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A 3 dB Microstrip Power Divider at 2.2 GHz with Floating Metals

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ABSTRACT: In this paper, a solid, inexpensive power divider of 2.2 GHz with a low-pass filtering response is proposed, analyzed and designed. Following results have been achieved, S11 -14.7 dB, S12 -3.318 dB, S13 -3.008 dB. Design is based on the vertical slits around the corners, and eight floating parallel metals that keep the divider in current free state. It is symmetrical along the middle which provides significant compatibility in manufacturing process. Can be used within microwave band of frequencies in 2-4 GHz spectrum band in electromagnetics. Provides substantial stability and reliability in its working domain.

1. INTRODUCTION

In radiofrequency and microwave circuits, power dividers and the low-pass filters are essential irreplaceable elements. They are used for dividing the energy on the input side and dispensing of the unwanted signals. Recent research proposes various methods to style such integrated circuits [1]. As an example of their use, we can take common microwave circuits, such as reflectometers, mixers, and modulators. The most common power divider is the Wilkinson [2]. It divides power in microwave systems because it provides excellent isolation between two output ports, little transmission loss, and a simple building procedure. It is commonly used with quarter-wave transmission lines to facilitate the process of matching the split ports to the common port. However, due to the utilization of quarter-wave transmission lines, particularly at lower frequencies and with a narrow bandwidth [3], it is massive in size. Although it has a tiny bandwidth and functions best at a central frequency, this divider has a wide range of applications in microwave circuits and antenna feeds. Several ways have been proposed to increase its bandwidth [4], [5]. Multiband antennas [6] can cover a wide range of wireless technologies; however, in microstrip patch antennas, the U-slot was primarily used to increase bandwidth rather than introduce a band notch, and it was acknowledged that the U-slot technique can be used to manufacture patch antennas with both dual and multi-band attributes. According to the research on U-slot patch antennas described [7], it can be used not only for wideband applications, but also for multiband (dual and triple-band) applications. In contrast with WPD proposed in this paper and Unequal Dual-Frequency Wilkinson Power Divider with Optional Isolation Structure [8], beside frequency band being used, achieved unequal power division and perfect matching at dual-frequency, a novel structure was made out of four dual-frequency transformers. Low-pass filtering and power division responses are both obtained by using two symmetrical units of interdigital line resonators (ILRs). The use of inductors with two sets of transmission lines was utilized to miniaturize the size and reduce broad harmonics [9]. Mirzavand et al. [9] also provide four distinct designs that can have equal or uneven power distributions. It does, however, enable narrowband power division. Embedded dual-mode resonators were employed in [10] to achieve bandpass response and equal power division. It is not only takes up more space, but it also has a significant insertion loss and a small stop band. Instead of having a strong isolation property and a

good attenuation band performance, power dividers [11], [12] have a significant in-band insertion loss. The fundamental goal of this proposed effort is to create an FPD with a small footprint, excellent selectivity, a wider attenuation band, and good isolation. Although suggested by [13], a wideband divider for single operating frequency can be designed using coupled lines without the use of isolation resistors stubs. A resistor of 100 Ω could be connected between the output ports for better isolation. The FPD operates at 2.2 GHz with a wide range (−14.77 dB) of harmonic suppression from 4 to 5 GHz. Tang and Chen [14] also attempted to minimize the size of the typical power divider using the SITL folding approach. Furthermore, Sedighy et al. [15] proposed that altering the Wilkinson power divider can result in a fractional bandwidth of 100% with -10 dB isolation or a fractional bandwidth of 40% with -20 dB isolation, hence improving power splitting performance. On the contrary, their architectures are extremely complicated, which increases the difficulty of circuit construction. WPD that this paper proposes is just 321 mm x 254 mm.

The main problems with existing power divider designs are narrow frequency band, bad selectivity, high insertion loss, low isolation, and large footprint

The fundamental goal of this proposed effort is to create an FPD that addresses all the problems mentioned above. Also, a major problem with Wilkinson design could be choice between equal or uneven power distribution, Mirzavand et al. [9] provided four designs that addresses however, it not only takes up more space, but it also has a significant insertion loss and a small stop band. Instead of having a strong isolation property and a good attenuation band performance, power dividers have a significant in-band insertion loss. We proposed solution to these problems, although keeping the insertion loss incredibly low in a relative wide band (0-5 GHz). Proposed design could work up to 10 GHz, with wideband harmonic suppression, as seen in Figure 3.

2. BACKGROUND

Many unique designs have been proposed for FPD such as an Unequal Wilkinson Power Divider [8], Compact Filtering Power Divider with high selectivity and wide stopband [11], Dual-band Wilkinson divider with coupled output port extensions [6], microclass. Design that was inspiration for all on them was initial Wilkinson Power Divider circuit proposed by Ernest Wilkinson.

Our design is based on two identical portions of ILR unit (impedance of 50), an isolation resistor (100) in the signal plane, and DGSs in the ground plane- Figure 1. The graph response of the FPD is presented Fig. 2., demonstrating that the output ports are properly matched (S21 = S31). The in-band insertion loss is 3.52 dB. It is also noted that minimum is at -14.77 dB. When compared to traditional power dividers, the suggested microstrip FPD construction achieves a 33.4 percent size reduction.

Because the proposed FPD circuit is symmetrical, even-mode and odd analyses are possible. To accomplish filtering power division response, the LPF's transmission co-efficient should be comparable to S21e, and S11e, S22e, and S22o must be zero. Where the symbol e and o stand for even and odd modes, respectively. Figure 1 has the top view and Figure 2 has the S parameters response.

$$S11 + S11e \tag{1}$$

$$S21 = S31 = \frac{1}{\sqrt{2}} S21e \tag{2}$$

$$S21 = S31 = \frac{1}{2}(S22e + S22o) \tag{3}$$

$$\frac{1}{2}(S22e - S22o) \tag{4}$$

$$= \begin{matrix} S11e & \frac{1}{\sqrt{2}} S21e & \frac{1}{\sqrt{2}} S21e \\ \frac{1}{\sqrt{2}} S21e & \frac{1}{2}(S22e + S22o) & \frac{1}{2}(S22e - S22o) \\ \frac{1}{\sqrt{2}} S21e & \frac{1}{2}(S22e - S22o) & \frac{1}{2}(S22e + S22o) \end{matrix} \tag{5}$$

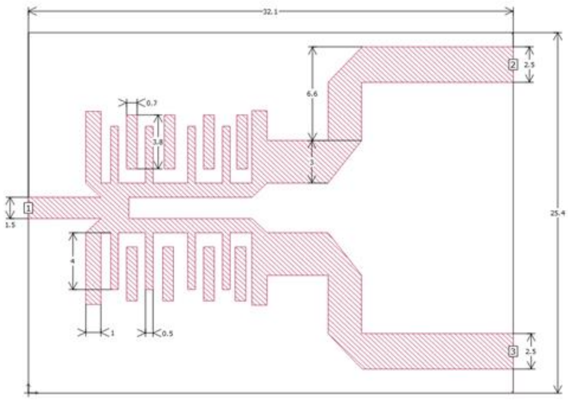

Figure 1: Top view of the Power Divider

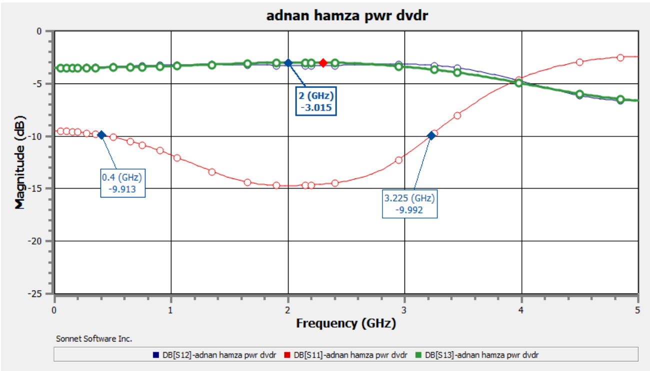

Figure 2: Simulated response

3. MATERIALS AND METHODS

In development of our project, we used Sonnet as the development software. We used FR4 (flame retardant) as our material since the existing works used the costlier substrate with very low tangent loss. It is cheaper for making a prototype, but it is also lossy. It is readily available flame resistant and since the main goal of our whole project is to ensure that the FPD we make is consisted of good qualities such as mere perfect selectivity, wide attenuation band, solid isolation, and a compact footprint, choosing the FR4 was clearly the unilateral decision which made the most sense.

Since we used the Sonnet, the best available software for experimenting on the project, we had multiple phases of the project. We started it by drawing the proposed FPD, as we imagined it to look. After doing the parametric study and making simulations to see which dimensions make the least losses in our system, we agreed on the dimensions as seen in the Figure 1. After defining the dimensions of the project and box size it is going to fit on our FR4 card, we had to do a study based on the dielectric constants and the thickness of the dielectric itself. Running the simulations, we found out the best results are gotten by using 3.8x0.7 mm dimensions with 4.4 as a dielectric constant and 1.55mm as a thickness of the dielectric, as can be seen in the Table 4 and Table 5. To produce the final work of our product, we are going to print the FPD in a laboratory using FR4 microstrip, then drill the holes and solder the ports and make it ready for testing and use.

To obtain all the data and represent it we used Sonnet and we are going to represent the data tabularly and graphically. Since we tried modifying our model with different dimensions and scaling of eight rectangles in the middle of the upper and lower symmetrical section. We started off by setting the width of the eight parallel strips to a certain value and changed the length to obtain the best possible results. We made three measurements as can be seen in the Table 1, Table 2 and Table 3. We obtained the data and decided that the best option is to have the eight parallel rectangles in dimensions of 3.8x0.7 (mm) with dielectric constant of 4.4 and the thickness of the dielectric of 1.55 (mm). The observation of the current flow through the FPD at 2.2 GHz, which is our working frequency, can be seen in the Figure 4.

Current distribution in the proposed circuit at different frequencies is shown in Figure 4. It is observed that current values at port 2 and port 3 are at its highest magnitude around lower frequencies. Hence, it is prominent that circuit elements are active at lower frequencies, and they get inactive near 5GHz, but are significant and usable until 10 GHz. If we look at ports 2 and 3, in the working freq. of FPD, it is noted that values are around 5.65 Amp/m, especially on its edges, while transmitting almost 2.47 Amp/m in the middle. Respectively values around port 1 stay around 6.35 Amp/m.

Table 1: Width of parallel strips set at 0.5

Width of the eight parallel strips: 0.5	S11 (-dB)	S12 (-dB)	S13 (-dB)
3.8	14.0729	3.38419	3.05978
3.9	14.2094	3.40712	2.99474
4.0	14.3209	3.40979	2.95795
4.1	14.4012	3.41082	94877

Table 2: Width of parallel strips set at 0.6

Width of the eight parallel strips: 0.6	S11 (-dB)	S12 (-dB)	S13 (-dB)
3.8	14.16781	3.40011	3.0011
3.9	14.3114	3.40159	2.94121
4.0	14.3902	3.41011	2.94092
4.1	14.4121	3.41512	2.93988

Table 3: Width of parallel strips set at 0.7

Width of the eight parallel strips: 0.7	S11 (-dB)	S12 (-dB)	S13 (-dB)
3.8	**14.6922**	**3.31809**	**3.00801**
3.9	14.4143	3.41069	2.94267
4.0	14.3847	3.41331	2.94243
4.1	14.3778	3.41501	2.94201

Table 4: Changing the dielectric constant with chosen dimensions and dielectric thickness

Dielectric constant with 3.8x0.7x1.55 (mm)	S11 (-dB)	S12 (-dB)	S13 (-dB)
4.35	14.3908	3.41262	2.94262
4.37	14.4111	3.41142	2.94225
4.4	**14.1607**	**3.30901**	**3.06411**
4.43	14.7226	3.31636	3.00757
4.45	14.7352	3.31553	3.00751

Table 5: Changing the Dielectric thickness with chosen dimensions and dielectric constant

D. thickness dim. 3.8x1.55 d.const 4.4	S11 (-dB)	S12 (-db)	S13 (-dB)
1.50	14.4749	3.40018	2.94783
1.53	14.4485	3.40594	2.94451
1.55	14.6922	3.31809	3.00801
1.57	14.4146	3.41347	2.94015
1.6	14.391	3.41898	2.93691

Figure 3 has the current distribution. Its seen from the colors that input port (1) has double current value and color as compared to output ports 2 and 3.

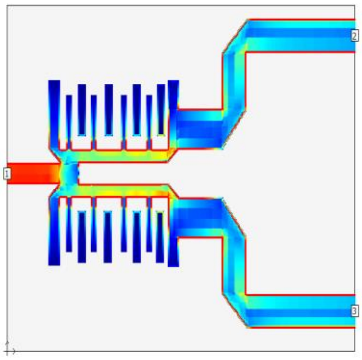

Figure 3: Current flow at 2.2 Ghz

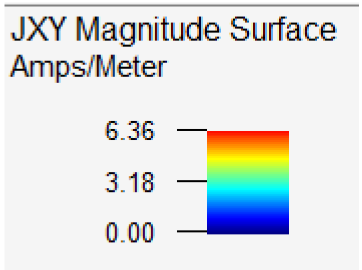

Figure 4: JXY Magnitude surface Amps/Meters

CONCLUSION

A miniaturized FDP with low-pass response was presented in paper above. It consists of two identical IRLs. The operating frequency of presented FDP is 2.2 GHz and following has been achieved, S11- 14.7dB, S12- 3.318dB, S13- 3.008dB. While design works best from 0 GHz to 6 GHz, it is also noted that design could work up to 10 GHz. The in-band insertion loss is also noted, at it is equal to -3.52 dB. Respectively the proposed design has low insertion loss, compact size, works at wide-band freq. range and has low-pass response. It is best suited for microwave circuit designs and applications.

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