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Design and Development of a High Performance Hybrid Patch Antenna with Enhanced Bandwidth for Wireless Communication

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Abstract—In the current scenario of modern antenna design, patch antennas have emerged as a fundamental component in modern wireless technology due to their compact size, low profile, and versatility in diverse applications. However, to meet the ever-increasing demands for higher data rates, extended bandwidth, and improved radiation characteristics, innovative design approaches have become essential. In conclusion, this research paper showcases the current state of modern patch antenna design, emphasizing the significant improvements in performance and versatility. The research work introspects into the design of a hybrid patch antenna with a modified cutting-edge design employing an optimization techniques resulting in a high performance Patch antenna with better bandwidth and high gain in comparison to its counterparts. The results obtained insights provided in this study will be valuable for researchers, engineers, and designers in the field of antenna technology, paving the way for the development of more efficient designs in hybrid antenna technology.

Keywords-Bandwidth, defected ground structure efficiency,hybrid patch antenna and reconfigurable antennas

I. INTRODUCTION

A Microstrip patch antenna came into existence in the middle of twentieth century. Within a span of two decades, this antenna became so popular due to its inherent advantages that were quite appreciated by the researchers [1]. Furthermore, printed circuit technology was effectively employed in the Microstrip patch antenna that paved ways for integration of antenna within existing wireless systems. This resulted in the fabrication of standalone systems comprising of an array of such elements arranged in a particular pattern [2]. .Recent years have shown a tremendous utilization of Wireless data transmission networks resulting in expansion of Wi-Fi distribution. In order to address the increasing demand of consumers, antennas with higher bandwidth and smaller dimensions are best suited. Figure 1 represents the basic structure of a patch antenna .It primarily comprises of a Rectangular patch coupled with a feed line. In order to facilitate the analysis prediction of the fabricated antenna, the patch shape is generally selected as rectangular circular, triangular, elliptical or some other regular shape[3] Usually for a rectangular patch, the length of the patch ranges from 0.33λ to 0.5λ[4] .

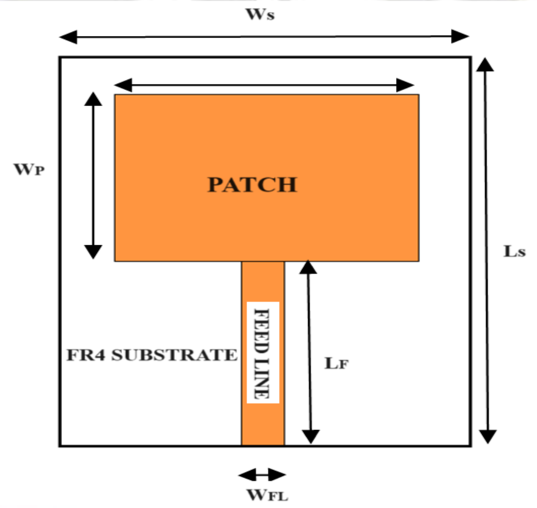

Figure 1. A front view of the proposed Rectangular Microstrip patch Antenna. with dimensional details provided in table 1

Table 1 represents the dimensional details and the design parameters applicable to a conventional patch antenna. This article proposes a hybrid patch antenna design using a combination of T-Shaped and F-shaped patches. The proposed antenna has been fabricated and achieves a bandwidth and gain enhancement by a marginal factor.

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II. DESIGN PROCEDURE

This section provides the design description of the proposed Hybrid rectangular patch antenna using FR-4 operating at design frequencies

A. Adopted Procedure

Figure 2 shows the steps initiated for designing a patch antenna using software simulation techniques. In this paper antennas have been designed at a frequency of 70 GHz. All the four elements have been designed by modifying the patches using a combination of T-shaped and F-shaped elements as shown below. The design makes use of FR4 as a substrate with a permittivity of 3.3[5].It comprises of two rectangular patches of T and F shape that are fabricated on the sides of the patch. The length of the patch is designated as L. In order to estimate the performance comparison of the antennas have been constructed with two different thicknesses.One antenna with a thickness of 0.65mm and 1.35mm for a frequency band of 15 GHz and with thickness of 0.15mm and 0.30 mm for a frequency band of 75 GHz.

The design specifications employed in the proposed design are represented in Table 2.

B. Design Specifications

The proposed patch antenna topology is represented in the Figure 3 below. It comprises of F-shaped and T-shaped slots organized in a symmetrical structure.In Figure 3, the proposed design specifications are represented as L-Length of the patch,

Table 1. Typical design parameters of a Rectangular patch antenna employing FR4

Parameter (symbol)	Details	Typical value
W_S	Width of the substrate	20mm
W_P	Width of the patch	18mm
L_P	Length of the patch	14mm
L_S	Length of the substrate	30mm
f_o	Operating frequency	7GHz
εr	Permittivity of the material	4.5

width of the patch,W_T is the thickness of the Microstrip transmission line.

III. MODELLING TECHNIQUES AND TOOLS

Prior to hardware implementation, circuits and componentsto be used in filter design are simulated in a three dimensional environment known as Field Solvers.. Theseelectromagnetic field solvers provide reliable simulationresults that finally match with the experimentation resultson actual hardware. This aids in reducing the EM designcosts and provide valuable analytical data through whicha designer can visualize how microwave componentsactually behave. This speeds up the design convergenceand leads to design convergence and optimized designselection by validating number of design options in a lessertime. Commercial EM tools currently available amounts totremendous compactness in component size and hence theresultant structure. Trimming techniques are carried out toremove excessive roughage in multilayered devices beforeactual simulation is carried out.Simulation Field solver techniques can be virtually appliedto all microwave components but they render efficientresults for filters.The following field solver techniques have been used forDesign optimization and enhancement in the EBGgeometries for producing efficient devices and components:

A. IE3D

IE3D software is the first scalable Electromagnetic designand verification platform. It is attributed to high modelingaccuracy both for the high-frequency circuit design andsignal integrity engineers across multiple design domains.The high design capacity requirements posed by currenttechnological advancements are addressed by IE3D bothat circuit and component level..This simulation is poweredwith multi-threaded and distributed simulation architectureproviding cost effective solutions coupled with compactdesigns and parametric enhancements. It delivers thedesired design accuracy.IE3D has been extensively used forantenna design

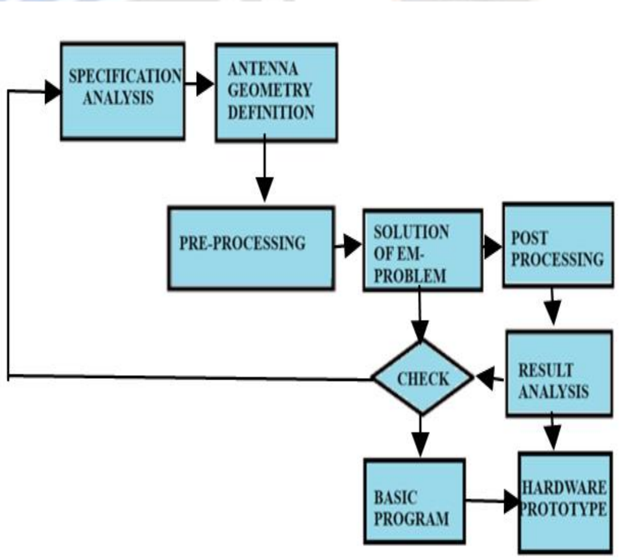

Figure 2. Design steps followed in modern Hybrid patch antenna design

Table -3 represents the design specifications employed in the proposed structure tested for two sets of fabricated antenna configurations.

This is effectively carried out by designinga high capacity unit array cell and the cell is replicated tocreate a large antenna array structure. It also satisfies theboundary conditions and

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offers space optimization desiredfor a large array antenna. It is also used for RFID designthat combines antenna and embedded passive design.Using accelerateddesign closure capabilities of this software, theperformance of the resulting RF-ID tag can be improvised.Furthermore,it can be implemented for complete designingand validation of multi-chip system architectures exploringfull 3D capabilities.

B. HFSS

HFSS(High frequency structure simulator) is a 3D simulation software for designing and simulation of high frequency devices such as antennas,filters,IC packagesPrinted circuit boards. This software is most suitable forhigh frequency circuits suitable for fabricating radars,satellites, Internet of Things(IOT).This software is integrated with versatile solvers and abrilliant Graphic user interface(GUI) for introspectionin 3D EM problems. It is loaded with tools such asthermal, structural and fluid dynamics that are suitablefor multi-physics analysis. HFSS is categorized in thegold standard accuracy range due to its adaptive meshingand sophisticated solving techniques. This is superior as itenhances the quality of design, improves product reliability, compactness and performance.

C. CST Studio

CST(Computer Simulation Technology) studio is capableof simulating and solving problems in all segments ofElectromagnetic spectrum ranging from low frequencyapplications to high frequency, microwave and opticalfrequencies.It comprises of seven different studios namely- MicrowaveStudio, EM Studio, Design Studio, Particle Studio,

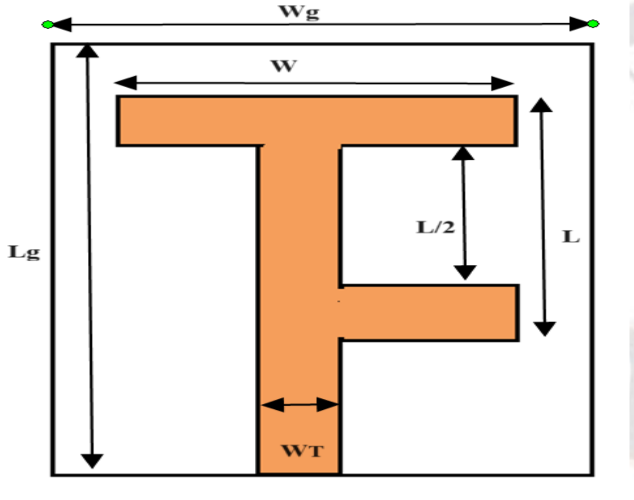

Figure 3. A hybrid patch antenna with T and F shaped rectangular patches for bandwidth enhancement

MPHYSISCS Studio,Cable Studio and PCB Studio.Each studio is utilized for designing of a specific area ofapplication. It provides accurate, efficient computational solution forEM designs. This software can be coupled to performhybrid simulations and the whole system can be visualizedand analyzed in terms of components. It facilitates shorter development cycles and reduced costs. The current areasof interest in which this software is used potentially are-Performance improvement in filters and Antenna circuits,Electromagnetic Interference (EMI), Exposure to fields,Thermal effects in high power devices.

IV. RESULTS

Table 2 presents the results obtained in terms of bandwidth enhancement The parametric details of the incorporated dielectric material, feeding method used and the type of simulation software employed in design-1.In this case the FR-4 substrate with a resonant frequency of 4.06 GHz produces a return loss of -6.4 dB whereas glass epoxy operating at a resonant frequency of 4.1 GHz produces a return loss of -10.4 dB. It is observed that the bandwidth of the antenna in the design is enhanced drastically by around 300 MHZ which is quite phenomenal. It is observed that in the proposed methodology, the simulated and measured values of the return loss display a close agreement which is a figure of merit.

Table 2 Results of antenna performance with two different operating frequencies and dimensions

	Dimensions in mm				Frequency band
	L	**W**	**L_T**	**Wt**	**fr**
Antenna 1	28	33	25	5	15GHZ
Antenna 2	28.5	33	25.1	5.8	75GHz

The set of fabricated antenna s is shown below in Figure 4

V. CONCLUSION

The presented work has highlighted the use of a hybrid combination of elements to fabricate a Patch antenna. The antennas were tested on a set of operating frequencies and different dimensions. It has been established that a trade off between the bandwidth and gain has to be worked out. With increasing gain, we have to compromise with bandwidth and vice-versa.

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CONFLICTS OF INTEREST

The authors state that there is no conflict of interest regarding the publication of this paper.

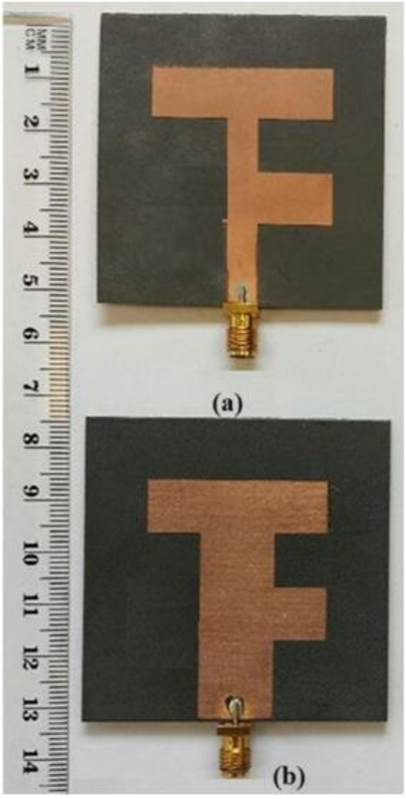

Figure 4. Fabricated antennas with a combination of T and F elements

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