

RECOMMENDATION ITU-R M.1454*, **, ***

e.i.r.p. DENSITY LIMIT AND OPERATIONAL RESTRICTIONS FOR RLANs**
OR OTHER WIRELESS ACCESS TRANSMITTERS IN ORDER TO ENSURE
THE PROTECTION OF FEEDER LINKS OF NON-GEOSTATIONARY
SYSTEMS IN THE MOBILE-SATELLITE SERVICE IN
THE FREQUENCY BAND 5 150-5 250 MHz**

(Questions ITU-R 212/8, ITU-R 142/9 and ITU-R 284/4)

(2000)

Scope

This Recommendation recommends the mean e.i.r.p. density limit and operational restrictions for RLANs or other wireless access transmitters in order to ensure the protection of feeder links of non-geostationary systems in the mobile-satellite service in the frequency band 5 150-5 250 MHz. It includes the methodology and parameters used in the sharing studies and provides suggestions for implementing mitigation techniques to further reduce interference into FSS systems from RLANs.

The ITU Radiocommunication Assembly,

considering

- a) that the band 5 150-5 250 MHz is allocated worldwide to the fixed-satellite service (FSS) (Earth-to-space) for use by feeder links of non-geostationary (non-GSO) systems in the MSS on a primary basis without restriction in time as per RR No. S5.447A;
- b) that the band 5 150-5 250 MHz is also allocated on a worldwide primary basis to the aeronautical radio navigation service (ARNS) under RR Article S5;
- c) that the band 5 150-5 216 MHz is allocated to the FSS (space-to-Earth) under RR No. S5.447B and under the provisions of RR No. S9.11A for the use of non-GSO MSS feeder links on a worldwide basis;
- d) that the band 5 150-5 216 MHz is also allocated to the feeder links of the radiodetermination-satellite service (RDSS) (space-to-Earth) subject to RR No. S5.446;
- e) that the band 5 150-5 250 MHz is also allocated per RR No. S5.447 to the mobile service on a co-primary basis in 26 countries in Regions 1 and 3, and subject to coordination under RR No. S9.21;
- f) that administrations are considering the introduction of RLANs in the band 5 150-5 250 MHz on a national basis on an unlicensed and un-coordinated basis;
- g) that administrations have and are considering designating bands other than 5 150-5 250 MHz for RLAN applications in the 5 GHz band;
- h) that the large-scale deployment of RLAN transmitters and other wireless portable transmitters in the band 5 150-5 250 MHz may cause unacceptable levels of interference and reduction in satellite capacity to non-GSO MSS satellite receivers operating their feeder-uplinks in this band under RR No. S5.447A and that therefore the medium- to long-term sharing may not be feasible;

* This Recommendation was jointly prepared by Radiocommunication Study Groups 4, 8 and 9, and further revisions will also be undertaken jointly.

** This Recommendation should be brought to the attention of Radiocommunication Study Group 3.

*** Radiocommunication Study Group 5 made editorial amendments to this Recommendation in 2008 in accordance with Resolution ITU-R 44.

**** In this Recommendation, RLAN means radio local area network or any other portable or fixed devices offering local network connectivity (wired LAN (WLAN) or others) (see also Recommendations ITU-R F.1244 and ITU-R M.1450).

- j) that there is a need to protect different types of satellites, including those being developed, employing various modulation and access schemes (e.g. narrow-band time division multiple access (TDMA) – frequency division multiple access (FDMA) and wideband code division multiple access (CDMA)-FDMA);
- k) that there is a need to protect the current and long-term use of the 5 150-5 250 MHz band by the non-GSO MSS feeder links (Earth-to-space) RR No. S5.447A (e.g. non-regenerative and regenerative satellite systems);
- l) that there is a need to specify an appropriate e.i.r.p. density limit and operational restrictions for RLAN and other wireless access transmitters in this band in order to protect non-GSO MSS feeder links;
- m) that RLANs are intended for both indoor and outdoor use;
- n) that the excess path loss provided by the indoor-to-outdoor propagation environment is beneficial to the sharing between non-GSO MSS and RLANs,

recommends

- 1** that administrations should ensure that the mean* e.i.r.p. density limit of RLAN or other wireless access transmitter devices operating in the band 5 150-5 250 MHz should be no greater than 10 mW in any 1 MHz (or equivalently 0.04 mW in any 4 kHz) per transmitter (see Notes 1, 2 and 3);
- 2** that, in addition, administrations should take measures to ensure that RLAN or other wireless access transmitters are operated indoors in the band 5 150-5 250 MHz;
- 3** that for protection of MSS feeder links, power flux-density (pfd) limit of total RLAN interference observed at the victim satellite receiver, for satellites using full earth coverage antennas, should be no greater than the pfd levels specified in Recommendation ITU-R S.1427 – Methodology and criterion to assess interference from radio local area network (RLAN) transmitters to non-GSO MSS feeder links in the band 5 150-5 250 MHz. A lower pfd level should be used as a trigger for administrations to take actions to protect non-GSO MSS feeder links from aggregate RLAN interference (see Notes 4 and 5);
- 4** that administrations should consider implementation of mitigation techniques to further reduce interference into FSS systems from RLANs (see Note 6).

NOTE 1 – Annex 1 contains a methodology and parameters that have been used in sharing studies.

NOTE 2 – For a particular type of RLAN standard (i.e. HIPERLAN type 1) the e.i.r.p. density limit in *recommends* 1 should apply only in payload transmission. Its overall e.i.r.p. should be limited to 200 µW per device. The provisional date of validity of this Note is until 1 January 2003.

NOTE 3 – For RLAN carriers with less than 1 MHz bandwidth, the e.i.r.p. density should not exceed 0.01 µW/Hz over the carrier bandwidth.

NOTE 4 – On a provisional basis, the pfd trigger level should be 3 dB below that in Recommendation ITU-R S.1427, but further study is required.

NOTE 5 – The criterion of interference from RLANs to non-GSO MSS feeder links in this band is given in Recommendation ITU-R S.1426 – Aggregate power flux-density limits, at the FSS satellite orbit for radio local area network (RLAN) transmitters operating in the 5 150-5 250 MHz band sharing frequencies with the FSS (RR No. S5.447A).

NOTE 6 – Two possible mitigation techniques are power control and spectral spreading.

ANNEX 1

Methodology and parameters used in sharing studies

1 Introduction

In order to protect non-GSO MSS feeder links operating in the band 5 150-5 250 MHz from interference due to RLANs, it is necessary to define operational conditions for RLAN use in the band. These conditions are derived from a sharing analysis based on the following considerations:

* The mean power refers here to the e.i.r.p. radiated during the transmission burst at the power control protocol which corresponds to the highest power, if power control is implemented.

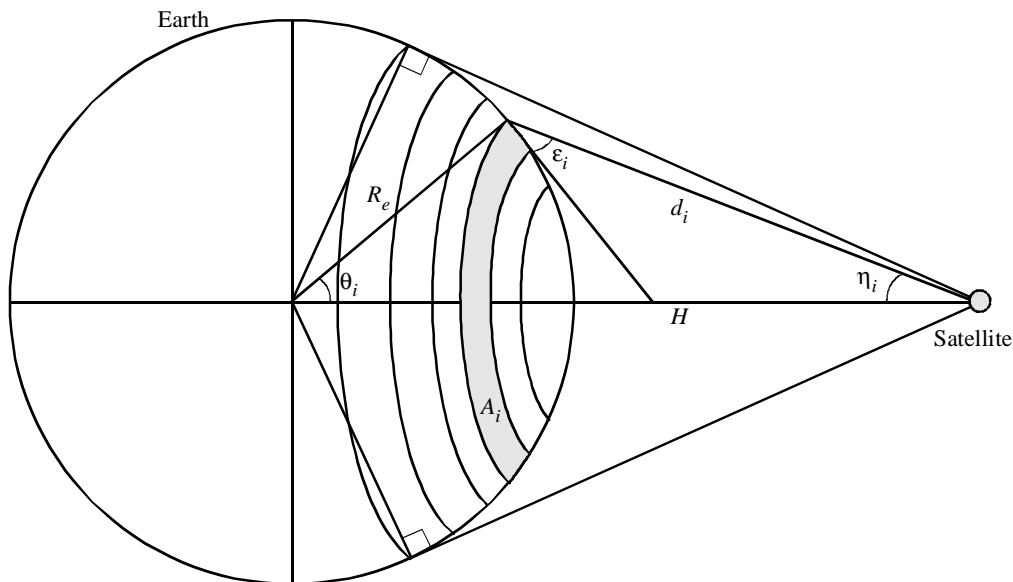
- the criterion necessary to protect the non-GSO MSS feeder links;
- the receive characteristics of the non-GSO MSS satellites;
- the transmit characteristics of the RLANs;
- the propagation environment;
- the number of RLAN devices.

It is noted that there is a significant uncertainty associated with a number of the above considerations. Analysis of the interference environment, as addressed in the following sections, is based on two non-GSO MSS satellite systems intending to use the 5 150-5 250 MHz FSS allocation for their feeder links, namely, LEO-D and LEO-F. Other non-GSO MSS satellite systems are also intending to use this frequency allocation for their feeder links.

2 Overall methodology

The two satellite systems being considered here both provide global satellite receive antenna coverage for their feeder links. Because of this it is necessary to integrate across the satellite field of view in order to obtain the average effect of variations in satellite antenna gain, free space path loss and building loss. This approach can be represented by Fig. 1.

FIGURE 1
Geometry for aggregating the interference



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Assuming a certain density of RLAN devices, i.e. D_R , then the total number of RLAN devices seen by a satellite (assuming the devices are evenly distributed over the Earth's surface) is given by $N = D_R \times A_T$, where A_T is the total surface area seen from the satellite at height H from the Earth's surface ($A_T = 2\pi R_e^2 \times [1 - R_e/(R_e + H)]$). Since the devices are not equidistant to the satellite, the visible Earth's surface is divided into concentric surface strips (as in Fig. 1), so that one can assume that all of the RLAN devices within the i -th surface strip are at the same distance, d_i , to the satellite, and are seen with the same nadir angle, η_i and the same elevation angle, ϵ_i . The number of RLAN devices within the i -th strip is given by $N_i = A_i \times (N_T/A_T) = A_i \times D_R$, where $A_i = 2\pi R_e^2 \times [\cos(\theta_i) - \cos(\theta_{i-1})]$, (where $\theta_i < \theta_{i-1}$).

The aggregate RLAN interference power, I , at the non-GSO satellite receiver is therefore given by summation of the i -th component I_i as below:

$$I(W) = \sum_i I_i = \sum_i N_i \cdot \frac{e.i.r.p.R \times \alpha(\epsilon_i)}{(4\pi d_i f_0/c)^2} \cdot G_{Rx}(\eta_i) \cdot B_f$$

where:

- $\alpha(\epsilon_i)$: attenuation due to any obstacles between the RLAN device and the satellite, and is assumed to be elevation dependent, $0 \leq \epsilon_i \leq 90^\circ$
- $G_{Rx}(\eta_i)$: satellite antenna receive gain which depends on the nadir angle η_i , i.e. the angle between the sub-satellite point and the RLAN device
- $B_f = B_W/B_R$: ratio between the victim carrier (wanted) bandwidth and the interfering carrier bandwidth (RLAN transmissions) (if $B_W < B_R$, otherwise $B_f = 1$), which determines the amount of interfering power falling into the victim's "filtered" bandwidth
- f_0 : carrier frequency
- c : speed of light.

If the total aggregate interference power at the satellite is taken to be the tolerable interference power, and average values (see Note 1) are used for the parameters identified above, the expression can be rearranged to derive a maximum tolerable number of simultaneously active RLAN devices, N_R , as follows:

$$N_R = \begin{aligned} & \text{The tolerable interference power at a satellite (dBW)} \\ & \text{minus the average e.i.r.p. of an RLAN (dBW)} \\ & \text{minus the average building blockage across the satellite's field of view (see Note 2) (dB)} \\ & \text{minus the average free space path loss across the satellite's field of view (see Note 3) (dB)} \\ & \text{minus the average satellite antenna off-beam gain across the satellite's field of view (dBi)} \\ & \text{minus the bandwidth correction factor (dB)} \end{aligned}$$

It is the above relationship that forms the basis of the calculation template described in this Annex. Other factors associated with the parameters identified above are addressed in the following sections.

NOTE 1 – Using average values for the relevant parameters on an individual basis gives rise to an error of a few tenths of 1 dB.

NOTE 2 – The attenuating effect of building blockage is represented by a negative dB value.

NOTE 3 – The attenuating effect of free space path loss is represented by a negative dB value.

3 Non-GSO MSS interference criterion

Recommendation ITU-R S.1426 specifies that the criterion appropriate to the assessment of interference from RLAN transmitters to non-GSO MSS feeder links in the band 5 150-5 250 MHz should be $3\% \Delta T_{satellite}$. This can be translated into a tolerable interference power level at the satellite receiver due to an aggregation of power received from all transmitting RLAN devices within the field of view of the satellite.

4 Non-GSO MSS receive characteristics

The key characteristics of the non-GSO MSS receiver necessary to determine the sharing environment are:

- Average satellite receive antenna gain across the field of view (and the associated free space path loss (FSPL) also averaged across the satellite field of view) (see subsections below).
- Satellite noise temperature: 400 K (LEO-F), 550 K (LEO-D).
- Feed loss: 0 dB (see Note 1) (LEO-F), 2.9 dB (LEO-D).
- Polarization discrimination: a value of 1 dB has been assumed to reflect the fact that RLAN interference is not polarized.
- Receiver bandwidth: 25 kHz (LEO-F), 1.23 MHz (LEO-D).

NOTE 1 – This value is consistent with notified data for LEO-F. Due to the data format specified in the RR there is no means to specify a feed loss. It is therefore implicit in the notified value for the satellite receive system noise temperature.

4.1 LEO-F

The satellites orbit at a height of 10 390 km and each satellite has a 44.8° field of view covering an area on the Earth's surface of just over 158 million km² (approximately 31% of the Earth's surface corresponding to an area that can include both North America and Europe simultaneously). The LEO-F satellite receive antenna pattern is shaped to provide a uniform gain of 10 dBi over the whole of its coverage area (i.e. the visible surface of the Earth).

The FSPL from a LEO-F spacecraft to its sub-satellite point is 187.2 dB and to the edge of the field of view is 190.6 dB. Integrating across the whole field of view gives an average value of 188 dB.

The average value of the combined satellite antenna gain and FSPL across the field of view can therefore be considered to be 178 dB.

4.2 LEO-D

The satellites orbit at a height of 1 414 km and each satellite has a 109.9° field of view covering an area on the Earth's surface of just over 46 million km² (approximately 9% of the Earth's surface corresponding to an area which can include the whole of North America).

The LEO-D receive antenna gain at the sub-satellite point is about 2.5 dBi and the gain at the edge of the field of view is about 4.5 dBi, with a maximum gain of about 6 dBi at 45° satellite off-axis angle. The average antenna gain across the satellite field of view is calculated to be 5.2 dBi.

The average value of the combined satellite antenna gain and FSPL across the field of view is calculated to be 168.9 dB. Taking into account the average antenna gain of 5.2 dBi, the FSPL across the field of view is therefore 174.1 dB.

5 RLAN transmit characteristics

The key characteristics of the RLAN transmitters necessary to determine the sharing environment are:

- device e.i.r.p.;
- modulated carrier bandwidth relative to the bandwidth of the satellite receiver;
- averaged large scale device activity.

In general it is expected that the RLANs operating in this band will be high bit rate, and therefore wideband, devices having a modulated bandwidth wider than the bandwidth of the MSS carriers. It is therefore necessary to define the RLAN radio characteristics in terms of e.i.r.p. spectral density.

6 Averaged transmit-to-silent ratio

The interference into the non-GSO MSS satellite at any instant is due to the number of RLAN devices that are simultaneously transmitting at that instant. The relationship between the number of devices actually in the field of view of the satellite and the number of those devices transmitting at any instant can be reflected by an activity factor called the transmit-to-silent ratio.

This factor is the result of other factors such as the data rate of the RLAN devices, the amount of information being transmitted, the percentage of time the devices are switched on and in use.

This ratio should take into account the access method used by the RLAN devices.

7 Propagation environment

The average FSPL across the satellite's field of view has been addressed earlier, in association with the average satellite receive antenna gain. The other key factor insofar as the propagation environment is concerned relates to the additional shielding afforded by buildings and surrounding obstacles when RLAN devices are operated indoors.

7.1 Building blockage

The effect of building blockage in relation to a single RLAN device is assumed to be elevation dependent. A number of models have been proposed to arrive at a large-scale average value across the field of view of the satellite: the actual value depends upon the altitude of the satellite. These models take into account the radio transparency of different materials, incidence effects, distribution of RLANs within buildings, etc.

Depending on the assumed input values and the aggregation methods used, these methods give different values. At the time this Recommendation was drafted, agreed building blockage models were not available.

7.2 Indoor/outdoor usage

The building blockage discussed above provides an important level of shielding insofar as interference into the non-GSO MSS satellites is concerned. The degree of shielding will therefore depend on the proportion of RLAN devices operating indoors.

The proportion of devices operating indoors will depend not only on the applications foreseen for RLANs. For this frequency range, a regulatory restriction to “indoor use” is expected. Given this restriction, it is expected that outdoor use will account for not more than 1% of the total population of RLANs operating in this frequency range.

8 Number of RLAN devices

It is difficult to establish reliable market projections for these devices. Some opinion is based on professional applications and therefore gives rise to relatively low numbers of devices and other opinion is based on consumer applications with a far larger potential market.

Taking account of all the factors discussed previously allows for the derivation of a tolerable number of RLAN devices in the field of view of a non-GSO MSS satellite, assuming certain RLAN operating parameters. This calculated tolerable number of RLAN devices can then be compared with appropriate market projections in order to determine whether the RLAN e.i.r.p. level will protect non-GSO MSS feeder links adequately.

Market projections for RLAN devices in the field of view of a satellite range between the values shown in Table 1.

TABLE 1
Market projections for RLAN devices (millions)

LEO-D			
Lower projection		Higher projection	
2005	2010	2005	2010
5	16	30	80
LEO-F			
Lower projection		Higher projection	
2005	2010	2005	2010
8	34	118	315

In making use of the values in Tables 1, the possibility that additional spectrum for RLANs may become available has to be taken into account.

9 Parameter values for further study

Table 2 lists the parameters on which further studies are required. For each a range of values is given.

TABLE 2
Parameter values

Parameter	Lower proposed value	Higher proposed value
Average transmit to silent ratio (%)	1.0 ⁽¹⁾	5 ⁽²⁾
Average building blockage (dB)	7	17

(1) Current measurements of this value are significantly less than 1%.

(2) Applications in the future could have values higher than 5%.

10 Assessment model

Based on the methodology and relevant characteristics discussed in the preceding sections it is possible to construct a template that will allow the assessment of a tolerable number of RLAN devices. Such a template is shown in Table 3. Other factors such as special signalling and/or modulation may have to be taken into account. An example is HIPERLAN Type 1 as referenced in Note 2 of this Recommendation, which has a low bit rate header and uses contention and signalling which together has an average effect of 6 dB on e.i.r.p. density.

TABLE 3
Template for calculating the number of RLANs tolerable by non-GSO MSS
feeder links operating in the band 5 150-5 250 MHz

Parameter	LEO-F	LEO-D
$T_{satellite}$ (K)	400	550
Criterion (%)	3	3
$\Delta T_{satellite}$ (K)	12	16.5
Free space path loss (average) (dB)	-188	-174.1
Polarization discrimination (dB)	1	1
Feed loss (dB)	0	2.9
Satellite antenna gain (average) (dBi)	10	5.2
Tolerable RLAN power per MSS channel (dBW)	5.2	17.3
MSS receive bandwidth (MHz)	0.025	1.23
RLAN bandwidth (MHz)	20	20
Bandwidth factor (dB)	29.0	12.1
Tolerable RLAN power per RLAN channel (dBW)	34.2	29.4
Outdoor use (%)	1	1
Loss in excess of free space for indoor devices (dB)	(1)	(1)
Average excess loss effect (dB)	(1)	(1)
Maximum tolerable interference per RLAN channel (dBW)	(1)	(1)
Average RLAN e.i.r.p. (dBW)	(1)	(1)
Number of active users	(1)	(1)
Silent to transmit ratio (%)	(1)	(1)
Maximum tolerable number of RLANs per RLAN channel (million)	(1)	(1)

(1) The value is for further study.