FCC Technical Standards and Baseband S/N

J. Samborski and T. M. Straus
Hughes Aircraft of Canada Limited

Abstract

It is well known that S/N depends directly on C/N, but its dependence on other parametêrs affecting picture quality such as C/CTB has not previously been fully explored. Since a measurement of C/N is in any case also required, it is suggested that a simultaneous measurement of S/N will yield a worst case number for C/CTB. This technique would not only satisfy the letter of the FCC requirement, but also, since S/N is an excellent indicator of overall picture quality, assure the cable operator that he is supplying a quality product to his customers without the onerous need of service interruption.

BACKGROUND

Proof of performance tests to demonstrate compliance with the recently established minimum FCC technical standards would normally require a measurement of C/CTB. This test is to be performed twice a year at a minimum of 6 test locations on at least 4 separate channels. Typically this could add up to over 100 channel service interruptions per year if the test is performed in the traditional manner. With the increased emphasis on quality of service, the cable industry is seeking means to minimize service interruptions while still assuring that the technical standards are maintained. A number of test methods are under consideration. One possible method, herein proposed, is the measurement of baseband S/N and the correlation between this parameter and C/CTB.

The NCTA Recommended Practices describes three methods of measuring C/CTB. The first method is the one that has been most commonly used but requires that the carrier be turned off during the second part of the measurement. A spectrum analyzer is used, and the value recorded is read directly from the face of the analyzer unless the thermal noise floor is close to the CTB level, in which case a correction is made for the proximity of this noise. Note, however, that the definition of C/CTB does not include the correction of the noise-like CTB distortion for the error in spectrum analyzer reading of absolute noise level[1].

Both the second and third NCTA methods of C/CTB measurement avoid the necessity of turning off the video signal. One drawback of the second method is that it cannot account for C/CSO. A drawback of the third method is that it must depend on the assumption that the variation of C/CTB with channel frequency remains constant so as to permit the calculation of C/CTB for various channels from a single out of band measurement.

Yet another method of measurement has been suggested[2]. However, the measurement of S/N is based on test equipment which is readily available. One caution should be noted before applying the results reported in this paper since the characteristics of the test equipment employed could differ in such a way as to affect the relationships suggested herein. In general, however, it is proper to observe that both CSO and CTB can be expected to influence the baseband S/N.

FACTORS INFLUENCING S/N

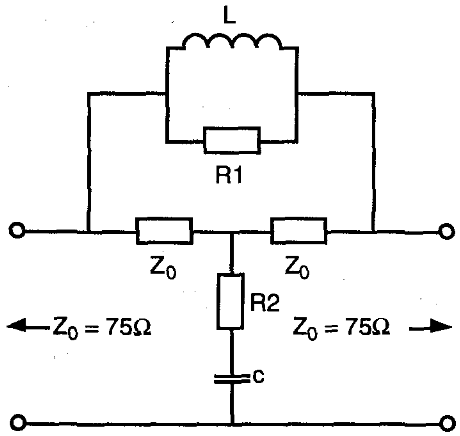
The relationship between baseband S/N and NCTA C/N has previously been analyzed[3,4]. The CCIR adopted a unified noise weighting network[5], shown in Figure 1, which supersedes the descriptions given by Figures 1 through 4 of reference (3). The resulting relationship, now also valid for the EIA[6], is

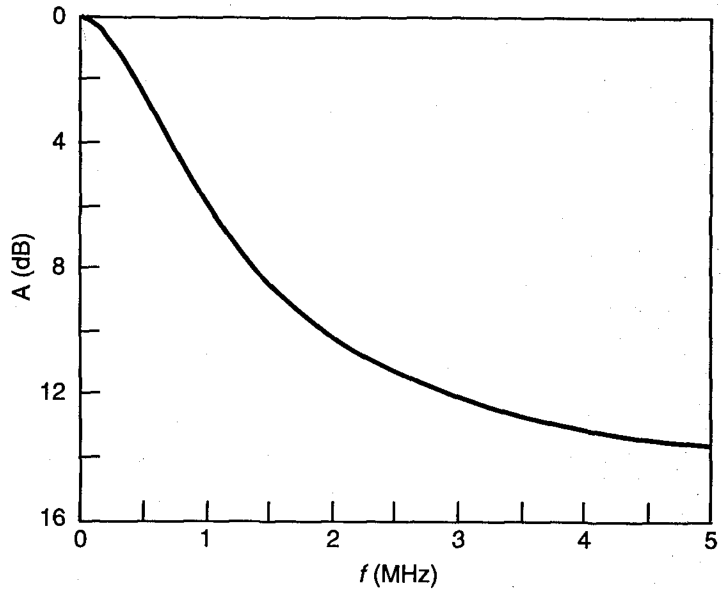
$$S/N = C/N + 0.6 \text{ dB} \qquad (1)$$

The influence of phase noise on S/N has also undergone analysis[7]. It is shown that

$$S/N = C/N_p \qquad (2)$$

where N_p is measured in a 1 KHz resolution bandwidth at a 20 KHz frequency offset from the carrier and it is assumed that the phase noise falls off at a rate of 6 dB per octave. On a spectrum analyzer, the distinguishing feature of phase noise is that it varies with frequency whereas thermal noise is essentially flat over a 6 MHz channel width. When measuring phase noise in this manner, it is important to keep in mind that the spectrum analyzer contribution is not necessarily insignificant. The analyzer contribution can be measured by utilizing a known very low phase noise signal such as from a crystal oscillator. In any case, the shape of the phase noise is in general more complex than the assumed 6 dB/octave roll off and therefore its contribution to S/N is best established by a single channel measurement (no CTB or CSO) with very high C/N.





$$A = 10 \log \frac{1 + \left[\left(1 + \frac{1}{a}\right)\omega\tau\right]^2}{1 + \left[\frac{1}{a}\,\omega\tau\right]^2}$$

$L = Z_0 \cdot \tau$ $\qquad R2 = \frac{Z_0}{a}$

$C = \frac{\tau}{Z_0}$ $\qquad a = 4.5$

$R1 = a \cdot Z_0$ $\qquad \tau = 245$ ns

Figure 1. Unified weighting network for random noise.

To assess the influence of CTB on S/N, consider the impact of any narrow-band noise-like signal centered on the VSBAM carrier frequency. In particular, assume a 30 KHz rf bandwidth and a total lack of noise at any other frequency. Following the notation of reference (4), the integration to determine the video noise power, N_v, is greatly simplified since over the 30 KHz interval the response is essentially constant and the video noise is just $N_v = (2GV_n)^2/R \times 0.03/4$. Substituting this result into the ratio of rf and baseband S/N, one obtains C/N_{rf} = S/N + 1.1 dB. However, keeping in mind the correction of reference (1) and the definition of CTB, C/N_{rf} = C/CTB - 2 dB, so that

$$S/N = C/CTB - 3.1 \text{ dB} \qquad (3)$$

The noise weighting filter does not play a role since the frequency is so close to the carrier. However, for CSO, 7.4 dB weighting corresponding to 1.25 MHz offset must be taken into account. On the other hand the VSBAM receiver response is now at its maximum, adding 6 dB to the previous result so that a net 1.4 dB change is applied; i.e.

$$S/N = C/CSO - 1.7 \text{ dB} \qquad (4)$$

EXPERIMENTAL RESULTS

The measurements of S/N were made using a Tektronix 1450-1 demodulator and a Rohde and Schwartz UPS-F2 S/N meter. The standard method of S/N measurement not only involves the noise weighting network, but also a 10 KHz high pass filter intended to exclude low frequency noise contributions. Since CTB noise falls primarily in this low frequency regime, the most interesting result is obtained with the high pass filter disabled. Thus the data presented here is with this filter disabled, although it is worth mentioning that when only broadband thermal noise was present, the S/N with the high pass filter on measured only 0.2 dB greater than with the filter off.

Figure 2 shows the measured dependence of S/N on C/N. At very high levels of C/N, other noise terms, such as internal phase noise in the measurement system, predominate. Since the S/N deviates by 1 dB from a linear dependence at 64 dB, an absolute, test equipment back to back limit of 70 dB is implied. On the other hand, the region of linear dependence shows

$$S/N = C/N + 1.9 \text{ dB} \qquad (5)$$

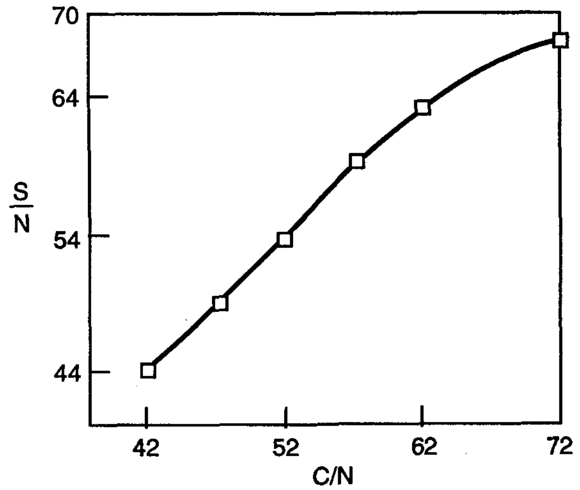


Figure 2. S/N vs C/N.

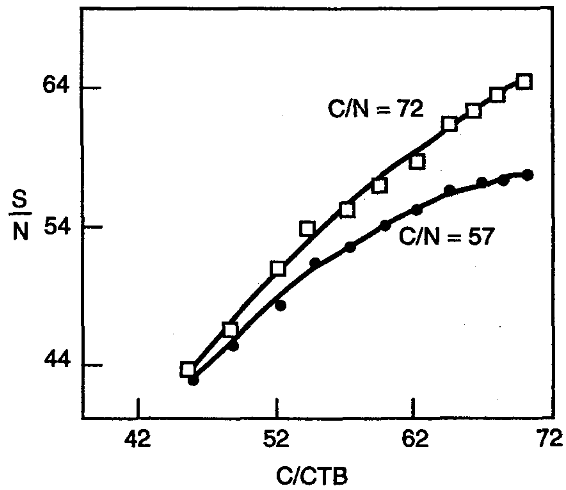


Figure 3. S/N vs C/CTB.

There is a clear 1.3 dB discrepancy compared to the theoretical result stated in equation (1). Whether this discrepancy is due to test equipment calibration error or divergence from ideal VSBAM receiver response is unknown. For this reason, readers are cautioned to "calibrate" their test setup under controlled conditions before applying these results to field measurements.

No attempt was made to vary the system phase noise in a controlled fashion. Nevertheless, this measurement illustrates how the phase noise contribution to S/N, for instance of a typical converter to be supplied to a customer, could be obtained; i.e. the test is performed with only 1 channel on to avoid intermodulation products, and the level is increased to obtain data at very high C/N when the thermal noise contribution is relatively unimportant.

In the next series of tests, summarized by Figure 3, C/CTB was varied in a controlled fashion. A cw Matrix generator provided the multiple frequency tones which resulted in the generation of CTB in a VHF amplifier. When CTB dominates compared to thermal noise, the result is

$$S/N = C/CTB - 2.6 \text{ dB} \qquad (6)$$

This is in fairly good agreement with equation (3) considering the uncertainty in the spectrum analyzer correction factor as well as random measurement errors. The 10 KHz filter of course had a major impact on the measured S/N, but as previously indicated, the results presented are with the filter off. It should also be noted that the CSO was negligible compared to the CTB.

The next series of tests centered on the output of two microwave systems, one utilizing a broadband high power SIBT transmitter[8], and the other a new low cost short range 18 GHz system dubbed the Streetcrosser. When fully loaded with rated channel capacity C/N was the dominant noise contributor but other terms including phase noise entered into limiting the S/N. For the SIBT based system, a measured C/N of 56.4 dB was associated with an S/N of 55.4 dB. The Streetcrosser, depending upon net link loss, showed C/N ranging from 55.9 down to 51.1 dB with corresponding S/N of 54 to 51.8 dB. These C/N and S/N relationships may be contrasted with a recently measured cable system[9] for which a C/N of 45.6 dB was coupled with an S/N reading of 47.3 dB. Another cable system test resulted in C/N of 46.1 and 43.5 dB on two widely separated channels. The corresponding S/N were 47.4 and 44.9 dB respectively.

ALLOWABLE S/N

The minimum C/N required under the FCC regulations is presently 40 dB but will rise to 43 dB by June 1995. The worst C/CTB or C/CSO permitted is 51 dB. By measuring both C/N and S/N, and assuming the relationship given by equation (5), a calculation of the combined S/N contribution of all other sources can be made. For instance, consider the above measured cable system C/N and S/N of 45.6 and 47.3 dB respectively. Application of equation (5) gives S/N due to thermal noise as 47.5 dB. This is only 0.2 higher than the measured total S/N. This implies a S/N contribution of 60.5 dB from whatever is the contributing noise source. If it were C/CSO, equation (4) would predict a value of 62.2 dB. Similarly, from equation (6), C/CTB can be no worse than 63.1 dB. Thus the FCC requirements are easily met. Indeed, the distortion on this cable system was immeasurably small.

Application of equations (5) and (4), together with the 51 dB limitation, permit one to calculate a minimum acceptable S/N corresponding to a measured C/N. The result is given in Table 1. It is of course possible that the FCC requirements are met even though the S/N is slightly below the minimum indicated. For instance converter phase noise could contribute enough to S/N to tip the scale. If that should be the case, a separate measurement of CSO and CTB must be made to assure compliance.

TABLE 1
MINIMUM ACCEPTABLE S/N

C/N	S/N
43	43.6
44	44.3
45	44.9
46	45.5
47	46.1
48	46.6
49	47.0
50	47.4

SUMMARY

It has been shown that many factors influence the reading of S/N, particularly if the 10 KHz high pass filter is turned off during the measurement. In particular, both CTB and CSO will have an effect and therefore a measurement of both C/N and S/N will provide a worst case limit for these distortions without necessitating turning off the channel. It is therefore suggested that the measurement of S/N provides the cable operator with another alternative to assure that the FCC requirements are met and that a high quality signal is being provided to the customers.

REFERENCES

1) Hewlett Packard Spectrum Analysis Application Note 150, pp 31-33, November 1, 1989.
2) R.K. Ward, private communication.
3) T.M. Straus, "Defining S/N", CED, February 1986.
4) NCTA Recommended Practices, 2nd Ed., Appendix C., 1993
5) CCIR Recommendation 567-1, Vol. XII, p 23, Geneva 1982
6) EIA-250-C, Television Transmission Systems Standard.
7) Rezin Pidgeon and Dan Pike, "Oscillator Phase Noise and its Effects in a CATV System", 1988 NCTA Technical Papers.
8) John Hood and Tom Straus, "AML Technology Review", CCTA Technical Papers, 1992.
9) Ted Hartson, private communication.