BERZIET UNIVERSITY

FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

ENEE 4113

communication Laboratory.

Experiment 8

Delta Modulation & demodulation

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Abstract:

In this experiment, the student will be introduced to how they can deal with delta modulation using written python code in GitHub simulator, they will apply various types of messages to this modulation type and study the performance, slope, and the angular noises for LDM, after that they will be Introduced to two algorithms for adaptive (nonlinear) delta modulation for various types of messages then line coding for both types, seeing the difference between both algorithms in terms of noise and line coding. Lastly, as any modulation method there is a demodulation algorithm, they will apply this for both types.

Contents

Procedure:

Define message signals:

First of all we define three message signals, linear message $m1(t)=3t$, step message $m2(t)=sgn(Amsin(2\pi fmt))$, sinusoidal message $m3(t)=Amsin(2\pi fmt)$ as shown below.

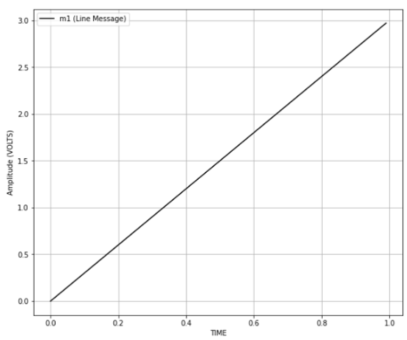


Fig 1 => m1(t)

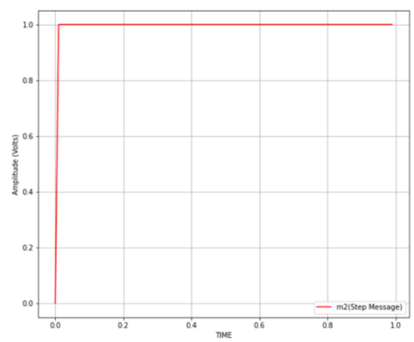


Fig 2 => m2(t)

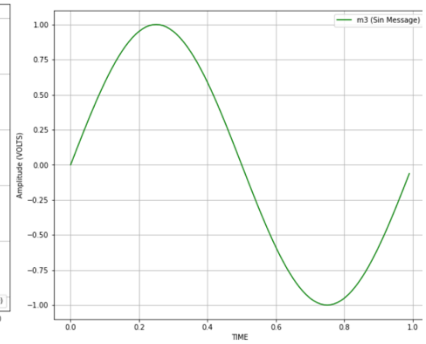


Fig 3 => m3(t)

Performance of Linear Delta Modulation (LDM) on the 3 Messages:

Here we quantize the error of message signal not the message signal itself, this process can be described as the following equations:

$\boldsymbol{e[n]=m[n]-mq[n-1]}$; describes the error of the message

$\boldsymbol{eq[n]=\Delta sgn(e[n])}$; describes the error quantized signal that gives us either plus or minus delta.

$\boldsymbol{mq[n]=mq[n-1]+eq[n]}$; describes the error quantized plus the previous quantized value.

We will display $mq[n]$ for three messages with step size $4\pi/100$ and shows the results below:

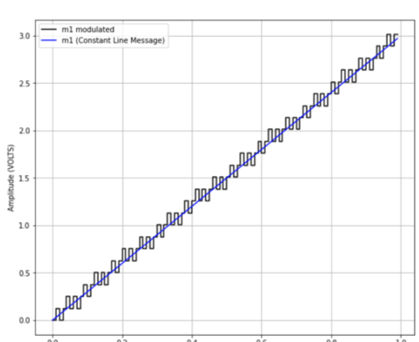
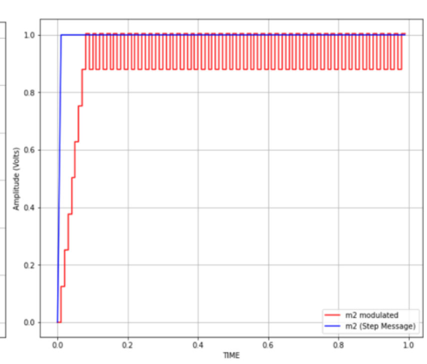


Fig 4 => LDM of m1(t)



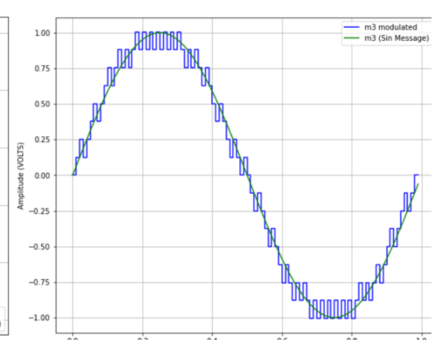


Fig 6 => LDM of m3(t)

From above figures we can observe that as the step size or delta is **higher** than the message signal(in red), a **reduction** of *one delta* is added to the staircase, on the other hand, if the delta is lower than the message signal, an increase of *one delta* is made. Here the delta is constant value called step size.

If we change the frequency of sin wave to 4 as in Fig7 the staircase signal cannot catch up with the message signal then the noise will be increase if the frequency increase. The same idea if we increase the amplitude to 4 as in Fig8. Same as if we increase the slope of linear message.

Fig 5 => LDM of m2(t)

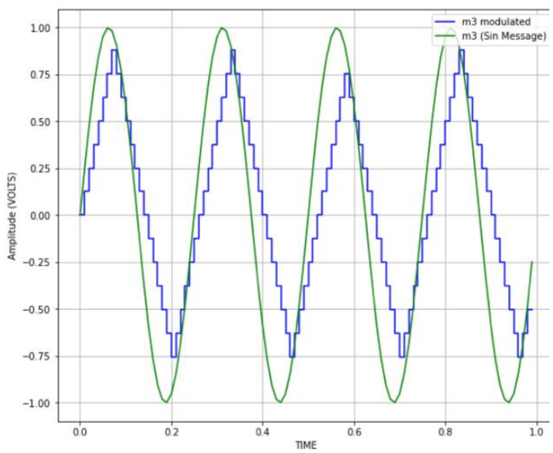


Fig 7 => LDM of m3(t) when fm=4

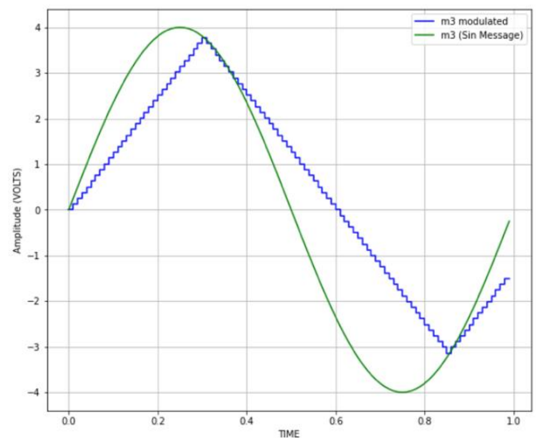


Fig 8 => LDM of m3(t) when Am=4

Line coding for LDM:

In this part, we will encode the LDM signal to 0's and 1's in order to send it over communication channel, the encoder will process it as the following: if plus delta then send 1 else if minus delta then send 0.

The following figures shows the output of this process:

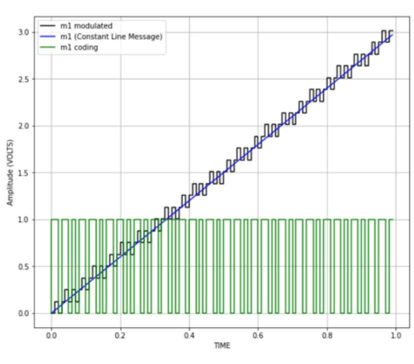


Fig 9 => m1(t) coding

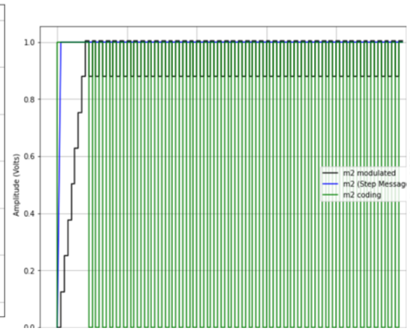


Fig 10 => m2(t) coding

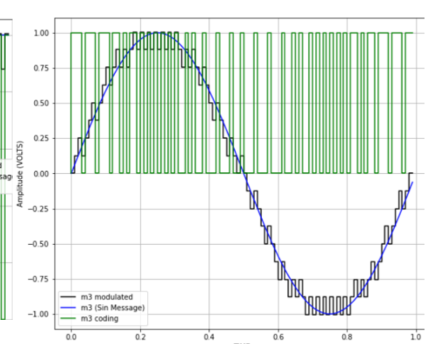


Fig 11 => m3(t) coding

To demonstrate the theory let’s take a closer look if sinusoidal coding:

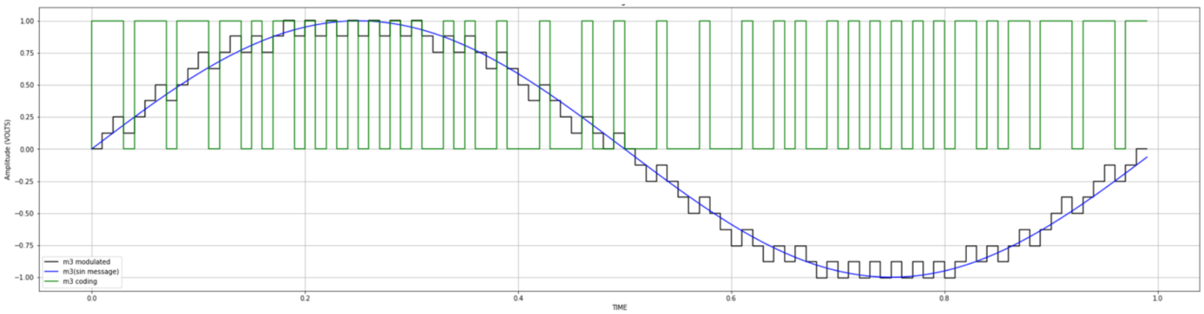


Fig 12 => m3(t) coding zoomed-in

As we can see from figure above that when the delta is positive (staircase increases) 1 will be sent to the receiver, 0 will be sent if the delta is negative.

The LDM method has much advantages like that the transmitter and the receiver is simple in delta modulation since that there is no analog to digital converter. However, it has disadvantages too since it has slope overload distortion.

Bit sequence for half period[0-0.50] is : 1110111011110110101101010101010100101001000010001001

The second half is the complement of the first half

Noises in Delta Modulation:

In this part, we will demonstrates the main drawbacks of delta modulation. **Slope over load distortion** arises because of large dynamic range of the input signal To reduce this error, the step size must be increased when slope of signal x(t) is high, **Granular noise** occurs when the step size is too large compared to small variation in the input signal, The solution to this problem is to make the step size small.

*Note that to observe the noise, the first original messagef m(sin wave frequency) was **doubled**, the slope of message m1 was **tripled**, and the **step size(delta)** was **halved**.*

The results shown below:

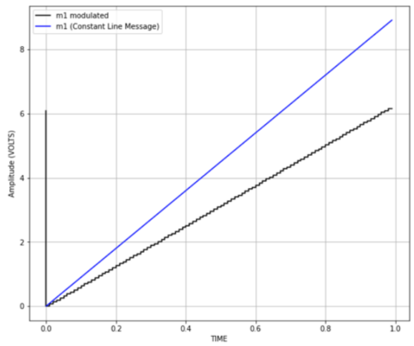


Fig 13 => m1(t)

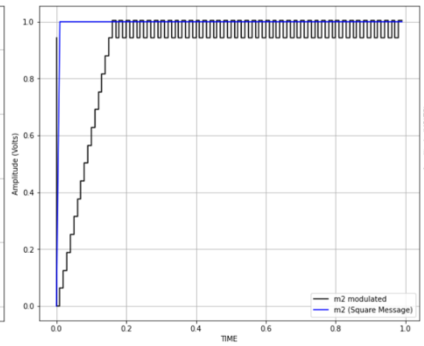


Fig 14 => m2(t)

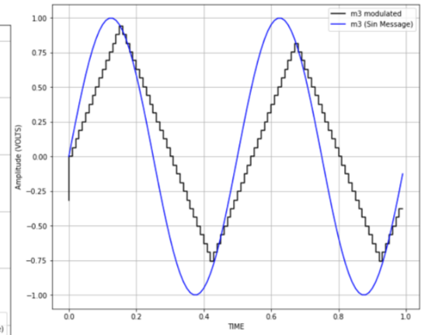


Fig 15 => m3(t)

We observe that if we increase the Fm of sinusoidal or increase the slope of linear or decrease the step size, the slope over load distortion will increase and vice versa. But when increasing the step size the granular noise will be increase.

Performance of Adaptive (nonlinear/DCDM) Delta Modulation algorithm(1):

In this part, we will introduce a new algorithm to vary the step size in order to avoid the distortion seen in the previous section, the main concept follow a simple rule of step size will be adapted to the variation of the message. Physically we add a voltage controlled amplifier that controls the step size.

*Note here that **fm3** was **doubled** in comparison to the LDM part, **delta** was **halved** , and the slop for the constant line message was **tripled** as the previous section in order to observe the effectiveness of DCDM.*

The results shown below:

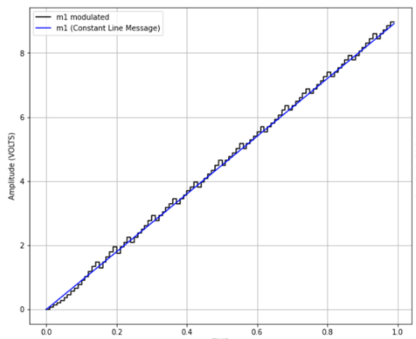


Fig 16 => m1(t)

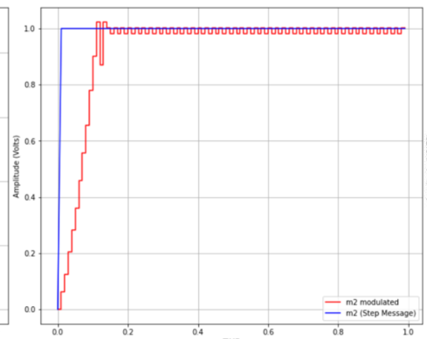


Fig 17 => m2(t)

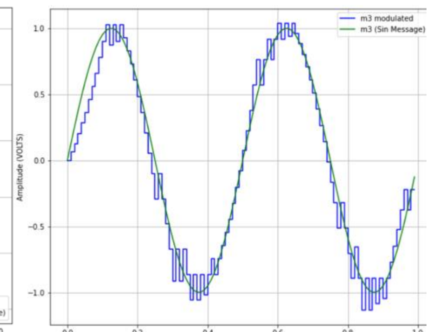


Fig 18 => m3(t)

Clearly, we can see that the result got much better than the previous section, the effect of both slope overload and the granular noise have decreased, that’s because the step size varied according to the variation of the message, actually increasing the step size by 25% if the slope is high to catch up with the message in case of slope overload this can be observed if 3 consecutive qual values were modulated, or decrease the step size by 25% to avoid the granular noise as mentioned in the introduction of the previous part.

Let’s take a closer look to the sinusoidal message and encode it as the following:

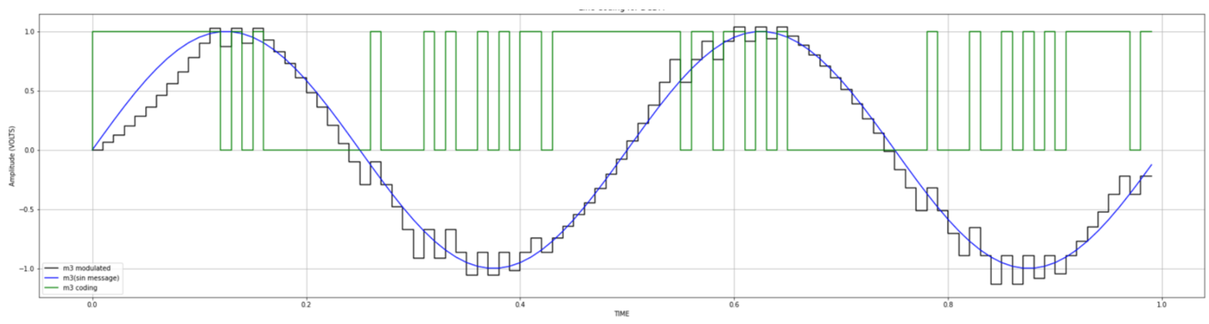


Fig 19 => m3(t) zoomed-in with coding

Bit sequence for half period[0-0.50] is :

1111111111101010000 0000001000010100101 0 1101111111

Surely there is a difference between the linear and non-linear delta modulation.

Performance of Adaptive (nonlinear/DCDM) Delta Modulation algorithm(2):

In this part, we will introduce another algorithm to vary the step size in order to avoid the distortion, like the previous algorithm, but this time we will depend on the slope to verify the step size, the concept of this as that the algorithm will check the current relative to the previous slope of sample, if it's bigger by 20% then increase the step size by 50%, if lower then decrease the step size by 50%.

Let's show the results when applying this algorithm to sinusoidal signal used in the previous part as shown below:

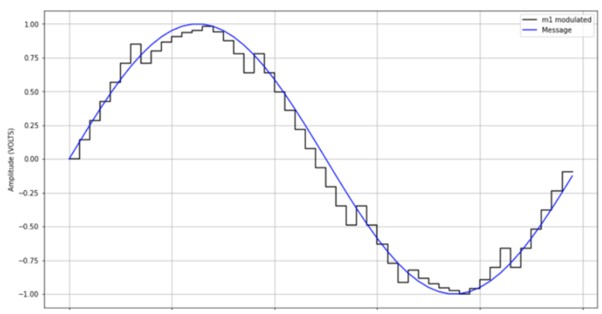


Fig 20 => m3(t) with algorithm2

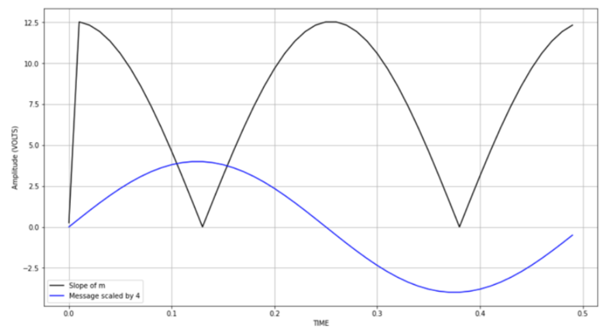


Fig 21 => message and slope variation

Fig20 shows the message signal (blue signal) and the staircase signal (black signal), Fig21 shows the message signal multiplied by 4 -to make it seenable- (blue signal) and a signal shows the slope variation (black signal) that can build this algorithm based on it.

If we change the frequency of the message signal to 3Hz we can see that the staircase signal got worse because that the step size cannot catch-up with the message and the slope varies quickly regarding to the step size variation as shown in Fig22.

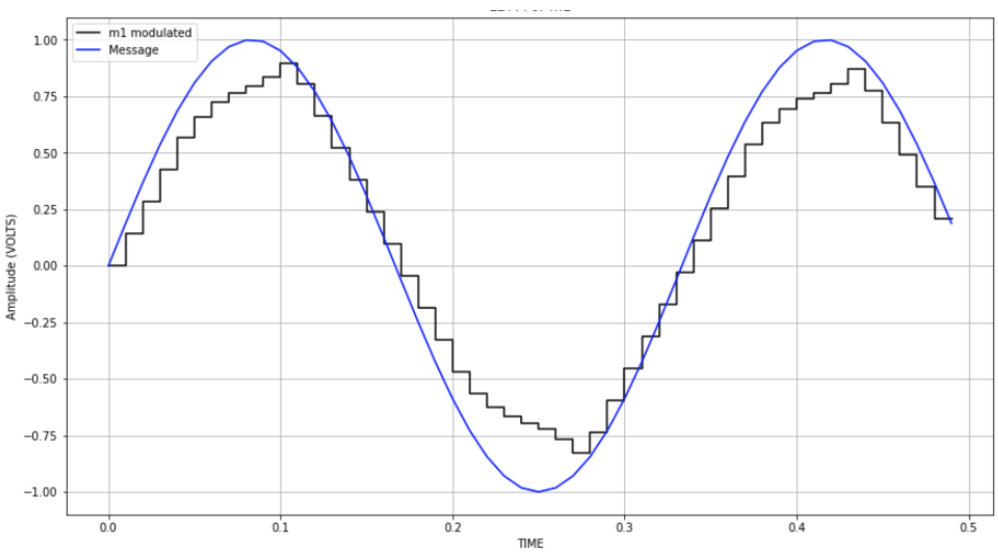


Fig 22 => message signal with Fm=3Hz

We can avoid this by more than way, one of them if the algorithm will vary the step size by 60% rather than 50% as shown in Fig23, another way is to vary the step size by 50% if the slope is lower or higher than the previous by 30% rather than 20% as shown in Fig24. The best way to do that is to mixing the two algorithms with each other to introduce a new algorithm, we will prove this in the future inshallah.

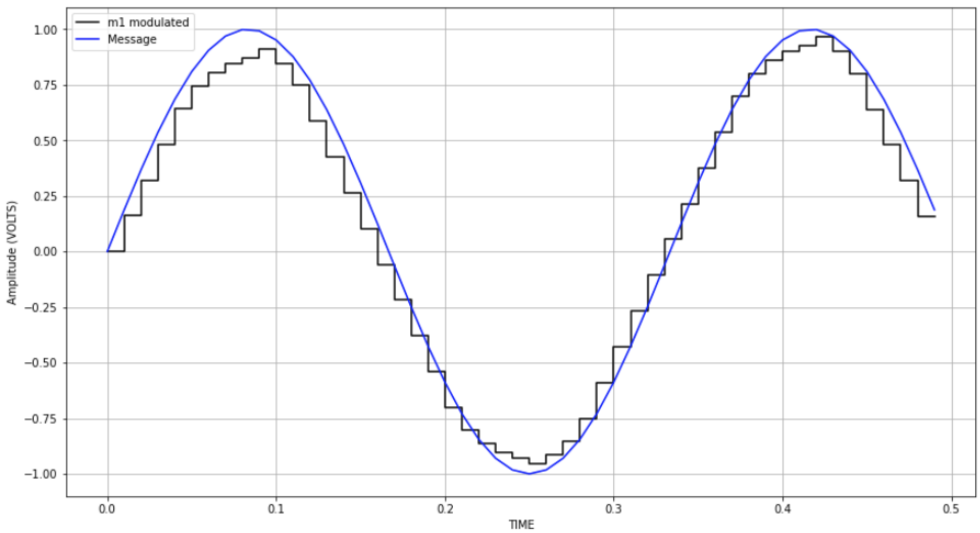


Fig 23

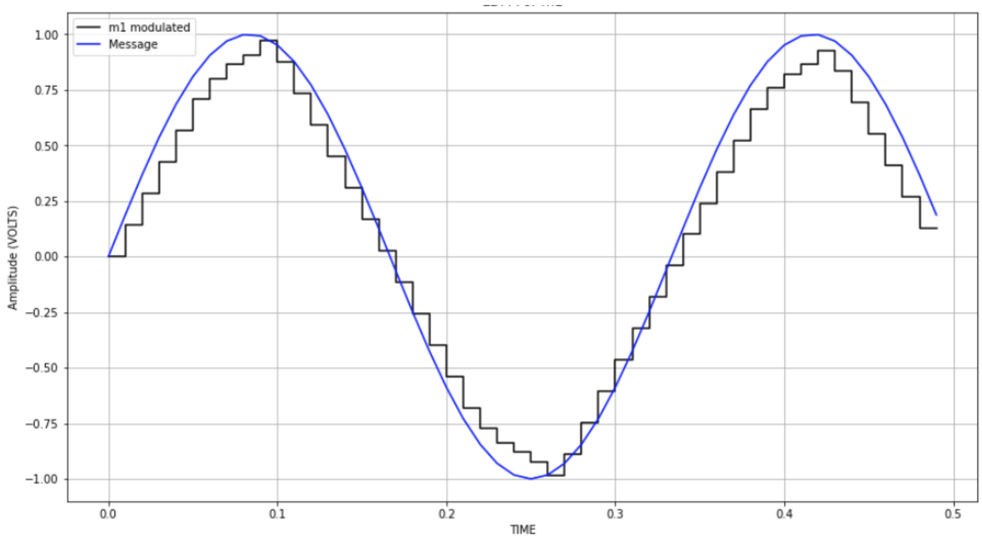


Fig 24

Demodulation of LDM:

In this part, we will introduce the demodulation process in the receiver side that will receive a sequence of bits to reconstruct the original signal by decoding the received bits and then integrated, if it receive 1 then increment delta, else if 0 then decrement delta, this process will gives us the staircase signal, to make it smooth we apply this signal to LPF.

As an example, we will see the results of m3(t)= $Amsin(2\pi fmt)$ with Fm=1, Am=1, and delta=$4\pi/100$ as shown below:

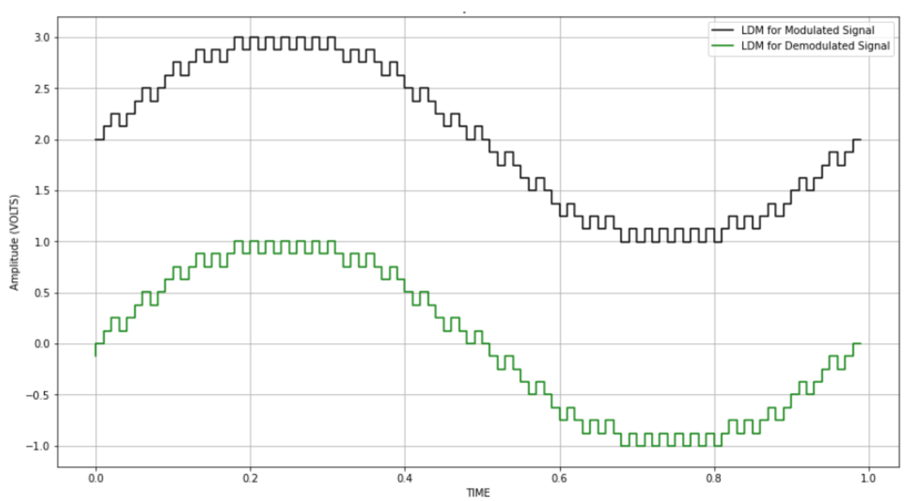


Fig 25

Fig25 shows the staircase signal in the transmitter side (black signal) and the staircase signal in the receiver side (green signal).

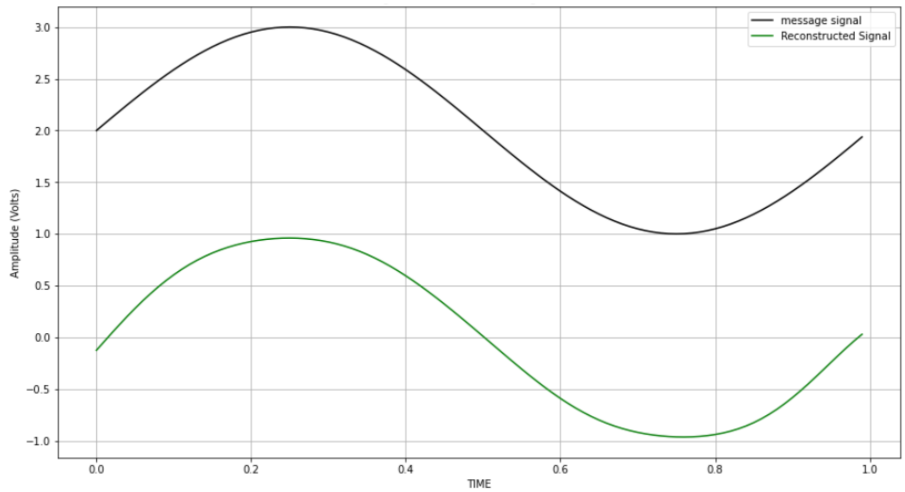


Fig 26

Fig26 shows the original signal (black signal) and the reconstructed signal (green signal) it's the stair case signal implied to LPF to make it smoother.

Let's change the Fm of the message to 4Hz and the delta size to $2\pi/100$ and see the results below:

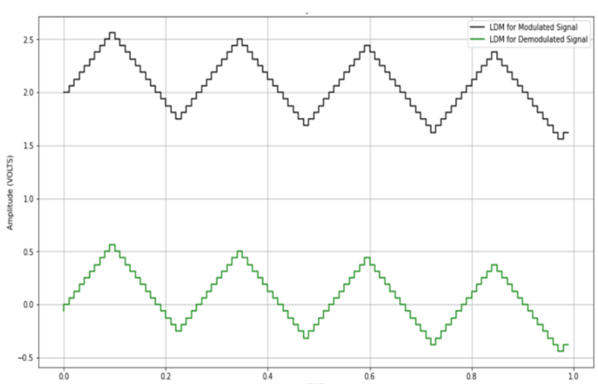


Fig 27

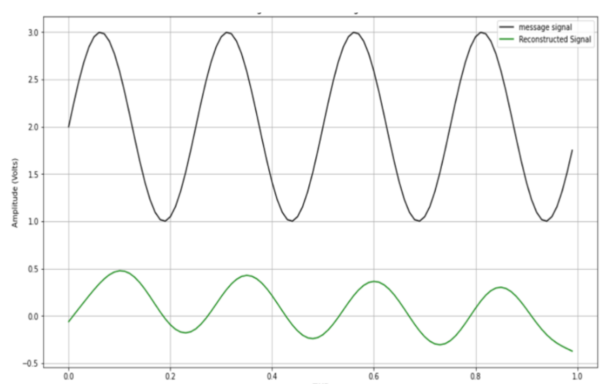


Fig 28

Fig27 shows the staircase signal in the transmitter side (black signal) and the staircase signal in the receiver side (green signal).

Fig28 shows the original signal (black signal) and the reconstructed signal (green signal) it's the stair case signal implied to LPF to make it smoother, we observe that the reconstructed signal is not equal to the original signal because we have slope overload noise, the delta cannot catch-up with the message, to solve this we have to increase the step size or apply the adaptive delta modulation.

Demodulation of DCDM (algorithm1):

In this part, we will demodulate message signal m3(t)= $Amsin(2\pi fmt)$, Fm=2, Am=1, and delta=$4\pi/100$ but this time the message was modulated by DCDM as we made previously, the results shown below:

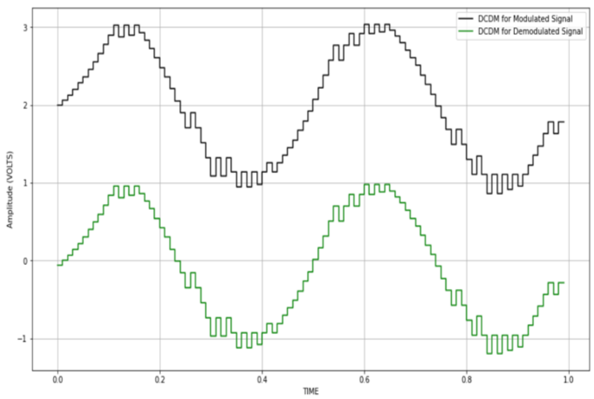


Fig 29

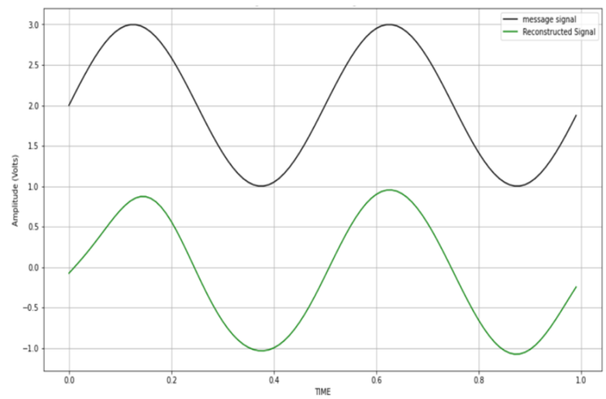


Fig 30

Fig29 shows the staircase signal in the transmitter side (black signal) and the staircase signal in the receiver side (green signal).

Fig30 shows the original signal (black signal) and the reconstructed signal (green signal) it's the stair case signal implied to LPF to make it smoother, we observe that the reconstructed signal is almost the same as the original signal.

Let's change the Fm of the message to 4Hz and the delta size to $2\pi/100$ to compare the performance of the previous one at the same frequency the results can be shown below:

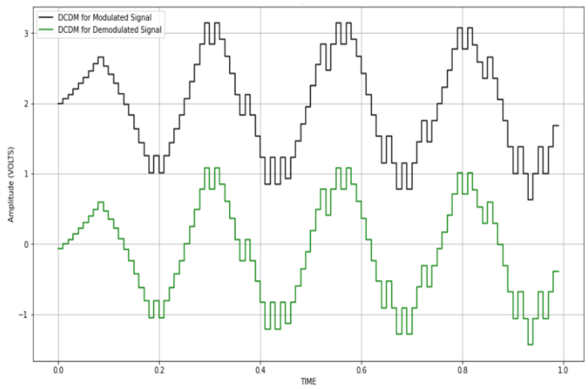


Fig 31

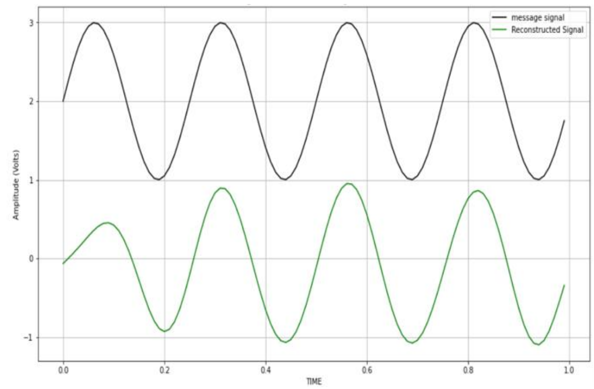


Fig 32

Fig31 shows the staircase signal in the transmitter side (black signal) and the staircase signal in the receiver side (green signal).

Fig32 shows the original signal (black signal) and the reconstructed signal (green signal) it's the stair case signal implied to LPF to make it smoother, we observe that the reconstructed signal is almost equal to the original signal, in other words the DCDM algorithm is much better than the linear modulation, that's because the delta size varied according to the variation of the message

<u>**Note: all codes of simulation can be found in the link can be found in reference.**</u>