CIRCULAR SHAPE USING SUBSTRATE INTEGRATED WAVEGUIDE (SIW) TO ENHANCE THE GAIN OF PLANAR MONOPOLE ANTENNA FOR ULTRA WIDEBAND (UWB) APPLICATION

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Abstract

Ultra wideband is a wireless technology that uses low energy. UWB antenna has wide bandwidth results in low antenna gain. In this thesis, the UWB antenna is designed using a planar antenna with a circular patch and the substrate FR4(lossy) which operates at a frequency of 3.1 Ghz to 10.6 Ghz. UWB antenna has dimensions of 40x36x1.6 mm3 and VSWR ≤ 2. Then the SIW structure is designed for increase the gain of the UWB antenna. The SIW structure is designed under the UWB antenna with Dimensions 40x36x1.6 mm3 and between the structural design of the SIW and the UWB antenna are given layer FR4(lossy). The SIW structure consists of circular slots with a radius of 0.4mm in the shape of a squares parallel to the patch antenna UWB. Slots are made to penetrate the SIW structure that is consists of FR4(lossy) coated metal copper on the bottom and top. Expected design produces an increase in UWB antenna gain of 1 dBm and has VSWR ≤ 2.Design antenna using CST studio and the design results will be presented with a comparison the gain and VSWR values of UWB antennas that do not use the SIW method and those that do not using the SIW method.

Keywords: **Ultra-wideband (UWB), Planar Antenna, Gain, Substrate Integreted Waveguide (SIW)**

1. Introduction

Advances in communication technology show very rapid development, especially in wireless communication. Wireless communication is believed to be more effective and efficient because it does not require cables and has constant transfer power. In wireless communication, an antenna is required to send and receive infor-mation signals. An antenna is a transducer that can convert electromagnetic energy in the transmission line to electromagnetic energy emission in free space. There are various types of antennas used in wireless communication, based on the way they are applied [1].

UWB is one of the most widely developed antennas today. UWB antennas have many advantages: wide bandwidth, high data rate, simpler and cheaper transceiver components, low transmit power, and low interference. According to the Federal Communications Commission (FCC), Ultra-Wideband (UWB) is defined as wireless transmission which has a fractional bandwidth of at least 25 % of the center frequency or a minimum of 500 MHz (at a minimum center frequency of 6 GHz). UWB works at a frequency of 3.1–10.6 GHz [2]. UWB transmits multiple radio frequencies simultaneously which causes the antenna to transfer data quickly. Wide bandwidth also affects the number of signals emitted by the antenna. In addition,UWB antennas have the accuracy, high detection on target, immune to noise, jamming, and interference.

In the UWB antenna design, a planar antenna with a circular patch and FR-4 substrate is used. The planar antenna is an antenna that can work at high frequencies. It consists of a ground plane, a substrate, and a patch. Planar antennas were chosen because of their low profile, compactness, low weight, and small dimensions, so they are often used in wireless communication [3]. In addition, planar antennas can be modified by giving slots in the antenna structure layer s and antenna parameter values that can increase the gain and directivity of the antenna [4] [5]. The selection of circular patches also makes it easier to modify the antenna.

After that, the substrate integrated waveguide method is employed to the results of the UWB antenna design. SIW is a structure that can be used in complex microwave systems as interconnects and filters. SIW is a transmission line that passes high-frequency signals with small losses and can integrate components. Combining a waveguide and planar transmission lines will produce a new channel that maintains the advantages of its constituent channel. A transmission line with a cylinder diameter d and pitch distance p is made with a transition model-specific [6]. The SIW design is slightly different from microstrip, coplanar, and coaxial cable transmission lines. In this design, a suitable transition mode is also made for minimum power loss and an extensive frequency range [7].

2. Research Method

2.1 Planar Monopole Antenna

Planar antenna is one type of antenna that can work at high frequencies. Planar antennas have small dimensions, are light and thin. So that planar antennas are one type of antenna that can function in wireless communication. Planar antennas consist of layers of the ground plane, substrate, and patch. Antennas have several simple patch shapes such as circles, rectangles, triangles, and others. Planar antennas are composed of flat antennas and solid cables, which are an extension of omnidirectional antennas. An omnidirectional antenna is an antenna that emits radiation with the same strength in all directions. In addition, planar antennas have a narrow bandwidth and small gain for one patch. In the development of planar antennas, giving slots in the antenna layer with a specific shape and modification of antenna parameter values are often done to increase the gain, return loss, the directivity of the antenna [11] [12] [13]. The selection of antenna forming materials can also determine the value of gain, VSWR, and antenna's directivity.

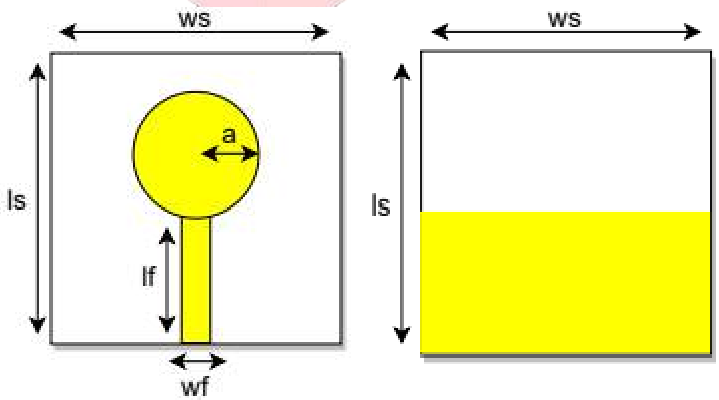

Figure 1 Structure Planar Antenna : Front and Back View

2.2 Ultra-Wideband Antenna

UWB technology was first discovered when Marconi used spark plug transmitters (short electric pulses) for wireless communication. Then in 1920, this technology was banned from commercial use. UWB technology is only used in defense applications. In 1992 UWB technology began to receive world- wide attention. UWB technology was first developed in radar, communications, consumer electronics, wireless personal area networks, localization, and medical electronics. Since then, a lot of knowledge and development of the technology UWB. Even in 2002, UWB was able to transmit data at a speed of 480 Mbps. UWB can also operate at speeds up to 100 times faster than Bluetooth and is expected to replace Wi-Fi devices. UWB (Ultra Wide Band) is a short-range communication system that has an extensive bandwidth so that it can be categorized as UWB communication with a fractional bandwidth requirement of 25 % of its Center Frequency or a minimum of 500 MHz (at a minimum center frequency of 6 GHz) [2].UWB emits RF (Radio Frequency) bursts, where the radiation radiates over a wideband, transmitting so many frequencies simultaneous [8].UWB has signal interference which is small because the transmission is spread over the radio spectrum and the spread of the signal is difficult to inhibit. UWB systems are spread spectrum, which means that the data is encoded into broadcast waves over a wide range of frequencies. It allows breakneck data transfer speeds. The resulting signal is low-power and spreads across the spectrum to share space with existing radio communications and not cause service disruptions. UWB has many advantages, namely: wide bandwidth, high data rate, simpler and cheaper transceiver components, low transmit power, and also low interference [3]. Ultra-Wideband (UWB) is a technology that uses an extensive frequency with a frequency range between 3.1 GHz – 10.6 GHz.

In general, UWB antenna designs use microstrip antennas because of their low profile, compact, low weight, and small dimensions [9] [10]. In UWB communication, the antenna is a significant pulse-forming filter, anydistortion of the signal in. The frequency domain distorting the transmitted pulse can increase the complexity of the detection mechanism at the receiver. In UWB technology, no modulation is needed in the telecommunication system. The antenna needed must have a wide bandwidth because the more influential the pulse, the smaller the bandwidth, and conversely, the narrower the pulse, the greater the bandwidth.

2.3 Substrate Integretd Waveguide (SIW)

Substrate integrated waveguide is a transmission channel capable of de- living high-frequency signals with small losses but can integrate many components. SIW can be used in complex microwave systems as interconnects, filters, and others. There is a frequency cut-off that determines the frequency that can be transmitted as a filter [14]. SIW is a method that is applied by forming a row of metal cylinders as a sidewall of the waveguide embedded in a dielectric substrate that connects the patch and ground plane. The need for a high performance wave system, SIW, can be used as a solution because it is low cost, compact, and can work at high frequency. The waveguide can overcome the problem of radiation loss and low insertion. The SIW structure consists of a thin dielectric substrate coated by metal and adds two parallel metal rows as a barrier for wave transmission. There is a metal cylinder diameter and a distance between pitch p. This component will be designed with a specific value and arrangement that can realize the results of the antenna [6]. SIW is different when connected to the type of transmission line such as microstrip, copla-nar, and coaxial cable. The difference is making a transition channel that aims to lose power minimum and work at the broadest possible frequency. Tapered transition to convert the microstrip to SIW is used on thin sub-states, causing radiation losses in the microstrip path to be smaller [7] [15]. However, there is a more significant leakage on thicker substrates so that coplanar can be used as a solution with the loss of a narrower bandwidth value. There are also transitions in the form of lines embedded in the same substrate. Where no direct transition occurs from the coaxial channel to the SIW, another planar line is created to change the propagation mode of coaxial TEM to TE SIW. SIW technology also found some disadvantages that may occur due to the conductivity of the dielectric medium, external metallic conductivity, loss of tangent of the dielectric medium, and radiation effects. SIW losses can be comparable or smaller than traditional structures such as microstrip and coplanar at high frequencies. Moreover, if the substrate is thick enough, then the losses are dominated by the dielectric behavior of the substrate. SIW is widely used to increase gain, bandwidth, impedance, and other values. SIW can increase the Q factor. Providing additional structures such as slots and other materials can also realize the value of the antenna [16].

3. Design and Simulation of The Antenna

3.1 UWB antenna

In this thesis, a planar antenna with a circular patch is used. The circular patch is the most frequently used form and is easier to analyze. Research on an antenna with a circular patch will be easier to modify to get the desired radius, impedance, vswr, and gain patterns. The antenna will work at a frequency of 3.1 Ghz to 10.6 GHz. The antenna design uses FR-4 (lossy) (er=4.03 and h=1.6) on the substrate and copper on the ground. Antenna simulation results using CST studio are expected to have VSWR ≤ 2.

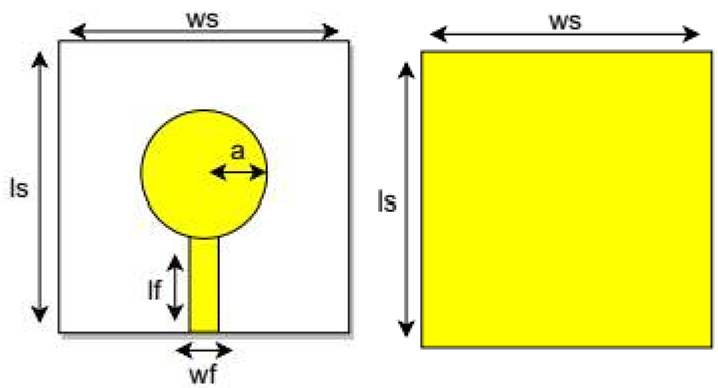

Figure 2 The Initial Antenna 1 : Front and Back View

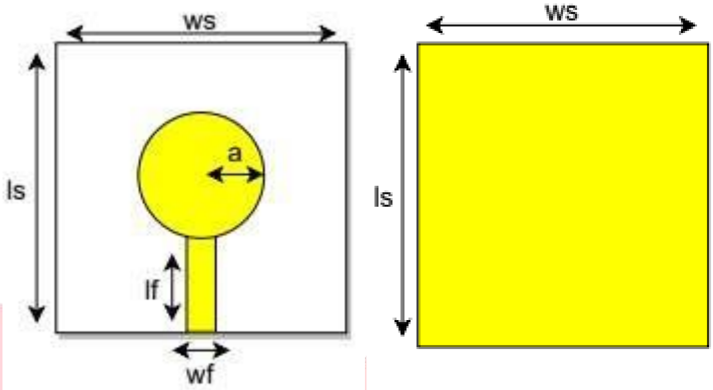

Figure 3 The Itnitial Antenna 2 : Front and Back View

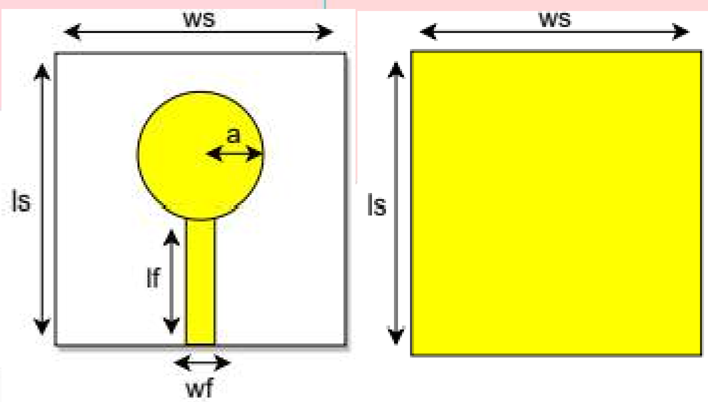

Figure 4 The Itnitial Antenna 3 : Front and Back View

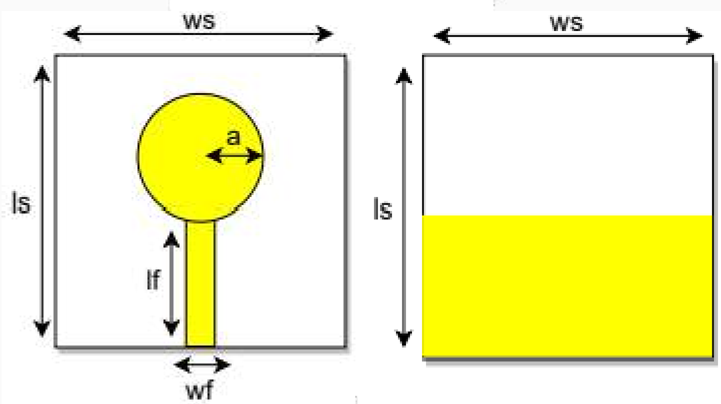

Figure 5 The Initial Antenn 4 : Front view and Back View

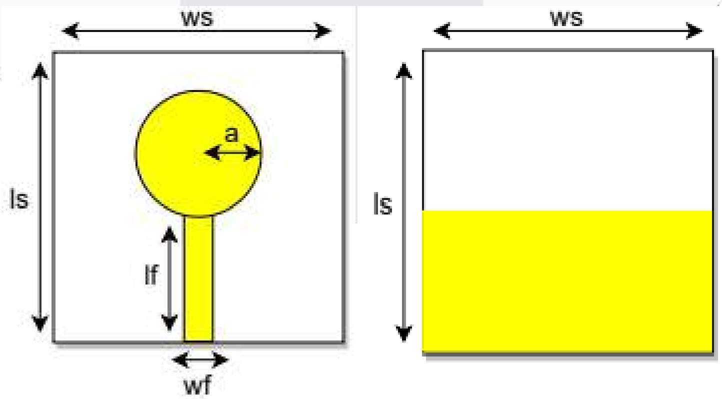

Figure 6 Final Antenna Design : Front and Back View

Table 1. The Final Antenna Dimension

Parameter	Value (mm)
Thickness of Substrate(ts)	1.6
Thickness of Conductor	0.035
Substrate Width (ws)	40
Ground plane Width (wg)	40
Substrate Length (ls)	36
Ground plane Length (lg)	36
Feed Width (wf)	2
Feed Length (lf)	40
Radius(a)	8

3.2 Designing UWB Antenna with SIW method

Design UWB antenna with SIW method.

The SIW design is made at the bottom of the UWB antenna. the SIW layer is made of parallel slots and is accompanied by several circular slots with a larger diameter on the side. the combination of the two slots is designed to increase the antenna gain. after the SIW layer, there is a substrate layer of FR-4 (lossy) and The next layer is the UWB antenna. In the picture below, the shape of the UWB antenna design is described with the SIW method.

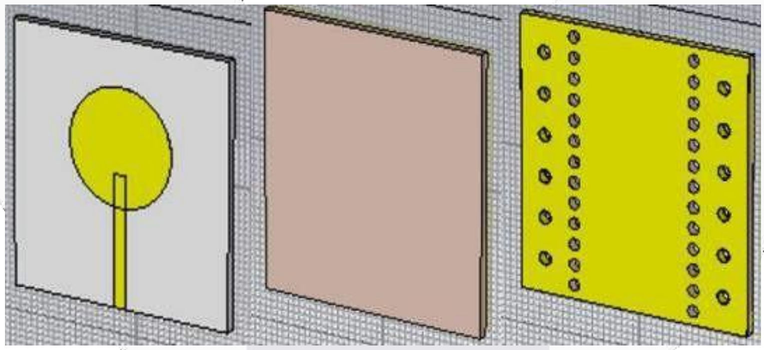

Figure 7 Antenna design.

Table 2. The Final Antenna Dimension

Parameters	Value (mm)
Thickness of Substrate(ts)	1.6
Thickness of Conductor	0.035
Substrate Width (ws)	38
Ground plane Width (wg)	36
Substrate Length (ls)	40
Ground plane Length (lg)	10
Feed Width (wf)	2.1
Feed Length (lf)	30
Patch Radius(a)	9
Radius 1 (r1)	0.9
Radius 2 (r2)	1

Final Design UWB antenna with SIW method.

In this design, the SIW method design is only found at the bottom of the UWB antenna. SIW and substrate layers are added and then the top is the UWB antenna design. the SIW slot design is square in shape around the patch antenna but the SIW slot is only found in the SIW method layer or the slot does not reach penetrate the substrate and UWB antenna design. for more clarity, the UWB antenna design with the SIW method is shown in Fig. 3.8. In table 3.5 the antenna parameter values and the SIW method are also explained.

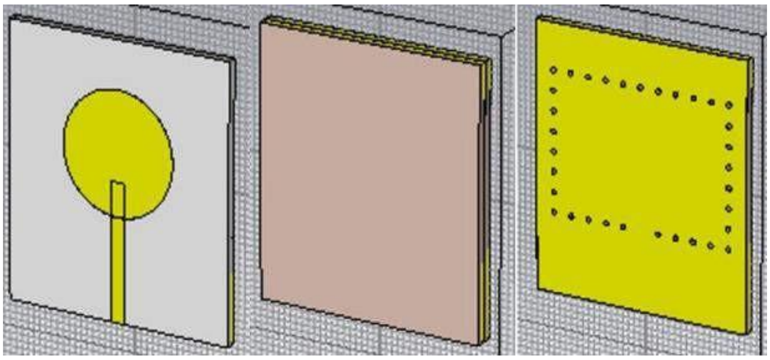

Figure 8 Antenna design.

Table 3. The Final Antenna Dimension

Parameters	Value (mm)
Thickness of Substrate(ts)	1.6
Thickness of Conductor	0.035
Substrate Width (ws)	38
Ground plane Width (wg)	36
Substrate Length (ls)	40
Ground plane Length (lg)	10
Feed Width (wf)	2
Feed Length (lf)	32
Patch Radius(a)	9
Radius (r)	0.4

4. Result and Analysis

4.1 VSWR and Gain result of final design UWB Antenna

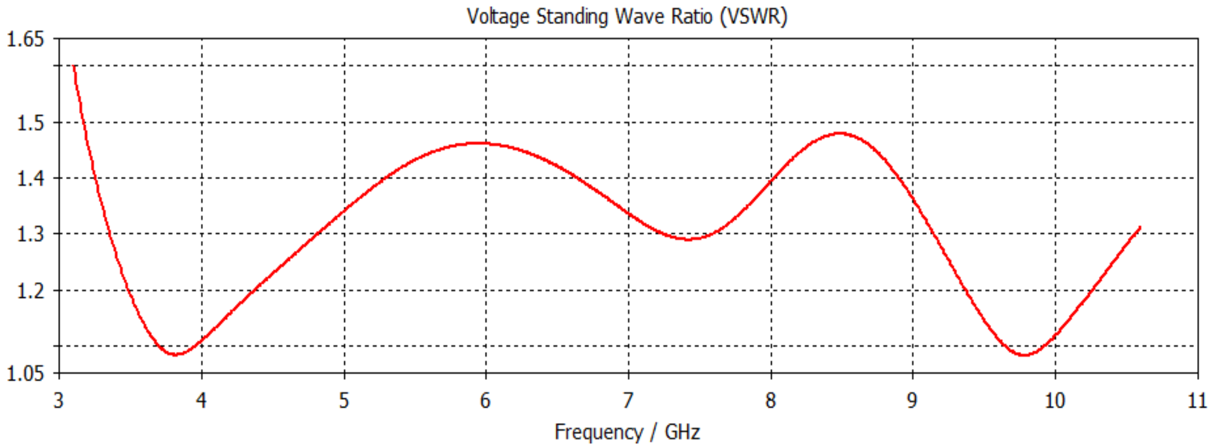

Figure 9 Antenna VSWR

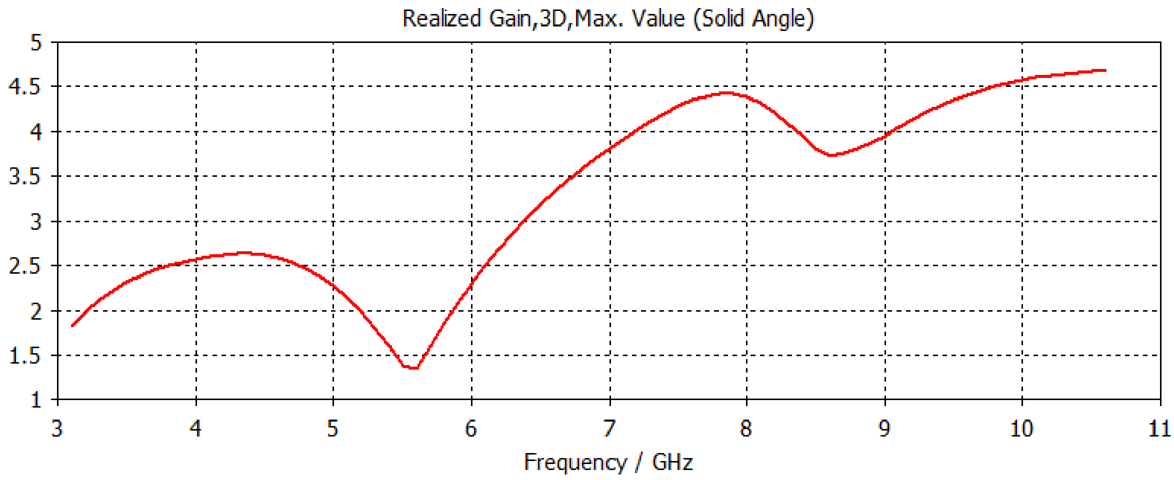

Figure 10 Antenna Gain

4.2 VSWR and Gain result of Design UWB Antenna with SIW method

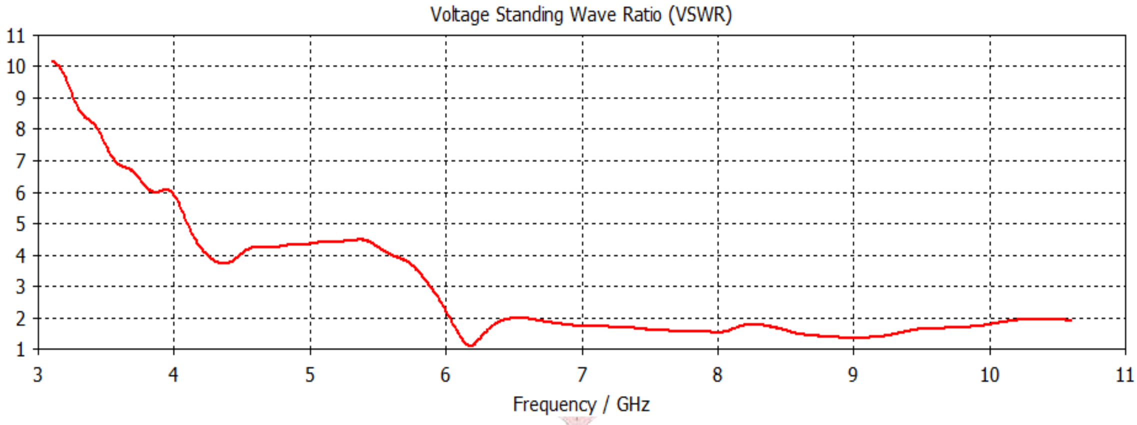

Figure 11 Antenna VSWR.

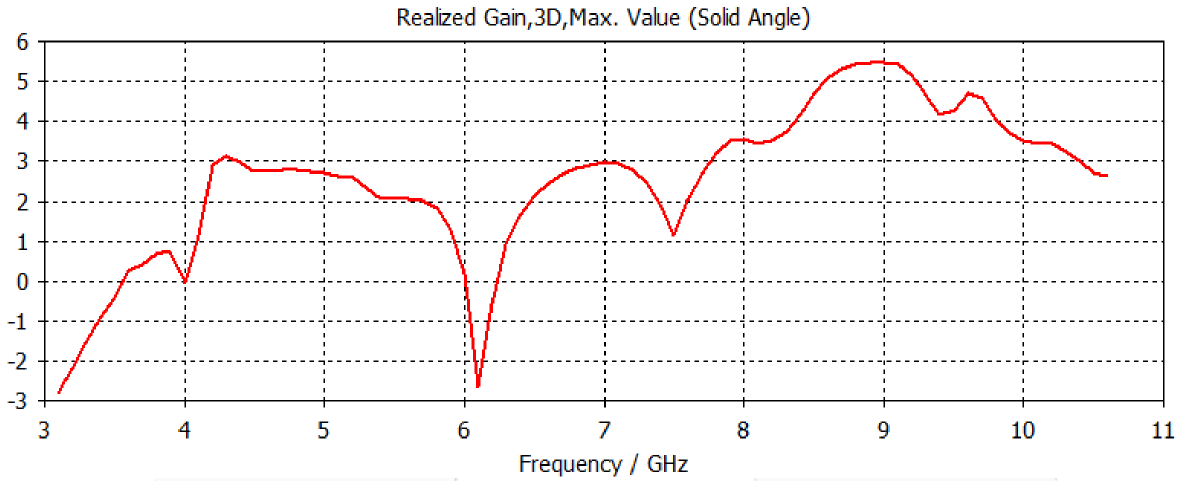

Figure 12 Antenna Gain.

4.3 Comparison VSWR and Gain Antenna

Gain Antenna.

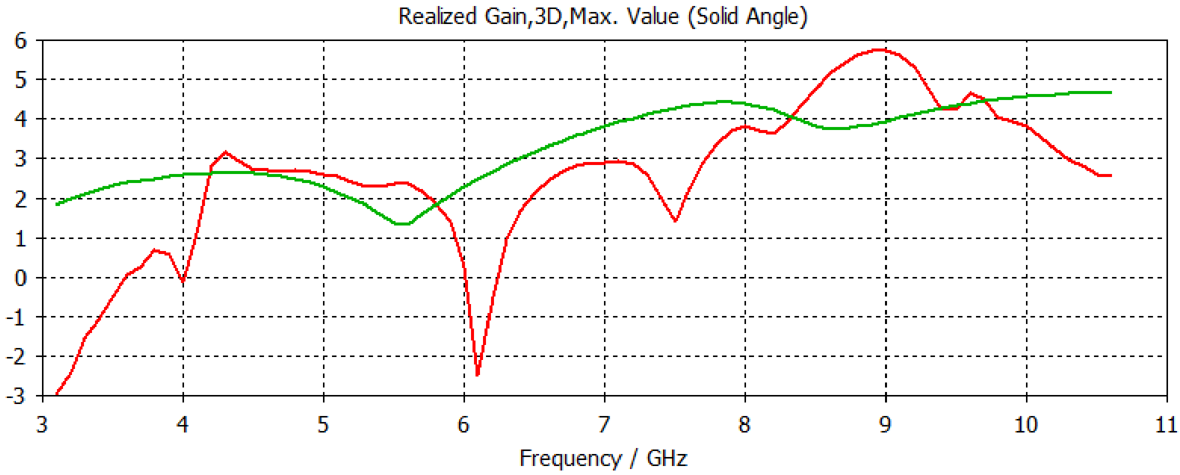

Figure 5 Gain UWB antenna and UWB antenna with SIW method.

VSWR Antenna.

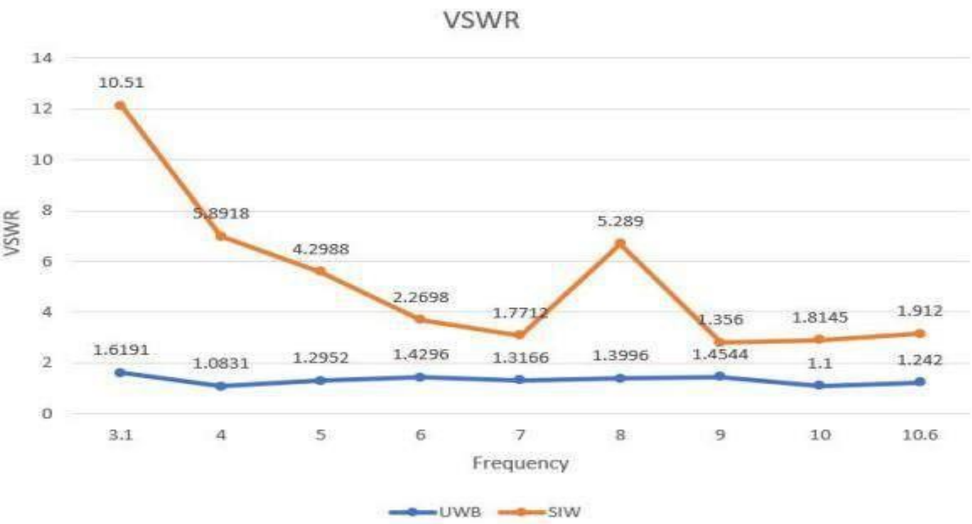

Figure 5.1 VSWR UWB antenna and UWB antenna with SIW method.

5. Conclusion

From the analysis and simulation of increasing the gain of the planar antenna using the SIW method, the following conclusions can be drawn:

1. A Planar antenna is an antenna that can work at ultra-wideband. UWB antenna design results with VSWR ≤ 2 and gain from 1 GHz to 5 GHz. Antennas are easy to design with Modify the parameter values, suitable antenna base material, and the shape of the antenna layer to get the desired results.

2. The increase in the gain of the UWB antenna with the SIW method has not obtained satisfactory results because the increase in gain has not occurred at all frequencies of the UWB antenna.Addition FSS to the antenna can increase the VSWR value, but the gain will also increase at the whole frequency range

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