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AN ANALYTIC DESIGN APPROACH FOR 2-18 GHz PLANAR MIXER CIRCUITS

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ABSTRACT

A design procedure for planar broadband mixers is proposed which employs filter synthesis for exact balun design and nodal analysis to check for deleterious port interactions. The method has been successfully used to obtain working mixers in one thin film fabrication cycle on alumina and fused quartz substrates. A representative design is presented with experimental data.

INTRODUCTION

Planar thin film mixers offer advantages in repeatability, ease of assembly, and amplitude and phase tracking performance. Good isolation characteristics and simultaneous impedance matching of the RF, LO and IF ports hinge on effective balun design. Hallford[1, 2] has reported various planar mixers employing resonant baluns which have relied on empirical design. This paper describes a design procedure which minimizes costly thin film iterations by applying two restrictions to resonant baluns, using filter synthesis techniques and checking port interactions with a nodal analysis of the mixer circuit.

MIXER CONFIGURATION

The basic form of the double balanced mixer to be described is illustrated in Figure 1. The diode ring is constructed with a monolithic beam lead pair on the top side of the suspended substrate connected to a diode pair on the bottom side via two plated through holes. Beam lead pairs offer good balance, repeatable mounting and low parasitics for broadband operation. This configuration promotes good isolation, since the LO energy fed by two edge coupled strips is orthogonal to the RF signal present on the two broadside coupled strips. The RF balun is a nonresonant tapered type, typically a quarter wavelength long at the lowest RF frequency. The bottom conductor follows a cosine taper while the top conductor varies in width to provide a DolfChebyshev impedance taper along the length of the balun.

RESONANT BALUN DESIGN

Matsumoto, has analyzed the coaxial Marchand balun as a three port, four conductor network as shown in Figure 2.[3] Restricting the immitance matrix representation to balanced currents and voltages at nodes 2 and 3 results in the following conditions: (1) the capacitance to ground of conductor 2 and conductor 4 must be zero and (2) the capacitance to ground of conductors 1 and 3 must be equal. Meeting these two requirements will provide a balanced output regardless of frequency. The VSWR performance of the network is restricted only by its filter characteristics. The balun design is reduced to a distributed high pass filter synthesis problem. Cloete, for example, has published element impedance values for a four element coaxial balun based on exact filter synthesis.[4] With the aid of a filter synthesis program a variety of topologies may be investigated to provide realizable element values, parasitic absorption, bandwidth, and impedance tranformation.

Figure 1 illustrates the realization of a typical balun. Z_1 and Z_2 are microstrip. Z_3 and Z_4 are inverted microstrip and must be equal in impedance. Their dimensions are calculated using the routines of Smith, making sure the strips are wide enough to shield the microstrip from the lower lid of the mixer housing.[5]

IF PORT DESIGN

The resonant balun provides a convenient low inductance IF ground. When coils are not desirable, the IF can be summed through a shunt shorted stub. To provide this stub, an RF bandpass filter is synthesized. Since the stub is a quarter wavelength at the RF band center frequency, it is quite short for even relatively high IF frequencies. The balanced filter elements are shown in Figure 3 along with even and odd mode impedances present when the housing lids are considered. These coupled mode values were determined from the equations of Bahl and Bahrtia[6].

The remaining design task is to determine the shunt effects of the RF filter and tapered balun on the IF port. To do this, the tapered balun is modeled as multiple sections of uniform asymmetric line. The two even mode and two odd mode impedances for each section are calculated ignoring the dielectric. The lowest of these impedances are used in the coupled line model shown in Figure 3 and analyzed on a microwave circuit analysis program. The aim of the calculation is not a highly accurate prediction of the shunting impedance, but a guide to avoid severe matching problems. In practice the IF impedance is measured and a simple match added, typically a series capacitor.

RESULTS

Several dual mixers have been built on both alumina and quartz substrates. The circuit of Figure 3 was used for 6 to 16 GHz operation with a 2 GHz IF. The alumina substrate dimensions were 1.1" x .85" x .010". The quartz mixer shown in Figure 4 uses coils to sum a 100 MHz IF signal. The conversion loss and amplitude matching appears in Figure 5. LO to RF port isolations are typically better than 25 dB and phase tracking within ±3 degrees over the 2 to 18 GHz band.

CONCLUSION

A simple mixer design technique has been outlined which is applicable to a variety of planar mixers which use a resonant balun. The method has proved useful in the design of thin film mixers where empirical approaches can be costly. Resonant planar baluns can be designed with virtually any high pass filter topology which includes two equal inverted microstrip shunt grounded stubs shielding the microstrip elements. This enables the realization of broadband impedance matching baluns.

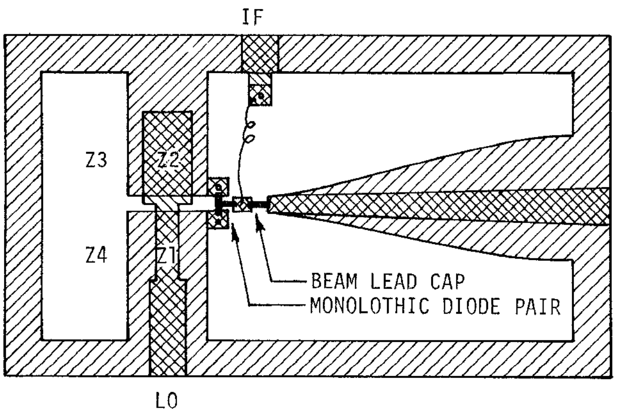

Figure 1. Basic suspended substrate double balanced mixer.

References

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2. B. R. Hallford, "A Designer's Guide to Planar Mixer Baluns", Microwaves, December 1979, Vol. 18, No. 12, pp. 53-57.

3. Akio Matsumoto, Advances in Microwaves Supplement 2, Adademic Press, New York, 1970, pp. 295-306.

4. J. H. Cloete, "Exact Design of the Marchand Balun", 1979 European Microwave Conference, pp. 480-484.

5. J. I. Smith, "The Even and Odd Mode Capacitance Parameters for Coupled Lines in Suspended Substrate", T-MTT, Vol. 9, No. 5 May 1971, pp. 424-431.

6. I. J. Bahl and P. Bhartia, "Characteristics of Inhomogeneous Broadside-Coupled Striplines", T-MTT, Vol. 28, No. 6, June 1980, pp. 529-535.

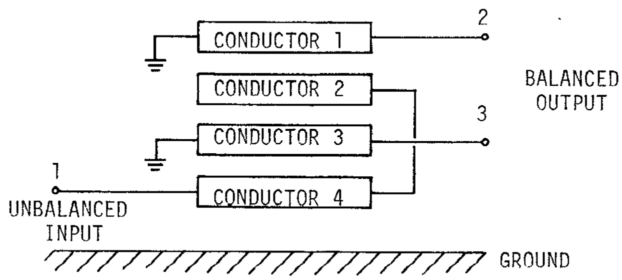


Figure 2. Generalized resonant balun (after Matsumoto).

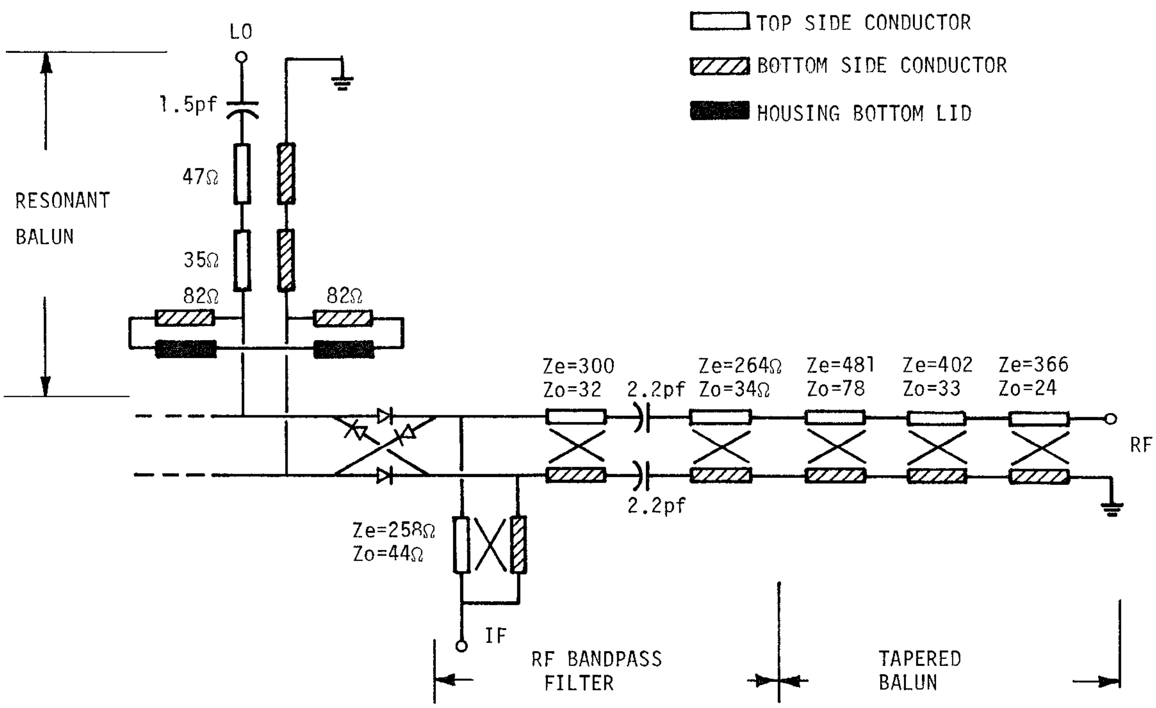
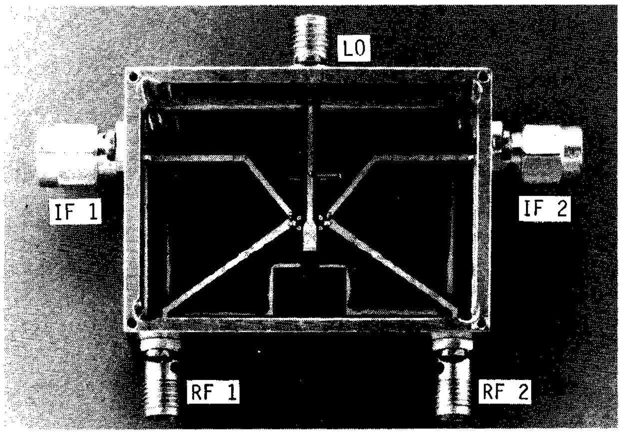
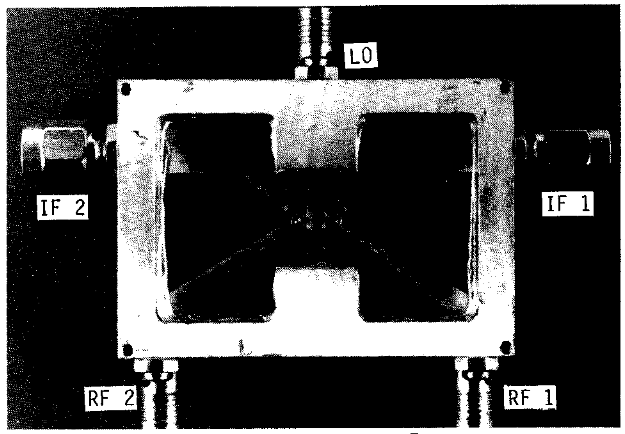


Figure 3. Nodal model for a dual alumina mixer.



(a) TOP SIDE



(b) BOTTOM SIDE

Figure 4. 2-18 GHz dual quartz mixer.

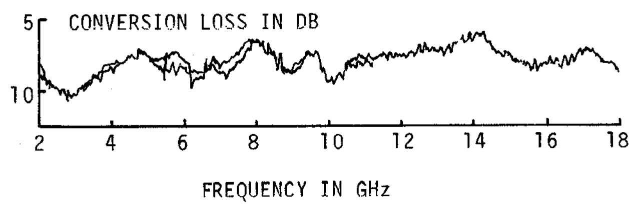


Figure 5. Amplitude tracking of dual quartz mixer.