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DESIGN OF COMPACT COUPLED LINE WIDE BAND POWER DIVIDER WITH OPEN STUB

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ABSTRACT

A generalized coupled line power divider structure is proposed here for a wide band operation. The proposed design which consists of four coupled line makes the power divider to operate in wide band with better isolation. This coupled line structure is analyzed with odd mode and even mode impedance characteristics and contains two lumped resistors for providing isolation between the coupled lines. This structure also contains open stubs for improving the operation bandwidth. The proposed compact 3dB power divider has 50% area reduction while comparing it to the previous dual band coupled line power divider structure. Comparing the previous dual band structure, the proposed power divider has better isolation bandwidth and insertion loss. By using the basic Wilkinson power divider design equations, the new design of coupled line structure is proposed and designed to operate in wide band range 0.8-2.8 GHz.

Keywords: wilkinson power divider, coupled line, wide band, stub.

1. INTRODUCTION

In recent years, there has been more interest to develop more versatile components, which can fulfill the requirements of the multi-frequency operation. The power combiner or divider has been long of interest, which is extensively used in microwave and communication systems. The power divider and combiner are very important components for microwave power amplifiers. Recent years have seen a worldwide effort to develop dual-band power dividers [1] due to the trend of multiband mobile phones. The original power divider developed by Wilkinson [9] consists of two quarter-wavelength lines and operates in a single band. To satisfy arbitrary dual-band operations, new modified power dividers have been proposed in [2]–[5].

A coupled line has advantages, such as compact structure and flexible to design. Since 2009, coupled-line power dividers for single band [2] or dual-band [3], [6] systems have been attracting more and more research interests. The existing dual band power divider circuit has two-section coupled lines and two isolation resistors [1]. It occupies large area due to its lengthy coupled lines. In this paper a new approach is proposed with four quarter wavelength coupled lines and two resistors. The lumped resistors used to provide better isolation in the range. The insertion loss is also reduced by using stub between the coupled lines.

2. THEORY

When the micro-strip line is considered, the impedance matching network can be easily incorporated with the micro-strip feed line to realize wider impedance bandwidth. A popular impedance matching technique is a single open-circuited or short-circuited length of transmission line (a *stub*) connected either in parallel or in series with the transmission feed line at a certain distance from the load. For transmission line media such as micro-strip or strip line, open- circuited stubs are easier to fabricate since a via hole through the substrate to the ground plane is not needed.

Stubs can be used to match load impedance to the transmission line characteristic impedance. The stub is positioned a distance from the load. This distance is chosen so that at that point the resistive part of the load impedance is made equal to the resistive part of the characteristic impedance by impedance transformer action of the length of the main line. The length of the stub is chosen so that it exactly cancels the reactive part of the presented impedance. That is, the stub is made capacitive or inductive according to whether the main line is presenting an inductive of capacitive impedance respectively [10].

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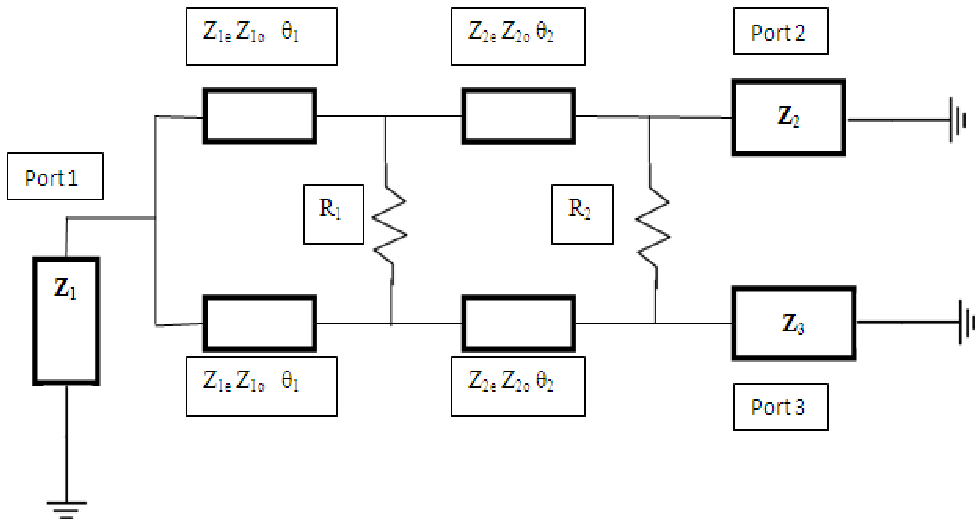

Figure-1. Existing dual band coupled line power divider.

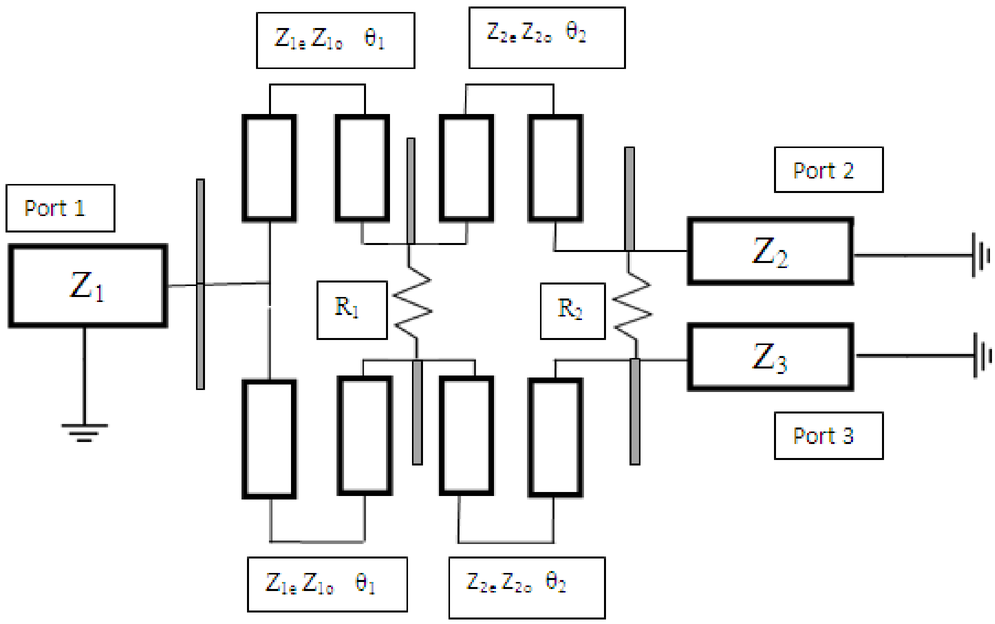

Figure-2. Proposed wide band coupled line power divider.

3. DESIGN EQUATIONS

After even- and odd-mode analysis, the relationship between electrical length θ and operating frequency f is positive linear. For the center frequencies f_1 and f_2=gf_1, where, g is frequency ratio and is given in (1) and g≥1. We can obtain the θ conditions from (2a) and (2b) for arbitrary dual-band applications as [1]

$$g = \frac{f_2}{f_1} \quad (1) \qquad \theta_1 = \frac{\pi}{1+g} \quad (2a)$$

$$\theta_2 = \frac{g\pi}{1+g} \quad (2b)$$

The width of input and output port transmission line can be calculated from (3a) and (3b) [1]

$$Z0 = \frac{\frac{120\pi}{\sqrt{\varepsilon_{eff}}}}{W/_h + 1.393 + 0.667\ln[W/_h + 1.444]} \quad (3a)$$

Where,

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \quad (3b)$$

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The length of each section coupled line can be calculated from (4) and it is the quarter-wavelength transmission line. [1]

$$l = \frac{\lambda_0}{4\sqrt{\varepsilon_r}} \qquad (4)$$

Where, $\lambda_0 = \frac{c}{f_0}$ And

$$f_0 = \frac{f_1 + f_2}{2}$$

The even-mode and odd-mode characteristic impedance of two coupled line sections are calculated from (5a), (5b), (6a) and (6b). [1]

$$Z_{1e} = Z_0 \sqrt{\frac{\left(\sqrt{1 + 8\tan^4\theta_1} - 1\right)}{\tan^2\theta_1}} \qquad (5a)$$

$$Z_{2e} = Z_0 \sqrt{\frac{\left(\sqrt{1 + 8\tan^4\theta_2} + 1\right)}{2\tan^2\theta_2}} \qquad (5b)$$

$$Z_{1o} = Z_0 \frac{4}{5}\left(1 + \frac{g}{20}\right) \qquad (6a)$$

$$Z_{2o} = Z_0 \frac{17}{20}\left(1 - \frac{g}{30}\right) \qquad (6b)$$

The lumped resistor of each coupled line section is found by (7) and (8).[1]

$$R_1 = \frac{2Z_{1o}Z_{2o}\tan^2\theta_1}{\sqrt{(Z_{1o}+Z_{2o})\tan^2\theta_1[Z_{1o}\tan^2\theta_1 - Z_{2o}]}} \qquad (7)$$

$$R_2 = \frac{2Z_0 Z_{2o}^2 (Z_{1o}+Z_{2o})\tan^2\theta_2 + 2Z_0^2 Z_{2o}\sqrt{(Z_{1o}+Z_{2o})\tan^2\theta_2[Z_{1o}\tan^2\theta_2 - Z_{2o}]}}{Z_0^2 Z_{2o} + \left(Z_{1o}Z_{2o}^2 - Z_0^2 Z_{1o} + Z_{2o}^3\right)\tan^2\theta_2} \qquad (8)$$

The coupling coefficient of each coupled line in this power divider is calculated from (9a) and (9b),[1]

$$C_1 = 20\log\frac{Z_{1e} + Z_{1o}}{Z_{1e} - Z_{1o}} \qquad (9a)$$

$$C_2 = 20\log\frac{Z_{2e} + Z_{2o}}{Z_{2e} - Z_{2o}} \qquad (9b)$$

4. PROPOSED DESIGN LAYOUT

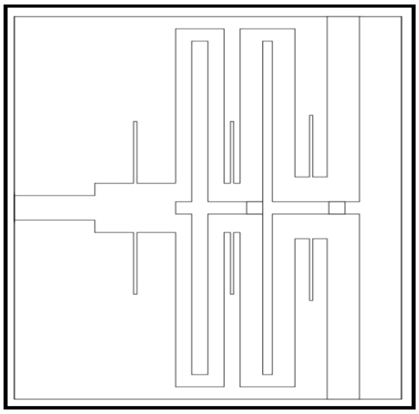

Figure-3. Layout of proposed power divider.

The proposed design consists of four coupled lines. The coupled line widths are 1 mm and 1.4 mm. All the three port line width is 2 mm. The stub length is 5 mm and width is 0.2 mm. Six open stubs are connected in the coupled line. The resistors are connected at the end of each coupled line section. By adjusting the length and width of the stub the impedance matching is obtained.

5. SIMULATION RESULTS

The proposed wide band power divider is designed to operate in 0.8-2.8 GHz have been simulated by using the simulator Ansoft HFSS (High Frequency Structure Simulator) and the scattering parameters are analyzed. The power divider is simulated with Taconnic-RF35 substrate which has 0.79 mm thick and a relative permittivity of 3.5. The port impedances are 50 Ω. The length of each coupled line is 14mm and the coupling space between the first coupled line is 1mm and 0.6 mm for the second coupled line. The coupled line width is 1mm for the first coupled line and 1.4 mm for the second coupled line. The resistor values which are used between the coupled lines are 100Ω and 330Ω. Simulation results show that the impedance matching for the proposed power divider strongly depends on the location of the stub. Thus the impedance bandwidth is widened by maintaining width and length of the stub.

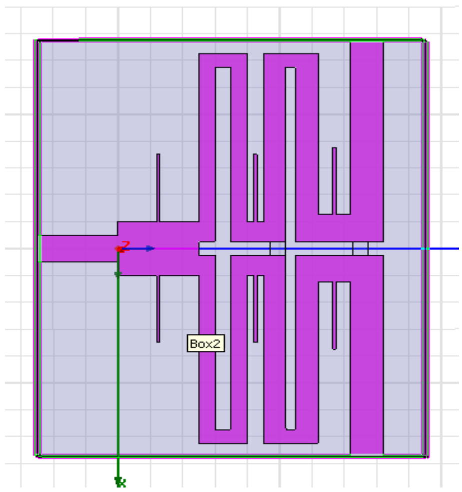

Figure-4. View of proposed power divider.

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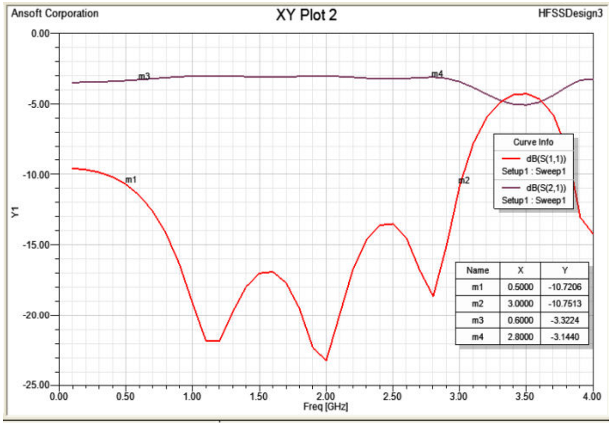

Figure-5. S_{11}, S_{21}.

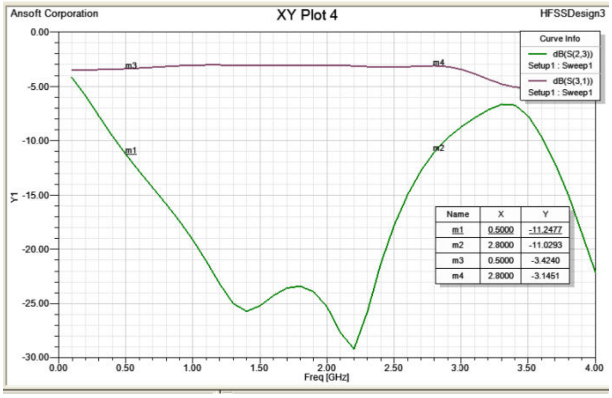

Figure-6. S_{23}, S_{31}.

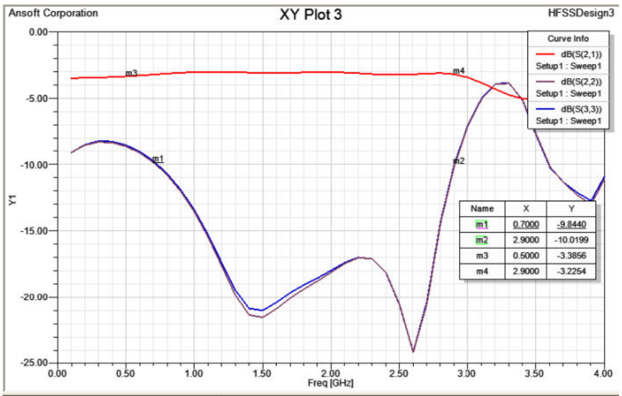

Figure-7. S_{22}, S_{33}, S_{21}.

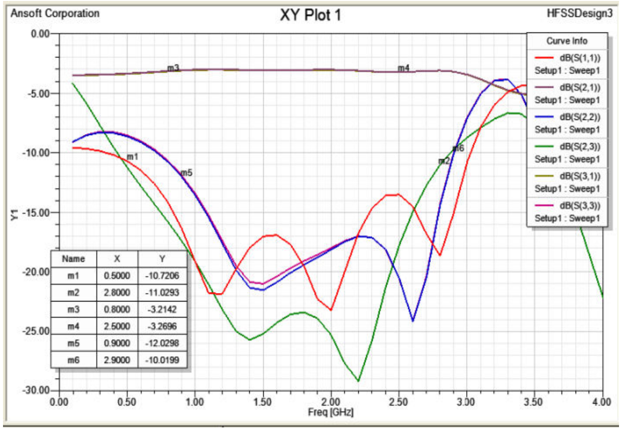

Figure-8. Simulated output - s parameters.

Table-1. Simulated results by using hfss.

S-Parameter	Simulated result
S_{11}	Below -10 dB in 0.5 to 3 GHz
S_{22} , S_{33}	Below -10 dB in 0.8 to 2.9 GHz
S_{23}	Below -10 dB in 0.5 to 2.8 GHz
S_{21}, S_{31}	Maintained at -3.21 to -3.26 dB

6. CONCLUSIONS

The proposed power divider works under the wide range of band 0.8-2.8 GHz. It has the reduced size compared with the previous dual band coupled line power divider. It has the 50% of size reduction. The return loss is also reduced up to -22dB. Isolation between the ports is obtained -25 dB. Insertion loss is maintained -3.2dB. So the proposed power is well suited for L Band, S band applications like GPS, GNSS systems (1.2-1.6 GHz), Mobile phone networks like GSM 1.8-1.9 GHz, WiMAX (Wireless Interoperability for Microwave Access) 2.3-2.5 GHz, Mobile Broadband Wireless Access (MBWA) 1.6-2.3 GHz to give mobility, ISM band applications 2.4 GHz.

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