Design of dual band elliptical microstrip antenna for satellite communication

Abstract. A microstrip antenna with an elliptical patch is designed. The antenna has dimensions of (19x23x1.6) mm$^3$, it is mounted on a substrate with 4.3 relative dielectric constant ($\varepsilon_r$) and 0.025 loss tangent ($\tan\delta$) and it can be used for satellite communication. The antenna covers a bandwidth of (9.89-10.49) GHz and (17.4-19.24) GHz, the gain in the mentioned bands is (1.5-3.3) dBi and (4.6-2.8) dBi respectively with a voltage standing wave (VSWR) less than 2. The antenna is adjusted by adding a slot in the ground and steps in the feed line in order to get a better group delay characteristics. The simulation results are obtained using CST software.

Keywords. Microstrip elliptical antenna, UWB, satellite communication, dual-band, microstrip line feed.

1. INTRODUCTION

The wireless network has become an important part of our lives, the most important part of the wireless system is the antenna, it is an electrical device that sends and receives electromagnetic waves from space. The microstrip antenna draws more attention because of the need for a compact low profile and lightweight antenna for aircraft, spacecraft, etc. The microstrip antenna has features such as low profile, low cost, lightweight, easy fabrication and compatibility with a printed circuit board. Despite its features, there are also several disadvantages including narrow bandwidth, low gain and surface wave excitation [1][2]. The Federal Communication Commission (FCC) permitted an ultra-wideband (UWB) in the frequency range (3.1-10.6) GHz for mercantile purposes in 2002. The UWB technology attracts attention because of the need to provide more information with a high data transfer rate for more users, it has features like high data in short-range, high multipath immunity, low power consumption, low cost, spectrum reuse and simple hardware architecture [3]. Despite its features, there is also interference with the narrowband communication system in the frequency range (3.4-3.69) GHz and (5.15-5.825) GHz, to solve this a lot of researches for band notch have been done. The UWB antenna is the most important part of the UWB system and should have features such as high impedance bandwidth, stable radiation behavior, stable gain and efficiency in the operation bandwidth[4][5]. Many microstrip antenna designed for UWB application like in (2019) Mohamed S. Soliman, et al. designed an elliptical patch microstrip antenna with a partial ground for UWB application, the antenna has a band-reject characteristic for frequency range (5.1-5.9) GHz and (3.3-3.8) GHz[6]. In (2018) Raad H.Edhem and Zainab S. Jamel designed a dual-band antenna, the bands are centered at 3.5GHz, and 5.8GHz, it has gain in the mentioned frequency of 3.93 dBi and 4.91 dBi respectively [7]. In (2018) Raad H. Edhem and Ali Khalid
designed an elliptical patch antenna that works in the band (6.95-30.94) GHz and has a gain of 6.8 dBi[8]. In (2016) Ahmed A. Ibrahim and mahmond A. Abdall designed microstrip antenna with a half-circle patch for UWB application with a band notch characteristics for the frequency range (5.1-5.9) GHz and (3.3-3.8) GHz[9]. In (2016) Ankur saxena and R.P.S. Gangwar proposed a compact slot UWB antenna that has a band notch for the frequency range (5.1-5.9) GHz and (3.3-3.8) GHz[10]. In (2014) Md. Saad-Bin-Alam and Sanjida Moury suggested a modify to microstrip antenna with a rectangular patch and steps near the feed line that works for UWB to work in Bluetooth and UWB[11]. In (2014) Juhang Shen, et al. designed a microstrip antenna for UWB application with a heart-shaped patch that has a band notch characteristics in the frequency of (5.1-5.9) GHz and (3.3-3.8) GHz[12]. In (2011) Peng Gao, et al. proposed an integrated plane microstrip antenna with a partial ground and it has a band-notch in the frequency of (4.96-5.29) GHz and (5.54-6.01) GHz, it can be utilized for Bluetooth band and UWB[13]. In (2011) Sanjeev Kumar Mishra, et al. designed microstrip antenna with a fork-shaped patch with partial ground that works in Bluetooth band and UWB[14]. In this research, an elliptical patch antenna was designed for satellite communication. The antenna operates at the frequencies (9.89-10.49) GHz and (17.4-19.24) GHz, the gain in these bands is (1.5-3.3) dBi and (4.6-2.8) dBi respectively. The antenna is adjusted to achieve better group delay characteristics by inserting a slot in the ground and steps in the feed line. The necessary design equations are listed below[2].

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

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

\[L_g = L + 6h\]

Where \(L_g\) the length of ground and \(L\) is the length of patch.

\[W_g = w + 6h\]

Where \(W_g\) is the ground width .

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

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

\[\lambda_g = \lambda \sqrt{\varepsilon_{ef}}\]

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

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

2. THE PROPOSED ANTENNA

The designed antenna is shown in Figure (1). The antenna substrate is assembled from FR-4 with 4.3 relative dielectric constant (\(\varepsilon_r\)) and with a thickness of 1.6 mm and 0.025 loss tangent (tan \(\delta\)). The patch and the ground are
made up of copper annealed with a thickness of 0.035 mm. Table 1 displays the best values we obtained for the antenna parameters via a parametric study.

![Image of the designed antenna](image)

FIGURE 1. The designed antenna (a) front view (b) back view

| parameter | value  | parameter | value  |
|-----------|--------|-----------|--------|
| h         | 1.6mm  | substrate width | 23mm   |
| t         | 0.035mm| b         | 7mm    |
| Lf        | 6mm    | a         | 5mm    |
| Wf        | 1.75mm | u         | 4mm    |
| Lg        | 19mm   | v         | 1mm    |
| Wg        | 23mm   |           |        |

Substrate length | 19mm

As shown in Figure (2) the antenna cover the frequency ranges (9.9-10.5) GHz and (17-19.4) GHz with reflection coefficient \((-41.2\) dB and \((-47.2\) dB respectively.

![Graph of S-Parameters](image)
FIGURE 2. S11 Variation with frequency

The transmitted signal from the antenna should have a minimum distortion. From Figure (3) we can see that the group delay that measures the distortion in the transmitted signal has a range from (8.9) ns to (-10.2) ns so the transmitted signal would have a high distortion and thus the proposed antenna should be modified as shown in the next section.

FIGURE 3. Group delay of the created antenna

3. THE MODIFIED ANTENNA

Because of the high distortion of the proposed antenna, steps are added in the feed line and slots are made in the ground as shown in Figure (4) so that the modified antenna will have better impedance matching characteristics and less distortion.

FIGURE 4. The adjusted antenna (a) front view (b) back view

Figure (5) shows that the modified antenna covers frequency ranges (9.8-10.4) GHz and (17.4-19.2) GHz with a S11 (-38.8) dB and (-27.6) dB respectively.
From Figure (6) we notice that the distortion in the transmitted signal will be less as compared to the first design (i.e. group delay from (0.88) ns to (-1.3) ns).

Figure (7) illustrates the variation of the gain with frequency. For the frequency ranges (9.89-10.49) GHz and (17.4-19.24) GHz the antenna has a gain of (1.5-3.3) dBi and (4.6-2.8) dBi respectively.

The surface distribution for the modified antenna at frequency 10.1 GHz and 18.3 GHz with maximum current $106 \text{A/m}$ and $137 \text{A/m}$ is demonstrated in Figure (8).
The far-field (H-field and E-field) at frequencies of 10.1 GHz and 18.3 GHz is shown in Figure (9).

Figure (10) demonstrated the 3D radiation pattern of the modified antenna at frequencies of 10.1 GHz and 18.3 GHz and with maximum directivity of 5.7 dBi and 6.4 dBi respectively.
4. CONCLUSIONS

An elliptical microstrip antenna for satellite communication is created and simulated. The antenna has dimensions of (19x23x1.6 mm$^3$) and is installed on a substrate with a relative dielectric constant ($\varepsilon_r$) of 4.3 and loss tangent ($\tan \delta$) of 0.025. The designed antenna covers a bandwidth of (9.89-10.49) GHz and (17.4-19.24) GHz and it has a gain of (1.5-3.3) dBi and (4.6-2.8) dBi respectively. The antenna is modified by adding steps to the feed line and slot in the ground, this will improve the performance especially the reduction of distortion (i.e. less group delay) so that the group delay of the adjusted antenna is in the range from (0.88) ns to (-1.3) ns this will ensure a low transmitted signal distortion and good impedance matching characteristics. In the near time we hope to manufacture the antenna and test it practically and it will be modified to cover more applications.

ACKNOWLEDGMENTS

The authors wish to thank Al-Mustansiriyyah University for the support of the research work.

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