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Introduction to Conducting Polymers in Designing Microstrip Patch Antenna for 5.8 GHz Wireless Applications

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***Abstract*-The paper highlights the possibility of using Polypyrrole (PPy) for planar microstrip patch antenna (MPA).The MPA has been designed using a conducting polymer PPy and Plexiglas™ laminate with a thickness of 1.8mm. The bulk conductivity of polypyrrole is 1200 and thickness is taken as 90mm.An analogous structure is designed using copper patch validating the design and comparing the performance. The antenna was designed for operations at 5.8 GHz. The PPy structure shows a gain of 4.6dB in contrast to 4.8dB gain of Cu structure. A comparative analysis is done between performance characteristics of Cu and PPy material fabricated on Plexiglas substrate results with good performance of PPy material. The result obtained confirms the advantage of using polymer materials in microwave applications as compare to the copper generally used.**

***Keywords*- Polypyrrole, Plexiglas, microstrip patch antenna (MPA), Conducting polymers.**

I. Introduction

Microstrip antennas are the widely used in wireless applications due to their compact size and higher bandwidth. In last some years a lot of research is done on MPAs including planar as well as non-planar structure resulting in flexible design. The change in the operating frequency of a thin substrate microstrip antenna due solely to small tolerance-related change of the substrate dielectric constant may be expressed as:

$$\delta f / f o = -\delta \epsilon_r / 2\epsilon \qquad (1)$$

Where f_o is the resonant frequency ε_r is the relative dielectric constant, δ_f is the change in resonant frequency $\delta\varepsilon_r$ is the change in relative dielectric constant. [1]

MPA finds high applications in mobile communication. Recently research is focused on search of new efficient material for MPA designing. This follows the trend of using CP (conducting polymers) for planar MPA antenna. In this proposed structure dielectric constant technique is being used by deploying an unconventional substrate material as Plexiglas acrylic sheet.

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It is lightweight transparent thermoplastic used in place of glass. Another modification is the use of conducting polymer i.e. PPy as an alternative to copper for planar antennas. This finds application where light weight, inexpensive, or wearable or conformal antennas are a consideration.

The conductivity of conducting polymers is 10^{-10} to 10^{7} S/m which lies between the range of insulators and conductors [3]. These are known as “organic metals”. Plexiglas is an organic structure acrylic material having better properties than its Plexiglas founds applications in various fields such as residential, commercial, industrial and professional. It has numerous properties such as dimensional stability, i.e expansion and contraction due to temperature and humidity. Electrical conductivity defined as an excellent insulator with high dielectric constant which changes with frequency variations leading to certain tunable applications [7]. Due to these properties the selection of Plexiglas as substrate for the structure was on the premise that a successful antenna design on Plexiglas may lead to development of some interesting low-cost conformal and planar future design including optically transparent microwave antennas.

There have been isolated efforts in the past towards using CP as material for antenna design. The same structure has been simulated at 2GHz frequency. In particular, Solberg Jr. *et al.*[4] used a conducting polymer (CP) composite to build a non-planar direction finding antenna operating in the frequency range of 30MHz to 1GHz. Cichos*et al.* [5] has tried using polymeric film silver flakes for designing low cost RFID coil antenna. Rmili*et al.* [6] has reported fabricating a rectangular micro strip patch with the fabricating element made of polyaniline (PANI), a CP having a bulk DC conductivity of 6000S/m.

For future perspective the bulk conductivity of PPy can be made equal to that of copper by its more efficient oxidization. PPy when convolved with Plexiglas may make a promising light weight, low power conformal antenna. For PPy material the dielectric constants and optical conductivities were determined at microwave and infra-red region by analysis of reflection and transmission intensities at normal incidence. Thus, PPy can be highly advantageous in infra-red optics and electronics where material characteristics like reflection, absorption and conduction are highly critical to analyze [7].

II. Antenna design

Two identical MPAs are designed and simulated using HFSS using Plexiglas as substrate of 1.8mm, dielectric constant of 3.4 and loss tangent of 0.001.The first MPA is designed with 90µm PPy thickness. An identical MPA is designed using copper on Plexiglas having thickness of 17µm respectively for direct comparison of relative performances. The design is coaxially fed.

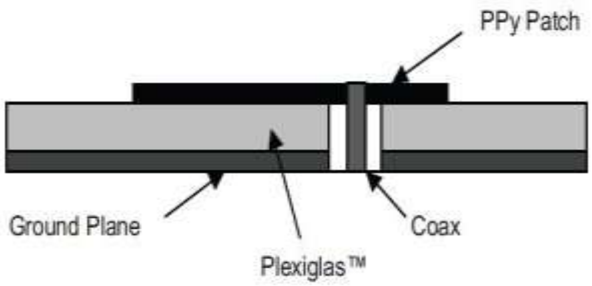

Fig 1: Side view of PPy design

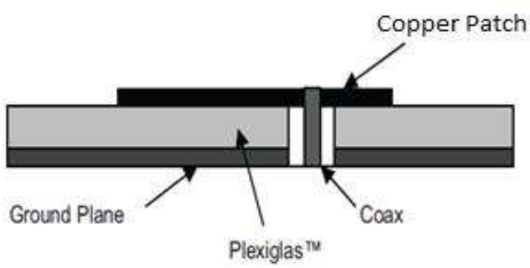

Fig 2: Side view of copper design

TABLE 1.DESIGN SPECIFICATIONS OF ANTENNA STRUCTURE

PARAMETERS	COPPER-MSA	PPy-MSA
SUBSTRATE		
Thickness	1.8mm	1.8mm
Dielectric constant	3.4	3.4
Loss tangent	0.001	0.001
Dimension	80mmX80mm	80mmX80mm
PATCH		
Length	14.16mm	14mm
Width	12.9mm	12.9mm
COAXIAL FEED		
Off center	(0.3.61mm,0)	(0,3.21mm,0)

The relative permittivity of Plexiglass ranges from 2.4 to 3.7, the chosen one is according to the compromise for both the structure. The design parameters of both the structures are shown in table 1.

Patch calculation are based on operating frequency 5.8GHz.The patch thickness is of great importance when dealing with PPy material. The skin depths for the patch antennas at 6 GHz are 145 µm for PPyand0 .85 µm for Cu [6].

III. Results

The basic design of both the MSA in software are shown below:

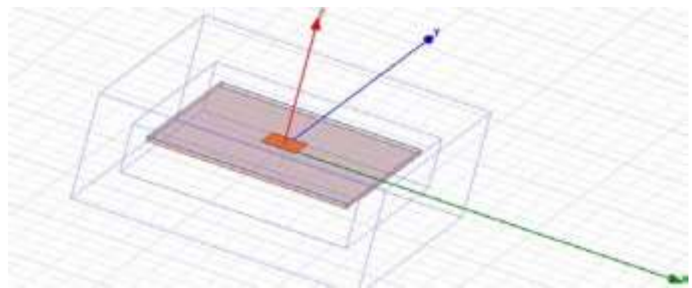

Fig 3: Design of antenna structure

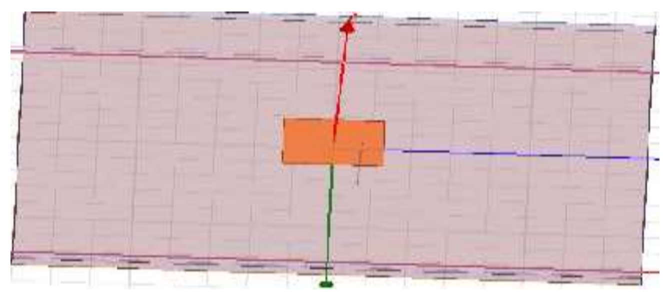

Fig 4: Patch design with coaxial feeding

The return loss measurement of PPy and Cu structure is shown in figure below:

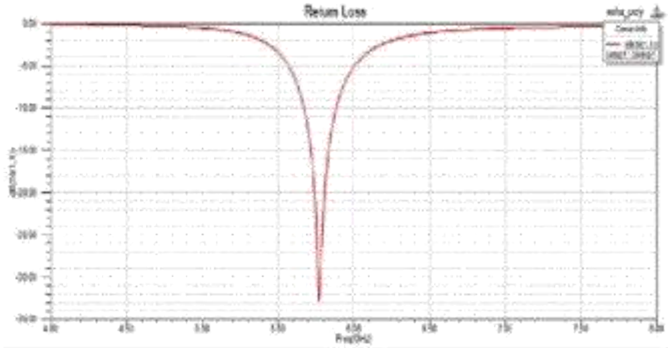

Fig 5: Return loss of PPy MPA as -32 dB at 5.8GHz

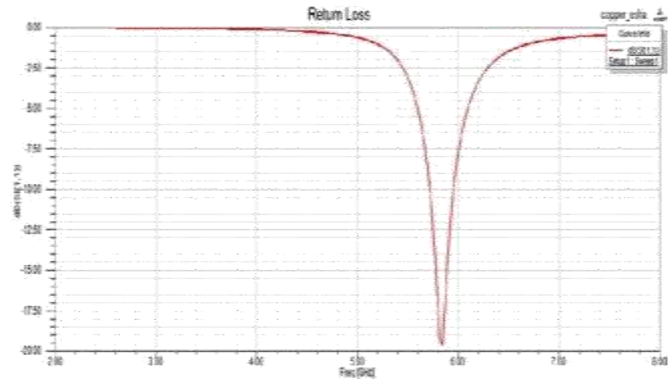

Fig 6: Return loss of Cu MSA as -19 dB at 5.8 GHz

The return loss shows a good agreement between resonant frequencies and bandwidth which validates the structure and also the use of Plexiglas. Also the performance comparison for both the structures on the basis of return loss is efficiently done with better result of PPy design.

Smith chart plots are of great importance for antenna design as it involves VSWR calculation and inductive/capacitive behavior of antenna at resonant frequency. Hence, the input impedance for both the designs are plotted and compared below

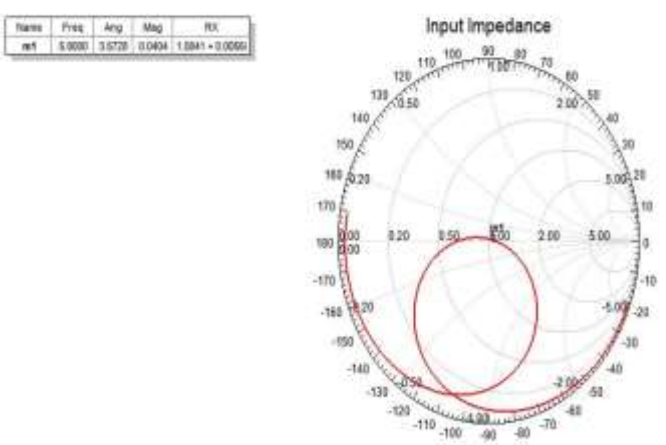

Fig 7: Input impedance of PPy structure

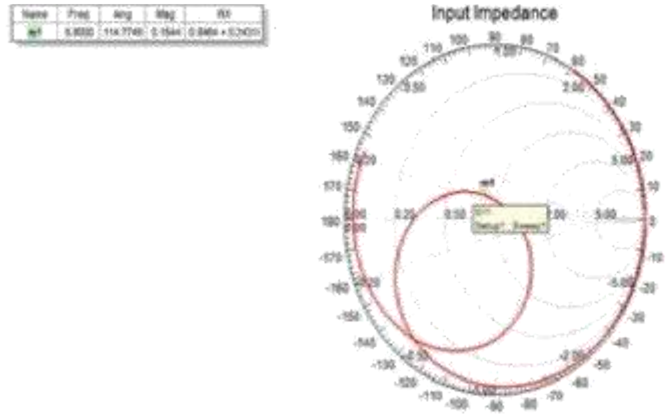

Fig 8: Input impedance of Cu structure

From above plotted figures showing input impedance variation at different frequency, VSWR of 2.5 is calculated for PPy patch and 1.5 for Cu patch. Figures above clearly show that PPy structure has better matching from copper structure, also improved VSWR.

Gain plots of both the designs are shown in which gain is plotted with respect to theta angle of orientation in space.

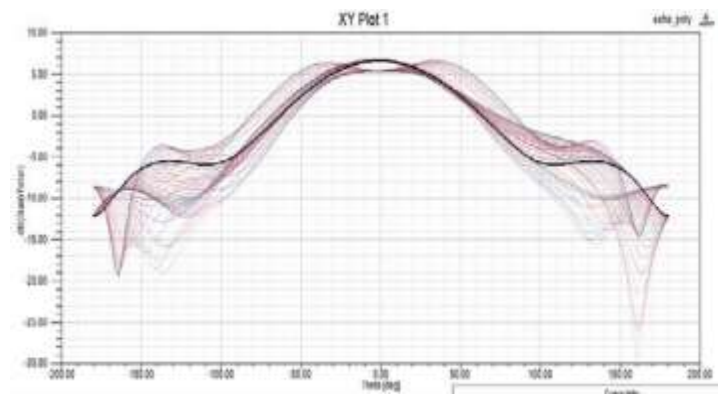

Fig 9: Rectangular gain plot for PPy patch

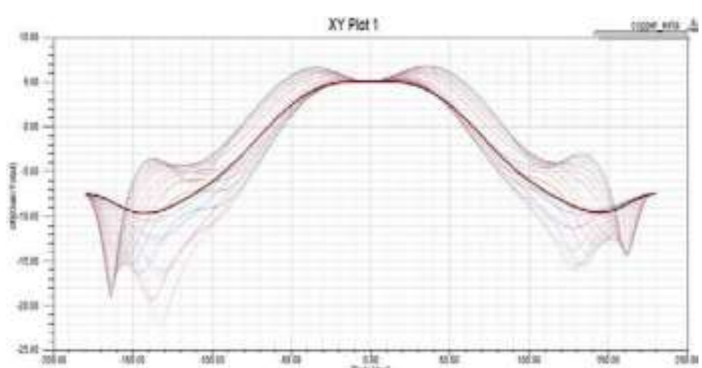

Fig 10: Rectangular gain plot for Cu patch

From figures plotted above maximum gain for both designs is analyzed where $gain_{max}$ of 5.2 dB at θ=0˚is obtained for PPy patch and $gain_{max}$ of 4.1 dB for θ=0˚ for Cu patch respectively. The above plots can also be justified by polar plots curve for both designed antennas.

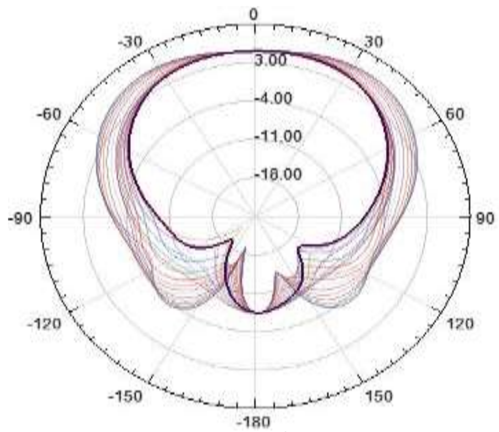

Fig 11: Polar plot for Cu patch

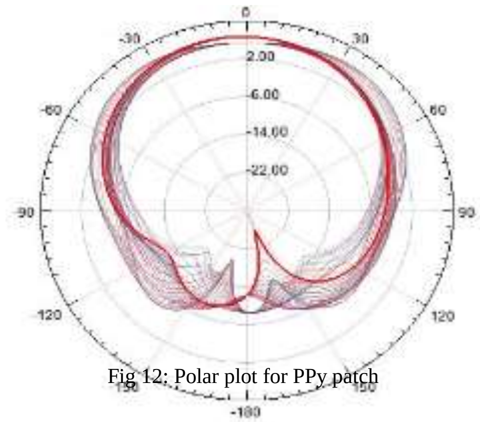

Fig 12: Polar plot for PPy patch

Analyzing the above results we can summaries the simulated results for both the structures as given in table 2 below.

TABLE 2: SIMULATED RESULTS COMPARISON

PARAMETERS	PPy MPA	Cu MPA
Maximum U	0.0007329 W/Sr	0.0008147 W/Sr
Peak Directivity	4.857	5.03
Peak Gain	4.618	4.87
Front to Back ratio	13.5254	12.587
Radiation Efficiency	.960	.964
Return Loss	-33 dB	-19 dB
VSWR	1.5	1.8

IV. Conclusion

This paper presented a proposed structure of microstrip structure with PPy patch and a non-standard substrate, Plexiglas. A reference structure with copper patch has also been designed which shows equivalent performance of both the structures. It shows that the proposed structures of PPy and Plexiglas shows analogous applications to copper in microwave applications. In this way, use of Plexiglass and PPy patch can bring a new era of advancements in antenna designing. From the comparison between two designs, it can easily be concluded that Plexiglass material gives a good competition to copper with the comparative values for gain and return loss respectively.

This structure in future can be used as a resonant one in antenna deployment. Array design of PPy MPA results in more high directivity and radiation intensity. More conducting polymers are now area of interest for researchers to obtain much better results for Electronics Communication system.

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