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***Research Paper***



# Design and Development of a 3dB Quadrature Patch Hybrid Coupler

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## Abstract

In this paper a -3 dB, 90-degree phase shift RF quadrature patch hybrid coupler is designed to operate at 2.4GHz. Hybrid coupler is a four-port device, that's accustomed split a signaling with a resultant 90 degrees' section shift between output signals whereas maintaining high isolation between the output ports. The RF quadrature patch hybrid coupler is used in various radio frequency applications including mixers, power combiners, dividers, modulators and amplifiers. The desired hybrid coupler is designed using FR-4 substrate with 1.6mm height in High Frequency Structure Simulation (HFSS) and the same is fabricated and tested. The designed Hybrid coupler is examined in terms of parameters like insertion Loss, coupling factor and return Loss. The simulation and measurement results are compared. Major advantages of the RF quadrature patch hybrid couplers are that they are compatible with integrated circuit technology.

**Keywords**: *Coupling factor; FR-4 substrate; Insertion loss; Return loss; Quadrature patch*

## 1. Introduction

Microwave couplers are devices whose primary functionality is to divert some amount of information from one path to another path [15]. The signal which is coming from the output side of first path is called "direct signal" Because it is directly connected to the input Port. Signal coming from the second path of output side is called the "coupled" signal. In this letter a -3 dB, 90-degree phase shift quadrature patch hybrid coupler is designed to mainly operate at the frequency 2. 4GHz.A -3 dB, 90° hybrid coupler is a four-port device that can split an input signal equally or un equally with a resultant 90° phase shift between two output ports or to combine two signals by maintaining high isolation between the ports. [5] The performance of any hybrid coupler is examined with help of the following parameters [9].

- Insertion loss
- Isolation
- Coupling factor
- Phase shift
- Band width

### 1.1. Insertion Loss:

Insertion loss in telecommunication is due to the insertion of a device. the quantity of insertion loss for any device is expressed in terms of decibels and it's indicated with IL. Ideally the insertion loss for hybrid coupler is 3dB. If the power transmitted to the load before insertion is P1 and therefore the power received by the load once insertion is P2, then the insertion loss in dB is calculated by using the below formulae [6],

$$IL\ (dB) = 10 * \log_{10}(P1/P2) \quad (1.a)$$

$$IL\ (dB) = 10 * \log_{10}(P1/P3) \quad (1.b)$$

### 1.2. Coupling Factor:

Coupling factor is the parameter which occurs when the power is transferred from one circuit element to other circuit element [3]. Sometimes coupling factor is also called as coupling loss or Connection Loss and it is indicated with C. Normally coupling factor value is expressed in terms of dB. If the power at port1 is P1and power at coupling port is P3, then the coupling factor value can be expressed as [17]

$$C\ (dB) = 10 * \log_{10}(P4/P1) \quad (2)$$

### 1.3. Isolation:

Isolation is the parameter which will gives information about power transmitted between the unwanted ports. [4] In quadrature hybrid coupler the port 4 act as back port. Ideally there is no power is transmitted between port 1 and port 4 and isolation is considered as zero. But in practical case there will be some minimum power will be transmitted between port 1 and port 4. The isolation will give how much power is observed at port 4. If the power at port 1 is P1 and power at port 4 is P4 then isolation can be calculated using the formulae [8].

$$I(dB) = -10 * \log_{10}(P4/P1) \quad (3)$$

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### 1.4. Phase Shift:

Phase shift is the measure of phase difference between two signals and it is expressed in terms of degree. in hybrid coupler the phase shift is calculated between the signals coming at port2 and port3.normally a quadrature hybrid coupler provides a 90-degree phase shift between signals coming out at port1 and port3. [13]

### 1.5. Band Width:

Band width for quadrature patch hybrid coupler is defined as the range of frequencies for which hybrid coupler exhibits VSWR value less than 2. Sometimes bandwidth can be expressed in terms of percentage of bandwidth with respect to center frequency. [7] The percentage of bandwidth for a hybrid coupler can be calculated using the formulae [12]

$$\%BW = 100\times (F_H - F_L)/F_C \quad (4)$$

Where
$F_H$ is the higher cut-off frequency
$F_L$ is the lower cut-off frequency
$F_C$ is the center frequency

## 2. RF Quadrature Patch Hybrid Coupler

Desired hybrid coupler having 4 Ports namely Port 1, Port 2, Port 3 and Port 4 are shown in fig1 is designed using Micro strips. [1] The complete hybrid coupler consists six Z0 (50 ohm) Microstrip lines and two Z0/√2 (35.5 ohm) Micro strip lines. If the power is applied at port1 then the power coming at other ports will be calculated using the mathematical expressions. Let us assume the power incident at Port1 is P1, powers coming at Port 2, Port3 and Port4 are P2, P3 and P4 respectively.

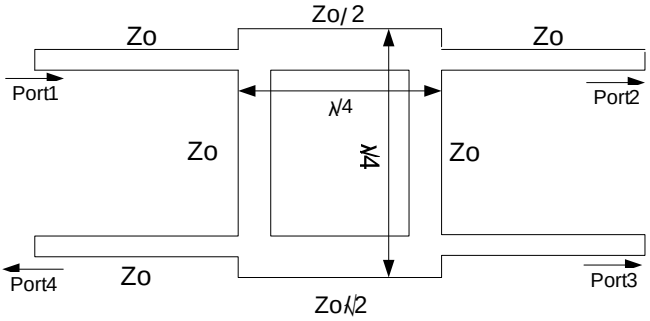



**Fig1.** Structure of quadrature hybrid coupler: $Z_0$= impedance of free space, λ=Operating Wave Length

Each Microstrip line is considered as λ/4 length and the phase shift (Θ) over the Microstrip can be calculated using the relation between phase shifts and operating wave length [16].

$$\Theta = \beta * L \quad (5)$$

Here $\beta = 2 * \pi / \lambda$
$L = \lambda/4$

Now the signals coming out at port 2 and port 3 will be having a phase difference of 90 degrees.

## 3. Advantages

- Low return loss.
- Light weight and have in a small size [11].
- It is easy to connect with other microwave devices [14].
- Less expensive.

## 4. Applications

Some applications of Quadrature Patch Hybrid Coupler are [10]:

- Power dividers.
- RF amplifiers.
- Mixers.
- Transmitters and Receivers

## 5. Designing Procedure

The quadrature hybrid coupler is designed using ANSYS HFSS software. the material used for designing is FR-4 and thickness of the material is 0.8mm

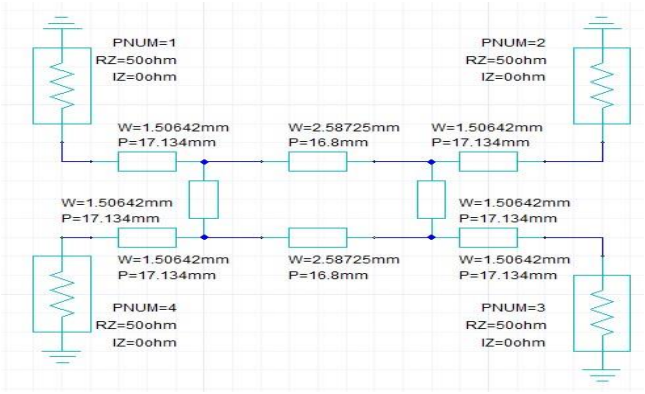



**Fig 2.** Schematic of proposed quadrature patch hybrid coupler: w=width of the Microstrip, p=length of the Microstrip

The figure 2 shows the schematic of proposed 3dB quadrature patch hybrid coupler. [2] It has four ports and all four ports are matched with 50 ohm Microstrip line. The 50 ohm Microstrip line length and width values are calculated using the Microstrip line calculator the length is 17.23mm and width is 1.506 mm. similarly in the schematic two 35.3 ohm Microstrip lines are used to design the 3dB Hybrid coupler. The length of the 35.3 ohm Microstrip line is 16.8mm and width is =2.58mm.

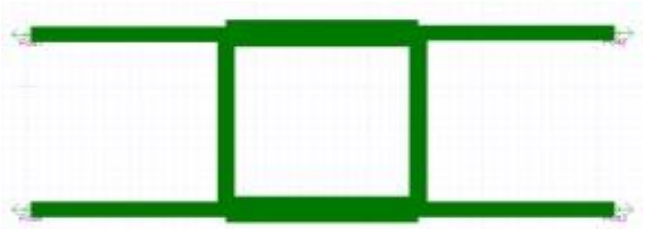


**Fig 3.** Layout of proposed hybrid coupler

The figure 3 shows the layout for proposed hybrid coupler and itis used for implementing practically. The same model is etched on FR-4 substrate having thickness 0.8mm.

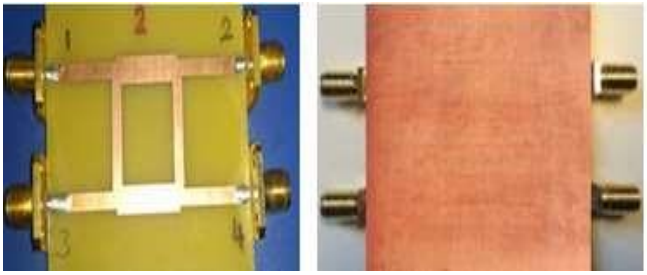


**Fig 4.** Fabricated patch hybrid front view and back view

The figure 4 shows the front view and back view of hybrid coupler designed on FR-4 substrate.4 ports are connected to 50 ohm SMA connectors.one side of the dielectric substrate Consists quadrature patch and other side consists completely ground plane.

## 6. Results

The desired antenna is designed using ANSYS HFSS and the simulation results (return loss, insertion loss coupling factor) are observed. The same model is fabricated using FR-4 substrate and practical results are observed using a vector network analyzer and both the results are compared.

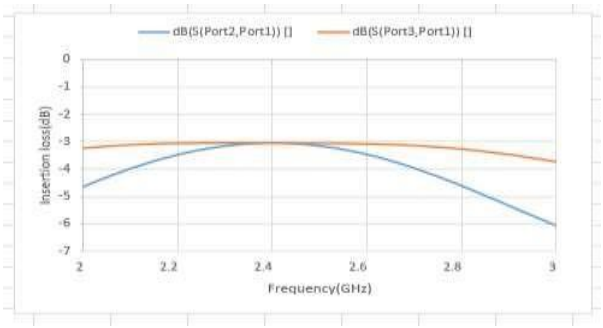



**Fig 5.** Insertion loss at port 2 and port 3

The figure 5 shows the simulated insertion loss at port 2 and port 3. The insertion loss obtained in this investigation is -3dB and the directional is dividing the power equally and the phase difference observed is 90 degrees.

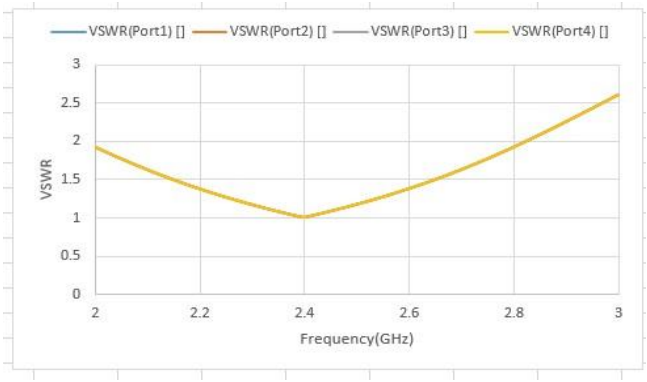



**Fig 6.** VSWR at port 1, port2, port3 and port 4

The figure 6 shows the simulated frequency versus VSWR value at all ports of quadrature patch coupler. The value obtained in the simulation is unity which means the device operation is very good for the frequency 2.4GHz.and also the impedance band width from the graph is observed nearly 500MGHz.

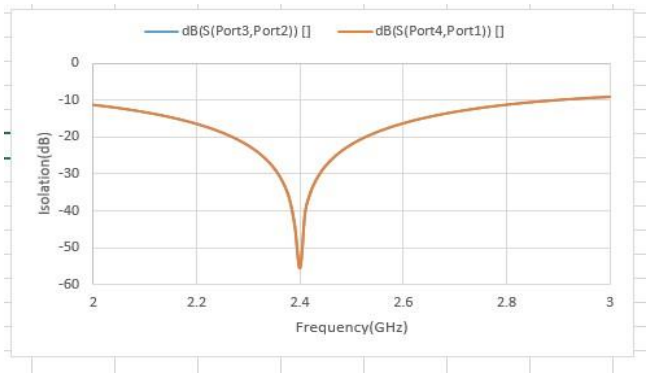



**Fig 7.** Isolation between ports 2 &3, ports 4& 1

The figure 7 shows the simulated isolation between ports 2& 3 and ports 1&4 the value obtained in this investigation is very less nearly -60dB and no power is coupled between port2 and port3 and the no power is coupled between port1&port4.

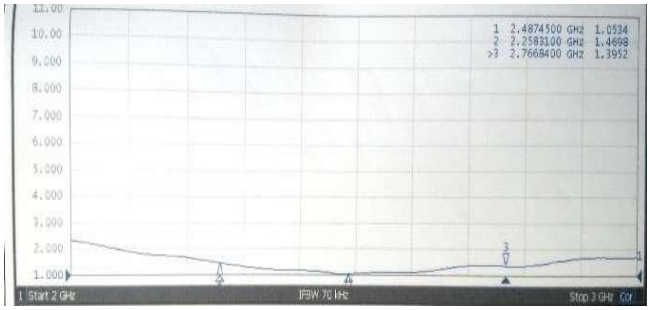


**Fig 8.** VSWR at port 1, port2, port3 and port 4

The figure 8 shows the frequency versus VSWR value plot at all ports of quadrature patch coupler measured using Anritsu ms2028c Vector Network Analyzer. The IF band width considered is 70KHz. The VSWR value obtained in the simulation is 1.0723 and also the impedance band width from the graph is observed nearly 500MGHz.

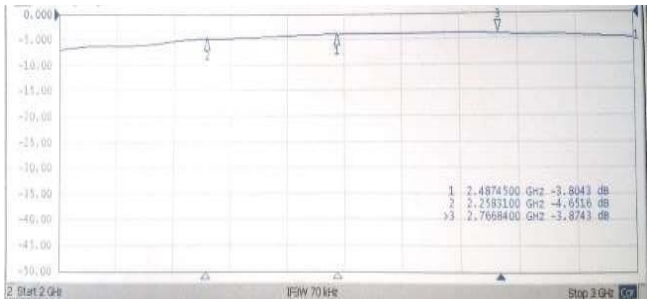


**Fig 9.** Insertion loss at port 2 and port 3

The figure 9 shows Graph between frequency versus the Insertion Loss at Port 2&Port 3.the insertion loss obtained is nearly -3dB at both the ports.

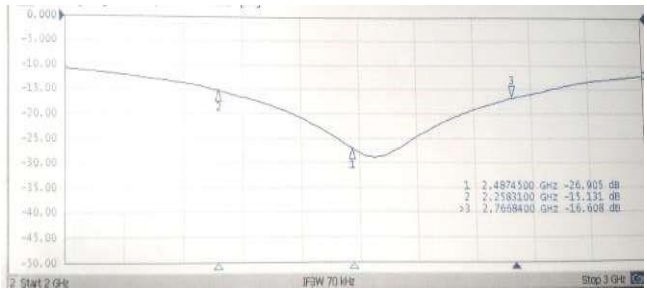


**Fig 10.** Isolation between ports 2 & 3, ports 4& 1

The figure 10 shows Graph between frequency versus the isolation between ports 2&3,1&4.the designed hybrid coupler provides very good isolation nearly-26dB.

## 7.Conclusions

In this paper, -3 dB, 90 degrees Phase Shift RF quadrature patch hybrid coupler has designed using FR-4 material to operate at a frequency of 2.4GHz. The desired hybrid coupler is tested in terms of simulation as well as practical. The simulated results were verified by modelling the schematic and layout with ANSYS HFSS Software and also practically implemented the hybrid coupler and tested with the Network Analyzer. The simulated return loss,

VSWR, insertion loss, coupling loss, isolation and the phase shift for the center frequencies are plotted. The simulated and measured results are in good agreement.

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