Correction to "Microstrip Discontinuity Capacitances for Right-Angle Bends, T Junctions, and Crossings"

P. SILVESTER AND P. BENEDEK

In the above paper,[1] due to a programming error, Fig. 7 on page 345 for bend capacitance is incorrect and should appear as shown in the following. The other curves are not affected. Stephenson and Easter's [1] measured result, marked on the figure, is $C_{\text{bend}}/W = 159.79 \pm 6.37$ pF/m (for a 50-Ω microstrip line on $\epsilon_r = 9.9$ substrate, $w/h = 1$). This compares well with the calculated $C_{\text{bend}}/W = 155.5$ pF/m.

For $w/h > 1$, the bend capacitance was also checked using

$$C_{\text{bend}} = C_{\text{total}} - 2^*C_{OC} - 2^*C_l \tag{1}$$

with reference to Fig. 1 on page 342.[1] C_{total} was calculated using PARCAP [2], a new program for calculating the capacitance of a planar N-conductor system. The agreement was to better than 5 percent.

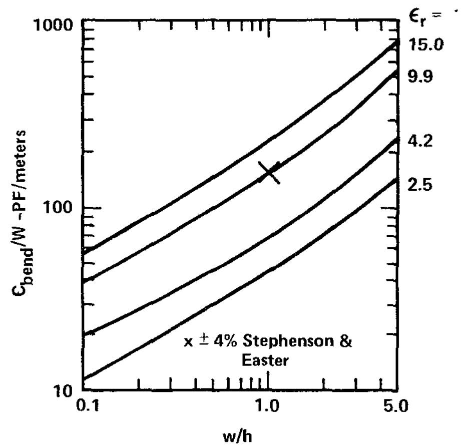

Fig. 7. Microstrip bend capacitance, normalized to strip width, as a function of width-to-height ratio and substrate permittivity.

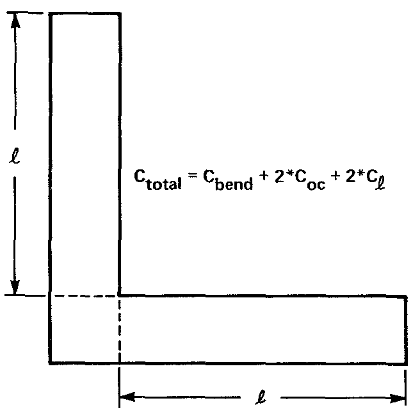

Fig. 1. Microstrip bend ($l \gg h$).

REFERENCES

[1] I. M. Stephenson and B. Easter, "Resonant techniques for establishing the equivalent circuits of small discontinuities in microstrip," *Electron. Lett.*, vol. 7, pp. 582–584, Sept. 23, 1971.
[2] P. Benedek, "Capacitances of a planar multiconductor configuration on a dielectric substrate by a mixed-order finite-element method," in *Proc. IEEE Int. Symp. Circuits and Systems*, to be published.

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[1] P. Silvester and P. Benedek, *IEEE Trans. Microwave Theory Tech.*, vol. MTT-21, pp. 341–346, May 1973.

Comments on "An S-Band Radiometer Design with High Absolute Precision"

NIGEL J. KEEN

In the above paper,[1] a highly stable noise-balancing radiometer at 2.7 GHz for satellite applications, with a claimed absolute measurement precision of 0.1 K, is reported. The purpose of this letter is to indicate a source of calibration error which can be seriously underestimated.

The radiometer of Hardy *et al.* has a bidirectional coupler, which therefore injects $(T_0 - T_c)$ out of the antenna, as well as into the receiver. Although $(T_0 - T_c)$ is the correct noise level to balance the receiver with the antenna looking at free space, a voltage reflection coefficient Γ in front of the antenna results in the injected noise being modified by the feedback loop. For a narrow-band system ($l \cdot \Delta f \ll$ velocity of propagation) with $|\Gamma| \ll 1$, the new level of injected noise is

$$(T_0 - T_c) \cdot [1 + 2\,|\,\Gamma\,|\cos(4\pi l/\lambda_0)]$$

to a very close approximation, where l is the probe-cryoload separation. Hardy [1] quotes $|\Gamma| = 0.01$ for the cryoload used, and $(T_0 - T_c) \approx 220$ K. Hence the calibration error could have maximum possible values of ±4.4 K, although for the radiometer of Hardy *et al.*, $l \cdot \Delta f = 0.56 \times$ velocity of propagation, so that the maximum noise error is reduced by

$$\frac{\sin 1.12\pi}{1.12\pi} \approx 0.1.$$

This reduces the maximum possible error to ±0.44 K. The preceding considerations are for a radiometer with single input; for reception of circular polarization, the situation is improved since circular polarization directions are reversed on reflection. Ideally, this should reduce the effect to a negligible magnitude; experimentally, the cross polarization of the cryogenic load and the limited bandwidth of the quarter-wave plate will somewhat limit this improvement. The preceding expression is, of course, a simplification, since the horn and transducer have significant fixed reflection coefficients;

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[1] W. N. Hardy, K. W. Gray, and A. W. Love, *IEEE Trans. Microwave Theory Tech.*, vol. MTT-22, pp. 382–390, Apr. 1974.

Γ is therefore the complex difference between reflection coefficients of cryoload and horn, etc.

The problem of coherent multiple reflections on low-noise antennas was predicted by Silver [2], and is familiar to radioastronomers [3]. Since such reflections result from the addition of complex-voltage reflection coefficients, considerable attention has to be paid to such problems as coupler directivity, circulator isolation, and inherently well-matched waveguide sections and antennas. In the case of the radiometer of Hardy *et al.* a −20-dB cross coupler should have at least 20 dB of directivity, or a waveguide isolator should have at least 20 dB of isolation. They would, of course, have to be integrated into the temperature-controlled enclosure, and would somewhat increase the mass. Another possibility would be multiprobe coupling into the waveguide, or noise injection in the coaxial line, following an input isolator. In any event, caution is necessary when employing low-directivity noise injection in sensitive radiometers.

REFERENCES

[1] W. N. Hardy, "Precision temperature reference for microwave radiometry," *IEEE Trans. Microwave Theory Tech.* (Short Papers), vol. MTT-21, pp. 149–150, Mar. 1973

[2] S. Silver, Ed., "Microwave antenna theory and design," (M.I.T. Radiation Lab. Series 12). Cambridge, Mass.: M.I.T. Press, 1948, p. 157.

[3] N. J. Keen, "Broad-band microwave measurements of receiver noise temperature and antenna temperature," in *1973 Proc. West German Int. Sci. Radio Union*, pp. 483–495 (Kleinheubacher Berichte, Band 17; FTZ Darmstadt).

Computer Program Descriptions

The ZEPLS Program for Solving Characteristic Equations of Electromagnetic Structures

PURPOSE: The program calculates the zeros of an analytic function in particular zones of the complex plane, inside the region where the function is holomorphic and single valued.

LANGUAGE: Fortran V for the Univac 1110 computer.

AUTHORS: P. Lampariello and R. Sorrentino, Istituto di Elettronica, Facoltà di Ingegneria, Università di Roma, 00184 Rome, Italy.

AVAILABILITY: ASIS/NAPS Document No. 02551.

DESCRIPTION: Many electromagnetic problems concerning either open or closed structures lead to the equation

$$f(z) = 0 \qquad (1)$$

where z is a complex variable and $f(z)$ an analytic function, generally many valued, sometimes having polar singularities.

The program presented in this description is based on the well-known formula which gives the Nth-order moments of the n_z zeros of a holomorphic function within a closed region D

$$s_N = \sum_{l=1}^{n_z} z_l^N = \frac{1}{2\pi j}\int_{+\partial D} z^N \frac{f'(z)}{f(z)}\, dz, \qquad \text{if } f(z) \neq 0,\ \forall\, z \in \partial D. \qquad (2)$$

Although the use of rectangles would appear to be a more logical choice, for better accuracy the most suitable shape of D was found to be a circle, which can be deprived of some internal circles. Such circles allow the exclusion of regions where $f(z)$ is not single-valued and/or is not holomorphic. The integral in (2) has therefore to be calculated as the sum of the integrals along the n_c circumferences constituting the contour of D. Each integral has been calculated numerically by means of the formula of Delves and Lyness [1]. Once the moments s_N are known, the zeros $z_l (l = 1,2,\cdots, n_z)$ can be calculated by solving an algebraic equation of degree n_z.

During execution the program goes through the following steps:

1) The examined function, which has to be defined through a specific routine, is evaluated along the n_c circumferences in the n_{si} points chosen for the ith circumference. It is possible that some zeros (in number of $n_{zk} \geq 0$) may be previously known and given among the input variables. In any case, the number n_{zu} of unknown zeros must be less than 5. During this first step, program execution is interrupted and returned to the calling program in the following cases: a) the number of unknown zeros is either $=0$ or ≥ 5; in the latter case it is necessary to reduce the size of D; b) the variation of the function is too rapid between consecutive points along the ith circumference; in such a case it becomes impossible to determine the number n_z of the zeros in D and it is necessary to increase n_{si}; c) either a zero or a pole is recognized along one of the circumferences.

2) At the second step, the integrals which give the moments s_N are evaluated.

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