New CCIR Papers on Telecommunications for Deep Space Research

N. F. de Groot
Telecommunications Systems Section

Eight JPL papers dealing with telecommunications for deep space research were recently adopted by Study Group 2 of the International Radio Consultative Committee (CCIR). A brief description of the preparation and adoption of the papers was given in TDA Progress Report 42-68, along with the paper on preferred frequency bands in the 20-120 GHz range. In this article we present three more papers.

Study Group 2 of the Comité Consultatif International des Radiocommunications (CCIR) met in Geneva last October to consider papers for inclusion in the 1982 edition of Reports and Recommendations of the CCIR. Study Group 2 deals with radio communication aspects of space research and radio astronomy. The adopted ensemble of papers included eight that were based on input documents prepared by the JPL Spectrum Engineering Group and are:

Doc. 5007 New Recommendation	Protection Criteria and Sharing Considerations Relating to Deep-Space Research.
Doc. 5008 New Recommendation	Preferred Frequencies and Bandwidths for Deep-Space Research.
Doc. 5010 New Report	Frequency Bands in the 20-120 GHz Range that are Preferred for Deep-Space Research.
Doc. 5015 Revision of Report 683	Frequency Bands in the 1-20 GHz Range that are Preferred for Deep-Space Research.
Doc. 5023 Modification of Question 14	Feasibility of Frequency Sharing Within and Among Space Research Systems.
Doc. 5024 Revision of Report 685	Protection Criteria and Sharing Considerations Relating to Deep-Space Research.
Doc. 5025 New Report	Potential Interference Between Deep-Space Telecommunications and the Fixed-Satellite and Broadcasting Satellite Services in Harmonically Related Bands.
Doc. 5026 Modification of Study Program 14B	Frequency Sharing Between Deep-Space and Other Space Research Systems.

In this issue of the TDA Progress Report we present three papers. The first, Doc. 5025, considers the potential for interference between deep-space links and some satellite links in harmonically related bands. Harmonic bands are those with frequencies that are an integer multiple of frequencies that lie within the band in question. Radio transmitters typically produce unwanted harmonic signals, and it is these signals that can cause interference.

In the past, problems of harmonic band interference have been minimal and generally ignored in the context of international frequency management. The spatial and propagation characteristics of the rapidly growing number of satellite links in several bands are, however, creating a significant new potential for interference with space systems in harmonically related bands. The new paper treats a part of the problem as it affects deep space research.

The other two papers, Docs. 5007 and 5008, are recommendations. A CCIR Recommendation (Ref. 1) is "A statement issued in response to a Question or Study Programme which the CCIR considers to be sufficiently complete to serve as a basis for international cooperation." (A Question or a Study Programme is a formal CCIR statement of the scope and content of a technical area to be studied.)

Recommendations are based on CCIR reports and generally represent an official position concerning some aspect of radio frequency use and regulation. Recommendations serve to guide the administrative conferences that lead to the international treaty that is expressed in the Radio Regulations (Ref. 2).

The reports presented in this article are drafts. They may have editorial modifications when formally published.

References

1. *Recommendations and Reports of the CCIR*, Vol. XIII-1, p. 248, International Telecommunication Union, Geneva 1978.

2. *Radio Regulations*, Edition of 1982, International Telecommunication Union, Geneva, 1982.

Documents
CCIR Study Groups
Period 1978-1982

Doc. 2/5025-E
(Ref. 2/210)
19 October 1981
Original : English/
French/
Spanish

Working Group 2-B

DRAFT NEW REPORT*

POTENTIAL INTERFERENCE BETWEEN DEEP-SPACE TELECOMMUNICATIONS AND THE FIXED-SATELLITE AND BROADCASTING-SATELLITE SERVICES IN HARMONICALLY RELATED BANDS
(Question 19/2)

1. Introduction

The possibility of harmful interference resulting from unwanted emissions to and from space stations in the geostationary orbit is of increasing concern to deep-space research. This concern is prompted by the expected increase in utilization of the geostationary satellite orbit in frequency bands adjacent to and harmonically related to the operational frequencies used for deep-space telecommunications.

This Report presents the results of an analysis of potential mutual interference caused by unwanted emissions from the United States Deep-Space Network (DSN) of the space research service, and from the fixed satellite and broadcasting-satellite services. The study also includes an assessment of potential interference to a future deep-space relay station on the geostationary satellite orbit.

2. Interference analysis

Frequency bands harmonically related to the DSN operating frequencies are shown in Table I. The harmonically related bands are direct multiples and submultiples of the deep-space bands. Fixed satellite and broadcasting-satellite service allocations which fall within these bands are indicated in the table.

Of the many potential interference situations resulting from the relationships shown in Table I, certain typical cases have been examined and analyzed parametrically in this Report. Since the levels of unwanted emissions from transmitters in harmonically related bands are not specifically known, this analysis treats the problem parametrically by using the out-of-band emissions of the interferor as an independent variable. In this Report that variable is called "level of suppression". It is expressed with respect to the energy contained in the fundamental frequency. The results of the analysis can then be used to determine suppression levels of unwanted emissions necessary to meet the interference criteria of the services involved.

---

* This Report should be brought to the attention of Study Group 4 and JWG 10-11S.

TABLE I

DSN EARTH STATION TRANSMIT FREQUENCIES	HARMONIC BANDS			
	2nd	3rd	4th	5th
2110 - 2120 MHz	4220-4240 MHz	6330-6360 MHz All regions: Fixed-Satellite Service (E-to-S)	8440-8480 MHz	10.55-10.6 GHz
7145 - 7190 MHz	14.29-14.38 GHz All regions: Fixed-Satellite Service (E-to-S)	21.435-21.57 GHz	28.58-28.76 GHz All regions: Fixed-Satellite Service (E-to-S)	35.725-35.95 GHz
16.6 - 17.1 GHz	33.2-34.2 GHz	49.8-51.3 GHz All regions: Fixed-Satellite Service (E-to-S)	66.4-68.4 GHz	83.0-85.5 GHz All regions: Fixed-Satellite (S-to-E) Broadcasting-Satellite Service
DSN EARTH STATION RECEIVE FREQUENCIES	SUBHARMONIC BANDS			
	1/2	1/3	1/4	1/5
2290 - 2300 MHz	1145-1150 MHz	763-767 MHz	573-575 MHz	458-460 MHz
8400 - 8450 MHz	4200-4225 MHz	2800-2817 MHz	2100-2113 MHz	1680-1690 MHz
12.75 - 13.25 GHz	6375-6625 MHz All regions: Fixed-Satellite Service (E-to-S)	4250-4417 MHz	3188-3313 MHz	2550-2650 MHz All regions: Broadcasting-Satellite Service. In region 2: Fixed-Satellite Service (S-to-E)

Pointing statistics for a given DSN Earth station have been obtained from a computer study of the trajectories of 40 realized and potential deep-space missions. Figure 1 presents pointing angle toward the geostationary arc as a function of time for one DSN Earth station. It should be noted that some deep-space missions do not require antenna pointing to within 5-10 degrees of the geostationary arc for many months or even years of mission duration.

3. Harmonic Interference

3.1 Interference to a DSN Earth Station From a Fixed-Satellite Earth Station

The 2nd harmonic of an Earth station in the Fixed Satellite Service transmitting in the frequency range 6.375-6.625 GHz has the potential for interference to a DSN Earth station receiving 12.75-13.25 GHz.

The coordination distance between a transmitting Earth station in the Fixed Satellite Service and a receiving DSN Earth station was computed for two modes of propagation according to the procedure described in Appendix 28 of the Radio Regulations.

Those modes are:

- Clear air propagation mode 'a'.
- Rain scatter propagation mode 'c', in Zone 4.

The following assumptions were made for both modes of propagation:

- Permissible level of interference to a DSN Earth station is -220 dB (W/Hz).
- Elevation angle of transmitting and receiving antennae is taken to be 5° above the horizon.

Assumed Fixed Satellite Earth station e.i.r.p.'s* at 5° off-main beam axis are:

Case 1.	21.0	dB(W/4 KHz)	for satellite network with a large Earth station antenna
Case 2.	14.5	dB(W/4 KHz)	for FM-TV or SCPC global systems
Case 3.	8.5	dB(W/4 KHz)	for FDM-FM systems.

For various suppression levels of spurious emissions from a fixed satellite Earth station the coordination distance for propagation modes 'a' and 'c' is shown graphically in Figures 2 and 3.

*See Report 453-2.

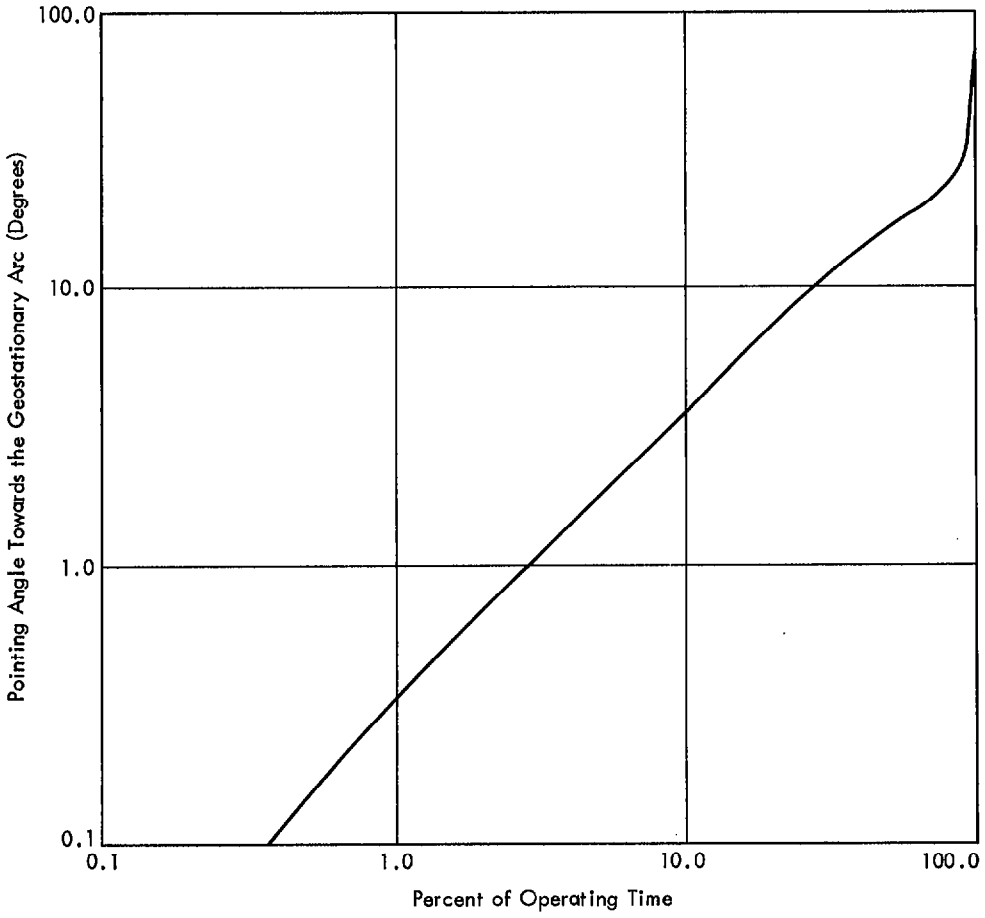
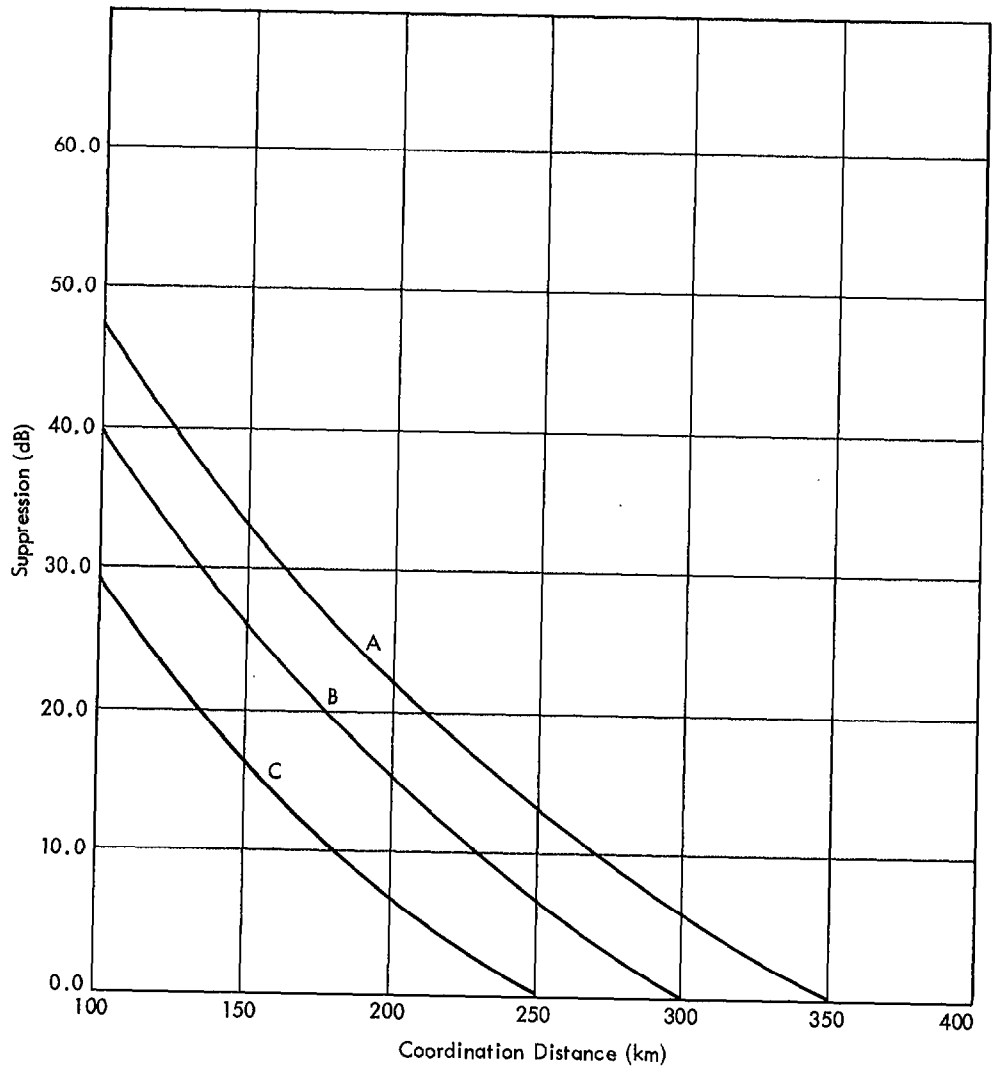


FIGURE 1
Pointing statistics of a DSN earth station



LEGEND

A = Case 1
B = Case 2
C = Case 3

FIGURE 2

Coordination distance between a transmitting FSS earth station and a receiving DSN earth station for clear air "Mode A"

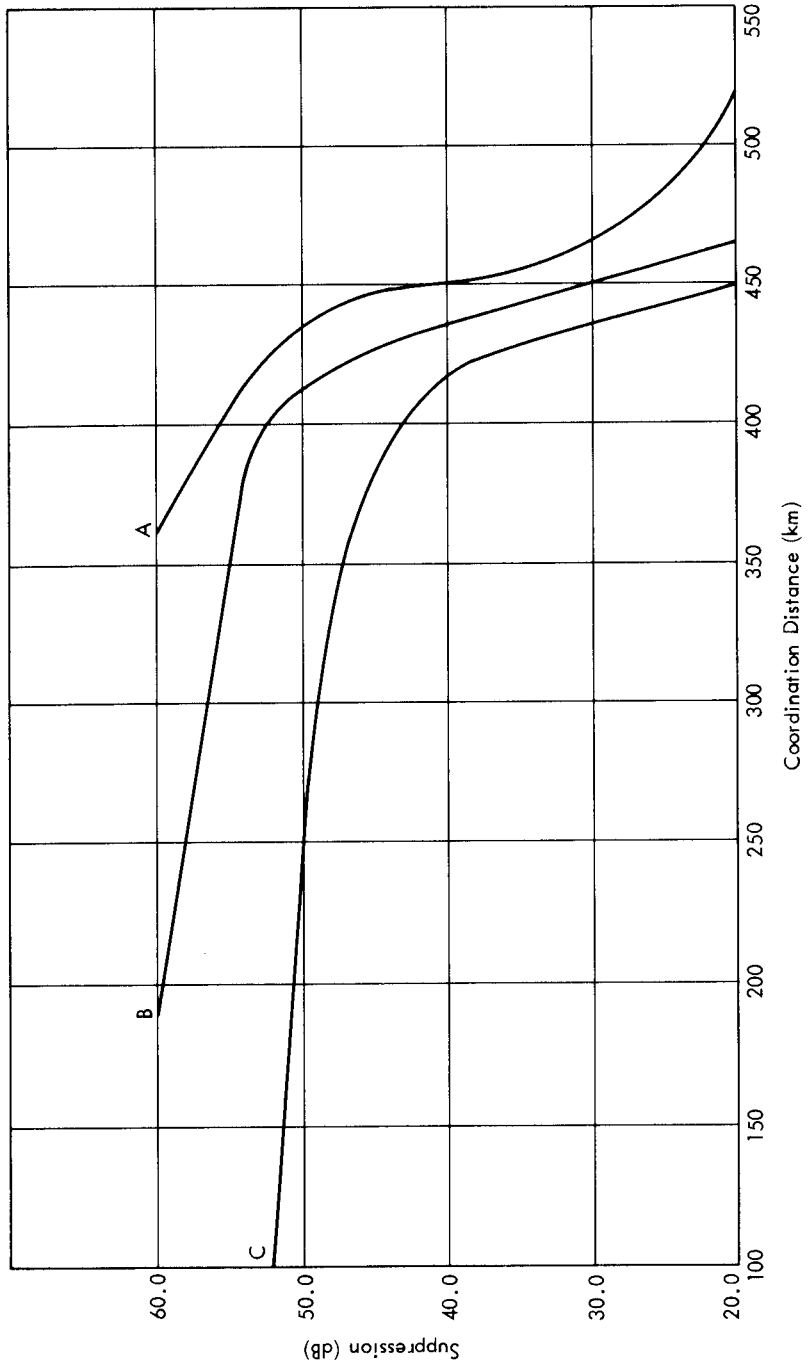


FIGURE 3

Coordination distance between a transmitting FSS earth station and a receiving DSN earth station for rain scatter "Mode C"

3.2 Interference to a Satellite of the Fixed Satellite Service from a DSN Earth Station

Potential interference exists to a satellite of the Fixed Satellite Service receiving in the 6330-6360 MHz range from the 3rd harmonic of a DSN Earth station transmitting in the 2110-2120 MHz band.

The assumed DSN Earth Station transmitting characteristics are:

- Frequency 2.1 GHz
- R.F. Power 50 dBW
- Antenna Gain 62 dBi
- R.F. Bandwidth:

  Ranging 10 MHz

  Telemetry 3 MHz

  Command 0.3 MHz

It is also assumed that the DSN Earth station is transmitting 100% of the time.

Typical receiver noise temperature and antenna gain of a Fixed Satellite are 3000°K and 23.0 dBi, respectively (Report 207-4). The interference criterion is taken to be 4%* of the noise power of the satellite receiver. It should be noted that this 4% criterion is used only as an indicator, to determine those situations in which a more detailed analysis should be performed.

Figure 4 shows the percent of time that a DSN Earth station will cause a 4% increase in Fixed Satellite noise power for various levels of DSN spurious energy suppression.

3.3 Interference to a DSN Earth Station from a Fixed-Satellite

The 5th harmonic of a Broadcasting-Satellite or Fixed Satellite transmitting in the 2550-2650 MHz frequency range has the potential for interference to a DSN Earth station receiving at 12.75-13.25 GHz.

According to Article N26 of the Radio Regulations, the maximum permitted power flux density limit on the surface of the Earth is -137 dB (W/m^2) in any 4 KHz band for a Broadcasting-Satellite operating in the 2-3 GHz band.

---

*Modified Appendix 29 of the Radio Regulations as per WARC 1979

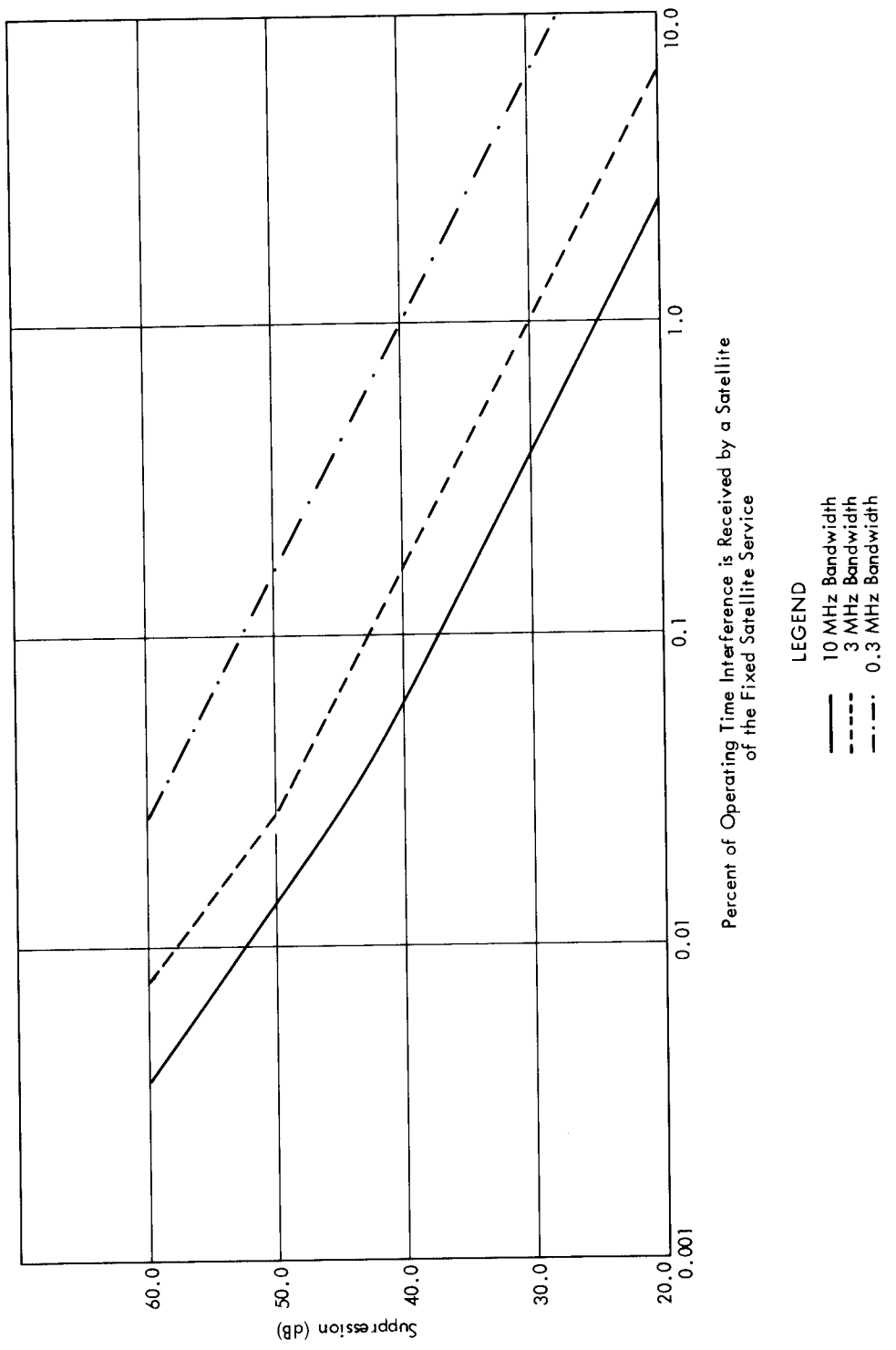


FIGURE 4

Interference from the third harmonic of a DSN earth station to a satellite of the fixed-satellite service

Further assumptions made in this part of the analysis are:

- Broadcasting-Satellite transmitting 100% of the time.
- DSN Interference criterion = -220 dB (W/Hz).

The percentage of time that the interference criterion is met for various levels of suppression of the interfering harmonic signal is shown in Figure 5. This is based upon the pointing statistics of the DSN as described in Figure 1.

Significant interference to a DSN Earth Station from more than one satellite is not considered likely since Broadcasting-Satellite systems using spot beams will probably not illuminate the same service areas on the Earth at the same frequency, due to the problem of mutual interference.

3.4 Interference to an Earth Station of the Fixed Satellite or Broadcasting-Satellite Service From a DSN Earth Station

The potential interference to an Earth station of the Fixed Satellite or Broadcasting-Satellite Service from the 5th harmonic of a DSN Earth station transmitting in the band 16.6-17.1 GHz is not considered in this report due to lack of information on 80 GHz space systems.

3.5 Interference to DSN Geostationary Relay Satellite

A satellite in the geostationary satellite orbit may be used in the future to relay signals from deep-space research spacecraft to Earth. Although this relay spacecraft may employ other frequencies than those currently used for deep-space research (especially in the geostationary satellite-to-earth links) this portion of the analysis is directed at a brief assessment of interference potential at harmonics of the same frequencies as those analyzed in the previous sections of this paper.

3.5.1 Interference to a DSN Relay Satellite from Fixed Satellite Earth Station Transmissions

The 2nd harmonic of an Earth station in the Fixed Satellite Service transmitting in the frequency range 6.375-6.625 GHz has the potential for interference to a DSN relay satellite receiving from deep-space at 12.75-13.25 GHz.

For this analysis it is assumed that the DSN relay satellite has a 45 m receiving antenna and a gain of 0 dBi toward the transmitting FSS Earth station. Additionally, the same values of harmful interference (-220 dB (W/Hz) and FSS Earth station transmitting characteristics, as assumed in section 3.1, are used. For various levels of spurious harmonics, the required geocentric separations of the receiving fixed-satellite and the DSN relay satellite have been calculated. Even on a worst case basis of 0 dB suppression the required spacing is small, as demonstrated below:

FSS Earth station transmit power:		-36 dB (W/Hz)
Free space loss	:	-207 dB
Received power density	:	-243 dB (W/Hz)

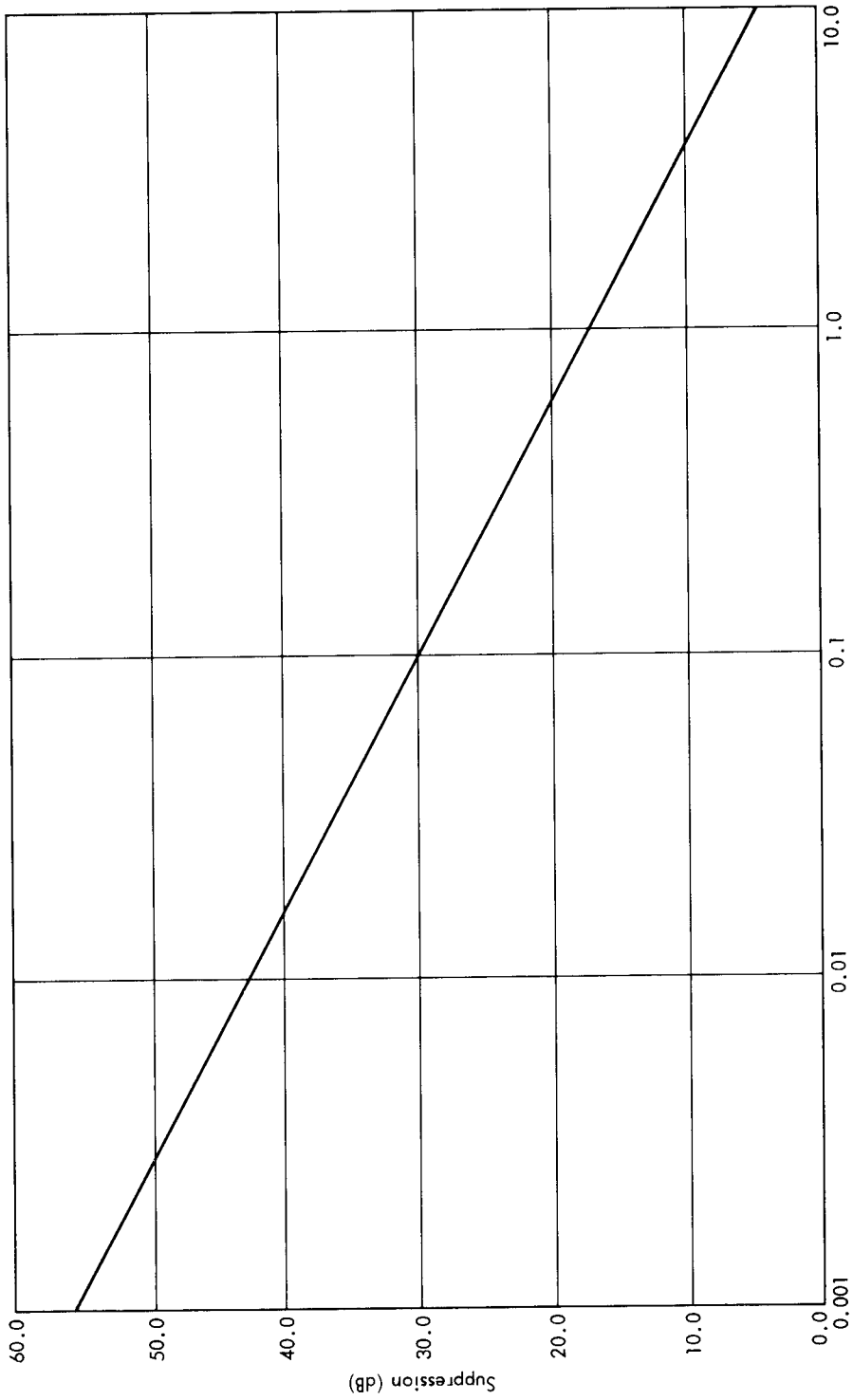


FIGURE 5

Interference to a DSN earth station from the fifth harmonic of a broadcasting satellite with -137 dB(W/m²) power flux density at the surface of the Earth

Using -220 dB (W/Hz) as the interference criterion would mean that the gain of the FSS Earth station toward the DSN relay satellite could be as high as 23 dB. This translates via the reference antenna pattern of 32-25 log (θ) to a spacing on the order of 2.3°.

At higher levels of harmonic suppression, the required separation is correspondingly less.

3.5.2 Interference to DSN Relay Satellite From FSS Satellite Transmissions

The 5th harmonic of a Broadcasting or Fixed Satellite transmitting in the 2550-2650 MHz frequency range has the potential for interference to a DSN relay satellite receiving from deep-space in the 12.75-13.25 GHz band.

In this analysis it is assumed that:

- The gain of the fixed satellite toward the DSN relay satellite is 0 dBi.
- The maximum value of PFD allowed on the Earth's surface is -137 dB ($(W/cm^2)(4\ kHz)$).
- The DSN relay satellite interference criterion is -220 dB (W/Hz).

Figure 6 presents the angle that the DSN relay satellite must point away from a Fixed or Broadcasting Satellite as a function of the geocentric spacing between the two. These curves are shown parametrically for various levels of energy suppression.

Although pointing statistics of a DSN relay satellite are not currently known, it can be assumed that a DSN relay satellite would point toward the geostationary orbit (for a given mission) for the same or less length of time as an Earth based DSN station.

If a DSN relay satellite is receiving only when the shortest distance between the line of sight to a DSN probe and the surface of the earth is greater than or equal to 200 km, the assumed pointing statistics of the relay satellite can be used, together with the geostationary arc length visible to the relay satellite, to give some indication of the percentage of time a single satellite may cause interference to the relay satellite.

When this is done for a single FSS satellite spaced 1° away from the relay satellite, it is found that for energy suppression levels of 50, 40, 30 and 20 dB, the percentages of time interference is received by a DSN relay satellite are 0.003%, 0.017%, 0.104% and 0.35% respectively. For the same levels of suppression, the percent of time a relay satellite receives interference from a single satellite located at greater distances from the relay satellite is found to be correspondingly less.

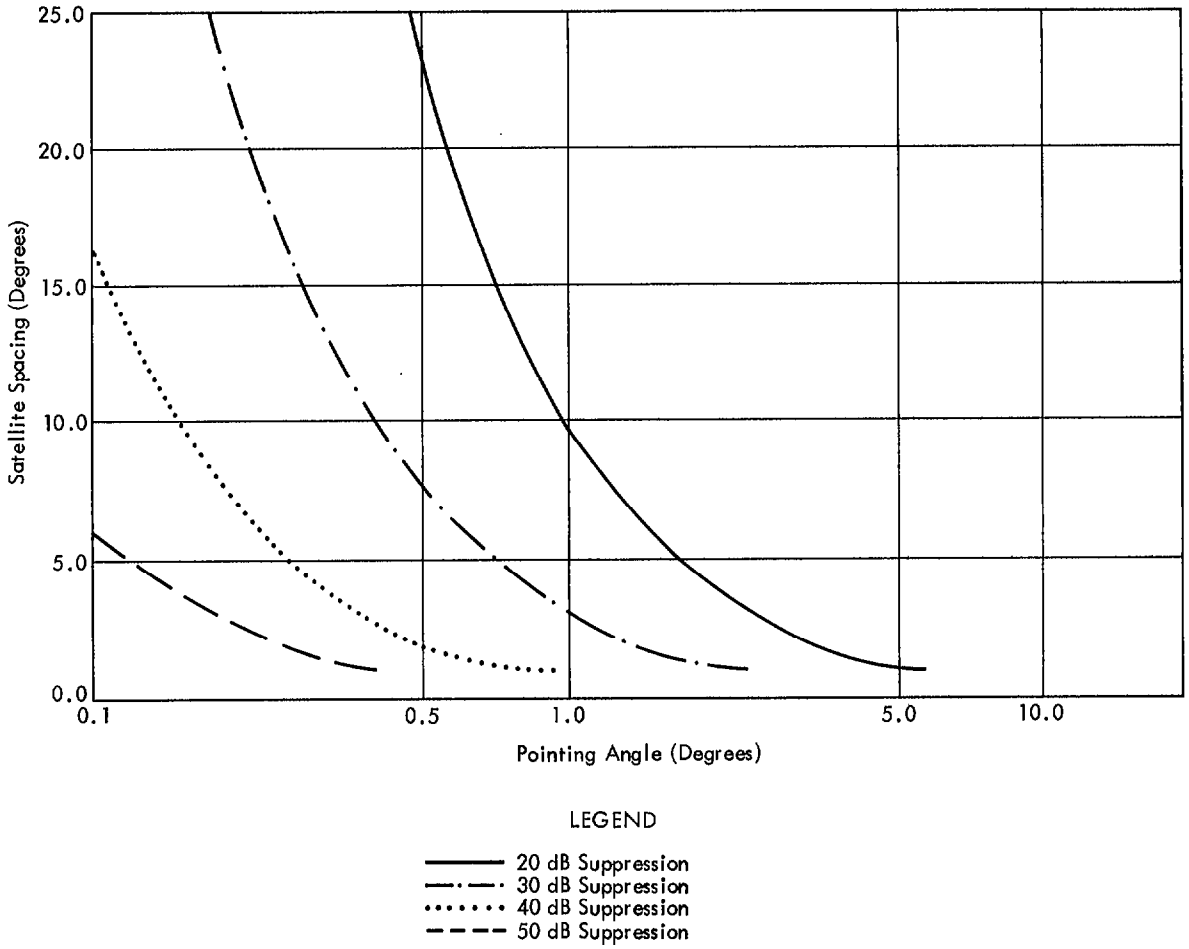


FIGURE 6

Interference from the second harmonic of a fixed or broadcasting satellite to a DSN relay satellite

4. Adjacent Band Considerations

In addition to the potential for interference from unwanted emissions in harmonically related bands, there is the possibility of interference from unwanted emissions of service in adjacent bands. Specific analysis of this possibility has not yet been accomplished with respect to the services considered in this report.

5. Conclusions

Because of the high gain antennas, high power transmitters, and extremely sensitive receivers employed by DSN earth stations, deep-space research and the other satellite services in harmonically related bands may be subjected to interference from unwanted emissions unless measures are taken to suppress the energy of these emissions to acceptable levels.

Precise levels of unwanted emissions that are acceptable for all services cannot be determined in this Report as this requires a detailed interference analysis of the services involved and their individual characteristics. However, from the parametric analysis of "worst case" situations, it appears that significant interference would be avoided if harmonic emissions were suppressed by at least 50 dB.

In most cases the severity of interference between earth stations can be reduced by proper separation and site shielding. In the case of interference to and from space stations, additional filtering may be required to suppress the power in unwanted emissions to an acceptable level. In the case of harmonic band radiation, extra filtering is easily achieved at frequencies far removed from the fundamental.

Analysis of interference from unwanted emissions from services in adjacent bands remains to be done.

Documents
CCIR Study Groups
Period 1978-1982

Doc. 2/5007-E
(Ref. 2/191)
19 October 1981
Original : English/
French/
Spanish

Working Group 2-B (ED)

DRAFT RECOMMENDATION AE/2*

PROTECTION CRITERIA AND SHARING CONSIDERATIONS RELATING TO DEEP-SPACE RESEARCH

(Question 1-1/2)

The C.C.I.R.,

CONSIDERING

(a) that manned deep-space research has unique requirements for extreme reliability of telecommunications so as to ensure safety of life;

(b) that both manned and unmanned deep-space research have unique requirements for extreme reliability of telecommunications so as to ensure successful reception of valuable scientific data collected at particular critical times, and that repeat transmission of these data is often not possible;

(c) that the extreme sensitivity of deep-space earth stations results in unusually low levels of permissible interference;

(d) that some terrestrial and earth stations in other services have sufficient e.i.r.p. to cause interference to stations in deep-space;

(e) that sharing studies and protection criteria have been presented in Report 685 (MOD F) for deep-space research earth stations and for stations in deep-space;

(f) that protection criteria for relay stations in earth orbit, used for deep-space research, have not yet been determined and are not considered in Report 685 (MOD F),

RECOMMENDS

1. that protection criteria for deep-space research earth stations be established as follows: -222 dB (W/Hz) in the 2 GHz region, -220 dB (W/Hz) in the 8 GHz region, -220 dB (W/Hz) in the 13 GHz region, and -216 dB (W/Hz) in the 32 GHz region;

*This Recommendation is brought to the attention of Study Groups 4, 8, 9 and JWG 10-11S.

2. that protection criteria for stations in deep-space be established as follows: -191 dB (W/20 Hz) in the 2 GHz region, -189 dB (W/20 Hz) in the 7 GHz region, -186 dB (W/20 Hz) in the 17 GHz region, and -184 dB (W/20 Hz) in the 34 GHz region;

3. that calculation of interference that may result from atmospheric and precipitation effects be based on weather statistics for 0.001% of the time;

4. that with coordination, deep-space research can share Earth-to-space bands with stations in other services except:

   - receiving aeronautical mobile stations, receiving satellite stations, and microwave sensor satellites, when any of these may come within line-of-sight, and

   - receiving mobile stations that come within the separation distance required for interference protection, and

   - transmitting terrestrial stations having an average e.i.r.p. exceeding 81 dBW in the 2 GHz region and 84 dBW in the 7 GHz region.

5. that with coordination, deep-space research can share space-to-Earth bands with stations in other services except:

   - the radio astronomy service, and

   - transmitting aeronautical mobile stations, transmitting satellite stations, and active microwave sensor satellites, when any of these may come within line-of-sight, and

   - transmitting mobile stations that come within the separation distance required for interference protection.

Documents
CCIR Study Groups
Period 1978-1982

Doc. 2/5008-E
(Ref. 2/196)
19 October 1981
Original : English/
French/
Spanish

Working Group 2-B (ED)

DRAFT RECOMMENDATION AF/2

PREFERRED FREQUENCIES AND BANDWIDTHS FOR DEEP-SPACE RESEARCH

(Question 22/2, Study Programme 22A/2)

The C.C.I.R.,

CONSIDERING

(a) that frequencies most suited for telecommunications between the Earth and Spacecraft in deep-space are determined partly by atmospheric and interplanetary propagation phenomena;

(b) that technology also influences the selection of preferred frequencies;

(c) that requirements for telecommunication reliability must be satisfied during periods of adverse atmospheric effects;

(d) that the same frequency may be used for spacecraft at different celestial coordinates, but that different spacecraft in the vicinity of the same coordinates and within the beamwidth of an earth station antenna will usually require different frequencies;

(e) that it is practical and desirable to effect telemetering and tracking functions on the same space-to-Earth link, and telecommand and tracking functions on the same Earth-to-space link;

(f) that to effect precision tracking, a pair of coherently-related Earth-to-space and space-to-Earth frequencies is desirable;

(g) that for more accurate calibration of the effects of charged particles on the velocity of propagation, simultaneous use of links with coherent frequencies in two or more widely separated bands is required;

(h) that voice and video links associated with manned spacecraft in deep-space could use frequency bands allocated for telemetering, telecommand and tracking functions;

(i) that Report 683 (MOD F) considers the selection of preferred frequencies for deep-space research in the 1 to 20 GHz range;

(j) that Report ... (Doc. 2/192) considers the selection of preferred frequencies for deep-space research in the 20 to 120 GHz range.

RECOMMENDS

1. that frequency bands for deep-space research in the 1 to 20 GHz range be located, with due regard to the feasibility of sharing, in the preferred frequency regions listed in Table III of Report 683 (MOD F);

2. that frequency bands for deep-space research in the 20 to 120 GHz range be located, where sharing is feasible, in the preferred frequency regions listed in Table I of Report ... (Doc. 2/192);

3. that allocation widths at the preferred frequencies be in harmony with the bandwidth requirements discussed in Report 536-1 (MOD I) in order to provide for present and future deep-space telecommunications in a multi-spacecraft, multi-mission environment.