SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

This investigation is a continuation of Part 1 of the study on pfd limits for satellites that operate in the 2025-2300 MHz frequency range (Farrar,1982). A review of the spectrum use in the United States in this frequency range is made and the rules, criteria, and guidelines set by the ITU and CCIR pertinent to the determination of the pfd limits are studied. The limits developed here are appropriate for the United States and the assumptions used in their derivation should be reviewed for use by other administrations. The pfd limits for the satellites in the frequency ranges 13.4-14.0 GHz and 14.5-15.35 GHz are not treated in this analysis. However, the methodology developed in this analysis is applicable in treating pfd limits in these frequency ranges.

The pfd limits protecting the Fixed Service using line-of-sight techniques in the 2025-2300 MHz frequency range are included in the ITU Radio Regulations (RR) and are described in Article 28, Section IV, Nos. 2556 and 2557 (RR, 1982). Nos. 2556 and 2557 are as follows:

"2556 (2) Power flux-density limits between 1525 MHz and 2500 MHz."

"2557 (a) The pfd at the Earth's surface produced by emissions from a space station, including emissions from reflecting satellite, for all conditions and for all methods of modulation, shall not exceed the following values:

-154 dB(W/m^2) in any 4 kHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;

$-154 + 0.5\ (\delta - 5)$ dB(W/m^2) in any 4 kHz band for angles of arrival (in degrees) between 5 and 25 degrees above the horizontal plane;

-144 dB(W/m^2) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizontal plane."

These limits relate to the pfd which would be obtained under assumed conditions. These same limits are contained in the NTIA Manual for systems in line-of-sight operation. No. 2559 of the ITU Radio Regulations specifies that the limits in No. 2557 are applicable to the frequency range 2290-2300 MHz. However, ITU footnotes 747 and 750 specify that these limits are also applicable to the bands 2025-2110 MHz and 2200-2290 MHz.

Two computer models, the Geostationary Model (GM) and the Non-Geostationary Model (NGM), developed earlier for the determination of the pfd limits in the frequency bands shared between systems in the Fixed Service and satellites were found useful for this analysis. The models were modified extensively in order to conduct the analysis and to determine the pfd limits in the frequency range 2025-2300 MHz. Modifications to these computer models were identified in Part 1 of this analysis. The computer models may be used

to determine pfd limits for any shared band; however, the preparation of the input parameters for these models requires a careful assessment of the usage of the spectrum and the technical characteristics of the systems.

The following are the conclusions and recommendations which resulted from a detailed analysis of the pfd limits in the frequency range 2025-2300 MHz.

GENERAL CONCLUSIONS

Effects of each modification to the computer models on the value of the pfd limits were determined separately. Some of the effects were significant. A summary of the modifications and their separate effects on pfd limits is as follows:

1. An approximate formula for the transfer function of typical radio receivers in the 2025-2300 MHz frequency range was evaluated. Based on modulation indices and emission spectrums of typical systems in this frequency range, the analysis indicated that the transfer function allowed the pfd limits to be relaxed by 3 dB as calculated by the GM or NGM computer models.

2. Data on fading obtained in the United States were incorporated in both the GM and NGM computer models. The results indicated that the use of this fading data in the computer models did not show any significant change (less than 1 dB) in the pfd limits.

3. A modification was made to the NGM computer model in order to be able to calculate pfd limits when interfering satellites are in different orbits. This modification simulated a more realistic method of operating satellites and the results indicated an increase of approximately 1-3 dB in the interference power received from satellites in non-geostationary orbits.

4. The pfd limits which protect the analog systems in terrestrial services should also protect the digital systems operating in the same frequency range. The results of calculations show that for an operating condition simulated by typically "worst case" Gaussian noise interference, the bit-error-rate is less than 10^{-3} for practical signal-to-noise ratios used in the design of terrestrial microwave systems. Hence, the digital systems are generally less susceptible to interference than their analog counterparts.

5. Single hop aeronautical telemetry mobile systems with very sensitive receivers and relatively high gain receive antennas (gain greater than 30 dBi) temporarily pointed toward satellites in geostationary or low orbits may occasionally experience potential interference. Analysis shows that the probability of potential interference from satellites in low orbits to these telemetry systems is approximately 1×10^{-3} and the duration of interference is a few seconds.

6. Potential interference from satellites to aeronautical telemetry systems was found to be manageable by using frequency management, coordination, antenna reorientation or scheduling. The report by ECAC

(White, 1977) documents the frequency management techniques that are used presently for coordination at the eastern and western test ranges.

SPECIFIC CONCLUSIONS

1. Potential interference from satellites in the geostationary orbit to terrestrial systems in the Fixed Service increases as the terrestrial systems are moved in latitude from the equatorial to approximately 50 degree latitude. The potential interference to terrestrial systems then decreases to 83 degree latitude. The worst interference occurs when the trendline for a terrestrial system is pointed toward the geostationary orbit. (a)

2. Analysis shows that for a given pfd, regardless of the altitude of low orbit satellites, the interference to terrestrial receivers generally increases as the inclination angle decreases as shown in Figures 13-16.

3. Analysis indicates that pfd limits for geostationary satellites may be considered separately from those for non-geostationary.

4. The results of analysis based on spectrum use and the characteristics of systems in the terrestrial and space services in the United States indicate that the the pfd limits for 2025-2300 MHz frequency range may be relaxed without degrading the operation of line-of-sight terrestrial systems. PFD limits for geostationary satellites should be changed to the following values:

-144 dB(W/m^2) in any 4 kHz for angles of arrival between 0 and 5 degrees above the horizontal plane;

$-144 + 0.5\ (\delta - 5)$ dB(W/m^2) in any 4 kHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane;

-134 dB(W/m^2) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizonal plane.

PFD limits for satellites in low orbits are similar to those given above except that they may be relaxed an additional 6 dB.

5. In the United States, the Government Fixed Service allocation in the sub-band 2200-2290 MHz is for line-of-sight transmission. Internationally, the band may be used by systems designed for tropospheric scatter transmission. Noise criteria due to interference from satellites to systems using tropospheric transmission has not yet been recommended by the CCIR. The pfd limits for satellites to troposcatter systems have not been determined.

Note a. A trendline consists of communication line between two points connected by a number of repeaters.

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 modifications of established rules, regulations, and procedures. It is recommended that:

1. The pfd limits, given in conclusion 4 above for satellites in geostationary and non-geostationary orbits, be adopted by the NTIA in the 2200-2300 MHz frequency range.

2. Footnote US90 be modified as suggested below:

> US90-In the band 2025-2110 MHz earth-to-space and space-to-space transmissions may be authorized in the space research and earth exploration-satellite services subject to such conditions as may be applied on a case-by-case basis. Such transmissions shall not cause harmful interference to non-Government stations operating in accordance with the Table of Frequency Allocations. All space-to-space transmission reaching the earth's surface from satellites in geostationary orbit shall adhere to a power-flux-density of between -134 and -144 $dBWm^2/4$ kHz depending on angles of arrival discussed in ITU Radio Regulations No. 2557. All space-to-space transmission from satellites in non-geostationary satellite orbits reaching the earth's surface shall adhere to a power-flux-density of between -128 and -138 $dBW/m^2/4$ kHz depending on angles of arrival stated in ITU Radio Regulations No. 2557.

3. The pfd limits in the frequency ranges 13.4-14.0 GHz and 14.5-15.35 GHz discussed in Part 1 be reviewed using the approach used in this investigation.

4. Similar analysis should be undertaken to develop pfd limit in the 2025-2300 MHz frequency range appliable to other ITU administratons.

5. The power density-limit for systems using troposcatter transmission be determined after permissible noise levels due to interference from satellites to these systems have been recommended by the CCIR.

6. Coordination among NASA, DOD and DOE in the 2200-2290 MHz frequency range be continued and enhanced to mitigate potential interference from satellites to telemetry systems in the Aeronautical Mobile Service in conjunction with the adoption of the new pfd limits in Recommendation 1.