important in realizing sufficiently small reflection. On the basis of the analysis, the location and the diameter of the post are optimized: reflection below −30dB is realized over a 4% bandwidth. A noniterative procedure is proposed for the general design of the T junction.

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A Theoretical Examination of Tangential Signal to Noise Ratio

Harry E. Green

***Abstract*—The tangential signal to noise ratio (TSNR) continues to be used as a measure of receiver sensitivity. It is found in practice to be remarkably robust against a variety of equipment and observers. Based on the physiology of the eye, an explanation of why this is so is given in this note. The theory leads to a result for TSNR which is very close to the generally agreed value.**

I. Introduction

A measure of receiver system sensitivity which dates from the early days of radar is the tangential signal to noise (TSNR). The term continues to be used in technical data; e.g., diodes used in direct detection receivers are commonly characterized in terms of TSNR in manufacturers' catalogs.

When one looks at an A-scope in which signals in the form of rectangular pulses are present together with noise, the display has something of the appearance shown in Fig. 1. Between the pulses there are bands of light produced by the noise having fuzzy but nonetheless discernible edges. At the position of the pulses the noise is lifted up on a pedestal. When the pulse signal power is adjusted so that the lower edge of the noise trace thereon is level or tangential with the upper edge of the noise-only trace, a TSNR is said to have been achieved.

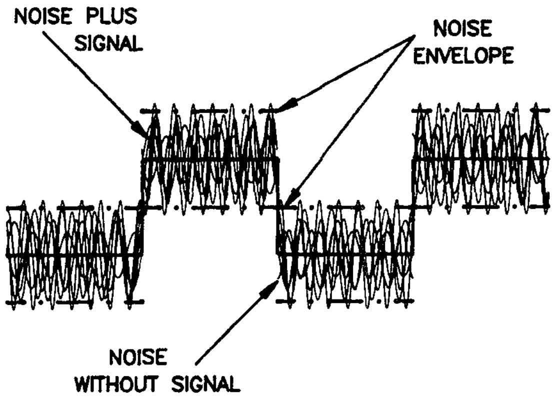

Fig. 1. Signal and noise with a tangential signal to noise ratio.

The advantage of the method, particularly when first devised, is that it can be carried out simply with ready-to-hand apparatus. On the other hand, the very range of possible measuring equipment, the ill-defined experimental conditions, and the physiological variations between observers would lead to an expectation of fairly meaningless results. In practice this turns out not to be the case. Remarkably consistent results are obtained by a range of observers using a variety of equipment.

In this note the reason for this consistency is investigated. Based on measurements made by various observers, it seems generally agreed that TSNR corresponds to a signal to noise ratio of about 8 dB [1]–[3]. A figure very close to this results from the simple theoretical considerations presented herein.

II. Theoretical Development

The human eye has a resolving power of around one minute of arc and the minimum viewing distance which produces no fatigue is about 450 mm [4]. At this range there will therefore be about 8 pixels/mm and a typical laboratory CRO screen will divide vertically into about 1000 pixel width strips (PWS's).

Imagine that we are viewing baseband noise band limited in B. Suppose that we divide each PWS into the vertical stack of pixels suggested in Fig. 2. If as the strobe passes through each PWS light is to be emitted essentially from a single pixel, then we require that the time of passage of the beam be small compared with the correlation time of the noise [5], i.e., $f_s \gg 0.001B$, where f_s is the strobe frequency (sweeps/s). On the other hand, if within a given PWS pixels painted in successive passes are to be statistically independent, the strobe period must be long compared with the correlation time, i.e., $f_s \ll B$. It is obvious that both constraints can be satisfied simultaneously with a large range of strobe frequencies.

The noise is assumed zero mean Gaussian with pdf

$$p(y) = \left(1/\sqrt{2\pi}\sigma\right)\exp-\left(y^2/2\sigma^2\right) \tag{1}$$

where σ is the rms noise voltage. Suppose that we set the vertical sensitivity of the CRO so that σ corresponds to a beam displacement from the axis of N pixels; i.e., each pixel is of height $\Delta = \sigma/N$. Then the probability that the electron beam

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The author is with the Surveillance Research Laboratory, High Frequency Radar Division, Defence Science & Technology Organisation, Department of Defence, P.O. Box 1650, Salisbury, South Australia, 5108, Australia.
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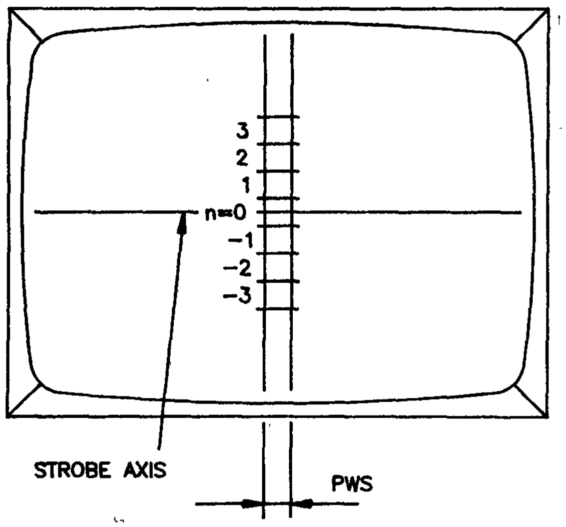

Fig. 2. Diagrammatic representation of a stack of pixels on a cro screen.

will paint the nth pixel in a given PWS is

$$P(n) = \Delta \cdot \rho(n\Delta) \approx (2/5N)\exp - (n^2/2N^2) \qquad (2)$$

and the average number of paints/s will be

$$M(n) = f_s \cdot P(n) = (2f_s/5N)\exp - (n^2/2N^2). \qquad (3)$$

The human eye has an integration time of about 0.06 s [6]. Even allowing for average phosphor persistence, light pulses emitted by a pixel will have a duration much less than this. Hence from each pixel the eye will be presented essentially with pulses of light in a pulse train where there is a pulse once each $\tau_s = (1/f_s)$ s with probability $P(n)$. It is this train which is integrated by the visual system to produce the sensory response. For a pixel to appear not to flicker requires reception on average of several pulses per integration time. A minimum of about 60/s would be typical. For the experiment to work at all this must be the case at least for the zeroth-level pixel ($n = 0$). We thus require

$$2f_s/5N = M_0 \qquad (4)$$

where $M_0 \approx 60$/s or more.

The eye will perceive the edge of the noise trace as being at a level where the picture starts flickering strongly. Typically this will occur when the average interval between pulses becomes comparable to the integration time, say around $M_e \approx 20$/s. The order of the pixel at which this occurs is then easily shown to be

$$n_e = N\sqrt{2\ln(M_0/M_e)} \qquad (5)$$

and the edge appears at a displacement from the axis of the illuminated strip of

$$y_e = n_e\Delta = \sigma\sqrt{2\ln(M_0/M_e)}\,. \qquad (6)$$

Let the system be pulsed with a square waveform (unity mark/space ratio) which is adjusted in amplitude until a TSNR is obtained. Then the trace displacement at the top of the square wave will be $y_s = 2y_e$ and the corresponding signal to noise ratio is

$$S/N|_{\mathrm{dB}} = 9.6 + 10\log_{10}\{\log_{10}(M_0/M_e)\}. \qquad (7)$$

This result is not sensitive to the precise choice of M_0/M_e and a wide range of observers exercising no great care in setting up the experiment can be expected to obtain similar results. Selection of $3 < M_0/M_e < 6$ produces only about a ± 1 dB variation about a mean of 7.5 dB. Experimental evidence has led to a consensus that TSNR corresponds to a signal to noise ratio of 8 dB. This agrees, perhaps surprisingly well, with the outcome of the somewhat ad hoc theory developed in this paper. More to the point, though, is that the theory can explain why this rather ill-defined experiment yields fairly consistent results independently of observer or equipment.

III. Conclusion

A theory based on the physiology of the human eye has been presented which explains the observed consistency of TSNR as a simple means for measuring receiver sensitivity. The theory arrives at the finding that under a wide range of conditions TSNR corresponds to a signal to noise ratio of 7.5 ± 1 dB, a result which compares well with a generally accepted empirical value of 8 dB.

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Cryogenic Performance of a GaAs MMIC Distributed Amplifier

C. R. Moore, W. C. Trimble, M. L. Edwards, and T. R. Sanderson

***Abstract*—A three-stage GaAs MMIC distributed amplifier chip, fabricated to our design, was specially packaged in a two-chip, six-stage amplifier for cryogenic operation from 1 to 10 GHz. When immersed in liquid nitrogen a fourfold reduction in amplifier noise was observed over the 4 GHz to 8 GHz frequency range. This is in agreement with the generally observed scaling with ambient temperature (in Kelvin) for discrete GaAs FET amplifiers.**

I. Introduction

GaAs MMIC technology shows great promise for enhancement of performance of broad-band (multioctave) devices. Integrating this technology with high-temperature superconductor devices will ideally require MMIC operation at cryogenic temperatures. In an effort to evaluate the possibilities and potential difficulties of operating GaAs MMIC devices at these temperatures, an internal research and development program was undertaken.

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The authors are with the Applied Physics Laboratory, Johns Hopkins University, Laurel, MD 20723.
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