NTIA REPORT 84-160

SPECTRUM RESOURCE ASSESSMENT OF THE 1530 - 1660.5 MHz BAND

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ABSTRACT

This report documents a spectrum resource assessment of the 1530-1660.5 MHz band. The impact of allocation changes resulting from the WARC-79 are addressed. Information is included on allocations, frequency assignments, system characteristics, and spectrum measurements made with the RSMS van. A review of previous analyses was conducted. No unmanageable spectrum management problems involving the major systems presently operating in, or firmly planned for, this band are identified. This report is based on information available through March 1983.

KEY WORDS

Electromagnetic Compatibility
1530-1660.5 MHz
Distress and Safety
Mobile Satellite
Aeronautical Radionavigation
Radio Astronomy
Spectrum Resource Assessment

SECTION 1

INTRODUCTION

BACKGROUND

The National Telecommunications and Information Administration (NTIA) is responsible for managing the radio spectrum used by the U.S. Federal Government. Part of NTIA's responsibility is to:

> "...establish policies concerning spectrum assignment, allocation and use, and provide the various departments and agencies with guidance to assure that their conduct of telecommunications activities is consistent with these policies" [Department of Commerce, 1978].

In support of these requirements, NTIA has undertaken a number of spectrum resource assessments. The objectives of these studies are to assess spectrum utilization, identify existing and/or potential compatibility problems between systems of various departments and agencies, provide recommendations for resolving any compatibility conflicts, and recommend changes to improve the efficient use of the radio spectrum and improve spectrum management procedures. This spectrum resource assessment considers the 1530-1660.5 MHz frequency band. The report is based on information available through March, 1983.

The World Administrative Radio Conference, Geneva 1979, (WARC-79) significantly changed the international allocations in the 1530-1660.5 MHz band which resulted in changes to the National Table of Frequency Allocations. The major changes are:

1. There are now ten bands. Prior to the WARC-79 there were nine.

2. The frequency ranges of all sub-bands have been changed.

3. An allocation for the Radionavigation-Satellite Service (Space-to-Earth) has been added.

4. The allocation for the Meteorological Aids Service (radiosonde) has been eliminated.

5. Allocations have been added for the Mobile-Satellite Service (Space-to-Earth) and for the Mobile-Satellite Service (Earth-to-space). Each of these services is allocated to a band one MHz wide. In conjunction with this, Footnote 728 has been added which states that the use of the bands 1544-1545 MHz (Space-to-Earth) and 1645.5-1646.5 MHz (Earth-to-space) by the Mobile-Satellite Service is limited to distress and safety operations.

Appendix C gives a brief history of the bands from 1535-1660 MHz up to 1974.

OBJECTIVES

This spectrum resource assessment has the following objectives:

1. Identify major existing and developing systems in the 1530-1660.5 MHz band and provide technical data on these systems.

2. Assess the need for a study of electromagnetic compatibility among existing and developing systems in the band.

3. Identify and document potential problem areas (including band-edge problems with systems in other bands).

4. Identify and outline specific areas which require additional analysis or measurement.

5. Review the status of the safety and distress systems in the band including a discussion of technical issues.

APPROACH

In order to accomplish the above objectives, the following approach was taken:

1. The Government Master File (GMF) and other existing files were reviewed.

2. The history of systems which are no longer in the band was reviewed.

3. Previous compatibility analyses and spectrum resource assessments within this band were reviewed.

4. The general impact of WARC-79 on specific systems in the band was reviewed.

5. Spectrum occupancy of Government portions of the 1530-1660.5 MHz band was measured with the RSMS van. The analyses of these measurements were incorporated in the spectrum resource assessment (SRA) on this band, as appropriate.

6. Potential interactions involving major systems presently operating in, or firmly planned for, the band were identified.

7. Problem areas that affect the management of the 1530-1660.5 MHz band were identified and recommendations made toward their solution.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

GENERAL

This section contains a summary of the conclusions and recommendations resulting from an analysis of the major systems presently operating in, and firmly planned for, the 1530-1660.5 MHz band. These major systems have been examined to determine if issues exist involving these systems; also, previous documentation of the band has been reviewed to determine if old issues still exist. Areas of future study are identified based on the latest allocations for the band.

CONCLUSIONS

1. Based on previous analysis, interference from radar altimeters into shipboard receivers of the Maritime Mobile-Satellite Service may be possible under worst case conditions. However, no instances of such interference have been identified; moreover, all Air Force and Navy altimeters are scheduled to be phased out of the band. These phaseouts are expected to be completed by 1989. This will account for most of the altimeters in the band. A periodic check is advisable to verify that shipboard receivers are experiencing no harmful interference.

2. A previous analysis concluded that interference to the AN/APN-133 and AN/APN-159 pulsed radar altimeters from shipboard terminals of the Maritime Mobile Service was possible. The analysis was based in part on measurements obtained on the AN/APN-133, and the results were extrapolated to the AN/APN-159. However, no instances of interference to these altimeters are known. It is understood that the nature of the AN/APN-133 altimeter is such that the altitude information would drop out rather than degrade, so the fact that no interference has been reported is an indication that there has been no interference problem associated with this altimeter. In addition, the Navy and Air Force altimeters are to be phased out of this band by 1989, thus accounting for most altimeters. A periodic check is advisable to verify that radar altimeters are experiencing no harmful interference.

3. The selection and design of the safety and distress systems for use in this band have not been finalized. Possible systems would have satellites in geostationary orbits, polar orbits that are at much lower altitudes, or a combination of both types. Major system tradeoffs are still being analyzed.

4. Footnote US40 provides for collision avoidance systems in the 1592.5-1622.5 MHz band, but there are no plans for such systems to become operational in this band. Footnote US40 could be eliminated after United States acceptance of the Traffic Alert and Collision Avoidance System (TCAS) which is being developed in a different band. The re-emergence of collision avoidance systems in this band would necessitate a study to determine potential interactions.

5. Region 2 administrations have not implemented aeronautical mobile-satellite systems in the band.

6. There is a possibility of interference to maritime mobile-satellite systems from aeronautical telemetry that is tuned above 1529.5 MHz. This is based on the design of the first generation INMARSAT system.

7. Designers of new maritime mobile-satellite systems, distress and safety systems, aeronautical mobile-satellite systems, and radio astronomy systems should be aware of the existence of the GLONASS and VOLNA systems. Resolution of any possibly harmful interactions between GLONASS or VOLNA and U.S. Government systems will be coordinated by the appropriate agency through the I.F.R.B. procedures.

8. There is a possibility of interference, in excess of the levels in CCIR Report 224-5 (CCIR, 1982C), to the Radio Astronomy Service from the proposed GEOSTAR and MOBILSAT systems.

9. More information is needed on the GLONASS system to assess the potential interference to the Radio Astronomy Service particularly at 1610-1614 MHz. It is understood that the United States has requested this information from the USSR.

10. Measured data on the sideband characteristics of the present GPS L1 emission spectrum would be useful in assessing the potential interference to the Radio Astronomy Service.

RECOMMENDATIONS

The following are NTIA staff recommendations based on the technical findings contained in this report. Any action to implement these recommendations will be accomplished under separate correspondence by modification of established rules, regulations or procedures.

1. A study should be undertaken to evaluate interactions between safety and distress systems and other systems in the band. This study should be performed when the selection and final designs of these safety and distress systems are known.

2. There are no collision avoidance systems in this band; however, if collision avoidance systems are implemented in the band, a study should be conducted to determine potentially harmful interactions. Consideration should be given to elimination of Footnote US40 in the event of acceptance of the TCAS system which is being developed in a different band.

3. As mobile-satellite systems are identified in the 1545-1559 MHz band, studies should be conducted to determine potential interactions to distress and safety systems in the 1544-1545 MHz band. As mobile-satellite systems (e.g., INMARSAT, GEOSTAR and MOBILSAT) are identified in the bands 1530-1660.5 MHz, studies should be conducted to determine potential interactions to distress and safety systems in the 1645.5-1646.5 MHz band and the radio astronomy systems in the 1660-1660.5 MHz band and the 1610.6-1613.8 MHz band.

4. To help preclude interference to maritime mobile-satellite systems, aeronautical telemetry transmitters in the 1435-1535 MHz range should be capable of constraining their occupied bandwidth to the region below 1530.0 MHz. This is based on the design of the first generation INMARSAT system. This recommendation should be re-evaluated after the design of the second generation has been finalized.

5. Additional analysis is recommended to help assess the potential for interference from the GPS L1 signal to the Radio Astronomy Service.

SECTION 3

RULES AND REGULATIONS

ALLOCATIONS

TABLE 1 gives the international frequency allocations established by WARC-79. New (post-WARC-79) national frequency allocations, also shown in TABLE 1, have also been approved by IRAC and are the same as the FCC proposed allocations in Notice of Proposed Rule Making (FCC 82-508) in a general docket (FCC, 1982). The footnotes for each of the sub-bands are referenced in these allocation tables and are given in TABLE 2.

This section gives the major changes in the allocations for each sub-band within the 1530-1660.5 MHz band.

1530-1535 MHz Allocations

In the United States, the Mobile Service (Aeronautical Telemetry) has been downgraded to secondary. The Mobile Service will continue to be secondary internationally. A new and primary allocation in this band both internationally and in the United States is the Maritime-Mobile Satellite Service (Space-to-Earth). Footnote US272 states that the allocation to the Maritime Mobile-Satellite Service in the band 1530-1535 MHz shall be effective from January 1, 1990. A sentence added to Footnote US78 states that the Maritime-Mobile Satellite Service will be the only primary service after January 1, 1990.

In Region 2, prior to WARC-79, the band 1525-1535 MHz was allocated to the Space Operation (Telemetering) Service on a primary basis and to the Fixed, Mobile and Earth Exploration Satellite Services on a secondary basis. In the new Region 2 allocation table, in the band 1530-1535 MHz, the primary allocation has been modified to apply to the Space Operation Service (Space-to-Earth) in lieu of the previous primary allocation.

A general footnote which applies to this band, as well as the other bands, is Footnote 722 which states that in the bands 1400-1727 MHz, passive research is being conducted by some countries to search for intentional emissions of extra-terrestrial origin.

1535-1544 MHz Allocations

Prior to WARC-79, the bands 1535-1543.5 MHz were allocated to the Maritime Mobile-Satellite Service. Both internationally and in the United States, the allocation is changed to Maritime Mobile-Satellite Service (Space-to-Earth) and the new band limits are 1535-1544 MHz. As before, the allocation is on a primary basis.

TABLE 1

ALLOCATION TABLE

INTERNATIONAL			UNITED STATES			
Region 1 *MHz*	*Region 2* *MHz*	*Region 3* *MHz*	*Band* *MHz* *1*	*National Provisions* *2*	*Government Allocation* *3*	*Non-Government Allocation* *4*
1530–1535 SPACE OPERATION (Space-to-Earth) MARITIME MOBILE-SATELLITE (Space-to-Earth) Earth Exploration-Satellite Fixed Mobile except aeronautical mobile 722 726	1530–1535 SPACE OPERATION (Space-to-Earth) MARITIME MOBILE-SATELLITE (Space-to-Earth) Earth Exploration-Satellite Fixed Mobile 723 722 726		1530–1535	US78 US272 722	MARITIME MOBILE-SATELLITE (Space-to-Earth) Mobile (Aeronautical telemetering)	MARITIME MOBILE-SATELLITE (Space-to-Earth) Mobile (Aeronautical telemetering)
1535–1544 MARITIME MOBILE-SATELLITE (Space-to-Earth) 722 727			1535–1544	722	MARITIME MOBILE-SATELLITE (Space-to-Earth)	MARITIME MOBILE-SATELLITE (Space-to-Earth)
1544–1545 MOBILE-SATELLITE (Space-to-Earth) 722 727 728			1544–1545	722 728	MOBILE-SATELLITE (Space-to-Earth)	MOBILE-SATELLITE (Space-to-Earth)
1545–1559 AERONAUTICAL MOBILE-SATELLITE (R) (Space-to Earth) 722 727 729 730			1545–1559	722 729	AERONAUTICAL MOBILE-SATELLITE (R) (Space-to-Earth)	AERONAUTICAL MOBILE-SATELLITE (R) (Space-to-Earth)
1559–1610 AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (Space-to-Earth) 722 727 730 731			1559–1610	US39 US40 US208 US260 722	AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (Space-to-Earth)	AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (Space-to-Earth)

TABLE 1 cont.

ALLOCATION TABLE

INTERNATIONAL			UNITED STATES			
Region 1 *MHz*	*Region 2* *MHz*	*Region 3* *MHz*	*Band* *MHz* *1*	*National Provisions* *2*	*Government Allocation* *3*	*Non-Government Allocation* *4*
1610–1626.5 AERONAUTICAL RADIONAVIGATION 722 727 730 732 733 734			1610–1616.5	US39 US40 US208 US260 722 732 733 734	AERCNAUTICAL RADIONAVIGATION	AERONAUTICAL RADIONAVIGATION
1626.5–1645.5 MARITIME MOBILE-SATELLITE (Earth-to-space) 722 727 730			1626.5–1645.5	US39 722	MARITIME MOBILE- SATELLITE (Earth-to- space)	MARITIME MOBILE- SATELLITE (Earth-to- space)
1645.5–1646.5 MOBILE-SATELLITE (Earth-to-space) 722 728			1645.5–1646-5	US39 722 728	MOBILE-SATELLITE (Earth-to-space)	MOBILE-SATELLITE (Earth-to-space)
1646.5–1660 AERONAUTICAL MOBILE-SATELLITE (R) (Earth-to-space) 722 727 730 735			1646.5–1660	US39 722 735	AERONAUTICAL MOBILE-SATELLITE (R) (Earth-to-space)	AERONAUTICAL MOBILE-SATELLITE (R) (Earth-to-space)
1660–1660.5 AERONAUTICAL MOBILE-SATELLITE (R) (Earth-to-space) RADIO ASTRONOMY 722 735 736			1660–1660.5	722 735 736	AERONAUTICAL MOBILE-SATELLITE (R) (Earth-to-space) RADIO ASTRONOMY	AERONAUTICAL MOBILE-SATELLITE (R) (Earth-to-space) RADIO ASTRONOMY

TABLE 2

FOOTNOTES TO THE ALLOCATION TABLE

722-In the bands 1 400 - 1 727 MHz, 101 - 120 GHz and 197 - 220 GHz, passive research is being conducted by some countries in a programme for the search for intentional emissions of extra-terrestrial origin.

723-In Region 2, in Australia and Papua New Guinea, the use of the band 1 435 - 1 535 MHz by the aeronautical mobile service for telemetry has priority over other uses by the mobile service.

726-The allocation to the maritime mobile-satellite service in the band 1 530 - 1 535 MHz shall be effective from 1 January 1990. Up to that date the allocation to the fixed service shall be on a primary basis in Regions 1 and 3.

727-Additional allocation: in Afghanistan, Saudi Arabia, Bahrain, Bangladesh, the Congo, Egypt, the United Arab Emirates, Ethiopia, Iran, Iraq, Israel, Jordan, Kuwait, the Lebanon, Malta, Morocco, Niger, Oman, Pakistan, Qatar, Syria, Somalia, Sudan, Sri Lanka, Chad, Thailand, Togo, Yemen (P.D.R. of) and Zambia, the bands 1 540 - 1 645.5 MHz and 1 646.5 - 1 660 MHz are also allocated to the fixed service on a secondary basis.

728-The use of the bands 1 544 - 1 545 MHz (space-to-Earth) and 1 645.5 - 1 646.5 MHz (Earth-to-space) by the mobile-satellite service is limited to distress and safety operations.

729-Transmissions in the band 1 545 - 1 559 MHz from terrestrial aeronautical stations directly to aircraft stations, or between aircraft stations, in the aeronautical mobile (R) service are also authorized when such transmissions are used to extend or supplement the satellite-to-aircraft links.

730-Additional allocation: in the Federal Republic of Germany, Austria, Bulgaria, Cameroon, Guinea, Hungary, Indonesia, Libya, Mali, Mongolia, Nigeria, Poland, the German Democratic Republic, Roumania, Senegal, Czechoslovakia and the U.S.S.R., the bands 1 550 - 1 645.5 MHz and 1 646.5 - 1 660 MHz are also allocated to the fixed service on a primary basis.

731-Alternative allocation: in Sweden, the band 1 590 - 1 610 MHz is allocated to the aeronautical radionavigation service on a primary basis.

732-The band 1 610 - 1 626.5 MHz is reserved on a worldwide basis for the use and development of airborne electronic aids to air navigation and any directly associated ground-based or satellite-borne facilities. Such satellite use is subject to agreement obtained under the procedure set forth in Article 14.

733-The bands 1 610 - 1 626.5 MHz, 5 000 - 5 250 MHz and 15.4 - 15.7 GHz are also allocated to the aeronautical mobile-satellite (R) service on a primary basis. Such use is subject to agreement obtained under the procedure set forth in Article 14.

734-The band 1 610.6 - 1 613.8 MHz is also allocated to the radio astronomy service on a secondary basis for spectral line observations. In making assignments to stations of other services to which the band is allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from space or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. 343 and 344 and Article 36).

735-Transmissions in the band 1 646.5 - 1 660.5 MHz from aircraft stations in the aeronautical mobile (R) service directly to terrestrial aeronautical stations, or between aircraft stations, are also authorized when such transmissions are used to extend or supplement the aircraft-to-satellite links.

TABLE 2 cont.

736-In making assignments to stations of other services to which the band 1 660 - 1 670 MHz is allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from space or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. 343 and 344 and Article 36).

US39-Radio altimeters are permitted to use the band 1600-1660 MHz only until such time as international standardization of other aeronautical radionavigation systems or devices requires the discontinuance of radio altimeters in this band.

US40-The band 1592.5-1622.5 MHz is allotted provisionally, but on a primary basis, for the collision avoidance function, noting the continued use of existing altimeters in the band 1600-1660 MHz.

US78-In the band 1435-1535 MHz, the frequencies between 1435 and 1485 MHz will be assigned primarily for the flight testing of manned aircraft, or major components thereof; the frequencies between 1485 and 1535 MHz will be assigned primarily for the flight testing of unmanned aircraft and missiles or major components thereof. Included as permissible usage for aeronautical telemetering stations in the band 1435-1535 MHz is telemetry associated with launching and re-entry into the earth's atmosphere, as well as any incidential orbiting prior to re-entry, of manned or unmanned objects undergoing flight tests. In the band 1530-1535 MHz the maritime mobile satellite service will be the only primary service after 1 January 1990.

US208-Planning and use of the band 1559-1626.5 MHz necessitate the development of technical and/or operational sharing criteria to ensure the maximum degree of electromagnetic compatibility with existing and planned systems within the band.

US260-Aeronautical mobile communications which are an integral part of aeronautical radionavigation systems may be satisfied in the bands 1559-1626.5 MHz, 5000-5250 MHz and 15.4-15.7 GHz.

US272-The allocation to the Maritime Mobile-Satellite Service in the band 1530-1535 MHz shall be effective from 1 January 1990. Up to that date the allocation to the Mobile Service will be on a primary basis.

1544-1545 MHz Allocations

A new and primary allocation has been created internationally and in the United States for the Mobile-Satellite Service (Space-to-Earth) in the new 1544-1545 MHz band. In a further restriction of the band, Footnote 728 states that the use of the band 1544-1545 MHz (Space-to-Earth) by the Mobile-Satellite Service is limited to safety and distress operations.

1545-1559 MHz Allocations

Under the pre-WARC-79 allocation tables, the 1543.5-1558.5 MHz band was allocated to the Aeronautical Mobile-Satellite (R) Service and this service shared the 1542.5-1543.5 MHz band with the Maritime Mobile-Satellite Service, all on a primary basis. Under the new international and U.S. allocation tables, the band 1545-1559 MHz is allocated to Aeronautical Mobile-Satellite (R) Service (Space-to-Earth) on a primary basis. The two services do not share the same spectrum. By Footnote 729, transmissions in the band 1545-1559 MHz from terrestrial aeronautical stations directly to aircraft stations, or between aircraft stations, in the Aeronautical-Mobile (R) Service are also authorized when such transmissions are used to extend or supplement the satellite-to-aircraft links.

A World Administrative Radio Conference for the Mobile Services, held in Geneva in 1983, made some significant changes to the Radio Regulations. Article 50 of the Radio Regulations (ITU, 1979) contains special rules relating to the use of frequencies in the Aeronautical Mobile Service. The Final Acts of the WARC MOB-83 for the Mobile Services (Geneva, 1983) modified paragraphs 3630 and 3633 of Chapter 10, Article 50. Paragraph 3630 now states that frequencies in any band allocated to the aeronautical mobile (R) service are reserved for communications related to safety and regularity of flight between any aircraft and those aeronautical stations primarily concerned with flight along national or international civil air routes. Paragraph 3633 now states that administrations shall not permit public correspondence in the frequency bands allocated exclusively to the aeronautical mobile service.

WARC MOB-83 also added Article 42A paragraph 3363 to Chapter 10. This appears to have the effect of extending Article 50 paragraph 3630 to the Aeronautical Mobile Satellite (R) Service. Paragraph 3363 states that Pending the detailed revision of Chapter 10 by a future world administrative radio conference, wherever the terms aeronautical station or aircraft station are employed they may be taken to refer, as appropriate, to the corresponding type of station in the aeronautical mobile-satellite service.

1559-1610 MHz Allocations

The 1559-1610 MHz band is allocated on a primary basis both internationally and in the United States to the Aeronautical Radionavigation Service and the Radionavigation Satellite Service (Space-to-Earth). Prior to WARC-79 there was no allocation for the Radionavigation Satellite Service in these bands, and the Aeronautical Radionavigation Service was allocated the 1558.5-1636.5 MHz band on a primary basis. The new tables also allocate the band 1610-1626.5 to the Aeronautical Radionavigation Service.

1610-1626.5 MHz Allocations

The band 1610-1626.5 MHz is allocated on a primary basis both internationally and in the United States to the Aeronautical Radionavigation Service. Footnote 732 states that the band 1 610-1 626.5 MHz is reserved on a worldwide basis for the use and development of airborne electronic aids to air navigation and any directly associated ground-based or satellite-borne facilities. Such satellite use is subject to agreement obtained under the procedure set forth in Article 14 of ITU (1979). By footnote 733, the band 1610-1626.5 MHz is also allocated to the Aeronautical Mobile-Satellite (R) Service on a primary basis. Such use is subject to agreement obtained under the procedure set forth in Article 14 of ITU (1979). Footnote 734 states that the band 1610.6-1613.8 MHz is also allocated to the Radio Astronomy Service on a secondary basis for spectral line observations. In making assignments to stations of other services to which the band is allocated, administrations are urged to take all practicable steps to protect the Radio Astronomy Service from harmful interference.

1626.5-1645.5 MHz Allocations

Prior to WARC-79, the bands 1636.5-1645 MHz were allocated to the Maritime Mobile-Satellite Service. Both internationally and in the United States the allocation is changed to Maritime Mobile-Satellite Service (Earth-to-space). This complements the space-to-Earth allocation at 1535-1544 MHz. The new band limits are 1626.5-1645.5 MHz. As before, the allocation is on a primary basis.

1645.5-1646.5 MHz Allocations

Complementing the space-to-Earth allocation at 1544-1545 MHz, a new and primary allocation has been created internationally and in the United States for the Mobile-Satellite Service (Earth-to-space) in the new 1645.5-1646.5 MHz band. Footnote 728 further restricts the use of this band by the Mobile-Satellite Service to distress and safety operations.

1646.5-1660 MHz Allocations

Complementing the space-to-Earth allocation at 1545-1559 MHz, the 1646.5-1660 MHz band is allocated to the Aeronautical Mobile-Satellite (R) Service (Earth-to-space) on a primary basis. As in the case of the space-to-Earth allocation, the new allocation table eliminates sharing with the Maritime Mobile-Satellite Service. By Footnote 735, transmissions in the band 1646.5-1660.5 MHz from aircraft stations in the Aeronautical Mobile (R) Service directly to terrestrial aeronautical stations, or between aircraft stations, are also authorized when such transmissions are used to extend or supplement the aircraft-to-satellite links.

1660-1660.5 MHz Allocations

The 1660-1660.5 MHz band is allocated on a primary basis to the Aeronautical Mobile-Satellite (R) Service (Earth-to-space) and to the Radio Astronomy Service. Prior to WARC-79, there was an allocation for the Meteorological Aids (Radiosonde) Service; also, there was no allocation to the Aeronautical Mobile-Satellite (R) Service in this 0.5 MHz. Footnote 735 states that transmissions in the band 1646.5-1660.5 MHz from aircraft stations in the Aeronautical Mobile (R) Service directly to terrestrial aeronautical stations, or between aircraft stations, are also authorized when such transmissions are used to extend or supplement the aircraft-to-satellite links.

There is a potential for harmful interference from these aircraft stations to the Radio Astronomy Service. Footnote 736 states that in making assignments to stations of other services to which the band 1660-1670 MHz is allocated, administrations are urged to take all practicable steps to protect the Radio Astronomy Service from harmful interference. Emissions from space or airborne stations can be particularly serious sources of interference to the Radio Astronomy Service (see Nos. 343 and 344 and Article 36 of ITU (1979).

TECHNICAL STANDARDS

This subsection identifies technical standards for systems that operate in the 1530-1660.5 MHz band. The primary source of information was the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management.

The tolerances for spurious emissions and transmitter frequencies applicable to the Government equipment in the 1530-1660.5 MHz frequency band are given in Chapter 5 of the NTIA Manual and are reproduced here in part for easy reference in TABLE 3.

Standards for the level of undesired emissions outside the authorized bandwidth for telemetering stations, excluding those for space radiocommunication, in the band 1435-1535 are given in Part 5.9 of the NTIA Manual.

Effective January 1, 1985, there will be a standard for unwanted emissions from the space services. These standards will be applicable to U.S. Government space systems including associated earth terminals operating in the spectrum above 1 GHz that is allocated to the space services. These standards are found in Part 5.11 of the NTIA Manual.

The International Telecommunication Union (ITU) has a table on transmitter frequency tolerances in Appendix 7 (ITU, 1979) for 470-2450 MHz. The table specifies transmitter tolerances for each category of station in the band. In addition, the ITU has specified maximum-permitted levels of spurious emission in terms of the mean power level of any spurious component supplied by a transmitter to the antenna transmission line (Final Acts, Appendix 8). Emergency position-indicating radio beacon stations and emergency locator transmitter need not comply with the requirement of Appendix 8. The appendix states that, for radiodetermination stations, until acceptable methods of measurement exist, the lowest practicable power of spurious emission should be achieved.

TABLE 3

TOLERANCES ON SPURIOUS EMISSIONS

Frequency Bands and Station Type	Tolerances			
	Category I[a]		Category II[a]	
BAND: 1215 to 2450 MHz	Spurious	Freq.	Spurious	Freq.
1. Fixed Stations				
1.1 100 W or less		300[b]	E	30
1.2 above 100 W		100[c]	E	10
2. Land Stations		300	E,I	30
3. Mobile Stations		300	E,I	30
4. Radionavigation Stations				
4.1 radar		800	J	800
4.2 other than above		500	E	800
5. Radiolocation Stations				
5.1 radar		800	J	800
5.2 other than above		500	E	800
6. Earth Stations		20[d]	K	20[d]
7. Space Stations		20[d]	K	20[d]

a. Transmitters authorized prior to 1/1/73 are subject to Category I and to Category II tolerances after 1/1/79. Transmitters authorized after 1/1/73 are subject to Category II tolerances.

b. For transmitters using time division multiplex, the tolerance of 300 may be increased to 500.

c. This tolerance applies only to such emissions for which necessary bandwidth does not exceed 3000 kHz; for larger bandwidth emissions, a tolerance of 300 applies.

d. Existing systems in the space service, replacement equipment for those systems, and new systems designed or in the process of being designed as of 11/24/70 may have a tolerance no greater than 50 ppm.

The letters E through K in the column headed "Spurious" refer to the spurious levels specified in the NTIA Manual (section 5.2.3).

SECTION 4

MAJOR SYSTEMS AND SPECTRUM OCCUPANCY

GENERAL

This section provides a brief description of the major systems operational in or being developed in the 1530-1660.5 MHz band. A brief discussion of proposed future systems is also included. Next, the present general usage of this portion of the frequency spectrum is discussed along with measurements from the RSMS van.

1530-1535 MHz MAJOR SYSTEMS

Telemetry

An NTIA report (Matos, 1983) describes a typical telemetry system for general usage in the band of interest:

> A typical telemetry equipment is the model CTS/CTL-500 manufactured by the Conic Data Systems division of the Loral Corporation. This transmitter operates in the 1435-1535 MHz frequency band with a nominal output of 18 Watts and a FM carrier deviation of ± 600 kHz. The typical receiver has a noise figure of 4.5 dB and an IF bandwidth of 1.5 MHz resulting in a sensitivity based on noise threshold of -108 dBm. The data is usually pulse-code-modulated at a rate up to 1 Mbps, which is frequency modulated onto the RF carrier.

A typical link budget for telemetry systems in the 1435-1535 MHz band was developed (Matos, 1983) based on parameters presented in AFTRCC (1982). That analysis is presented in TABLE 4. The receiver noise level is based on a noise figure of 4.5 dB and an IF bandwidth (3 dB) of 1.5 MHz. The 1.5 MHz bandwidth is the value mentioned by the AFTRCC document as typical of a 3 MHz wide channel.

Table 4 gives typical values for transmitter power (44 dBm) and transmitter antenna gain (0 dBi). Thus, a typical value of EIRP is 44 dBm. AFTRAC [1982] gives a worst-case value of -60 dB for [relative] power spectral density outside of the channel width. In the examples of the preceding subsection, the channel width is 3 MHz.

Maritime Mobile-Satellite Systems

There are no maritime mobile-satellite systems presently using the 1530-1535 MHz band. Advance plans for the second generation of the INMARSAT system to use this band as early as August, 1988. Technical parameters for the second generation of INMARSAT have not been finalized.

1535-1544 MHz MAJOR SYSTEMS

INMARSAT

The commercial portion of the INMARSAT system has been designed to provide voice and data communications between shore based subscribers and seagoing

TABLE 4

TYPICAL TELEMETRY LINK BUDGET

Transmitter power (25 watts)	=	44 dBm
Vehicle antenna gain (typical omni-blade)	=	0 dBi
Path loss (180 km)	=	-142 dB
Receiver antenna gain	=	20.5 dBi
Transmission line loss	=	-0.5 dB
Received signal level	=	-78.0 dBm

<u>Calculation of Fade Margin:</u>

Received signal level	=	-78.0 dBm
Minus Receiver noise level	=	-108 dBm
Minus Minimum acceptable C/N	=	9 dB
Fade Margin (Nominal C/N - Acceptable C/N)		21 dB

vessels as well as other maritime installations. Each of the three satellites has two wideband repeaters for service to users. One repeater translates shore-to-ship signals from 6 GHz to 1.5 GHz, while the other translates ship-to-shore signals from 1.6 GHz to 4 GHz. The satellite-to-ship link at 1.5 GHz and the ship-to-satellite link at 1.6 GHz are of interest in this spectrum resource assessment. In addition to this transmission and reception by the ship at 1.6 GHz and 1.5 GHz, there is transmission and reception by the "shore" earth stations in these same bands to monitor transmissions, to check satellite performance, and to enable compensation for frequency translation errors in the satellite.

The system provides the following routine communication services between ship and shore through the satellite:

- Telex (teleprinter)
- Telephony
- Data
- Facsimile

In addition to the routine services, the system incorporates features which permit:

- ship-to-ship calls via a double satellite hop
- handling of emergency calls on a priority basis over other traffic
- broadcast calls

TABLE 5 shows the deployment plans and orbital locations for the space segment of the INMARSAT system. The information for this table was extracted from INMARSAT (1982). INMARSAT uses three different, but similar, satellite types: MARISAT, MARECS and INTELSAT V-MCS. The new MARECS and MCS satellites are designed for higher capacity than the MARISAT satellites. However, INMARSAT will be using MARISAT in order to ensure the continuity of service in each region during the period of transition to the newer satellites. Following the transition period, the MARISAT satellites will generally act as back-up satellites.

The ship-to-satellite part of the ship-to-shore link is at 1.6 GHz, and the satellite-to-ship part of the shore-to-ship link is at 1.5 GHz. TABLE 6 gives the satellite transponder passbands for these two links. The information in TABLE 6 was extracted from INMARSAT (1982). Unless otherwise stated, all parameters used in this subsection were extracted from INMARSAT (1982).

Shore stations do not directly use these 1.6 and 1.5 GHz frequencies in communicating with ships, but do use these frequencies for testing and network coordinating functions. In addition, coastal stations transmit and receive continuous wave AFC pilot signals with a bandwidth of 100 Hz (normal operation).

INMARSAT is a sophisticated telecommunication system. Modulation types used are narrowband FM, 2-phase PSK, 4-phase PSK, narrowband CFM and CW. Data rates as high as 112 kbit/S are to be transmitted. In general the reader is referred to the INMARSAT system specifications for parameters and details of the system. Some key parameters for the 1.5/1.6 GHz segments of ship-to-shore and shore-to-ship links are given in the following paragraphs.

TABLE 5

INMARSAT SPACE SEGMENT DEPLOYMENT PLANS

Ocean Region	Satellite	Scheduled Ready for Service Date	Nominal Orbital Location (longitude)
Atlantic	MARISAT	In-service	15° W
	MARECS	In-service	26° W (or subsequently 23° W)
	MCS	Early 1983	21.5° W (or subsequently 18.5° W)
Indian	MARISAT	In-service	73° E
	MCS	Late-1982	63° E
	MCS	Mid-1983	60° or 66° E (63° E for operations)
Pacific	MARISAT	In-service	176.5° E
	MARECS	Late-1982	177.5° E
	MCS	1984-1985	179° E

TABLE 6

INMARSAT SATELLITE TRANSPONDER FREQUENCY BANDS

SATELLITE	TRANSPONDER PASSBAND (MHz)	
	Satellite-to-Ship	Ship-to-Satellite
MARISAT	1537.0-1541.0	1638.5-1642.5
MARECS	1537.5-1542.5	1638.5-1644 High-gain (SAR) channel: 200 kHz: 1644.3-1644.5 (for experimental use)
MCS	1535.0-1542.5	1636.5-1644

INTELSAT (1981) gives MCS transmit power characteristics. The minimum power per carrier applied to the ship earth station antenna is 12.9 dBW at 1.6 GHz. The minimum EIRP per carrier from the space station is 17.8 dBW at 1.5 GHz. The document cautions that these characteristics are still under review.

The total satellite-to-ship EIRP (high power mode) at edge of coverage (earth coverage) is 27 dBW for the MARISAT, 34 dBW for the MARECS and 33 dBW for the MCS. Neither the maximum value of EIRP within the main beam nor the position of the maximum is specified. Ideally, the EIRP at beam center would be less than at edge of coverage, but in practice this is not generally the case. For the ship-to-satellite link the power flux density at the satellite is on the order of -127.7 dBW per meter squared due to a 1.6 GHz band beam-edge carrier.

Each satellite has a single 1.6/1.5 GHz band receive/transmit antenna. MARISAT and MCS have a conical helix array antenna with a mainbeam gain of 16 dBi at edge of coverage. MARECS has a 1.8 meter diameter shaped-beam parabolic antenna with a gain of approximately 18 dBi at edge of coverage. All INMARSAT satellites transmit 1.5 GHz and receive 1.6 GHz with right-hand circular polarization (RHCP). The minimum value of receive G/T is -17.0 dB/K for MARISAT, -13.3 dB/K for MARECS and -15.0 dB/K for MCS.

Existing MARISAT Standard-A model ship earth stations will initially constitute the majority of ship users. These stations have the following typical values:

Receive G/T:	-4 dB/K
Antenna Diameter:	1.2 m
Antenna Gain:	23 dBi

Appendix B gives additional characteristics of the Standard-A ship earth terminals and summarizes the basic difference between Standards A,B,C, and D ship earth stations.

Finally, we return to the subject of the shore earth stations. These stations have a 1.6/1.5 GHz test-terminal. This terminal will include all the basic capabilities and characteristics of a Standard-A ship earth station but is required to achieve a G/T value of +2 dB/K. The transmitted 1.6 GHz-to-4 GHz AFC pilot has a nominal EIRP of 31 dBW.

1544-1545 MHz MAJOR SYSTEMS

COSPAS-SARSAT

The COSPAS-SARSAT Project is an international joint venture in satellite-aided search and rescue. The partners in this joint venture are Canada's Department of Communications, France's Centre National d'Etudes Spatiales, the United States' National Aeronautics and Space Administration, and the USSR's Ministry of Merchant Marine.

The concept involves the use of multiple satellites in low, near polar orbits "listening" for distress transmissions. The signals received by the satellites are relayed to a network of dedicated earth stations where the location of the emergency is determined by measuring the Doppler shift of the distress signals due to the satellite with a precisely known orbit. These downlink transmissions from the satellites will occur at a frequency of 1544.5 MHz and are, therefore, of interest in this resource assessment of the 1530-1660.5 MHz band.

Emergency Locator Transmitters (ELTs) activated by an aircraft crash and Emergency Position Indicating Radio Beacons (EPIRBs) for marine distress are used extensively. The COSPAS-SARSAT concept includes receiving signals from the existing ELTs/EPIRBs at 121.5 MHz (and 243 MHz in the case of SARSAT) and transmitting (repeating) these signals in real time to earth stations at 1544.5 MHz. But the concept also includes operations with experimental ELTs/EPIRBs operating in the assigned emergency band at 406 MHz. These signals would then be handled in one of three ways:

- repeated in real time at 1544.5 MHz
- processed and transmitted in real time at 1544.5 MHz
- processed and the information stored for later transmission at 1544.5 MHz

TABLE 7 briefly summarizes the COSPAS-SARSAT spacecraft output at 1544.5 MHz. This information is extracted from NASA (1980). That report gives an altitude of 850 km for SARSAT and 1000 km for COSPAS. Both spacecraft are to be in essentially circular orbits.

1545-1559 MHz MAJOR SYSTEMS

There are no assignments for this band listed in the GMF, and there are no major systems of Region 2 administrations known to be operating within the band. The Soviet Union's VOLNA satellites provide an aeronautical mobile-satellite service in this band.

In the subsection FUTURE SYSTEMS there is a discussion of two possible future aeronautical mobile-satellite systems.

1559-1610 MHz MAJOR SYSTEMS

Global Positioning System

The basic purpose of NAVSTAR Global Positioning System (GPS) is to provide a user with a highly accurate three-dimensional location anywhere in the world. All satellites are to be in non-geostationary orbits. The user computes his location using position and timing information from a minimum of four satellites. Thus, there are four equations and four unknowns. The unknowns are the user's three positional coordinates and the bias error in his on-board clock. Conceptually, the clock bias error enables the user to determine the propagation time of transmission from the satellites, which in turn enables the user to determine the distance to each satellite. Since the satellites periodically transmit information on their own position and the system time (clock), the user has the basic information with which to determine user position. When fully operational, the GPS will have 21 satellites, including three active spares, in six orbital planes. This will ensure the user has real-time information from at least four satellites at anytime or anywhere in the world. Earth stations, which collectively are known as the control

TABLE 7

COSPAS-SARSAT SPACECRAFT TECHNICAL PARAMETERS

Parameter	Value
Center Frequency	1544.5 MHz
Phase Jitter	10° RMS (measured in a 50 Hz bandwidth)
Modulation/Index (Total)	0.7 radian RMS (SARSAT)
	0.5 radian RMS (COSPAS)
Polarization	LCP
EIRP	13 dBW at Nadir, decreasing to 8 dBW at 60° off Nadir (SARSAT)
	4 dBW at Nadir, increasing to 6 dBW at 60° off Nadir (COSPAS)
Bandwidth (Composite)	See reference (NASA, 1980).

segment, track the satellites and use this information to update satellite position and the error in the satellite atomic clock.

Downlink signals from the satellites to the user are transmitted on two frequencies. These signals are broadcast for the use of any user with the proper receiving equipment. These frequencies are 1227.6 MHz (data link L2) and 1575.42 MHz (data link L1). The reason for two frequencies on the downlink is to have the capability to estimate and correct for irregular propagation delays due to the ionosphere. There are no transmissions from the user to the satellites.

In this report we are only concerned with the L1 data link (1575.42 MHz) since this is the only GPS link which falls within the 1530-1660.5 MHz band. The L1 link from each satellite to prospective users consists of two signals in quadrature which implies that they can be received simultaneously without interfering with each other. The two signals are known as the precision (P) signal and the clear/acquisition (C/A) signal. The P signals will provide highly accurately-timed data from which the position of the user can be determined to within 16 meters. However, this accuracy will be available only to authorized users such as the military services. The signals that will be accessible to the general users will provide the capability to determine user position within approximately 100 meters. An important purpose of the C/A signal is that it may be used to help acquire the P signals more quickly.

GPS (Civil-Use) Interference Susceptibility Criteria

Results of measurements performed on a GPS receiver at the MIT Lincoln Laboratory are given in an Electromagnetic Compatibility Analysis Center report (Mullen, 1982). The measurements showed that a minimum carrier-to-noise spectral density (C/N_O) of 35 dB-Hz is needed for signal acquisition, and that loss of lock occurs at a C/N_O of 33 dB-Hz. After accounting for manufacturing tolerances and aging, MIT recommended the interference thresholds shown in TABLE 8.

TABLE 8

INTERFERENCE THRESHOLDS FOR
CIVIL-USE GPS RECEIVER

	C/N_O	Maximum Interference Level
Minimum for acquisition	37 dB-Hz	-109 dBm
Loss of Lock	34 dB-Hz	-106 dBm

To gain some insight into these numbers, it is worthwhile to calculate the noise power from the carrier-to-noise density in TABLE 8. The noise power thus calculated may be compared to the "Maximum Interference Level" in the table. A paper (Spilker, 1978) gives the value -200.6 dBW/Hz as a typical noise power spectral density. The code clock rate is 60 dB-Hz. If a noise bandwidth equal to the code clock rate were assumed, then an estimate of noise power would be -141 dBW (-111 dBm). If a noise bandwidth equal to twice the code clock rate were assumed, then an estimate of the noise power would be -138 dBW (-108 dBm).

GPS Emission Characteristics

Spilker (1978) gives the minimum received power levels at the output of a 0 dBi user antenna with RH circular polarization. These levels are -163 dBW and -160 dBW for the precision and the clear/acquisition components respectively where the satellite is at an elevation angle of five degrees or more.

The general shape of the emission spectrum is determined by code clock rates. The code clock rate is 1.023 Mbps for the clear/acquisition component and 10.23 Mbps for the precision component.

1610-1626.5 MHz MAJOR SYSTEMS

With the exception of the band assignments (1600-1660 MHz) for the three types of radar altimeters, the GMF lists no assignments for this band. The AN/APN-155 radar altimeter sweeps the frequency range 1615-1645 MHz, therefore, this altimeter occupies most of the 1610-1626.5 MHz band. A second radar altimeter, the AN/APN-159, in contrast to the first altimeter, emits a pulse. The AN/APN-159 is capable of being tuned anywhere in the 1600-1660 MHz allocated frequency range, but is usually tuned to 1630 MHz. Therefore, the 16 MHz bandwidth will typically occupy part of the 1610-1626.5 MHz band. Both the AN/APN-155 and the AN/APN-159 altimeter are described in the subsection on the 1626.5-1645.5 MHz band. The third altimeter, the AN/APN-133, does not operate in this band.

Several U.S. radio astronomy observatories use the frequency band 1610.6-1613.8 MHz. They are listed in Table 12. The equipment characteristics and the requirements for protection from interference are identical to those which apply to radio astronomy observations in the band 1660-1670 MHz. CCIR Report 224-5 (CCIR, 1982C) provides interference levels for the radio astronomy service. The values which are applicable to this band are: Input Power -220 dBW or equivalently Power Flux Density -194 dBW/m^2.

Radio astronomers use the band for observations of spectral line emissions of the hydroxyl radical (OH). The line of interest has a rest frequency of about 1612 MHz, but it is observed over a range of frequencies, usually lower than 1612 MHz, because of the Doppler effect which results from relative motions of the emitter and observer.

The observing systems are becoming more and more sensitive, system noise temperatures as low as 30 degrees Kelvin are now being achieved. With the improved sensitivity, there is considerable pressure to extend the radio astronomy allocation below the present lower limit of 1610.6 MHz. CCIR Recommendation 314-5 states that a minimum of 1606.8-1613.8 MHz is necessary for adequate protection of radio astronomy observations.

1626.5-1645.5 MHz MAJOR SYSTEMS

INMARSAT

INMARSAT transmits from ship-to-satellite in this band and from satellite-to-ship in the 1535-1544 MHz band. INMARSAT is described in the subsection entitled "1535-1544 MHz MAJOR SYSTEMS".

Radar Altimeters

Historically there were as many as six designations of radar altimeters operating in the 1600-1660 MHz frequency band. Of these, only three are known to be currently in operation in the band. These are the AN/APN-133, the AN/APN-155 and the AN/APN-159. A summary of the number of units known to exist is included in the SPECTRUM OCCUPANCY subsection.

The AN/APN-133 and AN/APN-159 are altimeters of the pulsed carrier type of operation. Pulsed carrier types emit a short burst (pulse) of energy that is reflected by the terrain and is received by the receiver. Round-trip delay time of this pulse from the aircraft to the terrain and back is used to measure altitude relative to the terrain.

The AN/APN-155 altimeter emits frequency modulated CW. Since the frequency is swept in time, the difference in frequency between the currently transmitted signals and the frequency of the currently received signal is a measure of the altitude. A greater altitude implies a greater delay and this in turn implies a greater frequency difference.

TABLE 9 gives some of the key parameters necessary for analyzing the emissions and the susceptibility of the radio altimeters known to be in the band at the present time. The information was extracted from an Office of Telecommunications report (Haakinson and Kimball, 1974A). That report contains a more detailed list of parameters.

1645.5-1646.5 MHz MAJOR SYSTEMS

SAMSARS

The Maritime Administration has contracted to develop an experimental demonstration of low data-rate spread spectrum maritime communications. One application is the Emergency Position Indicating Radio Beacon (EPIRB). The idea is to use the INMARSAT system, which has satellites in geostationary orbit, to communicate the information to the proper coordinating facility. A future generation INMARSAT system would provide satellite reception of EPIRB signals at approximately 1646 MHz. The information would be transmitted to an earth station at a frequency of approximately 4200 MHz. A test of a spread spectrum signal over a MARISAT (now INMARSAT) link has already been conducted.

The system discussed here is the Satellite-Aided Maritime Search and Rescue System (SAMSARS). The United Kingdom is developing a spread spectrum system similar in concept to the SAMSARS, and there is cooperation between the two projects. The SAMSARS is participating in what is known as the Coordinated Trials Program (CTP):

> "The UK, USSR, US, Norway, Federal Republic of Germany and Japan have developed different satellite EPIRB systems to alert rescue authorities. Five of the systems have recently gone through an intensive series of trials to compare and evaluate them at the European Space Agency's satellite tracking station in Villafranca del Castillo, 30 km west of Madrid. The purpose of the trials is to see how well the systems meet the operational requirements of the International Maritime Organization (IMO). Under the requirements of a new global distress system, now being developed by IMO, most countries are expected to make it mandatory for all ocean-going vessels to carry such equipment in the 1990's." (Wright, 1982).

TABLE 9

RADAR ALTIMETER CHARACTERISTICS

PARAMETERS	SYSTEMS			
	APN-133	APN-133A	APN-155	APN-159
Nominal Operating Frequency	1640 MHz	1640 MHz	1630 MHz	1630 MHz
Frequency Range (Tuning Range for Altimeters)	1630-1650 MHz	1630-1650 MHz	Fixed	1600-1660 MHz
Peak Power Output	51.0 dBm	50 dBm	29 dBm	60 dBm
PRF	49,164 pps 9,830 pps	49,164 pps 9,830 pps	———	4,916 pps
Half Amplitude Pulse Widths (microseconds)	0.124 0.144	0.120 0.500	———	0.150 0.048
Emission Type	Pulsed CW	Pulsed CW	FM CW	Pulsed CW
Emission Bandwidth -3 dB -20dB -60dB	10 MHz 20 MHz 44 MHz (-30)	10 MHz 20 MHz 70 MHz (Estimated)	30 MHz 32 MHz 100 MHz (Estimated)	16 MHz 60 MHz 380 MHz
Frequency Stability	2000 ppm long term	2000 ppm long term	670 ppm long term	50 ppm
Antenna Power Gain (dBi)	8	8	8	12
Antenna Beamwidth (degrees)	55 Conical	50	50 Conical	Az 55 El 35

TABLE 9 (Continued)

PARAMETERS	SYSTEMS			
	APN-133	APN-133A	APN-155	APN-159
Polarization	Vertical	Vertical	Vertical	Linear
Receiver Selectivity (IF Bandwidth) -3 dB	4 MHz	8.5 MHz	15 kHz	10 MHz
Receiver Noise Figure	14 dB	14 dB	20 dB	15 dB (Assumed)
Frequency Sweep	_____	_____	± 15 MHz	_____

Distress systems such as the SAMSARS using geostationary satellites and distress systems which use polar orbiting satellites complement each other nicely. Polar orbiting satellite systems provide global coverage. Geostationary satellite systems do not provide global coverage, but can provide faster reporting of distress than low-orbiting polar satellites. It is possible that both types of systems will be employed for distress and safety, or that both types will be integrated into one system. The final choice of frequency bands is also yet to be made.

SAMSARS-B

TABLE 10 gives a power budget for a SAMSARS-B EPIRB transmitting to an INMARSAT satellite for translation and retransmission. This budget was based on parameters tentatively selected for the design of the experimental SAMSARS-B system. The budget was extracted from a paper (CCIR, 1981). The same paper gives a 12.8 kHz chip rate and a 25.6 kHz null-to-null signal bandwidth.

The SAMSARS-B EPIRB transmits a direct sequence spread spectrum signal with bi-phase PSK modulation. SAMSARS-B transmissions have a (sin x)/x voltage amplitude spectrum.

CCIR (1981) discusses the Acquisition Threshold for the SAMSARS-B. The tradeoff between [lower] transmitter power and [higher] data rate is subject to constraints that result from the requirement to achieve rapid synchronization. For a given basic configuration, these constraints place a lower limit on the required carrier-to-noise density, independent of data rate. For an operational system, this limit should be on the order of 20 dB-Hz or less for reliable operation with transmitters of 5 to 10 watts output power under the worst link conditions.

SUMMARY OF DISTRESS AND SAFETY SYSTEMS IN THE 1530-1660.5 MHz BANDS

The COSPAS-SARSAT project is described in the 1544-1545 MHz MAJOR SYSTEMS subsection, and the SAMSARS is described earlier in this subsection. Table 11 is a summary of distress and safety systems in the 1530-1660.5 bands.

1646.5-1660 MHz MAJOR SYSTEMS

This is the Aeronautical Mobile-Satellite Service (R) (Earth-to-space) band which, along with the adjoining 1660-1660.5 MHz band, is the complement to the 1545-1559 MHz Aeronautical Mobile-Satellite Service (R) (Space-to-Earth) band. The discussion in the subsection entitled "1545-1559 MHz" applies here also.

1660-1660.5 MHz MAJOR SYSTEMS

Radio Astronomy

Several radio astronomy observatories use the band of frequencies from 1660 MHz to 1660.5 MHz (see TABLE 12). The information for TABLE 12 is extracted from CORF (1983). An NTIA report (Flynn, 1981) contains a summary of those observatories operating in the band 1660-1670 MHz. The report mentions that radio astronomy receivers have a high sensitivity which makes them particularly sensitive to interference. The sensitivity of radio astronomy systems is discussed in CCIR Report 224-5 (CCIR, 1982C). This band is used for

TABLE 10

INMARSAT BASED SAMSARS POWER BUDGET
EPIRB-TO-INMARSAT LINK

SAMSARS Frequency, MHz	1646	
EPIRB Elevation Angle, degrees	5	
	SAMSARS SIGNAL	
Transmitter Power Output, dBW	7.0	
Transmitter Antenna Gain, dB	0.0	
EIRP, dBW	7.0	
Free Space Loss, dB	-189.0	
Miscellaneous Losses, dB	- 7.5	
Satellite G/T, dB/K	- 12.2	
-Boltzmann's Constant, dB(J/K)	-(228.6)	
Up-link C/N_o, dBHz	26.9	*
Satellite Transponder C/I_o, dBHz	34.0	**
Transmitted $C/(N_o + I_o)$, dBHz	26.1	***

* C/N_o = Ratio of Input Signal Power-to-Noise Power Spectral Density

** C/I_o = Ratio of Input Signal Power-to-Intermodulation Power Spectral Density

*** $C\ (N_o+I_o)$ = Ratio of Input Signal Power-to-Combined Noise and Intermodulation Power Spectral Density

TABLE 11

SUMMARY OF DISTRESS AND SAFETY SYSTEMS IN THE 1530-1660.5 BAND

System	Country	Type	1530-1660.5 Up	1530-1660.5 Down
DRCS	Germany	Geostationary	Yes	No
Unknown	Norway	Geostationary	Yes	No
Unknown	U.K.	Geostationary	Yes	No
SAMSARS	U.S.	Geostationary	Yes	No
SADKO	U.S.S.R.	Geostationary	Yes	No
FSK	Japan	Geostationary	Yes	No
SS PSK	Japan	Geostationary	Yes	No
SARSAT	U.S., Canada, and France	Low Orbit	No (121.5 MHz, 243 MHz, 406 MHz)	Yes
COSPAS	U.S.S.R.	Low Orbit	No (121.5 MHz, 406 MHz)	Yes

TABLE 12

SUMMARY OF U.S. RADIO ASTRONOMY OBSERVATORIES USING THE
1610.6-1613.8 and 1660-1660.5 MHz BANDS FROM CORF (1983)

Radio Name of Observatory	Location		Antenna Size/Type	System Noise Temperature
	Latitude	Longitude		
Fort Davis, TX (Harvard Univ.)	30°38'08"N	103°56'42"N	26m/Paraboloid	130K
Ohio State Ohio Wesleyan	40°15.1'N	83°02.9'W	103.8 x 21.4 M Standing parabola	
Vermillion River, IL	40°03'38"N	87°33'49"W	36.6m/Paraboloid	120K
* Green Bank, WV	38°26'08"N	79°49'42"W	91.4m/Paraboloid 42.7m	70K
Maryland Pt., MD	38°22'27"N	77°13'51"W	25.6m/Paraboloid	150K
* Owens Valley, CA	40°49'03"N	118°17.6'W	Three 10.4m Paraboloid	85K
* Hat Creek, CA	40°40'03"N	121°28.4'W	26m/Paraboloid	100K
R.G. Agassiz, MA	42°31'13"N	71°33.5'W	25.6m/Paraboloid	150K
* Haystack, MA	42°37'23"N	71°29'19"W	36m/Paraboloid	200K
* Arecibo, PR	18°21'12"N	66°45'11"W	305m/Spherical Reflector	60K
North Liberty, IO	41°46'11"N	91°34'22"W	18.3m/Paraboloid	75K
* Socorro, NM	34°04'43"N	107°37'04"W	Very Large Array	50K

* Only these observatories use the 1610.6-1613.8 MHz Band.

observations of spectral lines of the hydroxyl radical (OH). The rest frequencies of the lines are at about 1665 and 1667 MHz, but observations are made over a band of frequencies because of the Doppler effect. Observing systems are becoming more sensitive, and there is pressure to extend the radio astronomy allocation below 1660 MHz. CCIR Recommendation 314-5 (CCIR, 1982D) suggests the allocation should cover 1659.8-1670 MHz.

OTHER SYSTEMS (GLONASS AND VOLNA)

The following two subsections briefly discuss the GLONASS and VOLNA systems which serve the U.S.S.R. Interactions involving these systems are generally not addressed in this report. Coordination with these systems is handled through the I.F.R.B. by the appropriate agencies.

Possible interactions between the VOLNA system and the INMARSAT system are being coordinated by INTELSAT for the case of the INTELSAT MCS packages which serve INMARSAT. It is anticipated that some means of coordination will be necessary to resolve possible interactions between the VOLNA system and the second generation INMARSAT system.

GLONASS

The U.S.S.R. is establishing a worldwide aircraft radionavigation system called GLONASS (I.F.R.B., 1982). The system operates within the 1559-1610 MHz Radionavigation-Satellite (Space-to-Earth) band and also within the 1610-1626 MHz Aeronautical Radionavigation band over a frequency range 1597-1617 MHz. Operation in the Aeronautical Radionavigation band is in accordance with Footnote 732 of the Radio Regulations (ITU, 1982). There are to be 9-12 satellites in three orbital planes with 3-4 satellites in each plane. Orbits are circular at an altitude of 20,000 km. Users will determine their own location by passive measurement of the distance to each of three satellites. Space station antenna gain is 13 dB, and maximum spectral power density is -44 dBW/Hz. The noise temperature of the earth-station receiver is approximately 700 K. Interference between GPS and GLONASS is apparently precluded by the frequency separation between the two systems.

The United States has requested more information on GLONASS from the USSR because of the U.S. concern about interference to radio astronomy at 1610.6-1613.8 MHz and 1660-1670 MHz. This additional information is needed to assess what is potentially a serious problem for the Radio Astronomy Service particularly of 1610.6-1613.8 MHz.

VOLNA

The USSR is developing the VOLNA series of satellite networks within the 1530-1660.5 MHz bands. The VOLNA system is for communication with civil aircraft and sea-going vessels. Based on advance information, VOLNA satellites 1 through 8 are at orbital positions 25°W, 14°W, 45°E, 58°E, 85°E, 140°E, 170°W, and 90°E, respectively, though one or more of these positions may have been changed through the I.F.R.B. coordination process. VOLNA 1, 3, 5, and 7 are designed to operate in the frequency ranges 1543.5-1558.5 MHz and 1645-1660 MHz. These frequency ranges correspond to the pre-WARC-79 band allocations for the Aeronautical Mobile-Satellite (R) Service. This overlaps the WARC-79 bands serving maritime mobile-satellite systems and safety and distress systems on both the up-path and the down-path. VOLNA 2, 4, 6, and 8 are designed to operate in 0.5 MHz wide bands centered at the frequencies 1536.4, 1637.9, 1543.7, and 1652.37 MHz. The first two frequencies are for the Maritime Mobile-Satellite Service. The latter two frequencies are for the Aeronautical Mobile-Satellite Service; however, due to WARC-79, 1543.7 MHz is within the allocation for the Maritime Mobile-Satellite Service.

FUTURE SYSTEMS

Aeronautical Mobile Satellite Systems

Aviation Week and Space Technology (1982) reports that technical demonstrations of satellite digital data links for airline and business aircraft are being sought by INMARSAT. A possible system involves digital communication links. Possible uses include air traffic control communications, relay of techical and other information between aircraft and company ground facilities or headquarters, and data transmission from businessmen to the ground facility. The system would take advantage of existing investments in satellites and ground facilities for the maritime relay network.

PROSAT is an experimental satellite project for the relay of aviation and maritime communications. It was adopted in December 1981 as one of the ongoing projects by the Council of the European Space Agency (ESA). The project was conceived with the idea of replacing the adandoned Aerosat project by another project which would fulfill the same objectives and cost less.

Collision Avoidance Systems

Footnote US40 provides for the collision avoidance function to be in the band, but the firms which have built the collision avoidance systems for this band in the past reported no plans to actively market these systems in this band. Footnote US40 could be eliminated in the event of International Civil Aviation Organization (ICAO) acceptance of the Traffic Alert and Collision Avoidance Systems (TCAS). If such systems re-enter this band a new study should be conducted to determine electromagnetic compatibility with other systems.

Distress and Safety Systems

As part of its Future Global Maritime Distress and Safety Systems, IMCO requested a means by which a shore-based Rescue Coordination Center (RCC) would be able to quickly contact vessels in the vicinity of the distressed vessel. One proposal for the Shore-to-Ship Distress Alerting Channel (SHOSAC) is an inexpensive Receive-Only Ship Earth Station (ROSES). As described in a report (CCIR, 1982B), one idea is to connect even those vessels which do not have an INMARSAT ship earth station by using an inexpensive receiver operating at low bit rates through a satellite. Circular polarization would be used to reduce multipath effects due to the sea. An omnidirectional antenna would be used in conjunction with an uncooled receiver. The receiving station would be what is referred to as a low G/T ship earth station.

GEOSTAR Petition

GEOSTAR Corporation has petitioned the FCC for a notice of proposed rulemaking to allocate spectrum for the GEOSTAR Satellite System (GSS). In essence, the GSS is a service that would use three geostationary satellites to determine three position coordinates of airborne and terrestrial users. The system as envisioned for general usage would also include communications capability. Within the 1530-1660.5 MHz frequency range, the GSS would have user-to-satellite transmission in the 1610-1626.5 MHz band. This is an aeronautical radionavigation band. Footnote 732 reserves the band for the use and development of airborne electronic aids to air navigation and any directly associated ground-based or satellite-borne facility.

The petition states that the GSS is a radiodetermination satellite service that would provide for the exchange of geographical coordinates and brief coded messages. The GSS concept provides for aeronautical radiodetermination functions as well as terrestrial radiodetermination functions. The aeronautical radiodetermination function would be provided by digital channels between transceivers on aircraft and at airports and computing facilities at the GSS ground station. Terrestrial radiodetermination functions would include mobile fleet control, remote fixed operation control, and applications to emergency relief, public safety and crime prevention. Triggering of an emergency button would send an automatically encoded distress signal to the three satellites. In a mobile fleet control application, a supervisory office could determine the location of any mobile unit. In a fixed operation application, brief status and housekeeping information could be received from unmanned operations such as oil drilling rigs.

MOBILSAT Application

The Mobile Satellite Corporation (MOBILSAT) has applied to the FCC for authorization to construct and commercially operate a Mobile-Satellite System (MSS) on an experimental-developmental basis. The MSS would provide one-way and two-way communications with mobile units on land, water, or in the air via two geostationary satellites. These satellites would serve the entire United States and Puerto Rico. Fixed earth stations that are called gateways would interconnect the MSS with the public switched telephone network, with radio common carriers, and with private users. The application requests authorization to use several frequency ranges, two of which are within the 1530-1660.5 MHz band. The 1544-1559 MHz range would be used for the down-path from satellite to air or land mobile stations, while the 1645.5-1660.5 MHz band would be used for the up-path from air and land mobile to satellite stations.

An amendment to MOBILSAT's application is intended to present the Federal Aviation Administration with an opportunity to develop a satellite air traffic control (ATC) surveillance service within the 1544-1559 MHz and 1645.5-1660.5 MHz bands. Aircraft are interrogated by signals from a central ground station relayed through the two geostationary satelltes. The aircraft respond automatically with a signal which is relayed back through the two geostationary satellites to the central ground station. Aircraft position is based on the round trip propagation times via the two satellites along with the aircraft altimeter reading. The interrogation (polling) signal from the central ground station occupies a single 10 kHz wide channel in the 1545-1559 MHz band for transmission from satellite-to-aircraft. Up to 400 aircraft respond to each interrogation, one in each of 400 channels (each 10 kHz wide). These response transmissions from aircraft-to-satellite are within the 1646.5-1660.5 MHz band. Thus, the proposal is to accomplish surveillance with 10 kHz of bandwidth on the forward link to the aircraft, and 4 MHz of bandwidth in the return link from the aircraft.

SPECTRUM OCCUPANCY

This subsection describes, in a general way, the occupancy of the spectrum in the bands 1530-1660.5 MHz. Figure 1 graphically shows the occupancy of these bands by the major systems.

RSMS Van Measurements

Measurements in the field were performed in the 1530-1660.5 MHz band using the Radio Spectrum Measurement System (RSMS) van. Some measurements were made using the wideband scan measurement capability. A brief description of this procedure follows.

The wideband scan allows specification of many measurement parameters, including frequency range, number of frequency steps within the specified range, dwell time on each frequency step, bandwidth and RF attenuation. The program makes a measurement of peak amplitude received at each frequency, starting at the lower end of the frequency range and continuing until the upper end of the frequency range is reached. At each frequency, the system waits for a specified dwell time (typically five seconds) continually measuring the peak amplitude of the signal and updating its measurement when a still stronger pulse occurs. This procedure will give the largest peak power reading, which is the power recorded for that frequency. As the measurements are made, the measured data is graphed. The operator may add or subtract attenuation in 10 dB steps whenever action is required to keep the signal within the linear dynamic range of the system. The system corrects for input attenuation so that the data is continuous and appears to have been measured with a system with very large dynamic range. The wideband scan is typically operated with frequency steps slightly less than the measurement bandwidth.

For the RSMS van using an external preamplifier, the noise figure is approximately 5 dB. This leads to an approximate system noise power density of -199 dBW/Hz. Since the van actually measures the peak power at each frequency, it is usual to assume that the apparent noise floor is actually the 4 sigma noise voltage as opposed to the RMS noise voltage. This is equivalent to another 12 dB. Therefore, it would be unrealistic to expect the van to measure a signal below -187 dBW/Hz. For a 1 MHz receiver bandwidth this amounts to a noise floor power of -97 dBm. If the external preamplifier is not used, the noise figure is 12 dB instead of 5 dB, and the 1 MHz noise power is -90 dBm.

There are five major systems serving the United States which are presently operational in the 1530-1660.5 MHz band. These systems are NAVSTAR GPS, INMARSAT, the three radar altimeters (AN/APN-155, 159, 133), the telemetry systems, and the passive radio astronomy systems.

Signal strength received by the Global Positioning System L1 receiver is designed to be a minimum of -163 dBW for the precision signal and -160 dBW for the clear/acquisition signal. The van would not be expected to detect any L1 signal from any Global Positioning System satellite. The basic reason is that an actual GPS receiver is specifically designed for the GPS spread spectrum signals and is able to detect signals which are below the van noise level.

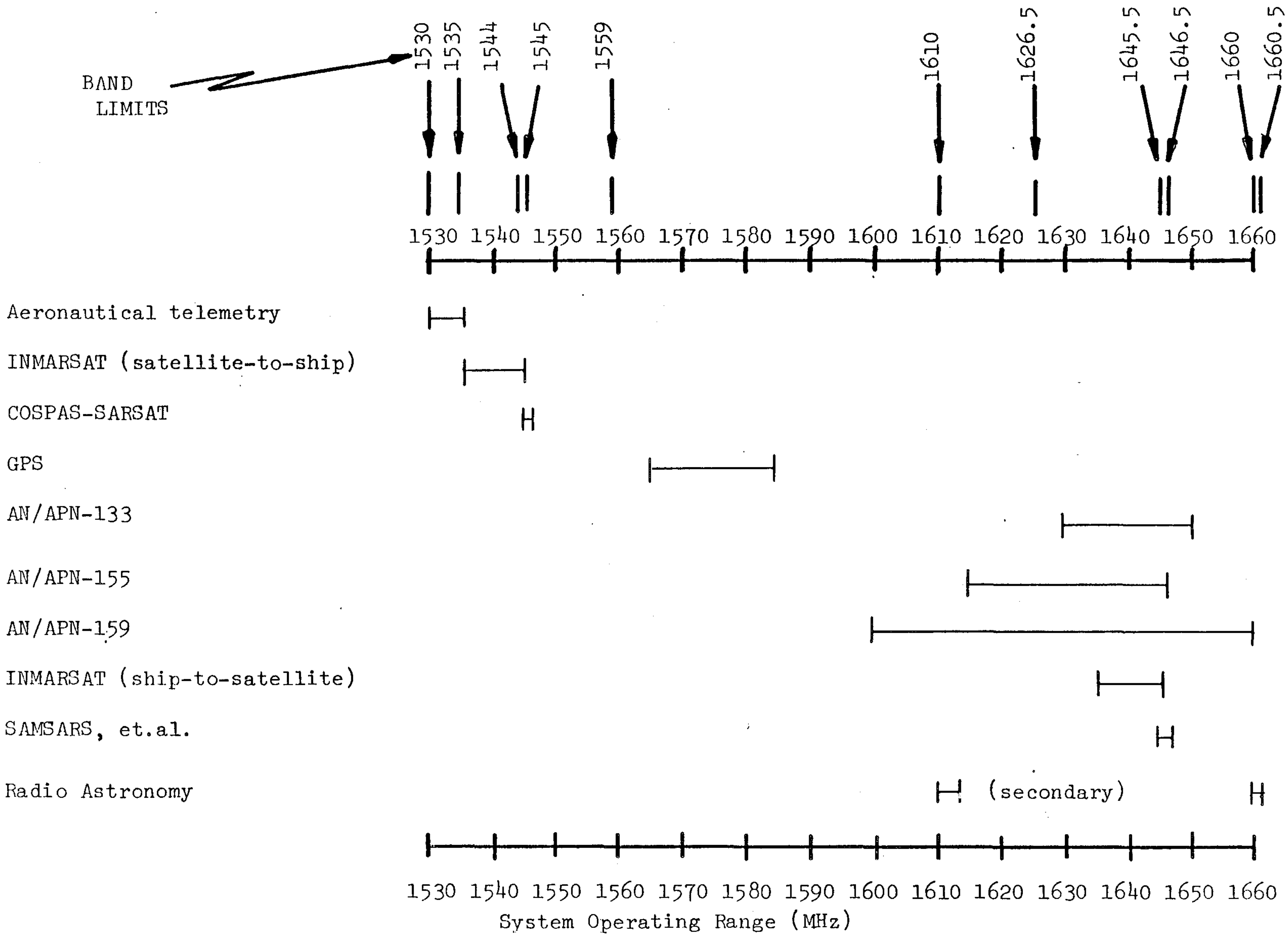

Figure 1. Spectrum Occupancy of Major Systems

Telemetry systems operate in the band 1530-1535 MHz. The EIRP for a typical telemetry link is 44 dBm (Matos, 1983). The van is using a 1 MHz IF bandwidth in these wideband scans. If an omnidirectional antenna is used by the van, then the line of sight distance is the typical criterion for reception and the maximum reception distance for typical equipment is approximately 400 km.

INMARSAT's MARISAT satellite effective isotropically radiated power (EIRP) at beam edge is 29.5 dBW at saturation in the high power mode. The van would not be expected to detect a signal from a MARISAT satellite with the van operating with a 1 MHz IF bandwidth and a 1 meter diameter dish antenna.

MARISAT transmits uplink (ship-to-satellite) signals in the 1626.5-1645.5 MHz band. A ship on either the Pacific or the Atlantic Ocean will have its mainbeam pointed away from the Continental United States. However, it is possible for the RSMS van to receive these transmissions with an omnidirectional antenna provided the van is at a relatively high elevation and a ship happens to be transmitting nearby. This may be seen from the following: The ship EIRP is 37 dBW in the direction of the mainbeam. Skolnik (1962) gives radiation pattern characteristics produced by various aperture distributions. The intensity of the first sidelobe of the antenna for a cosine squared feed illumination (assumed here) is 32 dB from the main beam level. Thus, the EIRP in the direction of the first sidelobe would be 5 dBW. Under these conditions the power received by a unity gain antenna at a distance of 1 km is -91 dBW. Since the noise floor of the van is -127 dBW (1 MHz) the margin at this 1 km distance for example is 36 dB. Therefore, reception is possible.

Radar Altimeters are permitted to operate within the band of frequencies from 1600-1660 MHz. Measurements of the spectra for these alimeters are desirable. The best location for such measurements would be the approach to a military runway. An analysis similar to that permformed on the MARISAT uplink was performed for the AN/APN -133, 155, and 159 radar altimeters. An omnidirectional receiving antenna was assumed. The results of these analyses are given in TABLE 13. This table lists the approximate maximum distance at which the RSMS van can receive signals from these altimeters, with the van operating as described.

RSMS Van Measurements Results

This subsection shows and describes the results of measurements taken in the 1530-1660.5 MHz bands.

Figure 2 shows a clear example of the spectrum of an AN/APN-155 Radar Altimeter. As can be seen from the figure, the measurements are in agreement with the nominal operating frequency of 1630 MHz and frequency sweep of 1615-1645 MHz given by Haakinson and Kimball (1974A) and Ax and Jennings (1972). This particular spectrum was measured during military exercises at Nellis Air Force Base during November 1981. The signal was emitted by an F-4 aircraft. A new procedure, Quick Search, was employed for the measurements of Figure 2.

Pratt (1983) notes that the signal at 1570 MHz in Figure 2 was present in approximately 45 percent of the frequency scans in this band. This signal has not been identified.

TABLE 13

RADAR ALTIMETER RECEPTION DISTANCE

	AN/APN-133	AN/APN-155	AN/APN-159
Peak Power	21 dBW	-1 dBW	30 dBW
Gain	8 dBi	8 dBi	12 dBi
Assumed Sidelobe level relative to mainbeam	-20 dB	-20 dB	-20 dB
3 dB Bandwidth	10 MHz	30 MHz	16 MHz
Reception Distance (with omnidirectional antenna)	32 km	1 km	112 km

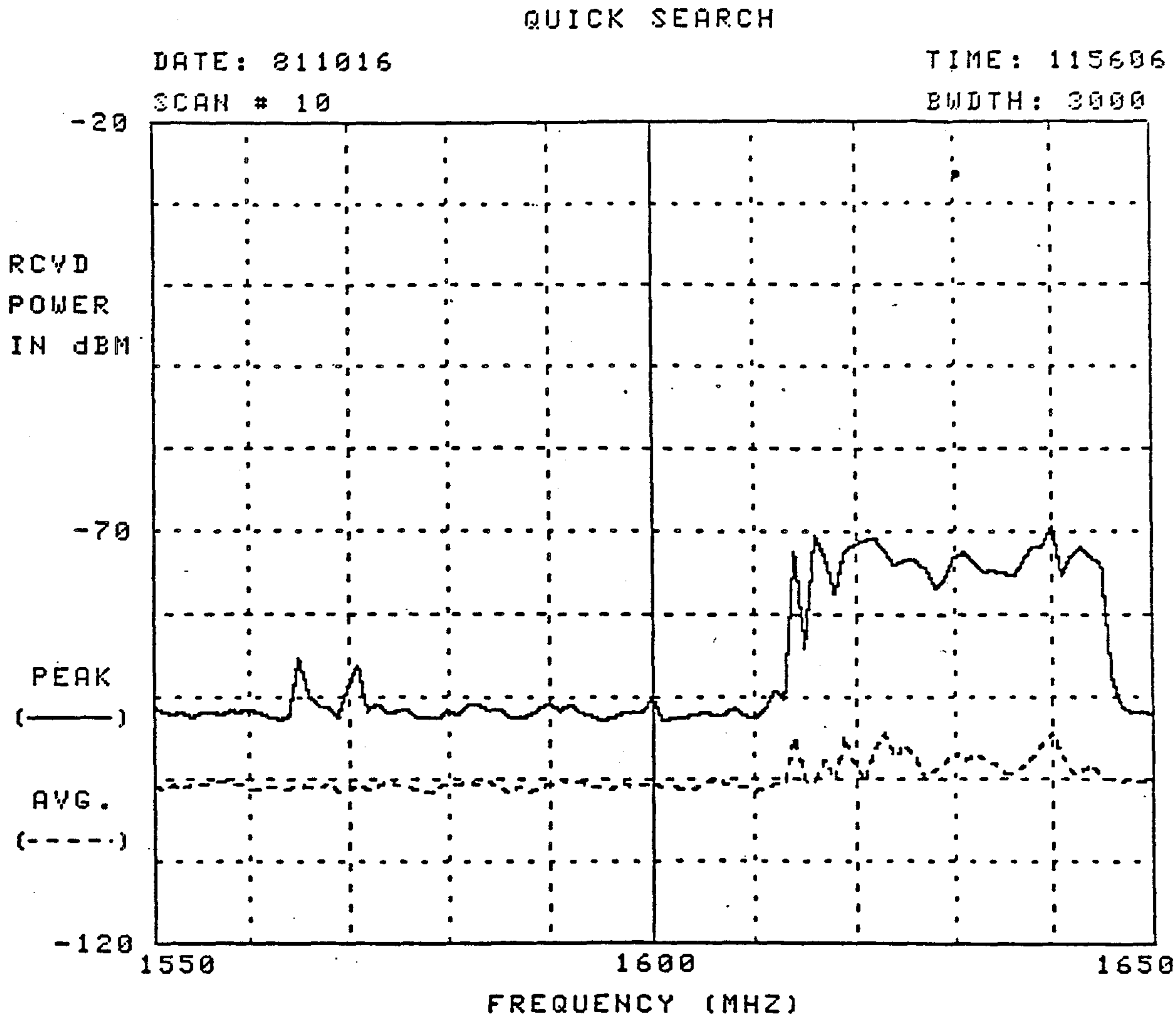

Figure 2. Example of Spectrum Occupancy Measurements During the EWCAS Exercise in 1558.5-1636 MHz Band (F-4 Aircraft Flying over RSMS Van) Showing Spectrum of AN/APN-155 Radar Altimeter.

Figure 3 shows wideband scan measurements taken at San Pedro Hill near Long Beach, California on September 25, 1980. The measurements were made with a 3-6 dB gain cavity backed spiral antenna. No activity is seen in the band of interest, except at a frequency of 1645 MHz. The van log for that day indicates the response at 1645 MHz was due to leakage when channel B of the [nearby] ARSR-1E turned on and radiated prior to dumping to the dummy load. Generally, blanking of the ARSR-1E was used during those measurements.

Figures 4 and 5 present some results of measurements taken on San Pedro Hill at a later date, January 27, 1981. Each shows the 1600-1660.5 MHz portion of the band of interest. The gain of the van antenna was 0 dB and the measurement bandwidth was 1 MHz. These measurements were conducted using the wideband scan, and pulse blanking of the ARSR-1E on San Pedro Hill was in effect. Each scan is clear except for one signal. Figure 4 indicates a signal at 1640 MHz and Figure 5 indicates a signal at 1645 MHz. San Pedro Hill is at an elevation of 1400 feet on the California coast only six miles from a company which has developed MARISAT ship terminals. A test ship for these terminals has operated in these waters. It is possible that the signal at 1640 MHz was connected with MARISAT system operations or development, but this could not be verified. The signal at 1640 MHz is within the MARISAT system bandwidth. The source of the signal at 1645 MHz has not been determined.

Spectrum Occupancy of the Bands

TABLE 14 is a band occupancy summary for the bands which constitute the 1530-1660.5 MHz bands (post-WARC-79). TABLE 15 is a similar summary for the bands which constituted the 1530-1660.5 MHz frequency range prior to WARC-79. The data base from which each summary was derived is the Government Master File (GMF). In bands allocated to the mobile services in particular, the GMF gives only a partial idea of the spectrum occupancy.

Based on conversations with the agencies, TABLE 16 is a summary of the number of radar altimeter units known to exist in the 1600-1660 MHz allocated frequency range.

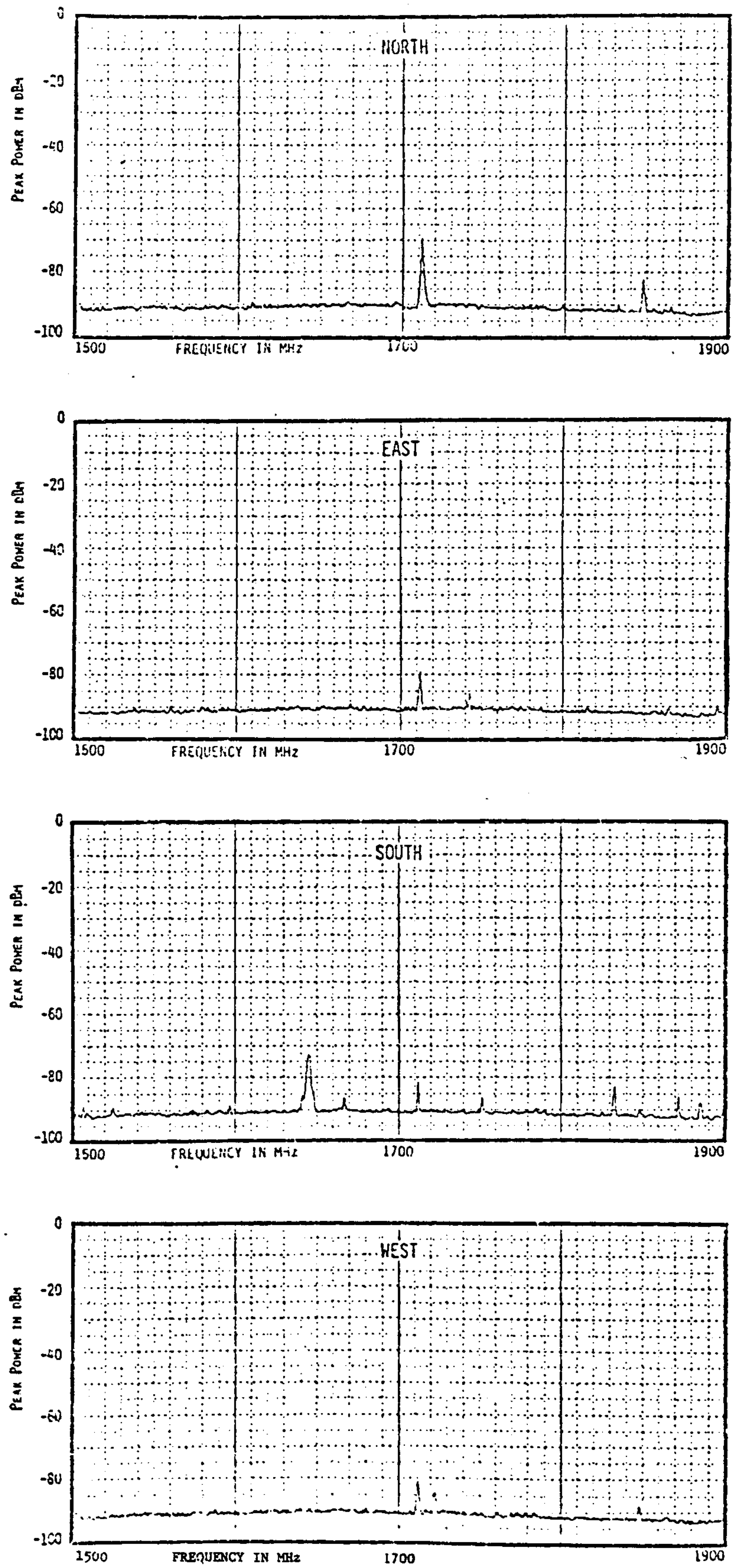

Figure 3. Measurements from San Pedro Hill taken September 25, 1980.

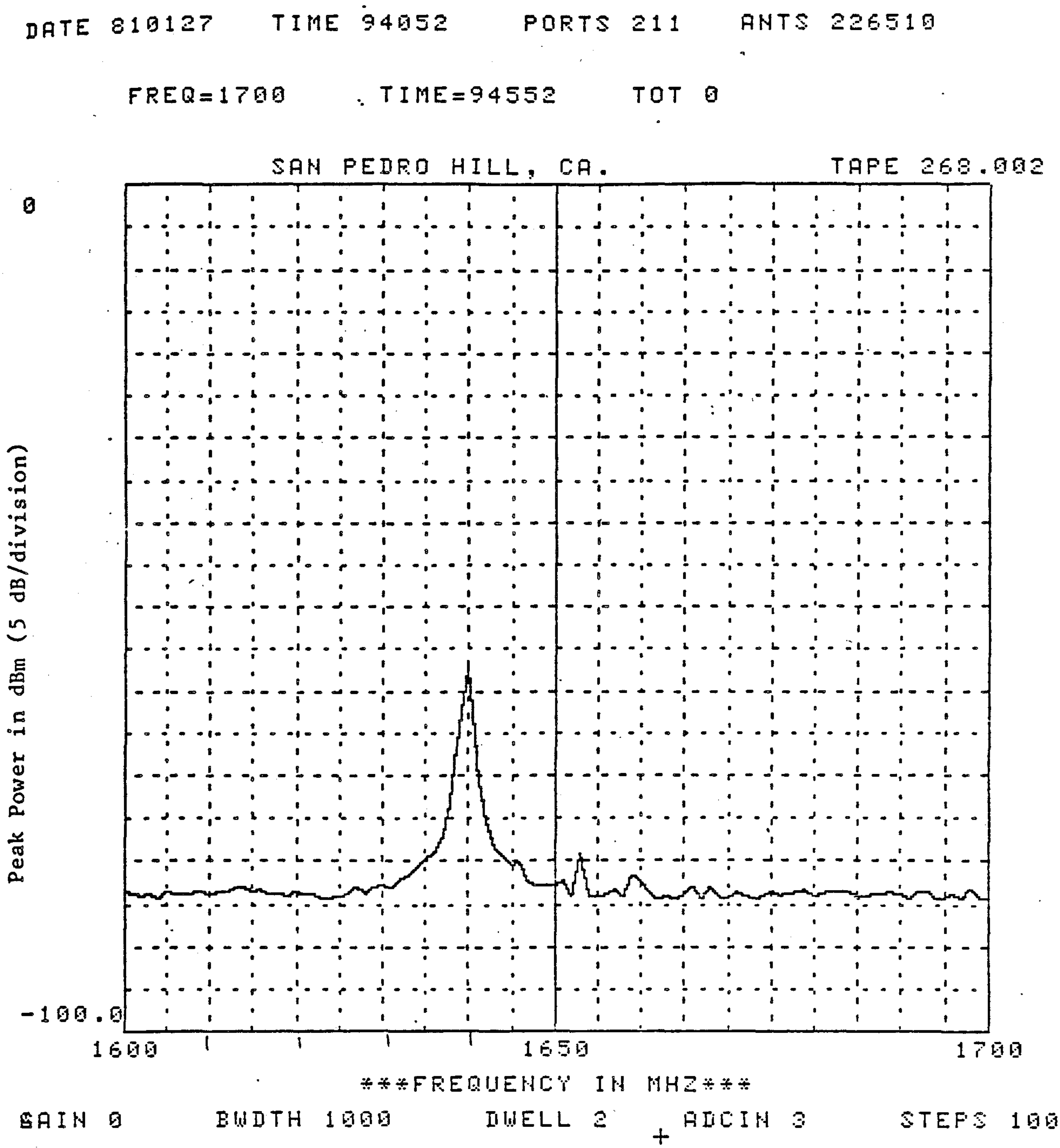

Figure 4. Measurements from San Pedro Hill taken January 27, 1981, signal at 1640 MHz.

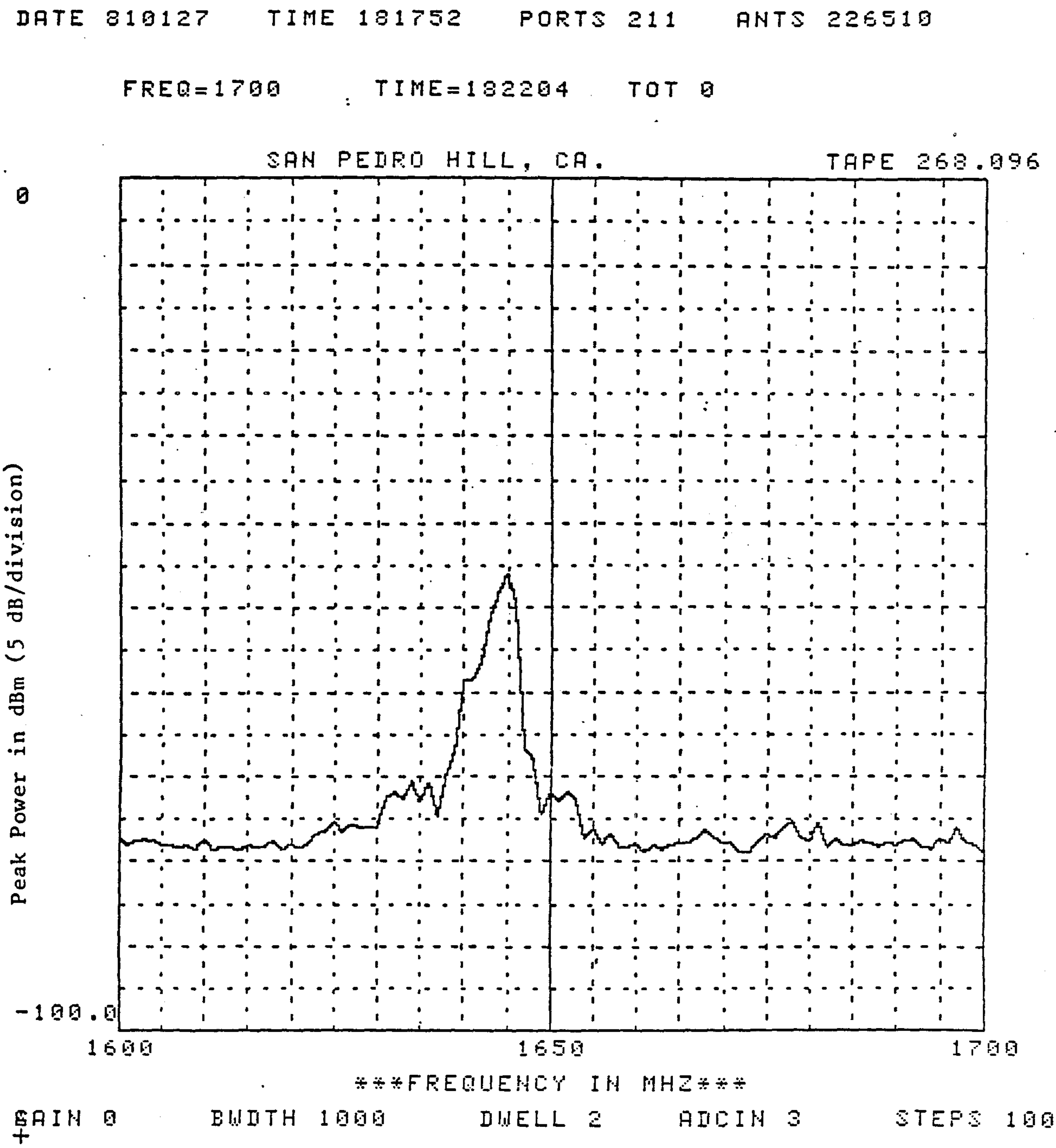

Figure 5. Measurements from San Pedro Hill taken January 27, 1981, signal at 1645 MHz.

TABLE 14

SUMMARY OF GMF ASSIGNMENTS

BY BAND (POST-WARC-79 BANDS)
(LOWER FREQUENCY $\leq$ BAND < UPPER FREQUENCY)

Lower Freq.	Upper Freq.	Number of GMF Assignments February 1983
1530	1535	34
1535	1544	10
1544	1545	1
1545	1559	0
1559	1610	20
1610	1626.5	0
1626.5	1645.5	14
1645.5	1646.5	0
1646.5	1660	0
1660	1660.5	0

TABLE 15

SUMMARY OF GMF ASSIGNMENTS

(PRE-WARC-79 BANDS)

Upper Frequency	Number of GMF Assignments on Given Date							
	1/72	1/73	1/74	1/75	1/77	1/78	1/79	7/79
1535.0 MHz	383	405	394	463	444	605	669	694*
1542.5 MHz	4	3	4	3	3	3	3	3
1543.5 MHz	0	0	0	0	0	0	1	1
1558.5 MHz	5	6	6	5	2	4	4	5
1635.5 MHz	25	39	39	53	38	56	50	52
1644.0 MHz	0	1	2	2	2	3	7	6
1645.0 MHz	0	0	0	0	0	0	0	0
1660.0 MHz	9	10	11	10	2	4	8	8
1670.0 MHz	13	7	6	5	0	0	0	0

* The frequency range of this band is 1435-1535 MHz as contrasted with a frequency range of 1530-1535 MHz in TABLE 14.

TABLE 16

RADAR ALTIMETER UNITS

Designation	Agency	1981 Approximate Number of Units	1983 Approximate Number of Units
AN/APN-133	USAF	590	650
AN/APN-133	USN	20	20
AN/APN-155	USAF	1400	1300
AN/APN-159	USAF	346	350
AN/APN-159	USN	50	50

Notes: 1. There are also a maximum of 22 of these altimeters operated by DOC, DOE, and NSF.

2. Non-Government altimeters are no longer produced. It is not known how many of these altimeters are still in operation.

SECTION 5

IDENTIFICATION OF PROBLEM INTERACTIONS

GENERAL

This section presents an interaction matrix for the 1530-1660.5 MHz band. The purpose of this section is to identify problem areas which have been analyzed in previous reports and also to identify areas requiring further study.

INTERACTION MATRIX

Figure 6 is a matrix of potential interactions between the major systems in the 1530-1660.5 MHz band. The rows of the matrix represent transmitter stations and the columns of the matrix represent receiver stations. Interactions are divided into four categories: (1) Manageable Problem, (2) Serious Problem, (3) Future Study Indicated, and (4) No Problem. The definitions of these categories follow:

(1) Manageable Problem - If a problem is encountered, it is expected to be manageable. Included in this category are those interactions that involve only one federal agency or only non-Government stations. Such problems would normally be resolved by that agency or the FCC.

(2) Serious Problem - A solution to this problem will be difficult to find.

(3) Future Study Indicated - This interaction should be analyzed in detail at an appropriate time in the future.

(4) No Problem - No problems are anticipated.

MANAGEABLE PROBLEM

INMARSAT Shipboard Transmitter to Altimeters

Ax (1972) identified the MARSAT, which was a precursor of today's MARISAT, as a potential interferer to radar altimeter receivers, and concluded:

> "Spectrum splatter from a shipboard transmitter of the MARSAT system may cause interference power at the input to a radar altimeter receiver sufficient to cause the desired signal to be undiscernible at separation distances as great as 16 nmi (see TABLE 4.5)."

TABLE 4.5, reproduced here as TABLE A-1 of Appendix A, shows the desired average signal power-to-minimum visible signal power ratios for radar altimeter AN/APN-133 as a function of separation distance from a MARSAT system shipboard transmitter. The table is based on a combination of measurement and computation. The report uses 20.0 dBW for ship power, and 10.4 dB for peak ship antenna gain. This is equivalent to an EIRP of 30.4 dBW (28.3 dBW with losses of 2.1 dB included).

TRANSMIT \ RECEIVE	MOBILE (Aeronautical Telemetry)	MARITIME MOBILE-SATELLITE (Space-to-Earth) INMARSAT	MOBILE-SATELLITE (Space-to-Earth) COSPAS-SARSAT	RADIONAVIGATION-SATELLITE (Space-to-Earth) GPS	AERONAUTICAL RADIONAVIGATION RADIO ALTIMETERS	MARITIME MOBILE-SATELLITE (Earth-to-space) INMARSAT	MOBILE-SATELLITE (Earth-to-space) SAMSARS, et. al.	AERONAUTICAL MOBILE-SATELLITE[1]	RADIO ASTRONOMY
MOBILE (Aeronautical Telemetry)		Manageable problem	F						
MARITIME MOBILE-SATELLITE (Space-to-Earth) INMARSAT			F						
MOBILE-SATELLITE (Space-to-Earth) COSPAS-SARSAT		F							
RADIONAVIGATION SATELLITE (Space-to-Earth) GPS									Manageable problem
AERONAUTICAL RADIONAVIGATION RADIO (RADAR) ALTIMETERS		Manageable problem					F		Manageable problem
MARITIME MOBILE-SATELLITE (Earth-to-space) INMARSAT					Manageable problem				
MOBILE-SATELLITE (Earth-to-space) SAMSARS, et. al.									
AERONAUTICAL MOBILE-SATELLITE[1]									F

☐ No problems are anticipated

F These interactions should be analyzed when final system plans and designs are available.

◺ Manageable problem.

1. Region 2 administrations have not implemented aeronautical mobile-satellite systems in the band

FIGURE 6: Interaction Matrix.

A later report (Haakinson, 1974B) states that no interference is predicted from maritime mobile-satellite systems to radar altimeter receivers. Plans for the newer MARISAT were available by this time and are mentioned in the report. This included significant changes from the MARSAT design considered in the earlier report (Ax, 1972). The MARISAT shipboard antenna was to have a higher gain, 23 dBi, and it would be steerable in lieu of the original MARAD fixed design. This later report gives an EIRP of 67 dBm. The report does not give the specific analysis upon which the conclusions are based; however, Haakinson (1974A) analyzes this interaction for the original MARSAT design with the non-steerable antenna. The assumptions on which that analysis was based may no longer be valid. For example, the analysis assumes cochannel operation to be an extremely rare event. Today, however, an AN/APN-133 altimeter will typically be tuned to 1640 MHz with a tolerance of about 5 MHz and a bandwidth of approximately 10 MHz. Therefore INMARSAT ship earth stations which transmit at 1636.5-1645.0 MHz will typically transmit within the bandwidth of the altimeter. A detailed analysis would be required to verify the no interference conclusion.

Based on available information from the field, however, this interaction is not a problem; moreover, the Air Force and Navy altimeters are to be phased out of these bands. Therefore, if the problem exists it appears to be manageable.

Radar Altimeters to INMARSAT Shipboard Receivers

CCIR Report 764-1, CCIR (1982), describes the current view of the possibility of interference from radar altimeters to the INMARSAT system shipboard receivers:

> "Radar altimeters can interfere with the shipboard satellite receivers when aircraft with operating alitmeters are in the shipboard antenna beam. It is understood however that the number of radar altimeters operating in this band is diminishing. Radar altimeter operation may be restricted to the high end of the allocated band to reduce the chances and duration of interference."

Of the three types of altimeters operating in these bands, only the AN/APN-159 can be tuned significantly higher in frequency. While retuning might reduce the chances of interference to the INMARSAT shipboard receiver, it would increase the chances of interference to the distress and safety and radio astronomy systems.

Based on available information from the field, however, this interaction is not a problem; moreover, as the CCIR report points out, the number of alitmeters in these bands is diminshing. Therefore, if the problem exists, it appears to be manageable.

Telemetry to INMARSAT Shipboard Receivers

Matos (1983) mentions a potential problem of interference to ship terminals of the Maritime Mobile-Satellite Service from telemetry systems and recommends a management alternative:

"The upper adjacent band of 1530-1535 MHz will cease to be a primary telemetry band in 1990, having been reallocated to the Maritime Mobile-Satellite (Space-to-Earth) Service on a primary basis with the Mobile Service (Aeronautical Telemetry) downgraded to secondary. In order to minimize adjacent band interference to the shipborne Earth terminals, plans should be made to use 1529.5 MHz as the highest telemetry channel and to have only those systems with an emission bandwidth or 1 MHz or less on the channel. That is, systems with emission bandwidths on the order of 3 MHz may have enough energy into the satellite terminals to produce interference."

If this recommendation is followed then there should be no interfence to the INMARSAT system, which operates in a frequency range down to 1535 MHz. Future maritime mobile-satellite systems should take into consideration the effect of transmissions from aeronautical telemetry systems.

Radar Altimeters to Radio Astronomy

There is a potential problem of interference to the Radio Astronomy Service in the band 1610.6-1613.8 MHz from radar altimeters. This problem appears to be manageable because transmissions outside the 1610-1614 MHz band are centered, concentrated transmissions probably occur only on approaches to military bases, and the Air Force and Navy altimeters, which account for most of the altimeters are scheduled to be phased out of this band by 1989.

Radar altimeters are also a potential occasional source of interference to the Radio Astronomy Service in the 1660-1660.5 MHz band; however, none is known to operate above 1645 MHz at present and again the Air Force and Navy altimeters, which account for most of the altimeters, are to be phased out of this band by 1989.

GPS to Radio Astronomy

The primary allocation for radio astronomy in the 1660-1660.5 MHz band provides for detection of Doppler shifted OH radical spectral lines nominally occurring at 1665.4 MHz and 1667.4 MHz. Available information is not sufficient to determine whether or not there is a potential for intereference from GPS to radio astronomy in that band. It is known that during the development of GPS, consideration was given to protecting radio astronomy in the 1664.4-1668.4 MHz band.

The theoretical spectrum of the GPS L1 signal indicates that there is a potential for interference from GPS to the Radio Astronomy Service (secondary) at 1610.6-1613.8 MHz. Measured data on the sideband characteristics of the present GPS emission would be useful in assessing the potential interference to the Radio Astronomy Service in each of these bands.

SERIOUS PROBLEM

No serious problems have been found involving systems presently occupying the band. However, potentially serious problems are posed by the sharing of the 1660-1660.5 MHz band between the Aeronautical Mobile-Satellite (R) Service (Earth-to-space) and the Radio Astronomy Service. See the section entitled Future Study Indicated for more information on this problem.

FUTURE STUDY INDICATED

Distress and Safety Systems

Future study is indicated for the interactions involving the safety and distress (EPIRB) systems. Such a study should take place when final selection and design of all safety and distress systems is known. An earlier study would offer an opportunity to point out potential problems, if any, at an earlier date. There are two basic types of safety and distress systems currently being developed; one type uses low orbiting satellites, the other type uses geostationary satellites. Since the two types appear more complementary than competitive, it is possible that there will be two safety and distress systems. One would be the low orbiting COSPAS-SARSAT system. The geostationary system would probably be INMARSAT based. The geostationary system would likely be the design of one of the countries participating in the Coordinated Trials Program. Another possibility is that the two concepts will be combined.

Due to the possible importance of the effect of altimeters on distress and safety systems in the 1645.5-1646.5 MHz band, a "quick look" analysis was performed to determine the effect of pulsed altimeters on the SAMSARS-B system and to give insight into this type of interaction. Approximate interference potential was calculated for a single AN/APN-133 or an AN/APN-159 pulsed radar altimeter interfering with the up-path of the SAMSARS-B safety and distress system. The following assumptions were made:

- o The altimeter signals suffer no loss during reflection from the Earth, and the surface is smooth flat water.
- o The bandwidth of the SAMSARS falls within the bandwidth of the altimeter.

A SAMSARS transmitter EIRP of 1 Watt was used for purposes of this analysis. For simplicity, both the SAMSARS and the altimeter were assumed to have the same propagation loss. Under these conditions, the carrier-to-interference ratio (C/I) is -4 dB for the case of the AN/APN-159 and 1 dB for the case of the AN/APN-133.

It is understood that the group partcipating in the Coordinated Trials Program for the CCIR is recommending a transmitter EIRP of 1 Watt and a C/I criterion of -15 dB on the up-path for the distress and safety system EPIRB. By these standards, neither altimeter would interfere with the SAMSARS. The AN/APN-159 altimeter would leave a margin of (-4)-(-15) = 11 dB, and the AN/APN-133 would leave a margin of 1-(-15) = 16 dB.

Thus, there appears to be no interference problem from a single interfering signal with the present design. However, the power level could be lower in the final EPIRB design and a less interference tolerant system may be chosen in the CTP competition with the SAMSARS. Therefore this interaction should be studied again when the final design of the safety and distress system is chosen and the orbital positions of the satellite are known. The analysis should be for a typical deployment of multiple altimeters and should include scattering of altimeter signals from the water.

In making this determination, the following result will prove useful: Assuming aircraft in level flight over smooth flat water, only aircraft within a great circle distance of 24 degrees of the sub-satellite point will have mainbeam energy reflected by the sea to the satellite.

Radio Astronomy

The Radio Astronomy Service shares the 1660-1660.5 MHz band with the Aeronautical Mobile-Satellite (R) Service (Earth-to-space), which is allocated the band 1646.5-1660.5 MHz. The shared 0.5 MHz allocations were adopted at the 1979 WARC. However, although the allocation to the Aeronautical Mobile-Satellite (R) Service is for the Earth-to-space direction, the expected non-directional character of the transmitting antennas poses potentially serious interference problems to radio astronomy. In addition, Footnote 735 extends the Aeronautical Mobile-Satellite (R) Service to aircraft-to-ground or aircraft links. Since there is no specific Aeronautical Mobile-Satellite system being considered at the moment, it is difficult to assess the potential for interference to radio astronomy. As soon as a system is identified, the interference potential should be evaluated.

NO PROBLEM

When the systems in the 1535-1660 MHz bands have "No Problem" indicated in the matrix, those conclusions have been taken from Haakinson (1974A and 1974B). Of course, this does not apply to the EPIRB systems, which were developed subsequent to those reports.

With the possible exception of the INMARSAT system interaction, mentioned as manageable, no problems involving telemetry are anticipated since no problems are now known to exist and the 1530-1535 MHz band will cease to be a primary telemetry band in 1990. A signal from the maritime mobile-satellite is not strong enough to interfere with the telemetry receiver on the Earth.

Although both the GPS and the altimeters are permitted within the 1559-1610 MHz band, there appears to be no possibility of interference to the altimeters from the GPS. The GPS, which operates at 1575.42 MHz, is separated from the altimeters in frequency. Of the three altimeter types, only the AN/APN-159 is capable of tuning into this band, and the bandwidth would not allow significant energy to fall below 1600 MHz. The altimeters are further protected by the fact that the GPS produces a relatively low PFD near the Earth. The low PFD is possible since GPS is a spread spectrum system which has a large processing gain in the receiver.

The conclusion of a previous study (Haakinson, 1974B) is that no altimeter interference is predicted to GPS receivers with normal operational system separation (greater than 100 feet) and sidelobe-to-sidelobe antenna coupling. Two important factors in these results are the low duty cycle of the pulsed altimeters and the frequency separation between the altimeters and the GPS.

Haakinson (1974B) concludes that the radar altimeters should not interfere with the MARISAT satellite receiver. While the analysis neglects the effects of multiple interferers and reflection and scattering from the sea, the conclusions are supported by the information from the field.

New systems coming into the various bands are reviewed for compliance with adjacent band criteria. Therefore, systems which are in different bands would not be expected to interfere. Most of the interactions in the matrix involve two systems in different bands; and with exception of the altimeters and possibly some telemetry, all are relatively new systems.

GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AFC - Automatic Frequency Control

C/A - Clear/Acquisition

CAS - Collision Avoidance System

CORF - Committee on Radio Frequencies, National Academy of Sciences

CTP - CCIR Coordinated Trials Program

ELT - Emergency Locator Transmitter

EPIRB - Emergency Position Indicating Radio Beacon

EIRP - Effective Isotropically Radiated Power

GMF - Government Master File

GPS - Global Positioning System

IMO - International Maritime Organization

ITU - International Telecommunication Union

LUT - Local User Terminal

ROSES - Receive-Only Ship Earth Station

RSMS - Radio Spectrum Measurement System

SAMSARS - Satellite Aided Maritime Search and Rescue System

SAR - Search and Rescue

SARSAT - Search and Rescue Satellite-Aided Tracking

SHOSAC - Shore-to-Ship Distress Alerting Channel

TCAS - Tracking Collision Avoidance System

WARC - World Administrative Radio Conference

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APPENDIX A

MARSAT EFFECT ON ALTIMETERS

Ax (1972) identified the MARSAT, which was a precursor of the MARISAT as a potential interferer to radar altimeter receivers. TABLE A-1, reproduced from that report, shows the desired average signal power-to-minimum visible signal power ratios for radio altimeter AN/APN-133 as a function of distance from the MARSAT system shipboard transmitter.

Table A-1 Desired average signal power (P_O)-to-minimum visible signal power (MVS) ratios (P_O/MVS) for radar altimeter AN/APN-133 as a function of separation distance from a MARSAT system's shipboard transmitter.

Separation Distance, nmi	1				2				4				8				16			
Altimeter Altitude, nmi	P_D (Avg), dBm	P_I, dBm	MVS, dBm	P_D/MVS, dB	P_D, (Avg), dBm	P_I, dBm	MVS, dBm	P_D/MVS, dB	P_D (Avg), dBm	P_I, dBm	MVS, dBm	P_D/MVS, dB	P_D (Avg), dBm	P_I, dBm	MVS, dBm	P_D/MVS, dB	P_D (Avg), dBm	P_I, dBm	MVS, dBm	P_D/MVS, dB
Low Altitude Mode																				
0.5	-57.3	-52.0	-69.0	11.7	-57.3	-58.0	-75.0	17.7	-57.3	-64.0	-81.4	24.1	-57.3	-70.0	-87.8	30.5				
1	-63.3	-34.0	-45.0	-18.3	-63.3	-58.0	-75.0	11.7	-63.3	-64.0	-81.4	18.1	-63.3	-70.0	-87.8	24.5				
High Altitude Mode																				
1	-68.5	-34.0	-52.4	-16.1	-68.5	-58.0	-81.3	12.8	-68.5	-64.0	-87.8	19.3	-68.5	-70.0	-93.8	25.3	-68.5	-76.0	-99.3	30.8
2					-74.5	-40.0	-63.3	-11.2	-74.5	-64.0	-87.8	13.3	-74.5	-70.0	-93.8	19.3	-74.5	-76.0	-99.3	24.8
4									-80.5	-46.0	-69.3	-11.2	-80.5	-70.0	-93.8	13.3	-80.5	-76.0	-99.3	18.8
8													-86.5	-52.0	-75.3	-11.2	-86.5	-76.0	-99.3	12.8

NOTE: In calculation of P_D, loss-free earth reflection has been assumed. Calculation of interfering signal power, P_I, assumes main beam-to-main beam antenna coupling when separation distance equals altimeter altitude and zero dB transmitting and receiving antenna power gains when separation distance does not equal altimeter altitude.

APPENDIX B

INMARSAT STANDARD-A EARTH STATION

INMARSAT (1982) gives the radio frequency parameters which characterize the INMARSAT Standard-A ship earth station. This information is presented here in TABLE B-1. Ship earth stations are typically of the Standard-A type, however there are other standard INMARSAT ship earth stations. TABLE B-2, extracted from CCIR Report 921, CCIR, (1982B), gives a brief comparison of the service capability of the various standard ship earth stations.

TABLE B-1

INMARSAT STANDARD-A EARTH STATIONS RF PARAMETERS

Receive G/T:	G/T $\geq$ -4 dB/K at 5 degrees elevation angle under clear-sky conditions
Polarization:	RHCP transmit and receive
Axial Ratio:	$\leq$ 1.3 transmit and receive (2 dB)
EIRP Requirements:	FM/SCPC, TMDA and RA: 36 dBW (+1, -2 dB) (37 dBW $\pm$ 1 dB for MARISAT Models) High speed data (option): 38 dBw (+1, -2 dB) (29 dBW $\pm$ 1 dB for MARISAT Models)
Capacity:	Single duplex telephony or telegraph call at any one time.

TABLE B-2

SUMMARY OF SHIP EARTH STATION STANDARDS

Ship earth station standard	(Assumed) Antenna gain (dBi)	(Assumed) G/T (dB/K)	Service Capability
A	23.5	-4	Full range of public correspondence
B	15	-12	Reduced quality voice and multiplex telegraphy
C	8	-19	Telegraphy only
D	32.5	+5	As standard A, plus high capacity services

APPENDIX C

BRIEF HISTORY OF THE 1535-1660 MHz SEGMENT OF THE 1530-1660.5 MHz BAND

Haakinson (1974A) gives a brief history of the bands from 1535-1660 MHz up to that date:

> "In 1959, the bands were allocated to the Aeronautical Radio Navigation Service on a worldwide basis. In 1963, at the Space Extraordinary Administrative Radio Conference (EARC), the portion from 1535-1540 MHz was reallocated to the Space (Telemetering) Service while the balance of the band between 1540 MHz and 1660 MHz remained allocated as before. However, new footnotes to the 1540-1660 MHz bands recognized and permitted the development of satellite-borne facilitites associated with electronic aids to navigation and the development of space communication techniques in support of the Aeronautical Mobile (R) Service.
>
> In 1971, the Space World Administrative Radio Conference on Space Telecommunications (WARC-ST) completely restructured the allocation table for the band abrogating the previous Space (Telemetering) Service allocation for the 1535-1660 MHz band and setting up a new pattern for the entire range 1535-1660 MHz. This pattern ... provides support for both Maritime and Aeronautical Mobile-Satellite Services and for the Satellite Radionavigation Services. As before, footnotes provide support for satellite radionavigation and communication facilities in the portion of the band allocated on a primary basis to Aeronautical Radionavigation.
>
> The 1535-1660 MHz bands were, until late 1960, employed by United States interests primarily for radar altimeters; both Government and commercial aircraft were outfitted with such devices. In 1968, non-Government interests received FCC approval (with Federal Government concurrence) to proceed with the development of Collision Avoidance System (CAS). Official Government and FCC endorsement of the provisional CAS activity followed in 1970 with the implementation of the US39A footnote permitting use of the sub-band 1592.5-1622.5 MHz for exploitation of the technique."

In the years subsequent to the publishing of the Haakinson report, CAS activity in these bands has ceased.

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15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report documents a spectrum resource assessment of the 1530-1660.5 MHz band. The impact of allocation changes resulting from the WARC-79 are addressed. Information is included on allocations, frequency assignments, system characteristics, and spectrum measurements made with the RSMS van. A review of previous analyses was conducted. No major spectrum management problems involving the major systems presently operating in, or firmly planned for, this band are identified. The report is based on information available through March 1983.

16. Key Words *(Alphabetical order, separated by semicolons)*

Electromagnetic Compatibility; 1530-1660.5 MHz; Distress and Safety; Mobile Satellite; Aeronautical Radionavigation; Radio Stronomy; Spectrum Resource Assessment

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