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A miniaturization of the UWB monopole antenna for wireless baseband transmission

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ABSTRACT

In this paper, a new monopole patch antenna is presented with enhanced bandwidth and minimized size of 22*20*1.6 mm^3. The power divider and etched slot in a ground plane stand for the adopted approaches in the projected antenna. Based on these approaches, the ultra-wideband antenna for 2.4 GHz to 9.6 GHz frequency band is a significant improvement. The flat gain is ranged from -5dB to 2.3dB over the frequency band of operation, which is provided to transmit and receive the output line code from rapid signal flux quantum (RSFQ) chip directly, based on the wireless baseband transmission without using the modulation techniques. The almost radiation patterns of the presented antenna have been bidirectional at E-plane, while they are omnidirectional at H-plane.

Keywords: Ultra-wideband response, Monopole patch antenna, Wireless baseband transmission, Small antenna

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1. Introduction

With great demand of wideband and small size antennas in commercial and military applications, microstrip patch antennas have been attractive due to their suitable properties of compact physical dimensions, low profile, planar feature, wideband possibility, and inexpensiveness of manufacturing. For that, they are used in short-range wireless devices at high data rates [1-2]. On the other hand, these antennas have low power, low efficiency, low scan performance and normally polarization purity [1].

Microstrip and monopole patch antennas have been mostly fabricated on substrates, such as FR4 and Duroid [4-6]. The progress in wireless communication antennas with ultra-wide bandwidth has increased in many emerging microwave technologies and applications as in mobile handset, missile, satellite, transient radar cross section and ground moving target indicators (GMTI). Ultra-wideband (UWB) technology becomes increasingly popular, which is suitable for the radiation of ultra-short pulses. The UWB antennas performance in both time and frequency domain makes theses antenna design a challenging and interesting field of among researchers after the large band (3.1-10.6GHz). These antennas have been available for commercial applications that are defined by Federal Communication Commission (FCC) in 2002.

The objective to design antenna in this study is to transmit and receive the output line code from RSFQ chip without any modulation techniques as in Wireless Baseband Transmission (WBT) between two different environments (4K-300k).The RSFQ logic circuits are an interesting alternative for supercomputers for producing and transmitting highly short quantized pulses [9-11].
Figure 1 depicts the model to transmit and receive the output of the RSFQ chip directly through antennas between two environments (4-300K). The diameter of the window between two environments is equal to 21-22 mm, so that the antennas can be inserted in this window in order to reduce the distance between these antennas.

Here in this study, the basic antenna design principle is explained analytically in section 2, while detailed results based on simulations are discussed in section 3. The antenna has been performed by using cutting notch in ground plane and radiating patch discussed in section 3. Finally, section 4 stands for the conclusions of this research work.

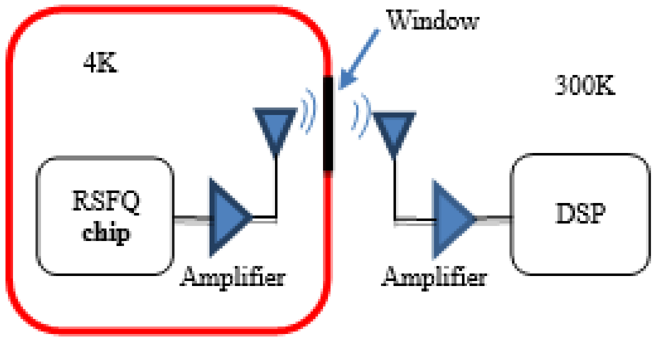


Figure 1. Model to send and receive the line code directly by antennas with window diameter range of 21 to 22mm

2. Antenna geometry and design

In recent years, planar monopoles with different geometries have been developed for UWB applications. In this paper, a small low-cost monopole antenna based on a power divider and slot in ground plane were calculated for transmitting and receiving the digital data with a data rate of 1 Gbps. The patch has driven at adjacent edges through a power divider, which can adjust the size dimensions of the patch using single or two, or more feeds [1]. The design of monopole antenna is simulated using ANSYS HFSS version 15 on a commercial inexpensive FR4 substrate thickness of 1.6 mm, a dielectric constant of 4.4 and a dielectric loss tangent of $\delta = 0.02$. The layout dimension of our antenna is explained in Figure 2. It is noticed that the antenna has dual power divider positioned at left and middle side of a radiation patch and gap at middle ground plane to obtain a broad bandwidth. The monopole antenna is fed by 50Ω microstrip line with calculated W_f of 3.4mm [9]. The ground plane area is reduced by removing the metal which is present under the feed slot with the dimension $W_f * W_g$ to get wideband impedance matching. The antenna dimensions are determined based on [1], where W and L stand for width and length of the patch, respectively.

$$w = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \qquad (2)$$

Where C stands for velocity of light (0.3G m/s), and f_r represents the resonant frequency at 6 GHz.

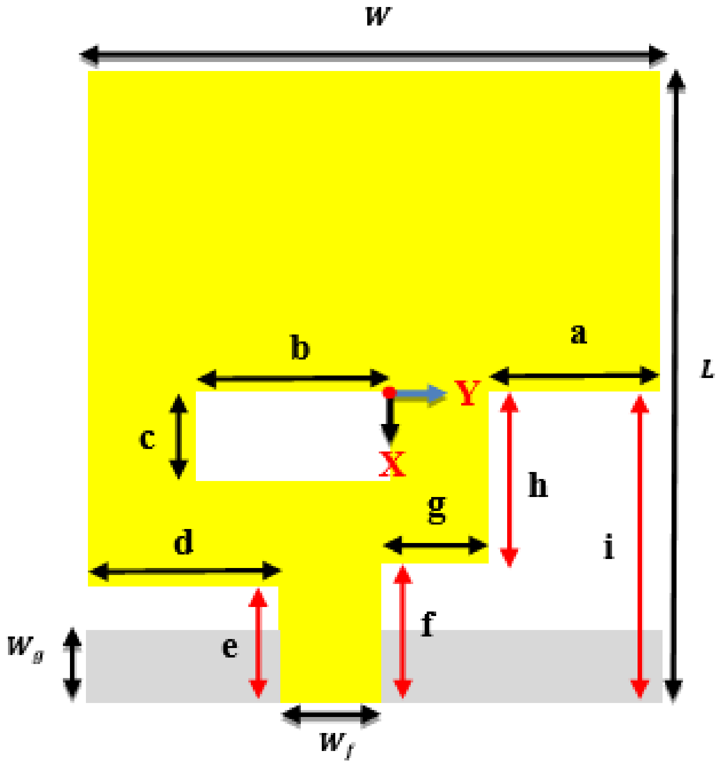


Figure 2. Layout of reference antenna

L = 22 mm, W = 20 mm, W_f = 3.4 mm, W_g = 2.5 mm, a = 6.6 mm, b = 6.3 mm, c = 3.6 mm, d = 6.6 mm, e = 3.94 mm, f = 4.2 mm, g = 3.4 mm, h = 6.8 mm, i = 11 mm.

3. Results and discussion

Figure 3 shows the simulated return loss of the antenna that reveals an UWB response with a bandwidth ranged from 2.4 to 9.6 GHz with antenna width (W) of 20 mm and length (L) of 22mm that equals to 0.176* λ, where λ stands for the wavelength at 2.4 GHz. Lowest operating frequency is governed by the cutting of rectangles from radiation patch of the antenna, and upper operating frequency can be adjusted by microstrip line feed.

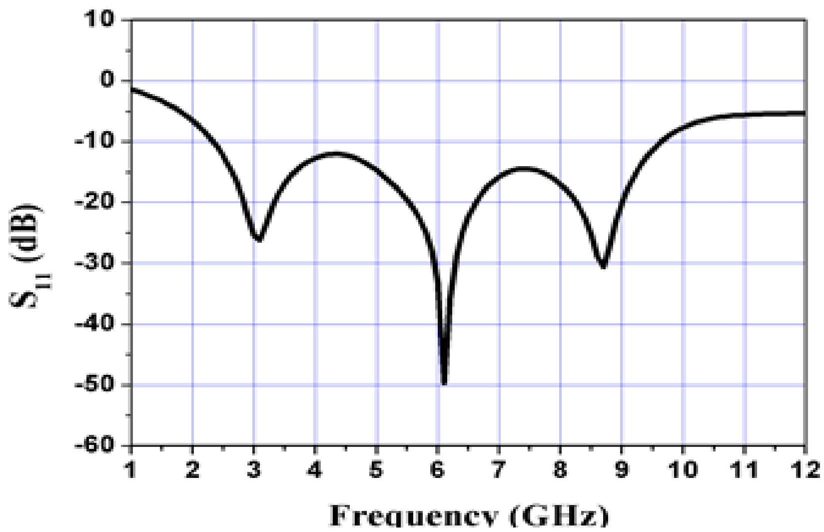


Figure 3. Simulation return loss. The size is $22 * 20 * 1.6\ mm^3$

3.1. Radiation patterns and current distribution

The simulated radiation patterns of projected antenna in two E-plane and H-plane have depicted in Figure 4 under frequencies of 2.4, 4, 6, 9.2 and 9.5 GHz. It is realized that the gain has closely bidirectional patterns at E-plane and omnidirectional patterns at H-plane. The distributions of surface current of designed antenna at the same frequencies have been illustrated in Figure 5. For the frequencies at 2.4, 4, and 6 GHz, the surface current distribution has been predominantly concentrated on the antenna feed line. On the other hand, for frequencies at 9.2 and 9.5 GHz, the surface current distribution have concentrated at the antenna line feed and radiation sides.

3.2. VSWR and gain

Figure 6 shows the simulated VSWR and gain results. It can be seen that impedance bandwidth of the antenna from 2.4 GHz to 9.6 GHz has been required below 2 across the all-inclusive UWB spectrum. Obviously, the VSWR is less than 1.8 over the frequency band for this antenna. As it can be perceived, the gain differs from -5 dB to 2.3 dB over the frequency range of operation that is provided for the application of our proposed antenna.

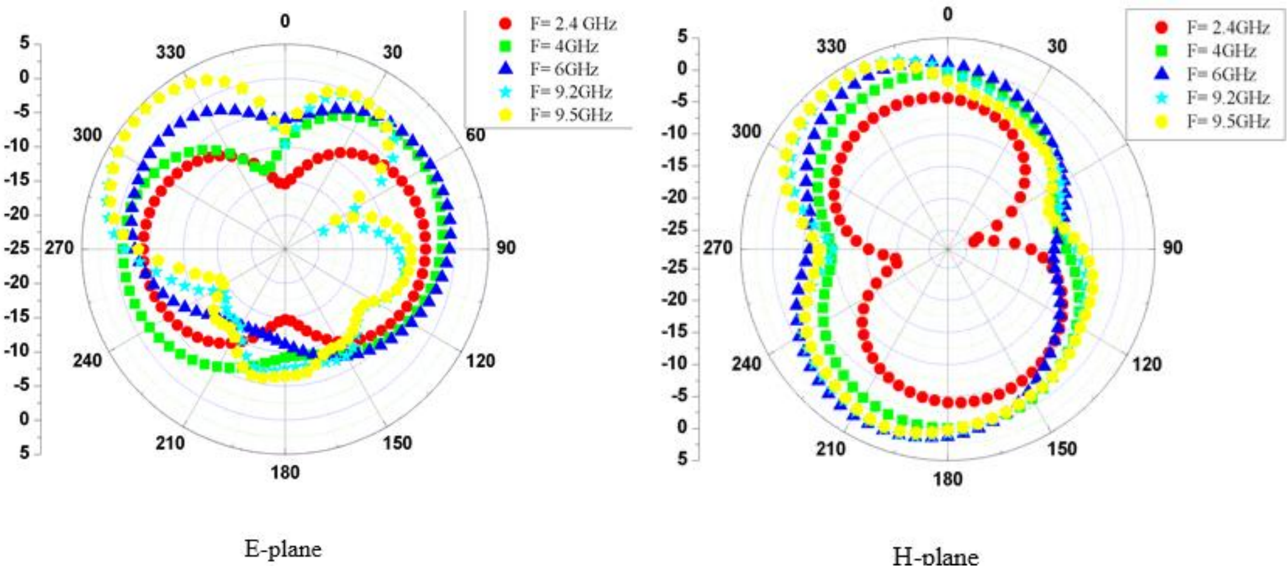
3.3. Changing the position for the slot on a ground plane

Figure 7 illustrates the variation of S_{11} response for diverse positions of the slot at 1.5, 2, 2.5, 3, and 3.5 mm. The impedance match has been susceptible to a change position of slot over a ground plane with fixed slot length (3.5mm) and width (2.5mm).

The S_{11} parameter response is good as depicted in this figure when the slot position at 2.5 mm and to be considered throughout the designed antenna.

3.4. Effect of an etched slot on a ground plane

Figure 8 shows the simulation return loss for two cases without and with slot on the ground plane. Clearly, we can see S_{11} parameter response with an etched slot on the ground plane is better without slot. The frequency range with slot has been from 2.4-9.6 GHz. However, without slot, the frequency range has been from 2.4-10.2 GHz.



(a) (b)

Figure 4. Simulation radiation patterns of the designed microstrip antenna in (a) E-plane and (b) H-plane, at 2.4, 4, 6, 9.2, and 9.5 GHz

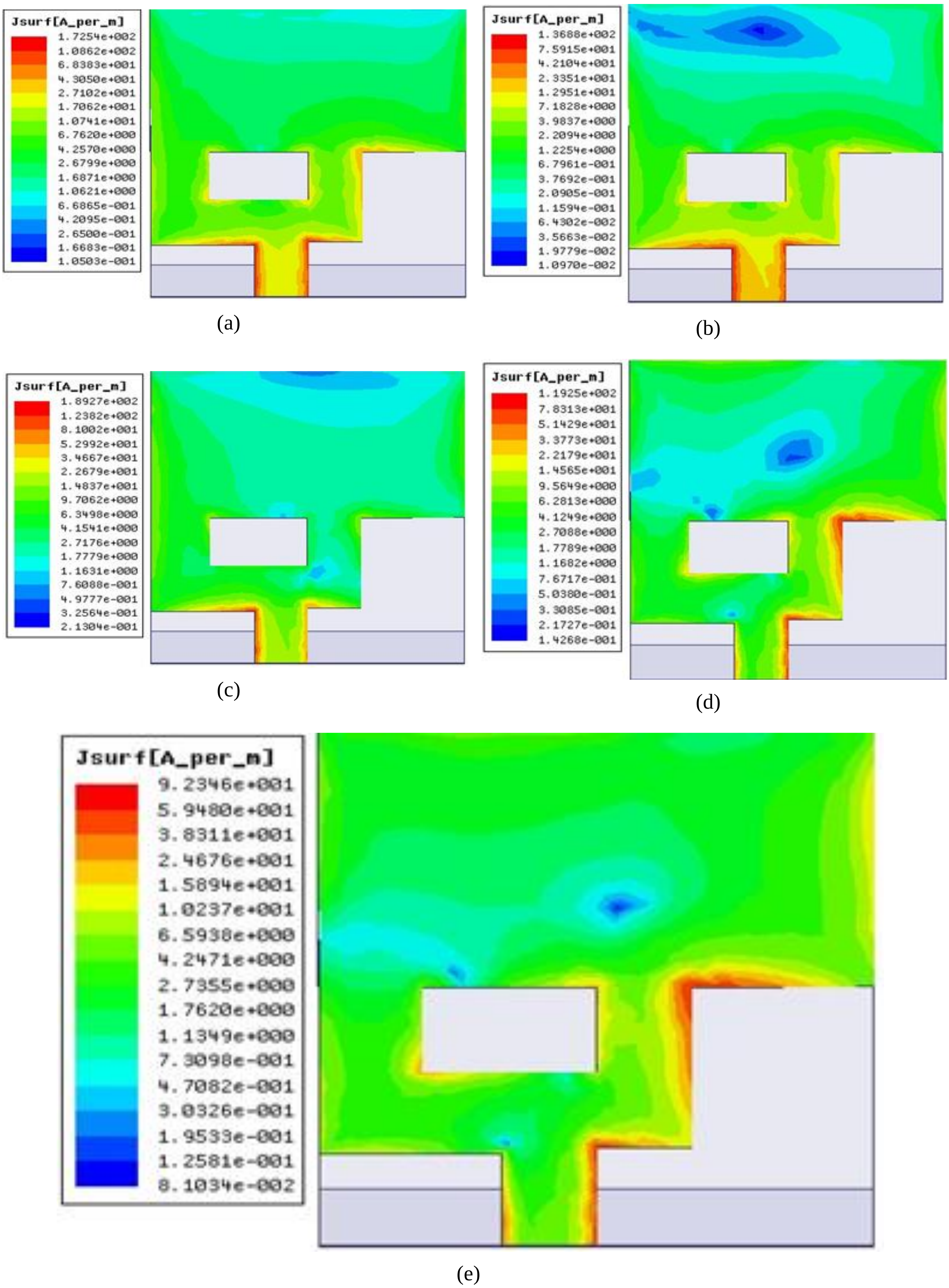


Figure 5. Simulated current distribution at: (a) 2.4 GHz, (b) 4 GHz, (c) 6GHz, (d) 9.2 GHz, (e) 9.5 GHz

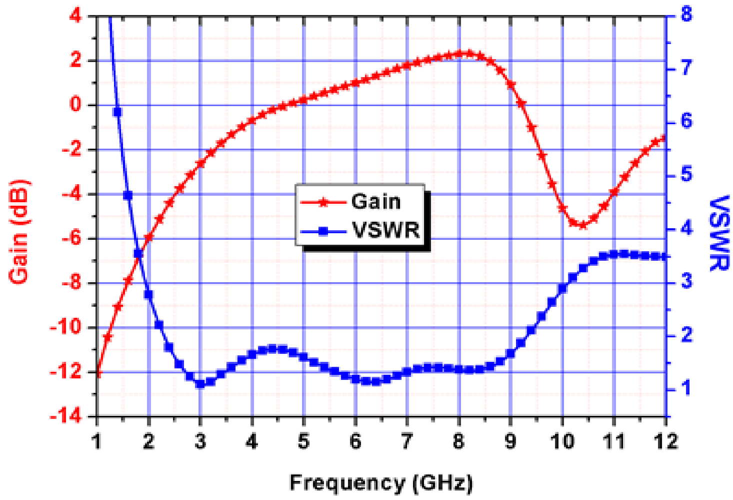


Figure 6. Simulation VSWR and gain versus frequency for proposed monopole antenna

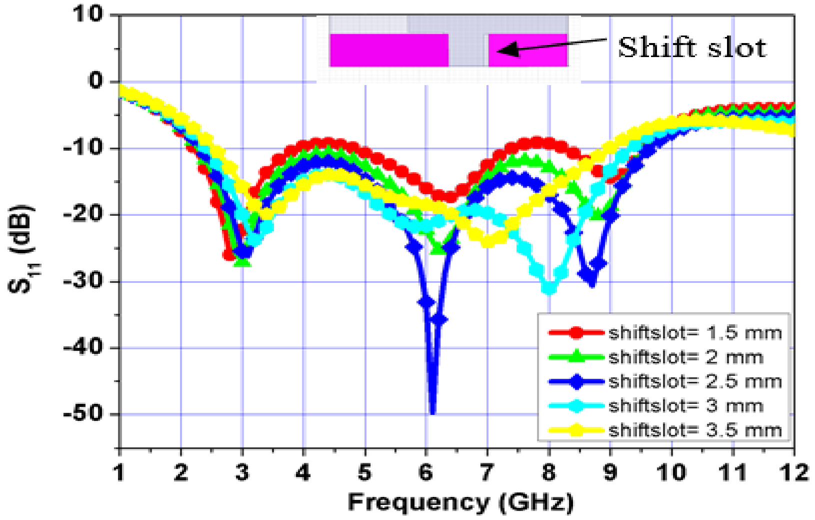


Figure 7. Return loss simulations of the our antenna for dissimilar locations of slot over ground plane at 1.5, 2, 2.5, 3, and 3.5 mm with fixed slot length (3.5mm) and width (2.5mm)

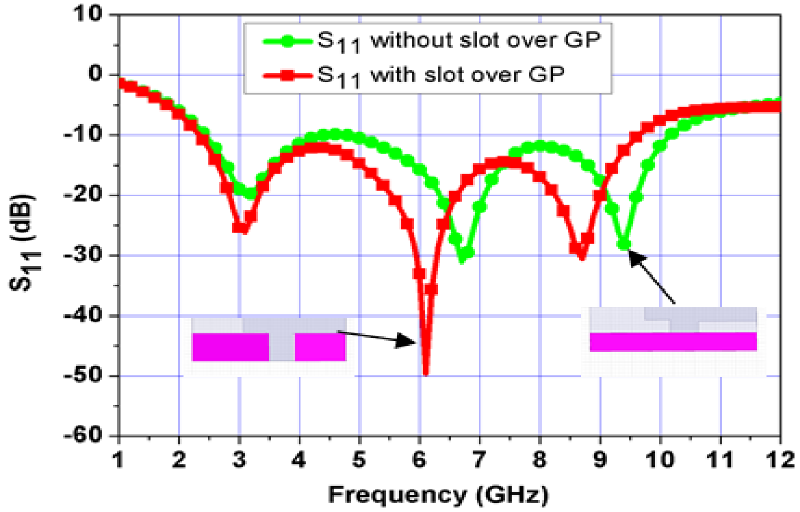


Figure 8. Return loss simulations of proposed antenna with and without slot over ground plane

4. Conclusion

A compact monopole patch antenna has been simulated on FR4 substrate employing a slot on the ground plane and power dividers. The proposed antenna with dimensions of 22*20*1.6 mm^3 gives a bandwidth of more than 120% (2.4-9.6 GHz), and it has a voltage standing wave less than 2 and peak gain of 2.3dBi. The radiation pattern shows the good omnidirectional and bidirectional patterns for the UWB frequency band. In comparison with other reported monopole antenna with UWB responses in the literature, the designed antenna in this paper has more miniaturized size that can be simply incorporated within many planar circuits. The results show that the present antenna is right candidate to convey and receive line code digital data by using WBT scheme with broadband, flat gain and linear phase characteristic in the short distance configurations.

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