5.5 Ghz Directional Antenna with 90 Degree Phase Difference Output

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***Abstract* - The wireless sensor network system requires two antennas that have an output 90 phase difference as a comparison and use a very expensive material for high frequency. 5.5 GHz microstrip antenna frequency equipped with two output 90 degree phase difference in one antenna has been proposed. This is a new technique in telecommunication systems to produce directional antenna use more precise and efficient phase comparators by using cheap and easy to find material at 5.5 GHz frequency. This system package consists of a circular patch, a reflector, a double transmission line with a via hole that has the same frequency in one antenna and quadrature 90 degree hybrid coupler integrated each other. This antenna produces a phase angle difference 87.752 degrees (5 degrees of standard tolerance) and gains 5.82 dBi at 5.5GHz frequency. Overall size of the proposed antenna design is 90 mm times 35 mm with Phenolic White Paper - FR4 with a dielectric constant is 4.4.**

Keywords* - *Microstrip antenna, Hybrid coupler, Phase difference

I. INTRODUCTION

Recently, there has been a tremendous increase of interest in microstrip antennas due to the development of communication and navigation technologies. Various antenna and phase shifter designs have been proposed [1]-[6]. Communication and navigation systems require a compact, practical, inexpensive and efficient antenna. In some practices, we use two antennas and use different types of electrical circuits in the process of signals comparison with 90 degree phase difference angles. This requires expensive material because each high-frequency antenna requires the material with the lowest loss. In addition, integrating the antenna has consequence in complicated fabrication to get 90 degrees phase difference so requires a lot of electric circuits that expensive[7]. The method using various electromagnetic line circuits more efficient than general electric circuit because it reduces the loss of power to convert energy process from the antenna to the next circuit [8]. In addition to performance and practical, this model is very easy to imitate, fabricate and can be utilized. With a small size and has, a high-frequency antenna is also capable of producing high gain. Even the proposed antenna is capable of providing circular polarization so that it can receive both vertical and horizontal transmission waves.

In this letter, a compact antenna consisting of a 5.5GHz double transmission line antenna with two additional through holes, circular patch and a reflector has been adopted to obtain capable to produce high gain and circular polarization a compact size antenna for navigation and communication applications combined with a 90o phase difference hybrid coupler[9]. This study provides a simple and effective method for designing double transmission line antenna without complex topology design, fabrication process and using cheap materials at high frequency.

II. RESEARCH METHODS

Fig. 1 and Table 1 shows the geometry of the proposed miniaturized 5.5GHz Antenna. In this Fig., double transmission lines and via hole of the $\lambda/4$ has been constructed using an FR4 substrate with the thickness of 0.8 mm. These double transmission lines are connected to the ground plane by means of via hole

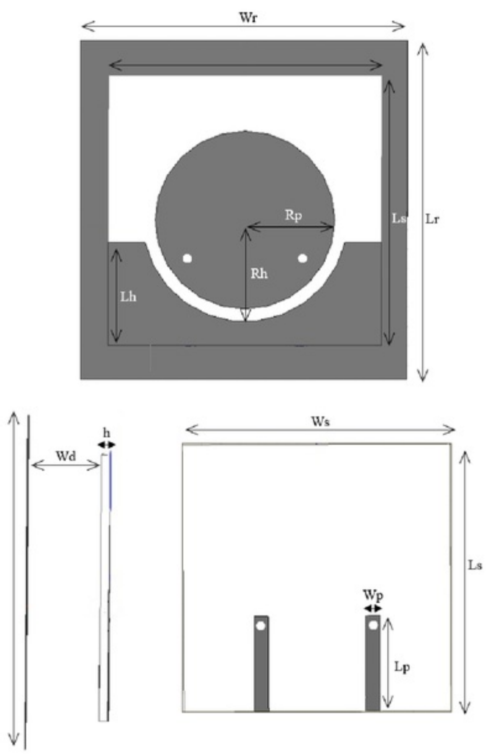

Fig. 1. Structure of the microstrip antenna
(a) Front, (b) Side, (c) Rear

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TABLE I. DIMENSION OF THE MICROSTRIP ANTENNA

Variable	Dimensions (mm)
Wr	35
Lr	35
Ws	30
Ls	30
Rp	9.2
Rh	10.5
Lg	10.7
Wd	5
h	0.8
Wp	1.5
Lp	10

In this paper, double patch rectangular shape used with connected to circular ground by via hole so the basic form is the circular patch, which is the radiating element radius dimensions can be obtained through the equation [10][5]:

$$\alpha = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{\frac{1}{2}}} \quad (1)$$

Where *a* is the radius of radiation element, *h* is the substrate thickness, ε_r is the relative dielectric permittivity of the substrate and F is the logarithmic function of the radiation element. The Double transmission line microstrip antenna design is done mathematically based on the material and references obtained from the literature [7][11]. Results of the draft then simulated using the design software to determine the parameters of the double transmission line antenna. Couple design and antenna simulation is important to represent the qualifications of the design whether it is appropriate or not as desired performance.[12]

In Fig. 2 the circuit design of the proposed miniaturized 90◦ hybrid couplers. In this Fig., the double transmission line of resonators and via hole of the λ/4 have been constructed using an FR4 substrate with the thickness of 0.8 mm. These 4 ports are two port as input from the antenna and two port as an output of the different phase

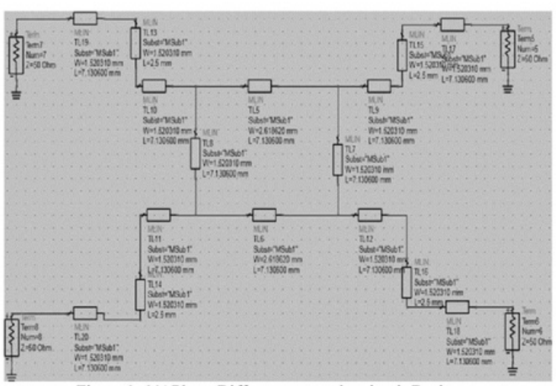


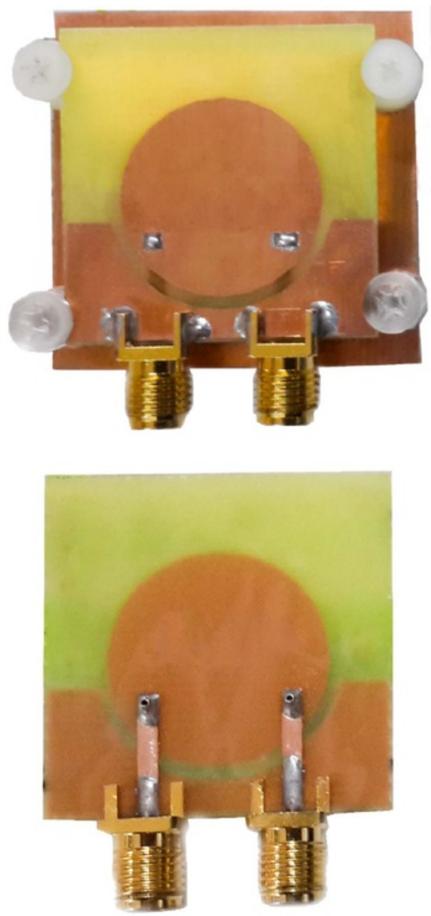
Figure 2. 90° Phase Difference coupeler circuit Design

The operation of the branch of line coupler is as follows : With all ports matched, power entering to port 1 is evenly divided between ports 3 and 4, with a 90◦ phase shift between these outputs at 5.5GHz frequency operation. No power is coupled to port 2 (the isolated port). The scattering matrix has the formula[13] :

$$[S] = \frac{-1}{\sqrt{2}}\begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix} \quad (2)$$

III. MEASUREMENT AND PARAMETER ANALYSIS

Fig. 3 shows the prototype of a double transmission line antenna that has been fabricated. The antenna has the main components they are antenna and reflector. The reflector is used to provide high efficiency and gain values with small and compact antenna sizes. The overall size of the proposed antenna is 35 mm x 35mm.



(a)

Fig. 3. Physical structure of the microstrip antenna

Comparison of measurement results and simulation results are shown in Fig. 4 and 5. There are two ports: S11 and S21 which have the same frequency operation.

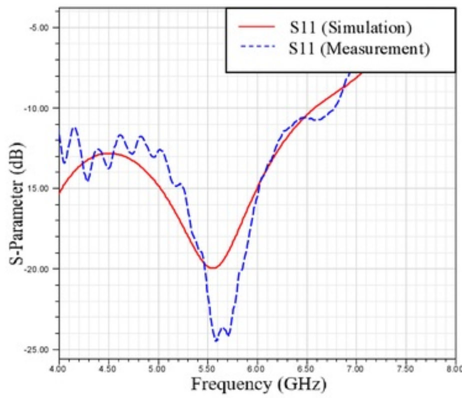


Fig. 4. S11 Antenna Result

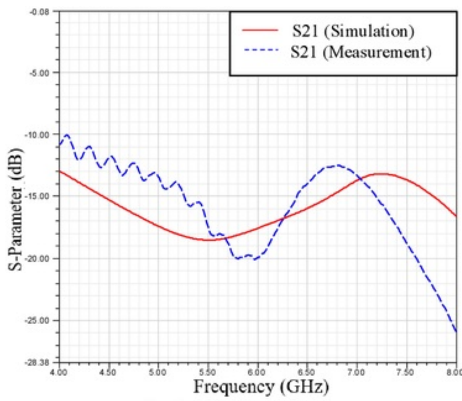
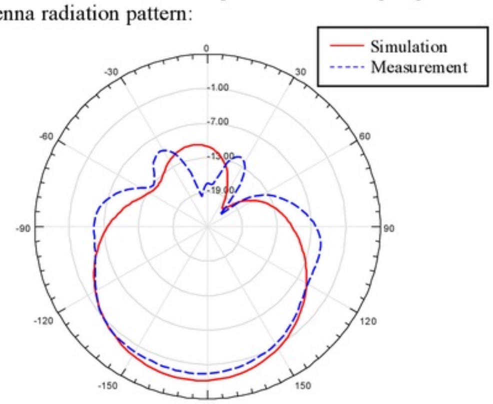
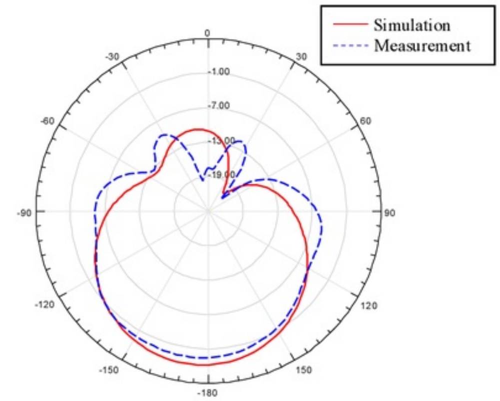


Fig. 5. S21 Antenna Result

S11 and S21 have good agreement return loss values to obtain from the simulation and measurement the value of S11 and S21 simulation is -19.84 dB and 18.51 dB. The value of S11 and S21 measurement is -21.47 dB and -17.39 dB. This antenna has a gain value 5.82 dBi. To draw the graphics properties of far-field antenna radiation from as a function of spatial coordinates (three dimensions) [14]. It is necessary to know the antenna radiation pattern. Following Figure is the antenna radiation pattern:





(b)

Fig. 6. (a) Theta angles of The radiation pattern, and (b) Phi angles of The radiation pattern

The radiation pattern of the simulation and measurement results has the good agreement magnitude of the shape and the value. From the shape of the radiation pattern has a main lobe of the largest and has a very small side lobe and back lobe, it can be concluded that the antenna radiation pattern is a directional radiation pattern. To know the strengthening power in the certain direction to the reinforcement of the antenna reference power hence need to know antenna gain value. Following gain value:

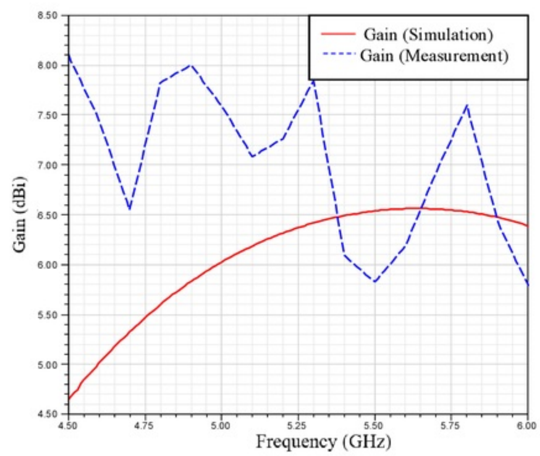


Fig. 7. The gain value comparison of the measurement and the simulation microstrip antenna

From Fig. 7, it is shown that the gain of the antenna has a value of 5.82 dBi. this shows that high antenna gain for microstrip antenna with frequency 5.5 GHz.

90^0 Phase Difference coupler is fabricated using the same material as the antennas FR4 with a cheap price and easy to find. Fig. 8 shows the physical form of the fabricated 90◦ Phase Difference coupler and Fig. 8 shows the S-parameter values of each port [15].

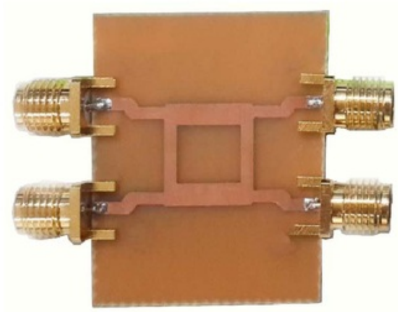


Fig. 8. Implemented 90◦ Phase Difference coupler

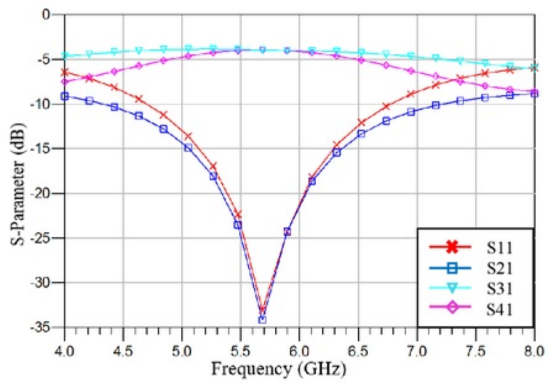


Fig. 9. S parameter 90^0 phase difference coupler

90 Degree Phase Difference coupler use 4 port SMA male with 50 ohm impedance each port. The branch line hybrid has a high degree of symmetry of 90◦ Phase Difference coupler, as any port can be used as the input and output port [16]. The output ports will always be on the opposite side of the junction from the input port, and the isolated port will be the remaining port on the same side as the input port [17]. The value of S parameter of each port at 5.5 GHz frequency operation can be follows: S11 has value -31.88 dB, S21 has value -23.44 dB, S31 has value -4.52 dB and S41 has value -3.20 dB.

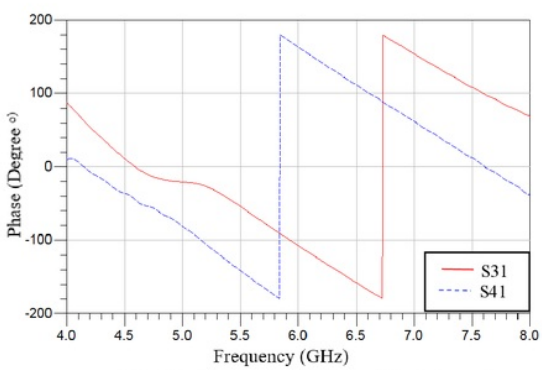


Figure 10. Phase output r 90^0 phase difference coupler

Fig. 10 shows the phase of the output of each output port. The phases are represented in phase parameters S31 and S41 with the following values S31 has a phase value -142.060° and S41 have a phase value -54.309°. S31 and S41 have differences in phase close to 90^0 that is 87.752 degrees its better then [3].

Fig. 11 shows the physical form 90° Phase Difference Double transmission line 5.5 GHz Antenna connected to female and female connector overall has a length : 90 mm and a width : 35 mm.

Fig. 11. 90^0 phase difference 5.5 Ghz microstrip antenna integration

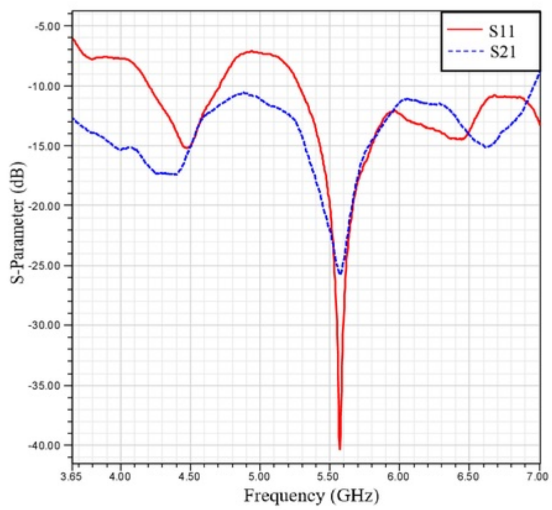


Fig. 12. S-Parameter antenna and 90^0 Phase Difference coupler integeration

Fig. 12 shows the output S parameters value the Antenna and 90◦ Phase Difference coupler. The S11 and S21 values of the 90◦ Phase Difference Double transmission line 5.5 GHz Antenna, S11 has a value of -20.17 dB and S21 has -22.13 dB. This shows that the antenna performance can work well on that frequency.

IV. Conclusion

In this letter, a compact prototype antenna, easy to fabricate and low-cost material that has FR4 material with ε_r = 4.4. This antenna has two resonators or transmission line $\lambda/4$ with the same working frequency at each resonator that is 5.5GHz. This antenna is a directional antenna with the high gain of 5.82 dBi, directional radiation pattern and linier polarization. The Coupler has two inputs from the antenna and two outputs which produce an 87.752 degrees phase difference and S output parameters under 20 dB that is S11 has a value of -20.17 dB and S21 has -22.13 dB.

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