METAMATERIAL INSPIRED THREE PORT COUPLER

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Abstract—*This paper presents a novel metamaterial inspired multi narrow-band filtering three port couplers with modified couple lines, which consist of power divider and phase shifter. The operating frequency of the proposed work is 2GHZ, which is simulated, fabricated and measured. From the outcomes, 40% of filtering bandwidth and -15dB return loss is shown by the coupler. The amplitude imbalance is below 0.5dB. Measurement results and Simulation results are compared, which shows good agreements. Wireless communication, CP antennas and Microwaves are the main applications of this paper.*

keywords: *power divider, phase shifter, filtering, coupler.*

1. INTRODUCTION

In radio frequency and microwave field, hybrid coupler with 180 degree or 90 degree phase difference plays an important role. It is used in microwaves and in different wireless communication systems, especially for balanced power amplifiers and various antenna feed networks. The 90 degree hybrid coupler is used in multi- feed circularly polarized antenna [1]-[3]. The main key components of the RF front end, coupler and filter are in increasing demand of being low loss, widely tunable, compact structure, low cost and convenient installation in recent years. In order to further suppress the interfering signal of the frequency/microwave front end, the coupler should be connected in series with the filter, which results in bulky circuit size and high insertion loss. Microwave device with filtering performance have been extensively studied because of high frequency selectivity and miniaturization [4]-[6]. There are so many efforts have been made to meet the requirement of wide-band communication systems with circularly polarized antennas by broaden the bandwidth of hybrid couplers [7]-[10]. The fact is that the conventional branch-line directional coupler is only applicable for narrow-band systems [7], the multi-section branch line topology and defected ground structure have been presented for enhancing bandwidth [8], [9]. The large circuit area is employed by cascaded multi-section structure. The proposed branching line coupler possesses a complex circuit board structure. The broadside coupled microstrip /slot couplers can conduct across ultra-wideband, the increase in circuit complexity by three layer structure and at the time of integration cause incompatibility with other components [10].

Three port couplers possess characteristics of the hybrid circuits. By integration of different balanced power divider and phase shifters, RF devices can be executed. To attain wideband performance, the hybrid coupler comprises of a wideband power divider and wideband phase shifter. Quite a few interfering signals occur at the RF front end.

In this paper, a novel metamaterial inspired multi- narrow-band filtering having three port coupler with modified couple lines will be proposed and developed. The coupler contains of power divider [12] and phase shifter [13].The simulated result exhibits that the 40% bandwidth and -15dB return loss.

2. WIDE BAND FILTERING THREEPORT COUPLER

It constitutes tight coupling and half-wavelength open circuit stub with cascaded coupled line sections for filtering power divider. Figure.1 shows the circuit model of the proposed wide band filtering with three port coupler, which is made up of a wide-band filtering power divider and a wide-band coupled-line phase shifter.

A. FILTERING POWER DIVIDER

To acquire a wide stop band and improve the high frequency selectivity, extra transmission poles and transmission zeros introduced by OCS at the center frequency.

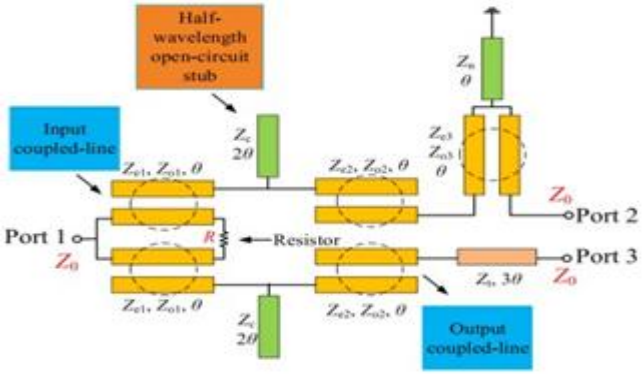


Figure 1: The block diagram of Wide band filtering three port coupler [11].

Impedance transforming can be extended by two cascaded CLs.

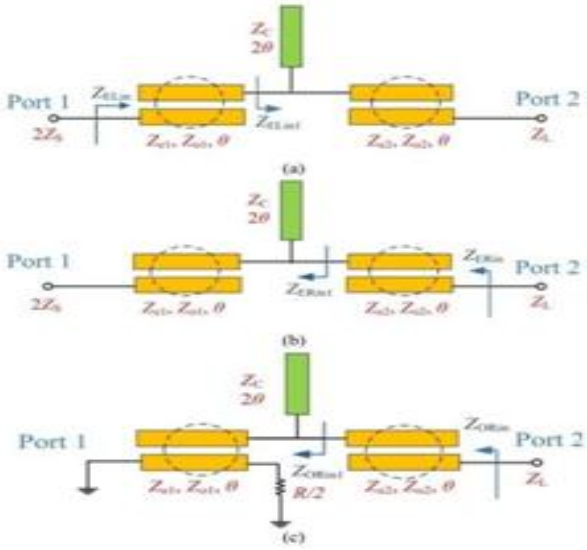
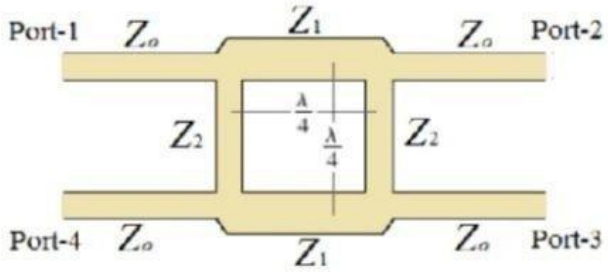


Figure 2: Equivalent circuit of the Filtering power divider [12].

The high all-pass band isolation can be achieved by using resistor. The S-parameter of the filtering power divider can be obtained. For simplification, in the even/odd mode equivalent circuits we have assumed that [12]. Where e and o indicate the even and odd mode, respectively.

B.WIDE-BAND COUPLED-LINE PHASESHIFTER

We assume the parameter ρ, it is used to indicate the coupling strength of the coupled line, for the wide-band coupled-line phase shifter [13].



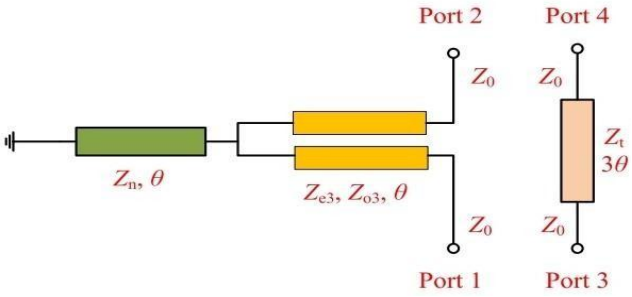


Figure 3: The circuit configuration of the Wide-band coupled-line phase shifter [13].

Coupling coefficient can be derived as:

$$C\ (dB) = -20 \log (\rho - 1)/ (\rho + 1)$$

The phase difference is expressed as:

$$\Delta\Phi = \text{Phase}\ (S_{21}) - \text{Phase}\ (S_{43})$$

The bandwidth of the phase deviation can be determined by the slope (k) at the cut-off frequencyf_0=2GHz.

3. PROPOSED METAMATERIAL INSPIRED THREE PORT COUPLER

A novel metamaterial inspired multi narrow-band filtering three-port coupler with a modified coupled line operating at 2GHz following four parameters will be investigated to prove that the proposed approach will be suitable for narrow band filtering

1. Reflection Coefficient (so-called return loss)
2. Transmission coefficient (so-called insertion loss)
3. coupling, $|S_{31}|$ at port-3
4. Isolation, $|S4_1|$ at port-4

By appropriately selecting the characteristics impedances (Z_o,Z_1 and Z_2) of the transmission lines, uneven power split between the two output ports (port-2 and port-3) at the center frequency can be achieved.

At center frequency (f_0), the power applied to the input port (port-1) is transferred equally to the two output ports (port-2 and port-3), with the fourth port in isolation (port-4).

Input match ($|S_{11}|$=0 at port-1) is perfect at f_0. The increase in branch sections causes improvement in bandwidth.

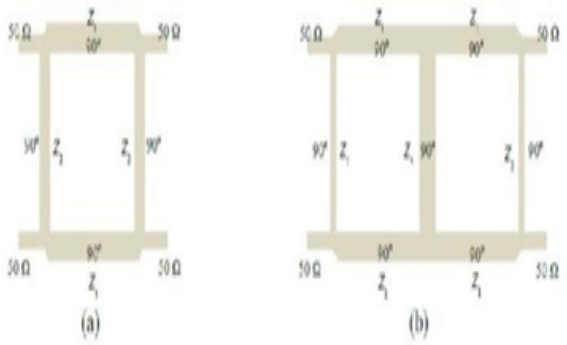


FIG.4: TWO AND THREE BRANCH LINE

1. Width of the line can be derived as:

$W = \{2h/\ \Pi\ \{B - 1 - ln\ (2B - 1) + \varepsilon r - 1/2\varepsilon r\ [ln\ (B - 1) + 0.39 - 0.61/\varepsilon r]\}$

$A=Zn/60\ \sqrt{\varepsilon r + 1/2} + \varepsilon r - 1/\varepsilon r + 1(0.23 + 0.11/\varepsilon r)$ and $B= 376.7\ \Pi/2Zn\sqrt{\varepsilon r}$

1. Length of the line can be written as:

$l=c/4fo\ \sqrt{\varepsilon eff}$ -0.421{(εeff + 0.3) (W /h + 0.264)/εeff 0.258) (W /h + 0.8)

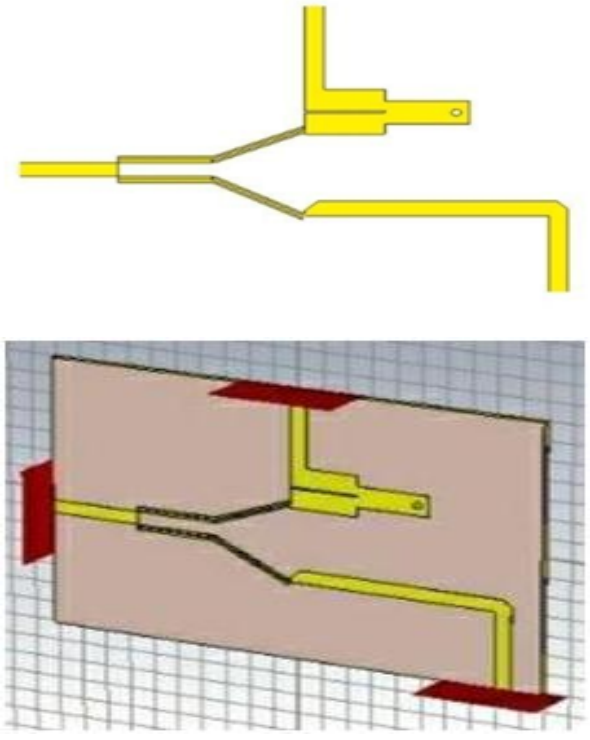


FIG 5. The circuit layout of proposed metamaterial inspired three port couplers.

Table 1. Proposed Metamaterial inspired three port coupler parameters

Parameter	Material/value
Material	copper
Medium	vacuum
Type	Lossy metal
Mue	1

The ideal and electromagnetic simulations are performed by CST software, and the measured results are acquired by the vector network.

There are four parameters describe the characteristics and performance of the branch line directional coupler as:

1. Reflection coefficient (so-called return loss), $|S_{11}|$ at port-1

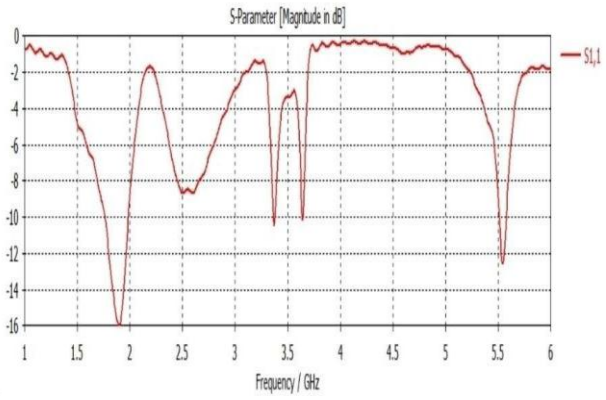
2. Transmission coefficient (so-called insertion loss), $|S_{21}|$ at port-2

3. Coupling, $|S_{31}|$ at port-3

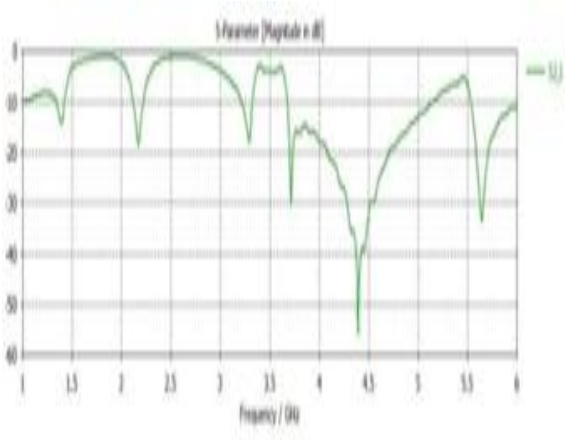
4. Isolation, $|S_{41}|$ at port-4

4. SIMULATIONRESULTS

The simulation of three port coupler design is done by using CST software. The proposed idea was demonstrated on the FR4 substrate. The S-parameter of the coupler design is shown in figure 6.



(a)



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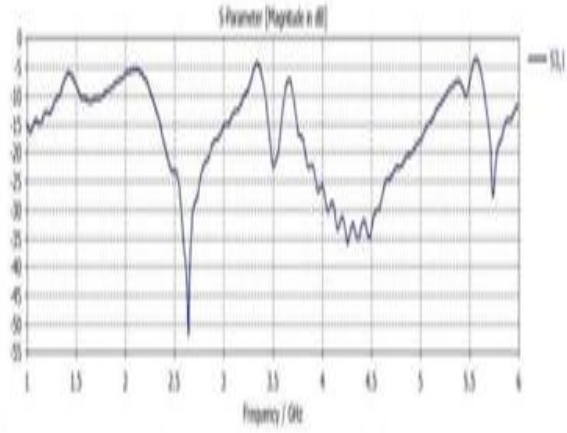

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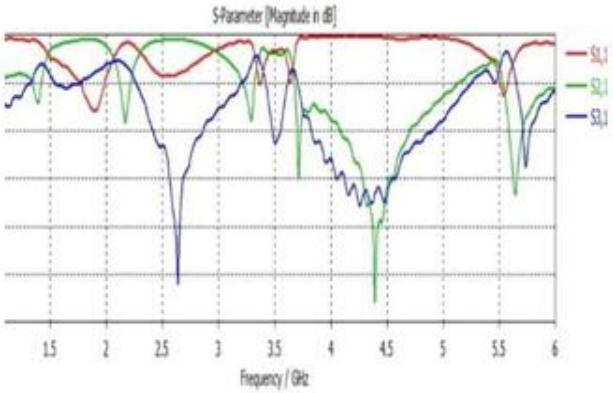
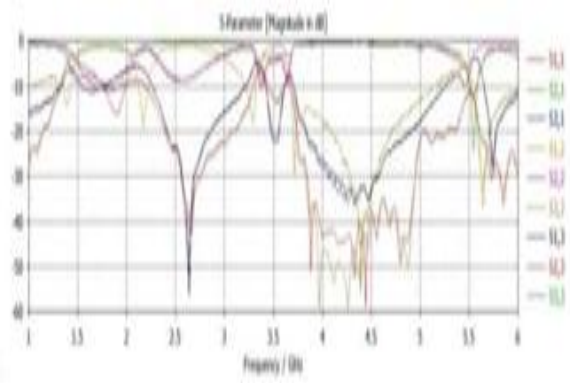
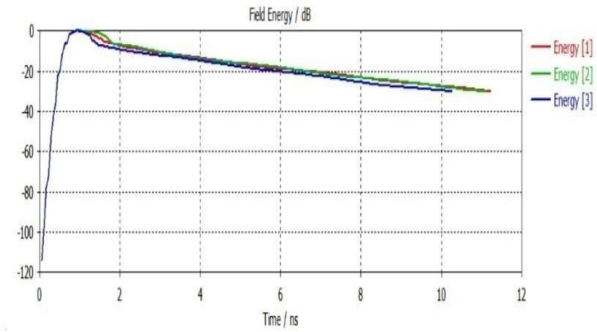


(d)

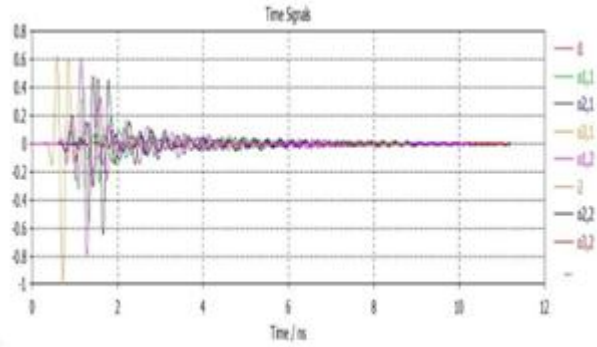


(e)

Figure 6. S-parameter of three port couplers.



(a)



(b)

Figure 9. The field energy results in dB (a) and time signal of three port coupler designs

The measured data are compared with the simulation and modeling (TLM) results. To further enhance the bandwidth performance, metamaterials are introduced to obtain a five-mode filtering directional coupler. Besides that, this multimode filtering directional coupler has wideband performance, with high roll off near to the cut-off frequencies. It has two zeros in S_{21} and S_{31}.

5. CONCLUSION

The measured data are compared with the simulation and modeling (TLM) results. To further enhance the bandwidth performance, metamaterials are introduced to obtain a five-mode filtering directional coupler. Besides that, this multimode filtering directional coupler has wideband performance, with high roll off near to the cut-off frequencies. It has two zeros in S_{21} and S_{31}.

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