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Reduced Size Koch Fractal Hybrid Coupler for IEEE 802.11b/g Wireless Applications

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Abstract: A new miniaturized Koch Fractal Hybrid coupler is proposed using Koch Fractal curve. In order to validate the results, the miniaturized Koch Fractal Hybrid Coupler is designed, fabricated and measured using Microstrip transmission line at operating frequency 2.44 GHz. The measured results verify the 182^o phase difference between two output ports. Also it has effectively improved bandwidth of the return loss and isolation. Further more size of the Conventional Hybrid Coupler is reduced while keeping the performance unchanged. Experimental results also show good consistent with the simulation results. This Koch Fractal Hybrid coupler can be used for IEEE 802.11b/g WLAN and Bluetooth wireless applications.

Index terms
Hybrid Coupler, Microstrip, Fractal curves, Space filling curves, Periodic structures.

I. INTRODUCTION

Hybrid coupler is indispensable component along with balanced mixers, amplifiers, frequency discriminators and phase shifters are essential part of wireless and RADAR subsystems. Some of the most commonly used couplers are 180^o Hybrid ring couplers and 90^o Hybrid ring couplers. The 180^o Hybrid ring couplers have many attractive features which include structural simplicity, wide bandwidth in power division and high isolation between the ports [1]. Miniaturization of RF circuits has become the goal of RF engineers in order to reduce the size and cost of the wireless systems. Recently lot of research efforts have been made to reshape the circular Hybrid ring coupler so as to reduce the occupied surface area while keeping the performance unchanged [2]-[3].In this paper, a novel Koch fractal technique is proposed to realize a reduced size of Hybrid coupler with wide bandwidth. Koch fractal curves have the ability to fit the same circumference in the same area [4]-[5]. This paper presents the features of Koch fractal curves, design parameters and relevant equations for the Koch fractal hybrid coupler. The Koch fractal coupler is fabricated tested and its performance is compared with conventional hybrid coupler.

II. FRACTAL KOCH CURVES

Fractal geometries have the major advantage of increasing the perimeter of the shape as the iteration increases, while still being confined in the same area. Thus mathematically the periphery can become arbitrarily large, while the area is still finite. In this paper Koch fractal structures are used to construct miniaturized Koch Fractal hybrid coupler. The required curve is the limit of the sequence when the iteration number tends to infinity. In practical applications quasi fractal shapes are used [6]-[7].The relationship between the area and perimeter for the proposed Koch curves are given below. Initiator and Generator are displayed as shown in figure 1 are introduced to help us understand the iteration of Koch curve. This is a method to produce the fractals called initiator, generator construction. In this method, one begins with the specified initiator and a generator is applied repeatedly in a lower scale to form the fractals. In figure 1, for example a_o is the initiator length L and K_o is the generator. Equation (1) describes the adhoc Iterative Function System (IFS) algorithm, which is used to obtain the various Koch curves. Figure (1) shows the geometrical properties of these fractals.

Koch Fractal Curve Construction:

$$b = a_{12}/a_o \text{ ------------------- } (1)$$

And other parameters satisfy the equations $a_{12}=a_{11}=a_{13}$ as shown in figure 1.The typical square patch 1st ,2nd ,3rd iteration Koch fractal patches are displayed in figure 2[6][8].

IFS Algorithm

The initiator length a_o corresponds to the $\lambda_g/4$ length. In order to construct the generator , n arbitrary transformations $K_o, K_1, K_2 \ldots K_{n+1}$ can be applied successfully using the below equations (2) and (3).The procedure can be represented symbolically by

$$K_{n+1} = a_o (K_n) = a_o U a_p K(n) \text{ --------- } (2)$$

Where p=1, 2, 3…..n;

$$K_{n+1}=a_{n1}(K_n)Ua_{n2}(K_n)..Ua_{np}(K_n) \text{--- } (3)$$

Koch fractal with iteration factor 0.25 is chosen to compare its characteristics with conventional hybrid ring coupler. The larger the iteration factor, the sharper the variety of curves becomes larger, that means the quality factor of the fractal coupler becomes larger. Also the increment of the iteration order, the resonance frequency becomes lower and the input resistance becomes larger.

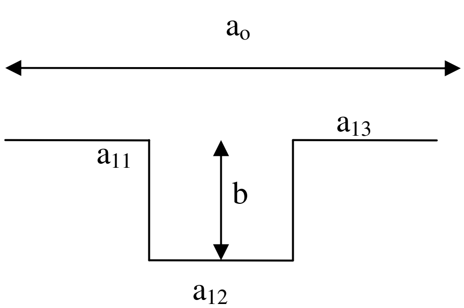

Figure 1. Initiator and Generator

Figure.2 square patch 1st, 2nd, 3rd Koch fractal patches

III. DESIGN AND FABRICATION

Design: Koch fractal curves have been used to realize a miniaturized Koch Fractal Hybrid coupler. The proposed coupler is implemented on a FR4 substrate with 1.6mm substrate thickness for operating frequency 2.44GHz.The design parameters of the conventional rat-race coupler and Koch fractal couplers are shown in Table 1.The Koch Fractal ring line width is the same as that of the conventional rat-race coupler ring line width with $\sqrt{2}\ Z_o$ impedance. All the design parameters are synthesized using Agilent ADS Line calc, Koch curve design parameters are calculated by using equation (1 -2) and optimized using ADS2002C.

Fabrication: Fabricated conventional ring coupler and Koch Fractal couplers are shown in figure 3. The dimension of the conventional ring coupler area is 68.35 X 59.193mm^2 where as the Koch Fractal Hybrid coupler area is 49.813 X 35.199 mm^2.

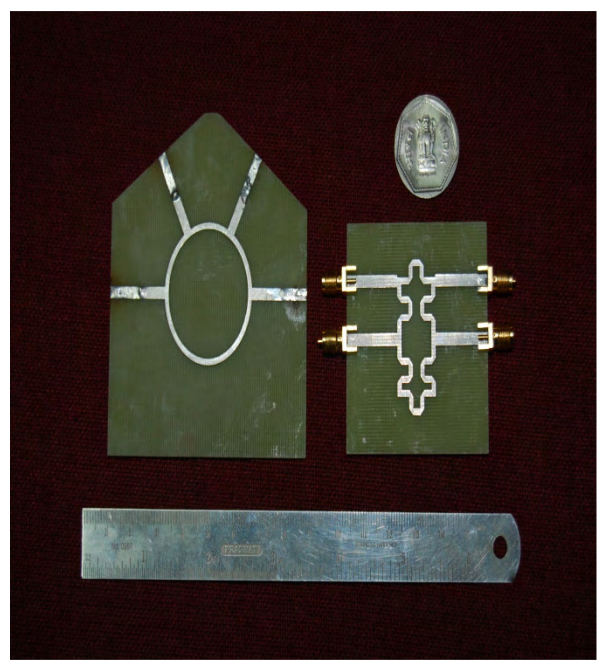

Figure 3: Fabricated Conventional Hybrid Ring Coupler and Koch Fractal Coupler.

Table I: Design Parameters for Conventional hybrid and Koch fractal hybrid couplers

Parameters	Width (mm)		Length (mm)		Area (mm X mm)
	Feed	Ring	Feed	Ring	
Conventional coupler	2.957	1.509	16.899	17.417	68.35 X 59.193
Koch Fractal coupler	2.957	1.509	16.899	11.61475	49.813 X 35.199

IV. RESULTS AND DISCUSSIONS

Conventional 180^{o} Hybrid coupler and Koch fractal coupler are simulated using Agilent ADS2002C.A prototype of Koch fractal hybrid coupler was fabricated and S parameter measurements were carried out using Agilent N5230A PNA series Network Analyzer. Table II shows the overall performance of the simulated, measured Koch fractal couplers and conventional hybrid couplers. Simulated and measured results are shown in figures from 5 to 8.Measured S parameter results are slightly different from simulated results. Because of the presence of sharp bend discontinuity in the Koch fractal hybrid coupler. Although it has a 1 GHz wider isolation and return loss bandwidth than the conventional ring coupler. Also it is 23% smaller in size than the Conventional hybrid coupler.

Table II: Performance Comparison for Koch Fractal coupler at 2.44 GHz

Parameter	S11 (dB)	S12 (dB)	S13(dB)	S14(dB)	Phase Difference (deg)	Band Width (GHz)	Phase Error
Conventional Hybrid Coupler	-32	-3	-25	-3	179.4	0.4	-0.6^{o}
Simulated Koch Coupler	-23	-3.01	-45	-3.0	173.2	1	-6.8^{o}
Measured Koch Coupler	-18.5	-4.04	-35.3	-4.3	182	1	+2^{o}

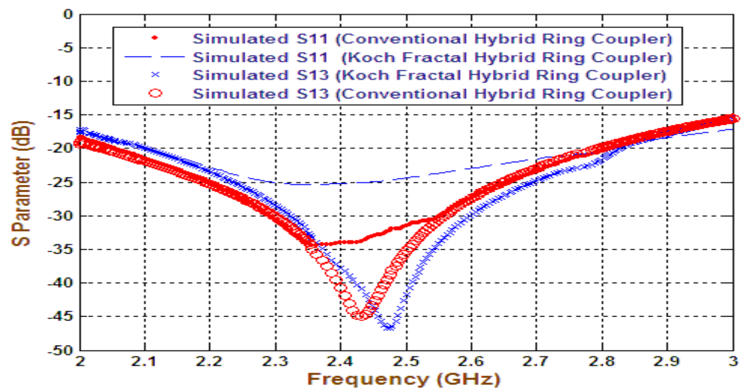

Figure 5a: Simulated $|S_{11}|$ and $|S_{13}|$ results for Conventional and Koch Fractal Coupler

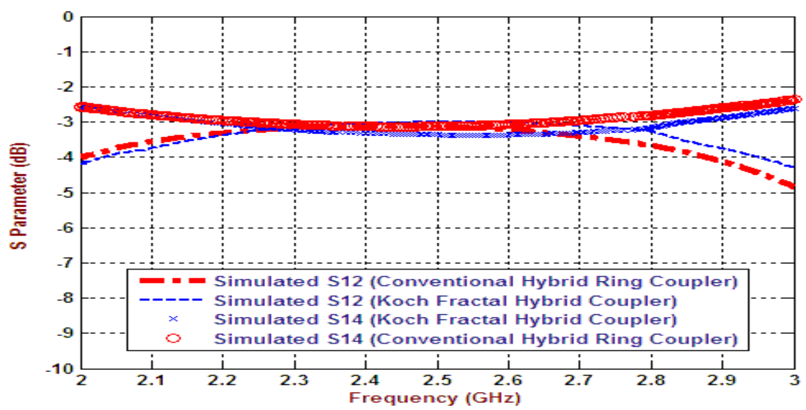

Figure 5b: Simulated $|S_{12}|$ and $|S_{14}|$ results for Conventional and Koch Fractal Coupler

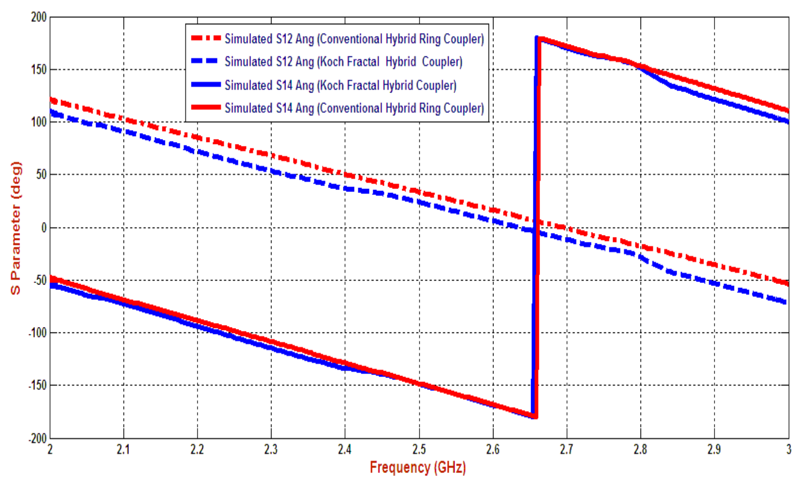

Figure 6: Simulated $\angle S_{12}$ and $\angle S_{14}$ results for Conventional and Koch Fractal Coupler

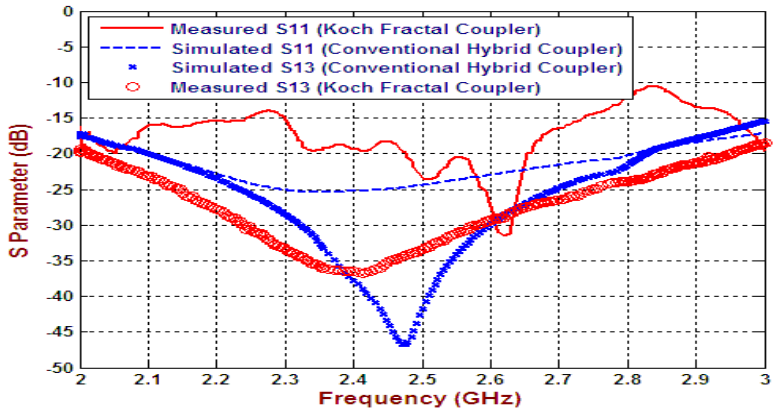

Figure 7a: Measured $|S_{11}|$ and $|S_{13}|$ results for Conventional and Koch Fractal Coupler

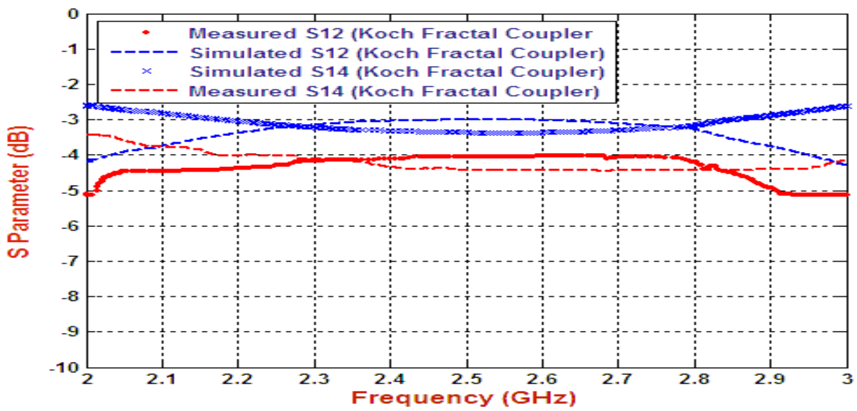

Figure 7b: Simulated $|S_{12}|$ and $|S_{14}|$ results for Conventional and Koch Fractal Coupler

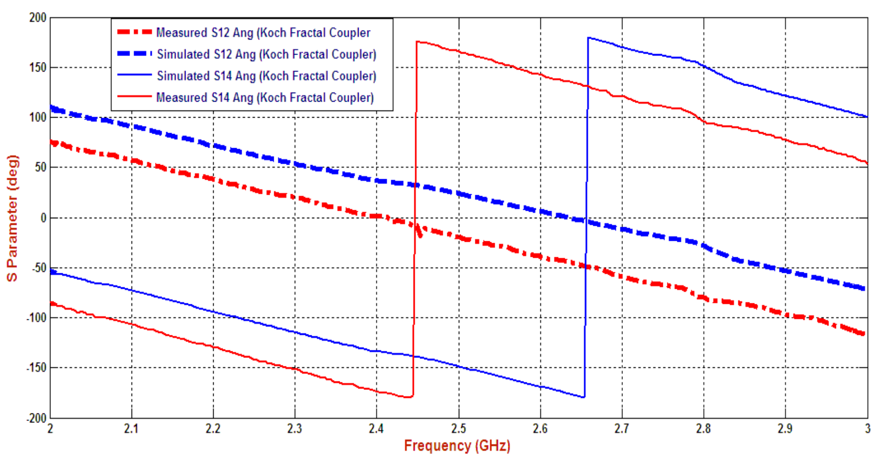

Figure 8: Measured $\angle S_{12}$ and $\angle S_{14}$ results for Conventional and Koch Fractal Coupler

V.CONCLUSION

This paper presented the design, simulation and fabrication of Koch Fractal hybrid couplers. Good agreement between the simulated and measured results was obtained. The realized Koch Fractal coupler is smaller than conventional rat-race coupler with overall good performance and wider isolation bandwidth. It can be used for IEEE 802.11 b/ g WLAN, Bluetooth wireless applications. It is concluded that coupling loss is -1db increased in measured result for Koch Fractal Coupler due to its meander nature and connector losses.

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