CHALMERS

Chalmers University of Technology

Applied Signal Processing

Project-1 Part-A Report

Group No: 19

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1 Project description

The project is to design a data transmission system over an acoustic channel transferring text messages between two units via sound in the air. Part A of the project addresses the following:
1. Signal encoding/decoding from the bit stream to symbols
2. Conversion to an analogue coding/decoding technique; orthogonal frequency division multiplexing (OFDM).
3. Transmission channel equalization.

2 Findings for different scenarios

2.1 1A

Case: channel = h1, cyclic prefix = 0, snr = inf, channel = known

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'Alice: Would you tell me, please, which way I ought to go from here?'

Observation and inference: In this case, the channel is known and is ideal. Since the channel does not cause distortion to the transmitted signal, we will be able to reconstruct the entire message at the receiver end without any error. Thus, y(n) = z(n). [Figure 1 and table 1]

EVM	2.76e-16
BER	0

Table 1: Observed parameter values for Q.1A

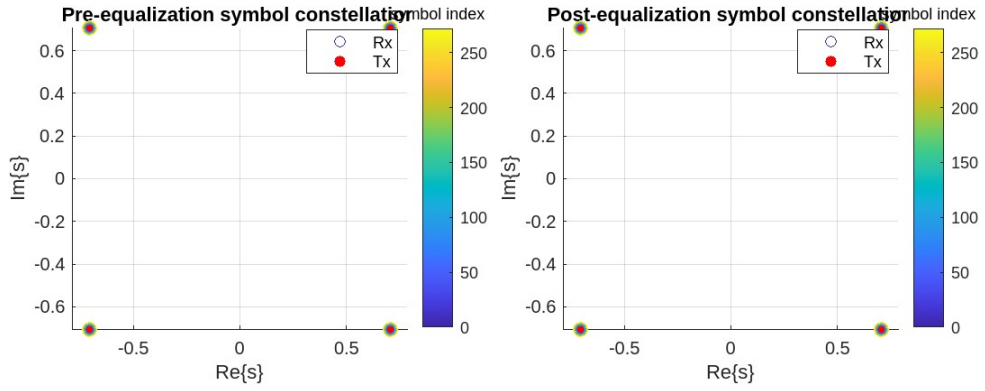

Figure 1: pre-post equalization symbol constellation for Q.1A

2.2 1B

Case:
channel = h1, cyclic prefix lengths - 3,10,50,100

Observation and inference: In this case we increased the cyclic prefix length to 3, 10, 50, 100 with channel h1 but EVM remained as 2.76e-16 at every case. From this, we inferred that varying cyclic prefix length for a channel with SNR = infinity might not give a near-zero EVM.[Table 2]

Ncp	0	3	10	50	100
EVM (x e-16)	2.76	2.76	2.76	2.76	2.76
BER	0	0	0	0	0

Table 2: Observed parameter values for Q.1b

2.3 1C

2.3.1 PartA

Case: zero cyclic prefix, channel = h2

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'Alice: Would you tell me, please, which way I ought to go from here?'

Observation and inference: In this case, channel is h2. The transmitted message was reconstructed properly at the receiver end without any error but the constellation got scaled by 1/2. [Figure 2 and table 3]. Here $\alpha = 0.5$.

EVM	0.75
BER	0

Table 3: Observed parameter values for Q.1c Part A

2.3.2 PartB

Case: zero cyclic prefix, channel = h3

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'Alice: Would you tell me, please, which way I ought to go from here?'

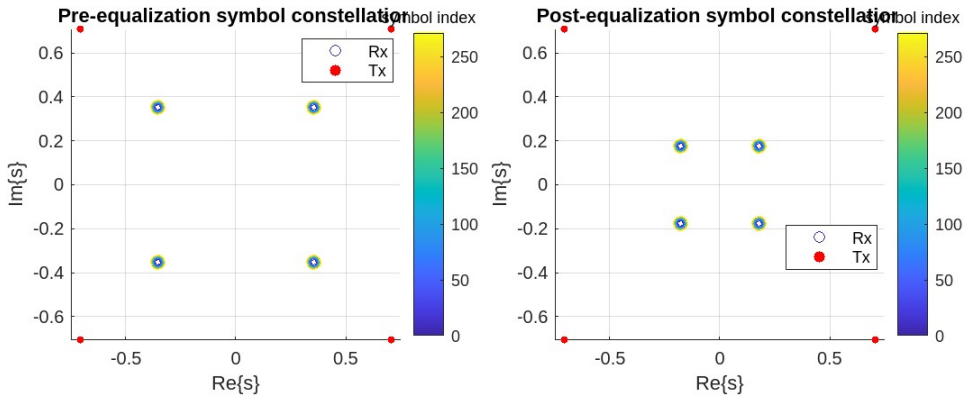

Figure 2: pre-post equalization symbol constellation for Q.1c Part A

Observation and inference: In this case, the channel is h3 which had caused a phase shift of 1/2 radian to the transmitted signal that had resulted in rotation of the constellation diagram. By removing the phase shift, it rotated the constellation back to its initial state and we were able to retrieve message properly at the receiver. [Figure 3 and table 4]. Here $\alpha = cos(1/2) + jsin(1/2)$.

EVM	3.07e-16
BER	0

Table 4: Observed parameter values for Q.1c Part B

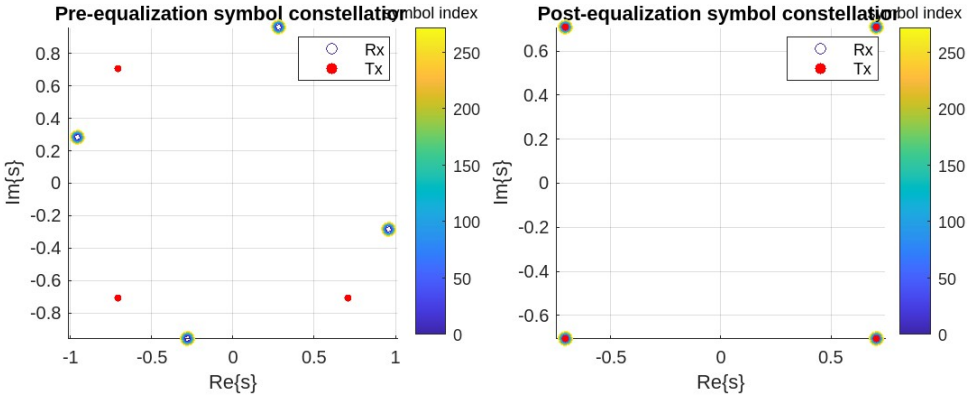

Figure 3: pre-post equalization symbol constellation for Q.1c Part B

2.4 1D

2.4.1 PartA

Case: sync error = +1

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'Alice: $W_t62_{50}66_40_{EEEEEm}here?'$

Observation: In this case, sync error of +1 is introduced. It can be observed that the starting and end part of the message is decoded properly at the receiver end but the entire middle part the message was having error. [Figure 4 and table 5]

EVM	1.4
BER	0.496

Table 5: Observed parameter values for Q.1d when sync error = +1

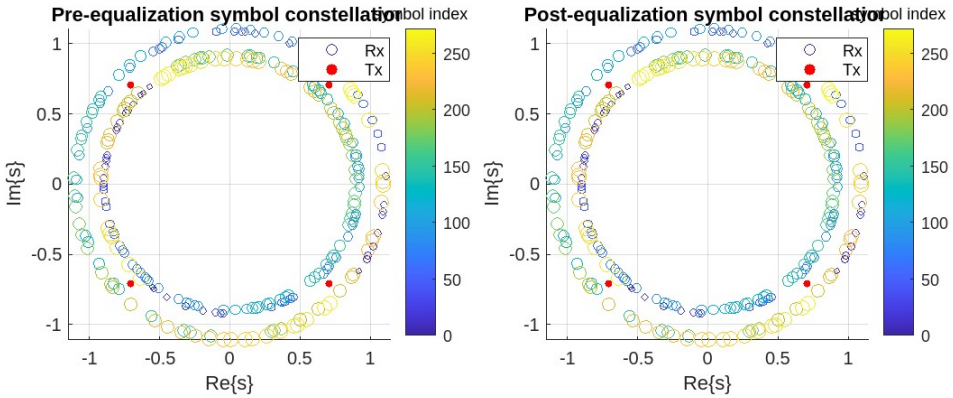

Figure 4: pre-post equalization symbol constellation for Q.1d when sync error = +1

2.4.2 PartB

Case: sync error = -1

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'Alice: $WJ_{EEEI}E_{,51} >_5 {}_15_{3o}mhere?'$

Observation: In this case, sync error of -1 is introduced. It can be observed that the starting and end part of the message is decoded properly at the receiver end but the entire middle part the message was having error. [Figure 5 and table 6]

EVM	1.41
BER	0.5

Table 6: Observed parameter values for Q.1d when sync error = -1

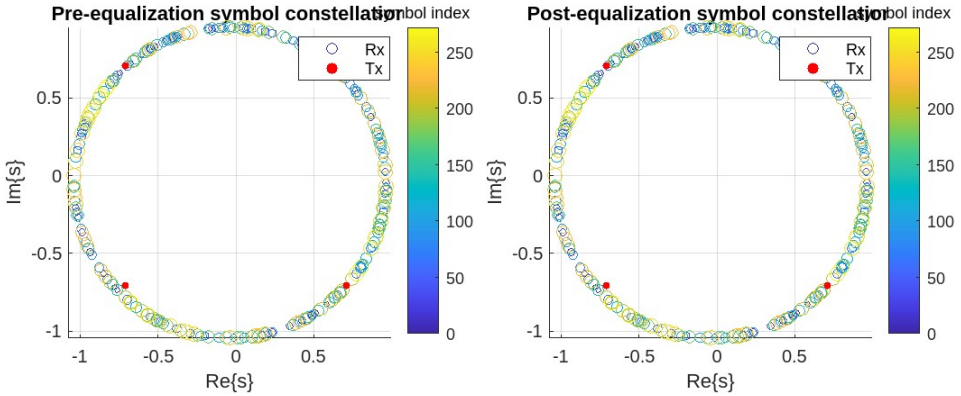

Figure 5: pre-post equalization symbol constellation for Q.1d when sync error = -1

2.4.3 PartC

Case: sync error = +2

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'Alict$_{56}$2$_{EI}E_e$, $whic$ 8,$_{5\ EEr}e$?′

Observation: In this case, sync error of +2 is introduced. It can be observed that the small portion of starting, middle and the end part of the message is decoded properly at the receiver end but the portion between start and middle and the portion between middle and end of the message was having error. [Figure 6 and table 7]

EVM	1.41
BER	0.493

Table 7: Observed parameter values for Q.1d when sync error = +2

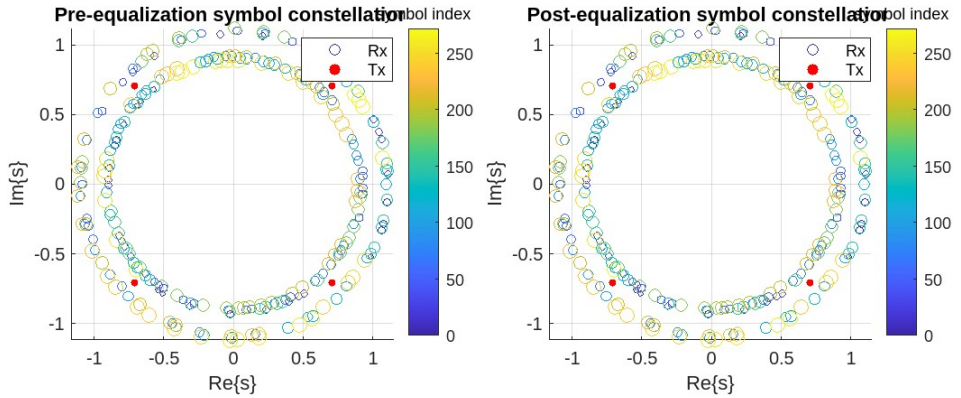

Figure 6: pre-post equalization symbol constellation for Q.1d when sync error = +2

EVM	1.41
BER	0.496

Table 8: Observed parameter values for Q.1d when sync error = -2

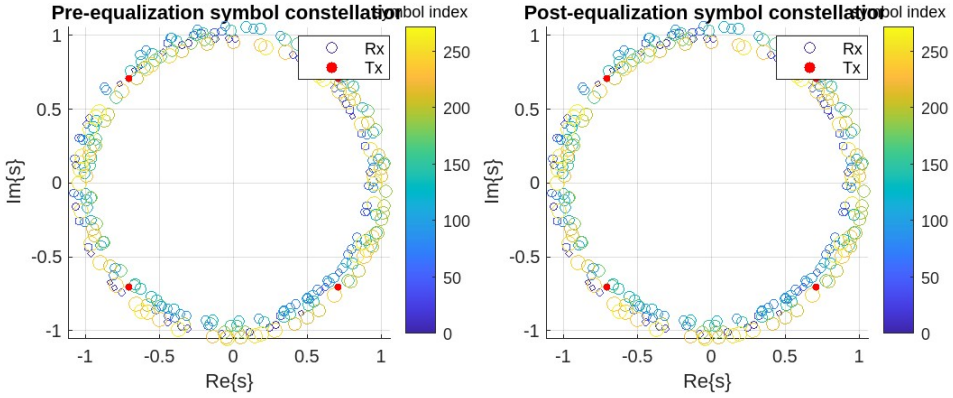

Figure 7: pre-post equalization symbol constellation for Q.1d when sync error = -2

2.4.4 PartD

Case: sync error = -2

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'AlicG'$E_{E4}0_6 09se, whicaE_{EE535}4_8$

Observation: In this case, sync error of -2 is introduced. It can be observed that the small portion of starting, middle and the end part of the message is decoded properly at the receiver end but the portion between start and middle and the portion between middle and end of the message was having error. [Figure 7 and table 8]

Inference: In case of sync error, It can be noticed that, small portion of the message is decoded properly but the remaining portion have error. This is due to early and delayed synchronization which is caused when we insert a positive or negative sync error respectively. Also it can inferred that, when we sync error magnitude was increased, the EVM and BER remained similar for all the four cases.

2.5 1E

2.5.1 PartA

Case: snr = 30

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'

Recieved: 'Alice: Would you tell me, please, which way I ought to go from here?'

Observation and inference: In this case, SNR=30 is introduced which resulted in spreading of the received signal's constellation points around the transmitted signal's constellation points due to the affect of noise. Since the magnitude of SNR was large the spreading of constellation points were less. So we were able to receive the message properly. [Figure 8 and table 9]

EVM	0.0293
BER	0

Table 9: Observed parameter values for snr = 30

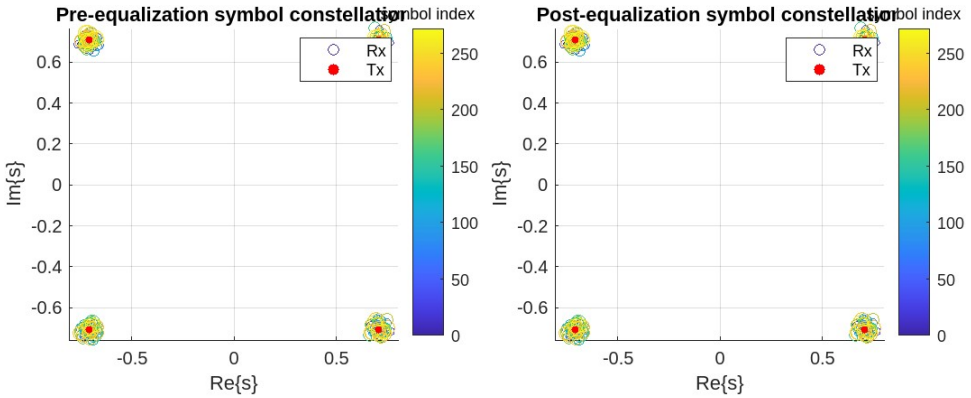

Figure 8: pre-post equalization symbol constellation for snr = 30

2.5.2 PartB

Case: snr = 5

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: '@licd2 Wotld yow tu|l(me$_0$*lease*, *which*1*wAx*'*Iougltto*(*gofsomhere*?'

Observation and inference: In this case, SNR=5 is introduced which resulted in spreading of the received signal's constellation points around the transmitted signal's constellation points due to the affect of noise. Since the magnitude of SNR was less the spreading of constellation points was more that means high noise disturbance. Thus resulted in more error in output message. [Figure 9 and table 10]

EVM	0.522
BER	0.0331

Table 10: Observed parameter values for snr = 5

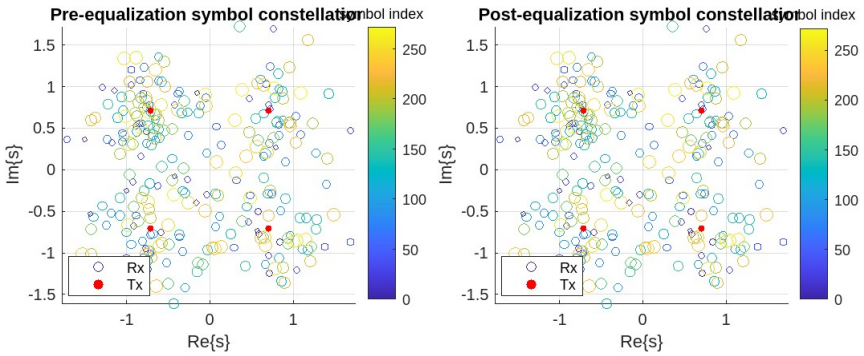

Figure 9: pre-post equalization symbol constellation for snr = 5

2.6 2A

Case: channel = h4 Low pass, cyclic prefix = 60

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'Alice: Would you tell me, please, which way I ought to go from here?'

Observation and inference: In this case, it can be observed that the each constellation point have change in their amplitude and phase such that we can see the constellation points are circulating around the transmitted signal's constellation point. From the amplitude graph, it can be oserved that there is drastic change in amplitude at beginning and at the end. Also drift in phase between -0.5 and +0.5 across k is observed. [Figure 10

2.7 2B

Case: channel = h4 Low pass, cyclic prefix = 60

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'Alice: Would you tell me, please, which way I ought to go from here?'

Observation and inference: In this case we get magic number, Ncp = 60 with EVM = 6.24e-16. The variation of EVM was observed less while varying Ncp. The EVM is lowest in this case because cyclic prefix length matches to that of the length of channel response. We can also infer that BER remained at 0 while varying the Ncp, thus BER is not affected by the Ncp. [Figure 11

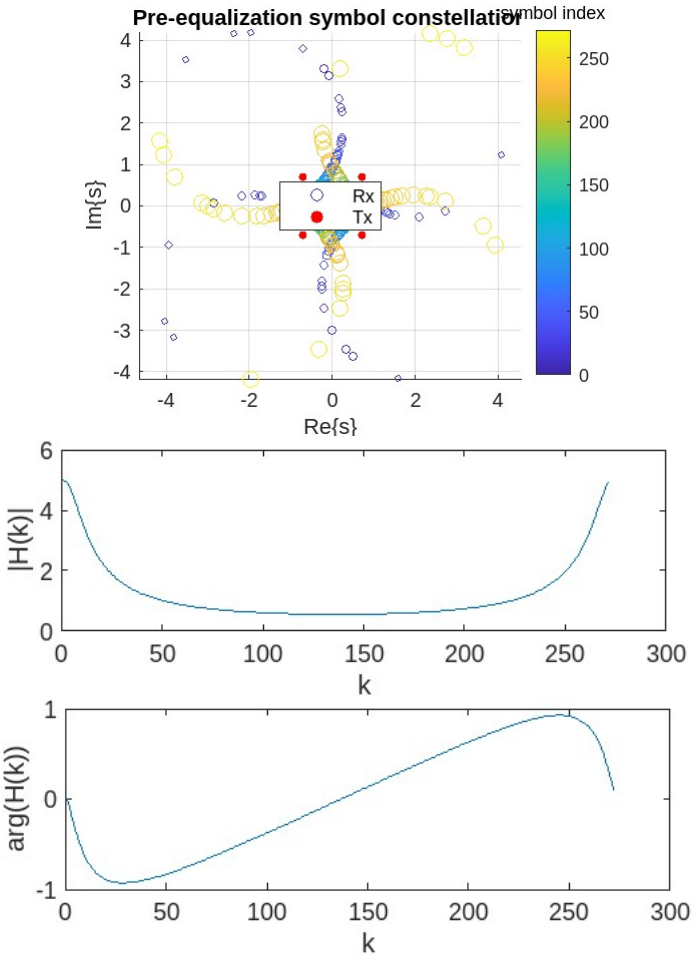

Figure 10: pre-post equalization symbol constellation and impulse response for Q2A

EVM	6.24e-16
BER	0

Table 11: Observed parameter values for Q2B

2.8 2C

Case: h4' = 0.99^n

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'Alice: Would you tell me, please, which way I ought to go from here?'

Observation and inference: In this case also we get magic number as Ncp = 60 with EVM = 3.74e-15 which is nearly zero EVM. But the variation of EVM was observed to

drastic while varying Ncp compared to case:2B due to the modified channel h4'. We can also infer that BER remained at 0 while varying the Ncp, thus BER is not affected by the Ncp. [table 12]
This time, the Ncp choice is critical. Because a unit change in Ncp gives a large change in EVM compared to h4 = 0.8n.

EVM	3.74e-15
BER	0

Table 12: Observed parameter values for Q2C

2.9 3A

2.9.1 PartA

Case: ideal channel h1, Ncp = 0, sync error = +1

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'Alice: Would you tell me, please, which way I ought to go from here?'

Observation: . [Figure 11 and table 13]

EVM	0.206
BER	0

Table 13: Observed parameter values for Q.3a Part A when sync error = +1

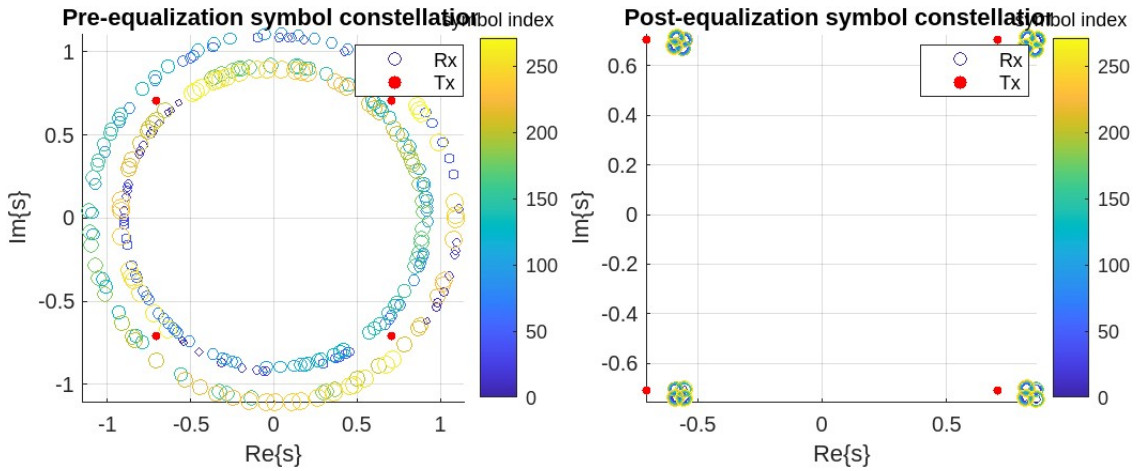

Figure 11: pre-post equalization symbol constellation for Q.3a Part A when sync error = +1

2.9.2 PartB

Case: ideal channel h1, Ncp = 0, sync error = -1

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'Alice: Would you tell me, please, which way I ought to go from here?'

Observation: This time it is possible to recover the message. In the known-h scenario, the post-equalization constellation points were in a circle centred to the midpoint of transmitted constellations. But here, the points are in circles which are centred in each transmitted constellation. [Figure 12 and table 14]

EVM	0.206
BER	0

Table 14: Observed parameter values for Q.3a Part B when sync error = -1

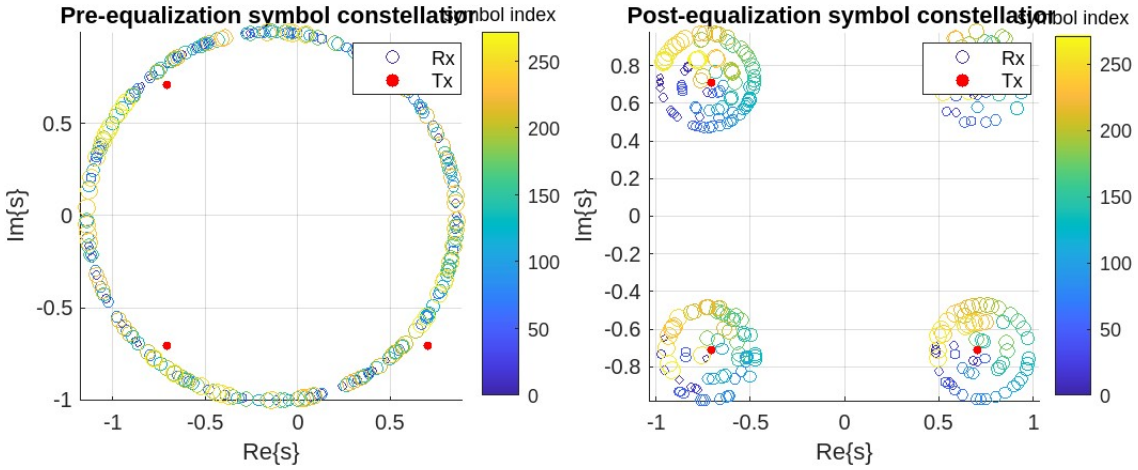

Figure 12: pre-post equalization symbol constellation for Q.3a Part B when sync error = -1

2.10 3B

2.10.1 PartA

Case: channel = h4, variation at Ncp = 60

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'Alice: Would you tell me, please, which way I ought to go from here?'

Observation: In this case, the channel h4 but the cyclic prefix length for zero EVM remained same as earlier i.e Ncp=60. [table 15]

EVM	0.874
BER	0

Table 15: Observed parameter values for Q.3b Part A when Ncp = 60

2.10.2 PartB

Case: channel = h4, Ncp = 60, SNR = 5 and 50

Observation: In case of SNR=5, EVM=1.57 and in case of SNR=50, BER is 0 and EVM is 0.00875, which is larger than the value of EVM obtained when the channel is known i.e detection is more worse as the channel estimation process is also present and it is more difficult since noise is also introduced. [Figure 13 and table 16]
When noise level increases, BER and EVM also increase.
This setup is more sensitive to noise than the known channel scenario. In the known channel scenario, we know only a part of the channel. The known-h and noise are together creating the 'actual' channel. The equalization is not successful if we consider only the known-h.
On the other hand, in the unknown channel scenario, we estimate the 'actual' channel.

SNR	5	50
EVM	1.57	0.00875
BER	0.232	0

Table 16: Observed parameter values for Q.3b Part B for SNR variation

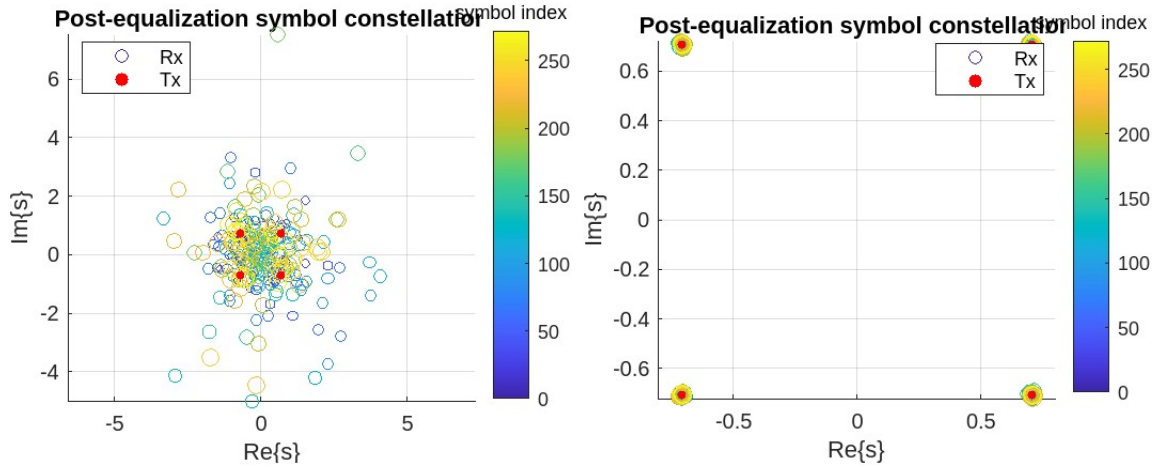

Figure 13: post equalization symbol constellation for Q.3b Part B for SNR variation

2.11 3C

2.11.1 PartA

Case: channel = h5, Ncp = 60

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: 'AlicU: Would"you tell0me, plebse, whicx way I mught to Go from kere?'

Observation: In case of channel h5(multi-path), some part of the message gets distorted even if don't add any noise or introduce any sync error due to the change in phase caused because of the channel. [Figure 14 and table 17]
This multi-path behaviour of the channels creates two copies of messages in different phase shifts. The resulting output gives bit errors.

EVM	0.298
BER	0.0202

Table 17: Observed parameter values for Q.3c Part A

2.11.2 PartB

Case: channel = h5'(modified h5), Ncp = 60

Transmitted: 'Alice: Would you tell me, please, which way I ought to go from here?'
Recieved: Alice: Would you tell me, please, which way I ought to go from here?'

Observation: In this case, it can be observed that due to the modified h5 i.e h5' the phase change caused by the channel is comparatively less than that of which caused by channel h5. Hence we were able to recover the message with BER=0. [Figure 15 and table 18]

EVM	5.71e-16
BER	0

Table 18: Observed parameter values for Q.3c Part B

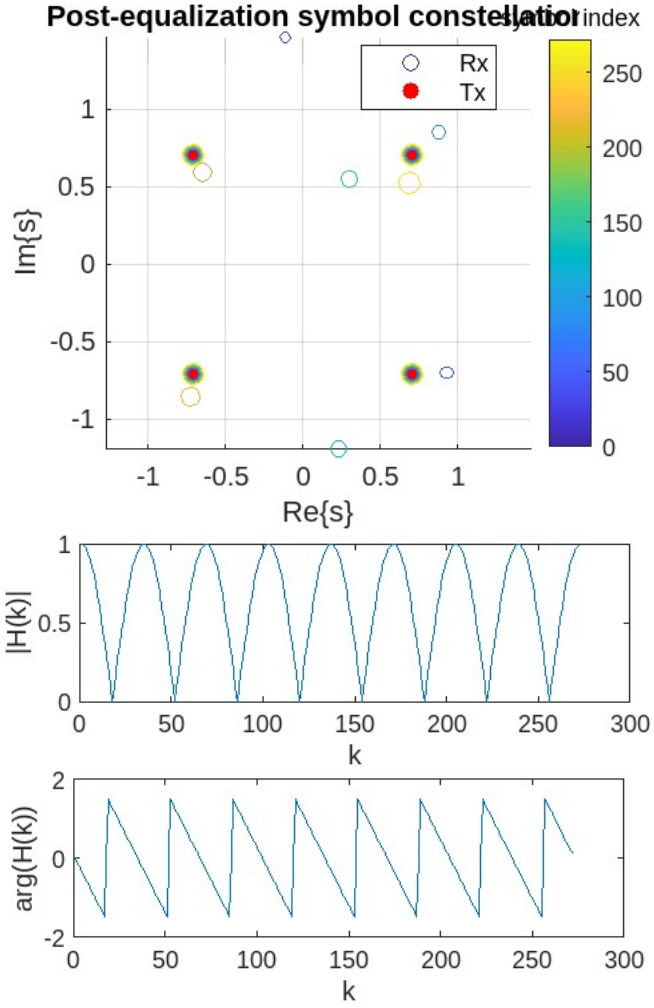

Figure 14: post equalization symbol constellation for Q.3c Part A

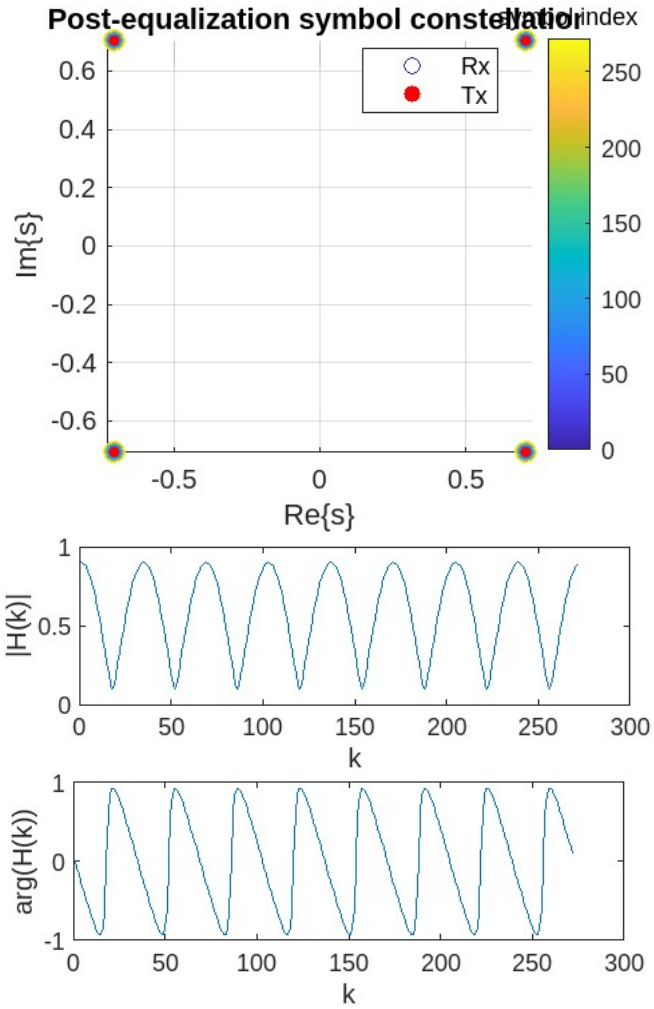

Figure 15: post equalization symbol constellation for Q.3c Part B