International Telecommunication Union

# ITU-R
Radiocommunication Sector of ITU

Recommendation  ITU-R  SM.332-4
(07/1978)

# Selectivity of receivers

SM Series
Spectrum management

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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.332-4*

**Selectivity of receivers**

(1953-1956-1959-1963-1966-1970-1974-1978)

**Scope**

This Recommendation provides measurements on selectivity of receivers.

**Keywords**

Receivers selectivity, single-signal selectivity, measurement, bandwidth


The ITU Radiocommunication Assembly,

*considering*

*a)*        that the selectivity of a receiver is a measure of its ability to discriminate between a wanted signal to which the receiver is tuned and unwanted signals;

*b)*        that economy in the use of the radio spectrum requires the maximum selectivity compatible with the technical and economic considerations relating to the particular class of receiver;

*c)*        that the method of single-signal selectivity is used to express the performance of certain characteristics of the receiver. The measurements are made with sufficiently low levels of input to avoid non-linearity (e.g. overloading) affecting the results; automatic gain control, automatic frequency control, etc., being rendered inoperative;

*d)*        that measurement of selectivity with more than one signal should be the general method for measuring the selectivity. Sometimes the non-linear effects are numerous, then it will be necessary to select the most representative cases to simplify the measurements;

*e)*        that defined methods of single-signal and multiple-signal selectivity measurements are desirable to permit comparison of receivers,

*recommends*

**1.**        that the bandwidth of the receiver shall be no wider than is essential for the transmission of the necessary modulation of the wanted signal without significant distortion (see also Recommendation ITU-R SM.328);

**2.**        that in establishing the selectivity of a receiver, account should be taken of:

2.1        the unavoidable spread of the spectrum of signals in adjacent channels (see Recommendation ITU-R SM.328);

2.2        the limitations of the selectivity of the receiver by unavoidable amplitude non-linearity, e.g. cross-modulation;

2.3.        the fact that an excessively large attenuation-slope may lead to serious distortion of the phase/frequency characteristic in the passband;

2.4        the fact that *selectivity* and *protection ratios* are different characteristics, the first being a property of the receiver only, the second being an agreed minimum value, taking into account characteristics of the emission, propagation and reception;

**3.**        that the filters which determine the selectivity shall be included as near as possible to the receiver input, and the amplifying stages preceding the filters shall be sufficiently linear, to avoid significant loss of selectivity, e.g. by cross-modulation of the wanted signal by strong unwanted signals;

**4.**        that, for the purpose of studying bandwidth or single-signal selectivity, the following definitions are used:

4.1        for amplitude-modulated signals (including single-sideband and independent-sideband emissions), the *passband* is the band of radio frequencies accepted by the receiver and measured at the detector input, limited by the two frequencies for which the attenuation exceeds that of the most favoured frequency by some agreed value; in general this value is 6 dB, except for high-quality radiotelephony receivers where the value is 2 dB;

4.2        for frequency- or phase-modulated signals, the modulation acceptance *bandwidth* of a receiver, other than those used for broadcast reception, is twice the frequency deviation of an input signal which, when applied at a level 6 dB higher than the maximum usable sensitivity level, and measured in accordance with Recommendation ITU-R SM.331, § 11, will produce a

$$\frac{\text{Signal} + \text{noise} + \text{distortion}}{\text{noise} + \text{distortion}}$$

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ratio equal to that specified for the maximum usable sensitivity level. This is an indication of the frequency deviation which the receiver will accept without excessive degradation of the ratio

$$\frac{\text{Signal + noise + distortion}}{\text{noise + distortion}}$$

4.3      *attenuation-slope:* the attenuation-slope on each side of the passband is the ratio:

–        of the difference in the attenuations corresponding to two different frequencies beyond the passband,

–        to the difference between these frequencies;

4.4      *image-rejection ratio:* the image-rejection ratio is the ratio:

–        of the input signal level at the image frequency required to produce a specified output power from the receiver,

–        to the level of the wanted signal required to produce the same output power.

The image frequency is the wanted signal-frequency plus or minus twice the intermediate frequency, according to whether the frequency-change oscillator is respectively higher or lower in frequency than the wanted signal-frequency.

If the receiver incorporates more than one frequency change, there will be more than one image frequency, and for each of these will be a corresponding image-rejection ratio;

4.5      *intermediate-frequency rejection ratio:* the intermediate-frequency rejection ratio is the ratio:

–        of the level of a signal at the intermediate frequency applied to the receiver input and which produces a specified output power from the receiver,

–        to the level of the wanted signal required to produce the same output power;

4.6      other spurious responses can occur when the intermediate frequency arises as the sum or the difference of the frequency of an interfering signal and a harmonic of the local oscillator frequency, etc.,

*spurious-response rejection ratio:* the spurious-response rejection ratio is the ratio:

–        of the input level at the interfering frequency required to produce a specified output power from the receiver,

–        to the level of the wanted signal to produce the same output power;

**5.**       that single-signal measurements be made of the passband, the attenuation slope, the image response, the intermediate-frequency rejection and other spurious-response rejection ratios as defined above and also, in frequency-modulation receivers, the modulation acceptance-bandwidth.

For the attenuation-slope, sufficient indication is generally obtained by considering the frequency difference corresponding to attenuations of 20, 40, 60 and if possible, 80 dB, reckoned from the limit frequencies of the passband. When the values thus obtained are essentially equal for the two sides of the passband, it is sufficient to give mean values.

For some purposes it is of interest to know the bandwidth at fixed levels corresponding to the above-mentioned attenuations. These figures can easily be deduced from the passband and the attenuation-slopes at the different levels (see Fig. 1).

Since, when plotted in decibels to a logarithmic scale of frequency, the sides of the selectivity characteristics are often almost straight beyond a certain frequency difference relative to the mid-band frequency, the attenuation outside the passband can also be expressed as the slope of the attenuation/frequency characteristic, in decibels per octave of the frequency difference. The frequency and attenuation at the starting point of such a slope, relative to the mid-band frequency, should be stated;

**6.**       that, for the purpose of studying the selectivity in the non-linear region with *two or more input signals* the following definitions are used:

6.1      *effective selectivity:* the effective selectivity is the ability of the receiver to discriminate between the wanted signal (to which the receiver is tuned) and unwanted signals (having frequencies generally outside the passband), the level of which is such as to produce non-linear effects, the wanted and unwanted signals acting simultaneously. The effective selectivity can be investigated by measuring blocking, adjacent-signal selectivity (or adjacent-channel selectivity, if there is regular channelling) and radio-frequency intermodulation, as follows:
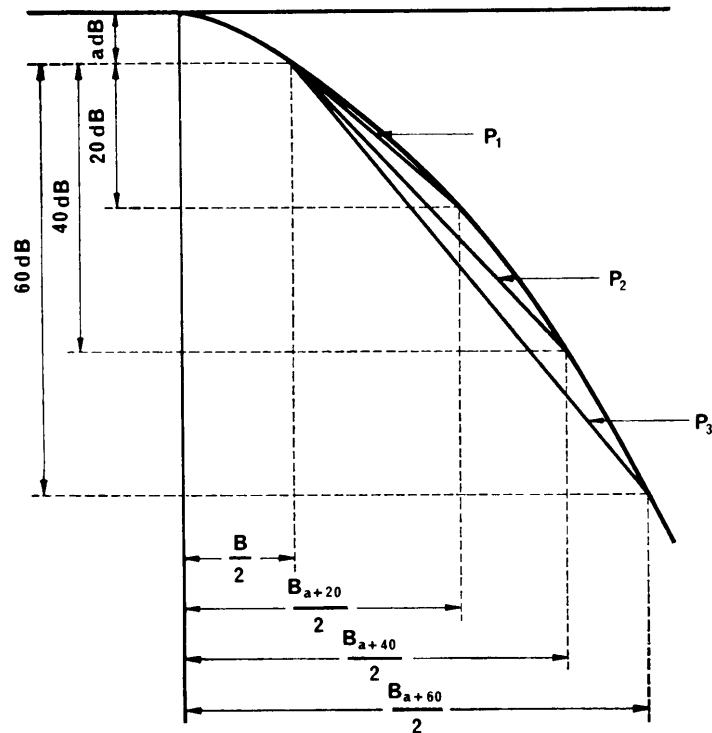
FIGURE 1 — *Conversion between methods of presentation of single-signal selectivity*

The formula: $B_{a+20n} = B + 20 \ (2n/P_n)$ can be used to convert to bandwidths at specified levels, where:

$a$:      the attenuation at the edge of the passband

$B_{a+20n}$:      the bandwidth at a level $(a + 20n)$ dB from the middle of the passband in kHz

$B$:      the bandwidth of the passband in kHz

$P_n$:      slope of the attenuation in dB/kHz

$n$:      an integer (1, 2, 3 or 4)

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6.2      *blocking:* blocking is measured by the level of an unwanted signal on a nearby frequency, e.g., in an adjacent channel, which results in a given change (generally a reduction) e.g., 3 dB, in the output power due to a modulated* wanted signal of specified level applied to the receiver input;

6.3      *adjacent signal selectivity:* one of two following principles of measurement is used:

6.3.1      The adjacent-signal selectivity is measured by the level of an unwanted modulated signal at a frequency near to that of the wanted signal which results in an output power from the receiver (sum of the power of all unwanted components) of a specified amount (e.g., 20 dB) below the power due to the modulation of the wanted signal (adjacent-signal selectivity type A).

     The measurement of the level of the unwanted signal may be made with the modulation of the wanted signal removed. In the case that the modulation is not removed, the output power due to the modulation shall be excluded from the measurement by adequate audio-frequency filtering or a wave analyzer shall be used to measure the unwanted components.

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*      Except for class of emissions A1A and A1B when an unmodulated carrier is used.

With receivers for amplitude-modulated classes of emission with reduced or suppressed carrier, the wanted signal shall be modulated.

6.3.2    The adjacent-signal selectivity is measured by the level of an unwanted signal[*] at a frequency near to that of the wanted signal which results in a degradation of the wanted modulated signal at the output of the receiver either[**]:

–    by a specified change in the ratio:

$$\frac{\text{Signal + noise + distortion}}{\text{noise + distortion}}$$

(e.g., of 6 dB) when measured at the maximum usable level of sensitivity (adjacent-signal selectivity type B1),

–    or to a specified value (e.g., 12 dB) when measured at values above the maximum usable level of sensitivity (adjacent-signal selectivity type B2).

The measurement of adjacent-signal selectivity includes the effects of cross-modulation and inadequate intermediate-frequency filtering.

The method given in § 6.3.2 is to be preferred for frequency-modulation receivers in the mobile services (class of emission F3E)[***].

*Note.* – For single-sideband and independent-sideband emissions, a modulated signal is deemed to comprise a reduced carrier (if applicable) and one sinusoidal component in only one of its sidebands.

6.4    *intermodulation:* intermodulation is measured in terms of the levels of two unwanted signals which, when applied together, produce at the receiver output either[****]:

–    a given level of intermodulation (e.g., 20 dB[*****]) below the level produced by a wanted input signal (intermodulation type A), or

–    a specified degradation in the ratio

$$\frac{\text{Signal + noise + distortion}}{\text{noise + distortion}}$$

(e.g., of 6 dB) if measured at the maximum usable sensitivity level (intermodulation type B1), or

–    a degradation of the ratio

$$\frac{\text{Signal + noise + distortion}}{\text{noise + distortion}}$$

to a specified value (e.g., 12 dB), when measured with signal levels in excess of the maximum usable sensitivity level (intermodulation type B2); when the frequencies $F_n'$ and $F_n''$ of these unwanted signals have:

6.4.1    a sum equal to the intermediate frequency ($F_{if1} = F_n' + F_n''$), in which case, tests should be made with frequencies such that the unwanted signals will have frequencies close to, but not equal to, half the intermediate frequency;

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[*]    The unwanted signal shall be modulated, except in those cases in which the modulation does not affect the result.

[**]    Certain Administrations do not agree with the method of measurement described in § 6.3.2, but Study Group 1 is awaiting results from the International Electrotechnical Commission (IEC) before deciding whether or not to amend this Recommendation.

[***]    When there is regular channelling, the value of the adjacent-signal selectivity measured for a frequency separation equivalent to the channel spacing is termed adjacent-channel selectivity.

[****]    Certain Administrations do not agree with the method of measurement described in § 6.4 concerning intermodulation types B1 and B2, but Study Group 1 is awaiting results from the IEC before deciding whether or not to amend the Recommendation.

[*****]    Other values may be desirable for certain classes of receiver.

6.4.2    a difference equal to the intermediate frequency ($F_{if2} = F'_n - F''_n$), in which case, tests should be made with frequencies such that the unwanted signal at the lower frequency should have a frequency near to that of the wanted signal, e.g., in an adjacent channel;

6.4.3    a sum equal to the frequency of the wanted signal ($F_{d1} = F'_n + F''_n$), in which case, the unwanted signals should have frequencies close to, but not equal to, half the wanted signal;

6.4.4    a difference equal to the frequency of the wanted signal ($F_{d2} = F'_n - F''_n$), in which case, the unwanted signal having the lower frequency should have a frequency near to that of the wanted signal, e.g., in an adjacent channel;

6.4.5    a sum equal to the image frequency ($F_{im} = F'_n + F''_n$), in which case, the unwanted signals should have frequencies close to, but not equal to, half the image frequency;

6.4.6    a difference equal to that between the wanted signal and the nearer unwanted signal intermodulation product being of the third order ($F_{d3} = 2F'_n - F''_n$), in which case, the nearer unwanted signal should have a frequency near to that of the wanted signal, e.g., in an adjacent channel.

Other orders of intermodulation products may occur. Those selected include those that are generally sufficient to describe the performance in respect to intermodulation.

The products that are most significant differ with receivers for different services.

Fifth and higher order intermodulation products may be significant in certain services, e.g., VHF land-mobile.

The frequency of one of the unwanted signals should be adjusted to make the interference a maximum, and that of both should be such that the receiver output power is negligible when only one unwanted signal is applied and modulated.

To determine the severity of intermodulation for a range of values of the strength of the wanted signal, a third signal (the wanted signal) should be applied at the frequency to which the receiver is tuned; suitable input levels may be +20 dB, +40 dB, +60 dB and +80 dB relative to 1 µV, or the maximum usable sensitivity level (see Note 2).

The unwanted signals should be equal in level; in receivers for A3E, they should be unmodulated, because the interference, resulting from the beat between the intermodulation product and the carrier of the wanted signal, is more severe than that due to any modulation; in receivers for R3E, B8E, J3E, F1B and F3E in the mobile services, they should also be unmodulated and the frequency of one unwanted signal should be adjusted to make the output power of the receiver have a frequency equal to or, if the signal is filtered out, near to that of the modulation initially applied to the wanted signal;

**7.**    that, to express the selectivity in the non-linear region, it is desirable that measurements be made of the effective selectivity in terms of the blocking, adjacent-signal selectivity and radio frequency intermodulation characteristics as defined above.

**8.**    that, with a view to the ultimate statistical treatment of the presented data, Administrations should be encouraged to provide results of measurements made on receivers of recent design, in accordance with the provisions of this Recommendation.

*Note 1* – The application of multiple-signal tests of effective selectivity to receivers for A1A, A1B, A2A, A2B and F1B signals is the subject of further study.

*Note 2* – To enable the measurements to be made with two signal generators, the sensitivity of the receiver can be adjusted by the use of a suitable potential applied to the automatic-gain-control circuit, to correspond to the input signals recommended. In this case, one of the unwanted signals should be modulated. A correction should be made for the depth of modulation.