FINAL PROJECT

PART-2

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CONTENTS

1 TASK

1. Use the AM and FM radios designed in previous labs.
2. Transmit the desired signal (try both music and voice signals) at the frequency band of choice.
3. Jam this signal by transmitting one of the two signals (interferer) mentioned below at the same frequency.
   a. White noise
   b. AM/FM modulated signal
4. Change the power of the interferer w.r.t. the original signal, starting at -5 dB (Interferer weaker than desired signal) to 5 dB (interferer stronger than the original signal) in steps of 3 dB. Estimate the MOS score for each SNR. You will need to design your own MOS definitions here. An example is shown at the end.
5. Your results table should look something like this:

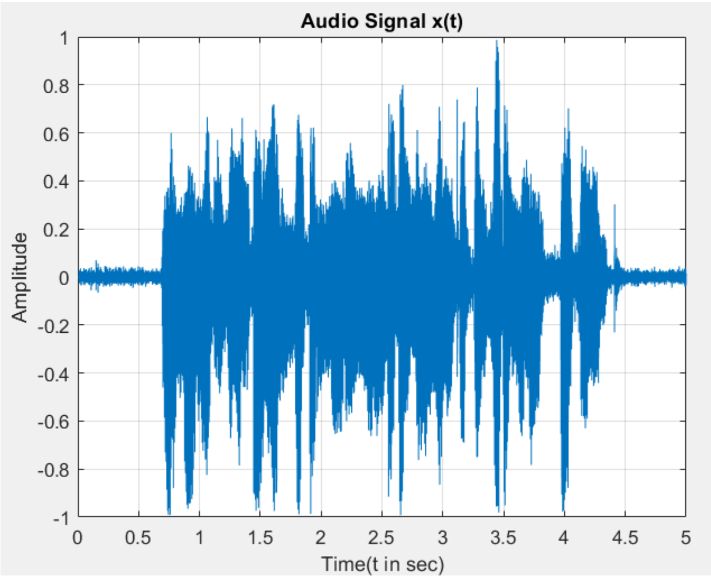
Interferer power/Original signal power (in dB)	AM Radio		FM Radio	
	White Noise	AM	White Noise	FM
-5 dB				
-2 dB				
1 dB				
5 dB				

6. Write your conclusions on
   a. Ability of AM and FM to resist jamming. Which one seems to do better? Will changing the modulation index of the FM signal help?
   b. If you are the jammer, what kind of jamming signal would you choose? Why?

2 SIGNAL PLOTS

Firstly let us have a look at the signals we are using and trying to receive.

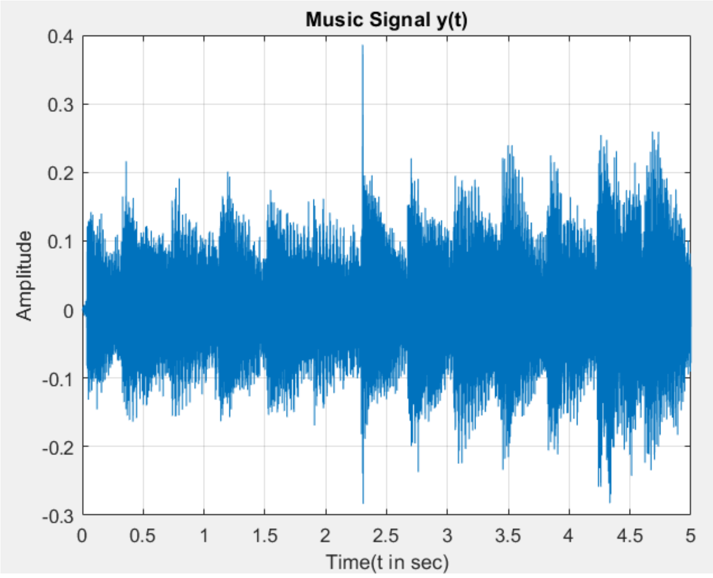
2.1 Channel 1



This my audio clip saying, "My name is V Sai Anvith and my roll number is IMT2018528"
I've used this as the message on first channel of both FM and AM radios.

For FM, this message is received if tuned to the channel at 15000Hz.
For AM, this message is received if tuned to the channel at 10000Hz.

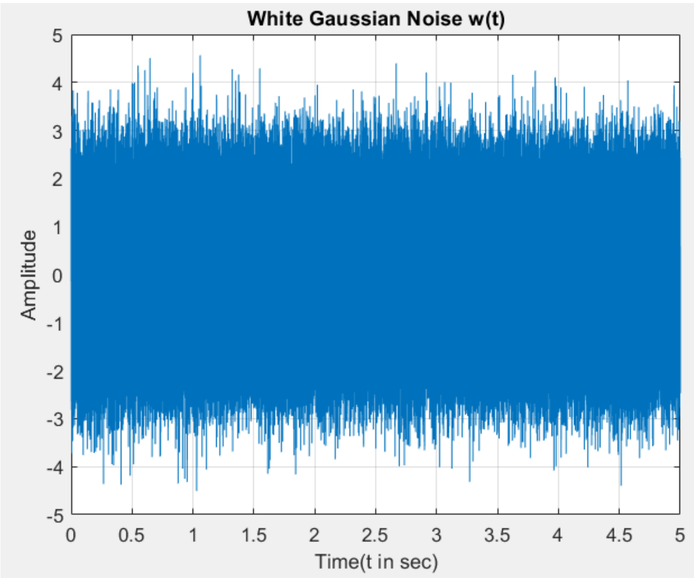
2.2 Channel 2



This audio is an excerpt taken from the popular classic, Beethoven's Moonlight Sonata played on Piano. Here we clearly observe each note of piano in the plot as individual trapezoid blocks.
I've used this as the message on second channel of both FM and AM radios.

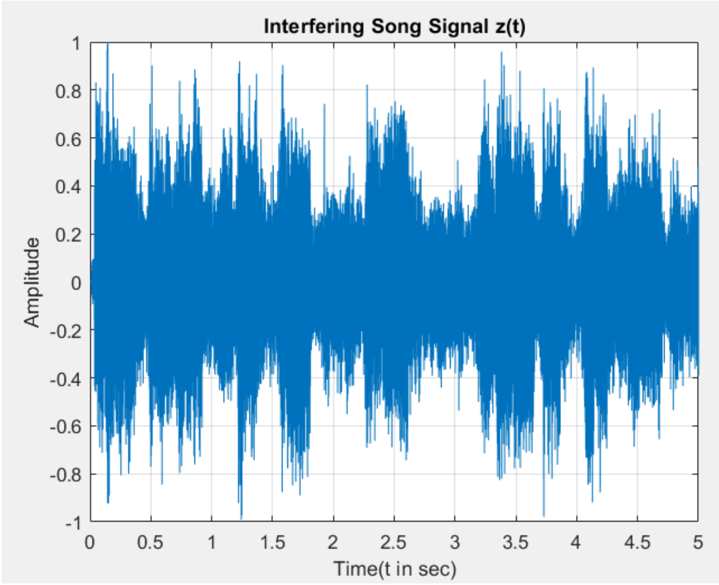
For FM, this message is received if tuned to the channel at 25000Hz.
For AM, this message is received if tuned to the channel at 16000Hz.

2.3 Interfering Signals



I've used this White Gaussian Noise as the message on interfering signal on every channel on both FM and AM stations.

*This WGN seen above is not fixed as it is a randomizing function.



I've used this song as the message on interfering signal on every channel on both FM and AM stations.

We shall study the impact of this interference and jamming technique as we discuss further.

2.4 Refining the Inputs

```
% All have same fs due to same recording source.
x = x(:,1);
y = y(:,1);
z = z(:,1);
% changing audio length to 5sec
x = x(1:5*fs);
y = y(1:5*fs);
z = z(1:5*fs);
% Increasing sampling rate
fs = 2*fs;
x = resample(x,2,1);
y = resample(y,2,1);
z = resample(z,2,1);
w = wgn(length(x),1,0); %this is the white noise
% soundsc(y,fs);%->to play the audio
t = (0:1/fs:(length(y)-1)/fs);
```

As seen in above code, I've converted all audios to 1D array.

Next I've changed the length of every audio signal to 5 seconds

Lastly I've increased the sampling of the messages to satisfy nyquist conditions everywhere. Then I've created the White Gaussian Noise of same length as the input signals.

3 MEAN OPINION SCORE (MOS)

A Mean Opinion Score (MOS) is a numerical measure of the human-judged overall quality of an event or experience. In telecommunications, a Mean Opinion Score is a ranking of the quality of voice.

Most often judged on a scale of 1 (bad) to 5 (excellent), Mean Opinion Scores are the average of a number of other human-scored individual parameters. Originally Mean Opinion Scores were derived from surveys of expert observers.

Now as asked I am assigning my own MOS scores on the following basis :
Score 5 : Same audio quality as original message signal, as if without interference.
Score 4 : Mild interference(other audio or noise) but message audio intelligible at least 50 percent of the time.
Score 3 : Audio almost/ totally unintelligible
Score 2 : Mild interference(message audio or noise) but interfering audio is intelligible and more dominant.
Score 1 : Receiving a total different audio only.

4 RESULTS

Now I'll change the power of the interferer w.r.t. the original signal, starting at -5 dB (Interferer weaker than desired signal) to 5 dB (interferer stronger than the original signal) in steps of 3 dB. And record my defined MOS score.

I'm using variable 'A' to define the power ratio in decibels.
Now we have to check and allot MOS score results for A = -5, -2, 1, 5(all in dB)

4.1 A = -5, AM Radio

4.1.1 *Channel 1, Jammed using: WGN*

MOS Score: 4
Mild background noise is heard. Message remained almost intelligible.

4.1.2 *Channel 1, Jammed using: AM signal*

MOS Score: 4
Considerable background interfering message part is heard. But message remained almost intelligible.

4.1.3 *Channel 2, Jammed using: WGN*

MOS Score: 4
Mild background noise is heard. Message remained almost intelligible.

4.1.4 *Channel 2, Jammed using: AM signal*

MOS Score: 3
Considerable background interfering message part is heard. Notes of the piano became harder to interpret.

4.2 A = -5, FM Radio

4.2.1 *Channel 1, Jammed using: WGN*

MOS Score: 3
Heavy background noise is heard. Message remained almost unintelligible.

4.2.2 *Channel 1, Jammed using: FM signal*

MOS Score: 3
Mostly noise is heard.

4.2.3 *Channel 2, Jammed using: WGN*

MOS Score: 4
Mild background noise is heard. Message remained almost intelligible.

4.2.4 *Channel 2, Jammed using: FM signal*

MOS Score: 4
Considerable background interfering message part is heard. At least greater than 50 percent of actual message is heard clearly.

4.3 A = -2, AM Radio

4.3.1 *Channel 1, Jammed using: WGN*

MOS Score: 4
Mild background noise is heard. Message remained almost intelligible.

4.3.2 *Channel 1, Jammed using: AM signal*

MOS Score: 4
Considerable background interfering message part is heard. But message remained almost intelligible.

4.3.3 *Channel 2, Jammed using: WGN*

MOS Score: 4
Mild background noise is heard. Message remained almost intelligible.

4.3.4 *Channel 2, Jammed using: AM signal*

MOS Score: 3
Considerable background interfering message part is heard. Notes of the piano became harder to interpret.

4.4 A = -2, FM Radio

4.4.1 *Channel 1, Jammed using: WGN*

MOS Score: 3
Heavy background noise is heard. Message remained almost unintelligible.

4.4.2 *Channel 1, Jammed using: FM signal*

MOS Score: 2
Mostly noise is heard. At least greater than 50 percent of interfering message is heard.

4.4.3 *Channel 2, Jammed using: WGN*

MOS Score: 4
Message is too faint but intelligible.

4.4.4 *Channel 2, Jammed using: FM signal*

MOS Score: 4
Considerable background interfering message part is heard. At least greater than 50 percent of actual message is heard clearly.

4.5 A = 1, AM Radio

4.5.1 *Channel 1, Jammed using: WGN*

MOS Score: 4
Considerable background noise is heard. Message remained intelligible.

4.5.2 *Channel 1, Jammed using: AM signal*

MOS Score: 2
Considerable background interfering message part is heard. But message remained too faint to hear and unintelligible.

4.5.3 *Channel 2, Jammed using: WGN*

MOS Score: 4
Mild background noise is heard. Message remained almost intelligible.

4.5.4 *Channel 2, Jammed using: AM signal*

MOS Score: 4
Both are comfortably intelligible

4.6 A = 1, FM Radio

4.6.1 *Channel 1, Jammed using: WGN*

MOS Score: 3
Heavy background noise is heard. Message remained almost unintelligible.

4.6.2 *Channel 1, Jammed using: FM signal*

MOS Score: 3
Mostly noise is heard.

4.6.3 *Channel 2, Jammed using: WGN*

MOS Score: 3
Message is too faint.

4.6.4 *Channel 2, Jammed using: FM signal*

MOS Score: 4
Both are heard almost equally and both were intelligible

4.7 A = 5, AM Radio

4.7.1 *Channel 1, Jammed using: WGN*

MOS Score: 4
Considerable background noise is heard. Message remained almost intelligible.

4.7.2 *Channel 1, Jammed using: AM signal*

MOS Score: 2
Considerable background interfering message part is heard. But message remained too faint to hear and unintelligible.

4.7.3 *Channel 2, Jammed using: WGN*

MOS Score: 4
Mild background noise is heard. Message remained almost intelligible.

4.7.4 *Channel 2, Jammed using: AM signal*

MOS Score: 2
Considerable background interfering message part is heard. Notes of the piano became harder to interpret and interfering song is dominant.

4.8 A = 5, FM Radio

4.8.1 *Channel 1, Jammed using: WGN*

MOS Score: 3
Heavy background noise is heard. Message remained almost unintelligible.

4.8.2 *Channel 1, Jammed using: FM signal*

MOS Score: 2
Mostly noise is heard. At least greater than 50 percent of interfering message is heard.

4.8.3 *Channel 2, Jammed using: WGN*

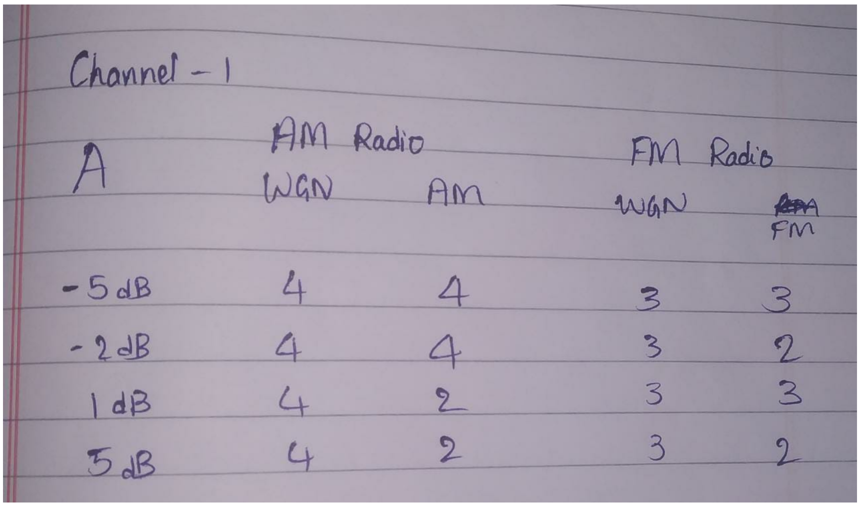
MOS Score: 3
Message is too faint.

4.8.4 *Channel 2, Jammed using: FM signal*

MOS Score: 2
Considerable background interfering message part is heard. Interfering song signal remained dominant

5 RESULT TABLES

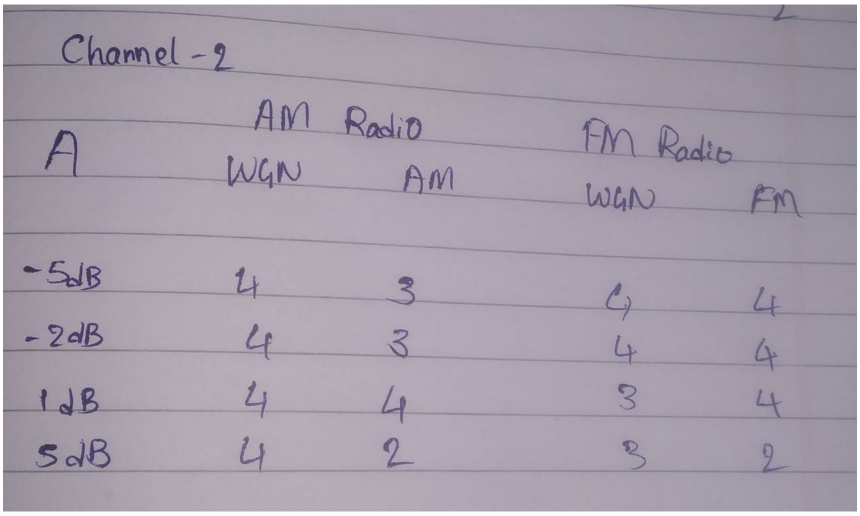
5.1 Channel 1



Channel - 1

A	AM Radio WGN	AM Radio AM	FM Radio WGN	FM Radio ~~AM~~ FM
-5 dB	4	4	3	3
-2 dB	4	4	3	2
1 dB	4	2	3	3
5 dB	4	2	3	2

5.2 Channel 2



Channel - 2

A	AM Radio WGN	AM Radio AM	FM Radio WGN	FM Radio FM
-5dB	4	3	4	4
-2dB	4	3	4	4
1dB	4	4	3	4
5dB	4	2	3	2

6 CONCLUSIONS

The ability of AM/FM to resist jamming according to my opinion, is greater for AM

Clearly from the above tables when we see, I understand that FM performs poorly compared to AM in MOS scores for both the channels with same Gaussian Noise. Hence if the interference element is Gaussian Noise, I'd prefer AM to deliver my message.

If the interference element is going to be another signal in the same channel, then AM has MOS scores quite similar to FM but in those cases a weaker interference seems to be enough to compromise the message in FM. So I'd say AM is stronger performer against interference.

If modulation index is increased in FM, I see MOS gets bad even more.

If I'm a jammer, I'd definitely use WGN if it is FM radio, Because chances to block the message and cost(power) also seems effective from the seen above tables. If it is AM, I'd rather use another message on same channel to disrupt it. In AM, WGN doesn't seem effective at all(unless it is high powered, which would be expensive of course).

7 CODE

```
close all; clc;
Fc = 25000; %Change this to tune to required station(15k/25kHz)
AM_Fc = 16000; %Change this to tune to required station(10k/16kHz)
A = 5; %Change the value in decibels

[x,fs]=audioread('audio.wav');
[y,fs]=audioread('music.wav');
[z,fs]=audioread('song.wav');
% All have same fs due to same recording source.
x = x(:,1);
y = y(:,1);
z = z(:,1);
% changing audio length to 5sec
x = x(1:5*fs);
y = y(1:5*fs);
z = z(1:5*fs);
% Increasing sampling rate
fs = 2*fs;
x = resample(x,2,1);
y = resample(y,2,1);
z = resample(z,2,1);
w = wgn(length(x),1,0); %this is the white noise
% soundsc(y,fs);%-->to play the audio
t = (0:1/fs:(length(y)-1)/fs);

%% Changing the power of the interferer w.r.t. the original signal
z_power = var(z);
w_power = var(w);

z_new_power1 = var(x)*10^(A/10);
z_new_power2 = var(y)*10^(A/10);
w_new_power1 = var(x)*10^(A/10);
w_new_power2 = var(y)*10^(A/10);

ratio1 = z_new_power1/z_power;
ratio2 = z_new_power2/z_power;
ratio3 = w_new_power1/w_power;
ratio4 = w_new_power2/w_power;

z1 = z.*sqrt(ratio1);
z2 = z.*sqrt(ratio2);
w1 = w.*sqrt(ratio3);
```

```
w2 = w.*sqrt(ratio4);

%% FM modulation, jamming & demodulation
fm = 2000;
m = 1;

x1 = fmmod(x,15000,fs,m*fm);
y1 = fmmod(y,25000,fs,m*fm);

x1_jammer = fmmod(z1,15000,fs,m*fm);
y1_jammer = fmmod(z2,25000,fs,m*fm);

x1_noise = fmmod(w1,15000,fs,m*fm);
y1_noise = fmmod(w2,25000,fs,m*fm);

f = x1 + y1 + x1_jammer + y1_jammer;
f1 = x1 + y1 + x1_noise + y1_noise;

fb = bandpass(f, [Fc-5000, Fc+5000], fs);
fb1 = bandpass(f1, [Fc-5000, Fc+5000], fs);

f_demod = fmdemod(fb,Fc,fs,m*fm);
f1_demod = fmdemod(fb1,Fc,fs,m*fm);
soundsc(f1_demod,fs);%->to play the audio

%% AM modulation & demodulation
[b, a] = butter(8,2000/(fs/2));

% To remove aliasing
x_filtered = filter(b,a,x);
y_filtered = filter(b,a,y);
z1_filtered = filter(b,a,z1);
z2_filtered = filter(b,a,z2);
w1_filtered = filter(b,a,w1);
w2_filtered = filter(b,a,w2);

Fs = 60000;

s1 = ammod(x_filtered,10000,Fs,0);
s2 = ammod(y_filtered,16000,Fs,0);

s3 = ammod(z1_filtered,10000,Fs,0);
s4 = ammod(z2_filtered,16000,Fs,0);

s5 = ammod(w1_filtered,10000,Fs,0);
s6 = ammod(w2_filtered,16000,Fs,0);

s = s1 + s2 + s3 + s4;
s_noise = s1 + s2 + s5 + s6;

s = bandpass(s, [AM_Fc-2000, AM_Fc+2000], Fs);
s_noise = bandpass(s_noise, [AM_Fc-2000, AM_Fc+2000], Fs);

s_demod = amdemod(s,AM_Fc,Fs,0);
s_noise_demod = amdemod(s_noise,AM_Fc,Fs,0);
% soundsc(s_demod,fs);%->to play the audio
```

```
%% plot of audio signal x(t)
% figure
% plot(t,x)
% title('Audio Signal x(t)')
% xlabel('Time(t in sec)')
% ylabel('Amplitude')
% grid on
```