RECOMMENDATION ITU-R F.612*, **

MEASUREMENT OF RECIPROCAL MIXING IN HF COMMUNICATION RECEIVERS IN THE FIXED SERVICE

(1986)

The ITU Radiocommunication Assembly,

considering

a) that frequency synthesizers are widely used in HF communication receivers;

b) that reciprocal mixing is an important characteristic of such receivers;

c) that it is desirable to be able to compare the reciprocal mixing performance of different models of receivers;

d) that to facilitate *(c)* it is necessary to standardize methods of measurement of reciprocal mixing;

e) that the methods of measurement should be independent of receiver noise factor,

recommends

that the reciprocal mixing performance of HF communication receivers should be established, using the methods of measurement specified in § 4 of Annex I.

ANNEX I

1. Introduction

Frequency synthesizers are widely used in modern high quality HF communications receivers. Besides having high frequency stability and accuracy, a frequency synthesizer is easy to operate and control. At present, however, the frequencies provided by the synthesizer are not always sufficiently pure, so that a considerable number of spurious components may accompany the wanted signals in its frequency spectrum. At the same time, on both sides of the wanted output there are noise skirts which degrade the interference rejection and noise characteristics of the receiver. In recent years, a new requirement has therefore appeared in the specifications of HF receivers, i.e. reciprocal mixing, defined as the degradation of the receiver output signal-to-noise ratio due to the mixing of strong interfering signals with the noise skirts of the synthesizer. This Annex provides a quantitative relationship between the synthesizer out-of-band noise characteristics and receiver reciprocal mixing so that the requirements for synthesizer out-of-band noise characteristics can easily be specified and performance comparison between various receivers facilitated.

* This Recommendation should be brought to the attention of Study Groups 1 and 8.

** Radiocommunication Study Group 9 made editorial amendments to this Recommendation in 2000 in accordance with Resolution ITU-R 44.

2. Effects of reciprocal mixing

Reciprocal mixing in a receiver occurs when, during the reception of a wanted signal, a strong out-of-band interfering signal mixes with out-of-band skirt noise from the synthesizer, producing mixing products which fall into the receiver IF band, causing the receiver output signal-to-noise ratio to be degraded (see Fig. 1).

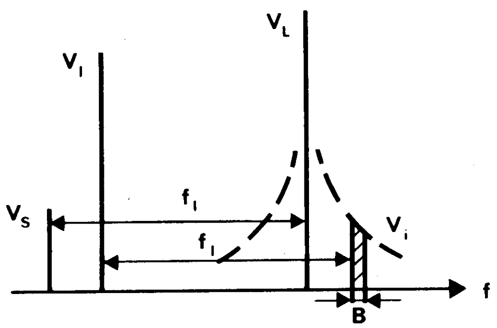

FIGURE 1 – *Reciprocal mixing*

B: bandwidth of the receiver (Hz)
f_I: first intermediate frequency
V_L: wanted output of the synthesizer
V_i: out-of-band noise density
V_I: a strong interfering signal at the receiver input
V_s: wanted signal

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From Fig. 1, an equation showing the relationship between V_I and the following items, i.e. receiver output signal-to-noise ratio S_o/N_r, synthesizer output signal purity V_L/V_i as well as the wanted signal V_s, can be derived:

$$V_I \text{ (dB(µV))} = \left(\frac{V_L}{V_i}\right)_{\text{dB}} - 10 \log B + V_s \text{ (dB(µV))} - \left(\frac{S_o}{N_r}\right)_{\text{dB}} \qquad (1)$$

Where S_o is the signal at the receiver output and N_r represents the reciprocal mixing products only when V_s is sufficiently large so that the front-end noise of the receiver can be neglected.

Assuming the noise density at 20 kHz away from the wanted output of the synthesizer of a given receiver is –120 dB/Hz relative to the wanted output of the synthesizer, $B = 2800$ Hz, $V_s = 40$ dB(µV), $S_o/N_r = 20$ dB, the $V_I = 105.5$ dB(µV).

It can be seen from the above, given the wanted signal V_s, the signal-to-noise ratio S_o/N_r at the receiver output, and the bandwidth B, the allowable level of interference V_I rises as the out-of-band noise density of the synthesizer V_i is reduced. It should be noted that, in the above calculation, the effects of second and subsequent down conversions are not taken into account. This is justified because the oscillators used are usually fixed and would have significantly less problems in maintaining spectral purity.

3. Measurement of reciprocal mixing

Up to now, there is no internationally adopted method for measuring reciprocal mixing. The differences in the measuring methods lie in the specified level of receiver input signals and in the method of measuring reciprocal mixing products at the output.

Methods commonly used for testing are given in Table I below:

TABLE I – Methods of measuring reciprocal mixing

Case	Wanted signal (dB(μV))	Method of measuring reciprocal mixing products at receiver output	Advantages	Disadvantages
1	No signal	Increase unwanted signal level to double the noise power N_r	Does not require a wanted signal	Dependent on noise factor. Pessimistic results compared with other methods
2	No signal	Increase the unwanted signal level until the noise power is equal to S_o dB(mW) obtained when a wanted signal 0 dB(μV) is applied to the input of the receiver	Independent of noise factor. Simple measuring configuration	
3	0	Increase unwanted signal level to raise the noise power by 10 dB		Dependent on noise factor. If NF > 15 dB, S_o/N_r too small to measure
4	10	Increase unwanted signal level to reduce the original signal-to-noise ratio by 10 dB		Dependent on noise factor
5	10	Increase unwanted signal level to make the S_o/N_r equal to 10 dB	Independent of noise factor	
6	40	Increase unwanted signal level to make the S_o/N_r equal to 20 dB	Independent of noise factor	Requires high level, typically +110 dB(μV) of unwanted signal which can cause errors due to blocking, etc.

In-depth studies and experiments indicate that the methods given in cases 2 or 5 would be suitable as standard methods as they are independent of receiver noise factor and approximate operational conditions. In addition, the signal levels involved fall within the normal linear dynamic range of good quality communication receivers. It is considered that if a higher level of wanted signal is used, the level of the unwanted signal would be so large that receiver blocking might occur.

4. Methods of measurement

4.1 *Method I* (see case 2, Table I)

The measurement shall be carried out with the receiver in a J3E mode (upper sideband with a nominal 3 kHz bandwidth), the automatic gain control inoperative, the RF/IF gain control at maximum and any input attenuator adjusted to minimum attenuation. Inoperative means that either the AGC is turned off or else the AGC is not affecting receiver gain.

The wanted signal shall comprise an unmodulated carrier at a level of 0 dB(μV) e.m.f. at a frequency 1000 Hz ± 3 Hz above the carrier frequency to which the receiver is tuned. The wanted signal shall be applied to the receiver input and the AF gain adjusted to provide a suitable level of output power, S_o. The wanted signal shall then be removed. The unwanted signal shall comprise an unmodulated carrier 20 kHz away from the wanted signal to which the receiver is tuned. The unwanted signal shall be applied to the receiver input and the level of the unwanted signal adjusted until the output noise power is equal to that obtained with the 0 dB(μV) e.m.f. wanted signal.

The reciprocal mixing characteristic is represented by the level of the unwanted signal.

4.2 *Method II* (see case 5, Table I)

The measurement shall be carried out with the receiver in a J3E mode (upper sideband with a nominal 3 kHz bandwidth), the AGC operative, the RF/IF gain control at maximum and any input attenuator adjusted to minimum attenuation.

The measurement shall be made by means of the simultaneous application of two test signals, the wanted signal and the unwanted signal to the input of the receiver. The signal-to-noise ratio shall be measured using a notch filter e.g. SINAD measuring equipment.

The wanted signal shall comprise an unmodulated carrier at a level of 10 dB(μV) e.m.f. at a frequency 1000 Hz ± 3 Hz above the carrier frequency to which the receiver is tuned.

The unwanted signal shall comprise an unmodulated carrier 20 kHz away from the wanted signal.

The level of the unwanted signal shall be adjusted until the output noise level is 10 dB below the wanted output signal level. It should be noted that wideband noise from the signal generator producing the unwanted signal may affect the measurement.

The reciprocal mixing characteristic is represented by the level of the unwanted signal.

4.3 Typical values

When the above two methods (case 2 and case 5) were used for measuring the performance of various receivers, it was found that the minimum and typical values of the reciprocal mixing characteristic were 90 dB(μV) and 96 dB(μV) respectively.