONS

A

SPECTRUM UTILIZATION

DATA SYSTEM

PREPARED BY:

D.T. Black
V. Lee Chong

DATE: December 1, 1970

Section 1

To define the information to be provided by a spectrum utilization data system -

The system should be able to provide statistical information concerning the occupancy of specific portions of the radio frequency spectrum. This statistical information should be capable of progressive up-dating and/or replacement by new data as obtained.

Tentative definitions

Transmission length - duration of uninterrupted energy above the noise level or other pre-determined threshold.

Break - a period of interruption between transmission which is equal to or greater than a pre-determined interval.

Message length - duration of a series of transmission terminated by a break and including all periods of interruption of less than the pre-determined interval.

Occupied time - the total time in an observation period which was occupied by messages.

$$\% \text{ occupancy} = \frac{\text{occupied time} \times 100}{\text{Total observation time}}$$

Proposed Statistics for each assignable Channel
(to be provided on a cumulative basis and to be obtainable on demand following each individual monitoring period).

Noise level
Number of transmissions
Average transmission length
Number of messages
Average message length
Maximum message length
Standard Deviation of message length*
Average break length
Occupied time
Observation time
% Occupancy
Identification of slack and peak load periods*
Traffic distribution by day, month and year*

* Available from cumulative records only

Section 2

To determine priority of frequency ranges -

It is recommended that automatic surveillance should be limited to frequencies below 1 GHz and that the following order of priority should apply:

(1) 138 to 174 MHz
(2) 1.6 to 54 MHz (selected portions)
(3) 450 to 470 MHz
(4) 410 to 420 MHz

Section 3

To determine priority of location (fixed or mobile)

Because of the anticipated high cost of an automatic spectrum surveillance installation it is likely that only one installation could be financed at a time. For this reason the following time-table is proposed:

(1) initial installation in a mobile van to be assigned to the more congested areas on a rotational basis.

(2) subsequent fixed or mobile installations should follow in the more congested areas, specifically Montreal, Toronto and Vancouver.

(3) as each local installation is commissioned the initial mobile unit can spend more time in the remaining locations as well as broadening its base of operations.

Section 4

To develop means for gathering spectrum utilization data -

It seems definite that the data must be gathered automatically in order to obtain a sufficient number and continuity of samples. Since there may be occasions when immediate statistics are desirable it is proposed to use spare computer time to do some preprocessing of data and to provide, on demand, a teletype printout of statistical averages for each channel at the end of any individual period of monitoring.

In general terms the system will involve five main elements:

(1) a scannable receiver capable of receiving noise and signals and providing amplitude information.

(2) a mini-computer which will

(a) control the operation of the receiver, timing of samples and interim storage of sample data from the receiver

(b) preprocess the data to provide statistical average and variance figures over each period of sampling

(c) control the operation of the recording equipment

(3) a teletype for communication with the computer and for print-out of preprocessed statistical data

(4) a recording system to transfer data and partially processed results from the interim processor to the final processor

(5) a final processor and data storage system which will be centrally located and may be a data processing computer already used by the Department.

Because of the vast amount of occupancy data in storage at the central location it is not envisaged that complete print-outs of stored data will be provided on any regular basis. Rather, it is anticipated that equipment terminals will be able to retrieve selected portions of data on demand. Typical requests might be: (a) "Provide statistical data for the ten least occupied channels between 160 and 174 MHz from observation point "Toronto 2"", or (b) "Provide % occupancy data only for all channels between 150 and 174 MHz from observation point 'Montreal 3'".

Section 5

To determine equipment and staff requirements -

Tentative performance specifications are provided in Appendix Gl, consisting of:

(1) scan width
(2) sampling rate
(3) receiver characteristics
(4) computer and preprocessing requirements
(5) data recording and interim storage requirements

With these basic requirements as a guide we have looked into some of the available equipment package. There is a definite advantage in getting a package if one can be obtained because the production of control and processing software can be greatly simplified.

Since the installation(s) will be highly specialized it is recommended that a permanent staff of two be attached to each installation with additional assistance from the monitoring/inspection staff of the applicable Region.

Equipment is now available which, with minor modifications, will meet our requirements. The most promising at present is the Fairchild MSMU/BTR-35 system but other companies such as Hewlett-Packard and Collins may be able to offer suitable systems.

Section 6

To carry out a cost benefit analysis -

Costs cannot be firmly established until detailed specifications are developed and tenders called. It is estimated that each installation will cost between $150,000 and $200,000 plus the cost of a vehicle or building.

Part I of Telecommision Study 2 (h) states on page 13 "The Committee finds that frequency assignment records of the radio spectrum below 30 MHz do not represent true occupancy or use" and, further "The Committee recommends that the D.O.C. determine, on a continuing basis, accurate statistics on spectrum occupancy and use below 30 MHz, since this data is prerequisite to management of these bands".

The above comments are equally applicable to the remainder of the spectrum with the exception of the broadcasting bands. It is impossible to accumulate complete occupancy data by any manual means so it is essential to employ high speed automatic surveillance equipment with provision for interface electronic data processing and storage equipment.

Section 7

To carry out an assessment of short and long term computer requirements -

It is proposed to transfer monitoring data in its entirety to a final processing computer through the medium of compatible magnetic tape records. There are several ways by which this can be done without consuming undue amounts of tape for intermediate storage. The final processing computer must be capable of reading magnetic tape, computing statistical averages and storing and updating files of statistical data. Final results should be stored on a disc or drum in preference to tape in order to improve access and updating.

The number of channels is approximately:

2 to 30 MHz		5500 channels
30 to 50 MHz		1000 channels
VHF to UHF		2600 channels
	TOTAL	9100 channels

If it is assumed that 60 items of statistical data are to be stored for each channel and that each item requires two words, storage requirements will approximate 1.1 million words per observation point.

APPENDIX G1

MONITORING SYSTEM REQUIREMENTS

Introduction:

1. The Monitoring system should be able to identify the frequency, measure the amplitude and establish the time occupancy of radio communication channels between 10 kHz and 1000 MHz.

2. The system should be able to process all data which it generates to give such useful statistical averages as defined elsewhere.

3. The system should be capable of operating in an automatic mode after having been programmed to do so.

4. The system should be a completely self-contained unit, including power supply, capable of being moved from one location to another and of being operated there either in a building or a van. All equipment shall be shock and vibration mounted.

General System Operations:

1. Speed of Operation

   The land mobile band covers 30-50 MHz, 138-144 MHz, 148-174 MHz, 410-420 MHz, 450-470 MHz, about 82 MHz. The equipment shall be capable of scanning this entire band in one hour or less, during which time at least 100 occupancy measurements shall be made on each channel. A partial statement of this requirement is that a group of 180 consecutive 30 kHz channels operating at r.f. near 160 MHz shall be scanned in one second or less.

2. Accuracy

   An occupancy measurement of a channel is defined as one which results in:

   (a) an identification of the frequency of the channel $\pm$ 1 kHz

   (b) a statement of the amplitude of the energy in the channel to an accuracy of $\pm$ 1 db

3. The system should be capable of being programmed to perform the following operations automatically:

   (a) scanning a particular segment of frequency spectrum repeatedly

   (b) stepping from one segment to another which may or may not be immediately adjacent.

4. The system shall operate according to specifications within a temperature range of $+5^{\circ}$ C to $+45^{\circ}$ C.

5. Resistance to Electromagnetic Environment

The system should have a shielding effectiveness of at least 130 db.

6. Self-Compatibility

No interference generated within the system, including its power supply, should prevent it from achieving its requirements.

7. The systems shall produce output of the following forms:

(a) frequency and amplitude data in digital form on magnetic tape, complete with any additional identification marks to permit compatible transfer to a final processing computer.

(b) Pre-processed statistical data in digital form on magnetic tape as in (a) above.

(c) Pre-processed statistical data printed in suitable format on teletype or similar print-out equipment.

(d) Analog sample data on real-time cathode ray display of frequency vs. amplitude.

Receiver Subsection Specifications

Frequency Range: at least 10 kHz to 1000 MHz without manual band changing

Impact Impedance: Nominal 50 ohms. No more than 3:1 VSWR on 50 ohm transmission line anywhere in the frequency range.

Sensitivity: 10 kHz to 30 MHz: better than -113 dB m at 3 kHz IF bandwidth and 12 dB SINAD ratio

30 MHz to 1000 MHz: better than -112 dB m at 10 kHz IF bandwidth and 12 dB SINAD ratio

Noise Figure:
30 MHz: 6dB
30 MHz 12dB

Bandwidth: 6 dB IF bandwidths of 1 KHz, 3 kHz and 10 kHz are to be provided, with shape factors not exceeding 3.5:1 between 60 dB and 6 dB points.

Intermodulation: Internally generated intermodulation signals shall not exceed a power level of 65 dB below the sum of the two input signal powers when this sum is -40 dB m or less, and the separation between the desired signal and the nearest intermodulation producing signal is 0.5% or less.

Dynamic Range: Instantaneous or impulse dynamic range shall be at least 70 dB. Under pulsed conditions the output response shall be within ± 1.0 dB of the true input value.

Scan width: Scan width shall be any value from 1 kHz to 1000 MHz. The system shall be able to cover non-contiguous channels or groups of channels in one scan.

IF, Image and Spurious Rejection: All signals outside of the IF pass band shall be attenuated at least 60 dB.

Frequency Accuracy: The receiver centre frequency shall be tuned to within the lesser of ± 0.1% or ± 1 kHz of the called frequency.

Local Oscillator Radiation: Local oscillator radiation shall not exceed -80 dB m.

Antennas: The system shall include omni-directional broad-band antennas which will allow operation over the entire frequency range above 30 MHz with a VSWR not exceeding 3:1. Any required antenna switching shall be accomplished under program control.

Amplitude accuracy: Amplitude output in both analog and digital form shall be provided accurate to within ± 1.0 dB of the true input level of any sample within the dynamic range of the receiver.

Program Control: The receiver shall be capable of program control of the following functions:

(a) Antenna selection
(b) Bandwidth or selectivity selection
(c) Band and frequency selection
(d) Scan width
(e) Scan mode

Control and Processing Requirements

The system must include a control and processing computer and associated peripherals to perform all necessary control and basic data processing functions. The speed of the control and processing equipment must be such that it does not limit the sampling capabilities of the receiving equipment.

The control and processing system must operate under software direction and must perform at least the following functions:

1) initiate and maintain sampling for a predetermined time, number of scans or number of samples
2) provide all necessary commands for setting receiver operation to sample the required channels or bands of channels, including antenna selection, frequency selection, bandwidth, etc.

3) Process receiver amplitude data in digital form for recording on magnetic tape and provide necessary time and frequency markers for channel identification.
4) Preprocess amplitude samples to provide basic statistical averages for each channel and store these averages for the duration of any one monitoring period.
5) At the conclusion of a monitoring period record the pre-processed data on magnetic tape and, on command, in the form of printed output.

SOFTWARE

Programs shall be provided to perform all the desired functions of controlling and processing:

1. Control

This should encompass commands to the receiver-antenna section to start, tune to frequency, sample channels for specified periods under specified conditions, output and halt. It should also command the processor to acquire data, convert as necessary from analog to digital, process as required, and output in either analog, printed or digital form as required.

2. Processing

This includes conversion from analog to digital or digital to analog; sorting and identifying of data; performing required mathematical routines to generate statistical averages about channel occupancy; generating the right kind of input for the various visual, printed or magnetic tape display and recording devices.

RECORDING

A magnetic tape recorder will be provided as the basic output record for the system. This tape will contain raw sample data as well as preprocessed statistical averages for each period of monitoring. The tape will serve as a transfer medium to a central data processing computer.

Recording will be in digital form representing alpha-numeric characters. Recordings will contain necessary calibration marks to associate each digital amplitude value with the correct channel. It will also contain frequency, date and time markings.

In order to avoid excessive tape consumption it is necessary that data be recorded at maximum allowable density. Because the data acquisition rate is only about 200 items per second it will be necessary to use an incremental recorder or some technique such as hold-and-dump in order to achieve acceptable data density.

Basic essentials of the Magnetic Recorder are:

Reel size: 10 1/2 inches, 2400 feet
Mounting: Standard RETMA rack
Operating Temperature: 5^{o} to 45^{o} C
Relative humidity: 15% to 95% non-condensing
Recording Format: 9 track ASCII or equivalent compatible code
Rewind Speed: 120 ips
Data density: 800 bpi
Type: Synchronous Write/Synchronous Read
 or Incremental Write/Synchronous Read
Synchronous Speed: 25 to 30 ips
Incremental Write Rate: 0 to 1000 steps/sec.
Start/Stop time (Synchronous): 15 ms (max.)
Tape: 1/2" wide, 1.5 mil mylar.

TEST EQUIPMENT TO BE SUPPLIED

1. Signal Source for verifying amplitude calibration with an accuracy of ± 0.5 db over a range of -40 dbm to -120 dbm.

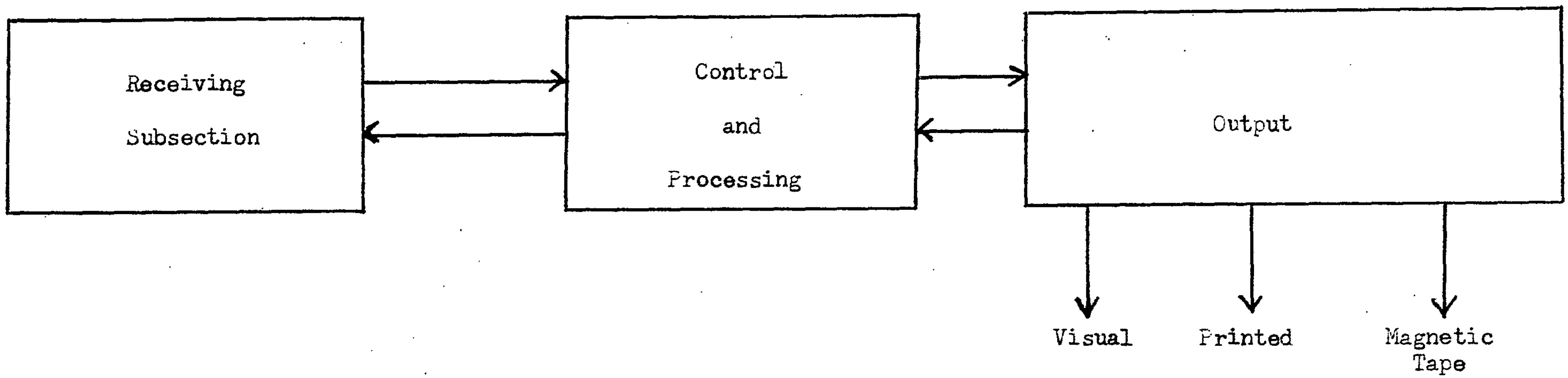
2. Frequency meter to verify frequency indication with an accuracy of 1 part in 1 million.

3. Oscilloscope to observe waveforms normally present in the system.

4. Voltmeter for routine voltage checks, both AC and DC, 1-300 volts, 1 ohm to 500 megohms.

5. All adapters, plugs, cables needed for all interconnection.

BLOCK DIAGRAM OF SYSTEM



SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1) Up-grading of positions in the monitoring service to levels equivalent to Radio Inspectors.

2) Greater use to be made of fixed and mobile monitoring facilities for spectrum surveys and off-air inspections.

3) Up-dating equipment at monitoring facilities for improving spectrum pollution control with emphasis given to VHF and UHF frequency bands where congestion is being felt.

4) Implementation of the recommended spectrum utilization information system.

5) Development of strategic and five-year plans for an expanded monitoring/inspection service in accordance with an evolutionary concept of spectrum management.

The findings and recommendations made in this report should be taken within the context of the primary objectives of Telecommunications Regulation Branch. The immediate goals were to find ways and means to increase the cost effectiveness of existing resources and to improve to the fullest extent possible the Branch's efficiency in its function of planning and managing of the radio frequency spectrum.