```
Port 1.1
   Sound of this signal sounds very femilier. It's like the click sound of
 the old phones,
                                                                                                                                                                                                                               ( -> this denotes the conversion
Part 1.2 (using the properties)
a) \chi(t) = e^{j2\pi f_0 t} = e^{j\omega_0 t} \longrightarrow \chi(j\omega) = 2\pi \delta(\omega - \omega_0)
 b) X(f) = cos (271fot) = cos (wot) -> X(jw) = TT ( &(w-wo) + &(w+wo))
c) \chi(t) = \operatorname{cecf}\left(\frac{t}{T_0}\right) = \begin{cases} 0 & \text{if } |t| > \overline{T_0} \\ \frac{1}{2} & \text{if } |t| = \overline{T_0} \\ 1 & \text{if } |t| < \overline{T_0} \\ 1 & \text{or } |t| < \overline{T_0} \end{cases} \xrightarrow{T_0} \begin{cases} T_0 \\ 1 & \text{or } |t| < T_0 \\ 1 & \text{or } |t| < T_0 \end{cases}
d) \chi(t) = e^{j2\pi f_{s}t} \cdot \operatorname{cect}\left(\frac{t}{T_{o}}\right) \rightarrow \chi_{1}(f_{w}) \times \chi_{2}(f_{w}) \left(\frac{f_{req}(f_{s})}{f_{req}(f_{s})}\right) = -\left(e^{-\frac{t}{2}w\frac{f_{s}}{2}} - e^{jw\frac{f_{s}}{2}}\right)
= \chi_{1}(f_{s}) \times \chi_{2}(f_{s}) \left(\frac{f_{req}(f_{s})}{f_{s}}\right) = 2\sin\left(\frac{f_{s}}{g_{s}}\right) \left(\frac{f_{req}(f_{s})}{f_{s}}\right) = 2\sin\left(\frac{f_{s}}{g_{s}}\right)
= \chi_{2}(f_{s}(w_{s})) - 2\sin\left(\frac{f_{s}}{g_{s}}\right) \left(\frac{f_{s}}{g_{s}}\right) + 2\sin\left(\frac{f_{s}}{g_{s}}\right)
= \chi_{2}(f_{s}(w_{s})) - 2\sin\left(\frac{f_{s}}{g_{s}}\right) \left(\frac{f_{s}}{g_{s}}\right) + 2\sin\left(\frac{f_{s}}{g_{s}}\right)
= \chi_{3}(f_{s}(w_{s})) - 2\sin\left(\frac{f_{s}}{g_{s}}\right) + 2\sin\left(\frac{f_{s}}{g_{s}}\right)
= \chi_{3}(f_{s}(w_{s})) - 2\cos\left(\frac{f_{s}}{g_{s}}\right) + 2\cos\left(\frac{f_{s}}{g_{s}}\right)
= \chi_{3}(f_{s}(w_{s})) - 2\cos\left(\frac{f_{s}}{g_{s}}\right) + 2\cos\left(\frac{f_{s
 -> sin ((w-ws) To/2) + sin ((w+ws) To/2)
   f \mid \chi(t) = rect\left(\frac{1-to}{To}\right) \longrightarrow e^{-j\omega to}, 2sin\left(\omega \frac{To}{2}\right) (Time shift)
   g) x(t) = ejwst. rect (++12) -> e-j(w-ws) to .2sin ((w-wo) Tyz)
    h) x(t) = \cos(\omega_0 t) \operatorname{rect}\left(\frac{t-1}{T_0}\right) = e^{-\frac{t}{2}(\omega_0 - \omega_0)} \cdot \frac{\sin((\omega_0 - \omega_0))}{\omega_0 - \omega_0}
                                                                                                                                                                           + e-j(w+wo). sin((w+wo) To)
   x Yes, the frequencies where the peck occur the ones used
      by DTMF fronsceivers.
```

Fourth digit calculation: $x_4(t) = x(t) (u(t-0.5)-u(t-0.75)$ The first method colculates all particular	770 Hz \rightarrow LSSB red/sec 941 Hz \rightarrow 5912 red/sec 1209 Hz \rightarrow 7596 red/sec 1693 Hz \rightarrow 10260 red/sec 1336 Hz \rightarrow 8394 red/sec 1693 Hz \rightarrow 10260 red/sec The function computes one digit of the number. From squere wave properties Second Digit Celculation $x_2(t) = \{Y'_2(t) \mid f \mid 0.25 \leq t \leq 0.5\}$ Second Digit Celculation $x_2(t) = \{Y'_2(t) \mid f \mid 0.25 \leq t \leq 0.5\}$ Second Digit Celculation $x_2(t) = \{Y'_2(t) \mid f \mid 0.25 \leq t \leq 0.5\}$ South digit celculation: $X_3(t) = X(t) (M(t-0.5)-M(t-0.75))$ The first method colculates all peaks together but the second that computes peaks one the second of the second that the second that the second computes peaks one the second of the second that the second t		1=271f we				
1209 Hz -> 7596 red/sec 1477 Hz -> 9210 red/sec 1336 Hz -> 8394 red/sec 1633 Hz -> 10260 red/sec ET function computes one digit of the number. from squere nave propertyey Second Digit Celculation 4(t) - {Y'z(t) if 0.25 < t 505 second x(1) = (u(t.0.25) - u(t.0.5)) Third digit celculation: X3(t) = X(t) (u(t-0.5) - u(t-0.75) Fourth digit celculation: Xu(t) = X(t) (u(t-0.75) - u(t-1)) The first method colculates all peaks together but the method computes peaks one has a contraction.	1209 Hz -> 7596 red/sec 1477 Hz -> 9250 red/sec 1336 Hz -> 8394 red/sec 1633 Hz -> 10260 red/sec To function computes one digit of the number. Crom squere neve propertyes Second Digit Celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculatio	697 Hz	- 4380 redise	1 8	8521/2 -5	353 rod/sec	
1209 Hz -> 7596 red/sec 1477 Hz -> 9210 red/sec 1336 Hz -> 8394 red/sec 1633 Hz -> 10260 red/sec ET function computes one digit of the number. from squere nave propertyey Second Digit Celculation 4(t) - {Y'z(t) if 0.25 < t 505 second x(1) = (u(t.0.25) - u(t.0.5)) Third digit celculation: X3(t) = X(t) (u(t-0.5) - u(t-0.75) Fourth digit celculation: Xu(t) = X(t) (u(t-0.75) - u(t-1)) The first method colculates all peaks together but the method computes peaks one has a contraction.	1209 Hz -> 7596 red/sec 1477 Hz -> 9250 red/sec 1336 Hz -> 8394 red/sec 1633 Hz -> 10260 red/sec To function computes one digit of the number. Crom squere neve propertyes Second Digit Celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculation (4t) - {42(4) if 0.25 < 4505 Second Digit celculatio	770 Hz -	-> L838 red /se				
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Second Digit Calculation $x_1(t) = \{Y_2(t) \mid f \mid 0.25 \leq t \leq 0.5\}$ Second Digit Calculation $x_1(t) = \{Y_2(t) \mid f \mid 0.25 \leq t \leq 0.5\}$ $X_1 = \{u(t, 0.25) - u(t, 0.5)\}$ Third digit calculation: $X_3(t) = X(t) \{u(t - 0.5) - u(t - 0.75)\}$ Fourth digit calculation: $X_4(t) = X(t) \{u(t - 0.75) - u(t - 1)\}$ The first method colculates all peaks together but the method computes peaks one to the content of the method computes peaks one to the content of the method computes peaks one to the content of	Second Digit Calculation $y(t) = \{Y_2(t) \mid f \mid 0.25 \mid f \mid 50.5\}$ Second Digit Calculation $y(t) = \{Y_2(t) \mid f \mid 0.25 \mid f \mid 50.5\}$ Second Digit Calculation $y(t) = \{Y_2(t) \mid f \mid 0.25 \mid f \mid 50.5\}$ Same for third digit calculation: $\{X_3(t) \mid f \mid $	FT functi	ion computes c	one digit	of the number	1	
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Fourth digit calculation: xult = x(t) (u(t-0.5)-u(t-0.75) The first method colculates all peaks together but the method computes peaks one him a first method computer peaks one him and all the	The first method colculates all peaks together but the seconethod computes peaks one he are not to the seconethod computer peaks of the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks of the seconethod computer peaks of the seconethod computer	Second Dig,	if Calculation	17(t) -	{ K2(d) if	0.25 515	0.5
Fourth digit calculation: xult = x(t) (u(t-0.5)-u(t-0.75) The first method colculates all peaks together but the method computes peaks one him a first method computer peaks one him and all the	The first method colculates all peaks together but the seconethod computes peaks one he are not to the seconethod computer peaks of the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks of the seconethod computer peaks of the seconethod computer	x. (1) = (y (1 000)	cond	0 , o.u		J
Fourth digit calculation: xult = x(t) (u(t-0.5)-u(t-0.75) The first method colculates all peaks together but the method computes peaks one him a first method computer peaks one him and all the	The first method colculates all peaks together but the seconethod computes peaks one he are not to the seconethod computer peaks of the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks one he are not to the seconethod computer peaks of the seconethod computer peaks of the seconethod computer	This I	11.0.25)- 061	.0.5))	X =		other dig
The first method colculates all peaks together but the method computes peaks one him a first with the	The first method colculates all peaks together but the seconethod computes peaks one him and all the seconethod computes peaks on the seconethod computes peaks	1	Call Genoti,	X3(+1 = ,	XITILMIT-	-0,5)-41.	1-020
method computes pecks one him a new little	rethod computes peaks one him a nit deether but the sec		110 CERCIANION	: Xu(+) =	X(4) / 4/4-	0,25/2.	(1 (1)
		The flise	method as	10,1,40		1/3	(5-1))
			(3)	(clere)	oll pecks d	ogether be	of the con
Clearly, to party to debamined Clearly,	actly to per of dolorinal Clearly,	method co	madel				1.6 2 50
						number c	enrot be det
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						number c	en not be do

Port 2 a) let x h(t)	(1) = 8(t) = 8(t) + \sum_{i=1}^{m} Ai 8(t-t)	we can find h(t) easily i) because it is a LTI system,
61	→ H(jw) = 1+2	The same of the sa
c) y(jw)	= X(jw) H(jw) , con	frequency domain vice verse,
d) X(jw)	cen be celculated b	y (j'w) H(j'w)
overlep	between my voice bee	of the sound, I realize there is an area of the delay.
for t	le recovered non-eer almost like the or	to version of the sound was

EEE321 Lab report 3

PLOTS

Part 1.2

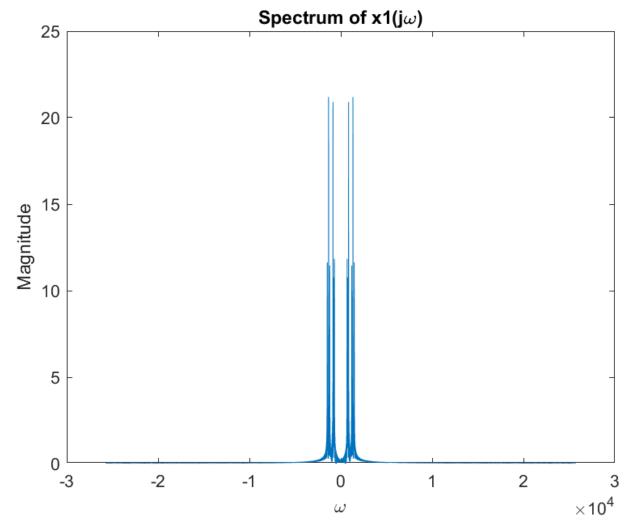


Figure 1: Plot of Spectrum of $x1(j\omega)$

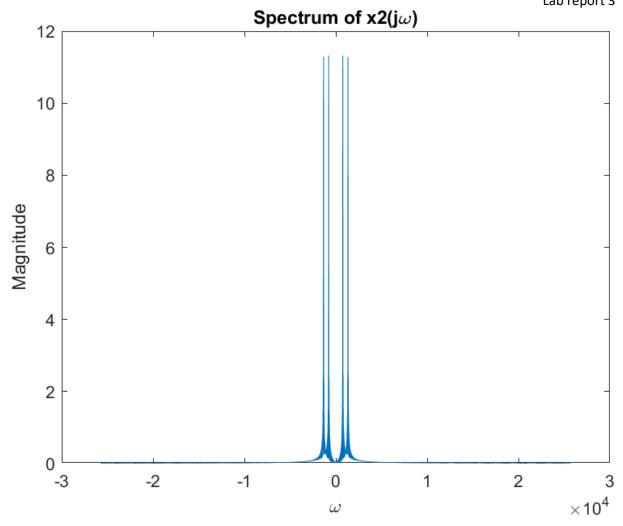


Figure 2: Plot of Spectrum $X(j\omega) = x2(j\omega)$



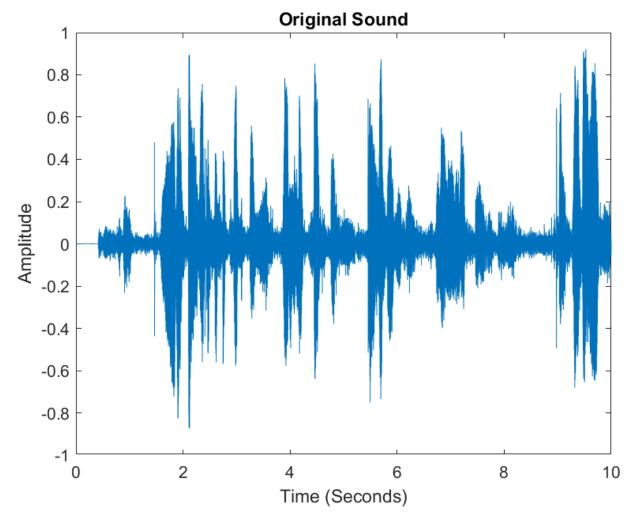


Figure 3: Plot of Amplitude of Original Sound

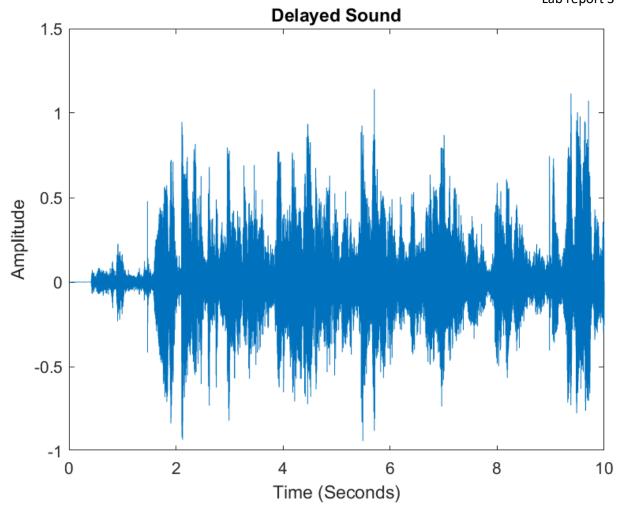


Figure 4: Plot of Amplitude of Delayed Sound

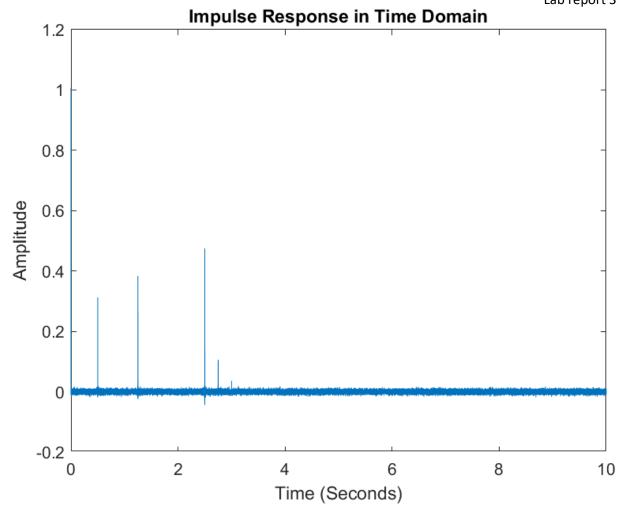


Figure 5: Plot of Impulse Response in Time Domain

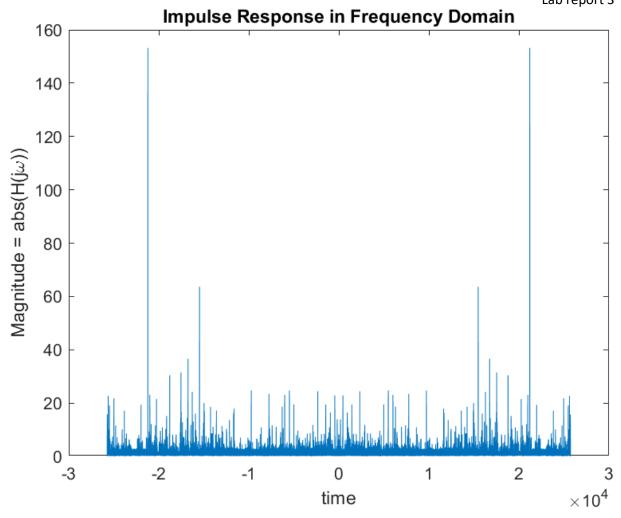


Figure 6: Plot of Impulse Response in Frequency Domain

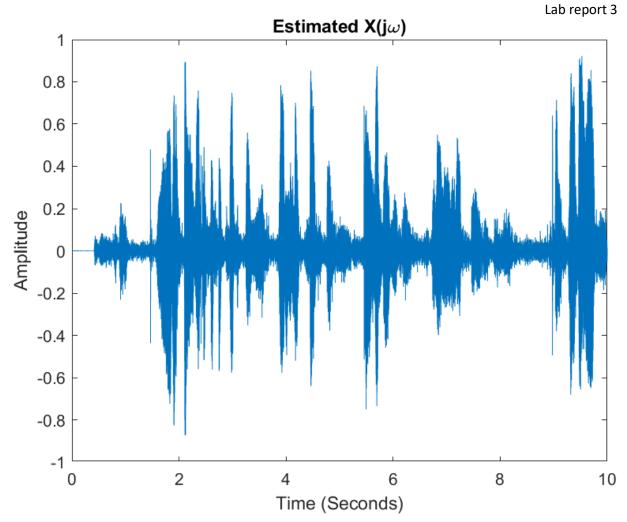


Figure 7: Plot of Estimated $X(j\omega)$

MATLAB CODES

```
%% PART 1.1 %%
Number = [05380639497];
x = DTMFTRA(Number);
%% PART 1.2 %%
clear all;
Number = [5 8 9 1]; %21801985
x=DTMFTRA(Number);
x1 = FT(x);
omega= linspace(-8192 * pi, 8192 * pi, 8193);
omega= omega(1 :8192);
figure;plot(omega,abs(x1));xlabel('\omega');ylabel('Magnitude');title('Spectrum of
x1(j\omega)');
y1= zeros(1,8192);
y1(1:2048)=1;
y1=y1 .* x;
x2 = FT(y1);
figure;plot(omega,abs(x2));xlabel('\omega');ylabel('Magnitude');title('Spectrum of
x2(j\omega)');
%% PART 2
record = audiorecorder(8192, 16, 1);
disp('Start Recording.');
recordblocking(record, 10);
disp('End Recording.');
% play(record);
original = getaudiodata(record);
t = [0: 1/8192: 10 - 1 / 8192];
A = 0.35 * delayseq(original, 0.5, 8192);
A = A + 0.5 * (delayseq(original, 1.25, 8192));
A = A + 0.65 * (delayseq(original, 2.5, 8192));
A = A + 0.05 * (delayseq(original, 3, 8192));
A = A + 0.15 * (delayseq(original, 2.75, 8192));
original_Delayed = original + A;
% soundsc(delayed, 8192)
figure(3); plot(t, original); xlabel('Time (Seconds)');
ylabel('Amplitude');title('Original Sound');
figure(4); plot(t, original_Delayed); xlabel('Time (Seconds)');
ylabel('Amplitude');title('Delayed Sound');
Y = FT(original_Delayed);
X = FT(original);
omega = linspace(-8192 * pi, 8192 * pi, 81921);
omega = omega(1 : 81920);
H = Y . / X;
h = IFT(H);
figure; plot(t, h); xlabel('Time (Seconds)'); ylabel('Amplitude');title('Impulse
Response in Time Domain');
figure; plot(omega, abs(H)); xlabel('time'); ylabel('Magnitude =
abs(H(j\omega))'); title('Impulse Response in Frequency Domain');
Xe = Y ./ H;
xe = IFT(Xe);
figure; plot(t, xe); xlabel('Time (Seconds)');
ylabel('Amplitude');title('Estimated X(j\omega)');
```

```
%% Functions
function [k]=DTMFTRA(Number)
    k = [];
    t = 0 : 1/8192 : 0.25 - 1 / 8192;
    for num = 1 : length(Number)
        if Number(num) == 1
            cos_sum = cos(2*pi*697*t) + cos(2*pi*1209*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == 2
            cos_sum = cos(2*pi*697*t) + cos(2*pi*1336*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == 3
            cos_sum = cos(2*pi*697*t) + cos(2*pi*1477*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == 4
            cos_sum = cos(2*pi*770*t) + cos(2*pi*1209*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == 5
            cos_sum = cos(2*pi*770*t) + cos(2*pi*1336*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == 6
            cos_sum = cos(2*pi*770*t) + cos(2*pi*1477*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == 7
            cos_sum = cos(2*pi*852*t) + cos(2*pi*1207*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == 8
            cos_sum = cos(2*pi*852*t) + cos(2*pi*1336*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == 9
            cos_sum = cos(2*pi*852*t) + cos(2*pi*1477*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == 0
            cos_sum = cos(2*pi*941*t) + cos(2*pi*1336*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == '*'
            cos_sum = cos(2*pi*941*t) + cos(2*pi*1207*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == '#'
            cos_sum = cos(2*pi*941*t) + cos(2*pi*1477*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == 'A'
            cos_sum = cos(2*pi*697*t) + cos(2*pi*1633*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == 'B'
            cos_sum = cos(2*pi*770*t) + cos(2*pi*1633*t);
            k = cat(2, k, cos_sum);
        elseif Number(num) == 'C'
            cos_sum = cos(2*pi*852*t) + cos(2*pi*1633*t);
            k = cat(2, k, cos_sum);
        else %D
            cos_sum = cos(2*pi*941*t) + cos(2*pi*1633*t);
            k = cat(2, k, cos_sum);
        end
    end
    x = k;
    soundsc(x,8192);
end
```

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```
function output=FT(input)
M=size(input,2);
t=exp(j*pi*(M-1)/M*[0:1:M-1]);
output=exp(-j*pi*(M-1)^2/(2*M))*t.*1/(M)^0.5.*fft(input.*t);
end

function output=IFT(input)
M=size(input,2);
t=exp(-j*pi*(M-1)/M*[0:1:M-1]);
output=real(exp(j*pi*(M-1)^2/(2*M))*t.*(M)^0.5.*ifft(input.*t));
end
```

References

https://www.mathworks.com/help/matlab/import_export/record-and-play-audio.html
https://www.mathworks.com/help/phased/ref/delayseq.html