Introduction

This laboratory illustrates the superheterodyne concept. AM and FM systems in presence of channel noise are then qualitatively studied. Objective is to analyze the noise effects in the demodulated speech signal and find the maximum threshold beyond which system behavior deteriorates.

The ratio of the signal power to the noise power in a noisy communication system is called Signal-to-Noise Ratio (SNR). Measuring SNR is the objective of the laboratory.

SNR is usually given as the ratio of powers and can be expressed as:

$$\frac{S}{N} = 10\ \log_{10}\left[\frac{Power\ of\ message\ signal}{Power\ of\ noise\ signal}\right]\ [dB]$$

If the message signal is present then so is the noise signal, i.e., message signal is not available alone. Hence SNR can be expressed as:

$$\frac{S+N}{N} = 10\ \log_{10}\left[\frac{Power\ of\ message\ signal\ plus\ noise\ signal}{Power\ of\ noise\ signal}\right]\ [dB]$$

In a laboratory environment, controllable noise signals are used to corrupt the message signal. It is the receiver system's responsibility to compensate for this distortion as much as possible and recover the message signal. Performance of the receiver system can be evaluated based on the SNR of the system. Observe that $[Power\ of\ message\ signal]$ is equal to $[RMS\ voltage\ of\ message\ signal]^2$ and $[Power\ of\ noise\ signal]$ is equal to $[RMS\ voltage\ of\ noise\ signal]^2$. Therefore, SNR can be expressed as:

$$\frac{S}{N} = 20\ \log_{10}\left[\frac{RMS\ voltage\ of\ message\ signal}{RMS\ voltage\ of\ noise\ signal}\right]\ [dB]$$

A.6 – Superheterodyne receiver, AM and FM with Noise and Signal-to-Noise Ratio

A.6.1. Experimental Setup for Superheterodyne System

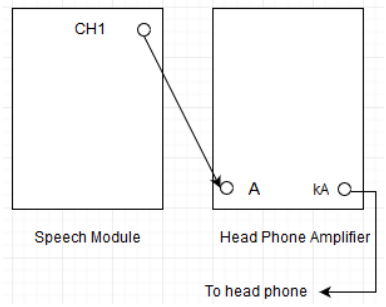

Figure A.6.1.a: Setup to verify recorded speech signal.

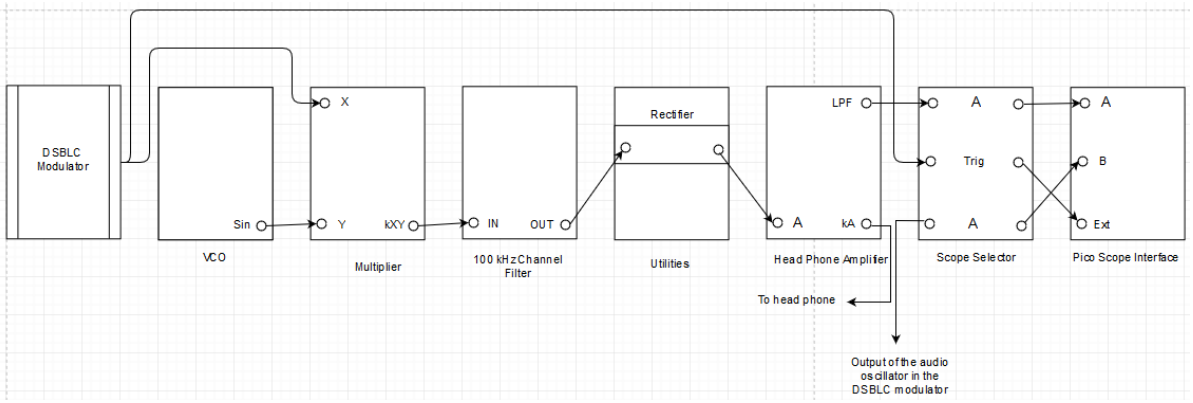

Figure A.6.1.b: Setup for receiver system.

A.6.2. Laboratory Exercise for Superheterodyne System

i. Toggle the front panel switch of CH1 of the speech module to record, speak into the mic of the speech module and toggle the front panel switch of CH1 of the speech module to play. Verify the recorded speech signal as shown in Figure A.6.1.a.

ii. Make the DSBLC modulator setup with modulation index of 1 and make the receiver system as shown in Figure A.6.1.b.

iii. Toggle the on board switch-SW2 of the VCO to VCO, toggle the front panel switch of the VCO to LO, toggle the front panel switch of the multiplier at the receiver to DC, toggle the front panel switch of the 100 kHz channel filters to DC and toggle the front panel switch of the headphone amplifier to IN. Turn the frequency knob of the VCO to minimum and turn the knob of the 100 kHz channel filters to position 2.

iv. Observe that the receiver system is a combination of the superheterodyne system and the DSBLC demodulator.

v. Adjust the frequency knob of the VCO to obtain the demodulated message signal.

vi. Observe that this ensures demodulation is successful for the given receiver system.

vii. Turn the frequency knob of the VCO to minimum.

viii. Unplug the signal from output of the audio oscillator to input of the multiplier at the modulator. Plug the signal from output of CH1 of the speech module to input of the multiplier at the modulator.

ix. Observe that the speech signal is modulated with DSBLC modulation process.

x. Listen to the demodulated speech signal with the headphone. Adjust the volume at the headphone amplifier if required. Increase the frequency knob of the VCO from minimum to maximum.

xi. Observe the changes in the demodulated speech signal. What do they signify?

xii. Toggle the front panel switch of the VCO to HI. Repeat step **vii** through step **xi**, accordingly.

A.6.3. Experimental Setup for Noise Analysis of AM System

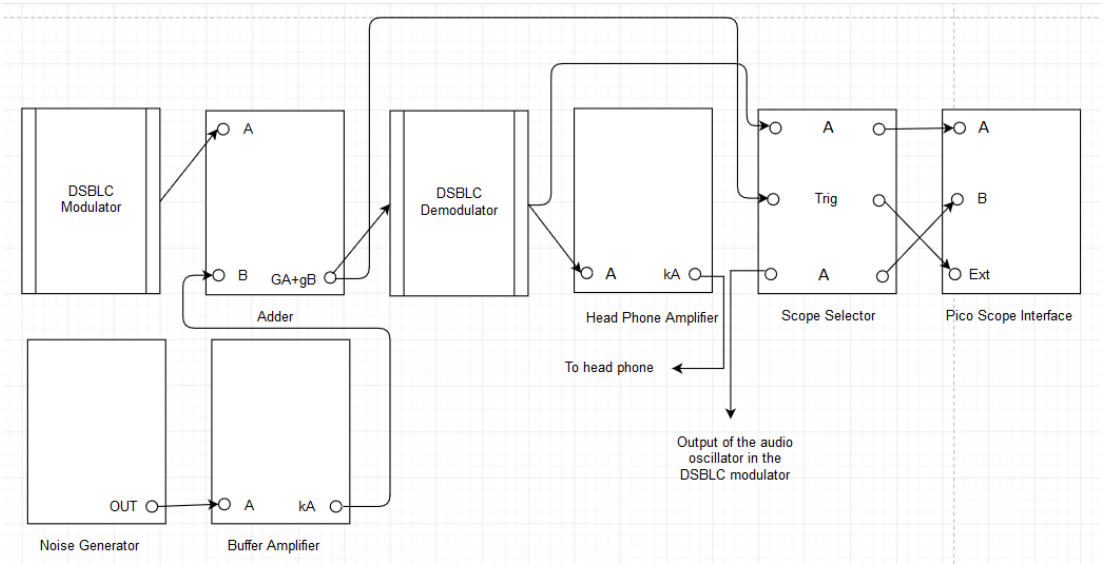

Figure A.6.2: Setup for noise analysis of AM system.

A.6.4. Laboratory Exercise for Noise Analysis of AM System

i. Record a speech signal with the speech module.

ii. Make the setup as shown in Figure A.6.2.

iii. Toggle the front panel switch of the headphone amplifier to IN. Turn the knob of the buffer amplifier midway, turn the noise signal at the channel adder to minimum, turn the modulated signal at the channel adder to maximum and turn the knob of the noise generator to 0 dB.

iv. For modulation index of 1, verify the demodulation process.

v. Unplug the signal from output of the audio oscillator to input of the multiplier. Plug the signal from output of CH1 of the speech module to input of the multiplier.

vi. Listen to the demodulated speech signal with the headphone. Adjust the volume at the headphone amplifier if required. Turn the noise signal at the channel adder to maximum.

vii. Tabulate the observations for modulation index of 1 and noise level of 0 dB, +4 dB, +8 dB, +12 dB, +16 dB and + 20 dB.

viii. Tabulate the observations for noise level of +6 dB and modulation index of 0, 0.4, 0.8 and 1.

A.6.5. Experimental Setup for Noise Analysis of FM System

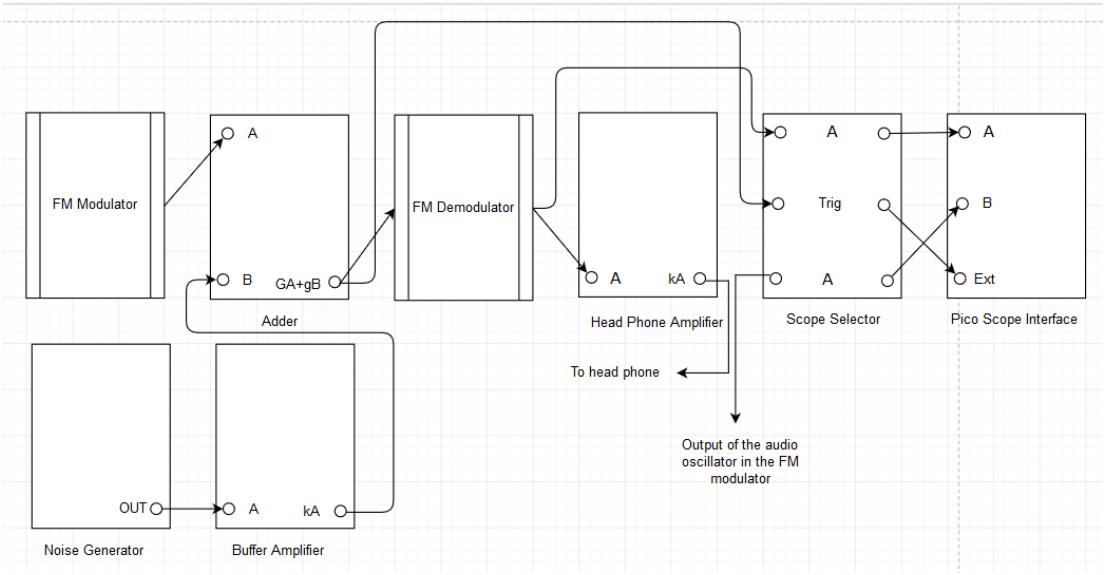

Figure A.6.3: Setup for noise analysis of FM system.

A.6.6. Laboratory Exercise for Noise Analysis of FM System

i. Record a speech signal with the speech module.

ii. Make the setup as shown in Figure A.6.3.

iii. Toggle the front panel switch of the headphone amplifier to IN. Turn the knob of the buffer amplifier to midway, turn the noise signal at the channel adder to minimum, turn the modulated signal at the channel adder to maximum and turn the knob of the noise generator to 0 dB.

iv. For modulation index of 1.45, verify the demodulation process.

v. Unplug the signal from output of the audio oscillator to input of the VCO at the modulator. Plug the signal from output of CH1 of the speech module to input of the VCO at the modulator.

vi. Listen to the demodulated speech signal with the headphone. Adjust the volume at the headphone amplifier if required. Turn the noise signal at the channel adder to maximum.

vii. Tabulate the observations for modulation index of 1.45 and noise level of 0 dB, +4 dB, +8 dB, +12 dB, +16 dB and + 20 dB.

viii. Tabulate the observations for noise level of +6 dB and modulation index of 0.3, 1.45, 2.45 and ≈ 5.

A.6.7. Signal-to-Noise Ratio

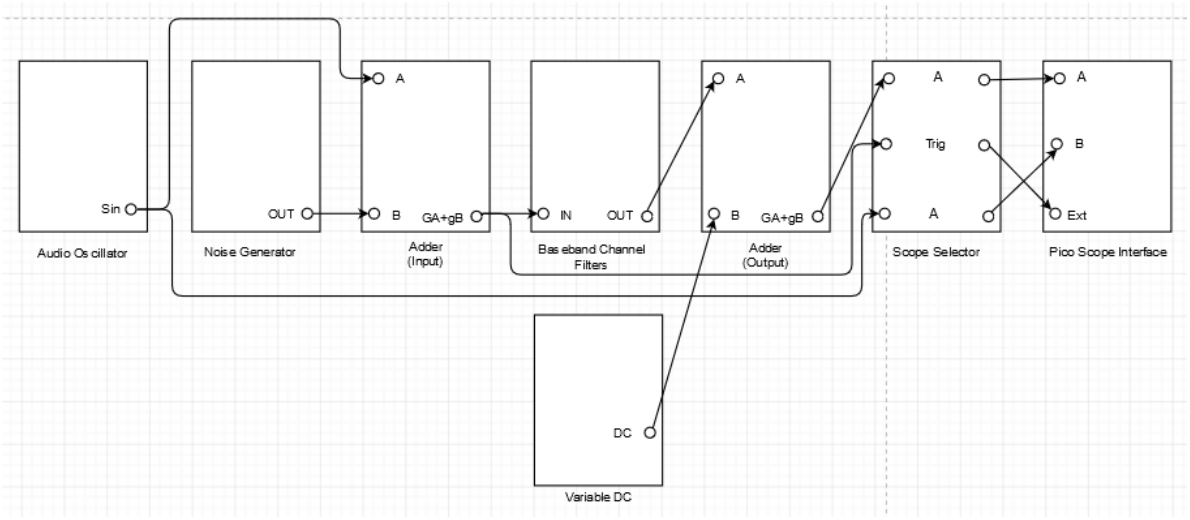

Figure A.6.4: Setup for noisy communication system.

NOTE: Above given experimental setup consists of two adders, i.e., input adder and output adder.

A.6.8. Laboratory Exercise for SNR

- **i.** Set an audio oscillator to generate 1 kHz sine signal.
- **ii.** Make the setup as shown in Figure A.6.4.
- **iii.** Toggle the front panel switch of the baseband channel filters to DC. Turn the knob of the noise generator to +22 dB, turn the knob of the baseband channel filters to position 1, turn the knob of the variable DC to minimum, turn both the knobs of the input adder to maximum and turn both the knobs of the output adder to maximum.
- **iv.** Unplug the signal from output of the audio oscillator to input of the input adder, i.e., current setup has noise signal.
- **v.** Adjust the knob of the variable DC to shift the noise signal to DC.
- **vi.** Adjust the noise signal at the output adder to obtain the noise signal with TRUE RMS as 1 V.
- **vii.** Take a screenshot of the output adder and output of the audio oscillator under the scope mode.
- **viii.** Turn the knob of the baseband channel filters to position 4 to obtain the noise signal with new TRUE RMS voltage. What does it signify?
- **ix.** Take a screenshot of the output adder and output of the audio oscillator under the scope mode.
- **x.** Unplug the signal from output of the noise generator to input of the input adder. Plug the signal from output of the audio oscillator to input of the input adder, i.e., current setup has message signal.

xi. Adjust the message signal at the input adder to obtain the message signal TRUE RMS voltage equal to the noise signal TRUE RMS voltage as obtained in step **viii**.

xii. Calculate the $\frac{S}{N}$.

xiii. Take a screenshot of the output adder and output of the audio oscillator under the scope mode.

xiv. Plug the signal from output of the noise generator to input of the input adder, i.e., current setup has message signal and noise signal.

xv. Calculate the $\frac{S+N}{N}$.

xvi. Take a screenshot of the output adder and output of the audio oscillator under the scope mode.

xvii. Repeat step **x** through step **xvi** twice, for increased message signal, accordingly.

xviii. Plot and analyze the graphs for SNRs [dB] vs. message signal [dB].