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**STUDY OF 25 KHz CHANNEL SPACING IMPLEMENTATION  
IN THE VHF AIR TRAFFIC CONTROL COMMUNICATIONS BAND FOR  
LOW ALTITUDE EN ROUTE AND TERMINAL FACILITIES.**

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FINAL REPORT

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**U.S. DEPARTMENT OF TRANSPORTATION**  
**FEDERAL AVIATION ADMINISTRATION**  
**Systems Research & Development Service**  
**Washington, D.C. 20590**

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| 16. Abstract<br><b>The FAA Spectrum Management Branch is responsible for making long range plans for the use of frequencies in the VHF air traffic control communications band (118 - 136 MHz). In February 1972 the decision was made to split channels in this band from 50 kHz to 25 kHz channel spacing. Plans were initially made to implement reduced channel spacing only in the high altitude en route sectors. The first of these assignments was made in June 1977. The purpose of the studies contained in this report was to form the basis of an implementation schedule for low altitude en route and terminal facilities. The effects of the newly proposed Terminal Control Areas as well as the effects of the expected growth in the number of new frequency assignments were studied and results indicated that 25 kHz channel spacing should be implemented in low altitude en route and terminal sectors in 1982 and 1984 respectively.</b> |                                                             |                                                                                                                                                          |           |
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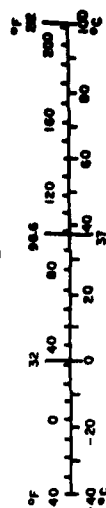
# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

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

## Approximate Conversions from Metric Measures

| Symbol                     | When You Know                     | Multiply by       | To Find                | Symbol     |
|----------------------------|-----------------------------------|-------------------|------------------------|------------|
| <b>LENGTH</b>              |                                   |                   |                        |            |
| mm                         | millimeters                       | 0.04              | inches                 | in         |
| cm                         | centimeters                       | 0.4               | inches                 | in         |
| m                          | meters                            | 3.3               | feet                   | ft         |
| m                          | meters                            | 1.1               | yards                  | yds        |
| km                         | kilometers                        | 0.6               | miles                  | mi         |
| <b>AREA</b>                |                                   |                   |                        |            |
| cm <sup>2</sup>            | square centimeters                | 0.16              | square inches          | sq in      |
| m <sup>2</sup>             | square meters                     | 1.2               | square yards           | sq yds     |
| km <sup>2</sup>            | square kilometers                 | 0.4               | square miles           | sq mi      |
| ha                         | hectares (10,000 m <sup>2</sup> ) | 2.5               | acres                  | acres      |
| <b>MASS (weights)</b>      |                                   |                   |                        |            |
| g                          | grams                             | 0.035             | ounces                 | oz         |
| kg                         | kilograms                         | 2.2               | pounds                 | lb         |
| t                          | tonnes (1000 kg)                  | 1.1               | short tons             | short tons |
| <b>VOLUME</b>              |                                   |                   |                        |            |
| ml                         | milliliters                       | 0.03              | fluid ounces           | fl oz      |
| l                          | liters                            | 2.1               | pints                  | pt         |
| l                          | liters                            | 1.05              | quarts                 | qt         |
| l                          | liters                            | 0.26              | gallons                | gal        |
| m <sup>3</sup>             | cubic meters                      | 35                | cubic feet             | cu ft      |
| m <sup>3</sup>             | cubic meters                      | 1.3               | cubic yards            | cu yds     |
| <b>TEMPERATURE (exact)</b> |                                   |                   |                        |            |
| °C                         | Celsius temperature               | 9/5 (then add 32) | Fahrenheit temperature | °F         |



\* 1 in. = 2.54 (exact). For other exact conversions and more detailed tables, see NBS Mon. Publ. 28b, Units of Weight and Measure, Price \$2.25, SD Catalog No. C13.10.286.

**FEDERAL AVIATION ADMINISTRATION  
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE  
SPECTRUM MANAGEMENT BRANCH**

**STATEMENT OF MISSION**

The mission of the Spectrum Management Branch is to assist the Department of State, National Telecommunications and Information Administration, 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 and to provide for the safe conduct of aeronautical flight by fostering effective and efficient use of a natural resource--the electromagnetic radiofrequency spectrum.

This objective is achieved through the following services:

- . Planning and defending the acquisition and retention of sufficient radio frequency spectrum to support the aeronautical interest 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, and standards, criteria, measurement equipment, and measurement techniques.
- . Conducting electromagnetic compatibility analyses to determine intra/ intersystem viability and design parameters, to assure certification of adequate spectrum to support system operational use and projected growth patterns, to defend 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.

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## 1. GENERAL

The purpose of the following studies was to evaluate the impact of new Terminal Control Areas and the expected growth in the number of frequency requirements on the implementation of 25 kHz channel spacing in the VHF air traffic control (ATC) communications band (118-136 MHz). The studies were performed by the Federal Aviation Administration (FAA) Spectrum Management Branch in cooperation with the Electromagnetic Compatibility Analysis Center (ECAC) using computer models developed and operated for the FAA by ECAC personnel.

## 2. BACKGROUND

- a. In the early 1970's, several studies were performed which indicated that the number of frequencies available for ATC communications was insufficient to satisfy all of the anticipated frequency requirements within the constraints of the assignment criteria. Of the solutions proposed, a change from 50 kHz to 25 kHz channel spacing was determined to be the most advantageous course of action.
- b. Public notice of FAA's intention to channel split was made in a "Notice of Invitation for Comments" published in the Federal Register on February 2, 1972. The following implementation schedule for 25 kHz channel spacing was proposed:

January 1976 - Introduced into selected high altitude en route sectors.

June 1976 - Deployment at high altitude en route sectors. Introduction into selected high density low altitude en route sectors.

June 1977 - Deployment at low altitude en route sectors.

June 1979 - Deployment at selected air traffic control tower facilities and selected flight service stations.

Comments received from the aviation community indicated agreement with the need to channel split, but that the proposed schedule was too ambitious for many of the users to meet. Based on these comments and the unexpected decline in the growth rate of aviation during the Arab oil embargo, the proposed schedule was revised. In the Federal Register dated May 21, 1973, the FAA gave notice that implementation of 25 kHz channel spacing would begin in the high altitude en route sectors in January 1977. The schedule to implement 25 kHz channel spacing in the low altitude en route and terminal sectors was not defined pending further study by the FAA.



- c. Between 1973 and 1976, the FAA undertook an equipment replacement program to prepare existing RCAG sites for 25 kHz channel spacing to be implemented beginning in 1977. The first 25 kHz assignments were made operational in June 1977. At present there are approximately forty 25 kHz assignments operational in the United States with additional 25 kHz assignments being made as needed. In some areas of the country, particularly the Great Lakes Region, it is nearly impossible to make a new frequency assignment, even on 25 kHz spaced channels, without shifting one or two existing assignments to other frequencies. As 25 kHz channel spacing is implemented in the high altitude en route sectors and as it becomes more difficult to make new frequency assignments, plans must be made to implement 25 kHz channel spacing in the low altitude en route and terminal sectors. The FAA has a commitment to publish a proposed schedule as soon as possible so the the aviation community may comment and have adequate time to prepare for the change.

### 3. DESCRIPTION OF THE ASSIGNMENT MODEL

To make long range frequency assignment plans, the FAA makes use of an automated frequency assignment model developed and operated for FAA by ECAC. With this assignment model, different assignment strategies can be simulated and the impact of each strategy on the spectrum available to ATC communications can be compared to determine the best course of action. This same model was used to plan 25 kHz implementation in the high altitude en route sectors. Since then the model has been modified and expanded to run more efficiently and to provide the user more flexibility.

#### a. Assignment Criteria

- (1) The frequency assignment model bases its calculations on standard FAA assignment criteria. Cochannel assignments must be afforded a 14 dB signal ratio at the victim aircraft receiver between the desired ground-to-air signal and the undesired air-to-air signal from an aircraft in another service volume. The service volumes of adjacent channel assignments (frequencies offset by one channel width for assignments with like channel spacing) must be separated by a least 2 nmi. (3.7 km). Since there is a mixture of 50 kHz and 25 kHz equipment in the environment during the transition to 25 kHz channel spacing, 50 kHz receivers must be protected from interfering transmissions offset by 25 kHz (25 kHz interleaving). The FAA assumes that a receiver designed for 50 kHz channel spacing will provide 6 dB of rejection to a signal offset by 25 kHz. Therefore, assignments offset by 25 kHz are afforded 8 dB of protection by geographic separation. This 8 dB plus the 6 dB obtained from the receiver rejection is equivalent to the 14 dB obtained in the cochannel case. Together, these three analyses are referred to as the intersite analysis.

- (2) Interference interactions between facilities located at or near the same site are as much of a problem as the cochannel and adjacent channel interference discussed above. ATC communications channels located at the same site must be separated by at least 500 kHz. For the computer model, the site is defined as having a radius of .2 nmi (.4 km). To avoid intermodulation interference, all two signal third order intermodulation products of nearby FM, TV, and VHF communications/navigation frequencies are calculated. Any ATC communications frequency which coincides with an intermodulation product will not be considered for assignment at the site. To avoid harmonic interference, the second and third order harmonics of FM and TV frequencies in the area plus the second and third subharmonics of local UHF ATC communications frequencies are calculated. Again if a harmonic or subharmonic coincides with an ATC communications frequency, that frequency is not considered for assignment. For the computer calculation, FM and TV channels within 15 nmi (27.6 km) and ATC communications/navigation stations within  $\frac{1}{2}$  nmi (.9 km) of the site are considered in the intermodulation and harmonic analyses. Together, the adjacent signal, intermodulation, and harmonic analyses form the cosite analysis. The intersite and cosite assignment criteria remain constant for all studies except for those designed to test the effect of a change in criteria.

b. Assignment Data Base

The intersite and cosite analyses require an extensive data base. Two data files, the requirements file for the intersite analysis and the background file for the cosite analysis, were developed by drawing information from a wide range of sources. The requirements file contains the existing VHF A/G communications assignments in the ATC portion of the 118-136 MHz band for the continental United States, Canada, and Mexico. Sources for this information are:

The Continental U.S. -- IRAC Government Master File  
Canada -- Data tape supplied by the Canadian Government  
Mexico -- ICAO CARSAM Frequency Listings

En route frequency records contain the coordinates of the associated multipoint tailored service volume. This information is extracted from the FAA's Adaptation Controlled Environment System (ACES) tapes supplied by each ATC center. The background file contains all the FM, TV, and VHF/UHF communications/navigation frequencies in the continental U.S. required for the cosite analysis.

Sources for this file are:

VHF/UHF Com/Nav, 108-136 MHz -- IRAC Government Master File  
225-400 MHz

FM & TV, 54-108 & 174-216 MHz -- Data tape supplied by the FCC

VHF Operational Control, 128.8-132.0 MHz -- ARINC data tape

Different assignment strategies can be simulated by manipulating the data base, the available frequencies, the allowable channel spacing, and the order of assignment. The impact of different strategies can then be compared to determine the most advantageous assignment plan. By adding a list of future frequency requirements to the data base, the impact of expected requirements can be assessed and a schedule for making a particular change in criteria such as reduced channel spacing can be developed.

#### 4. ANALYSIS OF THE PRESENT ENVIRONMENT

- a. Before trying to determine the impact of future frequency requirements, an analysis was made of the existing environment (as of January 1979). Three basic assignment strategies were tested:

1. All FAA frequency requirements were reassigned with only high altitude en route facilities eligible for 25 kHz spaced channels.
2. All FAA frequency requirements were reassigned with both high and low altitude en route facilities eligible for 25 kHz spaced channels.
3. All FAA frequency requirements were reassigned on 25 kHz spaced channels.

Each strategy was tested several times as cosite criteria, assignment order, and other parameters were varied.

- b. Results indicate that even reassigning every frequency requirement using the most efficient assignment method available would not relieve the frequency congestion problem. A few existing requirements in major terminal areas such as New York and Chicago could not be satisfied when only high altitude en route requirements were eligible for 25 kHz spaced channels (strategy 1). The cosite criteria had to be modified to account for the use of additional RF filtering and separate transmitter and receiver sites before frequencies could be found for these requirements. Adding low altitude en route requirements to those eligible for 25 kHz spaced channels (strategy 2) resulted in more requirements being assigned using the standard criteria, however this strategy still required the use of modified cosite criteria in some geographic areas. Strategies 1 and 2 both required the entire ATC spectrum to assign a frequency to every requirements. Only when every requirement was eligible for 25 kHz spaced

channels (strategy 3) did any spectrum remain unused. These results indicate that there is little if any reserve capacity for future requirements if only high altitude en route requirements are eligible for 25 kHz spaced channels. In some areas of high frequency congestion such as Chicago, this reserve is already being exhausted. The following studies will estimate when the reserve capacity will run out completely by adding frequency requirements for future facilities to the environment.

## 5. EFFECTS OF THE PROPOSED NEW TERMINAL CONTROL AREAS

On December 27, 1978, FAA Administrator, Langhorne Bond, issued the "Plan for Enhanced Safety of Flight Operations in the National Airspace System." Among other steps proposed, it was decided to establish 41 new Terminal Control Areas (TCA's). To upgrade many of these existing terminal areas to TCA's could require new frequencies and/or extended service volume radii and altitudes on existing facilities. These changes could have a major effect on the schedule for implementation of 25 kHz channel spacing in the low en route and terminal sectors.

### a. New TCA Requirements

- (1) The existing and proposed TCA locations are listed in Appendix A, grouped into implementation phases. Of the TCA's originally proposed by the Administrator, those for San Juan, Puerto Rico, Kahului, Hawaii, and Anchorage, Alaska were not considered in this study because they would not effect frequency congestion in the contiguous United States. In addition, on September 7, 1979, six of the proposed TCA's (Des Moines, Iowa, El Paso, Texas, Jacksonville, Florida, Lihue, Hawaii, Salt Lake City, Utah, and Tucson, Arizona) were withdrawn. Therefore, these were also dropped from this study. Three additional locations, (Honolulu, Hawaii, Tampa, Florida, and Pheonix, Arizona) were already in the process of being upgraded to TCA status before the Administrator's order; therefore changes to the frequency requirements for these sites were assumed to be complete. The remaining 32 locations were used to generate the future frequency environment. Originally proposed TCA's which were not used in the study are marked with a star in Appendix A.
- (2) Based on a study of existing TCA locations, the following frequency requirements were found to be common to all TCA's. Therefore, each new TCA should have as a minimum:
  1. One (1) ground control channel with a service volume range of 2 nmi (3.7 km) at an altitude of 100 feet (30 m).
  2. One (1) ATIS channel with an extended service volume range of 60 nmi (111 km) at 20,000 feet (6000 m).

3. At least one (1) approach control channel and one (1) departure control channel each with an extended service volume range of 60 nmi (111 km) at 20,000 feet (6000 m).
4. A minimum of two (2) local control channels (one for local control, one for clearance delivery each with a service volume range of 30 nmi (55 km) at 10,000 feet (3000 m).
- (3) Each of the 32 proposed TCA'S of interest were examined. New frequency requirements were added or existing requirements were extended in range if the above minimum was not existing at the location. Appendix A contains a list of the proposed TCA locations, the geographic coordinates assumed for their communication outlets, and the frequency changes which were necessary. The frequency assignment model was then used to assign the TCA frequency requirements which resulted from additions or changes to the existing frequencies for the location.

b. TCA Assignments Performed

Assignment of the projected TCA frequency requirements was made by year according to the Administrator's implementation schedule. Three different assignment strategies were used in which all new TCA frequency requirements were assigned with the high altitude en route requirements handled differently each time.

1. The high altitude en route requirements could not be reassigned (ie.fixed in frequency). This would be a very restrictive approach.
2. All high altitude en route requirements were reassigned on any available frequency. This simulates the present procedure of reassigning high en route requirements to accommodate a new terminal assignment.
3. All high altitude en route requirements were forced on to the odd 25 kHz frequencies (ie. the odd multiples of 25 kHz, such as 118.025, 118.125, etc.). This simulates the effect of one proposed change in assignment procedures.

All other existing requirements (low altitude en route and terminal) were fixed in frequency for each assignment strategy. The standard criteria for cochannel, adjacent channel 25 kHz interleaving, and cosite interference protection were used in each assignment. Assignments for terminal requirements were made starting with the lowest possible frequency (118.0 MHz) and working up while assignments for en route requirements were made using first the highest possible frequency (135.975 MHz) and working down.

c. Results of the TCA Assignment Study

Figure 1 is a tabulation of the assignment studies performed and the results. In each assignment, all high altitude en route requirements were reassigned without difficulty, therefore only the number of new TCA requirements which could not be assigned are listed in the table.

FIGURE 1  
Assignment Studies for Future TCA's

|                                    | # TCA<br>Requirements<br>to Assign | # of New TCA Requirements Not Assigned |                                               |                                                |
|------------------------------------|------------------------------------|----------------------------------------|-----------------------------------------------|------------------------------------------------|
|                                    |                                    | Assignment I<br>High's Fixed           | Assignment II<br>High's on any<br>25 kHz Freq | Assignment III<br>High's on odd<br>25 kHz Freq |
| Phase I<br>(complete end<br>1980)  | 32                                 | 3                                      | 1                                             | 0                                              |
| Phase II<br>(complete end<br>1981) | 68                                 | 29                                     | 24                                            | 1                                              |
| Phase II<br>(complete end<br>1983) | 17                                 | 10                                     | 5                                             | 1                                              |

Assignment II in the table reflects the existing assignment policy. It is apparent that by the end of 1981 under the existing policy, a serious problem could exist in trying to accommodate changes and additions required to implement new TCA's even if no other future frequency requirements were established. Assignment III indicates that all but two of the expected TCA changes could be assigned if all high altitude en route requirements were shifted to odd 25 kHz channels. While it would not be practical to physically reassign all existing high altitude en route requirements, Assignment III does give an indication of the benefits such a change in assignment procedures would have. If as many high altitude en route requirements as possible were shifted to odd 25 kHz channels over the next few years, the effect of establishing the new TCA's could be minimized.

## 6. ANALYSIS OF FUTURE REQUIREMENTS

The analysis of the proposed TCA's shows only the effects of the proposed TCA's and not the frequency requirements which result from normal growth. A separate analysis of other future requirements was also performed to show the effects of normal growth. The list of changes and additions to the frequency requirements at the proposed TCA's was not used in this study so that the effects of normal growth could be examined separately. However, the existing and proposed TCA's were used to identify the locations of major airports where the normal growth in the number of requirements could have a significant impact on frequency congestion.

### a. Number of Requirements

To estimate the number of expected new frequency requirements each year, a growth rate was determined by linearly extrapolating the growth in requirements from 1973 to 1979 on through 1985. A rate of growth in new requirements of 4% per year was obtained. This figure correlates very well with the actual and projected growth in IFR traffic over the same period. From 1973 to 1979, the ratio of the number of high altitude en route to low altitude en route to terminal assignments remained essentially constant. Therefore, the 4% per year growth rate can be applied to each type of facility without weighting one type over the others. Figure 2 is a list of the total number of frequency requirements expected each year through 1985.

FIGURE 2

Total Number of VHF ATC Frequency  
Requirements Expected Each Year Through 1985

| <u>Year</u> | <u>High Altitude</u><br><u>En Route Requirements</u> | <u>Low Altitude</u><br><u>En Route Requirements</u> | <u>Terminal</u><br><u>Requirements</u> |
|-------------|------------------------------------------------------|-----------------------------------------------------|----------------------------------------|
| 1979*       | 475                                                  | 612                                                 | 2049                                   |
| 1980        | 494                                                  | 636                                                 | 2131                                   |
| 1981        | 514                                                  | 661                                                 | 2216                                   |
| 1982        | 535                                                  | 687                                                 | 2305                                   |
| 1983        | 556                                                  | 714                                                 | 2397                                   |
| 1984        | 578                                                  | 743                                                 | 2493                                   |
| 1985        | 601                                                  | 773                                                 | 2593                                   |

\*From ECAC data based requirements file as of January 1979

**b. Location of Future Requirements**

To accurately predict the impact of future frequency requirements, their geographic locations are as important as their number. New en route requirements are usually established to fill holes in coverage and to cover new sectors created when old sectors become too heavily congested with air traffic. Coverage gaps and sector changes occur randomly across the country. Therefore, the geographic coordinates for future en route requirements were generated at random. Appendix B contains list of 60 new RCAG sites generated at random to accommodate the future en route requirements. Figure 3 is a map showing these locations. New terminal requirements result when new air traffic control towers (ATCT's) are established or when new services are offered at small airports. New terminal requirements would also be established at major airports to relieve congestion on existing frequencies. To simulate the creation of new ATCT's and services, some of the terminal locations were generated at random. It was assumed that each of these new sites would require 2 frequencies. To simulate new requirements being added at major airports, it was assumed that at least one new frequency per year will be required at each of the 60 existing and proposed TCA locations. Appendix B also contains a list of the geographic locations of the 60 TCA sites and 92 sites generated for new ATCT's and new services. Figures 4 and 5 are maps showing the locations of the TCA's and the randomly selected future terminal sites.

**c. Service Volume Dimensions**

Service volume radius and altitude are also important parameters in the assignment process. To simplify the generation of the future frequency environment, all new requirements were assumed to have circular service volumes with the following radii and altitudes:

- |                           |                                           |
|---------------------------|-------------------------------------------|
| 1. High Altitude En Route | 45,000 feet (13500 m) at 100 nmi (184 km) |
| 2. Low Altitude En Route  | 18,000 feet (5400 m) at 60 nmi (111 km)   |
| 3. Terminals              | 12,500 feet (3750 m) at 30 nmi (55 km)    |

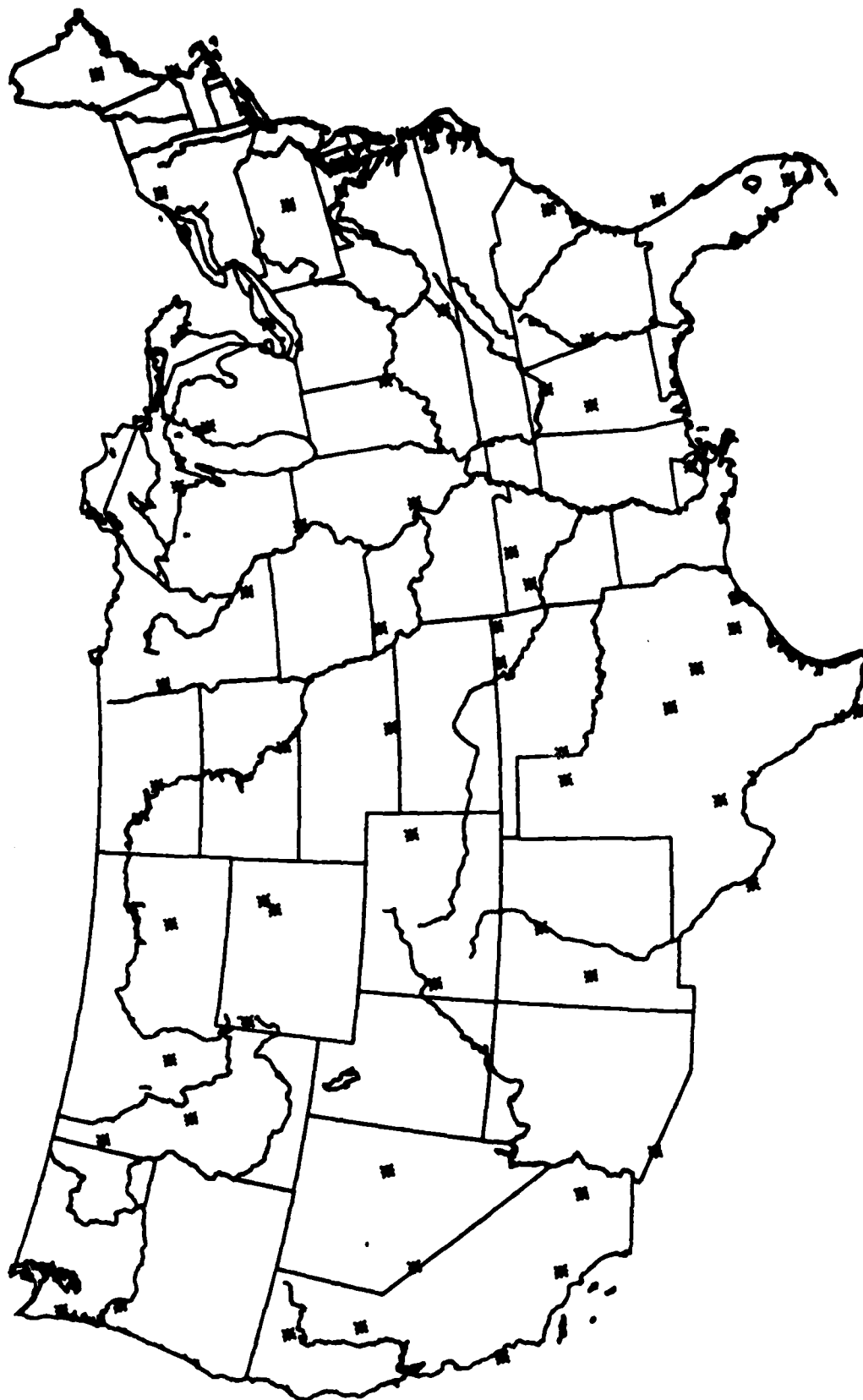
Service volumes #1 and #2 are of standard dimensions listed in existing FAA frequency assignment documents. Service volume #3 is an average of the standard dimensions listed for all the various types of standard terminal facilities.

**d. Future Requirements Assignment Study**

The future requirements generated above were added to the data base so that they would be assigned frequencies sequentially by year. All existing terminal requirements were fixed in frequency and the following strategies used to assign the future terminal, existing en route, and future en route requirements:



FIGURE 3  
Location of Future RCAG Sites



**FIGURE 4**  
Location of Existing and Future TCA's

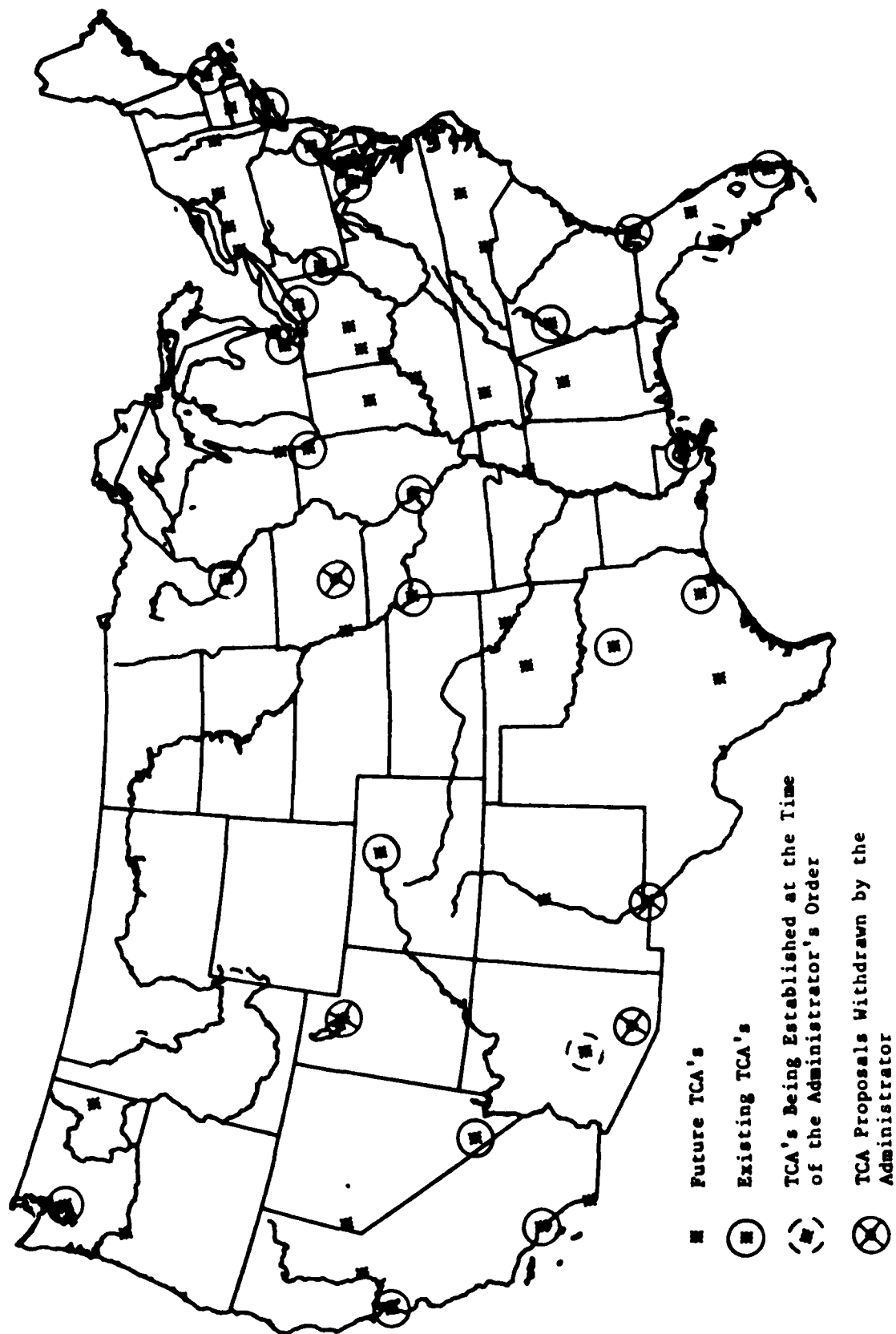
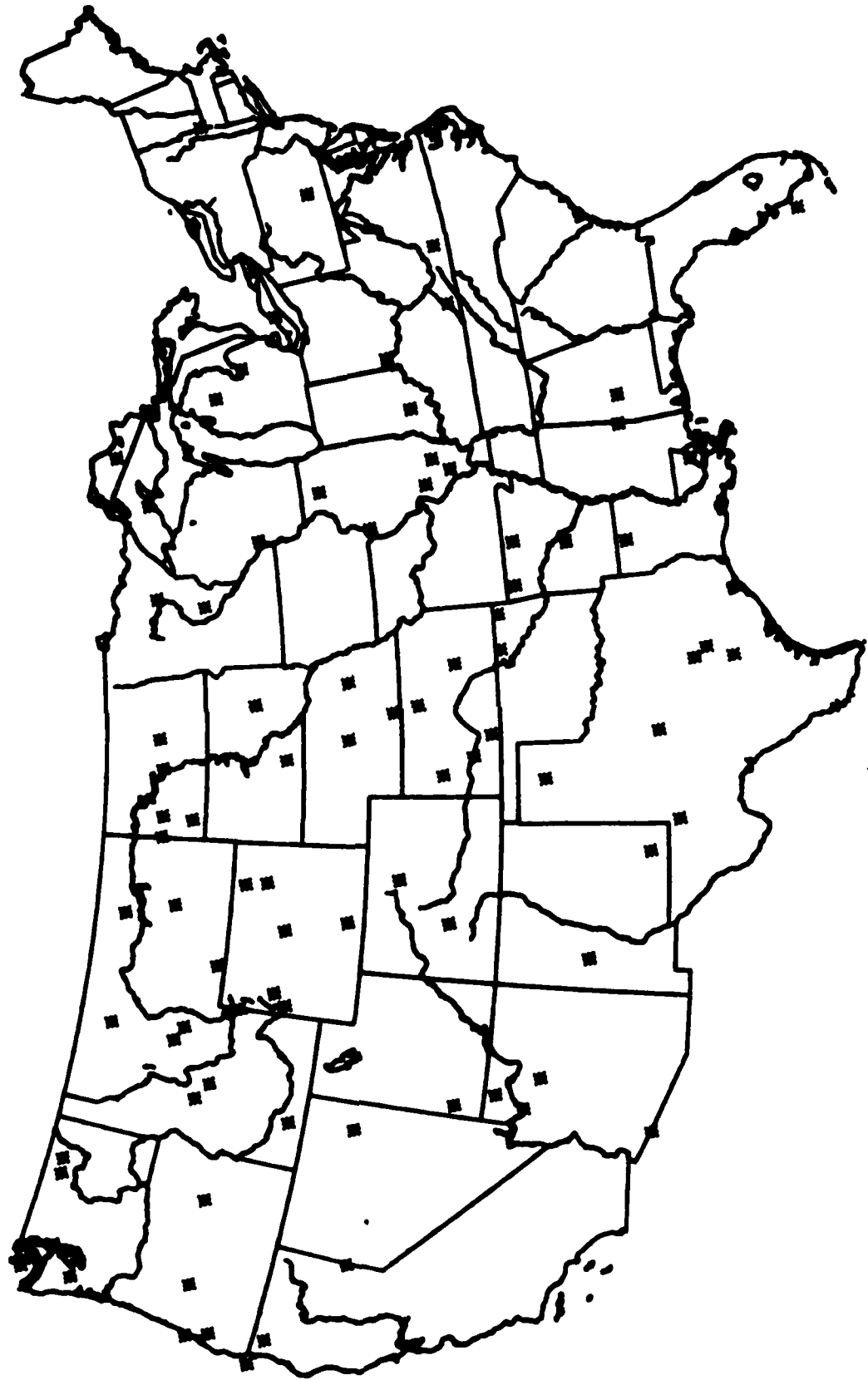


FIGURE 5  
Location of Future ATC  
Terminal Facilities



1. Future terminal requirements were assigned on any 50 kHz spaced frequency; existing low altitude en route requirements were fixed in frequency; future low altitude en route requirements were assigned on any 50 kHz spaced frequency; and all existing and future high altitude en route requirements were assigned on any 25 kHz spaced frequency. This assignment simulates the existing procedure where high altitude en route requirements are shifted to 25 kHz spaced channels to accommodate a new terminal requirement.
2. Future terminal requirements were assigned on any 50 kHz spaced frequency; all existing and future en route requirements were assigned on any 25 kHz spaced frequency. This assignment simulates how the present assignment procedure would probably be extended when low altitude en route facilities were made eligible for 25 kHz spaced frequencies.
3. This assignment was the same as Number 1 except that all existing and future high altitude en route requirements were forced on to odd 25 kHz frequencies.
4. This assignment was the same as Number 2 except that all existing and future en route requirements were forced on to odd 25 kHz frequencies.

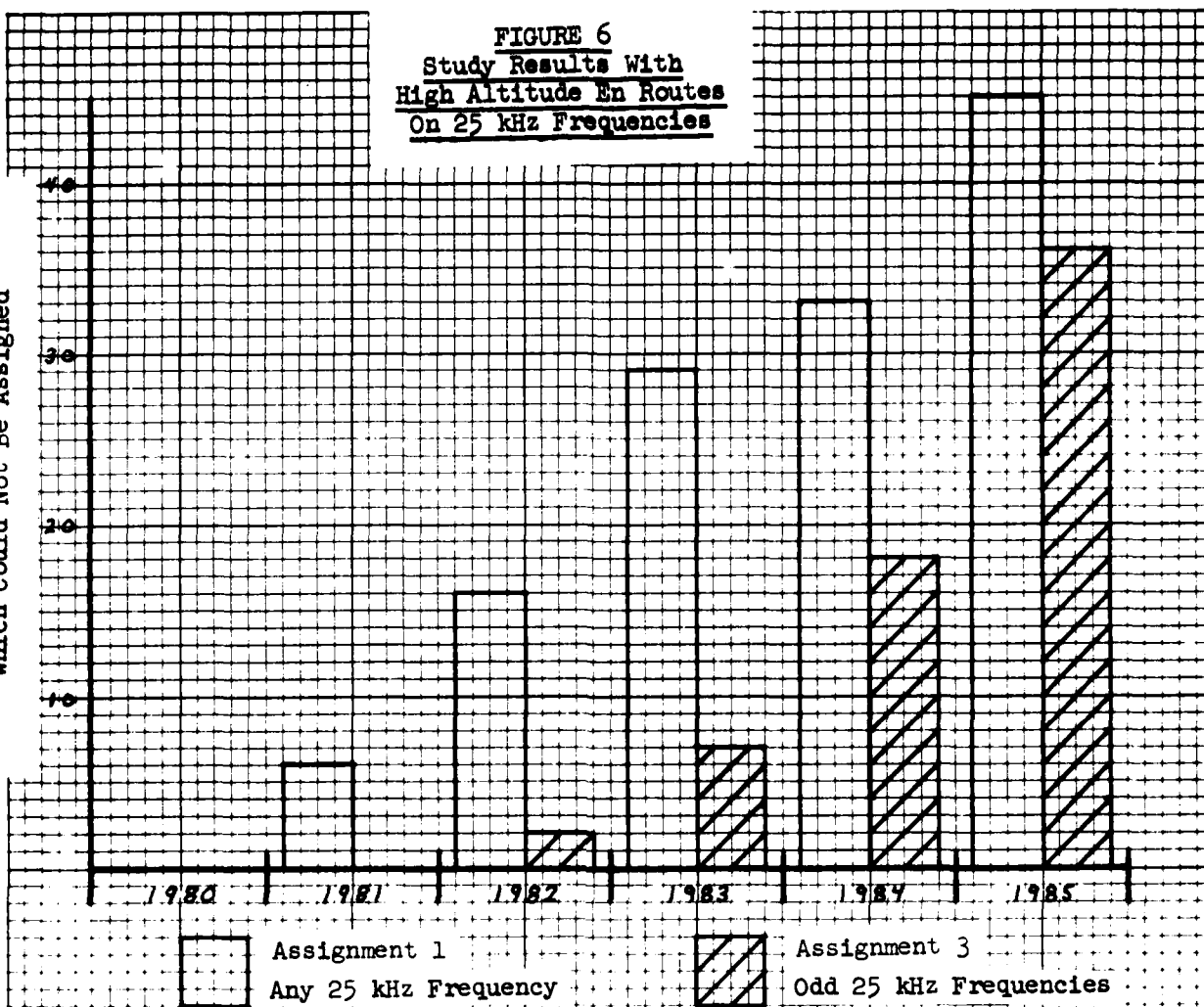
Again, the standard intersite and cosite interference protection criteria were used to assign terminal requirements on the lowest possible interference free frequency and en route requirements on the highest.

e. Results of the Future Requirements Assignment Study

Figures 6 and 7 are bar charts illustrating the number of requirements for which assignments could not be made each year from the end of 1980 through the end of 1985. Figure 6 is a comparison of Assignments 1 and 3 while Figure 7 compares Assignments 2 and 4. An examination of Assignment 1 in Figure 6 shows that by the end of 1981, all anticipated requirements cannot be assigned if only high altitude en route requirements are eligible for 25 kHz spaced channels. Therefore, beginning in 1982, 25 kHz assignments should be made for low altitude en route requirements. An examination of Assignment 2 in Figure 7 shows that by the end of 1983, all anticipated frequency requirements cannot be assigned if only en route requirements are eligible for 25 kHz spaced channels. Therefore beginning in 1984, 25 kHz assignments should be made for terminal requirements. Assignments 3 and 4 in Figures 6 and 7 respectively, illustrate the benefit of forcing requirements which are eligible (this includes low altitude en routes after 1982) on to the odd 25 kHz frequencies.

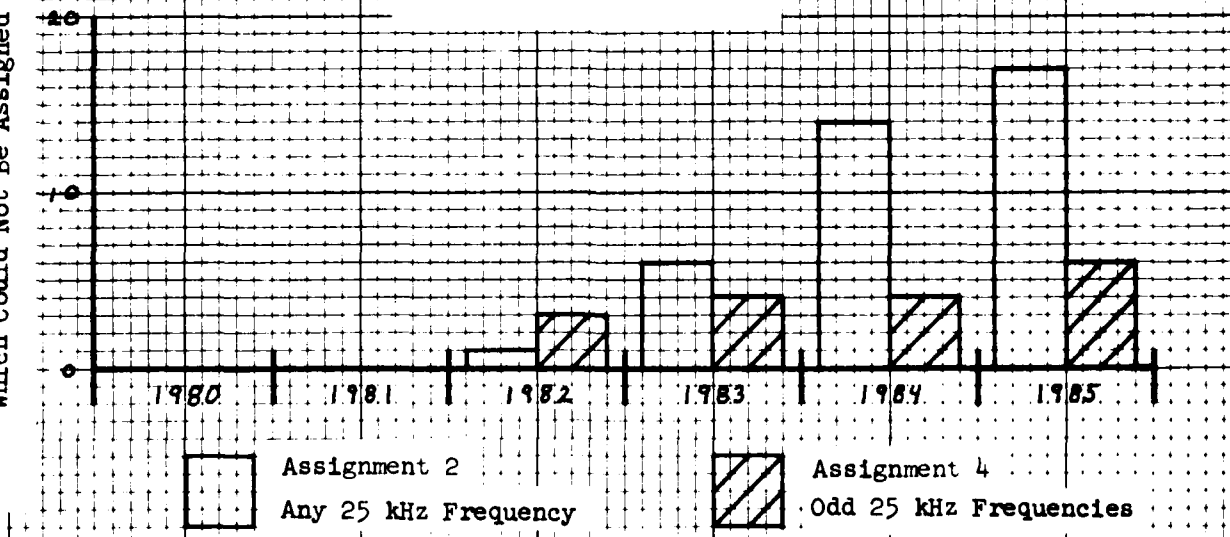
**FIGURE 6**  
Study Results With  
High Altitude En Routes  
On 25 kHz Frequencies

Number of New Requirements for the Year  
 Which Could Not Be Assigned



**FIGURE 7**  
Study Results With  
All En Routes  
On 25 kHz Frequencies

Number of New Requirements for the Year  
 Which Could Not Be Assigned



## 7. CONCLUSIONS

- a. The studies performed above were idealized examinations of possible future environments. There were several possible variables which could not be accounted for. For example, frequency requirements resulting from other proposed new services such as positive control of helicopter operations, automatic weather broadcasts, and Automatic Terminal Systems could not be predicted and may or may not be accounted for in normal growth. Other factors which affect the number of requirements which can be assigned (such as increases in the number of FM and TV broadcast stations and in the number of Canadian and Mexican assignments) were not included because information on projected growth in the number of these facilities was not available.
- b. The studies which were performed for future environments indicated that a change to 25 kHz channel spacing for low altitude en route requirements was necessary beginning in 1982. The future requirement studies indicated that a further change to 25 kHz channel spacing for terminal requirements would be necessary beginning in 1984. This study also indicated the benefit of forcing all facilities eligible for 25 kHz spaced channels (including low en route facilities after 1982) on to the odd 25 kHz frequencies. However, because of the impracticality of reassigning every en route requirement and because of the unaccounted variables discussed above, the years 1982 and 1984 should be milestones for further implementation of 25 kHz channel spacing in low altitude en route and terminal assignments respectively.

## 8. RECOMMENDATIONS

- a. Public Notice of FAA's intention to further implement 25 kHz channel spacing in low altitude en route and terminal sectors starting in January 1982 and January 1984 respectively, should be made as soon as possible. Public comments should be invited.
- b. Maximum use of the odd 25 kHz frequencies should be made when and where possible.
- c. An equipment replacement program similar to that instituted for RCAG sites between 1973 and 1976 should be established as soon as possible to prepare terminal sectors for the change to 25 kHz channel spacing by 1984.

## 9. REFERENCES

- a. Beall, L., R. Crisifulli, J. Morrow, and S. VanGaasbeck, An Automated FAA Frequency Assignment System, FAA-RD-73-184, December 1973.
- b. Department of Transportation, Federal Aviation Administration, "Notice of Policy Decision Regarding Air Traffic Control Radio Frequency Assignment," Federal Register, Docket 73-11127, June 5, 1973.
- c. Department of Transportation, Federal Aviation Administration, Plan for Enhanced Safety of Flight Operations in the National Airspace System, December 27, 1978.
- d. Department of Transportation, Federal Aviation Administration, "Proposed Integration of 25 kHz Spaced Channels into the National Airspace System: Notice of Invitation for Comments," Federal Register, Docket 72-1865, February 9, 1972.
- e. Federal Aviation Agency, VHF/UHF Air/Ground Communications Frequency Engineering Handbook, Order 6050.4A, June 1965.
- f. Hensler, Thomas, Automated VHF Frequency Assignment System (FAS) for FAA Air Traffic Control Communications, FAA-RD-76-14 and FAA-RD-76-14 Supp. 1, February 1976 and July 1978.
- g. Hensler, Thomas, FAA VHF ATC Frequency Assignment Plans, ECAC-CR-79-015, January 1979.
- h. Hensler, Thomas, FAA VHF Spectrum Utilization Study, ECAC-CR-80-008, February 1980.
- i. IFR Aircraft Handled, FAA-AVP-76-13, November 1976.
- j. U.S. Department of Transportation News, "FAA Drops Airspace Proposals," FAA-59-79, September 7, 1979.

## APPENDIX A    TERMINAL CONTROL AREAS

### 1. Existing TCA's

|                                          |                            |
|------------------------------------------|----------------------------|
| Atlanta, Georgia                         | Denver, Colorado           |
| Boston, Massachusetts                    | Detroit, Michigan          |
| Chicago, Illinois                        | Houston, Texas             |
| Dallas-Fort Worth, Texas                 | Kansas City, Missouri      |
| Los Angeles, California                  | Las Vegas, Nevada          |
| Miami, Florida                           | Minneapolis, Minnesota     |
| New York (Kennedy, LaGuardia,<br>Newark) | New Orleans, Louisiana     |
| San Francisco, California                | Philadelphia, Pennsylvania |
| Washington, D. C.                        | Seattle, Washington        |
| Cleveland, Ohio                          | St. Louis, Missouri        |
|                                          | Pittsburgh, Pennsylvania   |

### 2. Proposed TCA's

#### a. Phase I

|                         |                         |
|-------------------------|-------------------------|
| Memphis, Tennessee      | Tulsa, Oklahoma         |
| Orlando Florida         | * El Paso, Texas        |
| Portland, Oregon        | * Tucson, Arizona       |
| * Des Moines, Iowa      | * Salt Lake City, Utah  |
| Spokane, Washington     | San Diego, California   |
| Sacramento, California  | Albuquerque, New Mexico |
| Rochester, New York     | San Antonio, Texas      |
| * Jacksonville, Florida | Albany, New York        |

#### b. Phase II

|                           |                                |
|---------------------------|--------------------------------|
| * San Juan, Puerto Rico   | Omaha, Nebraska                |
| Fort Lauderdale, Florida  | Windsor-Locks, Connecticut     |
| Buffalo, New York         | Dulles, Virginia               |
| Baltimore, Maryland       | Columbus, Ohio                 |
| Cincinnati, Ohio          | Dayton, Ohio                   |
| Charlotte, North Carolina | Norfolk, Virginia              |
| * Kahului, Hawaii         | Syracuse, New York             |
| Nashville, Tennessee      | Raleigh-Durham, North Carolina |
| Louisville, Kentucky      | Birmingham, Alabama            |
| Oklahoma City, Oklahoma   |                                |

#### c. Phase III

|                       |                          |
|-----------------------|--------------------------|
| Milwaukee, Wisconsin  | * Anchorage, Alaska      |
| * Lihue, Hawaii       | West Palm Beach, Florida |
| Indianapolis, Indiana | Reno, Nevada             |

### 3. TCA's Presently Being Implemented

- \* Honolulu, Hawaii
- \* Tampa, Florida
- \* Phoenix, Arizona



#### 4. Changes Made to Data Base for TCA Assignment Study.

##### a. Phase I

| City            | Lat/Long.<br>(deg,min,sec)<br>for additions          | Changes or Additions to Data Base |              |                    |              |
|-----------------|------------------------------------------------------|-----------------------------------|--------------|--------------------|--------------|
|                 |                                                      | Func.                             | IRAC ID      | New Service Volume |              |
|                 |                                                      |                                   |              | Radius (NMI)       | Height (fee) |
| Memphis, TN     | 35 03 52<br>89 58 57                                 | ATIS                              | 702417       | 60                 | 20,000       |
|                 |                                                      | App                               | 692219       | 60                 | 20,000       |
|                 |                                                      | Dep                               | 723473       | 60                 | 20,000       |
| Orlando, FL     | 28 33 09<br>81 20 21                                 | ATIS                              | 732637       | 60                 | 20,000       |
|                 |                                                      | Dep                               | 712014       | 60                 | 20,000       |
|                 |                                                      | App                               | 702513       | 60                 | 20,000       |
|                 |                                                      | Grd Con                           | added        | 2                  | 100          |
| Portland, OR    | 45 35 50<br>122 36 34                                | ATIS                              | added        | 60                 | 20,000       |
|                 |                                                      |                                   |              |                    |              |
| Spokane, WA     | 47 40 50<br>117 19 08<br>or<br>47 37 14<br>117 39 17 | ATIS                              | 741617       | 60                 | 20,000       |
|                 |                                                      | Grd Con                           | added        | 2                  | 100          |
|                 |                                                      | Dep                               | added        | 60                 | 20,000       |
|                 |                                                      |                                   |              |                    |              |
| Sacramento, CA  | 38 41 59<br>121 35 33<br>or<br>38 40 20<br>121 24 37 | ATIS                              | 772522       | 60                 | 20,000       |
|                 |                                                      | App                               | 672036       | 60                 | 20,000       |
|                 |                                                      | Dep                               | added site 2 | 60                 | 20,000       |
|                 |                                                      | Loc Con                           | added site 1 | 30                 | 10,000       |
|                 |                                                      |                                   |              |                    |              |
| Rochester, NY   | 43 07 35<br>77 40 01<br>or<br>43 07 01<br>77 40 01   | App                               | 700884       | 60                 | 20,000       |
|                 |                                                      | Dep                               | 693259       | 60                 | 20,000       |
|                 |                                                      | ATIS                              | added        | 60                 | 20,000       |
|                 |                                                      | Loc Con                           | added        | 30                 | 10,000       |
|                 |                                                      |                                   |              |                    |              |
| Tulsa, OK       | 36 11 56<br>95 53 10                                 | App                               | 756469       | 60                 | 20,000       |
|                 |                                                      | Dep                               | 722068       | 60                 | 20,000       |
|                 |                                                      | Loc Con                           | 691167       | 30                 | 10,000       |
| San Diego, CA   | 32 41 00<br>117 14 00                                | ATIS                              | 724234       | 60                 | 20,000       |
|                 |                                                      | App                               | 770150       | 60                 | 20,000       |
|                 |                                                      | Dep                               | added        | 60                 | 20,000       |
| Albuquerque, NM |                                                      | ATIS                              | 741629       | 60                 | 20,000       |
|                 |                                                      | App                               | 756322       | 60                 | 20,000       |
| San Antonio, Tx |                                                      | ATIS                              | 757188       | 60                 | 20,000       |
| Albany, NY      | 42 44 40<br>73 49 20                                 | ATIS                              | 733214       | 60                 | 20,000       |
|                 |                                                      | App                               | 723439       | 60                 | 20,000       |
|                 |                                                      | App                               | 682988       | 60                 | 20,000       |
|                 |                                                      | Loc Con                           | added        | 30                 | 10,000       |

b. Phase II

| City                  | Lat/Long<br>(deg,min,sec)<br>for additions | Changes or Additions to Data Base |         |                    |               |
|-----------------------|--------------------------------------------|-----------------------------------|---------|--------------------|---------------|
|                       |                                            | Func.                             | IRAC ID | New Service Volume |               |
|                       |                                            |                                   |         | Radius(nmi)        | Height (feet) |
| Ft. Lauderdale<br>FL. | 26 04 28                                   | App                               | 691916  | 60                 | 20,000        |
|                       | 80 09 01                                   | Dep                               | 713700  | 60                 | 20,000        |
|                       |                                            | ATIS                              | added   | 60                 | 20,000        |
| Buffalo, NY           | 42 56 11                                   | App                               | 741615  | 60                 | 20,000        |
|                       | 78 44 39                                   | Dep                               | 741616  | 60                 | 20,000        |
|                       |                                            | ATIS                              | added   | 60                 | 20,000        |
| Baltimore, MD         | 39 11 04                                   | App                               | 711867  | 60                 | 20,000        |
|                       | 76 40 33                                   | ATIS                              | added   | 60                 | 20,000        |
|                       |                                            | Dep                               | added   | 60                 | 20,000        |
| Cincinnati, OH        | 39 02 36                                   | Dep                               | 752266  | 60                 | 20,000        |
|                       | 84 39 52                                   | App                               | added   | 60                 | 20,000        |
|                       |                                            | ATIS                              | added   | 60                 | 20,000        |
| Charlotte, NC         | 35 12 38                                   | App                               | 773962  | 60                 | 20,000        |
|                       | 80 56 12                                   | Dep                               | 691758  | 60                 | 20,000        |
|                       |                                            | Loc Con                           | 774055  | 30                 | 10,000        |
|                       |                                            | ATIS                              | added   | 60                 | 20,000        |
| Nashville, TN         | 36 08 05                                   | ATIS                              | 712621  | 60                 | 20,000        |
|                       | 86 41 30                                   | App                               | 691439  | 60                 | 20,000        |
|                       |                                            | Dep                               | 723042  | 60                 | 20,000        |
| Louisville, KY        | 38 13 39                                   | ATIS                              | 712003  | 60                 | 20,000        |
|                       | 85 39 39                                   | Dep                               | 680810  | 60                 | 20,000        |
|                       | or                                         | App                               | 720780  | 60                 | 20,000        |
|                       | 38 11 16                                   |                                   |         |                    |               |
|                       | 85 44 08                                   |                                   |         |                    |               |
| Oklahoma City<br>OK   | four sites<br>see IRAC ID<br>records       | ATIS                              | 756698  | 60                 | 20,000        |
|                       |                                            | Loc Con                           | 757184  | 30                 | 10,000        |
|                       |                                            | Loc Con                           | 757194  | 30                 | 10,000        |
|                       |                                            | App                               | 756843  | 60                 | 20,000        |
|                       |                                            | Dep                               | 756501  | 60                 | 20,000        |
| Omaha, NB             | 41 18 38                                   | ATIS                              | 672518  | 60                 | 20,000        |
|                       | 95 54 28                                   | App                               | 773651  | 60                 | 20,000        |
|                       | or                                         | App                               | 773984  | 60                 | 20,000        |
|                       | 41 07 23                                   | Loc Con                           | 744318  | 30                 | 10,000        |
|                       | 95 55 03                                   |                                   |         |                    |               |
| Windsor-Locks<br>CN   | 41 56 22                                   | Loc Con                           | 711096  | 30                 | 10,000        |
|                       | 72 40 31                                   | App                               | 724252  | 60                 | 20,000        |
|                       |                                            | App                               | 724251  | 60                 | 20,000        |
|                       |                                            | ATIS                              | added   | 60                 | 20,000        |
|                       |                                            | Loc Con                           | added   | 30                 | 10,000        |

|                      |          |         |         |    |        |
|----------------------|----------|---------|---------|----|--------|
| Columbus, OH         | 39 59 59 | ATIS    | 713721  | 60 | 20,000 |
|                      | 82 53 44 | Dep     | 681407  | 60 | 20,000 |
|                      |          | App     | 744445  | 60 | 20,000 |
| Dayton, OH           | 39 54 10 | ATIS    | 757692  | 60 | 20,000 |
|                      | 84 13 03 | Dep     | 681406  | 60 | 20,000 |
|                      |          | App     | 711006  | 60 | 20,000 |
|                      |          | Loc Con | added   | 30 | 10,000 |
|                      |          | Grd Con | added   | 2  | 100    |
| Dulles, VA           | 38 56 31 | ATIS    | 732742  | 60 | 20,000 |
|                      | 77 25 42 | App     | 713669  | 60 | 20,000 |
|                      |          | App     | 713665  | 60 | 20,000 |
|                      |          | Loc Con | 711089  | 30 | 10,000 |
|                      |          | Loc Con | added   | 30 | 10,000 |
| Norfolk, VA          | 36 53 27 | ATIS    | 732585  | 60 | 20,000 |
|                      | 76 12 25 | App     | 691850  | 60 | 20,000 |
|                      |          | Dep     | 691849  | 60 | 20,000 |
|                      |          | Loc Con | 691193  | 30 | 10,000 |
|                      |          | Loc Con | 682542  | 30 | 10,000 |
| Syracuse, NY         | 43 06 35 | App     | 711730J | 60 | 20,000 |
|                      | 76 05 51 | App     | 682110  | 60 | 20,000 |
|                      |          | ATIS    | added   | 60 | 20,000 |
|                      |          | Loc Con | added   | 30 | 10,000 |
| Raleigh-Durham<br>NC | 35 52 01 | ATIS    | 723058  | 60 | 20,000 |
|                      | 78 47 01 | App     | 723043  | 60 | 20,000 |
|                      |          | App     | 774654  | 60 | 20,000 |
|                      |          | Loc Con | 691252  | 30 | 10,000 |
|                      |          | Loc Con | added   | 30 | 10,000 |
| Birmingham, AL       | 33 34 27 | ATIS    | 681388  | 60 | 20,000 |
|                      | 86 45 12 | App     | 760900  | 60 | 20,000 |
|                      |          | Dep     | 711737  | 60 | 20,000 |
|                      |          | Loc Con | 691304  | 30 | 10,000 |
|                      |          | Loc Con | 766934  | 30 | 10,000 |

c. Phase III

| City                   | Lat/Long.<br>(deg,min.sec)<br>for additions | Changes or Additions to Data Base |         |                    |               |
|------------------------|---------------------------------------------|-----------------------------------|---------|--------------------|---------------|
|                        |                                             | Func.                             | IRAC ID | New Service Volume |               |
|                        |                                             |                                   |         | Radius (nmi)       | Height (feet) |
| Milwaukee, WI          | 42 57 00                                    | ATIS                              | 759081  | 60                 | 20,000        |
|                        | 87 54 03                                    | Dep                               | 720769  | 60                 | 20,000        |
|                        |                                             | App                               | 691747  | 60                 | 20,000        |
| Indianapolis<br>IN     | 39 43 44                                    | ATIS                              | 672479  | 60                 | 20,000        |
|                        | 86 17 53                                    | Dep                               | 713454  | 60                 | 20,000        |
|                        |                                             | App                               | 756832  | 60                 | 20,000        |
| West Palm Beach<br>FL. | 26 41 12                                    | ATIS                              | 732867  | 60                 | 20,000        |
|                        | 80 06 14                                    | App                               | 740984  | 60                 | 20,000        |
|                        |                                             | Dep                               | 696145  | 60                 | 20,000        |
|                        |                                             | Loc Con                           | 691206  | 30                 | 10,000        |
|                        |                                             | Loc Con                           | 696146  | 30                 | 10,000        |
|                        |                                             | Grd Con                           | added   | 2                  | 100           |
| Reno, NV               | 39 31 53                                    | ATIS                              | 741958  | 60                 | 20,000        |
|                        | 119 39 18                                   | App                               | 753700  | 60                 | 20,000        |
|                        |                                             | Loc Con                           | 713938  | 30                 | 10,000        |
|                        |                                             | Loc Con                           | 743842  | 30                 | 10,000        |
|                        |                                             | Dep                               | added   | 60                 | 20,000        |

# APPENDIX B FUTURE FREQUENCY REQUIREMENT LOCATIONS

## 1. Major Terminal Areas

| <u>Site #</u> | <u>City/State</u>     | <u>Latitude</u> | <u>Longitude</u> | <u>New Site</u> |
|---------------|-----------------------|-----------------|------------------|-----------------|
| T1            | Atlanta, Ga           | 33 39 28        | 84 25 33         |                 |
| T2            | Boston, Mass.         | 42 21 55        | 71 01 06         |                 |
|               |                       | 42 27 06        | 71 02 12         |                 |
| T3            | Chicago, Ill.         | 42 00 19        | 87 54 47         |                 |
| T4            | Dallas-Ft Worth, Tex. | 32 49 51        | 97 03 57         |                 |
| T5            | Los Angeles, Cal.     | 33 57 44        | 118 22 38        |                 |
| T6            | Miami, Fla.           | 25 48 09        | 80 21 07         |                 |
| T7            | New York, NY.         | 40 48 28        | 73 05 57         |                 |
| T8            | San Francisco, Cal.   | 37 37 14        | 122 21 52        |                 |
| T9            | Washington, D. C.     | 38 54 04        | 77 13 49         |                 |
| T10           | Cleveland, Ohio       | 41 30 55        | 81 40 55         |                 |
| T11           | Denver, Colo.         | 40 11 00        | 105 08 00        |                 |
| T12           | Detroit, Mich.        | 42 13 25        | 83 21 32         |                 |
| T13           | Houston, Tex.         | 29 58 44        | 95 19 55         |                 |
| T14           | Kansas City, Kans.    | 39 08 37        | 94 36 34         |                 |
| T15           | Las Vegas, Nev.       | 36 18 00        | 115 40 00        |                 |
| T16           | Minneapolis, Minn.    | 45 03 37        | 93 20 39         |                 |
| T17           | New Orleans, La.      | 30 02 35        | 90 01 33         |                 |
| T18           | Philadelphia, Pa.     | 39 52 33        | 75 14 41         |                 |
| T19           | Pittsburgh, Pa.       | 40 32 07        | 80 13 08         |                 |
| T20           | Seattle, Wash.        | 47 31 45        | 122 18 10        | X               |
| T21           | St. Louis, Mo.        | 38 48 52        | 90 23 09         |                 |
| T22           | Memphis, Tenn.        | 35 03 01        | 89 59 01         |                 |
| T23           | Orlando, Fla.         | 28 32 42        | 81 20 29         |                 |
| T24           | Portland, Ore.        | 45 35 21        | 122 35 32        |                 |
| T25           | Des Moines, Ia.       | 41 32 30        | 93 40 23         |                 |
| T26           | Spokane, Wash.        | 47 37 14        | 117 39 17        |                 |
| T27           | Sacramento, Cal.      | 38 40 20        | 121 24 37        |                 |
| T28           | Rochester, NY.        | 43 07 01        | 77 40 01         |                 |
| T29           | Jacksonville, Fla.    | 30 28 32        | 81 39 10         |                 |
| T30           | Tulsa, Okla.          | 36 13 56        | 95 54 10         | X               |
| T31           | El Paso, Tex.         | 31 52 00        | 106 29 30        |                 |
| T32           | Tucson, Ariz.         | 32 06 46        | 110 57 18        |                 |
| T33           | Salt Lake City, Ut.   | 40 46 43        | 111 57 21        |                 |
| T34           | San Diego, Cal.       | 32 44 10        | 117 11 20        |                 |
| T35           | Albuquerque, NMex.    | 35 00 04        | 106 36 13        |                 |
| T36           | San Antonio, Tex.     | 29 32 18        | 98 28 01         |                 |
| T37           | Albany, NY.           | 42 46 40        | 73 50 20         | X               |
| T38           | Ft. Lauderdale, Fla.  | 26 11 45        | 80 09 45         |                 |
| T39           | Buffalo, NY.          | 42 58 11        | 78 45 39         |                 |
| T40           | Baltimore, Md.        | 39 10 14        | 76 40 22         |                 |

| <u>Site #</u> | <u>City/State</u>     | <u>Latitude</u> | <u>Longitude</u> | <u>New Site</u> |
|---------------|-----------------------|-----------------|------------------|-----------------|
| T41           | Cincinnati, Ohio      | 39 06 30        | 84 25 28         |                 |
| T42           | Charlotte, NCar.      | 35 14 38        | 80 57 12         |                 |
| T43           | Nashville, Tenn.      | 36 08 01        | 86 41 01         |                 |
| T44           | Louisville, Ky.       | 38 13 39        | 85 39 39         |                 |
| T45           | Oklahoma City, Okla.  | 35 37 10        | 97 38 24         |                 |
| T46           | Omaha, Neb.           | 41 18 38        | 95 54 28         |                 |
| T47           | Windsor-Locks, Conn.  | 41 58 22        | 72 41 31         | X               |
| T48           | Dulles, Vir.          | 38 58 31        | 77 26 42         | X               |
| T49           | Columbus, Ohio        | 40 04 30        | 83 04 15         |                 |
| T50           | Dayton, Ohio          | 39 48 22        | 84 05 52         |                 |
| T51           | Norfolk, Vir.         | 36 56 21        | 76 17 43         |                 |
| T52           | Syracuse, NY.         | 43 08 35        | 76 06 51         | X               |
| T53           | Raleigh-Durham, NCar. | 35 38 01        | 78 40 30         |                 |
| T54           | Birmingham, Ala.      | 33 33 57        | 86 45 04         |                 |
| T55           | Milwaukee, Wis.       | 42 55 38        | 87 53 53         |                 |
| T56           | Indianapolis, Ind.    | 39 49 47        | 86 17 41         |                 |
| T57           | West Palm Beach, Fla. | 26 40 43        | 80 10 55         |                 |
| T58           | Reno, Nev.            | 39 29 38        | 119 45 59        |                 |
| T59           | Tampa, Fla.           | 27 59 51        | 82 32 35         | X               |
| T60           | Phoenix, Ariz.        | 33 25 40        | 112 01 13        |                 |

## 2. Locations of New Air Traffic Control Towers or New Services

| <u>Site #</u> | <u>Latitude</u> | <u>Longitude</u> |
|---------------|-----------------|------------------|
| 1.            | 43 06 11        | 110 40 55        |
| 2.            | 37 48 43        | 89 10 45         |
| 3.            | 38 37 42        | 89 39 49         |
| 4.            | 42 34 14        | 79 40 34         |
| 5.            | 35 50 53        | 113 28 00        |
| 6.            | 41 37 15        | 99 42 06         |
| 7.            | 40 29 07        | 91 08 46         |
| 8.            | 32 28 37        | 88 28 38         |
| 9.            | 48 09 05        | 107 30 09        |
| 10.           | 46 20 57        | 103 09 29        |
| 11.           | 41 33 18        | 97 20 27         |
| 12.           | 41 56 30        | 124 35 20        |
| 13.           | 38 28 35        | 106 55 45        |
| 14.           | 37 17 18        | 99 38 02         |
| 15.           | 41 56 02        | 89 21 20         |
| 16.           | 37 00 15        | 80 26 37         |
| 17.           | 32 33 27        | 104 02 23        |
| 18.           | 41 30 13        | 107 05 58        |
| 19.           | 40 01 01        | 120 03 50        |
| 20.           | 47 21 14        | 123 32 58        |

| <u>Site #</u> | <u>Latitude</u> | <u>Longitude</u> |
|---------------|-----------------|------------------|
| 21.           | 29 46 43        | 97 13 36         |
| 22.           | 30 35 01        | 96 51 34         |
| 23.           | 43 12 19        | 123 56 37        |
| 24.           | 43 47 56        | 124 17 21        |
| 25.           | 37 50 02        | 100 29 03        |
| 26.           | 42 28 36        | 115 15 46        |
| 27.           | 38 19 53        | 88 42 06         |
| 28.           | 47 14 01        | 88 54 31         |
| 29.           | 44 37 49        | 105 49 26        |
| 30.           | 47 16 22        | 93 13 00         |
| 31.           | 42 52 34        | 73 13 55         |
| 32.           | 45 57 38        | 112 08 45        |
| 33.           | 25 47 34        | 82 02 43         |
| 34.           | 43 21 28        | 107 37 04        |
| 35.           | 44 06 51        | 122 20 14        |
| 36.           | 35 28 15        | 112 18 50        |
| 37.           | 31 40 17        | 102 55 47        |
| 38.           | 36 41 38        | 113 04 24        |
| 39.           | 48 04 35        | 112 27 24        |
| 40.           | 44 19 38        | 118 57 17        |
| 41.           | 46 40 59        | 106 58 34        |
| 42.           | 32 12 51        | 99 43 38         |
| 43.           | 36 58 33        | 82 46 06         |
| 44.           | 37 49 55        | 113 38 16        |
| 45.           | 47 14 49        | 103 59 29        |
| 46.           | 46 11 25        | 112 44 46        |
| 47.           | 38 16 35        | 96 50 53         |
| 48.           | 35 40 53        | 101 22 22        |
| 49.           | 34 18 41        | 107 55 45        |
| 50.           | 39 10 41        | 84 25 17         |
| 51.           | 43 58 53        | 91 06 11         |
| 52.           | 30 58 48        | 97 12 48         |
| 53.           | 44 37 13        | 84 40 28         |
| 54.           | 38 43 47        | 86 34 32         |
| 55.           | 44 35 22        | 106 13 05        |
| 56.           | 36 10 42        | 92 18 23         |
| 57.           | 39 27 40        | 98 24 27         |
| 58.           | 32 42 47        | 92 45 51         |
| 59.           | 47 23 48        | 99 34 50         |
| 60.           | 45 13 52        | 109 21 43        |

| <u>Site #</u> | <u>Latitude</u> | <u>Longitude</u> |
|---------------|-----------------|------------------|
| 61.           | 36 51 33        | 96 25 06         |
| 62.           | 30 27 23        | 90 04 48         |
| 63.           | 44 23 31        | 111 02 13        |
| 64.           | 43 39 37        | 83 36 55         |
| 65.           | 40 35 04        | 115 04 59        |
| 66.           | 43 58 45        | 105 42 51        |
| 67.           | 48 34 20        | 118 46 55        |
| 68.           | 47 14 42        | 103 04 09        |
| 69.           | 40 01 26        | 105 18 55        |
| 70.           | 45 49 54        | 93 44 26         |
| 71.           | 36 14 45        | 93 59 49         |
| 72.           | 42 17 22        | 81 44 05         |
| 73.           | 38 46 33        | 101 11 01        |
| 74.           | 36 51 04        | 95 03 33         |
| 75.           | 43 31 54        | 100 29 55        |
| 76.           | 41 41 01        | 123 32 46        |
| 77.           | 32 09 46        | 113 45 54        |
| 78.           | 40 14 35        | 98 40 11         |
| 79.           | 47 17 00        | 100 55 59        |
| 80.           | 37 10 46        | 94 49 56         |
| 81.           | 44 25 50        | 98 08 57         |
| 82.           | 44 56 07        | 114 17 05        |
| 83.           | 32 21 31        | 87 25 29         |
| 84.           | 40 21 31        | 77 09 25         |
| 85.           | 34 34 06        | 92 32 27         |
| 86.           | 48 47 10        | 123 48 36        |
| 87.           | 48 29 16        | 119 27 11        |
| 88.           | 42 23 23        | 81 49 17         |
| 89.           | 41 35 25        | 123 24 07        |
| 90.           | 45 16 13        | 115 00 11        |
| 91.           | 43 28 35        | 110 14 03        |
| 92.           | 47 59 13        | 86 30 42         |

### 3. Location of Future RCAG Sites.

| <u>RCAG #</u> | <u>Latitude</u> | <u>Longitude</u> |
|---------------|-----------------|------------------|
| R 1.          | 38 17 49        | 118 49 38        |
| R 2.          | 47 02 11        | 96 26 57         |
| R 3.          | 40 21 55        | 94 42 37         |
| R 4.          | 45 51 47        | 123 01 27        |
| R 5.          | 44 18 25        | 92 43 02         |
| R 6.          | 39 05 56        | 77 19 18         |
| R 7.          | 30 31 02        | 101 49 51        |
| R 8.          | 35 04 12        | 100 54 22        |
| R 9.          | 44 06 37        | 110 44 31        |
| R10.          | 44 44 52        | 85 27 24         |
| R11.          | 29 39 48        | 104 44 38        |
| R12.          | 34 23 12        | 86 29 55         |
| R13.          | 47 35 25        | 116 37 53        |
| R14.          | 47 20 41        | 123 56 27        |
| R15.          | 29 43 58        | 95 55 29         |



| <u>RCAG #</u> | <u>Latitude</u> | <u>Longitude</u> |
|---------------|-----------------|------------------|
| R 16          | 42 46 46        | 70 37 12         |
| R 17.         | 39 39 25        | 102 52 23        |
| R 18.         | 35 48 43        | 106 17 59        |
| R 19.         | 42 26 02        | 90 12 10         |
| R 20.         | 35 44 01        | 93 33 02         |
| R 21.         | 43 27 57        | 99 19 21         |
| R 22.         | 40 46 16        | 77 17 37         |
| R 23.         | 39 31 00        | 115 36 53        |
| R 24.         | 44 21 21        | 75 14 17         |
| R 25.         | 38 47 26        | 108 30 40        |
| R 26.         | 36 49 07        | 75 52 27         |
| R 27.         | 41 09 08        | 73 01 43         |
| R 28.         | 39 21 09        | 121 18 48        |
| R 29.         | 41 12 01        | 122 13 24        |
| R 30.         | 35 08 28        | 99 54 48         |
| R 31.         | 34 05 03        | 115 25 51        |
| R 32.         | 33 07 28        | 87 21 42         |
| R 33.         | 29 51 01        | 80 39 45         |
| R 34.         | 43 39 22        | 106 04 08        |
| R 35.         | 35 27 29        | 121 16 03        |
| R 36.         | 26 15 57        | 99 09 40         |
| R 37.         | 32 51 18        | 84 59 26         |
| R 38.         | 45 57 40        | 87 46 27         |
| R 39.         | 39 09 40        | 84 58 14         |
| R 40.         | 38 53 36        | 89 54 32         |
| R 41.         | 31 51 35        | 98 30 07         |
| R 42.         | 45 16 13        | 115 00 11        |
| R 43.         | 47 17 00        | 100 55 59        |
| R 44.         | 40 14 35        | 98 40 11         |
| R 45.         | 32 09 46        | 113 45 54        |
| R 46.         | 36 51 04        | 95 03 33         |
| R 47.         | 42 17 22        | 81 44 05         |
| R 48.         | 43 58 45        | 105 42 51        |
| R 49.         | 30 27 23        | 90 04 48         |
| R 50.         | 36 51 33        | 96 25 06         |
| R 51.         | 36 10 42        | 92 18 23         |
| R 52.         | 30 58 48        | 97 12 48         |
| R 53.         | 34 18 41        | 107 55 45        |
| R 54.         | 46 11 25        | 112 44 46        |
| R 55.         | 36 58 33        | 82 46 06         |
| R 56.         | 46 40 59        | 106 58 34        |
| R 57.         | 44 56 18        | 69 32 24         |
| R 58.         | 33 09 16        | 80 01 48         |
| R 59.         | 34 20 02        | 118 05 56        |
| R 60.         | 25 50 42        | 80 58 30         |

#### 4. Requirements Added to Data Base by Year.

| Year | Number of<br>New Frequencies<br>Per Site | Function      | Site #  | Total<br>for<br>Year |
|------|------------------------------------------|---------------|---------|----------------------|
| 1980 | 2                                        | High En Route | R1-R9   | 124                  |
|      | 1                                        | High En Route | R10     |                      |
|      | 2                                        | Low En Route  | R1-R12  |                      |
|      | 1                                        | Terminal      | T1-T60  |                      |
|      | 2                                        | Terminal      | 1-11    |                      |
| 1981 | 2                                        | High En Route | R11-R20 | 130                  |
|      | 1                                        | Low En Route  | R10     |                      |
|      | 2                                        | Low En Route  | R13-R24 |                      |
|      | 1                                        | Terminal      | T1-T60  |                      |
|      | 2                                        | Terminal      | 12-23   |                      |
| 1982 | 1                                        | Terminal      | 24      | 136                  |
|      | 2                                        | High En Route | R21-R30 |                      |
|      | 1                                        | High En Route | R31     |                      |
|      | 2                                        | Low En Route  | R25-R37 |                      |
|      | 1                                        | Terminal      | T1-T60  |                      |
| 1983 | 2                                        | Terminal      | 25-38   | 140                  |
|      | 1                                        | Terminal      | 24      |                      |
|      | 1                                        | High En Route | R31     |                      |
|      | 2                                        | High En Route | R32-R41 |                      |
|      | 2                                        | Low En Route  | R38-R50 |                      |
| 1984 | 1                                        | Low En Route  | R51     | 147                  |
|      | 1                                        | Terminal      | T1-T60  |                      |
|      | 2                                        | Terminal      | 39-54   |                      |
|      | 2                                        | High En Route | R42-R52 |                      |
|      | 1                                        | Low En Route  | R51     |                      |
| 1985 | 2                                        | Low En Route  | R52-R60 | 153                  |
|      | 1                                        | Low En Route  | R1-R9   |                      |
|      | 1                                        | Low En Route  | R10     |                      |
|      | 1                                        | Terminal      | T1-T60  |                      |
|      | 2                                        | Terminal      | 55-72   |                      |
| 1985 | 2                                        | High En Route | R53-R60 | 153                  |
|      | 2                                        | High En Route | R12-R14 |                      |
|      | 1                                        | High En Route | R15     |                      |
|      | 2                                        | Low En Route  | R16-R30 |                      |
|      | 1                                        | Terminal      | T1-T60  |                      |
| 1985 | 2                                        | Terminal      | 73-92   | 153                  |
|      | 2                                        | Terminal      | 73-92   |                      |

## APPENDIX C ACRONYMS

|        |   |                                               |
|--------|---|-----------------------------------------------|
| ACES   | - | Adaption Controlled Environment System        |
| ARINC  | - | Aeronautical Radio Incorporated               |
| ATC    | - | air traffic control                           |
| ATCT   | - | Air Traffic Control Tower                     |
| CARSAM | - | Caribbean and South American                  |
| dB     | - | decibels                                      |
| ECAC   | - | Electromagnetic Compatibility Analysis Center |
| FAA    | - | Federal Aviation Administration               |
| FCC    | - | Federal Communications Commission             |
| FM     | - | frequency modulation                          |
| ICAO   | - | International Civil Aviation Organization     |
| IFR    | - | Instrument Flight Rules                       |
| IRAC   | - | Interdepartmental Radio Advisory Committee    |
| kHz    | - | kiloHertz                                     |
| km     | - | kilometer                                     |
| m      | - | meter                                         |
| MHz    | - | MegaHertz                                     |
| nmi    | - | nautical mile                                 |
| RCAG   | - | Remote Communications Air-Ground              |
| TCA    | - | Terminal Control Area                         |
| TSV    | - | Tailored Service Volume                       |
| TV     | - | television                                    |
| UHF    | - | Ultra High Frequency                          |
| VHF    | - | Very High Frequency                           |