January - February 2020
ISSN: 0193 - 4120 Page No. 11191 - 11196

Design and Analysis of Flexible Polyethylene - Terephthalate Substratepatch Antenna Using Printing Technique for Conformal Application

[1] Rahul Runthala[2]Bhupendra Sharma [3]R.K.Thapliyal
[1, 3] Assistant Professor, BKBIET, Pilani, Rajasthan [2] M.Tech, Amity University Rajasthan, Jaipur
[1] rahul.runthala@bkbiet.ac.in [2] bhupesh19@gmail.com [3] rk.thapliyal@bkbiet.ac.in

Article Info
Volume 82
Page Number: 11191 - 11196
Publication Issue:
January-February 2020

Article History
Article Received*: 18 May 2019*
Revised*: 14 July 2019*
Accepted*: 22 December 2019*
Publication*: 21 February 2020*

Abstract
This intense research work represents a design of low cost inset feed rectangular microstrip patch antenna using PET substrate for 10 GHz frequency. It is focused on many applications, and high frequency RF device model explored and it demonstrates new fields of applications in communication and networking domains by its flexible behavior. This paper is dedicated to the enhancement of return loss, directivity and bandwidth at software generated resonant frequency 9.95GHz at given PET base design of conformal printed antenna & comparison in simulation and modeling with PET substrate. This design and simulation using High frequency structure simulator software (HFSS-15), the expansion of bendable concept provides the idea attaining different performance of EM radiations including better performance. Different Sections of research is described in broad way as followed the steps and achieved satisfactory results in the stream of flexible inset feed patch antenna for high frequency domain. A flexi ble Polyethylene terephthalate (PET) substrate highly mechanically robust, light weight, high bendability strength with well deformability property. The antenna is feed by inset feed method and it is easy and provides good impedance matching. Here proposed structure antenna has been designed on PET substrate and operating frequency of the antenna is f=9.95 GHz, dielectric constant is 2.8, rectangular microstrip patch has dimension 8.9mm × 10.78mm and simulation results are illustrated for specific frequency allocated in particular applicationdomain.

Keywords: *Bandwidth, Directivity, Gain, HFSS, Inset feed patch antenna, PET substrate, and Return Loss*

I. INTRODUCTION

This section will be explains the performance analysis and result regarding patch antenna using PET (Polyethylene Terephthalate) substrate, with bending concept, the most common thermoplastic polymer resin of the polymer family. Mainly attention put on the design of the antenna part, because PET substrate is considered as one of the best candidate for UHF and other higher microwave application. Now a day there is several diverse PET materials are availableinmarketvaryingin coating,density,thicknessetc. In this particular task the results obtained from the inset feed patch antenna using PET substrate. We may have any shape of radiating patch like square, rectangle, circular, elliptical, triangular, H-shaped, L-shaped, U shaped etc. Here we have designed an antenna for X band frequency with various characteristics extensively used for civil, military, air traffic control and weather monitoring. This spectrum also finding many exciting applications in the field of RF sensing where flexible antenna is potential candidates for trustworthy sensors in medical, industrial and other strategic applications. Flexible electronics has opened new ways in many applications, where conventional rigid electronics is not appropriate. Flexible electronics has following advantages over conventional rigid electronics are widely

January - February 2020
ISSN: 0193 - 4120 Page No. 11191 - 11196

examined for their unparalleled characteristics like robustness, light weight, bendability, stretch or fold and mounting on unevensurfaces.

II. ANTENNAOVERVIEW AND FUNCTIONING

Antenna, the most widely used electrical equipment in the field of digital communication. The IEEE Standard Definitions of Terms for Antennas (IEEE std. 145–1983) defines the antenna or aerial as "a means for radiating or receiving radio waves" [2]. An antenna is fundamentally an element linked with the transmission and receiving of guided waves. Antennas of different sizes and shapes are used today for transmitting and receiving of waves for various applications. The entire digital communication and radio industry are relying heavily on extensive usage of different types of antennas. Other than that, antennas are finding its usage in various other industries and gaining more attentions day by day.

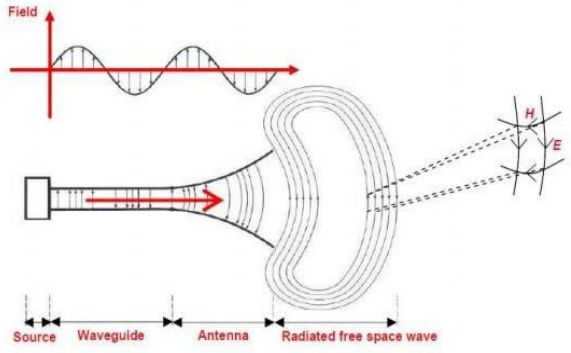

Figure 1 Antenna Radiation diagram [2]

III. MATERIAL EXPLORATION INANTENNA DESIGN

Thegeometryandmodelingofproposedantennaiss hownin figure 2. It consist a notch gap and copper feeding line with rectangular patch structure of antenna on ground plain. For designing of high frequency antenna at Ultra Wide Band section there are many factors are characterized such as permittivity, substrate material, and substrate height for off body communication link at high resonant frequency. The material of substrate is PET and antenna is constructed on this flexible substrate material having dielectric constantis

2.8. The thickness of substrate is in well-organized form for better interface of fringing field pattern, dielectric loss tangent is 0.003 value is allocated to library in HFSS to achieve best frequency feeding slot is designed with the help of calculation, micro strip feed line method is one of the easier method to merged with patch for conducting path and it is easy to controlling, matching for proper feeding point[4].

A. Flexible PET Material asSubstrate

This noble material have diversity of good qualities like low cost, good thermal stability, good spin ability, excellent moisture resistance, Polyester resins are known for their wonderful mixture of properties such as mechanical, chemical resistance along with dimensional stabilities [3].It is and outstanding commercial thermoplastic polymer resin of the polyester family.it is useful in flexible substrate in antenna and other non-silicon electronics devices. It has many application areas and suitable choice for packaging, fabrics, molded parts in electronics [5].This paper introduces low cost flexible PET substrate for high frequency domain. The RF characteristics of PET substrate are examined for the patch antenna having low cost issue, suits better economical point of view for industrial sector [6].This antenna is designed on flexible Substrate with loss tangent 0.003 and 0.16mm height, εr as 2.8, and it is highly important candidate forradiation.

Table I MATERIAL EXPLORATION OF PATCH ANTENNA

Copper –As Conductor on patch and ground	**PET Material -As Substrate**

TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 11191 - 11196

Material =Copper(Pure) Type lossy metal Mu = 1 Electrical Conductivity = $5.69e^{+07}$ (S/m) Rho = $8930(Kg/m^3)$ Thermal conductivity = 401(W/K/m) Heat capacity = 0.39 (kJ/K/Kg) Young's Module = $120(Kn/mm^2)$	Material = Polymer material (Polyethylene Terephthalate) Thermal Expension= 20-80 ($\times 10^{-6}$ K^{-1}) Youngs module = 2-2.7 ($10^9 Nm^2$) εr= 2.8 Water Absorption over 24Hr.=0.1% Upper working temperature=115-170 (^OC) Lower working temp.= -40 to -60 (^OC)

IV. DESIGNMETHODOLOGY

In this paper the proposed rectangular patch antenna is designed to operate at resonant frequency at 9.95 GHz with 50Ω input impedance. Antenna substrate material is PET having ε_r = 2.8, Dielectric loss tangent (δ) =0.003, substrate thickness h= 0.16mm.the inset feed parameter is calculated by standard antenna design equation as followed in separate section.

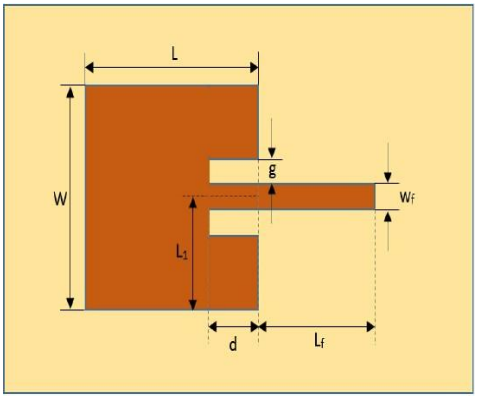

Figure 2 Inset feed patch antenna (Top View) diagram

For designing the Microstrip Patch antenna, we have to select the resonant frequency and a dielectric medium ε_r for which antenna is to be designed[7].

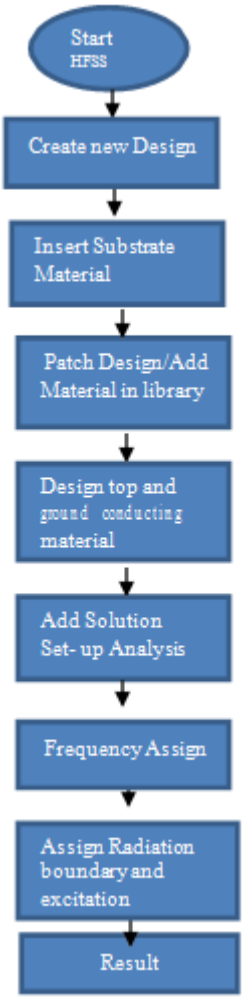

Figure 3. Flow Diagram of Patch Antanna Design Process in HFSS

Table II DIMENSION PARAMETERS OF ANTENNA

C	Speed of light in vacuum/free-space/air
f	Operating Frequency
h	Substrate height/thickness
d	Inset feed depth
L	Actual length of patch
W	Actual width of patch
Leff	Effective length of patch
Wf	Feed Width
Lf	Length of feed
g	Notch gap
εr	Substrate-dielectric constant
λ	Wavelength of signal
Zo	Characteristics input Impedance
δ	Loss Tangent
λg	Guided wavelength

V. ANTENNADESIGNANDSIMULATION RESULT

The design of antenna of normal inset feed

January - February 2020
ISSN: 0193 - 4120 Page No. 11191 - 11196

Rectangular Micro strip patch antenna are discussed below with analysis and simulated results are discussed below.

For the particular Project of Normal micro strip Inset Feed rectangular patch antenna, the selected parameters are discussed above in introduction and depicted in fig.3,suchas resonant frequency 9.95GHz.the patch antenna contains of a layer of flexible dielectric substrate named PET having a thickness (h) of 0.16mm.and dielectric loss of epsilon-r of 2.8.on the top side ,it has a rectangular patch layer with feed-Inset and on the bottom side a ground plane both are copper made with 0.035mm thickness. The structure creates an EM cavity that resonates on specific frequency [8]. Thus the parameters are calculated by mathematical process as tabulated in the TableIII.

Table III . DESIGN SPECIFICATIONS OF MICROSTRIP PATCH ANTENNA AT 9.95 GHZ FREQUENCIES

Antenna Parameter	Units (mm)
Patch width	10.78
Patch length	8.90
Substrate Length	21.76
Substrate Width	22.50
Inset feed length	12.94
Inset gap / Notch width	0.058
Microstrip line width	0.428

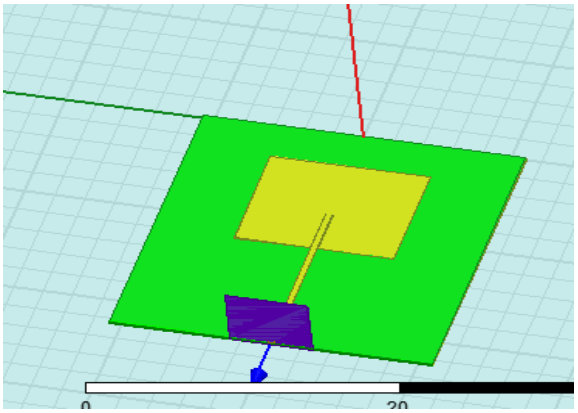

Figure 4 Inset Feed Rectangular Patch Antenna (side view)

The return loss (S11), VSWR and gain of designed antenna are shown in Fig.5, Fig 6 and Fig. 7 and combined simulated result is given at Table IV.

As shown above the antenna power is radiated as much and S11parameter gives Better performance of antenna it explains the input output relationship between ports. It plays an important role to describe radiatedpower.

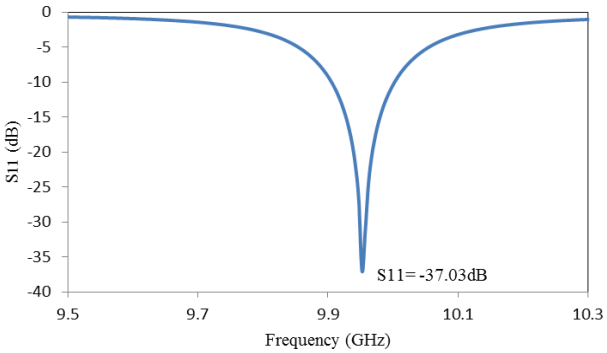

Figure 5 *R*eturn Loss value of Patch antenna

The VSWR is basically measure the impedance mismatch in between transmitter and antenna if VSWR is higher than mismatching increasing and losses occurs, when VSWR is unity it denotes better performance [2].The practical antenna impedance should have 50ohm and in this design we got better VSWR of 1.028 after simulation as shown in Fig. 6.

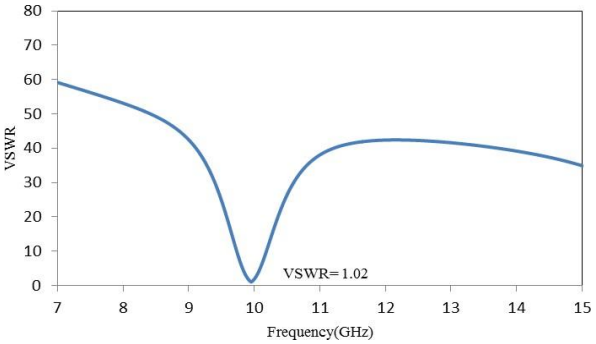

Figure 6 VSWR value of Patch antenna

Antenna Bandwidth again another important parameter, Simulation in HFSS using PET substrate based patch antenna. It is the range of frequency over which the input impedanceisperfectlymatched.Herethevalueof bandwidth is 97.10MHzobserved.

TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 11191 - 11196

How the antenna is capable to radiated power in to space in certain direction; here the Gain of patch antenna is 4.83dB as shown in fig. 7.

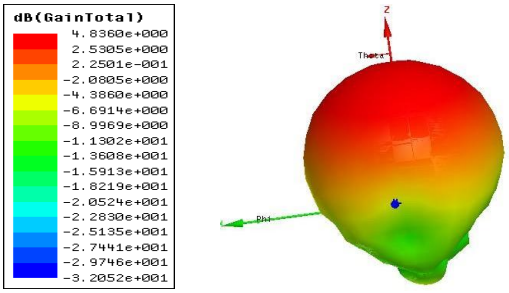

Figure 7. Gain of Inset feed Patch antenna

Table IV. PARAMETERS OF INSET FEED RECTANGULAR MICROSTRIP PATCH ANTENNA

Parameters	**Simulated Results**
f (GHz)	9.95
S11 Return Loss(dB)	-37.03
VSWR	1.028
Gain (dB)	4.83
Directivity (dB)	5.88
Bandwidth (MHz)	97.1
Impedance Z_O (Ω)	49.01

We have designed microstrip patch antenna with flexible substrate on ultra-wide band frequency range at 10 GHz. This is usually low energy and short range but large directivity and Satisfactory value of S_{11}= 37.03dB at resonance frequency
9.95 GHz range and observed in HFSS simulation and generates output of inset feed patch antenna using flexible PET substrate. The flexible antenna becomes conformal to the surface and can be used on non-planarsurfaces.

A. PrintingTechnique

Recently, printed electronics technology has appeared as a encouraging technology for new trends in application and broadly been explored as the technology is low-cost, easily accessible, and can operate with instant and single-step process [9]. The printed electronics has been used for mass fabrication of low-cost and flexible and non-silicon electronic devices such as radio frequency identification (RFID) antennas, organic light-emitting diodes (OLEDs), organic thin film transistors (OTFTs) and organic memory systems [9].The glass transition temperature of PET is in the range of 80–100 °C so that PET is frequently used for food container and artificial fiber. The proposed flexible antenna isprinted
on 0.16mm thick PET substrate so that it is completely transparent and fit for wearable devices. For antenna design, we use the HFSS and for antenna fabrication, we can use commercial inkjet printer for printing the pattern on PET substrate [9]. We have proposed a design and simulated on software, here we have introduced the flexible antenna but for fabrication process point of view the printing technology is easy to fabricate for bending and folding of antenna.

Table V.PARAMETERANALYSISOFPATCHANTENNAAT10GHZ VARIATIONS WITH FEEDWIDTH

Curve	**Feed Width fw (mm)**	**S11 (dB)**	**VSWR**
A	0.420	-28.36	1.07
B	0.423	-28.77	1.08
C	0.425	-29.22	1.06
D	0.427	-37.03	1.028

The paper presents flexible substrate embedded with antenna and the design frequency at 10 GHz discussed with performance and their graphical representation. In this paper we have designed and simulated the patch antenna on flexible material substrate. The results are shown in TableV. There are various parameters are analyzed and comparesuch as Return loss, VSWR when variation in feed width of inset feed patchantenna.

January - February 2020
ISSN: 0193 - 4120 Page No. 11191 - 11196

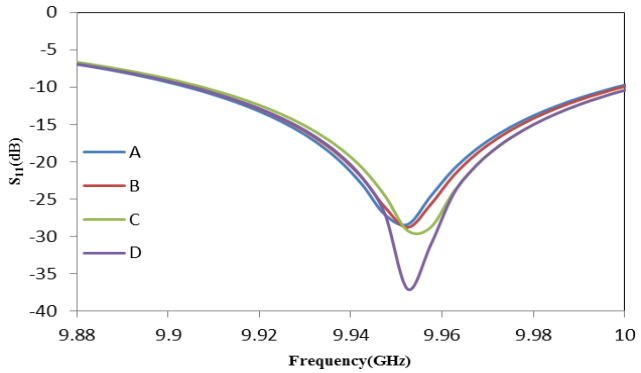

Figure 8. Effect on S11 during variation in feed width (fw)

We have demonstrated a class of microstrip patch antenna that is deigned on flexible substrate material that have extraordinary properties. The comparative study of proposed work is compared with another similar work is shown in the Table VI. The flexible antennas also illustrated to maintain the same properties as discussed in other similar literature work.

Table VI. COMPARATIVE ANALYSIS OF PROPOSED WORK (10 GHZ) WITH

Parameters	Proposed design (10GHz)	[10]	[11]
Resonant frequency (GHz)	9.95	9.21	10.90
S11 (dB)	-37.03	-22.40	-29.0
VSWR	1.028	-	1.0
Substrate	PET	PET	RT Duroid 5880
Conductive material	Cu	Ag	Cu
Patch area	95.94mm^2	1842.83 mm^2	107.45m m^2

VI. FUTUREWORK

We will fabricate flexible substrate material PET based inset feed patch antenna under the inspired and outstanding guidance for the purpose of high frequency applications.

VII. CONCLUSION

We have described this antenna for resonating frequency region at 9.95GHz. In this proposed design the Rectangular Microstrip flexible patch antenna design, simulation for UWB application purpose.

REFERENCES

1. C. A. Balanis, “Antenna theory: analysis and design. Hoboken”, NJ: Wiley Interscience,2005.
2. Omar E. Almanama,”Design of Micromachined Patch with performance Enhancement for millimeter wave application.
3. Faraj, Ibrahim, Kamarulazizi, Khalil Mohammed Ali, “PET as a plastic substrate for the flexible optoelectronic applications”, Journal of Optoelectronics andAdvancedMaterials-Rapid Communications, Vol 5, 879–882, Aug2011.
4. Srujanapothugunti and ChandanaViswanadham, “VSWR and Bandwidth Enhancement of an inset fed patch antenna”International Journal of Electrical and Electronics Engineering &Technology,ISSN. 2319-2518,Vol.6,No. 2,April2017.
   https://omnexus.specialchem.com/selection-guide/polyethylene-terephthalate-pet-plastic
5. Diego Betancourt and Joaquin Castan,”Printed Antenna On Flexible Low Cost PET Substrate for UHF Application”, Progress in Electromagnetics Research C,Vol.38,129-140,2013.
6. Muhammad AamirAfridi ,”Microstrip Patch Antenna − Designing at 2.4 GHz Frequency”, Biological and Chemical Research, Volume 2015, 128-132 | Science Signpost Publishing, Published,128-132 March 25,2015.
7. A.Benchirouf,,R.Zichner,C.Muller, O.Kanoun,“Electromagnetic simulation of flexible strain sensor based microstrip patch antenna “International Journal of Microwave and OpticalTechnology,Nov2015.
8. ArshadHasan, et al: “ Inkjet Printed antenna on thin PET substrate for dual band Wi-Fi communications”, Microsystems technologies Aug 2016 , DOI: 10.1007/s00542-016-3113-y.
9. PoojaSiriya, J. A. Shrawankar, S. S. Balpande, “Design And Development of Inset FeedMicrostrip Patch Antennas using Various Substrates”, International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Volume-8 Issue-9, July2019.
10. Pradeep H S “Inset Fed Microstrip Patch Antenna for X-Band Applications”, International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE), ISSN 2394-6849, Vol 5, Issue7, July2018.