Delhi Technological University

Department of Applied Physics

Ultra Wideband Simulation using MATLAB

Mid-term Evaluation Project Report

(EC-272) Communication Systems

A Project by:-
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His continued support & valuable criticism along with his guidance have been huge contributions towards the successful completion of this project.

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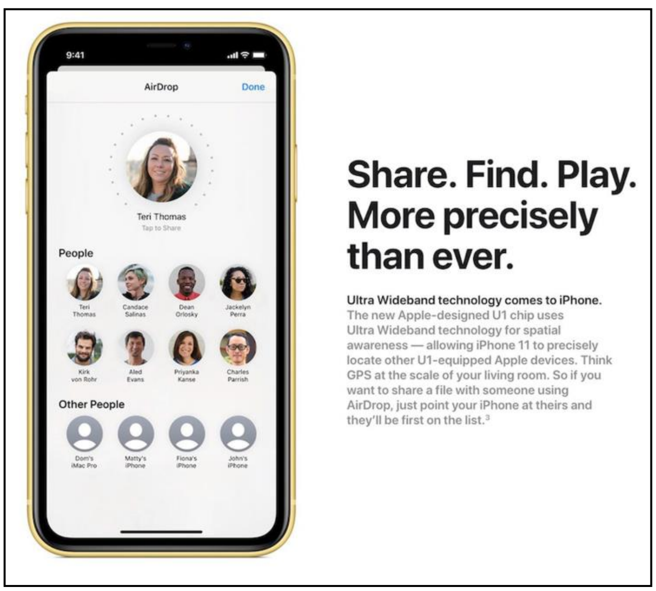
Introduction

Ultra-Wideband (UWB) is a technology for short-range, wireless communication that operates over a large portion of the radio spectrum.

Unlike similar radio based communication protocols such as Bluetooth & Wi-Fi, Ultra-Wideband operates at very high frequencies — a broad spectrum of GHz frequencies — and can be used to capture highly accurate spatial and directional data.

The American Federal Communications Commission (FCC) defines a UWB signal as one with a bandwidth higher than 20% of its center frequency, or a signal with a bandwidth higher than 0.5 GHz. The FCC specified a band of operation for UWB signals from 3.1 to 10.6 GHz in 2002.

While Ultra Wideband technology has been around for years, it has come to the forefront since it has been adopted in popular smartphones such as Apple's flagship phone from 2019, the Iphone 11 & the Iphone 11 pro.



As of September 2019, UWB support has started to appear in high-end flagship smartphones such as the Iphone 11 & the Samsung galaxy note 20.

In the early 2000s, UWB saw limited use in military radars and covert communications and was used briefly as a form of medical imaging, such as remote heart monitoring systems. Its adoption lagged until recently when commercial interests began exploring potential uses.

In today's scenario Ultra-Wide Band (UWB) is a promising technology which offers potential applications in sensor networks, broadband wireless data access and location finding applications.

Ultra wide Band is a cutting edge mode of communication that is revolutionizing communication systems around the world

Ultra-Wide Band (UWB) is also a topic of interest to researchers interested in the areas of sensor networks and wireless broadband data access in particular.

In this project we have made an attempt at designing and validation of a single transmitter and receiver system based on Ultra-Wideband spectrum across the multipath channel.

Theory

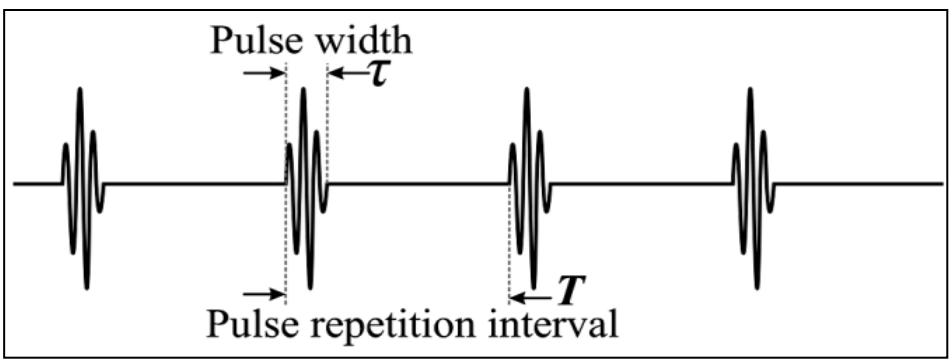
Most conventional radio-based communication systems work by varying:-

- Amplitude/Signal strength (used in AM Radio)
- Phase of Sinusoidal Radio waves (used in Bluetooth systems in the form of Phase Shift Keying)
- & the Frequency (used in FM Radio)

These are all popular modulation schemes used in modifying Radio waves. In general, modulation process is used in communication system to smooth the spectrum of a signal. Modulation process prevents the system from interference of the existing narrowband and wideband signals.

<u>Pulses in Ultra-Wideband</u>

UWB uses a modulation scheme that consists of very short duration (nanosecond) pulses called monopulses.

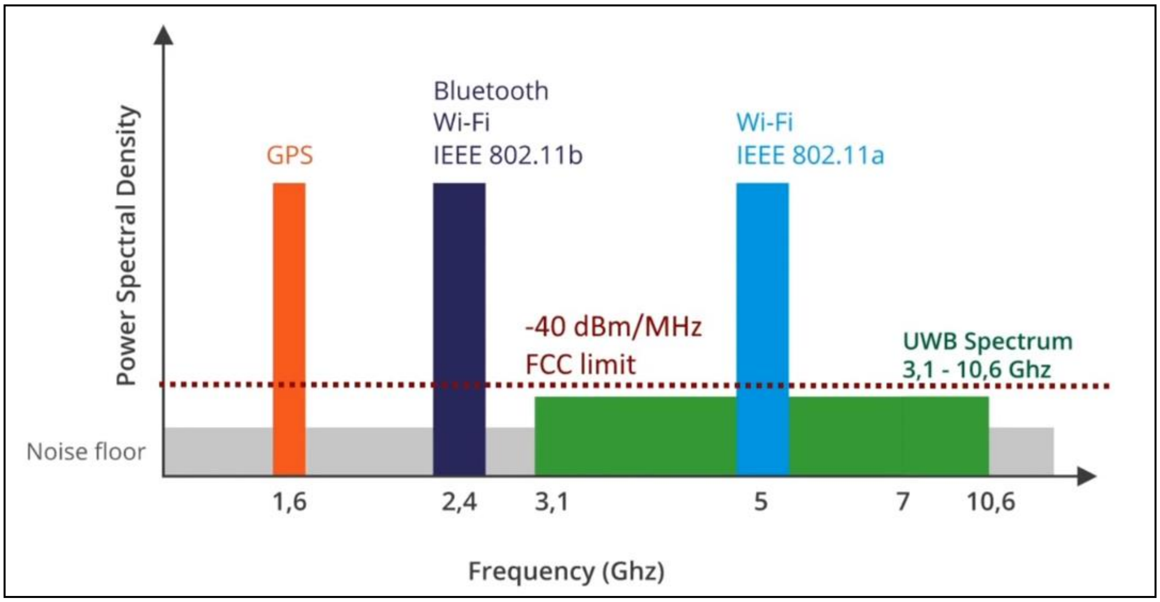


Typical pulse sequence transmitted by impulse radio representing pulse width & pulse repetition interval of a UWB pulse waveform

Monopulses spread the signal energy uniformly over a few gigahertz frequencies and make low duty cycle pulse train and consume very low power. The time interval between these pulses plays an important role in determining the properties the generated ultra-wideband signal. The time interval is generally around 1.4ns.

In practice, the selection of pulses depends on many factors. The radiation efficiency and spectrum shape are the two of general concerns.

UWB transmissions transmit information by generating radio energy at specific time intervals and occupying a large bandwidth, thus enabling pulse-position or pulse-amplitude modulation.



A diagram illustrating the difference in spread of frequency & power spectral density between different communication technologies & Ultra-wideband

In the power spectral density vs. frequency diagram shown above, the ultra wideband signal is observed to have a larger bandwidth/ frequency range as compared to other communication modes & its transmitted power is also seen to be below the noise floor line. Since UWB signals are operating below the noise floor, they provide better security, lower RF health hazards, and lower interference to other systems.

Since UWB pulses have this large bandwidth, a UWB system permits better immunity to multipath propagation and narrowband interferences, because these kinds of interferences only affect a part of the complete spectrum.

An Ultra - Wideband (UWB) signal is generally defined to be a radio signal with a fractional bandwidth larger than 0.25, where fractional bandwidth (η) is defined as

$$\eta = 2\,(f_H - f_L) / (f_H + f_L)$$

Where, f_H & f_L are the highest & lowest frequencies in the transmission respectively. Conventional radio service transmission and radar systems have small fractional bandwidths of much less than 0.25.

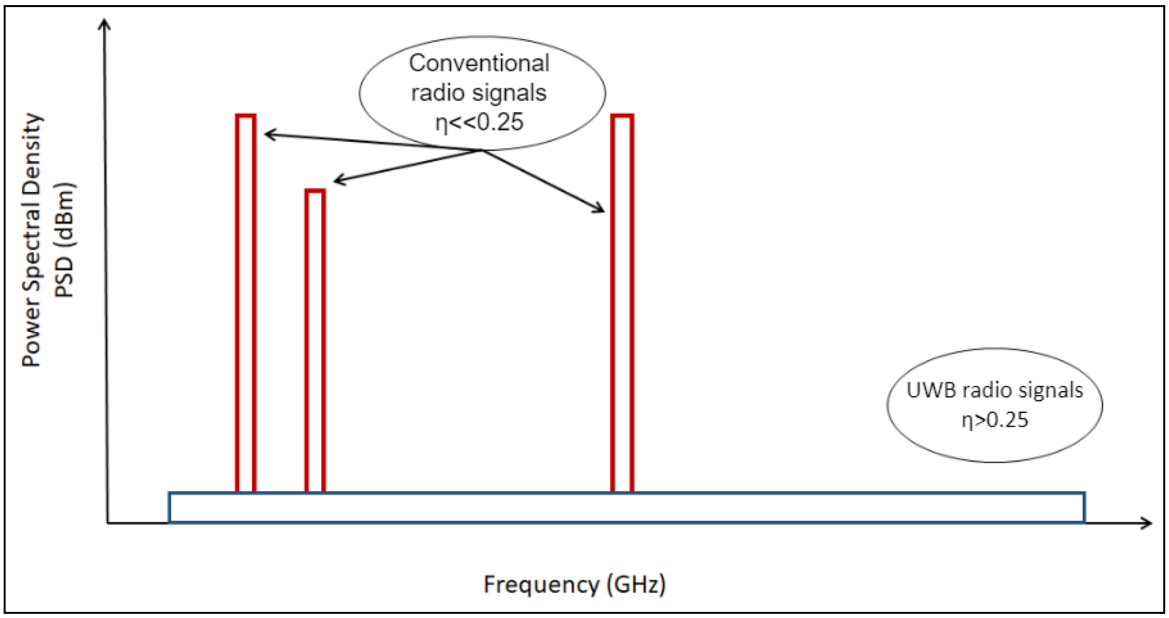


Figure: Power Spectral Density & Fractional bandwidth (η) of Ultra-Wideband vs conventional radio signals

Since Ultra-Wideband is a baseband technology, pulse shape is an important aspect for UWB transmission. The spectrum of an Ultra-Wideband is determined by mainly the pulse width & the pulse shape.

A UWB pulse shape consists of two factors. First one is to spread the energy in frequency to minimize the power spectral density and the interference. Second one is to avoid a dc component to maintain the antenna radiation efficiency.

As mentioned earlier, UWB uses a modulation scheme that consists of very short duration (nanosecond) pulses called monopulses.

We have covered three different monopulses under the scope of our project, these are as follows:-

1. Gaussian Monopulse (also known as Gaussian First derivative)
2. Gaussian Second Derivative (or Gaussian Doublet)
3. RZ Manchester

Among these, the most popular UWB pulse shapes are Gaussian waveforms and their derivatives. In time domain, the first derivative of the Gaussian monopulse can be expressed as follows:

$$w(t) = A\pi f_c t e^{-2(\pi f_c (t-t_c))^2}$$

Where, A represents the amplitude, t_c is the time shift, and f_c is the center frequency, which is the reciprocal of the monopulse duration.

However, the spectral characteristics of baseband Gaussian monopulses make it difficult to implement practical UWB systems that are compliant with current FCC regulations in the 3.1–10.6 GHz band. Since the regulated UWB spectrum is band limited, an alternative/better pulse shape is the Gaussian modulated sinusoidal pulse.

The Gaussian modulated sinusoidal pulse shape may be expressed as shown below:

$$p(t) = k_0 \cdot e^{-t^2/4\tau^2} \cdot \sqrt{2}\cos\left(2\pi f_c t + \phi_r\right)$$

where k_0 is a constant, τ is the time scaling factor, f_c is the desired centre frequency of the pulse and φ_r is an arbitrary phase that can be zero.

Gaussian second derivative monopulse can be expressed as follows:

$$w(t) = A(1-4\pi(f_c(t-t_c))^2)e^{-2\pi(f_c(t-t_c))^2}$$

Where, A represents the amplitude, t_c is the time shift, and f_c is the center frequency.

& finally, the last monopulse RZ-Manchester maybe mathematically expressed as follows:

$$w(t) = \begin{cases} -\sqrt{\dfrac{A}{\tau}} & (t_c + \dfrac{\tau}{6} < t \le t_c + \dfrac{\tau}{2}) \\ 0 & (t_c - \dfrac{\tau}{6} < t \le t_c + \dfrac{\tau}{6}) \\ +\sqrt{\dfrac{A}{\tau}} & (t_c - \dfrac{\tau}{2} < t \le t_c - \dfrac{\tau}{6}) \end{cases}$$

Where once again A represents the amplitude, t_c is the time shift & f_c is the center frequency

A comparison between the waveforms of these pulse shapes is shown in the plot below:

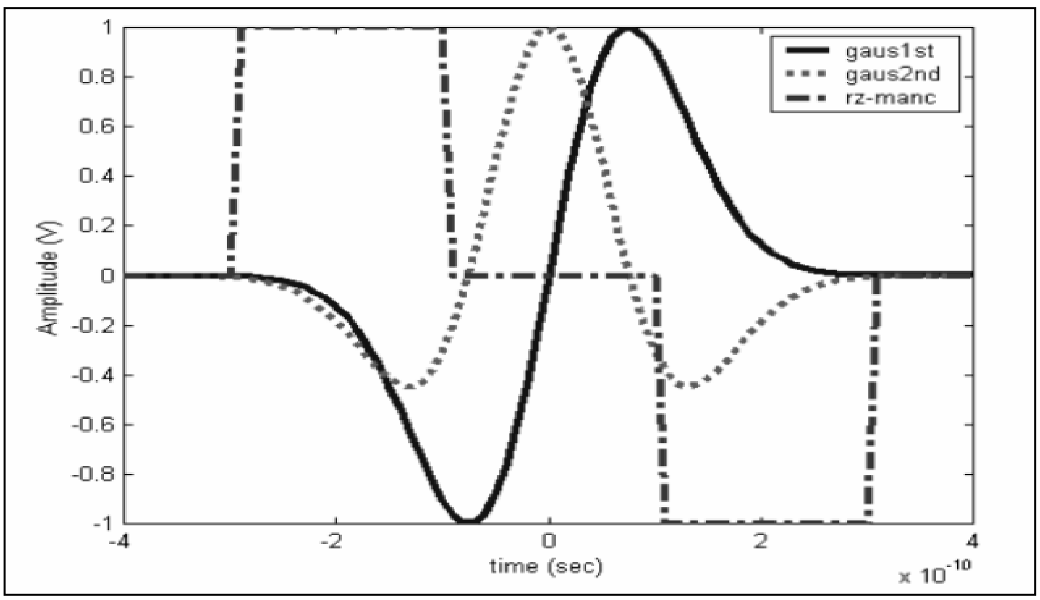


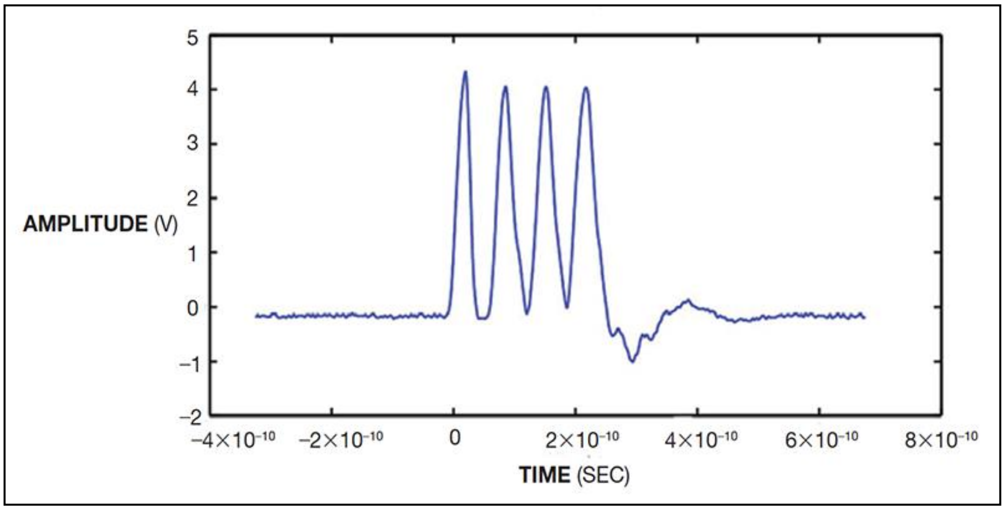
Figure: Plots of the Gaussian first derivative, Gaussian second derivative, and RZ Manchester monopulses respectively.

Features of Ultra-Wideband Technology

In this section, a few of the key features of ultra-wideband technology have been elucidated. Since UWB technology is still considered to be a relatively new field in communication systems, several new implementations of this unique technology remain to be discovered. A few key characteristics of Ultra-Wideband technology are as follows:-

Impulse based characteristic

UWB is a radio technology that modulates impulse based waveforms instead of continuous carrier waves as shown in the figure below:



The waveform of typical Pulses generated & used in Ultra-Wideband systems.

Ultra-wideband (UWB) radio technology uses very short (nanosecond order) time domain pulses. Using these kinds of pulses widens the signal in the frequency domain to be much wider than traditional communications that use narrowband frequency-multiplexed signals. A UWB signal is defined as a signal with a bandwidth higher than 20% of its center frequency, or a signal with a bandwidth higher than 0.5 GHz.

The time interval between these pulses plays an important role in determining the properties the generated ultra-wideband signal. The time interval is generally around 1.4ns.

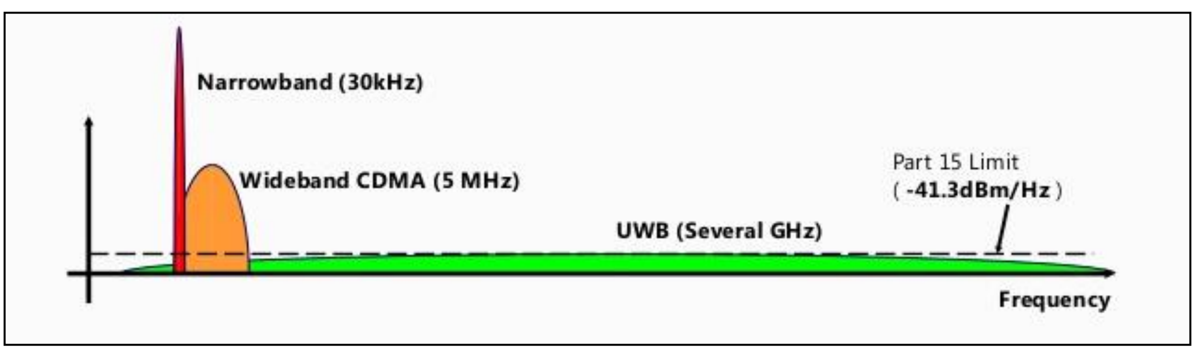
High data rate

Devices using UWB technology may operate at very low power levels and can support applications involving multiple users at high data rates (e.g. short-range wireless personal area networks (WPANs) at data rates greater than 100 Mbit/s). In addition, UWB technology achieves very high speed for data transmission.

UWB systems also possess the ability to effectively reduce fading and interference problems in different wireless propagation channel environments.

Wide Bandwidth

UWB transmits information across a large bandwidth (>500 MHz). This allows for the transmission of a large amount of signal energy without interfering with conventional narrowband and carrier wave transmission in the same frequency band.



This large bandwidth spectrum is available for high data rate communications as well as radar and safety applications to operate in.

The figure shown above draws a comparison between UWB bandwidth & others conventional radio signal bandwidths.

Robust & Secure Communication

UWB signals are potentially more covert and potentially harder to detect than other conventional radio communication signals. This is due to the fact that UWB signals occupy a large bandwidth as mentioned above.

It is known that the UWB pulse is generated in a very short time period (sub-nano second). Due to this UWB has spectrum below the allowed noise level. Thus UWB can be concealed to look like unintelligible noise, and can communicate with a unique randomizing timing code at millions of bits/s.

UWB signals are also more robust to multipath effects than traditional wireless technology. Devices using UWB technology are generally designed to have large processing gain, a measure of a device's robustness against interference.

Potential high-density use

Though most devices using UWB technology would operate at very low power, UWB could be integrated into many potential applications including but not limited to:

- Surveillance devices & location determination devices
- Improved public safety through the use of vehicular radar devices for collision avoidance, airbag activation and road sensors
- Liquid level detectors and sensors
- Short-range high data rate communication devices
- Replacement for wired high data rate connections over short distances

Low Power Consumption

The UWB technology has another advantage from the power consumption point of view. Due to spreading the energy of the UWB signals over a large frequency band, the maximum power available to the antenna is as small as in order of 0.5mW according to the FCC spectral mask.

This power is considered to be a small value and it is actually very close to the noise floor compared to what is currently used in different radio communication systems.

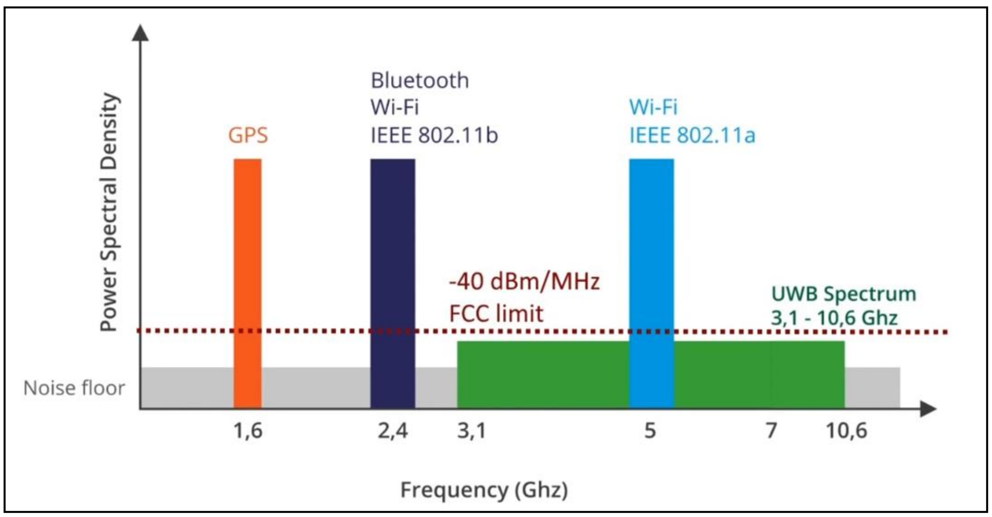
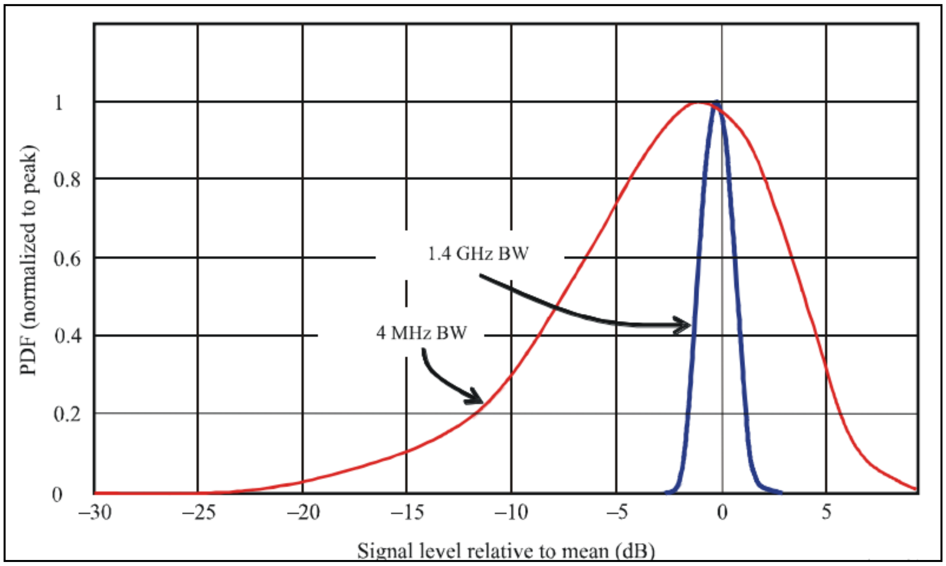


Figure: Power Spectral density vs. Frequency of different communication systems UWB systems can be observed to consume power below the noise floor.

Multipath effects

A wide transmission bandwidth is needed to overcome multipath fading in an indoor environment. UWB communication devices are therefore resistant to multipath fading in an indoor environment, because they have a wide transmission bandwidth and closely spaced multipath components can therefore be resolved in the receiver.

The figure shown below compares the signal statistics of multipath fading for signals with bandwidths of 4 MHz and 1.4 GHz. The wider bandwidth signal exhibits a lower probability of a deep fade relative to the mean signal level.



Small Size and Low Cost

The small size of UWB transmitters is a requirement for inclusion in today's consumer electronics. The main arguments for the small size of UWB transmitters and receivers are due to the reduction of passive components.

Ultra-wideband systems can be made nearly "all-digital", with minimal radio frequency (RF) or microwave electronics. The low component count leads to reduced cost, and smaller chip sizes invariably lead to low-cost systems. The simplest UWB transmitter could be assumed to be a pulse generator, a timing circuit, and an antenna.

Simulation using MATLAB

For the simulation aspect of our project, we decided to simulate an Ultra-Wideband based system. For this we developed 2 programs, namely:-

i) Generation of UWB pulse gaussian doublet

ii) Ultra-Wideband Analysis

Both these programs were developed in the widely used programming platform, MATLAB.

MATLAB is a widely used programming and numeric computing platform used by millions of engineers and scientists to analyze data, develop algorithms, and create models. We decided to implement our simulations using MATLAB since it allows effortless plotting of functions and data, implementation of algorithms, & seamless creation of user interfaces.

I. Generation of pulse used in UWB pulse Gaussian Doublet

This program plots the Gaussian Doublet or the Gaussian 2^{nd} derivative, the formula of which has been discussed under the "Theory" section. This program is a relatively simple implementation which plugs the pulse parameters 'tao' & 't' into the equation for a Gaussian 2^{nd} Deriavtive pulse/Gaussian Doublet pulse. The pulse parameters may be modified as desired by the user.

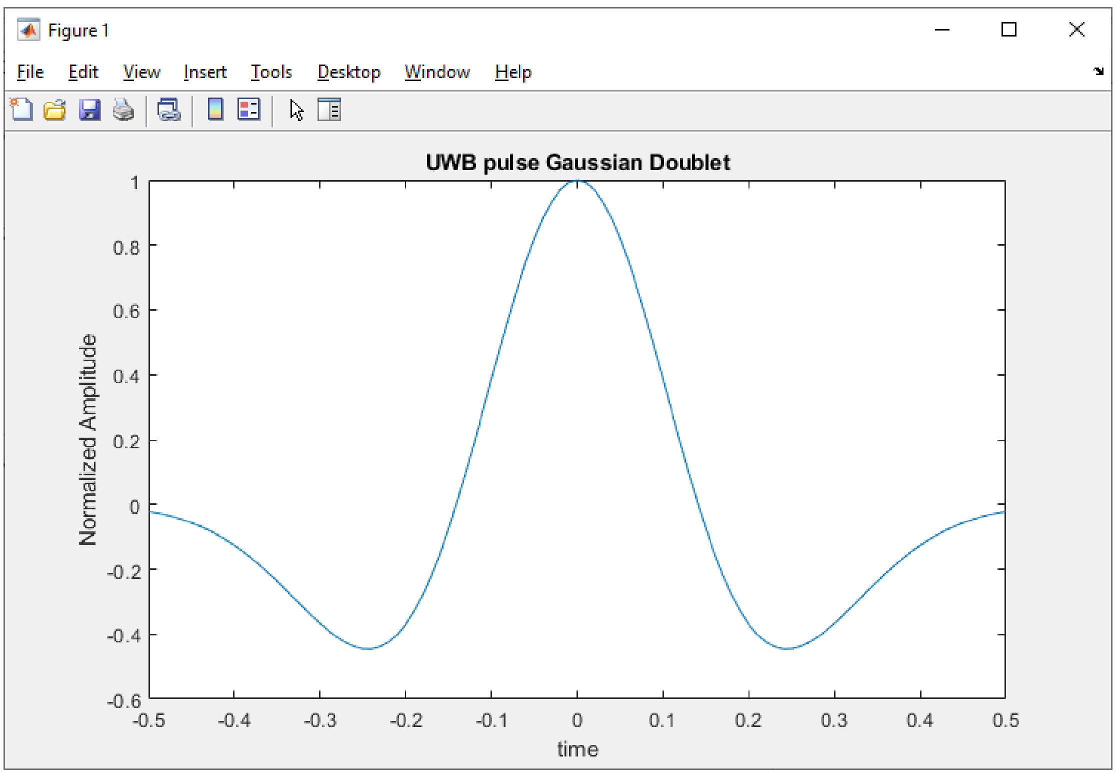
The code for this program is as shown below:-

```
clc; clear all; close all
% tao_m=input('Enter tao_m  ');
tao_m=0.5
t=-5:.01:5;
op1=(1-4*pi*(t/tao_m).^2); for i=1:1001
```

```
op2(1,i)=exp(-2*pi*(t(i)/tao_m)^2);
%       f(1,i)=1/t(1,i);
end
op=op1.*op2; plot(t,op)
xlabel('time');
ylabel('Normalized Amplitude');
title('UWB pulse Gaussian Doublet');
axis([-0.5 0.5 -0.6 1])
```

The Output of this program is observed to be as shown below.

Output Screen:



As observed, the popularly used gaussian doublet pulse is plotted in accordance to the pulse parameters & the corresponding Gaussian doublet pulse waveform provided.

II. Ultra-Wideband Analysis

This program is used for the PPM (pulse position modulation) and link analysis of UWB monocycle and doublet waveforms.This .m file plots the time and frequency waveforms for PPM 1st and 2nd derivative equations used in UWB system analysis.

It is important to note that Fudge factors might be required to correct for inaccuracies in the 1st and 2nd derivative equations. Fudge factors refer to arbitrary mathematical terms inserted into a calculation in order to arrive at an expected solution or to allow for errors especially of underestimation.

Some basic information regarding the programs functionality is given below:

Tail to tail on the time wave forms must be considered as the actual pulse width. 7*PW1 has about 99.9% of the signal power. The frequency spreads and center frequencies (f_c=center of the spread) are correct as you can verify (fc~1/pw1). Change pw (fudge factor) and t for other entered (pw1) pulse widths and zooming in on the waveforms. A basic correlation receiver is constructed showing the demodulated output information from a comparator (10101). Perfect sync is assumed in the correlation receiver.

The program is not considered to be the ultimate in UWB link analysis, but is configured to show basic concepts of the new technology.

The code for this program has been given below:-

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%                (2K19-EP-032) Dhruv Tyagi & Ayush Kumar (2K19-EP-030)
%
%                  Communication Systems Mid Term Evaluation Project
%               PPM & Link Analysis of UWB monocycle & doublet waveforms
%
```

```
%
%This m file plots the time and frequency waveforms for PPM 1st and 2nd
derivative
%equations used in UWB system analysis. Fudge factors are required to
%correct for inaccuracies in the 1st and 2nd derivative equations.
%Tail to tail on the time wave forms must be considered as the actual pulse
width.
%7*PW1 has about 99.9% of the signal power. The frequency spreads and center
%frequencies (fc=center of the spread)are correct as you can
verify(fc~1/pw1).
%Change pw(fudge factor)and t for other entered(pw1) pulse widths and
%zooming in on the waveforms. A basic correlation receiver is constructed
%showing the demodulated output information from a comparator(10101). Perfect
sync
%is assumed in the correlation receiver.
%Refer SETUP and other info at end of program.
%The program is not considered to be the ultimate in UWB link analysis, but
is
%configured to show basic concepts of the new technology.
%================================================
pw1=.5e-9;%pulse width in nanosec, change to desired width
pw=pw1/2.5;%Fudge factor to compensate for inaccuracies(approx. 4-5 for 1st
der. and
%approx. 2-3 for 2nd der.)
Fs=100e9;%Sample frequency
Fn=Fs/2;%Nyquist frequency (Highest frequency that can be coded at a given
sampling rate)
t=-1e-9:1/Fs:20e-9;%time vector sampled at Fs Hertz. zoom in/out using (-1e-
9:1/Fs:xxxx)
A=1;
%================================================
% EQUATIONS
%================================================

%1st derivative of Gaussian pulse=Gaussian monocycle
%y=A*(t/pw).*exp(-(t/pw).^2);

%2nd derivative of Gaussian pulse=doublet(two zero crossings)
y =A*(1 - 4*pi.*((t)/pw).^2).* exp(-2*pi.*((t)/pw).^2);

% y=y.*sin((2*pi*t*4.5e9).^2)%spectrum notches(multipath)
%================================================
%This series of pulses sets the pulse recurring frequency(PRF)
%at 400MHz(waveform repeats every 2.5e-9 sec)and a
%modulated bit stream(info bit rate=200MHz) of 10101 (5 pulses, can add more)
%using 0.2e-9 as the time delay PPM where a delay = a 0 bit and no delay = a
1 bit.
%One could expand the # of pulses and modulate for a series of
%111111000000111111000000111111 which would give a lower bit rate. You could
just
%change the PRF also. This series of redundant pulses also improves the
processing gain
%of the receiver by giving more voltage out of the integrator in a
correlation
%receiver. For loops or some other method could be used to generate these
%pulses.
%This is a brute force method and one can easily copy and paste.
```

```
%We will leave that for further extension. Since we basically have the
transmitter
%implemented it's time to move on to the correlation receiver design
%and add interference, multipath and noise with BER capability to
%see if we can demodulate and get 10101 bits out at the 200MHz information
bit rate.
%==================================================
% 1ST DERIVATIVE MONOCYCLE(PPM WITH 5 PULSES)
%==================================================
%yp=y+ ...
%A*((t-2.5e-9-.2e-9)/pw).*exp(-((t-2.5e-9-.2e-9)/pw).^2)+A*((t-5e-
9)/pw).*exp(-((t-5e-9)/pw).^2)+ ...
%A*((t-7.5e-9-.2e-9)/pw).*exp(-((t-7.5e-9-.2e-9)/pw).^2)+A*((t-10e-
9)/pw).*exp(-((t-10e-9)/pw).^2);
%==================================================
% 2ND DERIVATIVE DOUBLET(PPM WITH 5 PULSES)
%==================================================
%modulated doublet
yp=y+ ...
A*(1-4*pi.*((t-2.5e-9-.2e-9)/pw).^2).*exp(-2*pi.*((t-2.5e-9-.2e-9)/pw).^2)+
...
A*(1-4*pi.*((t-5.0e-9)/pw).^2).*exp(-2*pi.*((t-5.0e-9)/pw).^2)+ ...
A*(1-4*pi.*((t-7.5e-9-.2e-9)/pw).^2).*exp(-2*pi.*((t-7.5e-9-.2e-9)/pw).^2)+
...
A*(1-4*pi.*((t-10e-9)/pw).^2).*exp(-2*pi.*((t-10e-9)/pw).^2);
%unmodulated doublet
B=1;%This shows how the amplitude matching of templet and modulated signal
%plays an important part. Would require AGC on first LNA to hold modulated
%sig constant within an expected multipath range.(B=.4 to .5 causes errors).
yum=B*y+ ...
B*(1-4*pi.*((t-2.5e-9)/pw).^2).*exp(-2*pi.*((t-2.5e-9)/pw).^2)+ ...
B*(1-4*pi.*((t-5.0e-9)/pw).^2).*exp(-2*pi.*((t-5.0e-9)/pw).^2)+ ...
B*(1-4*pi.*((t-7.5e-9)/pw).^2).*exp(-2*pi.*((t-7.5e-9)/pw).^2)+ ...
B*(1-4*pi.*((t-10e-9)/pw).^2).*exp(-2*pi.*((t-10e-9)/pw).^2);
yc=yp.*yum;%yc(correlated output)=yp(modulated)times yum(unmodulated)
doublet.
% SO the correlator output is basically the modulated*unmodulated doublet
%This is where the correlation occurs in the receiver and would be the
%first mixer in the receiver.
%==================================================
% FFT %Discrete Fourier Transform
%==================================================
%new FFT for modulated doublet
y=yp;%y=modulated doublet
NFFY=2.^(ceil(log(length(y))/log(2)));
FFTY=fft(y,NFFY);%pad with zeros
NumUniquePts=ceil((NFFY+1)/2);
FFTY=FFTY(1:NumUniquePts);
MY=abs(FFTY);
MY=MY*2;
MY(1)=MY(1)/2;
MY(length(MY))=MY(length(MY))/2;
MY=MY/length(y);
f=(0:NumUniquePts-1)*2*Fn/NFFY;
%new fft for unmodulated doublet
y1=yum;%unmodulated doublet
NFFY1=2.^(ceil(log(length(y1))/log(2)));
```

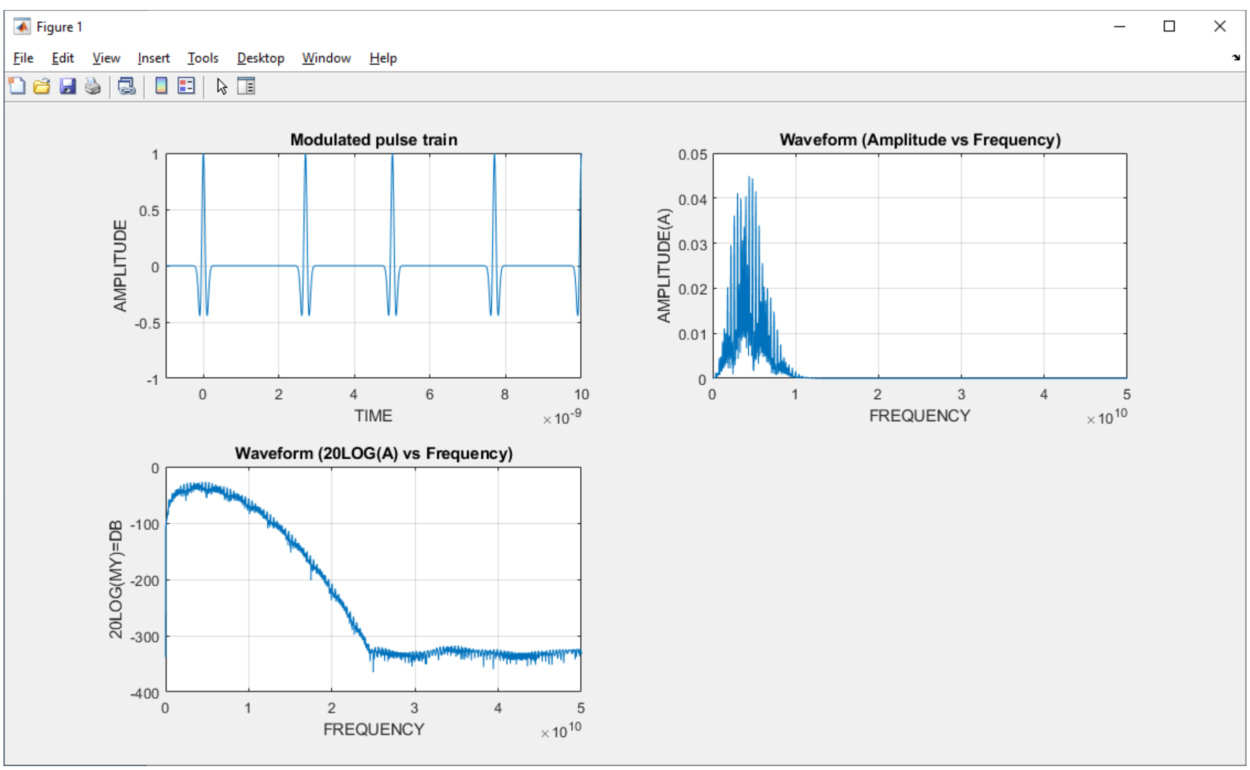
```
FFTY1=fft(y1,NFFY1);%pad with zeros
NumUniquePts=ceil((NFFY1+1)/2);
FFTY1=FFTY1(1:NumUniquePts);
MY1=abs(FFTY1);
MY1=MY1*2;
MY1(1)=MY1(1)/2;
MY1(length(MY1))=MY1(length(MY1))/2;
MY1=MY1/length(y1);
f=(0:NumUniquePts-1)*2*Fn/NFFY1;
%new fft for correlated yc
y2=yc;%y2 is the time domain signal output of the multiplier
%(modulated times unmodulated) in the correlation receiver. Plots
%in the time domain show that a simple comparator instead of high speed A/D's
%could be used to recover the 10101 signal depending on integrator design.
%We have not included an integrator in the program but it would be a properly
%constructed low pass filter in an actual receiver.
NFFY2=2.^(ceil(log(length(y2))/log(2)));
FFTY2=fft(y2,NFFY2);%pad with zeros
NumUniquePts=ceil((NFFY2+1)/2);
FFTY2=FFTY2(1:NumUniquePts);
MY2=abs(FFTY2);
MY2=MY2*2;
MY2(1)=MY2(1)/2;
MY2(length(MY2))=MY2(length(MY2))/2;
MY2=MY2/length(y2);
f=(0:NumUniquePts-1)*2*Fn/NFFY2;
%=====================================================
% PLOTS
%=====================================================
%plots for modulated doublet
figure(1)
subplot(2,2,1); plot(t,y);xlabel('TIME');ylabel('AMPLITUDE');
title('Modulated pulse train');
grid on;
axis([-1e-9,10e-9 -1 1])
subplot(2,2,2); plot(f,MY);xlabel('FREQUENCY');ylabel('AMPLITUDE(A)');
title('Waveform (Amplitude vs Frequency)');
%axis([0 10e9 0 .1]);%zoom in/out
grid on;
subplot(2,2,3);
plot(f,20*log10(MY));xlabel('FREQUENCY');ylabel('20LOG(MY)=DB');
title('Waveform (20LOG(A) vs Frequency)');
%axis([0 20e9 -120 0]);
grid on;
%plots for unmodulated doublet
figure(2)
subplot(2,2,1); plot(t,y1);xlabel('TIME');ylabel('AMPLITUDE');
title('Unmodulated pulse train');
grid on;
axis([-1e-9,10e-9 -1 1])
subplot(2,2,2); plot(f,MY1);xlabel('FREQUENCY');ylabel('AMPLITUDE');
title('Waveform (Amplitude vs Frequency)');
%axis([0 10e9 0 .1]);%zoom in/out
grid on;
subplot(2,2,3);
plot(f,20*log10(MY1));xlabel('FREQUENCY');ylabel('20LOG10=DB');
title('Waveform (20LOG(A) vs Frequency)')
```

```
%axis([0 20e9 -120 0]);
grid on;
%plots for correlated yc
figure(3)
subplot(2,2,1); plot(t,y2);xlabel('TIME');ylabel('AMPLITUDE');
title('Receiver correlator output');
grid on;
axis([-1e-9,10e-9 -1 1])
subplot(2,2,2); plot(f,MY2);xlabel('FREQUENCY');ylabel('AMPLITUDE');
title('Waveform (Amplitude vs Frequency)');
axis([0 7e9 0 .025]);%zoom in/out
grid on;
subplot(2,2,3);
plot(f,20*log10(MY2));xlabel('FREQUENCY');ylabel('20LOG10=DB');
title('Waveform (20LOG(A) vs Frequency)')
%axis([0 20e9 -120 0]);
grid on;
%================================================
%Comparator
%================================================
pt=.5;%sets level where threshhold device comparator triggers
H=5;%(volts)
L=0;%(volts)
LEN=length(y2);
for ii=1:LEN;
    if y2(ii)>=pt;%correlated output(y2) going above pt threshold setting
        pv(ii)=H;%pulse voltage
    else;
        pv(ii)=L;
    end;
end ;
po=pv;%pulse out=pulse voltage
figure(4)
plot(t,po);
axis([-1e-9 11e-9 -1 6])
title('Comparator output');
xlabel('Frequency');
ylabel('Voltage');
grid on;
%===================================================
%SETUP and INFO
%===================================================
%Enter desired pulse width in pw1(.5e-9).
%Change t=-1e-9:1/Fs:(xxxx) to 1e-9.
%Press F5 or run.
%With waveform in plot 2,2,1, set pulse width with fudge factor to .5e-9
%using #s corresponding to chosen waveform. Set from tail to tail.
%Change t=-1e-9:1/Fs:(xxx) to something like 20e-9.Zoom out.
%Press F5 and observe waveforms. Print waveforms to compare with next set of
%wave forms.
%Pick another waveform by commenting out existing waveform and repeat as
above.
%When comparing the waveforms we see that the second derivative
%doublet has a center frequency in the spread twice that of the first
%derivative monocycle.
%This is expected on a second derivative. Picking a doublet waveform
%for transmission (by choice of UWB antenna design) pushes the fc center
```

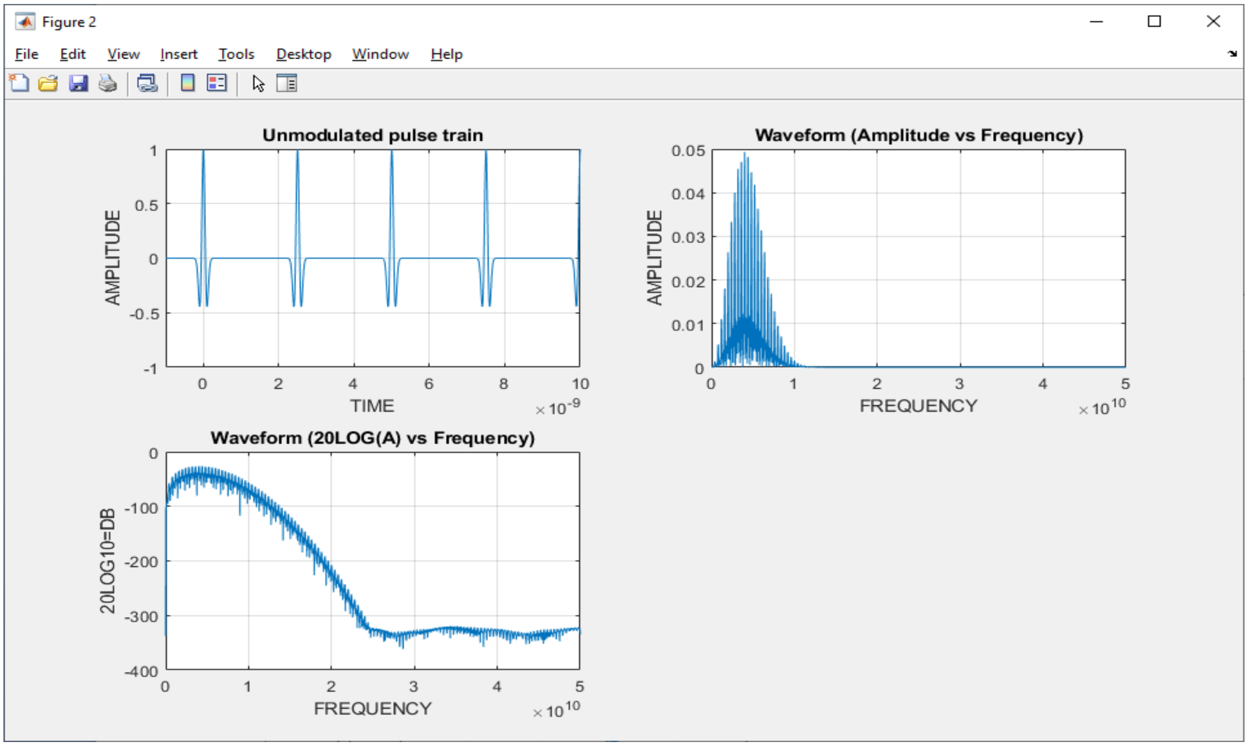
```
frequency
%spread out by (two) allowing relief from the difficult design of narrower
pulse
%generating circuits in transmitters and receivers. If a monocycle is
choosen, we would
%need to design our pulse circuits with a much narrower(factor of two)pulse
width to
%meet the tough FCC spectral mask from ~3 to 10GHz at-40Dbm. A
%pulse width of ~ 0.4 to 0.45 nanosec using a doublet at the proper
amplitude(A)
%could meet the requirements. The antenna choice at the receiver could
%integrate the doublet to a monocycle so a wave form for the modulated
%monocycle is included. Also an unmodulated monocycle template could
correlate with a
%modulated doublet extracting the information but the proper sense of the
%monocycle would be required along with proper information delay setup in
%the equations.
```

The output screens obtained upon running this program are shown below:-

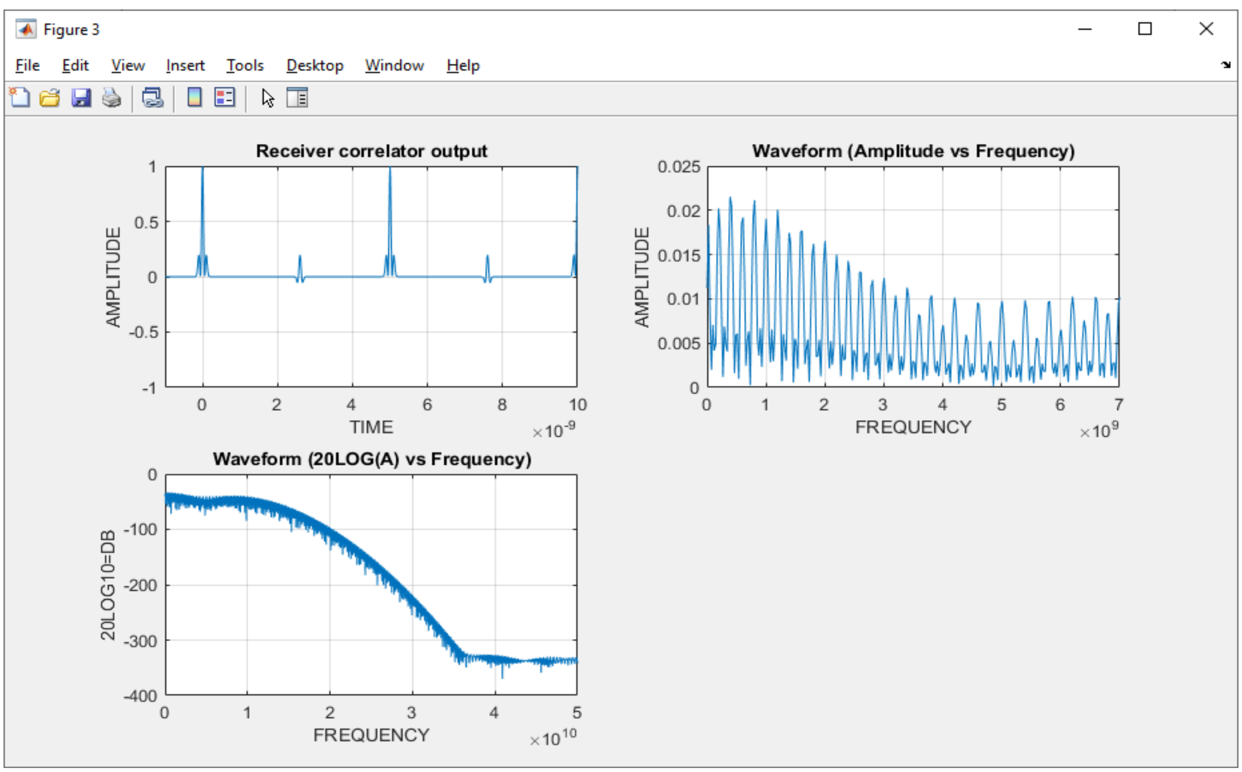
Modulated Pulse Train – Outputs



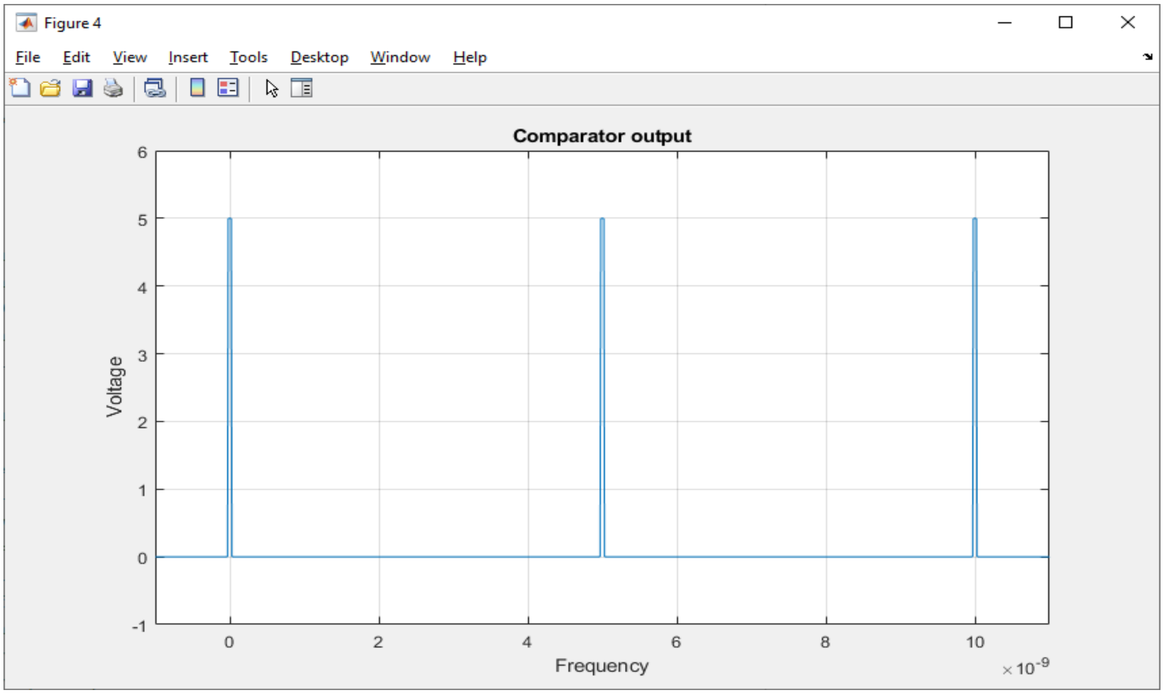
Unmodulated Pulse Train - Outputs



Receiver Correlator - Outputs



Comparator - Outputs



The 4 figure windows show the Outputs produced by the modulated pulse train, unmodulated pulse train, receiver correlator & the comparator circuits in the case of a ordinary Ultra Wideband based system.

The first 2 figure windows corresponding to the Modulated & Unmodulated pulse train outputs plot the waveforms of each pulse train & also the Amplitude vs. Frequency waveform plots for the case of both modulated & unmodulated UWB gaussian doublet waves.

The Receiver Correlator is a radio receiver circuit used in a simple radio interferometer in which signals from two antennas are multiplied together. The signals from the two sources (i.e. modulated & unmodulated pulse train waveforms) pass alternately into and out of phase, producing a characteristic fringe pattern as seen in the output of the Receiver Correlator circuit plotted in Figure 3.

A comparator is a device that compares two voltages or currents and outputs a digital signal indicating which is larger. The corresponding output for a comparator circuit is also shown in this program in Figure 4. These 4 outputs summarize our analysis of UWB systems as a whole.

Conclusion & Scope

To conclude, through this project we were able to learn about the newly emerging field of Ultra Wideband technology in communication systems. We were able to grasp the important role that ultra wideband technology offers in numerous near-field contactless control applications.

Through simulating an Ultra Wideband model we were able to gain an insight into the utility and resourcefulness of software's such as MATLAB in communication system based applications. The inherent capability for integration in low cost & ultra wide frequency bandwidth which allow for high data rates certify ultra wideband technology as a cutting edge communication technology.

Once again we would like to thank our professor Dr. Nitin Puri who gave us the opportunity to work on this project & further our knowledge on the topic to its current state.

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Links:

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