A Comparative Study Among the Possible Configuration of Double-Y Balun

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October 14, 2019

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***Abstract*—A comparative study has been done among all possible configuration of a double-Y balun. The comparison has been made in terms of their frequency domain response. Double-Y balun has an all-pass characteristic. Among all possible configuration of the double-Y balun, microstrip line to stripline transition from 100Ω unbalanced line to 100Ω balanced line shows the best response. This optimum double-Y balun shows all-pass characteristics over more than 10GHz bandwidth. An exponential taper is used to convert 100Ω unbalanced impedance to 50Ω unbalanced in microstrip line configuration and 100Ω balanced impedance to 100Ω balanced impedance in coplanar stripline configuration. This complete feed system can be used to feed a balanced planar Bi-blade antenna for ground penetrating radar application.**

***Index Terms*—Co-planar stripline, Co-planar waveguide, Double-Y Balun, GPR, Microstrip line, Ultra- Wideband.**

I. Introduction

A microwave balun behaves as a transformer between unbalanced network to a balanced network. Marchand balun and double-Y balun are the two significant class of balun described in literature [1]. Bandwidth over which matching can be obtained is the deciding parameter for the choice of the class of balun. Marchand balun gives bandpass characteristics, whereas double-Y balun provides all-pass characteristics. All pass characteristics of a double-Y balun depend on the following conditions

1) Characteristic impedance of all the six port should be equal.
2) $\beta_{bal} l_{bal} = \beta_{unbal} l_{unbal}$

i.e., the electrical length of balanced (bal) and unbalanced (unbal) transmission line section should be equal. β is the propagation constant. Few types of double-Y balun have already been reported in literature [2] , [3] and, [4]. A microstrip to microslot transition was studied in [2]. This double-Y balun has a transition between 50Ω to 50Ω, and It has a bandpass response. In [3] a CPW to slot transition had been studied. The VSWR response of this balun is ranging between 1.45 GHz to 8.7 GHz. This double-Y balun has a transition between 50Ω to 50Ω. These baluns are costly as they are fabricated on an expensive substrate. Double-Y balun has numerous applications as the feed for antennas required for ground penetrating radar (GPR) application. The double-Y balun has been used as a feeding network to uniplanar Bi-Blade antenna [7]. The balanced end of the balun is connected to the port of Bi-Blade antenna. It has also been used in balanced mixers and in microwave circuits. This paper provides a low-cost design procedure of double-Y balun. A comparison between the possible configuration of double-Y balun has been reported in this paper. Simulated result is also verified with the measured result for a double-Y balun which has Microstrip line (MS) to Co-planar Stripline (CPS) transition.

II. Description of Balun

A microstrip line to co-planar stripline transition double-Y balun having an impedance transition between 100Ω unbalanced to 100Ω balanced line has been studied in this paper. The characteristic impedance of the microstrip line in double-Y balun depends on the width of the top and bottom microstrip line. The variation of the characteristic impedance of the microstrip line section with the ratio of the width of the microstrip line is shown in the Fig.1. This curve is useful to choose a particular width ratio of the microstrip line corresponding to a required characteristic impedance. The characteristic impedance of the co-planar stripline in double-Y balun depends on the amount of the gap between two parallel strips. Fig.2 shows the variation of the characteristic impedance of the CPS section with the change of the gap distance. This figure will help a designer to choose a particular gap distance to obtain a specific characteristic impedance.

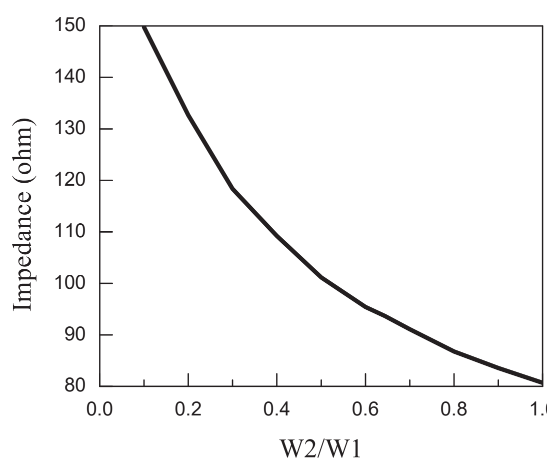


Fig. 1. Variation of the characteristic impedance of the microstrip line with width ratio

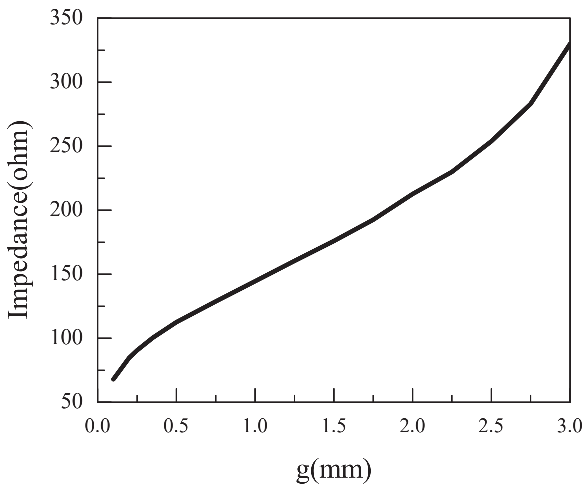


Fig. 2. Variation of the characteristic impedance of the co-planar stripline with the gap between two lines

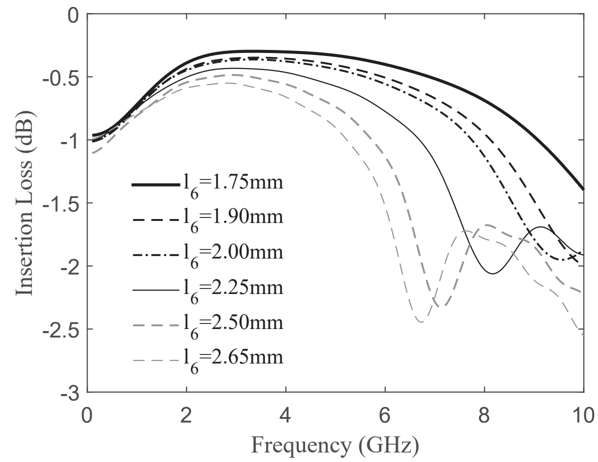
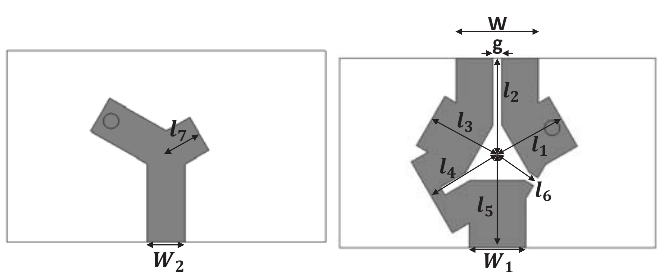


Fig. 4. Variation of the insertion loss with the length of the open ended CPS section

III. Simulation and Measured Results

A Double-Y balun having a transition between 100Ω MS line to 100Ω CPS line is designed in CST Microwave studio. The width ratio as obtained from Fig.1 to maintain 100Ω characteristic impedance of the microstrip line is 0.52. Whereas, the gap distance in the CPS line is required to be 0.35mm as obtained from Fig.2 to obtain 100Ω characteristics impedance of the CPS line.

Fig.3 shows the bottom and top view of the double-Y balun, which has a microstrip (MS) line to the co-planar stripline (CPS) transition. Here MS is an unbalanced transmission line, and CPS is a balanced transmission line.



(a) Top (b) Bottom

Fig. 3. Prototype of the Double-Y Balun

The insertion loss of the double-Y balun depends on the length of the open section of the CPS line. The variation of the insertion loss is plotted in Fig.4. It is observed from this figure that the length of the open section of the CPS section should be less than 1.75 mm. Loss increases beyond 1.75mm. The insertion loss characteristics have a sudden dip due to the parasitic effects of the transmission line sections of the double-Y balun [5], [6]. The parasitic effects become prominent at the lower frequency as the length increases beyond 1.75mm. Table.I tabulate the design parameters of the MS to CPS double-Y balun. A low-cost FR4 substrate of dielectric constant 4.3 and substrate thickness 1.6mm has been used for the simulation studies and fabrication.

TABLE I
Design Parameters of the Double-Y Balun

Design Parameters	Corresponding Values (mm)
l_1	3.00
l_2	4.00
l_3	3.05
l_4	3.00
l_5	3.00
l_6	1.75
l_7	1.50
W	3.25
W_1	2.88
W_2	1.5
g	0.35
Radius of Via	0.30

The simulated scattering parameters of the double-Y balun is shown in Fig.5. The return loss is almost below -20dB over the 10 GHz frequency band. The insertion loss is roughly around 0dB over this 10GHz frequency band.

The other possible configuration of the double-Y balun between unbalanced to the balanced transmission line can be viewed as the co-planar waveguide (CPW) to CPS transition, the coaxial transmission line to twin wire transmission line transition. A CPW to CPS transition double-Y balun is shown in Fig.6. A coaxial transmission line to twin wire transmission line transition is shown in Fig.7. The length and dielectric properties are keeping the same as MS to CPS transition double-Y balun discussed previously.

The return loss and insertion loss characteristics of three different configurations of a double-Y balun(DYB) have been

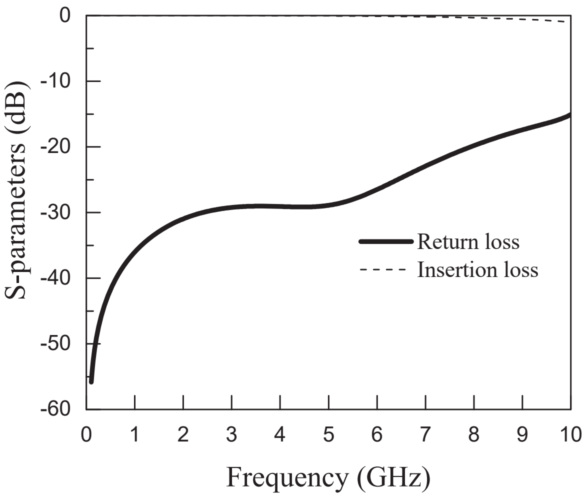


Fig. 5. Variation of the scattering parameters of double-Y balun

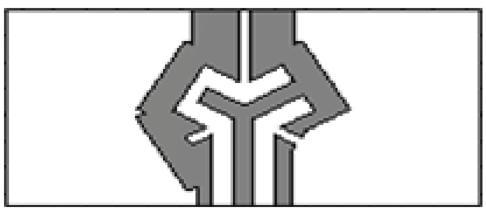


Fig. 6. Simulated prototype of co-planar waveguide to CPS transition based double-Y balun

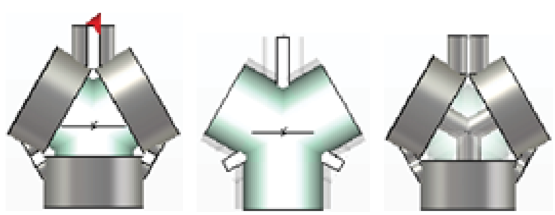


Fig. 7. Simulated prototype of co-axial transmission line to twin wire transmission line transition based double-Y balun

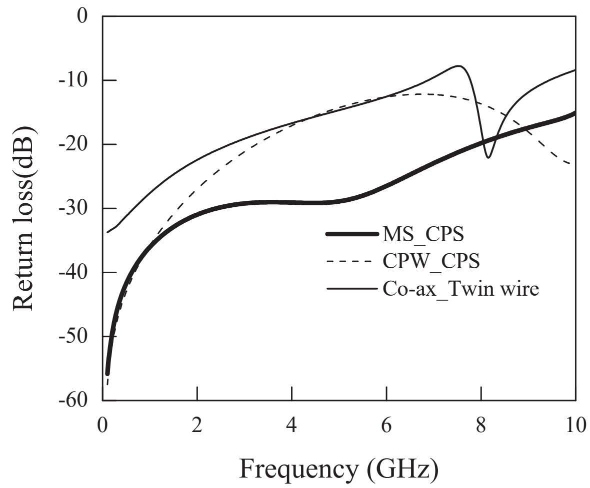


Fig. 8. Comparison of the return loss among the possible configuration of double-Y balun

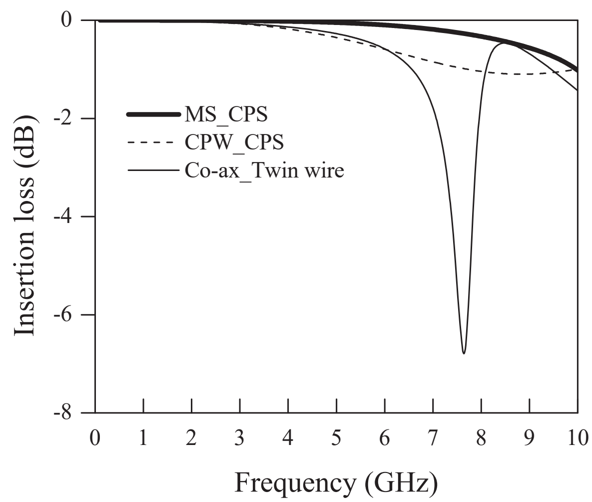


Fig. 9. Comparison of the insertion loss among the possible configuration of double-Y balun

compared. Fig.8 shows the comparison of the return loss among the different DYB configurations. It is observed that the microstrip line to coplanar stripline shows better return loss response than the remaining two configurations. Coaxial transmission line to twin-wire line transition shows the worst response among the three DYB configuration. Also, it limits the bandwidth. Fig.9 represents the variation of the insertion loss with frequency for three different DYB configurations. This variation also suggests that MS to CPS transition DYB provides less amount of loss than the remaining two configurations. Coaxial to twin-wire transition provides loss at a higher frequency. This again limits the overall bandwidth of operation.

DYB can be used as a feed for balanced Bi-Blade antenna employed in ground penetrating radar (GPR) application. The terminal impedance of the antennas for GPR application is maintained at 100Ω whereas the feed impedance of the SMA port is 50Ω. Therefore a transition is required from 100Ω MS line to 50Ω MS line. An exponential taper is used for this transition. Another transition has been used to transform 100Ω CPS line to 100Ω CPS line with the gradually increasing dimension of the CPS line section. This complete feed system, i.e., double-Y balun with exponential tapering, is simulated in the full-wave simulator (CST Microwave Studio) and fabricated. The top and bottom portion of the fabricated prototype is shown in Fig.10 and Fig.11 respectively. A 100Ω SMD resistor has been connected at the end of the CPS line. Length of the exponential line taper is 75mm.

The measured return loss of the complete feed system (DYB with exponential line taper) is shown in the Fig.12. The Measured return loss almost replicates the simulated result over the 10 GHz frequency band.

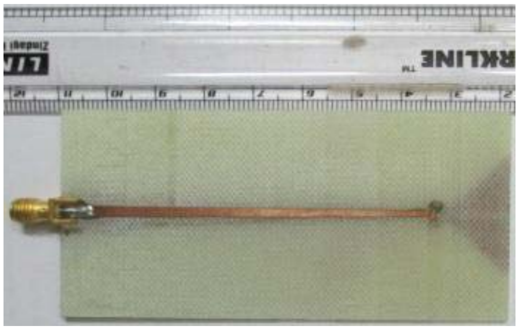


Fig. 10. Top view of the fabricated feed structure

Fig. 11. Bottom view of the fabricated feed structure

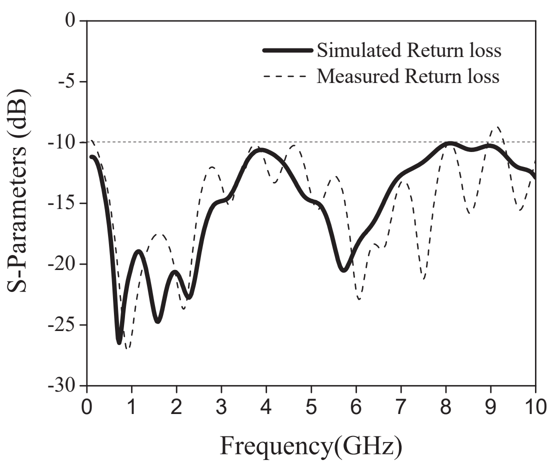


Fig. 12. Comparison of the measured and simulated return loss

IV. Conclusion

A comparative study among the possible configuration of double-Y balun has been studied in this paper. Microstrip to co-planar stripline provides best possible response than the other transition. The simulated result of the microstrip line to co-planar stripline transition of double-Y balun configuration has been verified through fabrication and measurement. The measured result more or less matched with the simulated response. This double-Y balun can be used as a feed system for the ground penetrating radar applications.

TABLE II
Comparison of the recent literature

Ref. No.	Type of Transition	Impedance trans-formation	Substrate Properties	Dimension of substrate (mm×mm)	Bandwidth (GHz)
[1]	CPW[FGP] to CPS	50Ω to 50Ω	ϵ_r=9.8 h=0.64mm	-	DC to 13
[2]	Microstrip to Microslot	50Ω to 50Ω	ϵ_r=10 h=0.51mm	25.4× 25.4	2 to 9
[3]	CPW to Slotline	50Ω to 50Ω	ϵ_r=9.8 h=0.64mm	50.8× 50.8	1.45 to 8.7
[4]	MS to CPS	93Ω to 93Ω	ϵ_r=9.8 h=0.64mm	46.5× 12.7	0.4 to 8
[8]	CPW[FGP] to CPS	50Ω to 50Ω	ϵ_r=9.8 h=0.64mm	-	0.003 to 4
[9]	MS to CPS	100Ω to 100Ω	ϵ_r=5.9 h=0.5mm	15× 8	1 to 18
This Paper	MS to CPS	100Ω to 100Ω	ϵ_r=4.3 h=1.58mm	12.5× 7.5	DC to $\geq$ 10

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