RECOMMENDATION 609-1*

PROTECTION CRITERIA FOR TELECOMMUNICATION LINKS FOR MANNED AND UNMANNED NEAR-EARTH RESEARCH SATELLITES**

(Question 113/7)

(1986-1992)

The CCIR,

considering

a) that limiting interference criteria for telecommunication links for near-Earth space research are determined by the technical considerations examined in Annex 1;

b) that, based on past experience, it is expected that up to 100 or more active near-Earth space research spacecraft may be in orbit simultaneously;

c) that there is an increasing use of near-Earth space by both manned and unmanned space research missions;

d) that two-way communication is required for many near-Earth missions, and is vital for manned missions;

e) that typical operating noise temperatures of earth stations can be as low as 70 K (equivalent to –210 dB(W/Hz)) in the 1-10 GHz frequency range;

f) that typical operating noise temperatures of space stations are near 600 K (equivalent to –171 dB(W/kHz)) in the frequency range below about 10 GHz;

g) that link margins for typical space-to-Earth or space-to-space links are small, typically between 3 and 6 dB;

h) that a 1 dB increase in overall system noise due to interference is considered harmful;

j) that a noise to interference ratio of about 6 dB results in a 1 dB increase in overall system operating temperatures;

k) that technical and/or regulatory limitations may restrict increases in spacecraft power as a means of minimizing interference;

l) that difficulties can be expected when frequencies are shared between near-Earth spacecraft in the space research service and stations in other services,

recommends

1. that protection criteria for earth stations in the space research service (see Annex 1) be established as follows:

1.1 –216 dB(W/Hz) at the input terminals of the receiver, for bands in the 1-20 GHz frequency range. For frequencies below 1 GHz, the permissible interference may be increased at the rate of 20 dB per decreasing frequency decade;

1.2 calculation of interference that may result from atmospheric and precipitation effects should be based on weather statistics for 0.001% of the time for manned missions and for 0.1% of the time for unmanned missions;

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* This Recommendation should be brought to the attention of Study Groups 1, 4, 8, 9, 10 and 11.

** Protection criteria for space research (deep space) can be found in Recommendation 578.

2. that protection criterion for space research space stations in low orbit be established as follows: –177 dB(W/kHz) at the input terminals of the receiver, for 0.1% of the time for both manned and unmanned spacecraft, for bands in the 100 MHz-30 GHz frequency range;

3. that frequency sharing be accomplished to the maximum extent feasible among near-Earth spacecraft in the space research service;

4. that note be taken of the potential difficulties to be expected in frequency sharing between near-Earth spacecraft in the space research service and certain types of stations in other services;

5. that note be taken of the difficulties to be expected in frequency sharing between near-Earth and deep-space stations in the space research service.

ANNEX 1*

Protection criteria relating to near-Earth space research systems

1. Introduction

Much of the spectrum suitable for space research is also allocated to one or more other services and consequently frequency sharing between the services is required. This Annex discusses factors which affect the susceptibility of systems in the space research service to interference, and specifies appropriate protection criteria for the service in the frequency bands up to about 30 GHz. The protection criteria are for use in interference analyses when actual system data are unavailable.

2. General considerations

Space research communications are required for four types of functions: telecommand, maintenance telemetering, stored scientific data and real-time scientific data.

For the telecommand function, it is a fundamental design principle of most research spacecraft that no false command should result in a completely aborted mission and that an unalterable state be reached as a result of any command. As there is usually an unavoidable severe dependence on the spacecraft telecommand system during critical mission phases such as during launch and injection sequences or during emergency situations, interference during these critical periods could severely compromise the mission.

Maintenance telemetering can be stored or sampled and transmitted in real time. Except during critical periods, such as launch and injection sequences, emergency situations, or during the transfer of bio-medical data of human occupants, a maintenance telemetry system is fairly tolerant of interruptions and interference. During critical periods, read-outs must of course be highly reliable. The diagnostic use of these data makes it clear that at critical times in a mission there may be long periods (several hours) in which the maintenance telemetry must be protected from harmful interference. For other periods of a mission, however, this class of function can accommodate limited interruption without serious effect.

Stored scientific data can usually be played back more than once for error detection. This is probably the class of data which is most tolerant of interference of limited duration.

Real-time non-stored data are the most susceptible to interference, in that the transmission occurs only once and is unrepeatable. Much of the value of an expensive spacecraft may be represented by such data, so it is imperative that this class be well protected against interruption or degradation. Usually, the time of reception of interesting non-stored data is known in advance to within several hours.

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* *Note from the Director, CCIR* – Report 985 was used in the preparation of this Annex.

Many space research systems employ PCM-PSK-PM modulating techniques and phase-locked loop circuitry for the demodulation of system carriers and sub-carriers. High data rate transmissions are usually based upon 2-PSK or 4-PSK modulation. Phase-locked loop circuitry is also used during search, acquisition and tracking sequences, and is employed in both ground and spaceborne receivers.

3. Protection criteria

In a communication link, the permissible ratio of interference to system noise may be determined by the portion of design margin allocated to external interference. In space-to-space and space-to-Earth links, the incentive is to minimize link margins in order to save weight and power, to comply with emission limits, and in the interest of economy. Typical link design margins to allow for the effects of non-ideal conditions are generally in the range of 3 dB to 6 dB for spacecraft operating at frequencies below about 10 GHz. For spacecraft operating at frequencies above about 10 GHz, larger link margins are usually required to offset the effect of weather conditions.

Considering these low link margins, interference can be harmful to typical space research systems if the link threshold performance is decreased by more than 1 dB. This corresponds to a required ratio of system noise spectral density to interference spectral density (N/I) of about 6 dB.

3.1 Reference bandwidth

The reference bandwidth in which a protection level must be specified depends upon the smallest bandwidth likely to be employed. For earth-station receivers, phase-locked loops may employ bandwidths of a few hertz. The detection bandwidth on the space station is usually greater (1 kHz or more) due to the need for rapid, automatic acquisition of signals from the Earth.

Thus, recommended values for the reference bandwidths for space research receivers are:

– earth-station receivers: 1 Hz

– space-station receivers: 1 kHz.

3.2 Reference percentage of time

When considering interference to space research earth stations, it is necessary to note that sporadic interference from man-made sources can be expected due to trans-horizon propagation, fluctuating weather conditions, and the changing gain in the link between the interfering station and the receiving station due to the relative motions of the antennas, etc. Therefore, any criterion of interference which is established must be stringent enough to minimize the possibility of this type of interference.

Further, as propagation data are usually presented in the form of a percentage of time that certain conditions are exceeded, it is necessary to relate outage time with propagation data. For manned space missions, a loss of more than 5 min of communication during critical periods would seriously affect the mission. However, it is usual that propagation conditions are such that the lowest transmission loss between two stations will persist for much longer periods than 5 min. Therefore, to provide protection which will prevent interference for longer than 5 min per day, it is necessary not only to consider the worst hour in the year, but also the worst 5 min within that hour. This is approximately 0.001% of the time. For unmanned missions, where safety of life is not a factor, the reference percentage of time is 0.1%.

3.3 Required protection levels

3.3.1 Earth-station receivers

In the 1-20 GHz region, the total noise temperature of receiving earth stations is typically about 70 K or greater depending on the antenna contribution. This contribution is a function of frequency, antenna elevation angle, existing meteorological conditions and ground and thermal radiation into the antenna side and back lobes. Below about

1 GHz, cosmic noise increases the operating noise temperature of the system at a rate of about 20 dB per decade of decreasing frequency. Therefore, based on the required *N/I* ratio of 6 dB established in § 3, and a receive noise temperature of 70 K, the following criterion is the most directly appropriate for the protection of earth stations.

In the frequency range 1-20 GHz, harmful interference can occur if the total time during which the power density of noise-like interference or the total power of CW-type interference in any single band or in all sets of bands 1 Hz wide, is greater than –216 dB(W/Hz) at the input terminals of the receivers for a period exceeding 0.001% of the time for manned missions, and 0.1% of the time for all other near-Earth space research missions. For frequencies below about 1 GHz, permissible interference may be increased at the rate of 20 dB per decreasing frequency decade. This interference criteria applies to all three of the down-link communication functions discussed in § 2.

3.3.2 Space-station receivers

The total noise temperatures of a typical space-station receiver are generally 600 K or more. These levels are due, in part, to the requirement that the spacecraft antenna points at the Earth (290 K). Based on the required *N/I* of 6 dB, the following criterion is most directly appropriate for the protection of space stations.

In the frequency range 100 MHz-30 GHz, harmful interference can occur if the power density of noise-like interference or the total power of CW-type interference in any single band or in all sets of bands 1 kHz wide, is greater than –177 dB(W/kHz) at the input terminals of the receiver.

Due to the motion of low-orbit spacecraft, which can be susceptible to this level of interference, the amount of time of exposure to the interference is limited to 0.1% of the time for both manned and unmanned missions.