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Branch Line Directional Coupler with Ultra Wide Bandwidth

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Abstract—*In this paper branch-line coupler is proposed, that is able to operate in ultra wide frequency range with operating frequency of 2.6GHz. Several types of microwave quadrature hybrids have been reported for the realization of balanced circuits, matched attenuators, and phase shifters. Due to convenience in design and implementation, the branch line coupler becomes one of the most popular hybrids. But, it offers limited bandwidth and requires a large circuit area. Thus, in this paper, a study and investigation of the simulation performance of microstrip branchline coupler is to be carried out using PUFF. By using the theoretical and analytical readings with the help of software, the bandwidth of the coupler can be extended upto the range of 3.1GHz to 10GHz using stubs.*

1. INTRODUCTION

The branch-line couplers find various applications in microwave and millimeter wave circuits. There are lots of applications of 90 degree hybrid and 180 degree hybrid branch-line tight couplers, such as 3-dB or 6-dB coupler in our modern microwave and millimeter wave communication systems. It can only be operated in the odd multiples of the fundamental band, which prevents itself from the versatile applications in dual-band or multi-band systems. Further, it avoids narrow line gaps and need for bond wires[1].

Generally branch-line couplers are 3dB, four ports directional couplers having a 90° phase difference between its two output ports named through and coupled arms. Branch-line couplers(also named as Quadrature Hybrid) are often made in microstrip form. Fig. 1, shows conventionalbranch line coupler in microstripline form [2].Fig. 2 shows the frequency response of a conventional branch line coupler with the given parameters in the software itself.

1.1 Defect ground structure

DGS is an etched periodic or non-periodic cascaded configuration defect in ground of a planar transmission line (e.g., microstrip, coplanar and conductor backed coplanar wave guide) which disturbs the shield current distribution in the ground plane cause of the defect in the ground. This disturbance will change characteristics of a transmission line such as line capacitance and inductance. In other words, any defect etched in the ground plane of the microstrip can give rise to increasing effective capacitance and inductance[3].

1.2 Stubs

At high frequencies transmission line segments in parallel can be used instead of lumped elements to deliver compatible performance. Open and shorted stubs are frequently used in transmission line segment. Very short line segments terminated in low impedances behave like inductors, while, very short segments terminated with high impedances behave like capacitors. Therefore a short circuited (to ground) parallel stub behaves inductive (a short segment here is defined as a segment of 5% to 10% of the effective wavelength). An open circuited parallel stub behaves like a capacitor.

2. PROPOSED APPROACH OF ULTRA WIDE BAND

The input impedance of transmission line is given

by $Z_{in}=Z_o\frac{Z_l+jZ0\tan\beta*l}{Zo+jZ_l\tan\beta*l}$ 1

$\Gamma_l=(Z_l-Z_0)/(Z_l+Z_0)$ 2

Where Γ_l is the reflection coefficient

here,

Z_0 is the characteristic impedance

Z_l is the load impedance

The input impedance of open circuit stubs is

$Z_{in}=-j\,Z_o\cot(\beta*l)$ 3

If $(\beta*l)=\lambda/4=90^0$ then $Z_{in}=0$

The input impedance of short circuit stubs is

$Z_{in}=j\,Z_o\tan(\beta*l)$ 4

If $(\beta*l)=\lambda/4=90^0$ then $Z_{in}=\infty$

Therefore short circuited stubs provide infinite resistance at the operating frequency and the frequency around the operating frequency to a greater extent. Similarly, open circuited stubs provide zero resistance at the operating frequency and the frequencies around it .

For a conventional 3dB branch line coupler where $\Theta_1 = \Theta_2 = 45^0$ the characteristic impedance of the series transmission line is $Z_0/\sqrt{2}$ and shunt transmission line comes out to be Z_0 where output comes out to be .

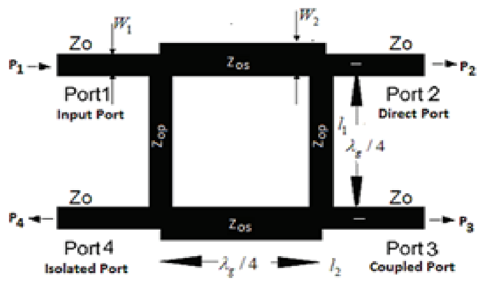

Fig. 1: Branch line coupler

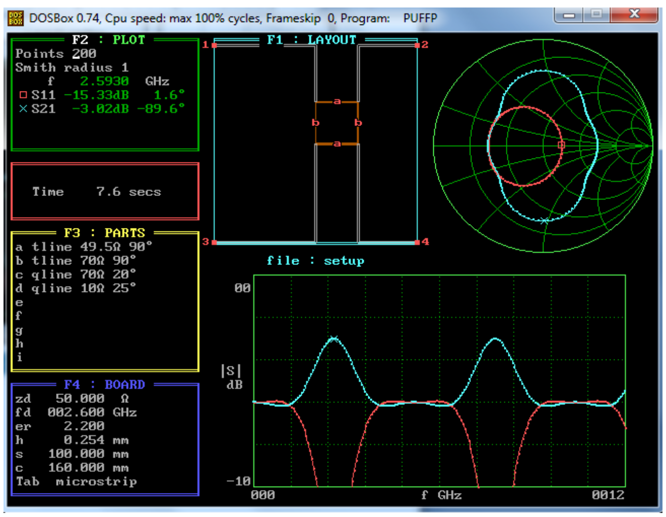

Fig. 2: Representation of bandwidth for the parameters as given in the figure.

The characteristic impedance with dielectric constant 2.2 for W/d ≥2 can be calculated as [5]

$Z_0=\{120\pi/\sqrt{\varepsilon_e}[W/d+1.393+0.667\log(W/d+1.44)]$

for W/d ≥1} 5

$\varepsilon_e = (\varepsilon_r+1)/2 + (\varepsilon_r-1)/2 * 1/\sqrt{(1+12d/W)}$ 6

Where $1 < \varepsilon_e < \varepsilon_r$ here W is width of transmission line , d is height of substrate , ε_e is the effective dielectric constant , Here ε_r is the relative dielectric constant.

Applying short-circuit stubs in the middle of the series transmission lines and shunt transmission lines increase the bandwidth to some extent but with high attenuation at some intermediate frequency. Thus addition of stubs,which have some finite impedance at frequencies other than the operating frequency changes the overall impedance of the transmission lines which distort the performance of the coupler.

2.1 Design parameters of the coupler

Initially, keeping the characteristic impedance of the coupler to be 50Ω and design frequency to be 2.6GHz and substrate of dielectric constant 2.2.

The attenuation of the coupler can be determined with the help of conservation of energy,

$$|S_{12}|^2 + |S_{13}|^2 = 1 \quad (7)$$

As the frequency changes, there is some finite impedance of stubs which overall changes the impedance of the series as well as shunt transmission for that frequency. Since the input impedance of the coupler is real at the center frequency, the scattering parameter is also real [4].

Input impedance of the short circuit stub is infinite if the electrical length of the stubs is 90^0. Open or closed stubs provide a perfect mismatch for the signal and reflection coefficient is either 1 or -1. Deviation from the center frequency creates less attenuation for the signal with the addition of stubs symmetrically.

With the help of theoretical and analytical analysis, we can determine the parameters of the coupler to give the output in ultra wideband .the scattering parameters of the coupler can be implicitly known from the software itself.With the help of stubs we can design high impedance line and further help in miniaturization.

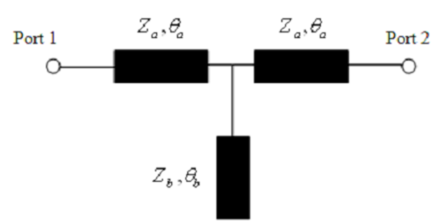

Fig. 3: Equivalent quarter wavelength transmission of T-model.

Hence with the help of ABCD parameters we can determine the overall impedance of the transmission line[11].

The ABCD matrix equation is given by

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\lambda/4} = \begin{bmatrix} 0 & JZo \\ jYo & 0 \end{bmatrix} \quad (8)$$

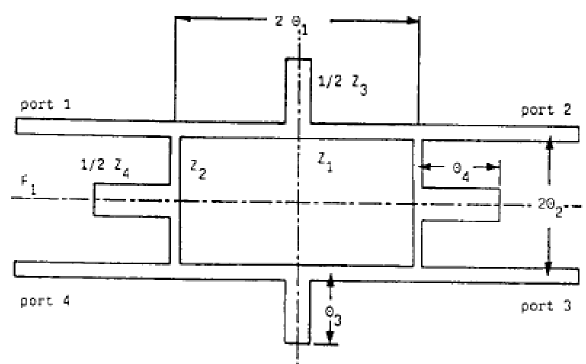

Fig. 4: Branch line coupler with open stubs

3. FREQUENCY RESPONSE OF A COUPLER WITH DIFFERENT PARAMETERS

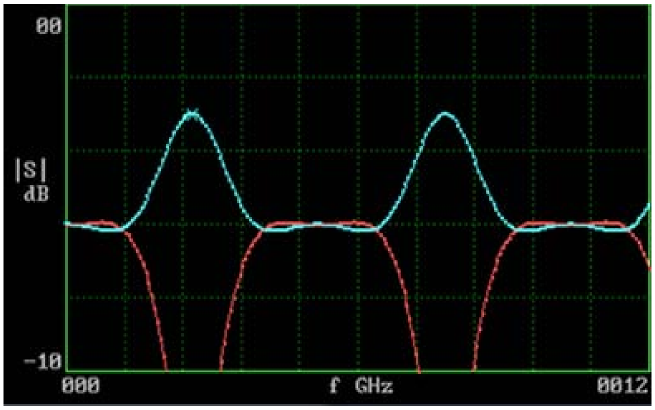

Fig. 5: Frequency behavior ofa simple branch line coupler with,Z_1=49.5Ω,Z_2=70Ω,Z_3=10Ω, Z_4=70Ω,$Θ_1=90^0$, $Θ_2=90^0$, $Θ_3=25^0$,$Θ_4= 20^0$ electrical length

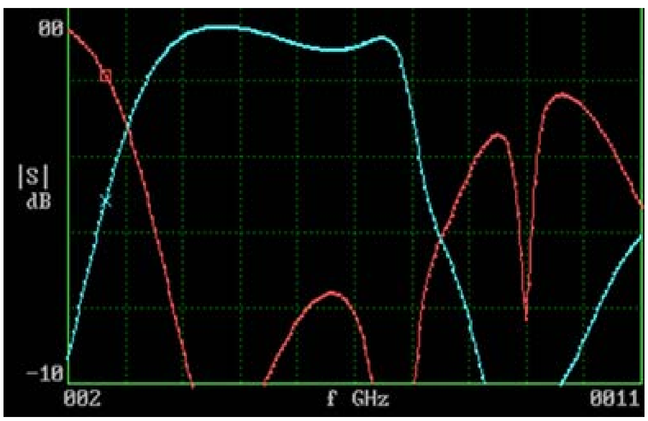

Fig. 6: Frequency behavior ofa branch line coupler open stubs with,Z_1=49.5Ω,Z_2=70Ω, Z_3=60Ω, Z_4=35Ω,$Θ_1=45^0$, $Θ_2=45^0$, $Θ_3=30^0$,$Θ_4= 10^0$ electrical length

Fig. 7: Frequency behavior ofa branch line coupler with decreased characteristic impedance,Z_1=35.5Ω,Z_2=80Ω, Z_3=70Ω, Z_4=40Ω, $Θ_1=45^0$, $Θ_2=45^0$, $Θ_3=30^0$,$Θ_4= 10^0$ electrical length

Fig. 8: Frequency behavior ofa branch line couplerwith increased electrical lengthwith Z_1=30.5Ω, Z_2=80Ω, Z_3=70Ω, Z_4=20Ω, $Θ_1=50^0$, $Θ_2=45^0$, $Θ_3=37^0$,$Θ_4= 10^0$ electrical length

Fig. 9: Frequency behavior ofa branch line coupler with ultra wide bandwidth with Z_1=52.5Ω, Z_2=80Ω, Z_3=80Ω, Z_4=20Ω, $Θ_1=58^0$, $Θ_2=27^0$, $Θ_3=36^0$,$Θ_4= 11^0$ electrical length.

The various values of the length and width of series and shunt transmission line obtained from figure.9are summarized in Table 1.

Table 1: Length And Width Of The Transmissiom Line In BLC With Closed Stubs

Parameters	Length(mm)	Width(mm)
A	13.543	1.603
B	6.431	0.782
C	2.476	5.685
D	8.574	0.782

In Table 1, ‘a’ defines the series transmission line, ‘b’ defines the shunt transmission line, ‘c’ and ‘d’ are the closed stubs in parallel with shunt transmission line and series transmission line respectively.

4. CONCLUSION

The analysis in this paper shows that with the help of varying parameters of shunt and series transmission lines and by varying the parameters of open or short circuit stubs around the design frequency, the operating bandwidth of the branch line coupler can be increased efficiently. Besides this, the performance of the branch line coupler can be increased with the help of different improved designs using PUFF. Further the open stubs help in designing high impedance lines, which help in miniaturization and enhanced output. The plots obtained gives all the scattering parameters implicitly on the specified design parameters.

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