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Implementation of an Enhanced Wilkinson's Power Divider using Low Pass Filters

Yashas Joshi (14BEC0573)[1], Smridh Malhotra (14BEC0570)[2]
[1,2]School of Electronics Engineering (SENSE) Vellore Institute of Technology Vellore, India

Abstract*: A novel design of power divider using pi-filter is proposed in this paper which suppresses the harmonics in the circuit. There are several advantages of using this design. The simplicity of the circuit is enhanced as the open circuited shunt stubs are used in Pi-filter. 3 GHz is the frequency that is used throughout the process as the operating frequency. The target of this implementation is to get an equal power division through the proposed power divider. On simulating the proposed design on AWR Microwave office suite, it was observed that the harmonics were suppressed above 3 GHz. The substrate that is used here for the implementation have the following specifications: Loss tangent = 0, thickness of the substrate = 1.6 mm, dielectric constant = 2.2 and metal thickness = 0.05 mm.

I. INTRODUCTION

There are an ample number of roles for a power divider in the microwave systems. The power dividing networks in any amplifier network and the input feeding network for an array of antennas are some of the most common uses of power dividers. The power dividers are basically classified into 3 different types which are namely, Lossless T Junction power dividers, Resistive power dividers, and Wilkinson's power divider. Because of the matching condition on all ports and the isolated outputs, it is the most common type of power divider and so is also widely used. Due to the incompetency of rejecting the harmonics during the operating frequency i.e. the quarter wave transmission line adoption, the undesired response pass after the cut-off frequency is the most significant disadvantage of the conventional Wilkinson power divider. Using defected ground structure, the problem of quarter wave transmission line adoption has been partially overcome and using the Electromagnetic band gap cells, the problem of harmonics suppression is overcome. Generally, these type of circuits entails either some additional lumped element or some external etching, which is difficult to use in the environment where mass production is to be done and with low cost. There are several revised structures of this kind of power divider which are based on the complexity of the design and structures. Shunt stubs are used to get a simple and feasible design while the same design can also be implemented using extended line but it may complicate the design and structure of the divider significantly. To suppress the harmonics, an alternative method may also be used. The introduction of transmission zeros at the desired frequencies can significantly suppress the harmonics. Except for the need of lower transmission line impedances and restricted bandwidth, the device could be proved very useful as without backside etching as well as lumped reactive components, this design can offer a wide band of frequencies having suppressed harmonics. To achieve the goal of further suppressed harmonics an enhanced Wilkinson's power divider design is implemented. A low pass Pi-filter is used to suppress the harmonics and hence to achieve our aim. There are several advantages of the implemented design over the above-mentioned methods like flexible to implement layout, simplified structure, average or moderate line impedance and the furthermore suppressed harmonics. The proposed power divider design at the operating frequency of 3 GHz is stimulated using AWR Microwave office suite and the outputs are attached to this document later.

II. CONVENTIONAL WILKINSON'S POWER DIVIDER

The block diagram of a Conventional Wilkinson's power divider is shown in Fig. 1. It is usually made using micro strip lines with any number of ports having a ratio of power division between one another. This ratio of power division depends upon the application of the device for which it is to be used. Once manufactured, the power division ratio between the ports cannot be changed as it is fabricated permanently. Assuming the ratio to be 1:1, we will make our first equal-split case. Here, the input power is divided between the two ports equally i.e. half of the input in each branch. There are several advantages of using Wilkinson's power divider over any other power divider. As all of the ports here are matched perfectly while leaving a large isolation between the output ports the [S] matrix of the device is reciprocal.

Due to a high degree of isolation between the output ports, this circuit finds a vast role in radio communication as the cross talks within the channels of this type of divider is reduced by a significant amount as compared to the other devices of similar kinds.

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The design of a conventional Wilkinson's power divider is done considering the following specifications,

A. Power division ratio (K^2) = P_3/P_2 = 1
B. Dielectric constant = 2.2
C. Loss tangent = 0
D. Substrate thickness = 1.6 mm
E. Metal thickness = 0.05 mm
F. Characteristic impedance of the circuit (Z_0) = 50Ω
G. Operating frequency (f) = 3 GHz

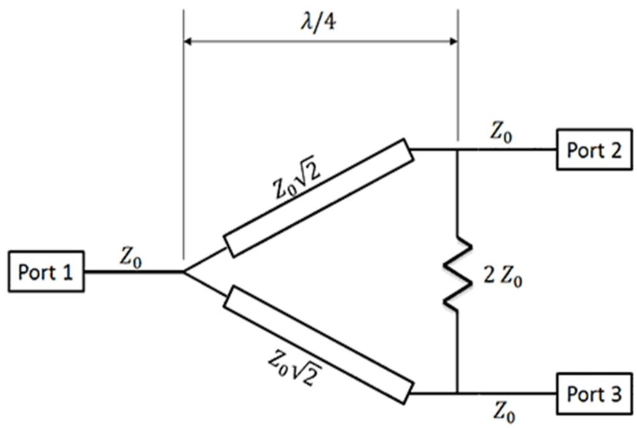


Fig .1 Conventional Wilkinson's Power Divider

As the network here is a reciprocal circuit,

$$S_{ij} = S_{ji}$$

Also all the ports are matched perfectly,

$$S_{11}=S_{22}=S_{33}=0$$

We know that the output terminals are isolated, hence we get,

$$S_{23}=S_{32}=0$$

Due to the equal power split assumed, we also have,

$$S_{21}=S_{31}$$

As we are talking about an equal split between the two outputs, the insertion loss between port 1 and 2 should be $1/\sqrt{2}$ and the insertion loss between port 1 and 3 should also be $1/\sqrt{2}$. This implies that,

$$|S12| = |S13| = 1/\sqrt{2}$$

On considering all the conditions mentioned above, the overall [S] parameter matrix for this type of power divider is given by,

$$[S] = \frac{-j}{\sqrt{2}}\begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix}^1$$

Using the below-mentioned formulas, the parametric values of a conventional Wilkinson's power divider can be calculated.

1. $Z_{03} = Z_0\sqrt{\frac{1+K^2}{K^3}}$
2. $Z_{02} = Z_{03}K^2$
3. $R = Z_0(K + {}^1/_K)$
4. $R_2 = Z_0 K$
5. $R_3 = {}^{Z_0}/_K$

For the specifications assumed earlier, the values of different impedances and resistances are to be calculated applying the above-mentioned formulas.

Table 1. Parametric values of a conventional Wilkinson's Power Divider

Z_0 (Ω) / W (mm) / L (mm)	Z_{02} (Ω) / W (mm) / L (mm)	Z_{03} (Ω) / W (mm) / L (mm)
50 /4.87 /18.17	70.71067 /2.755 /18.5	70.71067 /2.755 /18.5
R	R_2	R_3
100 Ω	50 Ω	50 Ω

The schematic diagram of a conventional Wilkinson's power divider circuit is showed in Fig. 2

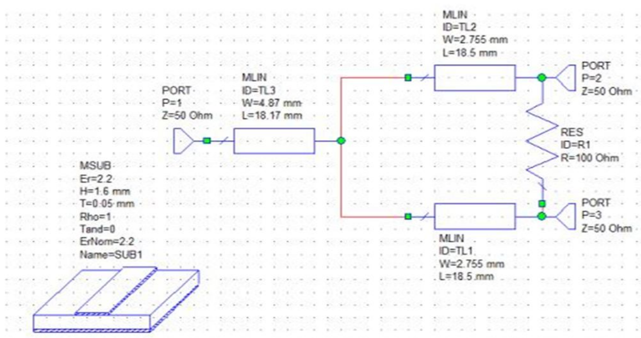


Fig. 2 Circuit Schematic of the conventional Wilkinson Power Divider

The results observed in the simulations of the above circuit are showed in Fig. 3. In the simulation, we can clearly see that in the desired frequency range, S_{11} contains some harmonics. These are the harmonics that are to be reduced by the help of new proposed design of the device using a Pi-filter.

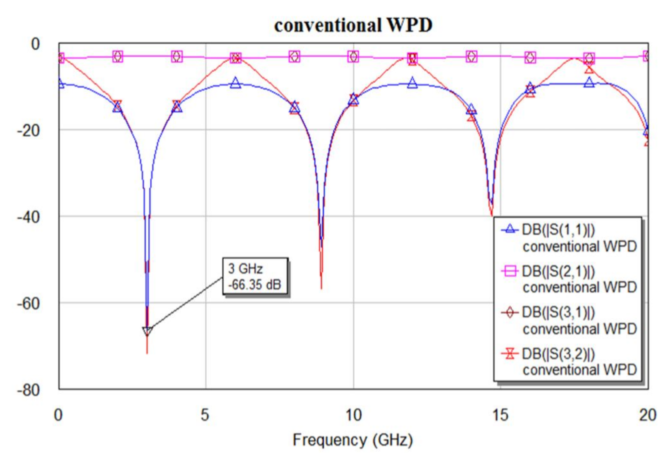


Fig. 3 Observed result of a Conventional Wilkinson's Power divider at an operating frequency of 3 GHz

On performing the same method and designing a similar power divider but for an operating frequency of 2.4 GHz, a similar output was observed when simulated in AWR microwave office suite. The matching at 2.4 GHz was obtained as desired and in this case, as well, the harmonics in S_{11} were significantly observed. The magnified simulation output is shown in Fig. 4 below.

Calculated parameters for 2.4 GHz power divider are,
For $Z_0 = 50\Omega$, at $\lambda/4$,
Width = 3.37 mm and Length = 19.19 mm
For $Z = \sqrt{2}Z_0 = 50\Omega$, at $\lambda/4$,
Width = 1.56 mm and Length = 19.86 mm

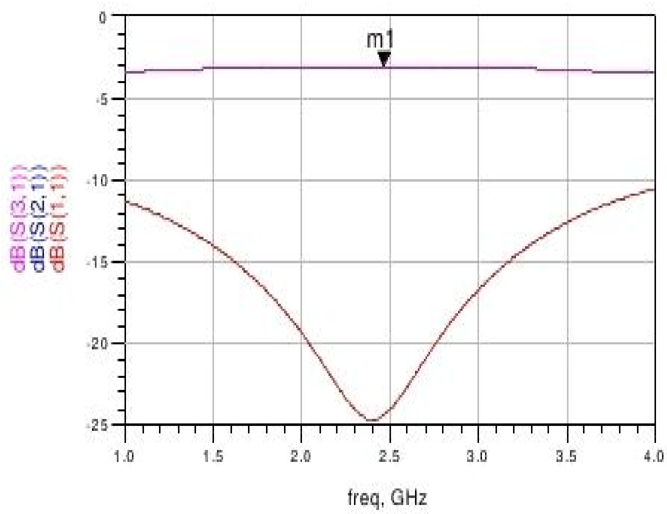


Fig. 4 Observed result of a Conventional Wilkinson's Power divider at an operating frequency of 2.4 GHz

III. WILKINSON'S POWER DIVIDER DESIGN USING PI-FILTER FOR HARMONICS SUPPRESSION

One of the biggest drawbacks of a Wilkinson's power divider is the harmonics produced at the higher frequencies. Now to compensate or this or to reduce these harmonics a low pass Pi-filter is used as a replacement of the inline arm impedance of a conventional Wilkinson's power divider. This low pass Pi replacement have the impedance equivalent to the arm impedence of the original conventional Wilkinson's power divider network.

The Pi filter consists of 2 open circuited stubs connected at the either ends of the filter and a transmission line connecting both of the open circuited stubs. The length of two open circuited stubs can be taken as Ls for each. The two stubs have characteristic impedance Zs. In between the two open circuited stubs, there is a section joining each of the stubs having length Lm and the characteristic impedance of Zm. The characteristic admittances of the open circuited stubs and the line connecting those are, Ys and Ym respectively. For a Pi-filter and for the specifications used above, we know that,

$$\begin{bmatrix} A_s & B_s \\ C_s & D_s \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ jY_s tan\theta_s & 1 \end{bmatrix} \begin{bmatrix} cos\theta_m & jZ_m sin\theta_m \\ jY_m sin\theta_m & cos\theta_m \end{bmatrix} \begin{bmatrix} 1 & 0 \\ jY_s tan\theta_s & 1 \end{bmatrix}$$

For the case of a primary pass band, the whole struct of the Pi-filter discussed above is can be considered as a transmission line with a characteristic impedance of Z and the effective electrical length of θ. The values of θ and Z are given by the following equations,

$$\theta = cos^{-1}(\cos\theta_m - Y_s Z_m \sin\theta_m tan\theta_s)$$

$$Z = \frac{Z_m sin\theta_m}{\sqrt{1-(cos\theta_m - Y_s Z_m tan\theta_s sin\theta_m)^2}}$$

As θ calculated here is the net length of the structure, it will be always bigger than θ_m. When the open circuited stubs used here in the Pi filter are of the length $\lambda/4$, a stop band of the frequency provided as cutoff frequency is observed. Hence,

$$Z_m = \frac{Zsin\theta}{sin\theta_m}$$

$$Z_s = \frac{Z_m tan\theta_s \theta_m}{cos\theta_m - cos\theta}$$

Table 2. Arm impedance values and its physical length and width of the designed Pi-filter

θ_m	θ_s	Z_m	Z_s
45^0	22.5^0	100 Ω	41.421 Ω
L_s	W_s	L_m	W_m
4.501 mm	6.415 mm	9.428 mm	1.361 mm

The length and width of the transmission line that is in between the two open circuited stubs is here denoted by L_s and W_s in the above table.

The schematic diagram of the low pass Pi-filter that is been used here and the simulation output is shown in the figures below. Here the Pi-filter that we used can be interpreted as a low pass filter which is the reason of suppressed harmonics after the cutoff frequency. For our power divider, the cutoff frequency that we are using is 3 GHz. On simulation of this Pi-filter, the cutoff frequency that has been observed is 4.52 GHz, hence the harmonics above 3 GHz are suppressed.

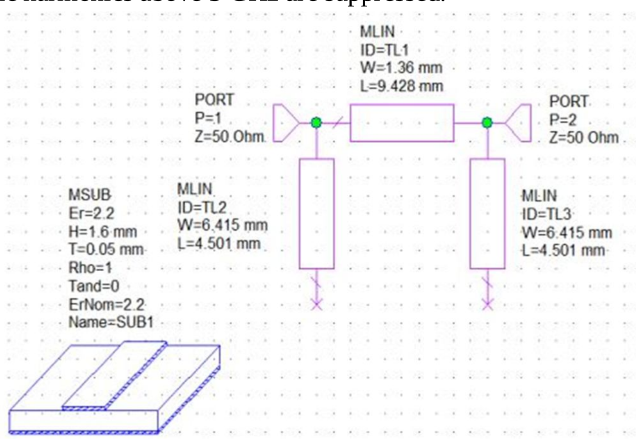


Fig. 5 Circuit Schematic of the required low pass π filter section

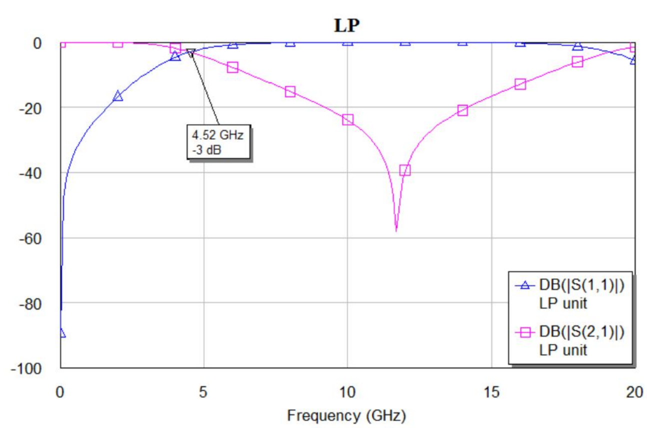


Fig. 6 Simulation output of the designed Pi-filter

On adding the designed filter to our main Wilkinson's Power Divider circuit, we obtain our design for enhanced Wilkinson's Power Divider with the suppressed harmonics. As discussed earlier, this Pi-filter is used as a replacement for the impedance line for the conventional Wilkinson's Power Divider circuit. The schematic of our final design is shown below in Fig. 7 in which the 'SUBSKT' component is the designed Pi-filter.

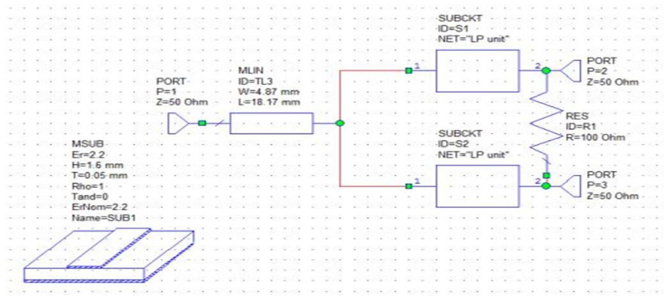


Fig.7 Circuit Schematic of the proposed Wilkinson's Power Divider

IV. THE RESULTS OBTAINED ON SIMULATION

AWR software was used to verify the design of the Wilkinson power divider designed. Substrate specification,

A. Thickness 1.6 mm
B. Dielectric constant 2.2
C. Operating Frequency 3GHz
D. Equal Power Division

Fig. 8 demonstrates the simulation results of proposed Power Divider with low pass pi filter. Return loss observed was -64.10 dB and insertion loss -3.10 dB. The results match the conventional power divider.

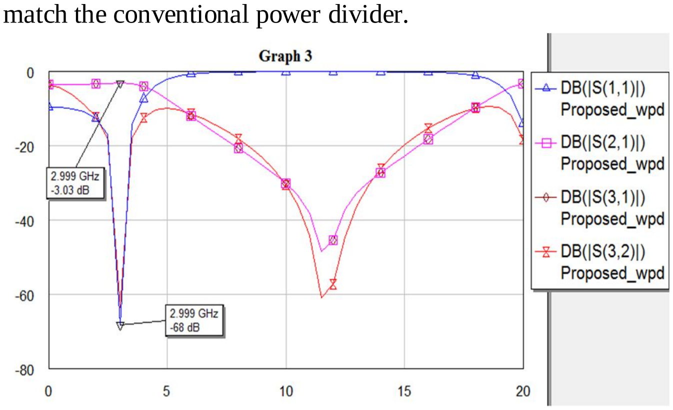


Fig. 8 The results obtained on simulation of the enhanced Wilkinson's Power Divider

Fig. 9 illustrates the comparison done between the conventional Wilkinson's power divider and the enhanced power divider with equal power split. This fig. clearly demonstrates the higher harmonics are suppressed.

$$S_{12} = S_{21} \;\&\; S_{13} = S_{31}$$

$$S_{11}S_{11}^{*} + S_{12}S_{21}^{*} + S_{13}S_{31}^{*} = 0.9965$$

From S parameters, it is clearly stated that the power divider is lossless.

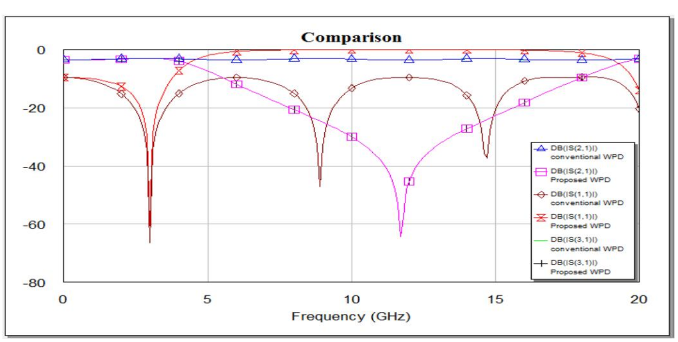


Fig. 9 The comparison done between the Conventional and the enhanced Wilkinson’s power divider

Table 3. S parameters obtained for Conventional and Enhanced Power Divider

S parameter	S_{11}	S_{12}	S_{21}
Conventional	-66.35	-3.0259	-3.0259
Proposed	-60.612	-3.0299	-3.0299
S parameter	S_{13}	S_{31}	S_{23}
Conventional	-3.0259	-3.0259	-71.798
Proposed	-3.0299	-3.0299	-64.007

V. DESIGN IN HFSS

Figure. 10 below shows the structure implemented in HFSS and figure 11 shows the simulation result obtained in HFSS.

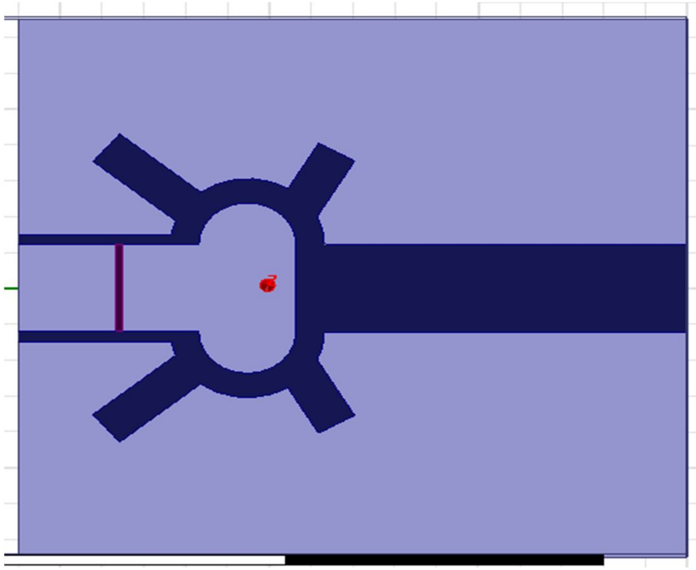


Fig. 10.a Designed structure in HFSS

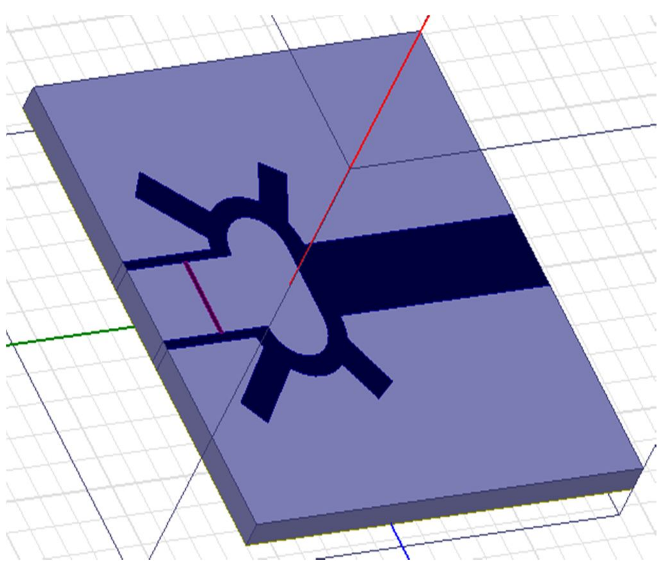


Fig. 10.b Designed structure in HFSS

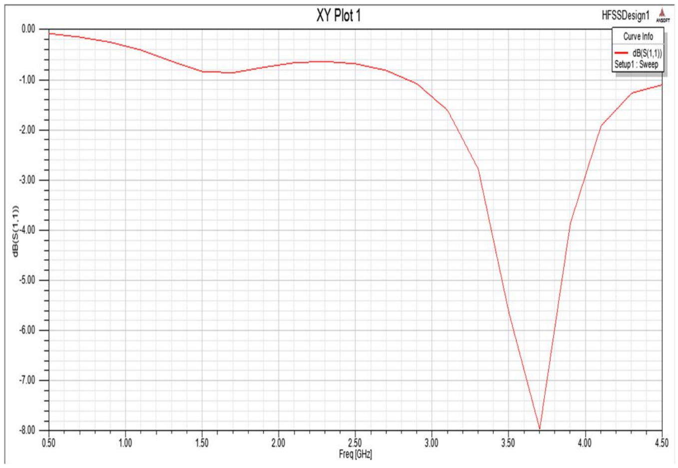


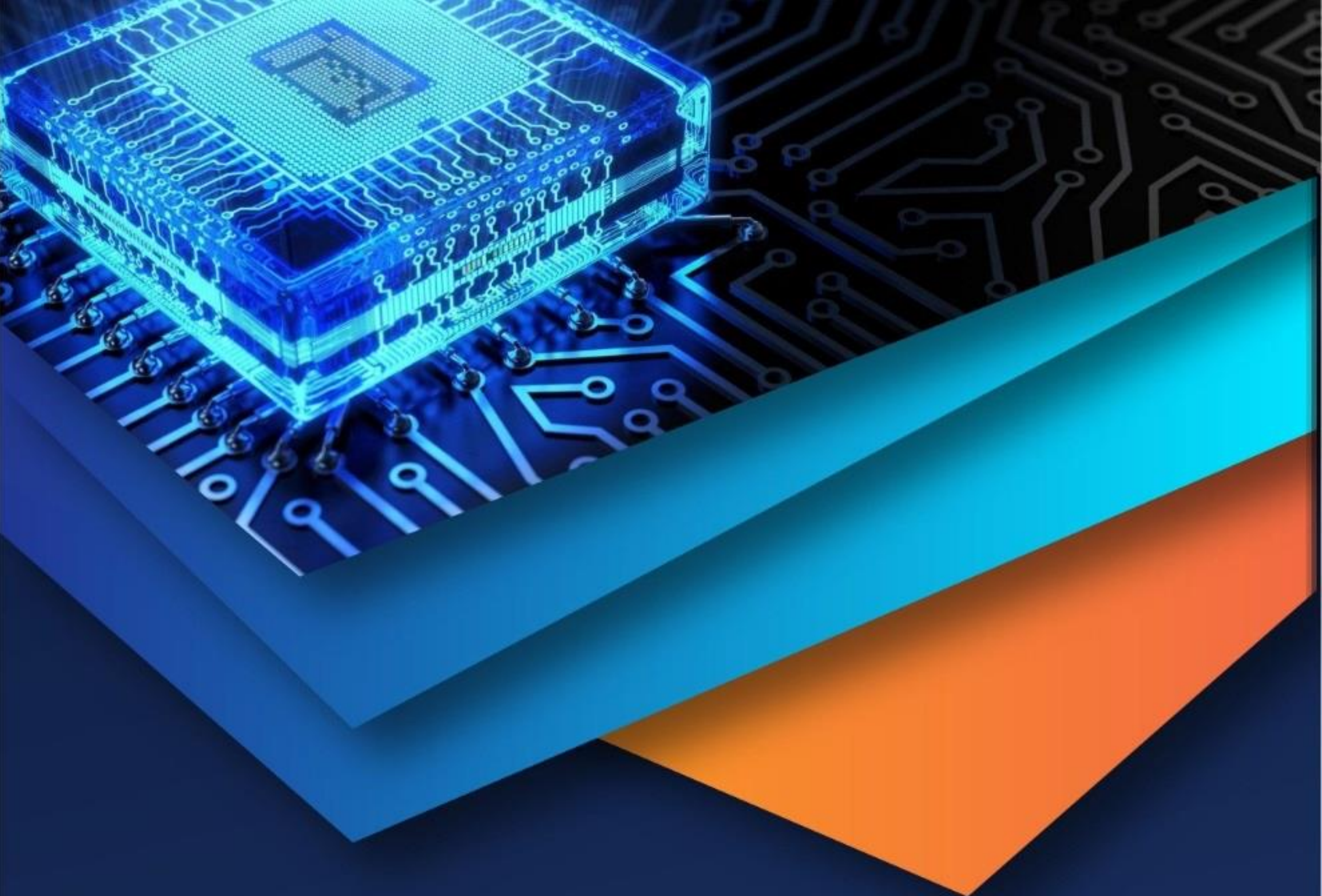
Fig. 11 – Obtained results in HFSS

VI. CONCLUSION

The design suppresses the higher order harmonics due to the low pass pi filter section. The S parameter justify that the design has all the characteristics of a conventional power divider. These results and design thus can be used for any frequency in microwave range.

REFERENCES

[1] D. M. Pozar, “Microwave engineering newyork,” John Wile Yand Sons, 2005.Third Edition.
[2] J. S. Kim, M. J. Park, and K. B. Kong, “Modified design of Wilkinson power divider for harmonic suppression,” Electron. Lett., vol. 45, no. 23, pp. 1174–1175, Nov. 5, 2009.
[3] I. C. Hunter, L. Billonet, B. Jarry, and P. Guillon, “Microw ave filters-applications and technology, microwave theory and techniques,” IEEE Transaction on vol. 50, Issue 3, pp. 794-805, March 2002.
[4] C. Kudsia, R. Cameron, and W.-C.Tang, “Innovation In microwave filters and multiplexing networks for communication satellite systems,” IEEE Trans. Microwave Theory Tech., vol. 40, pp. 11331149, June 1992.
[5] R. Levy, R. V. Snyder, and G. Matthaei, “Design of microwave filters,” IEEE Trans. Microw. Theory Tech., vol. 50, PP. 783-793, March 2002.
[6] G. L. Matthaei, L. Young, E. M. T. Jones “Microwave fillets, impedance matching networks and coupling structures,” Artchec House Inc.1988, 2th Edition.



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