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| **Recommendation ITU-R M.2046**  **(12/2013)** |
| **Characteristics and protection criteria for non-geostationary mobile-satellite service systems operating in the  band 399.9-400.05 MHz** |
| **M Series**  **Mobile, radiodetermination, amateur**  **and related satellite services** |

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| **TF** | Time signals and frequency standards emissions |
| **V** | Vocabulary and related subjects |

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| ***Note***: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.* |

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RECOMMENDATION ITU-R M.2046

Characteristics and protection criteria for non-geostationary mobile-satellite  
service systems operating in the band 399.9-400.05 MHz

(2013)

Scope

This Recommendation provides a description, and the corresponding protection criteria for broadband noise and narrow-band interference, of one mobile-satellite service system that uses the 399.9-400.05 MHz frequency band (Earth-to-space).

The ITU Radiocommunication Assembly,

considering

a) that the 399.9-400.05 MHz frequency band is allocated to the mobile-satellite service (MSS);

b) that the use of the 399.9-400.05 MHz frequency band by the MSS is limited to non‑geostationary (non-GSO) satellite systems;

c) that the 399.9-400.05 MHz frequency band is also allocated to the radionavigation‑satellite service;

d) that the allocation of the 399.9-400.05 MHz frequency band to the radionavigation-satellite service shall be effective until 1 January 2015;

e) that future MSS systems may be deployed in this band;

f) that the corresponding description of these future systems is needed;

g) that protection criteria are required to meet the desirable performance objectives in the presence of interference,

recommends

**1** that the analysis to determine the effect on non-GSO MSS systems in the 399.9‑400.05 MHz frequency band should be based on the following protection criteria:

– –197.9 dB(W/(m2 · Hz)) maximum aggregate acceptable spectral power flux-density (spfd) at the antenna of a non-GSO MSS ARGOS4 system for broadband noise interference (see Annex 1);

– –165.4 dB(W/m2) maximum pfd within a resolution bandwidth of 19 Hz at the antenna of a non-GSO MSS ARGOS4 system for each narrow-band interference (see Annex 1);

**2** that the protection criteria defined in *recommends* 1 should not be exceeded for more than 1% of time in the field of view of the MSS satellite.

Annex 1  
  
ARGOS4 system

# 1 Description and characteristics of the MSS system ARGOS4

The ARGOS data collection system (DCS) uses the band 399.9-400.05 MHz for the uplink and transmits split-phase, Manchester-encoded, phase-shift keyed (PSK) signals through satellites in low-Earth orbit. It operates at a 400 bit/s data transmission rate. The data collection platform (DCP) typically uses a low-gain (3 dBi maximum at 40° elevation angle) antenna.

The satellite DCS processor demodulates the uplink DCS data, multiplexes the data with other mission telemetry, and transmits the corresponding digital data to the ground in the 1 670‑1 710 MHz, 7 750-7 850 MHz and 8 025-8 400 MHz bands. Moreover, one downlink at 465.9875 MHz is implemented in order to send dedicated messages towards the DCPs.

Because of the DCS data demodulation in the satellite, downlink performance can be separated from uplink performance when conducting performance analysis.

The system Argos supports different kind of users applications with various DCPs using different output power and different types of antennas (whip antenna most of the time); under these conditions, the power received from one DCP will differ from that received from another since it depends on the environment and the type of antenna technology which is actually implemented on the platform.

# 2 Protection criteria for the ARGOS4 non-GSO MSS system in the band 399.9‑400.05 MHz against broadband noise interference emissions

## 2.1 Calculation of the spfd threshold level of interference

The addition of broadband noise to the ARGOS4 receiver on board the satellite will have the effect of increasing the system bit-error ratio (BER), and therefore adversely affect its performance requirement. This analysis identifies the maximum acceptable pfd associated with broadband noise in the MSS ARGOS4 uplink channel.

The receive antenna gain pattern specification is expressed according to the nadir angle in Table 1:

TABLE 1

Receive antenna gain pattern

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Nadir satellite angle | 62 | 59 | 54 | 47 | 39 | 31 | 22 | 13 | 5 | 0 |
| Gain in RHCP | 3.85 | 3.54 | 2.62 | 1.24 | –0.17 | –1.33 | –2.24 | –3.08 | –3.80 | –3.96 |
| Gain in LHCP | –5.69 | –6.23 | –7.52 | –9.39 | –11.39 | –13.12 | –14.52 | –15.77 | –17.17 | –18.00 |
| Axial ratio (see Note 1) | 6.02 | 5.85 | 5.59 | 5.26 | 4.90 | 4.57 | 4.31 | 4.11 | 3.78 | 3.49 |
| NOTE 1 – The axial ratio is the ratio of the lengths of the major and minor axes of the polarization ellipse. | | | | | | | | | | |

The ARGOS4 typical figures are: noise figure = 3 dB, worst-case background noise temperature = 1 200 K (measured value taking into account the industrial noise in Europe), attenuation between the antenna and the ARGOS4 receiver = 1.6 dB. Thus, the system noise temperature at the input of the ARGOS4 receiver equals 1 214 K and therefore, the noise spectral density equals   
*N*0 = –197.8 dB(W/Hz).

The worst-case specification states that the ARGOS4 is designed to operate correctly when the received signal has a power *C* = –160 dBW (minimum level of the received signal) at the input of the receiver, which provides an effective *Eb*/*N*0 = 8.3 dB in the bit detector of the ARGOS if we take into account the beacon waveform and the various losses.

Therefore, in order to achieve a BER of 2 × 10–4 that corresponds to a minimum *Eb*/*N*0 of 8 dB, the maximum acceptable degradation is 0.3 dB.

Hereunder, the additive noise corresponding to the 0.3 dB degradation for the *C*/*N*0 is calculated. Let *I*0 represent the additive noise power density. Therefore, the initial *N*0 noise becomes *N*0 + *I*0. The signal-to-noise ratio *C*/*N*0 becomes *C*/(*N*0 + *I*0). The degradation is 0.3 dB = 10 log ((*C*/*N*0)/(*C*/(*N*0 + *I*0))), thus *I*0 /*N*0 = –11.5 dB and *I*0 = –209.3 dB(W/Hz) which corresponds to a temperature of 86 K, and therefore an increase of 7% of the system noise temperature at the input of the receiver. Therefore, the maximum admissible level of noise density is *I*0 = –209.3 dB(W/Hz).

As indicated before, the noise density, *I*0, takes into account the attenuation and the antenna gain. As the spfd is required, it is necessary to transform this figure in dB(W/(m2 · Hz)). The equivalent surface area of an antenna having a gain *G* is:



Taking into account the highest satellite nadir angle (62°), the antenna surface equals 0.105 m2 or   
–9.8 dB m2. Then, the corresponding spfd equals –209.3 + 1.6 (losses) – 10 log10 *S* =   
–197.9 dB(W/(m2 · Hz)).

The maximum level of broadband noise interference in the band 399.9-400.05 MHz should not exceed –197.9 dB(W/(m2 · Hz)) to protect the ARGOS4 system.

Usually, the bandwidth of an ARGOS4 transmission equals 1 600 Hz. Therefore, the corresponding pfd limit equals –165.8 dB(W/m2).

## 2.2 Derivation of performance objectives

Recommendation ITU-R M.1475–Methodology for derivation of performance objectives of non‑geostationary mobile-satellite service systems operating in the 1-3 GHz band not using satellite diversity, provides a methodology for calculating the unavailability time allowances for both service links and feeder links.

For the service link, it is proposed that the unavailability time allowances should not be greater than 0.9 *X* (%), with *X* representing the BER in % (e.g. 0.1%, 1%, 10%, etc.) of a given MSS non-GSO link. Since the proposed pfd limit is based on a BER of 2 × 10–4, it implies the unavailability time allowances should not exceed 1.8 × 10–2%. Therefore, a less stringent 1% unavailability time allowance is indicated in *recommends* 2.

# 3 Protection criteria for non-GSO ARGOS4 system in the band 399.9‑400.05 MHz against narrow-band interference emissions

## 3.1 Protection requirement from narrow-band emissions

To better understand the rationale of this specification, it is necessary to briefly recall the behaviour of the receiver.

MSS ARGOS4 transmissions begin with 160 ms of unmodulated carrier to allow a phase-locked loop to lock more easily on the carrier. Figure 1 represents the ARGOS4 message format.

Figure 1

MSS message format



A spectrum analyser in the receiver continuously monitors the full coverage bandwidth in search of the pure carrier portion of the MSS messages. When the spectrum analyser detects such a line, it considers that it is the beginning of a MSS message. The theory is based on the detection of a pure carrier wave (sine wave) in a white, additive and Gaussian noise environment. The power spectral density of the received signal (pure carrier + noise) is computed using fast Fourier transform techniques, and each signal above the system threshold is processed as if it were a MSS beacon (see Fig. 2).



The ARGOS4 receiver processors are therefore designed to detect discrete spectral components (unmodulated beacon carrier) and the corresponding resolution bandwidth is 19 Hz. Signals above the threshold level are assigned to an on-board data recovery unit (DRU) for further processing and transmission to the Earth on the mission telemetry channel.

In order to satisfy ARGOS4 detection probability performances for a wide range of user applications, the ARGOS4 receiver has been designed to detect and process extremely weak signals. Its performance is such that any signal, *Cmin*, which exceeds the local noise density level by 21 dB(Hz) (*Cmin*/*N*0 > 21 dB(Hz)) would be assigned to a DRU for additional processing. Consequently, narrow-band interfering signals meeting this criterion would cause a DRU to be assigned to it. The consequence would be that the performance of the ARGOS system, in terms of capacity (e.g. the number of simultaneous DCS messages that are able to be processed), would be seriously degraded.

The ARGOS typical figures are: noise factor = 3 dB (ARGOS4 typical figure), worst-case background noise temperature = 1 200 K, attenuation between the antenna and the receiver = 1.6 dB. Thus, the system noise temperature at the input of the receiver equals 1 214 K and therefore, the noise spectral density equals *N*0 = –197.8 dB(W/Hz).

As *Cmin*/*N*0 = 21 dB(Hz), *Cmin* = –176.8 dBW. Therefore, any narrow-band spurious emission greater than –176.8 dBW at the input of the ARGOS4 receiver, would result in a degradation of the system capacity.

It is then necessary to compute this maximum admissible level of narrow-band interference at the input of the ARGOS4 antenna.

The ARGOS4 receive antenna gain pattern specification is expressed according to the nadir angle in Table 1 (see § 2.1 above).

Therefore, the maximum admissible power within the receiver and before the antenna equals   
–176.8 + 1.6 (losses) = –175.2 dBW. As the pfd is required, it is necessary to transform this figure in dB(W/m2). The highest satellite nadir angle is used to get an antenna gain of 3.85 dBi, which is transformed into an equivalent surface area using the formula: . Therefore, the corresponding pfd equals –175.2 – 10 log10 *S* = –165.4 dB(W/m2).

## 3.2 Conclusion

Following the above computations, the conclusions and recommendations regarding the impact of the aggregation of spectral narrow-band interference emissions, should not exceed   
–165.4 dB(W/m2) at the input of the ARGOS4 antenna for the frequency band 399.9-400.05 MHz, within a resolution bandwidth of 19 Hz.