FREQUENCY MODULATION (FM)

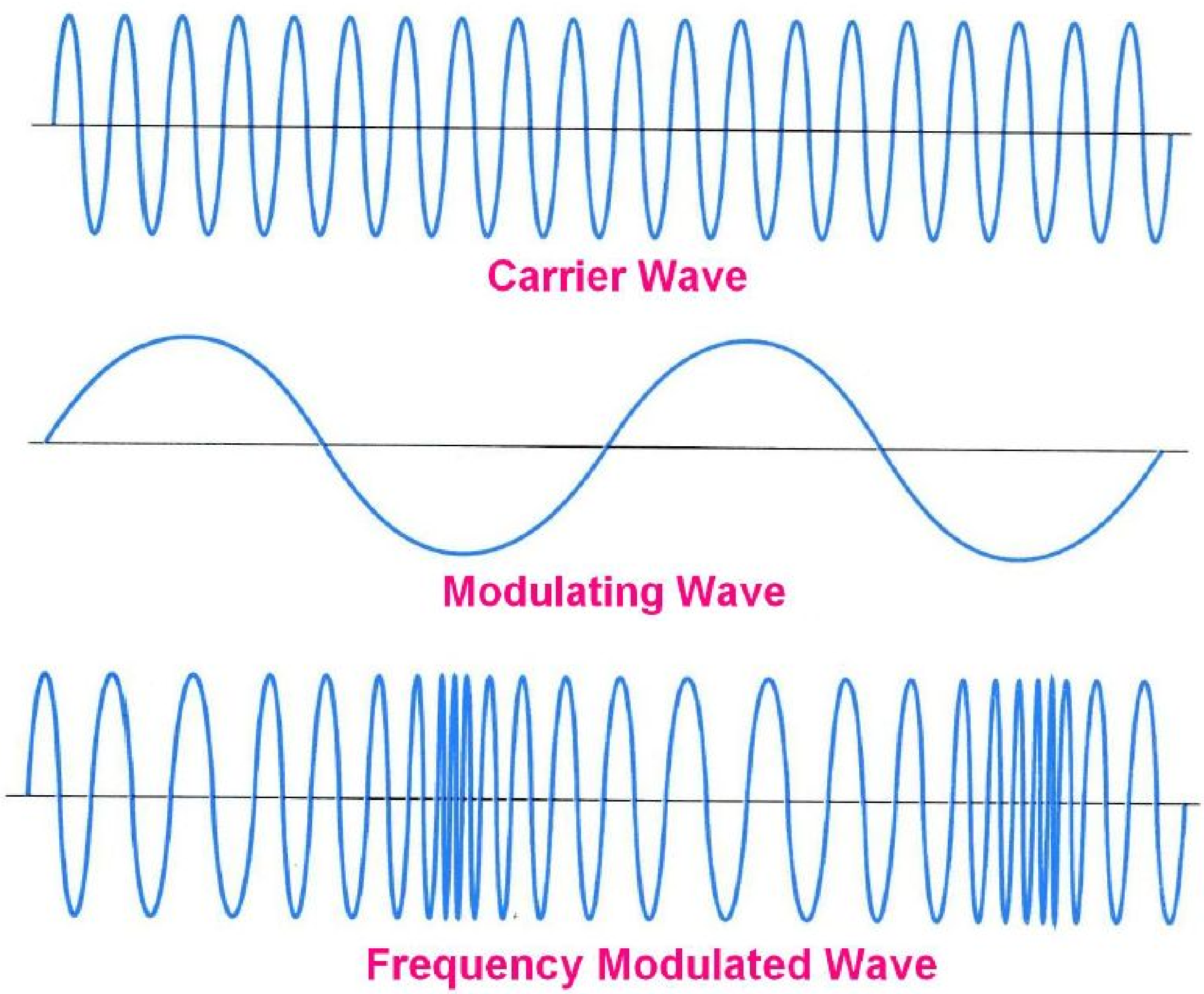
Experiment No: 6 **Date:**

Aim: To study frequency modulation and demodulation and observe the waveforms.

a) **Observe the spectra of FM signal in labAlive virtual communication lab and Calculate the modulation index for FM**
b) **To perform FM transmission via virtual lab labAlive for the audio signal**
c) **To perform FM reception via virtual lab labAlive for the obtained recorded signal**

Frequency Modulation (FM):

The frequency of the carrier waveform varies with the information signal



Frequency modulation is a system in which the amplitude of the modulated carrier is kept constant, while its frequency is varied by the modulating signal, the modulating signal is sinusoidal. This signal has two important parameters which must be represented by the modulation process without distortion: namely its amplitude and frequency.

If carrier signal, $e_c = E_c \sin sin\ \omega_c t$ and modulating signal, $e_m = E_m \sin sin\ \omega_m t$ then, the peak or maximum frequency deviation:

$\Delta f\ \alpha\ \ e_m$

$\Delta f = k_f e_m$

Where, k_f is proportionality constant[V/Hz], and e_m is the instantaneous value of the modulating signal amplitude. Thus the frequency of the FM signal is:

$$e_s\,(t) = e_c + \Delta f = e_c + k_f e_m(t)$$

$$\text{Then,}\quad e_s\,(t) = e_c + k_f E_m \sin sin\ \omega_m t$$

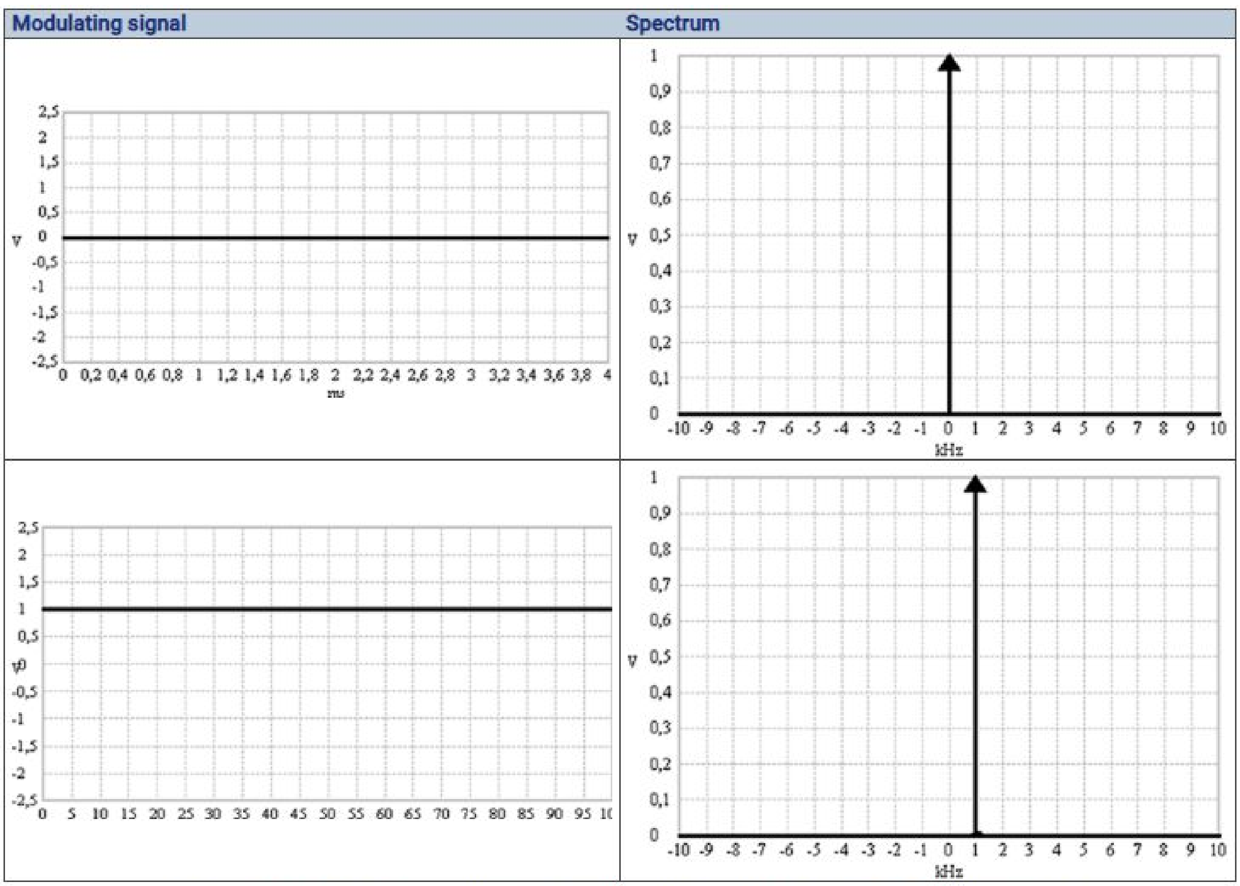
Then the equation for the FM signal is:

$$e_s\,(t) = E_c \sin sin\ (\omega_c t + \beta\ \ \sin sin\ \omega_m t\ )$$

Where, β = modulation index, which can be greater than 1. It is measured in radians

β = Freq. Deviation / Modulating Freq.

$$\beta = \frac{\Delta f}{f_m}$$

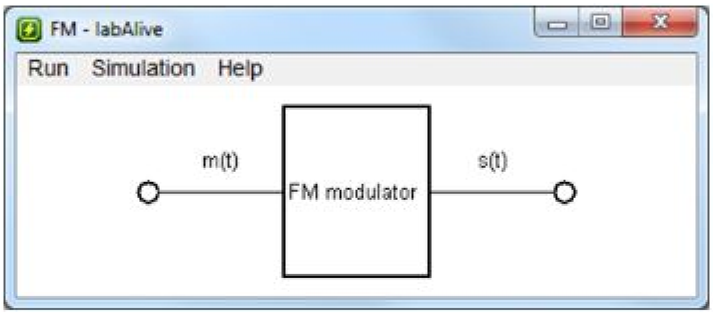


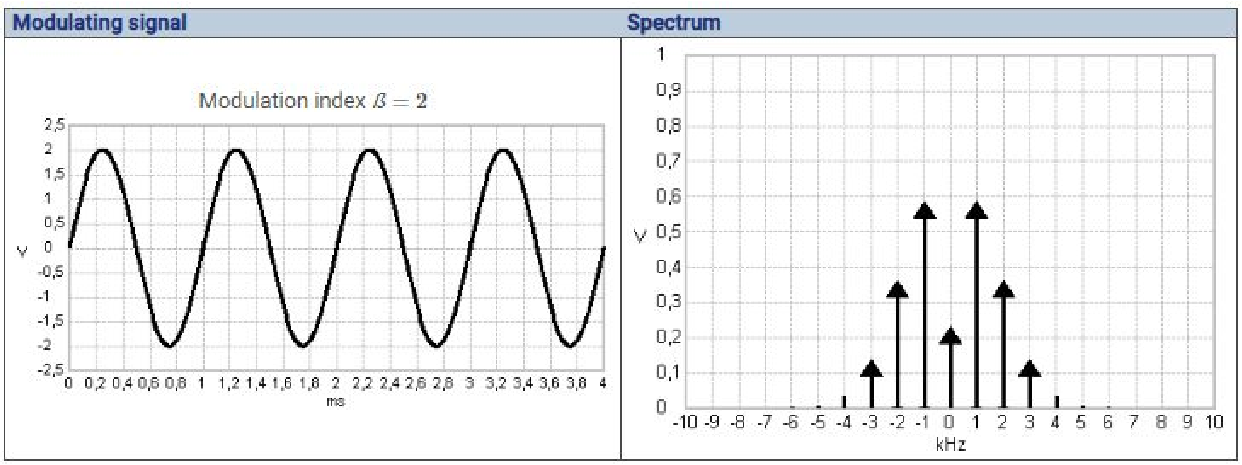
Frequency modulation example - frequency deviation is 1 kHz for a 1V-DC modulating signal

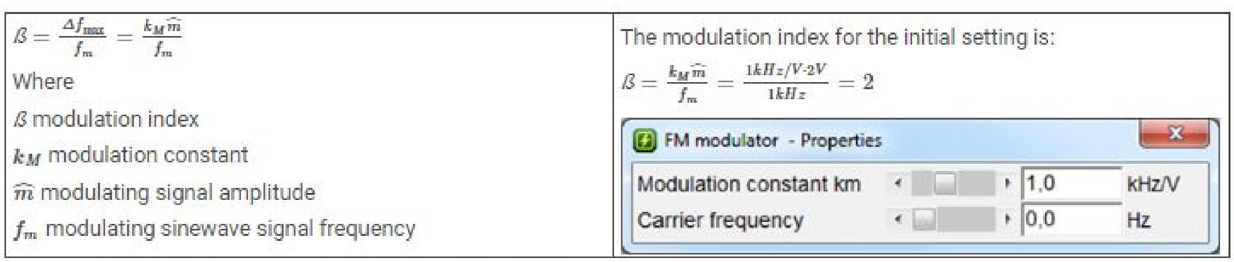
Part a): In this experiment a sinewave signal is frequency modulated. Modulating signal and modulator parameters determine the spectrum of the resulting FM transmission signal.

Procedure:

- On launching the experiment, you will see the following windows:



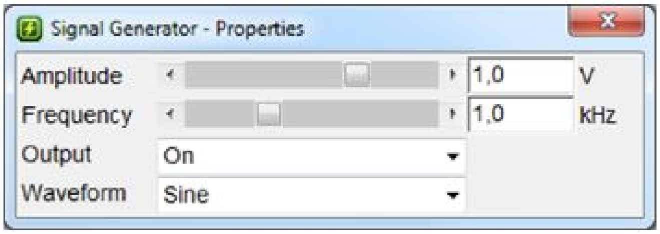




The modulation index β is the ratio of the maximum frequency deviation of the carrier to the frequency of the sinewave modulating signal.

The Bessel function values at the resulting modulation index determine the spectrum of the FM signal.

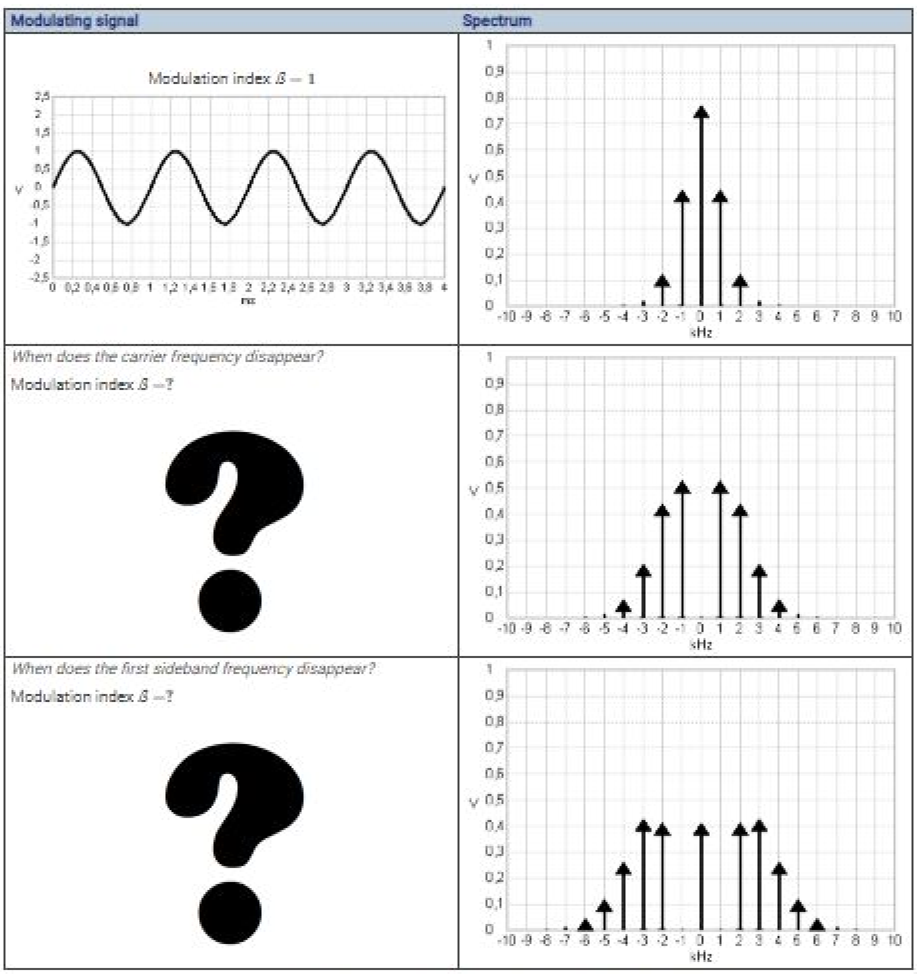
- Vary the modulating signal amplitude $\hat{m}$.



- The modulation index is proportional to the modulating signal amplitude. In this setting the amplitude in Volts is the modulation index:

$$\beta = \frac{\Delta f}{f_m} = \frac{k_f \hat{m}}{f_m} = \frac{\frac{1kHz}{V} \times \hat{m}}{1kHz} = \frac{\hat{m}}{V}$$

- The adjusted modulating signal amplitude determines the spectral amplitudes of the carrier and sideband frequencies. For some values the carrier or specific sideband frequencies disappear. This relates to zero crossings of the respective Bessel function at the corresponding modulation index.



FM signal spectra for sinewave modulation with different modulation indices.

The carrier frequency is 0 Hz in this setting. It might be changed via the modulator properties.

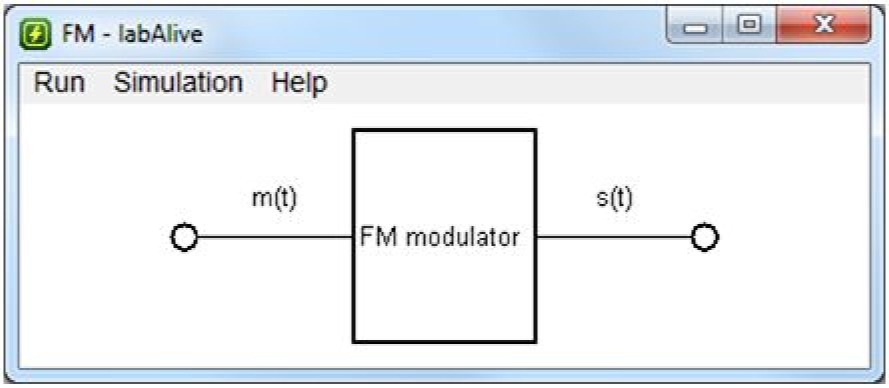
NEXT STEPS

- When do the 2nd and 3rd sideband frequencies disappear?

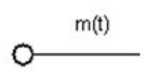
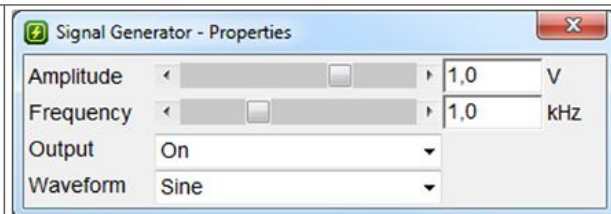
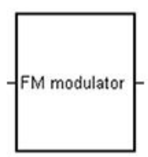
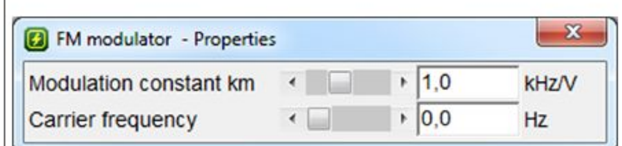
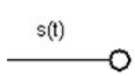
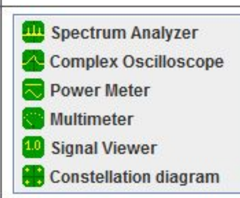
  ____

- Vary the modulating sinewave signal frequency.
- Select different waveforms (signal generator properties) and regard the FM spectrum.
- Use the Bessel functions to determine the spectrum of an FM signal with $\beta = 3$

This simulation implements frequency modulation. The FM signal is generated for the chosen modulating signal. Its spectrum is shown in a spectrum analyzer. All parameters of the modulating signal and modulator can be adjusted.



To change the different settings click on the corresponding wiring:

Adjust parameters of input signal 	
Adjust parameters of FM modulator Left click on FM modulator: 	
Open measure for transmission signal Right click on s(t): 	

Adjust parameters of FM

- Click on the launch tab on the link https://www.etti.unibw.de/labalive/experiment/fm/

- Change the amplitude and frequency of the modulating signal, observe the spectra (attach the output waveforms you observe) and complete the following observation table.
- Note down the frequency deviation from the spectra of FM signal as suggested in the figures below

Reference: Communication Systems by Simon Haykin, 4^{th} edition. Refer Example 2.2 on page 116-117.

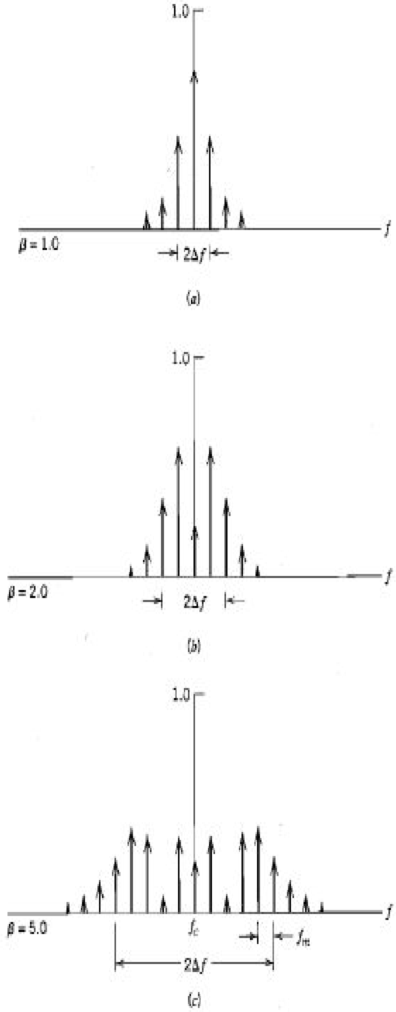


FIGURE 2.24 Discrete amplitude spectra of an FM signal, normalized with respect to the carrier amplitude, for the case of sinusoidal modulation of fixed frequency and varying amplitude. Only the spectra for positive frequencies are shown.

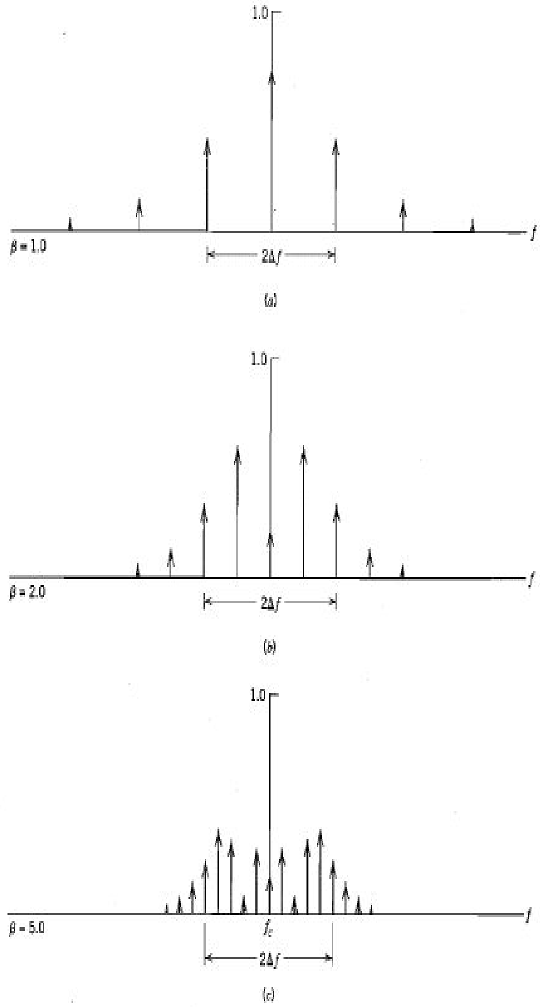


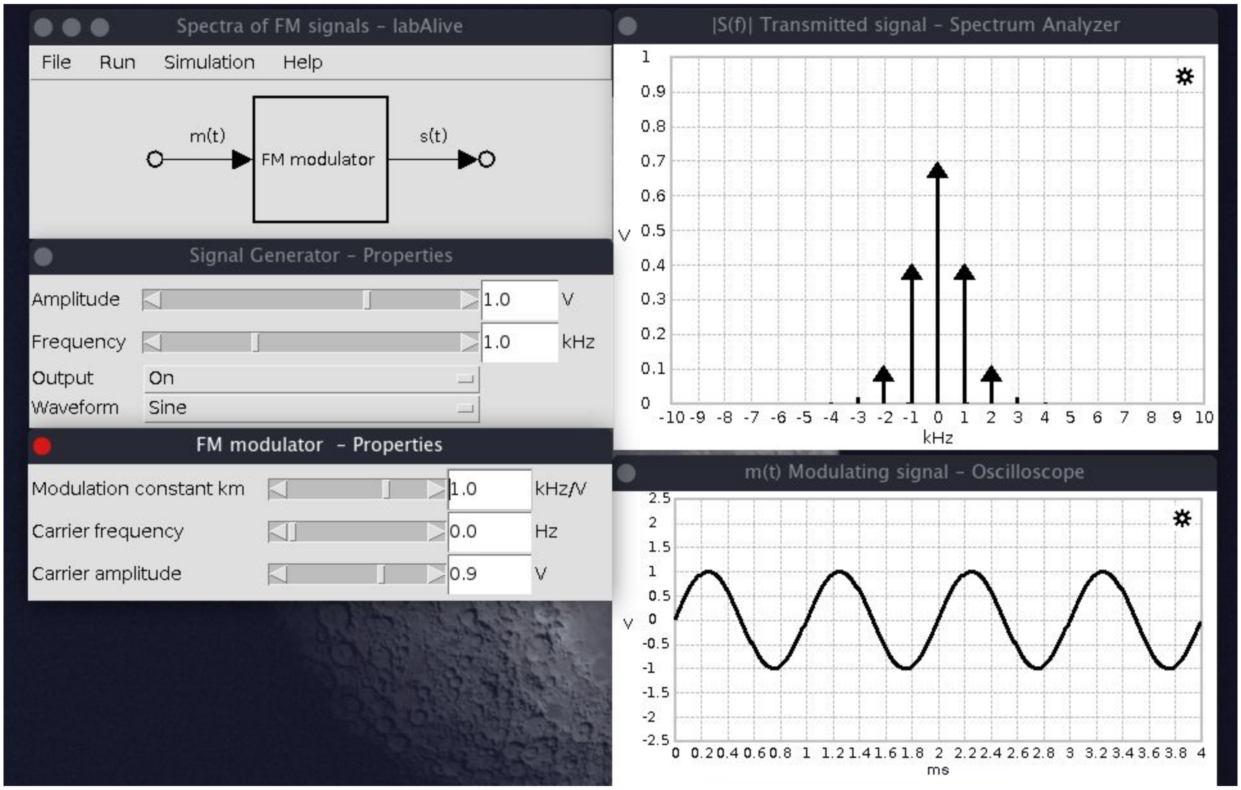
FIGURE 2.25 Discrete amplitude spectra of an FM signal, normalized with respect to the carrie amplitude, for the case of sinusoidal modulation of varying frequency and fixed amplitude. Only the spectra for positive frequencies are shown.

Sr. no	**Modulating Signal frequency, f_m**	**Modulating signal amplitude, $\hat{m}$**	**Frequency Deviation, Δf**	**Modulation Index, $\beta = \frac{\Delta f}{f_m}$**
1	1kHz	1.0V	1.0	1
		2.0V	2.0	2
2	2kHz	2.0V	3.0	1.5
		3.0V	4.5	2.25
3	3kHz	3.0V	9	3
		2.0	6	2

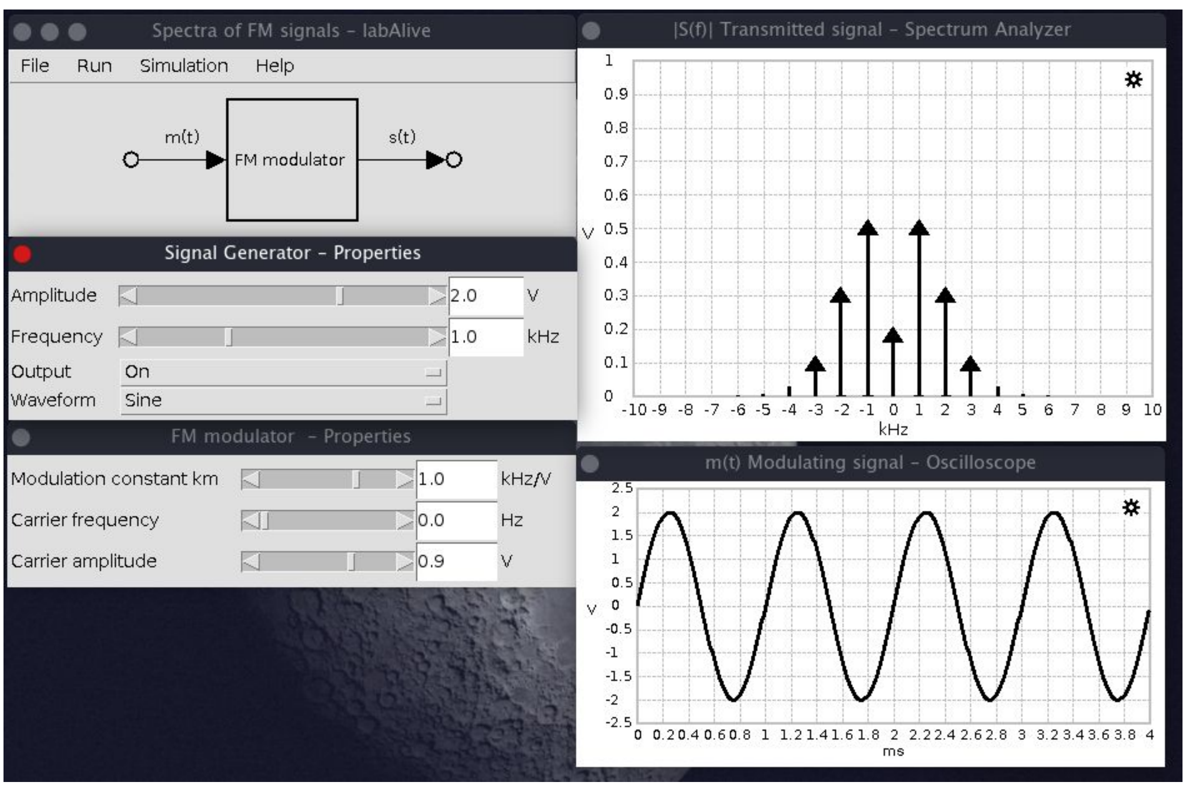
Follow this link for detailed procedure and setup

https://youtu.be/THzJ6bjf1HI, https://www.etti.unibw.de/labalive/experiment/fm/

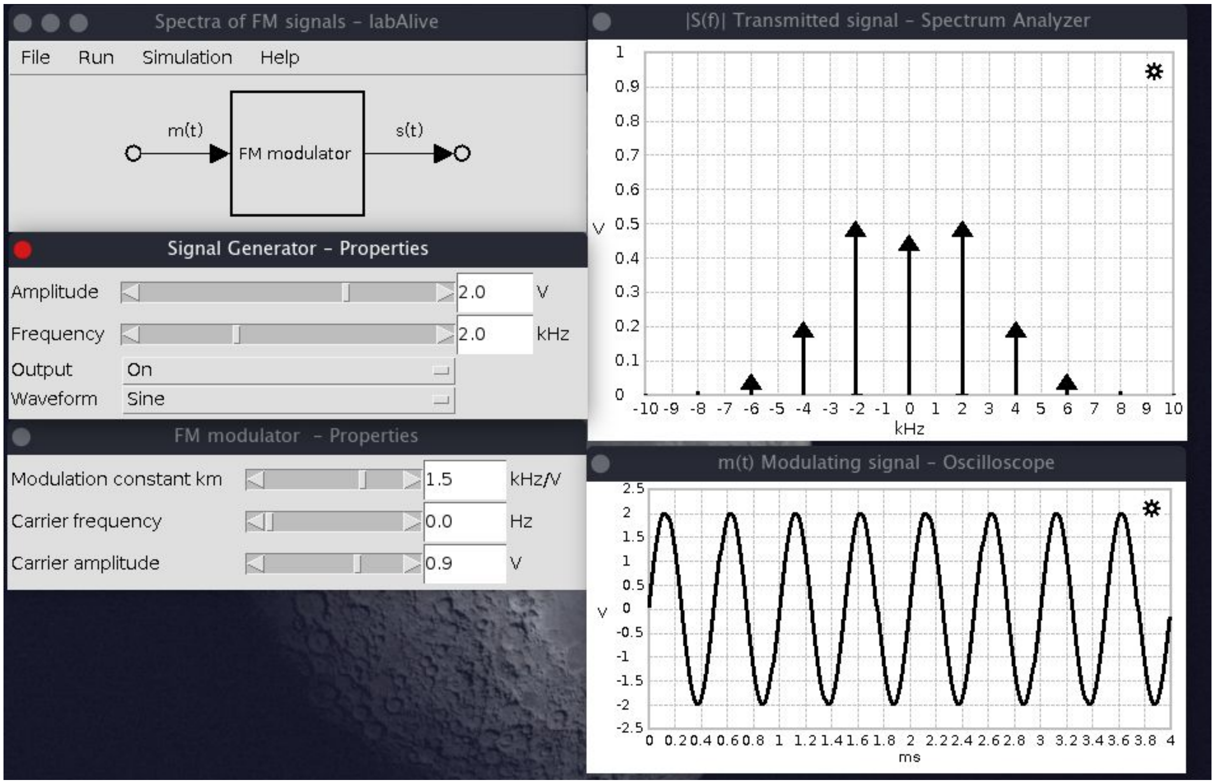
Output Waveforms:



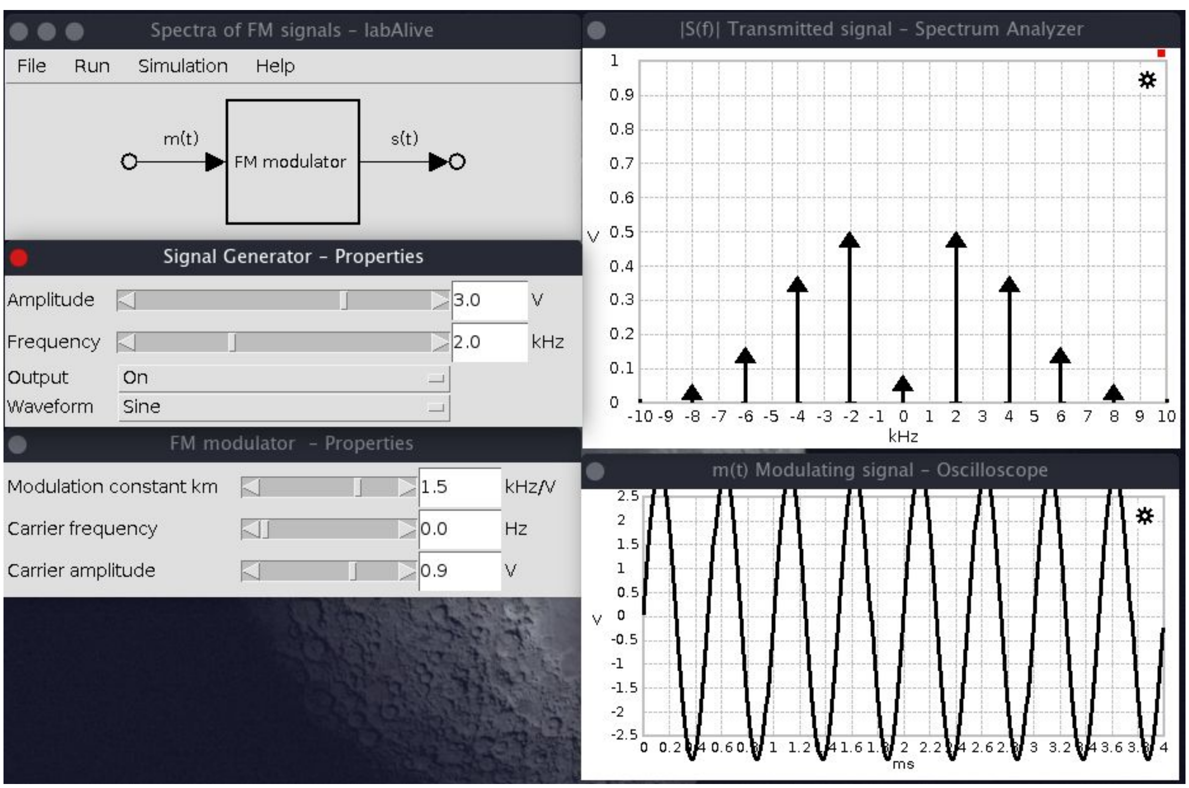
fm = 1kHz m=1.0V Beta=1



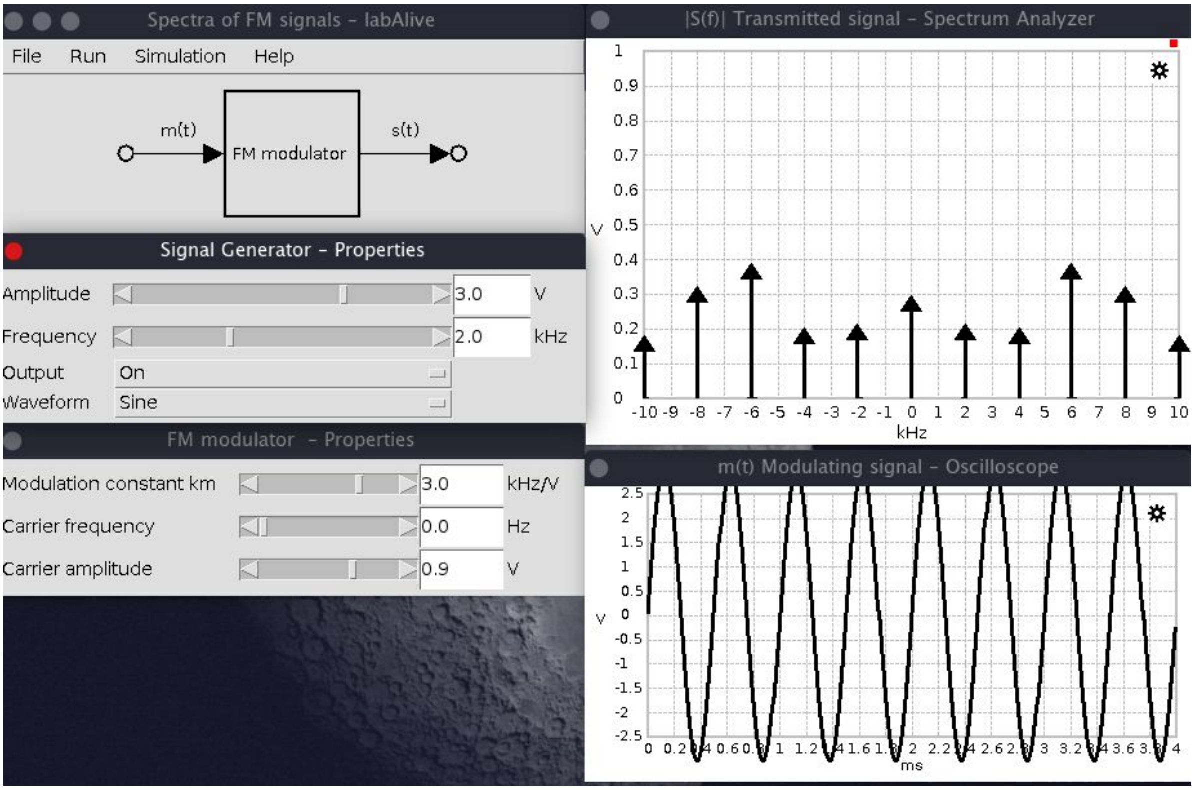
fm = 1kHz m=2.0V Beta=2



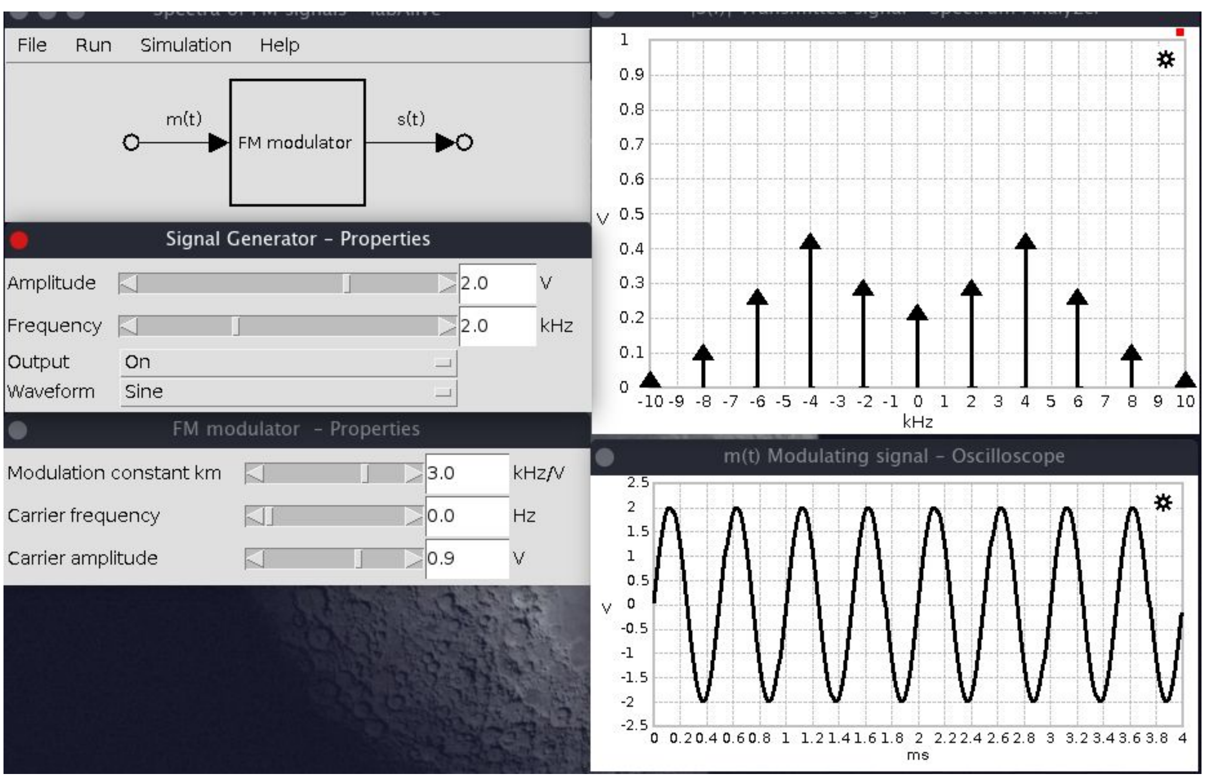
fm = 2kHz m=2.0V Beta=1.5



fm = 2kHz m=3.0V Beta=2.25



fm = 3kHz m=3.0V Beta=3

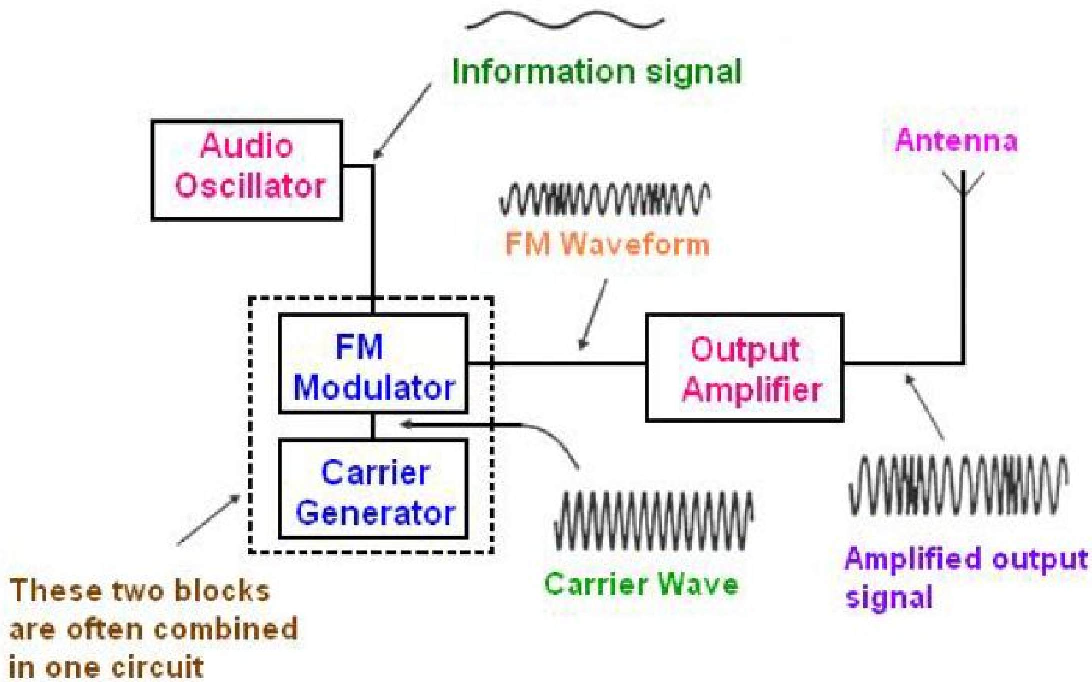


fm = 3kHz m=2.0V Beta=2

Part b) To send an audio file via FM transmission link

FM Transmitter:

The block diagram is shown in figure.



Procedure:

START

Initially a music signal provided by the server is frequency modulated. You might select your own audio file in the format 44.1kHz, 16 bit, stereo or the microphone *Line in*.

SET FREQUENCY DEVIATION

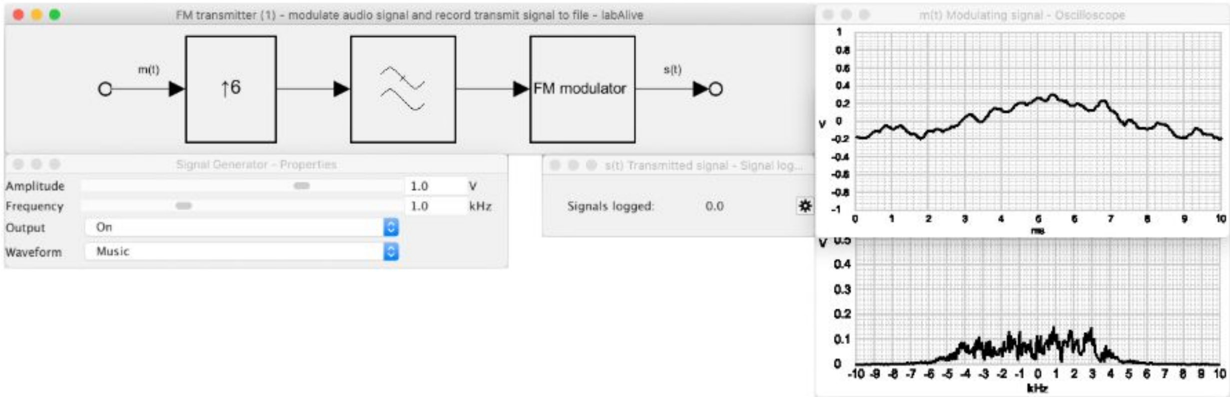
Increase the signal generator's amplitude so that the frequency deviation, i.e. the maximum shift away from the carrier frequency, is 75 kHz. In this base band simulation the carrier frequency is set to 0 Hz.

RECORD THE FM MODULATED SIGNAL TO A FILE

Open the settings of the signal logger - click the gear wheel settings icon. Click *Start save samples to file* to record the transmitted signal to a file.

DEMODULATE THE FM MODULATED SIGNAL

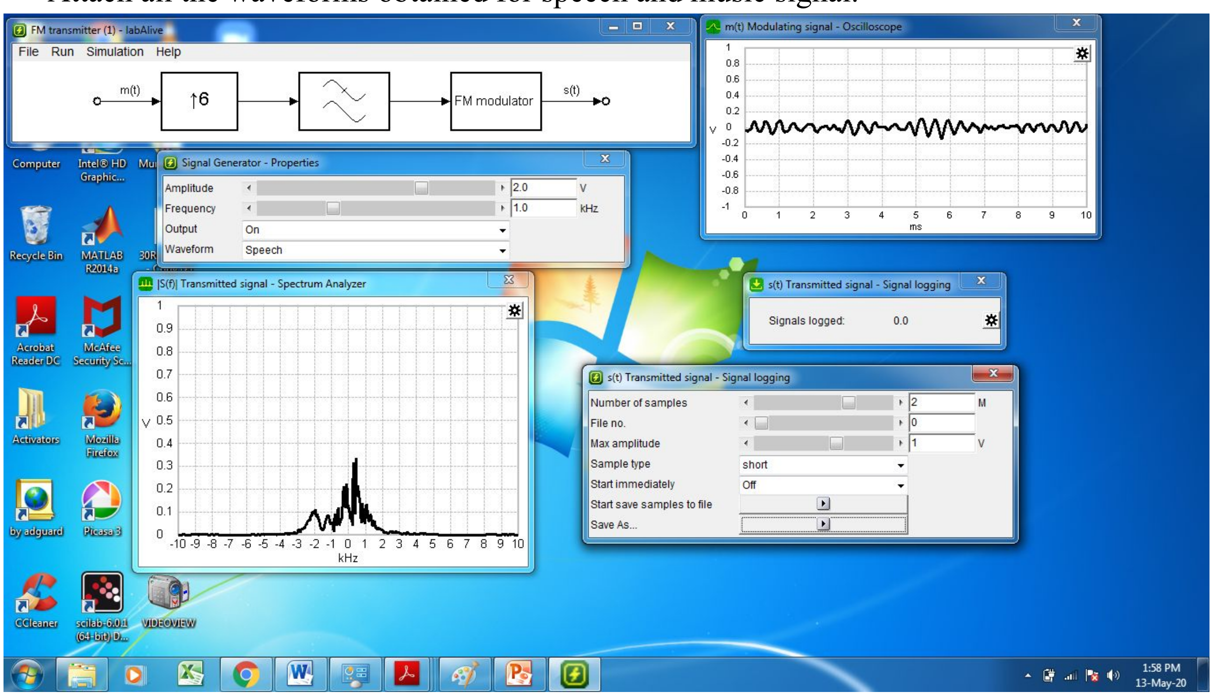
Go the the FM receiver and demodulate the FM transmitted signal.



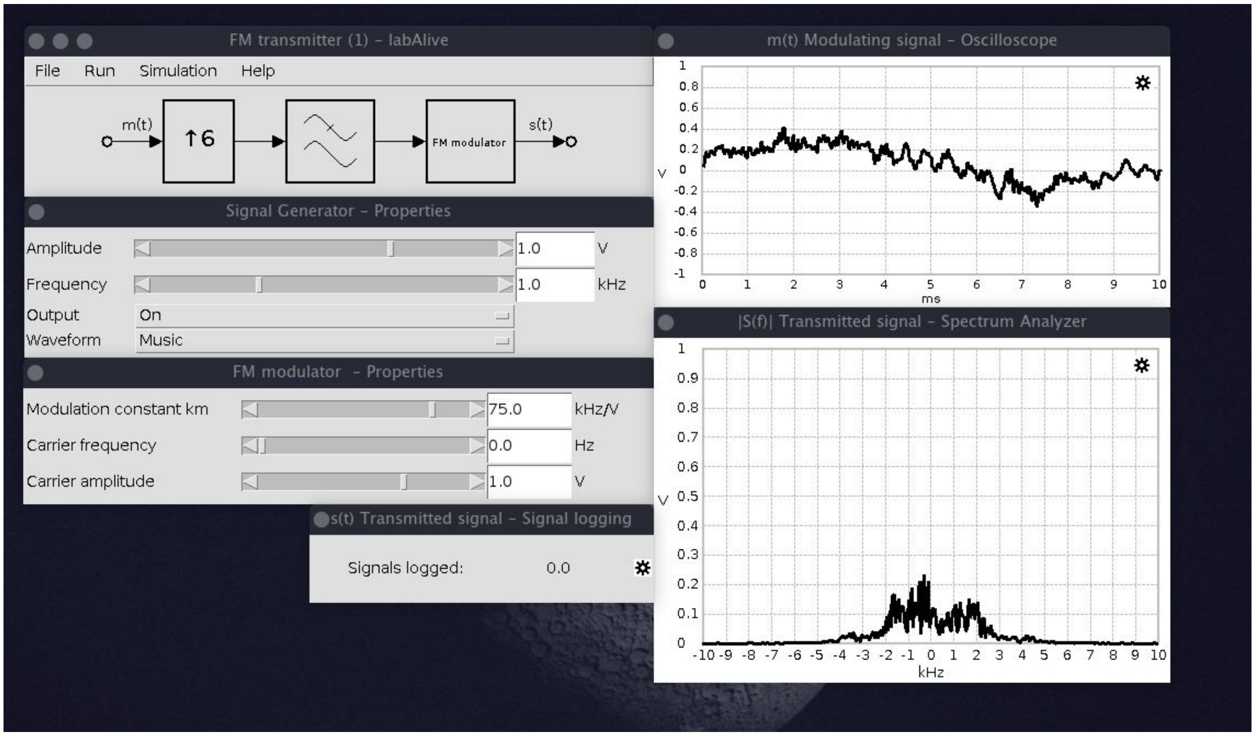
FM transmitter - modulate an audio signal and record the transmit signal to file.

Notes:

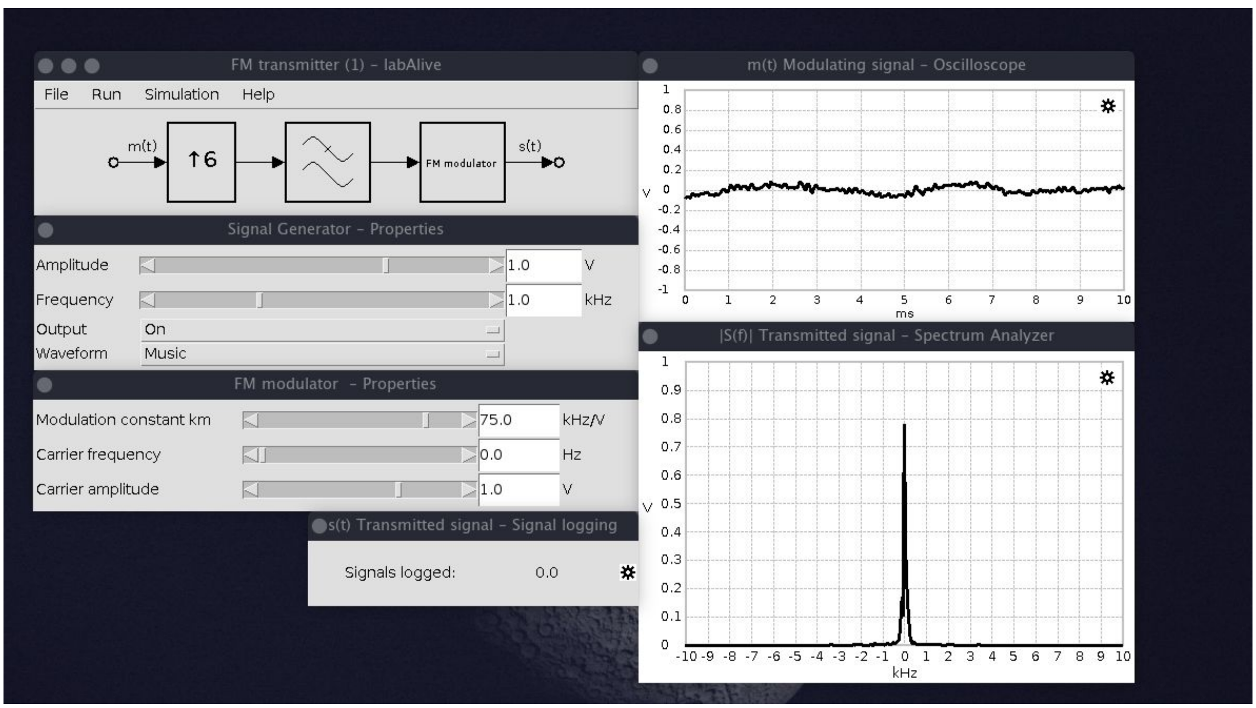
- You may modify the input signal from the signal generator properties
- Varying the frequency and amplitude of input signal will change frequency deviation.
- To save the samples, click on the settings icon in signal logging window and save it. You will use this same file for reception.
- You can scale the graph by clicking on setting icon in modulating signal window and frequency spectrum analyser window.
- Attach all the waveforms obtained for speech and music signal.



Output Waveforms:



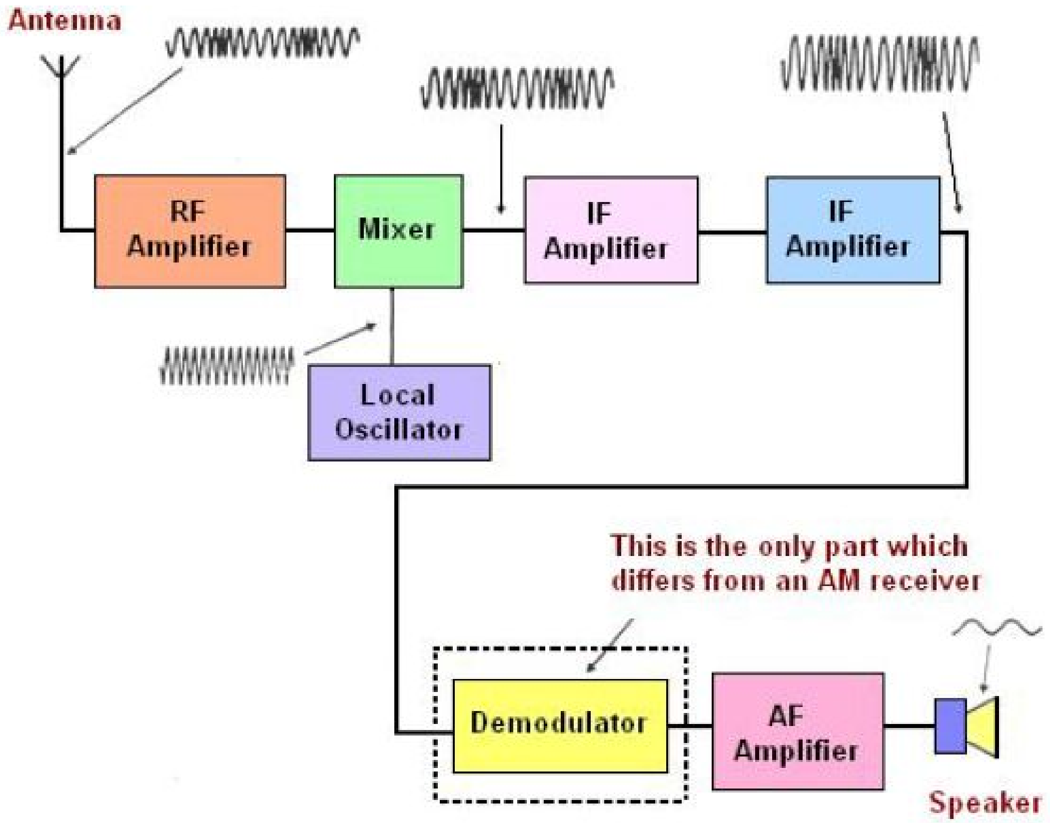
FM transmitter (1) - labAlive
File Run Simulation Help
m(t)
↑6
FM modulator
s(t)
Signal Generator - Properties
Amplitude 1.0 V
Frequency 1.0 kHz
Output On
Waveform Music
FM modulator - Properties
Modulation constant km 75.0 kHz/V
Carrier frequency 0.0 Hz
Carrier amplitude 1.0 V
s(t) Transmitted signal - Signal logging
Signals logged: 0.0
m(t) Modulating signal - Oscilloscope
|S(f)| Transmitted signal - Spectrum Analyzer



FM transmitter (1) - labAlive
File Run Simulation Help
m(t)
↑6
FM modulator
s(t)
Signal Generator - Properties
Amplitude 1.0 V
Frequency 1.0 kHz
Output On
Waveform Music
FM modulator - Properties
Modulation constant km 75.0 kHz/V
Carrier frequency 0.0 Hz
Carrier amplitude 1.0 V
s(t) Transmitted signal - Signal logging
Signals logged: 0.0
m(t) Modulating signal - Oscilloscope
|S(f)| Transmitted signal - Spectrum Analyzer

Part C): To receive an audio file via FM receiver.

FM receiver:



FM Receiver

Procedure:

START

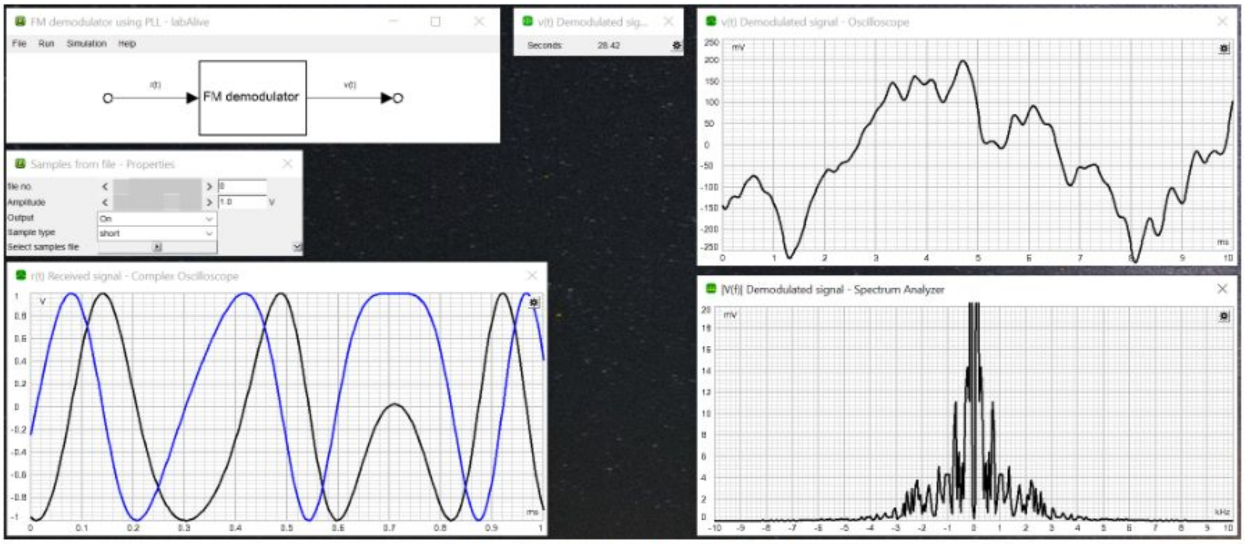
Select the file of the FM modulated signal you created with the FM transmitter.

LISTEN TO THE DEMODULATED SIGNAL

Enjoy the demodulated audio signal. It should be fine if you modulated the audio signal properly. If it's too quiet or distorted analyze if the frequency deviation is too large or too small.

VARY FREQUENCY DEVIATION AND CREATE DIFFERENT FM MODULATED SIGNALS

Vary the modulating signal's amplitude and thus also the frequency deviation using the FM transmitter.

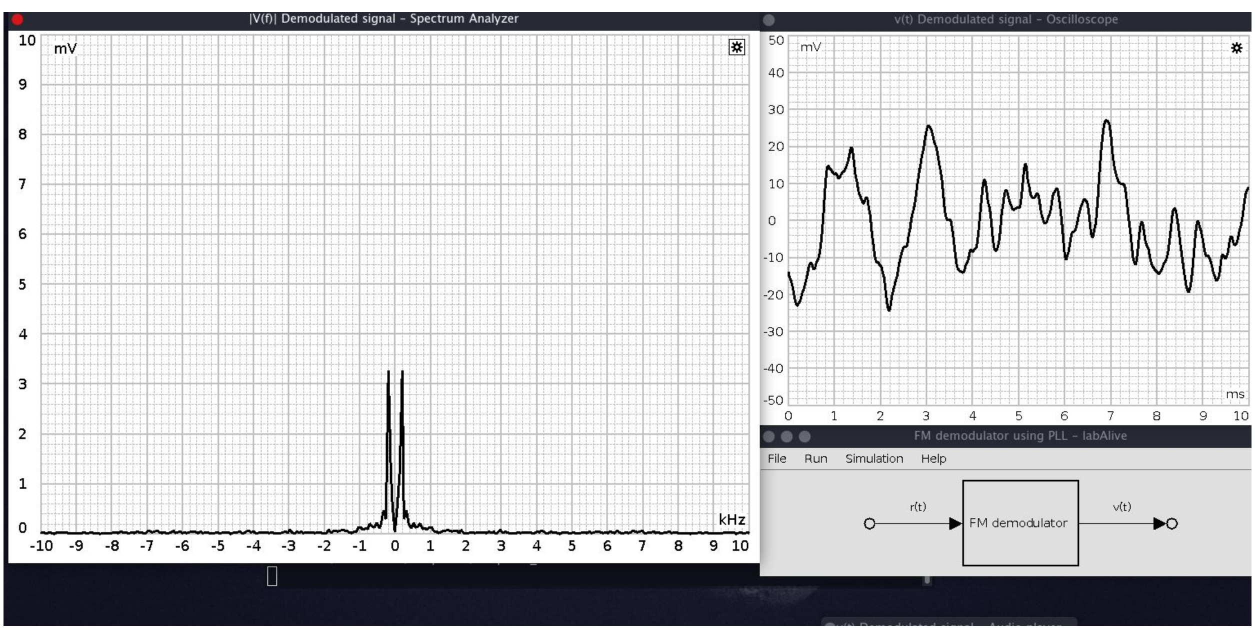


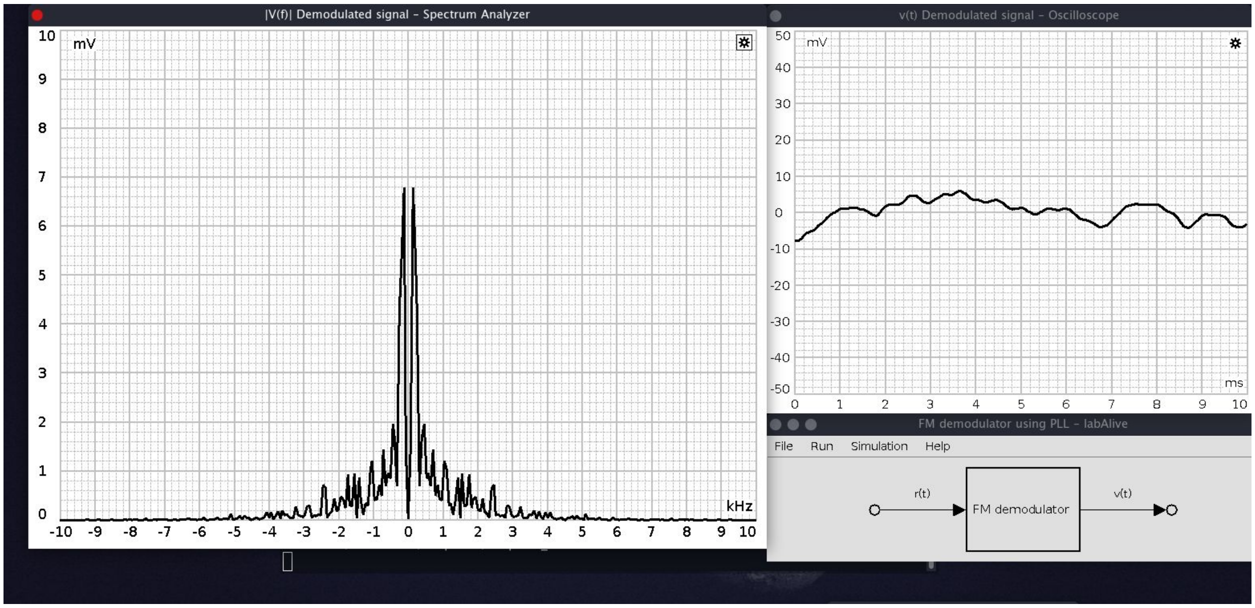
FM receiver using a PLL demodulator.

Notes:

- In the signal logging window, change the sample type to double and number of samples to 1G if you're not able to save the file.
- Listen to received audio signal and change the parameter values in modulator and demodulator block to listen the beat if hissing sound is coming.
- Take the screenshots of the graphs observed and paste it in the output waveforms

Output Waveforms:





Conclusion:

In this experiment, we have observed and studied the Spectrum of an FM signal using labAlive. We also performed FM Modulation and Demodulation of audio signals for various transmission parameters like Fm, Modulation Index, Message Signal Amplitude and observed their generated spectra.

Remark **Signature**