

RECOMMENDATION 331-4

NOISE AND SENSITIVITY OF RECEIVERS

(Question 57/1)

(1951-1953-1956-1959-1963-1966-1970-1974-1978)

The CCIR,

CONSIDERING

- (a) that the sensitivity of a receiver is a measure of its ability to receive weak signals and to produce an output having usable strength and acceptable quality; in many cases, to assess the quality of the output, it might be necessary to take into consideration the receiving equipment as a whole, including the parts giving the information in a printed, aural or visual form;
- (b) that the following parameters, which are determined by the particular service for which the receiver is used, are of special importance in relation to sensitivity;
- necessary output level;
 - necessary overall signal bandwidth;
 - necessary signal-to-noise ratio at the output;
- (c) that the following parameters relating to the internal noise of the receiver, which are determined by the receiver design, are also of importance in relation to the sensitivity of the receiver:
- the level of the internal noise, as defined, for example, by the noise factor;
 - the width of the effective overall noise band, which is not necessarily identical with the width of the signal band (see Recommendation 332);
- (d) that, in many cases, to economize in transmitted power, it is desirable that the sensitivity shall be as great as economic and technical considerations permit and justified by the external noise level;
- (e) that the conditions for obtaining high sensitivity, viz. the ability of the receiver to receive weak signals of the desired transmission, should be considered in connection with those for obtaining good protection against interfering signals (see Recommendation 332);
- (f) that Question 57/1 (Geneva, 1982) asks for additional data on noise factor and noise temperature for the various types of receiver used for reception of different classes of emission in the different services;
- (g) that, for the purpose of presenting, comparing, and using data on the sensitivity of receivers, it is desirable to define the following terms:
- maximum usable (noise-limited) sensitivity;
 - maximum usable (gain-limited) sensitivity;
 - reference sensitivity;
 - noise factor or noise temperature;
- (h) that often values for noise factor or noise temperature are particularly useful, since they are more uniform than values of maximum usable sensitivity for the various types of receiver used for the reception of different classes of emission in the different services and, other factors remaining unchanged, indicate the degree of improvement in maximum usable sensitivity which is theoretically possible;
- (j) that the noise factor or noise temperature is useful only for a linear receiver or for the linear part of a receiver, since in a non-linear receiver the noise factor is dependent on the signal input level;
- (k) that reference sensitivity is chiefly of value in comparing linear receivers;
- (l) that it is desirable to define a "linear" receiver;
- (m) that, for radiotelegraphy receivers for automatic reception:
- the use of a non-linear demodulator, discriminator or telegraph shaping circuit, or the use of narrow-band filters changes the effect of noise from an amplitude variation into a variation of the duration of the telegraph signal elements at the output of the receiver (signal distortion);
 - noise may cause mutilation of the signals by splits or extras;
 - signal distortion and signal mutilation may cause erroneous characters in the reproduced text;

- the foregoing considerations make it desirable to define receiver sensitivity with reference to signal distortion and mutilation or character errors in the reproduced text;
- (n) that for sound broadcast and television receivers, it is desirable to define sensitivity not only for a reasonably good output signal, but also for any usable output signal,

UNANIMOUSLY RECOMMENDS

1. that a *linear* receiver should be defined as one operating in such a manner that the signal-to-noise ratio at the output is proportional to the signal level at the input, and/or to the degree of modulation;
2. that the *noise factor* should be defined as follows: the noise factor is the ratio of noise power measured at the output of the receiver to the noise power which would be present at the output if the thermal noise due to the resistive component of the source impedance were the only source of noise in the system; both noise powers are determined at an absolute temperature of the source equal to $T = 293$ K;
- 2.1 that the *noise temperature* be defined as the value by which the temperature of the resistive component of the source impedance should be increased, if it were the only source of noise in the system, to cause the noise power at the output of the receiver to be the same as in the real system;
3. that the *width of the effective overall noise band* should be defined as the width of a rectangular frequency response curve, having a height equal to the maximum height of the receiver frequency response curve and corresponding to the same total noise power (see [CCIR, 1951]);
4. that the *maximum usable sensitivity* should be defined as the larger of the minimum input signal levels (expressed as the e.m.f. of the carrier)*, which must be applied in series with the specified source impedance (dummy antenna) to the input of the receiver to produce at the output:

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| <ol style="list-style-type: none"> 4.1 – the signal level 4.2 – the signal-to-noise ratio | } | necessary for normal operation when the normal degree of modulation** is applied to the carrier. |
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If the gain is sufficient to enable both conditions to be satisfied simultaneously, the maximum usable sensitivity is described as "noise-limited". Otherwise, the gain being insufficient, the maximum usable sensitivity is described as "gain-limited"; in this case the gain, being adjusted to a maximum, enables the condition of § 4.1 (necessary output level) to be satisfied without regard to the output noise level (condition of § 4.2);

- 4.3 – the ratio of (signal + noise + distortion) to (noise + distortion) necessary for normal operation; or
- 4.4 – the signal distortion or mutilation just acceptable for normal operation;
5. that, for the purpose of presenting and comparing data for particular classes of linear receivers and classes of emission for the different services (normally noise-limited) and for a particular frequency range, the *reference sensitivity* should be defined as the maximum usable sensitivity for specified values of:
 - signal-to-noise ratio;
 - receiver bandwidth;
 - degree of modulation;
 - source impedance (dummy antenna).

Within the linear range, the maximum usable sensitivity for any of these conditions should be derived from the reference sensitivity (the noise factor being considered as constant), and vice versa (see Annex I);

6. that in case of uncertainty with regard to terms of the formulae relating noise factor and reference sensitivity (see Annex I), e.g. the width of the effective overall noise band, independently measured values for these two quantities should be given;
7. that values for the maximum usable sensitivity and for reference sensitivity should be considered in connection with the values for the single signal and multiple signal selectivity (see Recommendation 332);
8. that, since the reference sensitivity is of particular value for a receiver working in a linear condition, for the markedly non-linear condition only, the maximum usable sensitivity and the noise factor for the normal operating conditions should be given;

* For frequencies above about 30 MHz, the input signal strength is sometimes taken as the available power from the source.

** Classes of emission A1A and A1B are considered 100% modulated.

9. that, although radiotelegraph receivers for aural reception can be operated linearly, those for automatic operation, in which non-linearity usually occurs, must be given separate consideration;

9.1 *maximum usable sensitivity* should be defined as the minimum input signal (expressed as the e.m.f. of the carrier), which must be applied in series with the specified source impedance (dummy antenna), to the input of the receiver to obtain at the output the desired signal level and the amount of signal distortion or mutilation permissible in normal operation; the maximum usable sensitivity as defined above should be described as "distortion limited" or "mutilation limited";

9.2 *maximum usable sensitivity, including the reproducing equipment*, should be defined as the minimum input signal (expressed as the e.m.f. of the carrier), which must be applied in series with the specified source impedance (dummy antenna), to the input of the receiver to obtain a specified character error ratio in the reproduced text;

9.3 defined methods for measuring signal distortion, signal mutilation, element error ratios and character error ratios should be used (see [CCIR, 1956; 1958a, b, c and CCIR, 1966-69a and b]);

9.4 for the purpose of comparing and presenting data (see Annex I, § 5), the maximum usable sensitivity should be given for specified values of:

- the amount of signal distortion and signal mutilation at the receiver output with a specified probability of occurrence (see § 9.1 and Annex I, § 5.4); or the character error rate in the reproduced texts (see § 9.2 and Annex I, § 5.5) and the receiver pre-detector and post-detector signal bandwidth;
- the frequency shift for F1B emissions;
- the source impedance (dummy antenna);

9.5 the performance of the receiving equipment in terms of signal distortion, signal mutilation or character error rate, instead of being defined by the maximum usable sensitivity, is often described by the *signal-to-noise* power ratio value in the receiver, just prior to the non-linear part; in this case, it is convenient to use a parameter called the "normalized signal-to-noise ratio" which is defined as the signal-to-noise power ratio per baud per unit bandwidth*; in Annex I, § 6, a formula is given relating the normalized signal-to-noise ratio to the e.m.f. of the carrier at the receiver input (in series with the equivalent source resistance);

10. that for sound broadcast and television receivers:

10.1 *a maximum sensitivity* should be defined as the minimum input signal applied, in series with the specified source impedance (dummy antenna), to the input of the receiver for which any usable signal with a specified output level can be obtained;

10.2 measurements of sensitivity be made in conformity with Recommendations 237-1 and 330 (Geneva, 1974);

11. that for receivers for single channel frequency-modulation for telephony (class of emission F3EJN) other than those used for sound broadcasting:

11.1 the maximum usable sensitivity should be defined as the minimum input signal applied, in series with the specified source impedance (dummy antenna) to the input of the receiver for which a specified value of

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

can be obtained at the output;

11.2 the measurement of (noise + distortion) should be made with the wanted modulation present, the output due to this modulation being removed by a filter;

11.3 this method of measurement is in accordance with the IEC proposals;

Note. — The characteristics of the filter used to remove the wanted modulation shall be such that, at the point at which the output meter used for sensitivity measurement is connected, the relative attenuation of the 1 kHz signal shall be at least equal to the specified

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

ratio plus 20 dB, and that at 2 kHz it shall not exceed 0.6 dB. Moreover, in the absence of the modulating frequency, the filter shall not cause more than 1 dB attenuation of the total noise signal power occurring within the specified receiver bandpass;

* The normalized signal-to-noise ratio is an energy ratio and it can be expressed in dB (see Report 195).