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Design and Analysis of Dual Band Electrically Small Antennas for GPS Applications

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Abstract: These days electronic devices are becoming compact in size. So, technocrats concentrated on Electrically Small Antennas (ESA) to reduce the size of the antenna, then it reduces the size of electronic system. A microstrip line feed single band antenna using copper as conducting material and kapton polyimide is used as substrate. A compact size of (38×34 mm) planar single band micostrip patch antenna is analyzed in this study. The substrate used is polyimide of thickness 0.1 mm with a dielectric constant of 3.4. The parameters analyzed are return loss, gain, radiation patterns with different phase angles, E-field, H-field. From the simulated and measured results, we can know that proposed antenna is suitable for 1.5 GHz frequency.

INTRODUCTION

Nowadays electrically small antennas plays a major role in communication compared to other antennas these are small and it is having less efficiency and challenging to design larger antennas. These antennas are shorter than the wavelength of the signal and it meant to transmit or receive. The length of the electrically small antenna is 2 h. Polyimide function as photoresist, sacrificial layers, structural Layer and it is used as a replacement for silicon as substrate. Polyimide is the most suitable substrate material for the design of flexible electronics. Polyimide is having some properties such as light weight, low cost, low coefficient, excellent electrical properties etc. Antennas are passive or active. Passive antennas use less power and limited cable length and they do not provide additional signal processing to the received signal. Before sending the signal to the receiver active antennas are amplify the GPS signal to reduce the signal loss in cable. The length of the antenna cable from sender to receiver is not >300 m. Antenna can be used as transmitting or receiving antenna, transmitting antenna can converts electrical signal into electromagnetic waves. Antennas can be classified based on the applications or operating principles. A micro strip antenna is also called as patch antenna or printed antenna. In telecommunication microstrip antenna using photolithographic techniques for fabrication on printed circuit board. Individual microstrip antenna contains a patch of metal foil of various shapes on the surface of PCB. Microstrip antenna consists of multiple patches in two-dimensional array. Microstrip antennas are used in RFID field and they are quite expensing due to their positioning. These are extensively used in many wireless communication applications. HFSS is a software used for antenna design and for complex radio electronic circuit elements, filters, transmission lines and packaging. It is a high frequency structure simulator. For simulation of 3D full wave electromagnetic field HFSS software is used. It is useful for the design of high frequency and highspeed component design. It integrates simulation, visualization, solid modelling, automation in easy to learn environment. Typical uses are packing modeling, PCB board modelling, EMC, antenna mobile communication, connectors, wave guide, filters[1-10].

In this study a single band flexible antenna is proposed using patch copper as a conductive material and polyimide as a substrate. The proposed antenna design and characterized system parameters are discussed below[11, 12].

MATERIALS AND METHODS

Proposed antenna design: A copper, single band planar antenna with kapton polyimide substrate. It is a material which is commercially available. Instead of complex feed techniques ,this antenna is fabricated using microstrip edge feed. It is quite challenging to design an antenna which is flexible, robust with good performance and radiation efficiency at the point when an antenna is expected to have low profile, light in weight and with good characteristics. The dimensions of the proposed antenna design is shown below.

The antenna performance and parameters are analyzed after simulation, after that we go for fabrication and compare results. For theoretical calculations there are some standard formulae which should be followed before designing an antenna they are: the length and width of the patch is calculated using the formulae shown below[13-18]:

$$W = \frac{V_o}{2F_r}\sqrt{\frac{2}{\varepsilon_r+1}}$$

The effective dielectric constant is given by:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+\left[\frac{12\text{ h}}{\text{w}}\right]\right]^{-1/2}$$

The actual length and width of the ground plane is calculated using following formulae:

$$Lg = 6h+L$$

Where:
L = Length of the patch
h = Thickness of the patch

Radius of the patch is calculated using following formulae as shown below:

$$\frac{F}{\sqrt{1+\frac{2\text{ h}}{\Pi\ \varepsilon_r}[\ln\ln\left(\frac{\Pi f}{2\text{ h}}\right)+1.7726]}}$$

where, $F = 8.791*10^9/f_r\sqrt{\varepsilon_r}$. The substrate used is kapton polyimide and the thickness of the substrate is 0.1 mm, relative permittivity of the substrate is 3.5 and relative permeability is 1.

Kapton polyimide is good at tolerating both extreme heat and cold and it has very good mechanical and physical properties. A copper patch is etched out on the surface of the dielectric substrate the thickness of the patch is 0.1 mm and the feeding to the patch is given using a technique called edge feeding (Table 1, 2 and Fig. 1, 2)[19-22].

Table 1: Parameters of proposed antenna design (All dimensions are in mm)

Parameters	Values	Parameters	Values
L	38	L_3	4.5
W	34	W_3	18
L_1	4.5	LA	17
W_1	32	WA	5.05
L_1	4.5	Ts	0.1
W_1	26	R	6

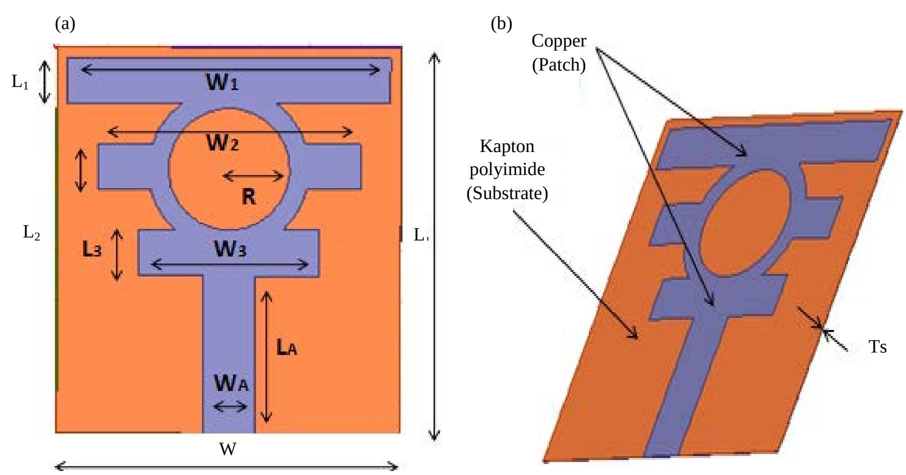

Fig. 1(a, b): (a) Top view and (b) Perspective view

Table 2: Design data of patch and substrate of proposed antenna

Parameters	Values	Units
Patch	Copper	-
Thickness	1.1	Mm
Density	8.96	g cm^{-3}
Electrical conductivity	58.7	siemens/m
Electrical resistivity	1.7	Ω.m
Thermal conductivity	386	W/m.K
Sheet resistance	0.5	mΩ/sq
Substrate	Kapton polyimide	-
Thickness	0.1	Mm
Dielectric constant (εr)	3.4	-
Loss tangent (tanδ)	0.002	-

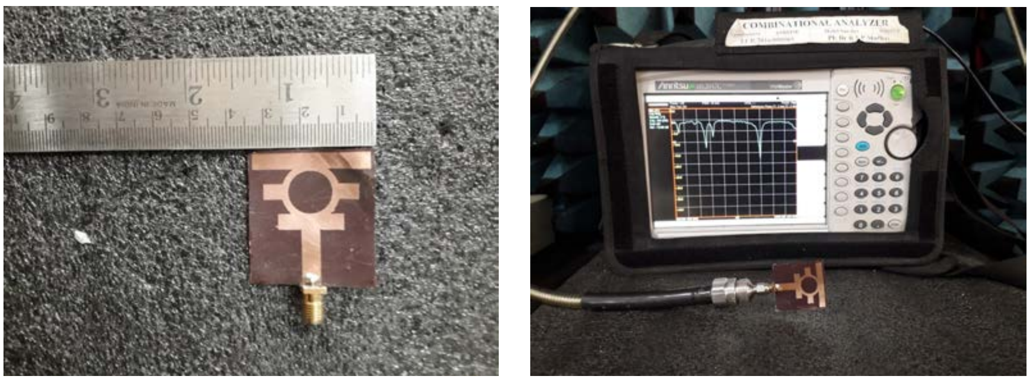

Fig. 2: Fabricated pictures of proposed antenna

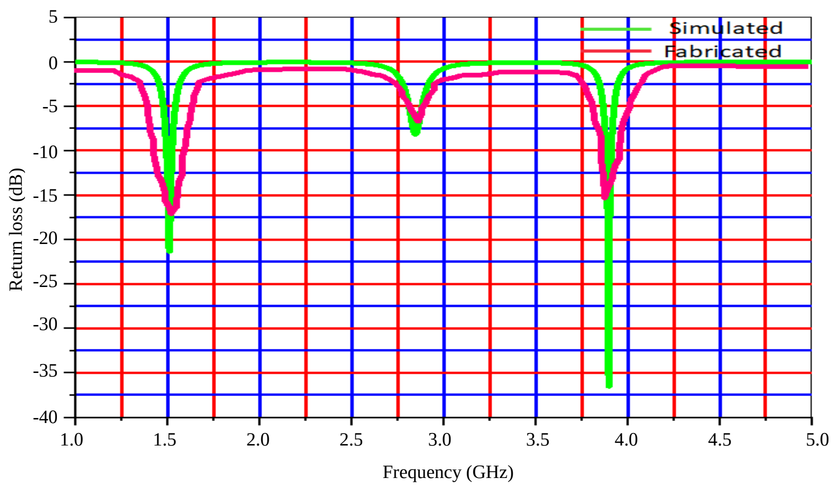

Fig. 3: Return loss comparison of both simulated and fabricated proposed antenna

RESULTS AND DISCUSSION

Antenna designed at single operating frequency that is 1.5 GHz and analyzed some important parameters. Figure 3 shows the measured and simulated return loss plots. Fabricated return loss is measured using vector network analyzer (VAN). To know that if an antenna is perfectly working or not following parameters must be considered. They are return loss, gain, VSWR[23-27].

The proposed antenna design is simulated using high frequency simulator (HFSS) software difference between incident and reflected power is known as return loss. In general to reduce the return loss there should be good impedance matching. Impedance matching is a measure of overall opposition of circuit to current. To ensure proper impedance matching the feeding should be done properly. The return loss of the proposed dual band antenna is -26.66 at 1.5 GHz and -26.32 at 3.9 GHz[28, 29].

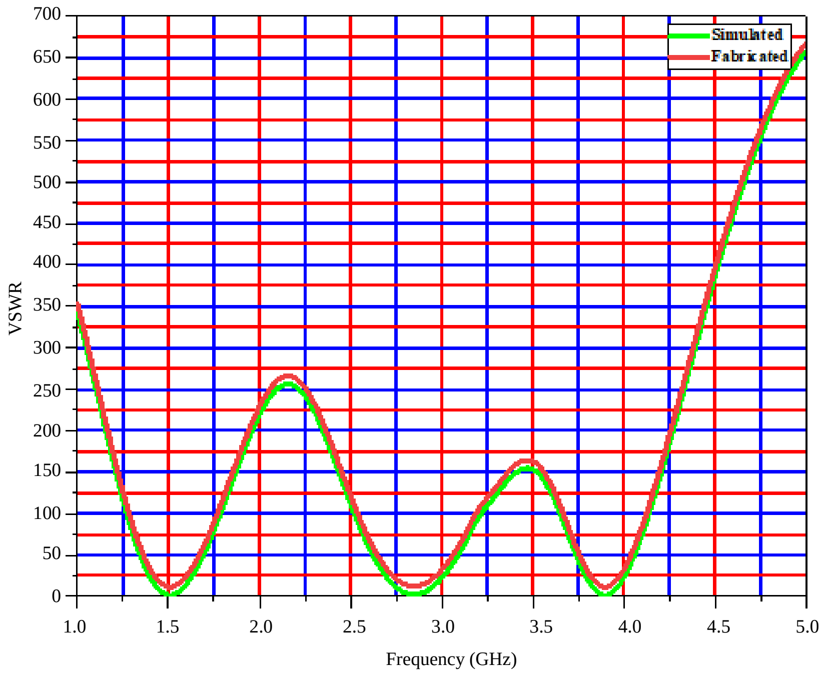

Fig. 4: VSWR comparison of both simulated and fabricated proposed antenna design

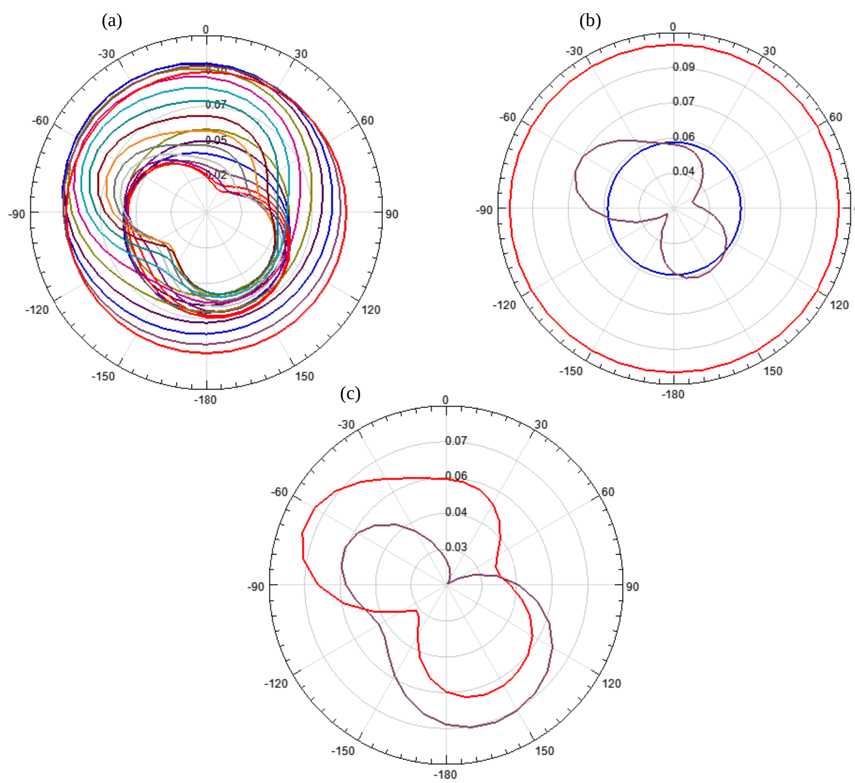

Fig. 5(a-c): Radiation patterns of proposed antenna at various phase angles, (a) Radiation pattern at all angles, (b) Radiation pattern at angles 0, 90, 180 and (c) Radiation pattern at angles 90,120

Voltage Standing Wave Ratio (VSWR) tells how efficiently power is delivered from source of antenna to load of antenna. The VSWR for this design is <2(1.55) which is acceptable for practical applications (Fig. 4).

Next, the important parameter is radiation pattern of the antenna. The energy radiated by an antenna is represented as radiation pattern. It is diagrammatical represented of radiated energy into space. For the proposed antenna below are the some of the radiation patterns at different phase angles (Fig. 5)[30-33].

CONCLUSION

A dual band electrically small antenna of frequencies 1.5 and 3.9 GHz is proposed and designed in this study. The dimensions of the design are 38×34 mm in size which satisfies the limitation the Ka value of the proposed antenna is 0.91 (ka<1), so, it is electrically small. From simulation and fabrication results the working of antenna is investigated and following parameters like return loss, VSWR, radiation patterns are analyzed. The is fabricated using conventional method and by analyzing all the results, we can say that the above antenna is suitable for the practical applications. As it is compact and small in size. These type of antennas can be used in small electronic devices. These type of antennas are useful for GPS applications and also used in WIFI hotspots and in many more communication devices.

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