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A novel Aperture Coupled Array Antenna for X -band Application.

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Abstract: In this communication, the return loss (RL) and directivity of a high-directivity electromagnetic bandgap (EBG) antenna operating in a broad frequency band are explored. This EBG antenna uses a frequency selective surface (FSS) as the superstrate layer and an aperture coupled microstrip antenna (ACMA) as the feeding source. When the superstrate layer, microstrip patch, and coupling aperture are used properly and simultaneously, different resonance frequencies are produced, giving RL a broad frequency range. Additionally, only the superstrate layer created by the FSS layer with square loop elements can be used to produce high directivity. A wideband ACMA is initially created to function in the x-band. In this step, choosing the right coupling aperture design is crucial. An aperture coupled array antenna for X-Band application is presented. X-Band frequency range is from 8.0 to 12.0 GHz. The proposed antenna consists of two substrates with H shaped slot. In this research approach, we have used FR4 substrate with the dielectric constant of 4.4 and 0.02 loss tangent is used. The Aperture coupling feeding technique is used so that spurious radiation from the feed element is minimized. The return loss achieved for our proposed approach is -13dB for 8GHz and -27dB for 12GHz.The radiation performance such as VSWR, return loss, Radiation Pattern, and Gain, are analyzed and presented.

KEYWORDS: Aperture coupled Antenna, gain, microstrip, radiation, VSWR.

INTRODUCTION

In recent times microstrip patch antenna has tremendous scope in wireless communication because of their extraordinary features for example minimal weight, less cost, low profile, and can be directly printed on circuit board. In [1] a T-Slot Aperture coupled antenna using sensitivity analysis and the Taguchi method was designed using FR4 substrate. In [2] the Aperture coupled square patch antenna was designed with 4x2 arrays for L Band applications. In [3] The Lens for circular polarization was designed using planar arrays for microwave applications. In [4] 16-element fully-integrated phased-array is implemented in SiGeBi CMOS at 60 GHz for applications like wireless data transfer and high-definition video links. In [5] a widespread bandwidth aperture coupled antenna fed through substrate incorporated waveguide is presented on V band (60

Hz) for WLAN applications. In [6] the UHF planar adjacent field antenna was designed for the use of RFID item tagging. In [7] linearly polarized ring aperture coupled antenna was designed for mobile services and satellite communication. In [8] a monolithically integrated reflects array using 90 RF MEMS switches was designed as well as fabricated to achieve the switching of the main beam.

In [9] circularly polarized dual band aperture coupled micro-strip meta-material RFID antenna was designed as well as fabricated using radio waves to interchange information between the reader as well as electronic tag for identification and tracking. In [10] wide band highly directive aperture coupled micro-strip antenna was designed via the FSS superstrate layer and it is operating in X-Band. In [11] reflect array was implemented by ohmic MEMS switches with electronic phase control and it is validated in X-Band for various applications like artificial aperture RADAR, automotive anti-collision sensors security scanners, base stations, and earth observation satellites.

In [12] An amplifying reconfigurable reflect array antenna was designed for a variety of wireless applications and also helps to suppress the interference from other devices. In [13] aperture coupled leaky-wave two-dimensional dual-beam microstrip antenna was presented for applications like low-cost transmitters and collision warning radar. In [14] low profile planar microwave lens using spatial phase shifters was designed which is operating in X-Band and is useful for various applications like imaging and radar systems. In [15] frequency reconfigurable stacked patch microstrip antenna was designed and it's becoming more important in defense and commercial wireless applications. In [16] circularly polarized dual-band omnidirectional antenna was presented and it is fed by a coplanar waveguide with back-to-back microstrip patches.

In [17] multi-layer microstrip antenna array on a low-temperature co-fired ceramic substrate for the system on the package was designed for 60 GHz. In [18] frequency reconfigurable microstrip patch antenna was implemented using silicone TC5005 substrate, patch is fabricated by injecting galinstan in a square reservoir into the elastomer substrate. In [19] reduced-an order technique with a mode-matching mechanism was designed and it is operating in Ka band for applications like radar antenna to process several dissimilar waveguide modules working at microwave as well as millimeter-wave frequencies. Periodic structures called aperture links can be used to regulate and control the propagation of electromagnetic waves.

A high directive antenna can be attained by properly designing the dielectric layers. The design of a dielectric layer can be done in a variety of ways. This layer needs to be thin, simple to make, and readily available on the market for low-profile antenna applications [4]–[7]. The aperture antenna has been designed using a variety of forms, including rings, patches, square loops, strips, and slot shapes [8] through [10].

The frequency bandwidth for the return loss and maximum directivity of the aperture antenna is one of the biggest design issues. The dielectric layer and feed source affect these parameters. The majority of the works that have been done focus on using an appropriate design of an aperture antenna to achieve a wide-frequency band or multi-frequency band [6], [11], [14], [15], [18], [19]. Several studies have been conducted on the aperture coupled antennas' feeding source, particularly concerning the antenna's return loss bandwidth.

X Band

A portion of the electromagnetic spectrum's microwave radio sector is the X band. In some circumstances, including in communication engineering, the X band's frequency range is arbitrarily chosen at roughly 7.0 to 11.2 gigahertz (GHz). The IEEE defines the frequency range for radar engineering as 8.0 to 12.0 GHz. The informal and incorrect term "X-band," where the "X" stands for "extended," is also used to describe the extended AM broadcast band. Satellite communications

The International Telecommunications Union (ITU) has designated the X band uplink frequency band (for delivering modulated signals) as being from 7.9 to 8.4 GHz for use by military communications satellites. The 7.25 to 7.75 GHz range is the downlink frequency band designated by the ITU. All of the frequencies in this spectrum are used by the US military, although only a few signals are on each frequency. An X band low-noise block converter's (LNB) typical local oscillator frequency is 6300 MHz. These two frequency ranges each have a 500 MHz width. This pair of frequency bands are sometimes referred to as the "8/7 GHz X band satellite communications system" in engineering.

Applications for the radar that employs the X band include continuous-wave, pulsed, single-polarization, dual-polarization, synthetic aperture radar, and phased arrays. In civil, military, and governmental institutions, X band radar frequency sub-bands are employed for weather monitoring, air traffic control,

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maritime vessel traffic control, defense tracking, and speed detection for law enforcement purposes. Modern radars frequently employ the X band. High-resolution imaging radars can produce greater resolution images in the X band for target identification and discrimination.

Terrestrial networking and communications Terrestrial broadband uses the X band 10.15 to 10.7 section in Ireland, Libya, Saudi Arabia, and Canada. Systems for this are produced by Alvarion, Cambridge, and Ogier, however, they are all incompatible. A full duplex Transverter is utilized by the Ogier system for DOCSIS over the microwave. A single coaxial wire with a power adapter connects the home/business CPE to a standard cable modem. Similar to the Ku band satellite TV LNB, the local oscillator typically operates at 9750 MHz. A 350 MHz TX offset is frequently used in two-way applications like broadband.

Communications in Space

The International Telecommunications Union (ITU) has designated a specific X band spectrum for deep space communications. The American NASA Deep Space Network is the main user of this allocation (DSN). DSN facilities are situated close to Madrid, Spain, Canberra, Australia, and Goldstone, California.

The Viking Mars landers, the Voyager missions to Jupiter, Saturn, and beyond, the Galileo Jupiter orbiter, the New Horizons mission to Pluto and the Kuiper belt, the Curiosity rover, and the Cassini-Huygens Saturn orbiter are notable deep space probe projects that have used X band communications.

With the two Viking program landers, the X band communications saw significant use. When, as viewed from Earth, the planet Mars passed in front of or behind the Sun,

Amateur Radio

Amateur satellite operations are permitted in the frequency range of 10.450 to 10.500 GHz, and amateur radio operations are permitted in the range 10.000 to 10.500 GHz under the Radio Regulations of the International Telecommunication Union. Amateurs refer to this as the 3-centimeter band, while AMSAT refers to it as the X-band.

1.1 OBJECTIVE

- To create a linked aperture antenna.
- To use an infinite ground plane in an H slot to achieve x band performance.
- To evaluate the functionality of microstrip patch antennas and some distinctive properties of antennas.

1.2 ORGANIZATION OF THE PROJECT WORK

Organizations are all covered in Chapter 1. Chapter 2 provides an overview of the antenna design approach along with the basic steps in the design and different antenna characteristics. The proposed antenna design, simulation results using ANSOFT High-frequency Simulation Software, and discussion are covered in Chapter 3. The conclusion and the range of future work are included in Chapter 4.

The invention of the microstrip antenna is one of the most exciting developments in antenna and electromagnetic history. It is perhaps the most adaptable answer to the many systems that call for a planner radiating element. The feed and radiating structure of a microstrip antenna is developed using printed circuit fabrication techniques, which is a subset of printed antenna radiating elements. Microstrip antenna is by far the most widely used and adaptable printed antenna, including dipole, slots, and tapered slots. This is due to all of its distinguishing characteristics, such as simplicity in fabrication, effective radiation control, and low cost of manufacture.

A section of the metallization layer makes up the microstrip antenna, which is made of patch metal and a dielectric substrate. Microstrip antennas were first used in the 1950s, and in the 1970s, substantial research into patch antennas followed, leading to a variety of practical design configurations. A microstrip antenna's performance and operation are primarily influenced by the geometry of the printed patch and the material properties of the substrate onto which the antenna is printed, according to decades of research.

2.2BASIC CHARACTERISTICS
Setup Feed

A metallic pattern is present on one side of a dielectric substrate of a microstrip antenna, and a ground plane is present on the opposite side. I concentrated on creating a microstrip patch antenna for this project. A microstrip patch on a dielectric substrate is shown in Figure 2.1.

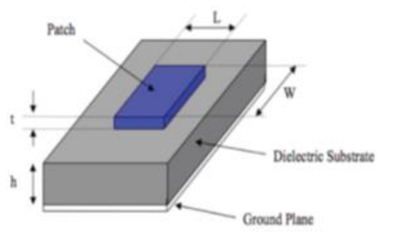

Figure 2.1. Structure of Microstrip patch antenna.

Although the antenna patch could be any shape, it is most frequently rectangular. The rectangular patch antenna contains the following parameters to estimate performance, where 0 is the wavelength in vacuum, also known as the free-space wavelength.

Length(L) :$0.3333\lambda 0 < L < 0.5\lambda 0$
Height(h) :$0.003\lambda 0 \leq h \leq 0.05\lambda 0$
Thickness(t) :$t << \lambda 0$
Dielectric cons tant(ε r) :$2.2 \leq \varepsilon r \leq 12$

Since the speed of light in a vacuum is very close to the speed of light in air, is frequently given in electromagnetic radiation in place of 0. The length of the patch is crucial when it comes to radiation, as will be discussed further in this chapter. The length is somewhat less than /2 when the length's specifications are taken into consideration. This is because the microstrip patch antenna is built using a theory based on a half wavelength.
feed line for microstrip

Since the patch antenna's feed line originated as a transmission line, the term "transmission line feed" is frequently used to describe it. Power is transmitted from the source through a coaxial cable, into the feed line, and finally to the patch thanks to the feed line's lower width and direct etching to the patch's edge. The feed line's function is to match the impedance from the patch without the use of any additional matching components, but because it is a patch, it has the potential to interfere with the patch with radiation, reducing its bandwidth.

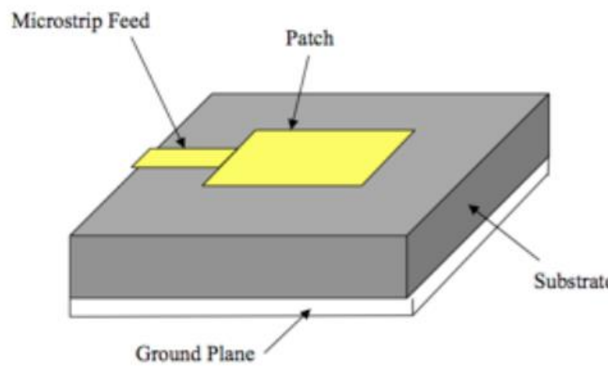

Figure 2.2 Microstrip feed line to the antenna.

2.3FEEDING METHODS

Cable Coaxial or Probe Feed

To eliminate radiation from the feed line, you can also connect the antenna directly to a coaxial wire. A coaxial cable attached to the patch is shown in Figure 2.3.

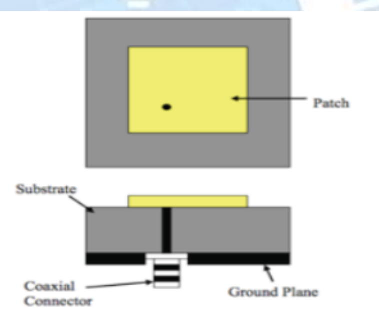

Figure2.3 Coaxial cable feed of patch antenna.

The coaxial feed, often known as a probe feed, is a widely used method of feeding the antenna. The inner conductor of the coaxial connector is soldered onto the patch at the ground plane, as can be seen in figure 2.3, where it extends through the dielectric substrate. This type of feed has the advantages of lower radiation and flexibility in a placement to match the impedance of the patch. The drawbacks include its limited bandwidth and difficulty in drilling through substrates. If you use a delicate dielectric substrate, you run the risk of breaking it or having power loss to air due to the inner connector's imperfect fit in the drilled hole.
Coupled (Indirect) Feeds

It is possible to modify the feeds above so they don't come into contact with the antenna. For instance, it is possible to trim the probe feed in Figure 2.4 so that it doesn't reach the antenna in its entirety. As seen in

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Figure 2.4, the inset feed can also be terminated just before the patch antenna.

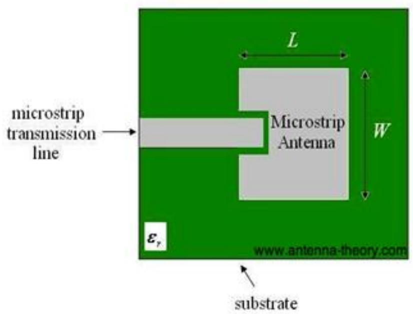

Figure 2.4. Coupled (indirect) inset feed.

The linked feed's benefit is that it gives the design an additional level of flexibility. The inductance that the probe feed adds can be countered by the capacitance that the gap adds to the feed.

Adaptive Feeds

The aperture feed is a further technique for feeding microstrip antennas. This method uses a conducting plane with a hole (aperture) to send energy to the antenna while shielding the feed circuitry (transmission line), as shown in Figure 2.5.

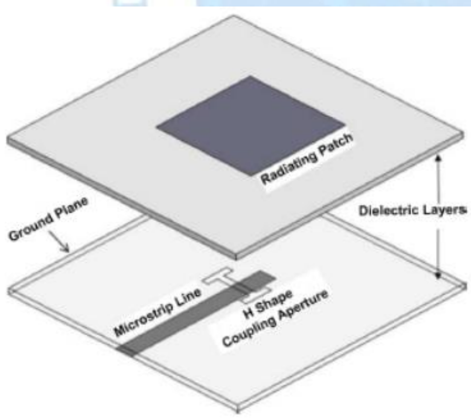

Figure 2.5. Aperture coupled feed.

Better radiation can be produced by making the upper substrate with a lower permittivity, which will result in loosely bound fringing fields. For strongly coupled fields without spurious radiation, the lower substrate can be independently manufactured with a high permittivity value. This method's drawback is that it makes fabrication more complex.

Distance-Coupled Patches

The proximity-coupled patch is the second type of noncontact fed patch designed to address the drawbacks of direct contact fed patches.

Fig. 2.6 displays a schematic for this printed antenna. A microstrip feed line is positioned on a grounded substrate that makes up the microstrip antenna. Another dielectric laminate with a microstrip patch engraved on its top surface is placed over this material. Please take note that the two dielectric layers are not separated by a ground plane. Instead of making direct contact with the patch, the electricity from the feed network is connected to it electromagnetically. Because of this, an electromagnetically connected patch antenna is a term that has been used for this particular type of microstrip patch.

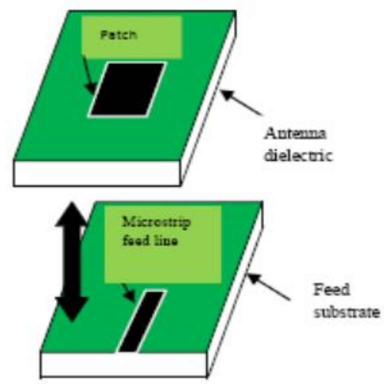

Figure 2.6 proximity coupled feed

This feeding method's main drawback is that it's challenging to construct due to the two dielectric layers that require accurate alignment. The antenna's overall thickness has also increased. Different Microstrip antenna structures can be found in a wide variety of antenna models, but antenna 2.5 generally consists of four basic components.

The patch, dielectric substrate, ground plane, and feed line are among them.

2.4 ANALYTICAL EVALUATION OF A RECTANGULAR PATCH ANTENNA

Radiation Intensity

By multiplying the square of the distance from the antenna to the designated solid angle, the radiation density is calculated.

Since the definition of radiation intensity is the power through a solid angle, the decreasing power density over distance caused by the inverse-square law is balanced by the increasing area of the solid angle caused by the same law, so the intensity of the radiation is independent of distance.

II.ANTENNA MODEL

The design of the proposed Aperture coupled antenna is shown in Figure. 1. The proposed antenna consists of H shaped slot on the radiating patch. The Aperture coupled antenna consists of two substrates with the radiating patch which can be etched on the top substrate and the feed-line placed on the bottommost substrate.

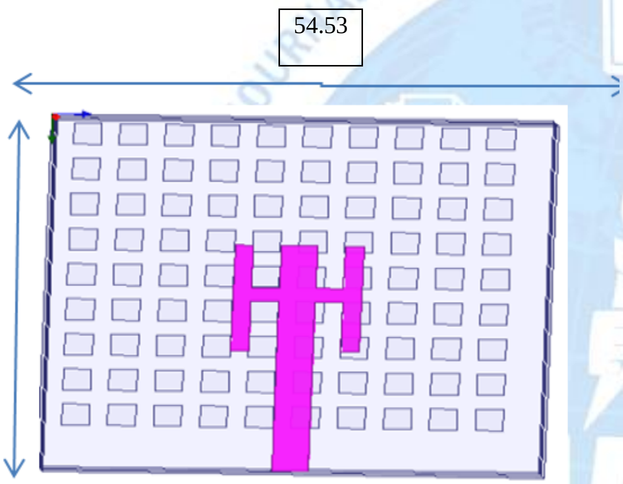

Figure 1. Aperture Coupled Array antenna

DIMENSIONS OF THE ANTENNA

PARAMETER	VALUE(IN MM)
Substrate bottom	Position –(0,0,0) X size-50.089 Y size-54.53 Z size-2
Substrate top	Position –(0,0,3.5) X size-50.089 Y size-54.53 Z size-2
Ground	Position –(0,0,2) X size-50.089 Y size-54.53
Feedline	Position –(18,25.265,2) X size-32.089 Y size-4
Patch	Position –(16,17.265,5.5) X size-19 Y size-20
Lumped port	Position –(50.089,25.265,2) y size-4 z size- -2
Radiation box	Position –(0,0,15) X size-50.089 Y size-54.53 Z size- -30

FR4 is used for both the upper and lower substrate with 4.4 permittivity and 0.02 loss tangent. The radiating patch is made up of copper. The gap between two substrates was selected such that to minimize the unwanted radiation from the feed. A lower permittivity substrate is proposed to minimize surface wave excitation and obtain wider impedance bandwidth.

The measurement of the proposed approach is computed using the transmission-line technique [20].

Patch width (w) is calculated by

$$w = \frac{c}{2fo\sqrt{\frac{\varepsilon r+1}{2}}} \qquad (1)$$

f_o- Operating Frequency

$\mathcal{E}_r$ - Substrate Permittivity

c - Light Velocity in m/s.

The effective dielectric constant (ε_{eff}) is calculated by

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \qquad (2)$$

h refers to the substrate height in mm;

The effective length (L_{eff}) is expressed as

$$L_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{eff}}} \qquad (3)$$

Hands-on approximations for the length extension lead (ΔL) are calculated by

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$$\Delta L = 0.412 * h\frac{(\varepsilon\varepsilon_{\mathrm{eff}}+0.3)*\left(\frac{W}{h}+0.264\right)}{(\varepsilon\varepsilon_{\mathrm{eff}}-0.258)*\left(\frac{W}{h}+0.8\right)} \quad (4)$$

actual patch length (L) is calculated by

$$\mathrm{L} = \mathrm{L}_{\mathrm{eff}} - 2\Delta\mathrm{L} \quad (5)$$

The above-described equations are useful to define the following dimensions, the dimensions of the proposed antenna such as the patch length PL, the patch width PW, substrate Length SL, substrate Width SW, substrate Height SH, Ground Length GL, Ground Width GW, Feedline Length is FL and the feedline width FW are represented in Table 1.

Table 1: DIMENSIONS OF PROPOSEDANTENNA

Parameter	Value (in mm)
PL	3
PW	3
SL	50.089
SW	54.53
SH	2
GL	50.089
GW	54.53
FL	32.089
FW	4

III. RESULTS EVALUATION

In this results evaluation section, we compute the simulated results of VSWR, return loss, radiation pattern impedance and gain characteristics of the proposed antenna are simulated and presented. ANSOFT HFSS simulation software is used for the simulation. The computational cost of the aperture coupled antenna was calculated using ANSOFT HFSS, windows 10, processor Intel (R) Core (TM) i3-5005U, CPU: 2.00 GHz, RAM:4.00 GB.

Figure 2 shows simulated VSWR, of aperture coupled antenna significance lesser than 2 achieves the impedance for the frequency range of 8-12 GHz. The measured VSWR is 1.51 for 8GHz and 1.12 for 12 GHz. VSWR is also called Voltage Standing Wave Ratio. The utmost common reason for measuring as well as examining VSWR is while the transmitting antennas are installed and tuned. VSWR is the purpose of measuring the reflection coefficient, which defines the power reproduced from the antenna. Preferably, the VSWR needs to be in the range of 1 to 2 which is attained in Figure 3.3 for the frequency range of 8-12GHz.

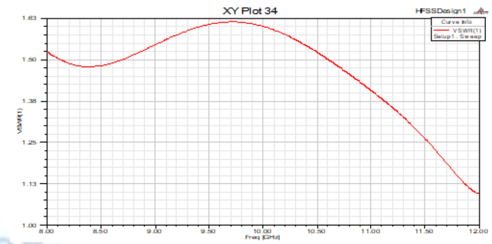

Figure 2: Simulated VSWR for Aperture coupled Antenna

Figure 3 shows simulated Return loss for aperture coupled antenna is less than -10dB. For 8GHz of the frequency the return loss is -13dB and for 12GHz the return loss is-27dB. The return loss simulation results for the 8-12GHz frequency range are shown in Figure 3.1. It satisfies the X-Band frequency of 8-12 GHz. In radar applications, the frequency range is stated by the IEEE at 8.0 to 12.0 GHz. The word "X-band" is moreover used formally to refer to the extended AM broadcast band. The variable "X" defines "extended".

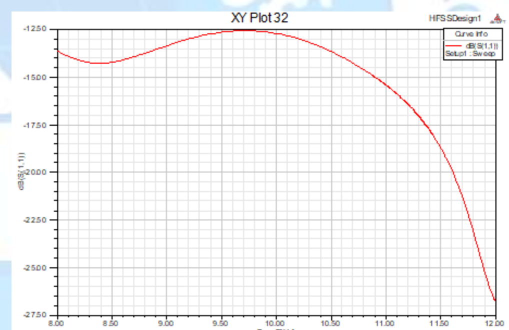

Figure 3 Simulated Return Loss for Aperture Coupled Antenna

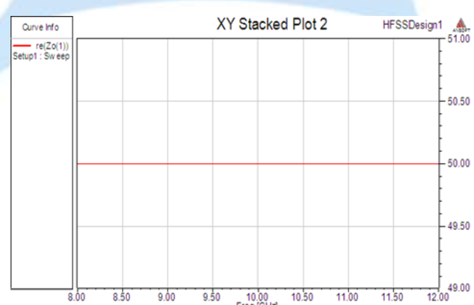

Figure 4: Simulated Impedance plot for aperture coupled microstrip patch array antenna is 50ohm

Figure 5 displays the simulated Gain of the antenna. The 3D radiation pattern for gain for the frequency of 8-12GHz is shown in Figure 3.2. The gain of an antenna in a particular direction is the volume of energy radiated in a precise direction with similar input power. Maximum power is defined by the antenna radiating in a particular direction. An antenna radiating with a large aperture has more gain than a smaller one.

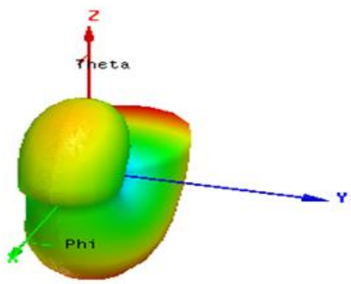

Figure 5: Simulated Gain Aperture Coupled Antenna

Figure 6 displays the radiation pattern of the Aperture coupled array antenna. The radiation pattern is maximum along the Z direction. The 3D radiation pattern of the proposed Aperture coupled antenna is presented in Figure 3.5 In the platform of antenna design, the word radiation pattern or else antenna pattern or far-field outline denotes the directional angular dependency of the strength of the radio waves from the antenna. The antenna far-field pattern can be determined experimentally at an antenna range, the near-field scanner is used to display the near-field pattern, and the radiation pattern is gathered by the computation.

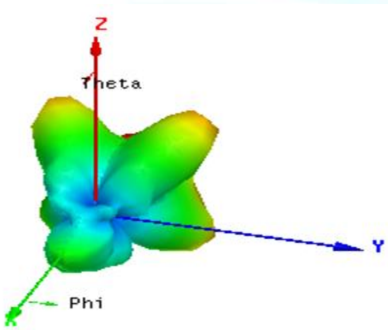

Figure 6: Simulated Emission for Aperture Coupled Array Antenna

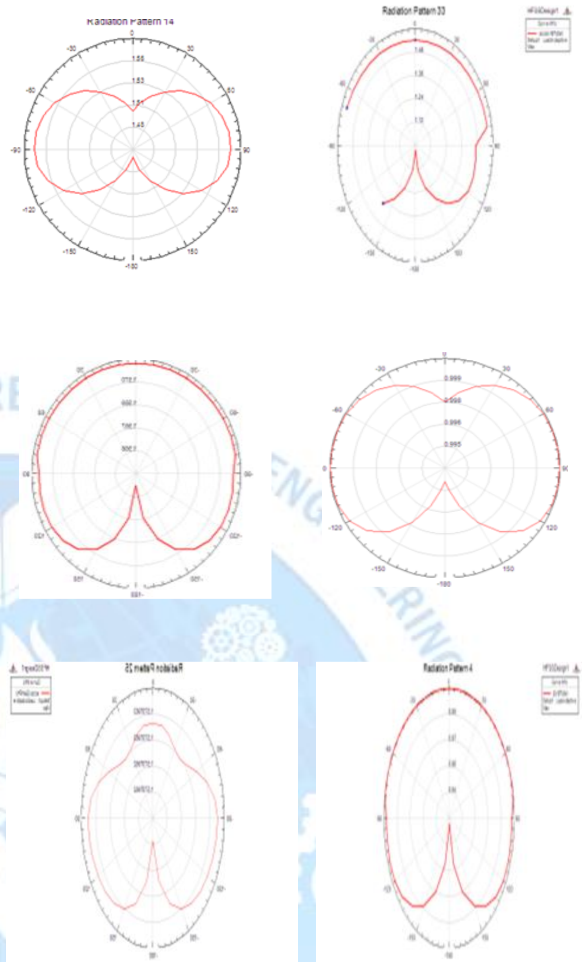

Figure 7 Radiation Pattern For 3D radiation Gain phi and theta Plot obtained using Aperture Coupled Array Antenna

Figure 8 shows a flawless portrait of the nature of polarization fields propagating all through the patch antenna. The surface currents mostly flow beside the edges of a patch as represented in Figure 8. The electric field strength radiated is related to the integral of the current distribution beside the antenna. The current at the midpoint is just driving current and the current must fall to zero at the ends of the antenna, while the conductivity drives to zero.

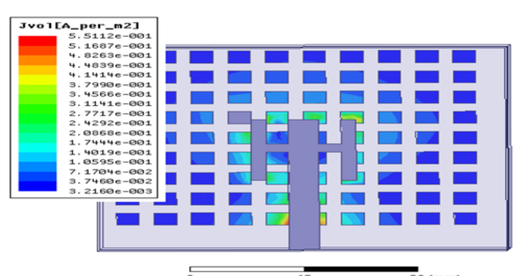

Figure 8- Simulated Current Distributions

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The surface current propagates towards the edges and produces radiating current distribution on the patch which leads to increasing the radiating aperture of the antenna.

Figure 9 displays the radiation pattern of peak gain obtained. The antenna directivity is the maximum value of its directive gain.

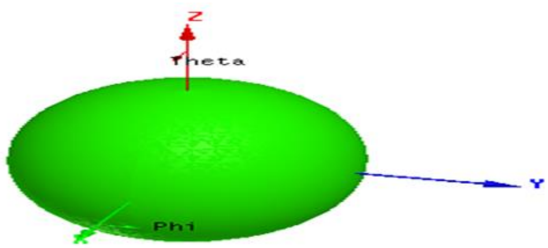

Figure 9- Simulated Peak Gain for aperture coupled antenna

CONCLUSION

In this proposed approach, an Aperture Coupled microstrip patch antenna is designed. The Simulated result of return loss at 8GHz of the frequency the return loss is -13dB and for 12GHz the return loss is-27dB. Aperture coupled antenna which operates at 8-12GHz is used for X-band applications like RADAR. The radiation pattern stays Omni directional arrangement for all of the operation bandwidth. The computed simulation gives satisfactory result outcomes for the requirements to fabricate a specific prototype that can be used for X band applications.

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