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A MINIATURIZED WILKINSON POWER DIVIDER USING DGS AND FRACTAL STRUCTURE FOR GSM APPLICATION

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Abstract—This paper proposes a miniaturization method for conventional Wilkinson Power Divider(WPD) by replacing the quarter wave sections with the help of fractals. The performance degradation is compensated by using Defected Ground Structure (DGS). The resultant device occupies 56% of the area in comparison to the conventional WPD. The simulation results show a reflection coefficient of -66.98 dB and isolation of 24.1021 dB at the centre frequency of 1.8 GHz. Finally a prototype model is developed on a low cost FR4 Glass Epoxy substrate and tested. The experimental results show a good agreement with the simulation results.

1. INTRODUCTION

Power dividers are one of the most important components in any microwave circuit. An equal split Wilkinson power divider divides the incident power into two equal parts with the help of quarter wave transformers and an isolation resistor. With the advent of MMIC circuits increasingly efforts are being put in to reduce the size of this power divider particularly for frequencies below X-band. In this frequency range the quarter wave section possess significant line length leading to large occupying area. The various techniques used in the past for the miniaturization of Wilkinson Power Divider involve 3D techniques [1], Planar artificial transmission lines [2], Capacitive loading [3], stepped impedances [4], large inductance through the application of transverse slits [5], substitution of quarter wave section with lumped parameters [6, 7], varacter tuning [8], open

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stub technology [9], periodically loaded stubs [10] etc. It is observed that the lumped element technique is dependent on the quality factor and self-resonant frequency of an inductor, and the capacitive loading method reduces bandwidth and insertion loss [11]. However, to achieve the quality performance while reducing the size of the power divider is still a complex task.

The proposed technique is a simple yet effective method to reduce the size of the WPD without degrading the performance parameters. In this paper the proposed technique involves reducing the quarter wave sections of Wilkinson power divider in length by using fractal technique [12]. In past fractal techniques have been widely applied to antenna design for the purpose of size reduction [12–15]. The fractal technique when applied in WPD leads to performance degradation of the WPD mainly in terms of input reflection coefficient. This is because of the fact that the miniaturization of the original WPD using fractal technique disturbs the matching at the I/P port which can be easily be compensated by using DGS in the ground plane. The DGS structure which is in fact a LC resonator having a one pole low pass filter characteristics increases the effective permittivity and the effective capacitance and inductance of the transmission line. The appropriately chosen dimensions of DGS along with its location and shape helps in adjusting the resonant LC parameters and effectively the impedance of the line, thus overcoming the performance degradation caused due to fractal configuration. The resultant proposed configuration, fractal along with DGS has an occupied area of 56% of the traditional Wilkinson power divider. Comparisons are shown in terms of return loss, insertion loss and isolation loss. Section 2 provides the design principles, followed by performance analysis and results in Section 3. Section 4 contains comparisons with conventional power divider and Section 5 deals with conclusions.

2. DESIGN PRINCIPLES

The basic idea is to replace the conventional $\lambda/4$ sections by their fractal equivalents. The arm length was repeatedly subdivided to obtain fractals upto three iterations using the concept of the Koch fractal curve. The simulation study is performed using IE3D EM simulator. The result is obtained for each iteration of fractal, and it is observed that iteration-2 provides the best trade-off between performance and size reduction.

However it is observed that after modifying the two output arms of the WPD by applying fractal technique upto two iterations, the operating frequency of the circuit shifts to the lower side. Therefore

Table 1. Performance comparison of power dividers.

	Original Power Divider	Reduced Fractal WPD (56%)	Reduced Fractal WPD with DGS	Experimental Results
Operating Frequency (GHz)	1.8	1.8	1.8	1.8
Reflection Coefficient (I/P) in dB	−68.534	−31.031	−66.980	−32.70
Reflection Coefficient (O/P) in dB	−25.798	−25.447	−26.117	−21.8
Isolation in dB	−26.341	−23.65	−24.102	−17.7
Insertion Loss in dB	−3.08483	−3.078	−3.0713	−3.8

size reduction is performed using proper scaling to bring back the operating frequency to 1.8 GHz. It is evident from the Table 1 that the size reduction degrades the I/P reflection coefficient. The compensation for this degradation is overcome by employing the DGS by etching a rectangular slot in the ground plane. The DGS can be represented as a parallel LC circuit and placing the DGS below the input transmission line increases the effective permittivity which in turn increases the effective series inductance of the microstrip line. This also helps in improving the characteristics of the proposed power divider by improving the matching at the I/P port. The inbuilt optimization tool of IE3D simulator is used to obtain the final dimensions as well as location for DGS for the desired characteristics. The quarter wave branches are substituted but the isolation resistor $(2 \times Z0 = 100)$ maintains its original position. The layout is shown in Figure 1.

3. PERFORMANCE ANALYSIS

The proposed structure is analyzed in the GSM frequency band using IE3D simulator. The resultant circuit is assigned port 1 for input and port 2 and 3 for output. Isolation (S_{23} and S_{32}) of 24.1021 dB

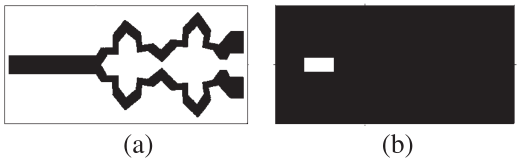

Figure 1. Layout of the proposed miniaturized Wilkinson power divider. (a) Top view. (b) Bottom view.

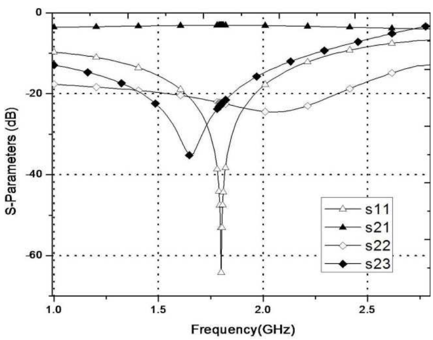

Figure 2. S-parameter characteristics of the proposed WPD.

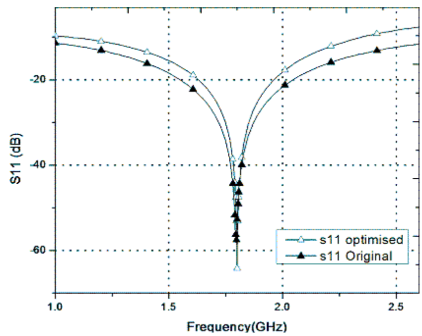

Figure 3. Comparison of S_{11} characteristics.

is reported at centre frequency 1.8 GHz. Reflection coefficients equal to −66.98 for the input port and −26.1168 dB for the output port are obtained. The coupling factor (S_{21} and S_{31}) are found to be −3.0713 dB at 1.8 GHz and it is fairly constant over the entire operating region. The S-parameter characteristics are shown in Figure 2.

Size reduction in lower microwave frequency region is achieved and the performance comparison is shown in Table 1. Although the resultant structure has a bandwidth reduction of 0.1 GHz but the S-parameters are comparable for both the circuits as shown in Figure 3.

4. EXPERIMENTAL RESULTS

The designed Wilkinson Power Divider is fabricated on FR4 Glass Epoxy substrate with dielectric constant of 4.4, loss tangent 0.016 and substrate thickness of 1.6 mm. The photograph of fabricated power divider is shown in Figure 4. To characterize the S-parameters of the fabricated Wilkinson Power Divider vector network analyzer is used. Good agreement between the simulated and experimental results is obtained in the process.

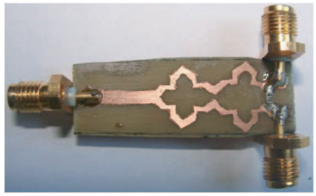

Figure 4. Photograph of 1.8 GHz power divider.

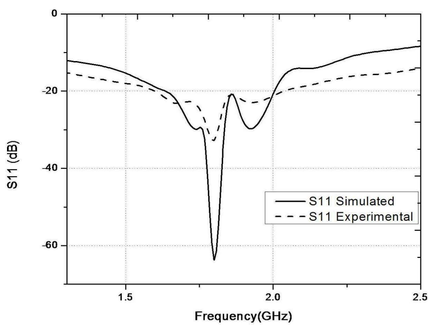

Figure 5. Comparison of reflection coefficient (I/P).

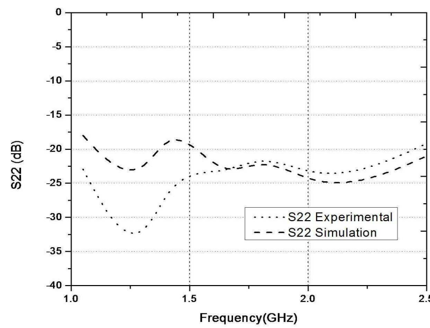

Figure 6. Comparison of reflection coefficient (O/P).

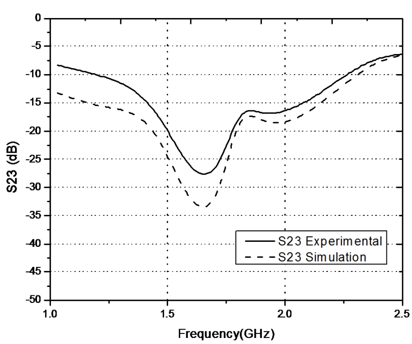

Figure 7. Comparison of isolation.

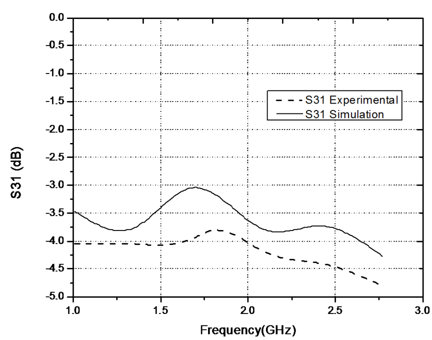

Figure 8. Comparison of insertion loss.

When operating at a centre frequency of 1.8 GHz the measured reflection coefficient is less than −30 dB. The measured bandwidth is less than the theoretical bandwidth but the difference is very small. The measured isolation is better than −15 dB at the operating frequency. However the frequency of highest isolation is around 1.72 GHz. The reported insertion loss is −3.8 dB at the centre frequency. The comparison of performance of simulated and fabricated power divider is shown in Figure 5 to Figure 8 respectively.

5. CONCLUSIONS

A miniaturized Wilkinson power divider is designed at centre frequency of 1.8 GHz for GSM application. It provides an effective area reduction of 56% while providing an insertion loss of −3.0713 dB and reflection coefficient less than 66 dB in simulation. Finally a prototype model is developed and its performance is compared with the simulated data. The measured result provides reflection coefficient of −32.70 dB. Also the isolation of the structure is obtained as −17.70 dB at 1.8 GHz.

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