



**مدينة زويل للعلوم والتكنولوجيا**  
**Zewail City** of Science and Technology

## Digital and wireless communications

### 3G communication system

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## Introduction

The third generation of cellular technology that enables mobile telephony is referred to as 3G. The third-generation standard follows the deployment of two previous generations on mobile networks and across mobile phones.

Third-generation mobile telephony standards, known as International Mobile Telecommunications 2000 (IMT-2000), were established by the International Telecommunication Union (ITU) to promote expansion, expand available bandwidth, and accommodate a wider range of applications.

In 2001, the first 3G networks began appearing, functioning as an overlay rather than a replacement for the older 2G networks. In addition to standard functions like texting and calling, 3G enables new ones like video chatting and Mobile TV.

The primary function of 2G technology is to transmit information via phone calls, while the primary function of 3G technology is to transmit information via data, such as photos and video. While 3G networks may reach download speeds of up to 42Mbps, 2G networks can only manage an average of 170 Kbps in data transfer.

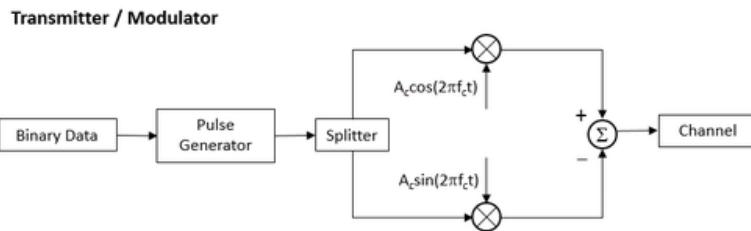
## Basic parameters

- **Pulse shape of base-band pulse:** The transmit pulse-shaping filter is a root-raised cosine (RRC) with roll-off  $\alpha = 0.22$
- **Bit rate:** up to 2 M bit/s
- **Maximum data rate:** 2048 kbps low range 384 kbps urban and outdoor.
- **Channel BW:** 5 MHz
- **Frequency band:**
  - 1920- 1980 MHz (uplink)
  - 2110-2170 MHz (downlink)

# Block Diagram

- **Transmitter**

- **QPSK is the modulation technique used in the 3G communication system:**



- **Steps:**

1. Separating the even and the odd bits into two vectors.
2. Multiplying the even bits by sin carrier and the odd bits by cos carrier. ( $F_c = 1927$  MHz for uplink signal and  $F_c = 2140$  MHz for downlink signal)
3. Adding the two signals (even and odd) together to be transmitted as a QPSK signal with root raised cosine pulse shaping.

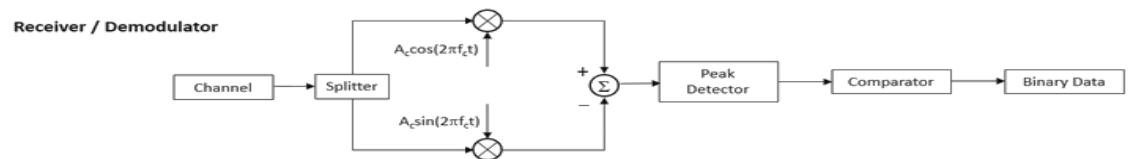
- **Channel**

It consists of three different effects

1. Rayleigh effect.
2. Rician effect.
3. AWGN Effect with different SNR values.

- **Receiver**

- **QPSK is the modulation technique used in the 3G communication system:**



- **Steps:**

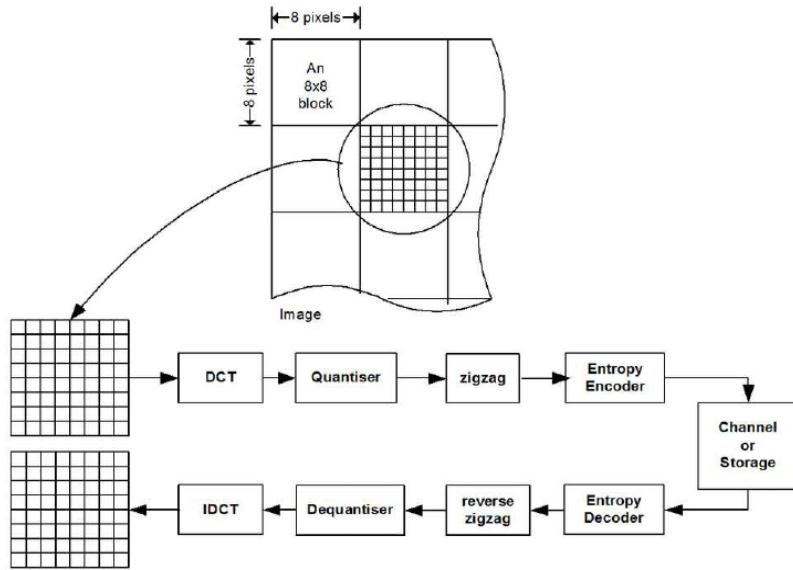
1. Separating the received signal into even and odd bits again by multiplying the received signal once by the cos carrier and once by the sin carrier (coherent detection).
2. Integrating the result of the multiplication along the symbol period (where the symbol consists of two bits).
3. Then a decision device is used where if the result of the integration is greater than 0 then it is symbol 1 and if the result is less than 0 then it is symbol 0.
4. Now the bits are ready for JPEG decoder in which it reverses all the effects of JPEG encoder except the quantization effect as mentioned above.

- **JPEG**

We have used JPEG encoding with low quantization table for the image used in Matlab which achieves a compression ratio = 2.466

- **Main Steps in JPEG encoding:**

- First: divide the image into 8\*8 Blocks.
- For each block:
  - compute DCT
  - Divide the result from DCT Block by a quantization matrix that causes some error but increases the compression ratio.
  - Read 8\*8 blocks in zigzag order.
  - Apply run length encoding on integer vectors after zigzag.
  - Concatenate the results of all blocks.
- Then apply Huffman encoding in the Entropy coding Block
- Now, the bits of the image become ready for the modulation part.
- **The JPEG decoder reverses these operations to get the image after the demodulation step, however, the quantization operation is irreversible.**

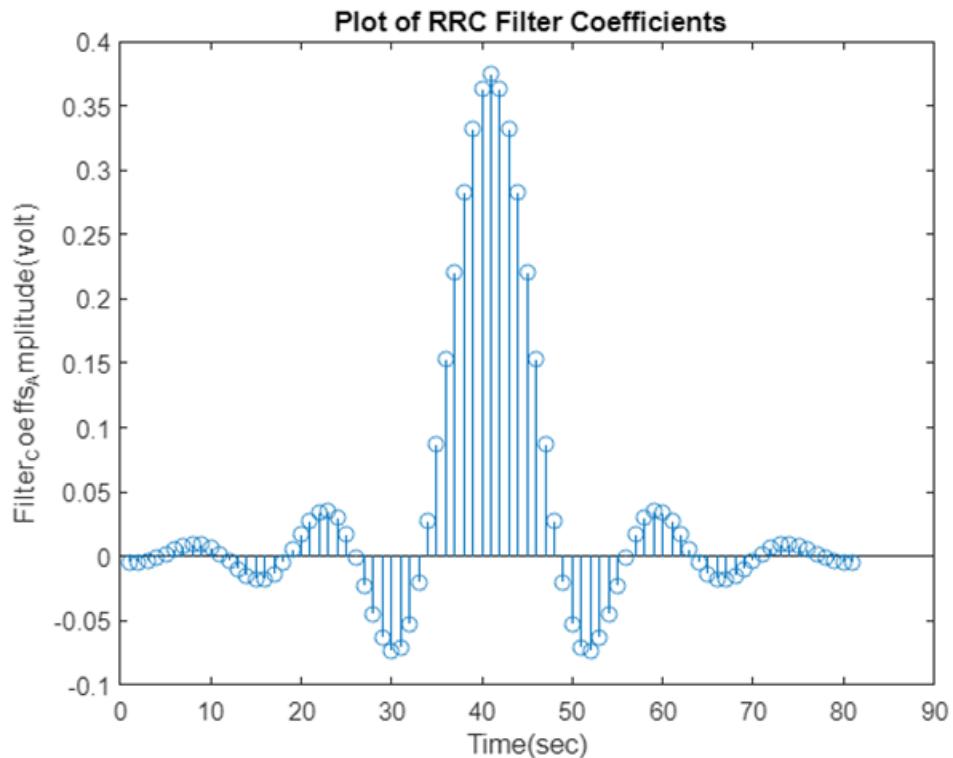


## MATLAB results

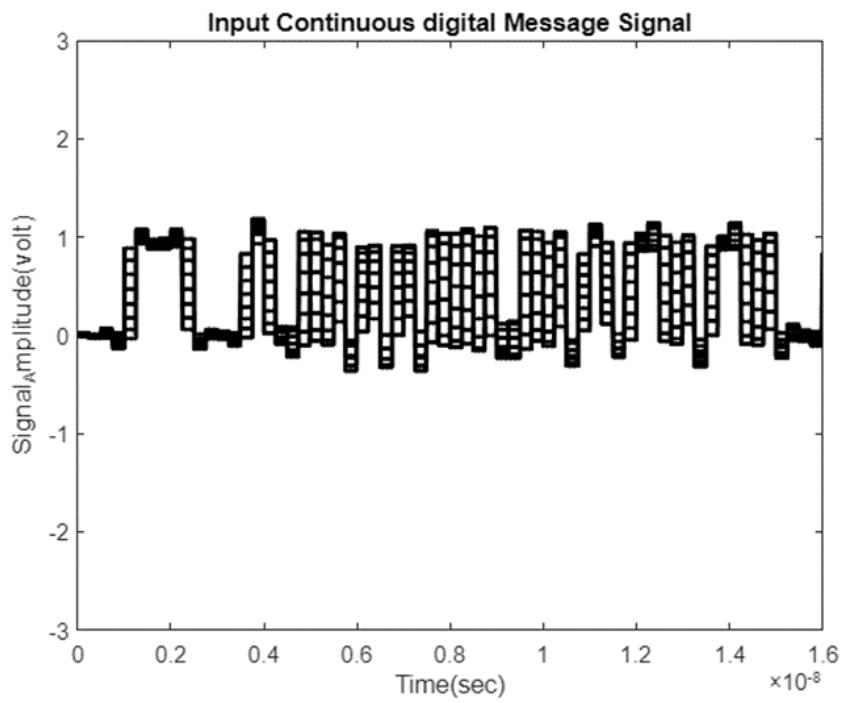
- Original
  - Original image



- RRC filter plot



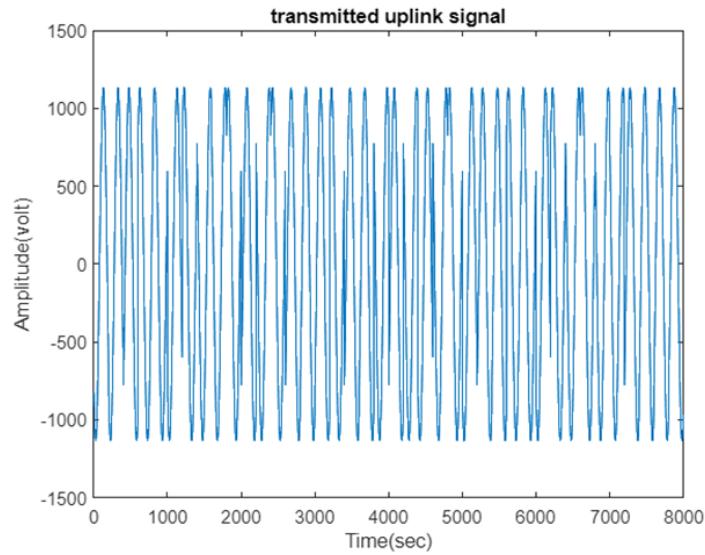
- Original image plot using RRC



- Modulation

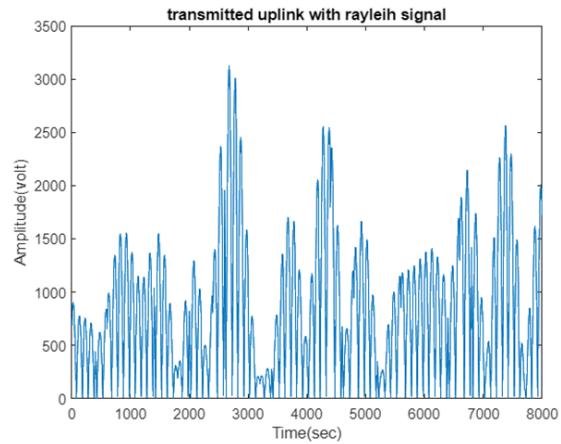
- Uplink

- Without noise

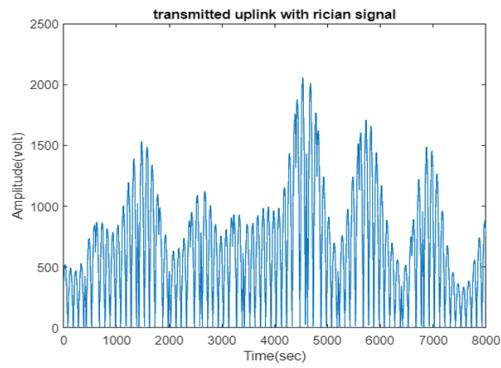


- With noise

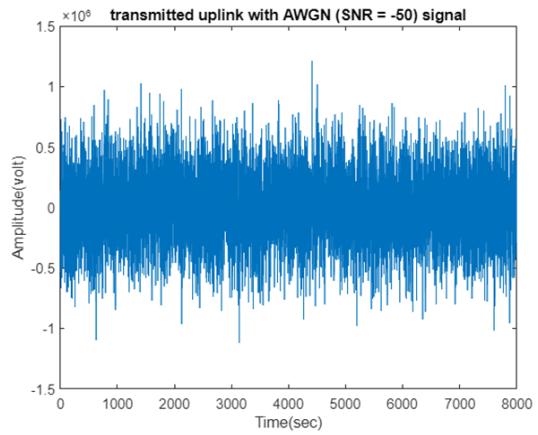
- Rayleigh



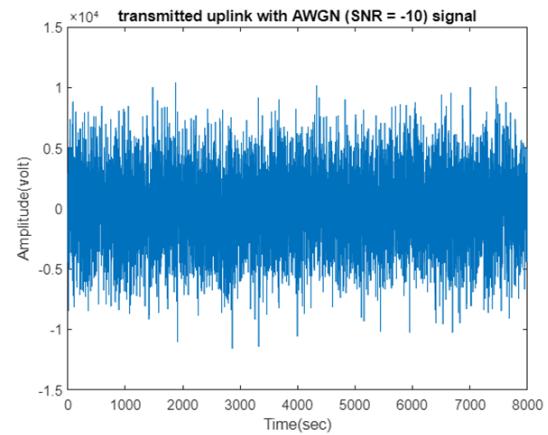
- Rician



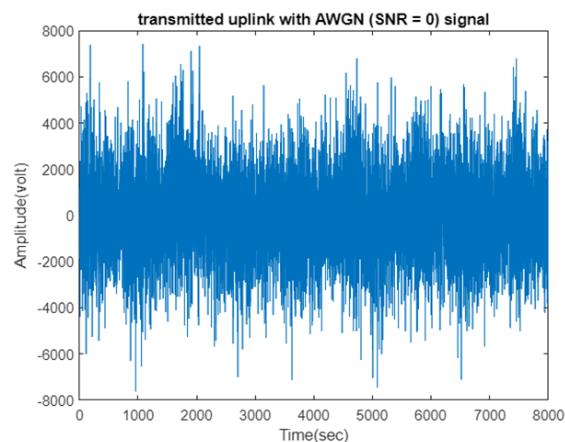
- AWGN
  - SNR = -50



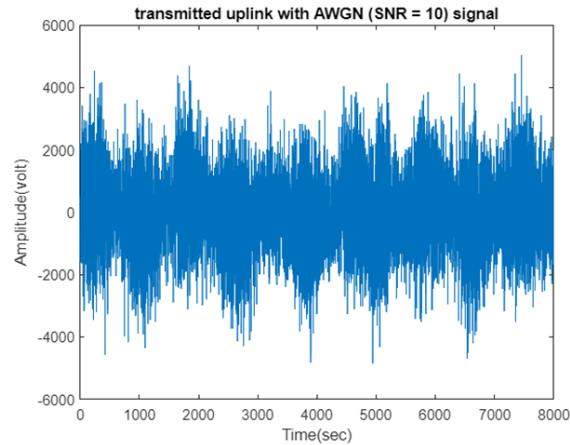
- SNR = -10



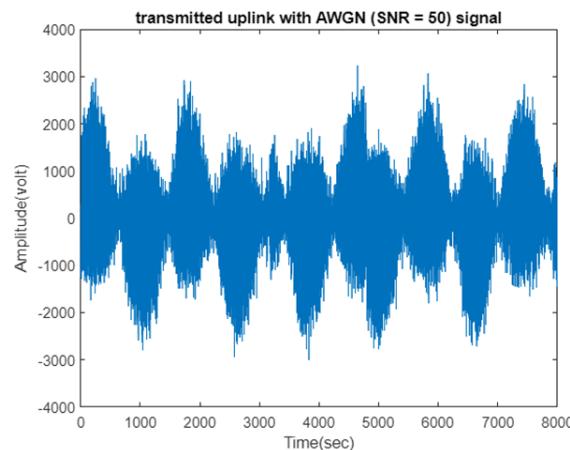
- SNR = 0



○ SNR = 10

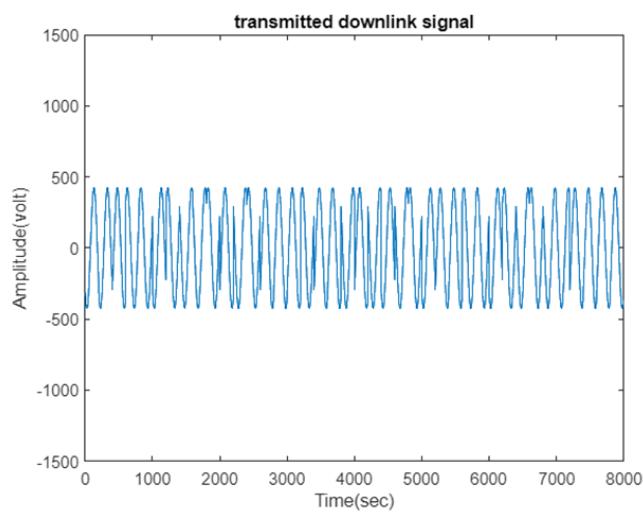


○ SNR = 50



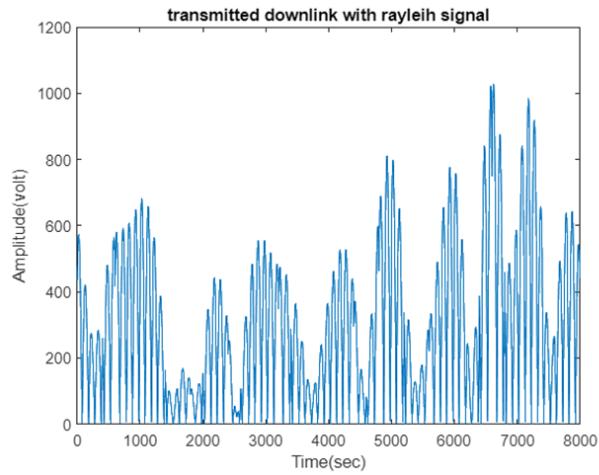
○ **Downlink**

■ Without noise

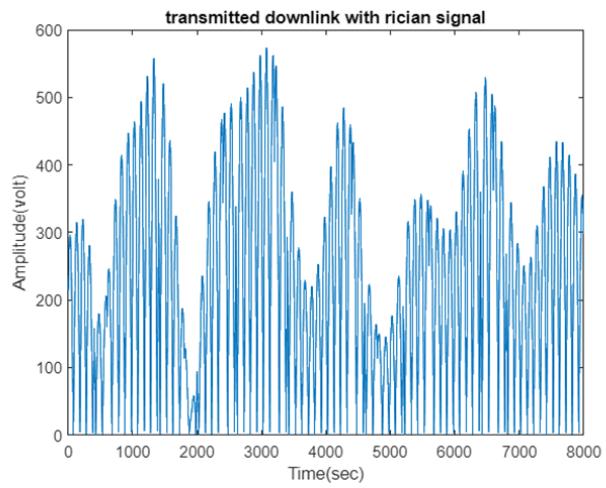


■ With noise

- Rayleigh

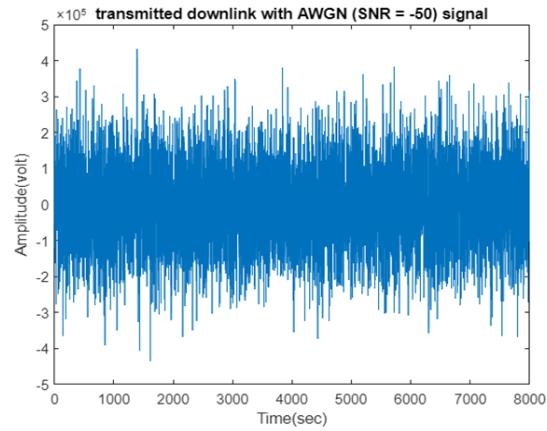


- Rician

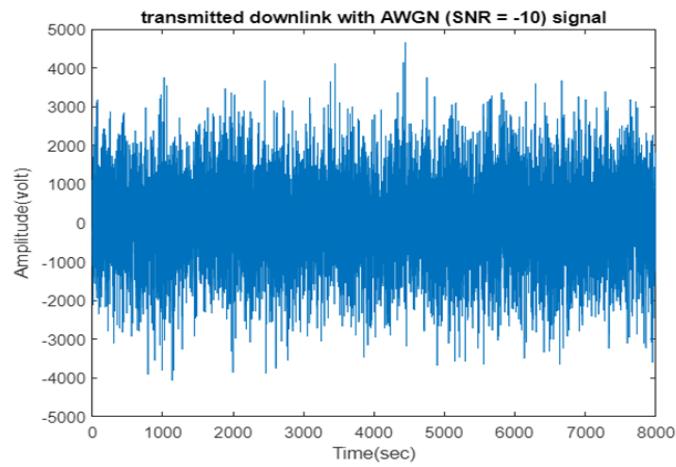


- AWGN

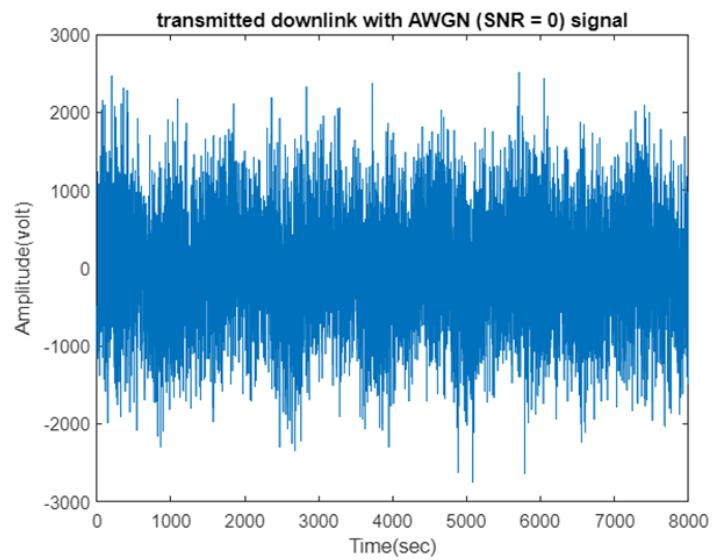
- SNR = -50



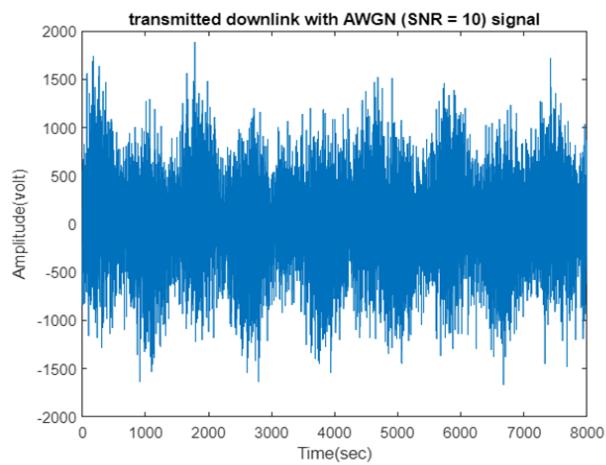
- SNR = -10



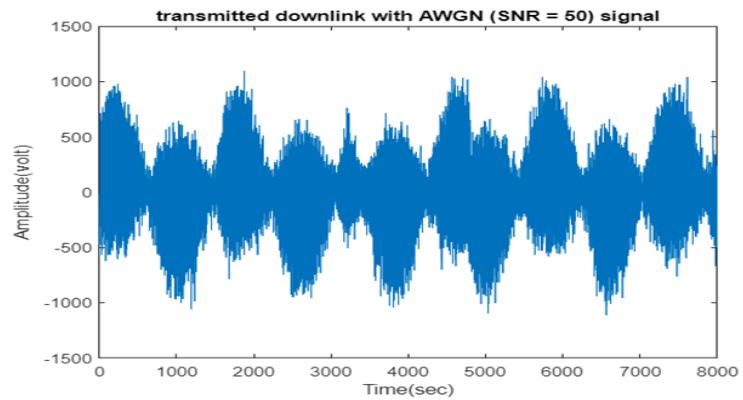
- SNR = 0



- SNR = 10



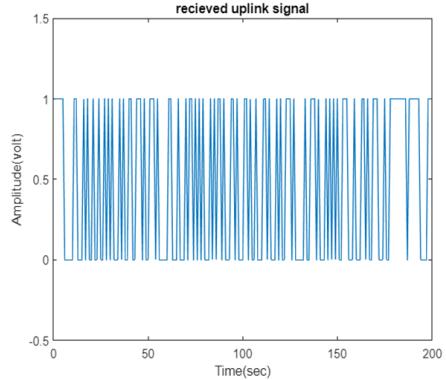
- SNR = 50



## ● Demodulation

### ○ Uplink

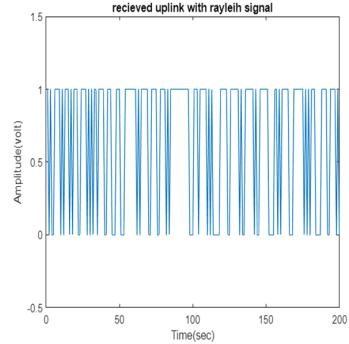
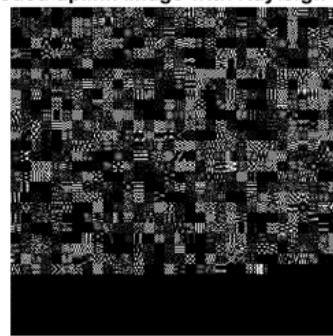
- Without noise (BER = 0%)



- With noise

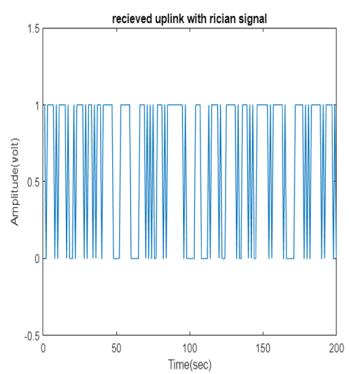
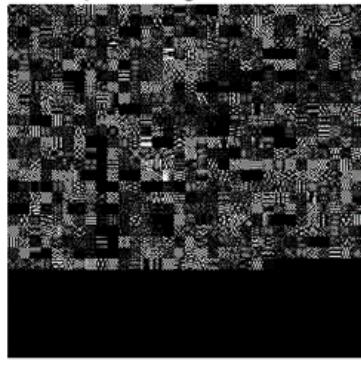
- Rayleigh (BER: 49.45%)

**Decoded uplink image with Rayleigh effect**



- Rician (BER = 48.42%)

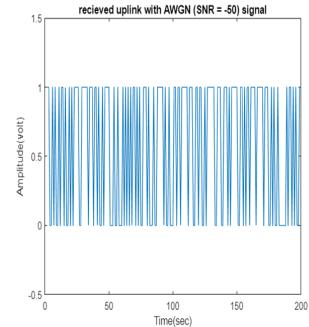
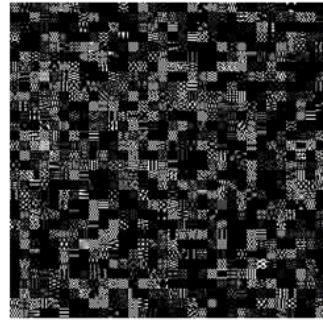
**Decoded uplink image with Rician effect**



- AWGN

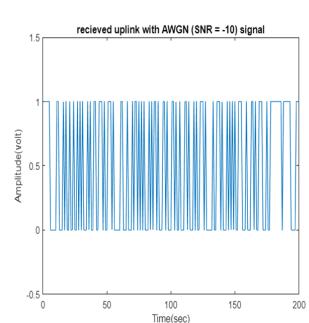
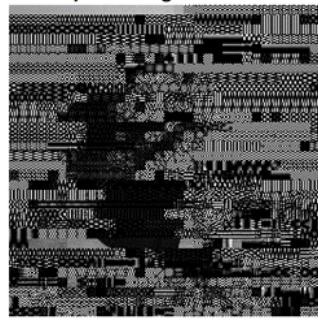
- SNR = -50 (BER: 94.13%)

**Decoded uplink image with AWGN effect**



- SNR = -10 (BER = 0.35%)

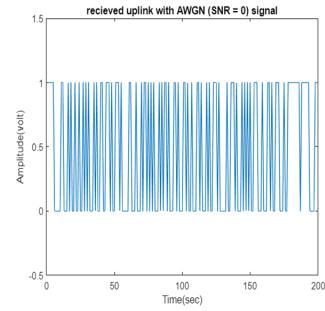
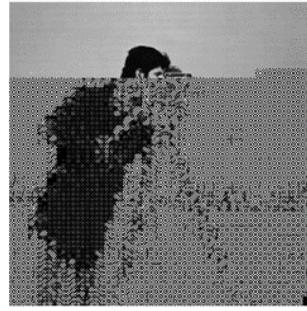
**Decoded uplink image with AWGN effect**



- SNR = 0 (BER = 0%)

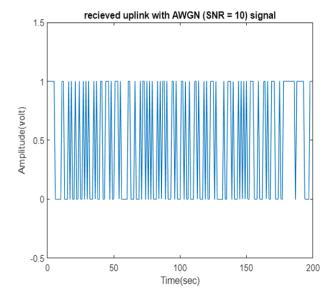
The loss in the image may be due to the JPEG effect.

**Decoded uplink image with AWGN effect**



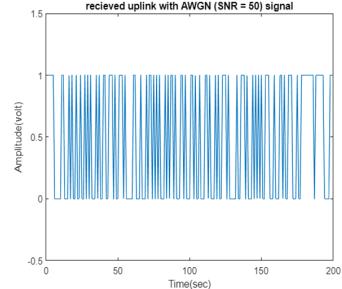
- SNR = 10 (BER = 0%)

**Decoded uplink image with AWGN effect**



- SNR = 50 (BER = 0%)

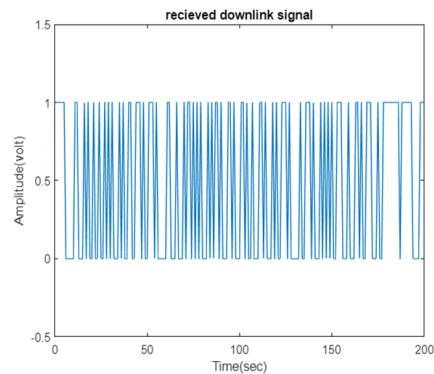
**Decoded uplink image with AWGN effect**



## ○ Downlink

- Without noise (BER = 0%)

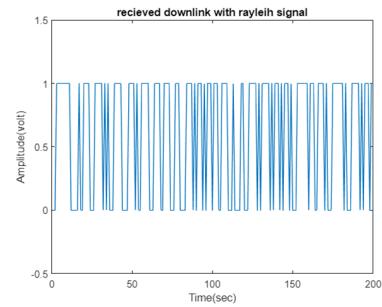
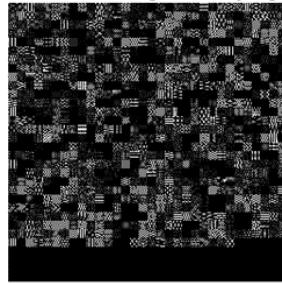
**Decoded downlink image without any effect**



■ With noise

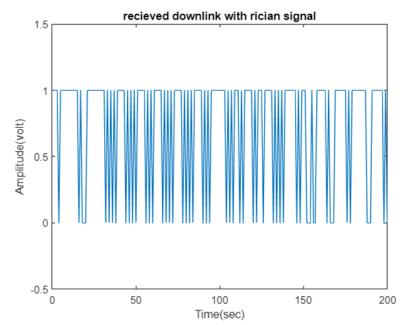
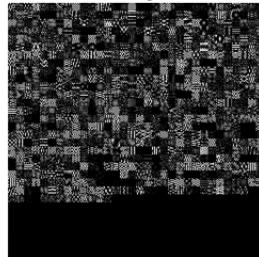
- Rayleigh (BER = 48.94%)

Decoded downlink image with Rayleigh effect



- Rician (BER = 48.35%)

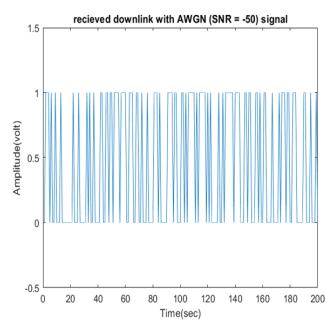
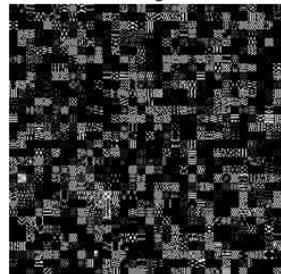
Decoded downlink image with Rician effect



- AWGN

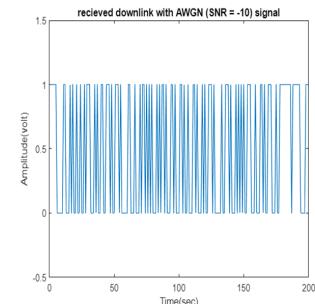
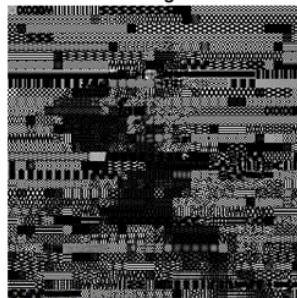
- SNR = -50 (BER = 49.02%)

Decoded downlink image with AWGN effect



- SNR = -10 (BER = 0.34%)

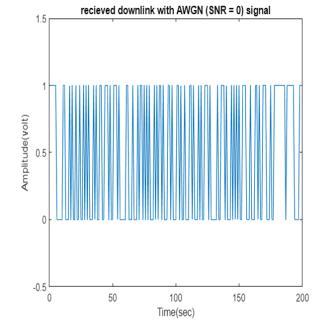
Decoded downlink image with AWGN effect



- SNR = 0 (BER = 0%)

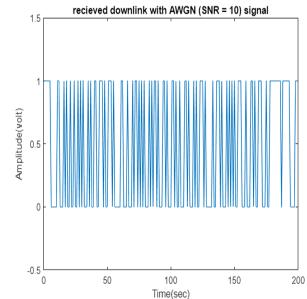
The loss in the image may be due to the JPEG effect.

**Decoded downlink image with AWGN effect**



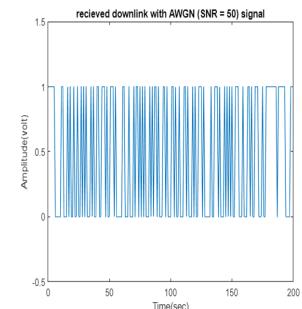
- SNR = 10 (BER = 0%)

**Decoded downlink image with AWGN effect**



- SNR = 50 (BER = 0%)

**Decoded downlink image with AWGN effect**

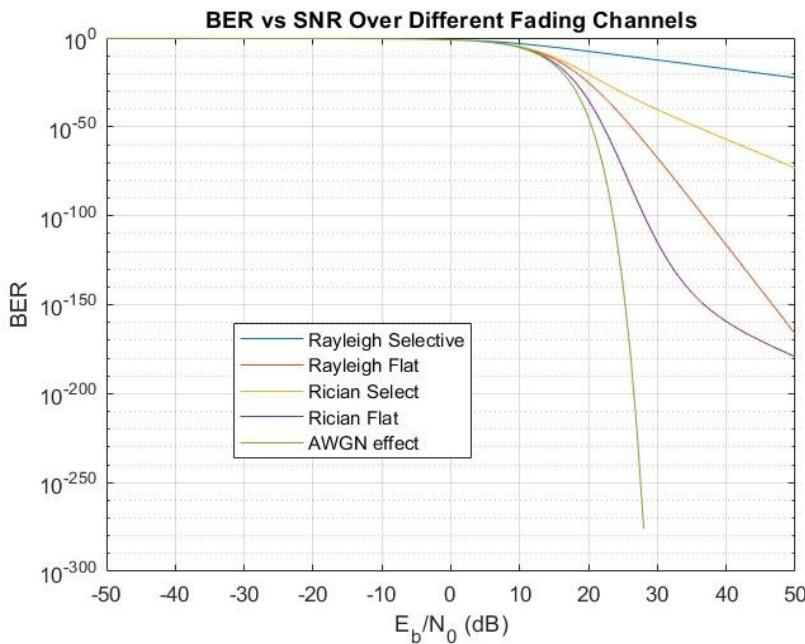


## ● Comments

1. The Rayleigh effect on the image is more than the Rician effect because the Rician effect has one line of sight while Rayleigh effect has no lines of sight.
2. The effects of Rayleigh and Rician on the image is slightly more on the uplink signal which has a lower Fc than the downlink signal.
3. The AWGN effect on the image is less as the value of SNR increases.

## BER vs SNR over different channels:

- Graph

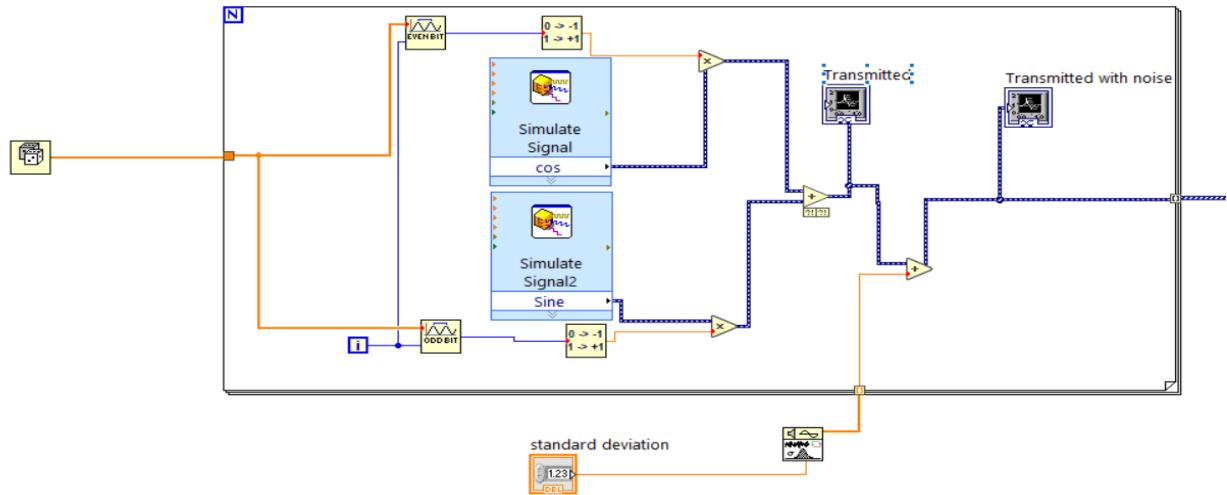


- Comments

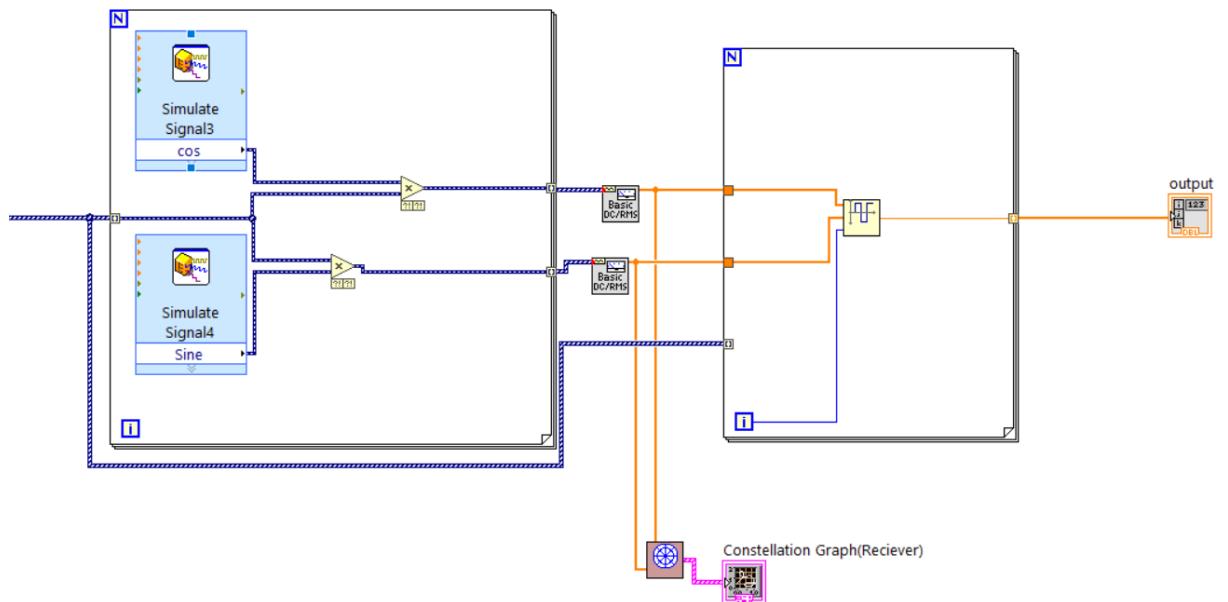
1. **For the same SNR and the same bit rate,** the BER for Rayleigh effect is more than Rician and AWGN effects.
2. **For the same BER and the same bit rate,** the Rayleigh effect needs more SNR value (Eb/No) than Rician and AWGN effects.
3. **For the same BER and the same SNR,** the Rayleigh effect has the least **bit rate**.
  - From the previous points, we can conclude that the AWGN has the least effect on the transmitted signal then the Rician effect and the Rayleigh effect, respectively.

## Labview Part

- Modulation Scheme

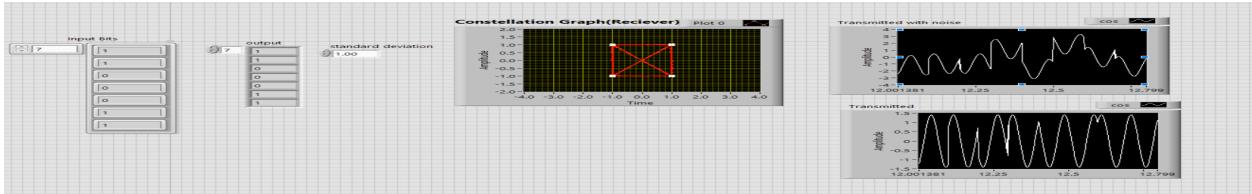


- Demodulation Scheme

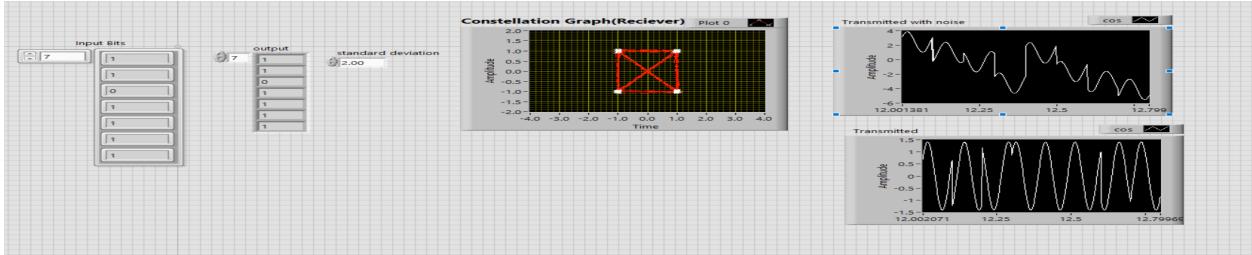


## ● Results

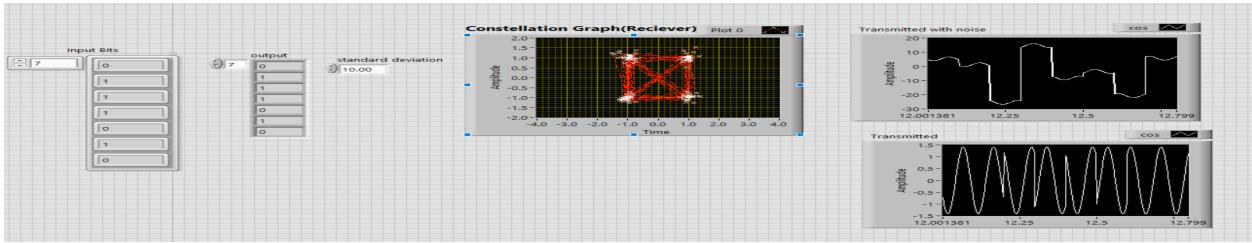
- Std = 1



- Std = 2



- Std = 10



## ● Comments

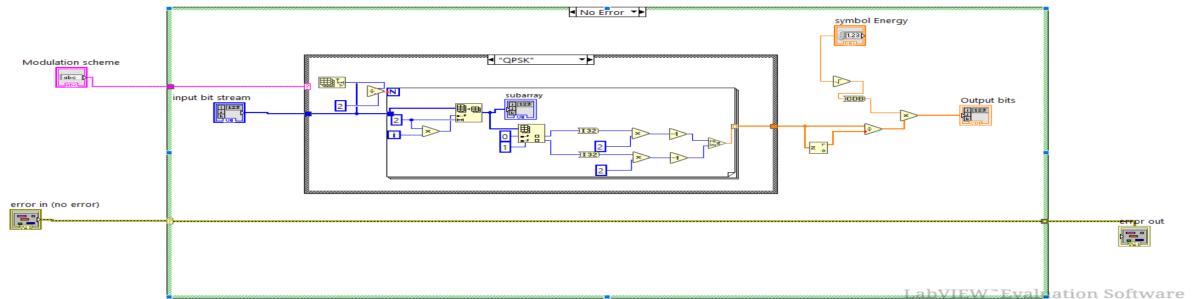
- We used a library that has each block for QPSK Modulation and Demodulation such as level encoder and even bit extractor, etc.
- Modulation: Inside a for Loop, we extract even bits and multiply them by the cos signal, odd bits are multiplied by the sine signal, add them together, then add noise to the transmitted signal.
- Multiply the received signal by cosie and compute the RMS value to extract the even bit, multiply the received signal by sin to extract odd bits and compare between two values, then compare values with a threshold to decide the final output.

## USRP Part

- First, we used Lab8 which builded the blocks of Transmitter and receiver for the BPSK.
- Then, we added a QPSK modulation scheme in the transmitter that is used in the 3G communication System.

So we modified the Student Modulate file to include QPSK

- **QPSK Modulation (Student\_Modulate)**

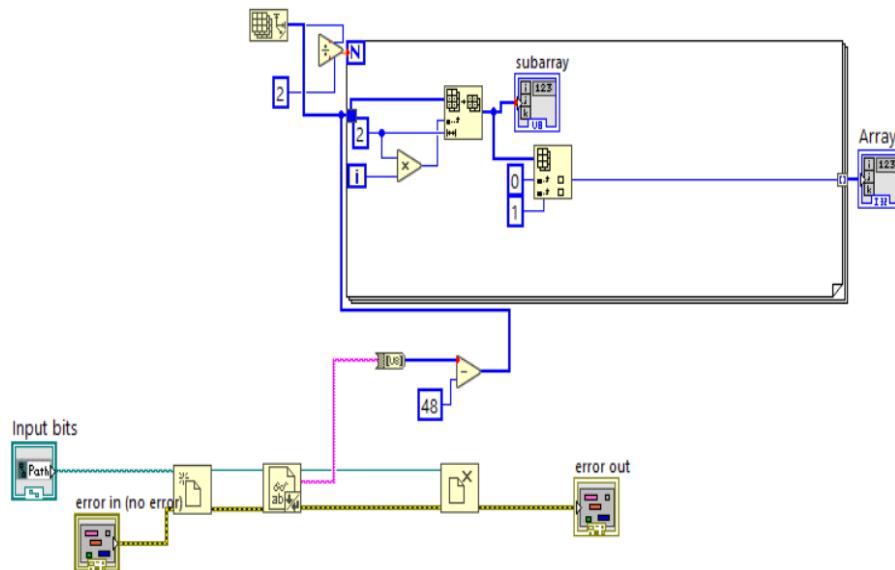


We added an additional case in the case structure which is QPSK, that takes the input bit stream and in the for loop, we take the even bits in the bit stream array as the real component of the output stream and the odd part as the imaginary part of the output stream.

The coding used here is a gray coding:

- 0: -1,-1
- 1: -1,1
- 2: 1,-1
- 3:1,1

- **Source: (Student\_source)**



- **Steps**

1. Reading a text file that has a stream of (cameraman image) encoded using JPEG encoder with Huffman source coding.
2. Converting the image bits into integers, and storing them in an array to be the input of the student Modulate block.
3. The for Loop here is mainly for neglecting the line end as the read text function converts the line end to an integer value.

- **Video:** [Video link](#)

- **Notes:**

- We transmitted the “windows” image using QPSK modulation with Carrier frequency=1.95 GHz, Pulse shaping filter: Root Raised Cosine with Roll-off factor=0.22.
- The receiver of the Lab 8 was just receiving only noise, we tried to trace the error but it did not work.
- So for recording the video, we used code from the LabVIEW website that transmits data using USRP because lab files do not work.

## References

- <https://www.techtarget.com/searchnetworking/definition/3G-third-generation-of-mobile-telephony>
- <https://hutch.lk/difference-2g-3g/>
- [http://www.emagtech.com/wiki/index.php/System-Level\\_Tutorial\\_Lesson\\_3:\\_Analyzing\\_a\\_Communications\\_System\\_Using\\_Virtual\\_Blocks](http://www.emagtech.com/wiki/index.php/System-Level_Tutorial_Lesson_3:_Analyzing_a_Communications_System_Using_Virtual_Blocks)
- [https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FBlock-diagram-showing-steps-of-JPEG-image-compression-and-decompression\\_file1\\_275641616&psig=AOvVaw3YIJJWwVvQkw1NalyQvhYK&ust=1673103187646000&source=images&cd=vfe&ved=0CBEQjhxqFwoTCNierZuZs\\_wCFQAAAAAdAAAAAA\\_BAE](https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FBlock-diagram-showing-steps-of-JPEG-image-compression-and-decompression_file1_275641616&psig=AOvVaw3YIJJWwVvQkw1NalyQvhYK&ust=1673103187646000&source=images&cd=vfe&ved=0CBEQjhxqFwoTCNierZuZs_wCFQAAAAAdAAAAAA_BAE)