

RECOMMENDATION ITU-R S.1512

Measurement procedure for determining non-geostationary satellite orbit satellite equivalent isotropically radiated power and antenna discrimination

(Questions ITU-R 231/4 and ITU-R 42/4)

(2001)

The ITU Radiocommunication Assembly,

considering

- a) that some frequency bands are allocated for use by non-geostationary satellite orbit (non-GSO) satellite networks;
- b) that the number of operational and planned non-GSO satellite systems has risen significantly in the past ten years;
- c) that the interference experienced by such systems will become increasingly significant to other users sharing the frequency bands on a primary basis;
- d) that operators of non-GSO satellite networks and administrations may wish to measure certain non-GSO satellite radiofrequency (RF) characteristics;
- e) that the RF characteristics of non-GSO satellites are more difficult to measure than those of GSO satellites since the non-GSO satellites are moving with respect to the surface of the Earth,

recommends

- 1 that the test procedure in Annex 1 may be used as a guide to determine the equivalent isotropically radiated power (e.i.r.p.) and antenna discrimination of non-GSO satellites. Annexes 2 and 3 may be used as part of the measurement procedure to determine the maximum and minimum signal levels received by the test station.

ANNEX 1

Measurement procedure for determining non-GSO satellite e.i.r.p. and antenna discrimination**1 Introduction**

The procedure which follows is intended to provide guidance to administrations wanting to perform repeatable measurements of the downlink e.i.r.p. and transmit gain pattern of operational non-GSO satellite.

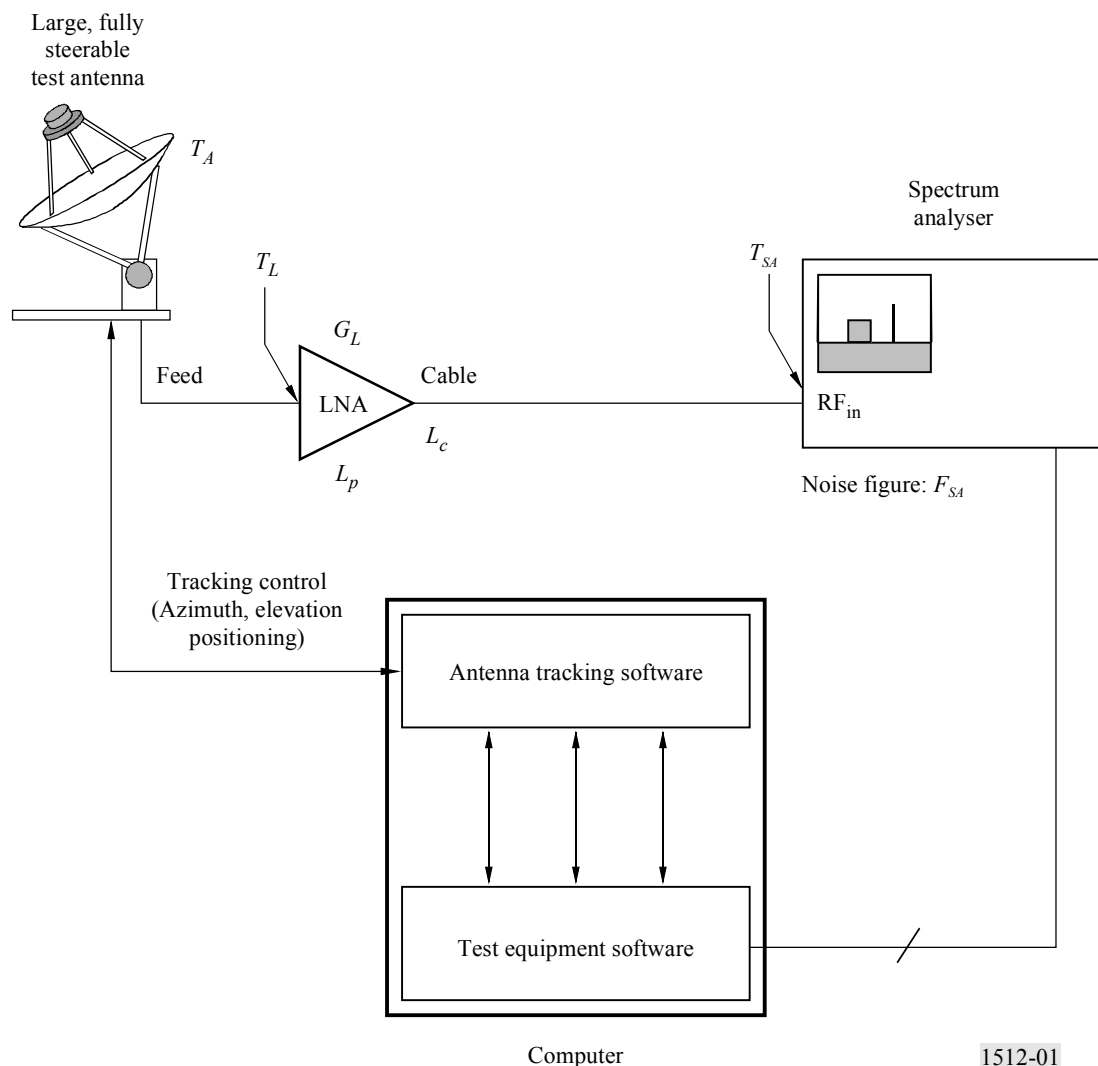
2 Equipment requirements

The test method involves the use of an earth station with a large, fully steerable antenna which is capable of tracking a satellite, a spectrum analyser capable of making the necessary measurements and a computer upon which operates an automated test program which can make the measurements and record the data on a file.

3 Description of measurement test-set

A block diagram of the measurement test-set is shown in Fig. 1. Each of the parameters shown in Fig. 1 is defined in Table 1.

FIGURE 1
Measurement test-set block diagram



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Test antenna: The test antenna should be fully steerable over as much of the horizon as possible. The antenna reflector should be as large as possible so as to have a larger receive gain which translates in a larger dynamic range in which to make measurements. However the antenna slew rate should allow the antenna to remain pointed at the non-GSO satellite as it moves across the sky. The low noise amplifier (LNA) should have as low a noise temperature as possible so as to minimize the test equipment noise floor. The cable connecting the LNA to the spectrum analyser should be as short as possible and be of good quality so as to minimize the noise it adds to the test set-up.

Spectrum analyser: A spectrum analyser is required that has the capability of being digitally controlled by a computer and of transferring measured data back to the computer. A data bus connection between the computer and spectrum analyser is typically used for such applications. Next, the spectrum analyser should have a noise floor which is lower than the equipment noise

floor, otherwise the spectrum analyser noise floor will limit the dynamic range over which measurements can be taken. This can be calculated analytically by determining the temperature of the set-up (Annex 3) and comparing it to that of the analyser. An alternate method to the analytical calculation is to attenuate the signal into the spectrum analyser by 10 dB and verifying that the $(I + N)/N$ has changed by less than 1 dB.

Computer system: The computer system serves two functions. First it must steer the antenna towards the non-GSO satellite and second it must collect the necessary data. To accomplish the first function requires orbital data of the non-GSO satellite (apogee altitude, perigee altitude, inclination, argument of perigee, and time of ascending node) being studied in order to predict where and when it will appear on the horizon. The satellite can then be tracked by predicting its location over time or by using a closed loop tracking system, which is part of the antenna subsystem. The second function of the computer is to take measurements at regular time intervals and record the measurement on a computer file along with other positional data such as the azimuth and elevation of the test antenna.

TABLE 1

Fixed parameters required for non-GSO satellite characterization tests

Parameter description	Symbol	Units	Value
Nominal non-GSO satellite parameters			
Transmit power into antenna	P_S	dBW	
Altitude of satellite	h_S	km	
Occupied bandwidth of downlink when modulated	B_{Soc}	MHz	
e.i.r.p. _S – L_S (if constant)	e.i.r.p. _S – L_S	dB	
Difference (e.i.r.p. _S – L_S) (variable) ⁽¹⁾	Dif. (e.i.r.p. _S – L_S)	dB	
Downlink frequency	f_D	GHz	
Reference bandwidth	B_{ref}	Hz	
Test antenna coordinates			
Latitude	f_{test}	dd:mm:ss.s	
Longitude	l_{test}	ddd:mm:ss.s	
Antenna height (amsl)	h_{test}	m	
Test antenna characteristics			
Diameter	D_{test}	m	
Receive gain (at f_D)	$G_{RX test}$	dB _i	
Noise temperature	$T_{A test}$	K	

TABLE 1 (*end*)

Parameter description	Symbol	Units	Value
Test-set parameters			
Antenna feed loss	L_F	dB	
Gain of LNA	G_L	dB	
LNA noise temperature	T_L	K	
Cable loss	L_c	dB	
Spectrum analyser data			
Make and model number			
Spectrum analyser settings during measurements			
Input attenuation		dB	
Reference level		dBm	
Amplitude resolution		dB/Div	
Centre frequency	F_C	GHz	
Frequency span	SPAN	kHz	
Resolution bandwidth	ResBW	kHz	
Video bandwidth	VBW	kHz	
Normalized noise-floor ⁽²⁾	No _{SA}	dBm	

- (1) In the case where sticky beams or an isoflux antenna is not used on the non-GSO satellite, the difference between the maximum on-axis e.i.r.p. – L_s and the minimum edge-of-beam e.i.r.p. – L_s for the intended service area should be given.
- (2) Displayed noise-floor is that which is determined after application of correction factors for log amplifier, envelope detector and resolution-to-normalized bandwidth.

4 Conduct of the measurement test

Maximum power calculation: The first step in preparing the equipment is to ensure that the set-up is not overloaded by the maximum received power in the entire bandwidth of the LNA. By adjusting gains or adding attenuation along the receive path, it is possible to ensure that the spectrum analyser is not over driven. The expression below can be used to calculate the received signal level of the test-carrier being measured at the input to the spectrum analyser.

$$P_{RX\ test} = P_s + G_s - \left(L_s + L_{abs} \right) + G_{RX\ test} + G_{test-set} \quad (1)$$

where:

- $P_{RX\ test}$: power of the received signal at the spectrum analyser (dBW)
- P_s : power at the flange of the satellite antenna (dBW)
- G_s : gain of the satellite antenna in the direction of the test station (dBi)
- L_s : free space loss which is calculated using the equation:

$$L_s = 10 \log \left(\frac{4\pi d}{\lambda} \right)^2 \quad \text{dB}$$

where:

d : distance from test antenna to satellite (m)

λ : wavelength of the signal (m)

L_{abs} : atmospheric absorption (dB)

$G_{RX\ test}$: gain of the test antenna including feed loss (measured at the output flange) (dBi)

$G_{test-set}$: gain of the test-set is calculated using the equation:

$$G_{test-set} = G_L - L_c \quad (2)$$

where:

G_L : gain of the LNA (dB)

L_c : loss of the cable (dB).

An example calculation of the maximum received power is given in Annex 2.

Minimum power calculation: The noise floor of the spectrum analyser and the test-set needs to be established to determine the dynamic range over which measurements can be made. The method for determining the practical minimum signal power that can be measured by the test set is explained in Annex 3.

e.i.r.p. calibration: The next step consists of calibrating the test set-up. Establishing the e.i.r.p. of the non-GSO satellite is most accurately done by measuring the energy level of a source with a known e.i.r.p. The measured level then serves as a reference power flux-density (pfd) which can be used to determine the e.i.r.p. of the non-GSO satellite. Various stable RF sources can be used as a calibration reference such as a GSO satellite beacon that is transmitted at a known e.i.r.p. or certain radio stars. If the equipment is not calibrated in this way, the measurements which are made will give information as to the relative gain of the non-GSO satellite in various directions but will not allow the exact power radiated in a given direction to be determined.

As part of the calibration process, it is important to measure the variation in receive gain of the test set across the frequency band which will be used for the tests. Since variations of 2 to 3 dB across the measurement band are not uncommon, it is important to know the extent of the gain variation between the frequency used to measure the reference e.i.r.p. level and the frequency at which the measurement will be taken.

Measurement of the non-GSO satellite signal: On each pass of a given non-GSO satellite, the tracking antenna follows the satellite and measurements are made of energy emanating from the satellite. At each measurement point, the azimuth and elevation of the antenna need to be recorded for later processing. Prior to each new measurement, the software will instruct the spectrum analyser to clear the trace. An average over three sweeps of the frequency span should be executed to minimize the effect of any short-term fluctuation in transmitted power level.

The time between data samples needs to be sufficiently short so as to capture the shape of the satellite antenna side lobes. The complexity of the non-GSO satellite transmit beam pattern and the altitude of the satellite are the two variables which will need to be considered when establishing the required time increment between measurements. The minimum set-up time required by the test-set