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COMm.PAT- Printed Antenna on a Non-Conventional Substrate for Communication

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Abstract: *Antennas used for communication purpose have been grown recently using the direct printing methods to ensure light weight technology, ease of fabrication and simply available flexible substrates in the field of printed electronics. The use of flexible non-conventional substrates in this regard has been the current issue for the provision of same results obtained as that of using a conventional substrate. In this paper, we propose low cost printed antenna on a non-conventional substrate that provides higher read range (using ISM Band) for Real time location systems (RTLS) (for e.g. wireless sensing). This antenna makes use of the deployment techniques that involve the selection of environment friendly RF substrate thatcan be served by the localized networking companies in low cost.It further evaluates the substrate characteristics and mathematical properties using the EM Simulator Software (HFSS-High Frequency Structure Simulator) followed by the fabrication of antenna, both on a conventional PCB (FR4) substrate and on a non-conventional substrate (Kodak photo paper) having different materialistic properties using a direct write printing technology. The results include the resonant frequency and the input impedance matching for the feed on a Vector Network Analyzer.*
Keywords:*Low cost eco-friendly Antenna, nano-silver particle ink, Non-conventional substrate, printed antenna design parameters,*

I. INTRODUCTION

Several researches have been conducted related to the organic substrate used in antennas for low cost and wider range applications. In this regard Patch antennas and other forms have also been developed for better utility and provision of reliable functions such as RFID and sensing applications and in other fields of photonics and microelectronics ([1], [2]). Not only in RFID sensing and tag systems, but the work has also been done on cognitive radios using the flexible antennas and Wireless sensing Modules in UHF band ([3], [4], [5]).

These proposed schemes didn't take into account the real time systems and their performance measurements to be used by the networking companies for transmitting the signals for communication; rather they focused on the energy consumption and storage of the field. We aim to develop an antenna that can be easily used by companies in place of the conventional antennas and the parameters chosen include resonant frequency, Impedance and field plots. The idea starts with the materialistic properties of conventional antenna formulated on EM simulation software (HFSS). The extensive study and design of antenna on a substrate like Ceramic and FR4 has been done so as to compare results with the antenna made on a non-conventional substrate [6]. The simulation and fabrication techniques using the conductive ink have been utilized in the above proposed articles and their deployment methods have been prominently used ([7], [8], [9]). In this paper, we aim to cover the following important technological aspects:

1. Flexible and low cost passive RF substrate utilization
2. To provide a reliable source of communication with printed antenna
3. Compact Size, Better performance and efficiency with in the available resources

The paper includes the Overview of COMm.PAT that describes the way of conduct and basic parameters considered during the research along with the brief introduction of simulation and fabrication techniques. It then extends with the Antenna Design which includes the antenna mathematical and materialistic properties that in turn affects the operating frequency, impedance and radiation patterns of the field. Later, Simulation and proposed Fabrication process using the nano-silver conductive ink is described in which three parameters were brought under consideration. i.e. Resonant Frequency, Radiation Field and Input Impedance.

II. OVERVIEW OF COMM.PAT

The key idea of COMm.PAT is to convert the patch antenna operating in the ISM range of frequency on a non-conventional substrate. This is done by studying the formally used patch antennas for communication purpose and their configurations on an EM design software and later the substrate properties of the non-conventional antenna (like photo-paper, Kapton film etc). The simulated design is then printed using both conventional and non-conventional printing techniques. This section covers the three basic phases and the challenges faced in every phase. The detailed design is described in Section III.

1.1 Antenna Overview

As the basic approach, the research was formulated by studying the basic antenna parameters involving gain, polarization, directivity, operating frequency etc. The next task after the basic study of antenna characteristics was to select the type of antenna for communication purpose and the feeding method for the patch antenna.

1.2 HFSS (EM Simulation Software)

The EM software chosen for simulation is ANSYS-HFSS. It is the industry-standard simulation tool for 3-D full-wave EM field simulation and is important for the design of high-frequency and high-speed component design. The ultimate task of our project is to reproduce an antenna used for communication on a non conventional substrate. Simulation of the antenna on a conventional substrate was completed and later three paper properties were selected where the characteristics were implanted with the dielectric constants and tangent loss properties on the substrate and results were evaluated for the cost of varying patch dimensions and resonant frequency.

1.3 Fabrication

The fabrication process included the printing of an antenna which was originally designed on a PCB (FR4 Substrate) so that it is used as a reference while evaluating the results of a non-conventional antenna. The fabrication process also includes the direct printing technique on the paper-like substrate of the antenna using a nano-conductive particle ink.

III. ANTENNA DESIGN

Paper is an organic-based substrate which is widely available everywhere. The frequent demand and the massive production of paper make it the cheapest material for any purpose. It is well suited for reel-to-reel processing and for being a perfect lossless dielectric insulator. The foremost approach is to find out the paper characteristics and its relationship with the antenna parameters. The information of the dielectric properties, such as the dielectric constant (ϵ_r) and the loss tangent (tanδ) are necessary for the design of any an antenna on the paper substrate and especially when it is to be kept inside the substrate. The properties of patch were evaluated and the relationship of the patch dimensions with the resonant frequency and effective dielectric constants were reviewed. This gives the following relationships:

$$\epsilon_{ref} = [(\epsilon_r + 1)/2 \ + \ (\epsilon_r - 1)/2] \times [1 + 12(h/w)]^{-1/2} \quad (1)$$

$$W = C / [2f_0 ((\epsilon_r + 1)/2)^{1/2}] \quad (2)$$

$$f_r = 1 / (2 L (\mu_o \epsilon_o \mu_r \epsilon_r)^{1/2}) \quad (3)$$

After finding out the material properties and the impact of these properties on the antenna, a proper antenna design was simulated on EM design software, i.e. HFSS- High Frequency Structure Simulator. For this purpose, the antenna design was selected which can be suitably converted on a non-conventional substrate and can give the same results as that of a conventional antenna. For this purpose a T-shaped antenna was studied that was meant to resonate at 2.4 GHz. Many T-shaped antennas were already formulated in researches and it was best found to work for WLAN applications to construct small networks up to the range of 100 meters shown in Figure 1. We found this kind of antenna best, to get started with.

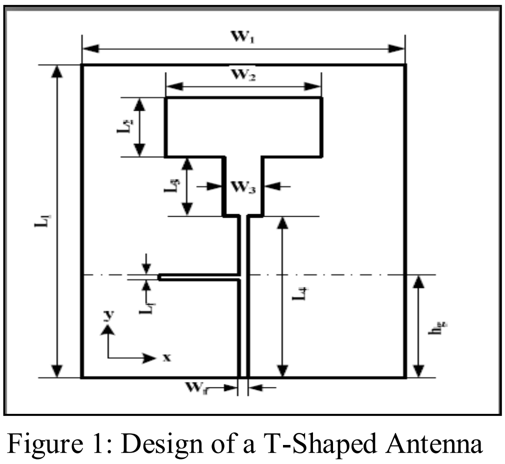

Figure 1: Design of a T-Shaped Antenna

IV. SIMULATION PROCESS

After studying the literature of antenna, it is simulated on an Al_20_3 substrate. This ceramic based substrate is widely available and is being used to design the patch antennas in the GSM modules and RF transmitters. Another conventional substrate (FR4) was simulated because of its better result provision and less spreading characteristics. The antenna was designed on HFSS with the patch's dimensions to resonate at 2.4 GHz; later the S11 parameters were observed (Fig. 2 and Fig.3). Note that the conventional antenna was first formulated so that it can be used to compare the results with the one designed on the paper.

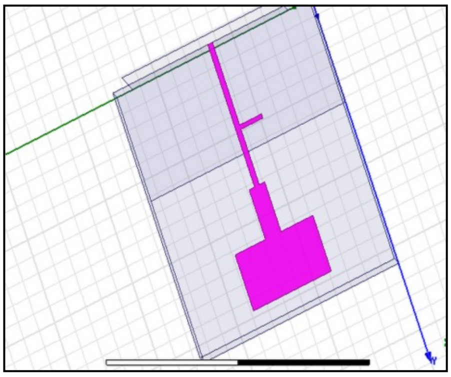

Figure 2: Design of the Patch Antenna on HFSS

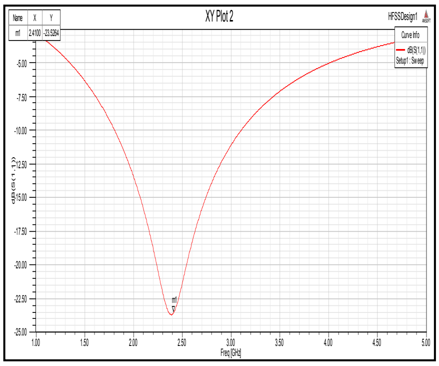

Figure 3: Result showing f_r vs. S11

After producing the results of the T-shaped antenna on a conventional substrate (i.e. FR4), the substrate was changed and the results were reproduced by varying the patch dimensions, wave port excitation and the substrate's thickness. Three photo papers were initially selected bearing the materialistic properties as shown in the TABLE.

Table 1: Different paper based substrates and their characteristics

Substrate	Thickness	Permittivity	Loss Tangent- @25 C
Kodak photo paper	250 um	3.3	0.077
Hp photo paper	250 um	3.3	0.04
Felix photo paper	250 um	3.2	0.077

The permittivity, loss tangent and thickness were put and the patch dimensions were varied respectively to get the same operating frequency (i.e. 24 GHz). The shape of the antenna did not change but according to the formulae described above, it was noted that increasing the length and width of the trace decreased the resonant frequency and the substrate thickness changed the permittivity (dielectric constant) respectively. Best results were obtained on the Kodak Photo Paper with a slightly different S11 value of 24.89 dB as compared to the previous value of 23.526, acceptable in our case. The results over all were exactly replicated and the radiation plots were evaluated as shown in Fig. 4 and Fig. 5 for conventional and non-conventional antenna respectively.

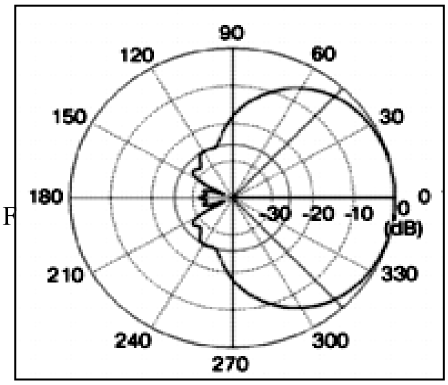

Figure 5: Elevation plane pattern on FR4

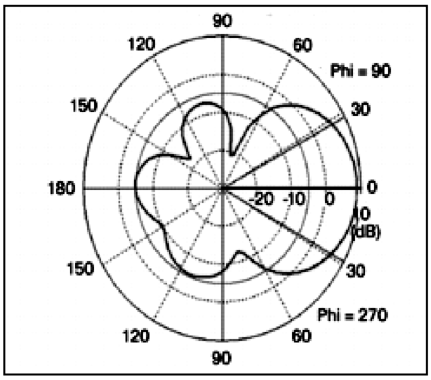

Figure 5: Elevation plane pattern on FR4

V. FABRICATION

The fabrication process includes the printing of the antenna on a non conventional substrate like paper. The purpose was to make the antenna using a non-conventional substrate conductive by using silver nano particle ink. For this purpose, a PCB antenna was designed on the FR4 substrate with its characteristics. Later its interconnections were set using Sub Miniature (SMA) connector that bounded the input impedance at 50 ohms. The interconnections were made using the soldering techniques as shown in Fig. 6. The antenna on a conventional (FR4) Substrate was tested using the Vector Network Analyzer (VNA), the results of which are shown in Fig.7. It was shown from the figures that results were obtained at 2.4GHz with a slight difference of VSWR. The next task is to translate the antenna on a paper-like substrate. The procedure is held using the nano-silver ink that produces conductive traces. The interconnections are meant to provide 50 Ohms input impedance and the final antenna was meant to resonate at the operating frequency equal to 2.4 GHz.

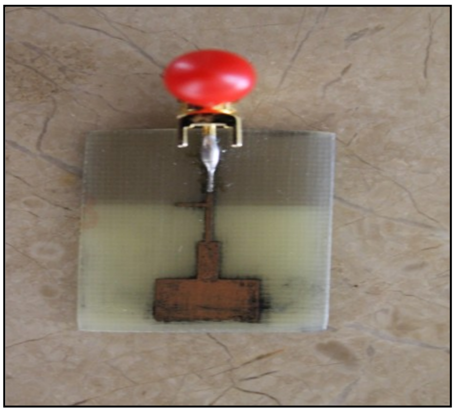

Figure 6: PCB Design of a T shaped Antenna

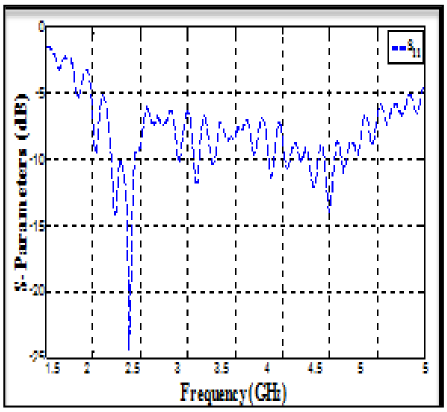

Figure 7: S Parameters and Frequency on VNA

VI. CONCLUSION

The antenna on a non-conventional substrate (Photo-paper) was achieved whose characteristics were similar to that of a conventional PCB. Further work will be done in this regard to bring the entire characteristics of the transmitter/receiver antenna on the paper. This will lead to the eco friendly utilization of the substrate with cost effectiveness.

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