Novel CPW-based Phase Shifter for LMCS/LMDS Applications

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ABSTRACT

This paper presents a novel application coplanar waveguide (CPW) series stubs. A 1-bit CPW phase shifter for LMCS applications (28 GHz) is designed. Switching between two filters with appropriate phase characteristics allows the introduction of a phase shift in the signal. This low loss and compact novel phase shifter easily accommodates the required 2 GHz bandwidth of LMCS with insertion losses of less than 0.8 dB. Being more compact than the traditional delay line, it is an attractive alternative o existing approaches, especially if combinged with potential micromachined (MEMS) switches.

INTRODUCTION

Phase shifters are vital components for steering an antenna beam without moving parts. The explosion of public demand for high bandwidth, true multimedia applications calls for solutions such as the Local Multipoint Communication System (LMCS). Providing LMCS through a directive antenna that has no moving parts significantly improves the flexibility and reliability of the system.

Recent advances in the use of CPW shunt stubs [l] allow new compact topologies to be built and applied to phase shifting. This l-bit phase shifter, with 180° phase difference between the two states, was synthesized with low-pass and a high-pass filters and two switching elements. The lumped element version of this l-bit phase shifter has been designed for operation at 28 GHz and is shown in Figure la.

There are several advantages of a CPW phase shifter using stubs filters. Lumped elements are not readily available for applications at 28 GHz due to unacceptable parasitic effects. The switched-line l-bit phase shifter occupies 55% more area than the CPW version presented here. This advantage of reduced space was obtained without much consideration given to the issue of real estate. Also, the symmetry that is realizable with the series and shunt stubs allows reduction of spurious modes with a smaller number of air bridges.

CHARACTERIZATION OF THE KEY ELEMENTS

The novelty of this phase shifter resides in the use of CPW filters to introduce the phase shift. To realize this phase shifter, a lumped element version was designed. A phase characteristic of f_1 = -90° for the LPF (upper branch) and f_2 = +90° for the HPF (lower branch) was implemented to get the required 180 degrees difference ($f_2 - f_1$ = 180°). This has been realized with capacitor and inductor values of 0.17 pF and 0.19 nH. The topology and simulation results are presented in Figure 1. A Tee topology has been chosen as it is simpler to realize in CPW. It should be noted that the simulation results for the lumped element include 45 degree ideal transmission lines at the input and the output to allow proper comparison with the CPW realization.

To realize the CPW version of the filters, it is necessary to replace the lumped reactances by their distributed equivalent. However, the direct relation is valid for only a given frequency (28 GHz in this application). 705 *m m* and 493 *mm* open-circuited stubs are required to obtain the necessary series and shunt capacitor, respectively. For the inductors, series and shunt element can be realized with 535 *mm* and 246 *mm* short-circuited stubs, respectively. Compensation for bends and discontinuities are included in these lengths. The CPW realization is presented in Figure 1 and the simulation results are in Figure 3, along with the lumped elements results. The results show that the distributed element and lumped elements phase shifters behave similarly.

FABRICATION AND MEASUREMENTS

The circuits were fabricated at the Communication Research Centre's facilities on a three inch, high resistivity silicon wafer (10 - 100 kΩ-cm, e_r = 11.6, tan$d$ = 0.0014, thickness = 250*mm)*. A 0.5 *mm* layer of gold is deposited on a 3000 Å layer of titanium-tungsten to pattern the filters. Air bridges are used to cancel the spurious modes that could be generated at the discontinuities.
The main 50 ohms CPW transmission lines are 180 microns wide with centre conductors of 83 *m*m. The dimensions for the stubs are give in the format: total width - centre conductor width - length. The dimensions for the elements are as following: HPF series stubs 15 *m*m-5 *m*m-705 *m*m; HPF shunt stub 54 *m*m-5 *m*m-252 *m*m; LPF series stubs 44 *m*m-21 *m*m-539 *m*m and the LPF shunt stub are 53 *m*m-12 *m*m-488 *m*m.

RESULTS

The novel CPW filters show good agreement with the simulation (Figure 3). It should be noted that the simulated losses do not include metal loss (which are approximately 0.5 dB). The LPF shows an insertion loss of 1.7 dB for a phase of 174°. The HPF shows 5.2 dB of losses and a phase of 22°.

The losses were greater than the simulation results since the simulation did not include conductor losses. The higher insertion losses for the HPF (compared to the LPF) was also expected due to the different nature of the series stubs. Series stubs alter the characteristic impedance of the section of transmission line in which they are located. This change in characteristic impedance therefore affects the return loss of the line.

In the case of series inductive stubs, the effect of the modified characteristic impedance is negligeable because, at resonance, the stub produces a series open circuit in the line and the reflection caused by this dominates the response. For the case of series capacitive stubs, however, the open circuit stubs produces a series short circuit in the line allowing the modified characteristic impedance to perturb the response.

Thus, even though the phase shifter losses are greater then expected, they can be reduced significantly. Reduction of the width of the series capacitive stubs would reduce the disturbances of the supporting CPW line. A different choice of lumped elements value can also reduce the losses (typically from 0.8 dB to 0.3 dB).

CONCLUSION

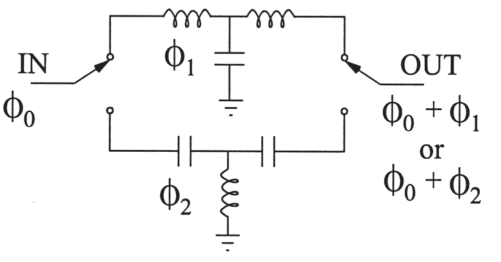
A novel CPW phase shifter for LMCS/LMDS applications has been proposed and implemented at 28 GHz. Good agreement was shown between the simulated and the experimental results which demonstrate a predictive behaviour of the device. It can easily be implemented with PIN diodes and offers potential for uses with the new MEMS technology. Insertion loss and phase difference characteristics can be improved by modification of the starting lumped elements values and the dimension of the stubs.

BIBLIOGRAPHY

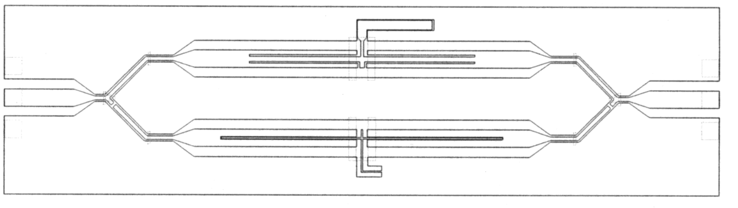
[l] K. Hettak, N. Dib, A. Omar, G. Deslisle, M. Stubbs, S. Toutain, "A useful new class of miniature CPW shunt stubs and its impact on millimeter-wave integrated circuits", in IEEE Trans. Microwave Theory Tech., vol.47, no. 12, pp. 2340-2349, Dec 1999.

[2] Pozar, David M., Microwave Engineering 2nd edition, John Wiley & Sons inc., New York, 1998, 716 p.

[3] Picard, Stéphan, 'Phase Shifter at LMCS Frequencies Using Micromachined Switches", master's degree thesis, to be published.

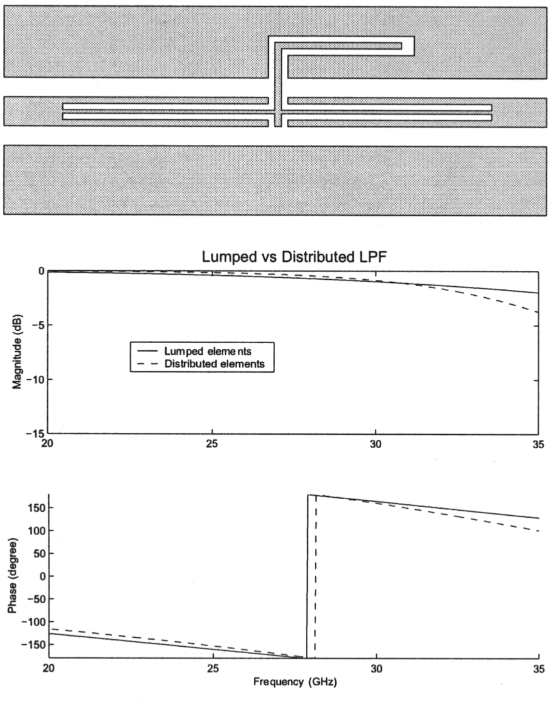


(a) Typical low-pass/high-pass phase shifter.

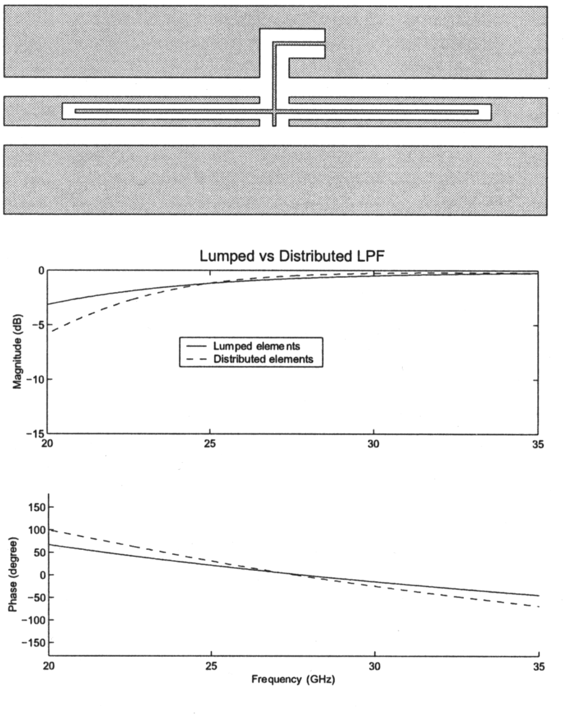


(b) CPW realization.

FIGURE 1. l-bit CPW phase shifter at 28 GHz.

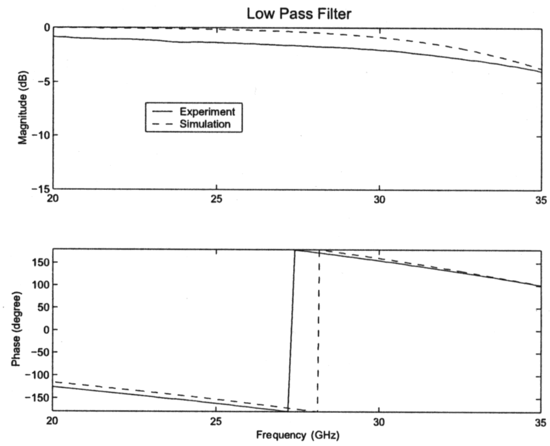


(a) Low pass filter.

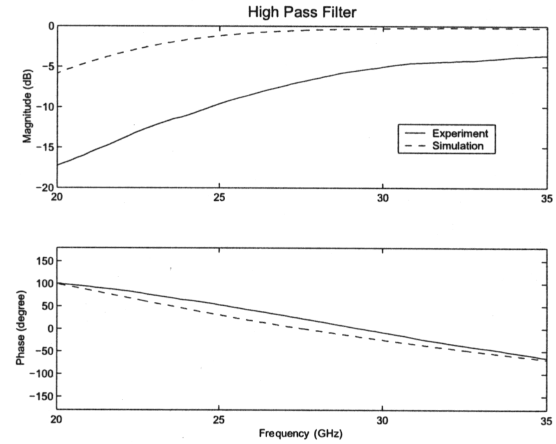


(b) High pass filter.

FIGURE 2. Key element of the CPW Phase Shifters.

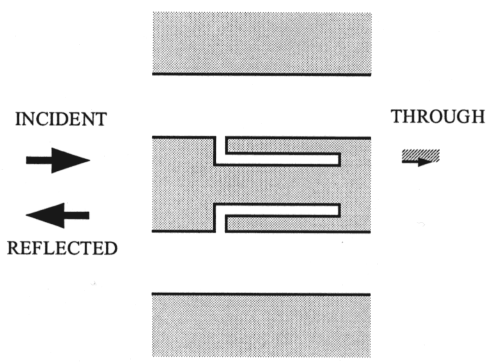


(a) Low pass filter.

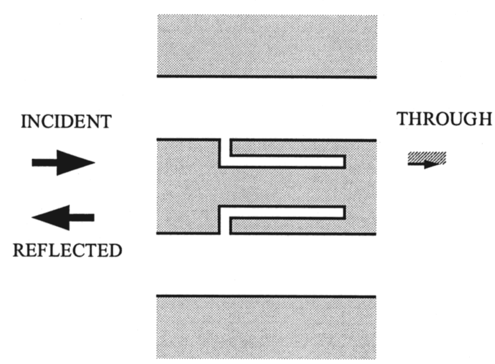


(b) High pass filter.

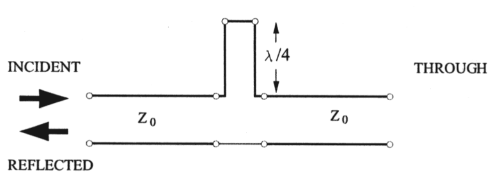
FIGURE 3. Measurements and simulation of the CPW phase shifter.



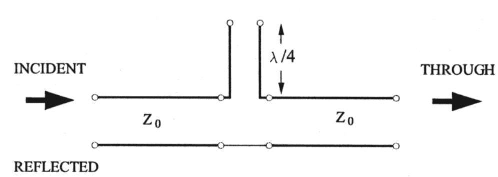
(a) Practical short circuit stub.



(b) Practical open circuit stub.



(c) Ideal short circuit stub.



(d) Ideal open circuit stub.

FIGURE 4. Quality factor difference for the CPW series stubs.