

İSTANBUL MEDİPOL UNIVERSITY



EECD1212913: DIGITAL COMMUNICATION LABORATORY

Lab report No. 6:

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Introduction

The objective of this lab is to observe the effects of the channel on the system performance using realistic signaling techniques. This has enabled us to familiarize ourselves with the following items:

- Performance evaluation in realistic multipath channel and comparison with direct cable connection.
- Multipath and fading channel and its effect on the system and signal design.
- Path loss, shadowing, and multipath profile.
- LOS and NLOS.
- Doppler Shift and Spread.
- Wideband and narrowband channels.
- Reverberation Chamber.
- Effect of environment in the received waveforms.
- Radio Channel Impulse Response (CIR) estimation using the sounding technique.

PATH-LOSS EXPONENT

Activity 1: The following two objects were initialized on MATLAB

Tx:

- Gain: -10dB
- CenterFrequency: 2.35GHz, 2.4GHz, or 2.45GHz (*change to not interfere to other SDRs*)
- BasebandSampleRate: 1e6 Samples/s
- RadioID: (select the serial number using findPlutoRadio command)

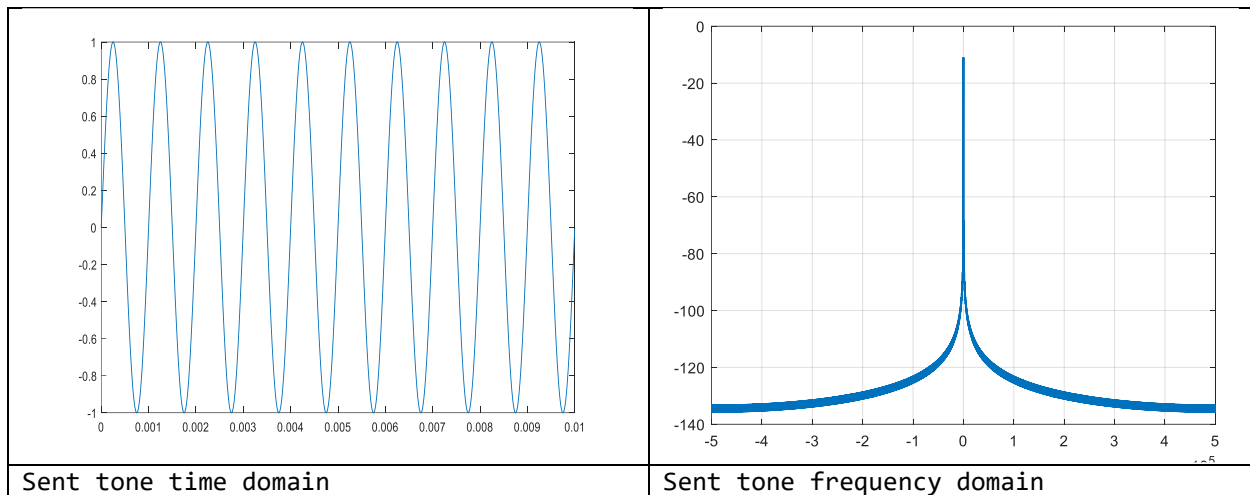
Rx:

- CenterFrequency: 2.35GHz, 2.4GHz, or 2.45GHz (match with Tx)
- BasebandSampleRate: 1e6 Samples/s
- SamplesPerFrame: 30e3 Samples
- GainSource: 'Manual'
- Gain: 20 (*you might need to change this value*)
- OutputDataType: 'double'
- RadioID: (select the serial number using findPlutoRadio command)

Activity 2

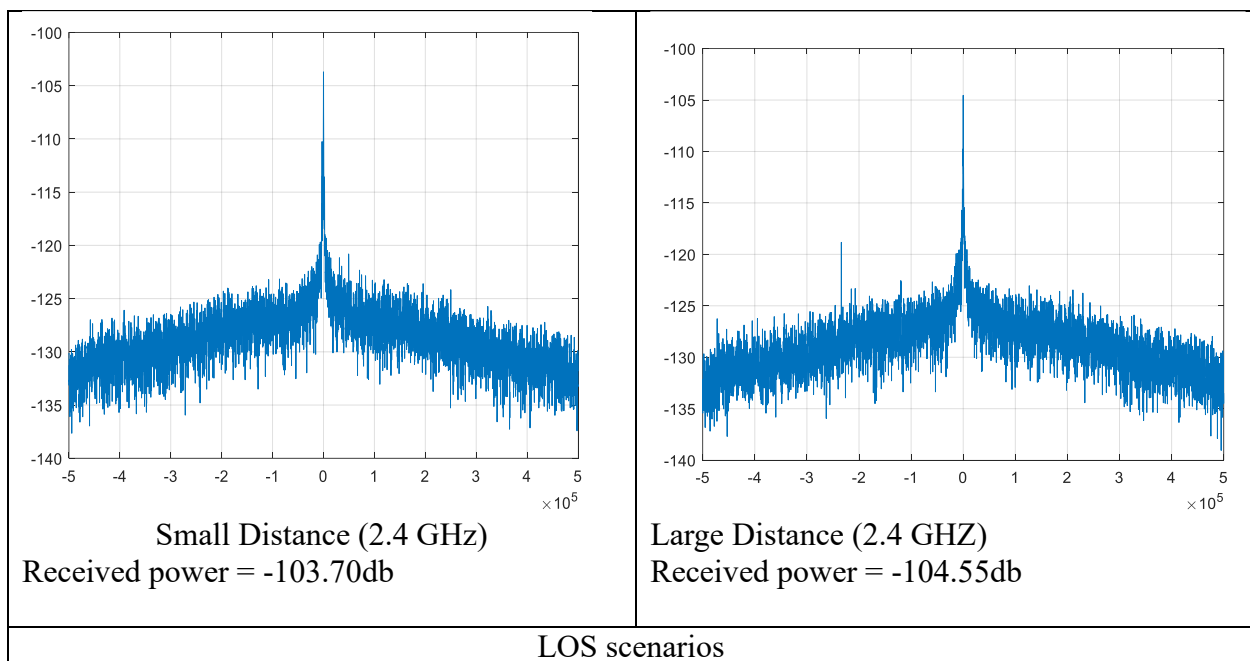
A baseband signal with no training data was built using the following equation with a baseband frequency of 1000, and a corresponding time span.

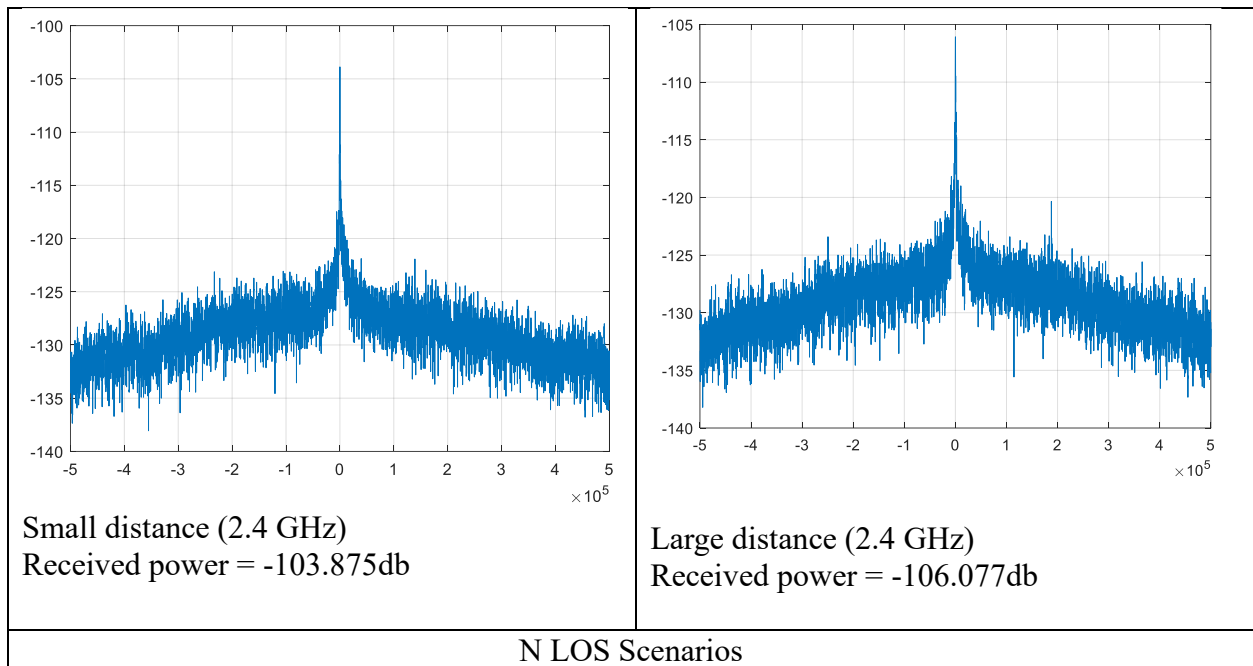
`sinusoidal_tone = sin(2*pi*baseband_frequency*t)+1j*sin(2*pi*baseband_frequency*t)`



Activities 3 and 4

The figure below shows received energy at two distances for cases of Line of Sight (LOS) and non-Line of Sight (NLOS).



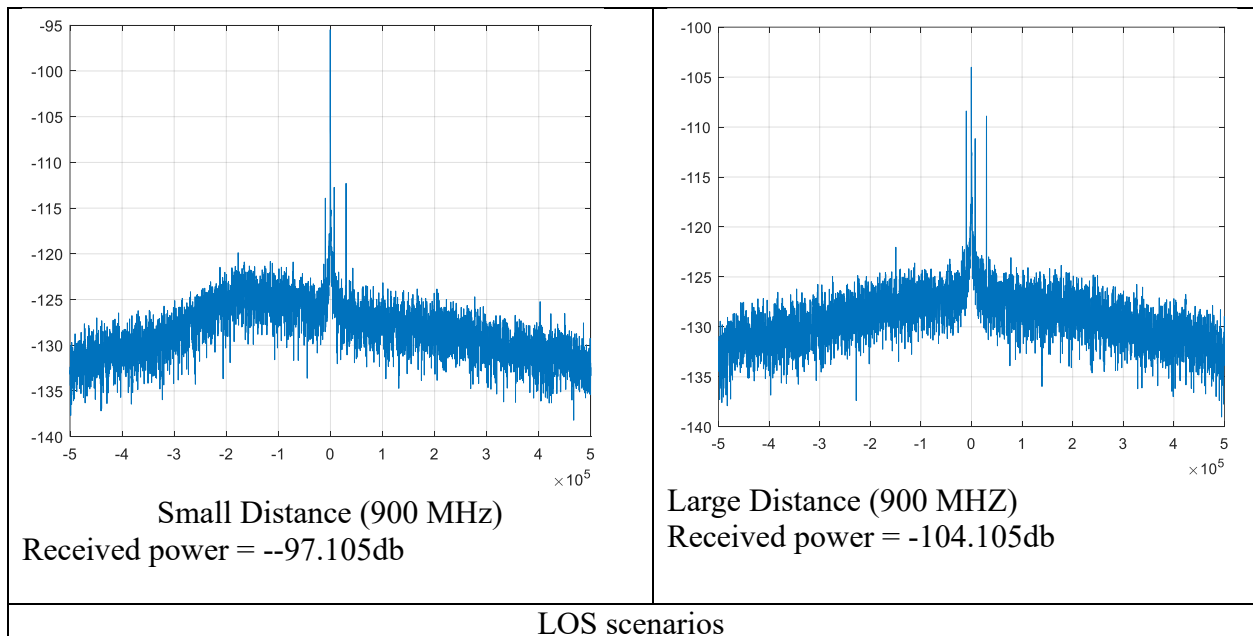


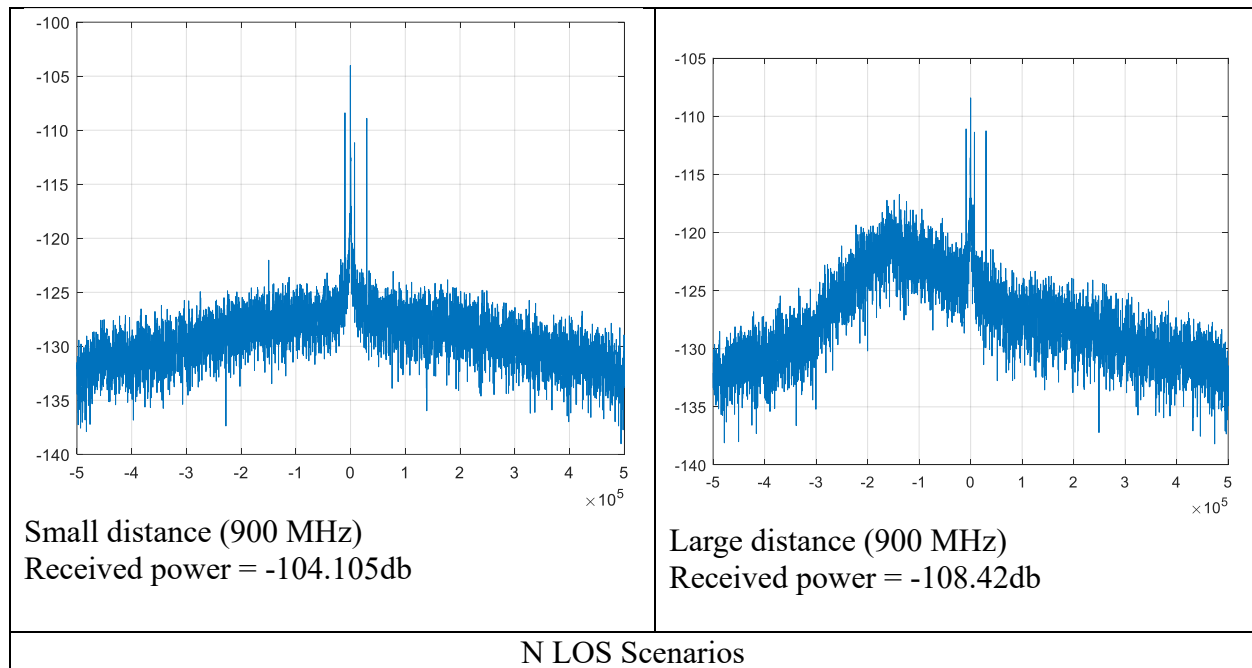
Activity 5

The LOS scenario gives greater gain compared to the NLOS, this can be attributed to the shadowing of the signal by blockers that are between the sender and receiver. Further, the distance between the sender and receiver in both cases (LOS and nLOS) affects path gains such that when the distance increases, more loss is experienced compared to when they are close.

Activity 6

The steps in the previous questions were repeated, for a frequency of 900MHz,





Observation and Inference

It was observed that at this lower frequency than the previous one, in each of the cases (LOS and nLOS) and each of the distances, the path loss experienced was lower compared to that of 2.35 GHz used in the previous case. This implies that path loss increases with carrier frequency, thus higher frequencies may give higher bandwidth but will have a shorter range.

FREQUENCY SELECTIVITY

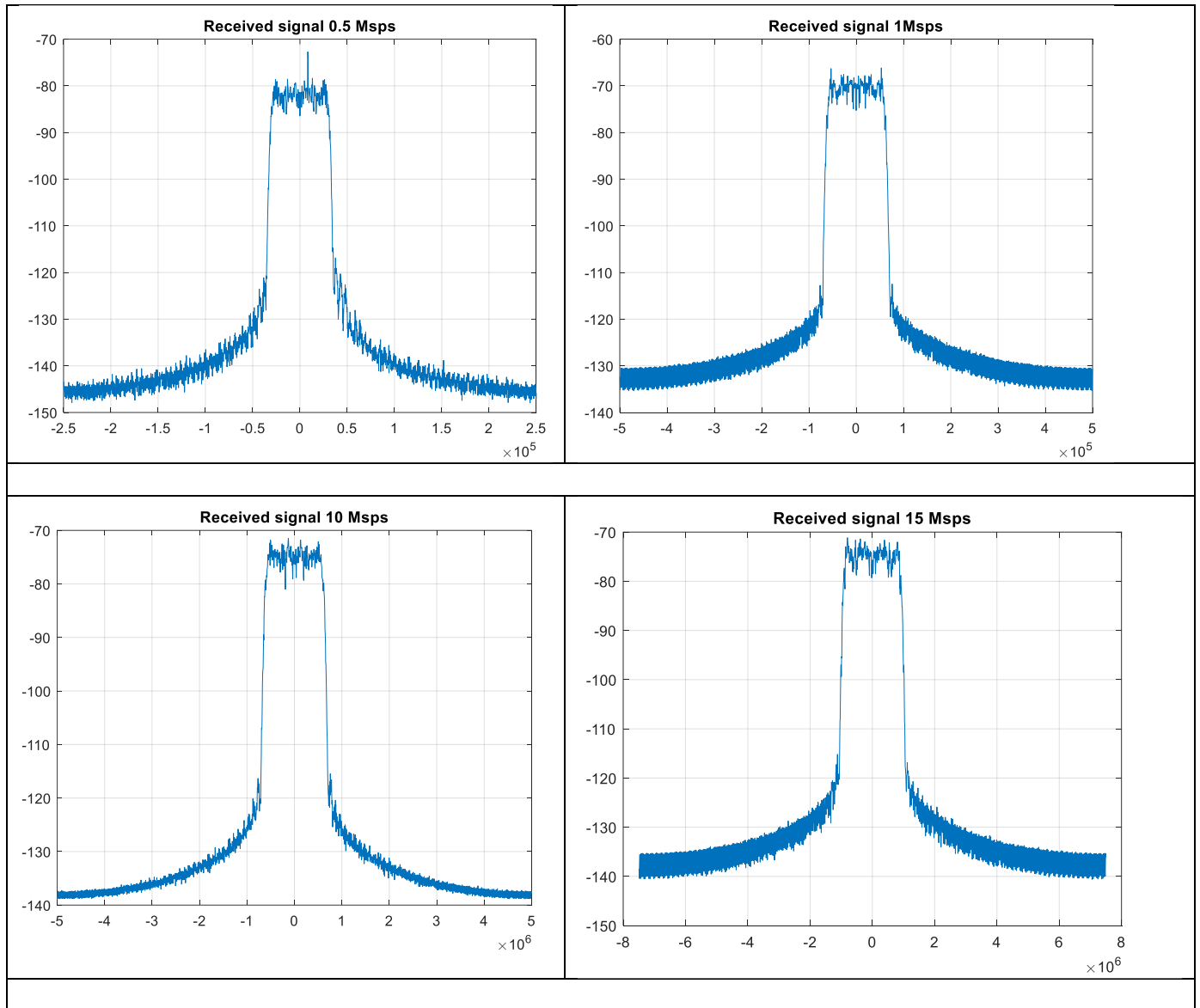
Activities 7 and 8

The gain in the Rx object was changed to '*AGC Fast Attack*' as instructed and a frame was built using the following structure.

- Preamble Symbols: two m-sequences, each of length $2e7-1$ symbols.
- Data Symbols: 512 BPSK symbols.
- Filtering: RRC filter with 0.1 roll-off factor and 8 samples/symbol oversampling ratio.
- Match Filtering was Enabled.
- Guard samples: $2e2$ samples at each end of the frame.

Activity 9

Different sample rates were used to send frames and the received signal was captured and their corresponding power spectral density was plotted for each received transmission.

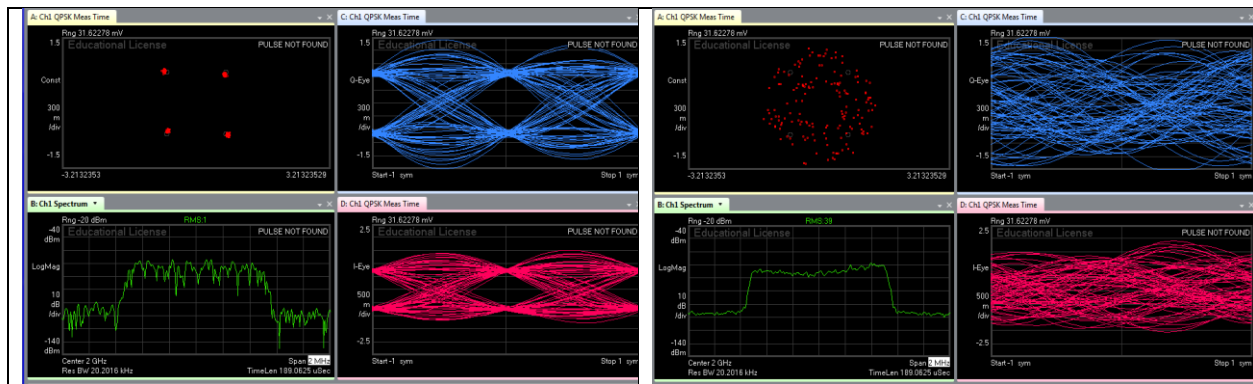


It can be observed from the figures that the increase in sample ratio, increases the selectivity, easily observed by considering the top part of the power spectrum, more variations can be observed in the 15 Msps compared to that of 10 Msps, and then 1 Msps and 0.5 Msps, the relatively irrelevant trend in received power can be attributed to the different times at which the simulations for each case of the Msps was conducted.

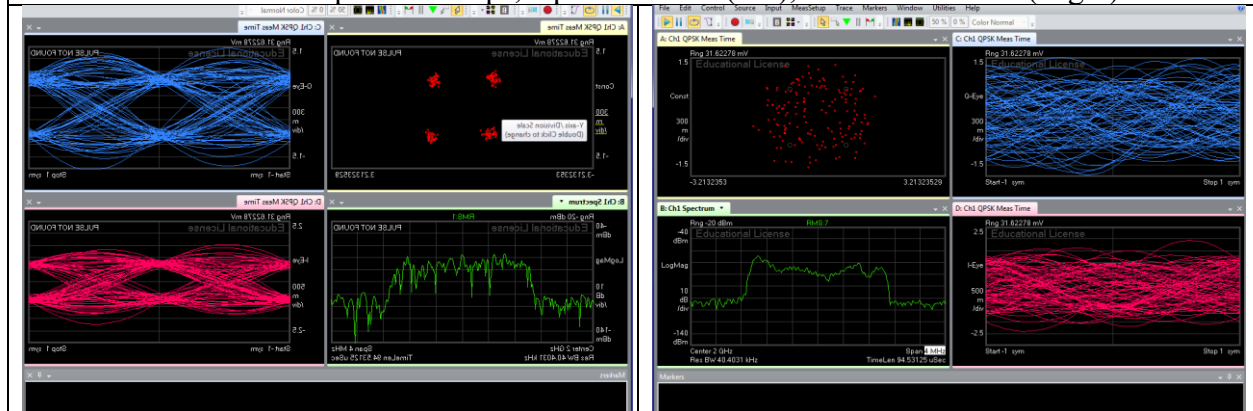
Activity 10

VSG and VSA were used to send and receive modulated signals at different symbol rates, the reverberation chamber was used to create multipath components, by opening and closing the chamber we could create more multipath components.

The following figures show how the signal power varied based on different symbol rates and in the presence of multipath components.



Effect of Multipath at 1Msps, Open chamber (left), Closed Chamber (Right)



Effect of Multipath at 2Msp, Open Chamber (left), Closed Chamber (Right)

Observation and Inference

Effect of Increasing Sample Rate

In both open and closed cases, the frequency selectivity increases with increasing sample rate, this is because the increase in sampling rate increases the occupied bandwidth which in turn increases the frequency range and hence the possibility of frequency selectivity; the green plots show that the selectivity is severe in the closed chamber case.

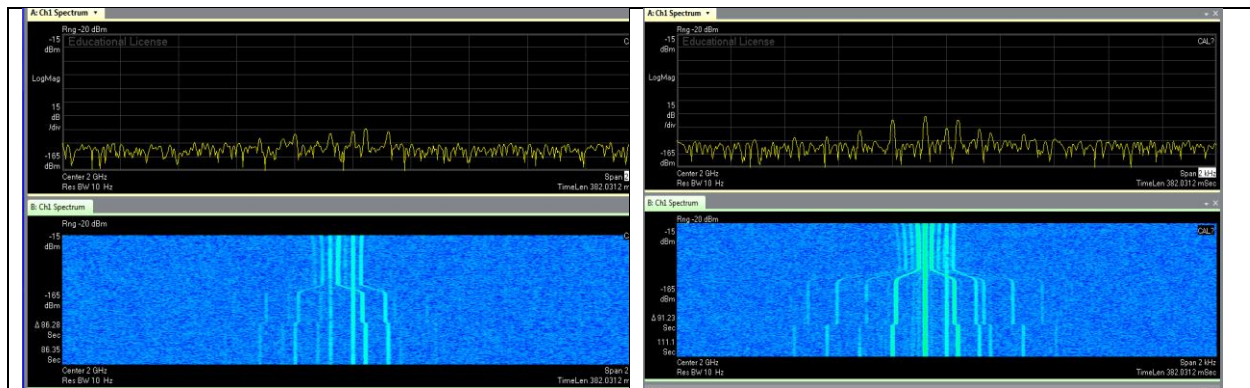
Effect of Closing and Opening the Chamber

By closing the chamber, we increase the number of multipath components thereby increasing the frequency selectivity of the channel, the variation of gain with time (shown by green plots) depicts that for a closed chamber selectivity increases such that its impossible to obtain an optimal sampling time of the signal (eye is completely closed) the constellation points are also to scattered.

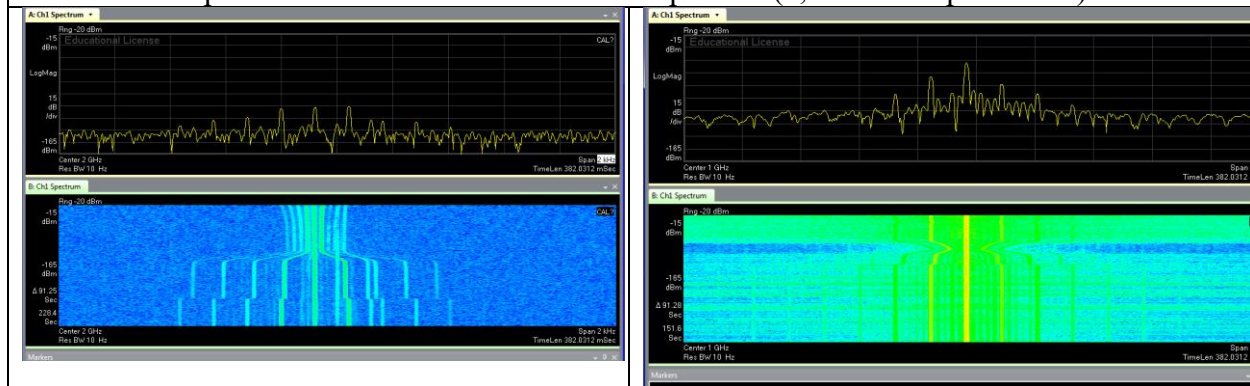
TIME SELECTIVITY

Activity 11, and 12

VSG and VSA were set to send and receive a tone at 2.4GHz, a fan was turned on inside the reverberation chamber to create Doppler spread. A test signal had to be selected such that, its bandwidth would be small to make frequency dispersion easily observable. The proper signal for this case would be a tone, since it only has one frequency, and deviations could easily be noted.



Effect of Doppler on the received signal (1MHz Left) and (500 MHz Right), the change in expansion of lines show different fan speed of (1, 5 and 10 speed units)



Effect of Doppler on the received signal (1 GHz Left) and (1GHz Right now in the chamber), the change in expansion of lines shows different fan speeds of (1, 5 and 10-speed units)

Observation and inference

As can be seen in the figures, when the fan was not rotating, the received signal appeared only at the central frequency, when the fan started to rotate, copies of the signal were also observed at frequencies other than the central frequency, that is at $2.4\text{GHz} \pm \text{Doppler frequency}$.

It is further observed that the speed of the fan determined more Doppler and hence more frequency dispersion. This can be attributed to the Doppler formula.

$$\text{Doppler frequency} = \frac{vf \cos \theta}{c} \quad (1)$$

Where v is the speed of the sender, receiver, or in our case, approximately the fan, c is the speed of light, and f is the central frequency at which we are transmitting, in our case 2.4GHz

Activity 13

The same procedure as in Activity 11 and 12 was repeated but this time with a frequency of 900MHz .

Observation and Inference

Based on equation 1, it can be observed that Doppler increases with frequency, at 900MHz we expect to experience less Doppler compared to 2.4GHz, this can also be observed in the provided figures.

The separation of frequency spread in 1MHz top left, 500MHz top left, and 1GHz clearly show that increasing the frequency increases the doppler spread, while also increasing the speed of the fan further increases the frequency spread.

Another important observation is when multipath was introduced on top of Doppler by putting the fan in a reverberation chamber, this can be seen in the figure at the lower right corner of the table above. The difference between this (Doubly dispersive channel) and the other figure where only the doppler can be considered significant is the spread in energy even between the prominent doppler component of the frequency spread as shown by the greenish color between those doppler components.

Activity 14

Using the previous setups, QPSK frames were sent, and pre-ambls and non-equalized symbols were obtained which were later used to estimate the channel and the actual symbols respectively.

For the sent preamble symbols $s(n)$, we have the received symbols $r(n)$, to estimate the channel we find \hat{h} such that.

$$\hat{h} = r(n) \times \frac{\text{conj}(s(n))}{\text{abs}(s(n)).^2}$$

We then use that to equalize the received data symbols by:

$$\text{Estimated_data} = r(n) \times \text{conj}(\hat{h})$$

The following code was then used for maximum likelihood detection

```

constellation      = pskmod(0:3,4,pi/4); % QPSK constellation

% Initialize variables
ml_symbols         = zeros(1, length(eq_smpls_rx));
detected_data      = zeros(1, length(eq_smpls_rx));

% Perform ML detection
for i               = 1:length(received_symbols)
    % Calculate Euclidean distance to each constellation point
    distances        = abs(received_symbols(i) - table);

    % Determine the index of the nearest constellation point (ML detection)
    [~, idx]         = min(distances);

    % Map index back to QPSK symbol
    ml_symbols(i)    = table(idx);

    % Map detected data to original data

```

```

detected_data(i)    = mod(idx-1, mod_stp.M_q14);
end

```

