HIGH GAIN 2.4GHz PATCH ANTENNA ARRAY FOR RURAL AREA APPLICATION

A PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this project report titled **"HIGH GAIN 2.4GHz PATCH ANTENNA ARRAY FOR RURAL AREA APPLICATION"** is the bonafied work of "**LIZA FLOWBELL.J [13BEC083], NIVETHA.T [13BEC098], PRIYADHRSHNI.S [13BEC112], RADHAMANI.R [13BEC115]**" who carried out the project work under my supervision. Certified further that to the best of my knowledge the work reported here in does not form part of any other project or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

The design and implementation of high gain 2.4GHz patch antenna array for wireless communication application in rural area is designed. Aside from having a high gain the antenna should have good enough directivity to ensure the reliability of communication from one point to another can be maintained properly. By attaining the patch antenna array with high gain and good directivity it is expected to minimize the need of tower that almost requires high cost of construction. In order to achieve high gain, the proposed antenna is constructed by 4x4 rectangular patches fed by coaxial feed. The antenna structure is then deployed on a Flame Retardent 4 Epoxy dielectric substrate which has the dielectric constant 1.6mm.

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LIST OF ABBREVIATIONS

HFSS   High Frequency Structural Simulator

VSWR   Voltage Standing Wave Ratio

FR4   Flame Retardant 4

WLAN   Wireless Local Area Network

SMA   SubMiniature version A

FEM   Finite Element Method

1. INTRODUCTION

Recently, the demand of antennas for numerous wireless communication systems including wireless local area network (WLAN), cellular phone, and satellite communication has rapidly increased. An easy to build, low cost production, and sufficiently high gain are some of requirements usually needed by the systems. Sometimes, other characteristics such as multi-band support and electrically-small size are also required for some specific wireless communication systems. In fulfilling those requirements, a patch antenna is one of antenna types which may answer for the application due to its inherent capabilities such as low cost, light weight, low profile and multi-band support.

In spite of a fact that the gain and bandwidth response levels of microstrip patch antenna remain unsatisfactory to the expectation, however, in recent years other facts have shown that the microstrip patch antenna was widely implemented for various applications with high gain and large bandwidth. Furthermore, for wireless communication application in rural area, aside from having a high gain the antenna should have good enough directivity to ensure the reliability of communication from one point to another can be maintained properly. By attaining the antenna with high gain and good directivity, it is expected to minimize the need of tower in rural area communication that usually requires high cost of construction. Some attempts to achieve those characteristics are by configuring some patches in an array, known as patch antenna array.

2. HARDWARE DESCRIPTION

2.1 PROJECT DESCRIPTION

In this project, a high gain patch antenna array for 2.4GHz wireless communications system is proposed for rural area application. The proposed patch antenna array which is designed on a 1.6mm thick FR4 Epoxy dielectric substrate is constructed of 16 rectangular patches arranged in 4 rows x 4 columns formation to obtain the high gain characteristic.Each of patch is fed using a microstrip feeding line in which each feeding line makes a configuration of corporate feeding network. In order to have an optimum design of patch antenna array, at first, a single patch is investigated to obtain its characteristics. After optimizing the separation between patches, the patch antenna array is then characterized to satisfy the design requirement.

2.2 PROJECT EXECUTION PLAN

In this project we design a 4x4 patch antenna using HFSS software. HFSS is a commercial finite element method solver for electromagnetic structures. It is one of several commercial tools used for antenna design, and the design of complex RF electronic circuit elements including filters, transmission lines, and packaging. In HFSS we can choose the desired type of dielectric material, vary the dimensions of various elements like substrate, patch etc.. We can also specify the type of feed needed to be used. We can analyse the radiation pattern and various other characteristics of antenna. We can vary the dimensions

and analyse to observe varying results. After finalizing the desired dimensions and type of the materials being used we can fabricate the antenna. After fabrication we can test it to obtain the practical results.

2.3 COMPONENTS AND ITS USES

Substrate:

It acts as a foundation for the patch that we design. As the antenna is loaded with a dielectric as its substrate, the length of the antenna decreases as the relative dielectric constant of the substrate increases.

Rectangular Patch:

They are mostly used at <u>microwave</u> <u>frequencies</u>. An individual microstrip antenna consists of a patch of metal foil of various shapes (a <u>patch antenna</u>) on the surface of a PCB, with a metal foil <u>ground plane</u> on the other side of the board.

Array:

An antenna array is a set of multiple connected antennas which work together as a single antenna, to transmit or receive radio waves. The individual antenna elements are connected to a single receiver or transmitter by feedlines that feed the power to the elements in a specific phase relationship. The antenna array helps in increasing the directivity which further increase the gain.

Coaxial cable feed:

Its a very common technique used for microstrip patch antenna. The inner conductor of the coaxial connector extends through the dielectric and is

soldered to the radiating patch, while the outer conductor is connected to the ground plane. The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance.

SMA Connector:

SMA (SubMiniature version A) connectors are semi-precision coaxial RF connectors developed as a minimal connector interface for coaxial cable with a screw-type coupling mechanism. SMA is designed for use from DC to 18 GHz, but is most commonly used for hand-held radio and mobile telephone antennas, and more recently with WiFi antenna systems.

2.4 DESIGN :

2.4.1. SIMULATED DESIGN :
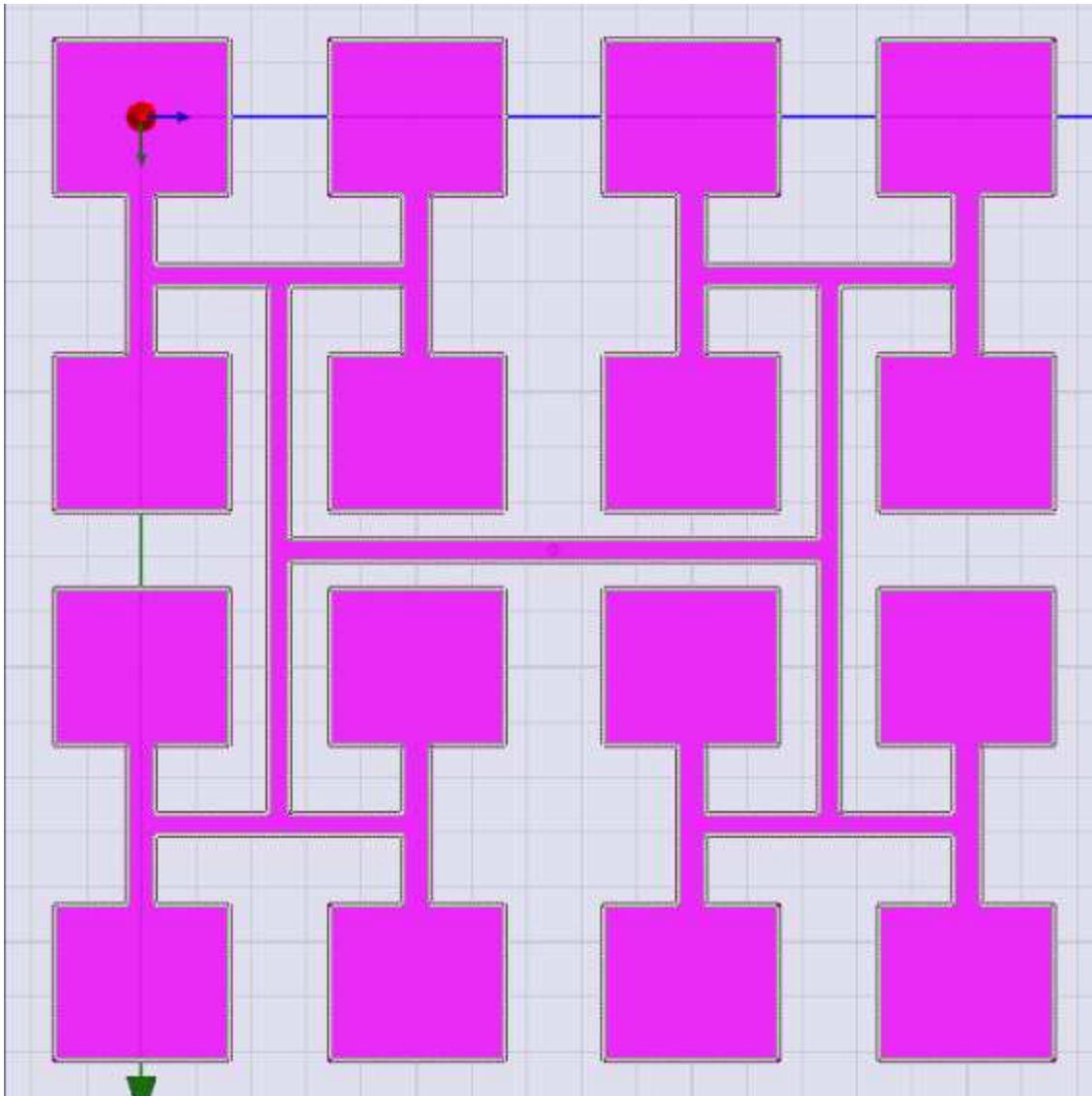
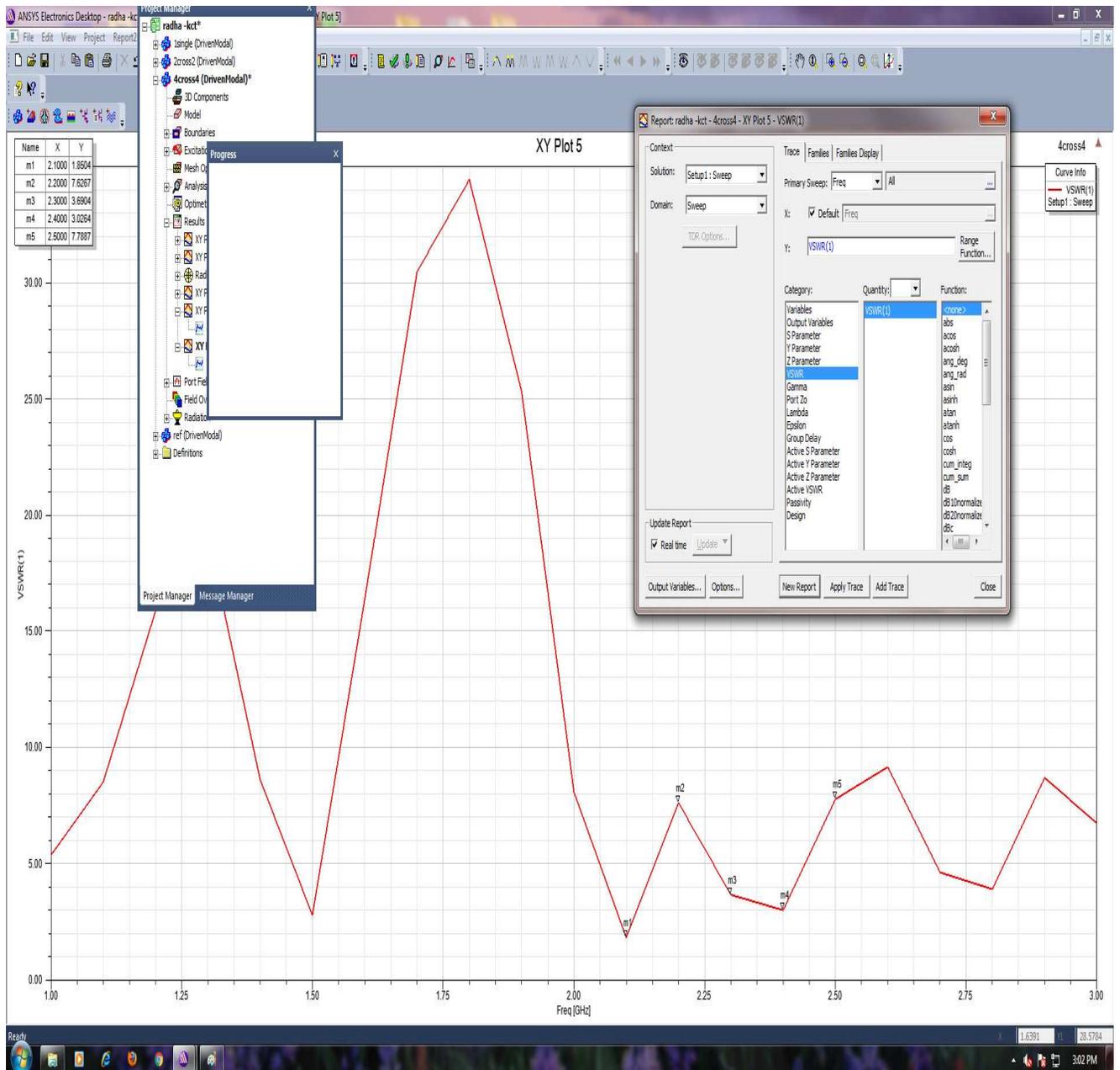**Fig 2.1. 4X4 rectangular patch antenna array**

Name	Length	Width	Thickness
Substrate	200	200	1.6
Ground	200	200	-
Patch	32	28.5	-

Table 1. Dimension of the Antenna

2.4.1.1.FREQUENCY vs VSWR :

Fig 2.2. Frequency vs VSWR

The parameter VSWR is a measure that numerically describes how well the antenna is impedance matched to the radio or transmission line it is connected to. VSWR stands for VoltageStanding Wave Ratio, and is also referred

to as Standing Wave Ratio (SWR) . VSWR is a function of the reflection coeffecient, which describes the power reflected from the antenna.

The VSWR is always a real and positive number for antennas. The smaller the VSWR is, the better the antenna is matched to a transmission line and the more power is delivered to the antenna. The minimum VSWR is 1.0. In this case, no power is reflected from the antenna, which is ideal.

S.No	Frequency	VSWR
1	2.1	1.85
2	2.2	7.62
3	2.3	3.69
4	2.4	3.02
5	2.5	7.78

Table 2. Frequency vs VSWR

The VSWR is 1.85 for a frequency of 2.1Ghz is the value nearer to the ideal VSWR.

2.4.1.2 FREQUENCY vs RETURN LOSS
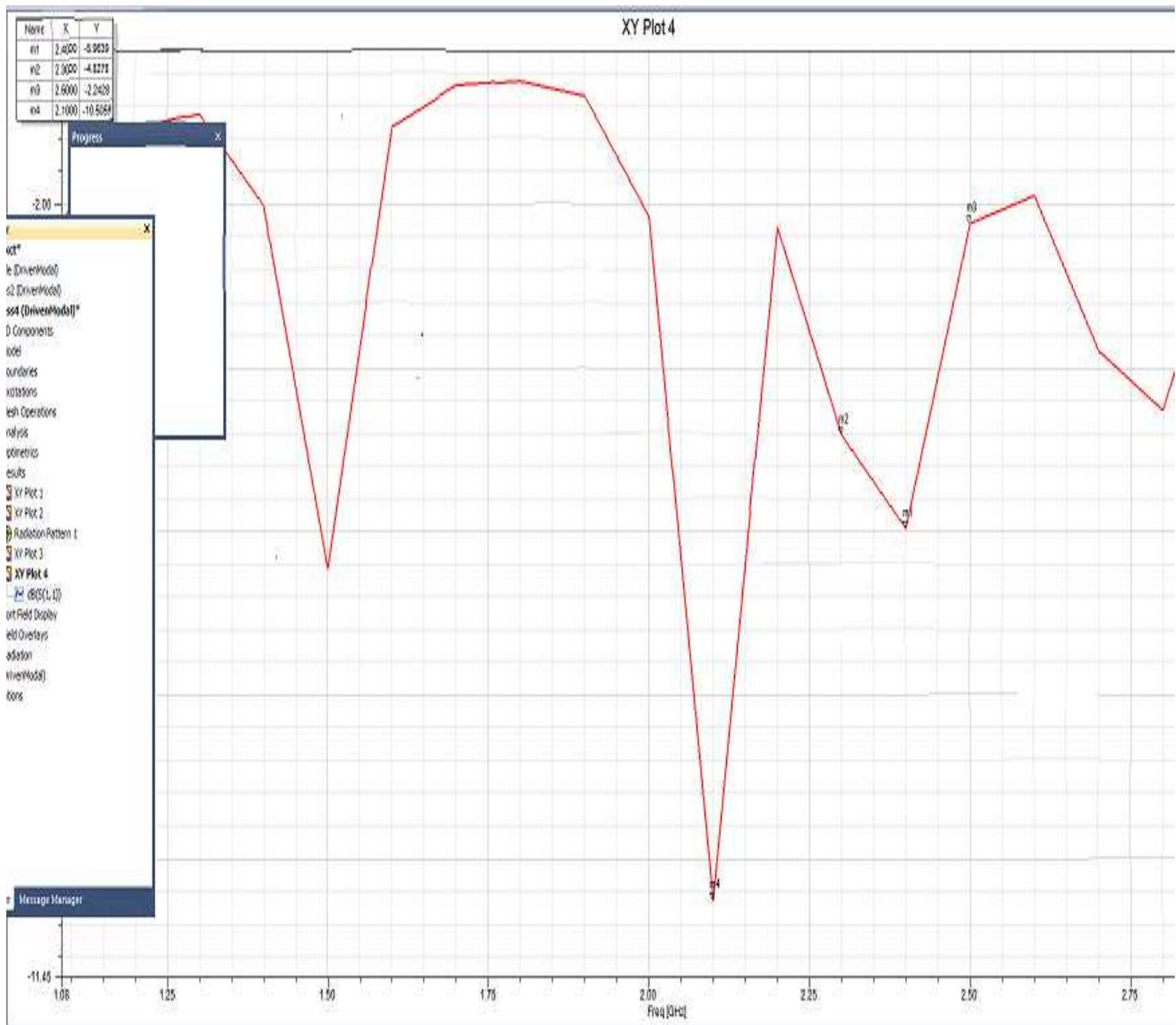
Fig 2.3. Frequency vs Reflection Coefficient

In practice, the most commonly quoted parameter in regards to antenna is S11. S11 represents how much power is reflected from the antenna, and hence is known as reflection coeffecient or return loss. If S11=0dB, then all the power is reflected from the antenna and nothing is radiated. If S11=-10dB, this implies that if 3dB of power is delivered to the antenna, -7dB is the reflected power. The remainder of the power was "accepted by" or delivered to the antenna. This

accepted power is either radiated or absorbed as losses within the antenna. Since antennas are typically designed to be low loss, ideally the majority of the power delivered to the antenna is radiated. VSWR is directly related to S11.

SNo	Frequency	S11
1	2.4	-5.67
2	2.3	-4.34
3	2.6	-2.78
4	2.1	-10.50

Table 3. Frequency vs S11

The S11 is -10.5 for a frequency of 2.1Ghz is the value nearer to the ideal S11.

2.4.2. PRACTICAL DESIGN :
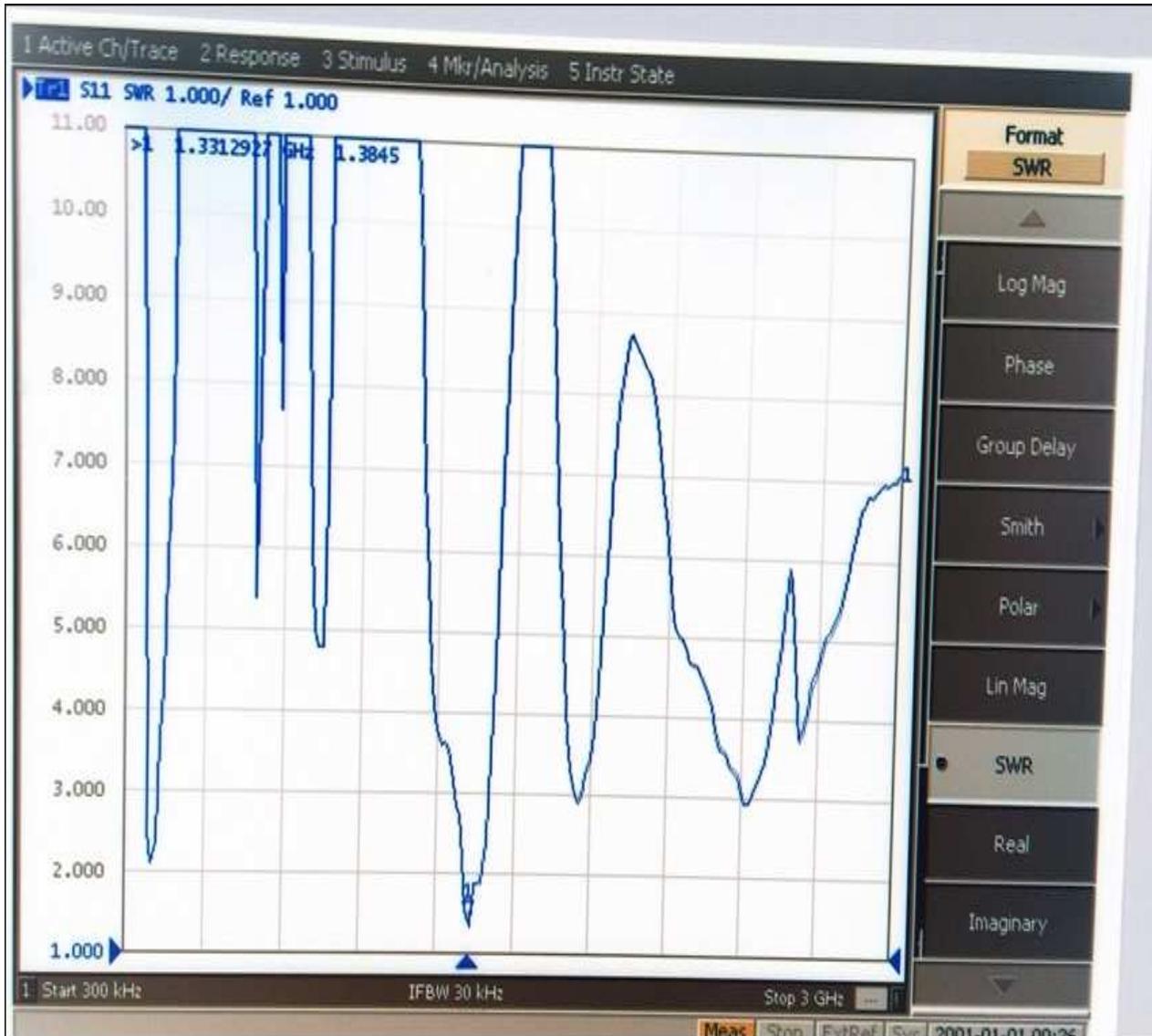
2.4.2.1.FREQUENCY vs VSWR :

Fig 2.4. Frequency vs VSWR(practical)

The VSWR is 1.38 for a frequency of 1.33Ghz which vary from the simulated result because of the used substrate. If we vary the substrate we can obtain more accurate results.

2.4.2.2. FREQUENCY VS RETURN LOSS :

Fig 2.5. Frequency vs Reflection Coefficient(practical)

The S11 is -16.13 for a frequency of 1.33Ghz which vary from the simulated result because of the used substrate. If we vary the substrate we can obtain more accurate results.

2.5 TESTING :

2.5.1 NETWORK ANALYZER :

A network analyzer is an instrument that measures the network parameters of electrical networks. Today, network analyzers commonly measure s–parameters because reflection and transmission of electrical networks are easy to measure at high frequencies, but there are other network parameter sets such as y-parameters, z-parameters, and h-parameters. Network analyzers are often used to characterize two-port networks such as amplifiers and filters, but they can be used on networks with an arbitrary number of ports.

Network analyzers are used mostly at high frequencies; operating frequencies can range from 5 Hz to 1.05 THz. Special types of network analyzers can also cover lower frequency ranges down to 1 Hz.

Architecture

The basic architecture of a network analyzer involves a signal generator, a test set, one or more and display.

Signal generator

The network analyzer needs a test signal, and a signal generator or signal source will provide one. Older network analyzers did not have their own signal generator, but had the ability to control a stand-alone signal generator. High-performance network analyzers have two built-in sources. Two built-in sources are

useful for applications such as mixer test, where one source provides the RF signal, another the LO, or amplifier intermodulation testing, where two tones are required for the test.

Test set

The test set takes the signal generator output and routes it to the device under test, and it routes the signal to be measured to the receivers.It often splits off a reference channel for the incident wave. In a SNA, the reference channel may go to a diode detector (receiver) whose output is sent to the signal generator's automatic level control. The result is better control of the signal generator's output and better measurement accuracy. In a VNA, the reference channel goes to the receivers; it is needed to serve as a phase reference.

Directional couplers or two resistor power dividers are used for signal separation. Some microwave test sets include the front end mixers for the receivers (e.g., test sets for HP 8510).

Receiver

The receivers make the measurements. A network analyzer will have one or more receivers connected to its test ports. The reference test port is usually labeled R, and the primary test ports are A, B, C,.... Some analyzers will dedicate a separate receiver to each test port, but others share one or two receivers among the ports. The R receiver may be less sensitive than the receivers used on the test ports.

For the SNA, the receiver only measures the magnitude of the signal. A receiver can be a detector diode that operates at the test frequency. The simplest SNA will have a single test port, but more accurate measurements are made when a reference port is also used. The reference port will compensate for

amplitude variations in the test signal at the measurement plane. It is possible to share a single detector and use it for both the reference port and the test port by making two measurement passes.

For the VNA, the receiver measures both the magnitude and the phase of the signal. It needs a reference channel (R) to determine the phase, so a VNA needs at least two receivers. The usual method down converts the reference and test channels to make the measurements at a lower frequency. The phase may be measured with a quadrature detector. A VNA requires at least two receivers, but some will have three or four receivers to permit simultaneous measurement of different parameters.

There are some VNA architectures (six-port) that infer phase and magnitude from just power measurements.

Processor and display

With the processed RF signal available from the receiver / detector section it is necessary to display the signal in a format that can be interpreted. With the levels of processing that are available today, some very sophisticated solutions are available in RF network analyzers. Here the reflection and transmission data is formatted to enable the information to be interpreted as easily as possible. Most RF network analyzers incorporate features including linear and logarithmic sweeps, linear and log formats, polar plots, Smith charts, etc. Trace markers, limit lines and also pass / fail criteria may also be added in many instances.

3.SOFTWARE DESCRIPTION:

3.1 HFSS:

The acronym originally stood for high frequency structural simulator. It is one of several commercial tools used for antenna design, and the design of complex RF electronic circuit elements including filters, transmission lines,and packaging.

ANSYS HFSS software is the industry standard for simulating high-frequency electromagnetic fields. Its gold-standard accuracy, advanced solvers and high-performance computing technologies make it an essential tool for engineers tasked with executing accurate and rapid design in high-frequency and high-speed electronic devices and platforms. HFSS offers state-of the-art solver technologies based on finite element, integral equation, asymptotic and advanced hybrid methods to solve a wide range of microwave, RF and high-speed digital applications.

HFSS delivers 3-D full-wave accuracy for components to enable RF and high-speed design. By leveraging advanced electromagnetic field simulators dynamically linked to powerful harmonic-balance and transient circuit simulation, HFSS breaks the cycle of repeated design iterations and lengthy physical prototyping. With HFSS, engineering teams consistently achieve best-in-class design in a broad range of applications including antennas, phased arrays, passive RF/mW components, high-speed interconnects, connectors, IC packaging and PCBs.

Design sign-off accuracy is provided by HFSS through its groundbreaking and industry-leading adaptive meshing technology. Its powerful

meshing and solver technologies enable you to design with confidence, knowing the results provided by HFSS can be relied on. Other tools simply give answers without any feedback regarding the accuracy of the solution, leading to uncertainty. When combined with ANSYS HPC technologies, like domain decomposition or distributed frequencies, HFSS can simulate at a speed and scale never before thought possible, further allowing you to more fully explore and optimize your device's performance.

3.2. HFSS ADVANTAGES:

HFSS is a 3D which means it solves all of Maxwell's Equations. The limit on accuracy is basically dependent on the mesh size. HFSS is very good at extracting s-parameters and fields.

HFSS is an interactive simulation system whose basic mesh element is a tetrahedrone. This allows you to solve any arbitrary 3D geometry, especially those with complex curves and shapes, in a function of the time it would take using other techniques.

Ansoft pioneered the use of the finite element method(FEM) for EM solution by developing / implementing technologies such as tangential vector finite elements, adaptive machine.

HFSS has evolved over a period of years with input from many users and industries. Ansoft HFSS is the tool of choice for high productivity research, development and virtual prototyping.

3.3. SIGNIFICANCE OF PROJECT:

The main aim of our project is to design an antenna which has the centre frequency 2.4Ghz.The reason we choose that frequency is we don't need to have license to use that frequency. This frequency is license free. Licensed frequency costs more and we can't use a particular frequency without getting license. Using an unlicensed frequency is illegal. That's why we choose 2.4Ghz.

This model is used in rural area application and this will avoid the use of tower(Repeater). We have designed a rectangular patch antenna array that has high directivity and so we don't need to plant a repeater which costs more. The entire rural area can be covered using the single antenna.We don't need to have repeater which strengthen the signal which was transmitted. That's why specifically we are designing it for rural area application. In case of urban area the area will be more.We can't cover the whole area using a single antenna without having repeaters. Its other inherent capabilities are low cost, light weight, low profile and multi-band support.
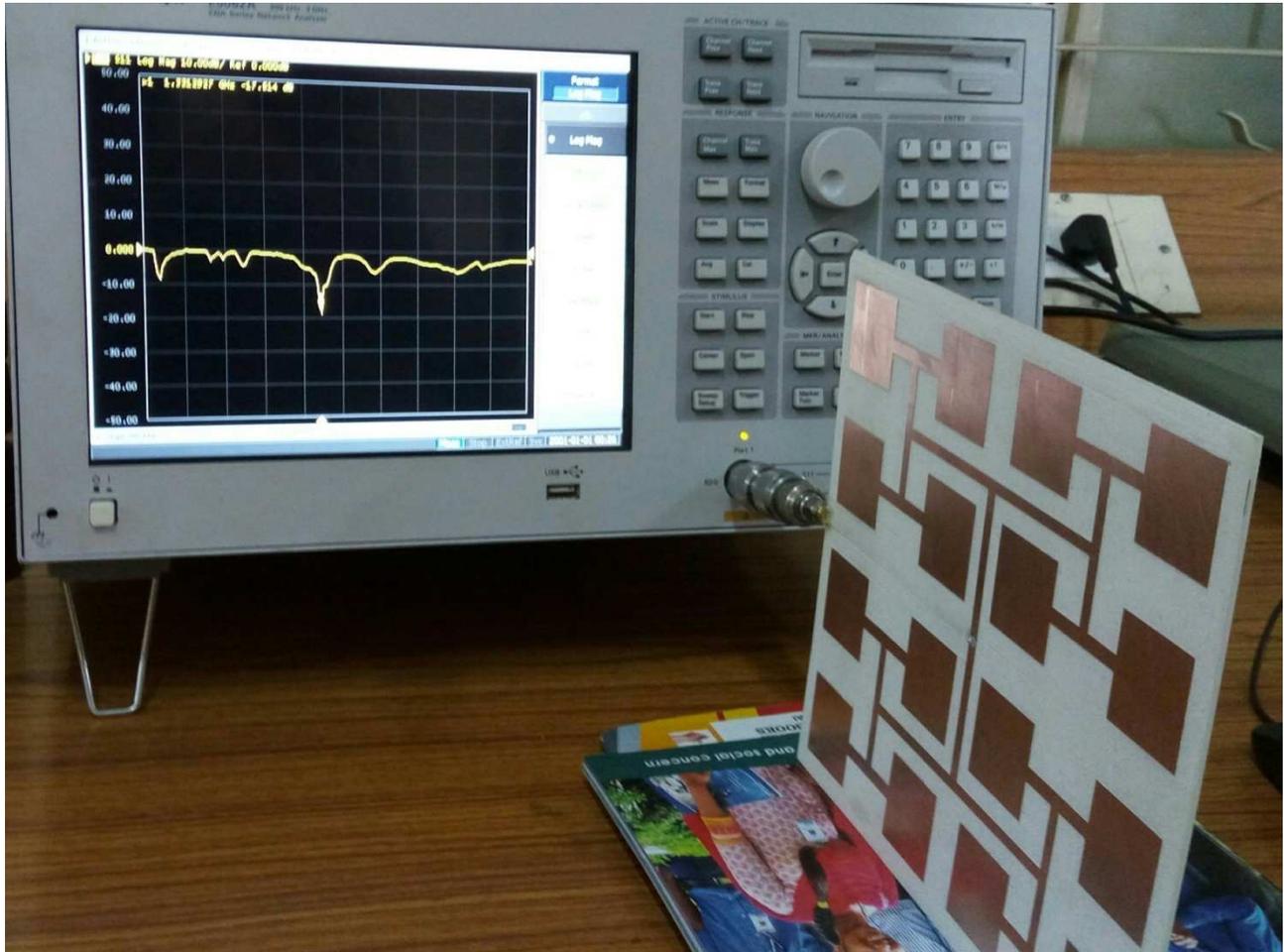
3.4. ENCHANCEMENT OF THE PROJECT :

In this project we use FR4 epoxy dielectric substrate. In simulated design we get better results at 2.1 GHz. But practically we get better results at 1.33GHz. This variation is due to the type of substrate used.

This drawback can be overcome by using Bakelite as substrate.

4. WORKING MODEL :

4.1 EXPERIMENTAL SETUP :

Fig 4.1 Experimental Setup

After fabricating an antenna,we test the antenna using network analyzer. Initially connect the antenna at port 1.We measure two parameters using network analyzer using calibrate option.They are

1.VSWR

2.Return loss

The VSWR is 1.85 for a frequency of 2.1Ghz which is the value nearer to ideal VSWR in simulation and VSWR is 1.38 for a frequency of 1.33Ghz.

The S11 is -10.5 for a frequency of 2.1Ghz which is the value nearer to the ideal S11. The S11 is -16.13 for a frequency of 1.33Ghz which vary from the simulated result because of the used substrate.

By varying the substrate used ,we can get better results.

4.2. ANTENNA FABRICATION

4.2.1. FRONT VIEW

Fig 4.2 Front View

5. CONCLUSION

The design and implementation of high gain 2.4Ghz patch antenna array for rural area application have been presented. The realized patch antenna array has been constructed by 4x4 rectangular patches and deployed on a 1.6mm thick FR4 Epoxy dielectric substrate. We get better results at 1.33GHz practically. This variation is due to the type of substrate and the distance between the patches. Better results can be obtained by varying the above mentioned parameters.

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