Design of a Dual Band Miniature Microstrip Patch Antenna

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Abstract. Microstrip patch antennas perform a major task in current communication techniques. In this paper we mainly specify the model of a dual-band miniature MPA for IoT application. The specific antenna is fed through a 50Ω microstrip line feed. And the architectural layout, and simulation of the expected antenna are done using HFSS software. The ground volume of the planned antenna is 10×6.5mm2. The projected antenna having a relative permittivity of 4.4 on the FR4 epoxy surface, 0.02 loss tangent, and 1.6 mm height. The antenna has a managing frequency ranging from 5.8GHz to 14. GHz with -35.84dB return loss and -17.17dB respectively. And studied in terms of gain and VSWR. The general configuration of the suggested antenna is applicable for easy designing and it can be utilized for Ku-band satellite applications, weather monitoring systems, etc.

Keywords: microstrip patch antenna; Dual band; HFSS.

1. Introduction

An electrical gadget which converts electrical energy to radio waves in an alternative way is called an antenna. We can use antenna as a radio transmitter and radio receiver. In transmission, the radio transmitter produces an oscillating radio frequency, which transmits current to the terminals of the antenna, and like electromagnetic waves (radio waves) transmits power from the antenna[1]. In the receiver, the antenna prevents some quantity of current of the electromagnetic wave to develop a slight voltage at its terminals, And they are connected with the receiver to propagate. Antennas are the basic elements of all gadgets that use the radio. Antennas are used in systems like a radio transmission, two-way radio, broadcast television, communication receivers, cell phones, radar and satellite communications, as well as vehicles, garage door openers, garbage monitors, wireless microphones, Bluetooth and wireless devices, RFID product Tags[2][3].

MPA was first seriously studied in engineering research in the 1970s, and the concept of the MPA was discovered in 1953 by Deschamps. [4] A very thin metal strip is used on microstrip antennas. Although in the MPA design a wide variety of substrates can be used, for the stability of the dielectric substation should be recognized as an antenna performance factors (bandwidth, power efficiency and radiation pattern) [5]. The dielectric constants typical length for microstrip antennas is 2.2 ≤ Ꜫr ≤ 12. The radiation area of microstrip patch antenna hinges on the number of patches acting like one antenna for receiving or transmit the radio waves. The goal of the antenna range is to achieve high gain (directivity) and patch variation (also known as MIMO) to strengthen communication reliability[6].
Planning of an antenna with high gain, low sidelobe level, and lower bandwidth is very challenging [7]. Single antennas do not meet the requirements of communication applications. The antenna yields the desired radiation pattern. There are some limitations to the implementation of thin feed lines due to technical limitations [8][9]. Moreover, when one parameter is designed to improve, the other parameters decrease. For better gain, communication antennas require a lower sidelobe level. In such cases, split ring resonators provide better performance than going for complex feed designs in microstrip antenna ranges [10].

2. About Microstrip patch Antenna

MPA for patch design comes in a variety of textures. In this paper, rectangular patches are adopted for antenna design. Using a variety of methods for implementing antenna modeling and transmission line modeling (TEM), it is designed from the basic configuration equations of the MPA and monitors the patch material radiation on the communication line resonator that does not accept any parallel field deviations. Communication line design is very easy to learn and MPA designing is not a very difficult process. Upcoming equations will be used to determine guidelines or processes for MPA beyond M [11, 12]. The policies are as follows:

1. Width (W) calculation: Having the specified height or thickness of the antenna patch and conforming the antenna patch width is the first step of the procedure. This is estimated by the below equation:

\[ W = \frac{C}{2fr \sqrt{\varepsilon r + 1}} \]

Here, the velocity of light=\(c\), dielectric surface constant =\(\varepsilon r\), \(fr\) = the desired resonance frequency.

2. Effective Dielectric Constant (\(\varepsilon_{reff}\)) calculation: It is estimated by the following calculation:

\[ \varepsilon_{reff} = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2} \left[ 1 + 12 \frac{h}{W} \right]^{-1/2} \]

Here, \(h\) = pinnacle of the dielectric surface, The dielectric persistent of the dielectric surface=\(\varepsilon r\), \(W\) = breadth of the antenna patch.

3. Patch Effective Length (\(Leff\)) is calculated: The patch effective range is estimated by the following calculation:

\[ Leff = \frac{C}{2fr \sqrt{\varepsilon_{reff}}} \]

Here, Light velocity = \(C\), \(fr\) = desired resonance frequency, \(\varepsilon_{reff}\) = constant for effective dielectric.

4. Patch Length Extension (\(\Delta L\)) calculation: As a consequence, the edge field effect around the boundary of the patch, the antenna appears like electrically more considerable than its actual physical size. The length of the patch extension is estimated by the following equation:

\[ \Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)} \]

Here, \(h\) = pinnacle or density of the dielectric surface, \(W\) = patch width, \(\varepsilon_{reff}\) = constant for effective dielectric.

5. Patch Real Length (\(L\)): The exact patch length is calculated by the equation:
Here, \( \text{leff} = \) patch effective pinnacle, \( \Delta L = \) patch pinnacle extension

6. Ground Dimension (\( W_g, L_g \)) Calculation: Ground, width length are calculated by the following equations, respectively:

\[
W_g = 6h + W, \quad L_g = 6h + L.
\]
Here, \( h = \) pinnacle or density of the dielectric surface, \( W = \) diameter of the patch, \( L = \) patch length [6][8].

3. ANTENNA DESIGN AND DIMENSIONS
The specific antenna design is shown in Fig. 1. 10 x 6.5 mm2FR-4 surface specified antenna design, relative permeability 1.6 mm thickness = \( r = 4.4 \), dielectric low tangent \( \delta = 0.02 \), and optimized antenna values as described in Table I.

![Figure 1: Proposed Antenna Geometry](image)

| Parameter | Value (mm) |
|-----------|------------|
| L         | 10         |
| W         | 6.5        |
| A         | 8          |
| B         | 1          |
| C         | 0.5        |
| D         | 1.5        |

Table 1: Antenna Dimensions Table
4. RESULTS AND DISCUSSIONS

|   |   |
|---|---|
| E | 0.25 |
| F | 2.25 |
| G | 2.25 |

Figure 2: Return Loss vs Frequency

Figure 3: VSWR vs Frequency

Figure II shows the lower curvature of the proposed antenna running at 5.8GHz and 14.2GHz. The return loss of -35.84 dB was located at 5.8GHz and -17.71 dB at 14.2GHz. Figure III shows the VSWR vs frequency, which in practical terms is calculated as VSWR < 2. The VSWR curve is at two resonant frequencies < 2. Figure IV shows the radiation diagram of a proposed antenna at resonant frequencies. As a MPA, the antenna has a great gain of 1.74dB at 5.8GHz and 1.91 dB at 14.2GHz.
Figure 4: Antenna Gain at 5.8GHz

Figure 5: Antenna Gain at 14.2GHz

Figure 6: Antenna Radiation patterns at 5.8GHz
Figure 7: Atenna Radiation patterns at 14GHz

Figure 8: E field distribution of an antenna

5. Conclusion
The design of dual-band MPA is suggested in this work. The preferred antenna size is 10 x 6.5 x 1.6 mm3. By changing the range of the patch, an improvement in the resonance frequency and an increased resonance band can be observed. Due to this change, the antenna performs dual-band operation. The antenna serves at two resonant frequencies of 5.8 and 14.2 GHz. Ku-band applications have reflection coefficients (S11) of -35.84 dB and -17.71 dB with gains of 1.74 and 1.91 dB respectively.

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