Abstract: A microstrip antenna with a triple band elliptical patch has been designed. The antenna has dimensions of (35x34x1.6) mm³ the antenna is suitable for satellite applications and is mounted on a substratum with a relative dielectric constant (εr) of 4.3 and loss tangent (tan δ) of 0.025. The antenna covers a frequency of (6.1-6.3) GHz, (7.4-7.8) GHz and (8-8.4) GHz and with a reflection coefficient (S11) of (-37.78), (-35.64), and (-41.8) respectively. The antenna gain ranges from 1.2 dBi to 2.59 dBi and standing voltage wave (VSWR) less than 2. The antenna has been adjusted by inserting steps in the feed line and slots to the patch to improve impedance matching and group delay characteristics. CST software used to obtain the simulation results.

Keywords: Microstrip elliptical antenna, UWB, satellite applications, triple-band.

1. Introduction

Antenna became an essential part in the field of wireless communication since 1888. The modern wireless communication system demands low profile, lightweight, high gain, and high-efficiency characteristics for an application like satellite, radar, mobile, etc.[1]. The microstrip antenna attracts more attention because of its features such as low profile, low cost, lightweight, easy fabrication and compatibility to the printed circuit board[2]. Despite its features, there are also some drawbacks like narrow bandwidth, low gain and surface wave excitation[3,4]. In 2002, the Federal Communication Commission (FCC) approved for mercantile purposes an ultra-wideband (UWB) at the frequency of (3.1-10.6) GHz. The UWB technology attracts attention because of the need to provide more information with a high data transmission rate for more users, and it has features such as high data in short-range, high multipath immunity, low power consumption, low cost, spectrum reuse and simple hardware architecture[5,6,7]. However, it interferes with the narrowband communication system in the frequency range (3.4-3.69) GHz and (5.15-5.825) GHz, to solve this problem a lot of researches for band notch were done[8,9,10]. The UWB antenna is the core element of the UWB system and should have features such as greater impedance bandwidth, stable radiation behavior, stable gain and operating efficiency[11,12]. Many microstrip antenna designed for UWB application like in (2020) Abhishek Patel and Manoj Singh Parihar designed a triple band notch
microstrip antenna. The antenna patch contains a rectangular shaped patch covering the frequency spectrum from 3.1GHz to 10.6GHz with a partial ground and an E-shaped resonator[13]. In (2018) Jeet Banerjee, et al. designed a compact printed triple band-notched UWB antenna with a partial ground the antenna has a band notch in frequency ranges (3.3-3.8) GHz, (5.15-5.85) GHz and (7.9-8.4) GHz[14]. In (2018) Sweta Agrawal, et al. designed a compact circular microstrip patch antenna with a partial ground structure for ultra-wide band application, the antenna is loaded with a C-shaped slot in the patch and S-shaped slot in the microstrip feed line. The C-shaped and S-shaped slots have been used to create band-notched characteristics for the band (3.30–3.60) GHz and band (5.10–5.80) GHz. The frequency band (7.25–7.75) GHz is notched using Split Ring Resonator as an electromagnetic coupling element near the feed line which creates band stop properties[15]. In (2017) Sayed Arif Ali, et al. They designed a microstrip antenna with Hexagonal Flower-shaped Patch and partial ground structure for the ultra-wide band application. The antenna consists of two C-shape slot resonators in the patch and two parasitic strips parallel to the microstrip feed line. The antenna has three-band notch characteristics in the bands (3.3-4.2) GHz, (5.15-5.825) GHz, and (8.025-8.4) GHz[16]. In this research, an elliptical triple-band antenna has been designed for satellite applications. The antenna operates at frequencies of (6.1-6.3) GHz, (7.4-7.8) GHz and (8.8-8.4) GHz, with a reflection coefficient (S11) of (-37.78), (-35.646) and (-41.8) respectively. The antenna is adjusted to get a better match impedance and group delay characteristics by inserting steps in the feed line and slots in the patch. The required design equations are outlined below [3]:

\[ \varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} \left[ 1 + 12 \frac{h}{w} \right]^{-1/2} \]  

(1)

Where \( \varepsilon_{eff} \) is effective dielectric constant, \( \varepsilon_r \) is the relative dialectical constant, \( w \) is the width of the patch (Semi-major axis), and \( h \) is the thickness of the substrate.

\[ L_g = L + 6h \]  

(2)

Where \( L_g \) the length of the ground and \( L \) is the length of the patch (semi-minor axis).

\[ W_g = w + 6h \]  

(3)

Where \( W_g \) is the ground width.

\[ \lambda = \frac{c}{f} \]  

(4)

Where \( \lambda \) the Wavelength, \( f \) is the frequency and \( c \) speed of light in vacuum.

\[ \lambda_g = \frac{\lambda}{\sqrt{\varepsilon_{eff}}} \]  

(5)

\[ L_f = \frac{\lambda_g}{4} \]  

(6)

Where \( L_f \) is the length of the feed line.

2. The proposed antenna

The designed antenna is shown in Fig 1. The antenna substance is built by using FR-4 with a relative dielectric constant (\( \varepsilon_r \)) of 4.3, \( h=1.6 \) mm, and 0.025 loss tangent. The patch and the ground are built by using annealed copper with thickness t=0.035 mm. Table 1 shows the best values we obtained for the antenna parameter through a parametric study. CST software has been utilized to obtain the simulation results.
Figure 1. The designed antenna (a) anterior view (b) posterior view

Table 1. The best values for antenna parameters

<table>
<thead>
<tr>
<th>parameter</th>
<th>Value</th>
<th>parameter</th>
<th>value</th>
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<tbody>
<tr>
<td>h</td>
<td>1.6mm</td>
<td>substrate width</td>
<td>34mm</td>
</tr>
<tr>
<td>t</td>
<td>0.035m</td>
<td>Semi-major axis</td>
<td>12mm</td>
</tr>
<tr>
<td>L_f</td>
<td>15mm</td>
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<td>10mm</td>
</tr>
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<td>Substrate length</td>
<td>35mm</td>
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<tr>
<td>L_g</td>
<td>35mm</td>
<td>W_g</td>
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The variation of $S_{11}$ with different frequencies is demonstrated in Fig. 2, where

$$S_{11} = 10 \log \Gamma$$

$$\Gamma = \frac{Z_R - Z_o}{Z_R + Z_o}$$

Where $\Gamma$ is the reflection coefficient, $Z_R$ is the load impedance and $Z_o$ is the Characteristic impedance[1].

One of the essential parameters for the UWB antenna is the group delay. The antenna should be able to transmit the signal with minimal distortion (i.e., small group delay) [1,3]. Fig. 3 shows the group delay of the designed antenna as the group delay ranges from -12.6 ns to 12.8 ns. Hence, it will be modified, as shown in the next section.

3. The modified antenna

Because of the high distortion of the designed antenna, steps added in the feed line and slots to the patch so that the designed antenna will have better impedance matching characteristics and less distortion (i.e. group delay from -1.08 ns to 2.75 ns). Fig. 4 demonstrated the adjusted antenna.
The S11 change with the frequencies is shown in Fig. 5, the antenna occupies a bandwidth of (6.1-6.3) GHz, (7.4-7.8) GHz and with a reflective coefficient (S11) of (8-8.4) GHz and (-37.78), (-35.646) and (-41.8) respectively.

The distortion of the modified antenna is less than that of the proposed antenna (i.e. group delay from -1.08 ns to 2.75 ns) as shown in Fig. 6.

The gain of the modified antenna demonstrated in Fig. 7, the gain of the modified antenna varies from 1.2 dBi to 2.59 dBi.

The modified antenna surface current distribution at frequencies 6.213 GHz, 7.624 GHz, and 8.287 GHz demonstrated in Fig. 8, with a maximum current of 110 $A/m$, 121 $A/m$ and 123 $A/m$ respectively.

**Figure 4.** The adjusted antenna (a) front view (b) rear view

**Figure 5.** $S_{11}$ Vs. the frequency for the adjusted antenna

**Figure 6.** The group delay of the adjusted antenna

**Figure 7.** Gain Vs. the frequency for the modified antenna
Figure 8. The surface current allocation of the adjusted antenna for (a) $f = 6.213$ GHz (b) $f = 7.624$ GHz (c) $f = 8.287$ GHz.

The far-field (H-field and E-field) pattern or also known as antenna pattern, Fig. 9 shown the far-field of the adjusted antenna at frequencies 6.213 GHz, 7.624 GHz, and 8.287 GHz.

The 3D radiation pattern of the modified antenna at frequencies 6.213 GHz, 7.624 GHz and 8.287 GHz.
GHz and with maximum directivity of 6.13 dBi, 5.8 dBi, and 5.44 dBi respectively is demonstrated in Fig. 10.

Figure 10. The 3D radiation pattern of the adjusted antenna in (a) f=6.213GHz (b) f=7.624GHz (c) f=8.287GHz

4. Conclusions

An elliptical triple-band microstrip antenna is designed for satellite applications. The antenna has dimensions of (35x34x1.6) mm$^3$. The antenna patch is mounted on a substrate with a relative dielectric constant ($\varepsilon_r$) of 4.3 and a tangent loss (tan $\delta$) of 0.025. The built antenna covers frequencies of (6.1-6.3) GHz, (7.4-7.8) GHz and (8-8.4) GHz. The antenna gain ranges from 1.2 dBi to 2.59 dBi. The antenna is adjusted by adding steps to the feed line and slots to the patch, which would improve the performance in particular by minimizing distortion (i.e. less group delay), giving it a better match impedance characteristics. We expect to fabricate the antenna and test it practically in the near future.

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Conflict of interest

The authors confirm that the publication of this article causes no conflict of interest.

5. References

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