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# Design of Multiband Hybrid Coupler with Open Circuit Stub

Suganthi Santhanam[1], Pavithra. S[2], Pennarasi. M[3], Priyanka. R[4]
[1, 2, 3, 4] *Department of ECE, K. Ramakrishanan College of Technology, Samayapuram, Trichy, Tamilnadu*

***Abstract: Directional couplers are passive reciprocal networks. It is a four-port network where all four ports are ideally matched and lossless. The wave incident in port 1 couples power into ports 2 and 3 but not into port 4. Nowadays, these components are essential to all communication systems as they play an important role in the monitoring and measurement of signal samples within an assigned operating frequency. In the first part of the project is to propose a broadside-coupled patch directional coupler. The substrate used is RO4003C with the Ɛr = 3.38 and H = 0.8128 mm or 32 mil. A travelling-wave sectoral slot resonator with three ports is presented in the second part. Computer Simulation Tool (CST) has been used to optimize the magnitude of the directional coupler. The simulated results have agreed well with ideal results. Parameter analysis has been conducted on the proposed directional coupler in order to study the effects of different design parameters. Discussion and recommendation have been made after each parameter analysis.***
***Keywords: Hybrid coupler, directional coupler , resonator, broadside coupler, operating frequency.***

## I. INTRODUCTION

In microwaves engineering, the term “microwave” mean the range of radio frequencies between 300MHz and 30GHz. The applications of microwave most concern in radar, communication and wireless systems. With Alexander Popov and Sir Oliver Lodge laying the groundwork for Guglielmo Marconi’s wireless radio developments in the early 20th century, Radio Frequency (RF) and wireless have been around for over century. Microwaves are highly developed in radar and communications system. For example, radar systems are used to detect and locate air, ground or seagoing targets and for air- traffic control systems, missile tracking radars, automobile collision-avoidance systems, weather prediction, motion detectors and a wide variety of remote sensing systems. Microwave communication systems handle a large fraction of the world’s international and other long-haul telephone, data and television transmissions. Nowadays many developed wireless telecommunications systems operating frequencies are between ranges 1.5 to 9.4 GHz, such as direct broadcast satellite (DBS) television, personal communications systems (PCSs), wireless local area computer networks (WLANS), cellular video (CV) systems and global positioning satellite (GPS) systems.

Table 1.1: Frequency band designation.

| Frequency, $f$ | Wavelength, $\lambda$ | Band |
|---|---|---|
| 30 – 300 Hz | $10^4$ – $10^3$ km | Extremely low frequency(ELF) |
| 300 – 3000 Hz | $10^3$ – $10^2$ km | Voice frequency(VF) |
| 3 – 30 kHz | 100 – 10 km | Very low frequency(VLF) |
| 30 – 300 kHz | 10 – 1 km | Low frequency(LF) |
| 0.3 – 3 MHz | 1 – 0.1 km | Medium frequency(MF) |
| 3 – 30 MHz | 100 – 10 m | High frequency(HF) |
| 30 – 300 MHz | 10 – 1 m | Very high frequency(VHF) |

Table 1.1 and 1.2 below are showing the frequency band designation and microwave frequency band designation. Table 1.1 shows the relationship between frequency and wavelength. Frequency ($f$) and wavelength ($\lambda$) are inversely proportional to each other and both related with speed of light (C) through a medium can prove by below equation:

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Table 1.2: Microwave Frequency band designation.

| Frequency, *f* (GHz) | Band Designation |
|---|---|
| 1 – 2 | L band |
| 2 – 4 | S band |
| 4 – 8 | C band |
| 8 – 12.4 | X band |
| 12.4 – 18 | Ku band |
| 18 – 26.5 | K band |
| 26.5 – 40 | Ka band |

To convey the microwave frequency signal, a microstrip technology will be used. Microstrip is a planar transmission line which similar to stripline and coplanar waveguide. Microwave components can be found in antennas, directional couplers, filters and power dividers which formed from microstrip. Microstrip was developed by ITT Ferearl Telecommunications Laboratories in Nutley New Jersey, as a competitor to stripline (first published by Grieg and Engelmann in the December 1952 IRE proceedings).

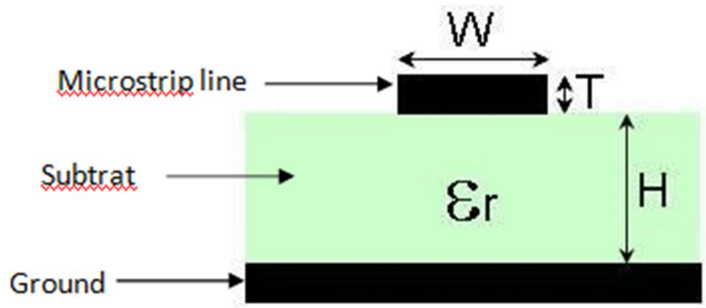



Figure.1. Microstrip structure

Figure 1.1 shows the general microstrip structure. Microstrip consist of conductive microstrip line and a ground plane which separated by a dielectric layer called substrate. To design a microstrip, width (W) and thickness (T) of conductive microstrip line and height (H) of the substrate are very important. $\varepsilon_r$ represent the dielectric constant or relative permittivity of the substrate. In this project we will use microstrip technology because all active components can be mounting on the top of the board. Apart from microstrip are much less expensive, lighter and more compact.

Intheoretical,effectivedielectricconstant($\varepsilon_{eff}$)andcharacteristicsimpedance($Z_o$)of the microstrip line will be introduced. To find effective dielectric constant, below equation can beused.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \frac{1}{\sqrt{1 + 12H/W}}$$

By using dimension of microstrip line H/W, characteristic impedance can calculated as

$$Z_o = \begin{cases} \dfrac{60}{\sqrt{\varepsilon_{eff}}} \ln\left(\dfrac{8H}{W} + \dfrac{W}{H}\right) & when \left(\dfrac{W}{H}\right) \le 1 \\ \dfrac{120\pi}{\sqrt{\varepsilon_{eff}} \times \left[\dfrac{W}{H} + 1.393 + \dfrac{2}{3}\ln\left(\dfrac{W}{H} + 1.444\right)\right]} & when \left(\dfrac{W}{H}\right) \ge 1 \end{cases}$$

By given the characteristic impedance and dielectric constant, dimension can be calculated by below equation

$$\frac{W}{H} = \begin{cases} \dfrac{8e^A}{e^{2A} - 2} \\ \dfrac{2}{\pi}\left[B - 1 - ln(2B - 1) + \dfrac{\varepsilon_r - 1}{2\varepsilon_r}\left\{\ln(B - 1) + 0.39 - \dfrac{0.61}{\varepsilon_r}\right\}\right] \end{cases}$$

Where

$$A = \frac{Z_o}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right)$$

$$B = \frac{377\pi}{2Z_o\sqrt{\varepsilon_r}}$$

## II. PROBLEM STATEMENT

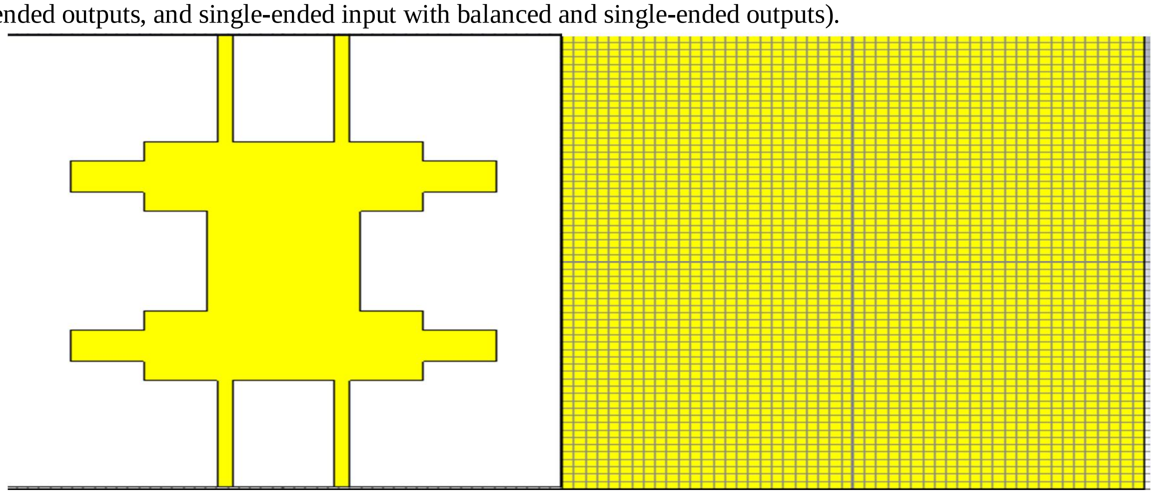
*A.* The Hybrid Direction Branch line coupler is used in balanced amplifier on order to achieve good return loss and good isolation.
*B.* It is also used in balanced mixer.
*C.* 90-degree hybrid couplers are often called branch-line couplers. As the name implies power is equally divided between the output ports and are therefore electrically and mechanically symmetrical.
*D.* These branch-line couplers are built using transmission lines and their size is proportional to the wavelength of the designated center frequency, which can be meters long.
*E.* Hybrid couplers can also be built by using lumped components, which are resistors, inductors, and capacitors with an ideal (lossless) connection.
*F.* The lumped component design is promising because it provides low insertion loss, wider bandwidth, and a smaller size circuit, making it a good fit for a monolithic microwave integrated circuit (MMIC).

## III. LITERATURE SURVEY

The following points has been noted from various paper studied. Common mode noise flow is in same direction as signal flow. The output phase difference shows less than 3 degree error from phase quadrature across 400 MHZ bandwidth. A universal approach for designing an unequal branch line coupler with arbitrary phase differences & input or output impedances which cannot be realized without additional phase shifters. Power handling capability is low. These are the disadvantages of previous paper which is overcome in this paper.

## IV. METHODOLOGY

*A.* Noting the overwhelmingly large spectrum of communication systems, it would be ideal for manufacturers to provide a solution which satisfies needs over a significant range of these frequencies
*B.* The proposed design is configured by 90degree and 180degree transmission lines, and the main advantage is that
*C.* The proposed design can be applied in three different system connection schemes Corresponding to the three schemes, the coupler can be with three operations (e.g. the operations of balanced input with single-ended outputs, single-ended input with single-ended outputs, and single-ended input with balanced and single-ended outputs).



(a) (b)

Figure.2. (a) Front view & (b)Back view of the proposed structure

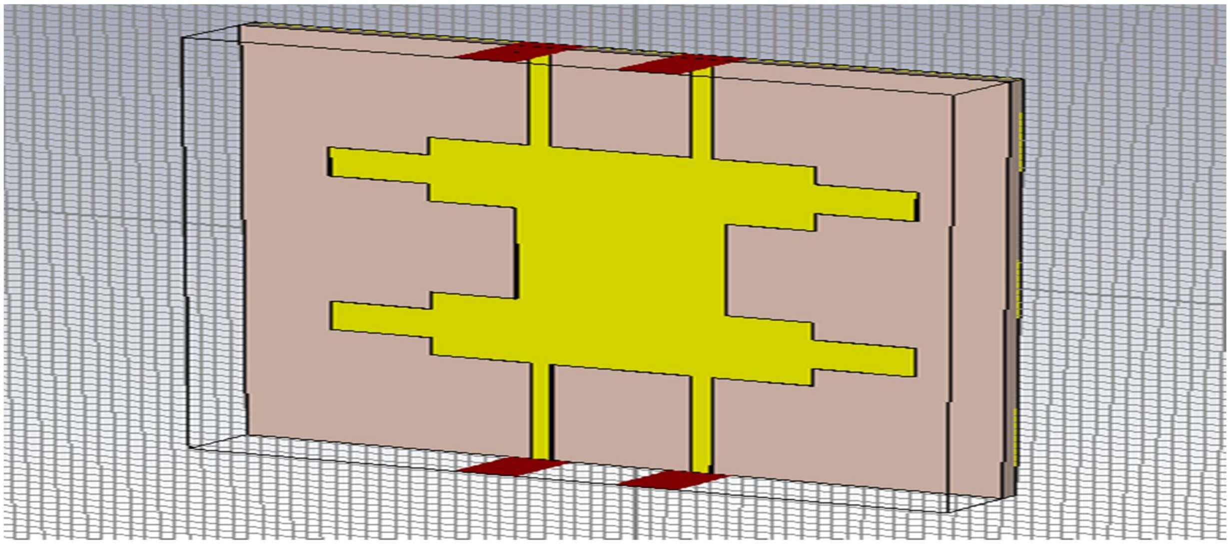


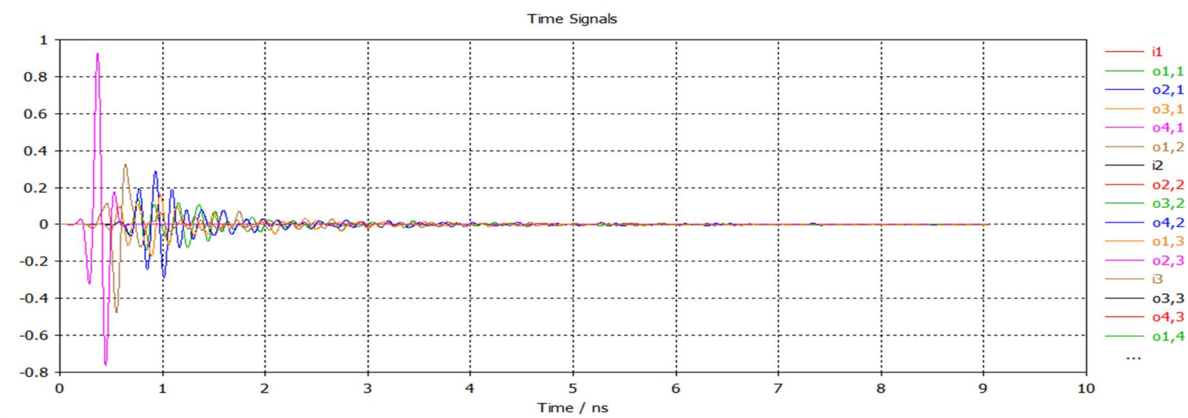
Figure.3. Perspective view of the proposed design

*D.* This can increase the fexibility and freedom of the coupler for systems with different connection types.

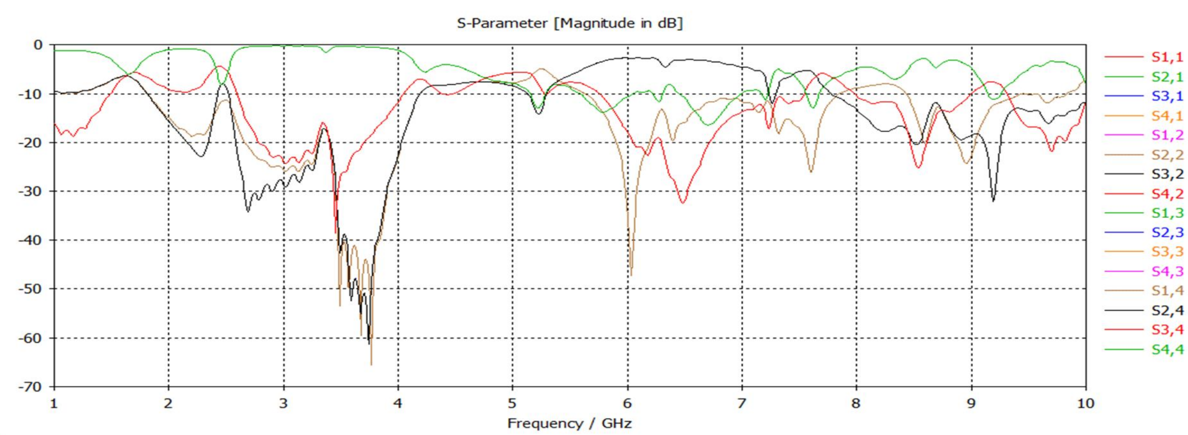
*E.* Furthermore, the common-mode suppression can be achieved under the operation.

*F.* The standard and mixed-mode S-parameters are utilized to deduce the circuit parameters.

*G.* Two prototypes using 3/4 g (g is the guided wavelength at the center frequency) transmission line (design I) and coupled line with two shorts (design II) to realize the 90-transmission line were designed.




(a)




(b)

Figure.4. All port (a) signal (b) S parameters

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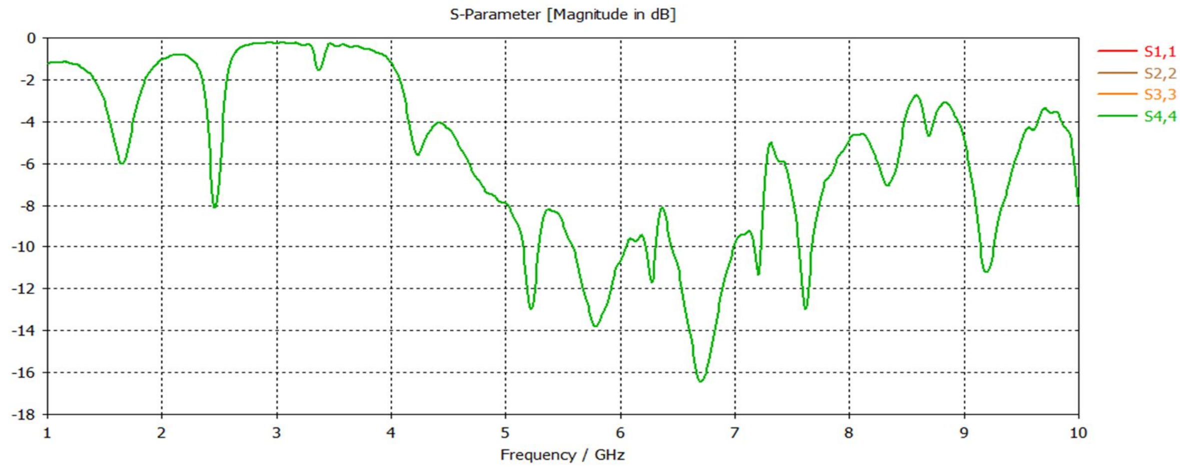
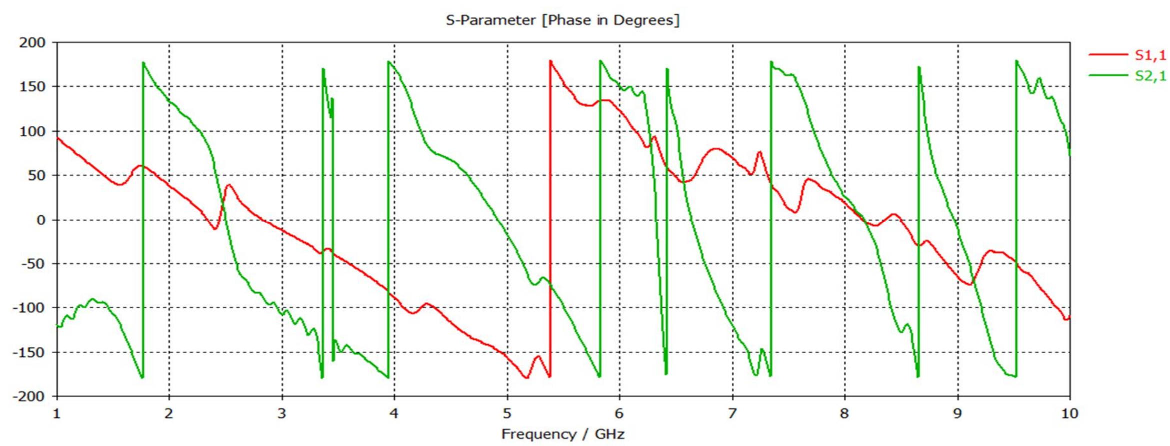
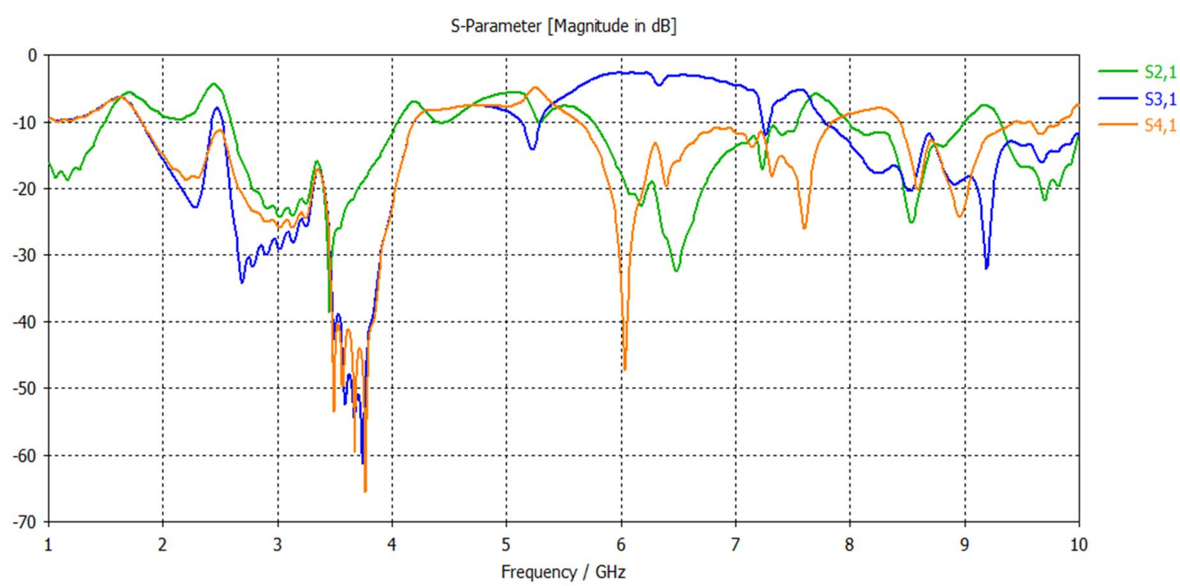



(a)




(b)




(c)

Figure.6.(a) Return Loss (b) Phase Differenc (c) Insertion loss

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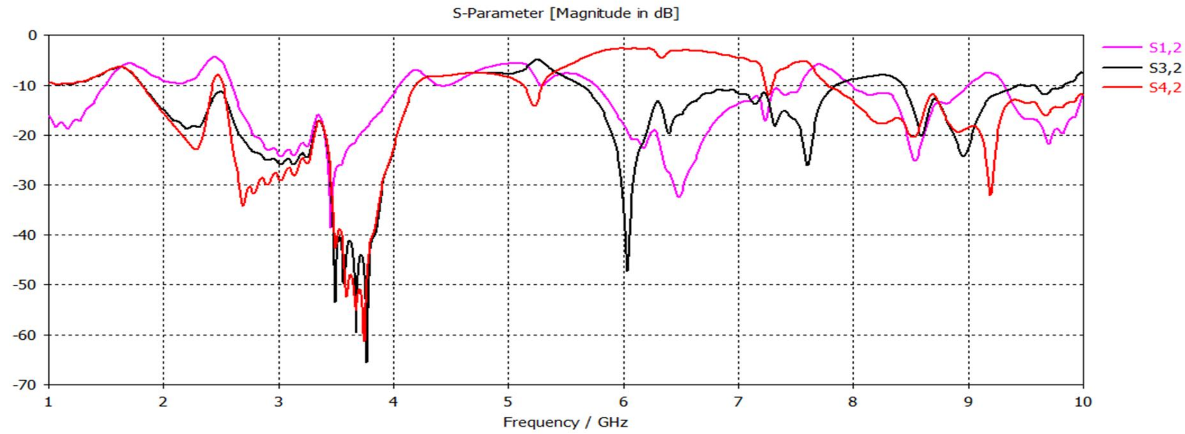
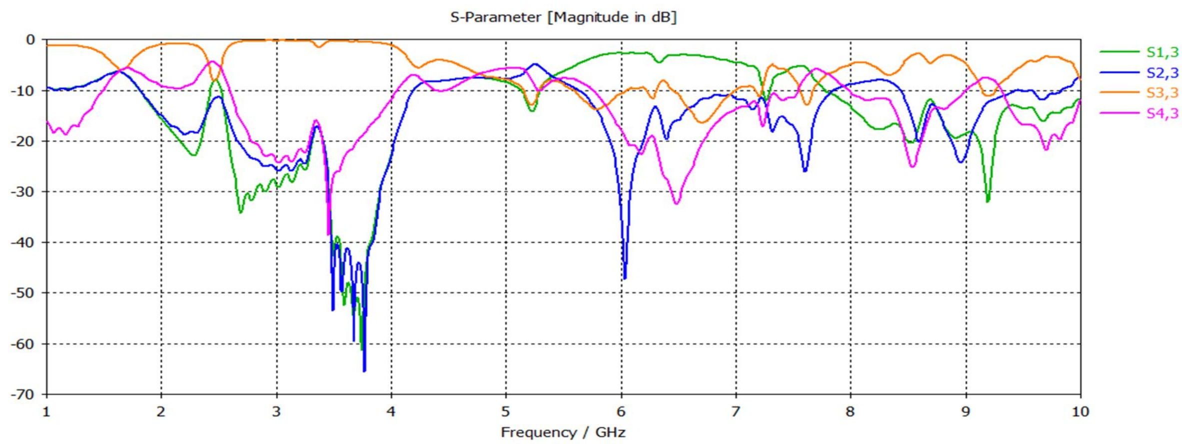
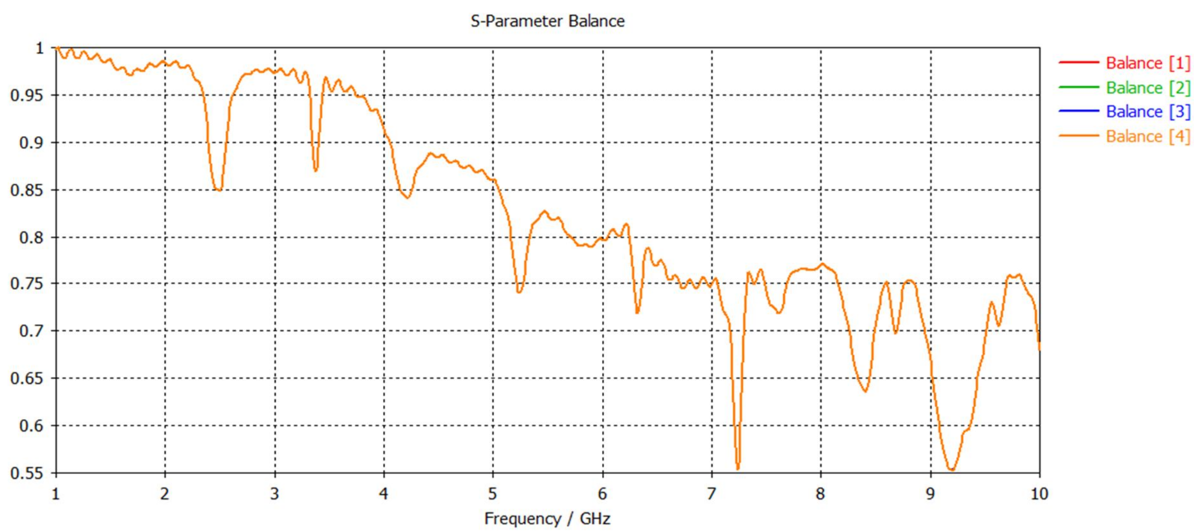
The proposed design has been simulated using CST software to extract its scattering parameter characteristics. The port signals from all, return loss and other S parameter, phase difference, energy balance detail and insertion loss has been obtained by simulation and all the results are given above:



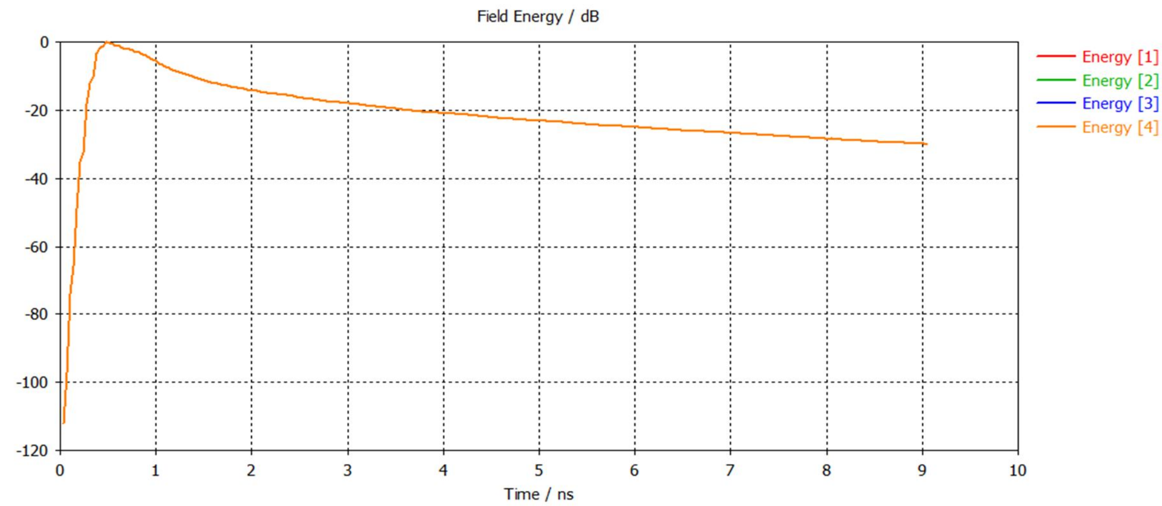

(a)




(b)




(c)




(d)

Figure.7. Enery balance detail (a) w.r.t to port 2 (b) w.r.t to port 3 (c) All port (d) Filed Enegry of all port

In this paper , a multiband branch line coupler and a multiband rectangular disc hybrid coupler have been fabricated . When comparing with the branch line hybrid coupler , the rectangular disc hybrid has a larger bandwidth and easier to be fabricated due to its simpler structure. A branch line multiband hybrid coupler and a rectangular disc hybrid coupler covering multiband frequency band have been designed and fabricated. Both of them have isolation and return loss better than 10 dB in their operating frequency band. They have acceptable insertion loss in their operating frequency band too.

## V. CONCLUSIONS

In this paper a multiband hybrid having open circuit stub with rectangular disk coupler has been designed and simulated to achieve better isolation and return loss better than 10 dB in the operating frequency. The designed coupler having mutli resonant at different frequency from 3 GHz to 9 GHz. This device having acceptable insertion loss and VSWR of 1.3 which makes it use for RF and microwave communication with wireless technology.

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