Time-Delay Phase Shifter Controlled by Piezoelectric Transducer on Coplanar Waveguide

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***Abstract*—A time-delay phase shifter controlled by piezoelectric transducer (PET) is realized on a coplanar waveguide (CPW). The effective dielectric constant, propagation constant, etc., of the CPW are varied by the perturbation controlled by a PET. Compared to the perturbation on a microstrip line, published previously, the new CPW device provides 50% more phase shift.**

***Index Terms*—Coplanar waveguide, piezoelectric transducer (PET), phase shifter.**

I. Introduction

A PHASE SHIFTER is one of many important components in microwave and millimeter wave systems. It is commonly used for beam steering and beam forming for antenna arrays, timing recovery circuits, phase equalizers, etc. Therefore, it naturally requires wideband and low loss characteristics.

Most of published results using MMIC, ferroelectric, and solid state phase shifters show narrow bandwidths, high losses, or small phase shifts [1]. Recently, a new phase shifter using a piezoelectric transducer (PET)-controlled dielectric layer to perturb the electromagnetic fields of a microstrip line was published [1], [2]. By the fact that the characteristic impedance of the line is only slightly affected by perturbation, this phase shifter could be used in very wideband applications [2].

This letter reports that an increased phase shift may be achieved by using a PET-controlled perturbation on a coplanar waveguide (CPW) rather than on microstrip. The electromagnetic fields on a CPW are less confined than those on microstrip lines, thereby making them more sensitive to perturbers placed above the guide [3]. Relative phase shifts on microstrip line and CPW of the same length are compared.

II. Design and Experiments

A PET–controlled dielectric layer is used to perturb the electromagnetic fields of CPW. A perturber attached to a PET plate is deflected in the up/down direction under an external voltage, as shown in Fig. 1. The air gap between the CPW and the perturber is changed. This varies the effective dielectric constant of the CPW and causes a different phase shift. The PET is composed of lead zirconate titanate and has dimensions of 2.75 in (length)$\times$1.25 in (width)$\times$0.02 in (thickness).

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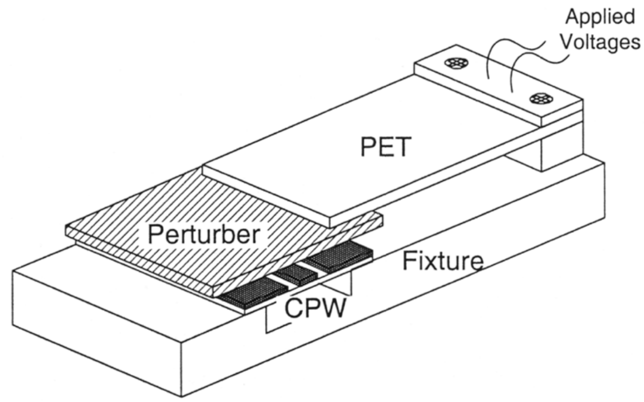

Fig. 1. Configuration of a phase shifter using dielectric perturbation controlled by a PET on CPW.

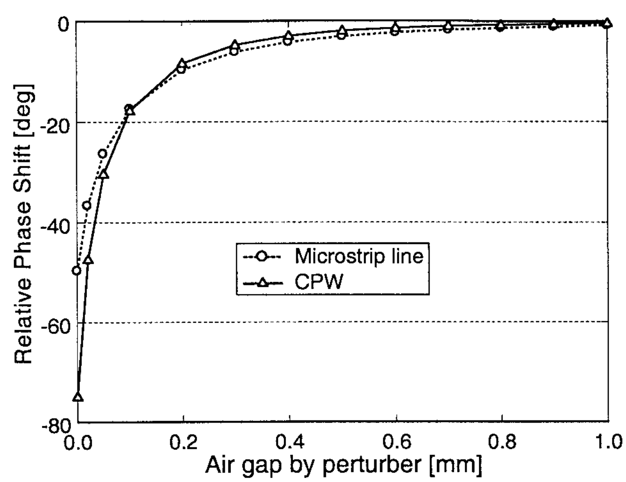

Fig. 2. Simulated relative phase shift as a function of the air gap between the transmission line (CPW and microstrip) and perturber at 5 GHz.

The substrate used for CPW and microstrip is RT/Duroid 6010.5 with a dielectric constant of 10.5 and a height of 25 mil. The CPW has a width of 16.4 mil, a gap of 10 mil, and a length of 2.9 in. The same length is used in microstrip line for comparison and the line width of microstrip is 22 mil. The characteristic impedances are 54 Ω and 52 Ω (for microstrip line and CPW). The dielectric perturber used has a dielectric constant of 6.15, a height of 50 mil, and a length of 1 in.

A commonly available software, PCAAMT [4], which uses a full-wave spectral domain moment method, is used to calculate the effective dielectric constant of the multilayered transmission line using CPW and microstrip. Fig. 2 shows the simulated results in both CPW and microstrip line. The phase shift in CPW is 50% larger than that in microstrip line at maximum perturbation.

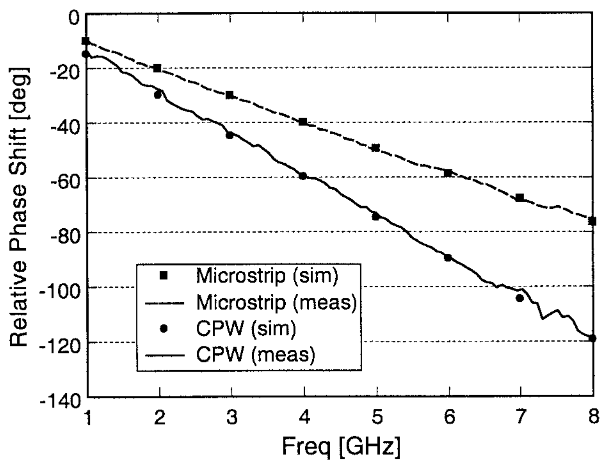

Fig. 3. Phase difference in microstrip line and CPW (at maximum perturbation). Both simulated and measured results are shown.

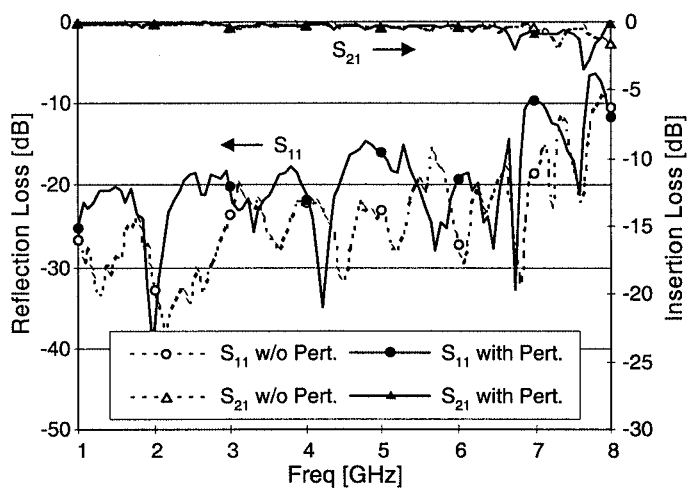

Fig. 4. S-parameters of the CPW phase shifter with the maximum perturbation and without perturbation.

An Agilent 8510C network analyzer is used to measure the phase shift and S-parameters, and thru-reflect-line (TRL) calibration is used to remove the effect of the coaxial connectors to the CPW/microstrip line transitions. Fig. 3 shows the measured and simulated relative phase shifts, which are the phase difference between the perturbed line and the unperturbed CPW or microstrip line. The maximum phase shifts along the CPW and microstrip line are 75° and 50°, respectively. The phase shift of CPW is 50% larger than that of microstrip line.

Fig. 4 shows the insertion loss (S_{21}) and return loss (S_{11}) for the CPW line with and without perturbation. The return loss and insertion loss are better than 10 dB and 1 dB, respectively, up to 6.5 GHz. The characteristic impedances of the line, which are calculated using the spectral-domain analysis of the moment method, change from 54 to 48 Ω in microstrip line and 52 to 43 Ω in CPW by perturbation. As the characteristic impedance of the line is relatively insensitive to the air-gap variation, the S-parameters doesn't change much by perturbation.

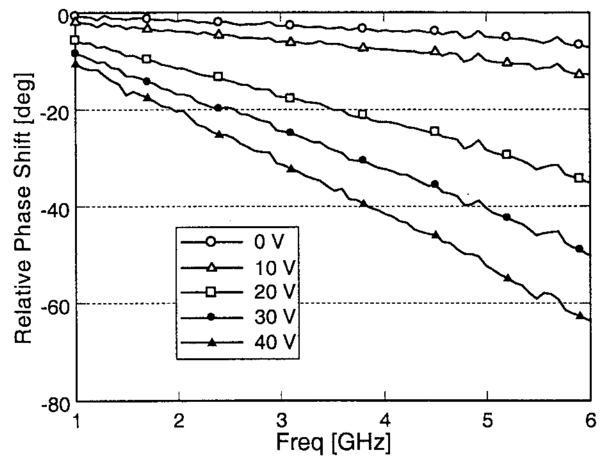

Fig. 5. Relative phase shift versus frequency at different PET voltages.

Fig. 5 shows the relative phase shifts with respect to the unperturbed case for applied voltages from 0 to 40 V. The amount of phase shift depends on the voltage-controlled PET deflection. A nonzero phase shift at 0 V is due to the initial alignment of PET. A larger phase shift can be achieved by a perturber with a higher dielectric constant not larger than that of a substrate.

III. Conclusion

A phase shifter using perturbed CPW controlled by PET has been realized and compared with that using microstrip line. The simulated results agreed very well with the measured data. The phase shift of CPW was 50% larger than that of microstrip, and the insertion loss was less than 1 dB.

Acknowledgment

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