A NEW COMPACT WIDEBAND BALUN

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ABSTRACT

A novel wideband balun has been developed for MMIC applications. The new approach utilizes simple RF reflection and coupling principles to achieve a wideband performance in a simple microstrip configuration. A balun with better than 2 dB of insertion loss, 1 dB and 5° of amplitude and phase balance over 7 to 19 GHz has been realized.

INTRODUCTION

The wideband MMIC balun has been a hot topic in recent years as it is a crucial element of the high performance mixers and transceivers. The difficulty often came from the wideband baluns being physically too big to fit into the MMIC chips. In some instances, it involved multilayer structures such as suspended substrates [1], which were impossible to fabricate in a monolithic form. In other cases, it involved multi-dielectric layer structures which required special processes. For example, Pavio [2] implemented a Marchand balun [3] in a multilayer dielectric form for the MMIC chip. Although the results were good, it required very thick dielectric layer (20 μm) to achieve the tight coupling. Chen, *et al.* [4] used the same approach in a wideband mixer. The thickness of the dielectric layer was still 3 μm thick. Raytheon's standard MMIC foundry process has a dielectric layer thickness of 0.2 μm. To realize a Marchand balun in this configuration is nearly impossible. Eisenberg, *et al.* [5] combined the co-planar waveguides, slot lines, and co-planar strips to realize a balun in a single planar structure, but the geometry was still too large because a good ground plane was hard to come by.

This paper first describes how this wideband balun works for a MMIC chip, how it was designed and what the computer simulated results were. A balun realized in a MMIC using Raytheon's standard MMC-04 process is described. Test results which match the computer simulation closely are presented. This approach is not only ideal for the MMIC applications, but also can be realized in conventional hybrid circuits.

DESCRIPTION OF THE APPROACH

A simple schematic is shown in Figure 1. If the open circuit impedance section (Z1) is about half-wavelength long (2d), the standing wave will form a short circuit node near the center of the section. At this center portion of the opened transmission line, the current will be at its maximum and the voltage will be equal and out of phase at d1 and d2. Two short circuited impedance sections, Z2 and Z3, are coupled to the open circuit transmission line at the first half and the second half, respectively. Signals come in at port 1 will be induced at the output port 2 and port 3, with equal amplitudes and opposite phases.

The induction, or the coupling is achieved by the interdigital couplers. Figure 2(a) shows a balun obtained by two crossed over interdigital couplers. Figure 2(b) shows that the crossed over couplers allow further simplification of the balun circuit.

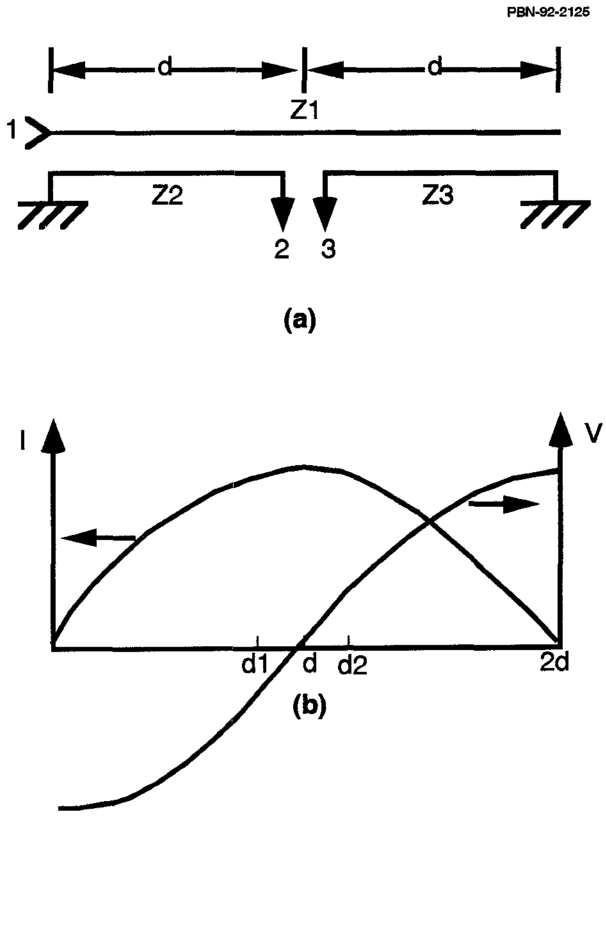

Figure 1. (a) A Schematic of the Balun, and (b) the Voltage and Current Waveform of the Opened Transmission Line.

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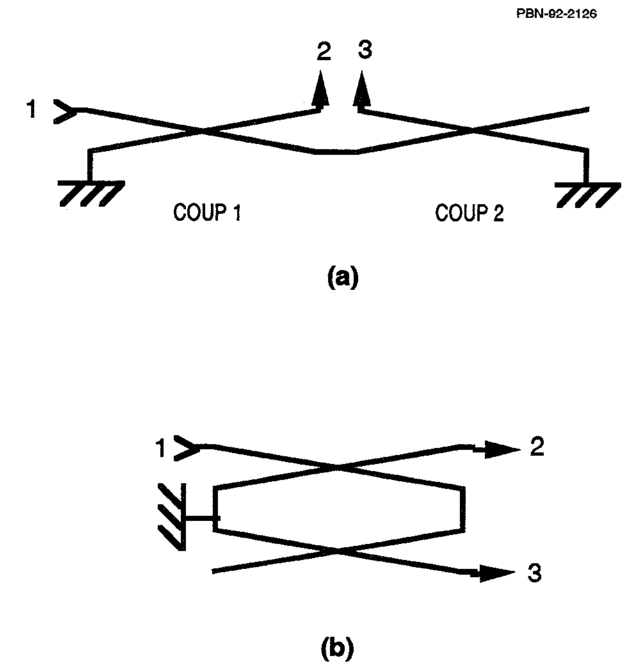

Figure 2. (a) Schematic Using Cross Over Couplers, and (b) Re-arranged Schematic Further Simplifying the Circuit.

CIRCUIT DESIGN

The two couplers used are the slightly under-coupled interdigital 3 dB couplers. The width of the couplers was 10 μm. The spacings between the lines were 12 μm on the coupler near the input port, coup 1, and 10 μm for coupler away from the input port, coup 2, to improve the coupling balance. These dimensions can be easily fabricated by MMIC processes. The ground was achieved through a via hole. The length of the coupler was 1660 μm. The circuit was laid out on a 100 μm thick GaAs wafer and processed at Raytheon's MMC foundry, using MMC-04 standard process. The chip size is 1 mm by 2 mm, as shown in Figure 3.

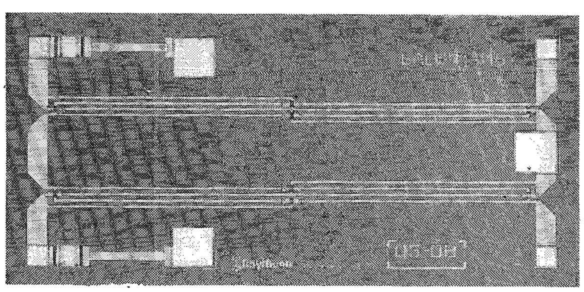

Figure 3. Photograph of the Balun.

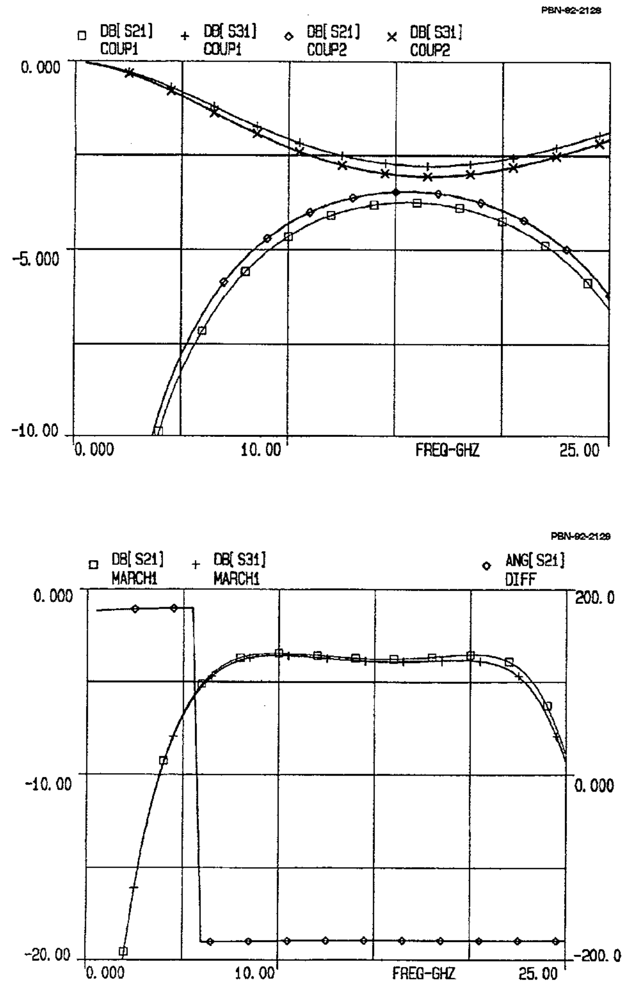

Figure 4. (a) Simulated |S21| and |S31| of the Two Individual Couplers, and (b) Simulated Insertion Loss and Phase Difference of the Balun.

Figure 4(a) shows the computer predicted performance of the individual couplers. Figure 4(b) shows that of the balun circuit. It is interesting that the balun circuit actually has a wider bandwidth than a coupler circuit. The design was intended for 8 to 18 GHz wideband mixer applications. The predicted performance showed the insertion loss was better than 2 dB from 7 to 19 GHz; the amplitude balance was less than 1 dB and the phase balance was less than 5° from the 180° phase difference.

TEST RESULTS

This MMIC chip with the wideband balun was evaluated using a flexible 4 port test jig. The jig was de-embedded to obtain the actual device performance. Figure 5 shows the insertion loss of the two output ports.

Figure 6 shows the amplitude and phase balances. These results show a very good agreement with the predicted performance. It should be pointed out that the amplitude and phase balance are good through a very low frequency from 0.1 GHz to 20 GHz. This performance is different from many other types of baluns or the 90° couplers where the amplitude and phase balances are only good for a certain frequency bandwidth.

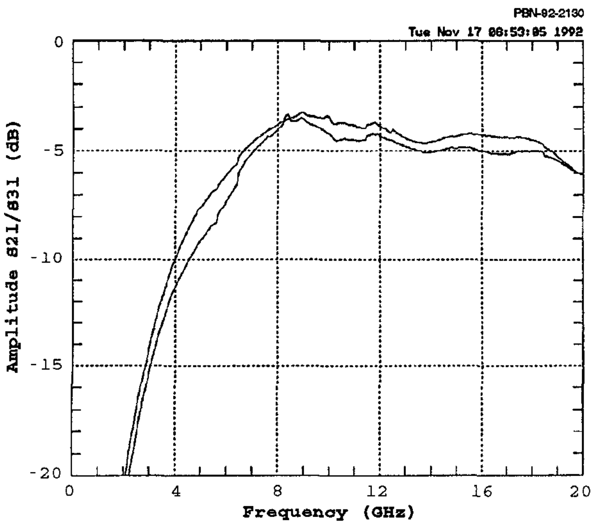

Figure 5. Tested Insertion Loss of the Two Output Ports.

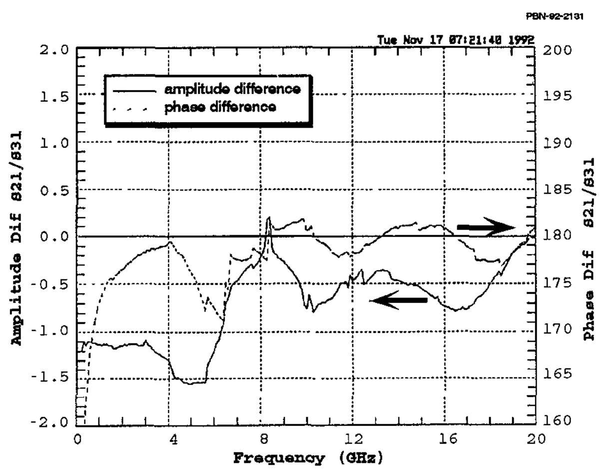

Figure 6. Tested Amplitude and Phase Balances of the Balun.

CONCLUSION

The newly developed wideband balun can be used in many wideband mixers, modulators, and transceivers. The advantages of this balun are the ease of fabrication and the planar configuration that makes it suitable for both the MMIC and conventional hybrid circuit applications.

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