A NEW HIGH-TEMPERATURE SUPERCONDUCTING DOUBLE-HYBRID COUPLER WITH WIDE BANDWIDTH

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ABSTRACT

We report on the design and performance of new high-temperature superconducting couplers fabricated in microstrip technology. We present experimental results for a 3 dB- and a 0 dB-coupler (i.e. a crossover device) at 10 GHz. The planar coupler structures were patterned into YBaCuO thin films deposited on MgO substrates on both sides. As a design tool, we employed a commercial microwave simulation program. Verification was done using special test chips. We attained extremely low insertion loss values over bandwidths of 45 per cent (3 dB-coupler) and 30 per cent (0 dB-coupler), respectively.

INTRODUCTION

In recent years, the development of high-temperature superconducting (HTS) microwave circuits has made great progress [1, 2, 3, 9]. In what follows, we present a new wideband coupling structure fabricated in microstrip technology from HTS YBaCuO thin films deposited on MgO substrates (on both sides). Several attempts were made to improve the performance of microstrip couplers [4, 5, 8]. The present coupling structure shows a very good performance within the designed wide bandwidth.

THE NEW COUPLING STRUCTURE

Fig. 1 gives a schematic of the new coupling structure which was introduced in 1992 by Mayer [6, 7]. We call the coupling structure, which evolves from the well-known branchline coupler, a double-hybrid coupler.

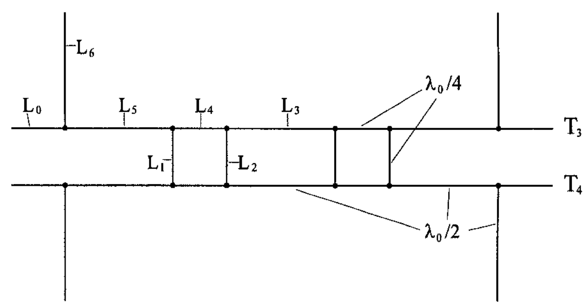

Figure 1: Coupling structure schematic (λ_0: wavelength at 10 GHz)

The coupler with its ports T_1 to T_4 is composed of two hybrid couplers (quarter wavelength transmission lines L_1, L_2 and L_4) which are interconnected by two half wavelength transmission lines L_3. Note that the transmission lines L_1 and L_2 differ in characteristic impedance. The half wavelength transmission lines L_5 and L_6 match the structure to a 50 Ω environment. As a planar fabrication technology, we take microstrip technology based on HTS YBaCuO films deposited on

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both sides of MgO substrates. The couplers have wide bandwidths of more than 25 per cent within which their coupling performance is nearly ideal in terms of transmission line theory: over its entire bandwidth we found a theoretical deviation of coupling magnitude of less than $\pm 0,05$ dB and of phase of less than $\pm 0,5^o$. By using this double-hybrid coupling structure, any coupling coefficient can be achieved by properly varying the lengths and widths of the transmission lines. One is even able to attain a nearly ideal crossover, i.e. an S_{41} of approximately 0 dB.

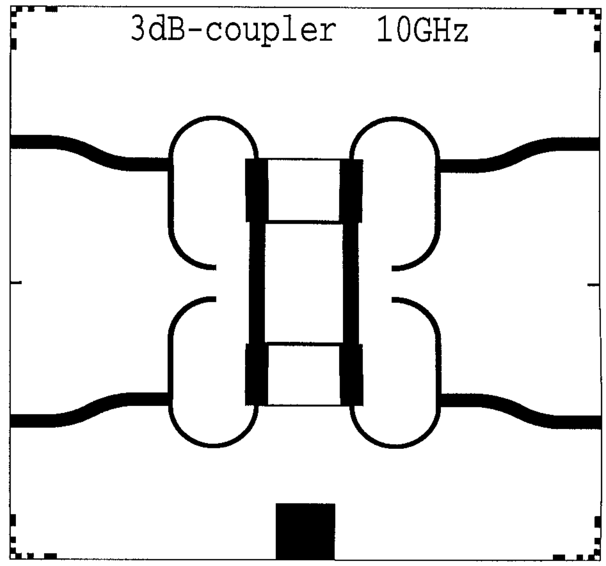

Figure 3: Layout of the 3 dB-coupler: 1×1 inch^2

DESIGN AND SIMULATION

After having tested a couple of commercial microwave simulators by comparing the simulation results against conventionally fabricated gold-on-Al_2O_3 microstrip test circuits, we found the *LINMIC* software to be the most feasible design tool. Fig. 2 shows as an example the simulated frequency response of the scattering parameters of the 3 dB-coupler, and Fig. 3 the layout of the 3 dB-coupler.

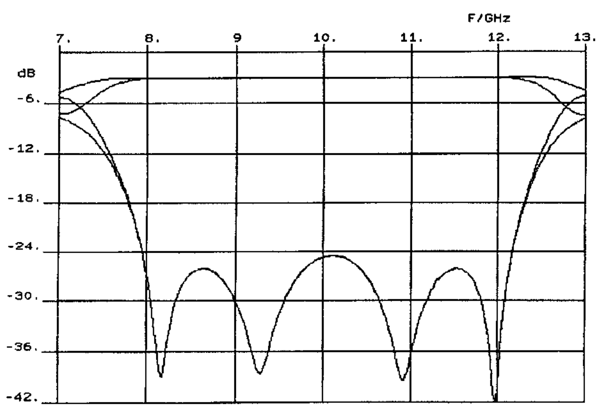

Figure 2: S-parameters of the 3 dB-coupler - LINMIC

EXPERIMENTAL RESULTS

Several 3 dB- and 0 dB-microstrip couplers were fabricated from HTS YBaCuO thin film on MgO substrates and characterized by S-parameter measurements performed in a vacuum chamber. The experimental results given in Figs. 4,5 refer to a temperature of 60 K.

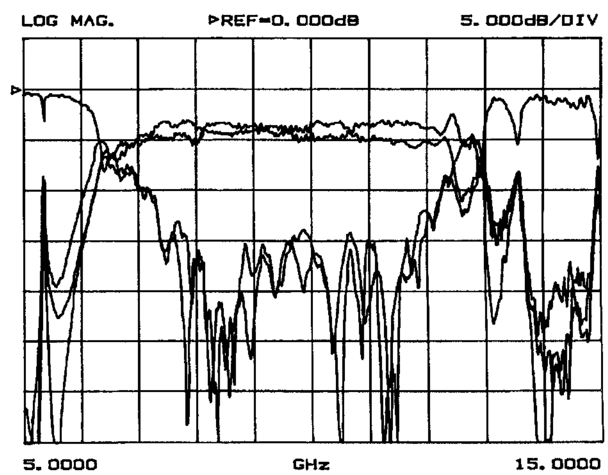

Figure 4: Frequency response of S-parameters of the HTS 3 dB-coupler

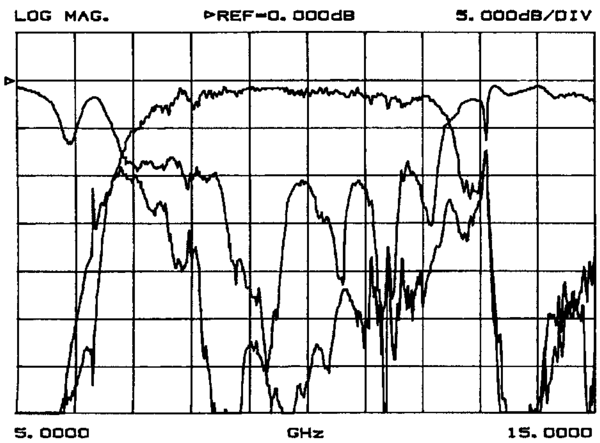

Figure 5: Frequency response of S-parameters of the HTS cross

We made the common 12-term calibration procedure between the ports T_1-T_2, T_1-T_3 and T_1-T_4, but we did not calibrate out the feed transmission lines and the SMA connectors which would be very difficult at those low temperatures. So, the losses and the passband ripples which are found in the curves are mainly due to the feed transmission lines and the SMA connectors. However, by carefully subtracting the losses from the experimental insertion loss levels we proved that the HTS coupler losses are extremely small and in any case below the measurement capabilities of the HP8510 network analyzer. For comparison, the insertion loss of the gold-on-Al_2O_3 microstrip test circuit is measured to 0,5 dB. We found the critical temperature T_c of the superconducting film to be 79 K. By theory, our HTS circuits (linewidths down to 100 microns, penetration depth at 200 nm, and $J_c = 2 \cdot 10^6$ A/cm^2 @ 77 K) should withstand at 10 GHz a power of approximately 40 dBm. Since we had only a power source delivering 30 dBm at 10 GHz at maximum, we could not investigate the maximum input power for temperatures lower than 70 K. What we found was, e.g., that the 0 dB coupler withstands a power of 30 dBm at 78 K. The couplers show coupling coefficients S_{41} of $-2,65 \pm 0,25$ dB (3 dB-coupler) and of $\leq -0,1$ dB (0 dB-coupler). With both couplers, the measured bandwidths are somewhat larger than the simulated values. The 3 dB coupler exhibits an experimental bandwidth of 45 per cent and the 0 dB coupler an experimental bandwidth of 30 per cent.

CONCLUSION

The present work demonstrates clearly the feasibility of the new HTS coupler structure. In particular, in the application of complex networks the HTS structures show their advantages. Momentarily, we are incorporating both couplers (i.e. the 3 dB one and the 0 dB one) into a 4-element Butler-matrix antenna feeding network [10, 11] with extremely low loss. Instead of heavy and bulky waveguide constructions the small and extremely low loss HTS circuits are to prefer. Fig. 6 gives the schematic and Fig. 7 the layout of this feeding network.

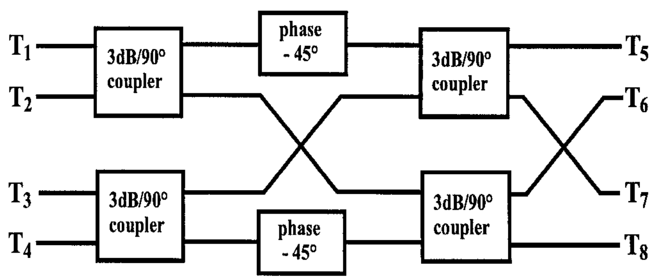

Figure 6: Schematic of the 4-element Butler-matrix

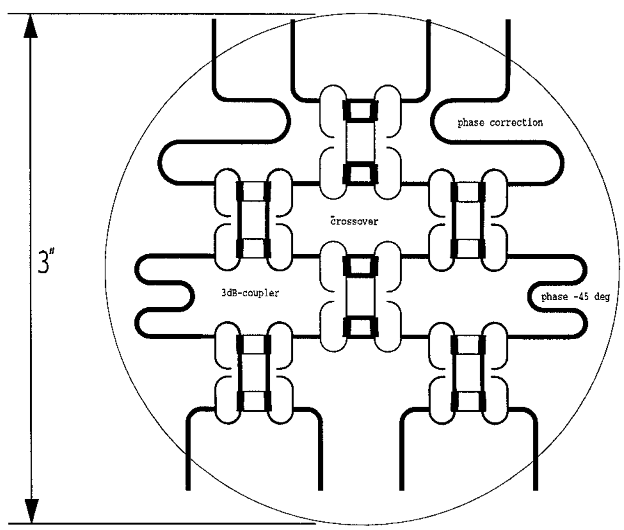

Figure 7: Layout of the 4-element Butler-matrix

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