DESIGN OF FLEXIBLE MICRSTRIP PATCH ANTENNA OF 2.4 GHz OPERATION FREQUENCY USING HFSS

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Abstract — *This is a research paper on "Design of Flexible Patch Antenna". Flexible patch antenna in recent years has made a great progress in the field of electronics due to various advantages provided by its design i.e. it's size, shape, conformity, ease of fabrication. This paper describes the design of a rectangular patch antenna in free space as required aided with special software. The software used to create a flexible patch antenna is Ansys HFSS.The calculations and simulations performed on the flexible Microstrip patch antenna are found and noted in this paper. We considered the frequency of 2.4 GHz for wide applications like that of WLAN, Bluetooth, etc. Dimensional parameter calculations are mentioned in this paper.*

Keywords — Patch Antenna, Flexible Patch Antenna, Special type of Substrate (Kapton Polymide).

INTRODUCTION

In the modern world, communication plays a vital role in human lives. Communication system is one of the most relied upon on daily basis, thus, the makes antennae as a vital part of this structure.

Of all the feeding techniques of Microstrip antenna, which includes Co-Axial feed, Inset feed, Aperture & Proximity coupled feed: Inset feed is the best way to fabricate the antenna. For this, the length of the inset feed is to be calculated along with its width.

An antenna (plural antennae or antennas), or aerial, is an electrical device which converts electric power into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an electric current oscillating at radio frequency (i.e. a high frequency alternating current (AC)) to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves(radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals that is applied to a receiver to be amplified. [1]

II. MOTIVATION

Conventional antennae are found to be quite rigid in its structure & hard to implement in places with low availability of spaces. Moreover, these structures may not be cost effective depending on the process involved to define them.

The complexity of the device could be far more intensive in nature depending on the requirement & nature of its design.

It can be very difficult to implement these antennae devices in the fast growing world, where the size of the devices tends to decrease every year.

MICROSTRIP PATCH ANTENNA

Microstrip patch antenna has a simple design. It has a ground plane on one side of the substrate. The substrate can be Benzocyclobuten, Rubber, Quatz, etc. The ground plane on one of the sides is a conduting material, which can be Copper or Silver, Aluminium, etc. On the other side, we have a patch, which is smaller than the substrate and feed with a Microstip line. The directivity is independent of substrate thickness. The substrate can be of different shapes, i.e. circular, rectangular, sqaure, eleptical, depending on the application.

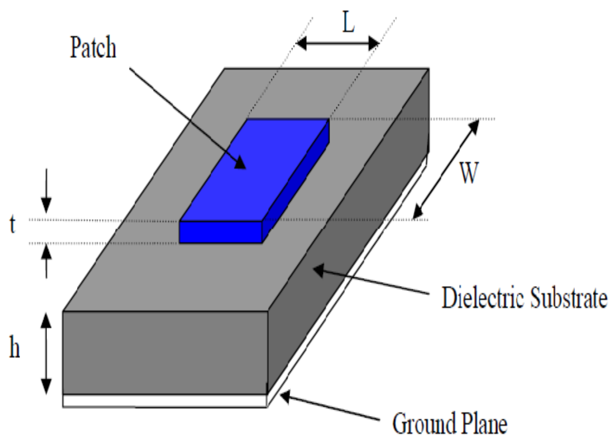

Fig. 1: Structure of a Microstrip Patch Antenna

APPLICATIONS

After analyzing the advantages and disadvantages of the microstrip antennas, it can be observed that its advantages significantly overshadow its disadvantages. Due to the fact that most present-day systems demand for small size, lightweight, low cost and low antennas, the employment of microstrip technology arises extensively over the years. Even though conventional antennas possess far superior performance over microstrip antennas, it is still clearly disadvantaged by the other properties of the microstrip antennas. Shown below are some typical system applications which employ microstrip technology [2]:

1. The telemetry and communications antennas on missiles.
2. Radar altimeters use small arrays of microstrip radiators.
3. Aircraft-related applications include antennas for telephone and satellite communications.
4. Satellite imaging systems.
5. Satellite communications
6. WLAN and WIMAX.
7. High speed GPS.

ADVANTAGES AND DISADVANTAGES OF PATCH ANTENNA

Sr. No	Advantages	Disadvantages
1	Light weight and low volume.	Narrow bandwidth
2	Low profile planar configuration which can Be easily made conformal to host surface.	Low efficiency
3	Low fabrication cost, hence can be Manufactured in large quantities.	Low Gain
4	Supports both, linear as well as circular Polarization.	Low efficiency

5	Can be easily integrated with microwave integrated circuits (MICs).	Extraneous radiation from feeds and junctions
6	Capable of dual and triple frequency operations.	Poor end fire radiator except tapered slot antennas
7	Capable of dual and triple frequency operations.	Low power handling capacity.

Table 1: Advantages & Disadvantages of Microstrip Patch Antenna [3]

VI. SUBSTRATE TYPES

The most commonly used flexible substrates are:

- Electro-textile
- Paper based
- Kapton Polymide film
- Flexible bow tie

Kapton Polyimide film has a loss tangent of about 0.002, with some adhering qualities like a profile of 50.8 μm, a good dieletric as well as tensile strength and temperature rating. The following chart describes its qualities with a comparision with others.

Character-istics	Polyimide based antenna	Textile antenna [4]	Paper based antenna [5]	Fluidic antenna [6]	Flexible Bow-tie antenna [7]
Size in mm	38 x 27	180 x 150	46 x 35	65 x 10	39 x 25
Thickness mm	0.05	4	0.25	1	0.13
Band/f□	Single/ 2.45 GHz	Dual/2.2, 3 GHz	Single/2.4 GHz	Variable	Single/7.6 GHz
Substrate	Polyimide □=3.4	Felt fabric □=1.5	Paper □= 3.4	PDMS □= 2.67	PEN film □=3.2
Dielectric loss	Low loss tan δ=0.002	Low loss tan δ=0.02	Medium loss tan δ=0.065	High loss tan δ=0.37	Low loss tan δ=0.015
Tensile strength	High (165 MPA)	Low (2.7 MPA)	Low (30 MPA)	Low (3.9 MPA)	High (74 MPA)
Flexural strength	High (50000 p.s.i)	Low (8900 p.s.i)	Low (7200 p.s.i)	Low (650 p.s.i)	High (13640 p.s.i)
Deform-ability	Low	High	High	High	Low
Thermal stability	High	Low	Low	Low	High
Fabrication complexity	Simple/ printable	Complex/Non-printable	Simple/Printable	Complex/Non-printable	Simple/Printable

Table 2: Comparative Study of Different Types of Flexible Antennas.[4]

VII. METHOD OF IMPLEMENTATION

To begin with, the dimensions of the rectangular patch were calculated using formulae as being shown below. The width of the substrate and ground plane is required to calculate the power efficiency & bandwidth which is dependent on the operating frequency and the substrate dielectric constant. [5]

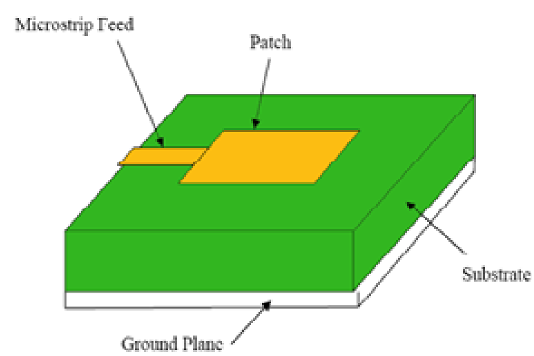

Fig. 2: Structure of The Patch[5]

A flexible, compact and low profile & high efficiency printed antenna is intended in this project.

The antenna is based on a concept of fabricating the antenna using ink-jet technology.

Use a highly conductive ink like that of Copper or Silver is preferred while preparation.

A flexible patch antenna is designed in HFSS. The length of the patch is 32.152 mm, the width of the patch is 42.11 mm and Permittivity of the substrate is 3.4 and the resonance frequency is 2.4 GHz. Kapton Polymide is used as a substrate with a substrate height of 1.00 mm. The rectangular patch was energized using coaxial probe feed. This patch was designed in HFSS. After design, the patch was simulated in HFSS to get the directivity, the gain curves along with the 3D visuals of the far field radiation and the 3D view of the designed antenna patch. Fig. 3.1 shows the design of the single rectangular patch in HFSS.

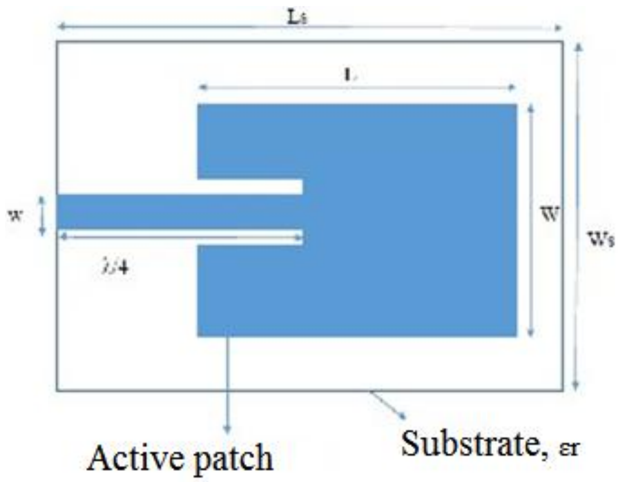

Fig. 3: The design of the single rectangular patch in HFSS.

The transmission line model equations are as follows:

(1) To find the length of inset (Fi)

$$F_i = 10^{-4}\,[(0.001699 * \varepsilon_r^{7}) + (0.13761 * \varepsilon_r^{6}) - (6.1783 * \varepsilon_r^{5}) + (93.187 * \varepsilon_r^{4}) - (682.69 * \varepsilon_r^{3}) + (2561.9 * \varepsilon_r^{2}) - (4043 * \varepsilon_r^{1}) + 6697]*(L/2)$$

(2) To find the width of substrate where the input impedance is usually 50 ohms.

$$Z_c = \frac{120\pi}{\sqrt{\varepsilon reff}\left[\frac{Wo}{h} + 1.393 + 0.667 \ln\left(\frac{Wo}{h} + 1.444\right)\right]}$$

(3) Foe effective radiation efficiency its value is given by (W)

$$W = \frac{C}{2Fo} * \frac{1}{\sqrt{\frac{\varepsilon r+1}{2}}}$$

Where C is the free-space velocity of light i.e. 3×108 m/s and εr is the dielectric constant of material.

(4) The Microstrip separates two dielectrics, i.e. air and substrate. Hence most of the electric field lines reside inside the substrate and some extend to air. This transmission line cannot support pure TEM mode of propagation since the phase velocities would be different in air and the substrate. Hence, effective dielectric constant must be obtained in order to account for fringing fields. [6]

The value of this effective dielectric constant is given by (ε_{reff})

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left(1 + 12\frac{h}{W}\right)^{-1/2}$$

Here, h is the height of substrate material.

W is the width of substrate material.

(5) To find the actual length L of the antenna, effective length (Leff) is given by,

Leff = $\frac{c}{2Fo\sqrt{\varepsilon reff}}$

The L is the length extension due to the fringing field and can be calculated using the equation,

$$\Delta \mathrm{L} = 0.412h\frac{(\varepsilon reff + 0.3)\left[\frac{W}{h} + 0.264\right]}{(\varepsilon reff - 0.258)\left[\frac{W}{h} + 0.8\right]}$$

(6) To find the actual length (L)

L= Leff - 2ΔL

(7) The width and length of the Ground plane is calculated as follows:

$L_g = 2 * \mathrm{L}$; $W_g = 2 * W$

Various parameters are calculated and the table is formulated as follows:

Serial Number	**Parameters**	**Values**	**Units**
1	Frequency, fo	2.4	Gigahertz (GHz)
2	Dielectric constant, εr	3.4	No unit
3	Substrate height, hs	1	Millimeter (mm)
4	Thickness of conductor, t	.035	Millimeter (mm)
5	Width of patch, Wp	42.11	Millimeter (mm)
6	Length of patch, Lp	32.152	Millimeter (mm)
7	Effective dielectric constant, εreff	3.26	No unit
8	ΔL	.475	Millimeter (mm)
9	Length of ground	38.152	Millimeter

	plane, Lg		(mm)
• 10	• Width of ground plane, Wg	• 48.1 1	• Millimeter (mm)
• 11	• Width of feedline, Wf	• 1.8	• Millimeter (mm)
• 12	• Length of Inset, Fi	• 8.98	• Millimeter (mm)
• 13	• Input Impedance, Zc	• 50	• Ohms (Ω)

Table 2: Calculated values of various parameters

VIII. OUTPUT

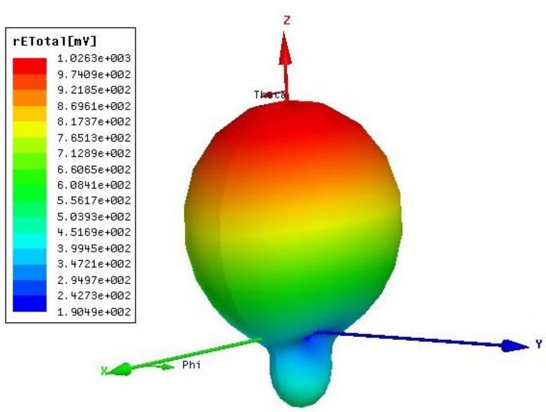

Fig. 4: Farfield Radiation Pattern

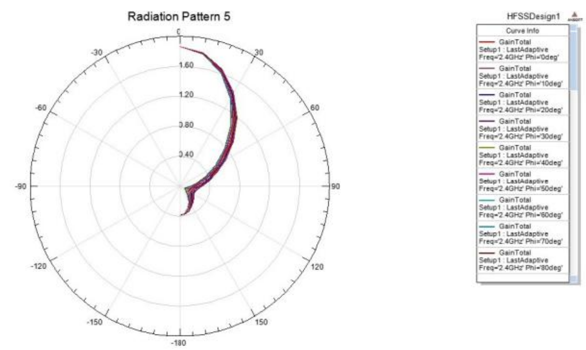

Fig. 5: Radiation pattern showing gain of antenna

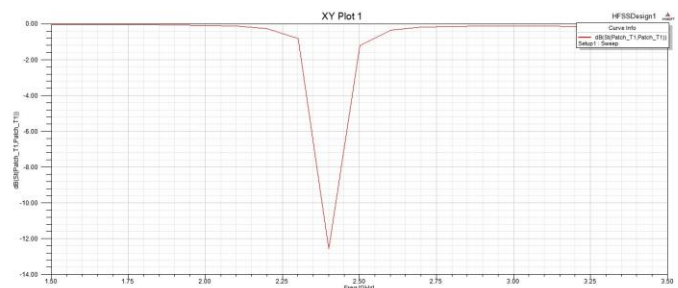

Fig. 6: S-Parameter rectangular plot

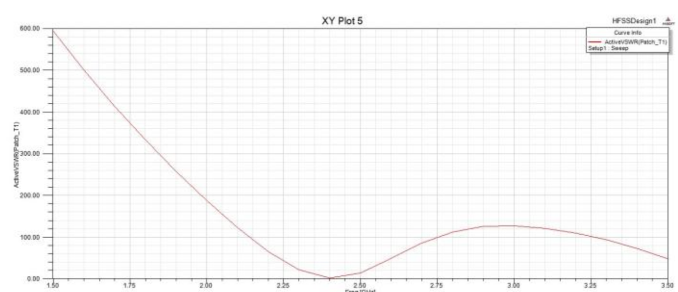

Fig. 7: VSWR rectangular plot

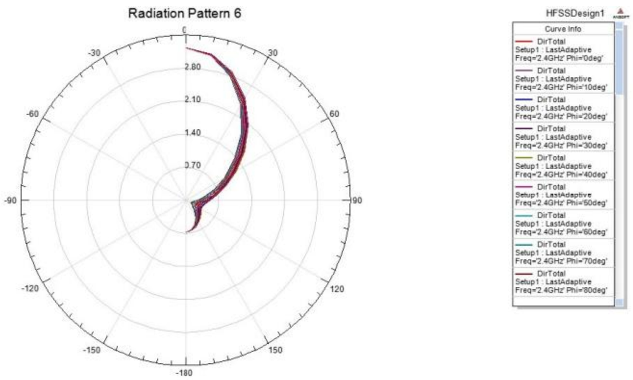

Fig. 8: Radiation pattern showing directivity of antenna

XI. CONCLUSION

The proposed design achieves an evolution from simple Rectangular Microstrip Patch antenna towards a flexible Microstrip patch antenna. The proposed designs includes the study of Microstrip patch antenna with substantially negligible thickness, on a Kapton Polymide substrate with the conductive ground plane as well as the patch made of Copper.

Thus, the proposed antennas designs represent a Flexible Patch antenna which is operable at robust, thin and has a low profile. These properties make it very useful in applications where space available is less and also where efficiency cannot be compromised.

X. REFRENCES

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BIOGRAPHIES

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