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T-shaped microstrip patch antenna for RF communications

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Abstract
The paper presents an upgraded configuration of compact T-shaped microstrip patch antenna design, simulation, fabrication, and test on 1.6mm FR-4 substrate. The microstrip patch antenna is simulated using Sonnet Software. The proposed design is developed to be used as a transmitting antenna operating at 2.4 GHz radio signals with bandwidth ranging from 2.2 GHz to 2.6 GHz, and with input, match S11 less than -27 dB on 2.4 GHz frequency. The gain of the proposed antenna is 7.28 dB. The antenna was fabricated and measured results match with simulated in terms of frequency but measured S11 is lower due to lossy dielectric FR-4.

Keywords: Microstrip antenna; T-shaped; FR-4; Gain

1. Introduction

In the modern IoT world, when we have a lot of smart devices for remote sensing and home automation, in some cases we need to have small suitable antenna for transmitting data to those smart home devices. Most of those devices are used to make our life easier. A lot of papers are introduced and the authors are talking about Wireless Sensor Network (WSNs) operating at 2.4GHz have turned out to be the one of the most exciting areas of research in the past few years [1, 2, 3]. Besides that, there are many interesting Microstrip antennas and array designs at 2.4Ghz, for Low Energy Bluetooth or RFID [4, 5], but in this paper the focus will be on simple design of transmitting antenna for 2.4GHz radio, which is widely used for remote sensing and remote control. In the literature a lot of different antenna designs for 2.4GHz can be found [6, 7]. The main focus for 2.4GHz antenna is that we wanted to make some small contribution for these widely used antennas. The goal was to use basic T-shaped inset fed patch antenna and to change geometry in order to have higher gain and bandwidth to make possible to use this type of antenna in multiple channel communications like WiFi or Low Energy Bluetooth, which is highly used is this era of IoT devices.

In section 2, detailed antenna design and description of the design can be found. Section 3 consists of simulation and experimental results and results comparison. At the end of this paper one can find conclusion, suggestions for future work and references.

To have a successful patch antenna design, it is important to achieve various performances by simulation results. Planar electromagnetic simulation software, called Sonnet Suites was used in this paper. To have a proper deign, first thing is impedance and antenna bandwidth. Input impedance was maintained by formulations on various antenna geometries and Network Analyzer is used to measure this parameter [8].

2. Microstrip antenna calculations

1) There are many calculations found in literature to design microstrip patch antennas. One of the most common equations for the width of the antenna is given as follows:

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_r}}\sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (1)$$

Where v_0 is the free-space velocity of light.

2) The effective dielectric constant of microstrip patch antenna is given as:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \qquad (2)$$

3) Expression of extension of length is given by:

$$\Delta L = h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left[\frac{W}{h} + 0.8\right]} \qquad (3)$$

4) Length of patch is given by:

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L \qquad (4)$$

Many techniques have been presented in order to reduce the size of microstrip patch antennas at fixed operating frequency. The antenna design proposed in this paper uses an inset microstrip-line feed. The inset-fed is used to reduce antenna size in order to have a smaller antenna and to operate at fixed frequency [9].
The antenna design is based on FR-4 substrate material of 1.6mm thickness. The proposed design is shown in Fig. 1. The antenna has an inset fed, and small metal areas around T shape. Those areas are used to ensure that the antenna has enough radiation power on resonant frequency, and better current distribution, that can be seen in Fig. 1, in the third section of the paper. Also, these small metal areas are added in order to increase the bandwidth of the antenna. This type of antenna is used for easier change of channels on 2.4GHz radio signal. For example, if the data rate is 1Mbps, channel spacing will we 1MHz. With bandwidth of 40MHz, it is possible to control a large number of remote devices. This antenna design is very simple and can be easily reproduced in any CAD software [10].

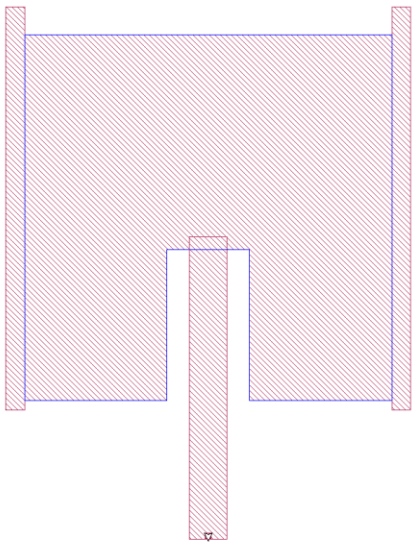

Figure 1. Top view of the antenna design

3. Results

This antenna is designed and analyzed using the Sonnet Software. In Fig. 2, the gain pattern of the antenna is shown. Horizontal polarization of the antenna has a 7.28 dB gain at the resonant frequency and cross polarization has the level of -40 dB as seen in Fig. 2.

Measured gain patterns of the proposed antenna at 2.4GHz are presented in Fig. 3. According to simulated results, gain of proposed antenna at 2.4GHz is 7.28 dB at horizontal polarization. The measurement results are different because of reasons which will be explained later in the paper. According to measurements results presented in Fig. 3, gain of fabricated antenna at 2.4GHz is 2.95dB at horizontal polarization.
In Fig. 4, it is shown that the input match is -27 dB at the resonant frequency of the antenna. The input match is less than a -10 dB in the frequency range between 2.2 GHz and 2.6 GHz. In the same figure it is presented measured vs. simulated S11 graph for the proposed antenna. As we can see from the graph, both simulated and measured curves have similar resonant frequency but with different input matches.

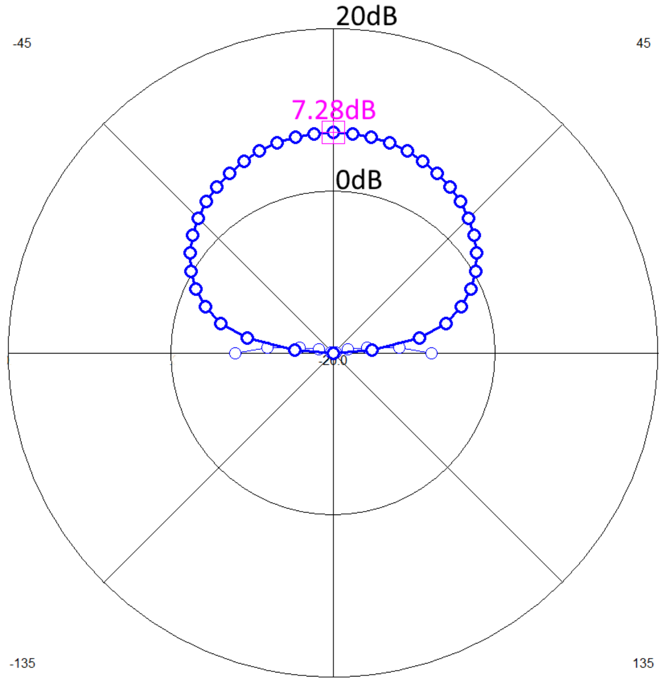

Figure 2. Gain pattern of the proposed antenna design at 2.4GHz

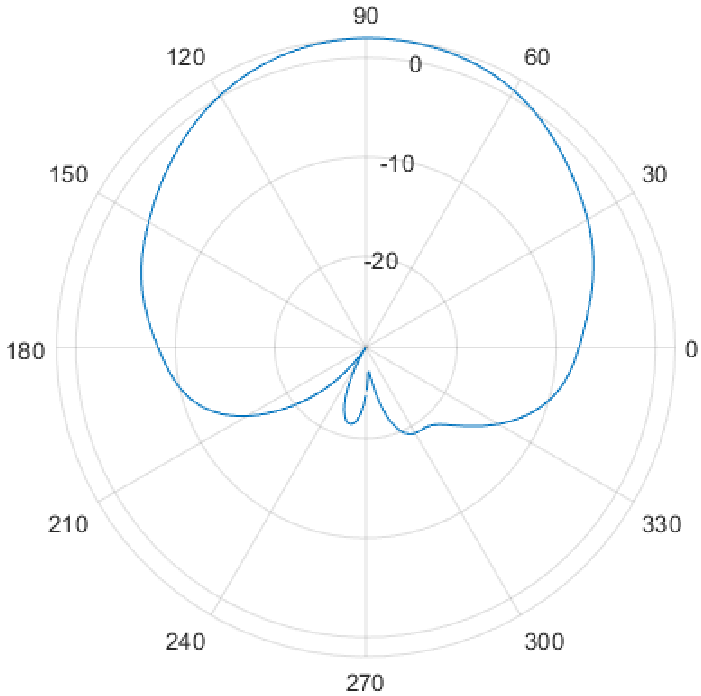

Figure 3. Measured gain pattern of the proposed antenna design at 2.4GHz

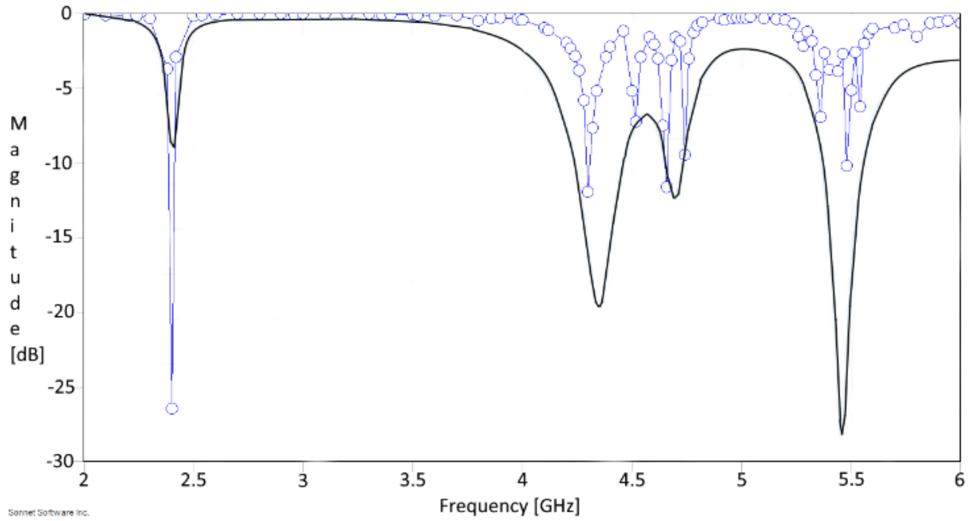

Figure 4. Simulated (bule) and measured (black) input match of proposed antenna from 2GHz to 6GHz

In the figure above, measured S11 graph (black colored) for the proposed antenna is depicted from 2 GHz to 6 GHz. From the measurement results can be concluded that according to measurement results this antenna can be used on different resonant frequencies. The main idea was to have simple antenna for 2.4GHz RF communication, because of this idea, gain measurements were not conducted on higher frequencies. The resonant frequency of 2.4 GHz was local minimum, according to this measurement graph.
Based on simulated and measured results from Fig. 4, it is possible to see that, the input match on 2.4 GHz frequency is -9 dB in measured graph; on the other hand in simulated one we can see -27 dB on 2.4 GHz. Also, at higher frequencies, we can see that we have local minimums on same spots on both graphs, but input match on measured and simulated graphs have amplitude differences due to simulation errors and lossy dielectric. Fig. 5 has the current distribution of the antenna, and it is possible to see that the radiation of the antenna comes mostly from the center of the T shape, and also from the additional metal regions on the left and right side of T shape.
The small metal parts on left and right hand sides are added in order to increase the antenna gain. Using Sonnet software, with multiple simulations, its discovered that highest current density is on edges, and in order to increase the density the metal parts are added. Fig. 6 has the fabricated antenna inside anechoic chamber. The anechoic chamber was used to measure antennas radiation pattern.

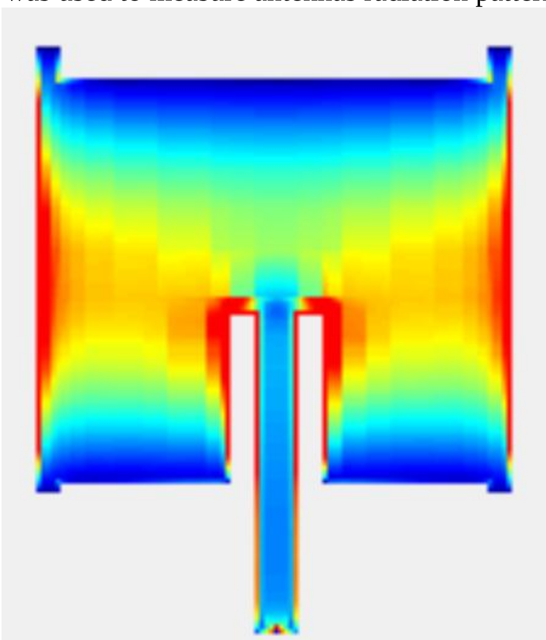
Figure 5. Current distribution of proposed antenna design at 2.4GHz

Figure 6. Fabricated antenna inside anechoic chamber

4. Conclusion

In this paper, an improved T-shaped inset-fed microstrip patch antenna for 2.4 GHz radio communication is presented. The antenna has simple design, similar to antenna presented in [1], and it can be easily drawn in any CAD Software. The antenna is designed on a FR-4 substrate, which has 1.6mm thickness. Because of the fact that FR-4 is a standard substrate for most of the printed circuit boards, this antenna design can be easily implemented on any printed circuit boards. The Sonnet simulations reveals that the designed patch antenna is capable of operating between 2.4GHz and 2.6GHz. Measurement data are a little bit different from simulation because of lossy dielectric.

Acknowledgements

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