©2022 Published in 10th International Symposium on Innovative Technologies in Engineering and Science 21-23 October 2022 (ISITES2022 Bursa - Turkey)
https://doi.org/10.33793/acperpro.05.03.8356

Effect of FR4 Ground Layer on Rectangular Microstrip Patch Antenna in terms of Length and Width

Seyit Ahmet Koç, Yusuf Yılmaz, Feyza Ramazan, Oğuzhan Mert, Rabia Özkan, *Mehmet Duman
Düzce University, Department of Electrical and Electronics Engineering, Konuralp Campus, Düzce, 81650, Turkey

Abstract

In this project, inset fed type rectangular microstrip patch antenna is designed in CST Design Studio program; produced by printed circuit method on FR4 substrate which has 1.6 mm thickness, 4.3 electrical conductivity value, and measurements are made using nano VNA device with SMA connection in near 2.46 GHz center frequency. Four types of grounding methods with five measurements (two measurements with the first one) which are different from each other in the literature, have been tried on the antenna and the results from the nano VNA device are given. In the study, -27.5 dB (random, according to the author method), -22.5 dB (random, according to the default substrate dimension method), -13.8 dB (2 times of W, L method), -23.8 dB (6 times of h plus W, L method) and -27 dB (12 times of h plus W, L method) S11 values are obtained, respectively, according to the different dimensions of the ground, and the dimensions are shortened in each measurement. The middle frequency takes values between the frequencies of 2.44-2.48 GHz and remains on WLAN frequencies.

Key words: Ground layer dimension, microstrip patch, antenna, nano VNA

1. Introduction

FR4 substrate, which is one of the dielectric materials frequently used in the production of microstrip antennas, is both easy to measure and cost-effective compared to other production types such as parabolic reflector type, is used [1]. In this study, inset fed microstrip patch antenna is produced, rectangular shape is implemented. The antenna, which is designed and manufactured in the laboratory with the intention of being planned as an antenna in Wi-Fi devices or any product operating at WLAN frequencies, has a thickness of 1.6 mm. The antenna, which has a conductor line thickness of 0.035 mm, has an ϵ_r value of approximately 4.3. Different S_{11} return loss values are obtained in antenna design with five different ground sizes from the four types of ground size methods in the literature [2-5]. One of these methods is the random method, which varies according to the author or default substrate dimensions [4], while the others depend on the h thickness of the substrate, which varies according to the value of dielectric substrate (ϵ_r) [2-3]. W_g or L_g (ground dimensions in terms of width and length) might be 6 times of h plus W or L (live side of microstrip antenna in terms of width and length). It might be 12 times of h plus W or L too. There is another method that depends on the W and L dimensions, most of the time double of the W and L [5].

In this work, differences in ground dimensions have been in question instead of other width or length dimensions or where they are obtained from.

*Corresponding author: E-mail address: mehmetduman@duzce.edu.tr, Phone: +90 850 8008181 / 4793

2. Materials and Method

Ground dimensions rather than the construction stages of the antenna or the selection of inset spaces are the main topic of this article. In this study, four different ground methods, found in the literature, are emphasized and five measurements are done. Measurements are made from the larger to the smaller ground size, respectively. The substrate layer is cut after each measurement.

In the first method [4]; the random values are used according to the author. In this method, W_g is chosen 135 mm and L_g is decided 124 mm. Here, W_g is the width of the whole plate, L_g is the length of the whole plate. The front side of the plate is microstrip antenna, while the back side is completely ground. In Figure 1, S_{11} input reflection coefficient value is given as -27.5 dB at 2467 MHz frequency. It has 54.1-j1.63 Ω impedance (the best is 50 Ω and no imaginary part) and 1.088 VSWR (the best is 1). Quality factor of this antenna is 0.03 which is quite close to the best value, 0.

This antenna can be used in all Wi-Fi technologies and applications but the dimensions are large for most devices. Large antennas have disadvantages to use in some applications.

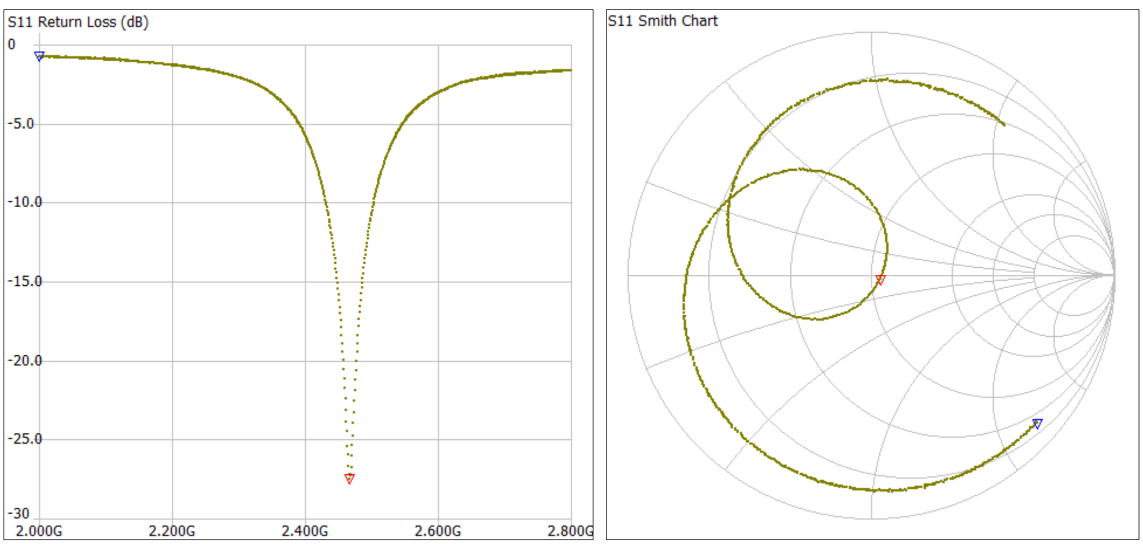

Figure 1. S_{11} return loss and impedance (on Smith chart) of the first method

In the second method [4]; the random values are used according to the default substrate dimensions provided from the provider. In this method, W_g is gathered 100 mm (97.5 mm exactly) and L_g is gathered 100 mm. In Figure 2, S_{11} input reflection coefficient value is shown as -22.564 dB at 2478 MHz frequency. It has 56.5-j4.57 Ω impedance and 1.161 VSWR. Quality factor of this antenna is 0.081. Dimensions are slightly reduced. This is good for WLAN applications. The input reflection coefficient has increased but is still available.

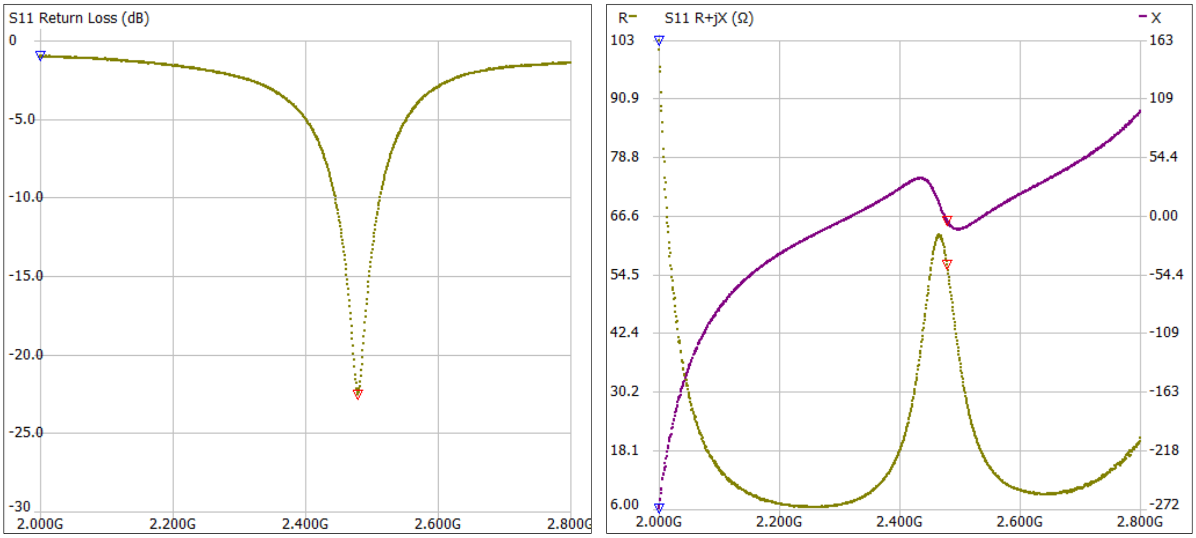

Figure 2. S_{11} return loss and impedance (on cartesian coordinates) of the second method

In the third method [5]; double of the W and L dimensions (2 times of W, L method) are calculated. Here, W is approximately 39 mm and L is approximately 28 mm (dimensions of microstrip antenna's live side) obtained previous works [6];

$$W_g = 2W = 78 \text{ mm} \tag{1}$$
$$L_g = 2L = 56 \text{ mm} \tag{2}$$

In Figure 3, S_{11} input return loss value can be seen as -13.838 dB at 2461 MHz frequency. It has 49.1+j20.5 Ω impedance and 1.51 VSWR value. Quality factor graph of this antenna is 0.419. Despite the smaller size and bad impedance matching, S_{11} of the antenna is still below -10 dB. Antennas used in RF circuits must have below of -10 dB S_{11} value to be usable. These rules are provided in this antenna.

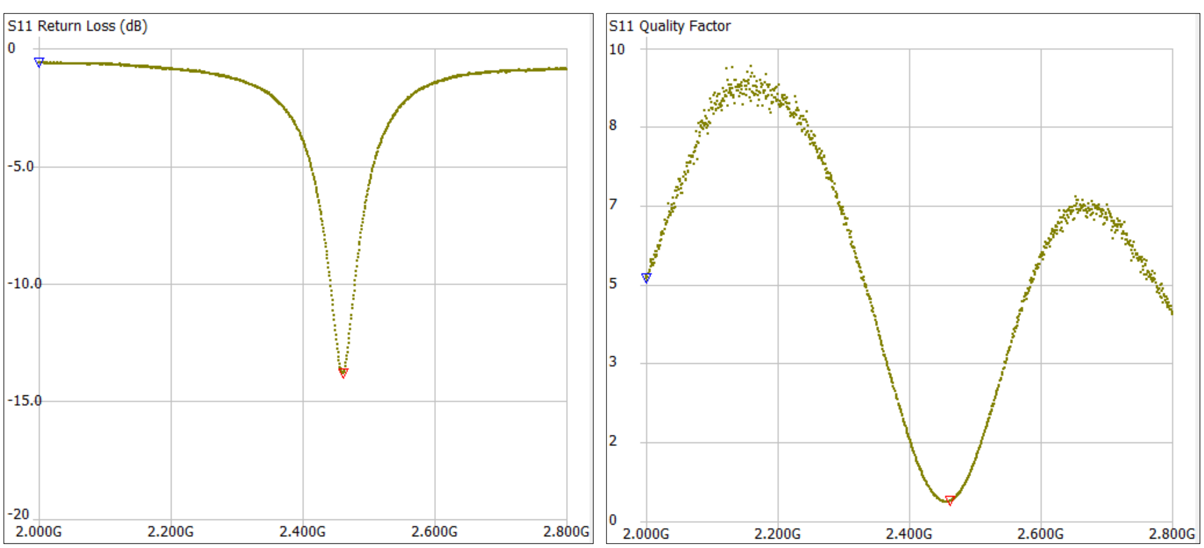

Figure 3. S_{11} return loss and quality factor of the third method

In the fourth method [3];

$$W_g = W + 12h \quad (3)$$
$$L_g = L + 12h \quad (4)$$

equations are used. W is the width of the rectangular microstrip patch antenna, L is the length of the rectangular microstrip patch antenna. Therefore; W_g will be 58.2 mm and L_g will be 46.7 mm. In Figure 4, S_{11} input return loss value can be seen as -23.892 dB at 2451 MHz frequency. It has 45.3+j3.93 Ω impedance and 1.136 VSWR value. Quality factor of this antenna is 0.087.

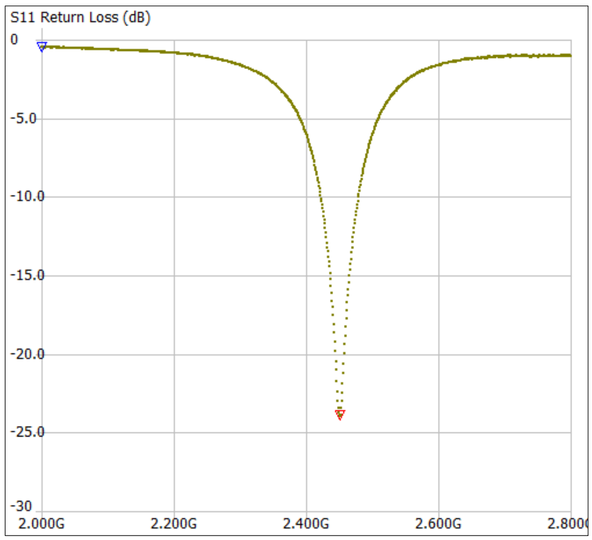

Figure 4. S_{11} return loss of the fourth method

While S_{11} is expected to perform worse than -13,838 dB, it is found as -23.892 dB. Whereas the ground dimensions of the antenna decrease, after a point, the deterioration in the S_{11} value stops and starts to improve again.

In the fifth method [2-3];

$$W_g = W + 6h \quad (5)$$
$$L_g = L + 6h \quad (6)$$

equations are used. W_g will be 48.6 mm and L_g will be 37.1 mm. In Figure 5, S_{11} input return loss value can be seen as -27.048 dB at 2.44 GHz frequency. It has 54.2+j2.03 Ω impedance and 1.093 VSWR value and 0.037 quality factor. This antenna, which is quite small in size and applicable, is also at desired levels as S_{11}. The imaginary part of the impedance is also very small. The real part is close to 50 Ω. The quality factor is close to 0 and the VSWR is close to 1. It appears to be an efficient antenna in every respect.

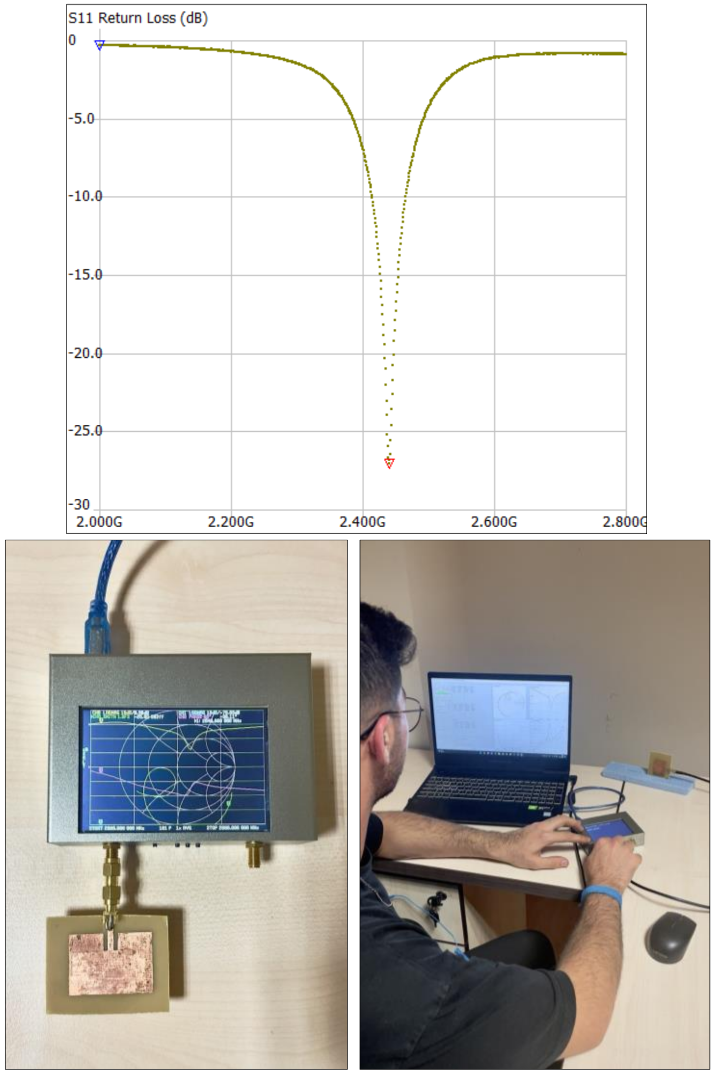

Figure 5. S_{11} return loss of the fifth method and views from the measurement

3. Results and Discussions

The measurement with the smallest ground dimensions out of the five measurements performed gave the best results. While the antenna performance parameters deteriorated with the decrease of ground dimensions, they started to improve after a certain point. All values from five measurements are given in Table 1.

Measurements were taken with the radiant part of the antenna facing up. The same VNA calibration and RF materials were used for all measurements.

Publications in the literature have been confirmed.

Table 1. All values from five measurements

	S_{11} dB	Centre frequency [MHz]	Impedance Ω	VSWR	Quality factor
First	-27.5	2467	54.1-j1.63	1.088	0.030
Second	-22.564	2478	56.5-j4.57	1.161	0.081
Third	-13.838	2461	49.1+j20.5	1.510	0.419
Fourth	-23.892	2451	45.3+j3.93	1.136	0.087
Fifth	-27.048	2440	54.2+j2.03	1.093	0.037

4. Conclusions

It can be seen that microstrip antennas can work very well with Wi-Fi frequencies. Their size can also be reduced as much as possible. It can make the desired radiation levels within the limits of the antennas. FR4 substrate is suitable for such applications. While checking the suitability of the S11 parameter, VSWR and quality factor should also be examined. The initial and final measurements are very similar, the only difference is the dimensions are minimum in the first and maximum in the last.

References

[1] Balanis CA. Antenna Theory: Analysis and Design, 3rd Edition, In John Wiley & Sons, Inc, Çeviri, Nobel Yayıncılık, 2016.

[2] Bankey V., Kumar NA. Design and performance issues of Microstrip Antennas. Int J Sci and Eng Res. 2015; 6(3), pp. 1572-1580.

[3] Islam MS., Ibrahimy MI., Motakabber MA., Hossain AK. A Rectangular Inset-Fed Patch Antenna with Defected Ground Structure for ISM Band, Proc of the 7th Int Conf on Comp and Comm Eng ICCCE, IEEE. 2018; pp. 104-108.

[4] Pradeep HS. Inset Fed Microstrip Patch Antenna for X-Band Applications, Int J of Eng Research in Electronics and Comm Eng. 2018; 5(7), pp. 1-5.

[5] Al-Khaffaf D., Alsahlany A. A return loss improvement of slotted square microstrip inset-feed patch antenna, Int J Latest Trends in Eng and Tech. 2018; 11(2), pp. 23-28.

[6] Özkan R., Mert O., Yılmaz Y., Ramazan F., Duman M. Attenuation of EM Waves Emitted From Inset Feed Type Microstrip Rectangular Patch Antenna by Wet Snow, Journal of Polytechnic, 2022, early view.