**EEE-321: Signals and Systems**

**Section-1**

**LAB Assignment 2**

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## 1. Part 1

### 1.1 DTMF Transmitter

| | 1209 Hz | 1336 Hz | 1477 Hz | 1633 Hz |
|---|---|---|---|---|
| 697 Hz | 1 | 2 | 3 | A |
| 770 Hz | 4 | 5 | 6 | B |
| 852 Hz | 7 | 8 | 9 | C |
| 941 Hz | * | 0 | # | D |

*Table 1: DTMF frequencies*

Matlab code of the transmitter function DTMFTRA is below:

```
function [x]=DTMFTRA(Number)
        N = length(Number);
        freqtable = [697, 770, 852; 1477, 1209, 1336];
        Ts = 1/8192;
        x =[];
        xtune= zeros(1,N*0.25/Ts);
        for i = 1:N
                t = (i-1)*0.25:Ts:(i-1)*0.25+0.25-Ts;
                digit = Number(i);
                if digit == 0
                        row_freq = 941;
                        col_freq = 1336;
                else
                        row_freq = freqtable(1, ceil(digit / 3));
                        col_freq = freqtable(2, mod(digit,3)+1);
                end
                xtune = cos(2*pi*row_freq*t) + cos(2*pi*col_freq*t);
                x = [x,xtune];
        end
end
```

This function creates the Dual Tone Multi Frequency (DTMF) signals for a given number array. To test the function following code is executed. Where Number array contains personal telephone number of mine.

```
Number = [0 5 0 6 3 2 3 1 6 4 5];
x= DTMFTRA(Number);
soundsc(x,8192)
```

Sound of every number was different since their frequencies are different. The sound I hear was very similar to the sound that I hear when I dial a phone number. This made me realize the logic behind that sounds that I did not know until this day.

### 1.2 DTMF Receiver

In this part, the task was to decode the received signal. My specific array to encoded in x(t) using the DTMFTRA function was `[4 4 4 3 1]`. First, magnitude of the Fourier transform of x(t) is computed over omega in order to get the peak values of the frequencies as in *Figure 1.*

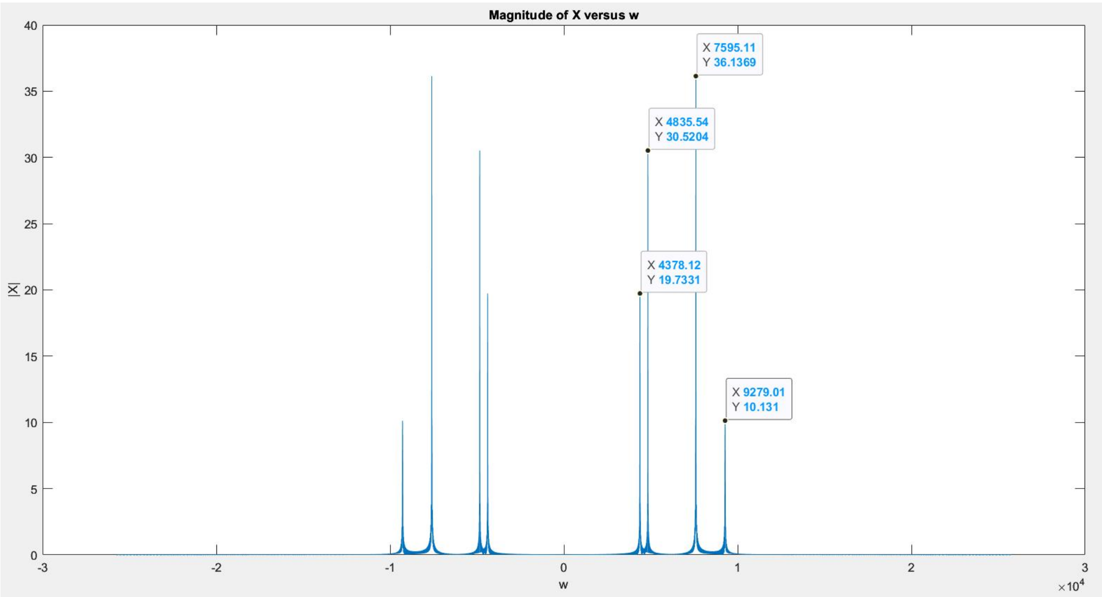

*Figure 1: Magnitude of the Fourier transform of x(t) computed over omega*

In *Figure 1*, there are 4 peak points which corresponds to frequency components of the received signal. Using $f = \frac{\omega}{2\pi}$ corresponding frequencies can be calculated as follows.

$$\frac{7595}{2\pi} = 1208.781793 \cong 1209Hz$$
$$\frac{4835}{2\pi} = 769.5141498 \cong 770Hz$$
$$\frac{4378}{2\pi} = 696.7803409 \cong 697Hz$$
$$\frac{9279}{2\pi} = 1476.798717 \cong 1477Hz$$

By looking at the *Table 1* these frequencies corresponds to 4, 3, 1 without order. By looking at the magnitudes it can be said that 4 occurs three times and 3 and 1 occur only one time each. But by just looking at this graph one cannot tell the order of the numbers because the plot gives no information about the numbers order.

In order to tell the numbers order, one should take the Fourier transform of the signal and plot magnitude versus omega graph of each number separately. This is done by the following MATLAB code for computing x1. x2, x3, x4, x5 are calculated similarly by only shifting the rectangular function by 0.25 after computing each of them as it can be seen from the following MATLAB code.

```
%myidnumber = 22103444
%mysection=1
Number = [4 4 4 3 1];
x=DTMFTRA(Number);
soundsc(x,8192)
X=FT(x);
omega=linspace(-8192*pi,8192*pi,10241);
omega=omega(1:10240);

Ts = 1/8192;
t = 0:Ts:1.25-Ts;
t_x1 = t -0.125;
rect1 = rectpuls(t_x1,25e-2);
x1 = x.*rect1;
X1=FT(x1);

figure
plot(omega,abs(X1))
ylabel('|X1|')
xlabel('w')
title('Magnitude of X1 versus w')

figure
tiledlayout(2,2)

t_x2 = t -(0.25*1+0.125);
rect2 = rectpuls(t_x2,25e-2);
x2 = x.*rect2;
X2=FT(x2);
nexttile
plot(omega,abs(X2))
ylabel('|X2|')
xlabel('w')
title('Magnitude of X2 versus w')


t_x3 = t -(0.25*2+0.125);
rect2 = rectpuls(t_x3,25e-2);
x3 = x.*rect2;
X3=FT(x3);
nexttile
plot(omega,abs(X3))
ylabel('|X3|')
xlabel('w')
```

```
title('Magnitude of X3 versus w')

t_x4 = t -(0.25*3+0.125);
rect2 = rectpuls(t_x4,25e-2);
x4 = x.*rect2;
X4=FT(x4);
nexttile
plot(omega,abs(X4))
ylabel('|X4|')
xlabel('w')
title('Magnitude of X4 versus w')

t_x5 = t -(0.25*4+0.125);
rect2 = rectpuls(t_x5,25e-2);
x5 = x.*rect2;
X5=FT(x5);
nexttile
plot(omega,abs(X5))
ylabel('|X5|')
xlabel('w')
title('Magnitude of X5 versus w')
```

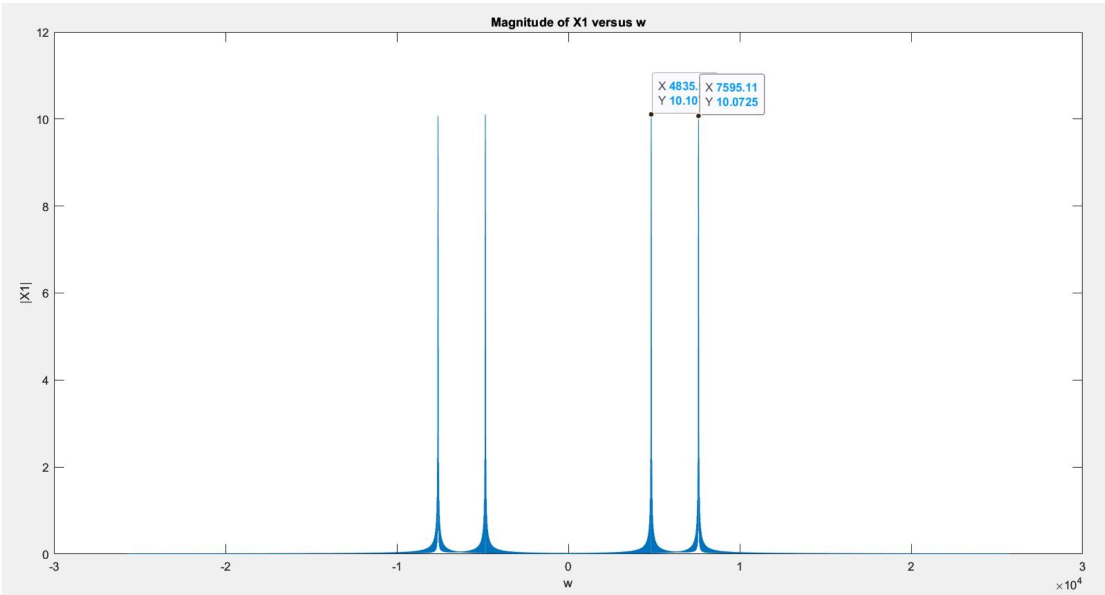


*Figure 2: Magnitude of the Fourier transform of $x_1(t)$ computed over omega*

In *Figure 2*, it can be seen from the graph that there are 2 peak points, first one corresponds to 770Hz and the second one corresponds to 1209Hz, so, from the *Table 1*, it can bee seen that $x_1$ is the DTMF signal of number ‘4’.

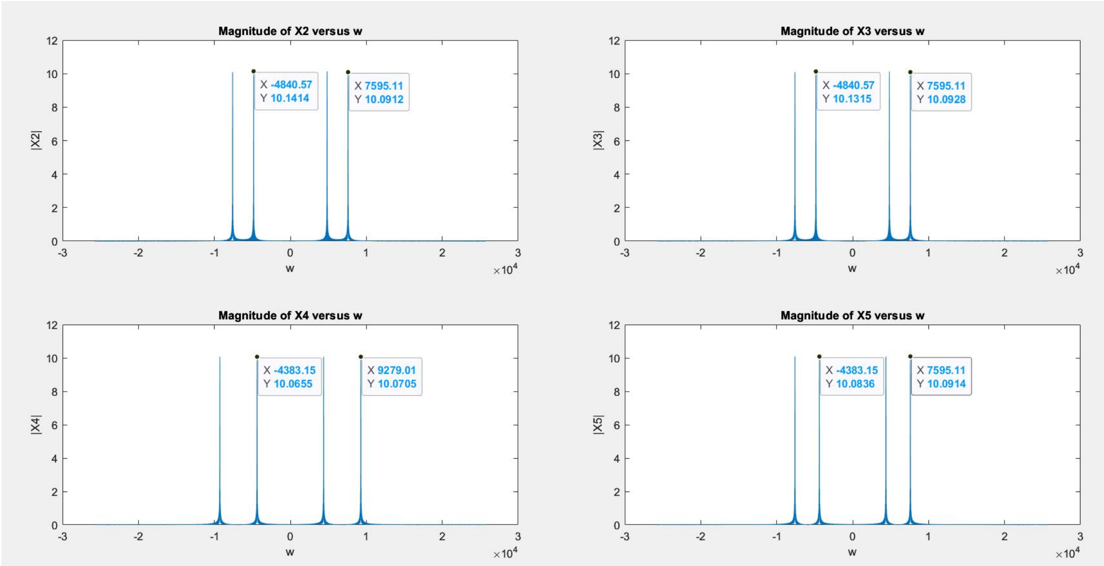


*Figure 3: Magnitudes of FTs of $x_2(t)$, $x_3(t)$, $x_4(t)$, $x_5(t)$ computed over omega*

Following the same method as before one can compute the corresponding numbers for $x_2(t)$, $x_3(t)$, $x_4(t)$, $x_5(t)$. Graphs of X2 and X3 are exactly the same with X1, therefore $x_2$ and $x_3$ are also DTMF signals of number '4'. For X4 first peak point corresponds to 697Hz and the second one corresponds to 1477Hz therefore $x_4$ is DTMF signal of number '3'. Lastly, for X5 first peak point corresponds to 697hz and the second one corresponds to 1209Hz, thus $x_5$ is the DTMF signal of number '1'. So the sequence has been found as [4 4 4 3 1] in order.