Compact Structure and Low Losses for Wilkinson Power Divider at 9400MHz Frequency for X-Band Antenna System

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Abstract

This paper presents design and implementation 2-way Wilkinson power divider at 9400MHz frequency which matched to 50Ω transmission line. This design applies Microstrip line with Roger Duroid 5880 Substrate and uses software simulation (ADS 2011) to help the design. This Wilkinson power divider designed at 9400MHz for use on Antenna X-Band Radar System. The desire objectives are a power divider can be used in compact circuit board with low insertion loss and good matching for all ports. The dimension of the devices after fabrication is 30mm x 40mm. The Voltage Standing Wave Ratio (VSWR) for all port for both dividers is less than 1.33. Forward transmission the devices as Divider or the Split power ratio (S21 and S31) is about -2.522dB, Reverse transmission the devices as Combiner (S12 and S13) is about -2.861dB. The Isolation between the both output ports shows a good isolation, less than -11.271dB. The overall result of simulation and fabrication show a fairly good result.

Keywords: Wilkinson power dividers, roger duroid, antenna system, x band radar

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1. Introduction

The Wilkinson power divider/combiner is one of the various basic components in microwave circuits and systems. It is applied and usually operated around a single frequency where the transmission lines in the power divider are a quarter wavelengths. General configuration of the power dividers is used Wilkinson Power Divider (WPD) because this configuration has a good parameter, is like lossless (if all ports are match) and it is have high isolation between the outputs port [1]. The Wilkinson Power Divider has been designed and fabricated for Radar S-Band that used for divide the power output from oscillator [2]. The Bagley polygon power divider for N-way with a center frequency at 1GHz has been designed and fabricated [3]. Power divider is not use an isolation resistor between the each output ports, but uses transmission line and can be easily extended to multiple output ports (N-way). However, the output ports for such divider are not matched and the isolation between them is not as good as that of the Wilkinson power divider [4].

In recent years, as mobile communications, satellite communications, radar and remote sensing technology continues to develop, the RF sending and receiving end of the communication need higher and higher technical requirements. As a core device, microwave filters directly affect the performance of the whole system [5-8]. Power dividers are frequently used in microwave and millimeter-wave circuits such as the feeding network for an antenna array and for high frequency oscillator. In this paper, Authors will present the development of the power divider focus on desired center frequency and determine the center frequency in order to make optimal in compact form and matching output. The power divider will be integrated with the X-band radar antenna on each patch array antenna so that the power divider should have a compact structure and small dimension because the physical dimension of the antenna structure limited.
2. Design Methodology

The 2-way WPD usually work at quarter-wavelength transmission line (λg/4) section at the design center frequency and Wilkinson power consists of two quarter-wavelength line segments at the center frequency (f_c) with characteristic impedance 2*Z_o, and a 2*Z_o lumped resistor connected between the output ports [9]. A popular basic configuration of the 2-way WPD is often made in microstrip or stripline form as depicted in Figure 1(a), and the corresponding transmission line circuit is given in Figure 1(b) [10].

![Diagram](image)

Figure 1. The Wilkinson Power Divider; (a) An equal-split Wilkinson power divider in microstrip form, (b) Equivalent transmission line circuit

The 2-way WPD with 9400MHz frequency center (f_c), Z_o = 50Ω will be designed and fabricated on a 0.787mm thick Roger Duroid 5880 substrate which has relative permittivity of 2.2, the dissipation factor is 0.0009 and conductor thickness of 35µm. The smallest insertion loss result depends on designing of the width of λg/4 section (W) at frequency center (f_c). Based on figure 1, the 2-way WPD has some ideal parameters that can be implemented into a microstrip transmission line. Using equation (1) and (2), the width of microstrip line from some ideal parameters of the 2-way WPD can be known [11].

\[ \varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(1 + \frac{12}{W}\right)^{-0.5} \]  

(1)

\[ Z_c = \frac{120\pi}{2\pi f_{re}} \left(\frac{W}{h} + 1.393 + 0.677\ln\left(\frac{W}{h} + 1.444\right)\right)^{-1} \]  

(2)

All physical dimension of microstrip line was obtainable with use TXLine tools software as presented in Figure 2. The development on these devices also refers to important of optimizing the matching output of devices. In addition to obtaining a good VSWR will also affect the wide of bandwidth and low insertion loss.

![Diagram](image)

(a) 50 Ω transmission line  
(b) 70.71 Ω transmission line

Figure 2. Microstrip Line with use TXLine Tools
3. Simulation and Measurement Result

The schematic and layout of the 2-way WPD has been designed is shown in Figure 3. The layout simulation is used for transmission line simulation at ADS 2011.10 software. The layout diagram will have some optimization by tuning the length of 70.71Ω transmission line and the length of input-output matching to improve the result on desired center frequency.

![Simulation Layout for 2-way WPD](image)

Figure 3. Layout for Simulation 2-way WPD

(a) Simulation result Return Loss (S11, S22, S33)
(b) Simulation result Insertion Loss Return (S12, S13, S21, S31)
(c) Simulation result Isolation between 2 ports (S23, S32)

Figure 4. The Result of the Simulation 2-way WPD
The simulation result of the 2-way WPD has been simulated and depicted on Figure 4. The result of this simulation contains graphs of the return loss, insertion loss and isolation of the proposed design of 2-way WPD. From the simulation result, the input and output port have return loss less than -43dB, this is indicating less than 0.005% of the power is reflected back. The insertion loss showed that this power divider divides the equal power with transmission loss about -3.045dB, its indicate the signal power will be transmitted only have a loss approximately 0.035dB from ideal split power of 2-Way WPD. The isolation between the both output ports has good isolations about -53.269dB, it means only 0.0022% transmitted signal through the output ports.

The photograph of the 2-way WPD on Roger Duroid 5880 Substrate is shown in Figure 5. The 2-way WPD was fabricated using SMA connector at three ports and soldered then a 100 ohm chip resistor placed between the both of output ports. The dimension of device is 30mm x 40mm, development is done toward the goal of compact devices.

The Figure 6 shows the Voltage Standing Wave Ratio (VSWR) matching input (S11) on 9400MHz frequency about 1.333 and reflection coefficient 0.14 its indicates that only 2.04% reflected power.

The Figure 7 shows the voltage Standing Wave Ratio (VSWR) matching output (S22) and (S33) on frequency 9400MHz is slightly same. The VSWR (S22) about 1.26 and reflection coefficient 0.115, its indicates that only 1.32% reflected power. The VSWR (S33) about 1.108 and reflection coefficient 0.051, its indicates that only 0.26% reflected power. The value between S22 and S33 are not different significantly it can be the factor of soldering at the SMA connector.
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Figure 7(a). Measurement Result VSWR Output (S22) of 2-Way WPD

Figure 7(b). Measurement Result VSWR Output (S33) of 2-Way WPD

The Figure 8 shows the forward transmission line (S21) of devices operate as power divider on 9400MHz frequency about -2.522 dB and it’s indicate the signal power transmitted have very small losses.

Figure 8. Measurement Result of Forward Transmission (S21) of Devices as Power Divider

The Figure 9 show the reverse transmission line (S12) of devices operate as power combiner on 9400MHz frequency about -2.861dB and it’s indicate the signal power transmitted approximately 47.7%.
The Figure 10 show the isolation between two port output (S32 and S23) on frequency 9300 MHz about -11.271dB and its indicate only 7.46% transmitted signal through the output ports.

Table 1. Comparison between 2-way WPD has been Simulated and Fabricated Result

| Parameters               | Simulated design | Fabricated design |
|--------------------------|------------------|-------------------|
| Insertion Loss, dB       |                  |                   |
| S12 (reverse transmission)| -3.045           | -2.861            |
| S21 (forward transmission)| -3.045           | -2.522            |
| VSWR                     |                  |                   |
| S11                      | 1.013            | 1.333             |
| S22                      | 1.014            | 1.26              |
| S33                      | 1.014            | 1.108             |
| Isolation (S32), dB      | -53.269          | -11.271           |

4. Conclusion

The 2-way Wilkinson Power Divider at frequency 9400MHz was designed, simulated and fabricated. There is a difference between the simulation results and fabrication because of SMA connector soldering factor and fabrication process on Duroid substrate. The measurement
result of the 2-way Wilkinson Power Divider shows a fairly good result, forward transmission of this device as power divider or called as the split power (S21 or S31) is about -2.522dB, reverse transmission of this device as power combiner (S12 or S13) is about -2.861dB and VSWR at all ports (less than 1.33) with isolation value about -11.271dB. The necessity of optimal results at the center frequency so the power divider will be integrated with the antenna system using in feeding network of antenna and phase shifter antenna.

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References
[1] Daniel D Harty. Novel Design of a Wideband Ribcage-Dipole Array and Its Feeding Network. Master Thesis. Worcester Polytechnic Institute: 2010.
[2] Taufiqqurrachman, Deni Permama Kurniadi. Design and Realization Wilkinson Power Divider at Frequency 2400MHz for Radar S-Band. IOSR Journal of Electronics and Communication Engineering (IOSR-JECE). 2012; 3(6).
[3] Iwata Sakagami, Tuya Wuren, Masafumi Fujii, Minoru Tahara. Compact Multi-Way Power Dividers Similar to the Bagley Polygon. IEEE. 2007.
[4] Khair Al Shamaileh, Abdullah Qaroot, Nihad Dib, Abdelfattah Sheta, Majeed A Alkanhal. Analysis and Design of Ultra-Wideband 3-Way Bagley Power Divider Using Tapered Lines Transformer. International Journal of Microwave Science and Technology (IJMST). 2012.
[5] Weng MH, Hung CY, Su YK. A hairpin line diplexer for direct sequence ultra-wideband wireless communications. IEEE Microwave and Wireless Components Letters. 2007; 17(7): 519-521.
[6] Puttadilok D, Eungdamrong D, Tanacharoenwat W. A study of narrow-band and compact size microstrip bandpass filters for wireless communications. SICE Annual Conference. 2007.
[7] Zhou MO, Tang XQ, Xiao F. Compact dual band bandpass filter using novel E-type resonators with controllable bandwidths. IEEE Microwave and Wireless Components letters. 2008; 18(12): 779-781.
[8] Wang H, Chu QX. A Narrow-Band Hairpin-Comb Two-Pole Filter With source-load coupling. IEEE Microwave and Wireless Components letters. 2010; 20(7): 372-374.
[9] Huang Guangpu, Qing Songlin, Fu Jeffrey, Kwang Lee Ching. Design of Narrowband and Broadband Wilkinson Power Divider. Design and Innovation Project, Nanyang Technological University.
[10] David M. Pozar. Microwave Engineering. New York: John Wiley & Sons Inc. 2005.
[11] Jia-Sheng Hong, MJ Lancaster. Microstrip Filters for RF/Microwave Application. New Jersey: John Wiley & Sons Inc. 2011.