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DESIGN AND SIMULATION OF COMMON FEED WITH DOUBLE MICROSTRIP PATCH ANTENNA FOR DUAL BAND SATELLITE APPLICATIONS

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Abstract:

This paper describes the design of a Common feed with double Microstrip patch antenna for satellite application using FR-4 substrate. The main contribution of the paper is optimized and achieves high gain, high efficiency, very low return loss and ease to adapt in MMIC technology. The proposed antenna is capable to maintain its high performance over wireless system operating at X - band (8-12 GHz) frequency range. The antenna resonates at dual frequency band and thus the antenna becomes a necessity for many applications in recent wireless communication, such as RADAR, Microwave and Space applications. The proposed antenna is fabricated on a FR4 substrate of thickness 0.8 mm and a dielectric constant of 4.4 and tested. The proposed antenna yields a VSWR of about 1.34 (7.99 GHz) and 1.27 (9.99 GHz) under simulation and 1.033 (7.99 GHZ) and 1.098 (9.99 GHz) in measurements respectively. The figure of eight radiation pattern is achieved with antenna gain of 5.63 dBi (7.99 GHZ) and 6.52 dBi (9.99 GHz) under simulation and measured peak radiation efficiency of 97.99% (7.99 GHZ) and 98.31% (9.99 GHz) are observed for the operating bands. Finally, the experimental outcome seems very nexus with the simulated ones for the proposed antenna.

Key Words: Efficiency, Gain, VSWR, Return Loss, Feed & Patch.

1. Introduction:

Antenna is an important device which has become an integral part of our day to day life. It has directional properties. It is the important component of a wireless communication system. There are number of antennas; but all operates with the basic principles of Electromagnetics. According to IEEE standard definitions of terms for antennas, an antenna or aerial is a means for radiating or receiving radio waves. The special class of antennas that is becoming more popular in recent years is microstrip antenna [1]. The microstrip antenna (MSA) is also called as patch antenna or printed antenna. As the MSA are directly printed on to the circuit boards, in the modern era of mobile phone market there is a no other best option than microstrip antennas. There are different types of microstrip antennas but all the types show following common features.

- ✓ A thin, flat metallic region which is commonly called patch.
- ✓ A dielectric substrate.
- ✓ A ground plane which is much larger than patch considering dimensions
- ✓ A feeding network which supply power to the antenna element.

As the fabrication process involved in manufacturing the microstrip antennas is simple to the complete production process and it is easy and very cheap. Due to low cost advantage, mess production of the MSA is easily achievable using modern advanced printing circuit technologies [2]. The MSA is the most suitable option where thickness and conformability to the surface of a platform are the main requirements. The microstrip antennas are narrow band antennas typically. In most of the applications it is observed that the bandwidth is limited further due to the mismatch of the impedance of antenna with feeding circuitry. So by selecting proper feed technique and feed location, a resonant resistance of antenna is matched with that of the feeding circuit and thus impedance matching is done over a limited bandwidth [3]. The feeding techniques used in the microstrip antenna are classified into two major types. Contacting feed: In this method, the patch is directly fed with R.F power using the connecting element such as microstrip line or co-axial line. Non-contacting feed: In this method, the patch is indirectly fed with the R.F power but instead power is transferred to the path from the feed line through electromagnetic coupling [7]. This paper is organized as follows: Section II deals with literature review. Section III illustrates the methodology of the proposed antenna. Section IV describes simulation and results. The final section summarize conclusion of the paper.

2. Literature Survey:

A fractal microstrip patch antenna of length 37.6218mm using Rogers RT duroid-5880 as a substrate of thickness 2.6mm and that antenna resonates at 6.48GHz, 7.51GHz,8.44GHz and 9.18GHz with moderate gain [1]. The microstrip patch antenna was designed with nylon fabric material with dielectric constant is 3.6 and designed frequency of 989MHz and gain of an antenna is 6.11dB and simulation was done using ADS simulation software [2]. A single element microstrip rectangular patch antenna with air gap was designed using FR-4 substrate and compared to other patch antenna gain was increased, antenna gain was increased from1.80dBi to 9.58dBi and the efficiency was enhanced from 30.2% to 94.6% [3]. An E-shaped microstrip patch antenna was designed for Ku band application and operating over 12.25GHz, 13.4GHz and 14.5GHz frequencies and simulation of the antenna was done over in-house MATLAB program software [4]. A Rectangular microstrip patch with-out need of an external coupler or polarizer and designed antenna has bandwidth from 6.85 GHz to 7.15 GHz and slits have been introduced on the collinear sides of the patch to improve return loss and decrease solution frequency and the simulation results states that the X band antenna achieve a high return loss beyond 27 dB [5]. The proposed antenna is compact in size (optimized the structure interms of length and width), high gain, high directivity, and low return loss. The CPS technique is not efficient than the Microstrip feeding technique. The feeding technique which is used in proposed system is very efficient and it is ease to adapt in MMIC (Monolithic Microwave Integrated Circuits) fabrication.

3. Methodology:

MSA is a planar antenna which consists of a metallic patch etched on the dielectric substrate, at a small wavelngth fraction away from the ground plane. The designed common feed with double microstrip patch antenna is shown in Fig. 2. I order to faciliate, a microstrip feeding line is provided. The design flow diagram and structure of proposed antenna are shown in Fig. 1 & Fig. 2 respectively. The wavelength can be calculated by the equation (1) and the basic antenna parameters like width and length can be derived by the equation (2 & 3) as follows. The ground length and width is expressed in equation (4 & 5).

$$\lambda = h * \frac{\sqrt{\varepsilon_r}}{0.06} \quad (1)$$

$$w = \frac{c}{2f_0} * \sqrt{\frac{2}{\varepsilon_r + 1}} \quad (2)$$

$$L = L_{eff} - 2\Delta L \quad (3)$$

$$L_g = 6h + L \quad (4)$$

$$W_g = 6h + w \quad (5)$$

The main aim of the paper is to optimize the structure of the proposed antenna to achieve the better outcomes with lossless FR4 material is used as substrate in MSA. The geometrical dimension for the common feed with double Microstrip patch antenna are tabulated in Table. 1. There are some parameters that affect the antenna performance. Two noticeable parameters that determine the performance of the antenna are length and width of the dimension [4]. The common feed with double Microstrip patch antenna which provides better radiation. The patch radiates efficiently at its edges.

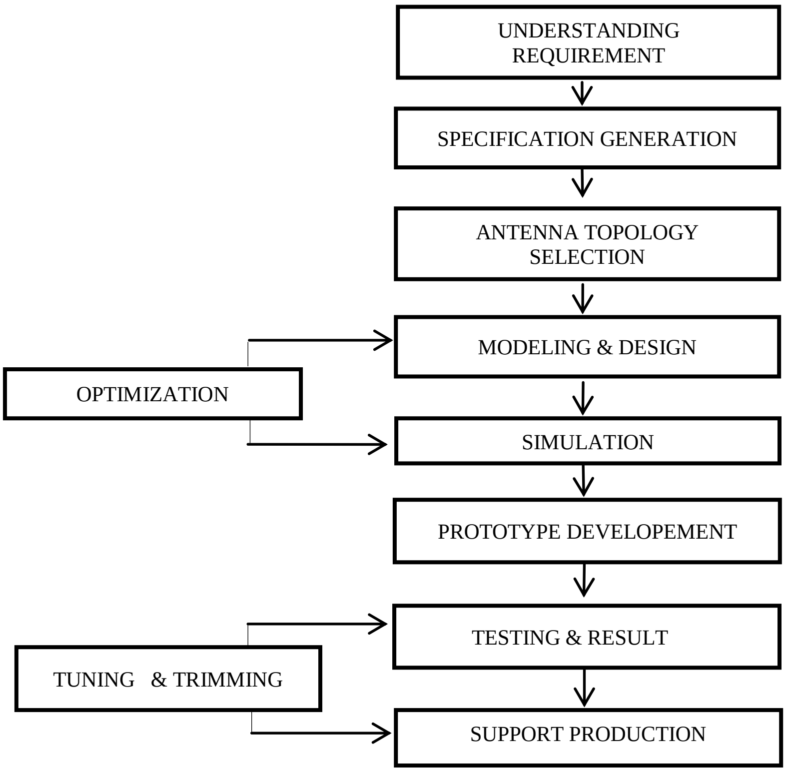

Figure 1: Design Flow Chart

Table 1: Design Parameter of Antenna

Description	Values (mm)
Length (L)	6.37
Width (W)	8.49
Wavelength	0.0279
Ground length (L_g)	22.36
Ground Width (W_g)	26.58
Substrate Thickness (h)	0.8

Moreover, the performance of the common feed with double MSA array is further enhanced with incorporation of its structure and further performance analysis is carried out [5,8]. The quality metrics are evaluated and comparative analysis is demonstrated at end of the next section. The structure of the fabricated antenna is shown in Fig. 3

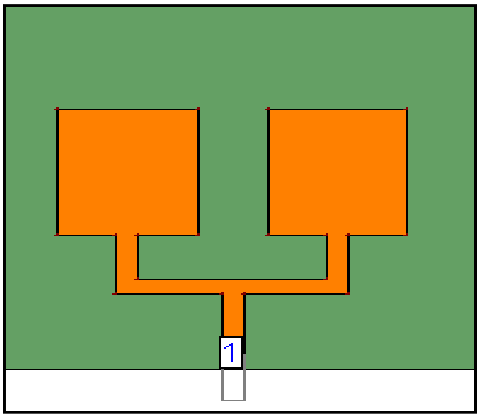

Figure 2: Schematic View of Proposed Antenna

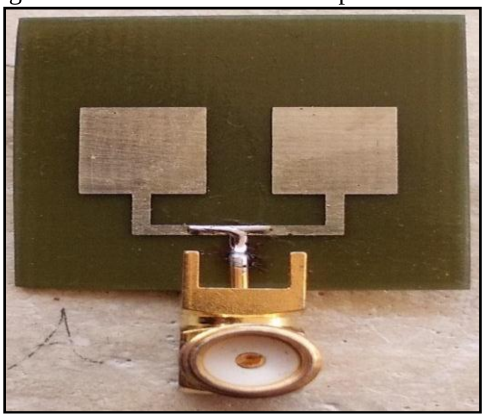
Figure 3: Structure of Fabricated Antenna

4. Simulation Results:

The common feed with double Microstrip patch antenna resonates at the frequency of 7.99 GHz and 9.99 GHz. The values of VSWR, Return loss and Efficiency (Basic Antenna Parameter) of the proposed antenna are tabulated in Table 2 as follows.

Table 2: Simulation Results

Description	Resonant Frequency (GHz)	
	@ 7.99	@ 9.99
VSWR	1.34	1.27
Gain	5.63 dBi	6.52 dBi
Antenna Efficiency	97.99 %	98.31 %
Radiation Efficiency	100 %	100 %
Directivity	5.72 dBi	6.64 dBi
Return Loss	-16.75 dB	-18.50 dB

4.1 VSWR: VSWR stands for Voltage Standing Wave Ratio. It is function of the reflection coefficient, which describes the power reflected from the antenna. The VSWR is always a real and positive number for antennas [6]. The value of VSWR is small, the antenna is matched to the transmission line and the more power is transferred to the antenna. The nominal / minimum value of VSWR is 1.0. At the resonant frequency @ 7.99 GHz VSWR is 1.34 and @ 9.99 GHz VSWR is 1.27 which represented in Fig. 4. It is always real and positive number for antennas. The value of VSWR is very low, it is easy to match with transmission line and the more power is delivered to the antenna and does not necessarily mean the power delivered is also radiated.

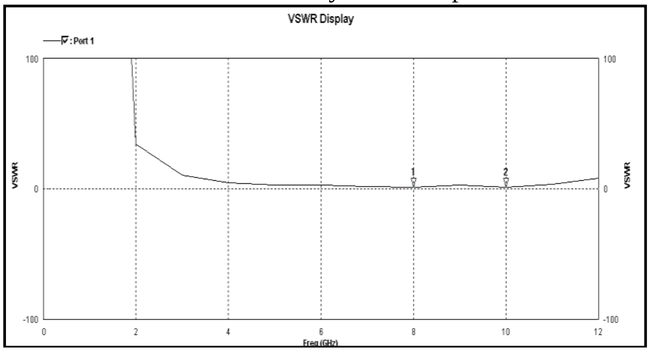

Figure 4: Simulated VSWR Measurement

4.2 Gain: Antenna gain is usually defined as the ratio of the power produced by the reference antenna from a far-field source on the beam axis to the power produced by a hypothetical lossless test antenna, which is equally sensitive to signals from all directions [9]. A plot of the gain as a function of direction is called the radiation pattern. The proposed antenna gain at 7.99 GHz is 5.63 dBi (≈ 8.53 dB) and at 9.99 GHz is 6.52 dBi (≈ 9.86 dB) which is represented in the Fig. 5.

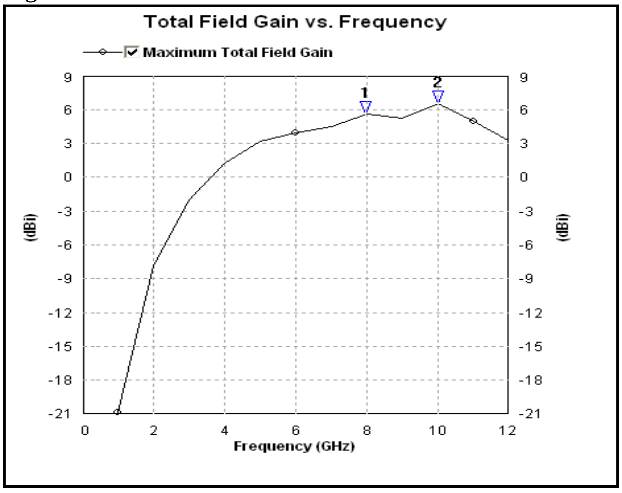

Figure 5: Simulated Gain Value

4.3 Antenna Efficiency: The Efficiency of an antenna is defined as the ratio of the power delivered to the reference antenna relative to the power radiated from the isotropic antenna. A high efficiency antenna has most of the power present at the antenna's input radiated away. A low efficiency of an antenna has most of the power absorbed as losses within the antenna, or reflected away due to impedance mismatch of the device [10]. The simulated efficiency at 7.99 GHz is 97.99% and at 9.99 GHz is 98.31% which is represented and shown in the Fig. 6.

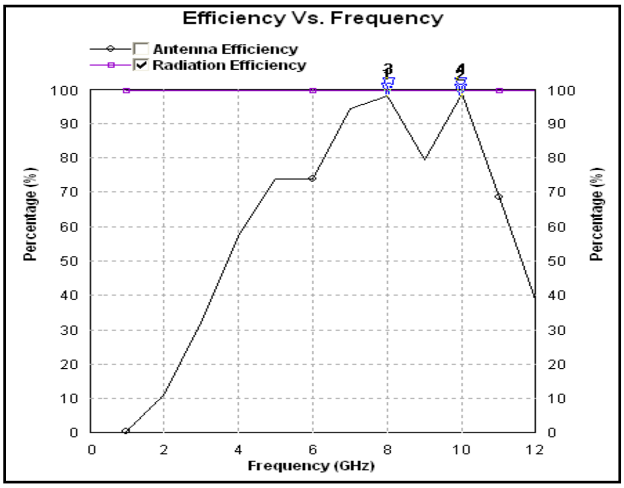

Figure 6: Simulated Efficiency

4.4 Directivity: Directivity of an antenna is the ratio of radiation intensity in a particular direction and the radiation intensity averaged over all directions. The amount of power radiated per unit solid angle. An antenna that radiates equally in all directions would have effectively zero directionality, and the directivity of these types of antenna would be 1.0 dB (or 0 dB). The directivity of proposed antenna at 7.99 GHz is 5.72 dBi (≈ 8.66 dB) and at 9.99 GHz is 6.64 dBi (≈ 10.06dB) which is shown in the Fig. 7.

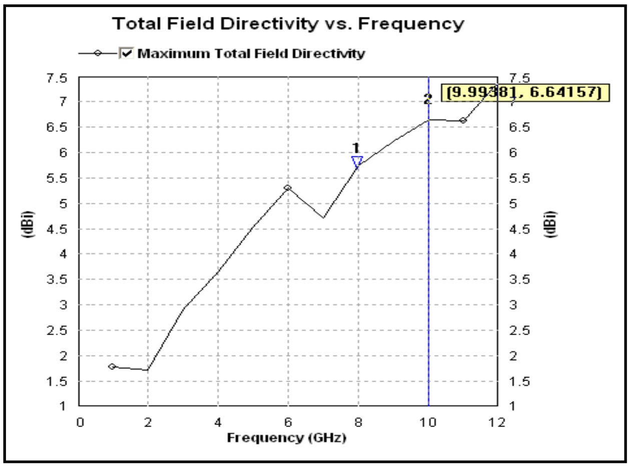

Figure 7: Simulated Directivity Value

4.5 Radiation Pattern: A radiation pattern is defined as a mathematical or graphical representation of the radiation properties of an antenna as a function of space coordinates. The radiation pattern of a proposed antenna is represented in the Fig. 8. It is a 3D figure and represented in spherical co-ordinates (r, θ, ϕ) assuming its origin the centre of spherical co-ordinate system [11]. Fig. 8. Show the figure of eight radiation pattern.

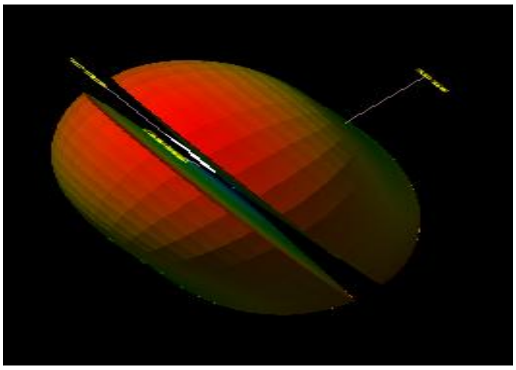

Figure 8: Radiation Pattern

4.6 Return Loss: S – Parameter describes the input and output relationship between ports. The simulated S – parameter value are – 16.75 dB at 7.99 GHz and -18.50 dB at 9.99 GHz respectively and it is shown in Fig. 9. It is a measurement of how much energy incident to a device is being reflected back and therefore, not entering the system. It is related to both Standing wave Ratio (SWR) and Reflection co-efficient. The antenna is the single port network, so the S-parameter is S_{11} which is the reflection coefficient [10]. So the return loss is calculated from 20 log ($1/S_{11}$).

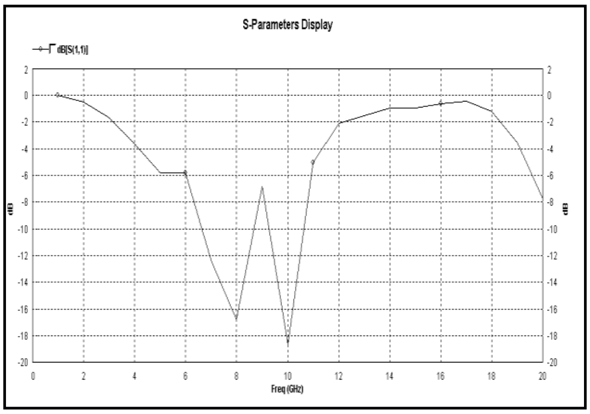

Figure 9: Simulated Return Loss

4.7 Network Analyzer: The prototype design can be tested by using Network Analyzer is shown in Fig. 10. It is an instrument that measures the parameters of the electrical networks. It measures return loss because reflection and transmission of electrical networks are easy to measure at high frequencies [12]. It gives the analysis of various parameters like VSWR, Return loss and Smith chart.

Figure 10: Network Analyzer

Table 3: Comparative Analysis of Performance Metrics

Parameters	Paper [1]	Proposed Antenna
Frequency band	Dual band	Dual band
Resonant Frequency	7.24 GHz & 8.6 GHz	7.99 GHz & 9.99 GHz
Size	18 mm * 28 mm	6.37 mm * 8.49 mm
Gain	4.19 dB & 5.21 dB	8.53 dB & 9.86 dB

To compare the results with an existing system [1], the values are tabulated and shown in Table 3. At last, the proposed antenna is tested using network anlayzer and results of an antenna are listed and shown in the Table 4. The main objective of the paper is to optimized the structure of an antenna (interms of length and width), to achieve high gain, directivity and operated over multiple band of frequency. Finally, the objective of the paper is achieved and results are satisfied.

Table 4: Results of Proposed Antenna

Parameter	Theoretical Value (dB)		Simulated Value (dB)		Tested Value (dB)	
	@ 7.99 GHz	@ 9.99 GHz	@ 7.99 GHz	@ 9.99 GHz	@ 7.99 GHz	@ 9.99 GHz
VSWR	1.23	1.25	1.34	1.27	1.03	1.09
Gain	-	-	8.53	9.86	-	-
Directivity	-	-	8.66	10.06	-	-
Return Loss	-16.8	-18.5	-16.8	-18.5	-41.6	-26.9

5. Conclusion:

MSA have become a rapidly growing area of research. Their potential applications are limitless because of their less weight, compact size, and ease of manufacturing. This paper proposes a common feed with double Microstrip patch antenna is used for Dual band satellite application. The paper proves that the novel approach of optimization of antenna embellishes the performance. Hence the performance of the antenna is carried out and illustrates with various plots. The design achieves the maximum gain of 8.57 dB and 9.87 dB at the appropriate resonant frequency. The introduction of common feed with double Microstrip patch antenna enhances the radiation efficiency more than 95% at compact size of the patch. For future analysis, the Meta material technique can be implemented in order to increase the gain much better. It improves the antenna gain as well as the directivity significantly.

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