



INTERNATIONAL TELECOMMUNICATION UNION

**ITU-T**

TELECOMMUNICATION  
STANDARDIZATION SECTOR  
OF ITU

**G.228**

**INTERNATIONAL ANALOGUE CARRIER SYSTEMS  
GENERAL CHARACTERISTICS COMMON TO ALL  
ANALOGUE CARRIER-TRANSMISSION SYSTEMS**

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**MEASUREMENT OF CIRCUIT NOISE  
IN CABLE SYSTEMS USING  
A UNIFORM - SPECTRUM RANDOM  
NOISE LOADING**

**ITU-T Recommendation G.228**

(Extract from the *Blue Book*)

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## NOTES

1 ITU-T Recommendation G.228 was published in Fascicle III.2 of the *Blue Book*. This file is an extract from the *Blue Book*. While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 In this Recommendation, the expression “Administration” is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

## Recommendation G.228

### MEASUREMENT OF CIRCUIT NOISE IN CABLE SYSTEMS USING A UNIFORM-SPECTRUM RANDOM NOISE LOADING

(Geneva, 1964; further amended)

The CCITT,

*considering that*

(a) it is desirable to measure the performance of cable systems for frequency-division multiplex telephony under conditions closely approaching those of actual operation;

(b) a signal with a continuous uniform spectrum (white noise) has statistical properties similar to those of a multiplex signal when the number of channels is not too small;

(c) the use of a signal with a continuous uniform spectrum to measure the performance of such cable systems is already widespread;

(d) it is necessary to standardize the frequencies and bandwidths of the measuring channels to be used for such measurements;

(e) for reasons of international compatibility it is necessary to standardize the minimum attenuation and the bandwidth of the stop filters which may have to be used in the white-noise generator;

(f) the CCITT has indicated, for the planning of telephone circuits, a mean value of signal power in the baseband of a multiplex telephone system to be taken into consideration during the busy hour (Recommendation G.223),

*recommends that*

**1** The performance of frequency-division multiplex cable systems should be measured by means of a signal with a continuous uniform spectrum in the frequency band used for the telephone channels.

**2** The nominal power level of the uniform spectrum test signal should be in accordance with the conventional load, specified in Recommendation G.223. If applied at the point of interconnection of the system corresponding to  $T'$  of Recommendation G.213, the absolute power levels of interest are shown in column 4 of Table 1/G.228.

2.1 The sending equipment should be capable of providing, at the output of an inserted bandstop filter, a loading level at least up to + 10 dB relative to the nominal power level defined above.

2.2 Within the bandwidth corresponding to the baseband of the system under test, the r.m.s. voltage of the white noise spectrum measured in a band of about 2 kHz should not vary by more than  $\pm 0.5$  dB. This degree of spectrum uniformity should be met in the level range up to +6 dB relative to the nominal power level, indicated in Table 1/G.228, column 4.

2.3 The white noise test signal should be available at the output of the sending equipment with a peak factor of about 12 dB with respect to the r.m.s. value.

**3** The nominal effective cut-off frequencies (the cut-off frequencies of hypothetical filters having ideal square cut-off characteristics and transmitting the same power as the real filters) and tolerances for the bandpass filters proposed for the various bandwidths of systems to be tested, should be as specified in Table 2/G.228. To reduce the number of filters required, compromises have been made between the nominal effective cut-off frequency and the system bandwidth-limiting frequency in some cases. The tolerances ensure that consequent calibration errors do not exceed  $\pm 0.1$  dB and errors in measurement of intermodulation noise do not exceed  $\pm 0.2$  dB assuming system pre-emphasis of about 10 dB.

TABLE 1/G.228

1	2	3	4
Number of telephone channels	Relative power level at point $T'$ (dBr)	Level of the conventional load (dBm0)	Nominal power level of the test signal at point $T'$ (dBm)
60	-36	6.1	-29.9
120	-36	7.3	-28.7
300	-36	9.8	-26.2
600	-36	12.8	-23.2
	-33		-20.2
960	-36	14.8	-21.2
	-33		-18.2
1 260	-33	16.0	-17.0
1 800	-33	17.5	-15.5
2700	-33	19.3	-13.7
3 600	-33	20.5	-12.5
10 800	-33	25.3	-7.7

TABLE 2/G.228

System capacity (channels)	Limits of band occupied by telephone channels (kHz)	Effective cut-off frequencies of bandpass filters (kHz)		Frequencies of recommended measuring channels (kHz)						
		Highpass	Lowpass							
60	60- 300	$60 \pm 1$	$300 \pm 2$	70	270					
120	60- 552	$60 \pm 1$	$552 \pm 4$	70	270	534				
300	60- 1 300 64- 1 296	$60 \pm 1$	$1 296 \pm 8$	70	270	534	1 248			
600	60- 2 540 64- 2 660	$60 \pm 1$	$2 600 \pm 20$	70	270	534	1 248	2 438		
960	60- 4 028 64- 4 024	$60 \pm 1$	$4 100 \pm 30$	70	270	534	1 248	2 438	3 886	
900	316- 4 188	$316 \pm 5$	$4 100 \pm 30$			534	1 248	2 438	3 886	
1 260	60- 5 636 60- 5 564	$60 \pm 1$	$5 600 \pm 50$	70	270	534	1 248	2 438	3 886	5 340
1 200	316- 5 564	$316 \pm 5$	$5 600 \pm 50$			534	1 248	2 438	3 886	5 340
1 800	312- 8 120 312- 8 204 316- 8 204	$316 \pm 5$	$8 160 \pm 75$			534 7 600	1 248	2 438	3 886	5 340
2 700	312-12 336 316-12 388 312-12 388	$316 \pm 5$	$12 360 \pm 100$			534 7 600	1 248	2 438 11 700	3 886	5 340
3 600	316-17 004 312-16 900 596-17 668	$316 \pm 5$	$17 300 \pm 150$			534 or 770 7 600	1 248 11 700	2 438	3 886 16 400	5 340
10 800	4 332-59 684 4 404-59 580	$4 370 \pm 70$	$59 600 \pm 600$			5 340 35 748	11 700 55 548			

3.1 The discrimination of a lowpass filter should be at least 20 dB at a frequency more than 10% above nominal cut-off and at least 25 dB at frequencies more than 20% above nominal cut-off. The discrimination of a highpass filter should be at least 25 dB at frequencies more than 20% below nominal cut-off.

3.2 To limit discrimination against measuring channels, the spread of losses introduced by any pair of highpass and lowpass filters should not exceed 0.2 dB over a range of frequencies which includes the upper and lower measuring channels.

4 Values of the characteristics for the discrimination in each stop-band at the output of a sending equipment are given in Table 3/G.228. These characteristics are intended to apply over a temperature range from 10 °C to 40 °C.

5 When the receiving equipment is connected directly to a sending equipment provided with bandstop filters which only just meet the requirements of § 4 above, the ratio of the noise power indicated by the receiving equipment when the bandstop filter is bypassed, to that indicated when the filter is in circuit, should be a minimum of 67 dB; this requirement applies when a conventional load is applied. The minimum effective bandwidth of the receiver should be 1.7 kHz; the maximum reading of absolute noise power arising from leakage given by a receiver of 1.74 kHz effective bandwidth and which just meets the foregoing leakage requirement is -85.6 dBm0p.

6 Additional measuring channels may be provided by agreement between the Administrations concerned.

*Note* - In Annexes A and B some general information is given on the measuring procedures, the choice of filter characteristics, correction methods and accuracy objectives.

TABLE 3/G.228

**Characteristics of bandstop filters**

Centre frequency $f_0$ (kHz)	Bandwidth (kHz), in relation to $f_0$ , over which the discrimination should be at least:				Bandwidth (kHz) in relation to $f_0$ , outside of which the discrimination should not exceed:	
	70 dB	55 dB	30 dB	3 dB	3 dB	0.5 dB
70	± 1.5	± 2.2	± 3.5	—	± 12	± 18
270	± 1.5	± 2.3	± 2.9	—	± 8	± 24
534	± 1.5	± 3.5	± 7.0	—	± 15	± 48
770	± 1.5	± 3.8	± 8.0	—	± 21	± 70
1 248	± 1.5	± 4.0	± 11.0	—	± 35	± 110
2 438	± 1.5	± 4.5	± 19.0	—	± 60	± 220
		± 15.0	± 30.0	—	± 110	± 350
3 886	± 1.5					
		± 1.8	± 3.5	± 8.0	± 12	± 100
5 340	± 1.5	± 2.2	± 4.0	± 8.5	± 14	± 150
7 600	± 1.5	± 2.4	± 4.6	± 9.5	± 16	± 200
11 700	± 1.5	± 3.0	± 7.0	± 11.0	± 20	± 300
16 400	± 1.5	± 4.0	± 9.0	± 14	± 30	± 500
35 748	± 1.8	± 2.2	± 3.5	± 5.0	± 20	± 150
55 548	± 2.5	± 3.5	± 6.0	± 9.5	± 30	± 200

*Note 1* - The characteristics recommended for the filters 70 kHz to 2438 kHz inclusive are based on coil-capacitor type filters. Those characteristics recommended for the filters at 5340 kHz and above are based on crystal-type filters. Optional characteristics are recommended for the 3886-kHz filter to permit a choice of design between a coil-capacitor type or crystal-type filter. The crystal-type filters at 35 748 kHz and 55 548 kHz are assumed to be operating in a higher harmonic mode of the crystal resonators. That is why the relative bandwidths of these filters show a discontinuity compared with the crystal-type filters up to 11 700 kHz.

Note 2 - The discrimination values quoted are relative referred to the minimum attenuation of the bandstop filters within the baseband frequency range defined by highpass and lowpass filters in Table 2/G.228. This implies that a bandstop filter suitable for measurements on one system is not necessarily suitable for measurements on a system of larger bandwidth.

Note 3 - The design of the receiver selectivity of 3886 kHz should be related to the characteristic of the crystal-type bandstop filter.

Note 4 - Due to spurious resonances, narrow spikes of the discrimination may occur in the upper passband of crystal-type bandstop filters. When resonators are operated in a higher harmonic mode narrow spikes can also appear in the lower passband. Those spikes of about 10-dB peak attenuation within 1 to 5 kHz bandwidth are admissible because they do not affect the measuring accuracy.

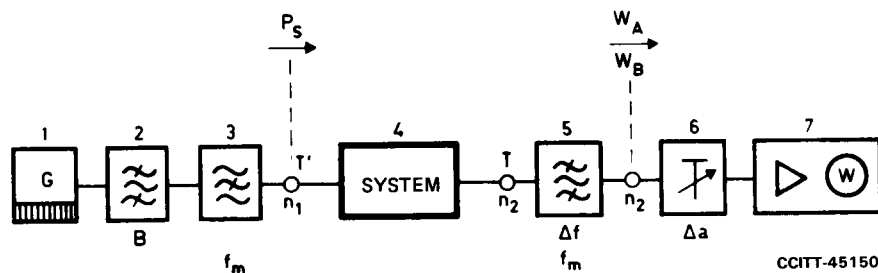
## ANNEX A

(to Recommendation G.228)

### Outline of the white noise measuring method

#### A.1 General principle

The principal components of the measuring setup are shown in Figure A-1/G.228.



- 1 = noise generator delivering variable test signal power  $P_S$
  - 2 = bandpass filter, effective bandwidth  $B$
  - 3 = bandstop filter, centre frequency  $f_m$
  - 4 = system under test
  - 5 = receiving bandpass filter, centre frequency  $f_m$ , bandwidth  $\Delta f$  about 2 kHz
  - 6 = variable receiver attenuator,  $\Delta a = 10 \log \frac{W_A}{W_B}$  dB
  - 7 = r.m.s. level meter
  - $W_A$  = noise power when bandstop filter is bypassed
  - $W_B$  = noise power when bandstop filter is inserted
  - $n_1$  = relative level at system input  $T'$
  - $n_2$  = relative level at system output  $T$
- } (see Recommendation G.213)

FIGURE A-1/G.228

#### Principle of the measuring set-up

#### A.2 Measuring procedures

Two methods for assessing the noise performance of a transmission system are in widespread use:

### A.2.1 Measurement of noise power ratio (NPR)

The noise power ratio

$$\text{NPR} = 10 \log \frac{W_A}{W_B} \text{ dB} = \Delta a \quad (\text{A-1})$$

is measured at various levels of  $P_s$ . The r.m.s. level meter serves as an indicator only. The value  $W_A$  is the noise power in the measuring channel without taking account of the effect of frequency gaps between groups of channels in actual operation.

In an  $N$ -channel system the following definitions are introduced:

$$P_s = N \cdot P_{CH}$$

$P_{CH}$  = variable signal power per channel

$$P_{CH} = -15 \text{ dBm0} + \Delta p = \text{load level per channel}$$

-15 dBm0 is the conventional load per channel according to Recommendation G.223 for systems with  $N \geq 240$ .  $\Delta p$  (dB) is the excess load relative to -15 dBm0

$p_n$  = weighted noise power level (dBm0p) measured at point  $T$  in a 3.1 kHz telephone channel.

The measured NPR values are usually plotted, as shown in Figure A-2/G.228, as a function of the excess channel loading  $\Delta p$ .

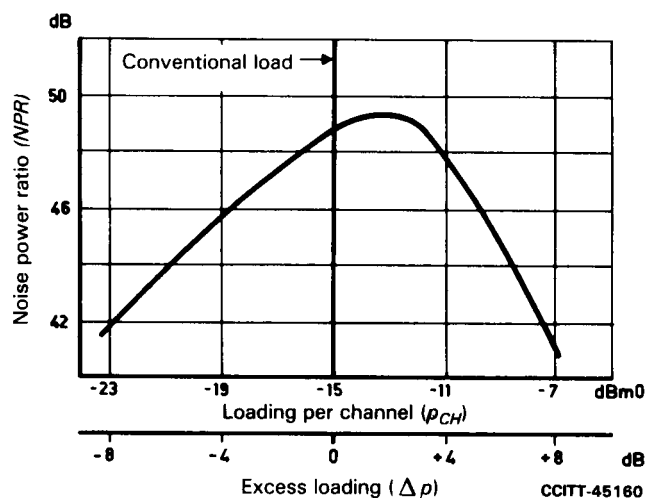


FIGURE A-2/G.228

NPR curve versus channel loading

The relation between NPR values measured on a channel and the weighted noise power level referred to a zero relative level point is:

$$p_n = (-\text{NPR} - 18.6 - 10 \log k + \Delta p) \text{ dBm0p} \quad (\text{A-2})$$

$k = B/4N$  ( $B$  in kHz) is a correction factor which takes account of the effect of the frequency gaps between groups of channels in the transmission system.

Table A-1/G.228 gives examples of the correction for some N-channel systems:

TABLE A-1/G.228

$N$	300	960	2700	10 800
10 log $k$ (dB)	0.14	0.22	0.46	1.08

### A.2.2 Direct measurement of weighted noise power level

With the particular choice of the effective receiver bandwidth

$$\Delta f = 1.74 \text{ kHz} (= 3.1 \text{ kHz} \cdot 10^{-0.25}),$$

the weighted noise power  $P_n$  in a telephone channel is:

$$P_n = W_B \text{ (see Figure A-1/G.228)}$$

and the weighted noise level  $p_n$ , referred to a point of zero relative level becomes:

$$p_n = \left[ 10 \log \frac{W_B}{1 \text{ mW}} + n_2 \text{ (dB)} \right] \text{ dBm0p} \quad (\text{A-3})$$

In this case the receiver (component 7 of Figure A-1/G.228) must be a calibrated power level meter.

### A.3 Examples of investigations using the white noise measuring method

Two kinds of investigations can be made on a system (with length  $L$ ) between flat relative level points  $T'$  and  $T$ . The one [case a)] investigates the effect on the noise performance of load deviations at the input of the system, whereas the other [case b)] indicates the influence of level misalignments along the transmission line:

- a) The test signal noise power  $P_S$  is varied and the weighted noise level  $p_n$  is determined in dBm0p. The result is plotted as indicated in Figure A-3/G.228.

Alternatively to the indication of the noise level for system length  $L$  in dBm0p, the noise power could have been indicated in pW0p/km.



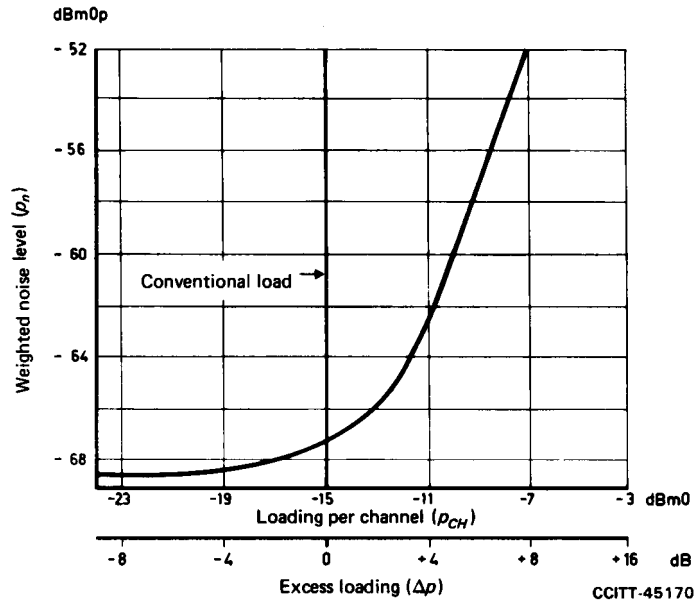


FIGURE A-3/G.228

**Weighted noise power level versus system load (relative levels of the system fixed according to plan)**

- b) The relative levels on the transmission line are varied by insertion of attenuators  $-\Delta n$  and  $+\Delta n$  at the input and output of the system as is illustrated in Figure A-4/G.228 which is an excerpt of Figure A-1/G.228.

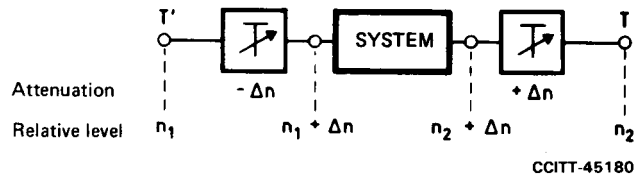


FIGURE A-4/G.228

**Variation of the internal relative levels of the system**

The test signal noise power  $P_S$  is set to the conventional value (-15 dBm0/4 kHz) at point  $T'$  and is kept constant. The noise power level in the measuring channel is determined at point  $T$  as a function of the relative level at the repeater output, for example. The result is plotted as shown in Figure A-5/G.228.

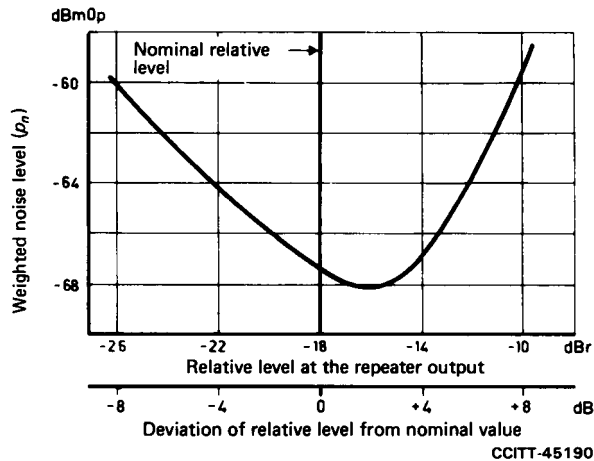


FIGURE A-5/G.228

**Weighted noise level in measuring channel versus relative level at repeater output**

ANNEX B

(to Recommendation G.228)

**Measuring accuracy considerations affecting the design of the measuring equipment**

B.1 *Introduction*

The Recommendations relating to the measurement of circuit noise in systems artificially loaded with uniform spectrum random noise simulating FDM telephone signals were agreed after carefully coordinated studies by three CCI Study Groups concerned. The different Recommendations provided for the application of the white noise measuring method to cable systems (CCITT Recommendation G.228), radio-relay systems (CCIR Recommendation 399 [1]), satellite systems (CCIR Recommendation 482 [2]) and translating equipments (CCITT Recommendation G.230). The objective of the coordination was that the separately recommended measuring equipments should conform with common measuring accuracy objectives and, as far as possible, be compatible and interchangeable.

The overall accuracy objective of the measuring equipment when used for routine maintenance measurements is  $\pm 2$  dB. A higher accuracy of about  $\pm 1$  dB is desirable when measurements are made for the purpose of assessing the noise performance of a system in relation to required performance. This can be achieved by following certain procedures and applying corrections as described in B.4 and B.5 below.

This Annex states how certain characteristics of measuring equipments were related to measuring accuracy objectives; any future extensions of the Recommendations to provide for measurements on new transmission systems, as yet unstandardized, should take account of those relationships.

B.2 *Bandstop fillers*

B.2.1 *Choice of centre frequencies*

In all cases the choice of nominal centre frequencies of band-elimination filters (i.e. of measuring channels) should take account of the need to minimize the combined discrimination of the pair of bandpass filters used when the

bandstop filter provides a lower or upper measuring channel. Therefore, as a rule the centre frequency of a lower measuring channel should be at least 15% above the effective cut-off frequency of the highpass filter and the centre frequency of an upper measuring channel should be more than approximately 5% below the cut-off frequency of the lowpass filter involved. Under § 3.2 of the text of this Recommendation it is prescribed that "the spread of losses introduced by any pair of highpass and lowpass filters should not exceed 0.2 dB over a range of frequencies which includes the outer measuring channels".

### B.2.2 *Leakage*

The discrimination of a bandstop filter in the neighbourhood of the centre frequency determines, jointly with the receiver selectivity the smallest noise-to-signal ratio that can be measured accurately, i.e. the "leakage" effect. The bandstop filter discrimination of 70 dB (Table 3/G.228) results in a ratio of the order of -67 dB-being measured when the noise is actually negligible. Leakage effect in the receiver is adequately limited by requiring (see § 5 in the text of the Recommendation) that the NPR value should be a minimum of 67 dB when connected directly to a send equipment with bandstop filters which only just meet the discrimination requirements of Table 3/G.228 and when a conventional load of -15 dBm/4 kHz is applied.

*Note* - According to Formula (A-2) of Annex A this value of NPR = 67 dB corresponds to a residual noise level of -85.6 dBm<sub>0p</sub> (i.e. 2.8 pW<sub>0p</sub>) at the most.

### B.2.3 *Effective bandwidth*

The basic requirement for the stopband is the condition that the discrimination should be at least 70 dB in a bandwidth of at least 3 kHz. The effective bandwidths (approximately the 3-dB points) recommended in Table 3/G.228 have been found to be technically feasible and lie in the order of 5% or less of the system bandwidth with coil-capacitor type filters and are less than 0.5% with crystal-type filters. It would present economic difficulties to reduce the relative bandwidth of the coil-type filters or to increase the relative bandwidth of the crystal-type filters.

#### B.2.3.1 *Third order nonlinearity products*

The attenuation of the noise loading signal in the vicinity of the measuring channel introduced by a bandstop filter causes an under-indication reading, erring on the low side, of third order nonlinearity noise power in that measuring channel. This under-indication is directly proportional to the effective bandwidth of the elimination filter.

Assuming that procedures B.4.3 and B.4.4 below are both observed, the under-indication of third order products in a system using no pre-emphasis is about 0.05 dB for a top measuring channel filter, the effective bandwidth of which is 1% of the system bandwidth. The error associated with a particular filter is at its maximum when the filter provides the top measuring channel of a system. When the same filter is used in wider band systems (thus corresponding to an intermediate measuring channel of the system) its bandwidth is a smaller proportion of the system bandwidth and the associated error is smaller.

When pre-emphasis is used but total signal power is unchanged the error is increased by the ratio of the signal density near the measuring channel of the pre-emphasized system to that of the system without pre-emphasis.

The effective bandwidths of crystal-type bandstop filters are so small that their effect on measurement errors is negligible.

The recommended effective bandwidths for coil-capacitor bandstop filters (Table 3/G.228) are such that the under-indication of third order nonlinear noise powers, when the filters provide top measuring channels of systems without pre-emphasis, falls in the range 0.25 to 0.30 dB. This range of errors becomes 0.60 to 0.90 dB for systems emphasized by 8 to 10 dB as is the case in FDM radio-relay systems (CCIR Recommendation 275 [3]) or in wideband systems on coaxial cables.

### B.2.3.2 *Second order nonlinearity products*

In long transmission systems third order nonlinearity products normally form a more significant proportion of the total system noise than those of second order. For this reason the recommended maximum effective bandwidths of bandstop filters have been determined on the basis of accuracy objectives for the measurement of third order nonlinearity products.

Nevertheless, measuring equipments may still be used for investigations of cases where second order nonlinearity products dominate. Corrections for known filter bandwidths may be made on the following basis:

- a) Again assuming that procedures B.4.3 and B.4.4 below are observed, the error in a reading of second order nonlinearity products introduced by the bandstop filter is an excess reading, rather than the under-indication in the case of third order nonlinearity products.
- b) The excess reading is directly proportional to the effective bandwidth of the bandstop filter expressed as a percentage of the system bandwidth. The approximate proportionality, assuming no system pre-emphasis:
  - for measuring channels located near the lower limit of the system bandwidth, an effective bandwidth of 1% system bandwidth causes an excess reading of 0.05 dB for second order intermodulation noise power;
  - for measuring channels located in the middle, or near the upper limit, of the system bandwidth, an effective bandwidth of 1% system bandwidth causes an excess reading of 0.1 dB.
- c) The effect of system pre-emphasis in the case of a bandstop filter near the lower limit of the system bandwidth, i.e. where the density of second order nonlinearity products tends to be greatest, is to reduce the error attributable to a given filter bandwidth in the same proportion that the signal density at that frequency is reduced by pre-emphasis.

### B.3 *Bandpass filters*

In order to reduce the number of different filters, compromises have been made in some cases between the nominal effective cut-off frequency and the system bandwidth limiting frequency (cf. § 3 of the text).

For the larger systems there may also be a significant difference between the frequency bandwidth  $4N$  kHz ( $N$  being the system capacity expressed in telephone channels) and the system bandwidth (Table 2/G.228).

Both these facts are taken into account by the correction factor  $k$  introduced in equation (A-2) of Annex A and in Table A-1/G.228.

The recommended tolerances on the nominal values of cut-off frequencies are such that the actual and nominal bandwidths of the signal load cannot differ by more than 1%. This ensures that calibration errors (in NPR measurements) due to this particular imperfection do not exceed about 0.05 dB.

The tolerances on the effective lowpass cut-off frequencies are in all cases less than 1.0% of the nominal system bandwidth and in most cases less than 0.8%. A difference of 0.8% leads to an error, in third order nonlinearity noise measurement, of 0.1 dB, this allowing for a pre-emphasis of 8 dB. Even allowing for a greater degree of pre-emphasis, the maximum error from this cause should not exceed 0.15 dB.

### B.4 *Procedures for high accuracy measurements*

The following measuring procedures are recommended for high accuracy type of measurements, for example checks that transmission system noise performance objectives are being achieved.

#### B.4.1 *Signal load adjustment*

The loading power should be adjusted to the nominal value by means of a true r.m.s. level measuring device. The maximum error, including reading error, should not exceed  $\pm 0.15$  dB.

#### B.4.2 *Receiver calibration*

B.4.2.1 Using the NPR method (§ A.2.1) the receiver should be set with reference to the received signal immediately before insertion of a bandpass filter.

B.4.2.2 Using the direct noise power measuring method (§ A.2.2) the receiver calibration error could be decreased to  $\pm 0.15$  dB at the particular measuring slot by checking the reading with the aid of a white noise signal and a d.c.-calibrated true r.m.s. level meter.

*Note* - The accuracy of measurements related to the zero relative level point (dBm0p or pW0p) also depends on how precisely the relative level at the measuring point ( $n_2$  of Figure A-1/G.228) is known.

#### B.4.3 *Insertion of bandstop filters*

Only one bandstop filter should be inserted at a time. This limits errors in measurement of intermodulation noise.

#### B.4.4 *Readjustment of signal load*

Normally, the signal load should be readjusted to the nominal value after the insertion of a bandstop filter. When measurements are specifically to investigate second-order intermodulation, or when this is known to dominate, greater accuracy is obtained by readjusting only for the specified passband insertion loss of the bandstop filter and not for the loss of spectrum energy in the measuring slot.

*Note* - The effect of the measuring slot bandwidth is negligible with crystal-type bandstop filters.

#### B.4.5 *Measurement at the receiver*

B.4.5.1 Using the NPR method the noise power ratio is now measured as the change required in the setting of an attenuator ( $\Delta a$  in Figure A-1/G.228) to restore the pointer of the indicating instrument to the original setting.

B.4.5.2 Using the direct measuring method the weighted noise level can be read in dBmp (or pWp) from the instrument. Optional means may be provided, e.g. to shift the calibration by setting a switch to the relative level  $n_2$  of the measuring access point  $T$  so that the dBm0p or pW0p values are indicated.

#### B.5 *Corrections for high accuracy measurements*

The effects of the following error sources can be reduced by applying corrections to the measured values:

##### B.5.1 *Receiver calibration in connection with NPR method*

###### B.5.1.1 *Irregularity of the noise source*

The tolerance for the spectrum regularity is  $\pm 0.5$  dB. A calibration table (or curve) should be available for each noise generator.

###### B.5.1.2 *Errors of effective system bandwidth*

A correction in the conversion of NPR values into noise levels (in dBm0p) by application of the correction factor  $k$  in equation (A-2) allows first, for the difference between nominal occupied bandwidth of the system under test and actual bandwidth  $B$  between bandpass filter effective cut-off frequencies and secondly, for the difference between nominal occupied bandwidth and the total bandwidth actually occupied by telephone channels (i.e.  $4N$  kHz).

###### B.5.1.3 *Passband attenuation distortion of bandpass filters at the measuring frequency*

The corrections in §§ B.5.1.1 and B.5.1.2 should ensure calibration to an accuracy of  $\pm 0.2$  dB.

### B.5.2 *Bandstop filter effects*

If coil-capacitor type bandstop filters are used, it might be worthwhile to assess the error of the measured intermodulation noise due to the effective bandwidth of these filters. To this end the rules quoted in B.2.3.1 and B.2.3.2 above should be applied.

Approximate corrections for this error are thus possible when the proportion of third- and second-order intermodulation noise has been determined.

### B.6 *Limitations of the noise loading measurement technique*

B.6.1 Very low noise levels of less than about -83 dBm<sub>0p</sub> (about 5 pW<sub>0p</sub>) cannot be expected to be measured with an error of less than 2 dB, where the inherent noise leakage of the white noise measuring set is at the limit corresponding to NPR  $\geq$  67 dB as explained in B.2.2 above.

B.6.2 Although the measurements made at the specified frequencies may confirm that the design objectives are met, the noise performance of a system between these frequencies cannot always be inferred accurately from these measurements. Whether this interpolation is justified or not has to be established for the system under consideration. An approximate indication of the frequency dependency can be gained from the frequency characteristic of the basic noise (without loading) which can be measured with the aid of a selective level meter and continuously varying the frequency. The total noise performance of a system may be evaluated, when necessary, by carrying out measurements using additional test equipment.

### **Bibliography on accuracy of white noise measuring methods**

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