Letters

Comments on "p-i-n Diode Attenuator with Small Phase Shift"

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The experimental result of the paper[1] in question showed that the spurious phase shift of a 9 GHz microstrip p-i-n diode attenuator could be reduced to 0.75°/dB attenuation at 20 dB attenuation or 0.17°/dB attenuation if the maximum attenuation was limited to 15 dB. The authors concluded that the result was better than that of previously published p-i-n diode attenuators.

We would like to point out that a similar work on p-i-n diode attenuator was done at the University of New South Wales in 1985. Apart from the study of a single p-i-n diode, two, three, and four p-i-n diodes connected in cascade were studied. The diode spacing was varied and its effect on the spurious phase shift was examined. The theoretical results were published in [1] and [2], where we concluded that a suitable diode spacing, which depends on the desired maximum attenuation, should be used in order to minimize the spurious phase shift.

For example, in the case of two diodes, if a diode spacing of 0.7λ is used, the phase error would be below 4.5° for a maximum attenuation of 33 dB. This means a spurious phase shift of 0.14°/dB attenuation at 33 dB. In the theoretical calculation, the p-i-n diode (HP 5082-3041) was replaced by the equivalent circuit model, and *ABCD* matrices for each subsection were used to compute the transmission coefficient and hence the spurious phase shift of the attenuator. An *X*-band stripline p-i-n diode attenuator with two p-i-n diodes separated by 0.7λ and consisting of the dc bias circuit (RF choke/dc block) and matching network was actually built and tested. The experimental result is shown here in Fig. 1.

The insertion loss of the attenuator is 1.5 dB and the phase shift at this state is used as the reference for measuring the spurious phase shift. The experimental curve follows the same shape as the theoretical curve, and it is believed that the theoretical curve for the spurious phase shift of the microstrip p-i-n diode attenuator studied by Baeten *et al.* should have the same shape as well. Instead, their experimental curve is flattened at low attenuation level. The discrepancy between our theoretical curve and experimental curve is mostly due to the disturbance of the dc bias circuit and matching network, which are not included in the calculation. Our experimental result indicates a 0.2°/dB attenuation for a range of 25 dB attenuation. If the maximum attenuation is 30 dB, the spurious phase shift becomes 0.32°/dB attenuation. For the microstrip attenuator described in the paper in question, two stages of attenuators in cascade with an isolator between each stage should be used to obtain the same level of attenuation. This means 0.34°/dB attenuation at 30 dB attenuation, and yet the result is obtained from an attenuator without any biasing and matching networks.

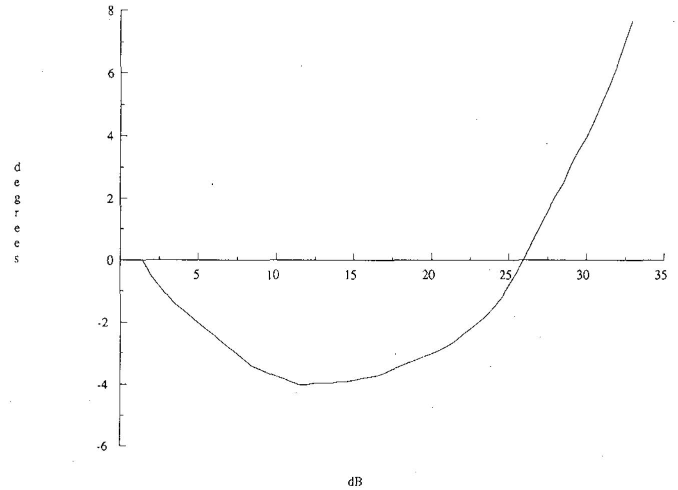

Fig. 1. Spurious phase shift introduced by the stripline p-i-n diode attenuator: experimental result.

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[1] R. J. Baeten, T. Koryu Ishii, and J. S. Hyde, *IEEE Trans. Microwave Theory Tech.*, vol. 36, pp. 789–791, Apr. 1988.

Reply[2] by Robert J. Baeten, T. Koryu Ishii, and James S. Hyde[3]

1) Evidently both our literature search by computer at the time of writing and the reviewers' literature search missed Lo and Vu's work. Their early work should be congratulated. Perhaps, an apology for not citing their work in our paper may be due.

2) While their attenuator is a two p-i-n diode attenuator, ours is a single p-i-n diode. These attenuators are in different categories and thus cannot be compared in a meaningful way.

3) Their design and performance may be frequency sensitive [3]. Frequency is not specified here in Fig. 1.

4) The spurious phase shift of our single p-i-n diode attenuator at 15 dB attenuation is 2.5°. That of Lo and Vu's two p-i-n diode attenuation at 15 dB is 3.8°.

5) The design and performance of both designs vary because of the different components and substrates used.

6) Both works suggest the possibility of zero phase shift for a spot frequency fixed attenuator, utilizing the zero crossing point.

References

[1] T. B. Vu and K. W. Lo, "Minimization of phase error in digitally controlled attenuator," *Electron. Lett.*, vol. 21, no. 22, pp. 921–922, Sept. 1985.
[2] T. B. Vu and K. W. Lo, "A microprocessor-controlled *X*-band attenuator," in *IREECON Dig.* (Melbourne) 1985, pp. 818–821.
[3] R. J. Baeten, "Analysis and characterization of microstrip PIN diode attenuators," M.S. thesis, Marquette University, Milwaukee, WI, May 1986.

[2] Manuscript received July 14, 1988.
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