# Letters

## Comments on "Some Pitfalls in Millimeter-Wave Noise Measurements Utilizing a Cross-Correlation Receiver"

H. J. SIWERIS, B. SCHIEK, AND K. M. LÜDEKE

In the above paper,[1] Sutherland and van der Ziel analyze some problems encountered during noise measurements at very low temperatures with a cross-correlation receiver. It is shown that, if a hybrid junction is used to split the noise signal from the device under test (DUT) into the two receiver channels, the correlation between the receiver input signals, which contains the useful information, vanishes if the remaining port of the hybrid is resistively terminated at a temperature equal to that of the DUT. The same effect occurs for a pure reactive termination, if the isolators used to decouple the receiver channels are also cooled down to the temperature of the DUT.

These results are absolutely correct but, as will be pointed out in this comment, they could have been obtained in a more straightforward and general way by the application of a very useful theorem, which was published by Bosma [1] already in 1967, but which does not seem to have received the appreciation it deserves. This theorem relates the Nyquist noise waves emanating from the ports of a passive, linear, but not necessarily reciprocal $n$-port at a homogeneous temperature $T$, to the scattering matrix $[S]$ of the network. Explicitly, for the noise waves $X_i$ and $X_j$ at ports $i$ and $j$, respectively, it states that

$$\langle X_i X_j^* \rangle = kT\Delta f N_{ij} \tag{1}$$

with $N_{ij}$ denoting the elements of the noise-distribution matrix

$$[N] = [I] - [S][S]^x \tag{2}$$

where $[I]$ is the identity matrix and $[S]^x$ the complex conjugate of the transposed scattering matrix. Thus, the cross-correlation of the noise waves $X_1$ and $X_2$ of a two-port is given by

$$\langle X_1 X_2^* \rangle = -kT\Delta f (S_{11}S_{21}^* + S_{12}S_{22}^*). \tag{3}$$

It follows from (3) that for all linear passive two-ports at a uniform temperature, the correlation vanishes if $S_{11} = S_{22} = 0$, i.e., if the two-port is perfectly matched. The same holds if the two-port is decoupled, i.e., $S_{12} = S_{21} = 0$.

The two-circuit configuration mentioned above, namely a hybrid with the DUT and a resistive termination in one case, and with the DUT, a reactive termination and two isolators in the other, are matched linear passive two-ports which, since all components are cooled, are at a homogeneous temperature. Thus, according to Bosma's theorem, the correlation of the noise waves must be zero.

However, the theorem no longer holds if the two-port is not at a uniform temperature. Consequently, Sutherland and van der Ziel obtain a correlation for a hybrid with a cold DUT and reactive termination, but uncooled isolators.

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[1]A. D. Sutherland and A. van der Ziel, *IEEE Trans. Microwave Theory Tech.*, vol. MTT-30, no. 5, pp. 715–718, May 1982.

### *Reply*[2] *by A. D. Sutherland and A. van der Ziel*[3]

We wish to thank H. J. Siweris, B. Schiek, and K. M. Lüdeke for calling our attention to Bosma's work, of which we were unaware. On checking that reference we found it to be a lengthy tome indeed, consisting of some 190 pages. It is packed with matrix equations which do not readily reveal their meaning upon first reading. In fact, it appears to be unabridged version of Bosma's Ph.D. dissertation. Tucked away as it is within those 190 pages, it is not surprising that the theorem cited by Siweris *et al.* has "not received the appreciation it deserves."

Although the treatment in our paper focused exclusively upon the noise problems introduced by utilizing a hybrid junction as a power divider, and therefore is not as general as the theorem cited due to Bosma, there are nonetheless advantages to the approach followed by us, i.e., a) the use of signal flow graphs, as used by us, avoids the need for matrix algebra, b) the *sources* of the noise emanating from the hybrid are readily identified, and c) there is no need to assume a homogeneous temperature for those noise sources, as does the theorem cited.

#### References

[1] H. Bosma, "On the theory of linear noisy systems," *Philips Res. Rep. Suppl.*, 1967, no. 10.

[2]Manuscript received December 2, 1982.

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## Comments on "The Dynamical Behavior of a Single-Mode Optical Fiber Strain Gage"

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### I. Introduction

In the above paper,[1] Martinelli [1] presents a very interesting and useful comparison between the dynamical response of a single-mode fiber optic and resistive strain gages in the frequency range 25–250 Hz. As shown by the author, the frequency spectrum of the phase change signal and the resistive strain gage signal are in very good agreement.

It is the purpose of the present letter to discuss two points which, in the opinion of the writers, need further clarification: a) the validity of the mechanical analysis with special reference to the single-mode approximation; and b) the effect of an axial force which may be present if the mechanical boundary conditions restrain the axial displacements of the structural element.

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[1]M. Martinelli, *IEEE Trans. Microwave Theory Tech.*, vol. MTT-30, no. 4, pp. 512–516, Apr. 1982.