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AUTOMATED VHF FREQUENCY ASSIGNMENT SYSTEM (FAS) FOR FAA AIR TRAFFIC CONTROL COMMUNICATIONS

IIT Research Institute
Under Contract to
DEPARTMENT OF DEFENSE
Electromagnetic Compatibility Analysis Center
Annapolis, Maryland 21402

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FINAL REPORT

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16. Abstract

An automated frequency assignment system (FAS) was developed as a means of providing frequency assignment plans for FAA Air Traffic Control (ATC) VHF communications facilities. The FAS consists of a series of computer models (described herein).

Examples are included of how the model inputs can be varied to investigate the advantages of different assignment procedures. The system can be used for assignment gaming, including partial and complete assignments, detecting violators, statistical analyses, and plots of service volume.

This report is an updating of FAA-RD-73-184, "An Automated FAA Air Traffic Control Frequency Assignment Model."

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METRIC CONVERSION FACTORS

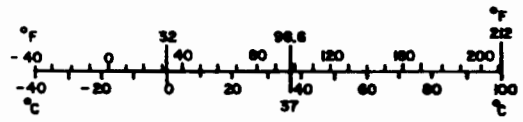
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 236, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



FEDERAL AVIATION ADMINISTRATION
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE
SPECTRUM MANAGEMENT STAFF

STATEMENT OF MISSION

The mission of the Spectrum Management Staff is to assist the Department of State, Office of Telecommunications Policy, and the Federal Communications Commission in assuring the FAA's and the nation's aviation interests with sufficient protected electromagnetic telecommunications resources throughout the world to provide for the safe conduct of aeronautical flight by fostering effective and efficient use of a natural resource--the electromagnetic radio-frequency spectrum.

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- Planning and defending the acquisition and retention of sufficient radio-frequency spectrum to support the aeronautical interests of the nation, at home and abroad, and spectrum standardization for the world's aviation community.

- Providing research, analysis, engineering, and evaluation in the development of spectrum related policy, planning, standards, criteria, measurement equipment, and measurement techniques.

- Conducting electromagnetic compatibility analyses to determine intra/inter-system viability and design parameters, to assure certification of adequate spectrum to support system operational use and projected growth patterns, to defend the aeronautical services spectrum from encroachment by others, and to provide for the efficient use of the aeronautical spectrum.

- Developing automated frequency-selection computer programs/routines to provide frequency planning, frequency assignment, and spectrum analysis capabilities in the spectrum supporting the National Airspace System.

- Providing spectrum management consultation, assistance, and guidance to all aviation interests, users, and providers of equipment and services, both national and international.

PREFACE

The Electromagnetic Compatibility Analysis Center (ECAC) is a Department of Defense facility, established to provide advice and assistance on electromagnetic compatibility matters to the Secretary of Defense, the Joint Chiefs of Staff, the military department and other DoD components. The Center, located at North Severn, Annapolis, Maryland 21402, is under executive control of the Office of the Secretary of Defense, Director of Telecommunications and Command and Control Systems and the Chairman, Joints Chiefs of Staff, or their designees, who jointly provide policy guidance, assign projects, and establish priorities. ECAC functions under the direction of the Secretary of the Air Force and the management and technical direction of the Center are provided by military and civil service personnel. The technical operations function is provided through an Air Force sponsored contract with the IIT Research Institute (IITRI).

This report was prepared for the Systems Research and Development Service of the Federal Aviation Administration in accordance with Interagency Agreement DOT-FA70WAI-175, as part of AF Project 649E under Contract F-19628-76-C-0017, by the staff of the IIT Research Institute at the Department of Defense Electromagnetic Compatibility Analysis Center.

To the extent possible, all abbreviations and symbols used in this report are taken from American Standard Y10.19 (1967) "Units Used in Electrical Science and Electrical Engineering" issued by the United States of America Standards Institute.

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EXECUTIVE SUMMARY

Because of the rapid increase in the amount of air traffic and limited spectrum availability, it is becoming increasingly difficult for Federal Aviation Administration (FAA) frequency managers to provide the necessary frequencies for adequate air traffic control (ATC) communications. This report describes an automated frequency assignment system (FAS) that can be used to provide frequency plans for ATC communications facilities. This model was developed in response to a request from the FAA for an automated means for examining alternate methods of solving the problem of providing assignments in the ATC frequency band at congested areas.

The Frequency Assignment System described herein consists of a series of computer programs that can provide channel assignments for existing or proposed FAA/VHF Air/Ground ATC facilities. Included in the FAS is a series of maintenance and retrieval programs that provide ready access to the FAA-supplied ATC data. The FAS can also be used to detect violators, to make statistical analyses, and to provide plots of service volumes. Assignment techniques are used that tend to make efficient use of the available spectrum.

The two basic modules that comprise the FAS are the matrix generator and the assignment model. An intersite channel-separation-matrix generator uses site location, ATC function, and service volume information to construct a matrix that reflects the channel separation between sites necessary to maintain a specified minimum desired-to-undesired signal ratio. The assignment model is based on two basic assignment techniques: 1) those requirements most difficult to assign, based on congestion, are considered first in the assignment process, and 2) the usage of each channel is maximized by assigning as many requirements on a given channel as possible. Cosite constraints to eliminate intermodulation and adjacent-channel interference are also accounted for by the assignment program.

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A INTERSITE ANALYSIS
B PROBABILITY METHOD OF FREQUENCY ASSIGNMENT
C NODE-COLORING ALGORITHM
D DATA BASE RECORD FORMAT
E COMPUTER PROGRAM RUN PROCEDURES

GLOSSARY

Actual Frequency - the frequency in MHz that is presently being used to satisfy the ATC requirement.

Air Traffic Control (ATC) Function - communication responsibility of each site (e.g., high-altitude enroute).

ATC Requirement - the requirement for an air traffic control frequency, such as a high-enroute requirement, at a specific site.

Background ATC Requirement - an ATC requirement whose frequency assignment is not to be considered as a candidate for reassignment by the assignment system (e.g., a Canadian assignment).

Banding - placing like ATC requirements (e.g., high-altitude enroute) in specific ranges of the frequency spectrum.

Cosite File - file containing the denied frequencies resulting from the cosite restrictions imposed on each site.

ID String File - a file that reflects the priority of the ordering of each requirement for assignment.

Interleaving - mixing unlike ATC requirements (i.e., mixing those that can use 25-kHz channels with those that cannot) throughout the spectrum; as opposed to banding.

Link Number - an identifier associating those ATC requirements that must be assigned identical frequencies.

Master File - a file containing information that is subject to a well defined updating and verification process.

GLOSSARY (Cont'd)

Node Coloring Algorithm - a mathematical technique (based on the theory of graphs) used for estimating the minimum number of channels required for a given frequency assignment plan and for determining the order in which requirements are to be assigned.

Operational Year - the activation date for a given requirement.

Ordering - the process of sorting and sequencing.

Pre-Assigned ATC Requirement - a definite frequency assignment that will not be changed by the FAS during a given exercise.

Project Sub-File - a file created from a master file for a particular assignment problem.

Protection Criteria - the desired-to-undesired (D/U) signal ratio that is the minimum ratio to be encountered anywhere in the sector in order for the desired and undesired signals to be assigned the same operating frequency.

Requirements File - a file containing data on each FAA ground-to-air communications ATC requirement.

Service Volume - the geometrical volume associated with each ATC site for which radio coverage is provided. Also referred to as Sector.

Tailored Service Volume (TSV) File - a file containing a description of the perimeter boundary for each multi-point ATC service volume.

Utilization Factor - as used in probability analysis, the proportion of time that a receiver/transmitter is in use.

GLOSSARY (Cont'd)

Violator - an ATC requirement that does not meet the intersite or cosite criteria.

Worst Case - the positioning of an aircraft in its service volume such that the D/U signal ratio is minimum.

SECTION 1

INTRODUCTION

BACKGROUND

The growth of aircraft traffic in the United States is placing unprecedented demands on Federal Aviation Administration (FAA) air traffic control facilities. The FAA frequency managers are finding it increasingly difficult, within the spectrum resources available, to provide frequency assignment plans compatible with the rapidly growing air traffic control (ATC) operational requirements.

Also, plans have been announced by the FAA to implement 25-kHz-spaced VHF communication channels in the 118-136 MHz band.[1] This band is presently divided into 50-kHz-spaced channels. Initially, only high-enroute requirements will use the new 25-kHz-spaced channels.

An earlier report[2] described an automated frequency assignment system developed by ECAC in response to an FAA request for a means of rapidly evaluating the relative merits of alternate courses of action that could be taken to meet the growing ATC communications requirements.

This report is an update of Reference 2 as well as a description of new capabilities developed in response to additional FAA requirements. An important new capability is the automated method for developing the data base, using the Interdepartmental Radio Advisory Committee (IRAC) data file and Air Route Traffic Control Center (ARTCC) master tapes. Additional capabilities include a model to assign new requirements and shift existing assignments as necessary, a program to calculate desired-to-undesired (D/U) signal ratios for an assignment, and a program to plot service volumes.

OBJECTIVE

The objective was to provide an automated frequency assignment system capable of determining frequency assignment plans for FAA ATC communication facilities, and extend the capabilities of the system as described in Reference 2.

---

[1] *Air Traffic Control Radio Frequency Assignment, Proposed Integration of 25 kHz Spaced VHF Communication Channels into the National Airspace System,* DEPARTMENT OF TRANSPORTATION, FEDERAL AVIATION ADMINISTRATION, Washington, DC., May 21, 1973.

[2] Beall, L., Crisafulli, R., Morrow, J., and Van Gaasbeck, S., *An Automated FAA Air Traffic Control Frequency Assignment Model,* FAA-RD-73-184, ECAC, Annapolis, MD, December 1973.

APPROACH

The automated frequency assignment capability, developed as described in Reference 2, was implemented by designing and applying a series of computer programs designated as the Frequency Assignment System (FAS).

The FAS was constructed using two basic program modules. The first module was developed to build an intersite constraint matrix that designates the channel separation between ATC requirements that is necessary to maintain a specified protection criterion (desired-to-undesired (D/U) signal ratio). Each ATC requirement is defined by its associated ATC function and geographical site/service-volume information. The desired signal is protected from an interfering cochannel or adjacent-channel signal under the "worst-case" condition. The worst-case condition may be defined as the positioning of an aircraft in its service volume[a] so that the D/U signal ratio is a minimum (see APPENDIX A).

The second basic module of the FAS was developed to make the frequency assignments. This module uses the channel-separation matrix described above and a data file that contains frequencies denied at each ATC site because of cosite requirements (intermodulation and adjacent-channel constraints). As assignments are made, the cosite file is appropriately updated. Since the order in which assignments are made can affect the total assignment efficiency (i.e., number of discrete channels required), a means was developed by which the FAS orders requirements[a] according to certain congestion criteria. A capability to reflect operational priorities was included in the system design.

A data base for the FAS was provided by the collection and verification of input information describing the requirements for FAA air traffic control. This task also included the design and programming of a retrieval and maintenance system for this data base.

Propagation losses were taken to be equal to the free-space propagation loss within the limit of radio line-of-sight (4/3 earth's radius). Beyond radio-line-of-sight, the loss was assumed to be infinite. All transmitters were assumed to have equal power and omni-directional antennas. Thus, the calculations of cochannel D/U ratios were made using only those distances within radio line-of-sight.

An adjacent-channel rejection value of 60-dB was assumed for airborne receivers that used the same channel spacing (25 or 50 kHz).

---

[a]See Glossary

This assumption may permit overlapping of service volumes for adjacent-channel analysis. However, according to the FAA Handbook[3], two nautical miles (nmi) of separation between airplanes on adjacent channels is needed to prevent the muting threshold from being exceeded in the airplane. Therefore, adjacent-channel protection was provided by requiring at least a 2-nautical-mile separation between service volumes in addition to the assumption of 60-dB adjacent-channel rejection.

For the cosite analysis, potential intermodulation and adjacent-signal interference were considered. Intermodulation calculations were restricted to the third-order 2-signal type considered by FAA to be most likely intermodulation annoyance to ATC facilities. Frequencies used in the intermodulation analysis include FM radio and television station frequencies and in-band (118-136 MHz) military frequencies. As an option, third-order 3-signal intermodulation can be considered by the model when at least one of the signals is a continuously operating transmitter, such as a television station. Selected transmit and receive frequencies used within a specified distance (2 nmi) of each ATC site were considered in the intermodulation analysis. For adjacent-signal analysis, possible interfering assignments were denied by making a geographic select of collocated equipments at each ATC site and eliminating candidate frequencies within a specified guard band (500 kHz) of any assigned frequency in the 117.5-136.5 MHz band.

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[3]Federal Aviation Agency, Washington, DC., *VHF-UHF Air/Ground Communications Frequency Engineering Handbook*, June 1965.

SECTION 2

SYSTEM DESCRIPTION

GENERAL DESCRIPTION

This approach to a compatible frequency assignment employs the technique of *first* generating an Intersite Matrix to designate the cochannel and adjacent-channel assignment constraints imposed on each requirement that needs an assignment.

The *second* step requires the development of a Cosite File that represents the cosite constraints imposed on the assignment by the collocated equipments. The *third* step requires the priority ordering of the requirements for the assignment process. The *fourth* and last step is the assignment process, which uses the results of the first three steps--the cochannel and adjacent-channel constraints, the cosite constraints, and the assignment order.

Using the Requirements File and the Tailored Service Volume File (TSV File), the Intersite Matrix is generated and recorded on magnetic tape for use by the assignment model. Each element in the Intersite Matrix represents the necessary channel separation between two requirements. This separation is based on the location of the requirements, the protection criteria designated, and the boundaries of the service volumes (sectors) served by each of the requirements.

The Cosite File contains those frequencies denied at a particular site. The file contains cosite frequencies at the site and all intermodulation products that result in denied frequencies. The assignment model first checks this file to determine the acceptability of any candidate frequency.

Before a frequency assignment plan is generated, it is of value to know if the number of channels allocated to the plan is sufficient for assignment of the specified requirements. An estimate of the minimum number of distinct channels needed can be achieved using a node-coloring algorithm on the intersite matrix.

In determining the minimum number of channels for a given assignment, the requirements are *ordered* to reflect the degree of difficulty of assignment. This ordering, in the form of an ID String File, is used in making the actual assignment.

Given the ID String File, the Cosite File, the Requirements File, and the Intersite Matrix, the assignment model assigns frequencies to

the specified requirements. It selects a candidate frequency and assigns this frequency to as many sites as possible. Those requirements not assigned to the first frequency are candidates for possible assignment to the next sequential frequency. If a frequency fails to satisfy any one constraint imposed on a requirement, the frequency is not assigned to that requirement. Each time a frequency is assigned to a requirement, the Cosite Record for that requirement is updated to reflect the resulting additional constraints (introduced by the assignment) to collocated requirements not yet assigned.

The four steps just described are discussed in greater detail in the paragraphs that follow. Steps two and three, the cosite file and priority ordering, are both discussed in the section entitled "Frequency Assignment File Preparation." Figure 1 shows the logic flow for the Frequency Assignment System.

CHANNEL-SEPARATION MATRIX CONSTRUCTION

The matrix-building phase of the Frequency Assignment System consists of three computer programs:

1. Matrix Generator Program
2. Matrix Transpose Program
3. Matrix Regeneration Program.

These programs are used to construct or alter channel-separation matrices. Since the matrix is symmetrical, i.e., element E_{ij} equals element E_{ji} ($E_{ij}=E_{ji}$), only a partial matrix is developed by the matrix generator. The complete matrix is symmetrical and is constructed by reflecting this partial matrix about the main diagonal using the Matrix Transpose Program. The Matrix Regeneration Program recalculates predetermined interaction values in a given matrix which eliminates the need to construct a new matrix if only a few requirements change. Figure 2 shows the relationship between these programs.

Matrix Generator Program

Inputs to the Matrix Generator Program include the Requirements File, TSV File, and user-specified information. These files provide data that describe the geographic coordinates, air traffic control function, and service volume definition. User-specified information includes the desired protection criteria levels according to ATC function.

The matrix produced by the program contains the intersite relationships between the requirements described in the Requirements File.

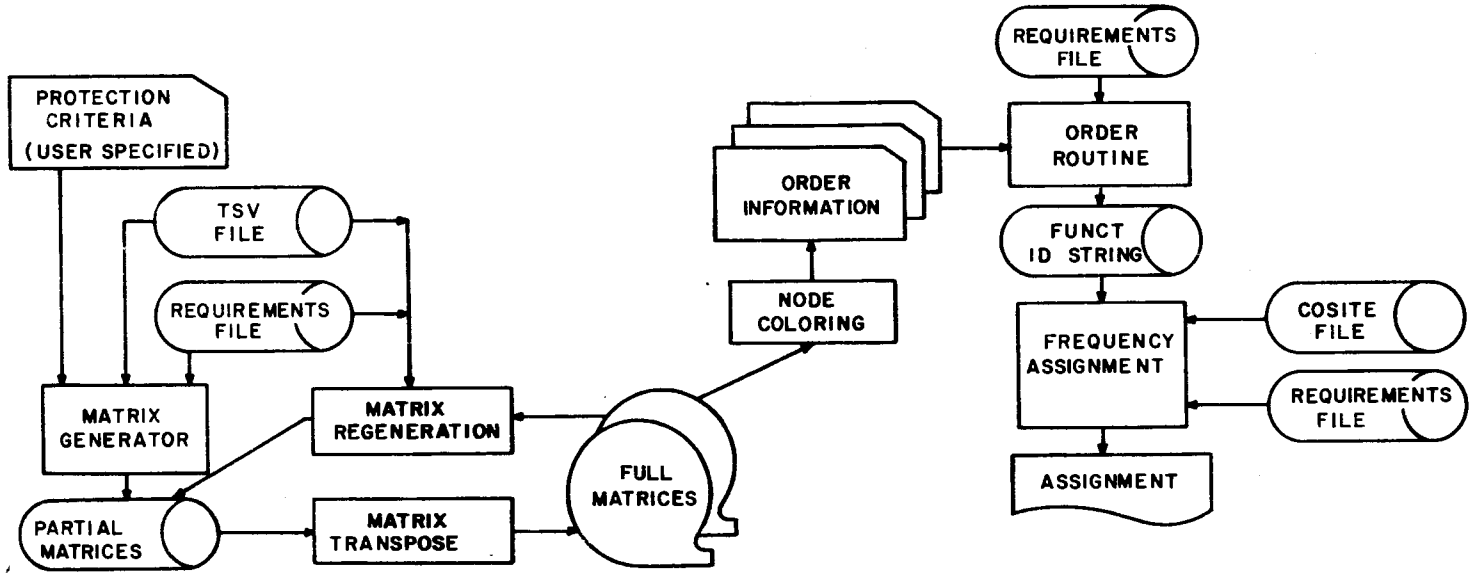

Figure 1. Frequency assignment system.

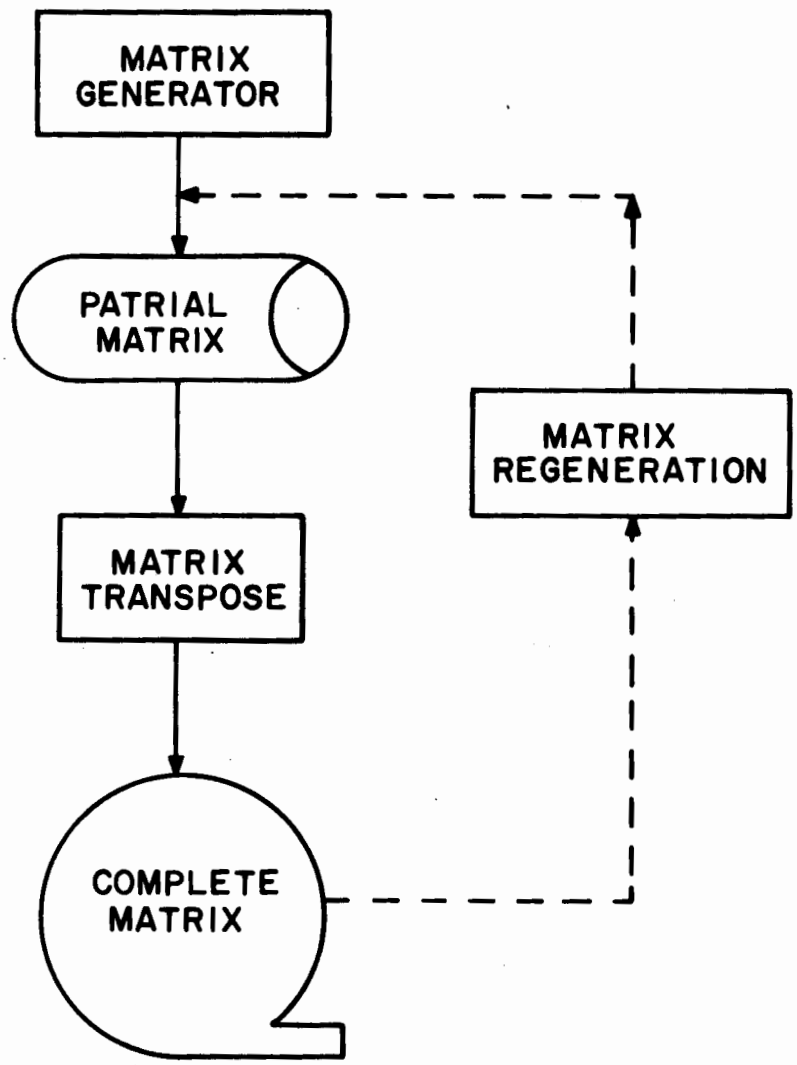

Figure 2. Matrix building phase.

Figure 3 shows the structure of this matrix. Each element of the matrix reflects the interaction between the requirement of a row and the requirement of a column. In Figure 3, element E_{ij} reflects the interaction between the requirement of row i and the requirement for column j.

The number of rows is less than the number of columns, due to pre-assignment of some requirements (Figure 3). If, however, there are no pre-assigned requirements, the matrix is square. Since the total matrix is symmetrical, calculations are performed only up to the diagonal elements. Hence, a partial matrix is produced.

Each intersite relationship is determined by a comparison of the service volumes for each site involved, and APPENDIX A provides a detailed description of the procedures involved in the service volume analysis. This analysis determines whether the sites for a particular interaction can be assigned cochannel, adjacent-channel, or neither. The corresponding element of the matrix is coded with an appropriate symbol, as designated in TABLE 1.

TABLE 1

MATRIX ELEMENT SYMBOLS

Symbol	Meaning
0	no channel separation required
1	requires separation of one or more channels
2	requires separation of two or more channels
7	row diagonal

A stop/restart capability was implemented to accommodate the extensive computer run time necessary for the generation of large matrices, since the size of the matrix and the number of calculations are directly proportional to the square of the number of requirements. This allows the program to resume at the place where a previous run had been terminated. The restart capability also permits new requirements to be added to an existing matrix when necessary.

The Matrix Generator Program has the option to make the cochannel analysis using probability. The probability method used is discussed in APPENDIX B.

The logic flow for the Matrix Generator Program is shown in Figure 4.

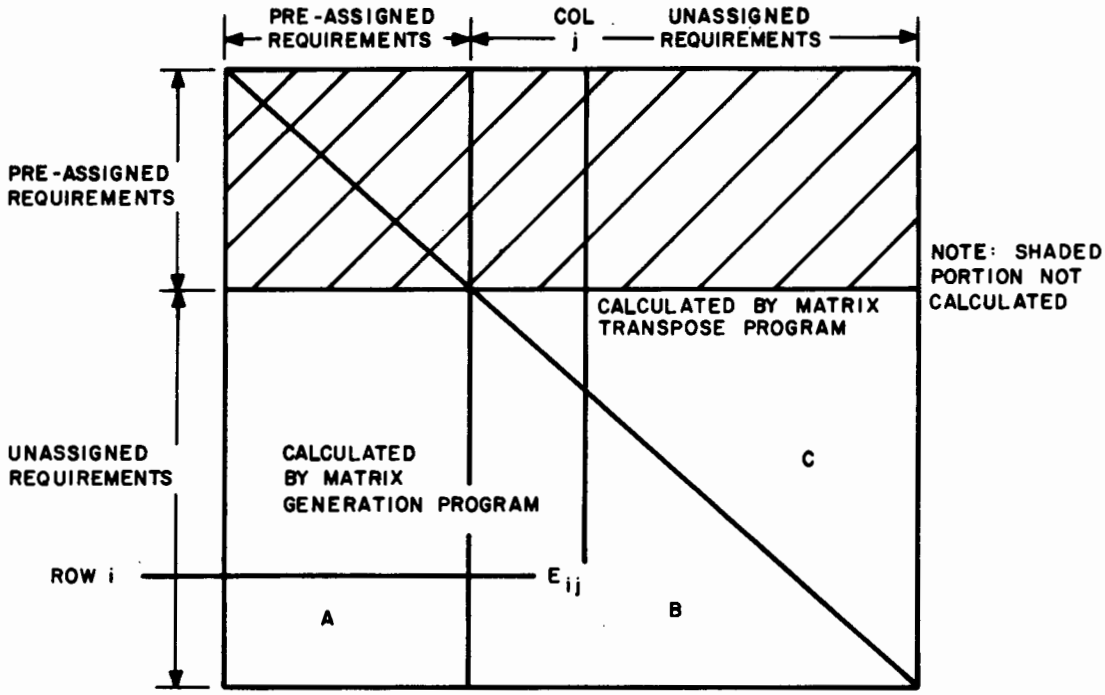

Figure 3. Partial matrix structure.

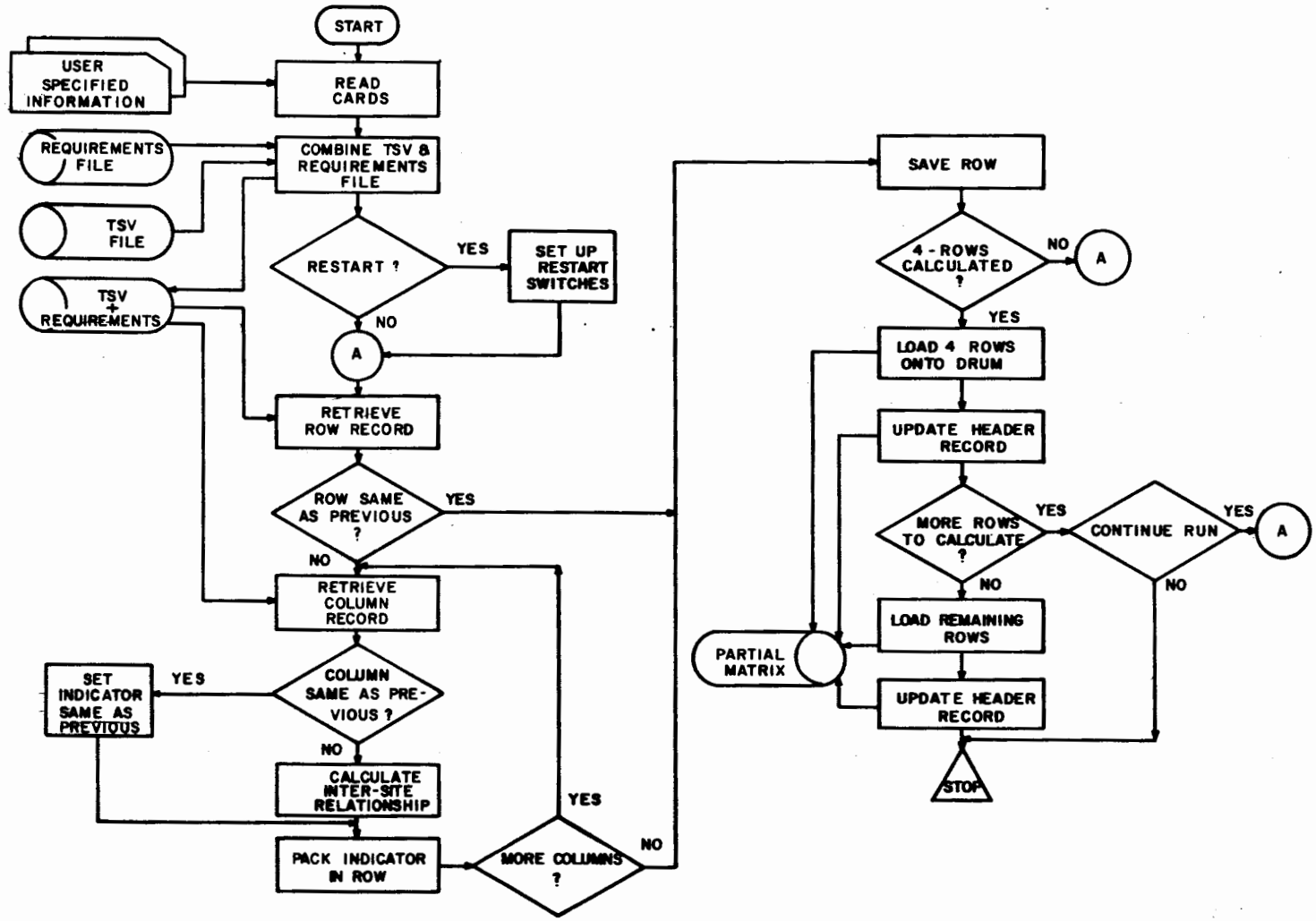

Figure 4. Matrix generator program.

Matrix Transpose Program

The Matrix Generator Program produces that portion of the intersite matrix that is unique. The intersite matrix is then completed using the Matrix Transpose Program that reflects a portion of the intersite matrix about the main diagonal. This is done to facilitate the assignment process where the entire matrix row is needed to make a compatible assignment. In Figure 3, portions A and B constitute the partial matrix calculated by the Matrix Generator Program. Portion C represents the portion created by transposing Portion B about the diagonal. Portion A, however, is not transposed, since this portion represents the intersite relationships between background requirements (Canadian, Mexican, etc.) and FAA ATC requirements. The matrix rows representing the background requirements are not needed, since these requirements are never reassigned.

Matrix Regeneration Program

When a Channel-Separation Matrix is generated, the protection criteria (D/U signal ratio) levels for each requirement are user-specified, usually based on the ATC function of the requirement. It is sometimes desirous to change the protection level for a requirement or group of requirements and not recalculate the entire matrix. Given a list of requirements and the desired protection levels, the Matrix Regeneration Program recalculates the necessary elements (only to the diagonal, Figure 3). The Matrix Transpose Program is then used to complete the matrix.

FREQUENCY ASSIGNMENT FILE PREPARATION

Prior to making the actual frequency assignment, two steps must be completed in addition to the generation of an Intersite Matrix. The first step is the creation of the intrasite file, which is called the Cosite File and is discussed here and in Section 3. The second step is the creation of a file called the ID String File, which reflects the ordering of requirements for the assignment model. The ordering technique used in this system is an output of the node-coloring algorithm.

Cosite File

A Cosite File is constructed for each frequency-assignment plan that is made. This file must represent the cosite situation at the time of assignment. Included in this file are frequencies of FM radio-broadcasting and television stations, plus administrative and emergency frequencies. It is therefore required that all ATC requirements that are considered as fixed (not to be reassigned by the

FAS) be so noted and must be reflected in this file along with any third-order intermodulation products caused by these fixed assignments. This ensures protection of existing and future assignments, as additional requirements are assigned at a given site. The assignment model updates the Cosite File as assignments are made, so that it remains current. The manner in which this file is developed is discussed in Section 3 of this report.

Requirement Ordering

The assignment model assigns the requirements in a prescribed order. It is therefore important to provide some rationale for that order. After investigating various ordering techniques, a node-coloring algorithm proved to be the most satisfactory technique. This algorithm is described in APPENDIX C and in a previous ECAC report.[4] It uses the Intersite Matrix to determine an estimate of the minimum number of channels necessary to successfully complete the assignment as well as to prescribe an ordering of the requirements. Each requirement is represented by a node, and an edge is drawn between two nodes if, and only if, cochannel operation is not permissible for the corresponding requirements. The minimum number of distinct channels required (two requirements connected by an edge are assigned different channels) represents the chromatic number of the matrix. Since an actual assignment involves more than cochannel constraints, the number of channels actually used may exceed, but in no case be less than, the estimated minimum channel requirements determined by this analysis. It should be noted that this process does not reflect cosite constraints. The order produced can be improved in some instances when cosite constraints become important. This is especially true for assignments that have limited bands into which only specified requirements may be assigned. (This type of assignment is referred to as a "band" assignment or "banding.").

FREQUENCY ASSIGNMENT

The assignment phase of the Frequency Assignment System can be satisfied by one of three models:

1. Site Exhaustive Model
2. Frequency Exhaustive Model
3. Reasssignment Analysis Model (RAM).

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[4]Metzger, B. H., *Analysis of Channel Requirements for Air Traffic Control Communication and Navigational Aid Systems,* ESD-TR-70-132, ECAC. Annapolis, MD, June 1970.

Site-Exhaustive Model

The FAS can employ a site-exhaustive technique (Figure 5). That is, having selected an available frequency, an attempt is made to assign this channel to each requirement in an ordered list (ID String File). This ordering reflects the difficulty of assignment and the attempt to assign is made within the constraints imposed by the Channel Separation Matrix (intersite constraints) and the Cosite File (intrasite constraints). The list of available frequencies, automatically initialized by the program, ranges from 118 to 136 MHz in either 50-kHz or 25-kHz incremental spacing, although many frequencies within this range are not eligible for assignment. For each assignment run, the user specifies the channel spacing (25 or 50 kHz) and the appropriate frequencies are then tested for assignment. The user may also specify the starting and ending frequencies for an assignment run.

When analyzing a requirement for possible assignment of a frequency, the requirement is first checked for cosite constraints. If the requirement fails the cosite analysis, the program selects the next requirement. If the cosite analysis is passed, the matrix is interrogated for intersite constraints. If all conditions are satisfied, the assignment is made. However, if the requirement is linked to other requirements, the linked requirements must be similarly tested before a permanent frequency assignment is made.

After each requirement has been assigned a frequency, intermodulation (IM) frequencies are calculated and any new denied frequency resulting from these IM frequencies is recorded in the requirement's cosite record. The cosite adjacent-channel constraint requires that a specified number of channels on either side of the assigned frequency be denied to other requirements assigned later at the same site.

Upon completion, the program generates a print of all new and preassigned frequency assignments.

A program restart capability is incorporated so that an assignment run can be resumed if it was terminated before completion.

Frequency-Exhaustive Model

This program is very similar in operation to the Site Exhaustive Program except that frequencies, rather than sites, are exhausted. The Frequency-Exhaustive Program selects a site and then tries each frequency until one is found that satisfies all constraints. The frequency-exhaustive and site-exhaustive models are identical in terms of data input, and cosite and intersite constraint checks.

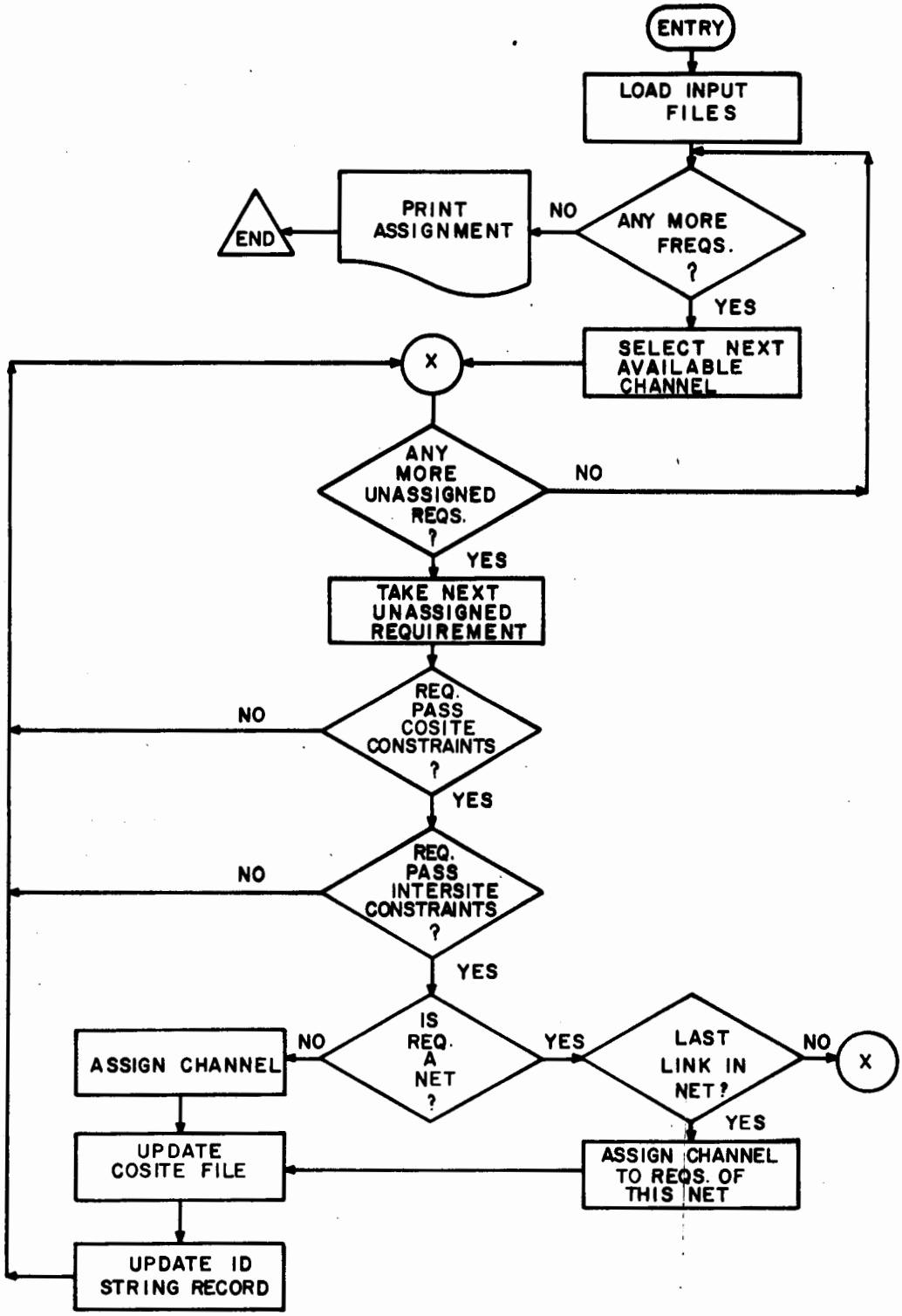

Figure 5. Frequency assignment program.

Reassignment Analysis Model (RAM)

RAM was developed to provide a more flexible assignment model for the FAS. It requires the same information as is provided to the other assignment programs (an ID String File, the Cosite File, the Requirements File, and the Intersite Matrix). RAM uses a frequency-exhaustive assignment procedure. The logic flow used by RAM is shown in Figure 6.

The primary advantage of RAM is that it will try to reach a violation-free assignment by shifting requirements, as follows. Initially, all requirements are assigned even if they create intersite violations. The violators are then purged from the assignment and reassigned. This process of assignment followed by purging and reassignment (referred to as cycling) continues until a violation-free assignment is reached. In addition, RAM can be terminated by specifying the number of cycles for an assignment run.

RAM has two modes of operation. The first mode is a normal assignment mode in which current and/or new requirements are integrated into an existing assignment. This mode assumes that all currently assigned requirements are violation free. The second mode of operation removes all existing violators and then proceeds to reassign them along with any new requirements as in the normal assignment mode. In both modes, RAM attempts to assign the requirements by shifting as few assignments as possible (in some cases no shifting may be required) until an acceptable assignment is achieved, or the user-specified number of assignment cycles is completed.

RAM has a very desirable feature in that requirements such as high-altitude enroutes can be placed on 25-kHz-spaced channels while terminal requirements (such as approach controls) can be placed on 50-kHz spaced channels during the same assignment run. This is a limitation in the other two assignment programs in that separate runs are required for assignments where more than one-channel spacing is desired. RAM will also handle the assignment that requires all similar functions to be within a specified band (banding) as well as an assignment that permits functions to be interleaved; i.e., mixing functions that are not similar and are permitted to be on either 25- or 50-kHz spaced channels.

ASSIGNMENT ANALYSIS TECHNIQUES

Prior to the implementation of any frequency assignment plan, the plan should be analyzed to determine any potential interference problems. Two capabilities were developed for analyzing existing FAA assignments. The first model is a mathematical technique that

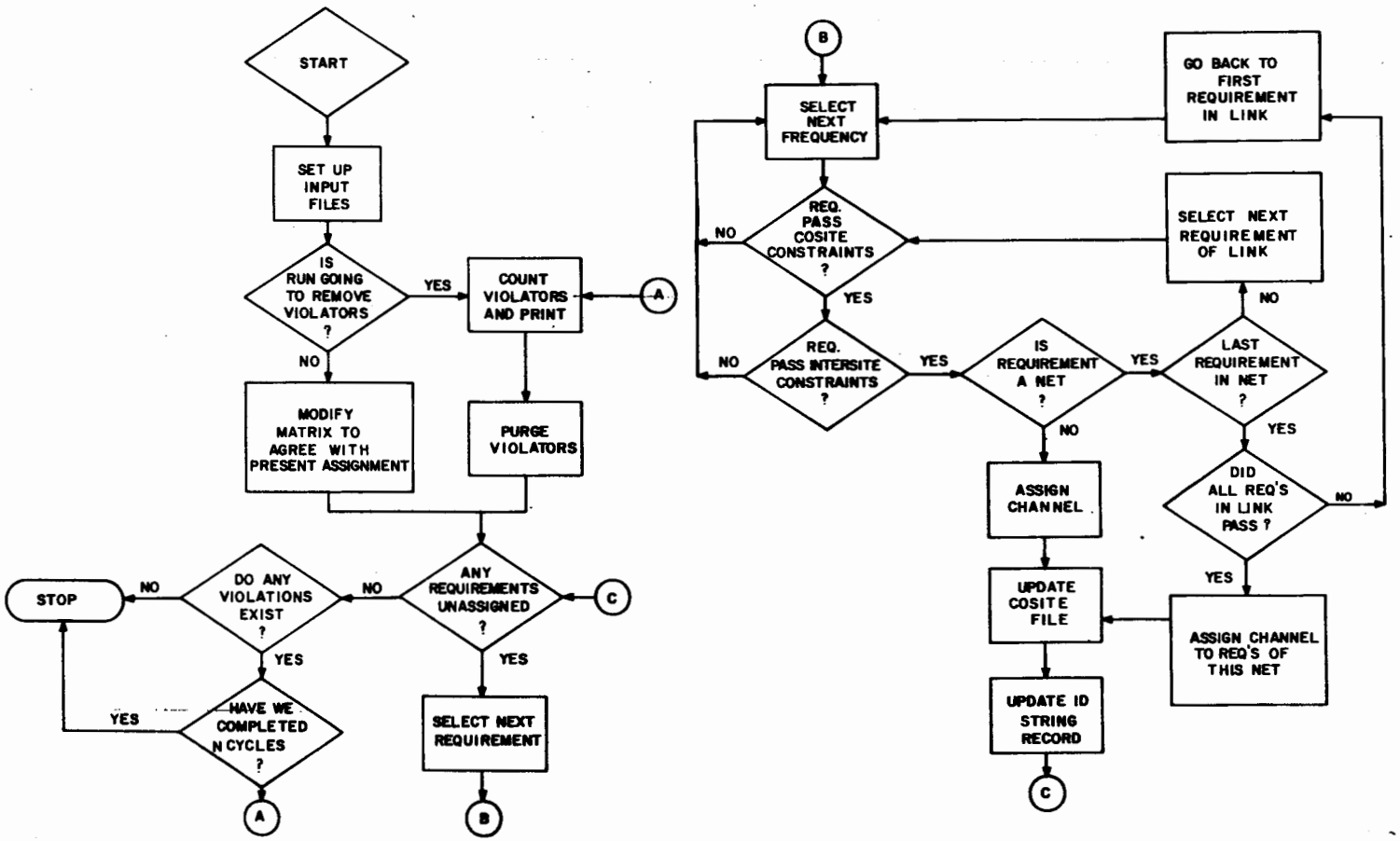

Figure 6. Reassignment analysis model (RAM) flow diagram.

calculates the desired-to-undesired (D/U) signal ratio. The other model is an ATC service-volume plot routine, and is a graphical technique.

These techniques complement one another, since plots of given frequency plans can be made after the D/U ratios are calculated, to graphically portray problem areas. The D/U and plot capabilities also provide a check of the data base used to develop the assignment. These verification checks may be made for any assignment, existing or planned.

Desired-to-Undesired (D/U) Ratio Program

This program calculates the D/U values for all requirements assigned the same frequency and produces, for each frequency, an array of the D/U values and a list of the requirements utilizing that frequency. When an acceptable level of protection is specified by the user, the list will indicate whether the particular assignment is a violator, victim, or both. No D/U value is printed in the array, if the service volumes are beyond radio line-of-sight of each other.

There are two types of service volumes: polygons and circles. In the case of polygons, D/U ratios are calculated for every point within line of site. In the case of circles, only the worst-case (lowest) D/U ratio within line of sight is calculated. If the ground site is located in the center of a circular service volume, the worst-case point is the point on the circle closest to the interfering service volume. If the ground site is not in the center of the circular service volume, the worst-case point can be anywhere on the circle, depending on the geometry involved. The worst-case D/U ratio for circles, and the minimum D/U ratio for polygons, are printed by the program.

Service Volume Plot Program

The Tailored Service Volume (TSV) Plot Program provides a composite plot of a given list of TSV's. The Lambert conformal map projection is used, with map scale and standard parallels provided as input. As an option, political boundaries may be plotted.

The input list of TSV's to be plotted may be generated in several ways. Specific TSV identification numbers may be given to the program, either individually, or in a range. TSV's may also be generated by choosing all the requirements on a given frequency, and obtaining their corresponding service volumes. This method of running the program is especially useful for a graphical verification of the data base, as discussed above.

Additional features of the plot program include the ability to select TSV's on the basis of ATC function code (e.g., all the 'high' functions may be plotted together) and the option to plot the sites associated with the selected service volumes.

SECTION 3

FAA VHF DATA BASE

FILE DESCRIPTIONS

The FAS data base at ECAC consists of two master files: the Requirements File and the Service Volume File. An additional file, the Cosite File, is a project file that is prepared when needed for assignments. These files contain data necessary for a compatible frequency assignment and are used as input to the various programs in the assignment sequence. Master files are continually updated as new/revised data become available.

Requirements File

The present FAA VHF Requirements File is developed from the Interdepartment Radio Advisory Committee's Government Master File (IRAC GMF). This file contains the frequency authorized for use at a particular site for a specific ATC function. Each record in the file contains data on an FAA requirement. These data include:

1. Requirement Identifier (REQ ID) - a unique identification generated by ECAC.
2. Site/Terminal Name - the name in the GMF.
3. Site Latitude - geographic site latitude in seconds.
4. Site Longitude - geographic site longitude in seconds.
5. Cosite File Identification - an identification link to the Cosite File.
6. Tailored Service Volume File Identification (TSV ID) - an identification link to the Service Volume File.
7. ATC Function - a one-character function descriptor (e.g., H = High, A = Approach control).
8. Altitude - height above sea level in 1000's of feet.
9. Operational Year - year of activation.
10. Channel Number - channel number corresponding to Item 15 (placed in a Requirements File by either the Maintenance Program or the ID String Generator).
11. Sort Key - a value placed in the file to permit sorting the file by ATC function.
12. Link Number - an identifier associating those function records requiring the same frequency assignment.
13. D/U Ratio - the specified minimum ratio of desired to undesired signal (desired protection criteria), given in dB.
14. Date of Latest Entry - year, month, day.

15. Background/Pre-assigned Frequency - the frequency (Item 16) in MHz for those requirements that are to be considered as preassigned by the assignment system.

16. Actual Frequency - the actual frequency in MHz that is presently being used to satisfy this requirement.

17. Operating Agency - a one-character agency descriptor (e.g., A = FAA, 2 = Air Force).

18. Service Volume Radius - the radius (in nautical miles) of the circular service volume as shown in the GMF.

19. GMF Identification (GMF ID) - the agency serial number taken from the GMF data file.

20. Receiver Latitude - geographic service volume center latitude, in integer seconds.

21. Receiver Longitude - geographic service volume center longitude, in integer seconds.

22. Region Code - a code placed in the file to permit sorting the file by FAA region.

The Requirements File is updated from the GMF as necessary and resides in permanent storage on a disc. Each record is 14 words in length, and the first record (header record) of the file contains general information about the file. APPENDIX D shows the record formats for the header records and the requirement records.

Tailored Service Volume File

The Tailored Service Volume File (TSV File) contains specific service-volume data for FAA-controlled sectors. This data is primarily latitude and longitude point descriptions, either in terms of a polygon or a circle. The multi-point sector data is derived from the Adaptation Controlled Environment Systems (ACES) tapes that are provided by the FAA centers on a periodic basis. The data representing geographic nodes and fixed posting areas on the ACES tapes are combined to form sectors that are defined by a series of latitudes and longitudes. These sectors are the tailored service volumes used in the FAS.

In some instances, a large or odd-shaped sector cannot be properly served by one frequency. The sector is divided into subsections and each subsection is served by one frequency. These subsections are represented in the TSV file by the intersection of GMF service volume circles and the sector constructed from the ACES tape. The GMF references the enroute sectors described by the data on the ACES tapes. The shaded area in Figure 7 represents such an intersection and would be the service volume used by the matrix generator in the intersite analysis.

The frequency assignment system can use circles, normal TSV's from the ACES tapes, or intersections as described above.

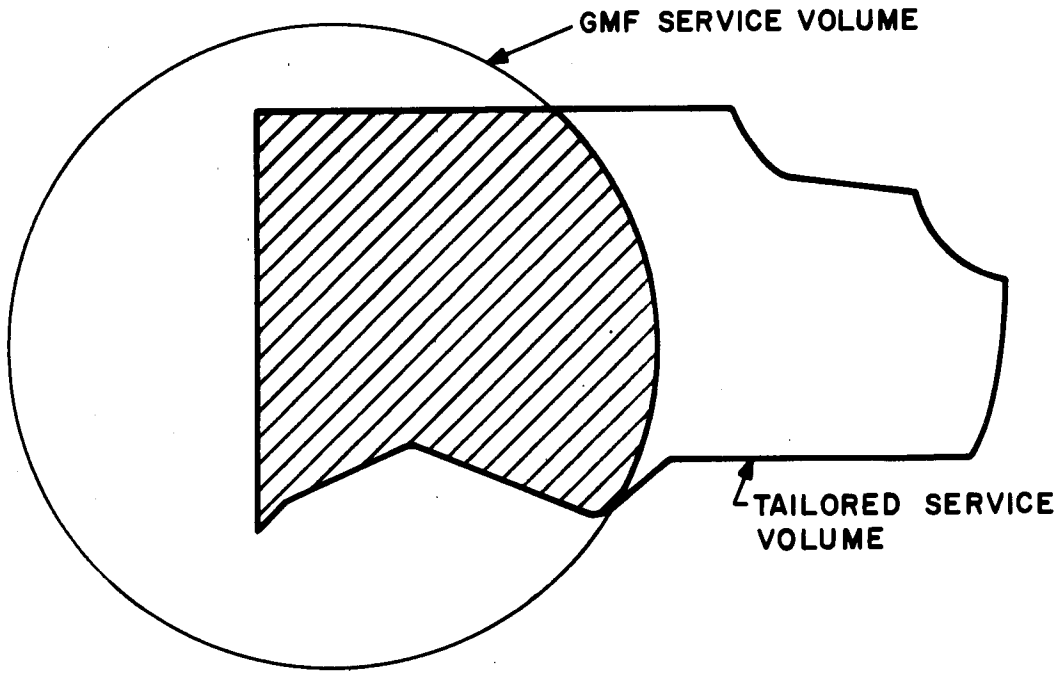

Figure 7. Intersection of TSV and GMF Service Volume Circle.

Each record in the TSV file contains the following data items:

1. TSV Identification (TSV ID) - a unique identification for each record.
2. Cell Type - a single character identifier pertaining to cell type (e.g., M = many points, C = circle).
3. Radius - radius in statute miles for smallest circle enclosing the TSV points (converted to nautical miles by the FAS).
4. Number of Points - number of points which describe the TSV polygon (maximum = 25).
5. Center Latitude - latitude in seconds for the center of the circle that encloses the TSV.
6. Center Longitude - longitude in seconds for the center of the circle that encloses the TSV.
7. Radius - radius in statute miles for sectors whose shape is described by a circular volume (converted to nautical miles by the FAS).
8. Latitude/Longitude Points - points corresponding to the vertices of the TSV polygon.
9. Sector Name - 6-character descriptor from ACES tape.
10. Sector Use Code - single-character identifier indicating sector use (e.g., H = High altitude, L = Low altitude).

The Master TSV File resides in permanent storage on a disc. Each record is 56 words in length, with the header record of the file containing general information about the file. Record formats for the header and TSV records are found in APPENDIX D.

Cosite File

The Cosite File is a project file created for each frequency assignment request. The file contains the denied frequencies resulting from the cosite restrictions imposed on each site due to frequencies of preassigned ATC requirements; frequencies used for emergency, ground control, private aircraft, flight test, and flight service stations; frequencies used by commercial airlines for administrative purposes; and frequencies used by radio and television stations. This file is constructed by first making a list that contains all preassigned frequencies and their corresponding geographical location. All frequencies in the list within a given radius of the site location associated with the Requirement Record form the basis for the Cosite Record for that requirement. The radius used is 2 nautical miles, except for broadcast stations which use 15 nautical miles. Intermodulation frequencies in the ATC bands calculated from this list of frequencies are flagged to prevent their use in assignment of a cosite requirement. All collocated requirements reference the same Cosite Record. The corresponding Record Identification is inserted into each Requirements Record. The Cosite File is an input file to the Frequency Assignment System and is updated each time a requirement is assigned. The file is stored on a disc where each record is 280 words in length. APPENDIX D contains the record formats for the Cosite File header record and frequency records.

MAINTENANCE/RETRIEVAL CAPABILITIES FOR PROJECT/MASTER FILES

Maintenance programs for the Requirements File and the TSV File feature single-record additions, changes, and deletion capabilities based on record ID (Requirement ID, GMF ID, or TSV ID). When a record is changed, one or more data items within the record can be altered. A multiple-change capability is available for any requirements file. This allows the modification of records which, as a group, have one or more data items satisfying given input criteria. The following multiple-change options are available:

1. Multiple altitude change based on ATC function and altitude.
2. A multiple change to D/U ratio based on ATC function and/or TSV range (e.g., set D/U ratio = 12 dB in all records with function = 'H' and TSV number within 1200-1299).
3. A change to background frequency on the basis of function and/or TSV number.
4. Multiple Frequency Initialization (e.g., set all background frequencies equal to actual frequencies).
5. Individual Background Frequency change based on actual frequency (e.g., set background frequency equal to actual frequency for all records with an actual frequency of 126.2 MHz).

Record retrieval for a function file is accomplished by means of a Select/Sort/Print Program. This program is run against the Requirements File and produces a full-record print of the selected records. This program also sorts a requirements file into a user-specified order.

The TSV File has two full-record print options. The user can designate a simple full-record print in TSV order, or include a full-record print of all requirements referenced by each TSV record.

The select/sort parameters of the Requirement File Select/Sort/Print Program are entered as card inputs under user control. The following fields in any combination are selectable items: ATC FUNCTION, FREQUENCY, REQUIREMENT ID, OPERATIONAL YEAR, TSV ID, OPERATING AGENCY, and all functions within a given radius of a specified location. As an option in ordering the selected records, the program allows the user to specify up to seven levels of sort.

Run procedures and data card formats for each of the maintenance/retrieval programs are described in APPENDIX E.

SECTION 4

TYPICAL FREQUENCY-ASSIGNMENT PROBLEMS

GENERAL

A general frequency assignment system must be versatile and adaptable to many types of assignment strategies. This FAA Frequency Assignment System can handle a variety of problems, some of which are listed below:

1. Determination of channel needs for present and future ATC requirements.
2. Determination of effects on frequency assignments realized by changing various assignment constraints, such as the cosite criteria.
3. Determination of effects on frequency assignments realized by using probability in the assignment system.
4. Determination of effects on frequency assignments realized by *banding* and/or *interleaving* requirements.
5. Determination of effects on frequency assignments by using either 25- or 50-kHz channel spacing, or a combination of both.
6. Determination of effects of partial or complete reassignment of existing requirements along with assignment of new requirements.
7. Determination of channel needs for assignment tasks to reassign requirements that are determined to be violators of present-day FAA criteria, and
8. Determination of effects of combinations of the above.

ASSIGNMENT CRITERIA

Assignment exercises were actually conducted using the following criteria, unless otherwise noted:

1. Intersite, cochannel requirements require a minimum D/U signal ratio of 14 dB.
2. Service volumes on adjacent channels are not permitted to overlap.
3. Collocated transmitters and receivers require a minimum frequency separation (Δf) of 500 kHz.
4. Assignments begin at the top of the upper ATC band, 135.975 MHz (for 25-kHz channel separation) or 135.90 MHz (for 50-kHz channel separation).

5. Frequencies 135.95 and 135.85 MHz are flight-test frequencies and are not used for ATC assignments. Also, military frequencies 126.2 and 134.1 MHz and Flight Service Station Frequencies 123.6 and 123.65 MHz are not used.

6. Each frequency is assigned to as many requirements as possible. Assignments continue until all requirements are satisfied or all ATC frequencies are exhausted.

7. Existing Canadian, Mexican, Cuban, and Caribbean ATC assignments are not disturbed. These are designated as preassigned and are protected.

8. Assignments that use probability for cochannel analysis are considered. The probability model used by the FAS is explained in APPENDIX B.

9. Assignments are protected from 2-signal 3rd-order intermodulation products, and protection from 3-signal 3rd-order intermodulation products is an option that is also available.

ASSIGNMENT TECHNIQUES

A variety of assignment techniques has been used for the exercises requested by the FAA. Some of these techniques are listed below:

1. Dummy frequencies below 118.0 MHz can be used for estimating the total number of channels required if more could be made available. Intermodulation products due to these dummy frequencies are not considered.

2. The node-coloring algorithm is used to order the requirements prior to assignment. For total CONUS assignment exercises, the node-coloring sequence is modified by "forcing" the assignment of high-altitude enroute requirements first.

3. Assignments can be made where requirements deemed to be violators are reassigned.

4. Assignments can be made that band similar ATC functions; e.g., high enroute and super-high enroute are one category, and low enroute and terminal functions are a second category.

5. Partial or complete reassignments can be made.

6. Either tailored multi-point service volumes or circular service volumes can be used for enroute requirements.

7. Assignments can be made on either 25- or 50-kHz spaced channels.

8. Assignments can be made that interleave 25-kHz requirements among the 50-kHz requirements by modifying the adjacent-channel criteria.

9. New requirements can be inserted into an existing assignment.

DISCUSSION ON SAMPLE PROBLEM ASSIGNMENTS

A number of initial studies were documented in Reference 2. The sample problems discussed here are an extension of those earlier studies and illustrate the versatility of the Frequency Assignment System. They are representative of the actual assignments expected to be encountered in the future.

Assignments to Investigate the Use of Probability

Three intersite matrices were constructed using data on the northeastern United States as a data base. Two of these matrices were developed using the probability model developed at the Institute for Telecommunication Sciences (ITS).[5] The third matrix used no probability; 14 dB D/U was required for cochannel protection.

There were 465 U.S. requirements to be satisfied and all three matrices used a pre-assigned Canadian and Mexican background of 607 assignments. Matrix one used circular-probability analysis which considered only the worst-case location on the circle as the point from which to calculate the D/U value. Matrix two considered all points of the multipoint tailored service volumes for the calculation of D/U values, and from these, the minimum D/U value was selected. The probability method used in the Frequency Assignment System is discussed in APPENDIX B. Matrix three was developed without using probability for cochannel analysis.

The results of the assignments (TABLE 2) using the three matrices indicated (as expected) that channel utilization can be increased with the use of probability for cochannel assignments. The matrix constructed without using probability had the highest node-coloring lower bound. The matrix constructed using probability and tailored multipoint service volumes had the lowest node-coloring lower bound.

Assignments Using Probability

Two intersite matrices were constructed using a CONUS data base. This first of these used probability *for the enroute ATC functions only* while the second matrix used probability *for all ATC functions*. The probability values used were equipment utilization factors for the aircraft and the site. The ratio of the service volume area within the 14 dB arc of interference to the total service volume area, was used as the probability that an aircraft would be within inter-

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[5]Juroshek, J. R. and Ax, G. G., *Probabilistic Interference Prediction Model, Air/Ground Voice Communications,* U.S. Department of Commerce, Office of Telecommunications, Institute for Telecommunication Sciences, January 1972.

TABLE 2

SUMMARY OF RESULTS COMPARING THE USE OF PROBABILITY

Assignment	Background	To Be Assigned	Results		Remarks
			Assigned	Unassigned	
1	Canada & Mexico = 607	N.E. subset of CONUS = 465	405	60	14 D/U No probability Lower Bound = 215 channels
2	Canada & Mexico = 607	N.E. subset of CONUS = 465	441	24	14 D/U probability applied to TCV (worst case) Lower Bound = 198 channels
3	Canada & Mexico = 607	N.E. subset of CONUS = 465	456	9	14 D/U probability applied to TSV (worst case) Lower Bound = 172 channels

fering distance from an aircraft in another service volume. The utilization values used in the model were: Aircraft = .1, Enroute Sites = .5, Terminals = .72.

Two assignments were made with the 2 matrices. The first assignment used the first matrix (probability for enroute functions only). The second assignment used the second matrix (probability for all functions). The high enroutes were assigned in the band from 134.250 to 135.975 MHz while the remaining requirements were assigned in the band from 118.00 to 134.20 MHz.

The results of the assignments are given in TABLE 3. In the table, part 1 reflects the assignments for the high enroutes and part 2 includes all other ATC functions. The use of probability reduces the spectrum required to complete an assignment.

Assignment to Investigate 25-kHz Channel Spacing with Probability for Enroute Functions

For this assignment the high-enroute requirements were placed in a specified area of the band, 134.250 MHz to 136.00 MHz. All other ATC functions were restricted to frequencies from 118.0 MHz to 134.2 MHz. The channel spacing was 25 kHz for the high-enroute band and 50 kHz for the lower band. The high-band cosite protection was 250 kHz while the low-band protection was 500 kHz. This assignment plan used probability for the enroute functions. The plan was forwarded to the FAA regional frequency managers for comments. This assignment served a three-fold purpose:

1. The nine regional frequency managers were given the opportunity to comment on the assignment system's ability to make assignments, particularly those made using probability.
2. The regional managers were able to verify the accuracy of the data base.
3. All parties concerned could see initial results of a 25-kHz assignment.

TABLE 4 gives a summary of the results of this assignment. All requirements were assigned.

Assignments to Investigate the Concept of Minimum Change

Three assignments were completed which used the philosophy that no existing assignment needed to be changed unless it was assigned in the wrong band (see *Banding* in Glossary). Less than 15% of the existing assignments required changing using this philosophy. The three assignments all used banding and are described below.

TABLE 3

SUMMARY OF ASSIGNMENT RESULTS USING PROBABILITY

Assignment		Background	To Be Assigned	Results		Remarks
				Assigned	Unassigned	
			1st Assignment			
1	Part 1	721 Canadian & Mexican 271 Military 992 Total	395 Highs	395	0	25 kHz channels 250 kHz cosite protection
	Part 2	992 From 1 395 Assigned in 1 1387 Total	2149 Lows & terminals	2073	76	50 kHz channels 500 kHz cosite protection
			2nd Assignment			
2	Part 1	721 Canadian & Mexican 271 Military 992 Total	395 Highs	395	0	25 kHz channels 250 kHz cosite protection
	Part 2	992 From 1 395 Assigned in 1 1387 Total	2149 Lows & terminals	2132	17	50 kHz channels 500 kHz cosite protection

TABLE 4

SUMMARY OF RESULTS OF MINIMUM IMPACT FREQUENCY REDEPLOYMENT PLAN

Assignment	Background	To Be Assigned	Results		Remarks
			Assigned	Unassigned	
1	721 Canadian & Mexican 271 Military 2104 CONUS Preassigned 3096 Total	330 Highs	330	0	25 kHz 250 kHz adjacent-channel protection
2	3096 Previous Background 330 Highs Assigned in 1 3426 Total	110 Non-Highs	110	0	50 kHz 500 kHz adjacent-channel protection

Assignment 1 used probability for the enroute ATC functions only. Utilization values used were .1 for aircraft and .5 for sites. The high-enroute functions were assigned first, followed by the low-enroute and terminal functions.

Assignment 2 did not use probability. The same banding procedure used in assignment 1 was duplicated in this assignment.

Assignment 3 was a combination of the first two assignments. The first step in this assignment was to assign all high enroutes in the upper band without using probability. Those high-enroute requirements that could not be assigned were then assigned with probability. There were 235 high-enroute requirements assigned without using probability. Twelve of the 16 unassigned were assigned in the second step of the assignment when probability was used. The same procedure was followed for the low enroutes, except these requirements were placed in the lower band. The non-enroutes were assigned without using probability. Thus, this assignment was made using probability only where required. The results of these three assignments are shown in TABLE 5.

Assignments to Investigate the Concept of Removing Violators

Three assignments were completed that were similar to those in the previous section except that all requirements determined to be violators (cochannel and adjacent channel) were reassigned along with those requirements in the wrong band. The results of these assignments are shown in TABLE 6.

Assignments to Investigate the Impact of Future Requirements

Three assignments were conducted to determine the amount of spectrum available for accommodating expected future requirements. A data base built from the GMF was used. Two-hundred *future* requirements provided by FAA were added to the data base. Three of the assignments interleaved the high-enroute functions on 25-kHz channels among the non-high-enroute functions on 50-kHz channels. The fourth assignment banded the high enroutes from 134.0 to 136.0 MHz on 25-kHz-spaced channels and the non-high-enroute functions were in the 118.0-133.950 MHz band on 50-kHz channels. The results of these assignments are described briefly in the following paragraphs and summarized in TABLE 7.

The interleaving assignments required a new adjacent-channel criterion for unlike ATC functions (high enroute vs. non-enroute). Unlike functions were given 14 dB D/U protection by assuming that 6 dB would be acquired in off-frequency rejection, and the additional 8 dB would be acquired in geographical separation of service volumes.

TABLE 5

ASSIGNMENT TO ASSESS MINIMUM CHANGE

Assignment Name[a,b,c] and Description	ATC Function	Number to be assigned			Assigned		Total Unassigned	
		Wrong band	Violators	Total	No probability	Probability		
1 - minimum change probability of interference = .05	High	251		251		251	0	5
	Low	80		80		79	1	
	Non-Enr.	44		44		40	4	
2 - minimum change no probability	High	251		251	235		16	24
	Low	80		80	76		4	
	Non-Enr.	44		44	40		4	
3 - minimum change combination of prob. and no prob.	High	251		251	235	12	4	9
	Low	80		80	77	2	1	
	Non-Enr.	44		44	40		4	

TABLE 6

ASSIGNMENTS TO ASSESS REMOVAL OF VIOLATORS

Assignment Name[a,b,d] and Description	ATC Function	Number to be assigned			Assigned		Total Unassigned	
		Wrong band	Violators	Total	No probability	Probability		
1 - remove violators- probability of interference = .05	High	260	14	274		274	0	126
	Low	94	134	228		204	24	
	Non-Enr.	49	603	652		550	102	
2 - remove violators- no probability	High	260	39	299	265		34	189
	Low	94	195	289	232		57	
	Non-Enr.	49	603	652	554		98	
3 - remove violators- combination of prob. and no prob.	High	260	39	299	265	19	15	151
	Low	94	195	289	177	33	79	
	Non-Enr.	49	603	652	595		57	

[a]Highs were assigned with 25-kHz channel spacing. Lows and non-enroutes were assigned with 50-kHz channel spacing.

[b]All collocated requirements are separated by at least 500 kHz.

[c]High band ends at 133.850 MHz.

[d]High band ends at 134.000 MHz.

TABLE 7

ASSIGNMENTS CONDUCTED TO INVESTIGATE THE IMPACT OF FUTURE REQUIREMENTS

Assignment		Present Requirements				Futures				Total			
		Highs	Lows	N-Enrs[a]	Total	Highs	Lows	N-Enrs[a]	Total	Highs	Lows	N-Enrs[a]	Total
Interleaving #1	To Be Assigned	175	0	0	175	11	16	173	200	186	16	173	375
	Assigned	166	0	0	166	8	13	160	181	174	13	160	347
	Unassigned	9	0	0	9	3	3	13	19	12	3	13	28
Interleaving #2	To Be Assigned	175	0	0	175	11	16	173	200	186	16	173	375
	Assigned	175	0	0	175	10	9	156	175	185	9	156	350
	Unassigned	0	0	0	0	1	7	17	25	1	7	17	25
Interleaving #3	To Be Assigned	383	0	0	383	11	16	173	200	394	16	173	583
	Assigned	348	0	0	348	7	15	164	186	355	15	164	534
	Unassigned	35	0	0	35	4	1	9	14	39	1	9	49
Banding (134.0-136.0 Highs Only)	To Be Assigned	248	68	63	379	11	16	173	200	259	84	236	579
	Assigned	242	68	54	364	8	14	155	177	250	82	209	541
	Unassigned	6	0	9	15	3	2	18	23	9	2	27	38

[a]Non-enroute requirements

For like ATC functions (high vs. high, non-enroute vs. non-enroute), the same criterion was used as in past assignments, which was that requirements on adjacent channels cannot have overlapping service volumes.

For an assignment trial entitled *Interleaving #1,* an attempt was made to re-assign all existing high-enroute requirements from 118.0-133.0 MHz on 25-kHz channels only (no frequencies evenly divisible by 50-kHz were used). Frequencies such as 135.125 and 135.175 were high-enroute frequency candidates, whereas 135.100 and 135.150 were not used. The objective was to clear some spectrum for future requirements. Nine of the existing high requirements were unassigned. Then, an attempt was made to assign 200 futures, consisting of 11 high-enroutes, 16 low-enroutes, and 173 non-enroutes. Nineteen of these futures were not assigned, leaving a total of 28 unassigned requirements.

Assignment trial *Interleaving #2* was identical to *Interleaving #1* except that the high-enroute requirements from 118.0-133.0 MHz were assigned using *all* 25-kHz channels from 118.0-135.975 MHz. All existing high enroutes were assigned. Of the 200 future requirements, 175 were assigned.

Assignment trial *Interleaving #3* was also identical to *Interleaving #1* except that an attempt was made to assign *all* high-enroute requirements on the 25-kHz spaced frequencies only, utilizing the entire ATC band (118.0-136.0 MHz). There were 35 existing high-enroute and 14 future requirements unassigned in *Interleaving #3,* leaving a total of 49 unassigned.

The banding assignment required all high-enroute requirements to be in the 134.0-136.0 MHz band with all other requirements in the 118.0-133.950 MHz band. The high band used 25-kHz-spaced channels while the other band used 50-kHz channels. There were 248 existing highs to be moved into the proper band and 131 non-high requirements to be moved. Six highs and 9 non-high requirements were unassigned, for a total of 15 existing requirements unassigned. There were 23 futures left unassigned, of which 3 were highs and 20 were non-highs. This left a total of 38 unassigned requirements in the banding assignment.

Assignments to Investigate the Impact of Inserting New Requirements with RAM

FAA requested that four proposed new requirements be added to an existing assignment. There were three high-enroute functions in the Great Lakes Region and a local control function in the Southern Region. The high-enroute functions were all assigned by RAM on 25-kHz

frequencies as desired. FAA requested a choice of frequencies for the local control function. Four frequencies were determined by RAM as acceptable assignments. Three of the 4 assignments required the shifting of a Southern Region high-enroute function to a 25-kHz frequency. The fourth frequency required the use of a filter for the local control and the shifting of a low-enroute function to a new 50-kHz frequency. This assignment utilized RAM's ability to shift existing requirements to accommodate new requirements.

SECTION 5

RESULTS

An automated frequency assignment system (FAS) was developed that is capable of determining frequency-assignment plans for FAA VHF air-traffic-control (ATC) ground-to-air communication requirements. This system consists of a series of computer programs that were developed for use on the UNIVAC 1110 computer.

The design of the FAS provides the necessary versatility to permit frequency managers to evaluate potential solutions to assignment problems and plan for future needs of air-traffic-control communications, as well as the ability to make individual assignments on a case-by-case basis. Capabilities of the FAS include the ability to:

1. generate channel assignments for existing or proposed FAA VHF ground communications requirements at ATC facilities.
2. produce frequency assignments in a manner that attempts to make efficient use of the available spectrum resources, with the criteria specified, while protecting cosite and intersite preassigned and FAS-assigned frequencies.
3. make frequency-assignment plans that conform with the technical and operational constraints specified by the user (e.g., intersite protection criteria, cosite adjacent-channel separation, frequency resource list, banding of similar ATC functions, interleaving 25- and 50-kHz channel assignments, etc.).
4. produce minimum-change frequency-assignment plans, changing only those existing assignments necessary to accommodate new requirements or violators.
5. construct and maintain a data base using data from Government Master File (GMF) and Adaptation Controlled Environment System (ACES) tapes.
6. perform statistical analyses of data.
7. plot service volumes and corresponding sites.
8. calculate D/U ratios and detect violators.

APPENDIX A

INTERSITE ANALYSIS

The channel-separation matrix represents the results of an intersite analysis that involves all possible pairs of requirements.

The basic programming logic is shown in Figure A-1. The decision-making process is dependent on calculations that involve three different types of service volume descriptors: Tailored Service Volume (TSV), Tailored Circular Volume (TCV), and Standard Service Volume (SSV). Enroute functions generally control multipoint TSV's while non-enroute functions control a TCV or SSV.

Each TSV may be described by a maximum of 25 boundary points joined to form a polygon. The TSV file also contains a circle with the minimum radius that will enclose the service volume. The radius of a TCV or an SSV and its center are extracted from the GMF and are stored in the requirements file. The TCV is a circle whose center is not necessarily at the site and has a radius value that is tailored for the particular site. The SSV is a circle with the site as the center and the radius defined according to ATC function. The formatting for these files is described in APPENDIX D.

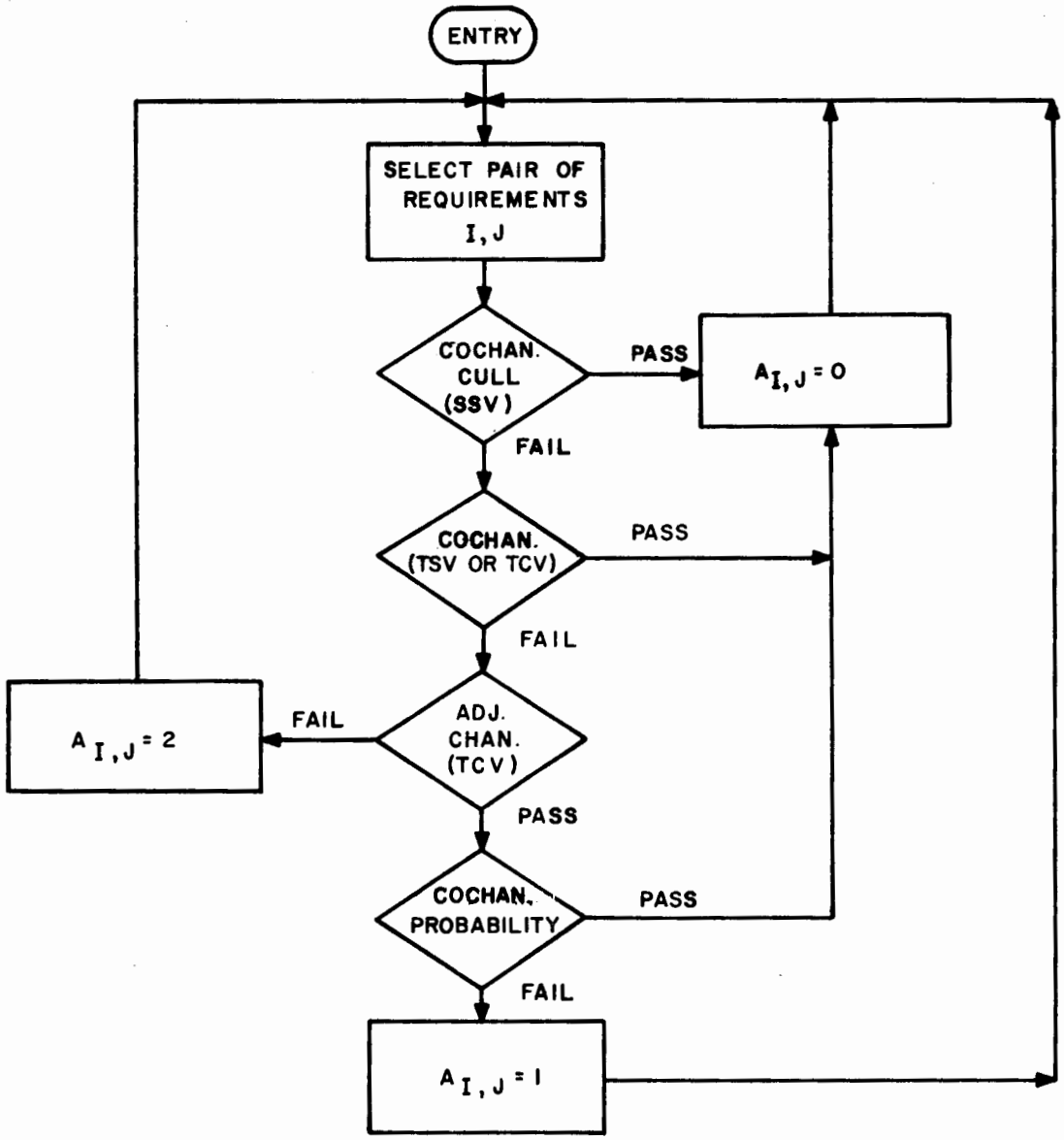
COCHANNEL CULL TECHNIQUE

This is the first step in the program logic and serves to reduce the number of overall calculations in the matrix-element-generation process. It is assumed that the aircraft associated with each service volume are restricted to communications within a cylinder, with the site at the center of the cylinder base. The required site separation for a given protection criterion is then a function of the site coordinates and radii of the cylinders involved.

Since the radii lengths are a result of ATC function, the required separation may be stored in a matrix table that contains pairs of ATC functions for a given protection criterion. This table is constructed prior to start of the matrix-generation process so that the cull analysis involves only the calculation of actual site separation, and is used as input to a table look-up procedure.

COCHANNEL TSV ANALYSIS

This analysis involves two sites (S_1,S_2) and their associated service volumes (V_1,V_2). Three types of interference are considered: air-to-air, ground-to-air, and air-to-ground.



Notes: $A_{I,J}$ = 0, if I and J require no channel separation

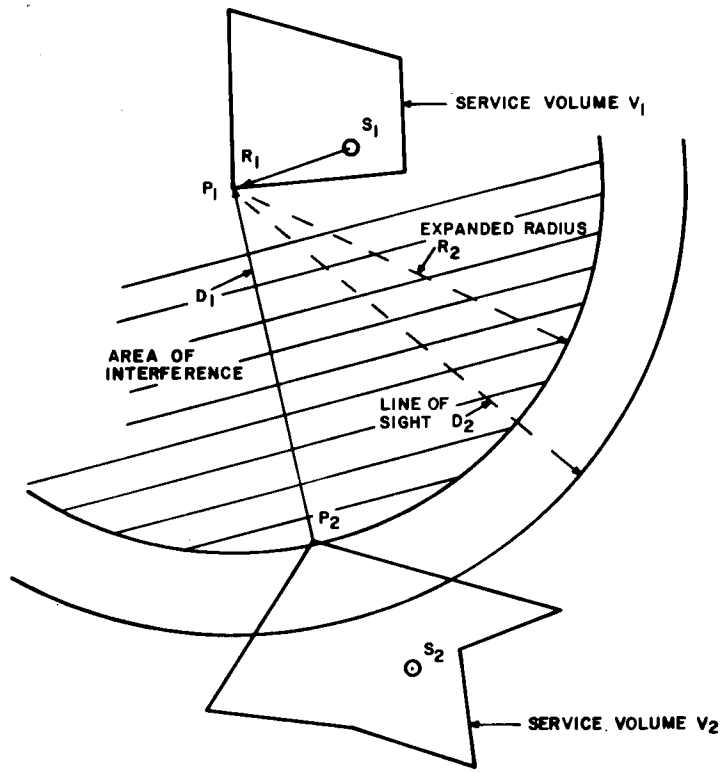
$A_{I,J}$ = 1, if I and J require separation of one or more channels

$A_{I,J}$ = 2, if I and J require separation of two or more channels

Figure A-1. Intersite Analysis Logic.

Air-to-Air

It is assumed that the desired signal is transmitted from site S_1 and received by an airplane located at a vertex P_1 of the associated TSV V_1 (see Figure A-2). The undesired signal is transmitted from an airplane at P_2 of the associated TSV V_2.



Note: In this example, the cochanneling of S_1 and S_2 is prohibited.

Figure A-2. Air-to-Air interference.

Let R_1 equal the distance from S_1 to P_1 corrected by the altitude of the sector. An expanded radius corresponding to the prescribed D/U ratio is calculated as follows:

$$R_2 = R_1 \cdot 10^{(D/U)/20}, \text{nmi}$$

In order to describe a circle of interference about P_1 the line-of-sight distance between airplanes located in V_1 and V_2 is calculated as:

$$D_2 = (\sqrt{2A_1} + \sqrt{2A_2}) \cdot (.87), \text{ nmi}$$

where A_1 is the altitude in feet of V_1 and A_2 is the altitude in feet of V_2. The radius R_{Int}=min (R_2,D_2) defines a circle of interference about the point P_1; i.e., if any interfering airplane lies within this circle the given protection criterion is violated, resulting in failure to pass this cochannel test. To determine if this is indeed the case, the distance (D_1) from P_1 to each vertex of the interfering polygon V_2 is calculated and compared against R_{Int}. Each vertex of V_1 is considered in like fashion. If this test fails for any combination of vertices, the analysis is terminated, indicating that the sites must be separated by at least one channel.

If every test is passed, using the sites and service volumes in the manner described above, their roles are interchanged (S_2 generates the desired signal) and the process is repeated. If again every test is passed, a zero is placed in the matrix indicating that the sites may be cochanneled.

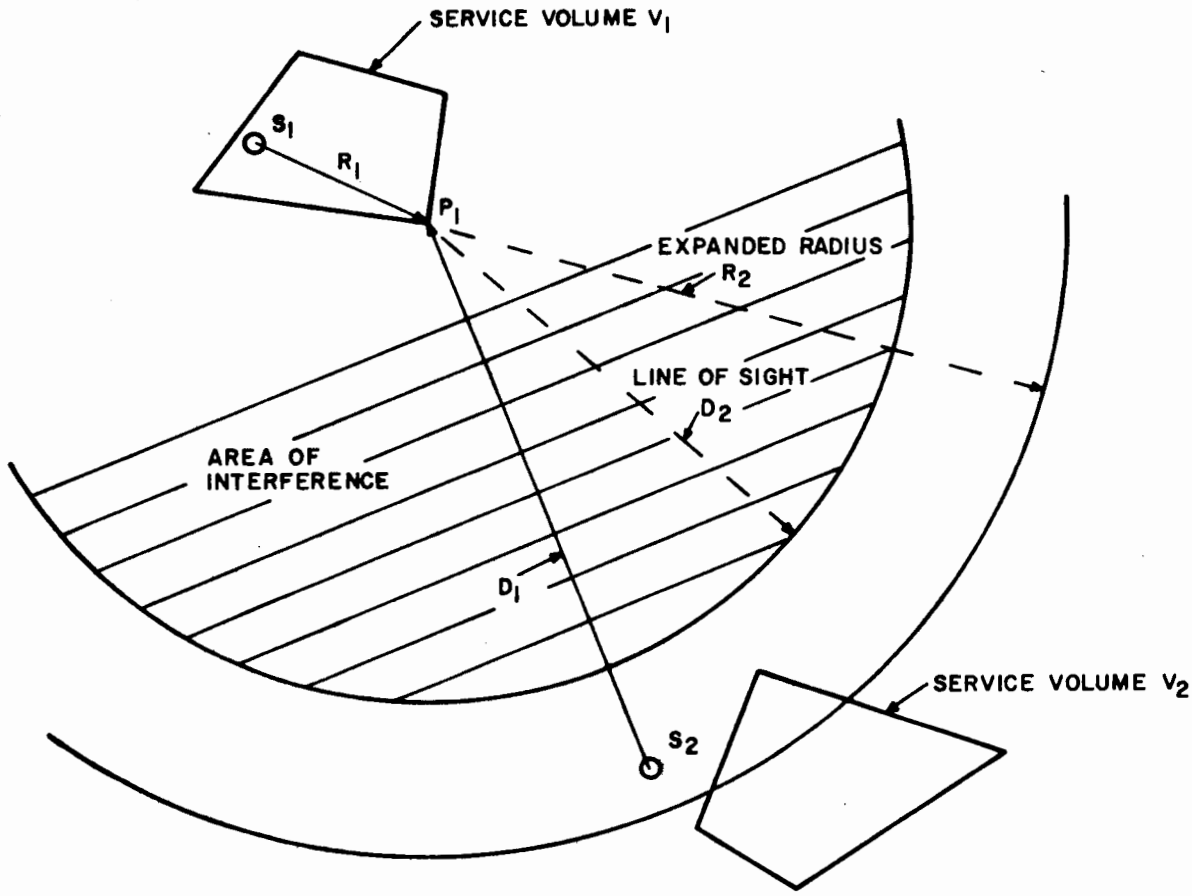
Ground-to-Air

This analysis assumes that the desired signal is transmitted from S_1 and the undesired signal radiated from S_2 (see Figure A-3). Both signals are received by an airplane located at P_1 in TSV V_1. A circle of interference is drawn about each vertex of V_1. Using for the radius, R_{Int} = min (R_2,D_2) nmi, R_2 is defined as above and D_2 is the line-of-sight distance from an airplane located at P_1.

$$D_2 = .87 \cdot \sqrt{2A_1} + 8.7, \text{ nmi}$$

Ground antenna height is assumed to be 50 feet.

The possibility of ground-to-air interference is then determined by computing the distance (D_1) from P_1 to S_2. If D_1 is less than R_{Int}, S_2 lies within the circle of interference and the cochannel protection criterion is violated. To test for ground-to-air interference where S_2 emits the desired signal, the analysis is reversed.

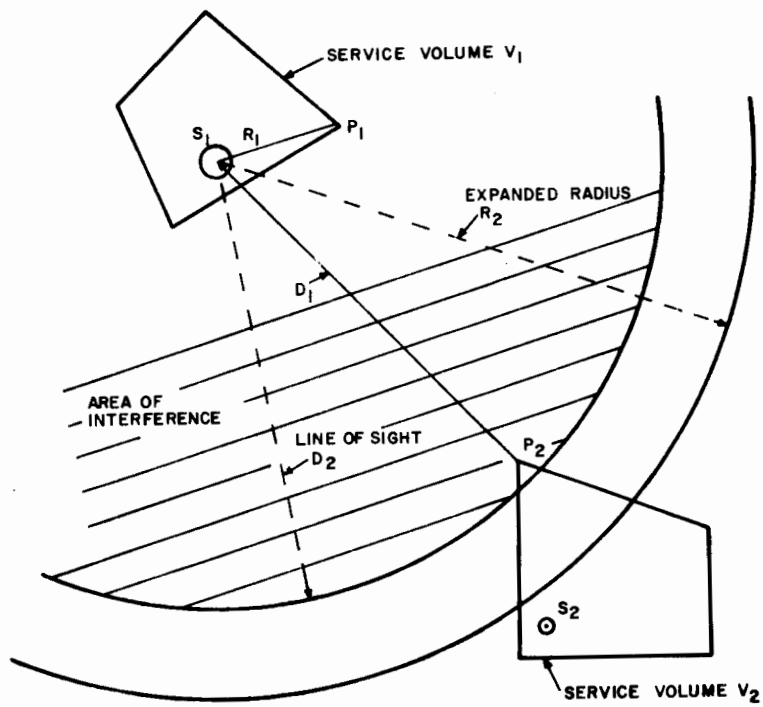


Note: In this example the cochanneling of S_1 and S_2 is not prohibited.

Figure A-3. Ground-to-Air Interference.

Air-to-Ground

In this case, the desired signal is transmitted from an aircraft located at vertex P_1 of V_1, and the undesired signal is transmitted from an aircraft at P_2 of TSV V_2 (see Figure A-4). The interference takes place at site S_1.



Note: In this example the cochanneling of S_1 and S_2 is prohibited.

Figure A-4. Air-to-Ground interference.

A circle of interference is drawn about S_1 using the radius R_{Int}. The possibility for interference is determined by calculating the distance (D_1) from S_1 to P_2 and comparing with the radius R_{Int}. If P_2 is found to lie within the circle of interference, S_1 and S_2 cannot be cochanneled. This process is repeated for each vertex of V_1. To determine the possibility of air-to-ground interference at S_2, the role of arguments is reversed.

$$D_2 = .87 \cdot \sqrt{2A_2} + 8.7, \text{ nmi}$$

COCHANNEL CYLINDRICAL SERVICE-VOLUME ANALYSIS

Some sites serve airspaces that have circular plots in lieu of polygon plots. In these cases, the TSV plots and TCV plots are identical. The basic concepts used in TSV cochannel analysis are modified to accommodate circular service-volume description. For TSV analysis, computations were made assuming that the airplanes were located at the vertices of the polygon service area descriptions. When a cochannel analysis is conducted for circular volumes, airplanes are assumed to be at worst-case position; i.e., the ratio of the distance from the desired signal to the distance from the undesired signal is maximized.

AN ALGORITHM FOR FINDING WORST-CASE LOCATION ON A CIRCLE

This analysis determines the worst-case position of an aircraft located in a sector V served by a site S. The location of the site is arbitrary and the sector is circular with radius r_1. Figure A-5 describes a typical orientation of the site, its service volume, and the location of an interfering transmitter.

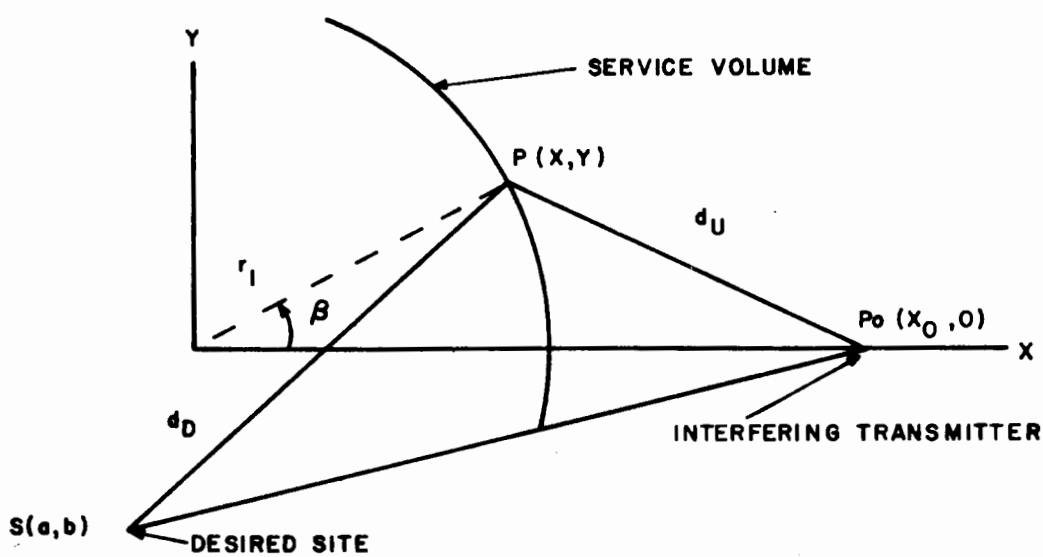


Figure A-5. Worst-case configuration.

The problem is to find the coordinates of P such that the ratio of d_D/d_U is maximized (thereby minimizing D/U Signal Ratio),

where

d_D = desired distance

d_U = undesired distance

which gives the following:

S (a,b) = site location (desired transmitter)

Po $(x_o, 0)$ = undesired signal transmitter location

r_1 = radius of sector

Knowing that P is on the perimeter of the circle we have,

$$x^2 + y^2 = r_1^2$$

The following distances can then be calculated

$$d_D = \sqrt{(x-a)^2 + (y-b)^2} \qquad \text{(A-1)}$$

$$d_U = \sqrt{(x-x_o)^2 + (y-o)^2} \qquad \text{(A-2)}$$

Now squaring, we have

$$d_D^2 = r_1^2 + a^2 + b^2 - 2(ax + by)$$

by letting

$$c^2 = r_1^2 + a^2 + b^2 \qquad \text{(constant)}$$

then

$$d_D^2 = c^2 - 2(ax + by) \qquad \text{(A-3)}$$

Now, squaring d_U we have

$$d_U^2 = r_1^2 + x_o^2 - 2x_o x \tag{A-4}$$

by letting

$$e^2 = r_1^2 + x_o^2 \qquad \text{(constant)}$$

we have

$$d_U^2 = e^2 - 2x_o x$$

Let

$$R = d_D/d_U$$

then

$$R^2 = \frac{c^2 - 2ax - 2by}{e^2 - 2x_o x} \tag{A-5}$$

and

$$2 \ln R = \ln (c^2 - 2ax - 2by) - \ln (e^2 - 2x_o x)$$

But

$$y = \sqrt{r_1^2 - x^2}$$

Therefore,

$$2 \ln R = \ln \left(c^2 - 2ax - 2b\sqrt{r_1^2 - x^2}\right) - \ln (e^2 - 2x_o x) \tag{A-6}$$

Now, taking the derivative with respect to x and setting it equal to zero we have

$$\frac{dR}{dx} = \left[\frac{-2a + 2bx(r_1^2 - x^2)^{-\frac{1}{2}}}{c^2 - 2ax - 2b\sqrt{r_1^2 - x^2}} + \frac{2x_o}{e^2 - 2xx_o}\right] \frac{R}{2} = 0$$

on simplifying, we obtain

$$(c^2x_o - e^2a)\sqrt{r_1{}^2 - x^2} = 2bx_or_1{}^2 - e^2bx \qquad \text{(A-7)}$$

Letting

$$x = r_1 \cos\beta$$

we have

$$(c^2x_o - e^2a)\sin\beta + e^2b\cos\beta = 2bx_or_1$$

Now, set

$$c^2x_o - e^2a = f$$

and

$$e^2b = g.$$

And substituting into the above

$$f\sin\beta + g\cos\beta = 2bx_or_1 \qquad \text{(A-8)}$$

then

$$\frac{f}{\sqrt{f^2 + g^2}}\sin\beta + \frac{g}{\sqrt{f^2 + g^2}}\cos\beta = \frac{2bx_or_1}{\sqrt{f^2 + g^2}} \qquad \text{(A-9)}$$

and

$$\sin\psi = \frac{g}{\sqrt{f^2 + g^2}}; \qquad \cos\psi = \frac{f}{\sqrt{f^2 + g^2}}$$

then

$$\sin(\beta + \psi) = \frac{2bx_or_1}{\sqrt{f^2 + g^2}} \qquad \text{(A-10)}$$

or

$$\beta = \sin^{-1} \left(\frac{2bx_o r_1}{\sqrt{f^2 + g^2}} \right) - \psi \qquad \text{(A-11)}$$

together with the radius r_1 define the point P (x,y)

INTERSITE ADJACENT-CHANNEL TCV ANALYSIS

Adjacent-channel assignment, by FAA practice, requires at least a 2-nmi separation between aircraft. The matrix generator module makes a conservative test by requiring that the circles associated with the sector TSV's do not overlap. For two requirements, this test is made by calculating the distance between the centers and subtracting the sum of the two radii. If the result is 2 nmi or more, the requirements may be assigned adjacent-channels and a 1 is entered in the matrix for this interaction; otherwise that element of the matrix is assigned a 2. See Figure A-6.

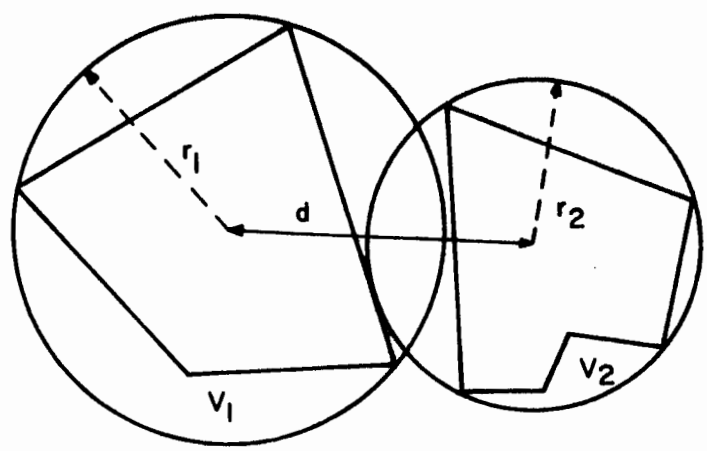


Figure A-6. Adjacent-channel analysis.

APPENDIX B

PROBABILITY METHOD OF FREQUENCY ASSIGNMENT (AIR-TO-AIR INTERFERENCE)

APPENDIX A provides a detailed explanation of the method used by the Frequency Assignment System (FAS) to ensure meeting the required cochannel assignment criterion. The cochannel criterion is an option selected by the user. (FAA has been using 14 dB desired-to-undesired (D/U) signal ratio.) This appendix presents the method used by the FAS to determine which cochannel assignments can be made using probability. The theory of this probability method is discussed in detail in Reference 5 where it is referred to as "Method 3."

Figure B-1 depicts a case of air-to-air interference. The aircraft in service-volume A is receiving a message from the ground site serving A at the same time that the aircraft in service-volume B is attempting to communicate with the ground site serving B.

The cochannel probability analysis takes advantage of the random use of the communication equipment and the random placement of interfering aircraft. The formula used to calculate the probability of interference, P(I), is given by:

$$P(I) = P(A) \times P(G) \times P(AI/SI)$$

where

P(A) = the probability that an interfering aircraft will be transmitting (aircraft communications utilization)

P(G) = the probability that a ground site will be transmitting (site communications utilization)

P(AI/SI) = the probability that an aircraft is in the area of interference (AI), given that the aircraft is in the sector of interference (SI). See Figure B-2.

The desired signal originates from the ground site while the undesired signal originates from the transmitter of another aircraft. Figure B-2 is a two-dimensional drawing showing a victim sector with its ground site and victim aircraft and a sector of interference. The 14 dB D/U arc of protection is drawn from the "worst-case" point in the victim sector through the sector of interference. The worst-

case location is defined as that point in the victim service volume that yields the minimum desired-to-undesired (D/U) signal ratio. The technique used to find this point is described in APPENDIX A. An aircraft in the area of interference (AI, the shaded portion of SI) could cause air-to-air interference (i.e., less than 14 dB D/U signal ratio) at the victim aircraft receiver. An aircraft in the non-shaded portion of SI would not cause air-to-air interference in the victim aircraft.

The utilization values for P(A) and P(G) can be estimated using actual FAA data. Typical values assumed are P(A) = 0.1 and P(G) = 0.5 or 0.7. The value of P(I) therefore can be determined as soon as P(AI/SI) is calculated. P(AI/SI) is the ratio of AI, the area of interference in SI, to the total area of SI.

$$P(AI/SI) = \frac{\text{area of interference}}{\text{total sector area}}$$

The determination of AI is made by calculating that portion of SI that is within the 14 dB D/U arc of protection drawn from the worst-case location on the victim service volume (see Figure B-2).

The FAS permits cochannel assignment only if the value of P(I) is less than 0.05. This value means that there would be no more than a 5% chance that interference would occur if the ATC requirements for these service volumes were given the same frequency.

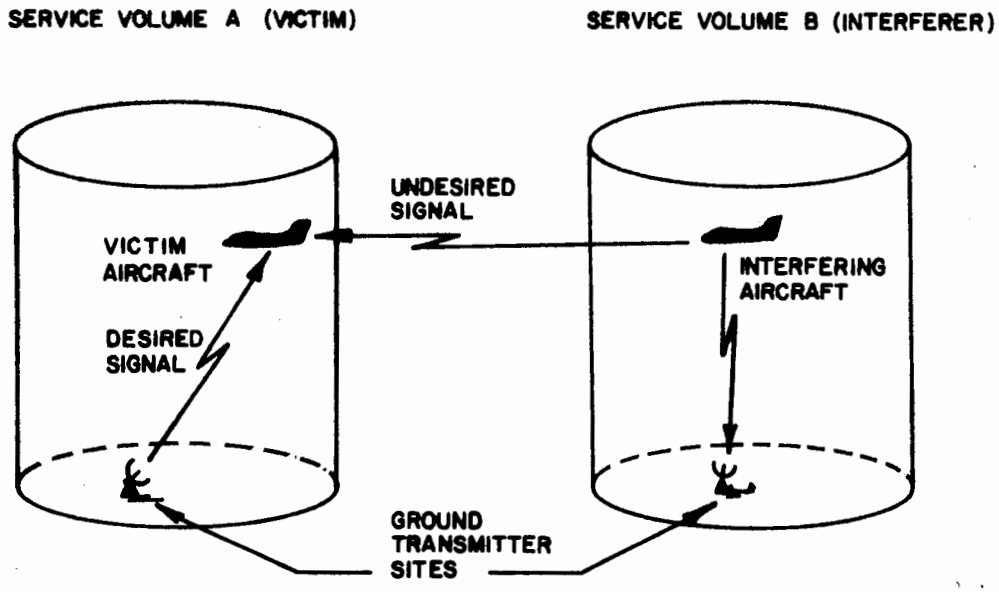


Figure B-1. Geometry of airborne transmitter in service Volume B interfering with airborne receiver in service Volume A.

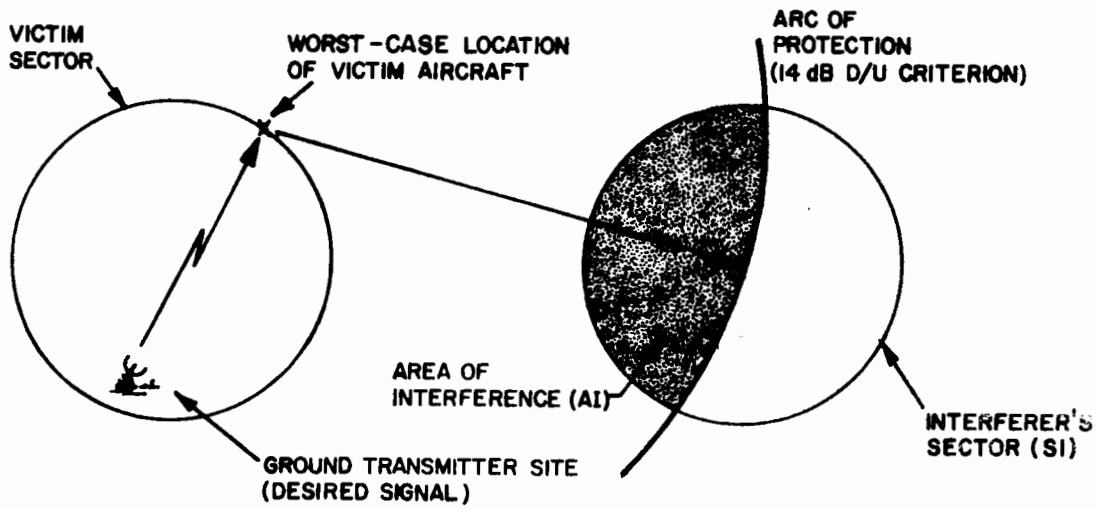


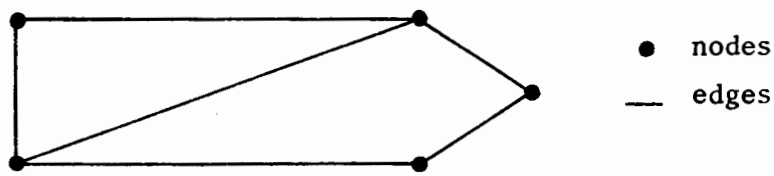
Figure B-2. Geometry involved in probability-of-interference calculation.

APPENDIX C

NODE COLORING ALGORITHM
(Requirement Ordering and Minimum Channel Determination)

The mathematical technique for determining a lower bound for the number of channels required for a given assignment, and for determining the order in which requirements are to be assigned, is based on the theory of graphs (Reference 4).

Graph theory is concerned with networks of nodes and connecting edges. The following diagram shows a graph consisting of five nodes and six edges.



A classic problem in the theory of graphs, called the node-coloring problem, is to color each node in the graph, such that:

1. two nodes connected by an edge are assigned different colors, and
2. the total number of colors used is a minimum.

The number of colors used to effect such a coloring is called the chromatic number of the graph. The graph in the above illustration has a chromatic number of three. That is, it is impossible to color the graph in accordance with the above rules using fewer than three distinct colors.

To identify the relationship between the node-coloring problem and the problem of determining minimal channel requirements, consider the intersite matrix generated for a given set of requirements. Each node is a requirement, and an edge is drawn between two nodes if and only if cochannel operation is not permissible for the corresponding requirements. The minimum number of distinct channels required such that two requirements (nodes) connected by an edge are assigned different channels (colors), is the chromatic number of the graph.

It should be noted that in determining the minimum channel requirement, consideration is given only to cochannel constraints.

In the actual assignment procedure, additional constraints must be observed, such as adjacent-channel restrictions between systems. Therefore, the number of channels used in an actual assignment may exceed, but in no case be less than, the minimum channel requirements determined by a cochannel analysis.

To obtain the minimum channel requirement using the intersite matrix, each requirement is analyzed with respect to every other requirement and an evaluation is made of the number of cases where cochannel assignment is not possible. Each requirement can therefore be associated with a number which depicts the number of cases where cochannel assignments are not possible. Requirements that are linked and must be assigned the same frequency are analyzed in a combined manner; i.e., the number of denied, cochannel, constraints for a particular link is calculated after analyzing each requirement in the link and combining the number of cases. The row and column for the requirement having the minimum number is then deleted from the matrix, and the same procedure is performed again on the matrix. This deletion sequence continues until the numbers of cochannel restrictions for the requirement remaining in the matrix are all equal to the number of requirements left.

The matrix at this point will have all non-zero elements. This means that all requirements have cochannel violations with all other requirements and therefore must be assigned different frequencies. The degree of this matrix is a lower bound for the number of frequencies required to make a total assignment.

In the deletion sequence process, a list is maintained of the order in which requirements are deleted. This list is later reversed and used to provide the order in which requirements are to be assigned. Since requirements are deleted according to the minimum number of denied-channel constraints, the reverse order tends to assure that those requirements hardest to assign will be considered first.

Given an intersite matrix, the node-coloring program normally analyzes all the requirements in the matrix. An option is also available whereby a subset matrix, which includes only those rows and columns so desired, can be formed from a larger matrix. The user simply defines the requirements to be included in the smaller matrix. Once the subset matrix has been formed, node-coloring is performed on it. This alleviates having to recalculate a new matrix.

APPENDIX D

DATA BASE RECORD FORMATS

WORD #	Format S1	Format S2	Format S3	Format S4	Format S5	Format S6	S1	S2	S3	S4	S5	S6
1	INT						Number of Requirements					
2	FLD						Date Created (1)					
3	FLD						Date Created (2)					
4	FLD						Date of Last Change (1)					
5	FLD						Date of Last Change (2)					
6	FLD						Date Verified (1)					
7	FLD						Date Verified (2)					
8	INT						Last Requirement ID Assigned					
9	INT	INT				INT	# of	S	# of	H	# of	L
10	INT	INT				INT	# of	A	# of	D	# of	C
11	INT	INT				INT	# of	G	# of	R	# of	P
12	INT	INT				INT	# of	T	# of	X	# of	V
13	INT						# of	W				
							S1	S2	S3	S4	S5	S6

NOTE: S - Super High Enroute
A - Approach Control
C - Clearance Delivery
T - Automatic Terminal Information Service
H - High Altitude Enroute
D - Departure Control
R - Helicopter Control
L - Low Altitude Enroute
C - Local Control
P - Precision Approach Radar
W - Approach/Departure Control (Canadian)
X - Clearance Delivery (Canadian)
V - ATIS (Canadian)

Figure D-1. Requirements file header sector format.

WORD #	Format S1	Format S2	Format S3	Format S4	Format S5	Format S6	S1	S2	S3	S4	S5	S6
1	INT			INT			Requirement Record ID			Channel No.		
2	FLD						State, City					
3	FLD						State, City					
4	INT						Latitude of Site (seconds)					
5	INT						Longitude of Site (seconds)					
6	INT			FLD	INT		Cosite Record ID			Operating Agency	Service Volume Radius (nmi)	
7	INT			FLD	FLD		TSV Record ID			ATC Function	Altitude/1000 (ft.)	
8	INT						IRAC ID					
9	Bits 0-3	Bits 5-9	Bits 11-17	INT			Date of Latest Entry Month / Date / Year			FTN SRT KEY		
10	INT			INT			D/U Ratio (dB)			Link No.		
11	INT				FLD		Latitude of TCV Center (seconds)				Op Year	
12	INT				FLD		Longitude of TCV Center (seonds)				Region Code	
13	FL PT						Background/Pre-Assigned Freq. (MHz)					
14	FL PT						Actual Freq. (MHz)					
							S1	S2	S3	S4	S5	S6

Figure D-2. Requirements file sector format.

WORD #	Format S1	S2	S3	S4	S5	S6	S1	S2	S3	S4	S5	S6
1	INT						Number of TSV Records					
2	FLD						Date Created (1)					
3	FLD						Date Created (2)					
4	FLD						Date of Last Change (1)					
5	FLD						Date of Last Change (2)					
6	FLD						Date Verified (1)					
7	FLD						Date Verified (2)					
							S1	S2	S3	S4	S5	S6

Figure D-3. Tailored service volume file header sector format.

WORD #	Format S1	Format S2	Format S3	Format S4	Format S5	Format S6	S1	S2	S3	S4	S5	S6
1	INT						TSVTCV ID					
2	FLD	INT				FLD	Cell Type	TCV Radius (Hundredths of Miles)				No. of Points
3	INT						Latitude (seconds)			Center of		
4	INT						Longitude (seconds)			TSVTCV Circle		
5	INT/FL PT *						Lat. #1 (seconds)/Radius * (Cell Type = C)					
6	INT						Long. #1 (seconds)					
7	.						Lat. #2 (seconds)					
8	.						Long. #2 (seconds)					
.	.						.					
.	.						.					
.	.						.					
.	.						.					
.	.						.					
.	.						.					
.	.						.					
.	.						.					
53	INT						Lat. #25 (seconds)					
54	INT						Long. #25 (seconds)					
55	FLD						Sector Name					
56	FLD						Sector Use Code					
							S1	S2	S3	S4	S5	S6

Figure D-4. Tailored service volume record format.
Many-point/circular (56 words/record)

WORD #	Format S1	Format S2	Format S3	Format S4	Format S5	Format S6	S1	S2	S3	S4	S5	S6
1	INT						Cosite Record ID					
2	INT						Number of Frequencies (100 max)					
3	FLD	INT					*	Frequency #1 (kHz)				
.		.					.	.				
.		.					.	.				
.		.					.	.				
.		.					.	.				
.		.					.	.				
.		.					.	.				
102	FLD	INT					*	Frequency #100 (kHz)				
103	INT						Auxiliary Record ID					
104	INT						Number of Channels (522 max)					
105	INT	INT				INT	Channel #1	Channel #2			Channel #3	
.	.	.				.	.	.			.	
.	.	.				.	.	.			.	
.	.	.				.	.	.			.	
.	.	.				.	.	.			.	
.	.	.				.	.	.			.	
.	.	.				.	.	.			.	
280	INT	INT				INT	Channel 520	Channel 521			Channel 522	
							S1	S2	S3	S4	S5	S6

Figure D-6. Cosite record format.

WORD #	Format S1	Format S2	Format S3	Format S4	Format S5	Format S6	S1	S2	S3	S4	S5	S6
1	INT						# of String Records					
2	INT						# of Preasg Records					
3												
4												
5												
6												
7												
8												
10												
.												
.												
.												
28	INT						Restart Freq.					
29	INT					INT	Site ID #				Cosite File #	
30	INT					INT	Channel #				Link #	
.	.					.	.				.	
.	.					.	.				.	
.	.					.	.				.	
55	.					.	.				.	
56	.					.	.				.	
							S1	S2	S3	S4	S5	S6

Figure D-7. Requirement ID string file format.

APPENDIX E

COMPUTER PROGRAM RUN PROCEDURES

REQUIREMENTS FILE GENERATOR PROGRAM

Data Card Formats

	Col(s)	Format	Description
Card No. 1	1-6	FLD	Name of output requirements file
	8-13	FLD	Write key for output requirements file
	15	FLD	Security classification for output requirements file
	17	FLD	TSV ID option; S = all TSV ID's from state codes blank = L, H, S, ENRT TSV ID's from AGN/SECT data, all others from state codes
	19	FLD	Record creation option; A = create requirements records from good & bad GMF records blank = create requirements records from *only* good GMF records
	21	FLD	Sector name/number print option; T = print the tables blank = don't print the tables

The following set of cards may be elements on a card-image disc file, in which case an '@ADD' card would be inserted after Card #1.

	Col(s)	Format	Description
Card No. 1	1-2	INT	Center number (1-21)
Card No. 2	1-20	FLD	Sector name
	21-22	INT	Sector number (1-99)

Repeat Card No. 2 for each sector in the center.

Card No. 3	1-6	FLD	'$$$$$$' represents end of data for this center

Repeat Card Nos. 1, 2 and 3 for each additional center.

REQUIREMENTS FILE GENERATOR PROGRAM (Cont'd)

Run Setup

```
@RUN
@ASG,T A.,T,UXXX                    @GMF  input tape
@DELETE,C QUAL*FILE/U/KEY.
@ASG,UP   QUAL*FILE/U/KEY.          @Assign output requirements file
@ADD,P    FAA*ADDFIL/U.GENFUN
      DATA CARDS
@PMD,ED
@FIN
```

TSV FILE GENERATOR PROGRAM

Data Card Formats

	Col(s)	Format	Description
Card No. 1	1-2	FLD	FAA Center number (1-21)
	4	INT	1=1st run only 2=additional card follows blank=normal run
	6-11	FLD	Name of TSV File
	15	INT	Number of altitudes $3 \geq X \geq 1$
	16-20	INT	Low Altitude
	21-25	INT	High Altitude
	26-30	INT	Super High Altitude
	41-43	FLD	L = Low H = High S = Super High
	47-76	FLD	Identifier
	77-80	FLPT	Epsilon value

Card No. 2 (used only if column 4 of Card No. 1 equals 2)

TSV FILE GENERATOR PROGRAM (Cont'd)

Col(s)	Format	Description
1-2	INT	Number of sectors to be mapped
		Sectors to be mapped X≤5
3-7		Sector #1
8-12		Sector #2
13-17		Sector #3
18-22		Sector #4
23-27		Sector #5
		Sectors to be mapped X≤5
28-32		Sector #1
33-37		Sector #2
38-42		Sector #3
43-47		Sector #4
48-52		Sector #5
	INT	Sectors into which mapping is done (≤5)
53-57		Sector #1
58-62		Sector #2
63-67		Sector #3
68-72		Sector #4
73-77		Sector #5

Run Setup

There are two modes of operation for the TSV File generator.

If the previous run was a success (initial runs are considered successes), use the success mode. If not, follow the failure mode setup.

Success Mode

```
@RUN
@ASG,T 2.,T,UXXX                          @FAA Center converted tape
@REWIND 2.
@QUAL FAA
@ASG,A FAA*FILE/U/KEY.                    @TSV File to be updated
@DELETE,C FAA*TSVDUM/U/BASFIL.
@ASG,UP FAA*TSVDUM/U/BASFIL.              @Good backup file in case
                                           of failure
@COPY FAA*FILE/U/KEY.,FAA*TSVDUM/U/BASFIL.
@ADD,P FAA*ADDFIL/U.TSVGEN
          DATA CARDS
@PMD,ED
@FIN
```

TSV FILE GENERATOR PROGRAM (Cont'd)

Failure Mode

```
@RUN
@ASG,T 2.,T,UXXX                    @FAA Center converted tape
@REWIND 2.
@ASG,A FAA*FILE/U/KEY               @Unsuccessful updated file
@ASG,A FAA*TSVDUM/U/BASFIL.         @Good backup file from pre-
                                     vious run
@COPY FAA*TSVDUM/U.,FAA*FILE/U/KEY.
@ADD,P FAA*ADDFIL/U.TSVGEN
          DATA CARDS
@PMD,ED
@FIN
```

REQUIREMENTS FILE MAINTENANCE PROGRAM

Input Card	Col(s)	Format	Description
	1-6	FLD	Requirements File Name
	8-13	FLD	Requirements File Write key
	15	FLD	Blank = changes done by REQ ID Y = changes done by GMF ID
Add/Change Card	1-6	INT	Requirements/GMF ID to be added/ changed*
	7-10	FLD	Site State/Country
	11-18	FLD	Site City
	19-24	INT	Site Latitude (DDMMSS)
	25-31	INT	Site Longitude (DDDMMSS)
	32-37	INT	TSV ID
	38	FLD	ATC function
	39-40	INT	Altitude (/1000) feet
	41-44	INT	Link number
	45-50	INT	Receiver latitude (DDMMSS)
	51-57	INT	Receiver longitude (DDDMMSS)
	58-64	FLPT	Background/Pre-assigned frequency (MHz)
	65-71	FLPT	Actual Frequency (MHz)
	72	FLD	Operating Agency
	73-75	INT	Radius (nmi)
	76-78	FLD	'VHF' or 'UHF' as appropriate
	80	FLD	A = add C = change

*Note: Changes made by REQ ID and GMF ID may *not* be combined in one run.

REQUIREMENTS FILE MAINTENANCE PROGRAM (Cont'd)

REQ ID/GMF ID Delete Card

Col(s)	Format	Description
1-6	FLD	REQ ID/GMF ID 1
13-18	FLD	REQ ID/GMF ID 2
25-30	FLD	REQ ID/GMF ID 3
37-42	FLD	REQ ID/GMF ID 4
49-54	FLD	REQ ID/GMF ID 5
61-66	FLD	REQ ID/GMF ID 6
76-78	FLD	'VHF' or 'UHF'
80	FLD	D = delete

Altitude Multiple Change Card

Col(s)	Format	Description
1	FLD	ATC Function Indicator
3-4	FLD	Existing altitude (/1000) feet
7-8	FLD	New altitude (/1000) feet
76-78	FLD	'VHF' or 'UHF'
79-80	FLD	'1M'

NOTE: the changes are made based upon the ATC function and the altitude.

D/U Ratio Multiple Change Card

Col(s)	Format	Description
1	FLD	ATC function indicator
3-8	FLD	TSV ID lower limit } inclusive
10-15	FLD	TSV ID upper limit } inclusive
18-22	FLD	New D/U ratio
76-78	FLD	'VHF' or 'UHF'
79-80	FLD	'2M'

NOTE: the changes are made based upon the ATC function and/or TSV ID range.

REQUIREMENTS FILE MAINTENANCE PROGRAM (Cont'd)

Background Frequency Multiple-Change Card

Col(s)	Format	Description
1	FLD	ATC function indicator
3-8	FLD	TSV ID
11-18	FLD	New background frequency (MHz)
76-78	FLD	'VHF' or 'UHF'
79-80	FLD	'3M'

NOTE: changes are made based upon ATC function and/or TSV ID

Frequency Initialize Card

Col(s)	Format	Description
76-78	FLD	'VHF' or 'UHF'
79-80	FLD	'4M'

NOTE: all background frequencies are set equal to the actual frequencies.

Background Frequency Change Based on Actual Frequency

Col(s)	Format	Description
1-7	FLPT	Actual Frequency
10-16	FLPT	New Background Frequency
76-78	FLD	'VHF' or 'UHF'
79-80	FLD	'5M'

NOTE: background frequencies are changed based on actual frequencies.

Run Setup

```
@RUN
@ASG,A QUAL*FILE/U/KEY.            @Assign requirements file
@ADD,P FAA*ADDFIL/U.FUNMNT
      DATA CARDS
@PMD,ED
@FIN
```

TSV FILE MAINTENANCE PROGRAM

Card No. 1

Col(s)	Format	Description
1-6	FLD	TSV File name

Card No. 2

Col(s)	Format	Description
1	FLD	A=add record D=delete record M=modify record
2	FLD	L=Lat/Lon point change O=other changes (use only when modifying)
3	FLD	C=change point 'N' D=delete point 'N' I=insert point between N-1 and N, where N equals the point to be inserted
5-6	INT	Point N (right justified)
15-18	INT	TSV ID
20	FLD	C=circular cell type M=many-point cell type
22-30	FLPT	TSV radius in nautical miles (circular cell type only)
31-36	INT	Circular cell type = 1 Many-point cell type = Number of points
40-46	INT	Latitude of TSV Center (DDDMMSS)
50-56	INT	Longitude of TSV Center (DDDMMSS)
60-65	FLD	Sector name from ACES tapes
66-71	FLD	Altitude Indicator L=Low H=High S=Super High

NOTE: Cols. 15-18 are always filled in. If Col. 1 equals D, then Cols. 15-18 are the *only* columns filled in. Cols. 20-71 are used only for Add and Modify options.

TSV FILE MAINTENANCE PROGRAM

Lat/Lon Card for Adding Multi-Point TSV's

Col(s)	Format	Description
1-2	FLD	'LL'
10-16	INT/FLPT	Latitude #1 (DDDMMSS) or Radius (nmi) if cell type = C
20-26	INT	Longitude #1 (DDDMMSS)
30-36	INT	Latitude #2 (DDDMMSS)
40-46	INT	Longitude #2 (DDDMMSS)
50-56	INT	Latitude #3 (DDDMMSS)
60-66	INT	Longitude #3 (DDDMMSS)

Lat/Lon Card for Modifying Many-Pointed TSV's

Col(s)	Format	Description
1-2	FLD	'LL'
10-16	INT	Latitude of New or Replacement Point
20-26	INT	Longitude of New or Replacement Point

Note: This card is used only when Col. 1 of Card No. 2 = M
and Col. 2 of Card No. 2 = L
and Col. 3 of Card No. 2 = C or I

Run Setup

```
@RUN
@ASG,A QUAL*FILE/U/KEY.            @Assign TSV file
@ADD,P FAA*ADDFIL/U.MNTTSV
        DATA CARDS
@PMD,ED
@FIN
```

REQUIREMENTS FILE SELECT/SORT/PRINT PROGRAM

Output Card

Col(s)	Format	Description
1-6	FLD	Output File Name
7-12	FLD	Output File Write key
80	INT	'1'

Input Card

Col(s)	Format	Description
1-6	FLD	Input File Name
80	INT	'2'

NOTE: If more than one input file, add file names in Columns 7-12, 13-18, 19-24 and 25-30. '//////' must follow last file name and there can be no more than 5 input files.

Select Card

Col(s)	Format	Description
1	FLD	Select Codes 1 = ATC Function 2 = REQ ID/GMF ID 3 = operational year 4 = TSV ID 5 = Background frequency 6 = Actual frequency 7 = Radius (nmi) 8 = operating agency
7-18	FLD	First Test Value (left adjusted)
19-30	FLD	If not blank, denotes that the first test value was the lower limit of the range and this is the upper limit
43-54	FLD	Second test value (or lower limit of second test value
55-66	FLD	Upper limit of second test value (if needed)
80	INT	'3'

NOTE: If selection on blank fields is necessary, Cols. 7-18 *must* be blank. If Cols. 43-54 are blank, it is assumed that the card has no alternative value.

REQUIREMENTS FILE SELECT/SORT/PRINT PROGRAM

Radius Select Card (if Col. 1 on Select Card = 7)

Col(s)	Format	Description
1	FLD	'7'
7-8	FLD	Latitude Deg.
9-10	FLD	Latitude Min.
11-12	FLD	Latitude Sec.
19-21	FLD	Longitude Deg.
22-23	FLD	Longitude Min.
24-25	FLD	Longitude Sec.
31-36	FLD	Radius (nmi)

Sort Card (Max. of 6 sort keys)

Col(s)	Format	Description
1	FLD	A = alphanumeric sort B = binary sort (INT & FLPT)
3-4	FLD	Bit position
6-7	FLD	Word number within record
9-10	FLD	Length of field in bits
80	INT	'4'

NOTE: for additional sort keys follow the same procedure in the following cols.
13, 15-16, 18-19, 21-22
25, 27-28, 30-31, 33-34
37, 39-40, 42-43, 45-46
49, 51-52, 54-55, 57-58
61, 63-64, 66-67, 69-70

REQUIREMENTS FILE SELECT/SORT/PRINT PROGRAM

Print Card

Col(s)	Format	Description
1	FLD	blank = print requirements records only C = print combined print of TSV and requirements records
2	FLD	A = all TSV records are printed, regardless of whether it has a requirement record or not
7-12	INT	Number of records to print (blank indicates *all* are to be printed)
13-18	FLD	TSV File Name
80	INT	'5'

NOTE: For 'C' option input requirement file must be in the TSV ID order.

NOTE: If the print card is omitted all requirement records are printed.

Run Setup

```
@RUN
@ASG,A QUAL*FILE/U/KEY.              @Assign Input Requirements File
@ASG,A QUAL*FILE2/U/KEY.             @Assign TSV File (if needed)
@DELETE,C QUAL*FILE3/U/KEY.
@ASGN,CP QUAL*FILE3/U/KEY.           @Assign Output Requirements File
                                      (if needed)
@ADD,P FAA*ADDFIL/U.FUNSEL
       DATA CARDS
@PMD,ED
@FIN
```

TSV FILE PRINT PROGRAM

Input Card

Col(s)	Format	Description
1-6	FLD	TSV File Name

Run Setup

```
@RUN
@ASG,A QUAL*FILE/U/KEY.            @Assign TSV File name
@ADD,P FAA*ADDFIL/U.PRTTSV
        DATA CARD
@PMD,ED
@FIN
```

MATRIX GENERATOR PROGRAM

Input Card

Col(s)	Format	Description
1-5	FLD	'INPUT'
8-13	FLD	Requirements file name
15-20	FLD	TSV file name

Output Card

Col(s)	Format	Description
1-6	FLD	'OUTPUT'
8-13	FLD	20 dB Matrix name
15-20	FLD	18 dB Matrix name
22-27	FLD	16 dB Matrix name
29-34	FLD	14 dB Matrix name
36-41	FLD	12 dB Matrix name
43-48	FLD	10 dB Matrix name
50-55	FLD	8 dB Matrix name
57-62	FLD	6 dB Matrix name

MATRIX GENERATOR PROGRAM (Cont'd)

Debug Card (optional)

Col(s)	Format	Description
1-5	FLD	'DEBUG'
8	INT	0 = no input print 1 = input print
10	INT	0 = no console print 1 = console print

Title Card (optional)

Col(s)	Format	Description
1-5	FLD	'TITLE'
9-80	FLD	User description

D/U Recovery Card (optional)

Col(s)	Format	Description
1-6	FLD	'DURECV'
8-9	INT	S recovery value
11-12	INT	H recovery value
14-15	INT	L recovery value
17-18	INT	A recovery value
20-21	INT	D recovery value
23-24	INT	C recovery value
26-27	INT	G recovery value
29-30	INT	R recovery value
32-33	INT	P recovery value
35-36	INT	T recovery value

Text Card

Col(s)	Format	Description
1-4	FLD	'TEXT'
5-6	FLD	D/U Ratio
9-80	FLD	User text

MATRIX GENERATOR PROGRAM (Cont'd)

Restart Card

Col(s)	Format	Description
1-6	FLD	'RESTAR'

NOTE: This card is needed only if the matrix was not completed in the initial execution of the program.

Run Setup

```
@RUN
@ASG,A  QUAL*FILE/U/KEY.            @Assign requirement file
@ASG,A  QUAL*FILE2/U/KEY.           @Assign TSV file
@DELETE,C  QUAL*FILE3/U/KEY.
@ASG,UP QUAL*FILE3/U/KEY.           @Assign output ½ matrix file
@ADD,P  FAA*ADDFIL/U.GENRAT
      DATA CARDS
@PMD,ED
@FIN
```

MATRIX FLIP PROGRAM

Data Card

Col(s)	Format	Description
1-6	FLD	Matrix File Name

Run Setup

```
@RUN
@ASG,A  QUAL*FILE/U.                @Assign input ½ matrix file
@ASG,T  O.,T,UXXXW                  @Assign output full matrix tape
@REWIND O.
@ADD,P  FAA*ADDFIL/U.FLIPIT
       DATA CARD
@PMD,ED
@FIN
```

NODE COLORING PROGRAM

Data Card

Col(s)	Format	Description
1	INT	1 = make all 2's in matrix equal to 1 2 = keep matrix as is
5-10	FLD	ID string file name

NOTE: The ID string as input is used to determine links, therefore, it is optional as input.

Run Setup

```
@RUN
@ASG,T  A.,T,UXXX                  @Assign input matrix tape
@ASG,A  QUAL*FILE/U.               @Assign input ID string (if needed)
@ADD,P  FAA*ADDFIL/U.NODE
        DATA CARD
@PMD,ED
@FIN
```

ID STRING GENERATOR PROGRAM

Data Card

Col(s)	Format	Description
1-6	FLD	Input Requirement File name
8-13	FLD	Output ID String File name
15-20	FLD	Output ID String Write key
22	INT	0 = no print of input requirements file 1 = print input requirements file

Run Setup

```
@RUN
@DELETE,C   QUAL*FILE/U.KEY.
@ASG,UP     QUAL*FILE/U/KEY.       @Assign output string file
@ASG,A      QUAL*FILE2/U/KEY.      @Assign requirements file
@ASG,A      QUAL*FILE3/U/KEY.      @Assign program file
@USE   P.,QUAL*FILE3/U.
@FOR,USW   P.UCODE,UCODE,UCODE
      FORTRAN CHANGE CARDS (IF NEEDED)
@ADD,P  FAA*ADDFIL/U.STRING
      DATA CARDS
@PMD,ED
@FIN
```

COSITE FILE PROGRAM

Card No. 1

Col(s)	Format	Description
5	INT	# of 28-word input tapes (units A,B,C,D,E)
10	INT	# of 84-word input tapes (units F,G,H,I,J)
15	INT	0 = no input frequency print 1 = print input frequencies
20-25	FLD	Input/Output requirements file name
30-35	FLD	Requirements file write key
40-45	FLD	Output cosite file name
50-55	FLD	Cosite file write key
60-65	FLD	Output frequency list file name
70-75	FLD	Frequency list write key
80	INT	0 = initial load 1 = add to present file

Card No. 2

1-2	INT	Latitude (deg)
4-5	INT	Latitude (min)
7-8	INT	Latitude (sec)
10	FLD	'N'
15-17	INT	Longitude (deg)
19-20	INT	Longitude (min)
22-23	INT	Longitude (sec)
25	FLD	'W'
30-39	FLPT	Frequency (MHz)
52-55	INT	Requirement ID
60	FLD	ATC Function code

NOTE: Card No. 2 is used only where there are additional requirements to be pre-assigned.

COSITE FILE PROGRAM (Cont'd)

Run Setup

```
@RUN
@ASG,A    QUAL*FILE/U/KEY.          @Assign Requirements File
@DELETE,C  QUAL*FILE2/U/KEY.
@ASG,UP   QUAL*FILE2/U/KEY.         @Assign output Cosite File
@ASG,T    A.,T,UXXXX                @Assign ARINC input tape
@ASG,T    B.,T,UXXXX                @Assign FCC input tape
@ASG,T    C.,T,UXXXX                @Assign MRFL input tape
@ADD,P    FAA*ADDFIL/U.AUZFRQ
      DATA CARDS
@ADD,P    FAA*CARDS/U.FUNCTN        @Add file of pre-assigned
                                     requirements
@PMD,ED
@FIN
```

D/U PROGRAM

Card No. 1

Col(s)	Format	Variable Name	Description
1-6	FLD	FDEF(1)	Requirements File name
8-13	FLD	TSVFIL	TSV File name
15	INT	ITYPE	0 = individual frequencies on following card(s) 1 = frequency ranges on following card(s) 2 = individual frequencies & new requirements for each frequency on following cards
17-19	INT	INUM	If ITYPE = 0 or 2; no. of frequencies ITYPE = 1; no. of ranges
21	INT	I1314	0 = select on frequency in word 13 of requirement file 1 = select on frequency in word 14 of Requirements File
23	INT	ISPACE	0 = 25 kHz increments (Used only when 1 = 50 kHz increments ITYPE = 1)
25	INT	INOTSV	0 = use TSV File to extract information 1 = extract all information from Requirements File

D/U PROGRAM (Cont'd)

Card No. 2 for ITYPE = 0 (individual frequencies)

Col(s)	Format	Description
1-7	FLPT	Frequency #1
9-15	FLPT	Frequency 2
17-23	FLPT	Frequency 3
25-31	FLPT	Frequency 4
33-39	FLPT	Frequency 5
41-47	FLPT	Frequency 6
49-55	FLPT	Frequency 7
57-63	FLPT	Frequency 8
65-71	FLPT	Frequency 9
73-79	FLPT	Frequency 10

NOTE: Repeat card for additional frequencies.

Card No. 2 for ITYPE = 1 (frequency ranges)

Col(s)	Format	Description
1-7	FLPT	Lower frequency of range 1
9-15	FLPT	Upper frequency of range 1
17-23	FLPT	Lower frequency of range 2
25-31	FLPT	Upper frequency of range 2
33-39	FLPT	Lower frequency of range 3
41-47	FLPT	Upper frequency of range 3
49-55	FLPT	Lower frequency of range 4
57-63	FLPT	Upper frequency of range 4
65-71	FLPT	Lower frequency of range 5
73-79	FLPT	Upper frequency of range 5

NOTE: Repeat card for additional frequencies.

Card No. 2 for ITYPE = 2 (frequency & additional requirements)

Col(s)	Format	Variable	Description
1-7	FLPT	FREQ(I)	Frequency
9-10	INT	IELT	Number of additional requirements associated with this frequency

D/U PROGRAM (Cont'd)

Card No. 3 for ITYPE = 2 (only)

Col(s)	Format	Description
7-18	FLD	Site name
19-24	INT	Site latitude (DDMMSS)
25-31	INT	Site longitude (DDDMMSS)
32-37	INT	TSV ID
38	FLD	ATC function code
39-40	FLD	Altitude (/1000 feet)
41-44	INT	Link number
73-75	INT	Radius (nmi)

NOTE: Repeat card 3 for additional requirements (IELT #) on this frequency
Repeat card 2 for additional frequencies

Run Procedure

```
@RUN
@ASG,A   QUAL*FILE/U.            @Assign requirement file
@ASG,A   QUAL*FILE/U.            @Assign TSV file
@ADD,P   FAA*ADDFIL/U.DUPROG
     *DATA CARDS*
@PMD,ED
@FIN
```

FREQUENCY ASSIGNMENT MODEL

Data Card

Col(s)	Format	Description
1	INT	0 = no, re-order 1 = yes, re-order
3	INT	0 = no tape output 1 = yes tape output
5	INT	0 = no restart 1 = yes restart
7-12	FLD	ID String file name
13-18	FLD	COSITE file name

FREQUENCY ASSIGNMENT MODEL (Cont'd)

Data Card (Cont'd)

Col(s)	Format	Description
19-24	FLD	Requirement File name
25-30	FLD	Updated ID String name
31-36	FLD	Updated COSITE File name
42	INT	1 = 720 channels 2 = 360 channels
47-48	INT	19 = 500 kHz denied channel range 9 = 250 kHz denied channel range
54	INT	0 = no statistics 1 = yes statistics
60	INT	1 = 25 kHz channel assignment 2 = 50 kHz channel assignment

Run Setup

```
@RUN
@ASG,T    A.,T,UXXX                  @Assign present matrix tape
@ASG,A    QUAL*FILE/U/KEY.           @Assign present Requirement File
@ASG,A    QUAL*FILE2/U/KEY.          @Assign input ID String File
@ASG,A    QUAL*FILE3/U/KEY.          @Assign input COSITE File.
@DELETE,C    QUAL*FILE4/U/KEY.
@ASG,UP      QUAL*FILE4/U/KEY.       @Assign output updated ID String File
@DELETE,C    QUAL*FILE5/U/KEY.
@ASG,UP      QUAL*FILE5/U/KEY.       @Assign output updated COSITE File
@ADD,P       FAA*ADDFIL/U.SITASG
    *DATA CARD*
@PMD,ED
@FIN
```

COMPOSITE PLOT PROGRAM

Card No. 1

Col(s)	Format	Variable Name	Description
1-6	FLD	INDEX	TSV File name
8-13	FLD	INDEX1	Requirement File name
14-17	INT	NOCELS	If JOPT=0; # of TSV ID's, REQ ID's, FREQS JOPT=1; # of cells in range (if KOPT=1; # of ranges) JOPT=2; # of centers on input card (KOPT must equal 0)
19	INT	JOPT	0 = values read in individually 1 = ranges 2 = input centers on following card (KOPT must equal 0)
21-24	INT	ISTART	starting value on TSV select range (KOPT=0 and JOPT=1)
26-28	FLD	ISEL(3)	ATC function select criteria If IOPT=0 or 1; select from 56-word TSV file IOPT=2 or 3; select from Requirement File
30	INT	IOPT	0 = TSV select; no RCAG plot 1 = TSV select; RCAG plot 2 = Requirement File select; no RCAG plot 3 = Requirement File select; RCAG plot
32	INT	KOPT	0 = select on TSV ID's 1 = select on frequency 2 = select on REQ ID's
34	INT	FOPT	0 = select on background freq. 1 = select on actual freq. (only used for freq. select)
36	INT	FSP	0 = .025 spacing (only used for freq. range) 1 = .050 spacing
38-76	FLD	HEDNG	Title for Plot (if KOPT=1; only 30 spaces are allowed for title)

COMPOSITE PLOT PROGRAM (Cont'd)

Card No. 2

Col(s)	Format	Description
2-3 5-6 8-9	INT	Lower standard parallel deg., min., sec.
12-14 16-17 19-20	INT	Upper standard parallel deg., min., sec.
24-25 27-28 30-31	INT	center of plot (latitude) deg., min., sec.
34-36 38-39 41-42	INT	center of plot (longitude) deg., min., sec.
46-49	FLPT	width of plot (in inches)
51-54	FLPT	length of plot (in inches)
55	INT	0 = no political boundaries 1 = political boundaries
57-64	INT	map ratio

Card No. 3 (individual select values only)

If KOPT = 0 or 2

Col(s)	Format	Description
1-4	INT	ID #1
7-10	INT	#2
13-16	INT	#3
19-22	INT	#4
25-28	INT	#5
31-34	INT	#6
37-40	INT	#7
43-46	INT	#8
49-52	INT	#9
55-58	INT	#10
61-64	INT	#11
67-70	INT	#12
73-76	INT	#13

COMPOSITE PLOT PROGRAM (Cont'd)

If KOPT = 1

Col(s)	Format	Description
1-7	FLPT	Frequency #1
9-15	FLPT	Frequency #2
17-23	FLPT	Frequency #3
25-31	FLPT	Frequency #4
33-39	FLPT	Frequency #5
41-47	FLPT	Frequency #6
49-55	FLPT	Frequency #7
57-63	FLPT	Frequency #8
65-71	FLPT	Frequency #9
73-79	FLPT	Frequency #10

Run Setup

```
@RUN
@ASG,A    QUAL*FILE/U.                  @Assign TSV file
@ASG,A    QUAL*FILE1/U.                 @Assign requirements file
@ASG,T    2.,16,PXXW                    @Assign plot tape
@ADD,P    FAA*ADDFIL/U.COMPLT
     *DATA CARDS*
@PMD,ED
@FIN
```

REASSIGNMENT ANALYSIS MODEL (RAM)

Card No. 1

Col(s)	Format	Description
1-6	FLD	Input Requirements File - The 14-word Requirement File from which the input ID string was selected.
8-13	FLD	Input ID String - The 2-word ID string selected from the Input Requirements File. The packed pre-assigned *MUST* be in the beginning of the ID string. The rest of the ID string may be in any order with assigned and unassigned mixed.
15-20	FLD	Input COSITE File - The 168-word COSITE file which reflects all the assignments in the Input ID string.
22-27	FLD	BACKUP ID STRING - A program-produced file reflecting the "current" status of the ID STRING.
36-41	FLD	RUN TYPE 'REMOVE' - This procedure removes assignments in the ID string which do not meet the matrix criteria. 'MODIFY' - This procedure changes the matrix to conform to the assignments in the ID STRING.
43-48	FLD	ID STRING ORDER "NORMAL" - The requirements are assigned in the order that they appear in the string. "PURGED" - The requirements are assigned in the order in which they were removed (most to least violators).
62-64	INT	Number of Cycles - A number indicating the maximum number of cycles to attempt. 1 Cycle = (Modify/Remove) + Assignment + Violation Count.
66	INT	INPUT MATRIX TAPE - Indicates the matrix tape assigned to the program is using a 2-or 3-bit code to represent intra-site conditions. MATRIX is the input file name. (2=2 bit, 3=3 bit)
68	FLD	OUTPUT MATRIX TAPE - If a 3-bit tape is input a 2-bit tape may be output to unit TWOBIT. 'Y' = output tape.
70	FLD	INPUT REQUIREMENTS FILE PRINT - A print of the initial input requirement file is done if this option is selected. 'Y' = print.

REASSIGNMENT ANALYSIS MODEL (RAM) (Cont'd)

Cards No.'s 2 & 3

Col(s)	Format	Description
1-7 (Begin)	FLT	Frequency Range - This is the closed band of frequencies used to assign the requirements.
9-15 (End)	FLT	The beginning frequency is the first one used; the end frequency is the last. (e.g., 118.0 to 136.0 or 136.0 to 132.0)
17-26	FLD	ATC Function Codes - Only those ATC codes listed here will be assigned to the previously defined band.
28-30	FLPT	Assignment spacing (kHz)
32-34	FLPT	Adjacent channel criteria (kHz)
36-38	FLPT	Cosite criteria (kHz)

NOTE: If one frequency band is used for all ATC function types, then card 3 must be included as a blank card.

Card No. 4 (optional)

If present, this card lists up to 10 frequencies in MHz (10(F7.0, 1X)) which are not protected in the assignment.

Run Setup

```
@RUN
@ASG,A    QUAL*FILE/U.          @Assign input requirement file
@ASG,A    QUAL*FILE2/U.         @Assign input ID string
@ASG,A    QUAL*FILE3/U.         @Assign input COSITE file
@ASG,T    MATRIX.,T,UXXX        @Assign matrix tape
@ASG,T    TWOBIT.,T,UXXXW       @Assign output 2-bit matrix (if needed)
@ASG,CP   QUAL*FILE4/U/KEY.     @Assign Backup ID String file (if
                                 needed)
@ASG,CP   QUAL*FILE5/U/KEY.     @Assign Backup COSITE file
                                 (if needed)
@ADD,P    FAA*FAAPRG/U.RAM
    *DATA CARDS*
@PMD,ED
@FIN
```