A 300 GHz 45º Hybrid Coupler for THz Wireless Communications using Subharmonic Mixers

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***Abstract*—A 300 GHz hybrid coupler with 45º phase difference at its output ports for subharmonic mixers in a THz transceiver is presented. It consists of a branch-line coupler with a stub loaded phase shifter fabricated with ±10 microns tolerances. The magnitude and phase imbalances were measured to be less than 0.5dB and 3º respectively from 285 to 325 GHz.**

I. Introduction

Quadrature hybrids are commonly employed in balanced and sideband-separating mixers [1-2], balanced amplifiers and power dividers and combiners for wireless applications. At submillimeter wave frequencies, the output power from signal sources of a local oscillator is generally low and not readily available. Hence, one of the ways to develop a 600 GHz transceiver with phase quadrature topology is to operate a local oscillator at a lower frequency of 300 GHz with subharmonic mixers. Here, the design of a 45º waveguide hybrid is used to divide the LO signal equally in magnitude while achieving a 45° phase difference at its direct and coupled ports. These signals can be used to drive the in-phase and quadrature-phase subharmonic mixers for a THz wireless transceiver.

II. Design

The design of the waveguide hybrid can be categorized into two sections: the 90° coupler and the stub-loaded 45º phase shifter [3]. Sobis [4] has designed similar hybrid for the 170 GHz band. Split E-plane type of construction was chosen here due to the simplicity of fabrication and good performance of the waveguide against imperfect contacts between the two halves even at 300 GHz.

In order to characterize the hybrid using the standard waveguide WR03 flange and for ease of fabrication, the height of the waveguide was maintained at a height of 432 μm and a width of 864 μm. The branch-line coupler which is suitable for split-block type of construction was chosen. Typically, smaller tolerances are expected at submillimeter waves and hence fabrication with CNC machining is non-trivial. Our challenge was to design with comparatively poorer tolerances of ±10 microns. This is in contrast to the better tolerances available to others [1, 2, 4]. The four branch lines were kept at the same height with equal width and separation between two branches as shown in Fig. 1. These three parameters were optimized for magnitude and phase imbalances, return losses and isolation in the Ansoft HFSS electromagnetic simulator which is based on finite elements method. The stub-loaded phase shifter was then designed separately before combining with the coupler and fine-tuned in a full 3D electromagnetic simulation within 10 microns tolerances.

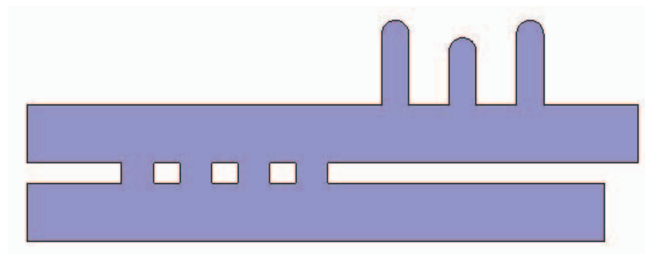

Fig. 1. Schematic of coupler and stub-loaded phase shifter..

The design was fabricated on aluminium blocks using CNC machining and gold-plated to a thickness of approximately 1 μm. The combined coupler and phase shifter structure for the waveguide hybrid measured only 4.53 mm x 1.52 mm. However, long waveguide sections and bends were added within the design in order to allow for characterization with a standard waveguide WR03 interface. This led to the final layout to be much larger, with dimensions of 60 mm x 50 mm as portrayed in Fig. 2.

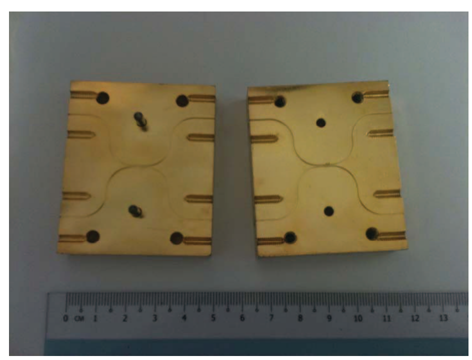

Fig. 2. Photograph of fabricated hybrid coupler in split E-plane construction.

III. Results

The hybrid coupler was measured with an Agilent N5245A PNA-X network analyzer connected to the WR03 OML millimeter wave VNA extenders via the N5260A millimeter head controller. Fig. 3 and 4 show the measured as well as the simulated results obtained from computer simulations using HFSS . It is evident that the measured and simulated results agree reasonably well. The phase imbalance is less than 3º at 45 degrees across the 40 GHz bandwidth from 285 to 325 GHz while the amplitude imbalance is about 0.5dB.

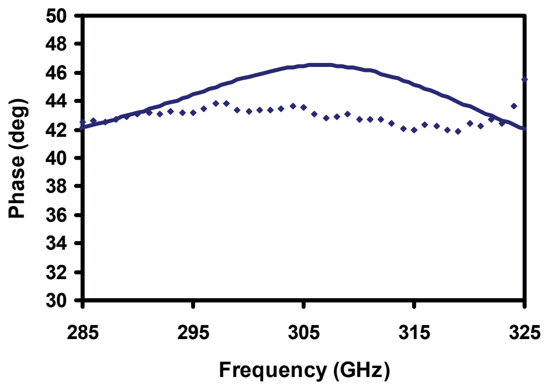

Fig. 3. Simulated (solid) and measured (dot) phase imbalance of the hybrid.

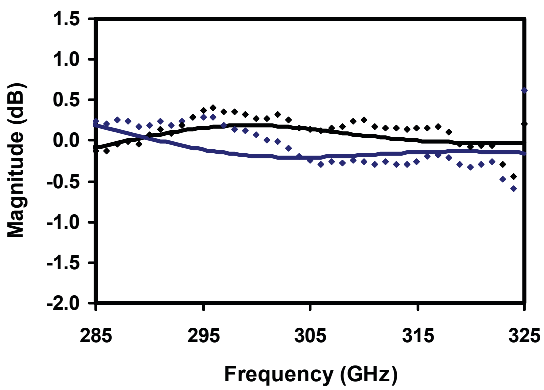

Fig. 4. Simulated (solid) and measured (dot) magnitude imbalance .

Our measured and simulation input return losses and isolation were better than -15dB. During the measurement process, it should be noted that extra care should be taken to ensure that the coupler was aligned and tightened properly with the WR03 flange of the VNA extenders so as to achieve correct measurement results.

IV. Conclusion

A 300 GHz 45° hybrid coupler with magnitude and phase imbalances of less than 0.5dB and 3° respectively has been fabricated and tested. The coupler was kept to the WR03 dimensions for ease of fabrication as well as to allow for characterization using available equipment. The design was fabricated with ± 10 microns tolerances as opposed to others with better fabrication facility.

This 300 GHz hybrid coupler can be integrated with two subharmonic mixers in a wireless transceiver.

References

[1] S. M. X. Claude, C. T. Cunningham, A. R. Kerr and S. K. Pan, “Design of a sideband-separating balanced SIS mixer based on waveguide hybrids,” *ALMA Memo 316*, Sept. 20, 2000.

[2] F. P. Mena, J. Kooi, A. M. Baryshev, etal, “Design of a side-band-separating heterodyne mixer for band 9 of ALMA,” *Proc. 16th Int. Symp. Space Terahertz Technology*, 2005, pp. 191-194.

[3] J. Dittloff, F. Arndt, and D. Grauerholz, “Optimum design of waveguide E-plane stub-loaded phase shifters,” *IEEE Trans. Microwave Theory Tech.*, vol. 36, no. 3, pp. 582-587, March 1988.

[4] P. J, Sobis, J. Stake, and A. Emrich, ”A 170 GHz 45° hybrid for submillimeter wave sideband separating subharmonic mixers*,” IEEE Microwave. Wireless Comp. Letters*., vol. 18, no. 10, pp. 680-682, Oct. 2008.