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A NEW UNIPLANAR BALUN

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Abstract. A new uniplanar CPW-slotline double junction balun has been proposed. Being realized as uniplanar equivalent of the microstrip-slotline double junction transition, this balun is well suited for MMIC's, and has better characteristics than other uniplanar baluns published up to now. Measured VSWR is less than 1.6 and insertion loss is about 0.7 dB for bandwidth ratio 1:6.

Key words: Balun, microstrip, VSWR, Marchand balun, CPW slotline, MMIC.

1. Introduction

Microwave baluns are transformers between balanced and unbalanced lines. They are used in different types of antenna structures, balanced mixers and other microwave circuits. There are two main groups of baluns: Marchand baluns or compensated baluns [8] and double Y baluns [9].

Although double Y baluns as all pass networks [1] have potentially superior frequency bandwidth when compared to Marchand baluns, the majority of baluns are realized as Marchand baluns. The development of printed baluns dates from 1969, when Cohn [3] suggested the first microstrip-slotline transition. Various microstrip-slotline transitions have been reported, following the development of double-sided MIC technology, based on combination of microstrip-slotlines on both sides of the substrate. In fact, these microstrip-slotline transitions represent only one of the possible realization

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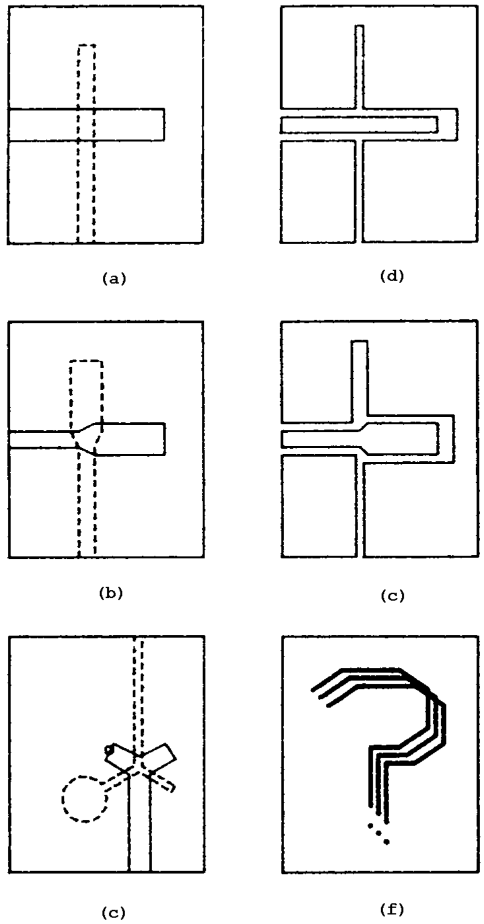

Fig. 1. Typical structures of microstrip-slotline transitions and equivalent uniplanar CPW-slotline baluns: (a)-(c) Microstrip-slotline transitions, (d)-(f) Equivalent CPW-slotline baluns.

of Marchand baluns, although for a long time, they have been designed without use of the theory of classical baluns [8], [2]. Typical MIC baluns known as microstrip-slotline transition are shown in Fig.1(a)-(c).

Microstrip-slot transition with 50Ω short circuited and open-ended quarter-wavelength long lines [3], [7] is given in Fig. 1(a). In order to widen frequency bandwidth of the transitions, the impedances of open and short circuited lines are changed as shown in Fig. 1(b).

There is variety of similar baluns containing uniform and nonuniform lines as well as soldered and virtually shorted microstrip lines depending on required frequency bandwidth [1]. The baluns in Fig. 1(a) and (b) are based on Marchand baluns.

The microstrip-slotline transition shown in Fig. 1(c) is not based on Marchand baluns, but on microstrip-slotline double junction [9]. This balun has an improved broadband characteristics because it is essentially different network than Marchand balun is, as was shown in [1].

During the last decade, the development of MMIC technology has produced an interest in uniplanar structures and various baluns realized using CPW-slotlines (coplanar waveguide-slotline), [5], [1] have been reported as it is shown in Fig. 1(d), (e).

Uniplanar structures are realized on one substrate side, with no metallisation on or connectors to the backside required. This feature alone can significantly reduce the substrate processing complexity and consequently the cost.

The main goal of this work is to present a design of new uniplanar CPW-slotline double junction balun which has superior characteristics when compared to other uniplanar CPW-slotline baluns.

According to Fig.1 there is an equivalence between double sided baluns which use microstrip lines and slotlines and uniplanar baluns containing coplanar waveguides and slotlines. Replacing microstrip line with CPW, we can transform a double-sided MIC balun into an equivalent uniplanar MMIC balun.

2. Review of uniplanar Marchand baluns

Marchand baluns are generally speaking 'band pass' networks. They can be designed to incorporate transformer action for application where the load and source resistance differ. Depending on required bandwidth, Marchand baluns are designed as second, third or fourth order baluns using the graphs of circuit elements [2] or closed form expressions [1]. Equivalent circuits of Marchand baluns are shown in Fig.2.

In practice, the most popular Marchand balun is the second order balun.

Just few uniplanar baluns are published until now. Among the first uniplanar baluns realized is CPW-slotline balun described in [5], Fig.3. Quarter-wavelength segments of 50Ω CPW and 70Ω slotline are open-ended shorted respectively. Ground plane segments A, B and C, D are mutually connected near CPW-slot junction, using wired air bridges. Figure 3. illustrates the measured back-to-back insertion and return losses. Measured frequency

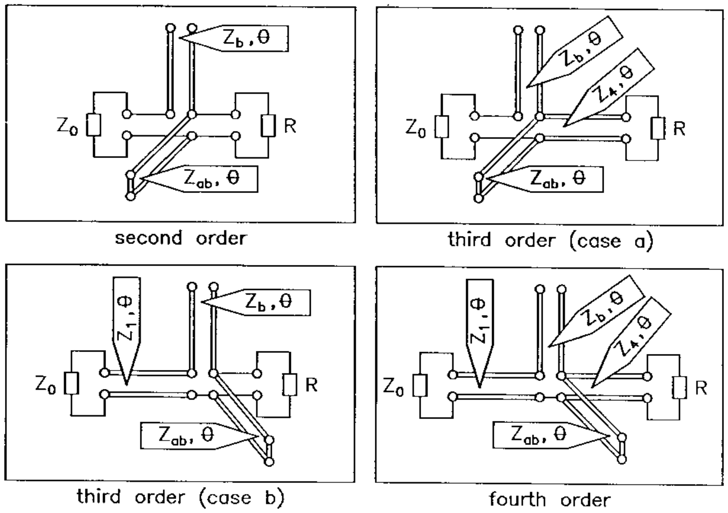

Fig. 2. Equivalent circuits of Marchand baluns.

bandwidth is 1:1.7 with a VSWR less than 2, for insertion loss less than 1.3 dB. The theoretical value of bandwidth calculated for this case is 1:3, that is in a good agreement with the results received with microstrip-slotline transitions [3], [7] (Fig.1.a).

Distinctly broader frequency bandwidth is received using compensated version of the balun in Fig.3. Open-ended CPW and shorted slotline, measuring quarter-wavelength at the centre frequency, have impedances 100Ω and 200Ω respectively, that differs from the input impedances of CPW and slotline. Measured back-to-back insertion and return losses are shown in Fig.4. Frequency bandwidth is 1:4, with a VSWR less than 2 and insertion loss less than 2 dB.

Generally speaking, the coplanar Marchand baluns show narrow bandwidth comparing to the theoretical results, because can not be neglected.

Among different realizations of Marchand baluns the best characteristics have been demonstrated with microstrip-slotline baluns.

3. Description of new uniplanar balun

The main reason for smaller frequency bandwidth obtained by uniplanar Marchand baluns is due to the asymmetry induced at the CPW-slotline junction. Using a CPW-slotline double junction it is possible to improve the

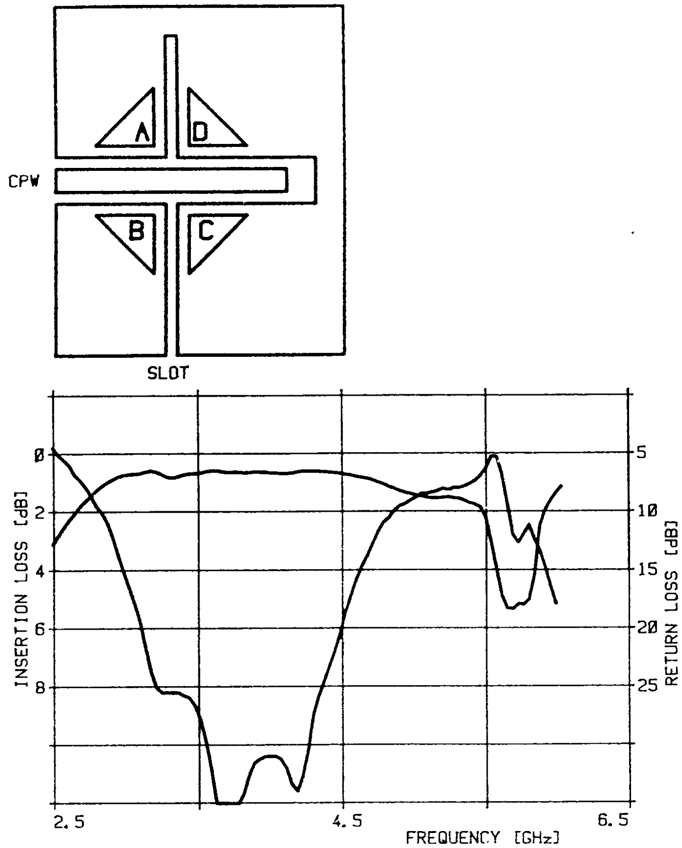

Fig. 3. View of uniplanar Marchand balun and measured back-to-back characteristics

overall performance of the balun.

A new uniplanar balun is based on six-port CPW-slotline junction (Fig.5) which consist of three balanced and three unbalanced lines placed alternately around the centre of the structures. In Fig.5 ports 1, 3 and 5 are realized with unbalanced CPW and ports 2, 4 and 6 with balanced slotlines. The junction is matched at ports 1 and 4 if the ports 2, 3, 5 and 6 are terminated by match loads, if the characteristic impedances of the CPWs and slotlines are the same, e.g. 50Ω, and if junction effects can be neglected. Ports 1 and 4 are uncoupled. Therefore, looking from port 1, the slotlines leading to ports 2 and 6 are parallel to one another and in series with the two parallel CPWs that lead to ports 3 and 5. As a result, the input impedance,

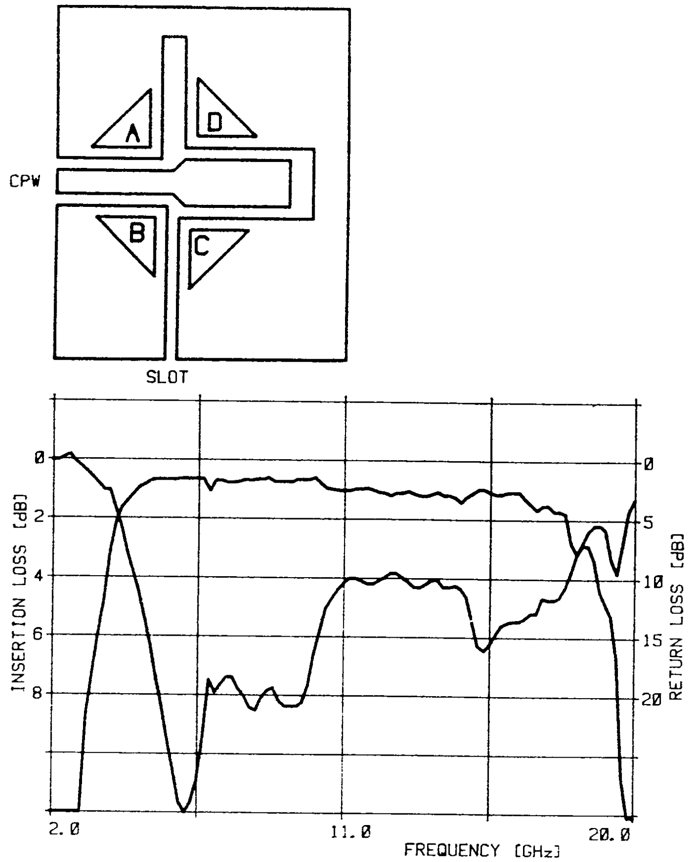

Fig. 4. View of uniplanar compensated Marchand balun and measured back-to-back characteristics

looking from port 1, is 50Ω. Similarly, looking from port 4, the slotlines leading to ports 2 and 6 are in series with one another and parallel to the serial CPWs that lead ports 3 and 5. Thus, looking from port 4, the input impedance of the double junction is 50Ω. Owing to symmetry, a similar statement holds for any other pair of CPW slotlines at opposite ports, i.e. 2 and 5 or 3 and 6.

The input signal from port 1 will be equally divided between output ports 2, 3, 5 and 6. If the output ports have the same reflection coefficient, the signal will be reflected back into port 1. Similarly, an input signal at port 4 will also be equally divided between ports 2, 3, 5 and 6 but in phase opposition at ports 2 and 5 with respect to ports 3 and 6. Again, an equal reflection coefficient at ports 2, 3, 5 and 6 will reflect the signal back into port 4.

In order to make a structure which works as a balun with perfect transmission between an opposite balanced and unbalanced ports, opposite pairs of lines should have reflection coefficient with opposite phases, i.e. one pair of lines should be short circuited, and the other one open-ended. View of the balun is shown in Fig.6 with shorted lines at ports 2 and 5 and open-ended lines at ports 3 and 6 (notation of the ports is the same as in Fig.5). The segments of ground planes are mutually connected near the junction by wired air bridges (a-f, b-c, d-e).

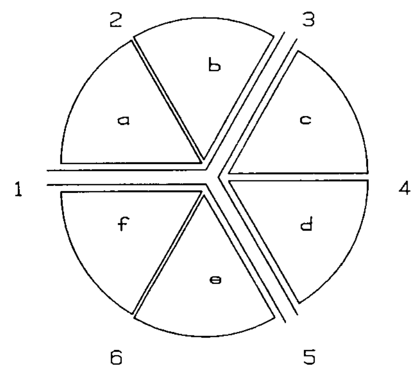

Fig. 5. Six-port CPW-slotline double junction.

The electrical length from the short and open circuits to the centre of the junction should be equal

$$\beta_{CPW} l_{CPW} = \beta_{slot} l_{slot}$$

where β is phase constant at the responding line and l is physical length of the open-ended and shorted lines measured from the centre of the junction.

To prevent radiation and circuit losses, the distance from the short circuit to the open circuit, i.e. $2l$, has to be less than a quarter wavelength. Also, the transverse dimension of the lines forming the double junction should be considerably smaller than one wavelength to minimize junction parasitic effects.

4. Experimental results

A double uniplanar CPW-slotline baluns has been constructed on a 50.8×50.8 mm alumina substrate ($\varepsilon_r = 10.2$, $h = 0.635$ mm). The 50Ω

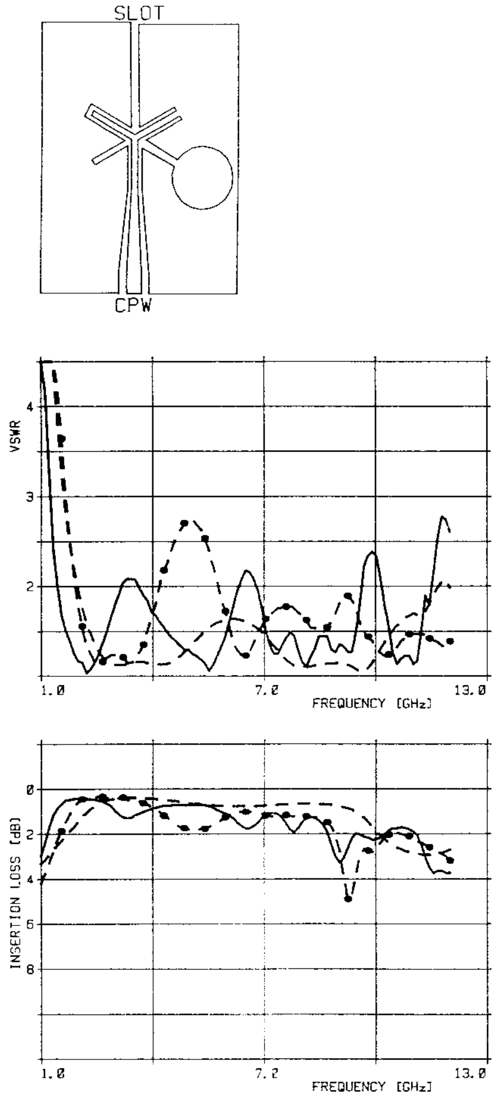

Fig. 6. View of new uniplanar balun and measured characteristics of new uniplanar balun with tapers l_1 (solid line) and l_2 (dash-dot line) and equivalent microstrip-slotline double junction balun (dash-line).

coplanar waveguide is excited by coaxial line. To minimize transverse dimension of the junction, the physical dimension of the CPW have been changed (strip width 0.25 mm and gap width 0.1 mm) through the linear transition, without changing the characteristic impedances. The slotline width is 0.1 mm and characteristic impedance according to [6] is 65Ω. The distance from short and open circuits to the centre of the structures is $\lambda/8$ at 10 GHz ($l_{CPW} = 1.6$ mm and $l_{slot} = 1.8$ mm). A slotline open circuit is realized with a diameter of 6 mm.

In Fig.6 the measured results for VSWR and insertion loss of the double (CPW-slotline-CPW) uniplanar baluns as well as for equivalent microstrip-slotline balun are shown. Two models of uniplanar baluns have been realized with different lengths of the linear CPW taper ($l_1 = 8.5$ mm and $l_2 = 6.5$ mm). The model with longer taper (solid line in Fig.6) has better VSWR characteristics (low ripples) that the other one. The measured VSWR for the double CPW-slotline-CPW balun is less than 2.5 and the insertion loss is lower than 2 dB in the frequency range 1.45-8.7 (1:6). Estimated VSWR for single CPW-slotline balun is less than 1.6 and insertion loss about 0.7 dB.

Measured frequency bandwidth of the new uniplanar balun is very close to its equivalent microstrip-slotline balun (dash line in Fig.6), which is not feasible in case of Marchand baluns.

5. Conclusion

It has been demonstrated that there is an equivalence between MIC baluns (microstrip-slotline transition), which can be used as a basis for the realization of the various uniplanar baluns. A new uniplanar CPW-slotline double junction balun has been proposed as an example of such equivalence and as a better solution for MMIC baluns than others published so far.

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