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Flexible Slotted Hexagonal Microstrip Patch Array Antenna for Wi-Max Application

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ABSTRACT

This paper introduces a small-sized, low-profile, planar and flexible slotted hexagonal microstrip patch array antenna using polyimide as the substrate. The antenna operates from 3.51 GHz for Wi-Max operation. The size of the antenna is 50mm × 82mm. An array of 2 antennae is formed. The thickness of the antenna is 0.372mm. The antenna is designed and simulated using the software HFSS (High Frequency Structure Simulator). In this paper we have discussed about various materials which can be used as a substrate in the design of antenna. It also includes the simulated results of flexible slotted hexagonal microstrip patch array antenna. Fabrication of flexible slotted hexagonal microstrip patch array antenna was done using photolithography technique. The fabricated antenna exhibits a gain of 7dB, return loss of -18.14dB and VSWR of 1.27.

Keywords:- Flexible Antenna, Flexible substrate, Array, slots, Microstrip Patch, Hexagonal

I. INTRODUCTION

Recent years have witnessed a great deal of interest from both academia and industry .In the field of flexible electronics. In fact, this research topic tops the pyramid of research priorities requested by many national research agencies. According to market analysis, the revenue of flexible electronics is estimated to be 30 billion USD in 2017 and over 300 billion USD in 2028 [1]. Communication plays an important role in the worldwide society and the communication systems are rapidly switching from "wired to wireless". Wireless technology gives a flexible way for communication and less expensive alternative compared to wired technology. Antenna is one of the important elements of the wireless communications systems. One of the types of antenna is the Micro strip patch antenna. Antenna is a Radiating element which Radiate Electromagnetic Energy uniformly in Omni direction or in some systems for point to point communication purpose in which increased gain and reduced wave interference is required. Antenna is a transducer designed to transmit or receive electromagnetic waves. Microstrip antennas have several advantages over conventional microwave antenna and therefore are widely used in many practical applications. It consists of a radiating patch on one side of dielectric substrate, ground plane on other side. [9]

In order to get these requirements, planar patch antenna is preferred because of their various advantages such as light weight ,low volume, low cost and ease for fabrication, availability of inexpensive flexible substrates (i.e.: papers, textiles, and plastics). Although the microstrip patch antenna has various disadvantages such as low gain, narrow bandwidth and low efficiency .These disadvantages can be overcome by making changes in the design of patch or by making changes in the substrate used for designing antenna.[8]

In the proposed paper we compared different flexible Materials which can be used as a substrate. The design antenna works at 3.5 GHz with return loss less than -20dB.The gain of antenna is 7 dB.This paper also includes comparison between simulated results and results achieved after fabrication.

II. LITERATURE SURVEY

Mainly the requirements of modern communication system are high gain, large, bandwidth and small size antennas which give excellent performance over a wide range of frequency spectrum. As the greater number of elements of an array, more is its directivity consequently antenna will have a greater gain. To achieve maximum radiation, substrate with low dielectric constant is mostly selected [9]. In [9] they had simulated triangular microstrip patch antenna, rectangular microstrip patch antenna, triangular microstrip patch array antenna and rectangular microstrip patch array antenna using

FR4 as a substrate. They had compared the simulated results of all four of them and through their simulated results they had proved that gain of the antenna increases if you convert a single antenna into an array. Gain of the antenna increases as you increases the elements in the array.

In ref [1] they have compared different materials like Polyimide, Textile, Paper, fluid, flexible bow tie. They had compared them on the bases of thickness, dielectric loss, tensile strength, flexural strength, deform-ability, thermal stability and fabrication complexity. They had discovered that polyimide gave the best results. They had also compared all fabrication techniques like screen printing, chemical etching, flexography, ink jet printing and benchmarking prototype. They had fabricated monopole antenna using ink jet printing. Antenna was tested under bending effects since it was expected to be mounted on curved surface.

In ref [3] they had fabricated flexible antenna using inkjet printing on three different substrates; Kapton, Plastibert PU coated stretchable textile and pre-treated 65/35 polyester/cotton. They had constructed the entire patch on substrate by printing a single conductive silver nanoparticle dispersion ink. They had measured and compared key parameters of the antennae on the three different flexible substrates.

III. METHODOLOGY

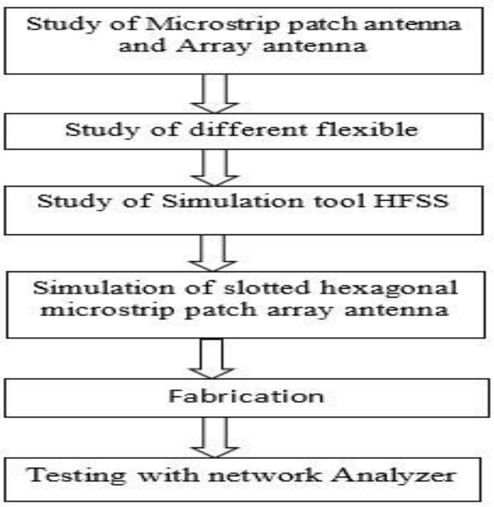

Figure 1 flow of antenna design

Figure 1 represents flow of the process of making antenna.

IV.SELECTION OF MATERIAL

The flexibility of an antenna depends on the flexibility of the substrate. In order to make the antenna flexible, alternative materials to replace existing substrates that are rigid have been considered. We can use different types of material as a substrate like paper, PDMS, cotton, denim or any other fabric to make antenna flexible. The basic idea is to lay a thin metal strip on top of a flexible substrate. This metal must maintain their conductivity even when it is stretched. [2] Size reduction is one of the advantages of antenna using high dielectric constant substrate. We had used ref [1] to compare different material.

Table1.Comparison between polyimide, textile, paper based antenna and bowtie antenna [1]

Characteristics	Polyimide based Antenna	Textile Antenna	Paper based Antenna	Flexible bow-tie Antenna
Size in mm	38x27	180x150	46x35	39x25
Thickness	0.05	4	0.25	0.13
Band/Freq.	Single/ 2.45GHz	Dual/ 2.2,3GHz	Single/ 2.4GHz	Single/ 7.6GHz
Substrate	Polyimide ε_r =3.4	Felt fabric εr=1.5	Paper εr=3.4	PEN film εr=3.2
Dielectric loss	Low loss tan δ=0.002	Low loss tan δ=0.02	Medium loss tan δ=0.065	Low loss tan δ=0.015
Tensile strength	High (165 MPA)	Low (27MPA)	Low (30MPA)	High (74 MPA)
Flexural Strength	High (50000 p.s.i.)	Low (8900 p.s.i.)	Low (7200 p.s.i.)	High (13640 p.s.i)
Deform-ability	Low	High	High	Low
Thermal stability	High	Low	Low	High
Fabrication complexity	Simple/ Printable	Complex/nonprintable	Simple/ Printable	Simple/ Printable

After comparison we had decided to make an antenna using polyimide as a substrate. Polyimide is the chemical name for the commercial Kapton product which was developed by DuPont. Kapton has very good stability and flexibility over a wide temperature range (normally from -273 ˚C to +400 ˚C) and resists many chemical solvents. It is also a good electrical insulator. Because of its chemical and physical properties, it is widely used in flexible electronics as a substrate or an insulating layer.[18]

In [4] they have investigated 3 different materials flexible adhesive copper tape an adhesive conductive fabric and a conductive thread. In the proposed paper substrate is a polyimide material and the ground and patch are of copper .Thickness of polyimide is 0.3mm, thickness of ground is 0.036mm and thickness of copper is 0.036mm.Geometryof the patch is hexagonal array with horizontal and vertical slots.

V. ANTENNA DESIGN

With the aim increasing gain of the microstrip patch array antenna we had used a slotted hexagonal geometry having slot of length 3mm and width of 2mm in the sides of the hexagonal of the hexagonal microstrip patch array antenna (in horizontal direction). We have also included a slot of length 3.5mm and width 2mm (in the vertical direction) all the other dimensions of the antenna were the same. Figure 2 represents the dimension of the slotted flexible hexagonal microstrip patch array antenna operating frequency of this antenna was 3.5 GHz. After simulation we had achieved gain of 8dB, bandwidth of 70MHz, VSWR of 1.04 and Return loss of -23.06 dB.

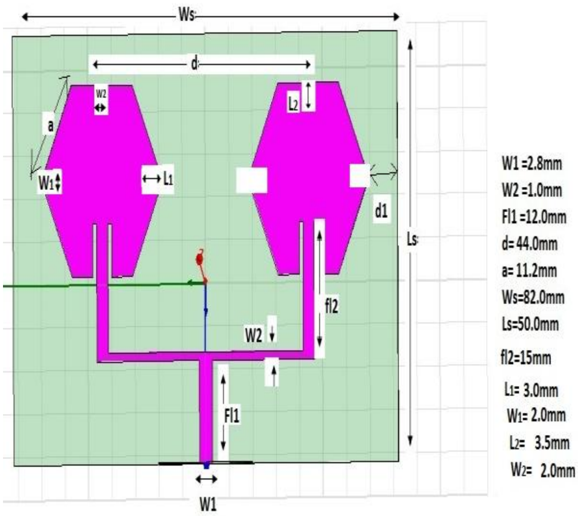

Figure 2 A 2x1 Flexible Slotted hexagonal array antenna

VI. SIMULATED RESULTS

Gain: the term antenna gain describes how much power is transmitted in the direction of peak radiation to that of an isotropic source. Figure 3 represents the simulated results of flexible slotted hexagonal microstrip patch array antenna.

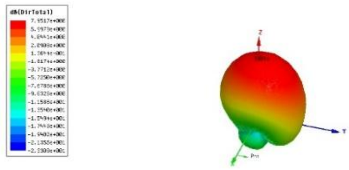

Figure 3 Gain=8dB

Return loss(S parameter): S parameter describes the input – output relation between ports (or terminals) in an electrical system.S11 represents how much power is reflected from the antenna, and hence is known as the reflection coefficient (sometimes written as gamma: Γ or return loss).Figure 4 represents the simulated results of return loss.

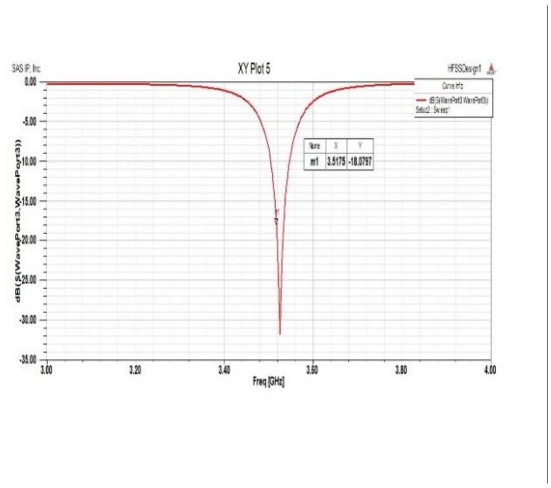

Figure 4 Return loss= -18.07dB

VSWR: VSWR stands for Voltage Standing Wave Ratio, and is also referred to as Standing Wave Ratio (SWR). VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna the typically desired value of voltage standing wave ratio (VSWR) to (indicate a good impedance match) is 2.0 or less, or S11 -10dB. VSWR 2 implies that almost 90% power is through to the antenna and only 10% power is reflected back. Figure 5 represents the simulated results of return loss.

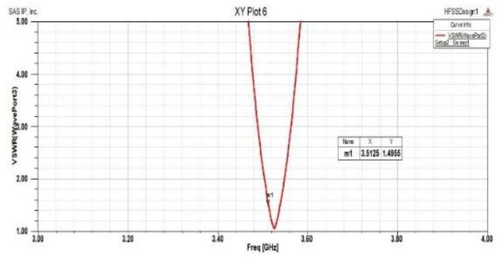

Figure 5 VSWR=1.4

Current distribution: Figure 6 shows the simulated result of current distribution of flexible slotted hexagonal microstrip patch array antenna.

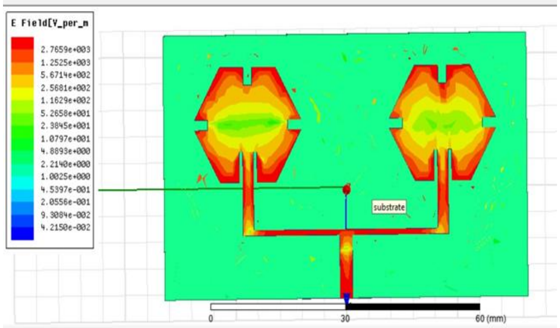

Figure 6 Current distribution

VII. FABRICATION

There are different methods of fabricating antenna such as Screen Printing, photolithography, Flexography, Ink Jet Printing and Benchmarking Prototype. We had used reference [1] to compare all the fabrication techniques. We had fabricated our antenna using photolithography technique as it gives better results compared to above mentioned techniques. Photolithography is the standard method of printed circuit board (PCB) and microprocessor fabrication. Photolithography, also termed optical lithography or UV lithography, is a process used in micro fabrication to pattern parts of a thin film or the bulk of a substrate. It uses light to transfer a geometric pattern from a photo mask to a light-sensitive chemical "photo resist", or simply "resist," on the substrate. A series of chemical treatments then either engraves the exposure pattern into or enables deposition of a new material in the desired pattern upon the material underneath the photo resist. After fabrication we had tested our antenna our antenna on VNA. We had achieved gain of antenna as 7 dB, return loss of -18.14 dB and VSWR of 1.278.Figure 7 represents the fabricated antenna

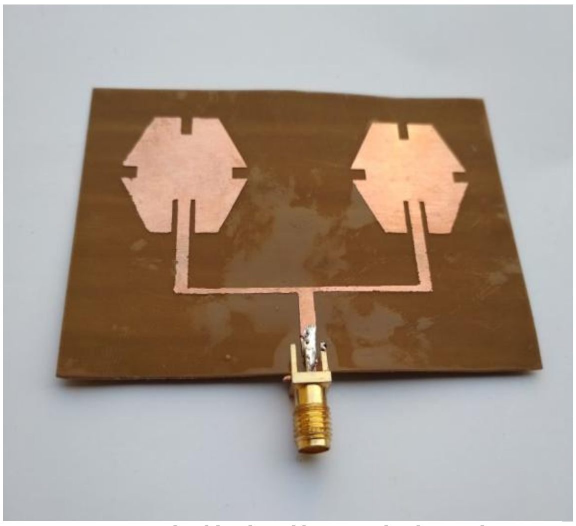

Figure 7 A 2x1 Flexible Slotted hexagonal Fabricated array Antenna

VIII. FABRICATED RSEULTS

Figure 8 represents the gain of fabricated flexible slotted hexagonal microstrip patch array antenna.

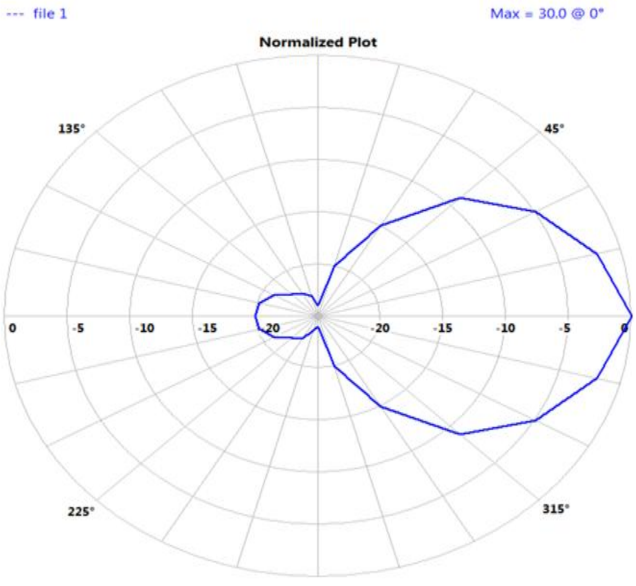

Figure 8 Gain=7dB

Figure 9 represents the return loss of fabricated flexible microstrip patch array antenna.

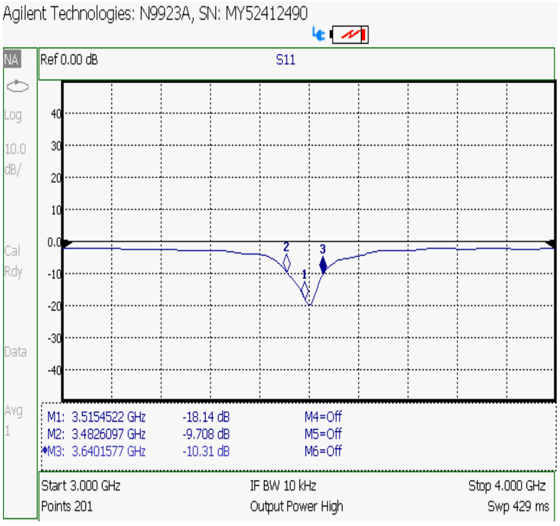

Figure 9 Return loss= -18.14 dB

Figure 10 represents the VSWR of fabricated flexible microstrip patch array antenna.

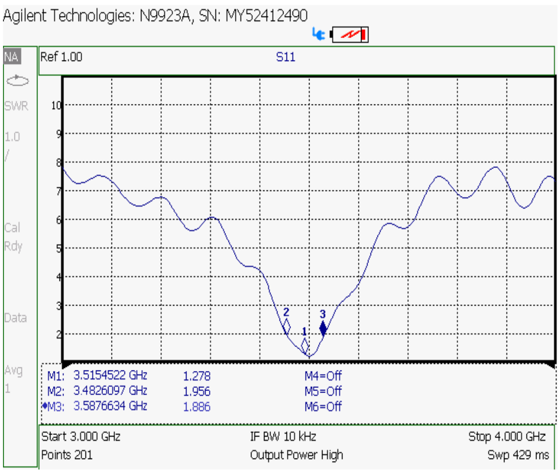

Figure10 VSWR=1.27

IX. COMPARISON TABLE

Table 2 .Comparison Table between Simulated Results and Fabricated Result of A 2x1 Flexible Slotted hexagonal array Antenna

Parameters	Simulated results	Fabricated Results
Frequency(GHz)	3.51	3.51
Return loss (dB)	-18.07	-18.14
VSWR	1.4	1.27
Bandwidth (MHz)	70	100
Impedance (Ohms)	51.8	50.2
Gain (dB)	8	7

X. CONCLUSION

In this paper the design, fabrication, and measurement of flexible antenna is discussed in details. Types of substrates and available fabrication methodologies for flexible antennas are reviewed. The reported design is based on Polyimide substrate which is known for its flexibility, robustness and low dielectric losses. We have mentioned about slotted flexible hexagonal microstrip patch array antenna. The prototype was fabricated using the photolithography technology. Results achieved after fabrication show that the Slotted hexagonal microstrip patch array antenna has gain of 7dB, return loss of -18.25dB and VSWR of 1.27 at the operating frequency of 3.51 GHz. Flexibility, robustness, compactness, fabrication simplicity good radiation characteristics, high gain along with high efficiency suggests that the reported methodology, antenna type and substrate are a reasonable candidate for integration within flexible electronics for Wi-Max application.

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