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A Microstrip Patch Antenna with Aperture Coupler Technique At 5.8 GHz & 2 GHz

Manpreet Kaur, [1] Mrs. Amanpreet Kaur, [2] Dr. Rajesh Khanna[3]
[1]Student, ECED Thapar University, Patiala
[2]Astt.Professor, ECED Thapar University, Patiala
[3]Professor, ECED Thapar University

Abstract: *This paper presents the basic design of a microstrip patch antenna with aperture coupling. This design is simulated using CST Microwave Studio 2009 software based on given operating frequency. The gain and Directivity of an antenna are 6.169dB and 5.580dBi at 5.8GHz & 7.699dB and 8.480dBi at 2GHz. The results are analyzed and discussed in terms of return loss, gain, directivity. E and H-fields and radiation pattern using CST Microwave Studio.*

Keywords: Aperture coupled microstrip patch antenna (ACMPA), return loss, bandwidth, gain, Single feed Single frequency, CST2009 Microwave Studio.

I. Introduction

Modern wireless communication systems are developing rapidly, and bandwidth requirement for many applications increases day by day, so an antennas which, is required to have a wideband, good radiation performances and gain. This requirement can be fulfilled by a new aperture coupled micro strip antenna for low &high frequencies. "A review of aperture coupled micro strip antennas". This paper gives history, operation, development and application of microstrip antenna [5]. Single layer microstrip line feed elements are typically limited to bandwidths of 2 to 5%.But aperture coupled antenna provides up to 10 to 15 % bandwidth with single layer [6-8]. The simple designing and easy manufacturability of the microstrip patch antenna make it preferred choice for many wireless applications. [1]

Figure1 shows an overview of a micro strip patch antenna design with aperture coupled technique. In this figure two substrates; one for feed line and another for patch are formed. A slot is formed at centre of ground and feed line is below the second substrate as shown in figure 1.

These types of antennas are more popular, because of the patches and slots can be any shape and this gives the improvement in the performance of micro strip patch antennas.

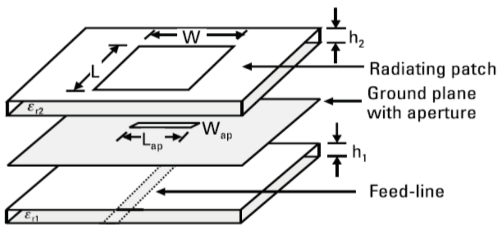


Figure1: Basic micro strip patch antenna with aperture coupler technique

II. Design-I: Microstrip patch Antenna at 5.8GHz

To design a single micro strip patch antenna which consists of a rectangular patch, a rectangular slot and a feed line are attached to different substrate or same substrate and these are interfaced to each other through slot in ground. The selection of antenna dielectric substrate is very important for better performance with required thickness and loss tangent. Substrate used is an important factor in designing a micro strip antenna .The dielectric constants are usually in the range of 2.2 $\leq\varepsilon_r\leq$12 depending on the substrate used.

Basicdesignsteps for designing are given below: [2].

1. For given value of dielectric constant 4.7 and operating frequency 5.8Ghz, & the height of substrate the remaining parameters for patch and feed line are calculated using the following equations and the final values are given in table (i):

The length and width of patch can be calculated after calculating the values of effective length(ΔL) and effective dielectric constant (ε_{eff}) by selecting any substrate (any value of ε_r) [9-10]. After calculation of LP and WP, next step is to calculate:

Now we calculate L and W of ground (Substrate Dimension):

a) We calculate W of ground using the equation given below:

$$W_g = 6h + W \text{.......................... (i)}$$

b) We calculate L of ground using the equation given below:

$$Lg = 6h+L \ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

TableI:-Dimension of the designed antenna with aperture feed:

Operating frequency	5.8GHz
Return Loss	<-10dB
Substrate Material	FR4
Substrate Height	1.6mm
Copper Thickness	0.035mm
Dielectric Constant	4.7
Patch	4.3×8.5mm
Feed	3.8×1.3mm
Slot	3×1.4mm

III. CST Simulation Results and patterns: Return Loss & Smith Chart

The return loss should be maximum for better performance and wideband requirement. Thus we measure required band at return loss -10dB. The return loss plot for the designed antenna with aperture feed is shown in figure 2 as below. The bandwidth is about 566.8MHz (6.216-5.6491GHz), from figure 3 it is clear that the antenna is matched at 50Ω impedance which shows the impedance bandwidth of the antenna is 567MHz [3].

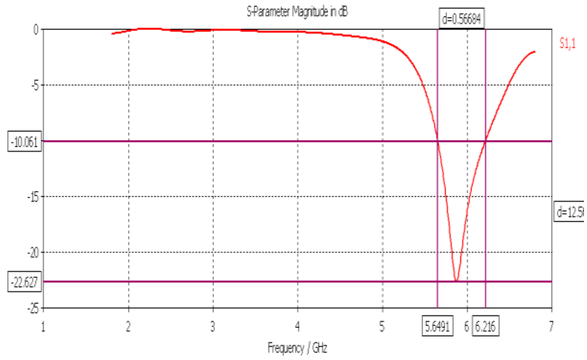


Figure 2: Return loss

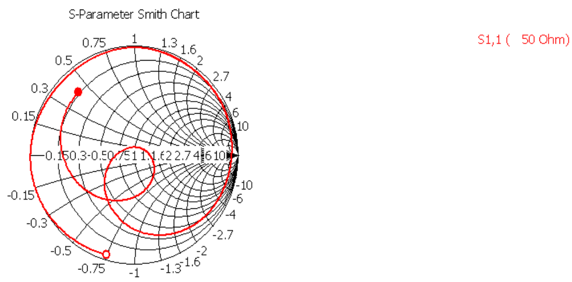


Figure3: Smith chart [S11]

Radiation Pattern:

An antenna radiation pattern is defined as "a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space co-ordinates. Figure 4 shows the 3Dradiation pattern plot for the proposed antenna with 6.169dB gain at 5.8GHz frequency.

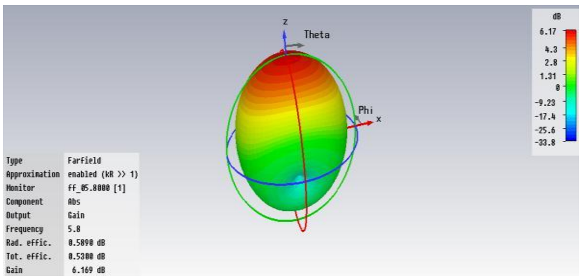


Figure4: 3D-Radiation pattern plot

E-field:
Figure 5 shows the E-field 3D-plot for the proposed antenna with E_{max} = 20.53dBV/m at 5.8GHz frequency.

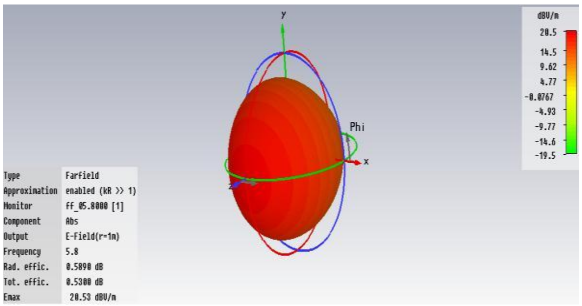


Figure5: 3D-field-plot

Gain:
Gain of an antenna in Figure 6 shows the gain is 6.169dB with main lobe 6.2dB for polar- plot of the proposed antenna.

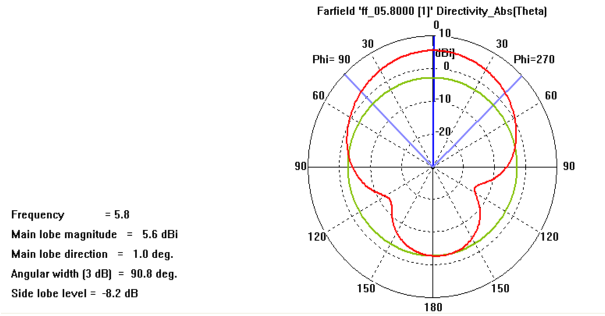


Figure6: Gain polar- plot

Directivity:
The directivity of an antenna is the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. Figure7 shows directivity 5.580dBi at 58GHz for far-field and polar-plot in Figure8

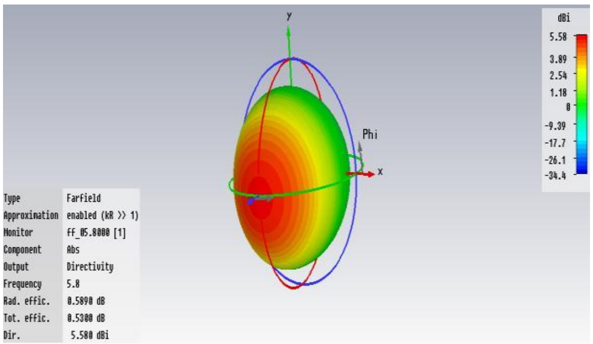


Figure7-3D directivity plot

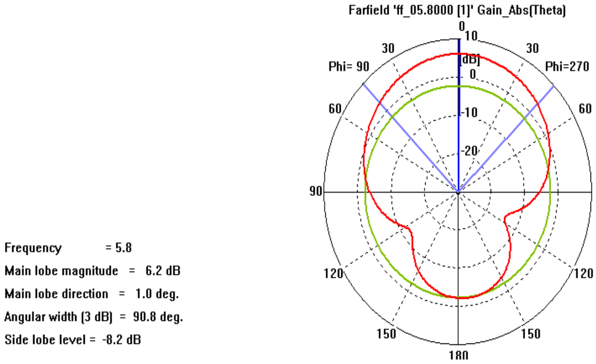


Figure8: polar- plot of directivity

VSWR:

The VSWR is shown in figure9 below. As it is known that for an antenna to have a considerable performance with best matching the VSWR should be<2, this antenna having a VSWR of 1.159 shows desired performance characteristics.

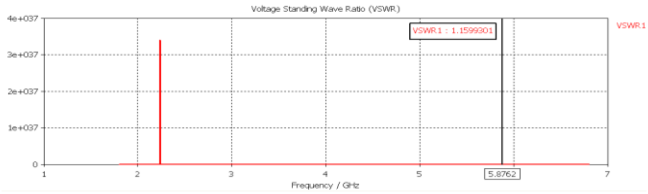


Figure9: VSWR

Design-II: Antenna at 2.2GHz (WLAN): This is another proposed antenna with aperture fed for WLAN covering the 2.4 GHz band. The radiating patch and the microstrip feed line are separated by the ground plane Coupling between the patch and the feed line is made through a slot or an aperture cut in the ground plane. Also there is a third substrate used between patch and ground. The dimensions which are considered from for increasing BW of the antenna with aperture feed are given in table below and these are calculated using the procedure discussed above in the eq: [4]

Table II:-Dimension of the designed antenna with aperture feed:

Operating frequen0cy	2GHz
Return Loss	-10dB
Substrate Material	FR4,Foam
Substrate Height (mm)	1.58,17
Patch	24×33mm
Dielectric Constant	4.4, 1.07

In the design air/foam (permittivity=1/1.07) has been used as antenna substrate with a thickness of 17mm.

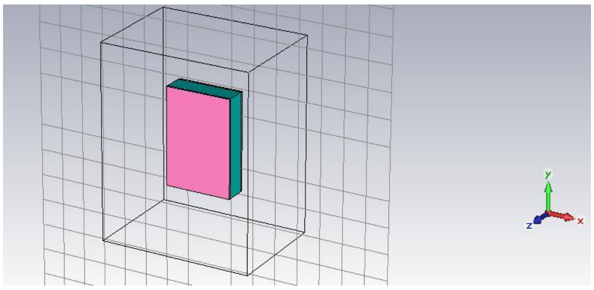


Figure10: Geometry dimension of antenna

This is diagram using CST2009 for aperture coupled antenna. In this case we use FR4, Foam material as a substrate and the basic dimentions are given in table above.

IV. Return Loss & Smith Chart

The return loss should be maximum for better wideband requirement. Thus we measure return loss at -10dB. The return loss plot for the designed antenna is shown in figure11 as below. The10dB BW is about 431.36MHz (2.3372-1.9059GHz).Figure 12 shows the smith chart results at 52.88Ω impedance.

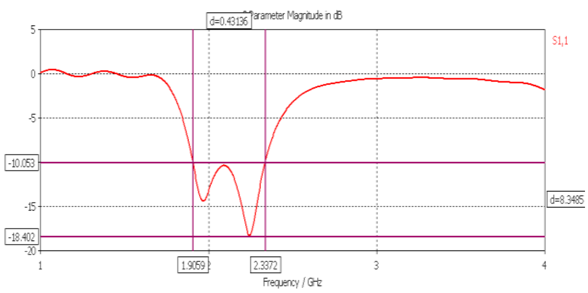


Figure11: Simulated return loss [S11]

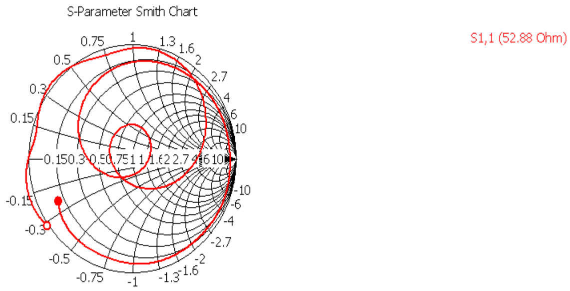
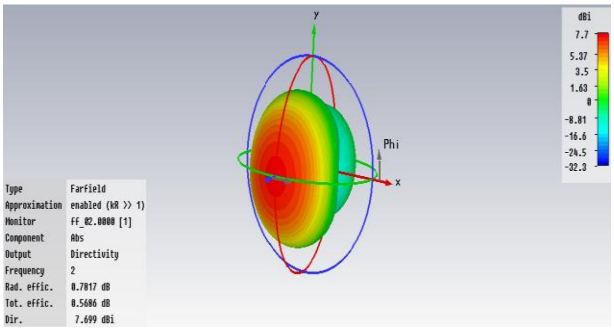


Figure12: Smith chart [S11]

Radiation Pattern:
Figure13 shows the radiation pattern plot for the proposed antenna with gain 8.480dB at



Figur13: 3D Radiation pattern plot

2GHz frequency for far-field

H-field:
Figure14 & Figure15 shows the H-field 3D-plot & H-field polar-plot for the proposed antenna with H_{max} = -28.49dBA/m at 2GHz frequency.

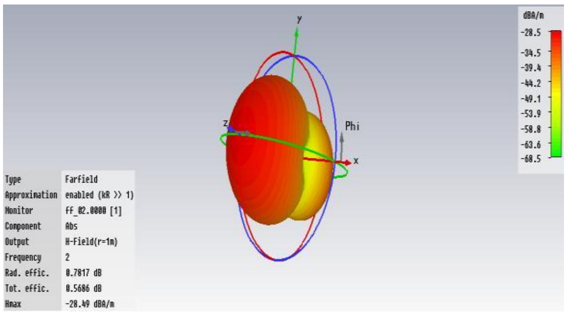


Figure14: 3D-plot H-field

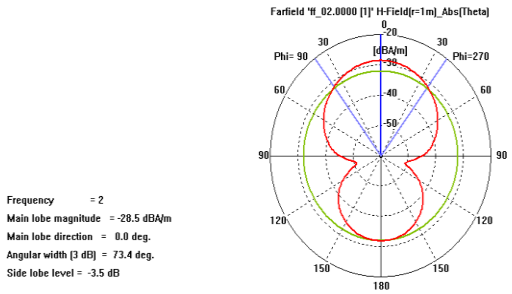


Figure15: polar-plot of H-field

Gain:
Figure16 shows the (gain) 3D-plot for the proposed antenna.

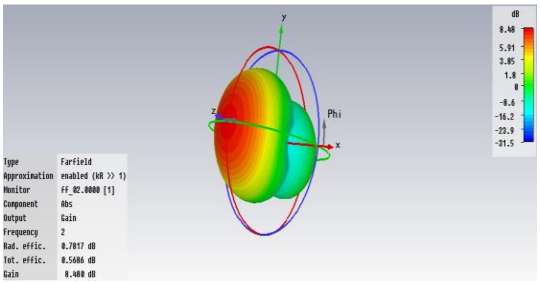


Figure-16

Directivity:
Figure17 show directivity 7.699dBi at 2GHz for far-field. Directivity polar-plot is shown below in Figure 23.

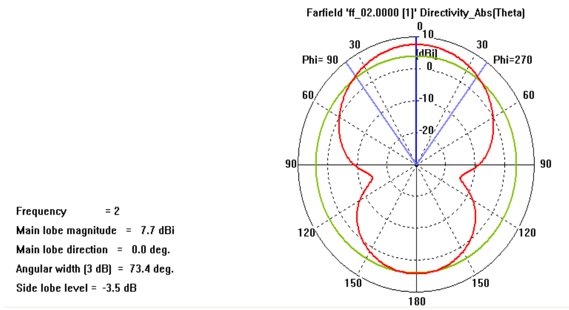


Figure17: polar- plot of directivity

V. Effects of varying different parameters of the antenna

Patch L and W:

As the patch length is increased the Resonating frequency decreases. And as patch width increased the resonant resistance decreases and it also affects the resonant frequency. Figure 18 shows the graph for width of patch. At w = 33 we are getting an optimized performance.

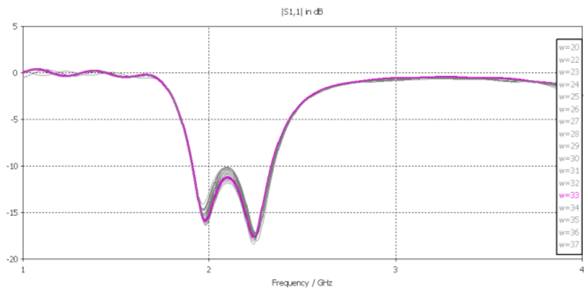


Figure18: width of patch

Slot L and W

The coupling level is primarily determined by the length of the coupling aperture, as well as back radiation level. The aperture should therefore be made no larger than is required for impedance matching. When the aperture length is increased then the return loss increased. If the ratio for L and W of slot is 1/10, there is decrease in the coupling level. Figure19 and figure20 shows the graph for sweep on width and selected width of slot, here „i" is slot width and „f" is the length, at figure21 and figure22 shows the length of slot. The i=2.8 and f=5.88 is selected.

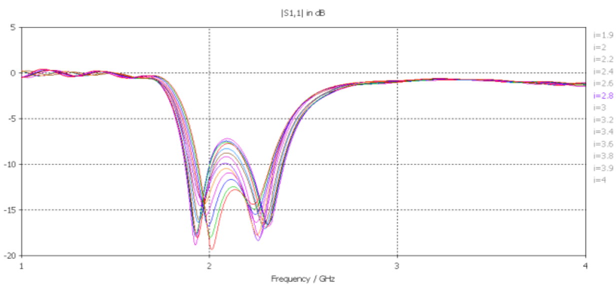


Figure19: Widthofslot

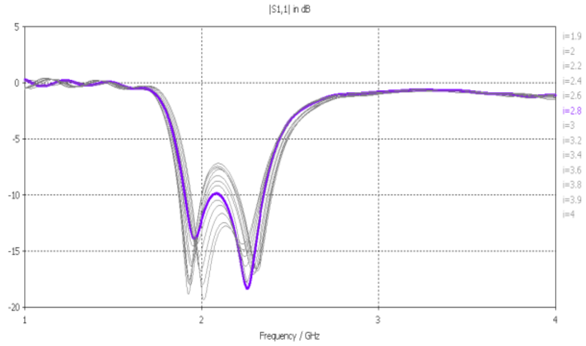


Figure20: Selected slot width

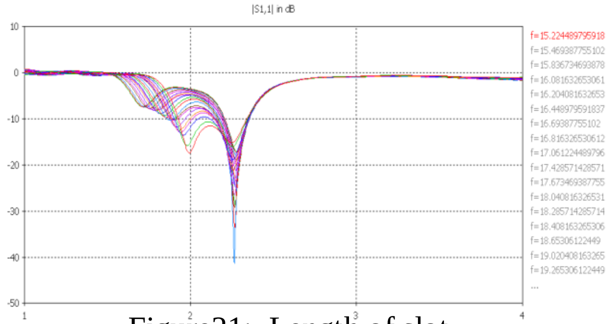


Figure21: Length of slot

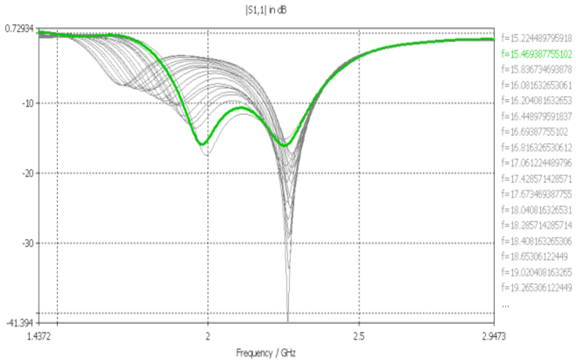


Figure22: Selected length of slot

Feed L and W:

The length of feed also affects the coupling level. When length of feed increased, there is decrease in coupling level. The width of feed controls the line impedance of the feed. The feed line width is represented by „p" as shown in Figure23 below and p=2 is selected.

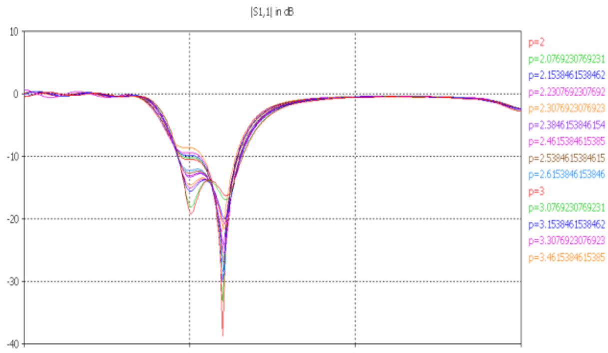


Figure23: Width of feed

VI. Results and discussion

The single band antennas, in first design, it resonates in (6.216-5.6491GHz) with BW of about 566.8MHz, which covers the WiMAX range. In second design, it resonates in (2.3372-1.9059GHz) with 10dB bandwidth is about 431.36MHz for WLAN. The minimum return loss is obtained at the resonating frequency 5.8GHz is -22.627dB. The line impedance of the antenna is 50Ω and at 2GHz return loss is -18.422dB with line impedance 52.88Ω. The parameters that are studied at different frequencies of antennas are listed in the TableIII.

TableIII: Comparision

Parameters	**Single Band**	**Single Band**
Frequency	5.8GHz	2GHz
Directivity (dBi)	5.580	7.699
Gain (dB)	6.169	8.480
E-field(dB V/m)	20.53	23.04
H-field(dB A/m)	-30.99	-28.49

VII. Conclusion and Scope

It is concluded that the antennas designed for resonant frequencies of 5.8GHz and at 2GHz give very good results with the optimized selected dimensions. The directivity and gain of the antenna are good enough to be used for the personal communication system and WiMAX/WLAN applications. The antennas has simulated for the desired results. Further the antennas can be fabricated using the selected substrates following IC fabrication techniques and then these can be tested for the desired performance in an anechoic chamber using a VNA.

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