A REPORT

ON

Beamforming Test Setup using Simulink

BY

Names of Student	ID	Discipline
Lakshmi Mounika Chaturvedula	**2019A8PS0621H**	**Electronics and Instrumentation**

Prepared in partial fulfillment of the
Design Project Course Nos.
ECE F376
Under the guidance of
Dr. Subendu Kumar Sahoo

AT

BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI

ACKNOWLEDGEMENT

I want to thank Dr. Subhendu Kumar Sahoo, the project guide, for giving me an opportunity to work on a real-life industrial project and for regularly checking the progress, and for ensuring that I understand the relevance, importance of my work.

I want to express my gratitude to Mr. Hariprasad, the project mentor, for taking time out of his busy schedule to share knowledge on the subject and helping in the progress of the project.

Abstract:

The objective of the project is to create a Simulink model to check the Digital Beamforming implementation which is achieved by a phased array model with a beamformer finally connected to the Ethernet Module.

Table of Contents

1. INTRODUCTION

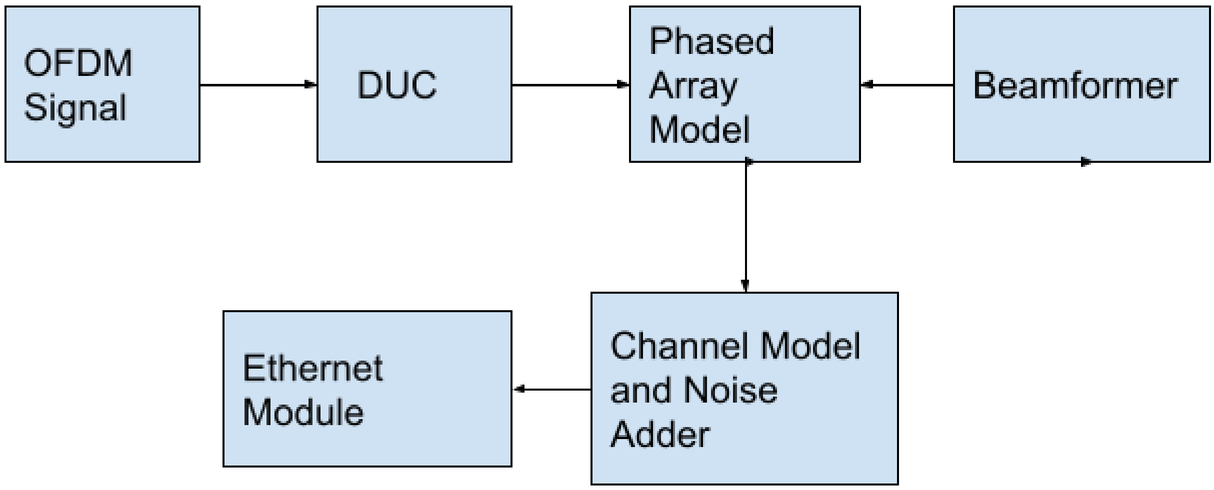
The world has seen a rise in the need for increased data rates to meet the necessities of the people. Recently, demand for technologies to identify a specific target has also been immensely increased for military purposes. In order to achieve this, we have to maximize the signal-to-noise ratio as much as possible so as to reduce the interference of noise. Beamforming is one of the most important techniques employed for the same.

Traditionally, a single antenna produces a wireless signal that radiates in all directions provided there are no obstructions. However, to focus the signal in a specific direction there should be a mechanism that transfers the intended data. This forms the basis of Beamforming, where there are multiple antennas located at the transmitter end, and specifically in the phased array model all the radiating elements constructively interfere to produce main lobes and sidelobes. The main lobe transfers the energy to the desired locations and wherever it destructively interferes forms sidelobes.

The project is developed using Simulink, where an OFDM signal is transmitted (of MHz range) and is digitally upconverted to a higher frequency range (of GHz). In the later part, the digitally upconverted signal is passed through a phased array model with the beamformer created in Simulink and then transferred through a noise channel which is finally passed through the Ethernet Module.

2. WORKFLOW

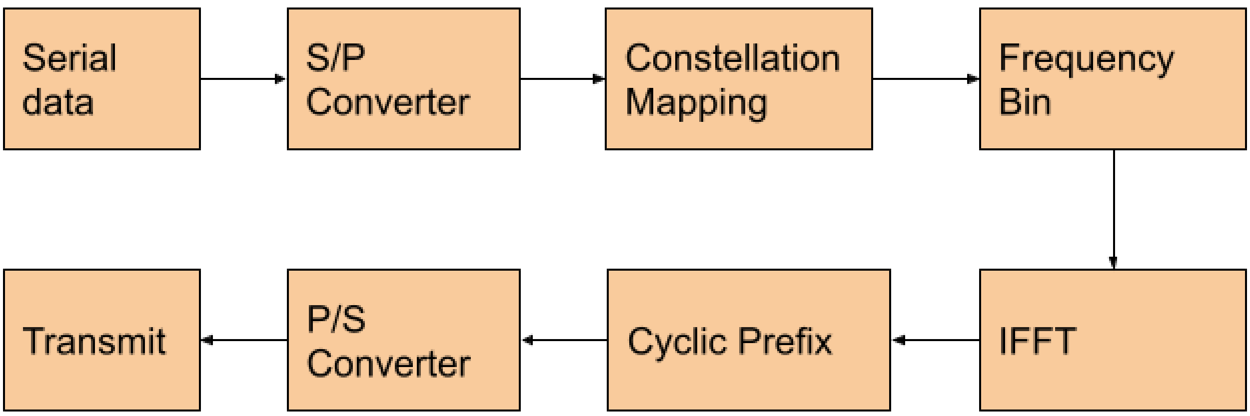
2.1.Block Diagram:



3. Modelling

3.1.OFDM:

BLOCK DIAGRAM OF OFDM:



Transmission of an OFDM Signal is the first step to be performed in the project. The principle of OFDM is employed for large bandwidth signals which when transmitted using a single carrier wide-band frequency experience distortion/may change the data initially intended to be transmitted.

For Ex: If the transmitted signal is having a bandwidth of 20MHz then the symbol time is 0.05μs and the delay spread is around 2-3μs. Since the symbol time is less than the delay spread it leads to intersymbol interference.

So, to avoid the ISI, the large bandwidth signals are divided into many narrowband signals which remove the ISI, the symbol time of the channel now becomes more than the delay spread. So, a system with multiple subbands and subcarriers form Multicarrier Modulation.

Ex: Let the transmitted signal of bandwidth 20MHz be divided into 1000 subcarriers where each subcarrier has a frequency of 20kHz, the symbol time becomes 100μs which is greater than the delay spread.

Equations and Steps of the transmission of the MCM Signal:

$Sk(t) = Xk * e^{j2\pi kf}$ ->is the equation for the kth Subcarrier of center frequency f.

The net transmitted MCM Signal is $S(t) = \sum Sk(t)$

To recover the Xk, take the inverse Fourier transform.

After IFFT Processing, to avoid the past symbols having an influence on the current symbols Cyclic Prefix should be added. Generally, the length of Cyclic Prefix is 1/4th of the length of subcarriers.

3.2.DUC:

The transmitted signal is then digitally upconverted to a higher frequency for transmission purposes. This is widely employed in 5G, LTE where signals with higher frequencies are of more significance.

4. Simulation Steps and Results:

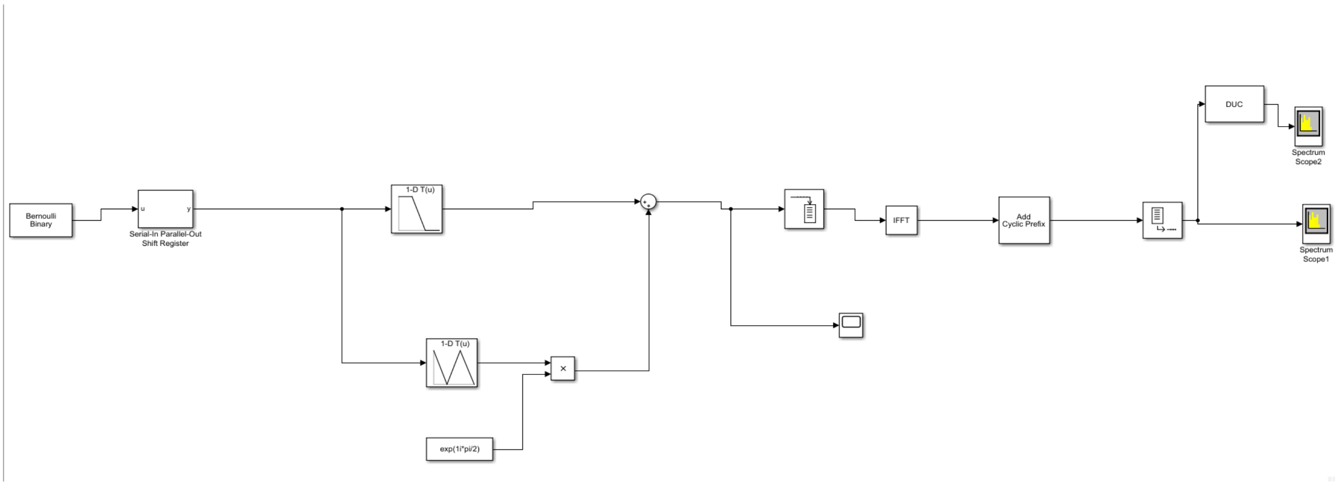
Steps for Generating OFDM Signal and Upconversion:

The data is generated using any random source generator. The received is mapped accordingly as per the constellation of the modulation schemes that we want to perform. In the project, the source is a Bernoulli binary generator and the bits are mapped as per the QPSK modulation scheme, where two bits are transmitted together.

Later, the transmitted bits are converted from serial to parallel, the buffer is used and the Inverse Fast Fourier Transform is computed with the help of the inbuilt IFFT block. For the addition of Cyclic Prefix, Multiport Selector in Simulink is used so as to append the last bits to the original data. The parallel data is unbuffered and analyzed using a spectrum analyzer which later sent to the next block (i.e DUC)

The OFDM signal is upconverted to a higher frequency for transmission purposes with the aid of Digital-Up Converter Block in Simulink

Simulation Steps:



Arrange the Simulink as mentioned in the above picture
Parameters and Blocks:

The Bernoulli binary generator takes the Sample per frame as 64 with the initial seed of 61(the data keeps repeating itself after 61-time units) with the sample time as 0.05exp(-6) because the assumed bandwidth of as signal is 20MHz.

In the Serial-In Parallel Out Shift Register, the number of samples is considered to be 2 because 2 bits are transferred in QPSK modulation.

The lookup table maps the bits as per the constellation of QPSK i.e, 00->1+j,01->1-j,10->-1+j,11->-1-j since the lookup table only takes real values as input and convert it to a complex value, multiplying with "j" is necessary.

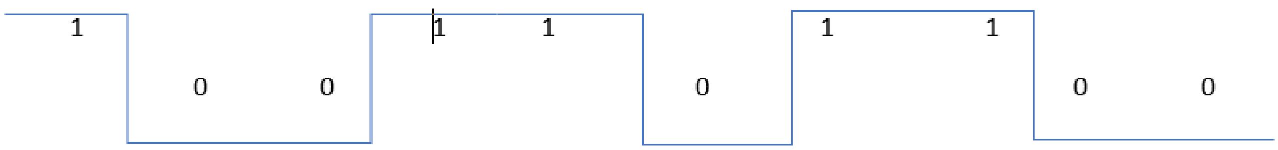
The buffer size per channel is considered as 16 (so that the serial data is converted into 4 subchannels).

The IFFT is performed by taking 64 points and it is then unbuffered to get back the original serial data.

Finally, the DUC Parameters are updated as per the requirements.

Simulation Results:

Let the input sequence be



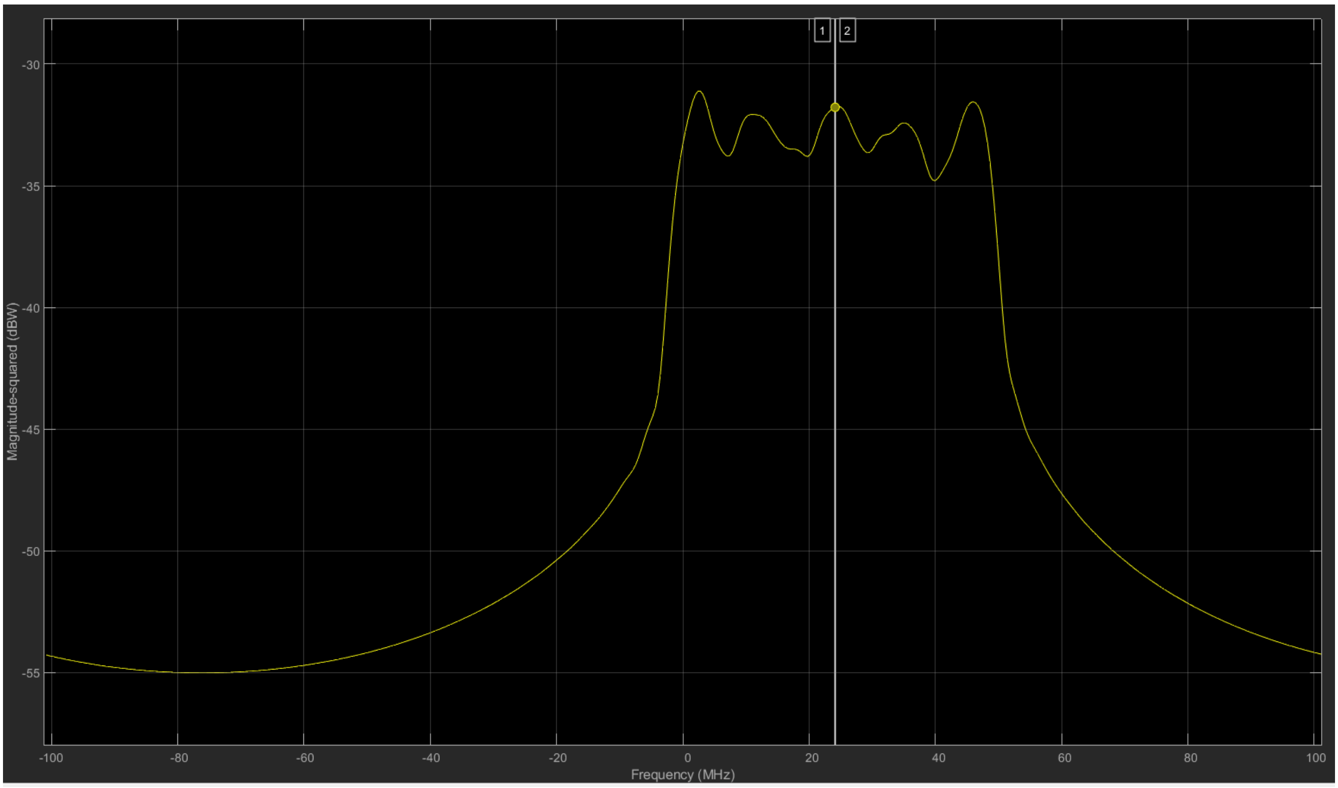
Since the modulation is QPSK, the corresponding constellation is

00->1+j; 11-(-1-j)
01->1-j;10-(-1+j) if there is an offset of π/4.

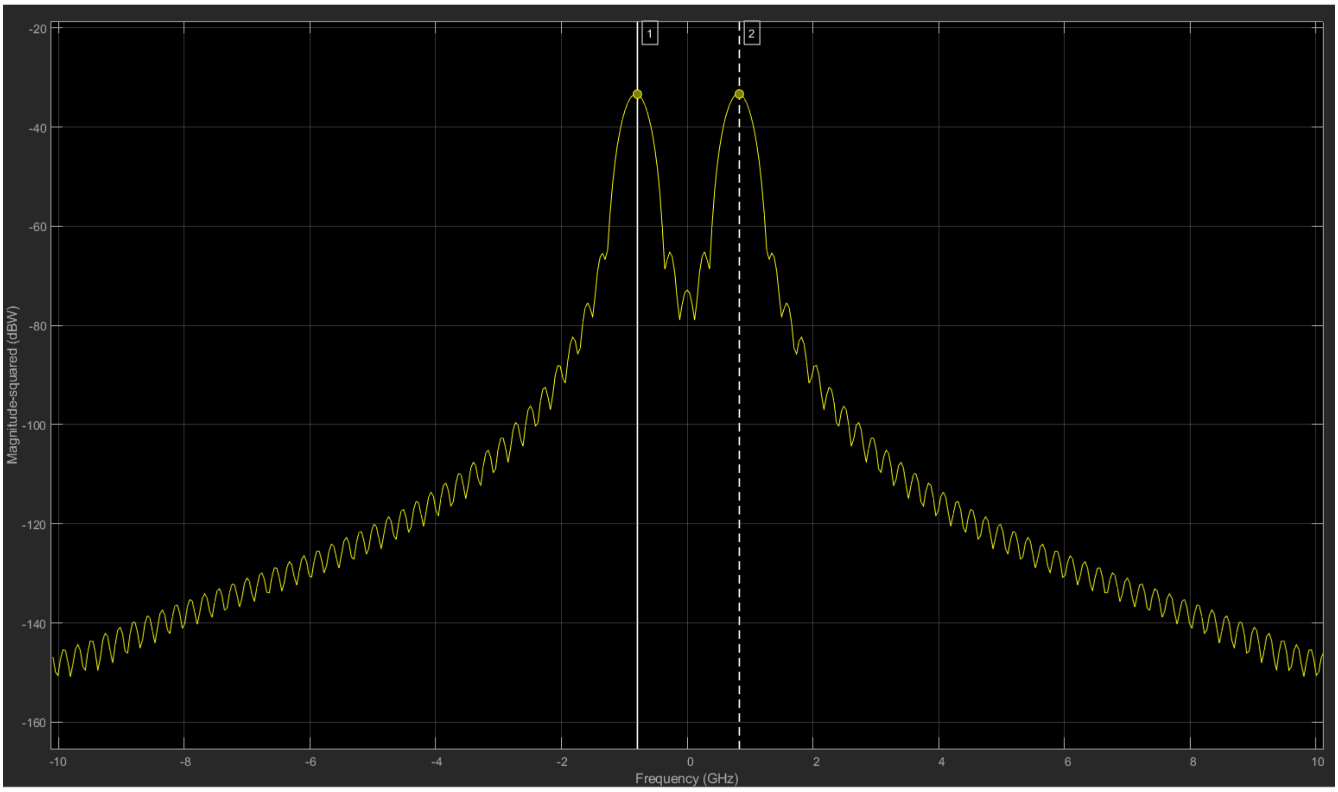
The input bandwidth is 20MHz.
If the number of subcarriers is 64 then the symbol time for each channel becomes 312.5KHz. Now the corresponding symbol duration of each subcarrier is 3.2µs, where the cyclic prefix duration is 1/4th of the symbol duration that is 0.8µs.
The total symbol duration is 4µs. The total number of samples hence becomes 80.

The OFDM signal is generated by QPSK Modulation with a length of 64 and is buffered into 4 parallel streams and it is centered at a frequency of approximately 20 MHz since the sample time in the Bernoulli Binary generator is 0.05exp(-6).

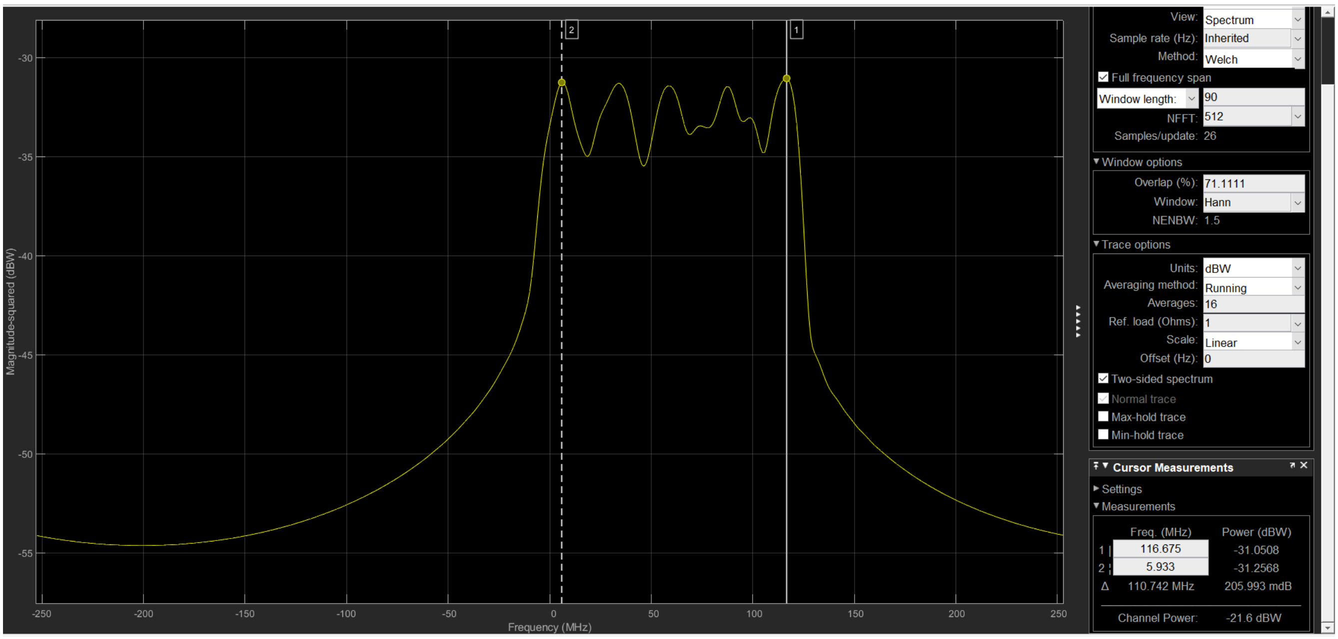
The OFDM signal after passing through the IFFT Block and Cyclic Prefix with a central frequency of approximately 20MHz matches with our initial condition of the addition of a cyclic prefix to the original signal



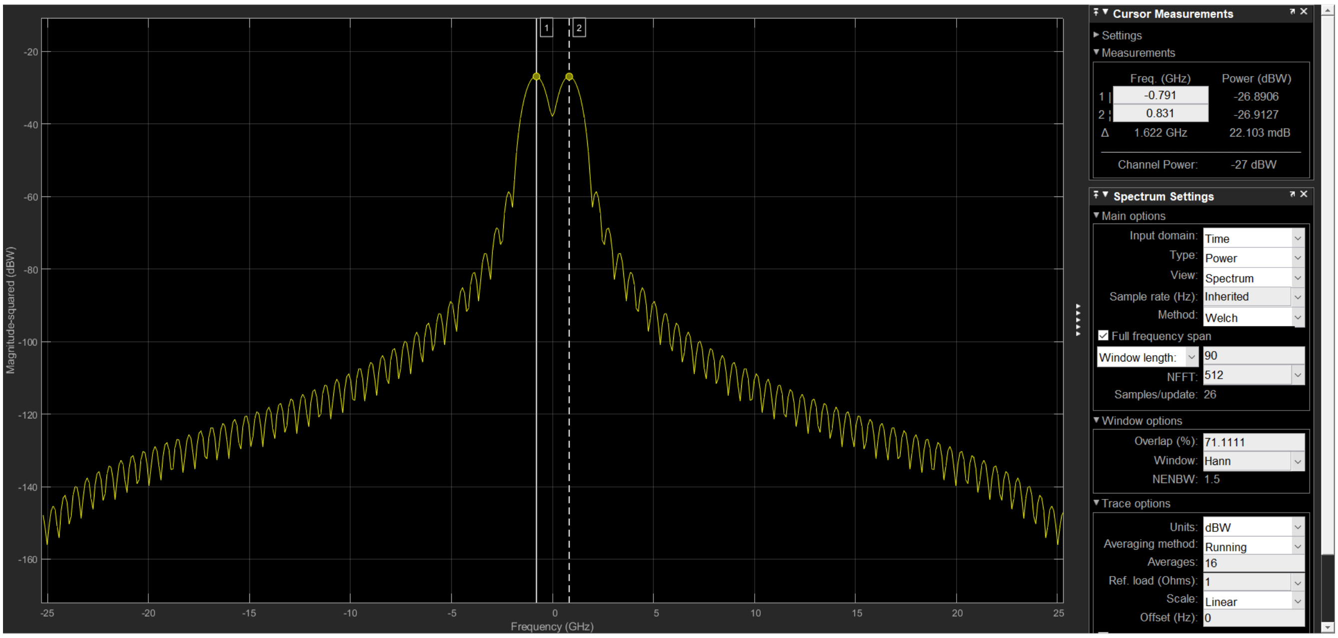
After passing through the Digital UpConverter, with the center frequency being set to 800MHz, the signal transforms as follows:



Similarly, if the input signal has a bandwidth of 50MHz, the corresponding OFDM Signal looks like



The DUC signal with a center frequency of 800 MHz looks like,


Magnitude-squared (dBW)
-20
-40
-60
-80
-100
-120
-140
-160
-25
-20
-15
-10
-5
0
5
10
15
20
25
Frequency (GHz)
1
2
Cursor Measurements
Settings
Measurements
Freq. (GHz)
Power (dBW)
1
-0.791
-26.8906
2
0.831
-26.9127
Δ
1.622 GHz
22.103 mdB
Channel Power:
-27 dBW
Spectrum Settings
Main options
Input domain:
Time
Type:
Power
View:
Spectrum
Sample rate (Hz):
Inherited
Method:
Welch
Full frequency span
Window length:
90
NFFT:
512
Samples/update:
26
Window options
Overlap (%):
71.1111
Window:
Hann
NENBW:
1.5
Trace options
Units:
dBW
Averaging method:
Running
Averages:
16
Ref. load (Ohms):
1
Scale:
Linear
Offset (Hz):
0

5. CONCLUSION

The project begins with understanding the important concepts like Beamforming, applications of Beamforming, and different optimization techniques and algorithms(QR-Decomposition) used to achieve it. Later, for designing the same an OFDM signal transmission is chosen which requires the knowledge of Single Carrier Transmission, Multi-Carrier Transmission, and Cyclic Prefix. Finally, the data is upconverted to a certain frequency and its utilization for the phased array model forms the crux of the project

6. REFERENCES

(1) Jun Zhang and Zhongpei Zhang, "Simulation and analysis of OFDM system based on simulink," 2010 International Conference on Communications, Circuits and Systems (ICCCAS), 2010, pp. 28-31, doi: 10.1109/ICCCAS.2010.5582049.

(2) Sahlli, Ehab & Ismail, Mahamod & Nordin, Rosdiadee & Abdulah, Nor. (2017). Beamforming techniques for massive MIMO systems in 5G: overview, classification, and trends for future research. Frontiers of Information Technology & Electronic Engineering. 18. 753-772. 10.1631/FITEE.1601817.

(3) A Brief History of OFDM http://www.wimax.com/commentary/wimax_weekly/sidebar-1-1-a-brief-history-of-ofdm

(4) *Sha, Xin & Zhou, Jian & Song, Yuan. (2014). Design and Simulation of OFDM System Based on Matlab. Applied Mechanics and Materials. 635-637. 1081-1085. 10.4028/www.scientific.net/AMM.635-637.1081.*

(5) https://rfmw.em.keysight.com/wireless/helpfiles/89600B/WebHelp/Subsystems/wlan-ofdm/Content/ofdm_basicprinciplesoverview.htm