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WIDE BAND SQUARE PATCH MICROSTRIP ANTENNA DESIGN FOR WLAN & WIMAX APPLICATIONS

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Abstract- In this paper, an inverted suspended microstrip patch antennas for WiMAX & WLAN applications is proposed which operates in wide frequency range of 5-6 GHz. Our proposed design involved ROGERS RO5433 laminate as a substrate material. This design achieves enriched performance with stable gain, sustainable VSWR and good impedance matching across desired frequency range with wideband characteristics. The designed patch appeared to be a suitable aspirant for wide beam width wideband array design. Antenna design has been carried out through extensive three-dimensional electromagnetic simulation tool i.e. CADFEKO & POSTFEKO.

Keywords: Microstrip Antenna, Inverted Suspended Microstrip, Gain, VSWR, Parasitic Patch.

I. INTRODUCTION

Wireless communication has been progressing extensively since last few decades and still demand for new technologies is enormous. Two major technologies among wireless communication systems that are serving this demand are WiMAX and WLAN. WiMAX provide high-speed data rates and internet access throughout wider coverage area. It operates at three different licensed bands i.e. 2.3-2.69 GHz, 3.2-3.8 GHz and 5.2-5.8 GHz [1]. On the other hand WLAN's 802.11 b/g standards are currently substantially operational at 2.4GHz license free ISM band and bears extensive interference due to huge number of subscribers. 802.11a is another WLAN standard that operates in between 5-6 GHz band. This band offers high data rate [2] and low interference for devices.

Microstrip Patch Antenna (MSA) is a good contender for this band because of its low cost, low profile and compatible characteristics. Nevertheless, there is always a tradeoff between different parameters such as Antenna Gain, Bandwidth, Directivity, Cross Polarization etc. Various techniques have been implemented to achieve stable tradeoff among stated parameters such as substrate thickness, parasitic patches, partial ground structures, inset feeds, coupling feeds etc. These tradeoffs attempt produced many antenna designs that have been designed as a single patch MSA working at a specific frequency, possess narrow bandwidth and have moderate beam width.

Recently a fuzzy logic investigation was carried in [3.] Additionally, among them is [4] where square-spiral antenna design was involved to build broader impedance bandwidth. E-Shaped patch was utilized in [5] to design dual band antenna operating at 3.5 GHz and 8.1 GHz. Then a cavity model was used in [6] to sustain wide bandwidth. A vernal design of dual band micrsotrip patch antenna for WLAN devices [7]. Another impact is aperture used in coupling and its analysis was demonstrated in [8]. T-shaped microstrip feed line and an annular-ring slot were also proposed in [9].

A multiband microstrip patch antenna was discussed in [10]. Patch antennas for WiMAX to operate from 4.4-5 GHz was articulated [11] with specified gain and its respective characteristic [12]. Elaborated slotted patch antenna operating from 5.2 GHz to 5.8 GHz with return loss of -15 dB and VSWR less than 2.

Our investigation aims to reach a single patch antenna that can having stable gain, wide bandwidth, low cross polarization and high front to back ratio and considered as a good element for array. This proposed work is presented in different sections. Section II describes the antenna design where initial point is jagged and lead to the optimal parameters of the designed MSA. Section III sketches parametric analysis with CADFEKO and POSTFEKO simulators. Furthermore Section IV concludes the investigation followed by Future Recommendations in Section V.

II. ANTENNA DESIGN

Modeling of MSA is based on inverted suspended microstrip design as shown in figure 1. This structure consist of dual layers of the substrate. ROGERS RO4533 laminate is used as substrate material having thickness of 0.762 mm and tangent loss of 0.002. The di-electric constant ε_r value for this substrate is 3.3. These two substrate layers are separated with an air gap in millimeters. The lower layer substrate is placed on the ground plane which will sustain the feed strip whereas top layer substrate is printed with a parasitic patch on the top and a capacitor at the bottom face. The parasitic patch is placed in the center of substrate and capacitor in the center of the edge that is extended on the positive y-axis.

A wire is suspended from the edge of the capacitor and landing on the top face of the bottom layer of substrate where strip is sketched. This strip is stretched to the end of the edge of substrate where they are connected to feed port and supplied with voltage source having an input impedance. Schematic diagram for modified antenna design and its transparent model produced in simulation tool i.e. CADFEKO is presented in Figures 2 and 3, respectively. Initial values of antennas parameters are given in Table 1 except the length of the parasitic patch.

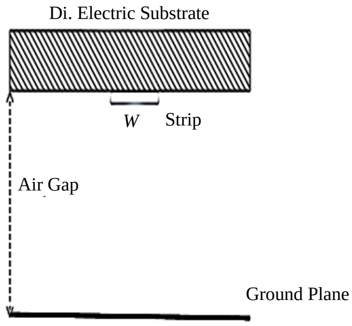

Figure 1. Inverted suspended microstrip structure

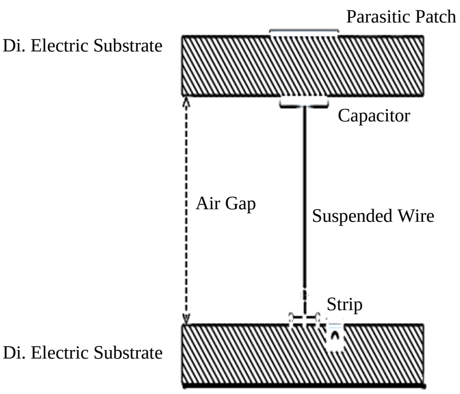

Figure 2. Modified suspended inverted microstrip structure

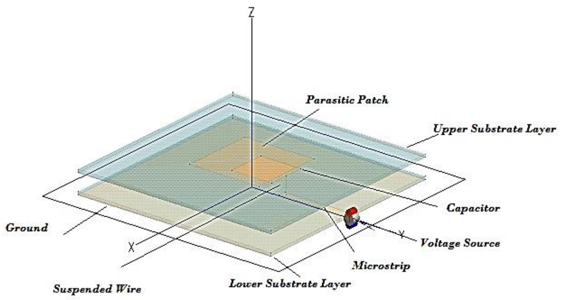

Figure 3. Simulation model of modified structure

MSA involves indispensable parameters such as width of strip, effective di-electric constant (ε_{re}), thickness of wire, dimensions of patch, thickness of the substrate, frequency (f_c) and other factors to control impedance matching characteristics. The presented antennas aims to have wide operational band with a center frequency of 5.61 GHz.

To acquire tentative dimensions of the square parasitic patch, we need to evaluate wavelength across the air gap between higher and lower layer of substrate. The effective di-electric constant and length calculation equations can be given from [13] as:

$$L = \frac{\lambda_d}{2} \tag{1}$$

$$\lambda_d = \frac{\lambda_o}{\sqrt{\varepsilon_{re}}} \tag{2}$$

$$\lambda_o = \frac{c}{f_c} \tag{3}$$

$$\sqrt{\varepsilon_{re}} = 1 + (\bar{a}_1 - \bar{b}_1 \ln\frac{W}{b}).(\sqrt{\varepsilon_r} - 1) \tag{4}$$

where,

$$\bar{a}_1 = \left(0.5173 - 0.1515 \ln\frac{a}{b}\right)^2 \tag{5}$$

$$\bar{b}_1 = \left(0.3092 - 0.1047 \ln\frac{a}{b}\right)^2 \tag{6}$$

where, λ_d is effective wavelength due to impact of di-electric material, λ_o is wavelength in air, L is length of the patch, c is speed of light in vacuum, ε_{re} is effective di-electric constant, $\bar{a}_1$ and $\bar{b}_1$ are coefficients, W is width of strip, a is thickness of substrate and b is the air gap between top face of the lower layer substrate and bottom face of the top layer substrate. Table 1 indicates the evaluated values of parameters from above stated equations:

Table 1. Evaluated Dimension Parameter Values

λ_o	$\bar{a}_1$	$\bar{b}_1$	$\sqrt{\varepsilon_{re}}$	λ_d	L
54.54 mm	0.48418723	0.18712894	1.13172	48.192 mm	24.096 mm

The tentative length for the patch is 24 mm. To reach an optimal patch size that can meet our design criteria, we executed simulations from where length is varied from 16 mm to 25 mm. Table 1 enlists complete parameter values. Return loss trends for different patch size are depicted in figure 4. It is marked from trends that finest results ($|S_{11}|$ in dB < -10 across the frequency range 5-6 GHz) were accomplished with length equivalent to 18 mm. Furthermore, to synchronize this structure with optimum value of air gap. We tested different values of air gap which was ranged between 3 mm to 8 mm with step size of 1 mm. Figure 5 illustrates impact of air gap with optimal patch size. The best value of air gap was found to be 5 mm i.e. from ground plane to top face of the upper layer of substrate.

It is also necessary the designed antenna structure should have stable gain. Thus, identical cases as indicated with different values of air gap were simulated and gain was evaluated. Gain remains very much stable i.e. above 4 dB across the desired frequency range. This is presented in Figure 6. Hence, the final optimal design parameters are given in Table 2.

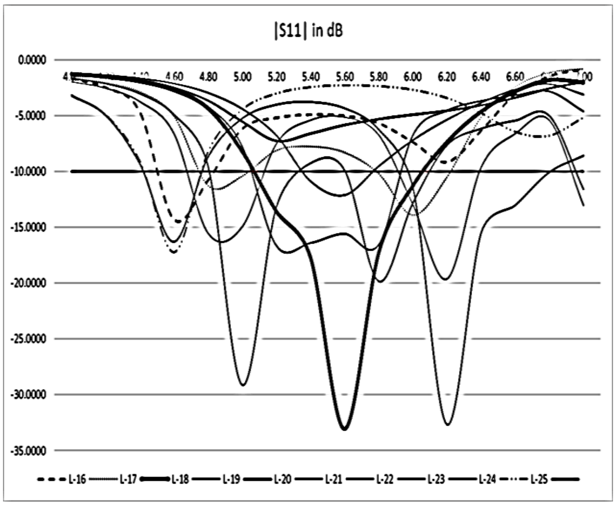

Figure 4. $|S_{11}|$ dB trends for different length sizes

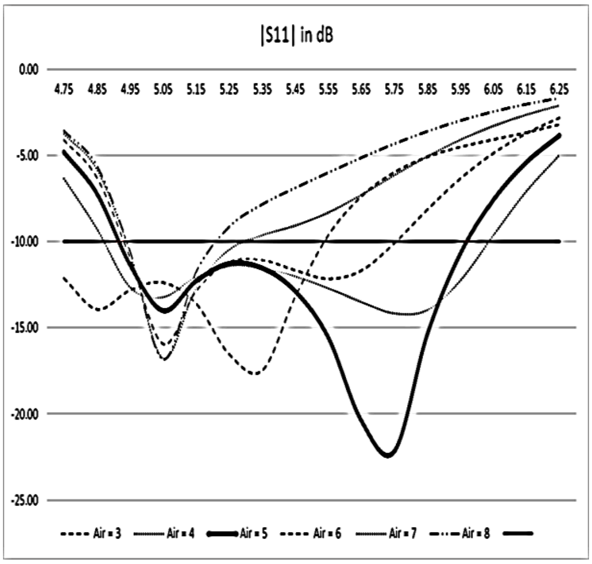

Figure 5. $|S_{11}|$ dB trends for different values of air

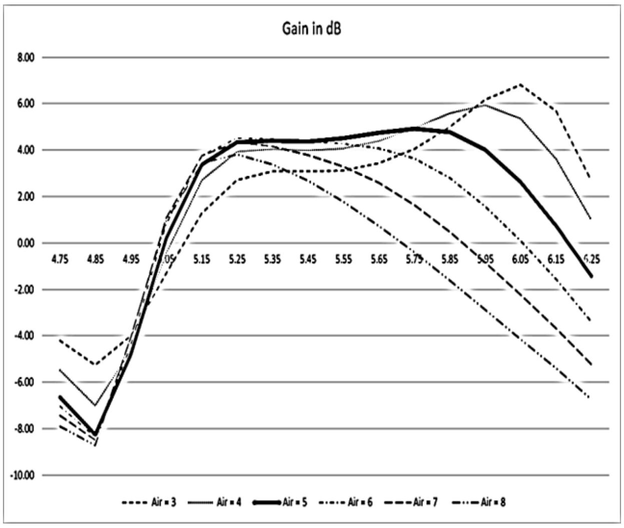

Figure 6. Gain in dB with different values of air gap

III. PARAMETRIC ANALYSIS OF ANTENNA DESIGN

A. Reflection Coefficient

Reflection coefficient specifies minimization of reflected power from the patch. $|S_{11}|$ dB is sketched against frequency in Figure 7. The $|S_{11}|$ is minimum i.e. -45.53 dB at 5.61 GHz which is at resonance frequency for designed model. The bandwidth achieved here is exactly 18.18% with lower frequency of 5.05 GHz and upper frequency of 6.15 GHz where return loss is equal to -10 dB. Thus, power radiated by antenna in defined frequency range will be contributing effectively in the radiation pattern. Additionally, return loss was depicted in smith chart in Figure 8 where locus resides inside unit radius circle indicating optimal impedance matching of the designed antenna.

Table 2. Values of optimized antenna design parameters

Parameter	Symbol	Values
Substrate Thickness	a	0.762 mm
Patch Length	L	18 mm
Patch Dimensions	--	18×18 mm
Capacitor Dimensions	--	10×10 mm
Radius of Suspended Wire	--	0.5 mm
Length of Strip	--	18 mm
Air Gap	b	3.476 mm
Width of Strip	W	2 mm
Dimensions of Ground	--	54×54 mm
Dimensions of Substrate	--	54×54 mm
Di-Electric Constant	ε_r	3.3
Tangent Loss	$\tan\delta$	0.002
Input Voltage	V_o	1 V
Input Impedance	Z_o	50 Ω

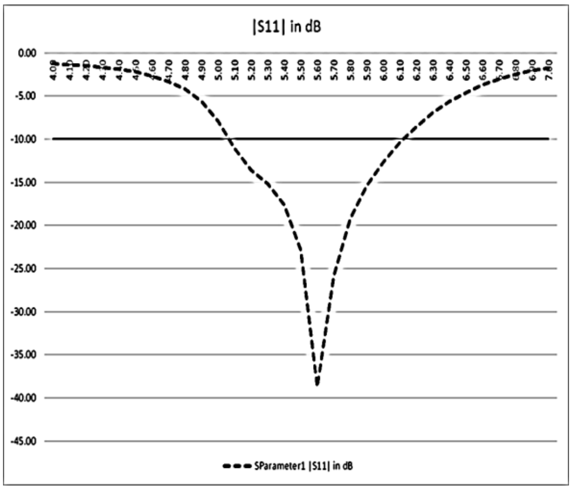

Figure 7. 2D-Plot of reflection coefficient against frequency

B. Voltage Standing Wave Ratio (VSWR)

VSWR values at different frequency are plotted in graph shown in Figure 9. VSWR trend illustrated here remains less than threshold value i.e. 2 from 5.05 GHz to 6.15 GHz.

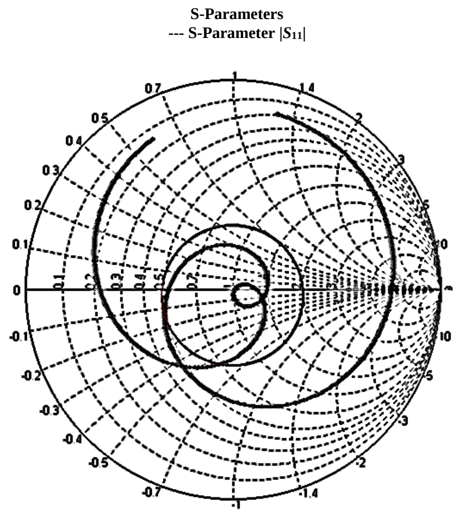

Figure 8. Smith chart of reflection coefficient against frequency

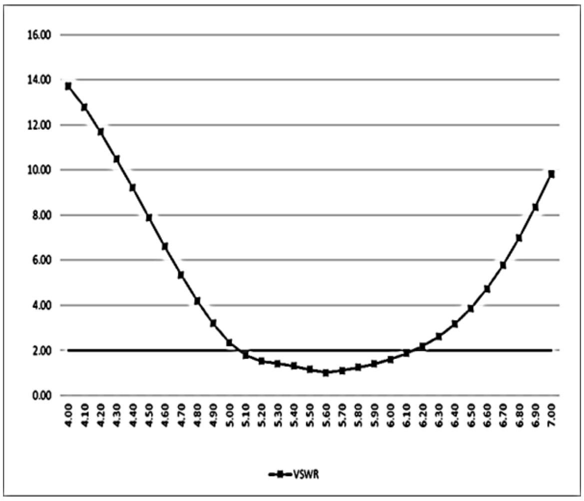

Figure 9. VSWR plot against frequency

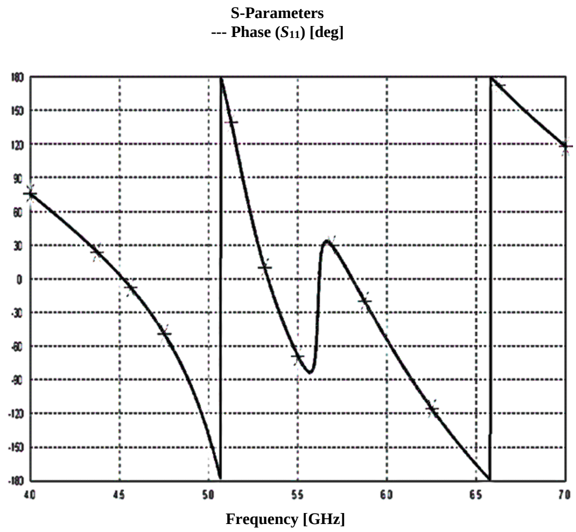

Figure 10. S_{11} phase against frequency

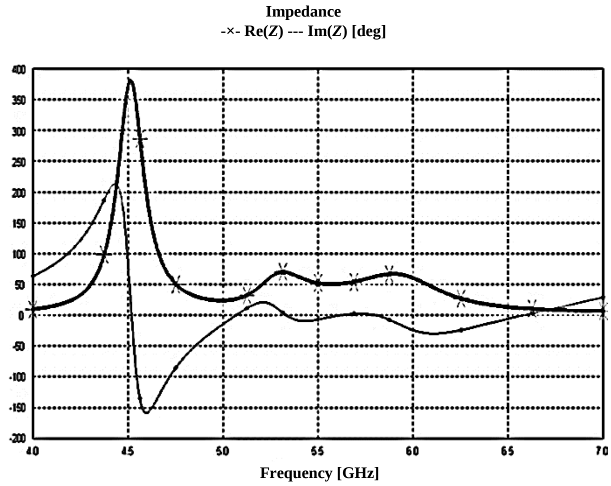

Figure 11. Resistive and reactive input impedance trends of proposed antenna

C. Reflection Coefficient Phase

Reflection Coefficient Phase values of antenna model are plotted against frequency as illustrated in Figure 10. The phase value is zero at 5.61 GHz which is resonant frequency for proposed antenna.

D. Input Impedance for Patch Antenna

Impedance matching is a crucial parameter that defines optimal power transference between a load and a source. Input impedance graph of the antenna model is represented in Figure 11. The resistive and reactive trends are very much inverse in the desired frequency range which indicates best impedance matching. The reference input impedance for designed model is of 50 ohm.

E. Cross Polarization

Figure 12 describes couple of normalized |*E*| trends with phi = 0^o and phi = 90^o. These two trends are a parted with a difference of -30 dB and separation between them is adequate to meet model requirements.

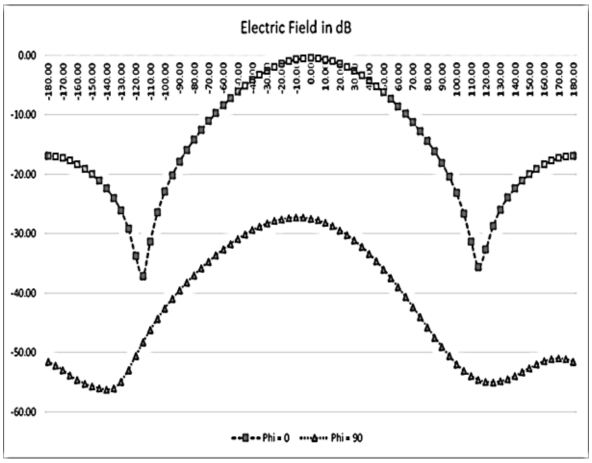

Figure 12. Cross polarization of proposed antenna

F. Antenna Gain

Gain for designed model antenna at different frequency values is detailed in Table 3. Figure 13 indicates peak and minimum trend in the working frequency range. Peak gain was achieved at 5.875 GHz with a value of 5.8 dB and minimum value of gain is at 5.031 GHz with a gain of -4.5 dB.

Table 3. Proposed antenna gain at different frequencies

Frequency (GHz)	Gain (dB)
5.031	-4.5
5.125	-3.3
5.312	3.7
5.406	4.7
5.5	5.1
5.688	5.5
5.875	5.8

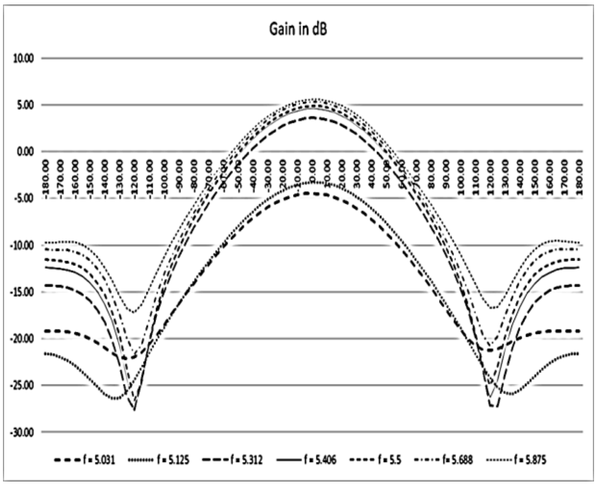

Figure 13. Proposed antenna gain at different frequency

G. Antenna Beam Width

Beam width in H-Plane at different frequencies for designed model in Table 4. It has maximum value of 80.35° at 5.031 GHz and minimum value of 66.3° at 5.875 GHz as illustrated in Figure 14.

Table 4 Beam width of proposed antenna at different frequencies

Frequency (GHz)	Beam Width (dB)
5.031	80.35
5.125	77.5
5.312	74.72
5.406	73.12
5.5	71.5
5.688	69.14
5.875	66.3

H. Directivity

Directivity for different frequencies are enlisted in Table 5. The peak values of 9 dB at 5.406, 5.5, 5.688 GHz and minimum value of 7.5 at 5.031 GHz of directivity are depicted in Figure 15.

Table 5. Antenna directivity of proposed antenna at different frequencies

Frequency (GHz)	Directivity (dB)
5.031	7.5
5.125	8.4
5.312	8.9
5.406	9
5.5	9
5.688	9
5.875	8.8

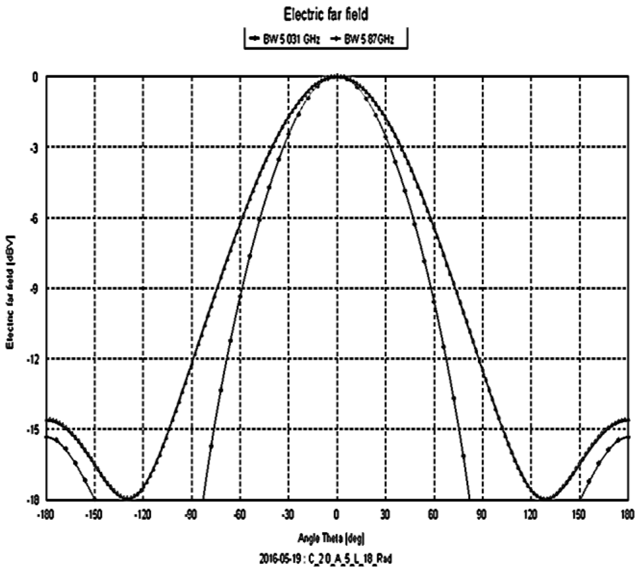

Figure 14. Maximum and minimum beam width of proposed antenna

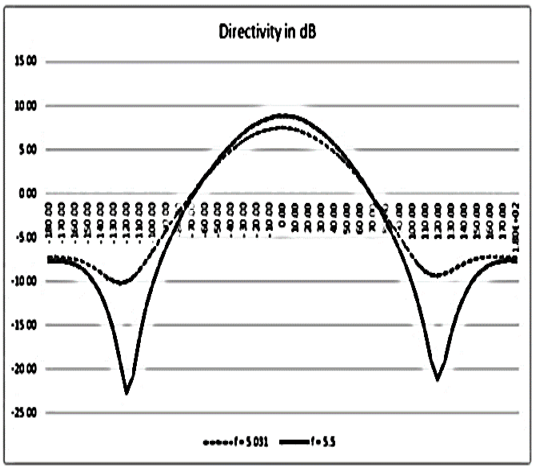

Figure 15. Maximum and minimum directivity of proposed antenna

I. Radiation Pattern

The radiation pattern for the antenna at frequency 5.875 GHz with maximum gain is shown in Figure 16.

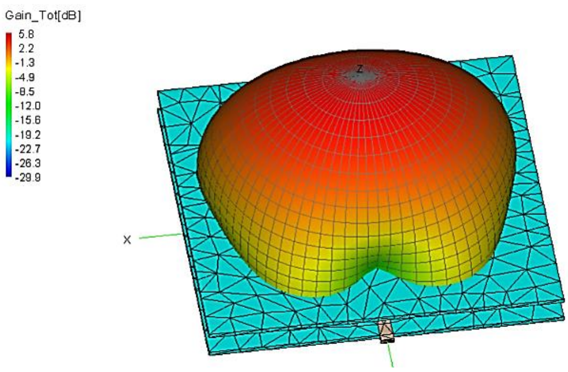

Figure 16. Radiation pattern for the proposed antenna

IV. CONCLUSION

Micrsotrip Patch Antennas have been effectively contributing in WiMAX and WLAN technologies. In this investigation, we have proposed MSA design that represents wideband characteristics accomplished by using inverted suspended microstrip structure with an air gap. Suspended wire and square capacitor involved in this design assisted in attaining optimal impedance matching. It works adequately across frequency range of 5.05 GHz and 6.15 GHz operating at a center frequency of 5.61 GHz. The return loss calculated at center frequency was about -42 dB which ultimately facilitated to maximum efficiency. Furthermore, it offers good cross polarization separation of around -30 dB, bandwidth of 18.18%, a peak gain of 5.8 dB and peak directivity of 9 dB. These features make proposed antenna a good fit for communication technologies working in ISM 5 GHz band.

V. FUTURE WORK

This exploration describes an effective microstrip antenna operating for WiMAX and WLAN technologies. The designed patch involved in antenna appears as a promising candidate for an array that can offer wide beamwidth across the whole ISM 5 GHz band due to its wide beamwidth in H-plane. Additionally, this single layer parasitic patch design approach can be further enhanced as multilayered parasitic patch design with effective patch sizes.

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BIOGRAPHIES

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