LABORATORY MANUAL
COMMUNICATIONS LABORATORY
EE 321

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DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
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Experiment 1

Part 1: Exercise 1-2 (Familiarization with the AM Equipment)
Part 2: Exercise 1-3 (Frequency Conversion of Baseband Signals)

Equipment Required

RF NOISE GENERATOR	FREQUENCY COUNTER	
AM/DSB/SSB GENERATOR	AM/DSB RECEIVER	
Function Generator A	DUAL AUDIO AMPLIFIER	OSCILLOSCOPE
Function Generator B	POWER SUPPLY	SPECTRUM ANALYZER

Brief description of the equipment:

1) Function generator A and B: These two function generator is used to generator message signals.
2) AM/DSB/SSB GENERATOR: It is used to for amplitude modulation and generator either double side band or single side band waveforms for transmission.
3) RF Noise Generator: This can be used to generate RF noise.
4) Power Supply: It is used to supply power to equipment
5) Dual Audio Amplifier: Use for amplifier signals from the receiver to a proper listening level.
6) AM/DSB Receiver: This equipment receives the amplitude modulated signals and demodulate it before sending it to audio amplifiers
7) Frequency Counter: This equipment can be used for monitoring frequency of signals.
8) Spectrum Analyzer: This equipment is used for displaying signals in frequency base for analysis.
9) Oscilloscope: Use to display waveforms in time domain.

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Part 1: Exercise 1-2 (Familiarization with the AM Equipment)

Purpose: The purpose of this part of the experiment is to get familiar with the AM/DS/SSB Generator and the AM/DSB Receiver. It is also the purpose to get familiar with some terminology used in AM modulation.

Step 1:

This step is to set up the equipment as follow:

FUNCTION GENERATOR A	FREQUENCY COUNTER
Function Generator B	AM / DSB RECEIVER
AM/DSB/SSB GENERATOR	OSCILLOSCOPE
POWER SUPPLY	DUAL AUDIO AMPLIFIER

Set up the equipment in a manner where it will be easy to counter the appropriate modules together. We need to make sure all the level and gain control is set to the minimum to avoid any incidents.

Step2:

Observe the variation as the result of the RF tuning from the AM/DSB/SSB generator. This can be accomplished by looking at the output of the generator at the oscilloscope as the RF tuning frequency is varied. The test is done with the gain and level control at the maximum level.

Step 3:

Find out the upper and lower limits in terms of frequency of the RF Tuning control of the AM/DSB/SSB generator. This can be accomplished by turning the control knob fully counterclockwise to get the lower limit, and fully clockwise to obtain the upper limit.

Result: f_{lower}=

f_{upper}=

Step 4:

Set the carrier frequency to 1000kHz and observe the results of the output due to changes from the FR Gain control and the Carrier Level control. The frequency can be set by connecting the output of the AM/DSB/SSB generator to the frequency counter.

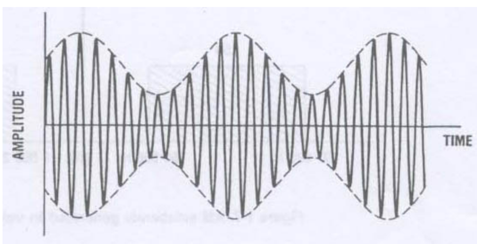
The effects the controls have on the waveform can be observe by the display of the oscilloscope.

Step 5:

Set a message signal of 2kHz with amplitude of 400mVp-p. It can be accomplished by connecting the output of the signal generator to the oscilloscope, adjust the amplitude and the frequency, use the oscilloscope to verify the settings.

Step 6:

Inject the message signal from step 5 into the Audio Input of the AM/DSB/SSB generator and observe the result of the carrier modulated by the message signal from the oscilloscope.



AM waveform

Step 7:

Vary the RF Gain and observe the result of the waveform displayed on the oscilloscope.

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Step 8:

What happens when the carrier level is varied. It can be accomplished by varying the Carrier Level control between min and max position.

Step 9:

Observe the change of the modulated waveform as we vary the frequency of the message signal.

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Step 10:

Adjust the message signal back to 2kHz and set the RF Gain to a one-quarter turn clockwise.

Step 11:

Connect the output of the AM/DSBRF OUTPUT of the Am generator to the RF INPUT OF THE AM/DSB Receiver. Connect the Audio Output of the receiver to the Audio Amplifier. Set the listening level to a comfortable level using headphone. The connections were done by using BNC cables linking the generators to receivers, receivers to amplifiers.

Step 12:

Determine the frequency of the Local Oscillator of the receiver. This can be done by varying the RF tuning control until the signal is the loudest on the headphone.

Result

Step 13:

Determine the f_{lo} for a carrier frequency of 1510kHz. From the relationship $f_{lo} = f_c + f_{IF}$, f_{IF} from Step 12 is determined to be 457kHz from $f_{IF} = f_{lo} - f_c$.

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Step 14:

Adjust fc to 1100kHz. This step can be done by connecting the output of the AM generator and temporary disconnect the Audio Input. Adjust the RF Tuning control to obtain 1100kHz display on the frequency counter.

Step 15:

Reconnect the message signal to the AM generator, readjust he RF gain to the one-quarter counter-clock wise. Retune the receiver to pick up the new broadcast and obtain the Local Oscillator frequency.

Step 16:

Calculate flo – fc for steps 12 and 15.

Result:

Step 12:

Step 15:

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Review Questions:

1) What is amplitude modulation:

2) Sketch an AM waveform, as well as its representation in the frequency domain, label clearly the carrier, envelope, USB and LSB.

3) What are the USB and LSB frequencies for a 960-kHz carrier modulated by a 3-kHz wave?
   f_{USB} = f_{LSB} =
4) What are the two equations showing the relationships between f_{LO}, fc, and f_{IF}?
   1. f_{LO} =
   2. f_{LO} =
5) Which is more useful for the analysis of communications signals, time domain observations or frequency domain observations? Explain.

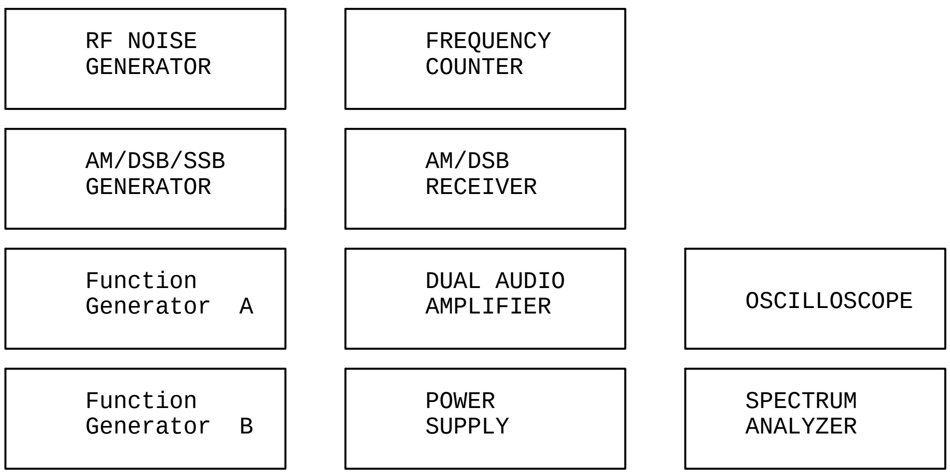
   .

Part 2: **Exercise 1-3 (Frequency Conversion of Baseband Signals)**

Purpose: The purpose of this part of the experiment is to use the AM communications modules and the Spectrum Analyzer to demonstrate frequency conversion (translation) of baseband signals.

Step 1:

Set up the equipment as follow:



Step 2:

Step 3:

Set the function generator A to frequency of 2kHz, peak-peak amplitude of 200mV, signal generator B to frequency of 3kHz and peak-peak amplitude of 300mV. This can be accomplished by connecting the output of each function generator to the oscilloscope. Set the desire frequencies and amplitude. Verify the setting from the oscilloscope.

Step 4:

Set the AM/DSB/SSB Generator output frequency to 1100kHz. This frequency will be the carrier frequency. This step can be accomplished by the following setting. Carrier Level and RF Gain controls are set to the maximum level. The carrier Level knob is pushed into the Linear Overmodulation position. Use the frequency counter to verify the frequency of the output.

Step 5:

Determine the expected f_{LSB}(lower sideband frequency) and f_{USB}(upper sideband frequency).

Step 6:

Step is to verify the lower sideband frequency and the upper side band frequency using the spectrum analyzer.

f_{LSB} =

f_{USB} =

Step 7:

Observe a combine 2kHz message with a of 3kHz message in the spectrum analyzer. The signal can be combined through a T-connector and send them into the Audio Input of the AM generator. The output of the AM generator is then connected to the spectrum analyzer.

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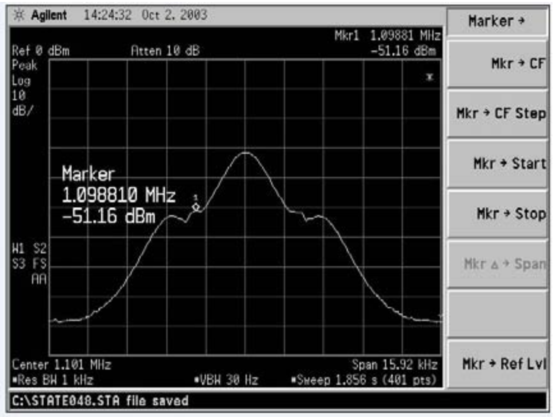
Step 8:

Show the spectrum response of the frequency spectrum of the two different messages.



Step 9:

Remove all the connection of the AM/DSB/SSB Generator, the cable on the spectrum analyzer, and the cables for the function generator B which produced the 3kHz message.

Step 10:

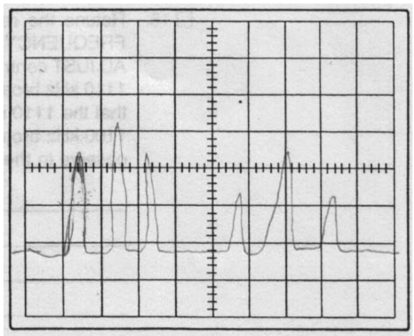
Set up a 3kHz Noise Source using a carrier of 1100kHz. The noise source can be created by connecting the 3kHz since wave from step 9 to the AMPLITUDE MODULATION INPUT of the RF/Noise Generator module. The RF carrier frequency is setup by adjusting the FREQUENCY ADJUST knob.

Step 11:

Iinstall the telescope antennal at the AM/DSI RF OUTPUT of the AM generator module.

Step 12:

Display the signals from the AM generator and the RF/Noise Generator. To accomplish this, the receiving antenna must be install first at the input of the spectrum analyzer. A wire antenna is then wrap around the receiving antenna.



Step 13:

Set up the wireless transmission and receiving between the AM generator module and the AM/DSB Receiver module. This can be accomplished by the following steps:

1) Establish the wireless receiving by installing a telescope antenna on the RF Input of the AM/DSB Receiver module.
2) Send the audio signal to the audio amplifier by connecting the Audio Output of the receiver to one of the inputs of the Dual Audio Amplifier.
3) Connect the headphones to one of the jacks on this module.

Step 14:

Fine tune the local oscillator frequency to 1555kHz. This is the frequency of broadcast for the 2kHz message signal. This can be accomplished by connect the Frequency Counter to the local OSCILLATOR OUTPUT on the receiver, and turn the RF TUNING knob to obtain a reading of 1555kHz on the Frequency Counter.

Step 15:

Find the shadow frequency to the right of the message signal. This can be accomplished by turn the RF TUNING knob on the receiver slightly to the right until a tone is heard.

.

Step 16:

Adjust one signal toward another signal to observe what happens what they start to interfere with other signals. This can be accomplished by adjust the Frequency Adjust knob on the RF/Noise Generator module to move the 1100kHz signals toward the 1110kHz signal to observe interference.

Step 17:

Determine the minimum distance between carriers before interference occurs. To accomplish this, turn the FREQEUNCY ADJUST control knob slightly until the next tone can be heard, turn the FREQUENCY ADJUST control knob slightly back so the tone is not heard. The distance between this point and the first tone is the minimum distance between carrier frequencies before interference.

Review Questions

1. What happens when amessage signal is combine with a carrier signal through a mixer?
   .
2. What are two reasons for frequency translation?
.
3. What is meant by the term baseband?

4. A 1500_kHz carrier is modulated by a baseband signal containing frequencies between 500 Hz and 4kHz. What are the frequency limits for the USB and the LSB?

5. Different AM baseband signals can be broadcast at the same time. What essential condition must be respected to allow an ordinary AM receiver to select each baseband signal individually.

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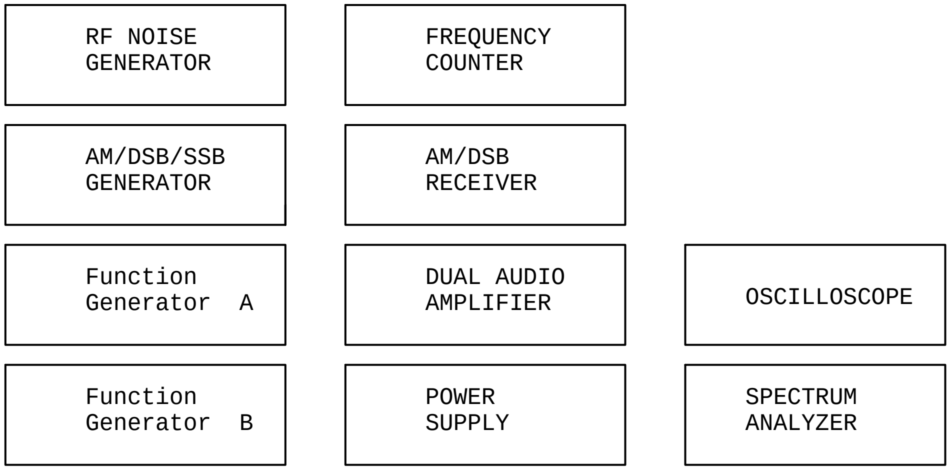
Experiment 2 (The Generations of AM Signals)

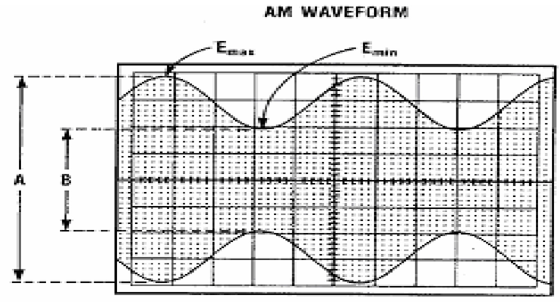
Part 1: Exercise 2-1 (An AM Signal)
Part 2: Exercise 2-2 (Percentage Modulation)

Equipment Required



Brief description of the equipment:

4) Function generator A and B: These two function generator is used to generator message signals.
5) AM/DSB/SSB GENERATOR: It is used to for amplitude modulation and generator either double side band or single side band waveforms for transmission.
6) RF Noise Generator: This can be used to generate RF noise.
4) Power Supply: It is used to supply power to equipment
5) Dual Audio Amplifier: Use for amplifier signals from the receiver to a proper listening level.
6) AM/DSB Receiver: This equipment receives the amplitude modulated signals and demodulate it before sending it to audio amplifiers
7) Frequency Counter: This equipment can be used for monitoring frequency of signals.
9) Spectrum Analyzer: This equipment is used for displaying signals in frequency base for analysis.
9) Oscilloscope: Use to display waveforms in time domain.



$$AM\ modulation\ index = \mu = \frac{message\ \ signal\ \ peak\ \ amplitude}{unmodulated\ carrier\ \ peak\ amplitude}$$

$$\mu = \frac{A - B}{A + B}$$

Figure 2-1

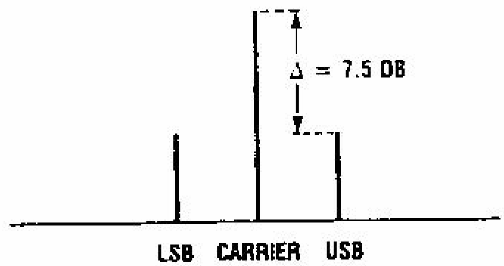


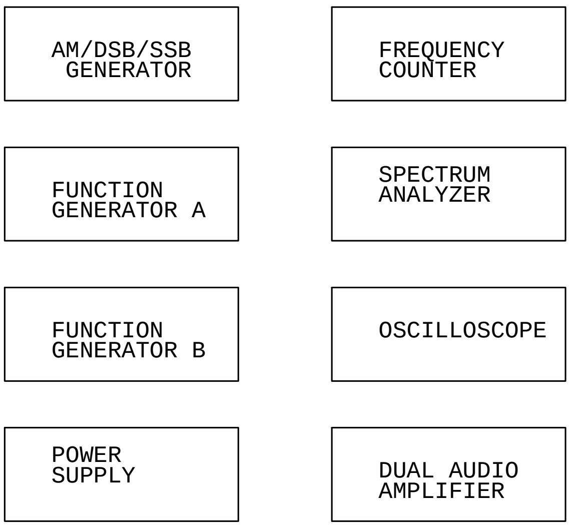
Figure 2-2 Difference between carrier and sideband power in dB.

Part 1: Exercise 2-1 (An AM Signal)

Purpose: The purpose of this part of the experiment to familiarize with the using the AM/DSB/SSB Generator to demonstrate and explain an AM signal in the time and frequency domain.

Step 1:

This step is to set up the equipment as follow:



This step is to set up the equipment in a manner where it will be easy to counter the appropriate modules together. We need to make sure all the level and gain control is set to the minimum to avoid any incidents.

Step2:

Adjust the function generator A to produce the following signal:

A. set the signal to a sine wave
B. Adjust the frequency to 10kHz
C. Set the output level to get a signal of 400mVp-p

Step 3:

Set the carrier frequency to 1100kHz. This can be accomplished by connect the AM/DSB Output terminal to the frequency counter. Adjust the FR Tuning knob to get the frequency to be 1100kHz display on the frequency counter.

fc=

Step 4:

Connect the output of the AM/DSB Output terminal to channel 1 of the oscilloscope.

Step 5:

Display the signal from function generator A to the oscilloscope and connect it to the Audio Input on the AM/DSB/SSB Generator. This can be done by splitting the signal from function generator A using a T connector. Connect one to the oscilloscope and the other one to the Input on the AM/DSB/SSB Generator.

Step 6:

Change the signal of function generator A from a sine wave to a square wave and observe the waveform.

Step 7:

Used different forms of message signal from function generator an observe the result waveform such as triangular and saw-tooth.

Step 8:

Set the message signal back to a sine wave, and observe the change in the modulated waveform to the change in frequency to the message signal.

Step 9:

Observe the change in the modulated waveform as the amplitude of the message signal is varied.

Step 10:

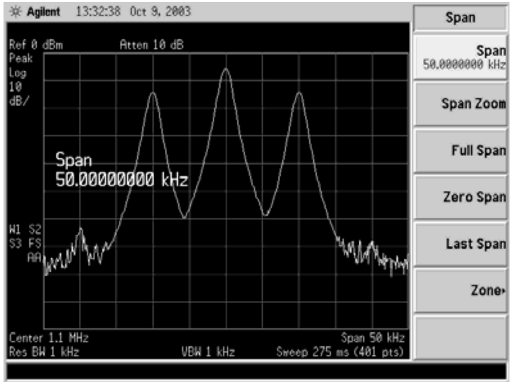
The change of the amplitude level of the information signal in step 9 corresponds to the variation of the modulation index.

Step 11:

Disconnect the oscilloscope and set up the spectrum analyzer. Set the center frequency of the spectrum analyzer to 1.1MHz.

Step 12:

Display the modulated signal to the spectrum analyzer. This can be accomplished by connecting the AM/DSB Output to he Input of the Spectrum Analyzer.



Step 13:

Determine the difference between the display of the frequency response shown in step 12 to the one given in Figure 2-1.

Step 14:

Observe the changes of the modulated signal in the spectrum analyzer as the frequency of the message signal is varied.

Step 15:

Observe the changes of the modulated signals in the spectrum analyzer as the amplitude of the message signal is varied.

Step 16:

Determine the effects of changes in the modulation index to the frequency spectrum.

Step 17:

Observe the change in the frequency spectrum when the message signal is changed from a sine wave to a square wave.

Review Questions:

6) Base on the results of this exercise, which signal produces a frequency spectrum could be compared to a complex message signal, the sine wave or the square wave? Explain.
7) Indicate in a simple sketch how changes in the frequency and in the amplitude of a message signal are reflected in the frequency spectrum of an AM signal.

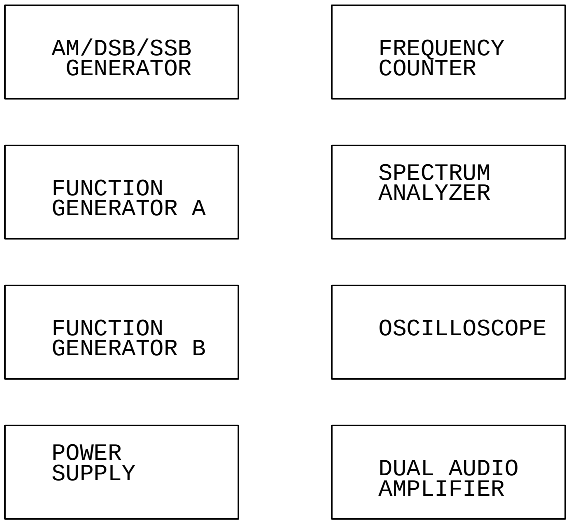
8) If the modulation index of an AM signal is increase, what effect does this have on the envelope of the AM waveform?

9) What happens to the envelope of the AM signal when the frequency of the modulating signal is increased?
5) When the message signal frequency increases, does the modulation index increase or decrease?

Part 2: **Exercise 2-2 (Percentage Modulation)**

Purpose: The purpose of this part of the experiment is to show the percentage of modulation either with an oscilloscope or a spectrum analyzer.

Step 1:



Step 2:

This step is to set the message signal to the following:

A) set the signal to a sine wave
B) adjust the frequency to 10kHz
C) set the amplitude level to get 400mVp-p

Step 3:

Set the carrier frequency to 1100kHz. This can be accomplished by connect the AM/DSB Output terminal to the frequency counter. Adjust the FR Tuning knob to get the frequency to be 1100kHz display on the frequency counter.

Step 4:

Measure the peak to peak amplitude of the carrier. This can be accomplished by measuring the signal in the oscilloscope.

Ac =

Step 5:

Determine the percentage of modulation base on the results of step 3 and step 4. The result can be determine using the relationship
% Mod. = m * 100%=(Am*/AC)*100% .

Step 6:

Display the modulated signal on the oscilloscope. Use the result from the graph to calculate the modulation index using m =(A-B)/(A+B).

A is the peak to peak amplitude of the envelop and B is the amplitude between valleys of the envelop. This can be accomplished by the following step:

A) Use a T connector to split up the message signal from function generator A and connect it to the Audio Input on the AM generator.
B) Set the largest usable display to show the waveform.

Step 7:

This step is to calculate the percentage of modulation using the results from the oscilloscope in XY mode and display it as follow:

Step 8:

Obtain modulation index 75% using the trapezoidal pattern by varying the level of the modulating signal. This step is tricky as level control on the message signal and the Gain control of the AM/DSB Generator must be varied back and forth to get the 75% modulation. Once B is determined, we can used the Level Control on the AM/DSB generator to obtain A for the other modulation levels.

Step 9:

Remove the cables from the oscilloscope and set up the spectrum analyzer and center the frequency at 1.1MHz.

Step 10:

This step is to connect the output of the AM/DSB/SSB Generator to the input of the spectrum analyzer.

Step 11:

Fine tune the center frequency button of the spectrum analyzer to center the modulated signal to the center of the display.

Step 12:

Calculate the modulation index from the spectrum analyzer. Use the relationship between sideband and carrier from the following figure 2-2 to calculate the modulation index.

Example of carrier and its sidebands

Δ = %Mod=

Step 13:

Compare the result in step 12 to the result from step 8.

Step 14:

Vary the amplitude of the modulating signal to obtain two intermediate values between 20 and 70% for the modulation index. This process can be done by using Figure 2-3 and obtaining the values of Δ.

Step 15:

Overmodulate the signal by max out the output from function generator A, and observe the result in the spectrum analyzer when the AM/DSB/SSB Generator is at the NONLINEAR OVERMODULATION position.

Step 16:

Observe happens when the Output Level on Channel A is varied between Min and Max so the modulation index varies above and below 1.

Step 17:

Connect the AM/DSB output of the AM generator in the oscilloscope (normal mode) when we repeat the same procedure as step 17.

Step 18:

Set the CARRIER LEVEL knob in the AM/DSB generator to LINEAR OVERMODUALTION position, and repeat step 16 and compare the results with step 17.

Step 19:

Use the XY mode of the oscilloscope obtain the trapezoid patter, use it to determine the overmodulation level.

Step 20:

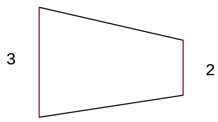
Sketch the trapezoidal pattern obtained when the modulation index is greater than

Step 21:

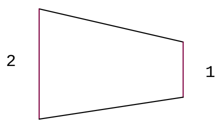
What happens to the small triangle on the right of the trapezoid pattern when the CARRIER LEVEL knob is pulled out to the NONLINEAR OVERMODUALTION position.

Review Questions

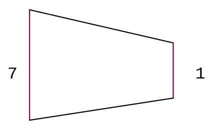
6. The following trapezoidal patterns are obtained for different AM signals. Determine the modulation index in each case.



M=(A-B)/(A+B)=.2



M=(A-B)/(A+B)=.33



M=(A-B)/(A+B)=.75

7. The amplitude of a sine-wave message signal is 500mVp-p, and the amplitude of the unmodulated carrier is 500mV peak. What is the theoretical modulation index?

8. What is mean by overmodulation, and why is it undesirable?

9. A technician uses the trapezoidal method to determine the modulation index of an AM signal. The resulting oscilloscope display shows the presence of a small triangle on the right side of the figure. What does this indicate?

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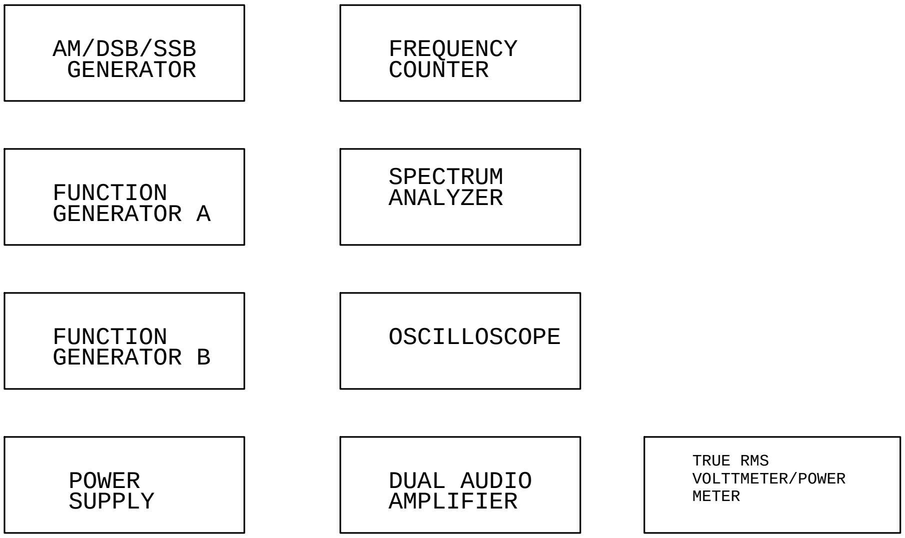
Experiment 2-3 (Carrier and Sideband Power)

Equipment Required



Brief description of the equipment:

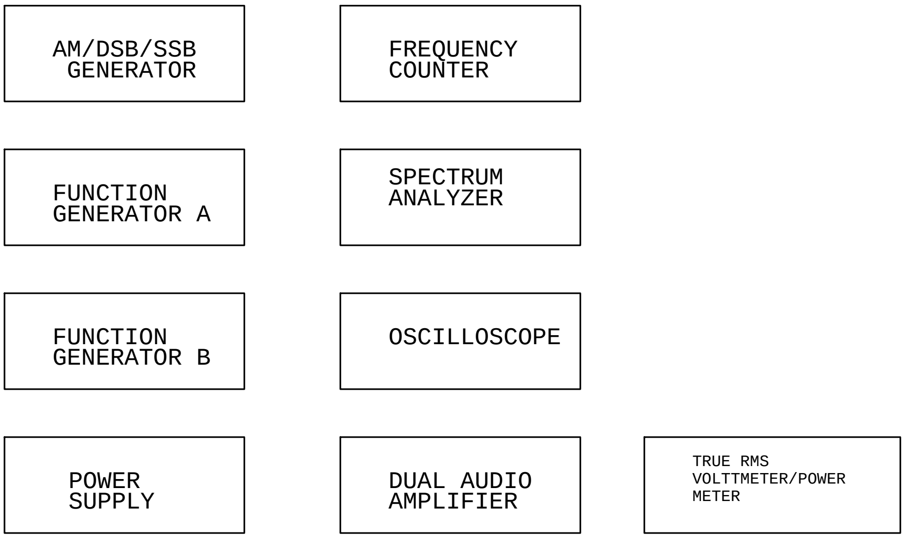
7) Function generator A and B: These two function generator is used to generator message signals.
8) AM/DSB/SSB GENERATOR: It is used to for amplitude modulation and generator either double side band or single side band waveforms for transmission.
9) TRUE RMS VOLTMETER/POWER METER: This equipment can be used to determine AC power. It has the option of display the signal level in terms of voltage, or display the signal strength in terms of dBM.
4) Power Supply: It is used to supply power to equipment
5) Dual Audio Amplifier: Use for amplifier signals from the receiver to a proper listening level.
6) AM/DSB Receiver: This equipment receives the amplitude modulated signals and demodulate it before sending it to audio amplifiers
7) Frequency Counter: This equipment can be used for monitoring frequency of signals.
10) Spectrum Analyzer: This equipment is used for displaying signals in frequency base for analysis.
9) Oscilloscope: Use to display waveforms in time domain.

Exercise 2-3 (Carrier and Sideband Power)

Purpose: The purpose of this experiment is to learn to use the modulation index to determine the sideband power and transmission efficiency for AM signals.

Step 1

Set up the equipment as follow:



Set up the equipment in a manner where it will be easy to counter the appropriate modules together. We need to make sure all the level and gain control is set to the minimum to avoid any incidents.

Step 2

Set up the message signal to the following conditions:

1. f=10kHz
2. amplitude = 200mV
3. sine wave

It can be accomplished by adjusting Function Generator A to the above condition.

Step 3

Adjust the carrier frequency to 1100kHz. This can be accomplished by connecting the output of the AM/DSB/SSB/Generator to the Frequency Counter, adjust he RF Tuning control until the Frequency Counter reads 1100kHz..

Step 4

Connect the output of the AM/DSB/SSB Generator to channel 2 of the oscilloscope.

Step 5

Connect the message signal to both the AUDIO INPUT on the AM/DSB/SSB Generator and channel 1 of the oscilloscope. This can be accomplished by connect a T connector to the output of Function Generator A, connect one of the split signal to the oscilloscope and the other one to the AUDIO INPUT on the AM/DSB/SSB Generator.

Step 6

Set the oscilloscope in X-Y mode. The X-Y mode is then used to determine the modulation index.

Step 7

Set the modulation index to .50. This can be accomplished by utilizing the trapezoidal pattern in step 6, adjust the output level of the message signal to obtain proper value of A and B to get modulation index .50 use the relationship m=(A-B)/(A+B).

Step 8

Measure the rms voltage of the message signal. This can be accomplished by disconnect the message signal from the AUDIO INPUT of the AM generator and connect it to the True RMS Voltmeter/Power Meter.

Result: Vrms=

Step 9

Measure the rms voltage of the message signal for modulation index of .75. It can be accomplished by repeating step 7 to obtain m=.75, then repeat step 8 to measure the rms voltage for the message.

Result: m=.75
Vrms=

Step 10

Measure the rms voltage of the message signal for modulation index of 1.0. This can be accomplished by repeating step 9 for the modulation index of 1.0.

Result: m=1.0
Vrms=

Step 11:

Set up the Spectrum Analyzer to center at 1.1MHz.

Step 12:

Connect the output of the AM Generator to both the TRUE RMS VOLTMETER/POWER METER and the Spectrum Analyzer. This can be accomplished using a T connector at the output of the AM Generator to split up the signal, connect one output to the TRUE RMS VOLTMETER/POWER METER and the other to the Spectrum Analyzer.

Step 13:

Fine tune the spectrum analyzer to center the signal as close to the center as possible. This can be accomplished by varying the Tuning knob on the Spectrum Analyzer until the carrier signal is at the center of the spectrum analyzer.

Step 14:

Determine the unmodulated carrier power using the TRUE RMS VOLTMETER/POWER METER. To accomplish this, the message signal must be removed from the Audio Input of the AM Generator. Make sure the Power Meter is in dBm, record the reading off the meter.

Result: Pc(unmodulated) =

Step 15:

Make sure the modulation index is still at 1.0. This can be done by using the trapezoidal pattern.

Step 16:

Determine the power of the modulated signal. To accomplish this, connect the message signal to the Audio Input of the AM Generator. Record the reading from the TRUE RMS VOLTMETER/POWER METER.

Result: PAM =

Step 17:

Determine the amplitude of the carrier and its lower and upper sidebands from the spectrum analyze. The measurements can be done by placing the marker at the center of the carrier, record the value for Pc. Adjust the marker at the f_{LSB}, which is the sideband to the left of the carrier frequency. Record the value as P_{LSB}. Next, adjust the marker to the f_{USB}, which is the sideband to the right of the carrier frequency. Record the value as P_{USB}.

Result: Pc =

P_{LSB} =

P_{USB} =

Step 18 & step 19:

Repeat the previous steps to find all the values to fill up the following table for modulation index of .75 and .50. Use figure 2-20 to convert dBm values to mW.

Step 20:

Make sure table 2-3 is complete.

Result:

			TRUE RMS VOLTMETER					SPECTRUM ANALYZER RESULTS					
m	μ	PSB/PT	Vaudio	Pc(unmodulated)		PAM(modulated)		PT = Pc + PSB		PLSB		PUSB	
	$m^2/(m^2+2)$	%	Vrms (mV)	dBm	mW	dBm	mW	dBm	mW	dBm	mW	dBm	mW
0.50													
0.75													
1.00													

Table 2-3

$P_{SB}/P_T = (P_{AM}-P_C)/P_{AM}$ (in mW) form columns 6 and 8

$P_T = P_C+P_{LSB}+P_{USB}$ (in mW) form columns 12, 14 and 16

Step 21:

Compare the theoretical value μ with the transmission efficiency μ for the three different modulation indexes.

Result:

M	μ	PSB/PT	% of difference
	$m^2/(m^2+2)$	%	%
0.50			
0.75			
1.00			

Step 22:

Compare the values of P_{AM} and P_T for the 3 different modulation indexes.

Result:

P_{AM}(modulated)		$P_T = P_c + P_{SB}$		difference = $P_T - P_{AM}$
dBm	mW	dBm	mW	dBm

Step 23:

Compare the sideband power obtain with the True RMS Voltmeter results with the corresponding values obtained using the Spectrum Analyzer results.

Result:

M	Psb (spectrum analyzer) =PUSB +PLSB (dB)	Psb (True RMS Meter) =PAM-Pc (dB)	% of difference (dB)
0.50			
0.75			
1.00			

.

Review Question:

1. Write in equation form the expression for 1) the total power of an AM signal. 2) the relationship between μ and m.

2. The maximum power transmission efficiency that can be obtained in AM is 33%. Explain.

3. Spectrum analyzer measurements of an AM signal show that Pc = 0dBm and P_{LSB} = P_{USB} = -6dBm. Determine the modulation index.

4. An AM signal is attenuated by 100 before measurements are made with a spectrum analyzer. The spectrum analyzer measurements show that Pc = 0dBm, and P_{LSB} = P_{USB} = -6dBm. Determine P_T, the actual power of the AM signal.

5. An AM station transmits an average carrier power of 10 kW. Spectrum Analyzer measurements show that the difference between carrier and sideband power is 8 dB (Δ = 8dB). Determine m, μ, P_T, P_{LSB} and P_{USB}.

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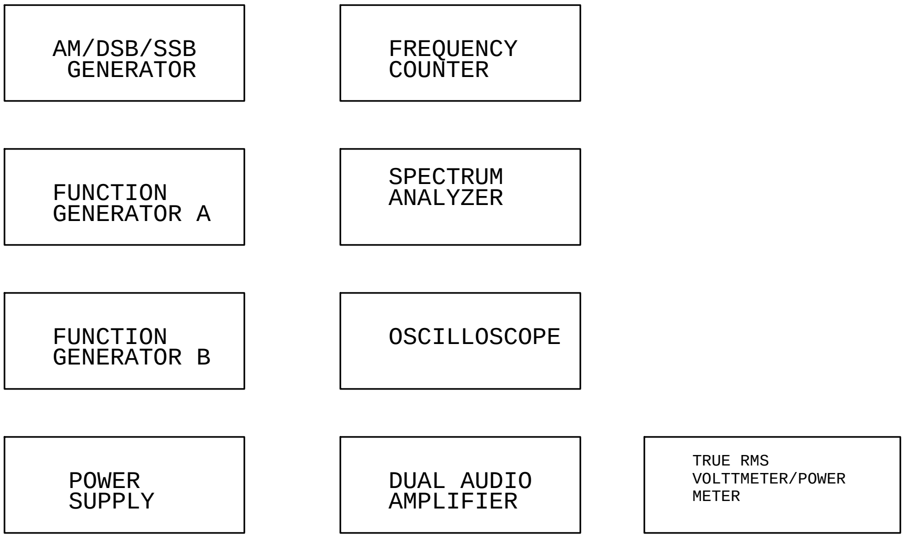
Experiment 3 (Reception of AM Signals)

Part 1: Exercise 3-1 (The RF Stage Frequency Response)
Part 2: Exercise 3-2 (the Mixer and Image Frequency Rejection)

Equipment Required



Brief description of the equipment:

10) Function generator A and B: These two function generator is used to generator message signals.

11) AM/DSB/SSB GENERATOR: It is used to for amplitude modulation and generator either double side band or single side band waveforms for transmission.

12) TRUE RMS VOLTMETER/POWER METER: This equipment can be used to determine AC power. It has the option of display the signal level in terms of voltage, or display the signal strength in terms of dBM.

4) Power Supply: It is used to supply power to equipment

5) Dual Audio Amplifier: Use for amplifier signals from the receiver to a proper listening level.

6) AM/DSB Receiver: This equipment receives the amplitude modulated signals and demodulate it before sending it to audio amplifiers

7) Frequency Counter: This equipment can be used for monitoring frequency of signals.

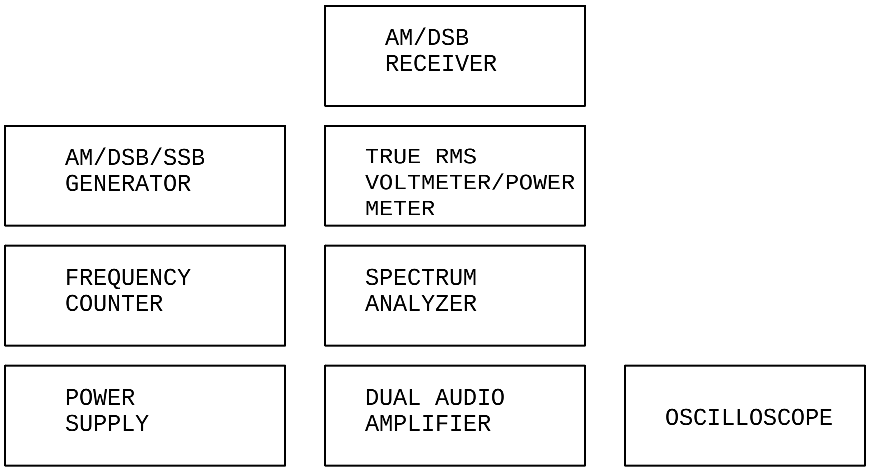
11) Spectrum Analyzer: This equipment is used for displaying signals in frequency base for analysis.

9) Oscilloscope: Use to display waveforms in time domain.

Exercise 3-1 (The RF Stage Frequency Response)

Step 1:

Set up the equipment as follow:



Set up the equipment in a manner where it will be easy to counter the appropriate modules together. We need to make sure all the level and gain control is set to the minimum to avoid any incidents.

Step2:

Set up the spectrum analyzer. Connect the RF Output of the AM/DSB Receiver to the input of the spectrum analyzer.

Step 3:

Set up the Local Oscillator frequency to 1405 kHz at the OSC OUTPUT on the AM/DSB Receiver.

The IF frequency is 450kHz

$f_{LO} = fc + f_{IF}$, $fc = f_{LO} – f_{IF} =$

Step 4:

Disable the local oscillator in the AM/DSB Receiver. This can be by opening the top panel of the module, and placing the FLT 2 switch under the small hinged cover in the 1(active) position.

Step 5:

Set up the AM/DSB/SSB Generator module so the carrier frequency can be continuously monitored with the frequency counter. This can be done by opening the top panel of the AM/DSB/SSB Generator, connect TP 13 of with clip wire on the generator. Connect the other end of the lead wire to the frequency counter.

Step 6:

Connect the output of the AM/DSB/SSB Generator to the Input of the AM/DSB Receiver. This can be done by setting eh CARRIER LEVEL on the AM/DSB/SSB Generator to the max position, make sure it is in the LINEAR OVERMODULATION position. Connect the output to the input of the AM/DSB Receiver.

Step 7:

Observe what happens when the RF TUNING on the AM/DSB/SSB Generator to get 950 kHz.

Step 8:

Center the frequency to the center of the spectrum analyzer. This can be done by varying the TUNING control of the spectrum analyzer until the signal is at the center of the spectrum analyzer display.

Step 9:

Adjust the height of the signal to the -10 dBm level. This can be done by adjust the RF GAIN control on the AM/DSB/SSB Generator until the signal level reaches -10 dBm.

Step 10:

Trace out the response of the filter in the spectrum analyzer. This can be done by selecting the "max hold" position on the trace, then slowly vary the RF TUNING control on the AM/DSB/SSB Generator to both sides of 950kHz to obtain the filter response.3

Step 11:

Calculate the 3dB, 10dB and 20dB bandwidth from the result of step 10. This can be accomplished by setting the marker on the top of the filter, note the amplitude. Adjust the marker to the right of 950kHz until it is 3 dB lower than the first marker, note this frequency. Adjust the marker to the left side of 950kHz until it is 3 dB lower than the amplitude at 950kHz, note this frequency. The difference between the right side and the left side is the 3 dB bandwidth. Repeat the same process for the 10 dB and 20 dB bandwidth.

<u>Result:</u>

	$f_{\text{High (kHz)}}$	f_{Low} (kHz)	Bandwidth (kHz)
3-dB BW			
10-dB BW			
20-dB BW			

Step 12:

Disconnect the input of the spectrum analyzer and place it to the input of the TRUE RMS VOLTMETER/POWER METER. Adjust the zero on the voltmeter module and switch the MODE to dBm.

Step 13:

Readjust the RF GAIN and the RF TUNING on the AM/DSB/SSB Generator to obtain a reading of 10dBm at 950kHz.

Step 14:

Generate a table to characterize the low pass filter using the TRUE RMS VOLTMETER/POWER METER. Vary the RF Tuning to obtain the frequencies. Record and fill out the corresponding columns.

Result:

Frequency (kHz)	850	870	890	910	930	950	970	990	1010	1030	1050
dBm Reading											

Step 15:

Calculate the corresponding dB values and sketch the frequency response using the data.

Result:

Frequency (kHz)	850	870	890	910	930	950	970	990	1010	1030	1050
dBm Reading											
Relative dB *											

0dB Reference= MAXIMUM dBm Reading

*Relative dB=(dBm Reading) – (0 dB Reference)

Step 16:

Determine the 3-dB, 10-dB and 20dB bandwidth from the results of step 15.

Result:

	Bandwidth (kHz)
3-dB BW	
10-dB BW	
20-dB BW	

Step 17:

Compare the result from step 11 and step 16.

	BW from step 11 (kHz)	BW from step 16 (kHz)	% of differerence (%)
3-dB BW			
10-dB BW			
20-dB BW			

Step 18:

Determine if the 3-dB BW of the filter is wide enough for a 5kHz message signal base on the fact the 3-dB BW must be twice as wide as the message signal.

Step 19:

Return the FLT 2 to the 0 (inactive position).

Review Question

1. What kind of receiver is the AM/DSB Receiver?

   .

2. What are the four principle operations involve in AM reception?

3. If a message signal contains frequencies up to 3kHz, what is the minimum bandwidth required for the RF stage if the message is to be demodulated correctly?

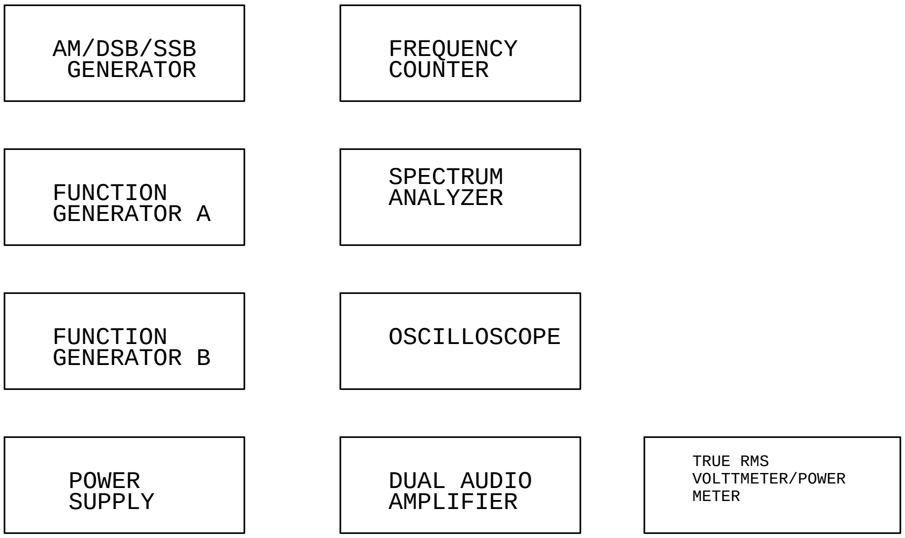
4. What is the result of mixing the incoming RF signal with the local oscillator signal?

5. The difference frequency of 455kHz in the AM/DSB Receiver is call:

Exercise 3-2 (The Mixer and Image Frequency Rejection)

Step 1:

Setup the equipment as follow:



Set up the equipment in a manner where it will be easy to counter the appropriate modules together. We need to make sure all the level and gain control is set to the minimum to avoid any incidents.

Step 2:

Adjust the carrier frequency to 690kHz and adjust the f_{LO} to 1145kHz. This can be accomplished by the following steps:

1. Connect TP 13 from the AM/DSB/SSB Generator to the frequency counter. Adjust the RF Tuning to get 690kHz.
2. Connect the output of the AM/DSB/SSB Generator to the 50 Ω input of the AM/DSB Receiver.
3. Connect the output of the AM/DSB Receiver to the frequency counter and adjust the RF Tuning to get 1145kHz.

Step 3:

Prepare the spectrum analyzer for measurement. This is done by center the frequency to 1MHz, select 0 dBm and FREQUENCY SPAN of 200 kHz/V.

Step 4:

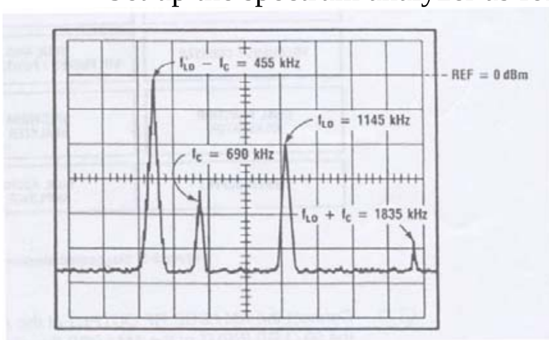
Set up the message signal to 5kHz, and amplitude of 200mV.

Step 5:

Verify fc is 690kHz and f_{LO} is 1145kHz. This step can be accomplished by connecting each output to the frequency counter and readjust if necessary.

Step 6:

Set up the spectrum analyzer as follow:



Step 7:

Measure f_{LO}, fc, f_{LO} = fc and f_{LO} – fc from the set up from step 6.

Result:

f_{LO} =	
f_{LO} + fc	

fc =	
f_{LO} - fc =	

Step 8:

Determine the amplitude difference between f_{LO} and IF component at 455kHz. .

Step 9:

Connect the IF OUTPUT of the AM/DSB Receiver to the NPUT of the spectrum analyzer and observe the display.

Step 11:

Adjust the RF GAIN on the AM/DSB/SSB Generator until we obtain 10dBm for the IF component.

Step 12:

Measure the amplitude of the AM signal using the TRUE RMS VOLTMETER/POWER METER.

Step 13:

connect the AM/DSB output to the RF INPUT of the AM receiver, and adjust he RF TUNING of the AM/DSB/SSB Generator to obtain a carrier frequency of 1600 kHz.

Step 14:

Readjust the RF GAIN to obtain 10dBm on the spectrum analyzer, and repeat step 12..

Step 15:

Determine the image frequency rejection ratio. This can be done by P_{AM} (1600kHz) – P_{AM} (690 kHz).

Review Questions

1. An AM receiver tuned to a station at 600kHz uses a 455 kHz IF and the local oscillator operates above the station frequency. What is the image frequency for this station?

2. The image frequency of an AM station is 2500kHz. What is the frequency of the station if the receiver uses 455kHz as the IF and $f_{LO} = fc + f_{IF}$?

3. What is the role of the mixer linking the RF and the IF stages of a Superheterodyne receiver?

4. Which stage of the receiver is responsible for most of the image frequency rejection?

5. How can intraband image frequencies be eliminated?

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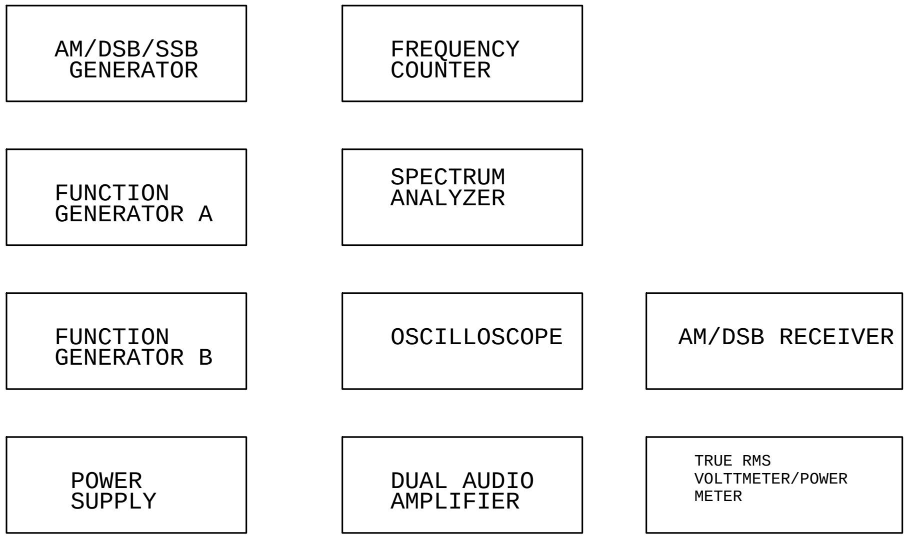
<u>Experiment 4 (Reception of AM Signals)</u>

Part 1: Exercise 4-1 (The IF Stage Frequency Response)
Part 2: Exercise 4-2 (The Envelope Detector)

Equipment Required



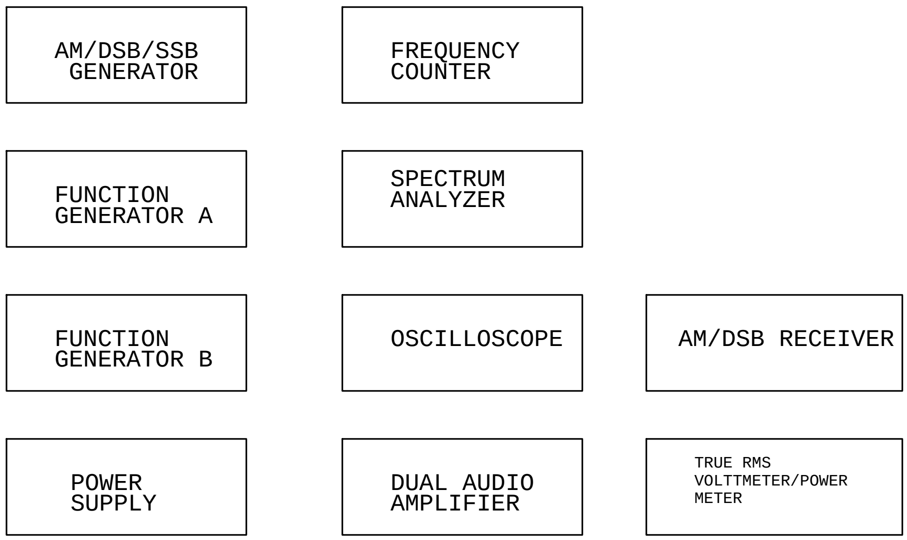
Brief description of the equipment:

13) Function generator A and B: These two function generator is used to generator message signals.
14) AM/DSB/SSB GENERATOR: It is used to for amplitude modulation and generator either double side band or single side band waveforms for transmission.
15) TRUE RMS VOLTMETER/POWER METER: This equipment can be used to determine AC power. It has the option of display the signal level in terms of voltage, or display the signal strength in terms of dBM.
4) Power Supply: It is used to supply power to equipment
5) Dual Audio Amplifier: Use for amplifier signals from the receiver to a proper listening level.
6) AM/DSB Receiver: This equipment receives the amplitude modulated signals and demodulate it before sending it to audio amplifiers
7) Frequency Counter: This equipment can be used for monitoring frequency of signals.
12) Spectrum Analyzer: This equipment is used for displaying signals in frequency base for analysis.
9) Oscilloscope: Use to display waveforms in time domain.

Exercise 4-1 (The IF Stage Frequency Response)

Step 1:

Set up the equipment as follow:



Set up the equipment in a manner where it will be easy to counter the appropriate modules together. We need to make sure all the level and gain control is set to the minimum to avoid any incidents.

Step 2:

Set up the Spectrum Analyzer module to center at .5MHz and connect it to the IF OUTPUT of the AM/DSB Receiver.

Step 3:

Place the AGC switch to the ((inactive) position and select the SYNC DETECTOR on the AM/DSB Receiver. Also ask the instructor to activate Fault 2 (Flt 2).

Step 4:

Set up the equipment to continuously monitor the frequency of the AM/DSB/SSB Generator. This can be accomplished by opening the top panel of the AM/DSB/SSB Generator and connect TP13 of the receiver to the frequency counter.

Step 5:

Set the proper carrier level on the AM generator and connect it to the AUX IF INPUT of the AM/DSB Receiver. This can be done first set the CARRIER LEVEL on the AM generator tot the maximum level. Next, make sure it is at the LINEAR OVERMODULATION position, and Adjust the RF GAIN to the ½ turn cw. The last step is to connect the AM/DSB RF OUTPUT to the AUX IN INPUT of the AM/DSB Receiver.

We should adjust he frequency carrier to <u>455kHz</u> if we are going to measure the frequency response of the fixed-frequency.

Step 6:

Adjust the RF TUNING control on the AM/DSB/SB Generator to 455kHz and observe the results on the Spectrum Analyzer.

Step 7:

Place the 455kHz IF signal in the center of the spectrum analyzer and select proper span.

Step 8:

Obtain the maximum output of the IF line. It can be accomplished by varying the RF TUNING control on the AM/DSB/SSB Generator until the maximum amplitude is obtained.

Step 9:

Thrace out the filter response on the spectrum analyzer. It can be accomplished by varying the RF TUNING control on the AM/DSB/SSB Generator both sides of the 455kHz while the "max hold" is selected on the spectrum analyzer.

Step 10:

Determine the 3-dB BW, 10-dB BW and 20-dB BW from the trace from step 9.

<u>Result:</u>

3-dB BW = <u>455 kHz</u> -

10-dB BW = <u>455 kHz</u> -

20-dB BW = <u>455 kHz</u> -

Step 11:

Setup the TRUE RMS Voltmeter/Power Meter for measurement of the power of the IF Output. This can be accomplished by connecting the IF Output to the TRM RMS Voltmeter/Power Meter. Zero the voltmeter and select the dBm position.

Step 12:

Center the filter to obtain the maximum power. This can be accomplished by varying the RF Tuning knob slightly left and right until the maximum power reading is obtained.

Step 13 & Step 14:

Fill out a table of data necessary to analyze the filter characteristics using the TRUM RMS Voltmeter/Power Meter, and sketch the frequency response curve corresponding to these values.

Result:

Frequency (kHz)	439	443	447	451	453	455	457	459	463	467	471
dBm Reading											
Relative dB											

Step 15:

Determine the 3-dB, 10-dB and 20-dB bandwidth using the results from step 13 and step 14.

Result:

3-dB BW =

10-dB BW =

20-dB BW =

Step 16:

Compare the results of step 15 to step 10?

Step 17:

Inject a signal at the AUX IF INPUT and connect the IF OUTPUT to the spectrum analyzer.

Step 18:

Make sure the frequency is at the center of the filter.

Step 19:

Send a 5kHz, 200mV signal from the Function Generator A to the AUDIO INPUT on the AM/DSB/SSB Generator.

Step 20:

Center the modulated signal at the center of the spectrum analyzer and observe the signal.

Step 21:

Injected signal and observe its response with respect to the change of frequency.

.

Step 22:

Use the f_{LSB} and f_{USB} to determine the 3-dB bandwidth of the filter. This can be accomplished by adjusting the f_{LSB} and f_{USB} to 3 dB lower than its maximum value.

Result: f_{LSB} = f_{USB} =

Step 23:

Compare the result from Step 22 to the result from step 13&14.

Step 24:

Compare the 3-dB bandwidth of the IF stage with the RF stage.

Review Question:

1. The typical bandwidth required to transmit a message signal in commercial AM is 10kHz. explain the influence, if an that this has on the bandwidth requirements of the IF stage.
   .

2. The IF stage bandwidth of a n AM receiver is measured and found to be 6kHz. What effect will this have on performance during reception of commercial AM stations?
   .

3. Which stage of a superheterodyne receiver is responsible for most of the receiver's selectivity?

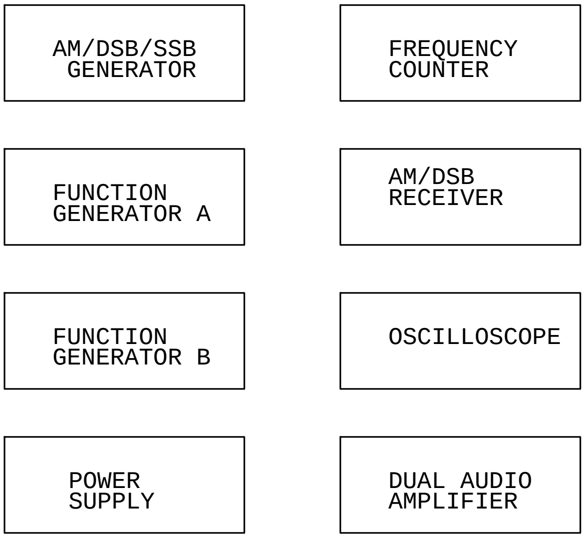
4. Why can the very large gain of the IF stage cause problems in a superheterodyne receiver?

5. During frequency-response measurements of the IF stage it is found that the LSB and USB are not attenuated equally. Can this be considered normal?

Exercise 4-2 (The ENVELOPE DETECTOR)

Step 1:

Set up the equipment as follow:



Set up the equipment in a manner where it will be easy to counter the appropriate modules together. We need to make sure all the level and gain control is set to the minimum to avoid any incidents.

Step 2:

Set up Function Generator A to send out a message signal of 1.0kHz and 200mV. If the modulation index (m) is equal to 1.0, the optimum value of the RC time constant for the 1.0kHz message signal is given by:

$RC_{optimum}=1/(m*2*\pi*fm)=$

Step 3:

Set up a carrier frequency of 950kHz. This can be accomplished by using the AM/DSB/SSSB Generator. Open the top panel and connect TP13 to the frequency counter to continuously monitor the frequency. Set the RF Gain to ¼ cw and make sure the CARIER LEVEL knob is pushed in and at the MAX position.

Step 4:

Determine the LO frequency on the AM/DSB Receiver to receive the 950kHz signal.

<u>Result</u>: fLO = fIF + fc

Step 5:

Adjust the RF TUNING control on the AM/DSB Receiver to 1405kHz and connect the AM/DSB RF OUTPUT to the AM receiver. Select the ENV DETECTOR and place the AGC switch in the 1 (active) position.

Step 6:

Connect the IF Output of the AM/DSB Receiver to channel 1 of the oscilloscope and connect the Audio Output to channel 2. Set the time base control to .5ms/DIV and set the oscilloscope to trigger on the Audio signal.

Step 7:

Set up the measurement of the oscilloscope. Both the channel should be set on the dc coupling mode with channel 1 at 1V/DIV and channel 2 at .5V/DIV. Set the reference level line for channel 2 on the 2^{nd} graticule line of the oscilloscope and position the dc reference for channel 1 on the 5^{th} graticule line.

Step 8:

Verify the carrier frequency at 950kHz and describe the signals displayed on the oscilloscope.

Step 9:

Approximate the modulation index. This can be accomplished by using one of the method described in UNIT 2 for approximation.

m =

Step 10:

Observe what happen when the CARRIER LEVEL control on the AM/DSB/SSB Generator between MAX and MIN.

Step 11:

Determine at what CARRIER LEVEL does the demodulated audio signal begin to be affected.

Step 12:

Overmodulate the AM signal by reducing the CARRIER LEVEL to MIN and pull the knob out to the NONLINEAR OVERMODULATION position and observe what happen.

Step 13:

Return the CARRIER LEVEL control to Max AND PUSH IT INTO the LINEAR OVERMODULATION position.

Step 14:

Place the AGC switch on the receiver in the 0 (inactive) position and set the RF Gain of the AM generator to ½ cw.

Step 15:

Observe what happens when the RF GAIN is slowly varied between 1/turn cw and MIN.

Step 16:

Observe what happens when the RF GAIN is varied with the AGC at 1(active position).

Step 17:

Return the RF GAIN to the ¼ turn cw position and set the channel sensitivity control of the oscilloscope at 1 VOLT/DIV.

Step 18:

Observe the difference on the demodulated signal between the SYNC DETECTOR AND THE ENV DETECTOR. This can be done by increase the amplitude of FUNCTION GENERATOR A until the modulation index is approximately 100%. Then switch between the SYNC DETECTOR AND THE ENV DETECTOR and observe what happens.

.

Step 19:

Determine which detector performs better as the modulation index is approaching 100% before distortion occurs.

Review Question

1. Sketch the circuit for a simple diode detector.

2. Explain briefly how a diode detector operates.
.

3. What effect does the .6V drop across the detector diode have on the demodulation IF signal.

4. Does an AGC circuit have any effect on the detection process? Explain.

5. Based on the results of this exercise, which detector coupled with an AGC circuit provides a demodulated audio signal having less distortion and a higher level.

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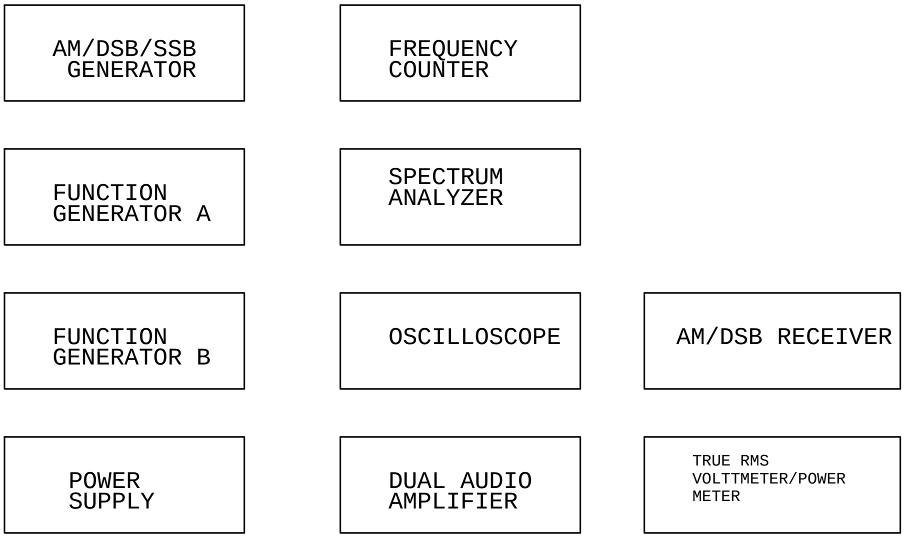
<u>Experiment 5 (Single Sideband Modulation -SSB)</u>

Equipment Required



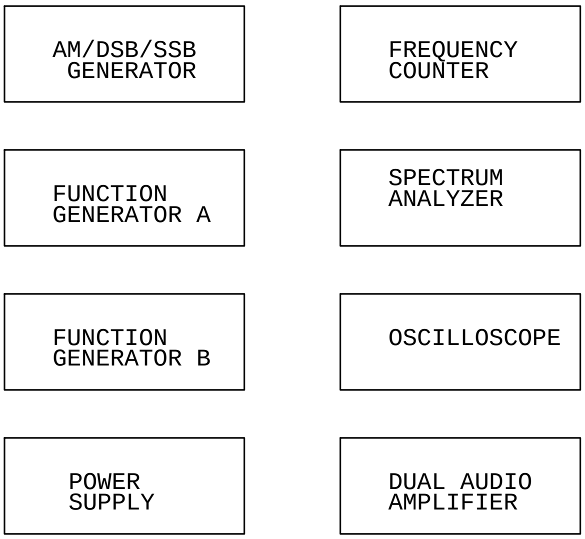
Brief description of the equipment:

16) Function generator A and B: These two function generator is used to generator message signals.
17) AM/DSB/SSB GENERATOR: It is used to for amplitude modulation and generator either double side band or single side band waveforms for transmission.
18) TRUE RMS VOLTMETER/POWER METER: This equipment can be used to determine AC power. It has the option of display the signal level in terms of voltage, or display the signal strength in terms of dBM.
4) Power Supply: It is used to supply power to equipment
5) Dual Audio Amplifier: Use for amplifier signals from the receiver to a proper listening level.
6) AM/DSB Receiver: This equipment receives the amplitude modulated signals and demodulate it before sending it to audio amplifiers
7) Frequency Counter: This equipment can be used for monitoring frequency of signals.
13) Spectrum Analyzer: This equipment is used for displaying signals in frequency base for analysis.
9) Oscilloscope: Use to display waveforms in time domain.

Exercise 5-1 (Generating SSB signals by the Filter Method)

Step 1:

Set up the equipment as follow:



Set up the equipment in a manner where it will be easy to counter the appropriate modules together. We need to make sure all the level and gain control is set to the minimum to avoid any incidents.

Step 2:

Generate a 2.5 kHz, 200mV sine wave from Function Generator A, and connect it to the AUDIO INPUT of the AM/DSB/SSB Generator.

Step 3:

Setup the AM/DSB/SSB Generator. The CARRIER LEVEL should be at the minimum position and push in the LINEAR OVERMODULATION position. Set the SSB RF GAIN (amplifier A_3) at ½ turner cw.

Step 4:

Adjust the BFO Output to 452.5 kHz using the BFO TUNIGN knob.

Result: BFO =

Step 5:

Adjust the FVO TUNING control to measure a frequency of 4355 kHz at VFO OUTPUT (terminal 5).

Result: f_{VFO} =

Step 6:

Prepare the Spectrum Analyzer ready for measurement. The center frequency should be center around ,5MHz.

Step 7:

Connect the SSB section to the input of the spectrum analyzer. Use the Tuning knob to place the spectrum analyzer of 455 kHz in the center of the screen.

Step 8:

Find the best setting to place the display in the center of the spectrum analyzer.

Step 9:

Sketch out the frequency spectrum .

f_{LSB} = f_{USB} =

Step 10:

Observe the frequency spectrum of the signal at the IF OUTPUT (terminal 4) and describe what happened.

Step 11:

Observe and explain what happened as f_{BFO} approaches 455 kHz.

Step 12:

Observe what happens when the message signal frequency is increased to 3.5 kHz.

Step 13:

Readjust the message signal to 2.5 kHz and tune the BFO to obtain 457.5 kHz. Observe what happens as f_{BFO} is increased from 455 to 457.5 kHz.

.

Step 14:

Of this step is to vary f_{BFO} between 453 and 457 kHz and observe what happens in the spectrum response as f_{BFO} varies between 453 and 457 kHz.

Step 15:

Set the spectrum analyzer up for the next measurement. Select the span to 1 MHz. Make sure SSB RF OUTPUT is at 455 kHz.

Step 16:

Select the right setting to make sure the image is centered.

Step 17:

Observe and describe the frequency spectrum using frequency span of 2 kHz/V.

Step 18:

Vary f_{BFO} between 453 and 457 kHz and observe what happens.

Step 19:

Conclude the effect caused by adjusting f_{BFO} at 452.5 or 457.5 kHz.

Step 20:

Determine the time waveform for an SSB signal modulated by a single-tone sine wave.

Step 21:

Observe the waveform of the SSB signal at the SSB RF OUTPUT of the AM/DSB/SSB Generator when f_{BFO} = 452.5 kHz. Compare the results with the predictions of step 20.

Review Question:

1. Sketch the frequency spectrum of an SSB signal (LSB and USB), and list the differences between an SB spectrum and those of an AM spectrum and a DSB spectrum.

2. What are the two principle advantages of SSB modulation over AM and DSB?

3. Describe briefly the filter method of generating SSB signals used in the Analog Communications Training System.

4. Observation of the spectrum at the output of an SSB generator shows that the spectrum is identical to the at of a DSB signal. Explain the problem with the generator.

5. The IF section of an SSB generator used for voice communications is tuned for operation at 455 kHz. The bandwidth of the IF stage is 2 kHz. What effect, if any, will the very narrow passband have on communications?

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Experiment 6: Fundamentals of Frequency Modulation

Equipment Required

DIRECT FM MULTIPLEX GENERATOR	TRUE RMS VOLTMETER POWER METER	
FUNCTION GENERATOR A	FM/PM RECEIVER	
FUNCTION GENERATOR B	SPECTRUM ANALYZER	
POWER SUPPLY	DUAL AUDIO AMPLIFIER	OSCILLOSCOPE

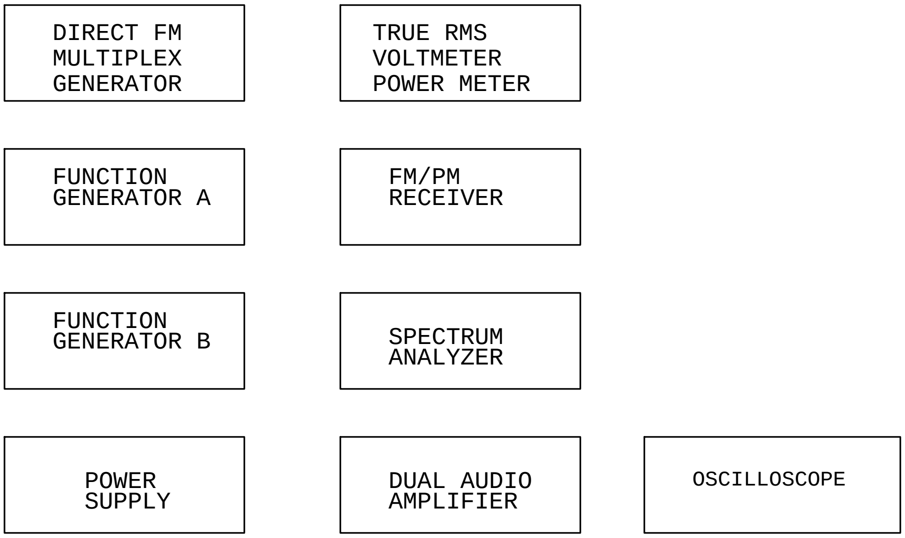
Brief description of the equipment:

19) Function generator A and B: These two function generator is used to generator message signals.
20) Direct FM Multiplex Generator: Equipment use for transmitting FM signals
21) TRUE RMS VOLTMETER/POWER METER: This equipment can be used to determine AC power. It has the option of display the signal level in terms of voltage, or display the signal strength in terms of dBM.
4) Power Supply: It is used to supply power to equipment
5) FM/PM RECEIVER: Receiver use for demodulating FM and PM signals
6) Frequency Counter: This equipment can be used for monitoring frequency of signals.
7) Spectrum Analyzer: This equipment is used for displaying signals in frequency base for analysis.
8) Oscilloscope: Use to display waveforms in time domain.

Exercise 6-1 (FM Modulation Index)

Step 1:

This step is to set up the equipment as follow:



Set up the equipment in a manner where it will be easy to counter the appropriate modules together. We need to make sure all the level and gain control is set to the minimum to avoid any incidents.

Step 2:

Set up all the test equipment for the experiment. The following is the setting for test equipment:

1. For Function Generator A, set the signal to sine wave, the frequency to 5 kHz, amplitude to 200mV.
2. On the TRUE RMS VOLTMETER/POWER METER, set the MODE to volt.
3. On the Direct FM Multiplex Generator, set the preemphasis to 0, Multiplix Signals to “all at 0 except L + R at 1”, Level to “Cal”, Deviation to “75 kHz (knob pushed – in), and the RF GAIN to “50%” cw.
4. On the Spectrum Analyzer, set the frequency span to 1MHz and the frqeuncy range to 85-115 MHz.

Step 3:

Connect the modulated signal and adjust the spectrum analyzer to appropriate span to observe the signal spectrum. It can be accomplished by connect the WBFM RF OUTPUT of the Direct FM Multiplex Generator to one of the WBFM RF INPUTS of the FM/PM Receiver and to the input of the Spectrum Analyzer. Use the Tuning control of the Spectrum Analyzer to move the carier line in the center of the spectrum analyzer, and decrease the Frequency Span to 10 kHz/V.

Step 4:

Adjust the carrier power level to +5 dBm.

Step 5:

Tune the frequency of the FM/PM Receiver to the frequency of the Direct FM Multiplex Generator. This can be accomplished by tuning the frequency tuning control on the FM/PM Receiver to until the green TUNING LED lights up.

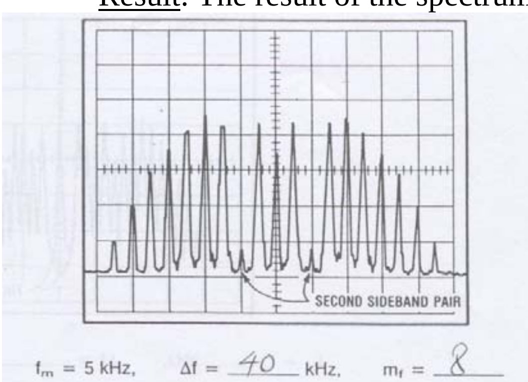
Step 6:

Connect the message signal from Function Generator A to both the Input of the True RMS Voltmeter/Power Meter and the LEFT AUDIO INPUT of the Direct FM Multiplex Generator.

Step 7:

Increase the amplitude of the message signal until the 2^{nd} sideband pair of the FM spectrum is at a minimum.

Result: The result of the spectrum is similar to the follow:



fm= Δf = m_f =

Figure 1

Step 8:

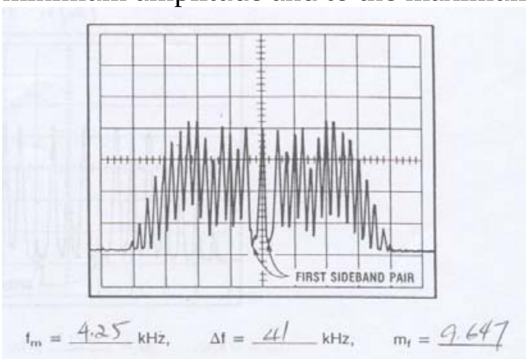
Obtain the frequency deviation and calculate the modulation index. The frequency deviation can be obtained by set the DEVIATION push-button to WBFM on the FM/PM Receiver. The frequency deviation is displayed, and the modulation index can be calculated using Frequency deviation Δf = frequency deviation /modulating signal frequency.

Result: Frequency deviation Δf =

m_f =

Step 9:

Decrease Frequency of the Function Generator until the 1st sideband pair pass to a minimum amplitude and to the maximum amplitude. The spectrum is show as follow:



fm= Δf = m_f =

Figure 2

Compare this spectrum to figure 1.

Step 10:

Determine the message frequency from function generator A.

Result: fm =

Step 11:

Read the frequency deviation from the receiver and calculate the modulation index using the relationship $mf = \Delta f/fm$.

Step 12:

Decrease in frequency of the modulating signal increases the modulation index.

Step 13:

Readjust FREQUENCY A to obtain figure 1.

Result: fm =

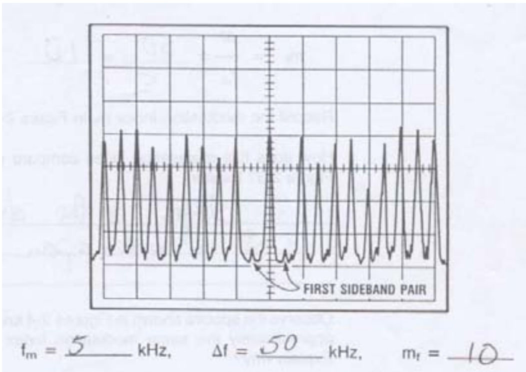
Step 14:

Zero the TRUE RMS VOLTMETER/POWER METER and measure the modulating signal level.

Result: Modulating signal level =

Step 15:

Increase the OUTPUT LEVEL A until we see the following frequency spectrum.



fm= Δf = m_f =

Figure 3

Step 16:

Measure the modulating signal level on the TRUM RMS VOLTER/POWER METER, and read the frequency deviation from the FM/PM Receiver.

<u>Result:</u> Modulating signal level =

Δf =

Observation: .

Step 17:

Calculate the modulation index and compare figure 3 to figure 1 and figure 2.

Step 18:

Readjust the amplitude for Function Generator A to obtain the frequency spectrum of figure 1.

Step 19:

Set the sensitivity k_f of the FM modulator to its minimum and observe what happen to the spectrum. This can be accomplished by turn the DEVIATION knob on the Direct FM Multiplex Generator completely counterclockwise, and pull it out.

Step 20:

Increase the sensitivity of the FM modulator to maximum and observe what happen to the spectrum, the frequency deviation and modulation index.

Review Questions:

1. An FM signal is modulated by a 10 kHz sinusoidal signal. What is the value of its modulation index if the frequency deviation is 10 kHz?

2. What is the relationship between the modulation index and the amplitude of the modulating signal?

3. What parameters can change the frequency devation?

4. An FM signal has a frequency deviation of 6 kHz when the modulating signal has an amplitude of 5 V, and a frequency of 1000 Hz. What will be the modulation index if the frequency of the modulating signal is doubled?

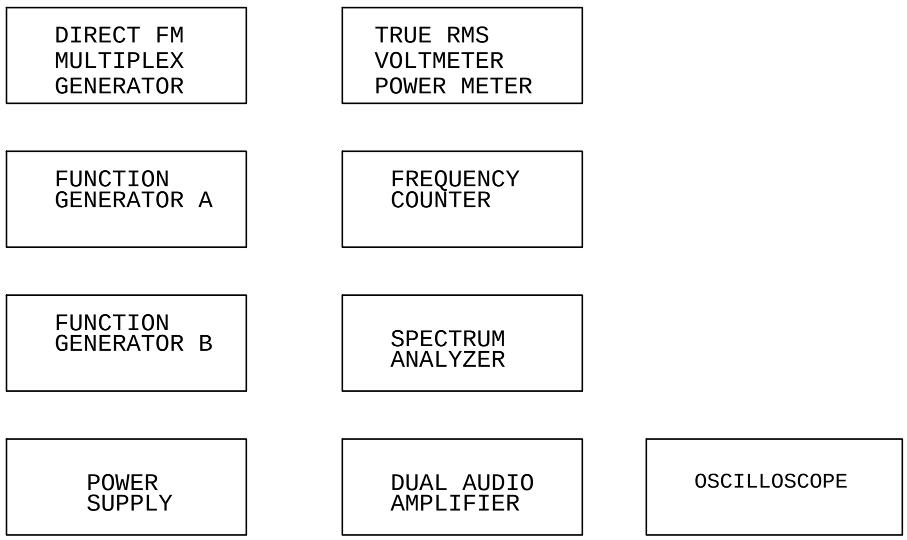
5. When the DEVIATION knob is adjusted, what parameter changes?

Table 1. Bsssel coefficient as a function of the modulation index.

Exercise 6-2 (POWER DISTRIBUTION)

Step 1:

This step is to set up the equipment as follow:



Set up the equipment in a manner where it will be easy to counter the appropriate modules together. We need to make sure all the level and gain control is set to the minimum to avoid any incidents.

Figure 1 . Relative amplitude of the components when the modulation index is 2.4 . The vertical scale of the Spectrum Analyzer is linear.

Step 2:

Adjust the function generator A, Direct FM Multiplex Generator and the spectrum analyzer to appropriate settings for the experiment.

1. Function Generator A: f = 5 kHz
   A = 200 mV
2. Direct FM Multiplex Generator
   RF Gain: 50% cw
   Deviation: 75 kHz (knob push in)

Step 3:

Calibrated the spectrum analyzer and connect it to the RF OUTPUT of the FM Multiplex Generator.

Step 4:

Center the carrier frequency at center of the display. Adjust the RF Gain control to obtain -10dBm output level using the spectrum analyzer at 10 kHz/V.

Step 5

Connect the message signal to the AUX INPUT of the Direct FM Multiplex Generator. Slowly increase the level of the modulated signal until the spectral line of the carrier disappears. The modulation index is now 2.4. The spectrum look like the following:

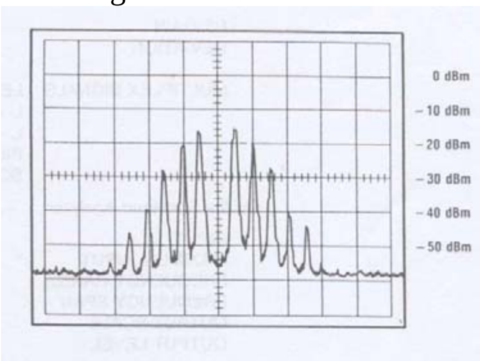


Figure 2

Step 6:

Slowly increase the signal level. Each time the amplitude of the center line goes through a maximum, record the value of the modulation index in the second column of Table 2. Use the table 1 to find the modulation index corresponding to each maximum. Continue to increase the signal level for three successive maxima.

Result:

MAXIMUM	M_f
1	
2	
3	
4	

Table 2

Step 7:

Determine how does the spectrum change when the modulation index goes from 0 to 10.5?

Step 8:

Evaluate the power Pn of figure 3 of the first three spectral components nearest the carrier frequency and of the carrier.

Figure 3 . FM Spectra for 3 successive maximum points of the carrier .

Figure 4 mW into 50Ω / dBm.

<u>Result:</u>

$m_f = 0$

mf = 0					
N	0	1	2	3	
Pn(dBm)					
Pn (mW)					Total Po + ∑2Pn
2Pn(mW)					

For figure 3a

mf = 3.5					
n	0	1	2	3	
Pn(dBm)					
Pn (mW)					Total Po + ∑2Pn
2Pn(mW)					

For figure 3b

mf = 7					
n	0	1	2	3	
Pn(dBm)					
Pn (mW)					Total Po + ∑2Pn
2Pn(mW)					

For figure 3c

mf = 10.5					
n	0	1	2	3	
Pn(dBm)					
Pn (mW)					Total Po + ∑2Pn
2Pn(mW)					

Step 9:

Observe the change in total power of the carrier and the spectral components when the value of the modulation index goes from 0 to 10.5?

Review Question:

1. If the modulation index is known, what other parameter must be known in order to determine the Bessel coefficient of a specific spectral component?
   .

2. A transmitter produces a signal with a total power of 100W. How much power is transmitted at the carrier frequency if the modulation index is 1.5?

3. What is the total power contained in the spectral components of an FM signal whose total power is 100W, if the power at the carrier frequency is 26W?

4. How does the spectral power distribution of a signal change when the modulation index increases?

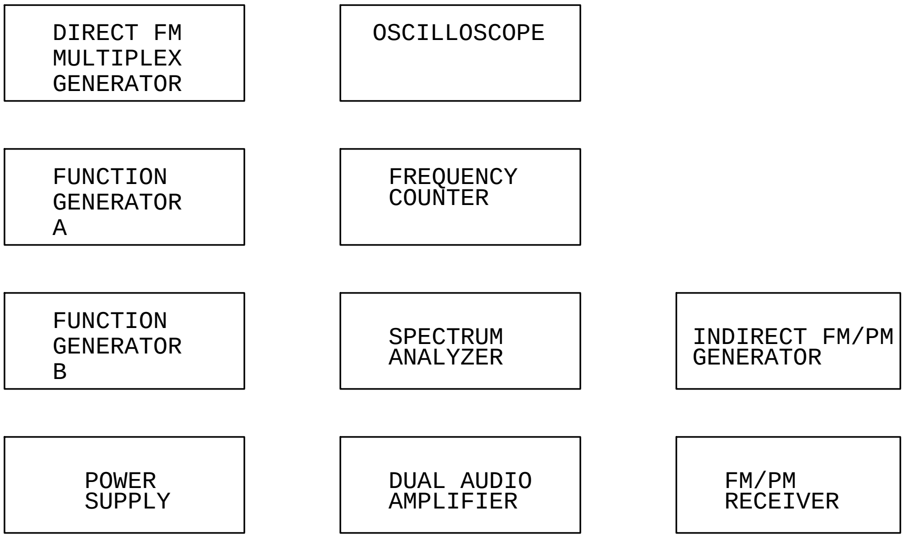
5. How can the power be calculate from the n-th spectral component?

<u>**EE321**</u>
<u>**K. Rad**</u>

<u>Experiment 7: Generation of FM Signals)</u>

Part 1: Exercise 7-1 (Direct Method of Generating FM Signals
Part 2: Exercise 7-2 (Indirect Method of Generating FM Signals)

Equipment Required



Brief description of the equipment:

22) Function generator A and B: These two function generator is used to generator message signals.

23) Direct FM Multiplex Generator: Equipment use for transmitting FM signals

3) Power Supply: It is used to supply power to equipment

4) FM/PM RECEIVER: Receiver use for demodulating FM and PM signals

5) Frequency Counter: This equipment can be used for monitoring frequencies.

6) Spectrum Analyzer: This equipment is used for displaying signals in frequency base for analysis.

7) Oscilloscope: Use to display waveforms in time domain.

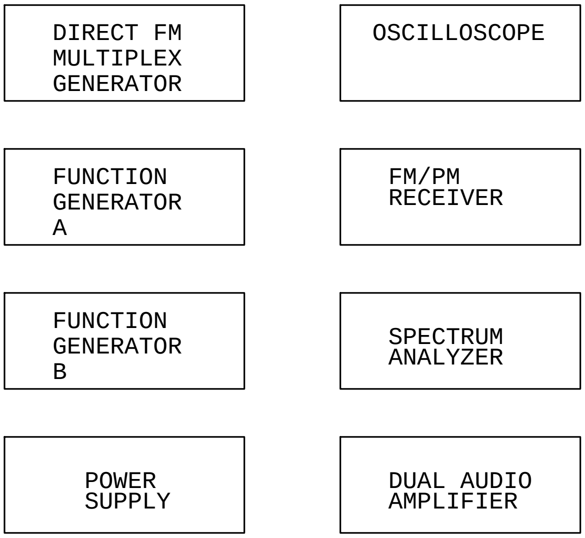
8) Indirect FM/PM Generator: Equipment use for generating FM/PM signals

9) FM/PM Receiver: Equipment use for detecting FM/PM signals

Exercise 7-1 (Direct FM Generations)

Step 1:

This step is to set up the equipment as follow:



Set up the equipment in a manner where it will be easy to counter the appropriate modules together. We need to make sure all the level and gain control is set to the minimum to avoid any incidents.

Step 2:

Set the following equipment to their proper settings to prepare for test measurements.

Function Generator A:

Frequency=6 kHz
Output Amplitude=300mV peak

Direct FM Multiplex Generator:

Multiplex Signals	Off
Level	Cal
Deviation	75 kHz (knob pushed-in)
RF Gain	50% cw

Step 3:

Set up the message signal, Direct FM Multiplex Generator and the FM/PM Receiver for testing. This can be accomplished by the following steps:

1) Connect output from Function Generator A to the AUX INPUT o fth eDirect FM Multiplex Generator and to Channel 1 input of the oscilloscope.
2) Connect the WBFM RF OUTPUT of the Direct FM Multiplex Generator to the WBFM RF INPUT of the FM/PM Receiver.

3) Using the RF Tuning knob, tune the FM/PM Receiver to the frequency of the Direct FM Multiplex Generator. When the green LED comes on, it indicates the frequency is properly tuned.

Step 4:

Record the frequency deviation. This can be accomplished by observing the digital readout that shows the DEVIATION of the modulated signal. Select the WBFM mode and record the deviation.

Step 5:

Vary the frequency of the message signal between 300 Hz and 15 kHz and observe the change in frequency deviation.

.

Step 6:

Observe the change in frequency deviation when the amplitude of the message signal is increased 10 times.

Step 7:

Vary the amplitude of the message signal and record down the corresponding frequency deviation and record on table 1. Calculate the sensitivity k_f using the relationship $k_f = \Delta f(\text{read})/Am$ and record it on table 1.

Result:

Am	Δf (read)	K_f
V peak	kHz	kHz/V
0.50		
0.75		
1.00		
1.25		
1.50		
1.75		
2.00		
2.50		
3.00		
TOTAL		
AVERAGE SENSITIVITY		

Table 1

Step 8:

Plot the curve of frequency deviation Δf as a function of the amplitude Am of the message signal.

Step 9:

Observe the frequency deviation when the DEVIATION knob is pulled-out. This can be accomplished by pull-out the DEVIATION knob, record the deviation for complete counterclockwise, and complete clockwise.

Step 10:

Make a table similar to table 1, but this time with the DEVIATION knob pull-out.

Result:

Am	Δf (read)	K_f
V peak	kHz	kHz/V
0.50		
0.75		
1.00		
1.25		
1.50		
1.75		
2.00		
2.50		
3.00		
TOTAL		
AVERAGE SENSITIVITY		

Table 2

Review Questions

1. What defines direct generation of an FM signal?

2. What is the basic principle behind the operation of a VCO?
.
3. What does the varactor do in a direct FM generator?

4. In a variable frequency LC oscillator, the variable element is a varactor. The characteristic of this varactor is shown in Figure 5-6. Knowing that the oscillation frequency of an LC oscillator is equal to $1/(2\pi\sqrt{LC})$, what happens to this frequency if the voltage applied to the varactor.

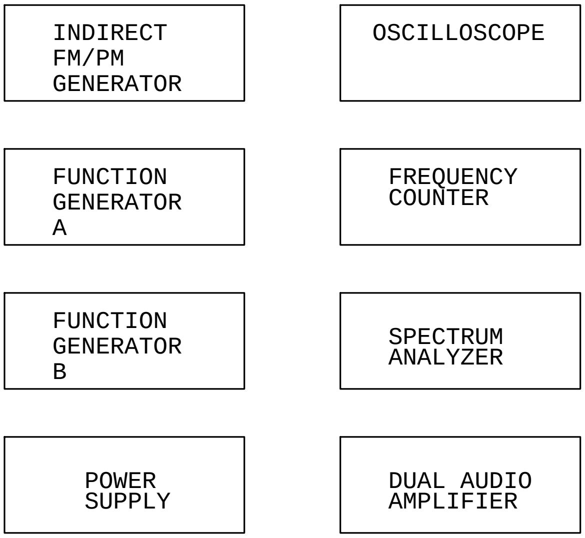
.

5. What is the frequency of the oscillator circuit in a direct FM generator if the level of the modulating signal is zero?

Exercise 7-2 (Indirect Method of Generating FM Signals)

Step 1:

This step is to set up the equipment as follow:



Set up the equipment in a manner where it will be easy to counter the appropriate modules together. We need to make sure all the level and gain control is set to the minimum to avoid any incidents.

Step 2:

Determine the frequency multiplication ratio between TP6 and the NBFM Signal. This can be accomplished by measure the frequency at TP 6 from the FM/PM GENERATOR using the frequency counter. Record it down and measure the frequency of the PM/NBFM RF OUT. Record it down and look at the ratio between the two frequencies.

.

Step 3:

Measure the frequency at TP20 and TP15 and determine their ratio. This can be accomplished by measuring the frequency at TP20 and TP15 using a frequency counter. Use the results to determine the frequency difference between TP20 and signal at the PM/NBFM RF OUTPUT.

Step 4:

Measure the frequency of the WBFM RF OUTPUT and determine the multiplication factor of the 2^{nd} frequency multiplier.

.

Step 5:

Set up the Spectrum Analyzer for measurement.

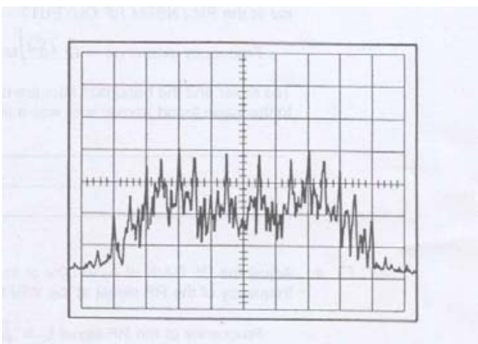
Step 6:

Connect the WBFM RF OUTPUT of the indirect FM/PM Generator to the INPUT of the Spectrum Analyzer. Set the span to 10 kHz/V while keeping the carrier line in the center of the screen. Adjust the RF Gain control on the Indirect FM/PM Generator to obtain a height of 5 division for the carrier frequency line and connect the modulation signal to the Audio Input.

Step 7:

Make sure the modulation signal is 5 kHz. Adjust the amplitude of the modulation signal until we obtain modulation index of 5.5 to obtain similar spectrum response as follow:

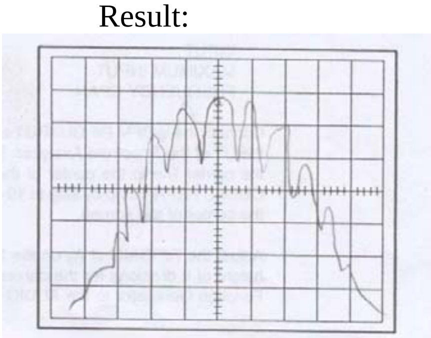
Result:



Step 8:

Connect the PM/NBFM RF OUTPUT of the Indirect FM/PM Generator to the INPUT of the Spectrum Analyzer. This can be accomplished by initially setting the span to 1 MHz, adjust the carrier line to the center of the spectrum analyzer. Slowly adjust the span down to 10kHz/V while maintaining the carrier line at the center of the spectrum analyzer.

Result:



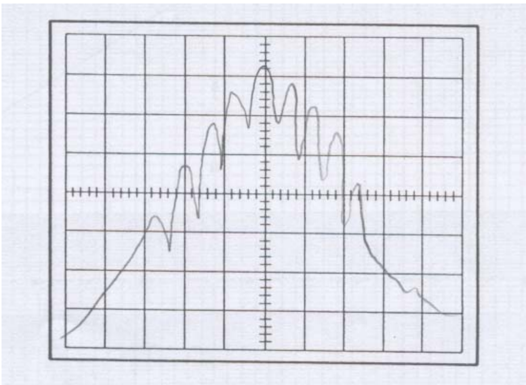
Step 9:

Determine the difference in dB between the carrier and the first spectra component and use the result to determine the modulation index.

Step 10:

Display the frequency characteristics of the output of the mixer at the PM/WBFM RF OUTPUT. This can be accomplished by centering the center frequency of the spectrum analyzer at 6.78 MHz and frequency span of 10kHz/V.

Result:



Review Questions:

1. Why do we say that the Armstrong method produces a WBFM signal indirectly?
2. What is the purpose of the filter after the mixer?
.
3. Why is very good frequency stability possible with indirect frequency modulation?
.
4. Why is frequency multiplication used?

5. What is the main purpose of the mixer?