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(08/2013)

Test procedure for measuring the 3rd order intercept point (IP_3) level of radio monitoring receivers

SM Series
Spectrum management

International Telecommunication Union

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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 SM.1837-1*

Test procedure for measuring the 3rd order intercept point (IP_3) level of radio monitoring receivers

(2007-2013)

Scope

This Recommendation belongs to a set of Recommendations describing the test methods to determine technical parameters of radio monitoring receivers that are important for the users of these receivers. When the described methods are followed by manufacturers, comparing different receivers is made easier. This Recommendation specifies the test procedure for the determination of the IP_3 of a monitoring receiver. This test procedure definition is recommended to all the manufacturers, with the advantage for the users of such receivers, that an easier and more objective assessment of product quality is possible.

Keywords

Test procedure, 3rd order intercept point, radio monitoring receiver

The ITU Radiocommunication Assembly,

considering

a) that ITU-R has published the Typical recommended specifications for analogue and digital monitoring receivers in the ITU Handbook on Spectrum Monitoring (2011), but that nothing is said about the test procedures behind such specifications;

b) that the specification of the 3rd order intercept point (IP_3) strongly depends on the test procedures applied;

c) that the IP_3 level specified in the data sheet of a receiver depends extremely on the test frequencies used, the spacing of the test signals, the levels of the test signals and the ambient temperature prevailing during the tests;

d) that the IP_3 characteristic has a direct influence on the suitability of a receiver to fulfil certain monitoring tasks, specially under real environment conditions (high-level signals in the spectra near to the tuned frequency);

e) that without a defined test procedure, the IP_3 specifications published by the manufacturers have to be made comparable by some kind of conversion and that this conversion might be complex or even impossible to perform;

f) that a defined test procedure for IP_3 must be independent of the receiver design;

g) that a well-defined test procedure for IP_3, if adopted by all the manufacturers of radio monitoring receivers, will have the advantage for the users of such receivers, that an easier and more objective assessment of products from different manufacturers is possible, avoiding ambiguities;

h) that supplementary information about these IP_3 measurements can be found in Report ITU-R SM.2125 – Parameters of and measurement procedures on H/V/UHF monitoring receivers and stations;

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

j) that when comparing the performance between two receivers, the IP_3 and the noise figure or the sensitivity are considered concurrently,

recommends

1 that the measurement method in Annex 1 should be used to determine the 3rd order intercept point (IP_3);

2 that each IP_3 figure should be accompanied by the noise figure or sensitivity during this IP_3's measurement condition.

Annex 1

Test procedure for measuring the 3rd order intercept point (IP_3) level of radio monitoring receivers

1 General aspects

The IP_3 level depends on:

– the RF spacing between the two test signals;

– the RF level of the two test signals;

– the frequency pool selected for the test;

– the temperature prevailing during the tests.

Furthermore, to correctly assess the IP_3 level:

– both intermodulation products generated by the receiver for each pair of test frequencies have to be measured and evaluated. If their levels are different, the higher one is to be considered;

– duplicated measurements (on so-called "image frequencies"), as they have influence on the mean value of IP_3, should be avoided. Duplicated measurements result in similar IP_3 level measurements, that do not really contribute to assessing the quality of the receiver;

– a *minimum value* for the IP_3 level must be specified and published by the manufacturer in the data sheet over the receiver's whole operating range. The measuring conditions for each measurement (spacing, levels of the test signals, equivalent input noise floor, AGC "on" or "off") must also be published in the data sheet. For each spacing, the value should be indicated as to the receivers test condition (defined in "definitions"). Since IP_3 values are frequency dependent, the manufacturer can choose to additionally specify IP_3 for selected frequency bands or ranges;

– a *mean value* (the arithmetic mean of a number of test measurements) may also be indicated.

Definitions

The following definitions apply for this Recommendation:

– The receiver test condition is defined as "*condition 1*" if both test signals pass through the complete analogue signal path including A/D converters or detectors. Applying "condition 1" is recommended for equipment that includes the whole signal processing

from analogue to digital and putting out result information like a spectrum, audible information, or I/Q baseband data. Such devices may be monitoring receivers as well as spectrum analysers for example.

– The receiver test condition is defined as "*condition 2*" if both test signals pass through the analogue signal path to an analogue IF output. Applying "condition 2" is recommended for equipment that contains the analogue signal path only and putting out results on an IF basis (e.g. IF3). Such devices may be analogue tuners as well as original equipment manufacturer (OEM) frontend modules for example.

– The receiver test condition is defined as "*condition 3*" if one or more of the test signals is removed at an intermediate stage of the receivers analogue signal path. Applying "condition 3" is recommended for equipment that contains the analogue signal path only and putting out results on an IF basis, where different IF stages (e.g. a wideband IF2 and a more narrow-band IF3) are distributed to different processing stages. Such devices may be analogue tuners as well as OEM frontend modules for example.

2 Basics of the concept "3rd order intercept point level (IP_3)"

Two unmodulated test signals of the same r.m.s.-power P_{in} each and the frequencies f_1 and f_2 ($f_1 < f_2$) are inserted into the antenna input of the receiver. Due to non-linearities, two intermodulation products of the frequency $f_3 = \{(2 \times f_1) – f_2\}$ and $f_4 = \{(2 \times f_2) – f_1\}$ may appear.

The IP_3 level is then calculated as follows:

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

where:

P_{in}: r.m.s.-power measured for each of the two inserted test signals (dBm)

a: difference (dB) between the level of the inserted test signals and the level of the intermodulation products at the measurement point. If the intermodulation products are of different level, the higher one is to be considered.

Variation of the receivers noise floor

The equivalent input noise floor of the receiver under test has to be measured during the whole IP_3 measurement with and without the test signals switched on. Details about the frequencies used for this test (f_5 and f_6) are in the paragraph *"measurement of the levels"*.

Test bench conditions

In making this measurement, it is important to have sufficient isolation between the two test sources to prevent IM products from being generated in the output stages of the sources at frequencies of f_3 and f_4. It may be necessary to use devices such as isolators, fixed attenuators, isolation amplifiers, or high isolation Wilkinson power combiners. Low-pass filtering may also be required to attenuate the 2nd harmonics of the sources.

To verify the reliability of all these devices in the test set-up, an IP_3 measurement of the test bench may be performed without connecting the receiver under test. The test bench IP_3 should be at least 10 dB better than the expected receiver IP_3.

Measurement of the levels

The levels are measured at f_1, f_2, f_3, f_4, and to ensure a constant equivalent input noise floor of the receiver also at f_5 and f_6 using the built-in level indicator of the receiver. f_5 and f_6 represent the adjacent channels of the bandwidth (BW) of the receiver ($f_5 = f_3 – BW$ and $f_6 = f_4 + BW$). Levels at f_5 and f_6 are measured with the test signals switched on and off. This built-in level indictor needs to

be calibrated over the amplitude range of the expected measured signal levels. The maximum allowed absolute error is ±1 dB and the readout resolution of the level indicator needs to be ≤ 0.1 dB. When the IF output is available, it is also allowed to use a spectrum analyser or measurement receiver connected to the last IF of the receiver as a level indicator, the same calibration and accuracy requirements as for the receivers built in indicator apply here but a relatively narrow measurement filter can be used to cope with difficulties that arise when measuring the IP_3 of receivers with a narrow bandwidth.

Phase noise

If the levels of the IM products at f_3 and f_4 are near the noise floor or phase noise skirts, the measured levels will represent the IM product level plus noise. The actual IM product level can be obtained by subtracting out the noise contribution.

Frequency spacing of the test signals

The frequency spacing between the frequencies f_1 and f_2 is chosen according to § 3 below and in such a way that both test signals comply either with condition 1, condition 2 or condition 3.

The chosen bandwidth used during the measurement has to be specified.

At least two frequency pairs per octave evenly distributed over the full frequency range of the receiver are chosen as test signals. The published IP_3 values have to be valid over the entire rated temperature range indicated in the data sheet. Limitations, if any, are mentioned in the data sheet. If a variable input attenuator exists, it must be set to 0 dB attenuation during the tests. In any other case, e.g. when the receiver design does not allow to change the attenuator setting manually, the attenuation used during the tests and the reason why another value than 0 dB was used must be specified. To more fully characterize a receiver, the measured performance at more than one attenuation setting may be provided. The receiver must be set up under normal operating conditions, and it must be indicated whether the AGC is switched on or off, depending on the measurement.

Configuration of the receiver under test

If a switchable preamplifier exists, the measurements must be done in the condition “preamplifier off”. Some receiver designs do not allow a physical amplifier switch off but use a combination of variable step attenuators. This combination of amplifier and attenuator should be set to 0 dB gain.

3 Definition of a test procedure for measuring the 3rd order intercept point level of receivers for the frequency ranges 9 kHz to 30 MHz and 20 MHz to 3 000 MHz

Parameters for the IP_3 test should be chosen with the typical use of the receiver in mind. For comparing receivers with an overlap in their fields of application this is sometimes difficult. The approach of this Recommendation is to test receivers under comparable conditions, and:

– the basic considerations in § 2 should be followed;

– the permitted level range of test signals f_1 and f_2 at the antenna input of the monitoring receiver is −30 dBm to 10 dBm;

– the IF filter bandwidth or resolution bandwidth (RBW) for the measurement can be chosen by the manufacturer but must be a realistic choice for the type of receiver and intended application. The chosen bandwidth (BW) for the frequency range 9 kHz to 30 MHz must be ≤ 5 kHz and for the frequency range 20 MHz to 3 000 MHz it must be ≤ 30 kHz;

– receivers should be tested with a range of frequency spacings for the test frequencies. A harmonically increasing list should be used starting at 1 Hz then increasing from 3 Hz, 10 Hz, 30 Hz, 100 Hz, 300 Hz, 1 kHz, 3 kHz up to 300 MHz. For many receivers and applications, it is not useful to measure the whole range of spacings. Another frequency

spacing for the first and last in the list can be chosen. It is however necessary to measure using all frequency spacings in between these start and stop frequencies;

– the tolerance of the frequency spacing should be $\leq 1\%$;

– measured values of IP_3 should be presented in a single table indicating condition 1, condition 2 and condition 3 measurements, or in separate tables, depending on the number of conditions. The table should contain for each measurement, the used frequency spacing, an indication under which condition (condition 1, 2 or 3) the measurement is performed, and the measured IP_3;

– each entry in the table should contain a note if the measurement performed represents a real life practical usage condition of the receiver. Additional information describing the measurements conditions can be added at the bottom of the table.