Principles of Communication systems FINAL PROJECT - I

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Contents

1 FM Broadcast system

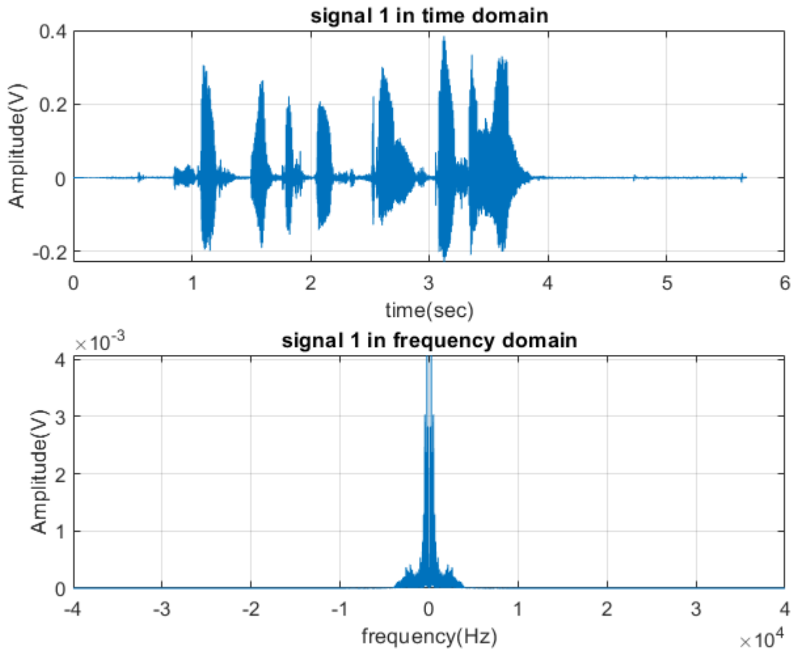
Description: We need to design an FM broadcast system which consists of a transmitter ,a AWGN noise channel and a receiver. So here we are sending FM modulated waves from the transmitter and hence it is FM broadcast system.

This system has 2 broadcast stations at carrier frequencies of 15 KHz and 25 KHz respectively. So each broadcast station has a bandwidth of 10 KHz. Here the modulating frequency is given as 2 KHz and modulation index is 1.

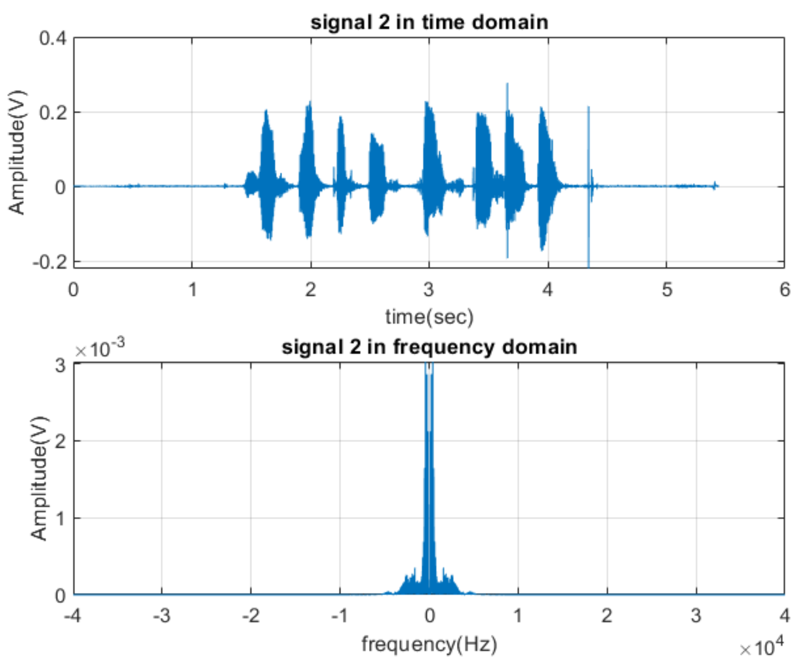
Modulation index:- The frequency modulation index is the equivalent of the modulation index for AM . The FM modulation index is equal to the ratio of the frequency deviation to the modulating frequency. The modulation index is independent of the carrier frequency.

Carson's rule:- Carson's Rule states that 98 percent of the signal power is contained within a bandwidth equal to the deviation frequency, plus the modulation frequency doubled.
So according to the carson's formula,The bandwidth of the FM modulated signal here is $2(2+2) = 8KHz$.. The remaining bandwidth of 2 KHz serves as a guardband for the broadcast stations.

The below graphs are the time domain and frequency domain representations of filtered message signals. we can use these plots to compare them with the final demodulated message signals and observe the difference.



signal 1 in time domain
Amplitude(V)
time(sec)
signal 1 in frequency domain
Amplitude(V)
frequency(Hz)

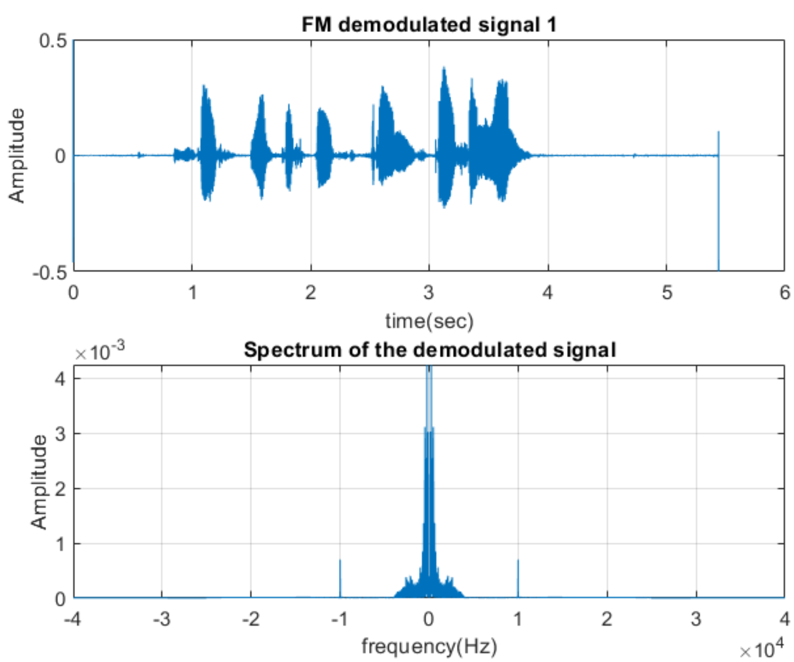


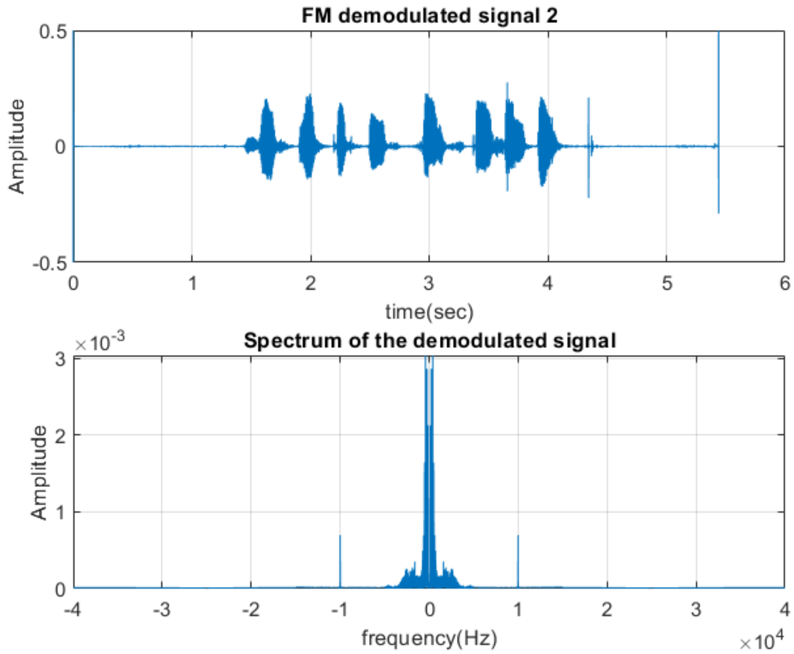
signal 2 in time domain
Amplitude(V)
time(sec)
signal 2 in frequency domain
Amplitude(V)
frequency(Hz)

1.1 Quality of the received signal

The audio signal consists of various frequency components but we have bandwidth limitation for the station as 10 KHz.So while transmitting the audio signal , we are filtering the signal to avoid interference with the neighbouring stations. So due to this restriction , the high frequency components in the audio signal will be lost.
Due to this, the received audio from the receiver is not as same quality as the original message signal,we can observe some loss of quality but still the information can be clearly understood.

The following plots are the time domain and frequency domain representations of received signals at broadcast station 1 and at 2 respectively:-

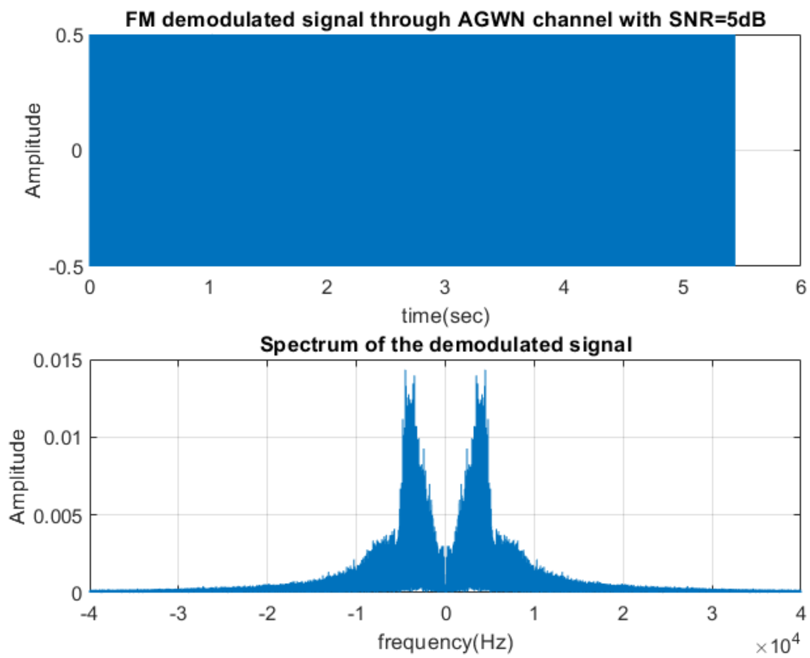


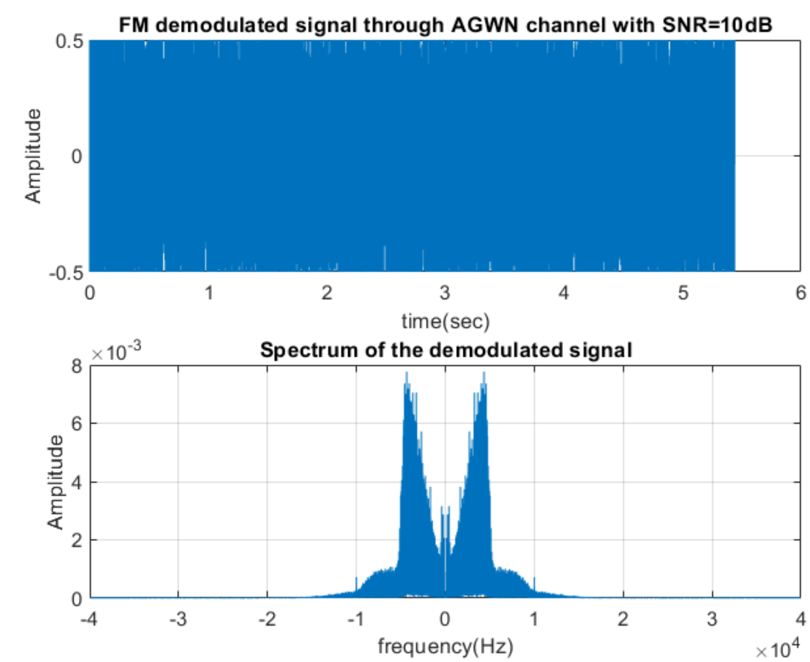


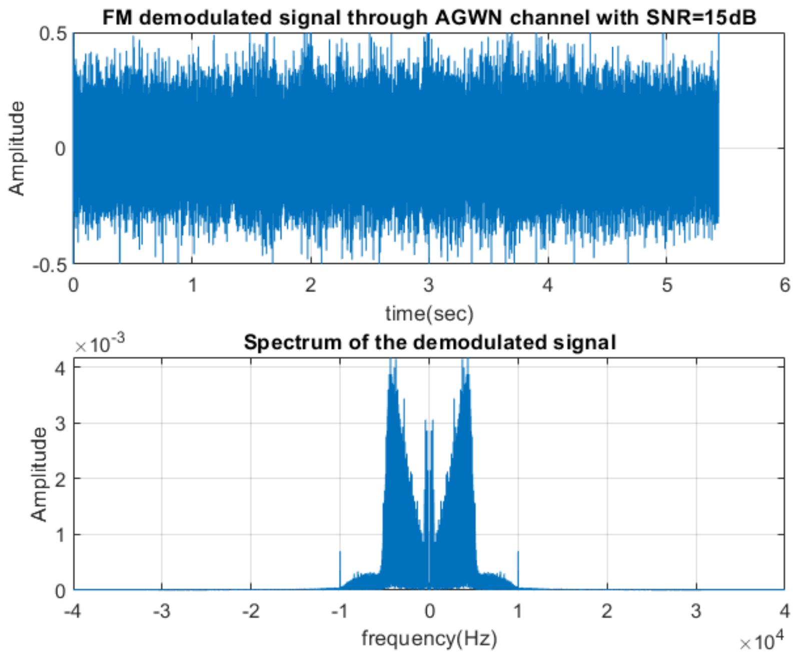
1.2 Introducing an AWGN channel

We will observe the received signal when AWGN noise is added to the signal in the channel which will effect the original message signal. Here the signal to noise ratio is increased from 5 dB to 15 dB and then the following graphs are the demodulated outputs for station 1 signal at the receiver end.

SNR:- Signal to Noise Ratio is the ratio of the original signal power to the power of the noise added to the signal.


FM demodulated signal through AGWN channel with SNR=5dB
Amplitude
time(sec)
Spectrum of the demodulated signal
Amplitude
frequency(Hz)
×10^4


FM demodulated signal through AGWN channel with SNR=10dB
Amplitude
time(sec)
Spectrum of the demodulated signal
×10^-3
Amplitude
frequency(Hz)
×10^4

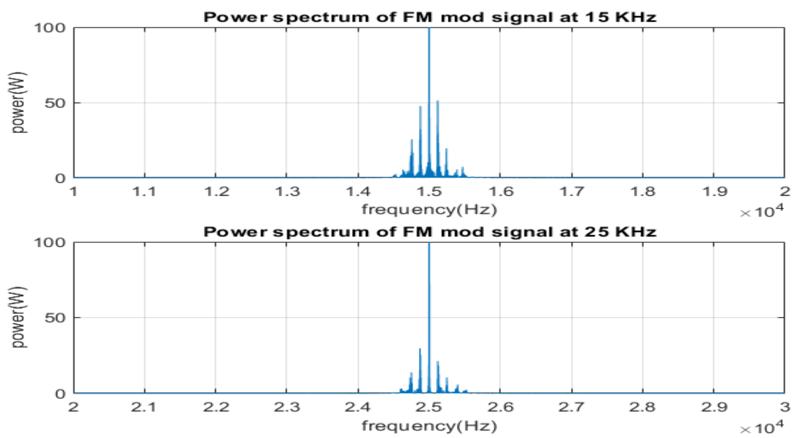


Observations:- After demodulation, we can clearly see that the audio quality is better for SNR = 15dB compared to SNR below 15 dB. As the SNR value increases, the received audio signal quality is better. We can clearly observe the difference when we listen to the received audio.
This is same for both music and speech signals. Much degradation of quality in music signals in observed compared to speech signal.

1.3 Power Spectra

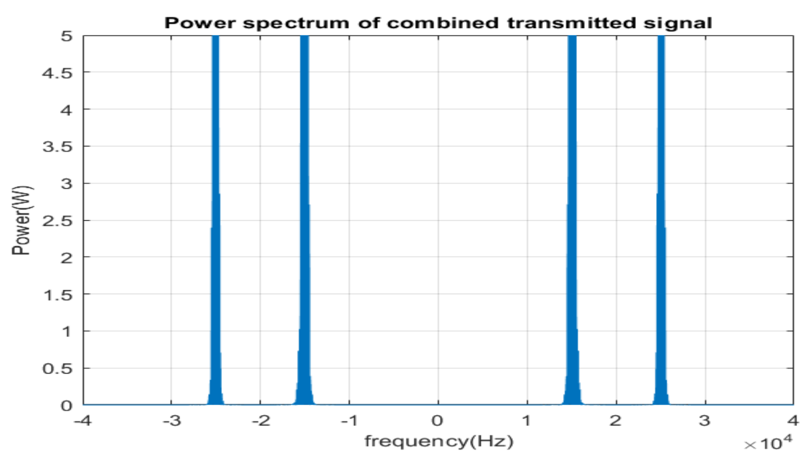
Aim:- i)To Plot the power spectrum of the FM modulated signal at each carrier frequency, ii)combined transmitted signal and iii)received signal (with and without noise).iv) Also plot the power spectrum of signal obtained before and after tuning to the stations.

i) The following is the power spectrum plot of FM modulated signals at each station carrier frequency i.e at 15 KHz and at 25KHz.

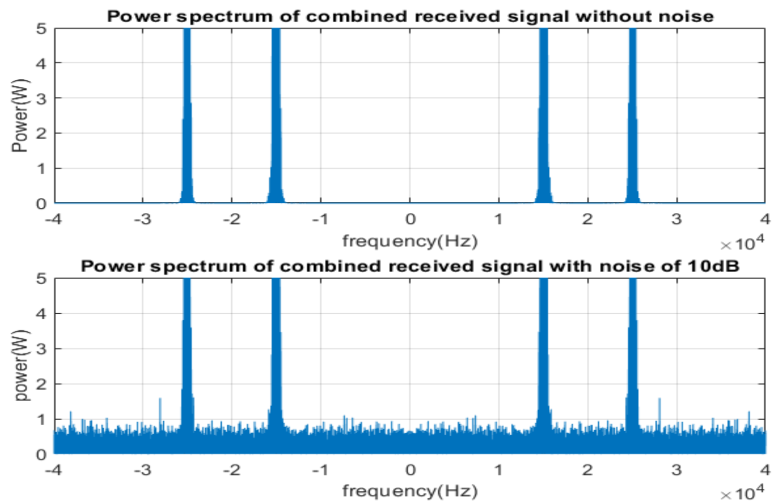


Here we can see that in the power spectrum, the power distribution with frequency. According to the carson's rule , bandwidth is 8 KHz. i.e 98 percent of power is in that range and the remaining power is beyond that. For example, for station 1 , 98 percent of power is present before 19KHz and remaining beyond that which is negligible.

ii) The following is the power spectra of combined transmitted signal. It consists of both the station frequencies.The plot here is zoomed to observe exact freq range.we can observe signals cantered at 15KHz and 25 KHz and it will be transmitted.

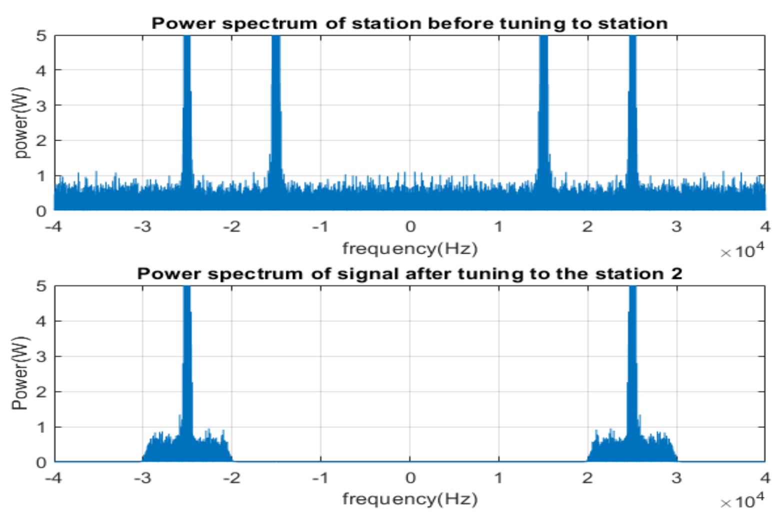


iii)The following are the received signals at the receiver without noise and with noise of SNR = 10dB .



In the second plot above , we can observe the noise due to the AWGN channel.

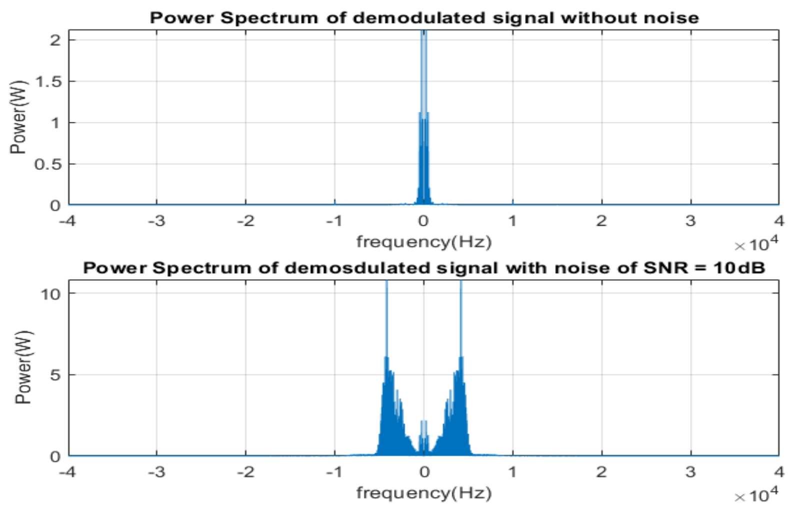
iv) The following is the power spectra of signal before tuning to station and after tuning to station 2.



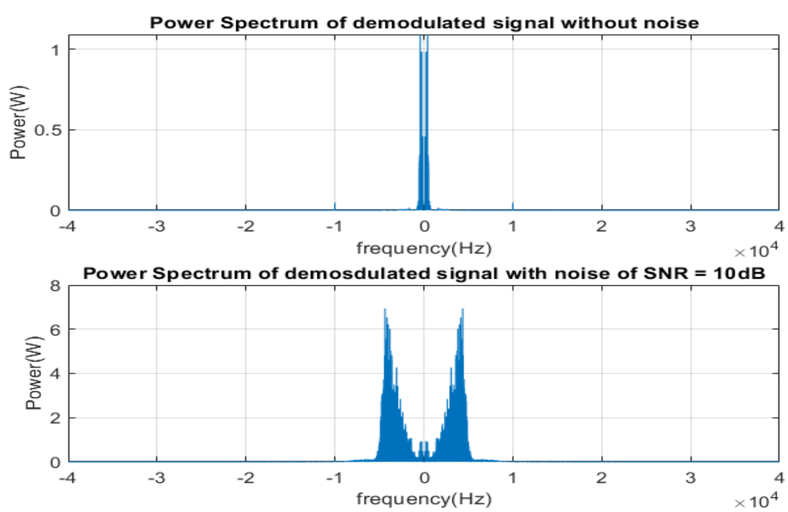
Before tuning to the station , all frequencies are present, once the signal is tuned to the station, it will take only the frequency components of itself. for example here, station 2 has a bandwidth of 10KHz . So it takes only components from

20KHz to 30KHz.

v) The following are the power spectra of the demodulated output signal at station 1 without noise and with noise.



These are the output at station 2



If there is noise , the quality of the received signal is attenuated. we can compare this received signal with the original message signal to observe the difference. The difference in the quality can be observed better listening to the audio.

2 MOS

MOS:- It is Mean Opinion Score which is a numerical measure to judge the quality of the signal.typically in the range 1–5, where 1 is lowest perceived quality, and 5 is the highest perceived quality. For MOS, other ranges also can be taken as per own interest.

MOS for the speech and music signals:-

MOS		
signal	SPEECH	MUSIC
Without noise	4	4
SNR of 15dB	3	2.8
SNR of 10dB	2.5	2.5
SNR of 5dB	1.9	1.5

3 Appendix

Matlab code:

```
%transmitter
s1_f = 15 * 10^3; s2_f = 25 * 10^3;
[s1_data,fs] = audioread('s1_audio.wav');
[s2_data,fs] = audioread('s2_audio.wav');
%%display(length(s1_data));
%%display(length(s2_data));
%soundsc(s1_data,fs);
s1_data = s1_data(:,1);
s2_data = s2_data(:,1);
%soundsc(s1_data,fs);
resample_freq = 8e4;
s1_resample = resample(s1_data,resample_freq,fs);
s2_resample = resample(s2_data,resample_freq,fs);
%soundsc(s2_resample,80000);
cutoff_frequency  = 4e3;

[b,a] = butter(6,cutoff_frequency/(40000));
```

```
s1_filter = filter(b,a,s1_resample);
s2_filter = filter(b,a,s2_resample);
%soundsc(s1_filter,80000);


figure(1);
subplot(2,1,1);
time_int = 1/resample_freq;
Nf = length(s1_filter);
tt = [0:time_int:(Nf-1)*time_int];
plot(tt,s1_filter);xlabel('time(sec)');ylabel('Amplitude(V)');
title('signal 1 in time domain');
grid on;
subplot(2,1,2);
ff = resample_freq/Nf.*(-Nf/2:Nf/2-1);
s1_fft = fftshift(fft(s1_filter,Nf));
s1_fft = abs(s1_fft(1:Nf))./(Nf/2);
plot(ff,s1_fft);
xlabel('frequency(Hz)');ylabel('Amplitude(V)');
title('signal 1 in frequency domain');
grid on;

figure(2);
subplot(2,1,1);
time_int = 1/resample_freq;
Nf2 = length(s2_filter);
tt2 = [0:time_int:(Nf2-1)*time_int];
plot(tt2,s2_filter);xlabel('time(sec)');ylabel('Amplitude(V)');
title('signal 2 in time domain');
grid on;
subplot(2,1,2);
ff2 = resample_freq/Nf2.*(-Nf2/2:Nf2/2-1);
s2_fft = fftshift(fft(s2_filter,Nf2));
s2_fft = abs(s2_fft(1:Nf2))./(Nf2/2);
plot(ff2,s2_fft);
xlabel('frequency(Hz)');ylabel('Amplitude(V)');
title('signal 2 in frequency domain');
grid on;


beta = 1;fm = 2000;
dev = beta * fm;
s1_mod = fmmod(s1_filter,s1_f,resample_freq,dev);
s2_mod = fmmod(s2_filter,s2_f,resample_freq,dev);
display(length(s1_mod));
display(length(s2_mod));
figure(3);
subplot(2,1,1);
s1_mod_fft = fftshift(fft(s1_mod));
amp1 = abs(s1_mod_fft);
pow1 = amp1.^2/Nf;
plot(ff,pow1);grid ...
    on;xlabel('frequency(Hz)');ylabel('power(W)');ylim([0 100]);
title('Power spectrum of FM mod signal at 15 KHz');grid ...
    on;xlim([10000 20000]);
subplot(2,1,2);
```

```
s2_mod_fft = fftshift(fft(s2_mod));
amp2 = abs(s2_mod_fft);
pow2 = amp2.^2/Nf2;
plot(ff2,pow2);grid ...
    on;xlabel('frequency(Hz)');ylabel('power(W)');ylim([0 100]);
title('Power spectrum of FM mod signal at 25 KHz');grid ...
    on;xlim([20000 30000]);



%s1_mod = s1_mod(1:435200);
%display(length(s1_mod));
%display(length(s2_mod));
s_mod = s1_mod(1:400000) + s2_mod(1:400000);
N = length(s_mod);

figure(4);
ff = resample_freq/N.*(-N/2:N/2-1);
s_mfft = fftshift(fft(s_mod,N));
s_mfft = abs(s_mfft(1:N));
pow  = s_mfft.^2/N;
plot(ff,pow);
xlabel('frequency(Hz)');ylabel('Power');
title('Power spectrum of combined transmitted signal');
grid on;

figure(5);
subplot(2,1,1);
ff = resample_freq/N.*(0:N-1);
s_mfft = fft(s_mod,N);
s_mfft = abs(s_mfft(1:N))./(N/2);
plot(ff,s_mfft);
xlabel('frequency(Hz)');ylabel('Amplitude');
title('Modulated signal from the transmitter');
grid on;
%soundsc(s_mod,60000);

%channel
snr = 10;
s_mod_noise = awgn(s_mod,snr);
N = length(s_mod_noise);
t = [0:time_int:(N-1)*time_int];

subplot(2,1,2);
ff = resample_freq/N.*(0:N-1);
s_fft = fft(s_mod_noise,N);
s_fft = abs(s_fft(1:N))./(N/2);
plot(ff,s_fft);
xlabel('frequency(Hz)');ylabel('Amplitude');
title('output from th AWGN channel');
grid on;

%receiver
r_freq = s2_f;
passage = [r_freq-4000,r_freq+4000];

s_mod_rec = bandpass(s_mod,passage,80000);
```

```
s_mod_rec_noise = bandpass(s_mod_noise,passage,80000);
s_out = fmdemod(s_mod_rec,r_freq,80000,dev);
s_out_noise = fmdemod(s_mod_rec_noise,r_freq,80000,dev);

soundsc(s_out_noise,80000);

figure;
subplot(2,1,1);
ff = resample_freq/N.*(-N/2:N/2-1);
s_fft = fftshift(fft(s_out,N));
s_fft = abs(s_fft(1:N));
pow_rec = s_fft.^2/N;
plot(ff,pow_rec);
xlabel('frequency(Hz)');ylabel('Power(W)');
title('Power Spectrum of received signal without noise');
grid on;
subplot(2,1,2);
ff = resample_freq/N.*(-N/2:N/2-1);
s_fft = fftshift(fft(s_out_noise,N));
s_fft = abs(s_fft(1:N));
pow_rec = s_fft.^2/N;
plot(ff,pow_rec);
xlabel('frequency(Hz)');ylabel('Power(W)');
title('Power Spectrum of received signal with noise of SNR = 10dB');
grid on;
```

4 References

[1]Upamanyu Madhow,Introduction to Communication Systems,January 17 2014, University of California, Santa Barbara
[2] MATLAB fmmod URL:https://in.mathworks.com/help/comm/ref/fmmod.html
[3] MATLAB BANDPASS URl:https://in.mathworks.com/help/signal/ref/bandpass.html