



Recommendation ITU-R BO.1659-1
(01/2012)

**Mitigation techniques for rain attenuation
for broadcasting-satellite service
systems in frequency bands between
17.3 GHz and 42.5 GHz**

BO Series
Satellite delivery



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SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
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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 BO.1659-1

Mitigation techniques for rain attenuation for broadcasting-satellite service systems in frequency bands between 17.3 GHz and 42.5 GHz

(2003-2012)

Scope

This Recommendation provides techniques to mitigate rain attenuation that should be considered in order to facilitate the introduction of BSS systems in frequency bands between 17.3 GHz and 42.5 GHz. Such techniques include increase in e.i.r.p., hierarchical transmission and broadcasting system assuming storage in receiver.

The ITU Radiocommunication Assembly,

considering

- a) that BSS systems using frequency bands from 17.3 GHz onwards have the possibility to deliver wide-RF-band digital multiprogramme services, which may consist of high-definition television (HDTV), audio and data programmes, possibly including interactivity;
- b) that, in the future, they can also be the appropriate channels to accommodate the higher bit-rate programmes, such as extremely high resolution imagery whose number of lines is much larger than HDTV, three-dimensional TV and high bit-rate data programmes;
- c) that the frequency allocations were made to the BSS by the World Administrative Radio Conference (Geneva, 1979) (WARC-79) in the 42 GHz and 84 GHz band, World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum (Malaga-Torremolinos, 1992) (WARC-92) allocated the band 17.3-17.8 GHz in Region 2 and the band 21.4-22.0 GHz in Regions 1 and 3 to BSS to be implemented after 1 April 2007, and the frequency allocation modification to the BSS from the 84 GHz band to the 74 GHz band was made by the World Radiocommunication Conference (Istanbul, 2000) (WRC-2000);
- d) that the atmospheric absorption and rain attenuation in the BSS bands from 17.3 GHz onwards are much larger than those in the 12 GHz band which is widely used for BSS;
- e) that the propagation attenuation may place a heavy restriction on service availability and/or system feasibility;
- f) that Report ITU-R BO.2007 describes technical information to introduce BSS into the 17/21 GHz band with reference to Resolution 525 (WARC-92). In the Annexes to this Report, detailed information is given such as:
 - possible coding and modulation approaches to improve service availability for digital HDTV satellite broadcasting;
 - an adaptive satellite e.i.r.p. control method for the 21 GHz band satellite broadcasting;
 - bandwidth efficient coding and modulation schemes for wideband HDTV applications supported by satellite and cable networks,

recommends

1 that the use of one of the following techniques to mitigate the rain attenuation or a combination of these techniques should be considered to facilitate the introduction of the BSS systems in frequency bands between 17.3 GHz and 42.5 GHz:

- increase in e.i.r.p. (see Annex 1);
- hierarchical transmission (see Annex 2);
- broadcasting system assuming storage in receiver (see Annex 3).

NOTE 1 – Supplementary information related to the rain attenuation in the BSS bands between 17.3 GHz and 42.5 GHz and some prospective feeder-link bands between 17.3 GHz and 30 GHz is found in Appendix 1.

Annex 1

Increase in e.i.r.p.

1 Concept of variable e.i.r.p. satellite

Adaptive power control is an effective and straightforward method to enhance the service availability under rain fade, while it reduces interference to the other services in the clear-sky condition.

The BSS system normally has a large service area covered by a single beam. The variable e.i.r.p. systems are categorized as to whether the e.i.r.p. can be locally-variable within the service area or not.

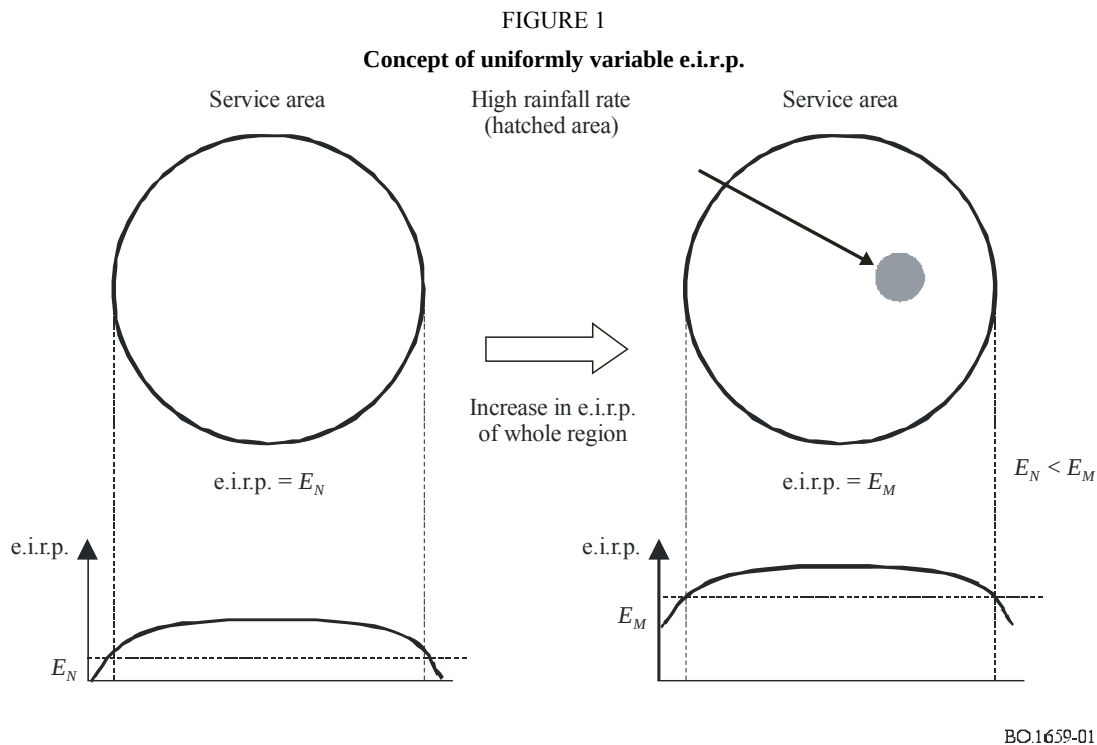
1.1 Uniformly-variable e.i.r.p.

In the system, total output power of the beam is controlled, while the antenna pattern is left unchanged. The e.i.r.p. in the service area varies uniformly.

Typically, strong rains occur locally. To compensate for local rain attenuation, the e.i.r.p. is increased for the whole coverage area. Apart from areas with strong rain, the rest of the service area in clear-sky conditions can be overcompensated. It is undesirable from the viewpoint of sharing with the other systems. In this respect, the adaptive power control of such single beam systems is less effective than those of multibeam systems.

The total required radiation power is high and the increase in radiation power is frequent since the single beam covers the whole region. The concept of the system is shown in Fig. 1. The following parameters are used for the definition of the system:

- e.i.r.p. value E_N with nominal condition in the service area;
- e.i.r.p. value E_M with maximum e.i.r.p. increase in the service area. The e.i.r.p. values in certain areas vary, ranging from E_N to E_M .



Alternatively, the following parameters can be used to define the system from the viewpoint of satellite design:

- nominal power supplied to the input of the antenna;
- maximum power supplied to the input of the antenna;
- gain contour of the antenna.

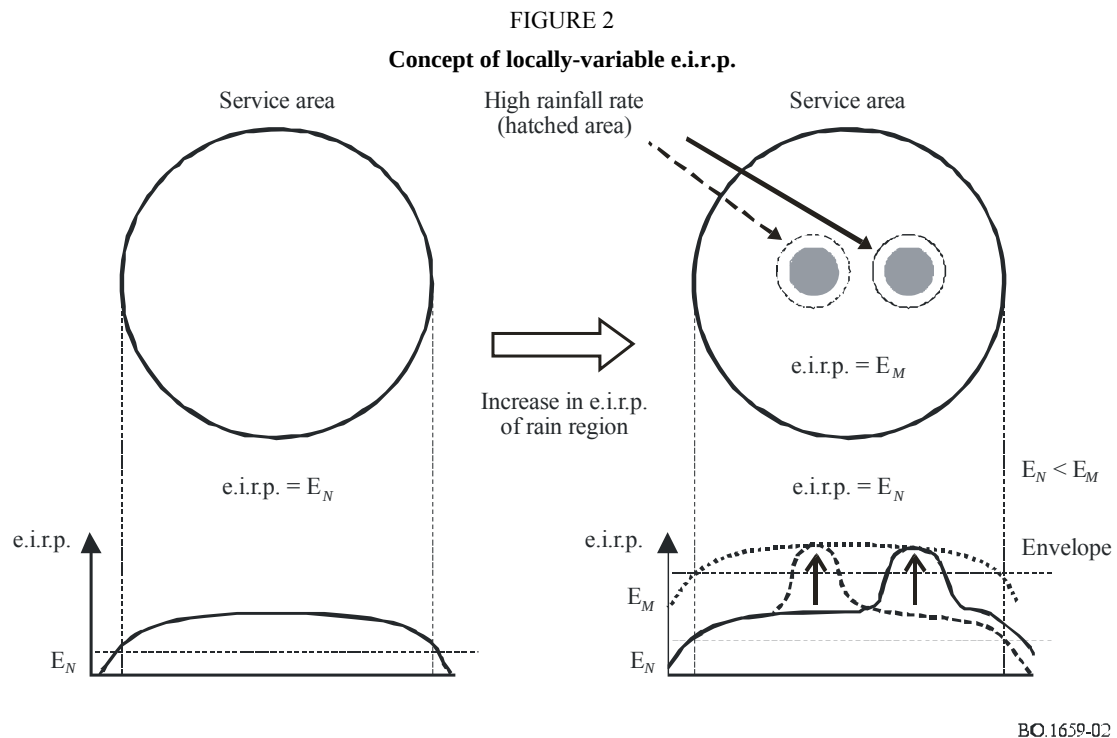
1.2 Locally-variable e.i.r.p.

The locally-variable e.i.r.p. system varies the distribution of the satellite e.i.r.p. of a beam within the service area locally, in accordance with the local distribution of rain attenuation. Total required radiation power of the satellite is to be reduced compared with a uniformly-variable e.i.r.p. system with the same service availability, because the probability of simultaneous occurrence of strong rain in a large portion of the service area is considered to be substantially low. Therefore a more stringent level of the spurious emission limitation is applied.

While a high e.i.r.p. may be required to compensate for large rain attenuation, the area and the duration of the boost are limited. Since the e.i.r.p. can be lowered for the area and duration with low rain attenuation, it has an advantage over satellite systems with a fixed or uniformly-variable e.i.r.p. in terms of sharing with other systems.

The concept of the system is shown in Fig. 2. The following parameters are used for the definition of the system:

- e.i.r.p. value E_N for the area with nominal condition (E_N);
- e.i.r.p. value E_M for the local area with maximum e.i.r.p. increase (E_M).



Alternatively, the following parameters can be used to define the system from the viewpoint of satellite design:

- nominal power supplied to the input of the antenna;
- nominal antenna gain contour;
- maximum power supplied to the input of the antenna;
- examples of antenna gain contour with local increase;
- envelope of maximum antenna gain with the results of all possible movement of intensified e.i.r.p.

2 Satellite technologies

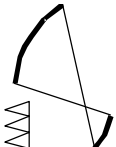
2.1 Satellite technologies for uniformly-variable e.i.r.p.

The system may be realized with a combination of a reflector antenna with a horn feeder and a variable-power high power amplifier (HPA). The HPA with considerably higher power will be employed to increase e.i.r.p. in the whole service area. The impact of the power control on the efficiency of the HPA needs to be studied.

2.2 Satellite technologies for locally-variable e.i.r.p.

The satellite antenna configurations shown in Table 1 can be used to realize the function.

TABLE 1
Antenna configurations for locally-variable e.i.r.p. systems

Antenna type	Multi-horn	Phased-array		
		Single reflector	Double reflector	Direct radiation
Schematic diagram				
Range of pattern synthesis	Fixed beam location	Limited beam steering angle	Greater than single reflector	Greatest
Peak gain	High	Lower than double reflector	Lower than multi-horn	High
Gain decrease with beam-steering	Large	Smaller than multi-horn	Smaller than single reflector	Small
Number of element	Small	Medium	Medium	Large
Complexity of structure	Simple	Medium	Complex (sub-reflector)	Complex (feed circuit)

2.2.1 Multi-horn antenna

In the antenna, multiple feed horns are placed at the focal plane of the reflector. Each horn corresponds to one of the beams generated by the antenna. When each beam radiates in phase, the beams form a single shaped beam. By controlling the power provided to the individual horns, a locally-variable e.i.r.p. system can be realized.

The range of power control is limited to the range of the corresponding HPA's output power. The impact of the power control on the efficiency of the HPA needs to be studied. Since the locations of the beams are fixed, the range of possible pattern syntheses is less than those of phased-array antennas.

2.2.2 Phased-array antennas

Compared with the multi-horn antenna, a greater range of pattern syntheses can be obtained using phased-array antennas. The direct-radiation phased-array antenna would show best performance in terms of the range of possible pattern syntheses. On the other hand, the complexity of the configuration may reduce the applicability to the on-board system.

In contrast to the multi-horn antenna, a large number of the radiation elements contribute to the power control of a small area. The minimum diameter of the intensified area is determined by the aperture diameter of the antenna. The performance and feasibility of each configuration should be examined further.

2.2.3 Case study on antenna pattern synthesis with local increase

An example of antenna synthesis is given to explain the feasibility of a locally-variable e.i.r.p. satellite. Its parameters are shown below:

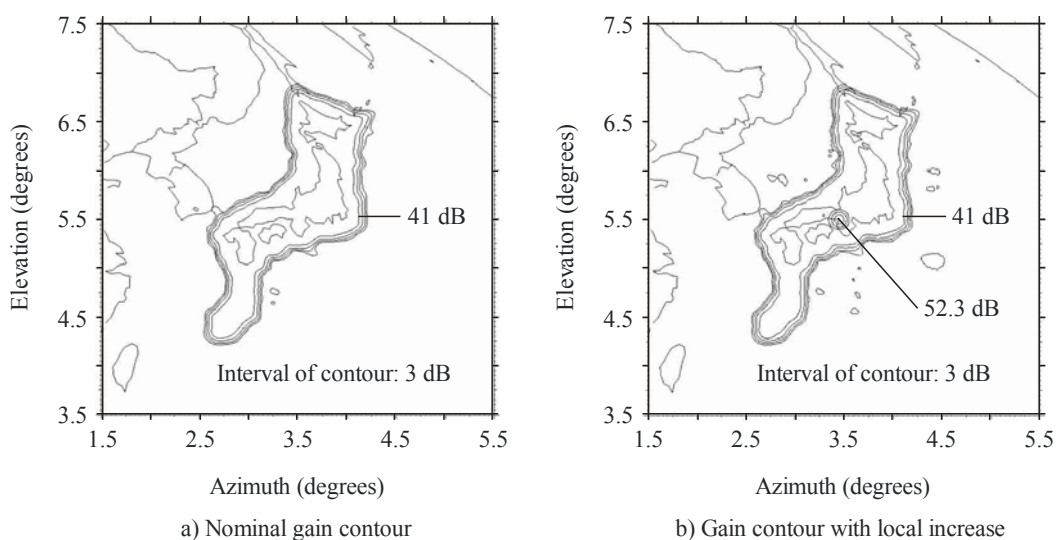
- Antenna configuration: array-fed single reflector antenna
- Aperture diameter of antenna: 10 m
- Frequency: 21.7 GHz
- Number of radiators: 227

– Interval of radiators: 1.5 wavelengths.

The calculated antenna gain contours are shown in Fig. 3. The left-hand Figure shows a radiation pattern under nominal conditions. Taking advantage of the large aperture antenna and the phased-array technique, a radiation pattern with a large gain plateau is obtained. The right-hand Figure is an example of the radiation pattern with a local gain increase. The peak gain increases by more than 10 dB from the nominal value. As a result of the local increase, gains in the remaining area slightly decrease.

FIGURE 3

Example of pattern synthesis (simulation)



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Antenna parameters such as the diameter and the number of radiators should be determined by taking into consideration the system parameters such as size and shape of the service area, minimum and maximum area to be compensated and required increase level as well as the feasibility of on-board equipment and the cost.

2.3 HPA technologies

Travelling wave tubes (TWTs) and solid state power amplifiers (SSPAs) can be used for the HPA of the satellites. In the 17/21 GHz band, the overall efficiency of a conventional TWT with an output power around 100 W exceeds 60%. On the other hand, the output power and efficiency of SSPAs are lower than those of TWTs. To use TWTs as amplifiers for an active array antenna of locally-variable e.i.r.p. satellites, mini-TWTs, whose cross-sectional dimensions are reduced compared with the conventional one, have been studied. A comparison is shown in Table 2.