SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

This section contains a summary of the conclusions and recommendations resulting from the investigation of IRAC tasks (IRAC Doc. 21512) related to the 2700-2900 MHz band which were assigned to the IRAC Technical Subcommittee. A detailed investigation into the feasibility of accommodating new systems planned for the 2700-2900 MHz band was conducted by the TSC Working Group 1. Information was obtained on the present and projected usage of the 2700-2900 MHz band through calender year 1989. Other areas investigated by the Working Group pertaining to the 2700-2900 MHz band included:

1. Rules and regulations.
2. Identification of heavily used areas and radar distance separation statistics.
3. Nominal radar equipment characteristics of existing and future planned systems.
4. Frequency-distance separation criteria for new systems planned for the band.
5. Emission spectrum characteristics of various transmitter output tube devices.
6. Adequacy of the RSEC in light of existing and future planned systems.
7. Environment signal characteristics (pulse width, pulse repetition frequency, and expected signal levels) which new radars may have to contend with in performing their operational requirements.

The above areas are discussed in detail in Sections 3 through 6 of this report.

CONCLUSIONS

Present Environment

The following are conclusions on the present environment in the 2700-2900 MHz band:

1. There are approximately 627 radars in the 2700-2900 MHz band. The major users of the band are the Air Force and FAA with 35.4 and 35.2 percent, respectively. Other users of the band are the Department of the Navy and Department of Commerce with 11.6 and 10.8 percent, respectively. The distribution of the radars by service are: 61.9 percent Aeronautical Radionavigation, 11.3 percent Meteorological Aids and 16.3 percent Radiolocation. Experimental stations account for 10.3 percent.

2. There are certain areas in the United States where it is difficult to accommodate new radars in the 2700-2900 MHz band. Areas where there are numerous radar deployments are the East coast megalopolis (Boston, Massachusetts to Washington, D.C.) and West coast areas of San Francisco, Los Angeles, and San Diego, California. Other areas which are heavily used include: Oklahoma City, Oklahoma and St. Louis, Missouri. Also large metropolitan areas near military bases are heavily used, such as: Miami, Jacksonville, and Pensacola, Florida; Millington, Tennessee; Norfolk, Virginia and Phoenix, Arizona. Figure 8 shows the designated heavily used areas. Approximately 35 percent of the radar assignments are in the designated heavily used areas.

3. An investigation into separation distances between radars revealed that 25 percent of the radars in the band have at least one radar within two statute miles (collocated condition). Also 55 percent of the radars in the band have at least one radar within 15 statute miles. These radar separation distance statistics indicate the need for well designed radar systems in order to accommodate new Government agency requirements in the band.

Future Environment

The following are conclusions on the future environment in the 2700-2900 MHz band projected for the 1980's:

1. The number of radar systems operating in the 2700-2900 MHz band will not increase in the 1980's. However, the number of radar systems transmitting on dual channels simultaneously may increase from 85 to 242 resulting in an approximate 22% increase in the number of operating channels by 1989.

2. The Air Force and the Navy plan to replace many of their Ground Control Approach (GCA) radars in the 1980's. GCA nomenclatures planned for full or partial replacement include: AN/CPN-4; AN/FPN-47, 48, and 55; and AN/MPN-11, 13, and 14. These GCA radars are scheduled to be replaced by the Air Force AN/GPN-20 and Navy AN/GPN-27 radars. The AN/GPN-20 and AN/GPN-27 are versions of the FAA ASR-7 and ASR-8 radars respectively.

3. There are two major new radar systems planned for the 2700-2900 MHz band in the 1980's. The FAA plans to replace all 96 of the ASR-4, ASR-5, and ASR-6 radars with ASR-7/8 or new ASR-9 radar systems which are scheduled to be deployed in 1986. The National Weather Service (NWS) of the Department of Commerce plans to replace their weather radars (WSR-57 and WSR-74s) with the NEXRAD radar system beginning in 1986. The FAA and Air Force also plan to deploy the NEXRAD radar system. By 1990, 135 NEXRAD systems are projected to be deployed by the NWS, FAA and Air Force.

4. The ASR-9 and NEXRAD system can be collocated (less than two mile separation distance) if waveguide filters are used and the radars can be separated in frequency by approximately 60 MHz. There are presently 18 radar sites in the United States where FAA and NWS radars are collocated.

5. The receivers of the ASR-9 and NEXRAD radar systems will use doppler processing and adaptive thresholding techniques. These types of receiver signal processing may be more susceptible to interference from other radars. However, the use of interference suppression circuitry can mitigate this susceptibility to interference.

Radar Spectrum Engineering Criteria (RSEC)

The current RSEC was reviewed as to its appropriateness in light of the existing radars and those planned for the future in the 2700-2900 MHz band. Also measurements of conventional magnetron, coaxial magnetron and klystron transmitter emission spectrum characteristics were made with the Radio Spectrum Measurement Systems (RSMS). Investigations of these areas led to the following conclusions related to the current RSEC:

1. Based on frequency-distance calculations and radar separation distance statistics, it was concluded that the current RSEC is adequate in some situations, but not adequate for approximately 55 percent of the assignments. These difficulties occur in heavily used areas and under collocated conditions. It should be noted that this does not imply that 55 percent of the radars in the band are presently receiving interference. This finding is based on the RSEC emission spectrum bounds, and an INR = 0 criterion (No Interference). As a result of this finding, the opinion of the Working Group was that appropriate changes to the current RSEC would enhance the accommodation of new radar systems in the 2700-2900 MHz band.

2. A conventional magnetron tube cannot meet the current RSEC Column B criteria without using a waveguide filter due to the inherent frequency pulling characteristics of the tube during the risetime of the modulating pulse.

3. The coaxial magnetron and klystron can meet the present RSEC column B criteria.

4. The noise floor level specified in the RSEC is approximately 60 dB down for typical parameters of radars in the 2700-2900 MHz band. The measured noise floor level of conventional and coaxial magnetron is approximately 70-75 dB down from the fundamental level, and the noise floor level of a klystron is approximately 110-115 dB down from the fundamental level. Therefore, for radars in the 2700-2900 MHz band the present RSEC noise floor level of 60 dB is conservative.

Spectrum Efficiency

More efficient use of the 2700-2900 MHz band can be achieved by incorporating Electromagnetic Compatibility (EMC) provisions in the design of the radar systems. For example:

1. Waveguide filters can be used to achieve more efficient use of the 2700-2900 MHz band. Narrower emission spectrum with lower spurious characteristics than the present RSEC can be achieved by the use of waveguide filters. Waveguide filters can be used with conventional magnetrons, coaxial magnetrons or klystrons to achieve up to an 80 dB per decade fall-off from the present RSEC 40 dB bandwidth.

2. The klystron transmitter output tube has significantly cleaner emission spectrum characteristics than the conventional magnetron or coaxial magnetron; thus permitting more efficient use of the band. Also it is easier to change the transmitter output power level in klystrons to permit more efficient use of the band.

3. The use of receiver interference suppression circuitry in radar systems will permit more efficient use of the band. Electromagnetic environmental signal characteristics to be considered in the design of receiver interference suppression circuitry of radar systems deployed in designated heavily used area and under collocated conditions are:

   Peak Interference-to-Noise Ratio at IF Output: $\leq$ 50 dB
   Pulse width: 0.5 to 4.0 us
   PRF : 100 to 2000 pps

The use of waveguide filters, variable transmitter power and receiving interference suppression circuitry may result in trade-offs in system performance such as: probability of detection, desired signal sensitivity, target azimuth shift, target resolution, etc. However, these trade-offs are generally minimal when the interference suppression circuitry is initially designed into the system.

Environmental Factors

In addition to the number of equipments in designated heavily used areas, there are environmental factors which contribute to the congestion of the 2700-2900 MHz band. Environmental factors which contribute to congestion are propagation anomalies such as ducting and multipathing. The following are conclusions related to these propagation anomalies, and how they affect the utilization of the band:

1. The ducting of microwave energy can complicate the problem of electromagnetic compatibility between radar systems by enhancing potential interfering signal levels. Several of the designated heavily used areas are in areas where the occurrence of elevated ducts is greater than 30 percent for all hours of the year. In some of the coastal areas, ducting occurs 50-60 percent for all hours of the worst month.

2. The FAA regional frequency managers take into consideration ducting in making frequency assignments in the 2700-2900 MHz band. In areas where ducting occurs frequently, the frequency separation is increased.

3. The major effect of multipathing is to cause stretching of the interfering radar pulse width, and additional interfering pulses when the difference in distance between the direct and reflected paths exceeds the distance that a signal can travel in one pulse width. Thus multipath propagation adds to the severity of potential interference between pulsed radars.

RECOMMENDATIONS

The following are recommendations by TSC Working Group 1 based on the technical findings contained in this report. Any action to implement these recommendations will be accomplished under separate correspondence by modifications of established rules, regulations or procedures. TSC Working Group 1 recommends that:

1. The Interdepartment Radio Advisory Committee (IRAC) approve the recommended Radar Spectrum Engineering Criteria (RSEC) contained in Appendix C of this report. The recommended RSEC changes are applicable to new fixed radars planned for the 2700-2900 MHz band, and will enhance the accommodation of new systems in designated heavily used areas and for collocated operation.

2. If the IRAC approves the proposed RSEC for fixed radars in the 2700-2900 MHz band contained in Appendix C of this report, the following action should be taken by the IRAC Frequency Assignment Subcommittee (FAS):

   a) Incorporate the designated heavily used area map (See Figure 8 and TABLE 22) in Annex D of the NTIA Manual as an aid in identifying areas where accommodation of new radar systems in the 2700-2900 MHz band may be difficult.

   b) Assign a Special-Note to frequency assignments in designated heavily used areas or for collocated operation when the additional EMC capabilities stated in the proposed RSEC are not installed in the initial deployment of the radar. This S-note should read as follows:

SXXX-This assignment, in the 2700-2900 MHz band, is for operation in a designated heavily used area or for collocated operation (see Annex D of the NTIA Manual). This equipment has the capability of implementing the additional Electromagnetic Compatibility (EMC) provisions of RSEC Criteria D under Section 5.3 of the NTIA Manual. Implementation of this capability may be necessary at a later date.

3. The effects of pulsed radar interference on doppler and adoptive threshold radar signal processing should be investigated.