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A Review on Printed BALUN Transformer

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Abstract: This paper is a detailed review of BALUN transformer. The paper covers the concept behind the transition of field from unbalanced line to balanced line. All the available techniques are discussed in details. The proposed paper also covers concept behind balanced and unbalanced line.

Keywords: Balanced line, unbalanced line, coplanar strip line, microstrip line, slot line, quarter wavelength line.

I. INTRODUCTION

Antennas available in practice are either balanced in nature or unbalanced in nature. Some fundamental antennas like dipole and loop are balanced in nature and are fed with balanced cable only. If these antennas are fed with unbalanced cable like coaxial then the return current from one balanced antenna flows through outer conductor and is available on inner and outer part of outer conductor. The current on outer side of the conductor leads to radiation and thus changes overall radiation property of antenna. Other than this these currents also alters the antenna impedance. Therefore, this mismatch between unbalanced cable to balanced antenna completely alters antenna's electrical and radiation properties. This issue is resolved using balanced to unbalanced (BALUN) transformer. This transition from balanced to unbalanced or vice-a-versa causes change in current distribution. Figure 1 shows the current distribution in balanced coplanar strip line and unbalanced microstrip line.

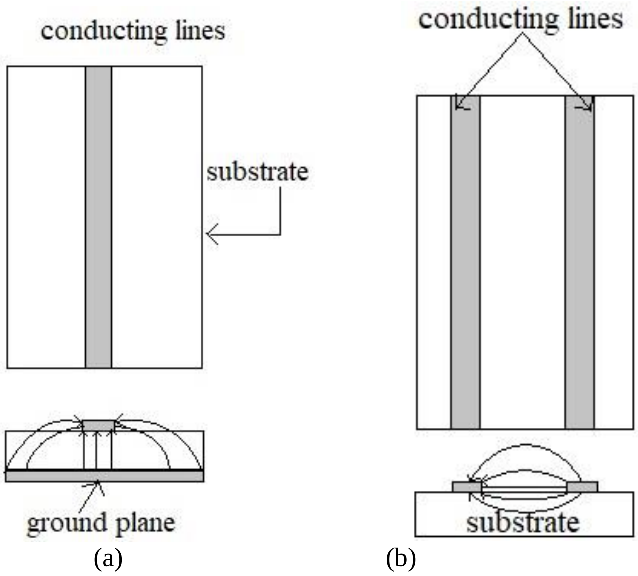

Fig. 1: (a) Field distribution in microstrip (MS) line and (b) coplanar strip (CPS) line.

Figure 1(a) shows microstrip line which is an unbalanced line and contains one signal conductor on one side of substrate and a ground plane on the other side of same substrate. The electric field is shared by these two conductors and is vertical w.r.t. direction of propagation i.e. conductors.

Figure 1 (b) shows coplanar strip line. There is no ground plane in this line and two conductors share electric field as shown in same figure. In this structure field is horizontal.

A BLAUN transformer converts electric field from vertical distribution to horizontal or vice-a-versa.

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II. CURRENT PRACTICES OF FIELD TRANSFORMATION

There are multiple techniques available to transform vertical field of microstrip line into horizontal line. A tapered microstrip line transforms a 50 Ω line into 100 Ω load with the help of a tapered line of length 28 mm.

This line is converted to a slot line of 100 Ω line,[1]. Insertion loss is not more than -1.5 dB. The tapered microstrip line is shorted with slot line to transform field with the help of vias. BALUN dimension is given in table 1 in mm. Bandwidth of the BALUN is from 4.4 GHz to 40 GHz.

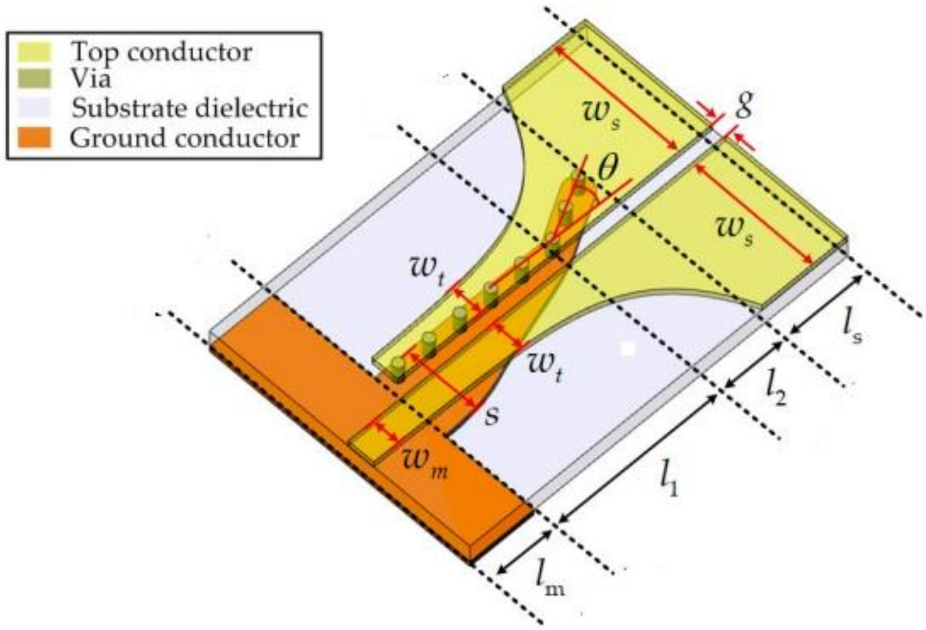

Fig. 1 Microstrip line to slot line transition [1].

TABLE I DIMENSIONS OF BALUN IN MM

w_m	w_s	g	l_m	l_1	l_2	l_3
0.762	5.08	0.127	5.08	12	1.905	3.175

Another approach to convert microstrip line to slot line is given in [2]. A microstrip line (MS) is coupled with slot line on the other side of substrate.

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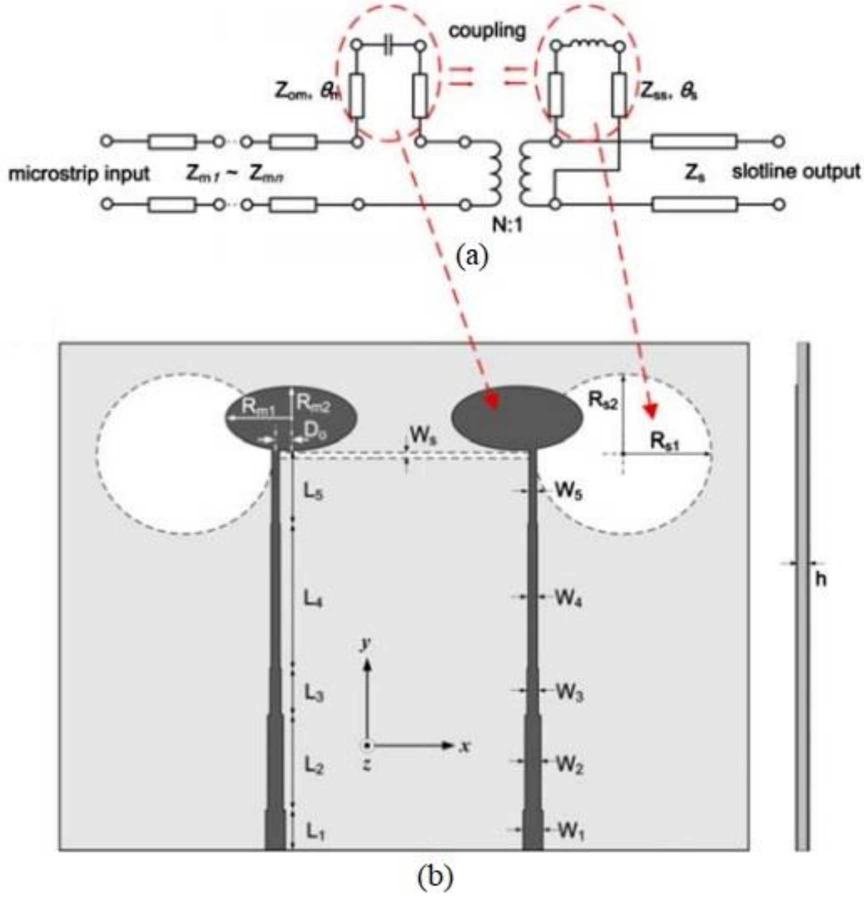

Fig. 2 BALUN using microstrip line to slot line transition [2].

Length of the proposed BALUN is 50.3 mm. Maximum width of the MS line is 1.65 mm as width of the substrate is 0.6 mm with dielectric constant of 2.23. The top layer comprises of stepped MS line for impedance transformation and end of the line is added with elliptical stub which produces magnetic coupling field. This field is coupled with the circular slot on the bottom side of the substrate as shown in Fig. 2. Fig. 2 also shows the electrical equivalent of the proposed BALUN. The measured return loss is better than 14 dB with back-to-back insertion loss 1.5- and 3-dB. The bandwidths of BALUN range from 0.42 to 3.50 GHz (1:8.3) and 0.42 to 9.23 GHz (1:22.0), respectively. The BALUN can also be designed using transition from MS to coplanar strip (CPS) line and is proposed in [3]. The proposed technique is based on the approach shown in Fig. 3.

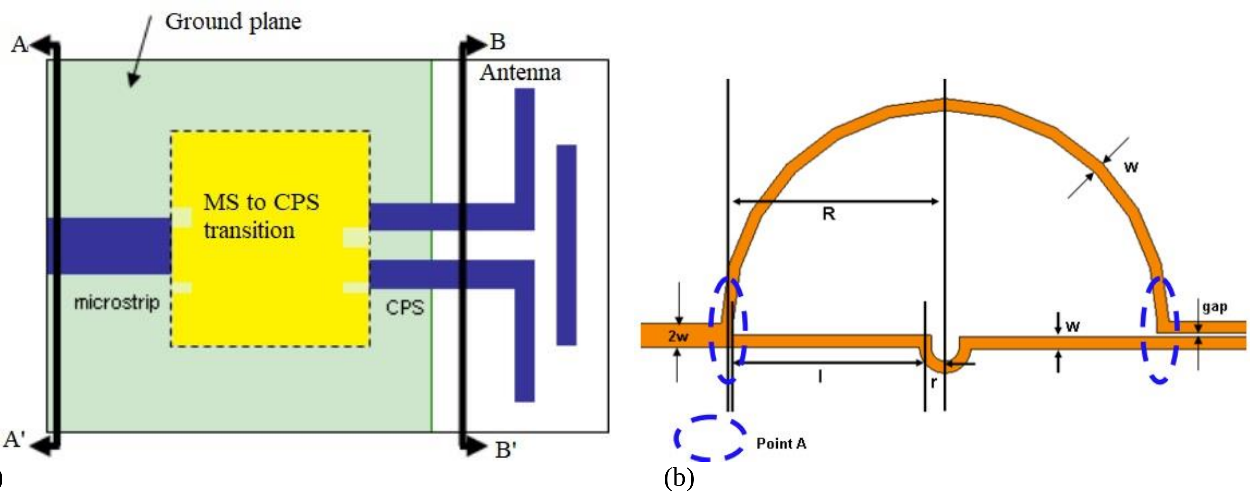

Fig. 3 (a) Unbalanced (MS) line to balanced (b) line (b) proposed MS to CPS transformation.

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CPS line ins balanced in nature therefore there is a phase difference of 180^0 between the two lines. This is achieved by increasing the lengths of one of the bisected lines is made λ/2 (half wavelength) long as compared to other line. R = 1.1 mm, r = 0.1 mm, w= 0.06 mm, gap = 0.02 mm and l = 1.8 mm given in Fig. 3(b). Dielectric constant of the substrate used is 3.16 and thickness is 0.0508 mm. Back-to-back bandwidth of the product is 14% with centre frequency 62 GHz. The insertion loss is better than 2.8 dB.

Similar approach is used to convert 50 Ω MS line impedance to 100 Ω CPS line for 50 to 70 GHz. Insertion loss is less than 3 dB and bandwidth is 60% [4].

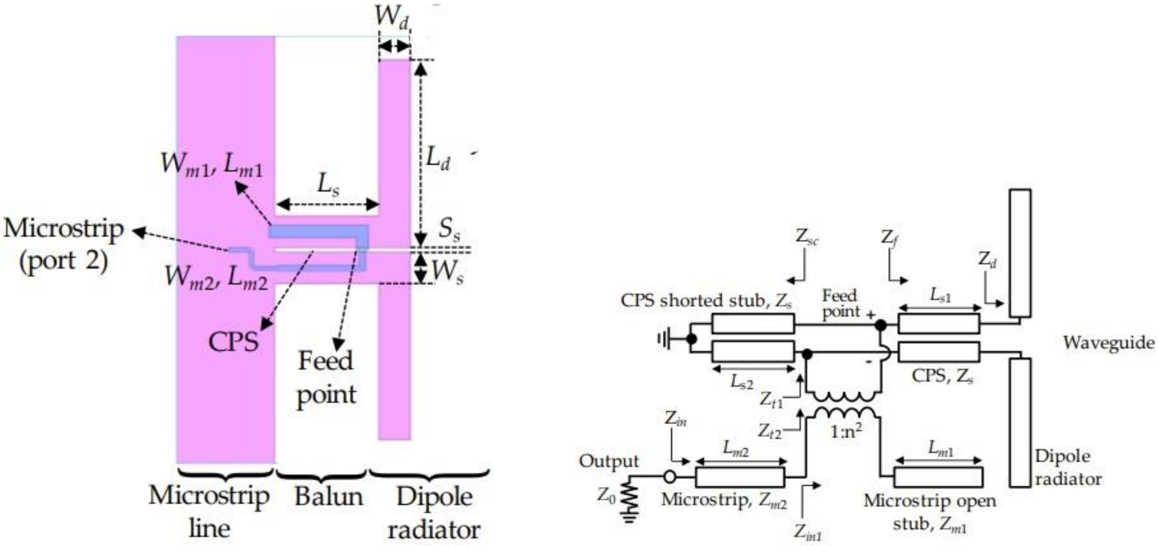
Techniques covered in [1] and [4] are used in [5] to design BALUNs to cover 5 GHz to over 20 GHz. BALUN without vias covers mid-band frequency range of 7 to 11 GHz whereas BALUN with via covers 6.5 to 12.5 GHz band. Insertion lass is less than 3 dB and amplitude difference in not more than 2 dB for first case and 1 dB for second case [5]. Another BALUN of length 12.7 mm using vias covers a band from 5.39 GHz to over 40 GHz with insertion loss less than 1 dB [6].

BALUN is also designed for on-chip applications at THz frequency range. Dipole is extended structure on the ground plane only. Unbalanced line is folded to form a rectangular structure as shown in Fig. 4. Feed point appears as shorted line and magnetic field produced at this point is coupled with dipole. Table 2 shows the dimensional details of the BALUN [7].

TABLE II DIMENSIONAL DETAILS OF ON-CHIP BALUN (um)

Lex	Wd	Ld	Ws	Ls	Ss	Wm1	Lm1	Wm2	Lm2
75	30	180	30	100	5	11.7	1.5	5.5	105

Electrical equivalent of BALUN is shown in Fig. 4(b). Shorted line is expressed as transformer which is used to transform MS line into slot line through coupling. This is achieved with the help of open circuited MS line of half wavelength line. It is well known that a half wavelength line is transforms open circuit condition into short and vice-versa.



(a) (b)

Fig. 4 (a) On-chip BALUN structure (b) electrical equivalent of BALUN.

Another compact most BALUN is transition of MS line into coplanar waveguide line is proposed in [8]. The proposed BALUN covers a 0.2 GHz to 6 GHz with insertion loss less than 3 dB. This BALUN is used to feed a Vivaldi balanced antenna.

Another way to reduce the BALUN size is proposed in [9]. The MS Klopfenstein transformer is first designed to transform 50 Ω input impedance of MS line into 100 Ω line and then is used to feed CPS line of 100 Ω. To reduce the size of this transformer, tapered Klopfenstein is bend into circle with broader width at one end and narrower end at the other end to support 50 Ω input impedance and 100 Ω load.

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The size of the circle can be reduced to control size of the overall transformer only at the cost of bandwidth. Maximum bandwidth covered is 159% at size reduction of 57% w.r.t. to reference straight BALUN.

III. CONCLUSION

There are two distinct approaches to reduce the size of the BALUN. MS line can be a tapered line to transform the impedance from reference value, mostly 50Ω, into desired load impedance. This line can be coupled with slot line. This slot line is used to feed balanced antenna. Slot line can be replaced with CPS line and MS line can be directly connected to it. Size of the BALUN can be reduced by bending the tapered line into circular path. It is observed that the tapered circular path reduces the overall dimension of the BALUN significantly. Such technique can be used to design compact size RF and microwave circuits to feed balanced line using unbalanced line.

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