APPLICATIONS OF ULTRA WIDEBAND

by

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ABSTRACT

APPLICATIONS OF ULTRA WIDEBAND

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Ultra wideband (UWB) is a new wireless communication system. It utilizes transmission signal at wide bandwidths. With wider bandwidth, it can provide for new useful applications. The first chapter in this thesis discusses the features and advantages of the UWB. Chapters 2 and 3 present two proposed UWB applications.

Chapter 2 presents the use of UWB in shipping containers. The security of shipping containers is an urgent issue for globally. UWB can provide a solution to secure containers. Our goal is to develop a system to enhance the transmission signals. In comparison with other system designs, our waveguide approach satisfies most of the requirements.

In chapter 3, we propose using UWB for medical implants. With its advantages, UWB provides benefits over other wireless systems. Our goal is to develop a method to

find the optimal position for the UWB transmitting antenna and yield better performance. We proposed an equivalent circuit method, verified by finite element approaches, to simplify design methodology.

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CHAPTER 1

ULTRA WIDEBAND WIRELESS COMMUNICATION

1.1 Introduction[1, 23]

In communication systems, analysis of signals is done in both the time domain and the frequency domain. The ultra wideband (UWB) system transmits signals across a much wider frequency range than conventional systems do (Figure 1.1). Formally, the definition of a UWB is its bandwidth should be greater than 500MHz. And, the frequency range is 3.1 to 10.6 GHz. For example, a UWB signal centered at 2 GHz would have a minimum bandwidth of 500 MHz and the minimum bandwidth of a UWB signal centered at 4 GHz would be 1 GHz. The most common technique for generating a UWB signal is to transmit pulses with durations less than 1 nanosecond.

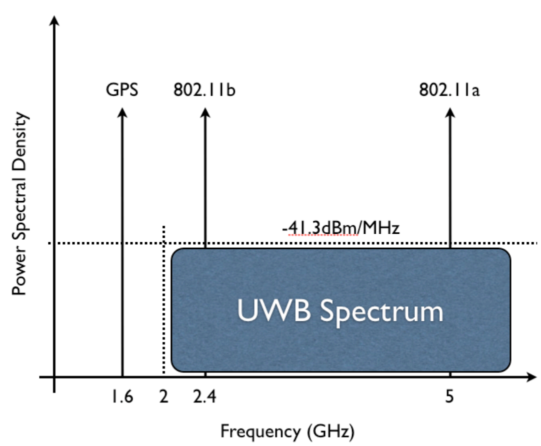


Figure 1.1 Comparison of different wireless communication systems in the frequency domain.

1.2 The Advantages of the UWB Technology [2][4]

1.2.1 Power Consumption

The Federal Communications Commission (FCC) power requirement for UWB systems is -41.3dBm/MHz (75nW/MHz) (Figure 1.1). Such a power restriction allows UWB systems to reside below the noise floor of a typical narrowband receiver and enables UWB signals to coexist with current radio services with minimal interference. UWB radio offers short-range communication that uses 1/1000 of the power required for equivalent conventional transmission methods. Low battery power consumption is a constraint for many wireless communication systems, especially in the transmission devices. Furthermore, since UWB signals use such low powers, they are less harmful to human.

1.2.2 High Security

Because of their low average transmission power, UWB communications systems have an inherent immunity to detection and interception. UWB pulses are time-modulated with codes unique to each transmitter and receiver. The time modulation of extremely narrow pulses will add security to UWB transmissions, because detecting pico-second pulses without knowing when they will arrive is next to impossible. Such security is a critical need for military operations.

1.2.3 Resistance to Interference [12]

Unlike the well-defined narrowband frequency spectrum, the UWB spectrum covers a vast range of frequencies. UWB signals then, are relatively resistant to intentional and unintentional jamming, because it is almost impossible to jam every frequency in the UWB spectrum at once. Thus, even though some of the frequencies are jammed, there will still be a range of frequencies that remain signal coding. UWB provides less interference than narrowband radio designs. Because of their low power spectrum density, unlicensed UWB radios will cause no interference to other radio systems operating in dedicated bands.

1.2.4 High Performance in Multipath Channels [22]

The phenomenon known as multipath interference is unavoidable in many wireless communications channels. When signals are transmitted between transmitter and receiver, they scatter, reflected from objects and surfaces along the path. At the receiver end, the receiver sees the superposition of delayed versions of the original signal. When signals are continuous-waves or sinusoidal waveforms, these ‘replicas’ may cancel the original signal due to the phase difference of the signals. UWB communication uses pulse waveforms and they tend not to overlap in time because of the extreme narrowness of the pulse. Because the transmission duration of a UWB pulse is shorter than a nanosecond in most cases, the reflected pulse has a small window of opportunity to collide with a line-of-sight (LOS) pulse and cause signal degradation.

1.2.5 Strong Penetration Ability

Unlike narrowband technologies, UWB systems can penetrate effectively through different materials. The low frequencies included in the broad range of the UWB frequency spectrum have long wavelengths, which allow UWB signals to penetrate a variety of materials, such as walls. This property makes UWB technology viable for through-the-wall communications and ground-penetrating radar. This is a great advantage for sealed space and body implant wireless communication.

1.3 Advantages of using UWB for Shipping Container [2][4]

Traditionally, wireless communication systems are based on narrowband technologies, they have limitations when used to penetrate a container. With the advantages of UWB, there will be three major benefits using them to identify shipping containers. First, conventional communication signals use narrow high carrier frequencies. The propagation losses are approximately proportional to the frequencies of the signals [14]. However, UWB technology includes relatively low frequency components. Such properties give UWB signals greater penetrating ability. Second, in the frequency domain, even if the transmission signal may be blocked at any single frequency, the signal will still transmit with the rest of the bandwidth. Third, when signals are transmitted into the container, they scatter and are reflected by objects inside. The receiver sees the superposition of delayed signals. These ‘replicas’ may cancel the original signal due to the phase difference of the signals. UWB communications use pulse waveforms and they tend not to overlap in time because of the extreme shortness of the pulse.

1.4 Advantages of using UWB for Medical Implant [16]

In transmitting the information signals from inside the human body, a wireless technology is necessary. UWB can deliver the following benefits. First, because of the power requirement of UWB communication systems, it does not need to transmit a high-power signal to the receiver. Hence, the UWB transmission device can have a longer battery life or be smaller to reduce the implant size. Furthermore, since UWB signals are required to have low powers, they are less harmful to human bodies [14, 15]. Second, the human body has several tissues absorb signals at certain frequencies [18-21]. Narrowband systems will suffer from transmission losses as the signals are blocked at particular frequencies. Because of the frequency bandwidth of UWB, some of the transmission signal will still pass through the tissues with minimal losses. Third, transmission security is also important for medical implants. Because of low powers and narrow pulses in the time domain, UWB provides high security.

1.5 Current Status of UWB Development [13, 23]

The developers of UWB have already achieved an advanced level. UWB radios can be used for handheld radios with low power and long distance, and be developed for wireless remote with high-speed data rate and wide range. Short-range navigation and positioning systems have attracted more and more attention. Short range positioning can be implemented in mobile UWB communication systems, such as UWB tags, for multiple access communication, and high-accuracy positioning system, such as precision geolocation, can help for storage houses with 3-D position control. There are several UWB radars using in different areas. First, collision avoidance backup sensor is made for auto-security. UWB intrusion detection radar can be used for detecting through the wall and also be used for security with fuze avoidance radar.

CHAPTER 2

FIRST APPLICATION FOR UWB: SHIPPING CONTAINER

2.1 Introduction

The U.S. maritime borders include 95,000 miles of open shoreline, 361 ports and an exclusive economic zone that spans 3.5 million square miles. We rely on ocean transportation for 95% of the cargo tonnage that moves in and out of the country. Each year more than 7,500 commercial vessels make approximately 51,000 port calls, and over six million loaded marine containers enter U.S. ports. Current growth predictions indicate that container cargo will quadruple in the next twenty years [24]. Issues need to be addressed for container security, along with considerations in resource and budget limitation.

The UWB combined with sensing technologies can provide the following [17]:

I. Security:
   i. Prevent and detect integrity breach of the containers,
   ii. Prevent identity theft of the containers.

II. Location:
   i. Tracking and monitoring,
   ii. Immediate response of locations.

III. Sensing and detection of internal objects and reporting

i. Humidity,

ii. Toxicity and pH,

iii. Temperature,

iv. Radiation,

v. Biochemical agents.

2.2 Experimental Setup

A regular shipping container has many chinks on the surface, and the gate of container is sealed by rubber. This is a part without metal and will be used to transmit the signal out of the container. The following experiment performs the measurement of signal traveling through such a metal box. The metal box is made of aluminum to imitate a real cargo container. The open seam models a chink on the metal surface. In order to avoid other wireless interference, such as wireless networks for cell phones, the following experiments were set up using a bandpass filter (3.1GHz~4.7GHz).

2.2.1 Experiment 1: Antenna Location Inside the Container to get Optimal Outputs

In order to understand the interference between the height of the antenna to the metal floor and the transmission signal, the following experiments show the relationship between received power and the distance, L, at different heights, h (Figure 2.1). L represents the distance between two antennas, and h represents the height between the antenna and the floor.

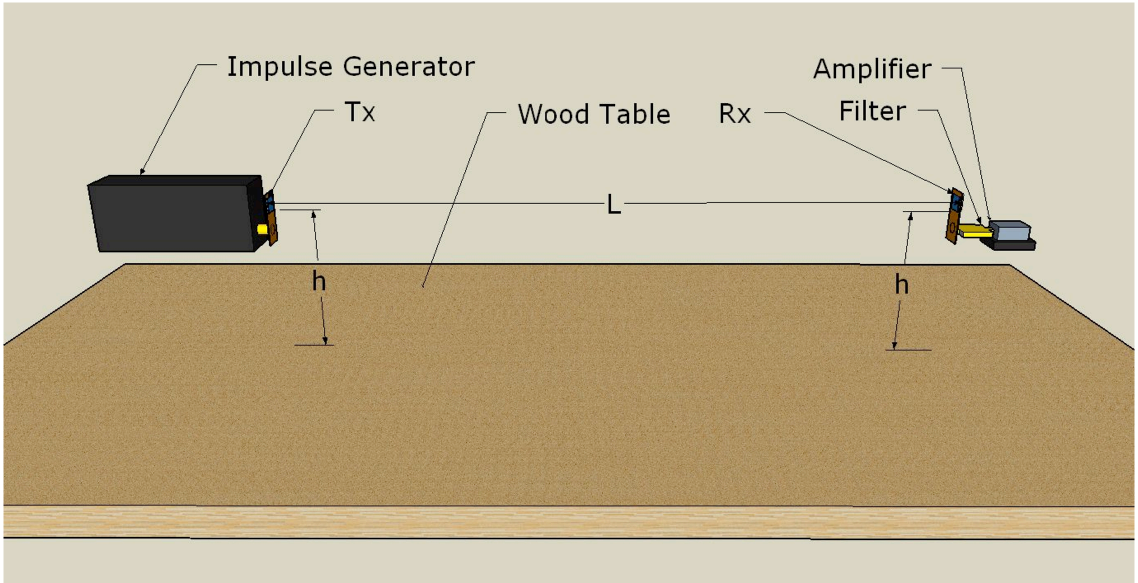


Figure 2.1 Experiment 1:
Received signal powers as a function of the distance L with various h.

2.2.1.1 Results

The signal power in wireless communication follows the inverse square rule. The results show that in the experiment 1, the h=46 cm result follows this rule but the h=3.5 cm result does not (Figure 2.2). In order to reduce multi-path interference by the metal floor, the rest of experiments will use a setup with a height of h=46 cm.

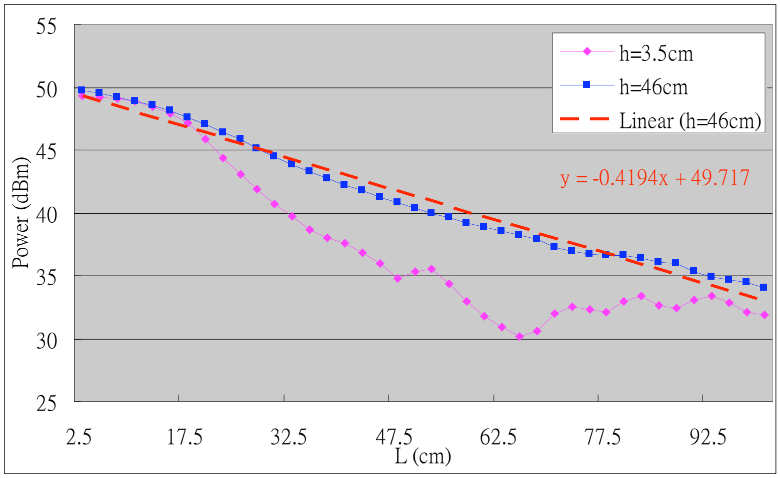


Figure 2.2 Received signal powers as a function of the distance L with various h.

2.2.2 Experiment 2: Setup of Transmitting antenna

In order to receive the maximum power, the following experiment (Figure 2.3) reveals the relationship between the polarization of the transmitting antenna, Tx (Figure 2.4), and the received signal power. The transmitting antenna changes the polarization by 90° step.

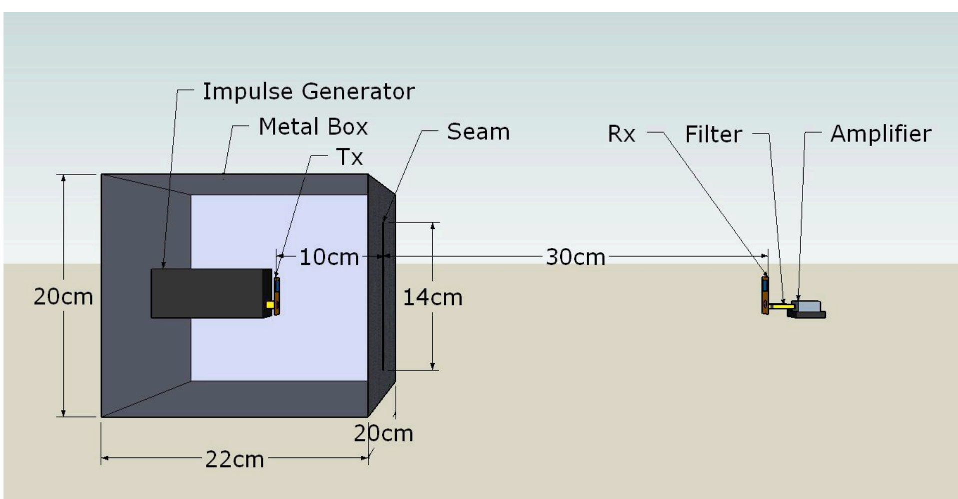


Figure 2.3 Experiment 2:
Received signal powers with different polarizations of the transmitting antenna.

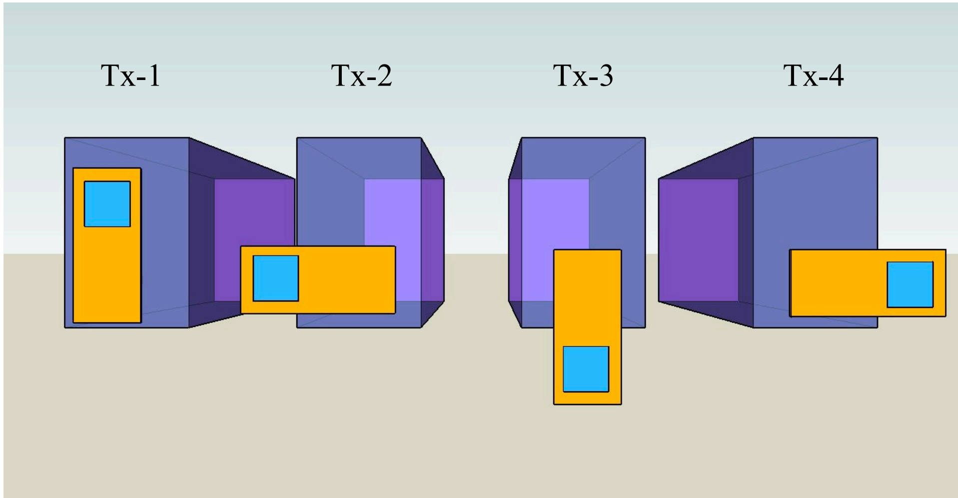


Figure 2.4 Setup of the transmitting antenna with different polarizations.

2.2.2.1 Results

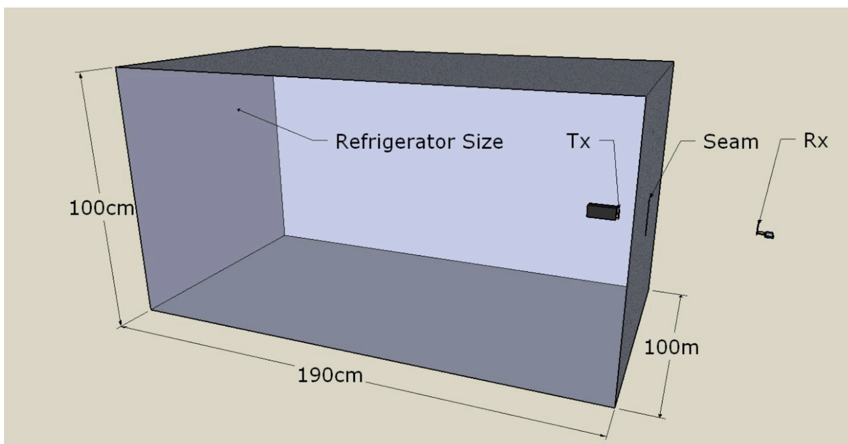
The results are showing in Table 2.1. The larger received signal occurs in the cases of "Tx-2" and "Tx-4". According to the results, the polarization dependence is due to the seam, which basically is a slot antenna. Therefore, the transmitting antenna should be in co-polarization with seam.

Table 2.1
Comparison of received signal powers and the polarization of the transmitting antenna.

Tx Polarization	Tx-1	**Tx-2**	Tx-3	**Tx-4**
Received Power	17.78dBm	**21.96dBm**	18.57dBm	**22.04dBm**

2.3 Comparison of the Seam Size and Signal Power in Various Conditions

To increase transmission power, two reflectors and two waveguides are introduced. The following experiments were set up to measure the relationship between received signal powers and the seam size. The distance between the receiving antenna and the seam stays fixed, and the size of the seam changes from 1 cm to 14 cm, with a step 1 cm. The dimensions are shown in Figure 2.5.



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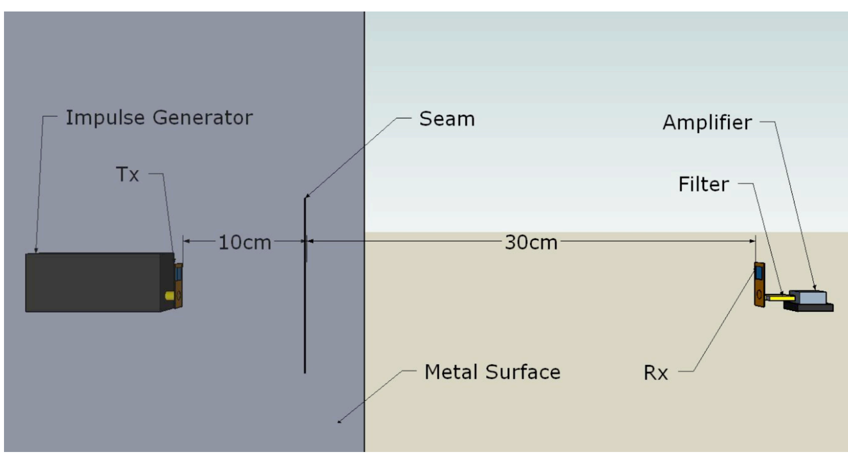
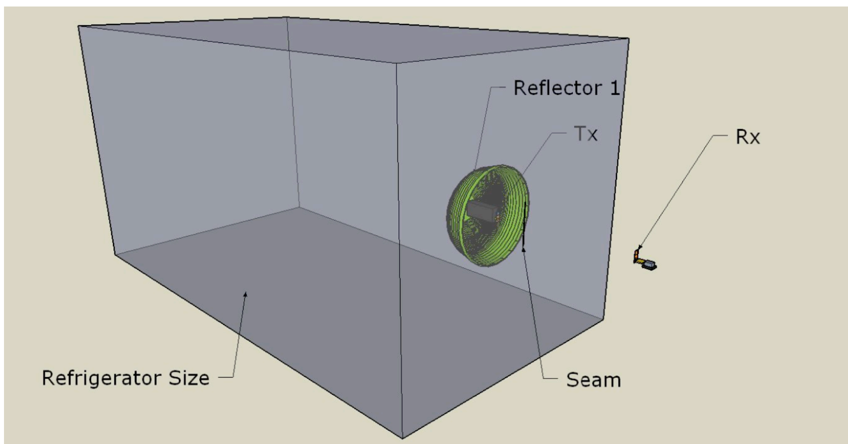


(b)

Figure 2.5 System setup of the experiments:
(a) the "refrigerator size", and (b) setup detail.

2.3.1 Reflectors

The reflector can bounce the signal from the back of the antenna to the front. Normally, it enhances the transmission signal with less loss. We used two reflectors in the experiments. The reflector 1 is shown in Figure 2.6, and the reflector 2 is shown in Figure 2.7. The difference is their sizes.



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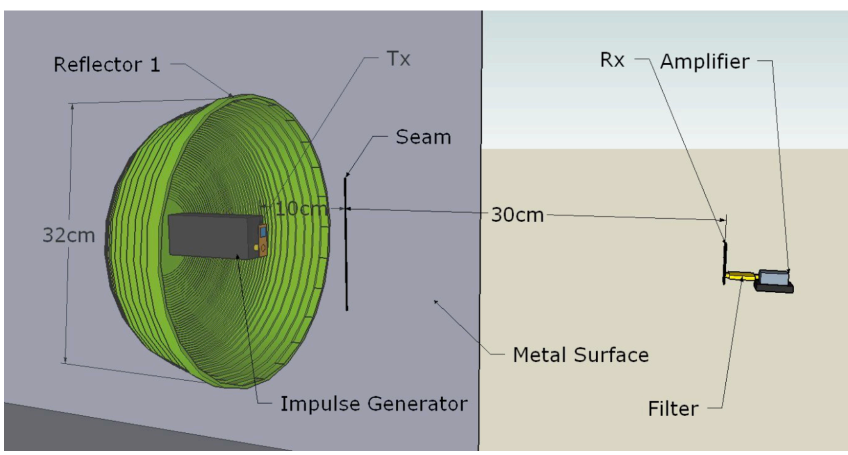

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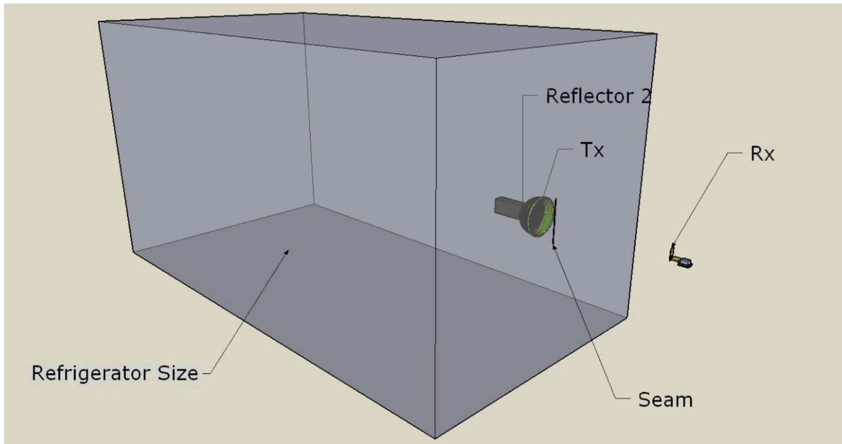
Figure 2.6 Setup of the reflector 1:
(a) the complete configure, and (b) a zoom view.



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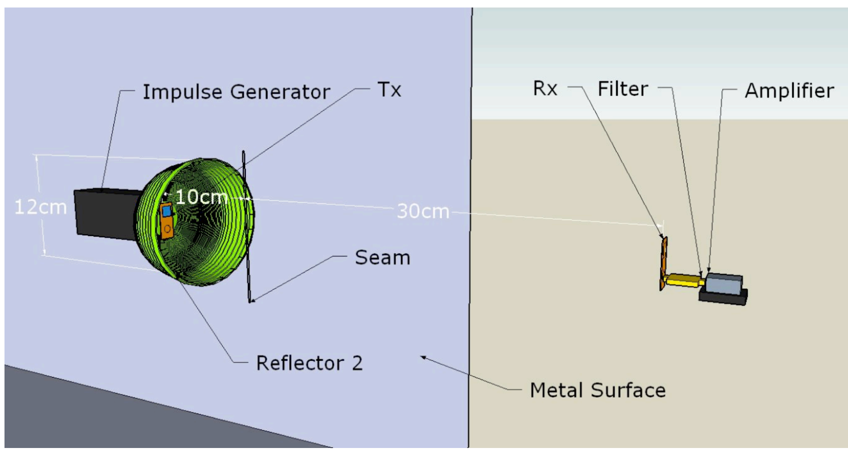
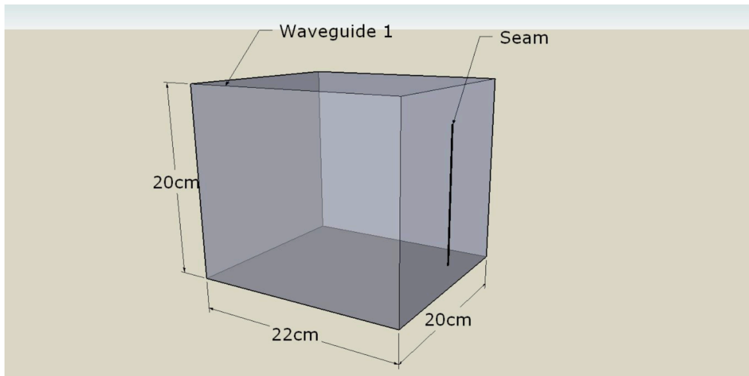


(b)

Figure 2.7 Setup of the reflector 2:
(a) the complete configure, and (b) a zoom view.

2.3.2 Waveguide

In the following experiments, the waveguide will shield and cover the space between transmission the antenna and the seam. There are two waveguides in these experiments. Waveguide 1 has rectangular form as seen in Figure 2.8, and it will be set in the middle of the surface on the refrigerator size. A rectangular form is chosen become the seam "slot antenna" is polarization-dependent, and it is easily to install. For comparison, Waveguide 2 is made in cylinder as seen in Figure 2.9.



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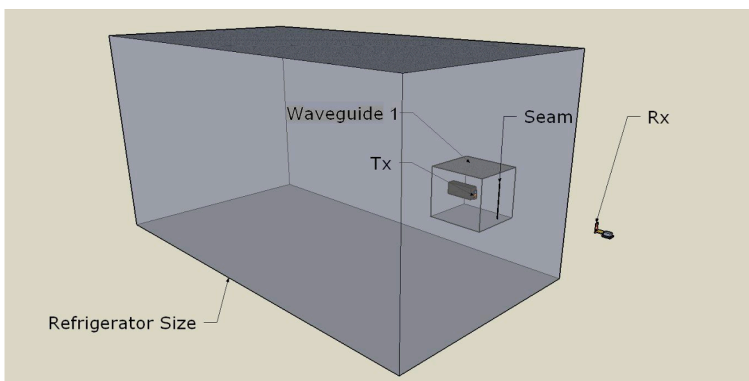

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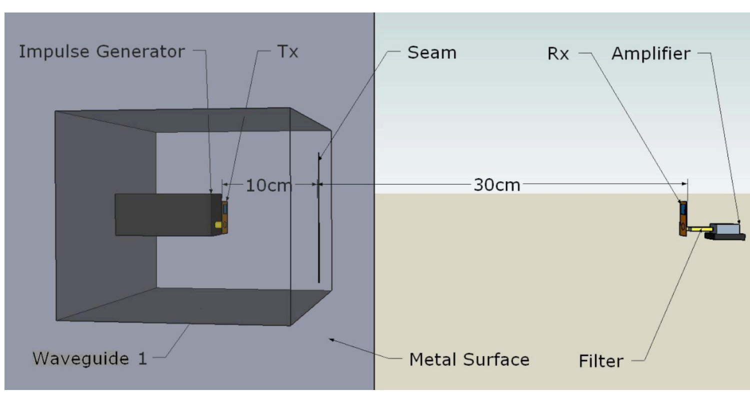


(c)

Figure 2.8 Setup of the waveguide 1:
(a) structure of waveguide 1, (b) waveguide 1 setup, and (c) the detail.

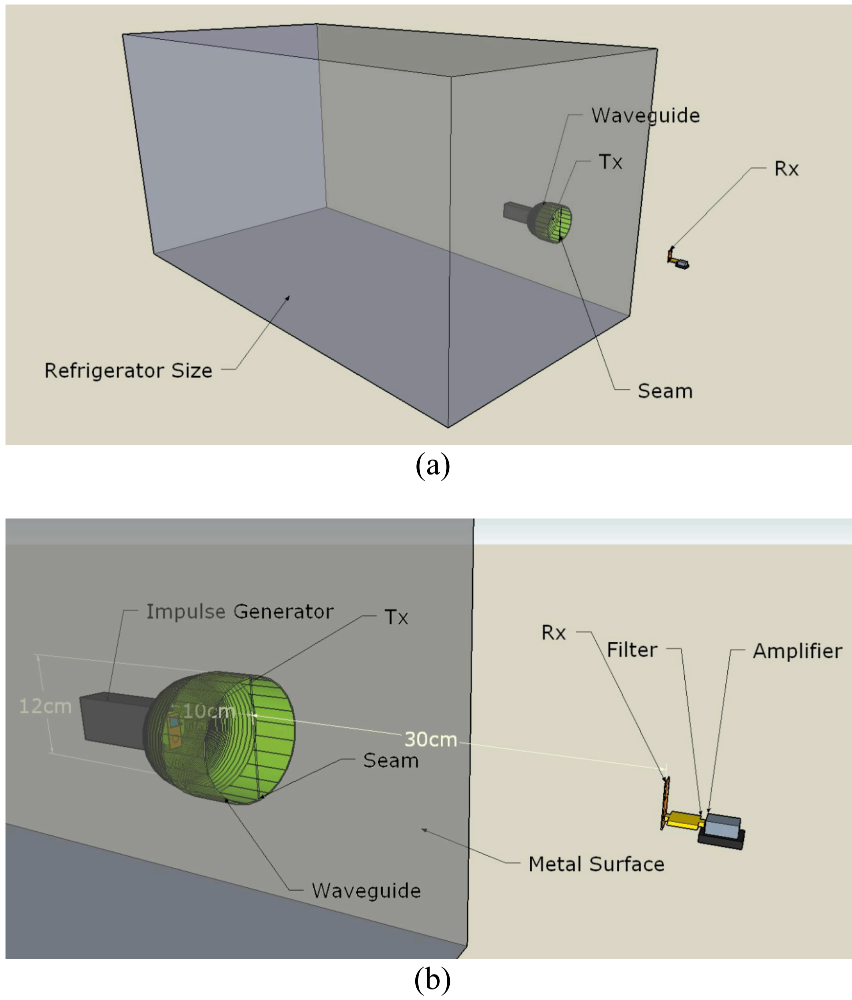


Figure 2.9 Setup of the waveguide 2: (a) setup, and (b) the detail.

2.3.3 Results

The results in Figure 2.10 include using the results for two reflectors, two waveguides, and a reference. In the results, both the reflectors and waveguides can enhance the transmission signal. However, the higher powers are in the cases of the waveguides 1 and 2. The waveguide 1 has 30dB greater than the reference. This means that a reflector cannot deliver the signal as well as a waveguide. Therefore, in order to enhance the transmission signal, a waveguide is needed.

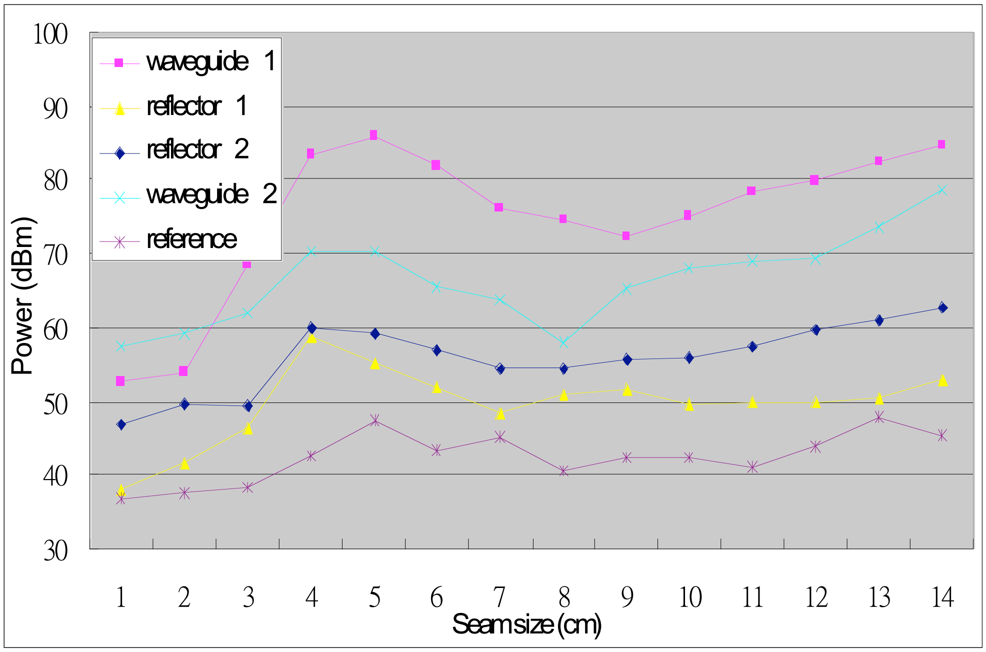


Figure 2.10 Comparisons of signal powers as a function of the seam size in different conditions.

2.4 Waveguide Design

Figure 2.10 demonstrates that waveguide is more suitable for UWB systems. Therefore, the following experiments show a method to design a waveguide, which is suitable for certain wireless communication systems. In order to maintain the EM field polarization, the waveguide is designed in rectangular form (Figure 2.11). This design follows that w=0.7λ, h=0.5λ, d1=0.7λ, and d2=0.4λ as shown in Table 2.2 [25], where λ is the free space waveguide. The fractal antenna has an operating frequency band at 3.1~5GHz. So, for comparison, we developed three waveguides which for different frequencies: 3 GHz (Figure 2.12), 4 GHz (Figure

2.13), and 5 GHz (Figure 2.14). For comparison, even though they have different sizes, the distance between the seam and the receiving antenna remains 30 cm. Thus, according to the different waveguide sizes, the seam sizes in three waveguides are different. The seam size is indicated as h in Fig.2.11.

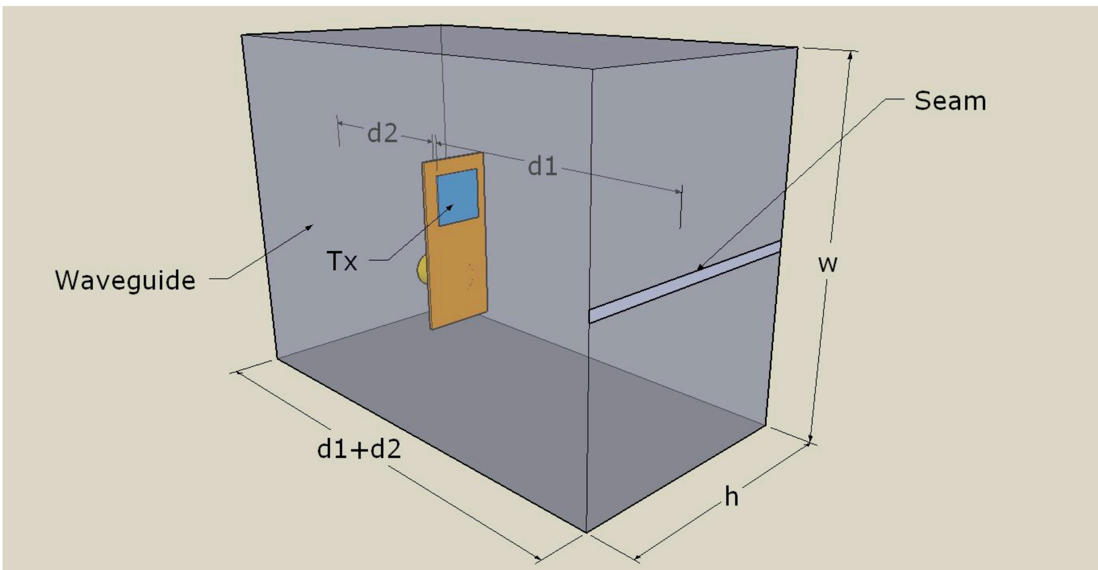


Figure 2.11 Structure of the rectangular waveguide.

Table 2.2 Parameters of waveguides at 3 GHz, 4 GHz, and 5 GHz.

frequency	w (cm)	h (cm)	d1 (cm)	d2 (cm)
5 GHz	4.2	3.0	4.2	1.5
4 GHz	5.3	3.8	5.3	1.8
3 GHz	7.0	5.0	7.0	2.5

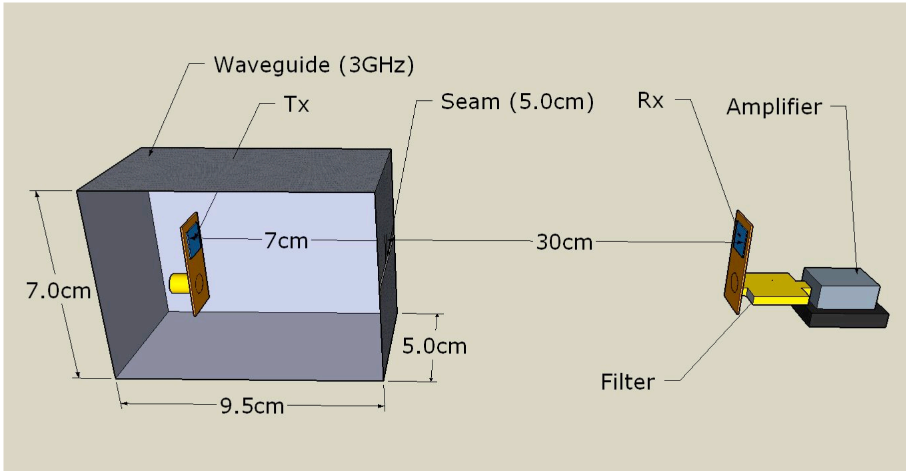


Figure 2.12 Waveguide design for the 3 GHz case.

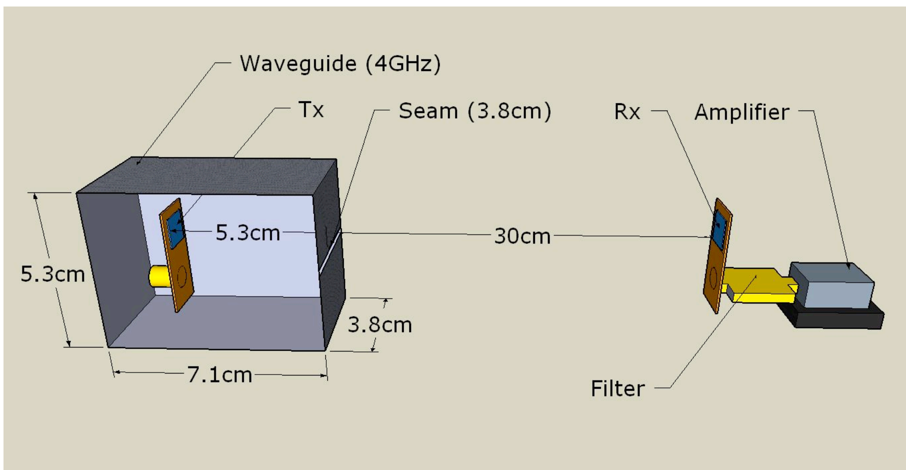


Figure 2.13 Waveguide design for the 4 GHz case.

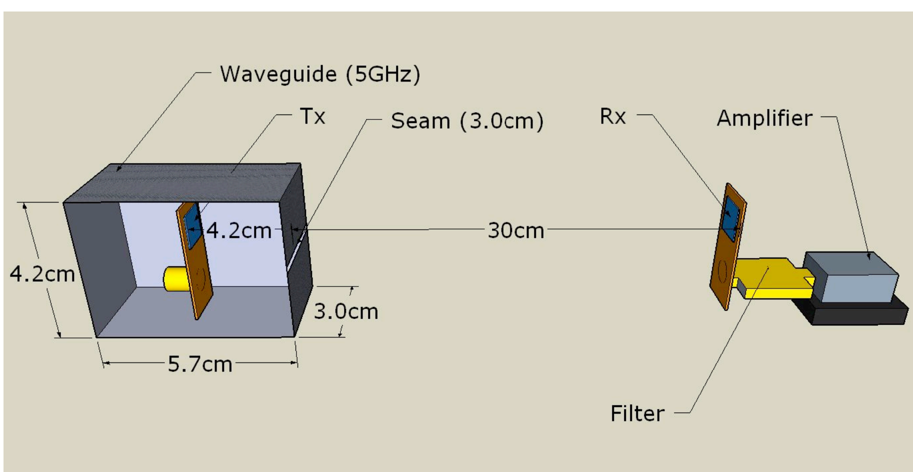


Figure 2.14 Waveguide design for the 5 GHz case.

2.4.1 Results

According to the results, the power levels in the waveguides are 49 dBm, 42.5 dBm, 33.5 dBm at 3 GHz, 4 GHz, and 5 GHz respectively. The 3 GHz waveguide provides the best performance. This can be explained in terms of the waveguide theory [26], which states that signals can propagate at frequencies above the cutoff frequency of the waveguide.

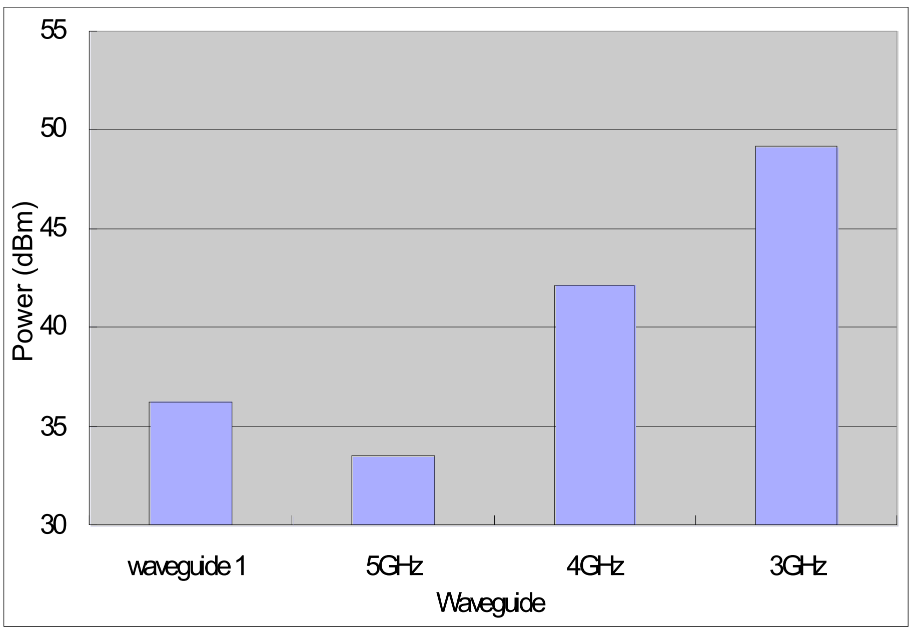


Figure 2.15 Comparison of the received signal power in different waveguides.

2.5 Conclusions

The UWB technology has been introduced in wireless communication systems in order to transmit a signal in a sealed container [2, 4]. In this chapter, we introduced waveguides because they can transmit the signal with less loss. For UWB, the waveguide dimension can be designed with the lower frequency limit of the band.

In the course of transmitting maximum signal power, a waveguide can simply be designed with the lowest operating frequency of the band. For example, if the antenna has a bandwidth of 2.0~6.0 GHz, the waveguide can be designed at 2.0 GHz. It is a further advantage that even though the containers have hundreds of different sizes and styles, one waveguide size can suit all of them.

CHAPTER 3

SECOND APPLICATION FOR UWB: BODY IMPLANT FOR TRANSMITTING ANTENNA LOCATION

3.1 Introduction

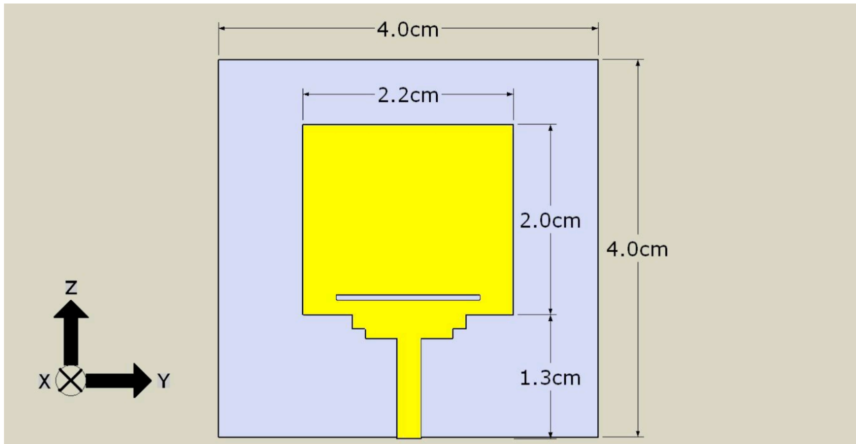
One application of the UWB technology is in patient health monitoring. UWB devices can be implemented together with sensors which can constantly monitor a patient's condition, such as body temperatures or heart rates. This chapter discusses the relationship between signal performance and the implant transmitting antenna position. Traditionally, coil antennas have been used for implanted devices; however, as shown in Table 3.1, the UWB antenna provide advantages. The position of the transmitting antenna could improve signal performance, which means less signal distortion, wider bandwidth, and greater receiver powers.

Table 3.1 Comparison of an UWB antenna and a coil antenna [2].

	UWB Antenna	**Coil Antenna**
Bandwidth	Ultra wideband	Narrowband
Transmission Range	10m	10cm
Data Rate	Large	Small
Signal-to-Noise Ratio	Low	High
Price	Cheap	Very Cheap

3.2 UWB Patch Antenna Design [5,7]

The conventional patch antenna is narrowband, and not suitable for UWB. A new UWB patch antenna with loaded impedance was introduced in [28]. Figure 3.1 shows the configuration of the UWB antenna, which consists of a rectangular patch with two steps, a single slot on the patch, and a partial ground plane. The antenna, which has compact dimensions of $2.2 \times 2.0\ cm^2$, is printed on the top layer of a substrate FR4 with a thickness of 1.6 mm and a relative permittivity of 4.2. The dimensions of the slot are $1.5 \times 0.05\ cm^2$ and the dimensions of the ground plane are chosen to be $4.0 \times 0.9\ cm^2$. The excitation is done through a 50Ω microstrip line printed on the partial grounded substrate. The dimensions of step 1 and step 2 are $0.15 \times 1.2\ cm^2$ and $0.1 \times 0.9\ cm^2$, respectively. To design the UWB patch antenna, there are three techniques to the proposed antenna: the use of (1) two steps, (2) a partial ground plane, and (3) a single slot on the patch, which can lead to a good impedance matching.



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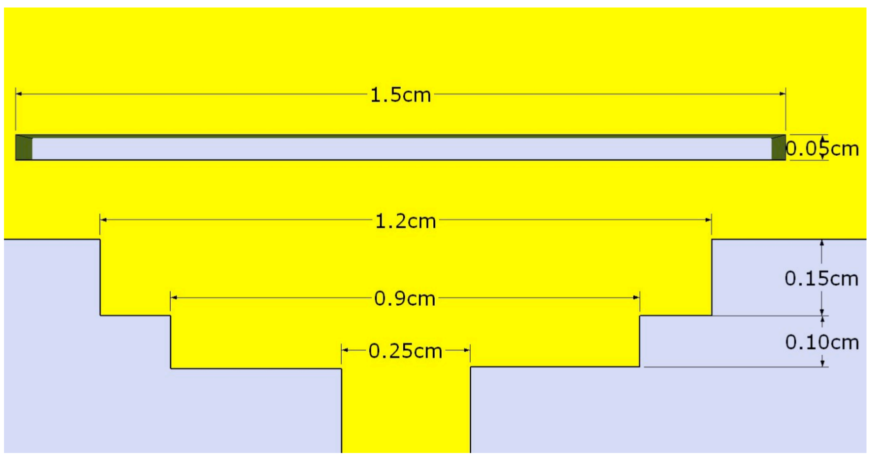

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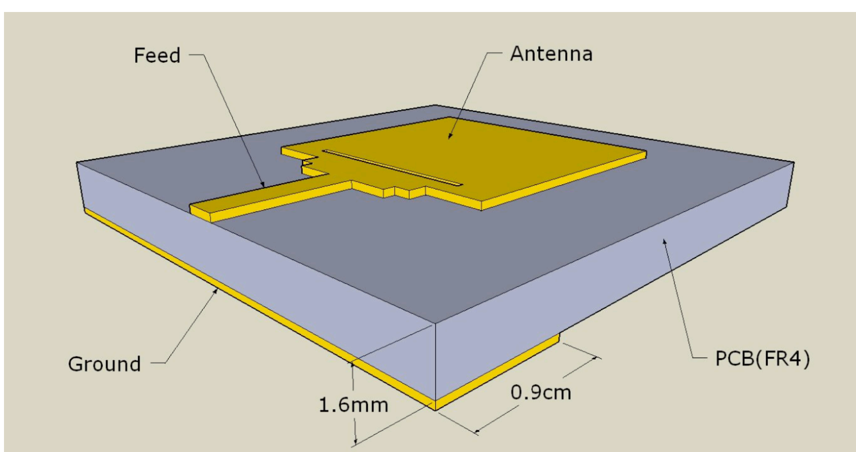


(c)

Figure 3.1 Structure of the UWB patch antenna:
(a) top view (b) zoom view, and (c) side view.

3.2.1 S_{11} and Impedance

In this chapter, the bandwidth of the antenna is defined by the frequency range where the S_{11} is lower than -15 dB. According to the structure shown in Figure 3.1, the antenna works in the frequency band from 2.0 GHz to 5.0 GHz, and the bandwidth is about 3.0 GHz (Figure 3.2).

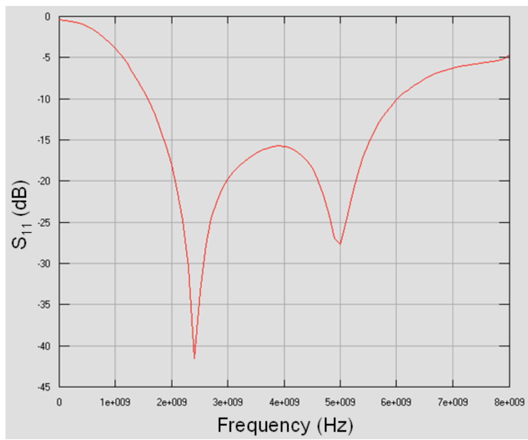


Figure 3.2 S_{11} results for the UWB patch antenna.

The impedance of UWB patch antenna is shown in Figure 3.3. The impedance at the band from 2.0 GHz to 5.0 GHz is around 50Ω.

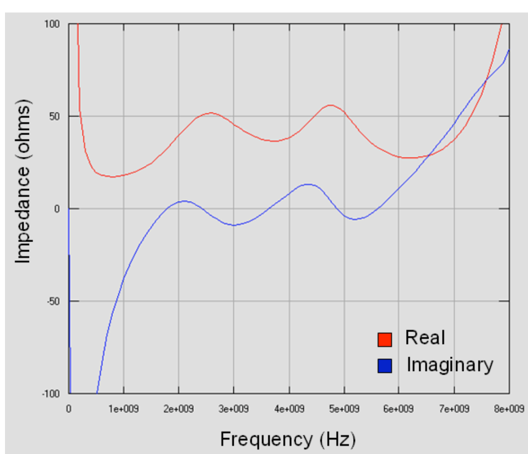


Figure 3.3 Impedance results for UWB patch antenna.

3.3 Simulation Configurations

In order to find out the relationship between the received signal level and the position of the transmitting antenna, the distance between the transmitting and receiving antennas was kept at 4 cm. The body tissue layer position was changed every 0.5 cm from zero to 4 cm (Figure 3.4).

For comparison, there are two different body tissues used in our simulations: skin and muscle. According to the antenna bandwidth (2.0 GHz~5.0 GHz), the dielectric properties of tissues are based on 3.0GHz, and the details are shown in Table 3.2. The average thickness of skin is between 0.5 mm to 2.0 mm [10, 11, 27]. For each tissue, there are three different thicknesses, 1.0 mm, 1.5 mm, and 2.0 mm.

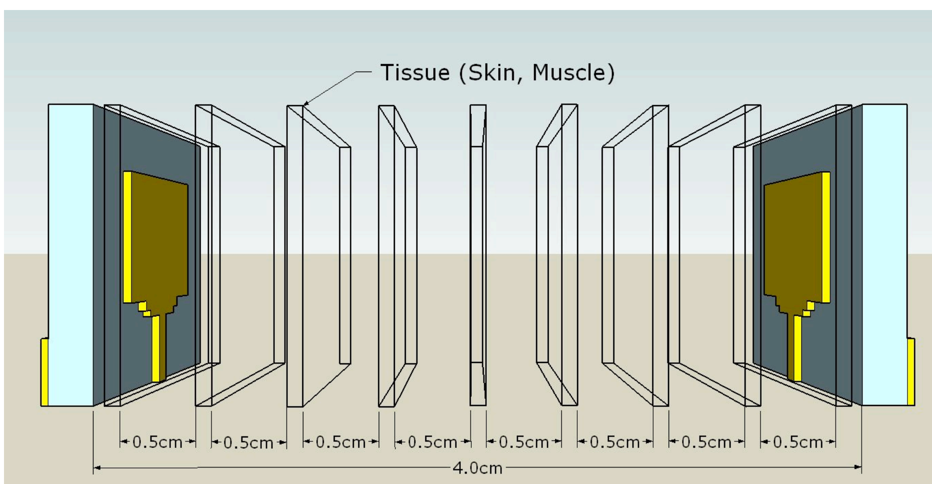


Figure 3.4 Simulation configurations of two antennas and body tissues.

Table 3.2 Dielectric properties of skin (dry) and muscle at 3 GHz [9].

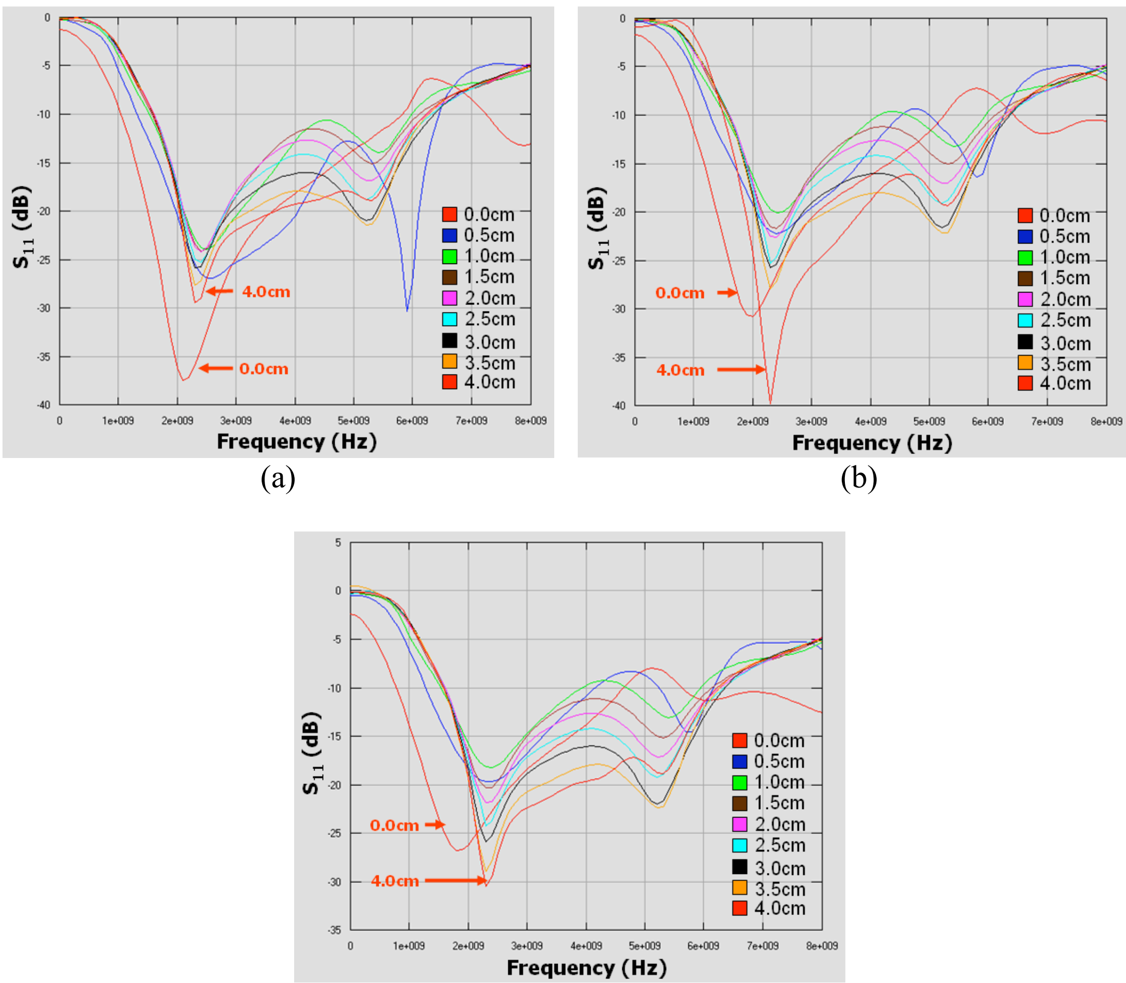
Tissue name	**Conductivity [S/m]**	**Relative permittivity**	**Loss tangent**	**Wavelength [m]**
Skin (Dry)	1.7406	37.45	0.27848	0.016176
Muscle	2.1421	52.058	0.24655	0.013748

3.4 Simulation of Human Tissue: Skin (Dry)

The simulation provide S-parameters and radiation patterns. The S parameters data is calculated for the 1.0 mm, 1.5 mm, and 2.0 mm thick tissue samples.

3.4.1 Simulation Results: S_{11} and S_{21}

According to the results (Figure 3.5), S_{11} changes with different distance in the frequency range from 2.0 GHz to 5.0 GHz.

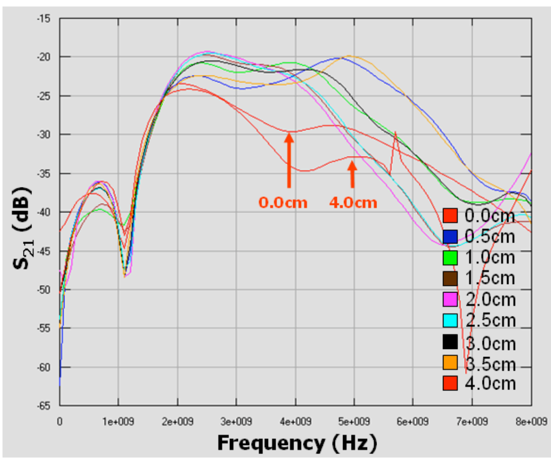


(a) (b)

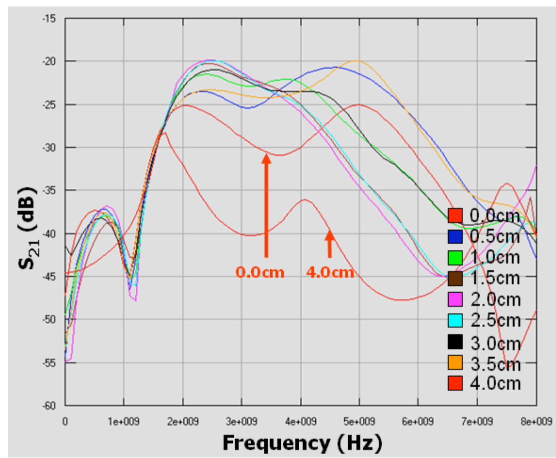
(c)

Figure 3.5 S_{11} for skin with different thickness:
(a) 1.0 mm (b) 1.5 mm, and (c) 2.0 mm.

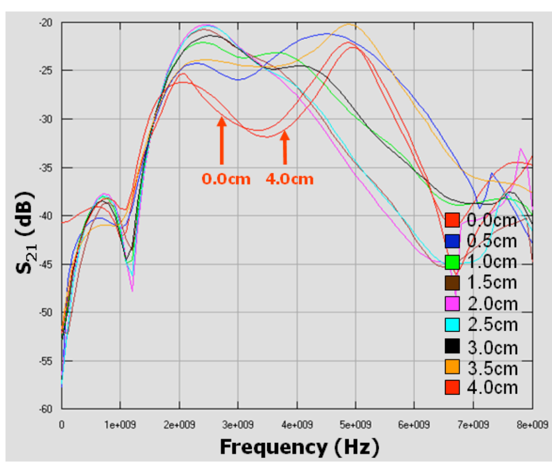
Furthermore, S_{21} shows signal distortion, received bandwidth, and received signal strength (Figure 3.6). First, when the signal travels through the skin, it was attenuated because the complex dielectric constants. The changes are also frequency dependent. According to the S21 results, the 0.0 cm and 4.0 cm cases are the worst. The signal was distorted in the frequency above 2.0GHz.



(a)



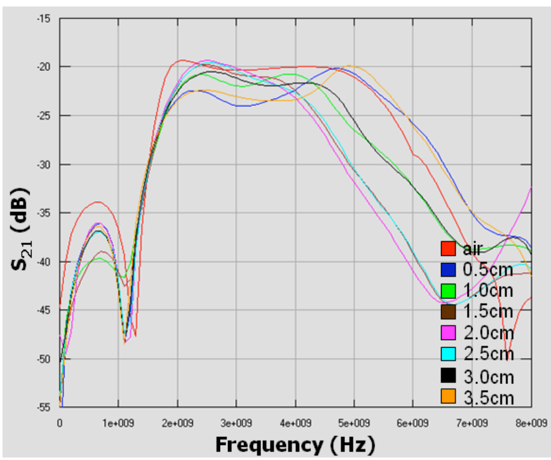
(b)



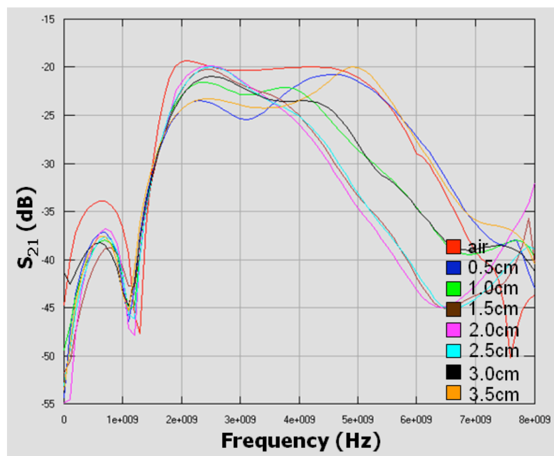
(c)

Figure 3.6 S_{21} for the case of skin at different thicknesses:
(a) 1.0 mm (b) 1.5 mm, and (c) 2.0 mm.

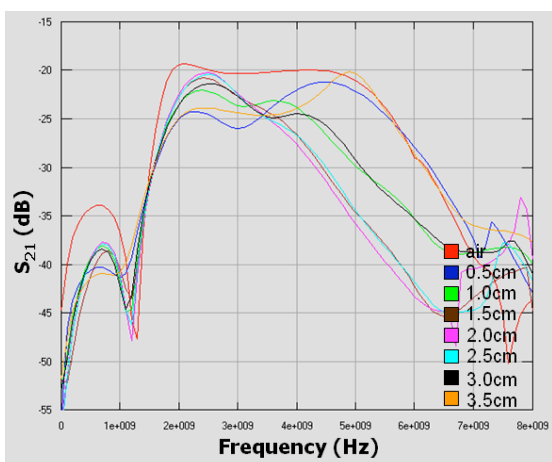
Significantly, Fig. 3.7 shows the comparison with the free space. According to the results, they have similar S_{21} patterns and average signal strengths, but with different bandwidth. The bandwidth is defined by S_{21} being above -25dBm. According to this definition, at 0.5 cm and 3.5 cm distances, they provide wider bandwidth than the others (Table 3.3).



(a)



(b)



(c)

Figure 3.7 S_{21} for the skin case compared with free space with different thicknesses: (a) 1.0 mm, (b) 1.5 mm, and (c) 2.0 mm.

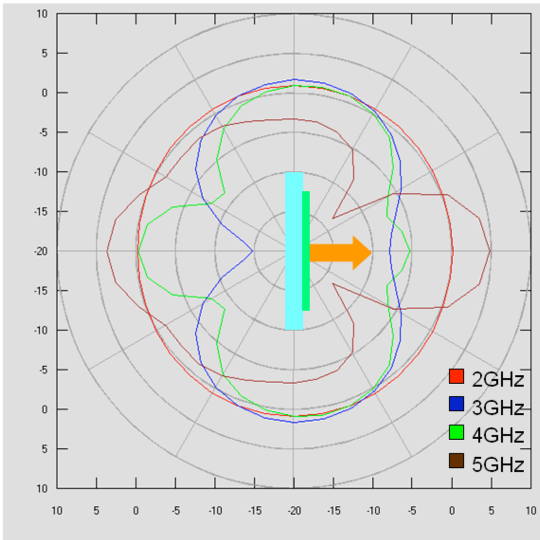
Table 3.3 Comparison of bandwidths with different distance and thickness of skin.

SKIN	Distance (cm)								
Thickness	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
1.0mm	*1.9GHz*	*4.1GHz*	*3.1GHz*	*2.6GHz*	*2.5GHz*	*2.5GHz*	*3.2GHz*	*4.2GHz*	*2.0GHz*
1.5mm	*1.7GHz*	*4.1GHz*	*2.8GHz*	*2.4GHz*	*2.0GHz*	*2.2GHz*	*3.1GHz*	*4.0GHz*	*0.8GHz*
2.0mm	*1.0GHz*	*4.0GHz*	*3.0GHz*	*2.1GHz*	*1.8GHz*	*2.0GHz*	*3.1GHz*	*3.8GHz*	*1.1GHz*

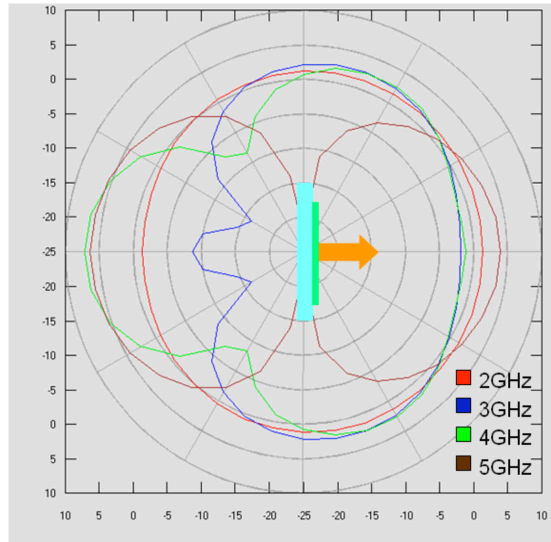
3.4.2 Simulation Results: Radiation Pattern

Figure 3.8 shows that the 2D radiation pattern in the x-y plane changes with four frequencies, 2 GHz, 3 GHz, 4 GHz, and 5 GHz. For comparison, it has three distances, 0.0 cm, 0.5 cm, and 1.0 cm. The radiation patterns can be seen in Figure 3.8 to go from the forward direction 0° to the side (90° and 270°). The 2GHz signal travels equally in all directions. The 3 GHz signal starts to go to the sides. The 4 GHz signal goes to the front and back direction. Finally, the 5 GHz signal has a stronger signal power in the front than in the other directions. Furthermore, the maximum signal power happens at 5 GHz at distances of 0.0 cm and 0.5 cm.

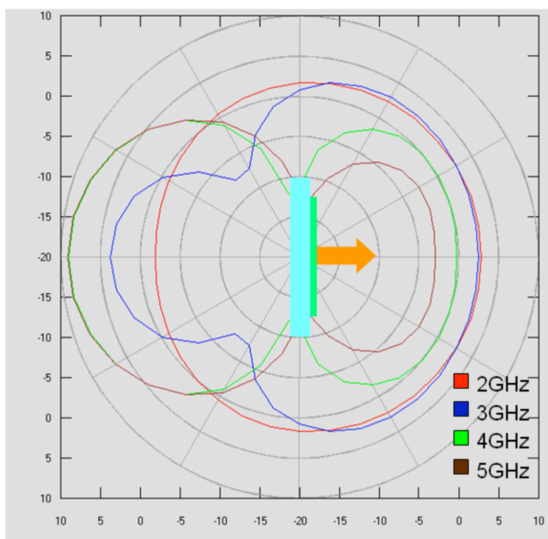
In additions, the radiation pattern can provide more information and signal powers. According to the Section 3.3, S_{21} gives very similar power in the frequency range from 2.0 GHz to 5.0 GHz. In order to compare the signal strength at different distances, Table 3.4 presents the signal powers at 0°. Table 3.4 shows the distance 0.5cm does not have a maximum power in every frequency, but it has a maximum average power.



(a)



(b)



(c)

Figure 3.8 Radiation patterns of the skin case in the x-y plane with different distances: (a) 0.0 cm, (b) 0.5 cm, and (c) 1.0 cm.

Table 3.4 Comparison of signal powers (dBm) at the 0° direction with different frequencies and distances to skin.

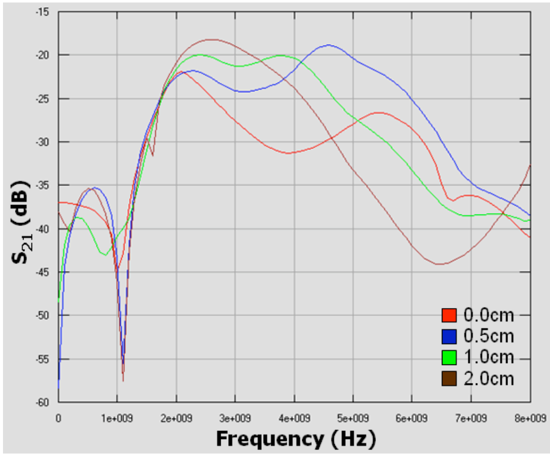
SKIN	Frequency				
Distance	2GHz	3GHz	4GHz	5GHz	Average
0.1cm	*0.10*	*-7.96*	*-5.30*	*4.77*	*-2.10*
0.5cm	*1.27*	*-1.94*	*-1.10*	*4.03*	*0.57*
1.0cm	*2.89*	*2.35*	*-0.41*	*-3.13*	*0.43*

3.5 Simulation of Human Tissue: Muscle

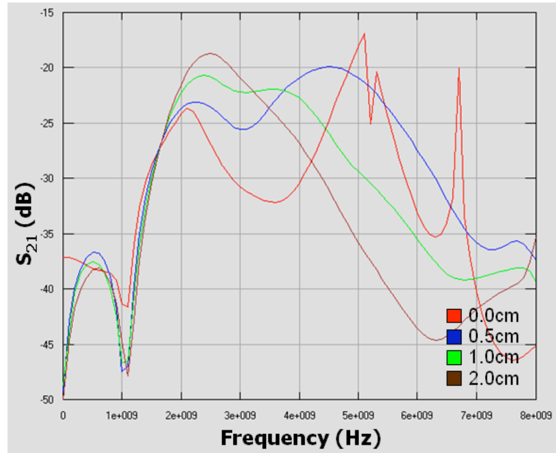
For comparison with skin, the following simulations are made for muscle. The difference in the simulations between skin and muscle is due to the dielectric properties (Table 3.2). According to Section 3.4, S_{21} provides information of the signal distortion and frequency bandwidth, and the radiation patterns provide signal strength. The simulations for muscle employ the same method has been used for skin.

3.5.1 Simulation Results: S_{21}

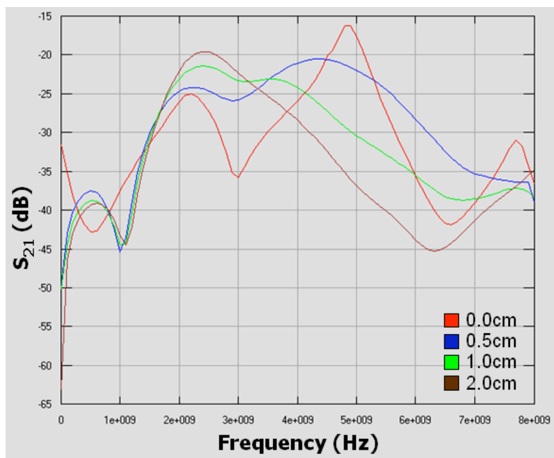
According to the results in S_{21}, the signal at 0.0 cm was distorted dramatically (Figure 3.9), and the rest of the data show a similar pattern. Table 3.5 shows the frequency bandwidth from S_{21} above -25 dBm. The wider bandwidth occurs at a distance of 0.5 cm.



(a)



(b)



(c)

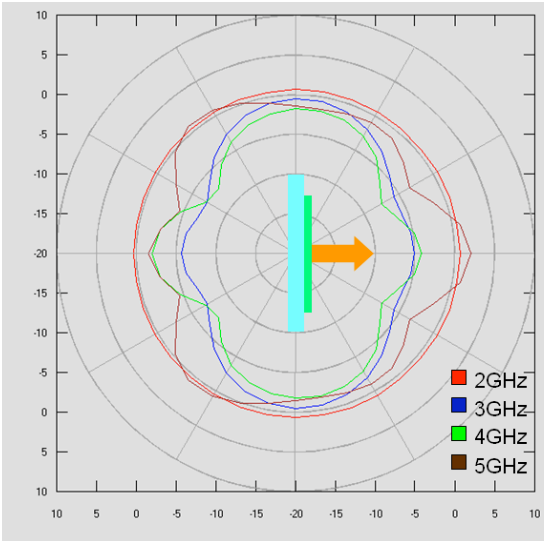
Figure 3.9 S_{21} for the muscle case in different thicknesses:
(a) 1.0 mm, (b) 1.5 mm, and (c) 2.0 mm.

Table 3.5 Comparison of bandwidths with different distances and thicknesses of muscle.

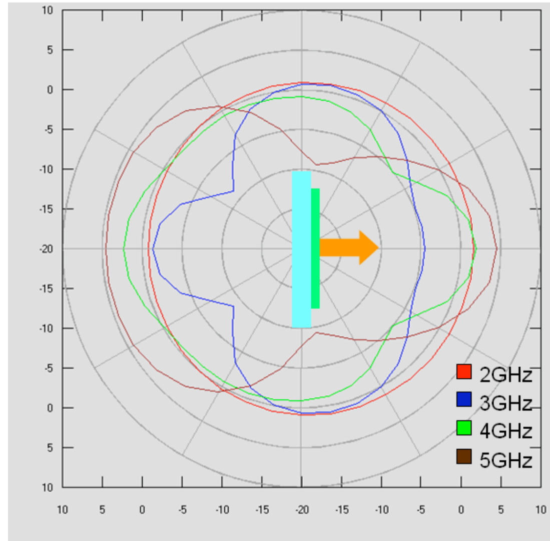
MUSCLE	Distance (cm)			
Thickness	0.0	0.5	1.0	2.0
1.0mm	*1.5GHz*	*4.2GHz*	*3.0GHz*	*2.3GHz*
1.5mm	*0.8GHz*	*3.9GHz*	*2.9GHz*	*1.8GHz*
2.0mm	*0.8GHz*	*4.0GHz*	*2.9GHz*	*1.8GHz*

3.5.2 Simulation Results: Radiation Pattern

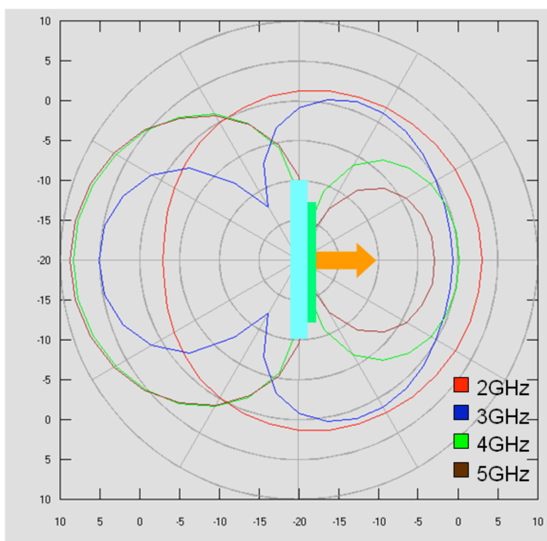
As showing in Figure 3.10, the radiation pattern goes from forward (0°) to the side (90° and 270°). The 2 GHz signal travels equally in all directions. The 3 GHz signal starts to go to the side. The 4 GHz signal goes to the front again and back. The 5 GHz signal has a stronger signal power on the front than in other directions. And, at distances of 0.0 cm and 0.5 cm, the 5 GHz signal has maximum powers. For signal power comparison, Table 3.6 presents the signal strength in 0° coming from the radiation pattern. As seen in Table 3.6, the maximum average power is located at 0.5 cm.



(a)



(b)



(c)

Figure 3.10 Radiation patterns for the muscle case in the x-y plane with different distances: (a) 0.0 cm, (b) 0.5 cm, and (c) 1.0 cm.

Table 3.6 Comparison of signal powers (dBm) at the 0° direction with different frequencies and distances of muscle.

MUSCLE	Frequency				
Distance	2GHz	3GHz	4GHz	5GHz	Average
0.1cm	*0.68*	*-5.12*	*-4.13*	*2.04*	*-1.63*
0.5cm	*1.55*	*-4.47*	*1.84*	*4.41*	***0.83***
1.0cm	*2.93*	*-0.69*	*0.16*	*-2.93*	*-0.13*

3.6 Modeling

In order to simplify the design methodology, circuit modeling is carried out. First, we used an equivalent circuit for the UWB patch antenna. The equivalent circuit results are shown in Figure 3.11. According to these circuits, it fits the S_{11} in the bandwidth range from 0.0 GHz to 8.0 GHz (Figure 3.12). Transmission lines are added as body tissue and the free space (Figure 3.13). The transmission line, T1, represents the distance between the transmitting antenna and the tissue. T3 represents the distance outside the tissue. T2 represents the human tissue.

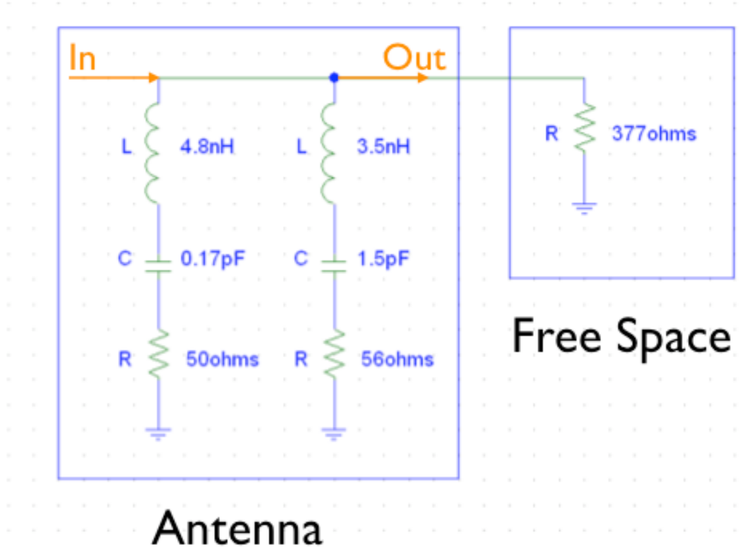


Figure 3.11 Equivalent circuits of the UWB patch antenna.

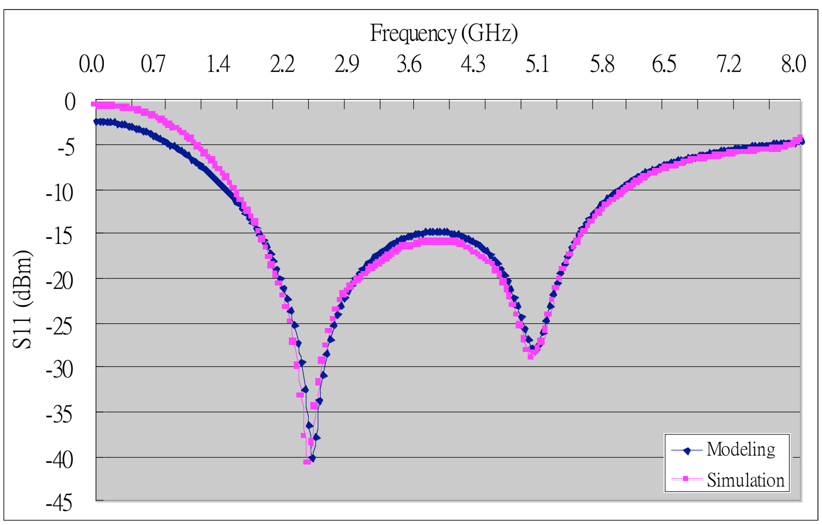


Figure 3.12 Comparison of S_{11} for the equivalent circuits and the FDTD simulation.

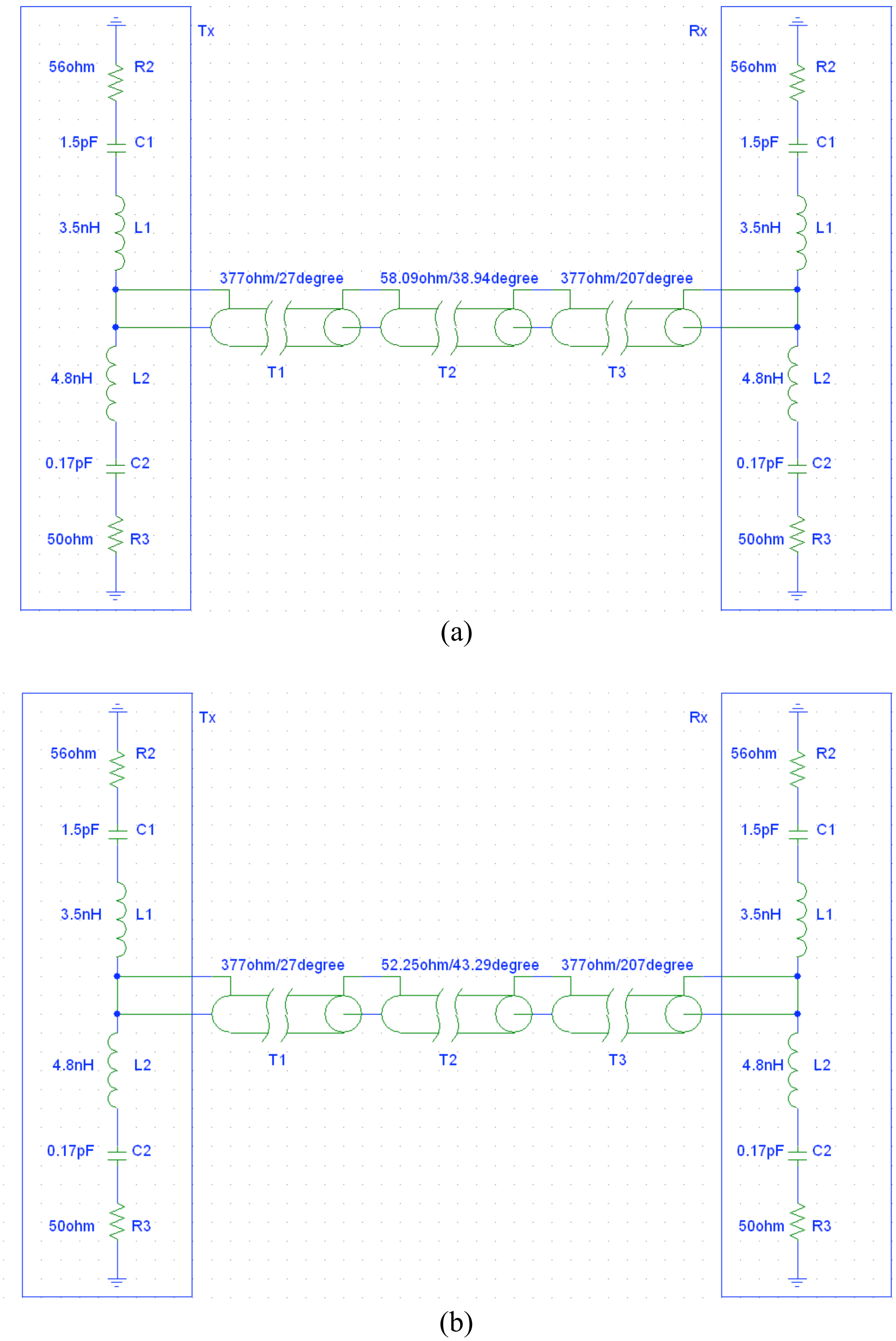


Figure 3.13 Equivalent circuits of the UWB patch antenna and human tissue: (a) skin, and (b) muscle.

Finally, in terms of these equivalent circuits, the S_{11} results are shown in Figure 3.14. According to the results, these two data are very similar, and both of them have a null at 5GHz. The reason for the null is the impedance match. The impedance changes with frequency, and it matches the input impedance, 50Ω, at 5GHz. Due to the impedance matches, most power goes out with little or no reflection. The transmission line at 3.5cm is equal to 0.5cm with a half wavelength. This is the reason that these two distances have similar results in simulations.

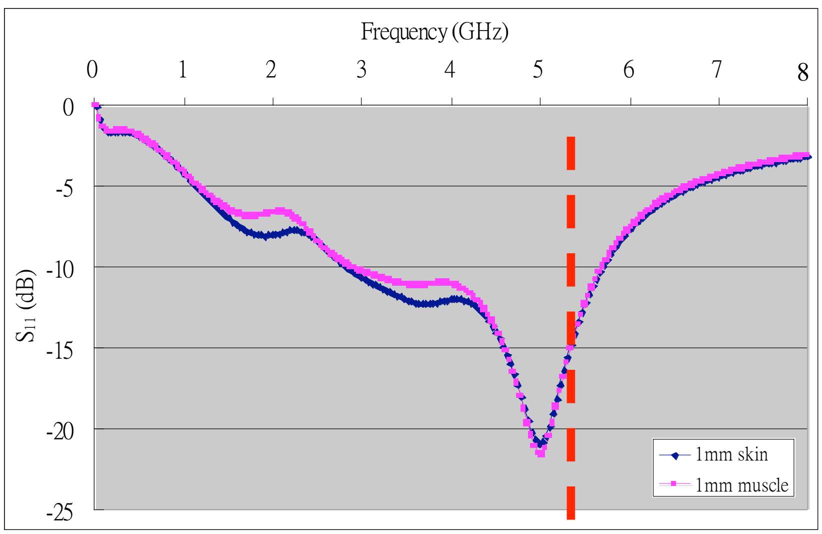


Figure 3.14 S_{11} of PUFF results in a distance 0.5 cm:
(Blue) 1 mm skin, and (Pink) 1 mm muscle.

Eventually, these equivalent circuits can provide a model of the whole system, as shown in Figure 3.15. The box on the left represents a transmitting antenna (Tx), and that on the right is a receiving antenna (Rx). The transmission line, T1, represents the distance between the transmitting antenna and the tissue. T3 represents the distance between the tissue and the receiving antenna. Then, T2 represents the human tissue at certain thicknesses. Table 3.7 presents the average S_{21} powers at several distances through the bandwidth 2.0~5.0GHz. According to the results, the distance of 0.5cm has a maximum average power.

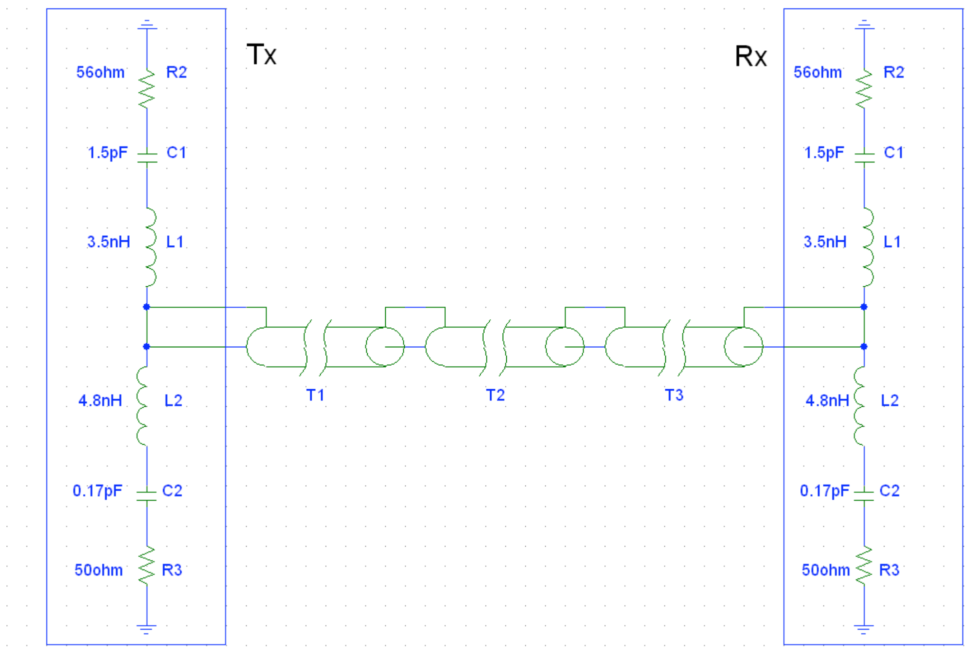


Figure 3.15 Equivalent circuits of signal propagation

Table 3.7 Comparison of average S_{21} (dB) at different distances and thicknesses.

S_{21}		Distance			
	Thickness	0.5cm	1.0cm	1.5cm	2.0cm
SKIN	1.0mm	*-22.78*	*-26.85*	*-29.23*	*-30.25*
	1.5mm	*-24.92*	*-30.01*	*-32.17*	*-32.99*
	2.0mm	*-26.67*	*-31.80*	*-33.66*	*-34.32*
MUSCLE	1.0mm	*-23.97*	*-28.67*	*-31.07*	*-31.98*
	1.5mm	*-26.46*	*-31.79*	*-33.78*	*-34.54*
	2.0mm	*-28.25*	*-33.23*	*-34.94*	*-35.52*

3.7 Conclusions

According to the simulation results, the 0.5cm data provides the best performance in UWB communication systems. The S_{21} results show less signal distortion and wider frequency bandwidth, and the radiation patterns show larger average signal strength. Furthermore, the results in Table 3.7 show that the 0.5cm distance has better signal power than the others. So, both simulation and equivalent circuits have the same results. Now, these equivalent circuits showed that they can be used with this certain antenna without running additional finite-element simulations. This chapter provides a simple method for finding a better position for the transmitting antenna in an implants:

I. Develop equivalent circuits for the antennas.

II. Find the dielectric properties, depending on tissue and thickness.

III. Build the systems in equivalent circuits including antennas and tissue.

IV. Read and compare the S_{21} results.

This method can save a lot of time for simulations, and is easy to implement for people who is not familiar with a wireless communication system.

CHAPTER 4

CONCLUSIONS AND FUTURE WORK

4.1 Conclusions

In wireless communications, ultra wideband has many advantages. This thesis introduces two applications of UWB.

UWB can transmit the signal in sealed containers without blocking, and because of the low interference, the transmission signal will not interfere or overlap with its reflection and scattering. The transmission devices can be easily developed with waveguides to increase transmission signal power.

With regard to power consumptions, UWB wireless communication systems can provide better battery life for devices with less harm to the human body. This thesis has developed a method for improving the performance of transmitting antenna. By using this method, users can have better signal performance by better placing of the transmitting antenna. Users can easily design their devices for implantation, reducing cost, and development time.

4.2 Future Works

Future works should concentrate on the design of whole systems in signal chips, making them portable and easy implementation in all situations. In the future, UWB chips can combine with bio-material, and used for prosthesis.

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BIOGRAPHICAL INFORMATION

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