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Parameters of and measurement procedures on H/V/UHF monitoring receivers and stations

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(2007-2011)

Executive summary

This Report describes the measurement procedures to determine the technical parameters of monitoring receivers and monitoring systems. This Report does not describe all possible solutions and also not automatically always the best solution for determining a parameter.

The Report describes in one section the verification of the key parameters of a monitoring receiver and in another section the verification of the technical parameters of monitoring stations and other integrated systems like direction finders. Both sections can show an overlap in contents and even bear the same name. However these items should be treated as different parameters.

The reason for splitting the specifications in key parameters and station parameters is the fact that monitoring receivers can be bought either as separate devices, or as an integrated system where the separate receiver parameters sometimes cannot be determined.

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1 Introduction

The ITU Handbook on Spectrum Monitoring (Edition 2011) contains typical specifications of monitoring receivers and direction-finder (DF)/monitoring stations but does not specify the measurement procedures to determine these specifications. The Handbook also does not take into account the specifications of complex systems like a complete monitoring/DF station built around the monitoring receiver.

NOTE 1 – The ITU Handbook on Spectrum Monitoring is not to set a standard but to try to give guidance on all aspects of spectrum monitoring.

The present Report states the relevant key receiver parameters and the station parameters. The discussed parameters can be determined either by the manufacturer or by the end user.

2 Key receiver parameters

2.1 IP_2/IP_3

Monitoring receivers operate in an environment where strong and weak signals are present at the same time. An important property of a receiver therefore is its capability to handle those signals at the same time without distortion. This property is referred to as the linearity of the receiver and a way to quantify this linearity is by the IP_2 and IP_3 values.

Although the front-end of the receiver contributes most to the IP_2 and IP_3 the IF amplifier filters in the case of a digital monitoring receiver and any other amplifiers influence the IP_2 and IP_3 . All these components therefore should be taken into account when an IP_2 and IP_3 measurement is performed. IP_2 and IP_3 measurements are performed by injecting two signals in the receiver input and measuring the response of the receiver. In the case of non-linearity, products of the two injected signals are generated, and the level of these products is a measure for the non-linearity of the receiver. Besides the linearity of the receiver component itself, the measured IP_2 and IP_3 values also depend on the following parameters:

- the difference in frequency and level between the two test signals applied;
- the selected test frequencies.

2.1.1 Principle of second order intermodulation product calculation

Two test signals of the same r.m.s. power (P_{in}) at frequencies f_1 and f_2 ($f_1 < f_2$) are inserted into the antenna input of the monitoring receiver. Due to non-linearities, two intermodulation products at frequencies f_3 and f_4 may appear:

$$f_3 = f_2 - f_1 \text{ and } f_4 = f_2 + f_1$$

These frequencies can also be written using the Δf parameter (frequency difference). Δf depends on the type of measurement:

$$f_1 = f_3 + \Delta f \text{ and } f_2 = 2 \times f_3 + \Delta f, \text{ with } \Delta f = 2 \times f_1 - f_2$$

The input second order intermodulation product shall then be calculated:

$$IP_2 = P_{in} + a$$

with:

- IP_2 : second order intermodulation product at the input to the monitoring receiver under test
- P_{in} : r.m.s. power (dBm) of the two inserted test signals
- a : difference (dB) between the level of the test signals and the level of the highest intermodulation product at the input.

2.1.2 Principle of third order intermodulation product calculation

Two test signals of the same r.m.s. power (P_{in}) at frequencies F_1 and F_2 ($F_1 < F_2$) are inserted into the antenna input of the monitoring receiver. Due to non-linearities, two intermodulation products at frequencies F_3 and F_4 may appear:

$$f_3 = [(2 \times f_1) - f_2] \text{ and } f_4 = [(2 \times f_2) - f_1].$$

These frequencies can also be written using the Δf parameter (frequency difference), Δf depends on the type of measurement

$$f_1 = f_3 + \Delta f \text{ and } f_2 = f_3 + 2 \times \Delta f, \text{ with } \Delta f = f_2 - f_1$$

The third order intermodulation products shall then be calculated:

$$IP_3 = P_{in} + a/2$$

with:

- IP_3 : third order intermodulation product at the input to the monitoring receiver under test
- P_{in} : r.m.s. power (dBm) of the two inserted test signals
- a : difference (dB) between the level of the inserted test signals and the level of the highest intermodulation products at the input.

2.2 Sensitivity

The sensitivity of a spectrum monitoring receiver is defined as the minimum signal voltage (μV) at the input of the monitoring receiver that allows demodulation and audible listening of the received signal.

The minimum audible signal level can be determined using a signal-to-interference ratio including noise and distortion (SINAD) measurement.

2.3 Receiver noise figure

The noise figure is one of the main specifications of a monitoring receiver. The noise figure is closely tied to the sensitivity of the monitoring receiver. The noise figure of a monitoring receiver is the factor by which the noise power delivered by the monitoring receiver increases when a reference noise is applied to it; the noise figure is measured on the input of the monitoring receiver.

The noise figure of a monitoring receiver can be measured by several methods:

- gain method;
- “Y-factor” method (noise diode method);
- sensitivity method.

2.4 IF filter characteristics

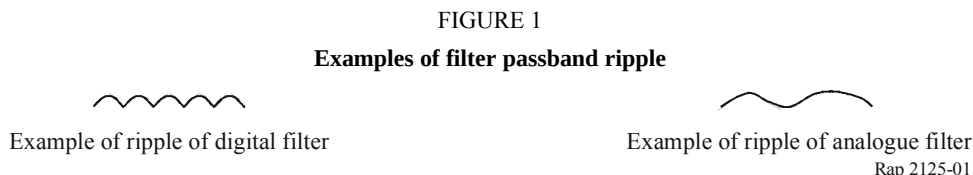
For most monitoring and measurement applications both the shape, the bandwidth and the quality of the various IF filters are important. Basically four parameters are used to describe the IF filter characteristics.

2.4.1 IF bandwidth

This is the bandwidth specified as the distance between the -3 dB and -6 dB points of the IF filter of the receiver.

2.4.2 IF filter passband ripple and asymmetry

The way ripple in the passband is specified depends on the manufacturer. Mainly there are two ways, and each has its advantage for either digital or analogue filtering. For analogue filters the peak-to-peak value is used because no notches are present and the distribution of ripples is not uniform. For digital filters a peak-to-average value is used because of the notches present and the uniform distribution of ripples (see Fig. 1).



2.4.3 IF filter passband curve and out-of-band suppression

Out-of-band suppression is the suppression of signals far from the edges of the filter specified on a certain distance from the centre of the filter. Dependent on the construction of the filter but also on its mounting and termination, different values can be found for various receivers offered. This parameter is especially important for receivers with digital filters where out-of-band suppression is dependent on the used A-D converters. This suppression can be dependent on the actual measurement distance from the centre frequency of the filter because of anomalies caused by improper termination of the filter.

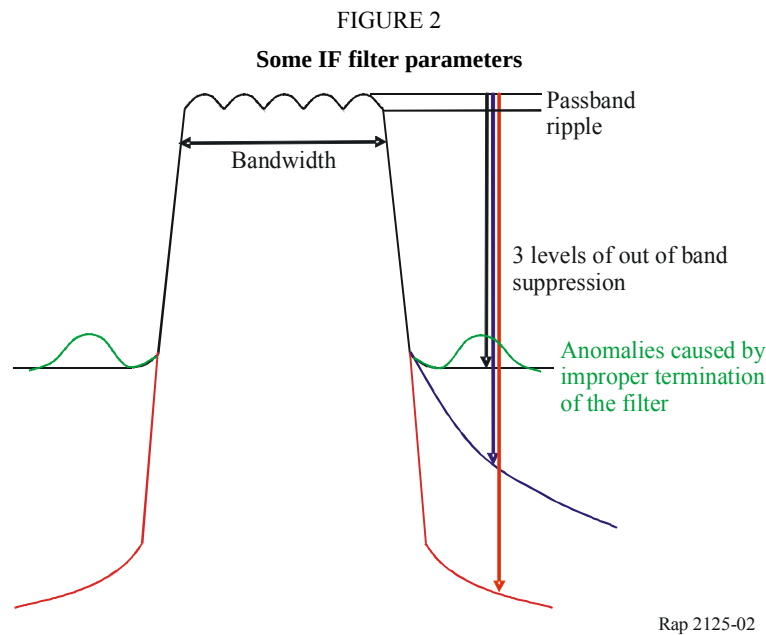
2.4.4 IF filter shape factor

The shape factor is defined as the ratio between the n dB bandwidth and the -6 dB bandwidth. The factor n has to be specified, e.g. $n = 60$ dB or $n = 50$ dB. It should be specified for each filter (see Fig. 2).

2.4.5 IF filter group delay

Group delay is the mutual difference in time it takes for a number of signals to travel through the IF filter of a receiver.

In an ideal filter all signals applied at different frequency positions inside the IF filter travel with the same delay, so the phase difference between the signals at the input is the same as the phase difference between the signals at the output of the filter. Group delay can also be called phase linearity of the filter.



A high group delay exhibits itself mainly near the edges of the passband of the filter, but in high order filters is also prominent inside the passband. As a rule of thumb, we can say that narrow filters and filters with a low shape factor (steep filter edges) have a higher group delay yielding lower performance. In this aspect there is basically no difference between digital and analogue filters.

What does this mean for the user of a monitoring receiver? These wideband steep-edged filters are used in receivers for demodulating digital signals and particularly phase demodulators suffer in performance if filter group delay is too high. Also aural monitoring can be a tiring exercise if the group delay of the filter is very high. The signals sound distorted and noisy. In a general-purpose monitoring receiver filter group delay should be within certain limits for each IF filter.

A way to measure filter group delay is to use a network analyser and sweep through the passband of the filter, and record the changes in phase/frequency behaviour. Group delay is expressed in time (microseconds, nanoseconds).

2.5 Receiver scanning speed

Scanning speed (sometimes called sweep speed) is a measure of how quickly a receiver can provide signal level values on a number of frequencies within a given frequency band. It is measured in MHz per second.

Scanning speed shall include the effect of any band switching time, end-of-sweep retrace time, local oscillator settling time and any computation time. In other words, the scanning speed parameter can be used to compute the revisit period. Optionally, the individual elements that affect scanning speed can be listed separately, so users can determine the revisit time for any arbitrary frequency range.

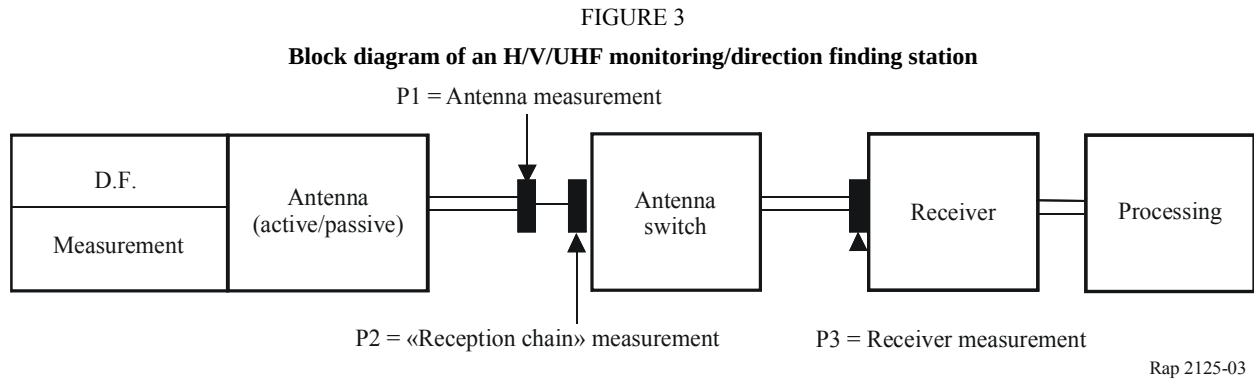
2.6 Key parameters for DF receivers

Depending on the parameters to be measured, the DF receiver shall be considered as a monitoring receiver or a DF station reception chain, and the corresponding parameters measurement shall apply.

3 Monitoring and DF station parameter measurement procedures

The typical block diagram of a spectrum-monitoring station (as well as a direction-finding station) is given in Fig. 3.

Several measurements points can be defined to characterize the antenna (P1), the reception chain (P2) or the receiver (P3).



The antenna is generally made up of a number of elementary antennas (dipoles or other). These elementary antennas can contain switchable amplifiers, adaptation cells, etc. These components shall be integral parts of the antenna if they are associated with a single elementary antenna.

On the other hand, the antenna switches used to select several elementary antennas (direction-finding or monitoring) shall not be considered as an integral parts of the antenna but as the reception chain antenna switch. Similarly, amplifiers, filters common to several elementary antennas, as well as frequency change or transposition components shall not be considered as part of the antenna, but as part of the receiving chain.

This section describes the antenna (P1) and receiving chain (P2) measurements; monitoring receiver (P3) measurements are described in § 2.

The cables implementing the station (and the reception chain) shall be representative of an operational station:

- for a mobile station, the cables used for the tests shall be 10 m;
- for a fixed station, the cables used for the tests shall be 20 m.

3.1 Monitoring and DF station IP_2/IP_3 measurement

Intermodulation measurements are dependent on the conditions in which they are made. So that end customers can compare monitoring receivers and spectrum monitoring and DF stations performances it is therefore important to specify the procedures for measuring second order (IP_2) and third order (IP_3) intermodulation products.

Second and third order intermodulation products are generated at all the levels of a spectrum-monitoring or DF station: at the antennas (direction-finding and/or listening antennas), at the antenna switches and cables, at the receiver.

In order to be able to understand the phenomena resulting from the intermodulation it is therefore necessary to know the intermodulation generated by the complete monitoring station.

In the example graphically given in Fig. 4, the IP_3 of the receiver is 20 dBm, but the same IP_3 measured at the antenna output is reduced to 7.5 dBm. This example shows that the performance of the receiver does not necessary reflect the performance of the station.