

Design of A 1:12 Power Divider at 5 GHz for Ground Surveillance Radar Application

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Abstract. Radio detection and ranging (radar) is a system that can be used to detect and map an object by using electromagnetic waves and the echoes. Radar technology is a system that can help state institutions and apparatus in mastering and securing a country. One of the most important components in a radar is an antenna. The function of antenna is to transmit and receive the signals that will detect the presence of objects around the radar. The antenna commonly used in a radar usually has the high gain, and one of the techniques to enhance the antenna gain is using an antenna array. An antenna array has an important part that is the power divider. In this paper, we will discuss regarding the 1:12 power divider for ground surveillance radar at C-band frequency. We use CST Studio Suite to design and simulate the power divider. In this design and simulation, we use FR-4 with a dielectric constant of 4.5, and the thickness is 1.6 as a substrate. According to the simulation results, it can be seen that this power divider has the bandwidth 200 MHz with the center frequency 5 GHz, VSWR is less than 1.5, and all the output ports are in phase.

1. Introduction

Radio Detection and Ranging (radar) is a useful system for detecting, measuring distances, altitude and mapping of an object. Can be used to detect, measure distances and create maps of objects, such as airplanes, motor vehicles and weather. Basically the radar uses the electromagnetic waves emitted by the transmitter to detect objects from a distance. Radar works by emitting electromagnetic waves in a certain direction, then object reflecting the emitted waves. The reflected signal is then captured by the radar [1]. One of the most important components on the radar is an antenna. The antennas used on the radar usually have high gain, and one of the techniques to increase the antenna gain is using antenna array. How to increase the dimensions of an antenna, without having to increase the size of individual elements, is an element of element assemblies that radiate from electrical and geometric configurations. This new antenna, formed by multielements, is called array [2]. An array of antennas has an important part that is the power divider.

Power divider is a passive microwave component used for power sharing or power merging [3]. The power divider doubles the input signal power into two or more output signals. Three port dividers can one T-junction independently four network ports can be directional coupler and hybrid. Power divider are often used in telecommunications, and radar technology. The Wilkinson method is a commonly used technique in this regard. Figure 1 shows the common Wilkinson power divider [4].



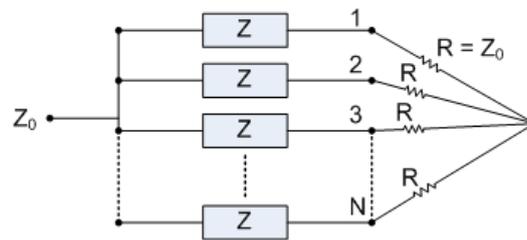


Figure 1. N-Way Wilkinson Divider/Combiner.

In the Wilkinson method, the value for impedance Z is given by the following equation:

$$Z = Z_0 \sqrt{N} \quad (1)$$

Where N is the number of branching points and Z_0 is the initial input impedance. The common power divider technique used in antenna array is T-junction. There are 2 types of T-Junction 50Ω which can be used as a power divider as shown in Figure 2 [4]:

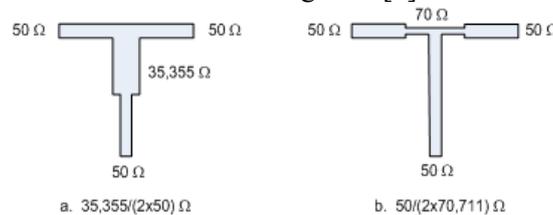


Figure 2. T-Junction 50 Ohm.

In this study, the design a 1:12 power divider using. The power divider is designed to work at C-Band center frequency of 5 GHz. The first stage is to create one element T-junction like in figure (a), then developed up to 12 outputs. This power divider is designed using a FR-4 substrate with dielectric constant of 4.5 and thickness 1.6 mm.

2. Design of power divider

The power divider designed and simulated by using CST Studio Suite [5] with FR-4 material as substrate. The input impedance of our power divider design is 50Ω . Before designing we do the calculation to get the expected impedance, then the width (W) of the feeder line is done with the following equation (3):

$$B = \frac{60\pi^2}{Z_0(\epsilon_r)^{1/2}} \quad (2)$$

$$W = \frac{2h}{\pi} \left\{ B - 1 - \ln(2B - 1) + \frac{\epsilon_r - 1}{2\epsilon_r} \left[\ln(B - 1) + 0.39 - \frac{0.61}{\epsilon_r} \right] \right\} \quad (3)$$

Where B is the magnitude of the impedance on the channel. With the value $Z_0 = 50 \Omega$; and $\epsilon_r = 4.5$, then the channel width of 50Ω is:

$$B = \frac{60\pi^2}{Z_0\sqrt{\epsilon_r}} = \frac{60(3.14)^2}{50\sqrt{4.5}} = 5.58 \text{ mm} \quad (4)$$

$$W = \frac{2(1.6)}{3.14} \left\{ 5.58 - 1 - \ln(2 \times 5.58 - 1) + \frac{4.5 - 1}{2 \times 4.5} \left[\ln(5.58 - 1) + 0.39 - \frac{0.61}{4.5} \right] \right\} \quad (5)$$

$$W = 3.01 \text{ mm}$$

W is the feeder width with 50Ω of impedance. After calculating the width of the feeder we must calculate the length of the feeder having a value of 50Ω and 35.35Ω . To calculate channel length (L) using the following equation:

$$L = \frac{c}{4fr\sqrt{\epsilon_r}} \tag{6}$$

$$w_1 = \frac{c}{2fr\sqrt{\frac{\epsilon_r+1}{2}}} = \frac{3 \times 10^8}{2 \times 5 \times 10^9 \sqrt{\frac{4.5+1}{2}}} = 19.09 \text{ mm} \tag{7}$$

$$\epsilon_{\text{reff}} = \frac{\epsilon_r + 0.3}{2} + \frac{\epsilon_r - 1}{2} \left[\frac{1}{\sqrt{1 + 12 \left(\frac{h}{w_1} \right)}} \right]$$

$$\epsilon_{\text{reff}} = \frac{4.5 + 0.3}{2} + \frac{4.5 - 1}{2} \left[\frac{1}{\sqrt{1 + 12 \left(\frac{1.6}{19.09} \right)}} \right] \tag{8}$$

$$\epsilon_{\text{reff}} = 3.64 \text{ mm}$$

$$L = \frac{3 \times 10^8}{4 \times 5 \times 10^9 \sqrt{3.64}} = 7.86 \text{ mm} \tag{9}$$

After we obtain the dimension of the T-junction, the next stage is simulating it on CST Studio Suite. To make it easier, we create the first 2 outputs, then 4 outputs, 6 outputs, and so on up to 12 outputs.

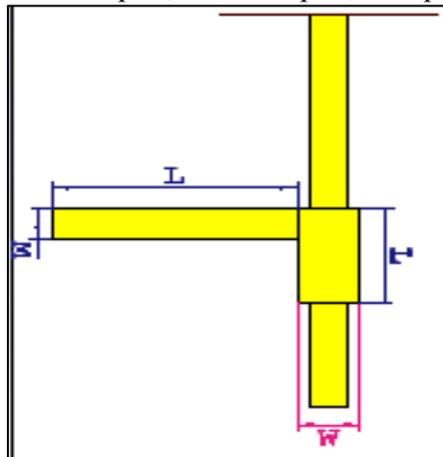


Figure 3. Parameters of 1:2 power divider.

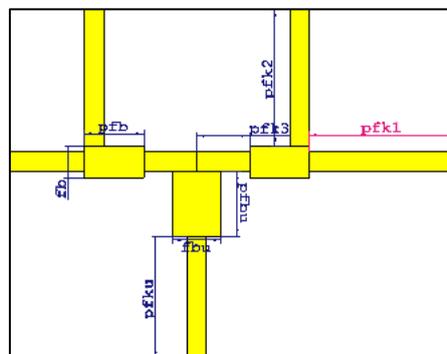


Figure 4. Parameters of 1:4 power divider.

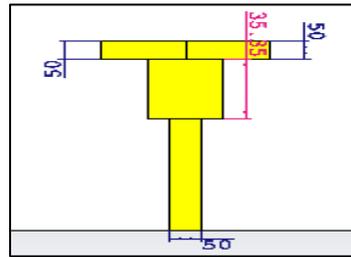


Figure 5. Parameters of T-junction.

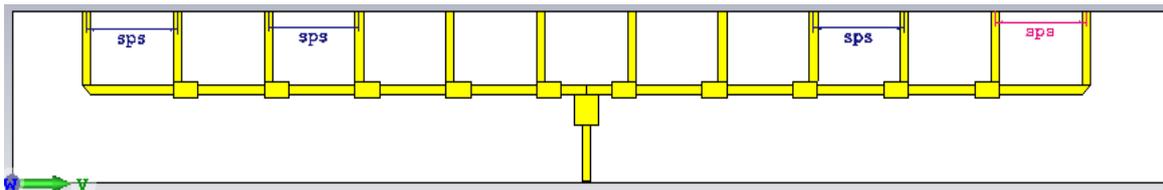


Figure 6. Front view of 1:12 power divider.



Figure 7. Back view of 1:12 power divider.

Figure 3 shows a 1:2 power divider with a description of W and L calculations. Figure 4 shows a 1:4 power divider with a description that can be seen in table 1. Figure 5 shows the parameters of T-junction power divider with impedance 50Ω and 35.35Ω as shown in Figure 2. Figures 6 and 7 show the antenna dimensions of 12 front and back 1:12 power dividers, and the table 1 is the optimization result to get the desired result.

Table 1. Dimension list of antenna design.

Parameter	Value (mm)	Description
ht	0.035	Thick of Ground & Patch
fk1	1.5	Width Small Feeder 1
fk2	1.5	Width Small Feeder 2
fk3	1.5	Width Small Feeder 3
hs	1.6	Thick of Substrat
fb	5	Width Big Feeder
pfb	8.8	Length Big Feeder
pfku	21.5	Length Small Feeder Prime
pfk1	23.95	Length of Small Feeder 1
pfk2	23.5	Length of Small Feeder 2
pfk3	9.1	Length of Small Feeder 3
s	19	Width Substrat
g	19	Width Ground
ps	105	Length of Substrat
pg	105	Length of Ground
pfbu	8.65	Length of Big Feeder Prime
sps	32.7	Space of element to element

After optimizing the dimensions obtained power divider with 12 outputs is 418.32 mm x 53.95 mm x 1.6 mm. The center frequency is 5.04 GHz, with impedance 50 Ω and VSWR <1.5. The optimization is done by changing pfk1, pfk2, and pflu to obtain the similar phase difference at 5 GHz. Changing the length or width can affect the frequency and phase of the power divider itself. The distance between elements is sps, where the distance between elements must be the same around 0.55λ-0.75λ. The power divider geometry is based on the T-junction model, but there are few modifications.

3. Results and Discussion

After optimized, the simulation result are return loss less than -10 dB with 50 Ω of impedance at input port and the phase difference on all output port are similar. The final design of 1:12 power divider can be seen in figure 8.

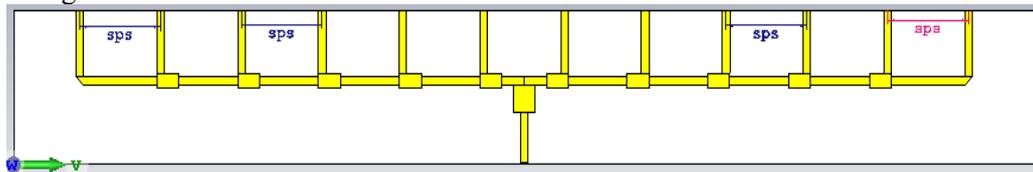


Figure 8. Final design of 1:12 power divider.

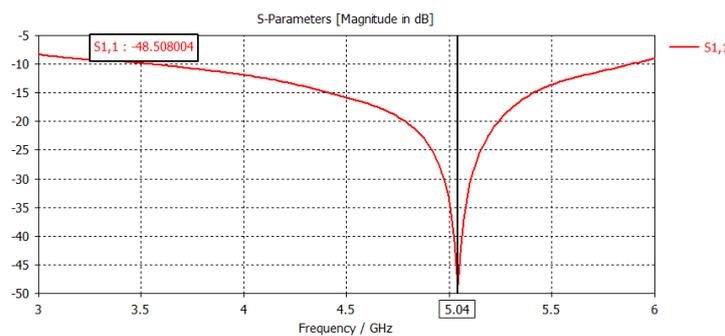


Figure 9. The result of 1:12 power divider shows a frequency of 5.04 GHz.

The power divider that is designed is in accordance with the desired result, where the frequency to be achieved is 5 GHz. At frequency 5 GHz return loss is -48,51 dB. The result can be seen in figure 9.

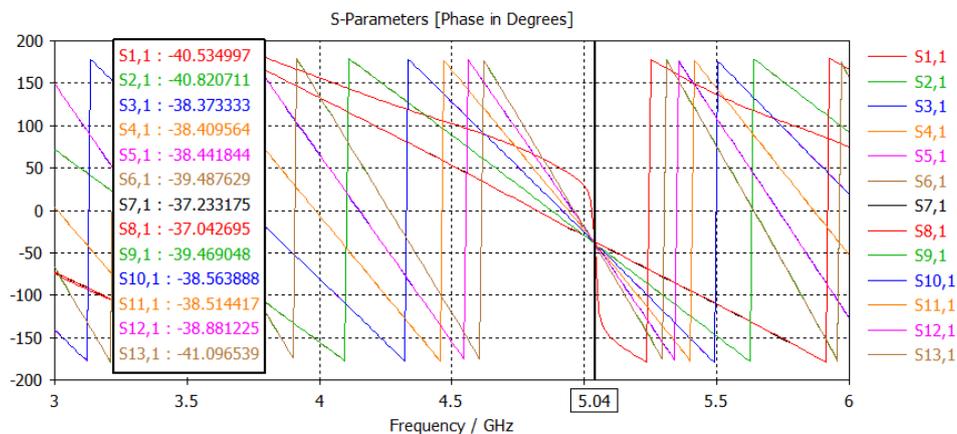


Figure 10. The value of phase of 1:12 power divider.

Figure 10 is a 1 phase divider of 1:12, where at a frequency of 5 GHz there is an intersection point of equal value. This phase indicates that the power distributed to each element is the same.

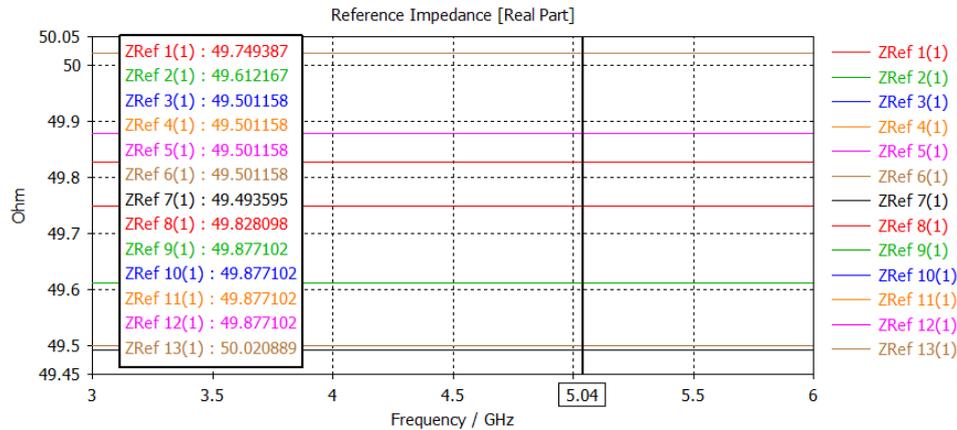


Figure 11. The impedance value of 1:12 power divider.

Figure 11 shows the impedance value for 1:12 power divider that already meets the value of 50.

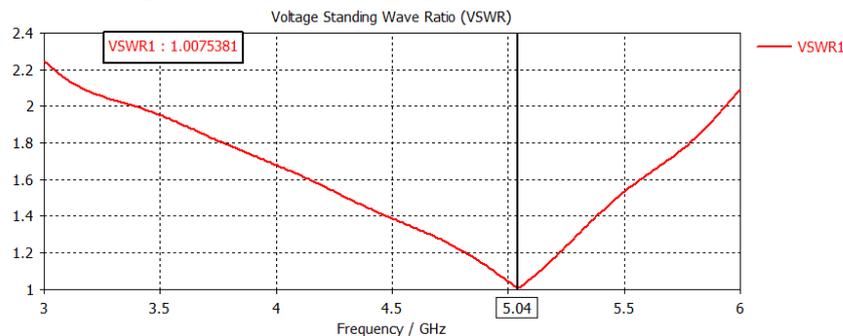


Figure 12. VSWR value of 1:12 power divider.

It can be seen from Figure 10 that at the 5.04 frequency shows the same phase value. Just as in Figures 11 and 12 shows impedances close to 50 Ω and VSWR 1 indicates that the power divider has matching.

4. Conclusions

This power divider design is made with 12 elements at a C-band frequency. The target of 12 elements at a frequency of 5 GHz has been reached with almost the same phase values. The length and width of each element will affect the frequency and phase. Things to consider in the design of power divider with 12 elements is the distance must be the same between elements, because it will greatly affect the results. The materials used in this power divider design are customers using FR4 with 4.5 dielectric constant, with size 418.32 mm x 53.95 mm.

References

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