RECOMMENDATION ITU-R SM.1681-0*

# Measuring of low-level emissions from space stations at monitoring earth stations using noise reduction techniques

(2004)

**Scope**

In view to protect passive services, and in particular the radio astronomy service (RAS) from interference, the measuring of low-level emissions from space stations of monitoring stations, earth stations, using noise floor reduction techniques is very important. Further to monitoring requirements, the Recommendation gives the concept to reduce the noise floor by means of digital signal processing.

**Keywords**

Low-level emissions, space stations, noise reduction techniques

The ITU Radiocommunication Assembly,

*considering*

a) that there is a need to protect the radio astronomy service (RAS) from interference;

b) that the objects in space observed on frequencies used by the RAS in principle are of extremely low pfd levels when arriving on the Earth's surface;

c) that for such observations receive techniques have been developed the sensitivity of which allows to recognize signals far below the noise floor;

d) that it is one of the tasks of monitoring earth stations to monitor levels of unwanted emissions of space stations as specified in the Radio Regulations;

e) that there may be a need for the exchange of the measurement results to other parties,

*recommends*

**1** that monitoring earth stations should measure unwanted satellite emissions according to:

**1.1** the monitoring requirements in Annex 1;

**1.2** the concept to reduce the noise floor by means of digital signal processing as described in Annex 2;

**2** that the results should be recorded as in Annex 3.

* Radiocommunication Study Group 1 made editorial amendments to this Recommendation in the years 2018 and 2019 in accordance with Resolution ITU-R 1.

# Annex 1

# Monitoring requirements

## 1 Introduction

To measure low-level spurious and out-of-band emissions for the protection of the RAS a space monitoring facility should be aware of the following requirements.

## 2 Monitoring pre-requisites

**2.1** An understanding of the pfd levels of the RAS to be protected.

**2.2** The technical capacity to perform the monitoring of low-level emissions.

**2.3** Order of magnitude of noise floor reduction as compared to the normal space monitoring criteria for the monitoring of space communication fixed and broadcasting services.

## 3 Parameters to be monitored

**3.1** The normal space monitoring values of parameters to characterize the sources of emission, i.e. frequency, orbital position, or elements, time, power density, polarization, bandwidth, modulation, spectral characteristics, access method, and continuous wave/burst transmission.

**3.2** The power density of emission should be recorded as pfd and spectral pfd.

## 4 Monitoring procedure (see also ITU-R Handbook – Spectrum Monitoring)

**4.1** Acquisition of interfering source.

**4.2** Measurement of frequency.

**4.3** Determination of polarization.

**4.4** Measurement of bandwidth.

**4.5** Measurement of pfd using noise reduction method described in Annex 2.

## 5 Confirmation of measurement results

Where possible the results should be confirmed by another monitoring earth station in the ITU List of international monitoring stations.

# Annex 2

## Concept to reduce the noise floor by means of digital signal processing

### 1 Introduction

In order to protect the RAS there are pfd limits specified that are below the noise floor for usual monitoring facilities. To reduce the noise floor different possibilities may exist. This concept here defines a method using digital signal processing.

### 2 Technical principle

The RF signal to be monitored is received by a directive antenna, and is then down converted to the IF level. The analogue IF signal is converted to digital signal samples. This digitized signal is then converted to the digital baseband. After that the conversion from the time domain into the frequency domain is achieved by means of the fast Fourier transformation (FFT). This measurement is repeated typically 10 000 times in order to acquire 10 000 recorded spectra.

This whole previous procedure is repeated to record comparison signals. For non-geostationary satellites this is done across the sky along the same track of the now absent satellite. For geostationary satellites the monitoring antenna needs to depart slightly from the orbit position. In both cases the comparison signals are recorded in the same environment including the noise of the station itself, however, without the wanted satellite. These 10 000 spectra for comparison contain the noise but no satellite signal.

At this point additional processing may take place, e.g. to eliminate Doppler shift where applicable.

Then the spectra of both wanted and comparison signals are averaged, and the linear values thereof subtracted. The result is a pfd spectrum of the relevant satellite emission with the noise suppressed in the order of typically 10 to 20 dB.

This method makes use of the fact that the wanted signal contributes with each of the large number of spectra to its appearance, whereas the noise in the large number of spectra cancels itself out due to its statistical properties.

The subtraction of the comparison spectra from the satellite spectra is for eliminating also interference sources recorded with the noise in both series of spectra.

A true correlative method could improve the suppression of the noise level even more.

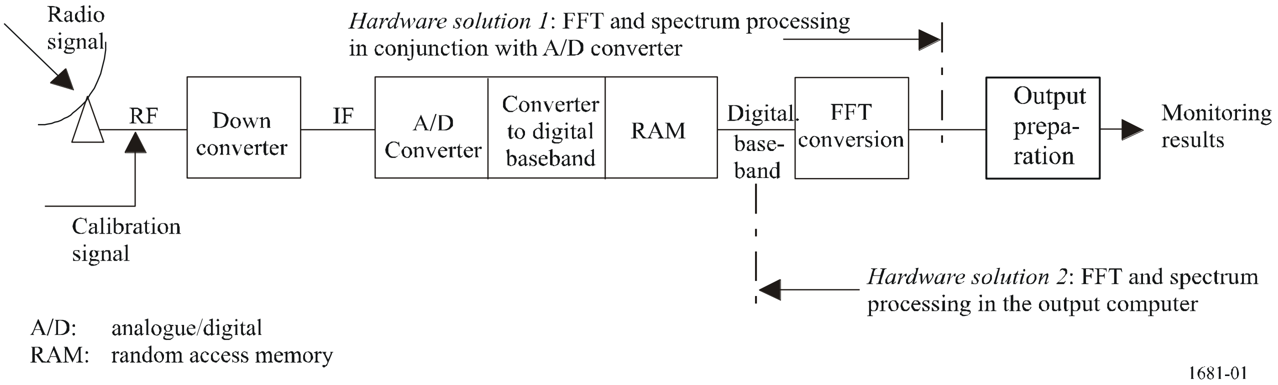
### 3 Concept of hardware and software

The block diagram for monitoring below the noise floor is shown in Fig. 1.

#### 3.1 Hardware

FIGURE 1

**Block diagram for monitoring below the noise floor**




The difference between the two hardware solutions shown in Fig. 1 lays in the equipment separation, i.e. the connection between different locations is done in solution 1 after the FFT conversion; in solution 2 the connection is accomplished before the FFT conversion. Therefore the type of connection between locations may be one criterion for one or the other solution. Other criteria may be the commercial availability of equipment component blocks and the maximum frequency band to be monitored.

## 3.2 Software

The software depends to a large extent on the hardware solution chosen. Therefore here the concept is best described as an example:

Assuming an A/D converter with 70 MHz IF, 95 MSamples/s sampling rate and half-band decimation is used. That would result, without decimation, in a bandwidth of:

$$0.4 \times 95 \text{ MSamples/s} = 38 \text{ MHz}$$

Decimated by 4 results in 95/4 = 23.75 MSamples/s and 38/4 = 9.5 MHz bandwidth.

Sampling an input signal for 10 min results in:

$$10 \times 60 \times 23.75 = 14\,250 \text{ MSamples}$$

Using a 16 384 points FFT results in 869 750 separate spectra which can be added for averaging.

In that example it is assumed that enough RAM is available to store that large amount of sampled data, or the signal processing is fast enough to work in real time. If that amount of RAM or the processing speed is not available, the 10 min interval can be digitized in several bursts of data collection and pauses.

# 4 Monitoring strategy

In normal practice the interfering signal is an unwanted emission generated by an emission on an assigned frequency. In such a case the knowledge of the properties of that emission is essential.

The monitoring strategy is dependent very much on the technical details of tasks.

The following criteria need to be observed in order to get appropriate results:

Prior to each monitoring campaign the set-up is to be calibrated. The calibration process includes:

– RF;

– system gain; and
– frequency response of the system.

This is achieved by using a carrier signal, a noise source, and possibly an astronomical radio source, paying attention to the appropriate amplitudes.

Attention needs to be paid to select the appropriate:
– dynamic range: it is necessary to avoid any distortion; it may be suitable to use a filter either in the RF or IF paths to suppress strong neighbouring signals;
– monitoring start and stop times;
– span to be displayed;
– frequency resolution;
– number of averaged spectra;
– elimination of Doppler shift;
– timing of burst transmission in the case of, e.g. TDMA transmissions.

These parameters above need to be adjustable by software means.

In the case of non-geostationary-satellite orbital tracks should be chosen that are not too much affected by the sun, the geostationary orbit or tracks of other satellites.

Further steps to improve sensitivity could be considered, as follows:
– the recording of the comparison spectra should be done on the same elevation for atmospheric noise reasons;
– monitoring at night avoids the possibility of solar interference;
– shorter intervals between taking interference and comparison spectra may improve the noise suppression;
– in the case of TDMA transmissions the comparison spectra could be taken during the gaps between the bursts.

## Annex 3

## Presentation of results

| **Monitoring of unwanted emissions from space stations to protect the RAS** | | | |
|---|---|---|---|
| **Monitoring station** | {name} | **Administration** | {name} |
| **Location (latitude – longitude – projection system)** | {coordinates} | **Name of the responsible person for measurement** | {name} |
| **Date of measurement (UTC)** | {dd/mm/yy} | **Contacts (phone, fax, e-mail)** | tel: ... / fax: ... / e-mail: ...@...} |
| **Quality of station** | {figure of merit of the monitoring earth station} | **References** | |

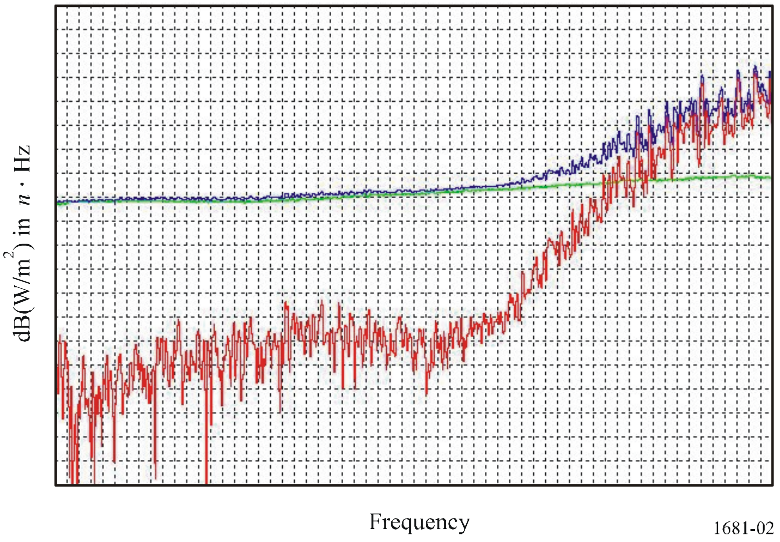
| Measurement results (and associated uncertainties) | | |
|---|---|---|
| $pfd_{RBW}$ (dB(W/$m^2$) in ... kHz or MHz) | {value} | Expanded measurement uncertainty – e.g.: 2 or 3 dB |
| Frequency (MHz) | {value} | Expanded measurement uncertainty – e.g.: $10^{-7}$ |
| Orbital position or elements of interference sources<br>GSO satellite (azimuth (degrees) and elevation (degrees)/longitude (degrees W/E))<br>Non-GSO satellite (azimuth (degrees) and elevation (degrees), both at start, maximum elevation and stop) | {values} | Expanded measurement uncertainty – e.g.: ...° |
| Polarization | {type} | Not applicable |
| Other indications<br>(e.g.:<br>A/D<br>estimation of modulation type<br>access method<br>behaviour of signal) | | |

**Spectra**

Three spectra traces are recommended: wanted signal – noise – {signal + inverted noise}

FIGURE 2

**Spectrum**




Information to be provided:

Centre frequency = {...} MHz

Span = {...} MHz

FFT: {number of} points

Resolution: {...} kHz

Averaging: {number of} samples

Times (UTC) of

wanted signal: start, stop

comparison signal: start, stop

intervals wanted/comparison signals:

mode of Doppler compensation:

**Observations**

**Expected identity of satellites**

**Glossary**

| | |
|---|---|
| A/D: | analogue/digital |
| FFT: | fast Fourier transformation |
| GSO: | geostationary-satellite orbit |
| IF: | intermediate frequency |
| pfd: | power flux-density |
| RAM: | random access memory |
| RAS: | radio astronomy service |
| RF: | radio frequency |
| TDMA: | time division multiple access |
| UTC: | Universal Time Coordinated |
| W/E: | West/East |