A MONOLITHIC OR HYBRID BROADBAND COMPENSATED BALUN

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ABSTRACT

A compact microstrip balun structure, capable of multioctave performance has been devised for monolithic or hybrid circuit applications. The structure requires no suspended substrate techniques; hence, it can be easily incorporated in the design of a variety of components such as mixers, multipliers and class B amplifiers.

INTRODUCTION

The most commonly used microwave component requiring some form of balanced structure is the mixer. Most modern systems employ double-balanced designs consisting of four diodes and two baluns (or hybrids) although there are a considerable number of single-balanced designs in use especially in commercial systems.The most difficult portion of the mixer to synthesize is the balun and traditionally it has been realized with transformer hybrids [1]. As the frequency of mixer operation is extended beyond several GHz, transformer hybrids can no longer be fabricated. By the time the operating frequency reaches 4 to 5 GHz, a few coupled inductors, fabricated on GaAs substrates, are the only structures resembling transformers that are found. At frequencies above 4 GHz, transmission line baluns are the only other realizable structures available to the design engineer.

DESIGN

The simplest of baluns can be realized by employing a trans-mission line 90 degrees in length, connected so that one conductor at the unbalanced end is grounded, with the balanced load (or source) connected across both conductors at the other end. The structure is indeed a balun, since the currents at the balanced end are equal and opposite and also equal in magnitude to the current at the unbalanced end. At the center frequency of the structure, the balanced end is also isolated from ground.

A slightly more complex structure, developed by Marchand in 1944, is shown in Figure 1(a) with its circuit model illustrated in Figure 1(b) [2]. This type of circuit is sometimes referred to as the compensated Marchand balun. The structure can be realized with as many as four different impedance transmission lines with different lengths. Hence, a considerable amount of flexibility in matching is possible since the balun is a multielement bandpass network. Usually, Z_1 and Z_2 are designed to be of equal value; Z_{s1} and Z_{s2}, which are effectively in series, are shunted across the balanced load and made as large as possible. Transmission line Z_b has a characteristic impedance value matching the balanced termination, although it can be used as a matching section. If proper filter synthesis methods are employed in the design of the compensated balun, excellent multioctave performance

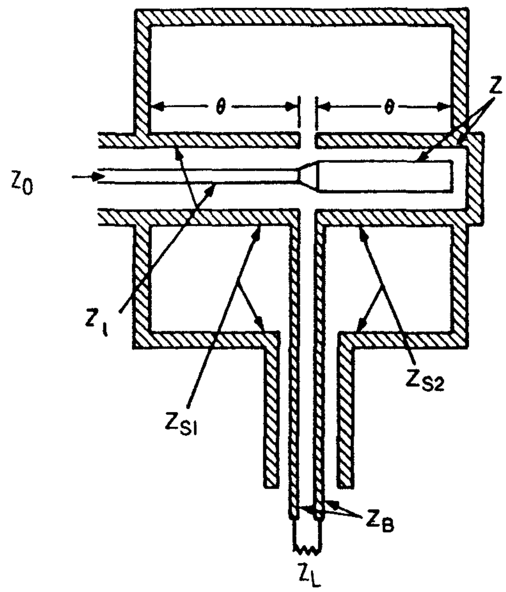

Figure 1(a). Marchand Compensated Balun; Coaxial Cross-section.

can be obtained. Coaxial structures are cumbersome to integrate into mixer topologies, but some designs employ simpler versions of the above structure realized using suspended microstrip techniques. However, suspended substrate techniques are completely impractical to implement with monolithic circuit techniques due to the circuit area involved and the fragility of the GaAs material.

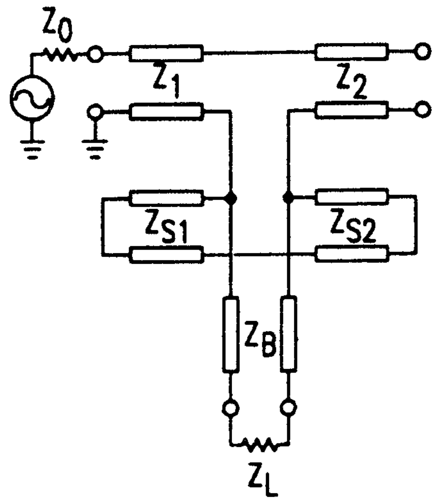

Figure 1(b). Marchand Compensated Balun; Equivalent Transmission Line Model.

An improved balun structure, which does not require suspended substrate techniques, is illustrated in Figure 2. The circuit relies on a multilayer conductor structure to achieve the extremely tight coupling required to form transmission lines Z_2 and Z_1. A cross-section of a typical structure is shown in Figure 3. Because of the tight coupling achievable with the proposed structure, the parasitics introduced from the bottom side of the balun with respect to ground do not impact circuit performance appreciably. These parasitics would normally destroy the performance of a non-suspended substrate balun. The second dielectric layer, that must be thin in order to achieve the coupling, can be realized in several ways. For ease of fabrication, the dielectric layer can be composed of Si_3N_4 and deposited on the GaAs surface in the same manner as in the fabrication of conventional MIM (metal-insulator-metal) capacitors. The dielectric layer can also be formed by using a polyimide film which can be applied to the GaAs surface. This balun structure can also be fabricated on an alumina substrate with polyimide as the second dielectric.

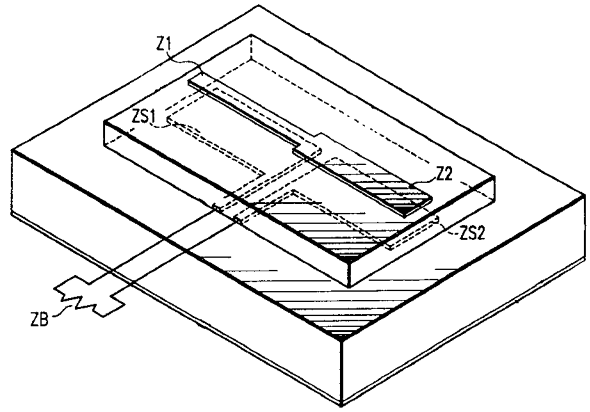

Figure 2. Circuit Construction of Monolithic or Hybrid Balun.

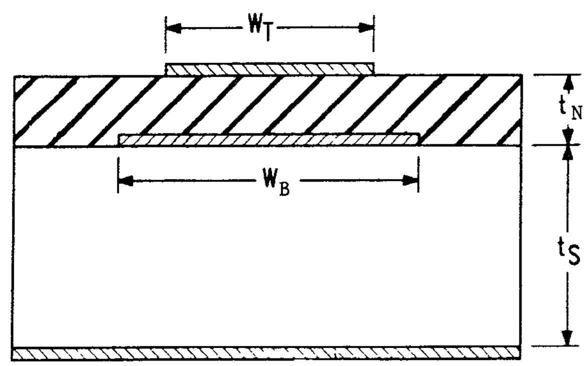

Figure 3. Typical Balun Structure Cross-section.

A variety of balun structures were designed for operation in the 6 to 18 GHz frequency range and fabricated on both GaAs and alumina substrates. The monolithic design was constructed on a0.100 mm thick GaAs substrate with a second dielectric layer of silicon nitride 20,000 Å thick. A photograph of the balun is shown in Figure 4 and the measured amplitude performance is shown in Figure 5. The graph shows that the amplitude balance is quite good throughout the entire 6 to 18 GHz frequency range. The phase matching between the output arms is nearly ideal at 180 +/- 2 degrees.

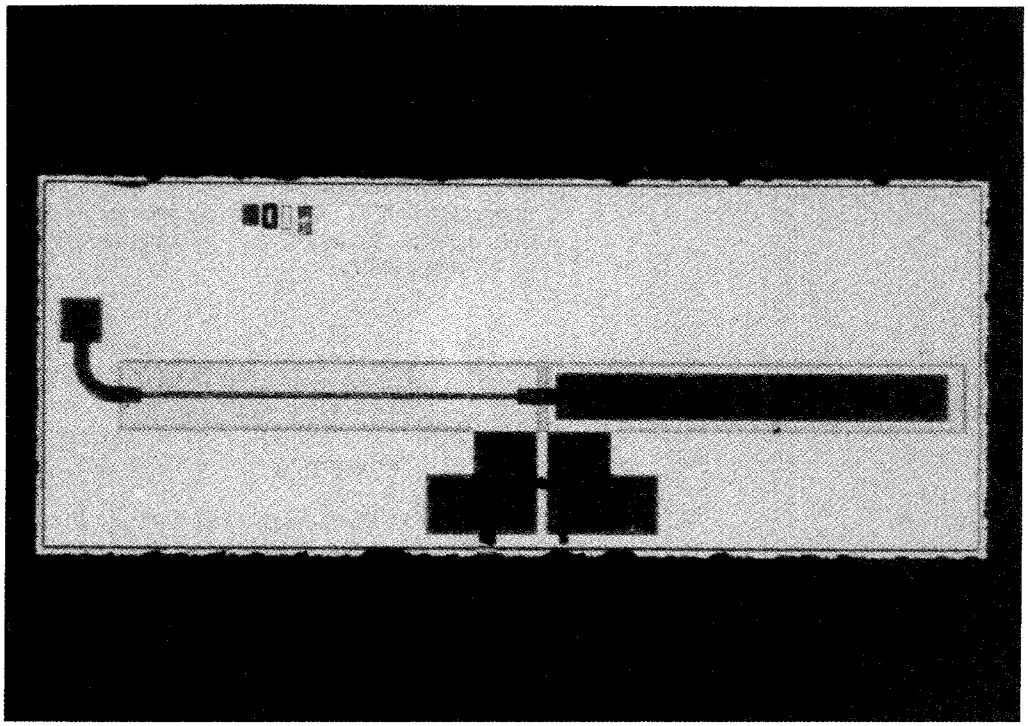

Figure 4. Monolithic Compensated Broadband Balun.

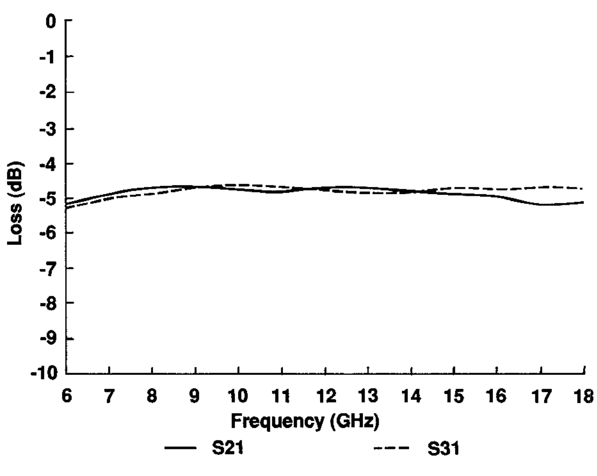

Figure 5. Measured Amplitude Balance of Monolithic Balun.

A similar balun was also constructed on an alumina substrate 0.125 mm thick. In this case the dielectric layer was 0.05 mm thick polyimide. A photograph of the balun is shown in Figure 6 and the measured amplitude performance is shown in Figure 7. As can be seen the amplitude balance is also quite good throughout the entire 6 to 18 GHz frequency range.

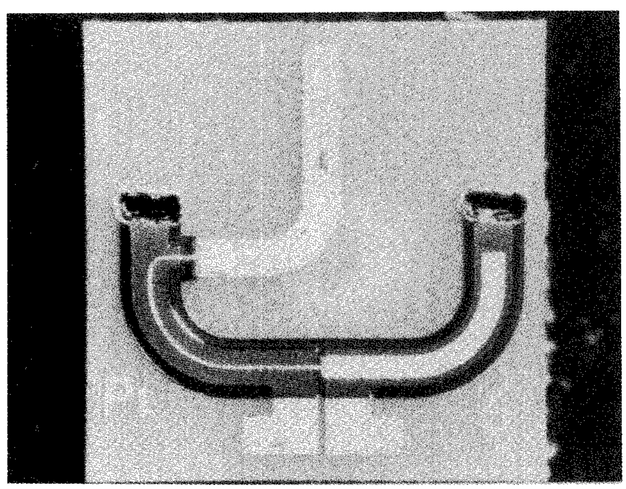

Figure 6. Broadband Hybrid Circuit Balun Constructed an Alumina Substrate.

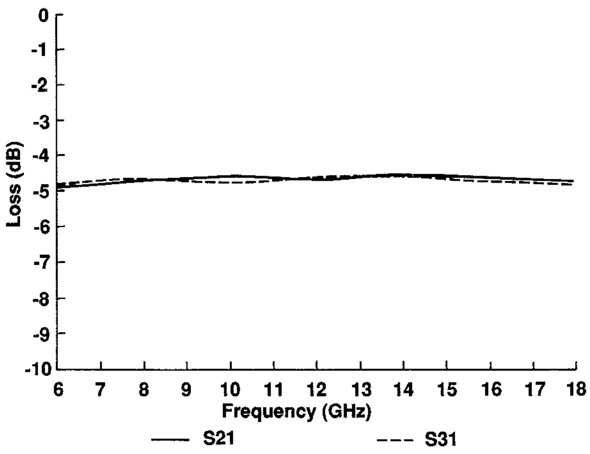

Figure 7. Measured Amplitude Balance of Hybrid Circuit Broadband Balun.

CONCLUSION

The above balun structure can be designed to occupy only a small amount of circuit area, thus allowing it to be easily integrated with a variety of monolithic circuit designs such as mixers, multipliers and class B push-pull amplifiers. If a matching network is incorporated with the balun structure, a 10:1 operational bandwidth can be achieved.

REFERENCES

[1] C.L. Ruthroff, "Some Broadband Transformers, "Proceedings of the IRE,Vol.47.

[2] N. Marchand,"Transmission line Conversion Transformers, "Electronics, Vol.17. No.12. 1944, p.142.