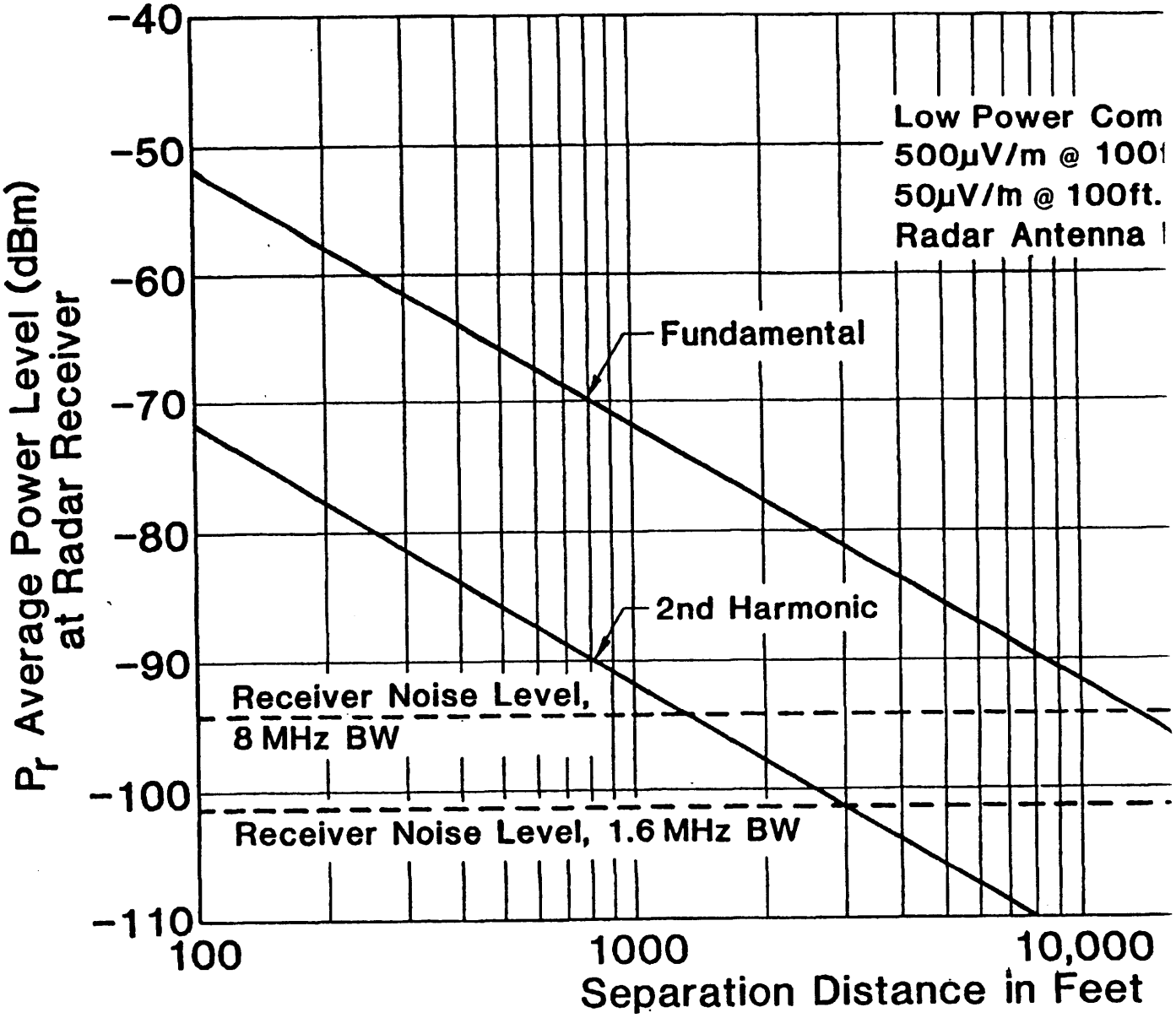

Figure 26. Low Power Communications Device/Radar Receiver Separation Dis
Based on In-Band Specifications. Radar Receiver Sensitivity
for Two Bandwidths (BW).

SECTION 7

SPECTRUM MANAGEMENT ISSUES

The effects of WARC-79 on the 5650-5925 MHz band are significant. The band which previous to WARC-79 was military radiolocation in the United States must now share the upper portion of the band (5850-5925 MHz) with the non-Government Fixed-Satellite Service. There is also heavy use of the ISM band (5725-5875 MHz) by the radiolocation service. The character of the band could change significantly in the next decade. The major spectrum management issues are discussed in the following paragraphs.

RADIOLOCATION AND THE FIXED-SATELLITE SERVICE

International communication satellite systems such as the INTELSAT VI series have the option to become operational in the 5850-5925 MHz portion of the band under study here in the 1985-86 time frame. As shown in Section 6 the interference potential to the satellite receiver system from in-band radar energy presents an incompatible situation. The earth station transmitter could also pose some compatibility problem for transponder systems in the Radiolocation Service sharing this portion of the band. However, only the first sidelobe provides enough energy to be a problem. There are existing COMSAT sites on either coast which seem to be desirable for minimizing the potential problem.

Measurement by the RSMS show this band to be heavily used by military test ranges and shipboard radars. However, few radars were measured above 5850 MHz. Transponders were found to operate above 5850 MHz and as mentioned previously, would experience possible interference from the FSS. As given in Section 6 there are existing COMSAT Earth-station sites that seem to provide possibility of limited sharing between the Radiolocation and Fixed-Satellite Services. However, radars whose tracking angles may cause mainbeam-to-mainbeam coupling with the satellite would have to be limited to radiated powers of 69.8 dBW if the satellite transponder carries FM/TV or 92.3 dBW if the satellite transponder system is limited to FDM/FM or similar modulations. Since it is not practical to limit the power of existing radars in the band, off-tuning the radars from the 5850-5925 MHz portion of the band is another viable option.

RADIOLOCATION AND ISM

Figure 2 in Section 4 shows that a large number of assignments (44%) in the Radiolocation Service fall within the 5725-5875 MHz portion of the band designated to ISM use. Although there was no use of the ISM band found by equipments classified as ISM, the potential for interference at some future time always exists. This could be of importance to the national defense if ISM equipment which is permitted unlimited conducted and radiated energy in the 5725-5875 MHz band were to proliferate. As stated earlier in this report, at least 27% (5850-5925 MHz) of the band will require some sort of restricted use by the high power radar systems to be compatible with the FSS. Even more spectrum would be unusable if off-tuning is used as shown in Section 6 the AN/SPS-16 tuning to no higher than 5760 MHz to maintain a C/I criteria of 15 dB. If the ISM band were to be heavily used by ISM equipments, it is possible that the portion of the band from 5725-5850 MHz would

also have only limited use by the military who are the prime users. As stated above, this is also the frequency range where a large number of radiolocation assignments exist.

There have been proposed changes to ISM standards considered over the past few years. The FCC issued a NPRM requesting comments for revising Part 18 which governs ISM equipment [FCC, 1978]. After receiving comments and suggestions from various manufacturers of ISM equipment, concerned government agencies, and other sources based on the first NPRM, a new NPRM is now being drawn up which is significantly different than the first. Although the second NPRM has not been issued at this report writing it will still deal with reduced frequency tolerances and stricter in-band and out-of-band emission limits.

RADIOLOCATION AND THE AMATEUR

The amateur-satellite service has new allocations in the 5650-5925 MHz band. The allocations are 5650-5670 MHz up-link and 5830-5850 MHz down-link. There is presently no known use of this band by the amateurs. However, even though the Amateur and Amateur Satellite Services operate secondary to radiolocation, interference potential particularly from the down-link can exist. Restrictions on the Amateur Satellite Service through the use of geographic location and power limitations could provide some protection to the radiolocation service. This method has been used previously, i.e., Footnote US7 used in the 420-450 MHz band which limits the power transmitted by amateur stations to 50 Watts near certain military test ranges. Also a National Memorandum of Understanding was established in the 902-928 MHz band which stated that the band was available for use by amateur stations only after coordination with and under conditions established by the DOD Frequency Coordinators in the stated areas. It is stated in the FCC Rules and Regulations, Part 97, Subpart C, that amateur stations shall not cause interference to the Government radiolocation service, however, a footnote would be beneficial both to the U.S. Government and the amateurs who would potentially use the band in that it would spell out definite coordination efforts and/or power levels to be used.

RADIOLOCATION AND RESTRICTED RADIATION DEVICES

The FCC Rules and Regulations, Part 15, states that certain restricted radiation devices may operate in the band 5725-5875 MHz. No use of the band was found by restricted radiation devices or reported incidence of interference from such devices. In light of the importance of this band to the U.S. Government, the FCC's assistance and cooperation would be needed to manage the growth of such devices in the private sector. Three specific areas of assistance would be needed as follows:

1. Change the band which can be used for such devices from 5800 ±75 MHz to 5800 ±50 MHz to help keep the possible interference potential to the smallest frequency subband as possible since radiolocation is already losing valuable flexibility in operating frequency within the 5650-5925 MHz band.

2. Make manufacturers aware of the importance of this band to the Government and request their support in helping to keep any devices considered for the band compatible.

3. Strict enforcement of the non-interference basis these devices must operate under per Part 15.311(b) for the 5750-5850 MHz subband.

APPENDIX A

PROBABILITY OF RADAR MAINBEAM-TO-SATELLITE ANTENNA COUPLING

The radars considered here are generally used for target tracking. The mainbeam of the antennas may be directed toward the target which is located at any arbitrary point in the hemisphere above the radar site. Since the geostationary orbit is visible to all the points on the earth except two small regions around the poles of the earth, it is easy to believe that, occasionally, in target tracking the mainbeam of the radar will be directed toward the satellite antenna. Here the probability, P, of the radar mainbeam-to-satellite antenna coupling is defined by

$$P = \frac{S}{S_t} \tag{A-1}$$

where S_t is the area of the spherical zone above the radar site and S is the area generated at the intersection of radar antenna mainbeam and the surface S_t, see Figure A-1.

The assumption in Equation A-1 is that the radar targets are uniformly distributed in the spherical zone above the radar site. The surface area of the spherical zone is given by

$$S_t = 2\pi R\, H \tag{A-2}$$

where H = R-r and the parameters R and r are described in Figure A-1. Considering the geometry shown, the surface area S may be expressed by

$$S = (D_1 - D_2 \cos \phi)\, 2\pi R \tag{A-3}$$

where the parameters D_1 and D_2 are defined in Figure A-1 and ϕ is one-half the 3 dB beamwidth of the radar antenna pattern.

D_1 and D_2 are related to the elevation angle of the radar by the expression

$$D_i = R \cos [\theta_i + \text{arc sin } (r/R \cos \theta_i)]/\cos \theta_i \quad i = 1,2 \tag{A-4}$$

where:

$\theta_i \neq 90°$

θ_1 = Radar elevation angle, and θ_2 = radar elevation angle plus ϕ.

Substituting Equations A-2 and A-3 in Equation A-1, we obtain

$$P = [D_1 - D_2 \cos \phi]/H. \tag{A-5}$$

Equation A-5 may be used to calculate the probability P for different values of radar beamwidth. Figure A-1 is a simplified model which was used in the derivation of Equation A-5. More sophisticated models require more detailed information beyond this report.

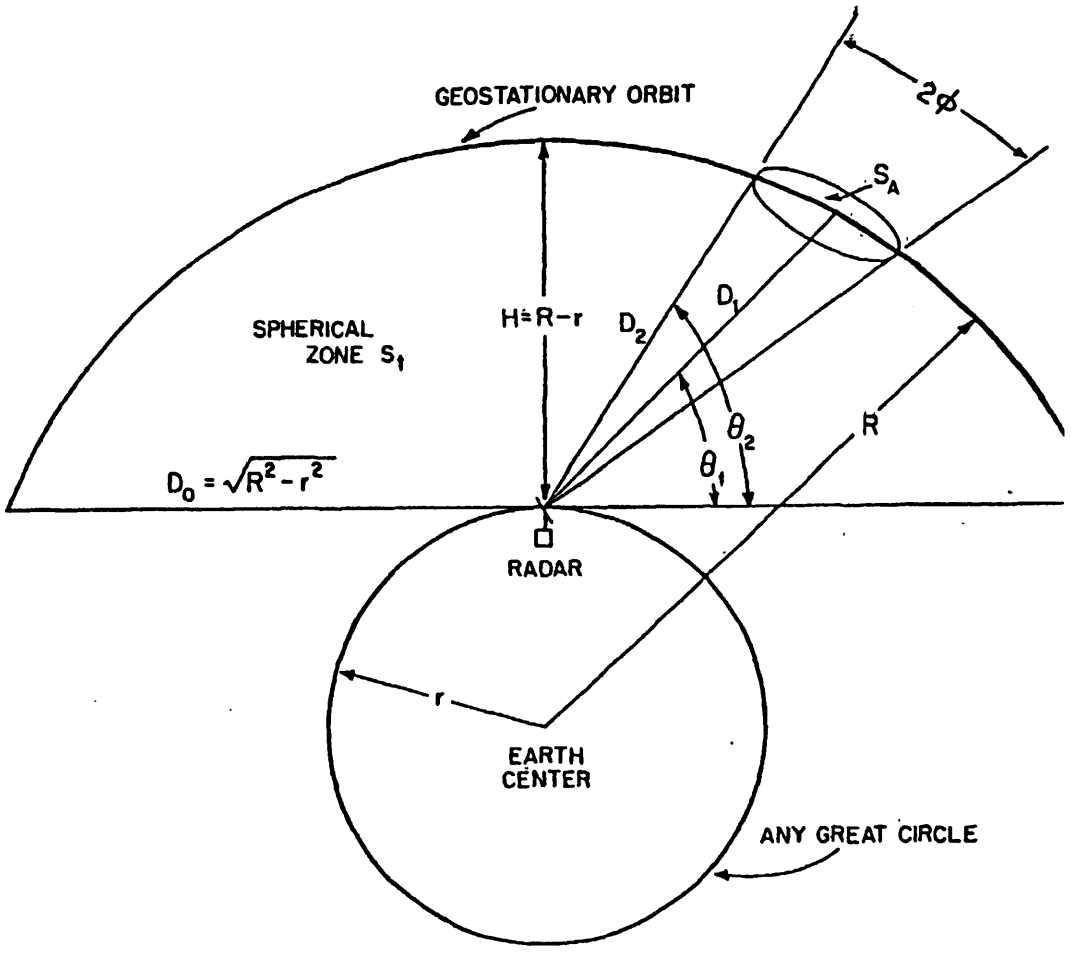

Figure A-1. Geometry for Probability of Radar Mainbeam to Satellite Co

APPENDIX B

ANNEX III

Radiation Patterns for Earth Station Antennae
to Be Used When They Are Not Published

When neither measured data nor relevant CCIR Recommendations accepted by the administrations concerned are available, then administrations should use the referenc patterns as described below (dB):

a) for values of $\frac{D}{\lambda}$ > 100* (maximum gain > 48 dB approx):

$$G(\phi) = G_{max} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda}\phi\right)^2 \quad \text{for } 0<\phi<\phi_m$$

$$G(\phi) = G_1 \quad \text{for } \phi_m<\phi<\phi_r$$

$$G(\phi) = 32 - 25 \log\phi \quad \text{for } \phi_r<\phi<48°$$

$$G(\phi) = -10 \quad \text{for } 48°<\phi<180°$$

where:

D = antenna diameter
λ = wavelength — expressed in the same unit
φ = off-axis angle of the antenna
G_1 = gain of the first sidelobe = $2 + 15 \log \frac{D}{\lambda}$

$$\phi_m = \frac{20\lambda}{D} G_{max} - G_1 \quad \text{(degrees)}$$

$$\phi_r = 15.85 \left(\frac{D}{\lambda}\right)^{-0.6} \quad \text{(degrees)}$$

b) for values of $\frac{D}{\lambda}$ < 100* (maximum gain < 48 dB approx.):

$$G(\phi) = G_{max} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda}\phi\right)^2 \quad \text{for } 0<\phi<\phi_m$$

$$G(\phi) = G_1 \quad \text{for } \phi_m \leq \phi \leq 100 \frac{\lambda}{D}$$

$$G(\phi) = 52 - 10 \log \frac{D}{\lambda} - 25 \log \phi \quad \text{for } 100 \frac{\lambda}{D} \leq \phi < 48°$$

$$G(\phi) = 10 - 10 \log \frac{D}{\lambda} \quad \text{for } 48° \leq \phi \leq 180°$$

The above patterns may be modified as appropriate to achieve a better representation of the actual antenna pattern.

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*In cases where $\frac{D}{\lambda}$ is not given, it may be estimated from the expression $20 \log \frac{D}{\lambda} = G_{max} - 7.7$, where G_{max} is the main lobe antenna gain in dB.

APPENDIX C

DEPARTMENT OF STATE

Washington, D.C. 20520

June 10, 1980

Mr. Irving Goldstein
Vice President and General Manager
International Communications
Communications Satellite Corporation
950 L'Enfant Plaza, S.W.
Washington, D.C. 20024

Dear Mr. Goldstein:

The 1979 World Administrative Radio Conference modified the International Radio Regulations, including the Table of Frequency Allocations (Article N7), in order that administrations may satisfy their existing and future telecommunications requirements. In many frequency bands the specific allocations provide for two or more services on a coequal primary basis. In our opinion, there are some bands or portions thereof in which the indicated primary services are not technically compatible. In these cases it may be necessary for each administration to choose which of the primary services it will implement. The United States fully supports the right of all administrations to determine, according to their own national interest, which service allocations they will implement.

Of concern to the U.S. Government and of particular interest to ComSat and INTELSAT are specific allocations to the Fixed Satellite Service below 10 GHz. Some of the most intense and difficult negotiations during the Conference took place with respect to the bands 3.4.-3.7 GHz and 4.5-4.8 GHz. In order to consummate an acceptable compromise, the United States, along with several other administrations, agreed to and signed a formal Declaration. A copy of that Declaration is enclosed.

We believe it is necessary that ComSat and INTELSAT be fully aware of the United States Government interpretation of the Declaration, as well as our current national policy as set forth in sub-paragraphs 1) and 2) below with respect to, and domestic implementation of, the revised allocations. ComSat and INTELSAT must be equally aware of technical incompatibilities among the various services in question.

1) 3.4-3.7 GHz Band

The United States will continue to operate vital radiolocation systems for worldwide use in the band 3.4-3.6 GHz. These sytems will be operating in accordance with the ITU Radio Regulations, and it should be understood that the U.S. Government cannot accept operational constraints. Although the United States will not withhold support for the implementation of the Fixed Satellite Service in the band, by INTELSAT, by reason of allocation table footnotes 3736 and 3736A, we will not guarantee protection from harmful interference to the Fixed Satellite Service from the Radiolocation Service. We are, however, prepared to participate in future studies and to make reasonable efforts to accomodate the Fixed Satellite Service, consistent with footnotes 3736 and 3736A and sound technical, operational and system financial planning by INTELSAT.

The 3.6-3.7 GHz can be made available for international systems in the Fixed Satellite Service in the United States on a very limited basis. The exact locations for implementation and the conditions which may be applicable to both the Fixed Satellite Service and to other services sharing this band will be subject to case-by-case electromagnetic compatibility studies.

2) 4.5-4.8 GHz Band

The band 4.5-4.8 GHz can be made available for international systems in the Fixed Satellite Service in the United States on a limited basis. The exact locations for implementation and the conditions which may be applicable to both the Fixed Satellite Service and other services sharing this band will also be subject to case-by-case electromagnetic compatibility studies.

We wish to draw to your attention the fact that, by virtue of footnote 3748B, this band will not be available in all countries which are members of INTELSAT. Furthermore the United States Government may find it necessary to discourage certain countries, particularly in Europe, from using this band for the Fixed Satellite Service in view of common national security interests.

3) In your capacity as United States Signatory, you are instructed to describe this U.S. national policy at all meetings of INTELSAT where this matter is discussed. You should remain in the closest possible contact with the State Department during consideration of these bands in such meetings. Following each session's consideration of these bands, but prior to the final session on this matter of any such meeting, you are further instructed to provide a verbal report on the relevant discussions; upon conclusion

of the meeting, we ask that you provide a written report.

4) You should explain, in a manner you deem expedient, this U.S. national policy to the Director General and his staff.

5) If there are any questions regarding the U.S. policy and the instructions contained in this letter, we will be pleased to arrange for any needed clarification.

Sincerely,

Arthur L. Freeman
Director
Office of International
Communications Policy

Attachment:

As stated.

ANNEX 3

DECLARATION

The Administrations of the USA, Canada, UK, Netherlands, Australia, Belgium, which are member-countries of INTELSAT, recognizing the importance of the bands 3.4 - 3.6 GHz and 4.5 - 4.8 GHz for use by the fixed-satellite service (FSS), agree as follows :

(1) They shall not by reason of footnotes 3736, 3736A and 3748B withhold support for the implementation of the FSS in these bands by INTELSAT either as to the space segment, or as to the use of the band 4.5 - 4.8 G in any country other than those listed in footnote 3748B.

(2) They shall make reasonable effort to accommodate FSS consistent with footnotes 3736, 3736A and 3748B and the normal procedures of the INTELSA Organization.

The above mentioned Administrations will advise their Signatories to the INTELSAT Agreement accordingly.

USA -
AUST.
BEL
UK
CAN
HOL

The foregoing Declaration shall be effective upon the adoption of the proposals contained in Annexes 1 and 2 without substantial modifications.

29 November 1979

DEPARTMENT OF STATE

Washington, D.C. 20520

December 19, 1980

Mr. Irving Goldstein
Vice President and General Manager
International Communications
Communications Satellite Corporation
950 L'Enfant Plaza, S.W.
Washington, D.C. 20024

Dear Mr. Goldstein:

Your letter of July 28, 1980 requested a more precise definition of the provisions of our June 10, 1980 policy statement regarding the use of certain frequency bands adopted by the 1979 World Administrative Radio Conference (WARC-79) as they impact upon INTELSAT planning for future international satellite facilities. That policy was developed in consultation with all appropriate authorities of the United States Government in accordance with the normal instructional process and is hereby reaffirmed as our national policy in this matter. This letter is intended to provide additional details that should allow ComSat to proceed with any urgent planning activities and to perform its role as U.S. INTELSAT Signatory in an informed manner.

As you are aware, the 3.4-3.7 GHz and 4.4-4.7 GHz bands have been allocated to the Fixed Satellite Service in the International Table of Frequency Allocations since 1963, but these allocations have never been included in the U.S. National Table of Frequency Allocations. However, in light of the policy stated in our June 10 letter, it is possible that, after domestic implementation of the WARC-79 results, the U.S. Table will include the Fixed Satellite Service in the bands 3.6-3.7 GHz and 4.5-4.8 GHz with footnotes limiting their use to international systems.

In the United States the band 3.4-3.6 GHz will continue, for the foreseeable future, to be available to radiolocation on a primary basis. At least part of this band may also be required by aeronautical radionavigation systems for which alternative spectrum accommodation cannot be provided. It should be re-emphasized that United States military forces will continue to operate mobile radiolocation systems worldwide in this band, well beyond the 1985 date referred to in footnote 3736A, due to the lack of suitable alternative bands. Because of the nature of mobile radiolocation operations, it is not considered possible now or in the future to establish and enforce operating discipline which would either guarantee or give assurances through intent that the Radiolocation Service would not cause interference to the Fixed Satellite Service. For these reasons, it is virtually impossible that the 3.4-3.6 GHz band will be allocated to the Fixed Satellite Service in the U.S. National Table. Because of our critical military requirements for radiolocation in the European (NATO) area, the United States will press its allies in that area for continued protection of radiolocation in this band for as long as requirements exist.

To emphasize our position in regard to the band 3.4-3.6 GHz, the United States will not withhold support for INTELSAT's use of the band by reason of footnotes 3736 and 3736A or of our own national defense requirements. At the same time it must be clearly understood that for the foreseeable future, we will not include the allocation in the U.S. National Table and we can neither guarantee protection to the Fixed Satellite Service nor accept any operational constraints on existing or future radar systems. Therefore, it appears to be essential that any INTELSAT consideration for use of the band 3.4-3.6 GHz must include a complete assessment of areas of the world where the band may not be domestically allocated as well as the probable interference and other risks which may exist under these given circumstances.

In the band 3.6-3.7 GHz the United States will continue to operate radiolocation and aeronautical radionavigation (terrestrial) systems on a primary basis for an indefinite period of time beyond 1985. To the extent that stations in the international Fixed Satellite Service can coordinate their proposed frequency assignments with radar operations in this band at specific U.S. sites, the Fixed Satellite Service would enjoy the protection afforded a primary service in the U.S. It is not possible to identify the specific location or number of earth stations where favorable coordination might be feasible since future requirements are subject to change and case-by-case EMC analysis of each proposed site will be required. At this time it is anticipated that one earth station on each coast can be successfully coordinated. However, it must be recognized that no guarantee for additional earth stations exist. Finally, it should be noted that the band 3.6-3.7 GHz is not included in the formal Declaration attached to my June 10 letter.

The band 4.5-4.8 GHz will continue to be available in the U.S. to the Fixed (including tropospheric scatter operations) and Mobile Services on a primary basis. To the extent that stations in the international Fixed Satellite Service can coordinate sites with other authorized users, the Fixed Satellite Service will be afforded the protection of a primary service in the United States. In this regard, you should understand that the introduction of any space service in this band in the U.S. will have a significant adverse impact on important existing and future fixed and mobile operations. However, consistent with our Declaration, we will try to accommodate the international Fixed Satellite Service on a case-by-case basis in the new band. At this time it is anticipated that one earth station on each coast can be successfully coordinated. However, it must be recognized that no guarantee for additional earth stations exists. It is not possible to identify specific locations since future requirements are subject to change and case-by-case EMC analysis of each proposed site will be required.

In NATO Europe in the band 4.5-4.8 GHz, there are extensive fixed (including tropospheric scatter) and mobile operations of critical importance that are implemented or planned by the U.S. and our allies, for which no suitable alternative frequency bands are available. We have recommended to our allies that they continue to exclude satellite communications from this band within their borders for the foreseeable future. As you are aware,

the position of some of these countries has already been made known to the Board of Governors. Additionally, because of the universality of our military systems, the U.S. will make similar requests to certain countries outside of Europe where we have critical military operations in the band 4.5-4.8 GHz.

In summary, the U.S. fully intends to honor its commitments with respect to the Final Acts of WARC-79 and we believe that the clarifications contained in this letter are consistent with the letter and intent of the Acts and the formal Declaration. It is not expected that the U.S. Government would seek action in the Board of Governors to prevent INTELSAT from planning to use the full 3.4-3.7 GHz and 4.5-4.8 GHz bands in its satellite systems, especially if the service they are proposing is to areas outside of the areas and/or frequency bands of critical concern, but we would be unable to provide guaranteed protection from interference. The policy stated in my letter of June 10, 1980 and the instructions contained therein are reaffirmed. We remain, however, prepared to participate in future studies and to make reasonable efforts to accommodate the Fixed Satellite Service, consistent with the National and International Tables of Frequency Allocations and sound technical, operational and system financial planning by INTELSAT.

Sincerely yours,

Arthur L. Freeman
Director
Office of International
Communications Policy

LB/MD:FESchrum:sp

Clearances: State - Ruffcatt
NTIA - Barnet, Darnat
FCC - Torak, Greenburg
DOD - Cook Hay Phillips

SECTION 8

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14 SUPPLEMENTARY NOTES

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 constitutes a Spectrum Resource Assessment of the 5650-5925 MHz band. Included is information on rules and regulations, allocations, technical standards, frequency assignments, system characteristics, and applicable compatibility analysis. Problems of concern to the U.S. Government usage of the band are identified, analyzed and recommendations made. Major issues concerned the introduction of a Fixed-Satellite Service (FSS) in the band and current usage of that portion of the band designated for Industrial, Scientific and Medical (ISM) purposes. It is concluded that power limitations for radars should be considered as an option to minimize potential interference problems with satellites which may become operational in the 5850-5925 MHz portion of the band. It is also concluded that in-band radiation limits be considered for the Industrial, Scientific and Medical designated frequency at 5800 ± 75 MHz to help protect Government investment and future Fixed-Satellite Service usage.

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

Amateur Service; Electromagnetic Compatiblity; 5650-5925 MHz; Fixed-Satellite Service; ISM: Radiolocation Service; Restricted Radiation Devices

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