Design and Analysis of Multiband Bloom Shaped Patch Antenna for IoT Applications

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Abstract: A Microstrip Bloom shaped patch antenna is proposed for Internet of Things (IoT) application. This antenna operates at multiband frequencies between 1.6 GHz to 2.45 GHz. The Bloom shaped antenna provides multiband response that examined in HFSS Software. In this proposed antenna design, FR4 substrate material is used because it is easily available and low cost. The proposed antenna structure simulated and analyzed in different experimental results including return loss measurement, Voltage Standing Wave Ratio measurement, radiation pattern measurement and gain measurement. This proposed Multiband Microstrip Bloom shaped patch antenna provides better experimental results in all the parameters

Keywords: Bloom shaped patch antenna, IoT applications, Radiation, Gain

1. Introduction

Compact and low-powered antennas are considered the prime alternative for wireless networks in the new age of wireless networking systems and applications. Figure 1.1 is the Multi-band Bloom shaped patch antenna. Multi-band Bloom shaped Microstrip patch antenna is low power, light weight, easy to make and fabricate, less cost, etc. Because of these focal points, they are used in variety of applications, for instance, satellite, biomedical, radar and communications.

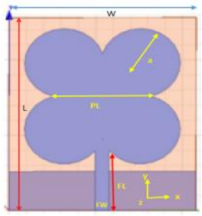

Figure 1.1: Multi-band Bloom shaped patch antenna

The low impedance bandwidth has become one of the major weaknesses of these kind of antennas. Certain other limitations are reduced power management, Excitation of surface wave, low quality of radiation, etc. Several scholars have taken these disadvantages as a challenge in recent decades. Different scientists are working on the construction of wideband microstrip antennas, with a range of methods, including the use of the multiple feeding techniques, shortening pins, the implementation of different slots systems, patch antennas, metamaterials, electromagnetic bandgap materials, etc. [5]. In order to achieve wide impedance bandwidth (0.75–2.48 GHz), circular polarization suitable for navigation and radar is implemented on all four sides using proximity-coupled feeds in square patch antenna. In the blossom shaped patch antenna supported with the circulatory split-ring resonator on the reverse side of the substrate, the researchers have applied fractal geometry. For the planned antenna structure, multiband efficiency can be achieved as per the paper [1].

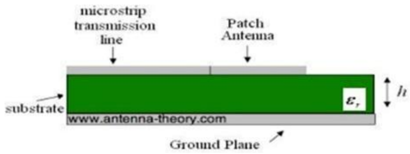

Figure 1.2: Patch

With their innate characteristics of tiny size, low weight, low profile, repeatability, usability, simple design , manufacturing, integration and portability, Microstrip patch antennas have fascinated researchers [6]. All the previously mentioned characteristics are used of these microstrip patch antenna for different applications including the clinical activities, military and space applications. [2] at first planned a rectangular microstrip patch antenna that gives a gain of single band of 7.45 dB. [4] proposed a rectangular microstrip patch antenna for X band which offering a peak gain of 7.69 dB. However, the traditional patch antennas are restricted to a single operating band and also have low antenna bandwidth and minimal gain. Through use of contemporary geometries provides improved features. For fixed satellite applications delivering dual band peak gains of 4.89dBi and 1.89 dBi respectively, a hazard-shaped microstrip patch antenna was proposed in [3]. With an apple-shaped patch that provided a peak gain of 10.12 dBi at 5.35 GHz and 4.27 dBi at 4.89 GHz, a creative geometry were proposed in [4]. Reduced gain and small bandwidth limitations can be solved by framework of either or a mixture of different methods, including the use of parasitic components, use of a small dielectric constant substrate, increasing substrate height, meta-material structures, piling and antenna array. Different resonance modes can be accomplished in a wide spectrum by adjusting the radiation strip / ground flat and the use of varying types. There have been various shapes of the patch antenna, including such E-shaped patch, H-shaped patch, S-shaped patch, etc., relative to all the shaped patch antenna, the E-shape patch antenna is preferable because it solves the detriment of the microstrip patch antenna. The antenna is shown in the figure1.2.

This means that the E-shaped patch antenna has two parallel antennas integrated in the microstrip antenna patch to increase bandwidth.

As per paper [5], the configuration of the broadband diagonally symmetrical bloom shaped patch antenna with reduced ground plane is clarified. For signal excitation, microstrip linefeed is provided with the intended antenna. The antenna is considered for the analysis using an HFSS simulator based on the finite elements and has a wider bandwidth of 1.47 GHz to 2.48 GHz. In order to achieve 49 percent 10dB impedance of the bandwidth relative to center frequency of 1.975 GHz, parametric analysis for substantial design parameters is performed. The prototype antenna is developed and verified to calculate various experimental effects, including loss of return, VSWR, pattern of radiation and gain. Acceptable consensus between simulated and calculated results is achieved [4].

The design of the concentric circular ring antenna is designed for IoT application as per [11] like WLAN, Bluetooth, ISM and WiMAX applications. The antenna provides the triple band characteristics frequencies ranging from 2.21-3.58 GHz having impedance bandwidth of 47.5% at the first band, 4.35-4.56 GHz with impedance bandwidth percentage of 8.9% at second operating frequency and third band ranging from 5.21-5.69 GHz with impedance bandwidth percentage of 10.1% is observed. This antenna provides a bidirectional and omni directional radiation patterns. The antenna provides the high gain of 1.95 at 3 GHz,3.9dBi at 4.29 GHz and 3.5 dBi at 5.4 GHz at three resonating frequency. The radiation efficiency at the three resonating bands is 96% at 2.05 GHz,93% at 4.3GHz and 86% at 5.4 GHz. The frequency reconfigurable properties are observed.

1.1.Gain

Antenna gain defines the proportion power emitted by an isotropic source in the direction of the strongest radiation. The gain in the antenna is cited more often than the direction in the parameters of an antenna since the individual losses are taken into account.

A three dB transmission antenna will result in a distant facility 3 dB higher than that generated from a lossless, isotropous, antenna that is equal input power. The transmission antenna is three dB higher. Keep in mind that an antenna with an output of 0 dB (or 100 percent) would have a lossless antenna. In a certain direction the receiver antenna will be 3 dB more driven than the lossless isotropic antenna with a gain of three dB.

1.2Bandwidth

Another main antenna parameter is bandwidth. The spectrum of frequencies in which the antenna can efficiently radiate or absorb energy is defined by bandwidth. The defined bandwidth is also one of the criteria that cannot be agreed upon by an antenna. Many types of antennas have very narrow bandwidths as an example and cannot be used for wideband service.

$$\text{BW broadband } \equiv \frac{f_h}{f_l} \text{BW narrowband}(\%) \equiv \frac{f_h f_l}{f_c}$$

Where, f_h = Upper frequency f_l = Lower frequency f_c = Centre frequency

Usually, bandwidth is quoted in VSWR terminology. An antenna may also be represented as operating with a VSWR at 150-450 MHz as an example.

1.3.Radiation pattern

The alteration of the antenna-radiated facility depends on the position far from the antenna in a radiation diagram. Such power difference is noted within the far field of the antenna as a function of the arrival angle.

1.4.Return loss

Return loss is the difference between forward and reflected power in dB usually determined on the antenna-connected coaxial cable input. If the source's transmitted power is and the reflected power is restored, the return loss is split by. Return losses should be as minimal as possible for full power conversion. This means that the Pr/Pt ratio should be as minimal as possible. A return loss of -40 dB, for example, is greater than a return loss of -20 dB.

2.Block Design

The overall design of an antenna has been described in a particular organized method which is shown in Fig 2.1. In the initial stage we are going to analyze all the specifications or requirements for the antenna design which is why the initial stage is termed as Analysis of specifications. After analyzing all the specifications, we calculated the geometry part of the antenna design which is done in Antenna geometry definition stage. In this stage the geometrical calculations for the required parameters of an antenna design is done. After the stage of Antenna geometry definition, we are going to check whether the required parameters are necessary in designing of an antenna. This will be implemented in the Pre-processing stage.

After analyzing all the specifications, the calculation of geometry part for the antenna design is done in Antenna geometry definition stage. The implementation of antenna design in HFSS software is done when all the parameters are verified in the Pre-processing stage. When the implementation of design is completed, the errors in the design are rectified in the Post-processing stage. The simulated plots for radiation patter, gain, return loss and

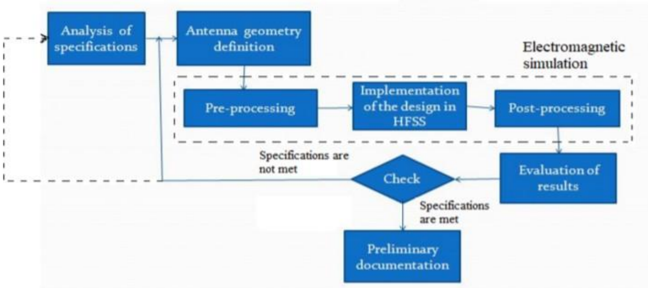

Figure 2.1: Block Diagram of Proposed Method

VSWR are displayed when the Post-processing stage is finished. This is done in Evaluation of results stage. By analyzing the results through the simulated plots, the verification of frequency is done. This has to be done so that we can check whether the proposed antenna design is achieved at desired frequency or not. If we achieve the desired frequency then the documentation of the design is done at preliminary documentation stage. If the desired frequency is not achieved then we should restart the process from the initial stage.

2.1.Bloom Shaped Patch Antenna

The antenna consumes just one patch that is easier than conventional wide-band Microstrip patch antenna. The size of Microstrip patch is portrayed by (L,w,h) and it is taken care of by a coaxial test at position(X_f,Y_f). To grow the reception apparatus data transfer capacity, two equal spaces are joined into this fix and situated evenly as for the feed point.

The mounted state of Microstrip patch takes after the letter bloom hence forth the name bloom molded patch antenna. The opening length (Ls), position (Ps) and width (Ws) are significant boundaries in hand over the reachable transmission capacity. As the correspondence innovation improves higher recurrence range accessible for the more drawn out transfer speed.

Compare to all patch shape bloom shape patch antenna is best because it overcome the disadvantage of Microstrip patch antenna. Due to this bloom shape patch, there is an increase in the bandwidth. It has low profile configuration, less volume, easily mounted, thin weight, low fabrication cost. Bloom shaped patch antenna shown in Figure 1.1.

2.2.Design Calculation

2.3.Width of the patch(mm)

$$W = \left(\frac{c}{2f_r}\right) * \sqrt{2}\varepsilon_r + 1$$

Where f_r =Resonating Frequency, c=free space Velocity-of-Propagation ($3*10^8$ m/s).

2.4.Effective Dielectric Constant

$$\boldsymbol{\varepsilon_{reff}} = \left(\boldsymbol{\varepsilon_r} + \frac{\mathbf{1}}{\mathbf{2}}\right) + \left(\boldsymbol{\varepsilon_r} - \frac{\mathbf{1}}{\mathbf{2}}\right) * (\mathbf{1} + \mathbf{12} * \boldsymbol{h/w})^{-\mathbf{1/2}}$$

Where h=Height of patch (mm), w=Width of patch (mm)

2.5.Length Extension

ΔL=0.412h ($\boldsymbol{\varepsilon_{reff}}$+0.3)(W/h+0.264)($\boldsymbol{\varepsilon_{reff}}$−0.258)(W/h + 0.8)

Where h=Height of patch (mm), w=Width of patch (mm)

2.6.Effective Length

$$L_{eff} = \frac{c}{(2f\sqrt{\boldsymbol{\varepsilon_{reff}}})}$$

2.7.Actual Length

L =$L_{eff} - 2\Delta$

3.Design Methodology

Antennas are more considerably than basic gadgets that are identified with each radio. Antenna also referred as transducers that convert the electrical signal to electromagnetic signal. Furthermore, they indicate radio pointers out of the air and convert them into a voltage for upgrading in a receiver. Antennas are in any case significant for sorting out and holding a trustworthy radio association. They can look confused and mysterious to greatest specialists, specifically EEs running with faraway bundles suddenly that arrive in an apparently endless sort of sizes and shapes.

3.1.Ground

As name indicates the antenna floor plane acts as a virtual. It is located that for a monopole antenna like a quarter wavelength vertical, the floor acts as aircraft to reflect the radio waves so that an print of the pinnacle half of the antenna is seen inside the Earth. It is feasible to simulate this characteristic by way of changing the real earth with an accomplishing plane.

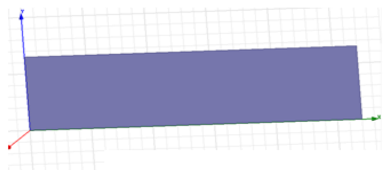

Figure 5.1: Ground

In reality it is not vital to have a complete circular carrying out plate for a floor plane. This might be hard to manipulate in terms cost and additionally the wind resistance. Instead it is normally sufficient to have a ground plane consisting of some of zone wavelength radials. Often 4 conducting radials are used and these regularly provide a sufficient simulation of the complete circular ground aircraft. The proposed antenna design consists the ground with a length (L_g) of 13mm and width (W_g) of 54mm.

3.2.Substrate

Substrate is a dielectric material which is used to analyze electric field and mechanical field stability. Substrate is used to reduce the size of the antenna and also it provides better permittivity and decreased in size of the antenna. Subsequently, a substrate can brighten receiving wire's radiation capacity. So as to plan a Microstrip patch antenna from the outset is to pick the substrate fabric and its thickness.

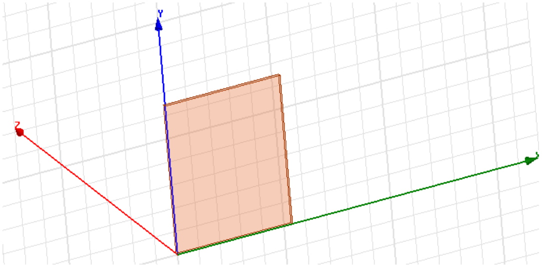

Figure 5.2: Substrate

The proposed antenna design consists of Substrate length (Ls) of 64mm width of the Substrate (Ws) is 54mm and Height of the Substrate (Hs) is 1.6mm. In this design,"FR4 epoxy" will go about as a substrate material with a permittivity of 4.4.

3.3.Patch

The radiation pattern mechanism emerges from incoherence at each shortened edge of the Microstrip transmission line. The edge radiation that reasons the antenna to act narrowly bigger electrically than its real time measurements, so all together for the reception apparatus to be resounding, a time of Microstrip transmission line somewhat more limited than one-portion of the frequency at the recurrence is utilized. The Patch antenna come in various sizes and styles and comprise of a fix of metallic straightforwardly over a ground plane. Figure 5.3 shows that Patch Design for Bloom shaped Microstrip patch antenna.

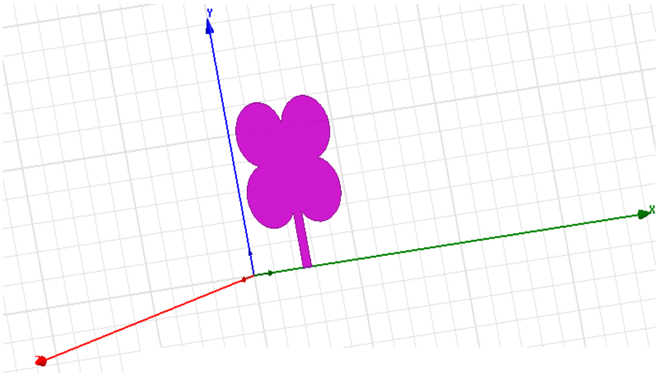

Figure 5.3: Patch Design

4.Bloom shaped Patch Antenna

The Bloom shaped Microstrip patch antenna has following specifications i.e the length of the patch (Lp) and width (Wp). The subtract length and width needs to be considered in Bloom shaped Microstrip patch antenna. Compare to all patch shape Bloom shape patch antenna is best because it overcome the disadvantage of Microstrip patch antenna. Due to this Bloom shape patch, there is an increase in the bandwidth. The antenna has less fabrication cost, effectively mounted, low volume and low-profile design. Operating frequencies of antenna are 1.6 GHz and 2.45GHz. The substrate FR4 is utilized for proposed radio wire with dielectric consistent 4.4 and thickness of 1.6mm.

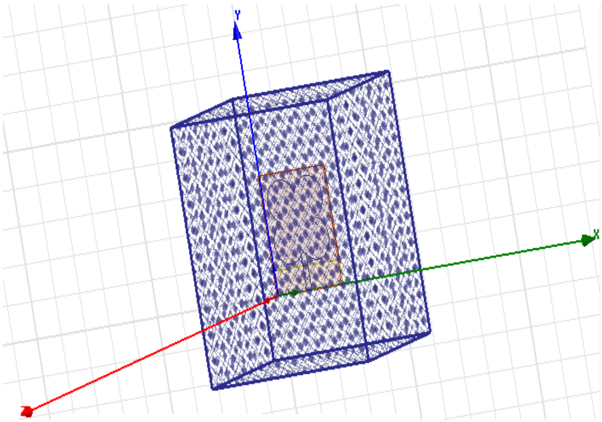

Figure 5.4: Bloom shaped Patch Antenna

5.Results And Discussion

5.1.Bloom shaped Microstrip patch design

Using HFSS tool, the Bloom shaped patch antenna was designed. The proposed antenna structure simulated and analyzed in different experimental results including return loss measurement, Voltage Standing Wave Ratio measurement, radiation pattern measurement and gain measurement. This proposed Multiband Microstrip Bloom shaped patch antenna provides better experimental results in all the parameters

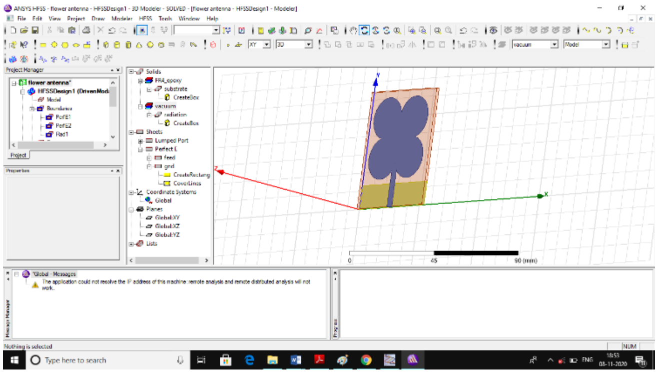

Figure 6.1: Antenna design using HFSS

5.2.Return Loss

The return loss can be appeared in the diagram with X-pivot as Frequency (GHz) and Y-hub as 11(dB). The underlying impedance of the general antenna is 50ohms. In the event that the return loss is - 10dB or less for any radio wire, at that point it will be considered as a decent antenna plan. The return loss is the loss of influence in the sign returned or reflected by an irregularity in a transmission line or optical fiber.

Return loss (dB) = $10\log_{10}(P_{out} / P_{in})$

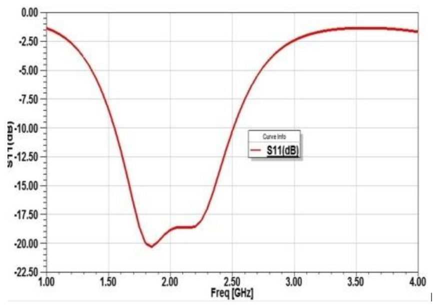

Figure 6.2: Return Loss (dB)

The recreated consequence of the proposed plan works with the recurrence scope of 1.6GHz to 2.45GHz with a return loss of - 20 dB to - 18 dB. Figure 6.2 shows that Return Loss (dB) of Bloom shaped Microstrip patch antenna

5.3.VSWR

VSWR simulation results are obtained using tools from HFSS. Figure 6.3 shows that Voltage Standing Wave Ratio of Bloom shaped Microstrip patch antenna. VSWR graph shows that frequency between 1.7GHz to 2.61GHz exhibits the VSWR in 1.14dB to 1.73 dB.

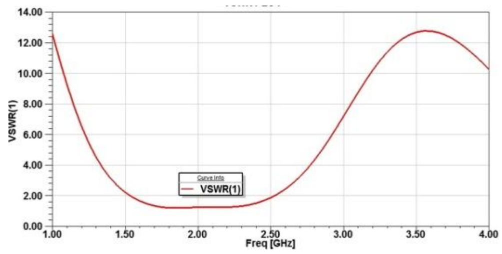

Figure 6.3: VSWR

5.4.Gain

In Figure 6.4 the directivity is the proportion of the grouping of an antenna's radiation design a specific way and proficiency represents the loss of the reception apparatus because of assembling flaws, surface covering anomalies, dielectric, opposition, VSWR, or some other factor. From the graph observed that Bloom shaped Microstrip patch antenna provides better gain compared to other Microstrip patch antenna.

Antenna gain = Directivity x Efficiency

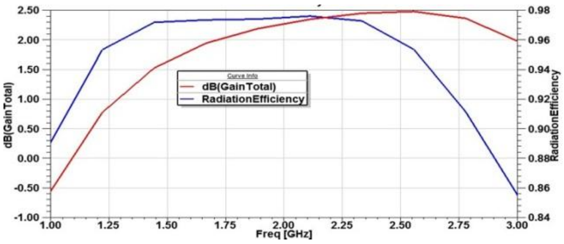

Figure 6.4: Gain

5.5.Radiation Pattern

Fig 6.5 shows that Radiation pattern of Bloom shaped Microstrip Patch Antenna. The Radiation pattern represents the signal power radiated by the antenna at a particular resonant frequency with regard to elevation and azimuth angle. It is clearly noted that a fair degree of arrangement between simulated patterns of radiation pattern is achieved

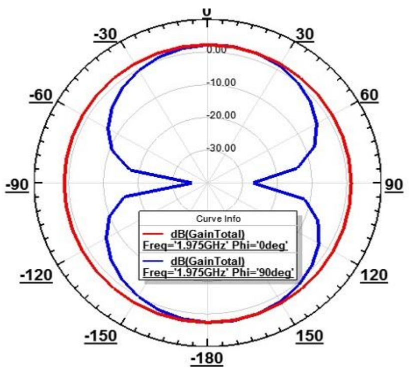

Figure 6.5: Radiation Pattern

6.Conclusion

A Microstrip patch antenna with a conservative size was introduced and researched. An antenna renovation is done on High Frequency Structure Simulator HFSS. The clarification of demarked reception apparatus is streamlined by directing parametric investigation on a few huge plan boundaries named as feed width, feed length, sweep of Bloom petals and decreased ground plane length. The de-sign method starts with deciding the length, width, tallness of fix plane by formulae. The recreated consequence of the proposed plan works with the recurrence scope of 1.6 GHz to 2.45 GHz with a return loss of - 20 dB to - 18 dB. The reception apparatus is appropriately coordinated with VSWR esteem. The planned antenna gives almost Omni directional radiation design broadside way all through the wide working recurrence range. The planned Bloom formed fix radio wire being reduced in size and with wideband execution, is fitting for different convenient applications including GSM, GPS, IMT, Wireless Local Area Network, Wi-Max applications and IoT applications. Our proposed antenna can be used in IoT application.

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