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Bandwidth Enhancement of CPW Double Patch Antenna for WLAN Application

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ABSTRACT

In this paper, the design of double patch antenna with coplanar waveguide (CPW) for the purpose of bandwidth enhancement is demonstrated. The proposed structure consists of rectangular patches which are printed on the both sides of Flame Retardant 4 (FR-4) substrate. The antenna is designed to operate at 5.1 to 5.8GHz oprating frequency which can be applied in wireless application. For the research, a Computer Simulation Technology (CST) Microwave Studio software is selected as a tool to design the antenna structure and to perform the simulation as well. Different size of substrate has been designed to study the effect of geometric variation to the antenna performance. From the measured return loss, gain and radiation patterns of the antenna, it shows that the structure is able to enhance the usable bandwidth with greater gain. The performance of the designed antenna was analyzed such as bandwidth, gain, return loss, Voltage Standing Wave Ratio (VSWR), and radiation pattern.

KEYWORDS:CPW, CST, VNA, VSWR, 5.1-5.8GHz.

INTRODUCTION

Microstrip antennas have been introduced over 30 years, and it started to be popular in 1970s. This type of antenna technology is expanding and most of the limitations have improved recently [6, 10]. The popularity is also due to its characteristics such as low profile, simple, cheap to fabricate using modern printed circuit technology, and easy to analyze or fabricate [4].

However, the major disadvantage of the microstrip antenna is its narrow bandwidth [3]. Several techniques were introduced to improve the impedance bandwidth such as employed a wide band impedance matching, stacked patches and used a thicker substrate as common methods. However, by employing the wide band impedance matching, it creates a potential of unwanted radiation at higher frequency in the presence of wide lines used for matching over a wide band. While, by increasing the height of dielectric, the axial ratio of the patch may increase following the excitation of higher order modes [5].

Another method to improve the bandwidth is by using a coplanar waveguide (CPW) feeding method.It has a simple configuration, repeatability and low cost [9]. CPW consists of a center strip with two ground planes located parallel to and in the plane of the strip. Even though the CPW will result the antenna to produce slightly higher losses and poor power handling capability, but it able to produce broadband output signal [2].

Besides, it offers the wider bandwidth, it also has a better impedance matching and easy to integrate with active device or monolithic microwave integrated circuits. The antenna which can produce a wide bandwidth signal which from 5.1 to 5.8GHz frequency range is suitable for ultra wideband wireless transmission such as for Wireless Local Area Network (WLAN) application which also can be used in commercial wireless application [9].

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METHODOLOGY

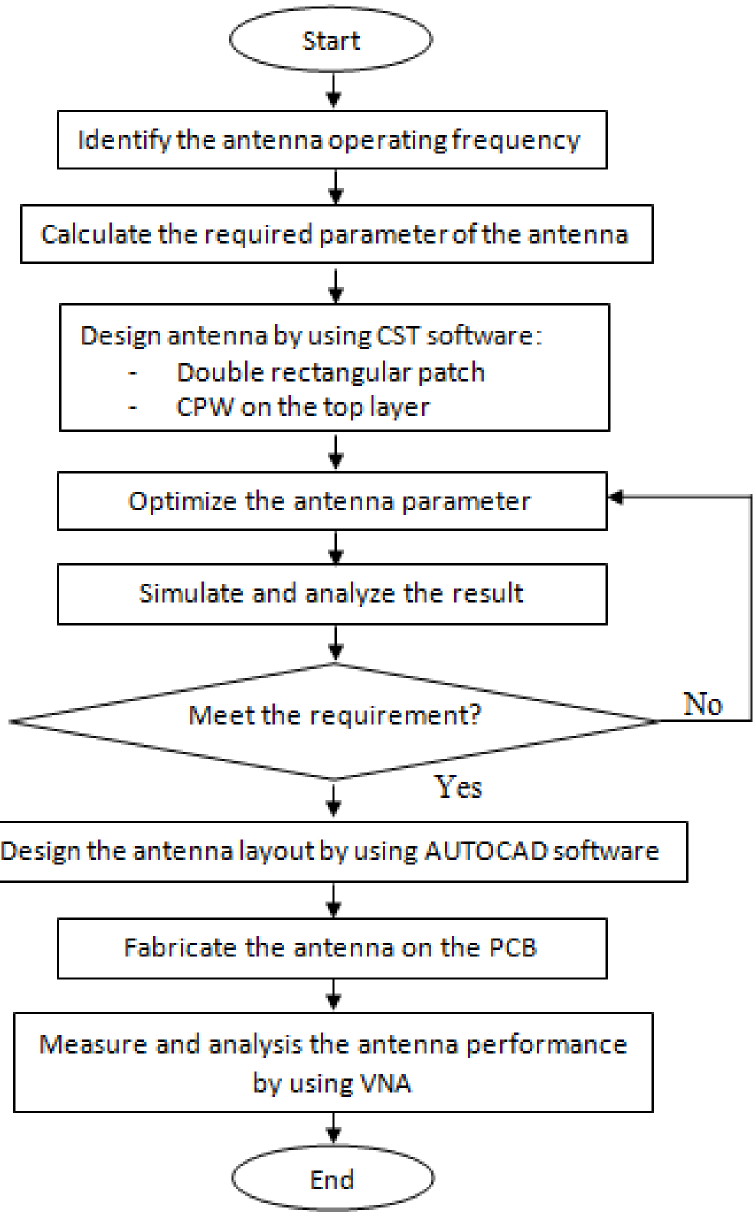


Figure 1: The flow chart of double patch antenna design with CPW feed

Figure 1 shows the flowchart for the proposed antenna. The procedure of designing and analyzing the double patch antenna with CPW feed is explained. By identifying the antenna operating frequency, the size of patch antenna can be determined by using(1) and (2).

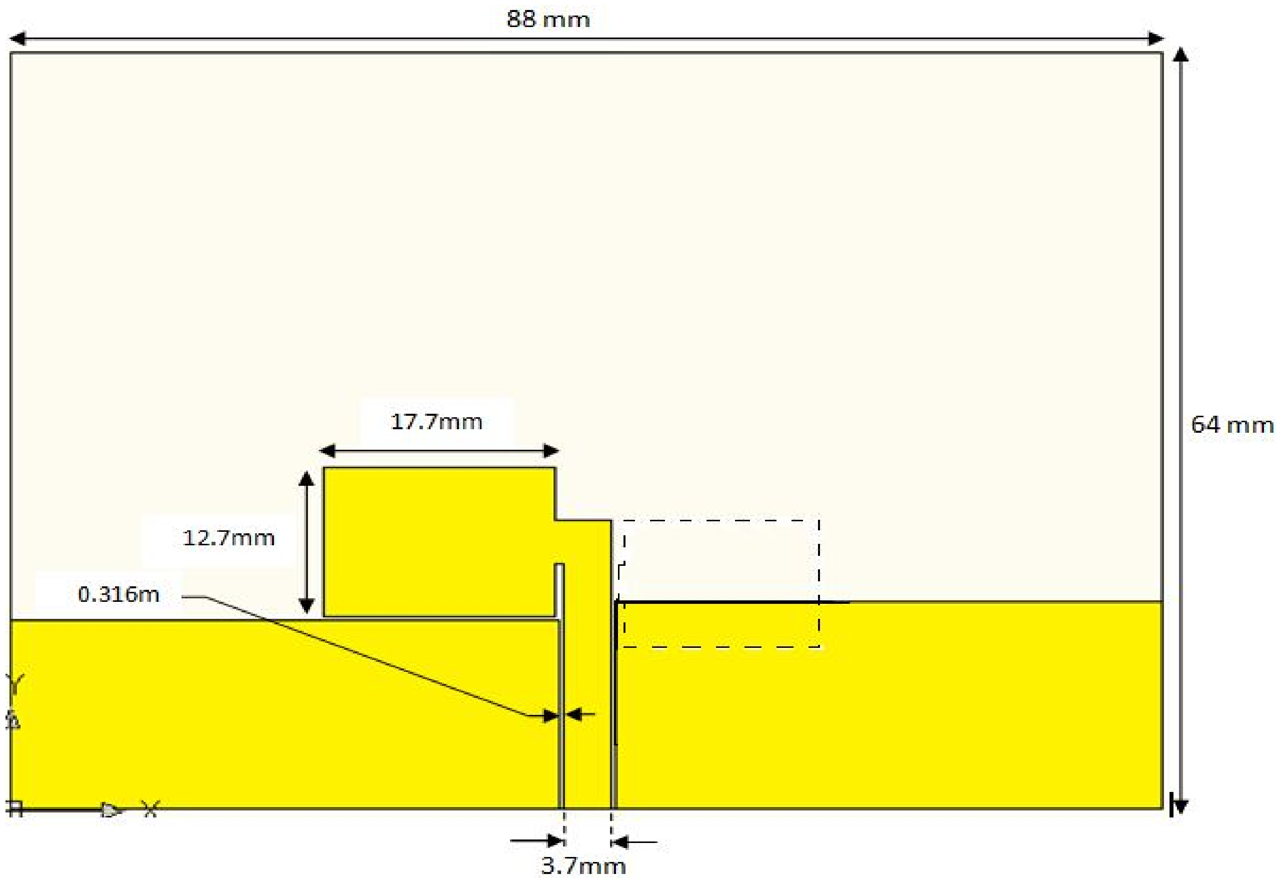
$$W = \left(\frac{c}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \right) \tag{1}$$

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_r}} \tag{2}$$

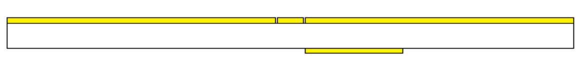
The patches dimensions are calculated at the resonant frequency,f_r = 5.4GHz, velocity of light, c = $3x10^8 ms^{-1}$and dielectric constant, ε_r = 4.7. Certain parameters of antenna need to be optimized in order to obtaina desired result. The step is repeated until the results show the antenna is operated effficiently as per determined. Then, the process is continued with a fabrication process until to the measurement process by using a Vector Network Analyzer equipment. Hence, the result that is obtained from the measurement can be compared and analyzed with the simulation result.CPW structure is incorporated in the proposed design to enhance the usable bandwidth. With the thickness of the patch (t), (3) shows the rule to determine the gap size (g) between ground and the feeder line, which is related to the CPW dimension.

$$t \geq 0.1g \tag{3}$$

ANTENNA DESIGN



(a)



(b)

Figure 2: Geometry design of double patch antenna with CPW (a) top view (b) side view

The geometry design of the microstrip double patch antenna with CPW is illustrated in Figure 2(a) and (b). The dimension is measured in millimeter (mm).The structure composes of an antenna element on the FR-4 substrate.Originally, each patch with a dimension of 12.7mmx16.3mm and thickness of 0.035mm is printed on the both side of FR-4 substrate. The substrate has a dimension of 32.5mmx55mm, adielectric constant (ε_r)= 4.7 and thickness (h)=1.6mm. FR-4 is selected due to its wide availability and low cost [7].

The size of the substrate is optimized from 32.5mmx55mm to 88mmx64mm in order to achieve a higher gain value. The CPW feeding technique is chosen to obtain a broader bandwidth range. Besides that, the technique which etches the slot and the feed line on the same side of the substrate eliminates the alignment problem needed in other wideband feeding techniques such as aperture coupled and proximity feed [2].

RESULTS AND DISCUSSION

(a) (b)

Figure 3: Fabricated antenna (a) front view (b) back view

Figure 3 depicts a fabricated design of double patch antenna with CPW technique. Front side of the substrate is printed with a single rectangular patch and CPW component while the back side is printed with another element of rectangular patch. The patch at the back side is to promote a higher gain value of the antenna while the CPW is to increase the usable bandwidth.

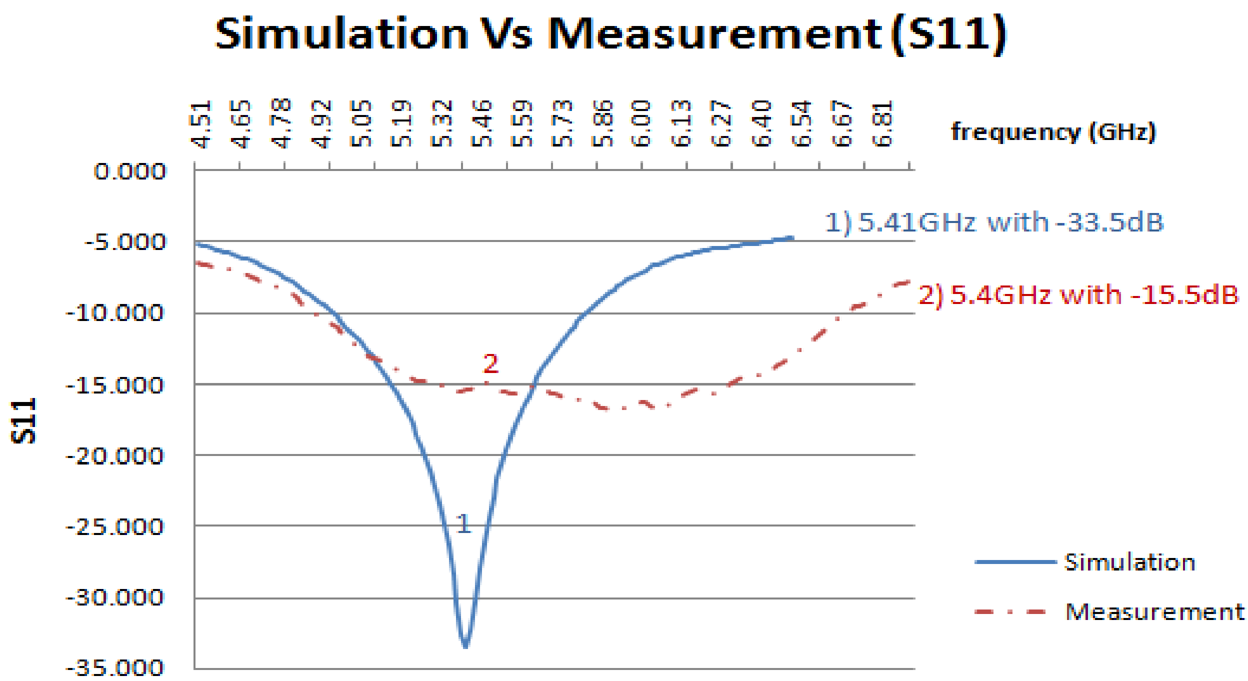


Figure 4: S-parameter between simulation and measurement results

Figure 4 indicates a comparison between the results of simulated and measured input return losses.The value of measured input bandwidth and simulated bandwidth is determined by referring to the value of return loss which is below than -10dB. From the simulation result, the bandwidth is from 4.9-5.8GHz while the measurement result is from 4.9-6.7GHz. The S_{11} for the simulated signal is -33.5dB at the frequency of 5.41GHz while the S_{11} for measured signal is -15.5dB at the first resonance frequency of 5.4GHz. The percentage of bandwidth from simulation process is 16.88% while the measurement results give the bandwidth of 31.41%.

The differences between simulation and measured results occur due to human error such as improper fabrication process, soldering technique and also during the measurement process as well. Besides that, the environmental effect and equipment error also contribute to the differences.

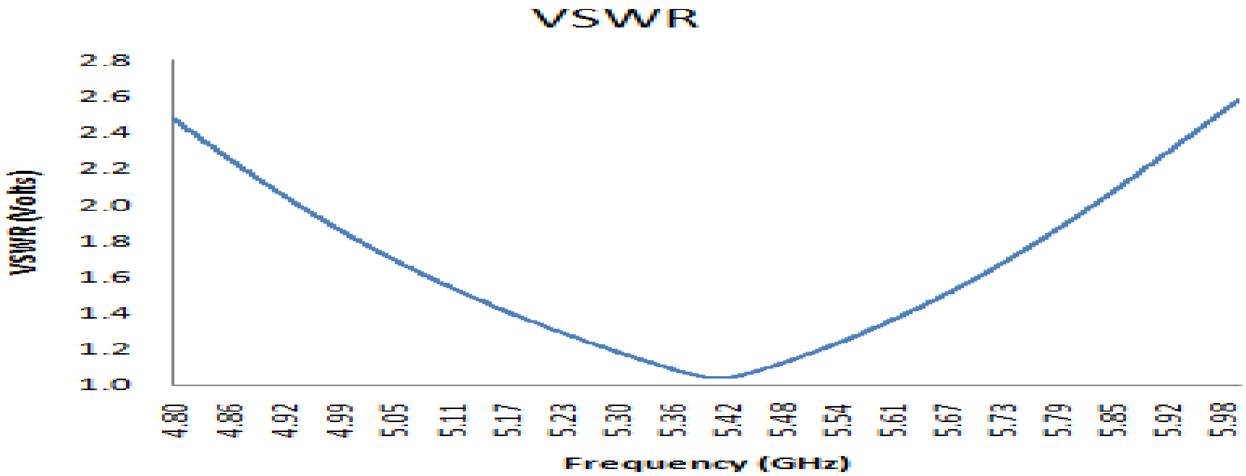


Figure 5: Simulation value of VSWR

Figure 5shows the value of voltage standing wave ratio (VSWR) during simulation process. VSWR indicates how much power is reflected back or transferred into a cable [3]. Hence, a perfect matched antenna would has a VSWR of 1:1 [8].Simulation result shows the VSWR is 1.036 at 5.4GHz frequency. The result has fulfilled the standard design requirement, since the ratio of VSWR is <2.

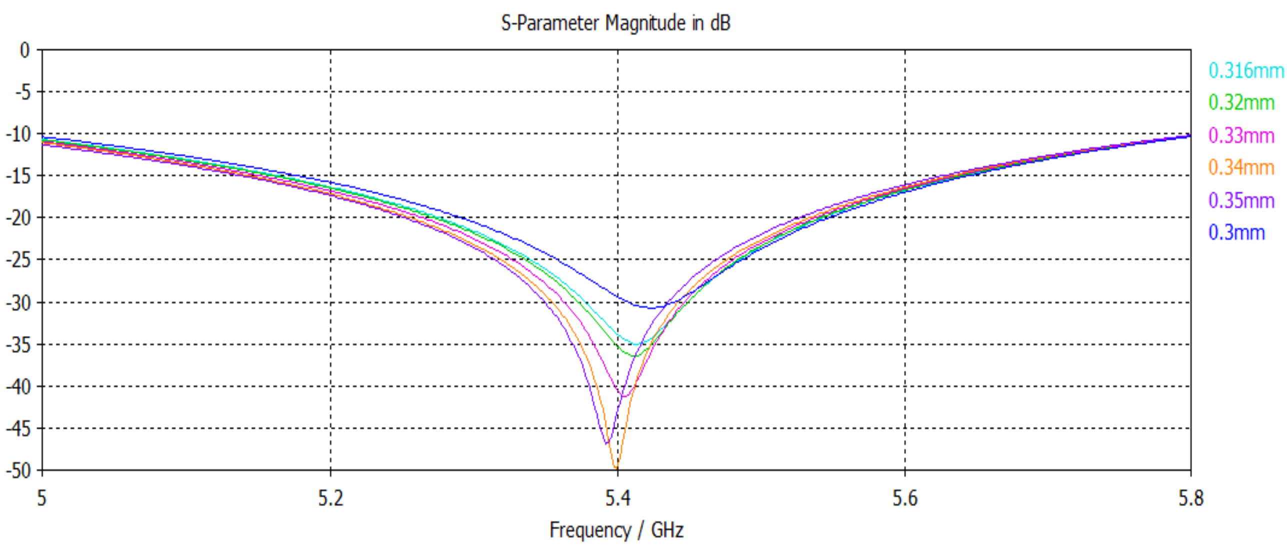


Figure 6: S-parameter for various size of gap

Table 1: Line impedance comparison between gap size

Gap Size (mm)	Line Impedance (Ω)	Gain (dB)
0.30	49.4199	8.199
0.316	50.2289	8.203
0.32	50.4257	8.204
0.33	50.9111	8.207
0.34	51.3876	8.207
0.35	51.8530	8.209

Figure 6 illustrates the S-parameter for various size of gap between the feed line to the ground. Gap size is referring to the gap dimension between the feed line and the ground. From the figure, it shows that the return loss can be improved by increasing the gap size. However, the trend in Table 1concludes that the line impedance will keep increasing if the gap size is increased. Hence the optimum value of the gap dimension is 0.316mm to achieve the good impedance matching of 50Ω. The gap size does not give greater effect to the gain value.

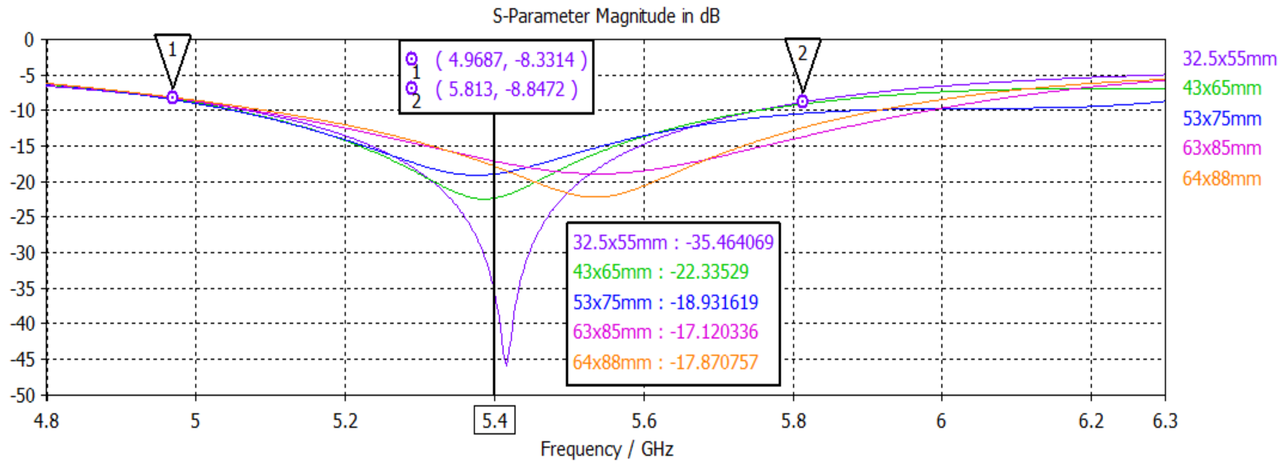


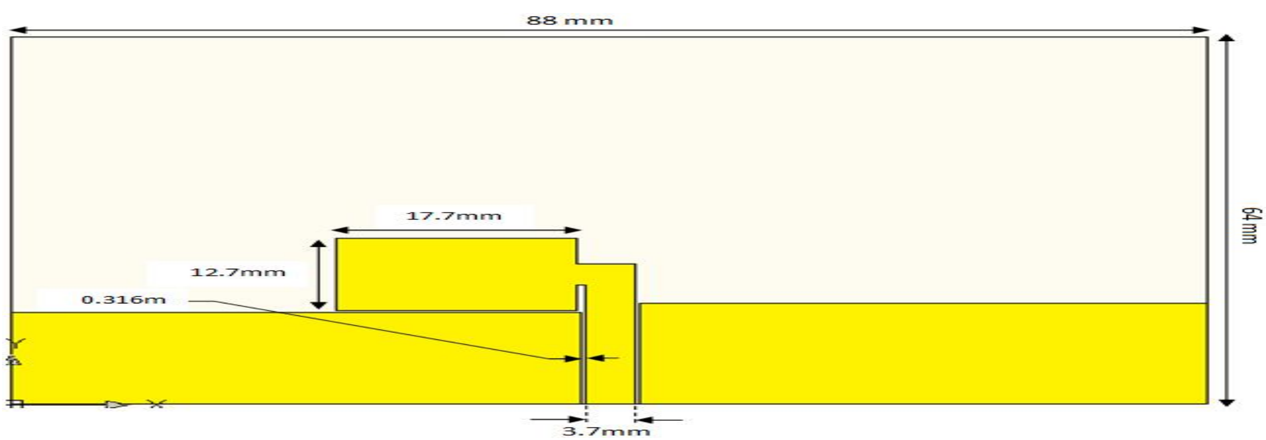
Figure 7: S-parameter for various size of substrate

Table 2: Gain comparison between substrate size

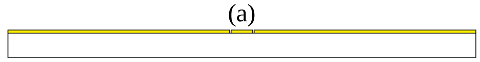
Substrate Size (mm)	Gain (dB)	S_{11} (dB)
32.5x55	4.994	-35.46407
43 x 65	5.622	-22.33529
53 x 75	6.394	-18.93162
63 x 85	7.455	-17.12034
64 x 88	7.751	-17.87076

Figure 7 depicts the s-parameter for various sizes of substrate from 32.2x55mm to 64x88mm while Table 2 lists the gain obtained from the different size of substrate. Result from the table shows that the gain is increased when the size of substrate is increased. Substrate size of 64x88 is finalized and parameter of feeder width and patch size is optimized to achieve the best result. The gain obtained is 8.203dB with S_{11} = 33.5dB.

Next step is to analyze the antenna performance between single patch and double patch antenna. In this design, single patch is referring to the antenna which only has one patch on the front side as shown in Figure 8 while double patch consists of two patches; one patch on each side, as shown in Figure 2. Both designs incorporated CPW structure on the front side.



(a)



(b)

Figure 8: Structure of single patch antenna with CPW (a) top view (b) side view

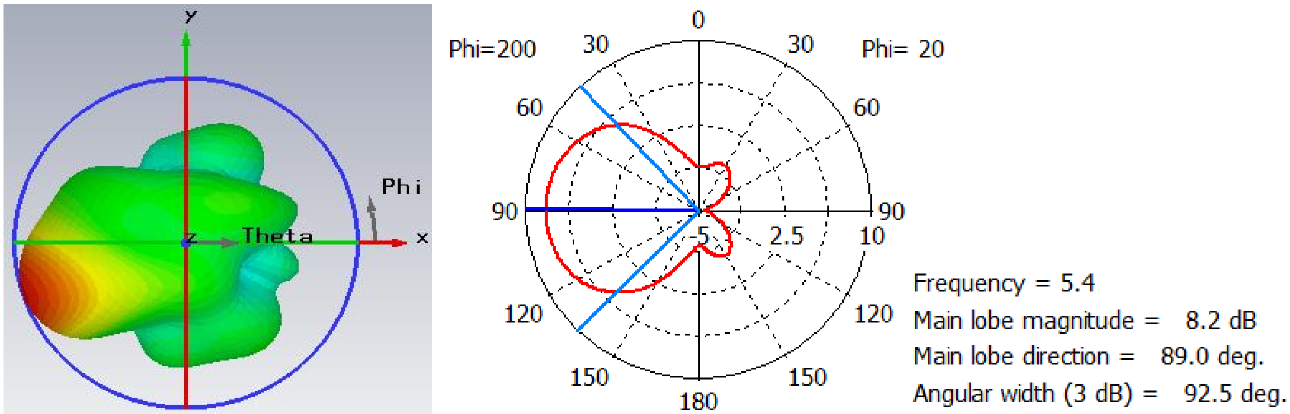


Figure 9: Radiation pattern from double patch antenna with CPW for 5.1-5.8GHz

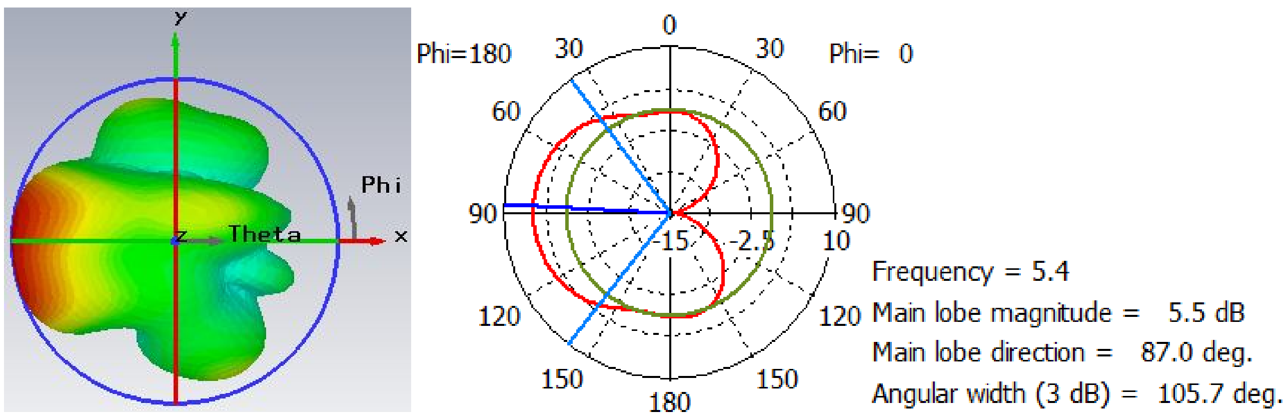


Figure 10: Radiation pattern from single patch antenna with CPW for 5.1-5.8GHz

Table 3: Performance comparison between single patch and double patch

	Single Patch	**Double Patch**
Return loss, S_{11} (dB)	-16.438	-33.499
Gain (dB)	5.593	8.203
Directivity (dBi)	5.707	8.451
Bandwidth (GHz)	0.6	0.7

Figure 9 and Figure 10 show the comparison of radiation pattern which radiated by double patch and single patch with CPW respectively. Radiation pattern is a graphical representation of the radiation properties of an antenna [8].The simulation frequency is from 5.1-5.8 GHz with center frequency of 5.4 GHz. Table 3 summarizes the value of return loss, gain and directivity which are produced by single patch and double patch antenna with CPW. By using the same parameter setting, the single patch antenna with CPW provides a wider angular width for 3dB which is at 105.7degree while double patch antenna with CPW has 92.5 degree. However,the result obviously shows that the double patch antenna with CPW has a gretaer gain compared to the single patch antenna.

CONCLUSION

In the paper, a microstrip double patch antenna with CPW has been designed, simulated, optimized and analyzed by using CST software. The antenna's performance was analyzed for bandwidth, gain, VSWR and radiation pattern. The broad bandwidth has been successfully achieved by using the proposed antenna which incorporate the CPW technique. The results indicate that the double patch antenna with CPW is able to make the gain to increase up to 31.82% compared to single patch. It can be concluded that the double patch antenna with CPW capable to enhance the usable bandwidth with greater gain value. Hence, the proposed structure would be greatly suitable to overcome the lower gain and narrow bandwidth in microstrip patch antenna. From the simulation, the percentage of bandwidth is 16.88% while the measurement result is 31.41%. For future recommendation, the measurement should be done in anechoic chamber to achieve better results.

Acknowledgment

The authors declare that they have no conflicts of interest in this research.

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