German Jordanian University
School of Electrical Engineering and IT
Department of Electrical and Communication Engineering

Communication Circuit Lab Manual

Experiment 9

AM Transmitter and Receiver

Theory

a) Frequency Components of Human Voice
b) A Simple Communication System
c) Amplitude Modulation (AM)
d) Carrier Wave
e) Modulator
f) Output Amplifier
g) DSB Receiver
h) Automatic Gain Control (AGC)

- **Experiment 1**
  - Double Sideband AM Generator
  - To calculator modulation index of DSB wave by Trapezoidal Pattern
  - Double Sideband AM Reception
- **Experiment 2**
  - Operation of the Automatic Gain Control Circuit (AGC)
  - To plot selectivity curve for radio receiver
  - To plot sensitivity curve for radio receiver
  - To plot fidelity curve for radio receiver

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Theory

Frequency Components of Human Voice

When we speak, we generate a sound that is very complex and changes continuously so at a particular instant in time the waveform may appear as shown in Figure 1 below.

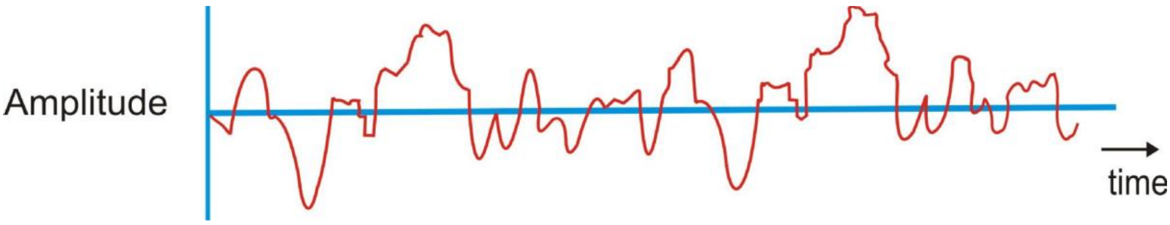


Figure 1

However complicated the waveform looks, we can show that it is made of many different sinusoidal signals added together.

To record this information we have a choice of three methods.

The first is to show the original waveform as we did in Figure 1. *The second* method is to make a list of all the separate sinusoidal waveforms that were contained within the complex waveform (these are called 'components', or 'frequency components'). This can be seen in Figure 2.

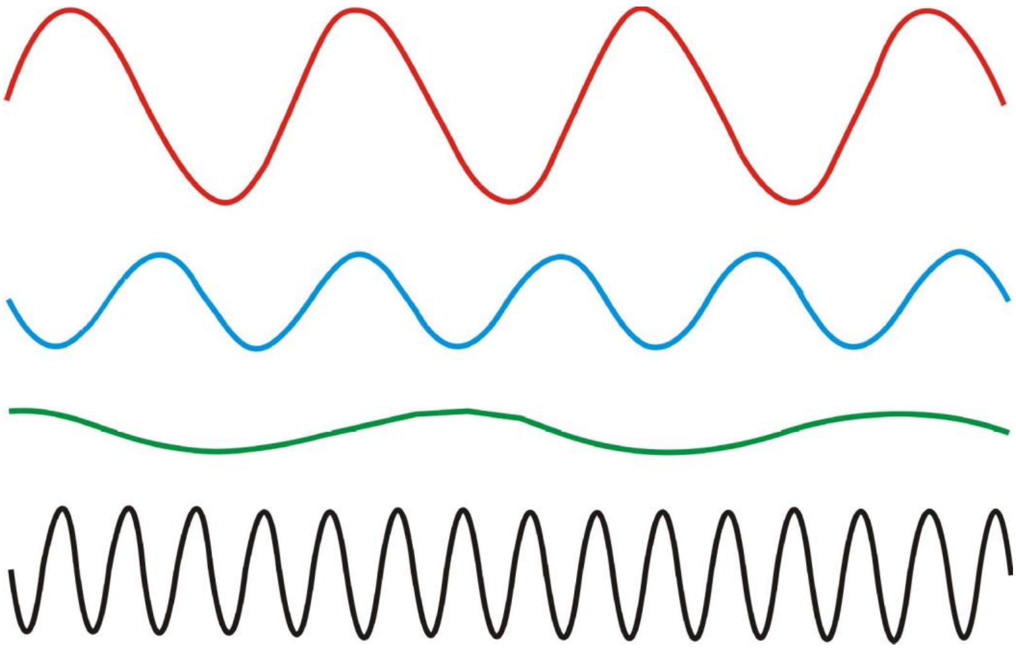


Figure 2

Only four of the components of the audio signal in Figure 1 are shown in Figure 2. The *actual number of components* depends on the shape of the signal being considered and *could be a hundred or more* if the waveform was very complex.

The *third way* is to display all the information on a diagram. Such a diagram shows the frequency spectrum. It is a graph with amplitude plotted against frequency. Each separate frequency is represented by a signal vertical line, the length of which represents the amplitude of the sinewave. Such a diagram is shown in Figure 3 below. Note that nearly all *speech* information is contained within the frequency range of 300 Hz to 3.4 KHz.

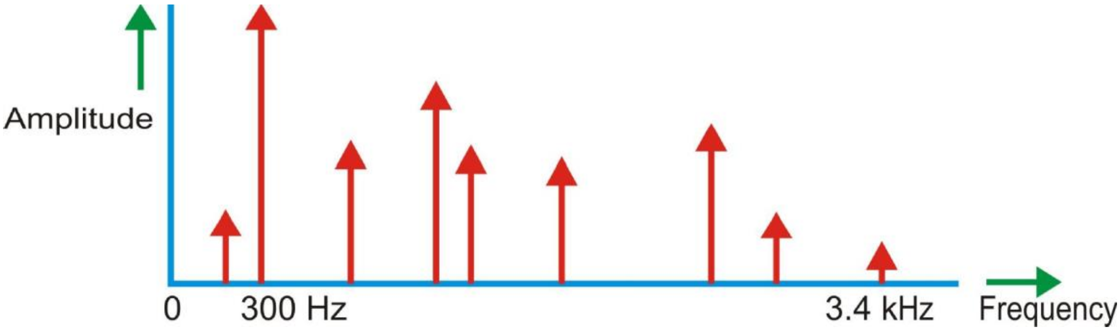


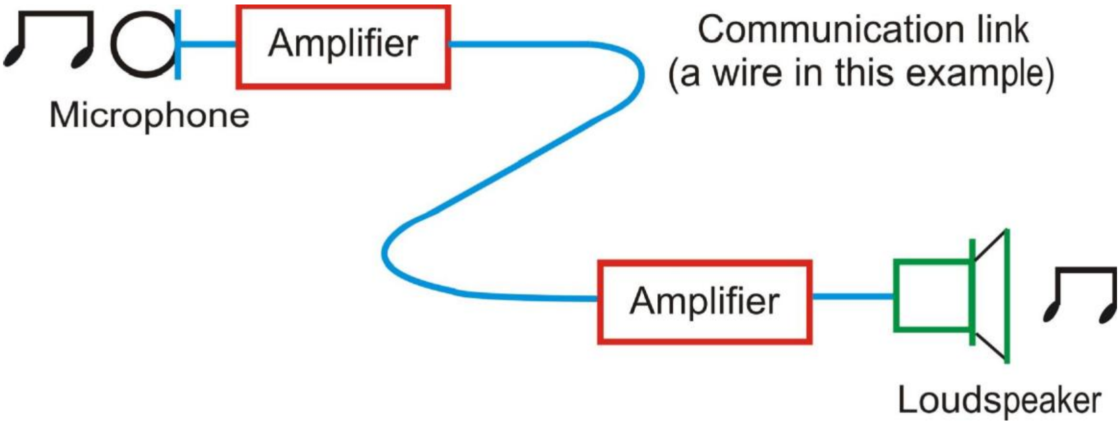
Figure 3

Although an oscilloscope will only show the original complex waveform, it is important for us to remember that we are really dealing with a group of sinewaves of differing frequencies, amplitudes and phases.

A Simple Communication System

Once we are out of shouting range of another person, we must rely on some communication system to enable us to pass information.

The essential parts of any communication system are transmitter, a communication link and a receiver, and in the case of speech, this can be achieved by a length of cable with a microphone and an amplifier at one end and a loudspeaker and an amplifier at the other.



Simple Communication System

Figure 4

For long distances, or for when it is required to send signals to many destinations at the same time, it is convenient to use a radio communication system.

Amplitude Modulation (AM)

The method that we are going to use is called amplitude modulation. As the name suggest, we are going to use the information signal to control the amplitude of the carrier wave. As the information signal increases in amplitude, the carrier wave, is also made to increase in amplitude. Likewise, as the information signal decreases, then the carrier amplitude decreases.

By looking at Figure 5 below, we can see that the modulated carrier wave does appear to 'contain' in some way the information as well as the carrier.

We will see later how the receiver is able to extract the information from the amplitude modulated carrier wave.

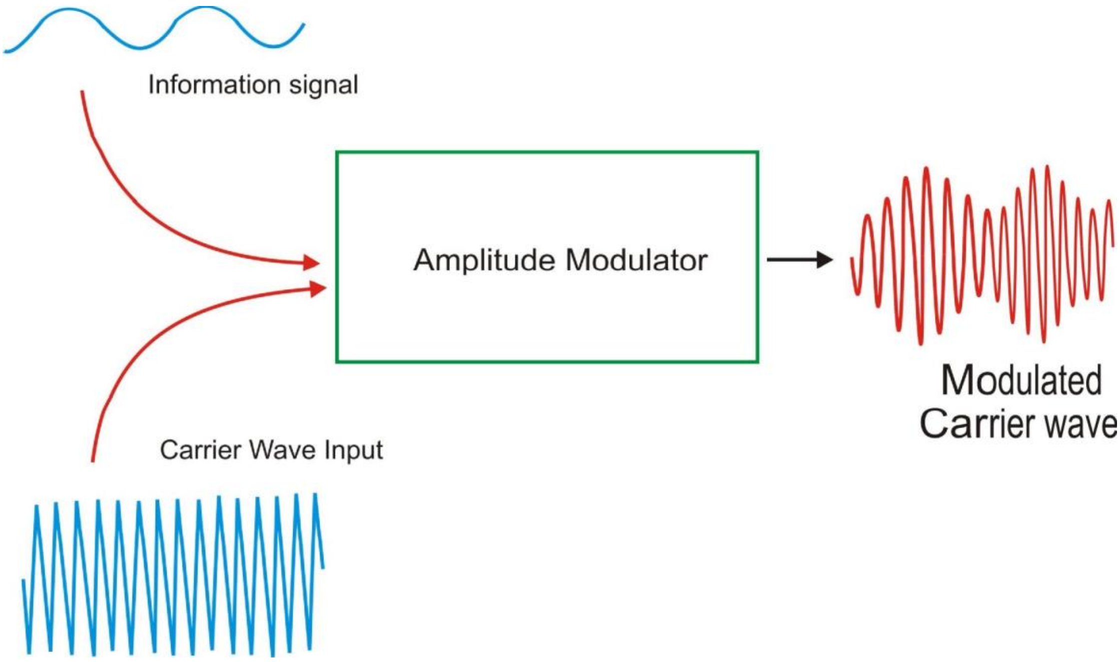


Figure 5

Depth of Modulation:

The amount by which the amplitude of the carrier wave increases and decreases depends on the amplitude of the information signal and is called the 'depth of modulation'.

The depth of modulation can be quoted as a fraction or as a percentage.

$$\text{Percentage modulation} = \frac{V\max - V\min}{V\max + V\min} \times 100\%$$

Here is an example,

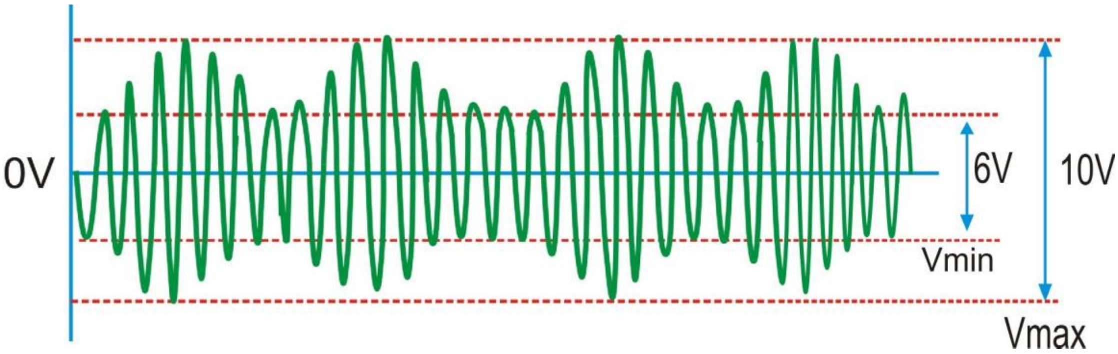


Figure 6

In above Figure 6 we can see that the modulated carrier wave varies from a maximum peak-to-peak value of 10 volts, down to a minimum value of 6 volts. Inserting these figure in the above formula, we get:

$$\text{Percentage modulation} = \frac{10-6}{10+6} \times 100\%$$

$$= \frac{4}{16} \times 100\ \%$$

$$= 25\% \text{ or } 0.25$$

The Frequency Spectrum:

Assume a carrier frequency (fc) of 1 MHz and amplitude of, say 5 volts peak-to-peak.

The carrier could be shown as,

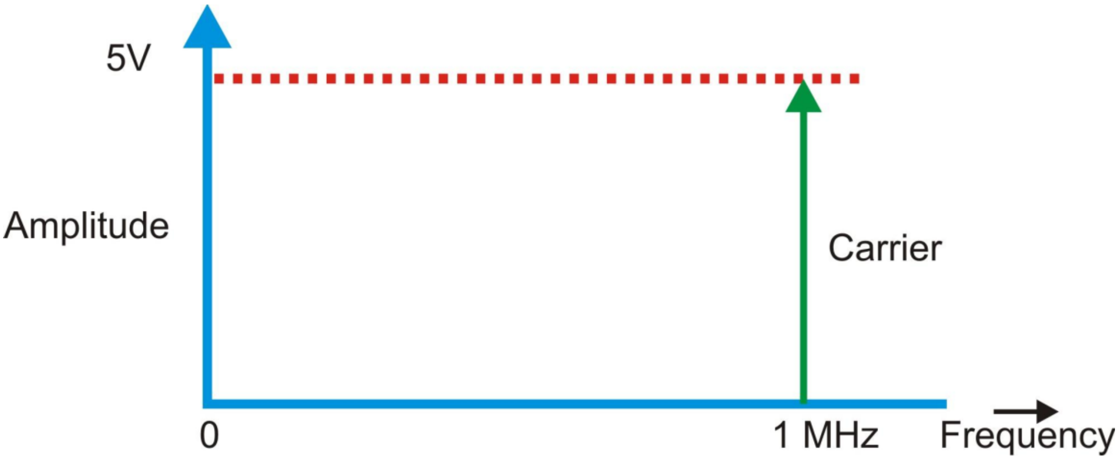


Figure 7

If we also have a 1 KHz information signal, or modulating frequency (fm), with amplitude of 2V peak-to-peak it would look like this,

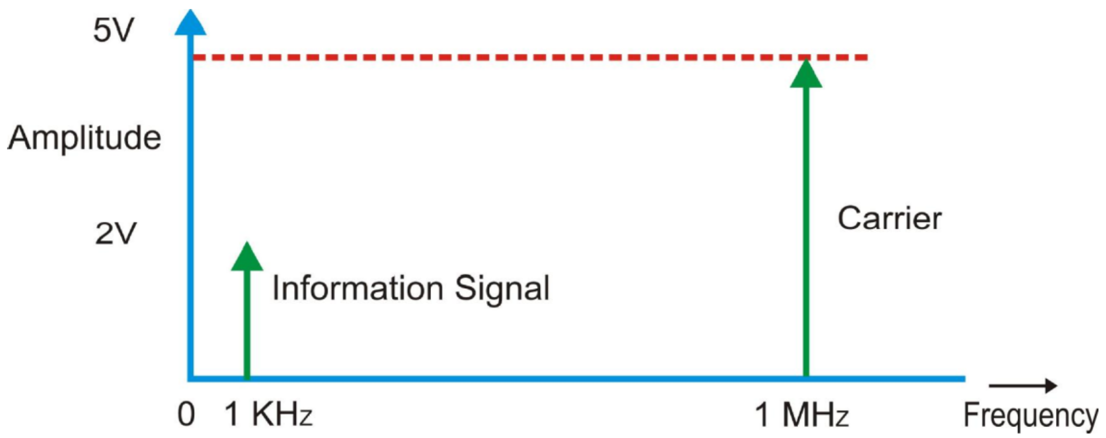


Figure 8

When both signals have passed through the amplitude modulator they are combined to produce an amplitude modulated wave.

The resultant AM signal has a new frequency spectrum as shown in Figure 9 *inserting changes that occurs as a result of the modulation process:*

1. The original 1 KHz information frequency has disappeared.

2. The 1 MHz carrier is still present and is unaltered.

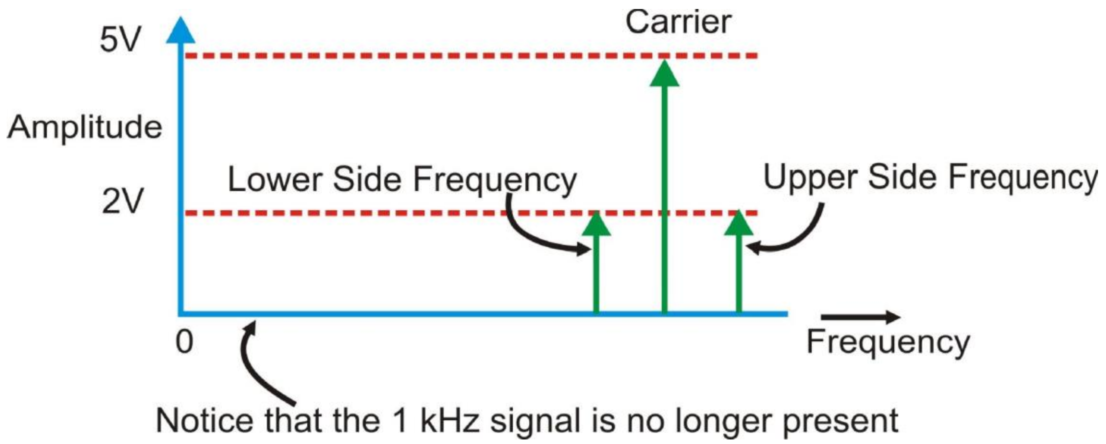


Figure 9

There are two new components:

1. Carrier frequency (fc) plus the information frequency, called the *upper side frequency* (fc + fm).

2. Carrier frequency (fc) minus the information frequency, called the *lower side frequency* (fc - fm).

The resulting signal in this example has a maximum frequency of 1001 KHz and a minimum frequency of 999 KHz and so it occupies a range of 2 KHz. This is called the bandwidth of the signal. Notice how the bandwidth is twice the highest frequency contained in the information signal.

Sidebands:

If the information signal consisted of range of frequencies, each separate frequency will create its own upper side frequency and lower side frequency.

As an example, let us imagine that a carrier frequency of 1 MHz is amplitude modulated by an information signal consisting of frequencies 500Hz, 105 KHz and 2 KHz. As each modulating frequency produces its own upper and lower side frequency there is a range of frequencies present above and below the carrier frequency. All the upper side frequencies are grouped together and referred to as the upper sideband (USB) and all the lower side frequencies from the lower sideband (LSB). This amplitude modulated wave would have a frequency spectrum as shown in Figure 10.

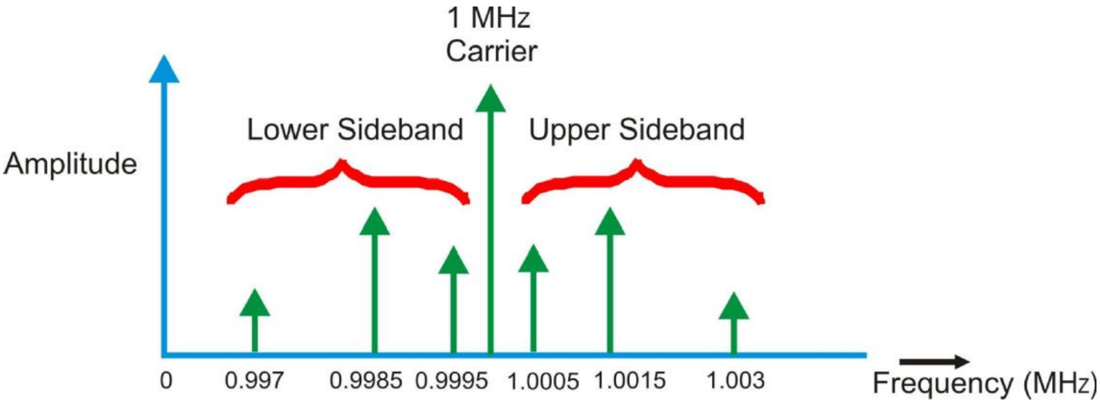


Figure 10

The Power in Sidebands:

The modulated carrier wave that is finally transmitted contains the original carrier and the sidebands. The carrier wave is unaltered by the modulation process and contains at least two thirds of the total transmitted power. The remaining power is shared between the two sidebands.

The power distribution depends on the depth of modulation used and is given by:

$$\text{Total power} = (\text{carrier power}) \frac{(1+N^2)}{2}$$

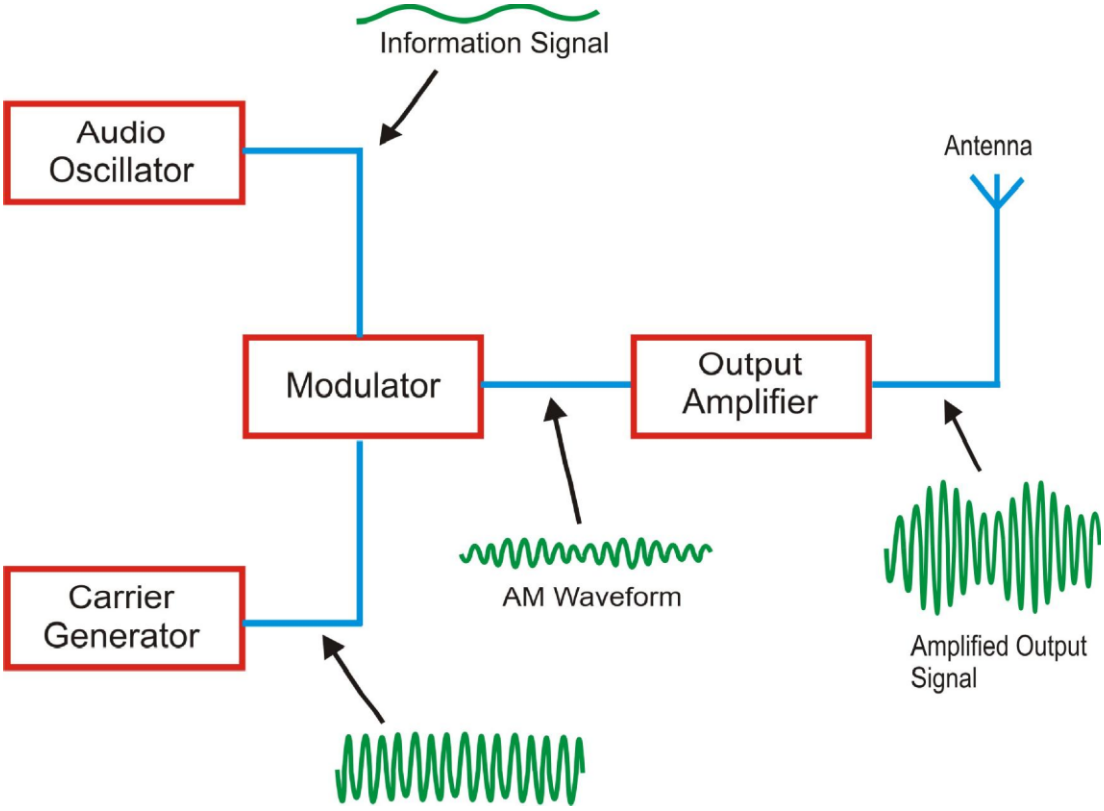
Where N is the depth of modulation. The greater the depth of modulation, the greater is the contained within the sidebands. The highest usable depth of modulation is 100% (above this the distortion becomes excessive).

Since, at least twice as much power is wasted as is used, this form of modulation is not very efficient when considered on a power basis. The good news is that the necessary circuits at the transmitter and the receiver are simple and in expensive to design and construct.

The double sideband transmitter:

The transmitter circuits produce the amplitude modulated signals which are used to carry information over the transmission to the receiver. The main parts of the transmitter are shown in Figure 11.

In Figure 11 & 12, we can see that the peak-to-peak voltage in the AM waveform increase and decrease in sympathy with the audio signal.



AM Transmitter System

Figure 11

To emphasize the connection between the information and the final waveform, a line is sometimes drawn to follow the peaks of the carrier wave as shown in Figure 12. This shape, enclosed by a dashed line in out diagram, is referred to as an 'envelope', or a 'modulation envelope'

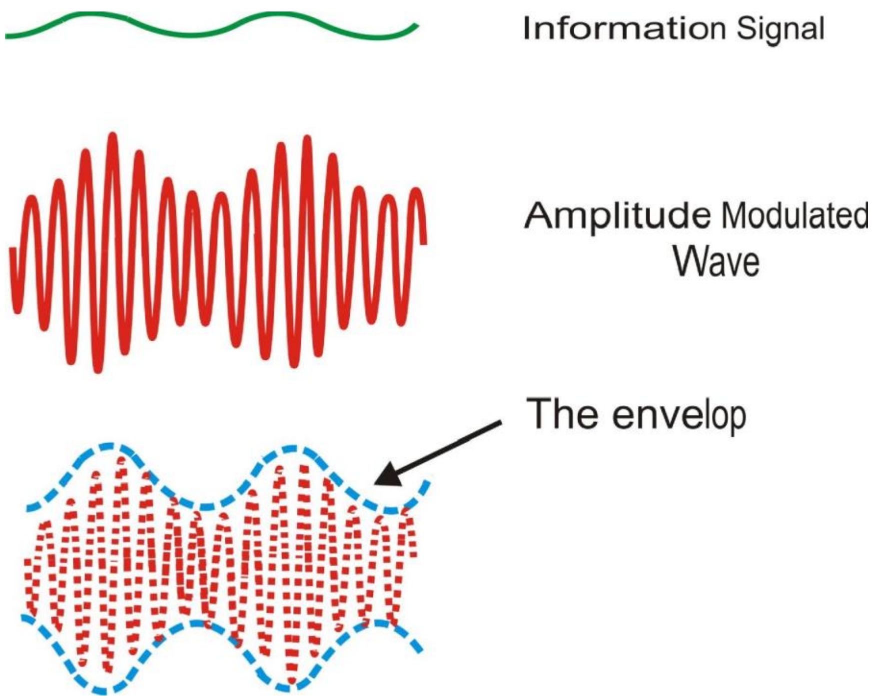


Figure 12

It is important to appreciate that it is only a guide to emphasize of the AM waveform.

Information Signal:

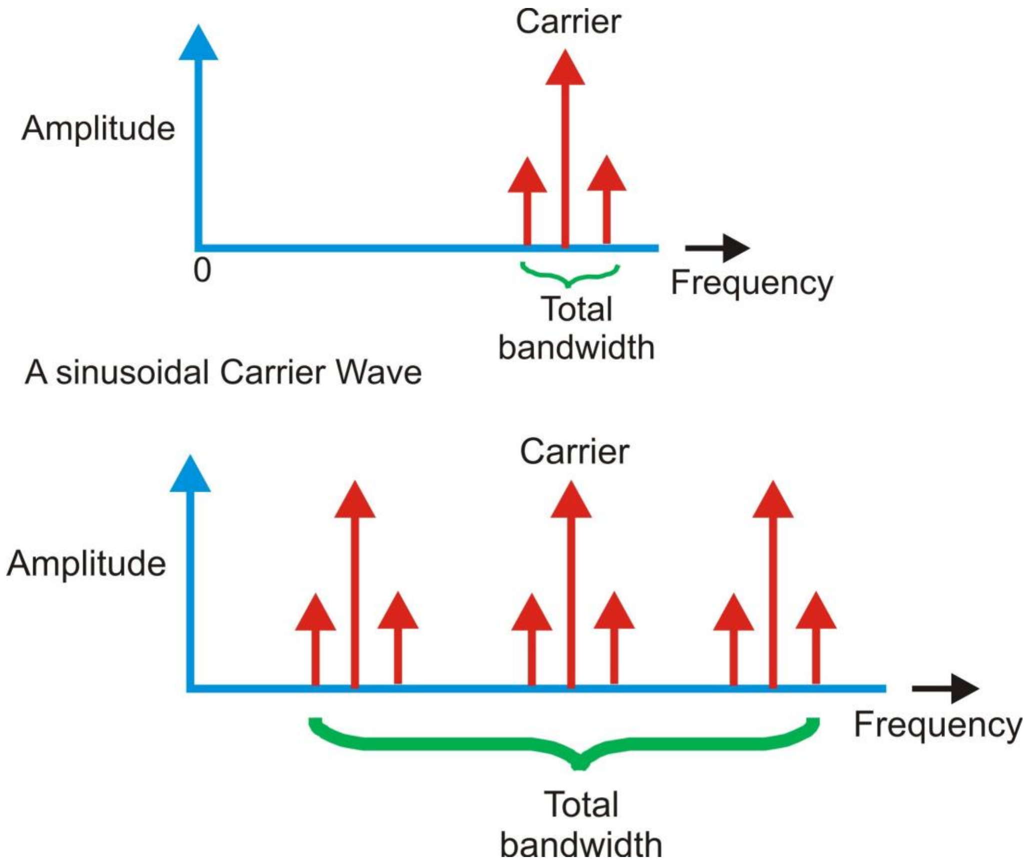
We have a choice of information signals on **Scientech 2201**. We can use the signal provided in the audio oscillator or audio signal by connecting microphone to external audio input and keeping the audio input select switch in ext. position. In test situations it is more satisfactory to use a simple sinusoidal information signal since its attributes are known and of constant value. We can then measure various characteristics of the resultant. AM waveform, such as the modulation depth for example. Such measurements would be very difficult if we were using a varying signal from an external source such as a broadcast station.

Carrier Wave

The carrier wave must meet two main criteria. It should be of a convenient frequency to transmit over the communication path in use. In a radio link transmissions are difficult to achieve at frequencies less than 15 KHz and few radio links employ frequencies above 10GHz. Outside of this range the cost of the equipment increases rapidly with very few advantages.

Remember that although 15 KHz is within the audio range, we cannot hear the radio signal because it is an electromagnetic wave and our ears can only detect waves which are due to changes of pressure.

The second criteria is that the carrier wave should also be a sinusoidal waveform because a sinusoidal signal contains only a single frequency and when modulated by a signal frequency, will give rise to just two side frequencies, the upper and the lower side frequencies. However, if the sinewave were to be a complex wave containing many different frequencies, each separate frequency component would generate its own side frequencies. The result is that the overall bandwidth occupied by the transmission would be very wide and on the radio, would cause interference with the adjacent stations. In Figure 13, a simple case is illustrated in which the carrier only contains three frequency components modulated by a single frequency component. Even so we can see that the over all bandwidth has been considerably increased.

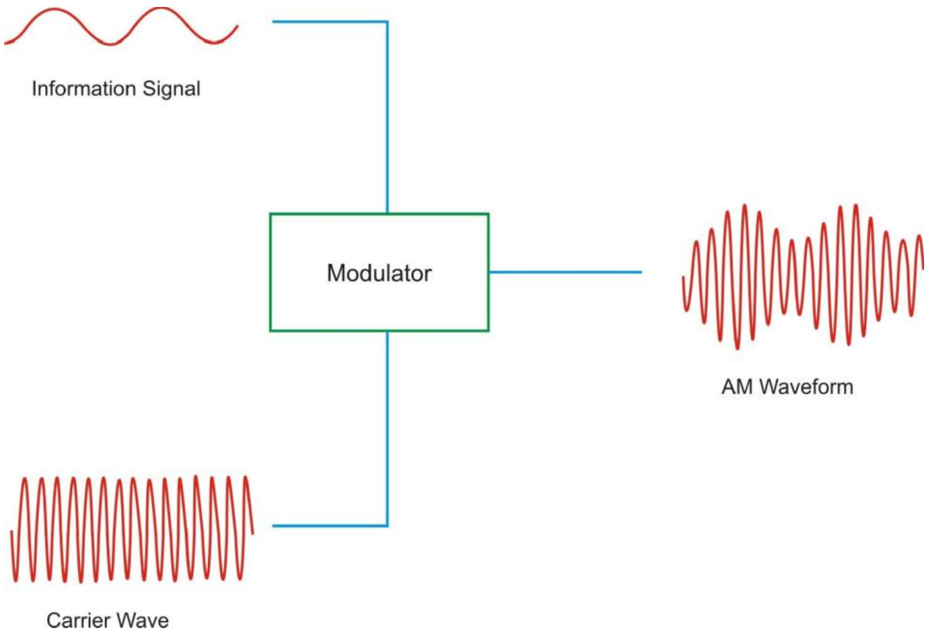


If the carrier contained several frequencies, each would produce its own side Frequencies

Figure 13

Modulator

In this circuit, the amplitude of the carrier is increased and decreased in sympathy with the incoming information signal.



AM Modulation Process

Figure 14

The modulated signal is now nearly ready for transmission. If the modulation process has given rise to any unwanted frequency components then a band pass filter can be employed to remove them.

Output Amplifier

This amplifier is used to increase the strength of the signal before being passed to the antenna for transmission. The output power contained in the signal and the frequency of transmission are the two main factors that determine the range of the transmission.

The Antenna:

An electromagnetic wave, such as a light ray, consists of two fields, an electric field and magnetic field. These two fields are always as right angles to each other and move in a direction which is at right angles to both the magnetic and the electric fields, this is shown in Figure 15, 16 & 17.

Figure 15 shows the electric fields moving out from the antenna. In this example the electric field is vertical because the antenna is positioned vertically (in the direction shown by y).

Figure 16 shows magnetic field is always at right angles to the electric field so in this case, it is positioned horizontally (in the direction shown by x).

Figure 17 shows an electromagnetic wave both fields exist together and they move at the speed of light in a direction that is at right angles to both fields (shown by the arrow labeled z).

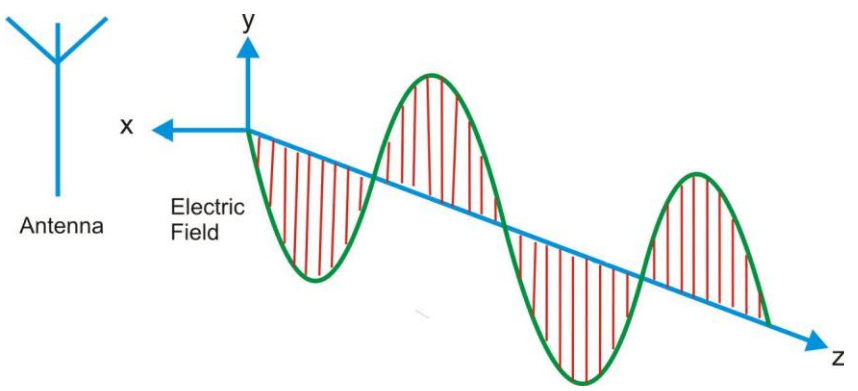


Figure 15

This shows the electric field moving out from the antenna. In this example the electric field is vertical because the antenna is positioned vertically (in the direction shown by y).

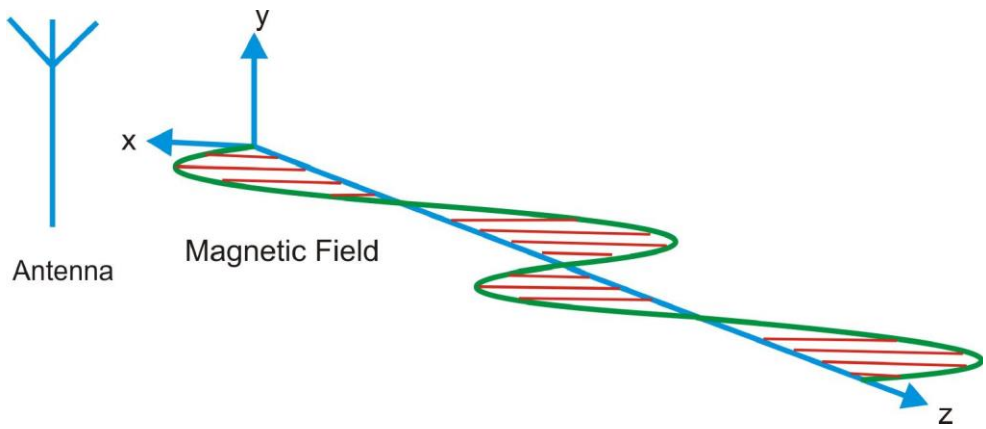


Figure 16

The magnetic field is always at right angles to the electric field so in this case, it is positioned horizontally (in the direction shown by x).

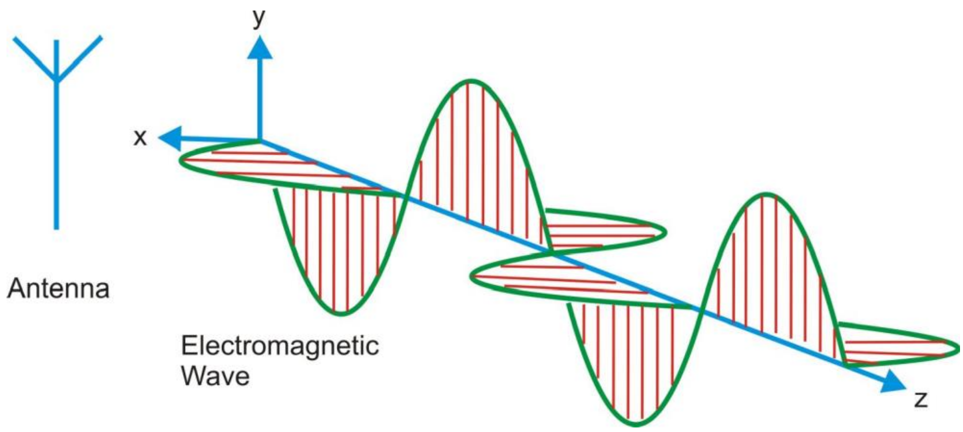


Figure 17

In an electromagnetic wave both fields exist together and they move at the speed of light in a direction that is at right angles to both fields (shown by the arrow labeled z).

The antenna converts the power output of the output amplifier into an electromagnetic wave.

How does it do this ?

The output amplifier causes a voltage to be generated along the antenna thus generating a voltage difference and the resultant electric field between the top and bottom. This causes an alternating movement of electrons on the transmitting antenna which is really an AC current.

Since an electric current always has a magnetic field associated with it, an alternating magnetic field is produced.

The overall effect is that the output amplifier has produced alternating electric and magnetic fields around the antenna. The electric and magnetic fields spread out as an electromagnetic wave at the speed of light (3×10^8 meters per second).

For maximum efficiency, the antenna should be of a precise length. The optimum size of antenna for most purposes is one having an overall length of one quarter of the wave length of the transmitted signal.

This can be found by,

$$\mu = \frac{v}{f}$$

Where

v = speed of light. μ = wave length and f = frequency in Hertz.

In the case of the **Scientech 2201**, the transmitted carrier is 1 MHz and so the ideal length of antenna is:

$$\mu = \frac{3 \times 10^8}{1 \times 10^6}$$

$$\mu = 300\text{m.}$$

One quarter of this wavelength would be 75meters (about 245 feet).

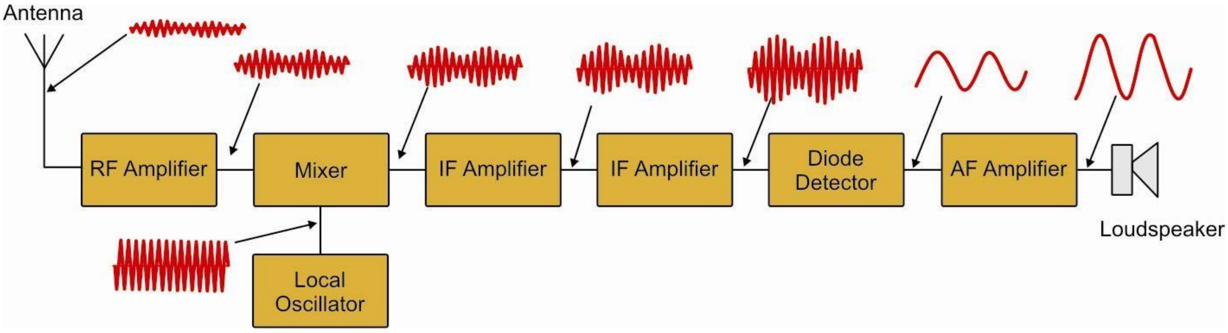
We can now see that the antenna provided on the **Scientech 2201** is necessarily less than the ideal size!

Polarization:

If the transmitting antenna is placed vertically, the electrical field is vertical and the magnetic field is horizontal (as seen in Figure 15, 16 & 17). If the transmitting antenna is now moved by 90° to make it horizontal, the electrical field is horizontal and the magnetic field becomes vertical. By convention, we use the plane of the electric field to describe the orientation, or polarization, of the 'em' (electromagnetic) wave. A vertical transmitting antenna results in a vertically polarized wave, and a horizontal one would result in a horizontally polarized 'em' wave.

DSB Receiver

The 'em' wave from the transmitting antenna will travel to the receiving antenna carrying the information with it.



DSB Receiver

Figure 18

We will continue to follow our information signal as it passes through the receiver.

The Receiving Antenna:

The receiving antenna operates in the reverse mode to the transmitter antenna. The electromagnetic wave strikes the antenna and generates a small voltage in it.

Ideally, the receiving antenna must be aligned to the polarization of the incoming signal so generally, a vertical transmitting antenna will be received best by using a vertical receiving antenna.

The actual voltage generated in the antenna is very small-usually less than 50 millivolts and often only a few microvolts. The voltage supplied to the loudspeaker at the output of the receiver is upto ten volts. We clearly need a lot of amplification.

Radio Frequency (RF) Amplifier:

The antenna not only provides very low amplitude input signals but it picks up all available transmissions at the same time. This would mean that the receiver output would include all the various stations on top of each other which would make it impossible to listen to any one transmission.

The receiver circuits generate noise signals, which are added to the wanted signals. We hear this as a 'background hiss' and are particularly noticeable if the receiver is tuned between stations or if a weak station is being received.

The RF amplifier is the first stage of amplification. It has to amplify the incoming signal above the level of the internally generated noise and also to start the process of selecting the wanted station and rejecting the unwanted ones.

Selectivity:

A parallel tuned circuit has its greatest impedance at resonance and decreases at higher and lower frequencies. If the tuned circuit is included in the circuit design of an amplifier, it results in an amplifier which offers more gain at the frequency of resonance and reduced amplification above and below this frequency. This is called Selectivity.

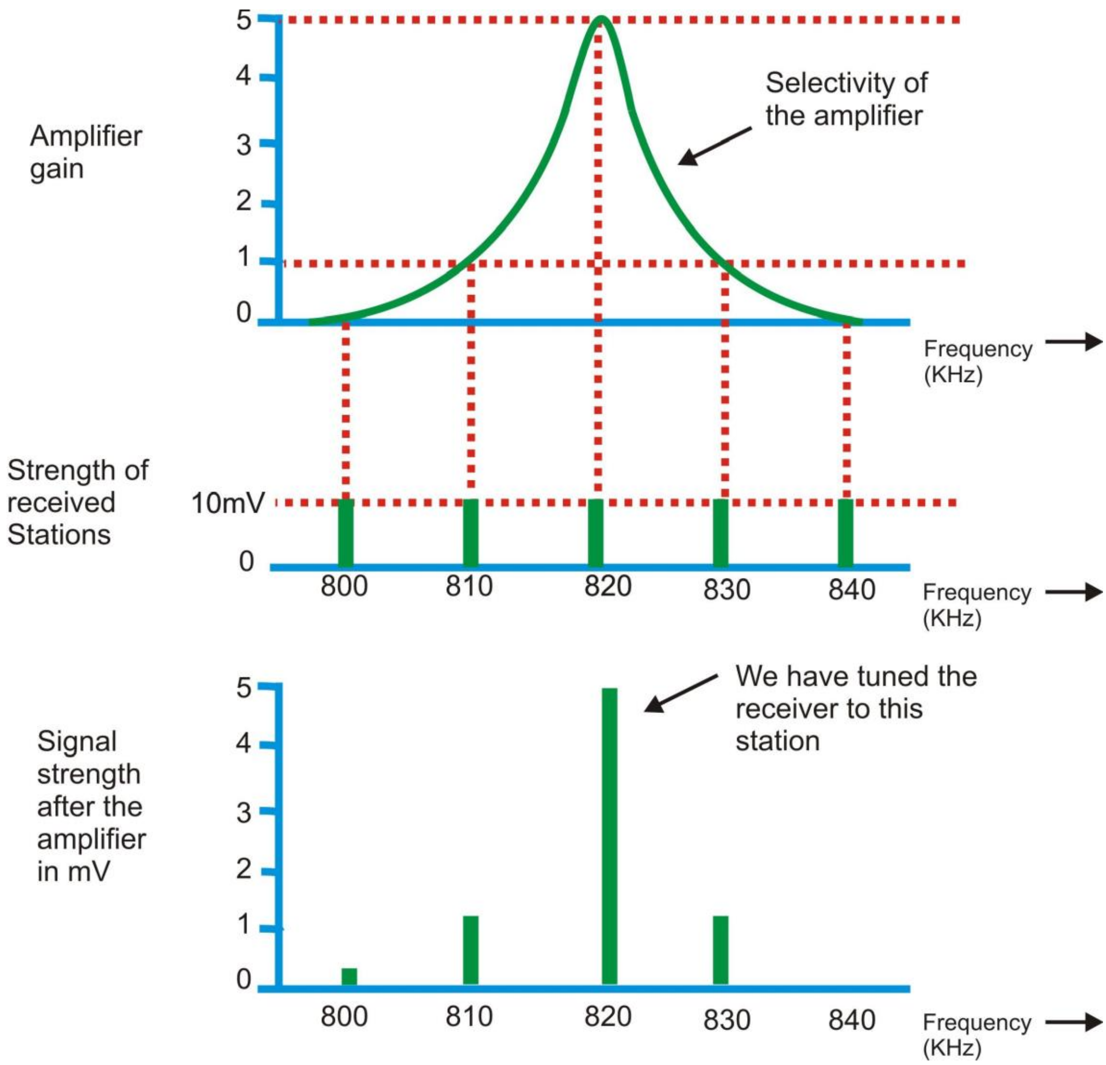


Figure 19

The radio receiver is tuned to a frequency of 820 KHz and, at this frequency; the amplifier provides a gain of five. Assuming the incoming signal has an amplitude of 10 mV as shown, its output at this frequency would be 5 x 10mV = 50mV. The stations being received at 810 KHz and 830 KHz each have a gain of one. With the same amplitude of 10m V, this could result in outputs of 1 x 10mV = 10mV. The stations at 800 KHz and 840 KHz are offered a gain on only 0.1 (approx). This means that the output signal strength would be only 0.1 x 10mV = 1mV.

The over all effect of the selectivity is that where as the incoming signals each have the same amplitude, the outputs vary between 1mV and 50mV so we can select, or 'tune', the amplifier to pick out the desired station.

The greatest amplification occurs at the resonance frequency of the tuned circuit. This is sometimes called the *center frequency*.

In common with nearly all radio receivers, **Scientech 2202** adjusts the capacitor value by means of the tuning control to select various signals.

The Local Oscillator:

This is an oscillator producing a sinusoidal output similar to the carrier wave oscillator in the transmitter. In this case however, the frequency of its output is adjustable.

The same tuning control is used to adjust the frequency of both the local oscillator and the center frequency of the RF amplifier. The local oscillator is always maintained at a frequency which is higher, by a fixed amount, then the incoming RF signals. The local oscillator frequency therefore follows, or tracks, the RF amplifier frequency. This will prove to be very useful as we will see in the next section.

Mixer:

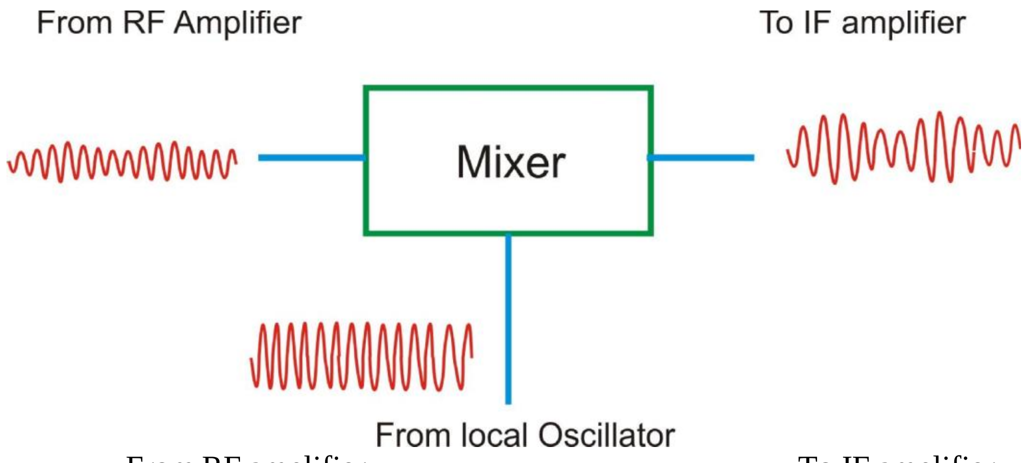
The mixer performs a similar function to the modulator in transmitter. We may remember that the transmitter modulator accepts the information signal and the carrier frequency, and produces the carrier plus the upper and lower sidebands. The mixer in the receiver combines the signal from the RF amplifier and the frequency input from the local oscillator to produce three frequencies:

C A 'difference' frequency of local oscillator frequency - RF signal frequency. **C**

A 'sum' frequency equal to local oscillator frequency + RF signal frequency **C** A

component at the local oscillator frequency.

Mixing two signals to produce such components is called a *'heterodyne'* process. When this is carried out at frequencies which are above the audio spectrum, called 'supersonic' frequencies, the type of receiver is called a *'super heterodyne'* receiver. It is not a modern idea having been invented in the year 1917.



From RF amplifier To IF amplifier

Figure 20

In the section the local oscillator, we read how the local oscillator tracks the RF amplifier so that the difference between the two frequencies is maintained at a constant value. In **Scientehc 2201 & Scientech 2202** this difference is 455 KHz (approximately).

As an example, if the radio is tuned to receive a broadcast station, which transmits at 800 KHz, the local oscillator will be running at 1.25 MHz. The difference frequency is 1.255MHz - 800 MHz = 455 KHz.

If the radio is now re-tuned to receive a different station being broadcast on 700 KHz, the tuning control re-adjusts the RF amplifier to provide maximum gain at 700 KHz and the local oscillator to 1.155 MHz. The difference frequency is still maintained at the required 455 KHz.

This frequency difference therefore remains constant regardless of the frequency to which the radio is actually tuned and is called the *intermediate frequency (IF)*.

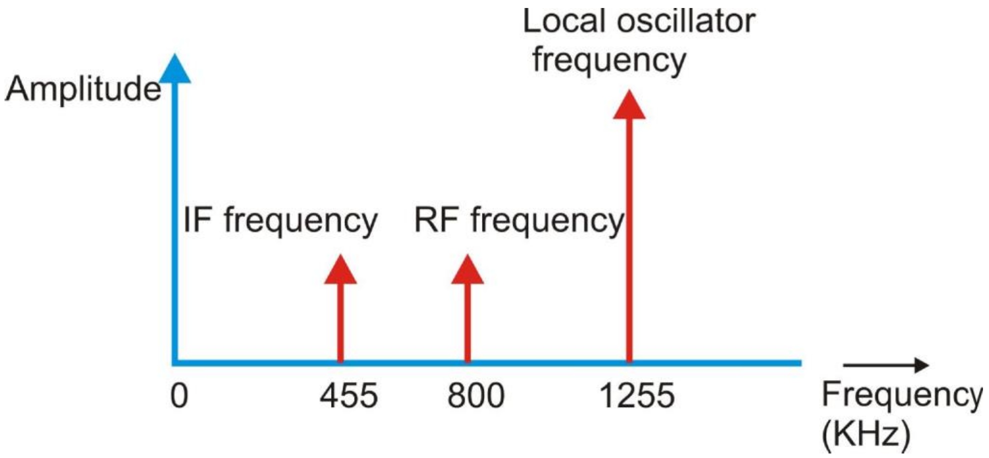


Figure 21

Note: *In Figure 21, the local oscillator output is shown larger than the IF and RF frequency components, this is usually the case. However, there is no fixed relationship between the actual amplitudes. Similarly, the IF and RF amplitudes are shown as being equal in amplitude but again there is no significance in this.*

Image Frequencies:

In the last section, we read we could receive a station being broadcast on 700 KHz by tuning the local oscillator to a frequency of 1.155 MHz. thus giving the difference (IF) frequency of required 455 KHz.

What would happen if we were to receive another station which was broadcasting on a frequency of 1.61 MHz?

This would also mix with the local oscillator frequency of 1.155 MHz to produce the required IF frequency of 455 KHz. This would mean that this station would also be received at the same time as our wanted one at 700 KHz.

Station 1:

Frequency 700 KHz, Local oscillator 1.155 MHz, IF = 455 KHz

Station 2:

Frequency 1.61 MHz, oscillator 1.155 MHz, IF = 455 KHz

An 'image frequency' is an unwanted frequency that can also combine with the Local Oscillator output to create the IF frequency.

Notice how the difference in frequency between the wanted and unwanted stations is twice the IF frequency. In the **Scientech 2201/Scientech 2202**, it means that the image frequency is always 910 KHz above the wanted station.

This is a large frequency difference and even the poor selectivity of the RF amplifier is able to remove the image frequency unless it is very strong. In this case, it will pass through the receiver and will be heard at the same time as the wanted station. Frequency interactions between the two stations tend to cause irritating whistles from the loudspeaker.

Intermediate Frequency Amplifier (IF Amplifiers):

The IF Amplifier in this receiver consists of two stages of amplification and provides the main signal amplification and selectivity.

Operating at a fixed IF frequency means that the design of the amplifiers can be simplified. If it were not for the fixed frequency, all the amplifiers may need to be tunable across the whole range of incoming RF frequencies and it would be difficult to arrange for all the amplifiers to keep in step as they are re-tuned.

In addition, the radio must select the wanted transmission and reject all the others. To do this the band pass of all the stages must carefully controlled. Each IF stage does not necessarily have the same band pass characteristics. The overall response is important. Again, this is something which is much more easily achieved without the added complication of making them tunable.

At the final output from the IF amplifiers, we have a 455 KHz wave which is amplitude modulated by the wanted audio information.

The selectivity of the IF amplifiers has removed the unwanted components generated by the mixing process.

Diode Detector:

The function of the diode detector is to extract the audio signal from the signal at the output of the IF amplifiers. It performs this task in a very similar way to a half wave rectifier converting an AC input to a DC output. Figure 22 shows a simple circuit diagram of the diode detector.

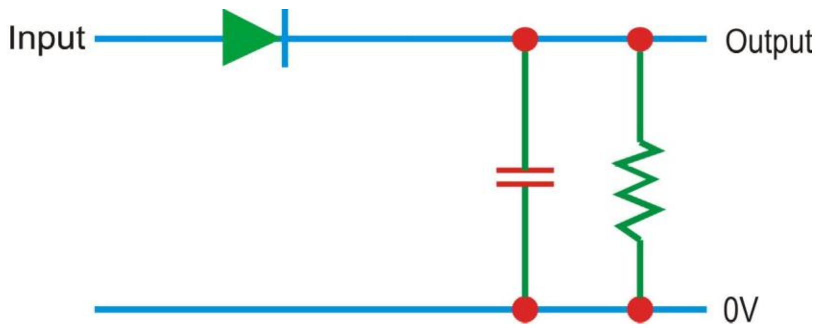


Figure 22

In Figure 22, the diode conducts every time the input signal applied to its anode is more positive than the voltage on the top plate of the capacitor.

When the voltage falls below the capacitor voltage, the diode ceases to conduct and the voltage across the capacitor leaks away until the next time the input signal is able to switch it on again. See Figure 23.

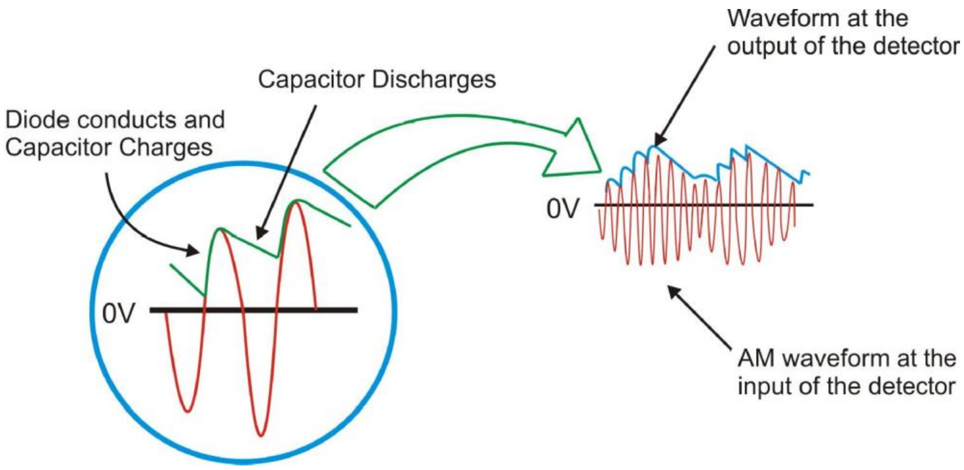


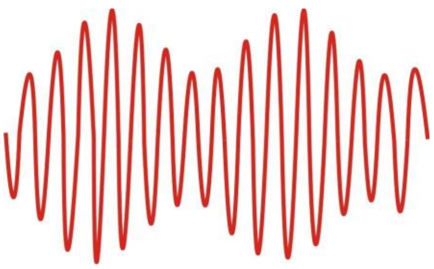
Figure 23

The result is an output which contains three components:

1. The wanted audio information signal.
2. Some ripple at the IF frequency.
3. A positive DC voltage level.

The Audio Amplifier:

At the input to the audio amplifier, a low pass filter is used to remove the IF ripple and a capacitor blocks the DC voltage level. *Figure 24 shows the result of the information signal passing through the diode detector and audio amplifier*.



The input to the diode detector from the last IF amplifier

Output of diode detector includes: a DC level, the audio signal, ripple at IF frequency

Output after filtering

Figure 24

The remaining audio signals are then amplified to provide the final output to the loudspeaker.

Automatic Gain Control (AGC)

The AGC circuit is used to prevent very strong signals from overloading the receiver. It can also reduce the effect of fluctuations in the received signal strength. The 'AGC circuit makes use of the mean DC voltage level present at the output of the diode detector.

If the signal increases, the mean DC voltage level also increases, IF the mean DC voltage level exceeds a predetermined threshold value, a voltage is applied to the RF and IF amplifiers in such a way as to decrease their gain to prevent overload.

As soon as the incoming signal strength decreases, such that the mean DC voltage level is reduced below the threshold, the RF and IF amplifiers return to their normal operation.

AGC Off:

At low signal strength the AGC circuit has no effect

This part of the transmission will overload the receiver and cause distortion

AGC On:

The AGC has limited the amplification to prevent overload and distortion

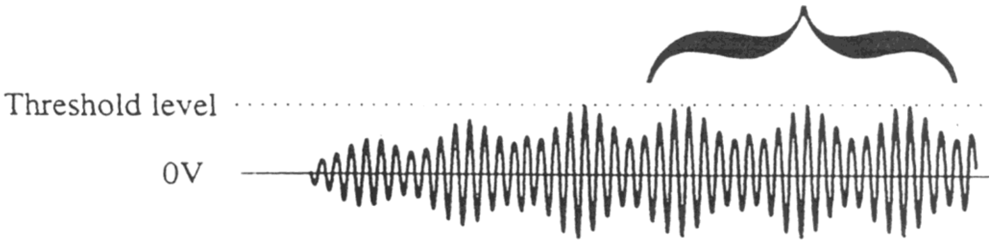


Figure 25

Recommended testing instruments for experimentation:

1. 20MHz, dual trace oscilloscope 201.
2. Switchable probe.
3. Function Generator (1 MHz).
4. Frequency Counter (10 MHz) preferable.

Experiment 1

Part 1

Objective:

Double Sideband AM Generation

Procedure:

This experiment investigates the generation of double sideband amplitude modulated (AM) waveforms, using the **Scientech 2201** module. By removing the carrier from such an AM waveforms, the generation of double sideband suppressed carrier (DSBSC) AM is also investigated.

1. Ensure that the following initial conditions exist on the board.
   a. Audio input select switch should be in INT position to select onboard generated audio signal as a modulating signal.
   b. Mode switch in DSB position to connect the DSB signal to Output Amplifier section.
   c. Output amplifier's gain potentiometer in full clockwise position for maximum amplification.
   d. Speakers switch in OFF position.

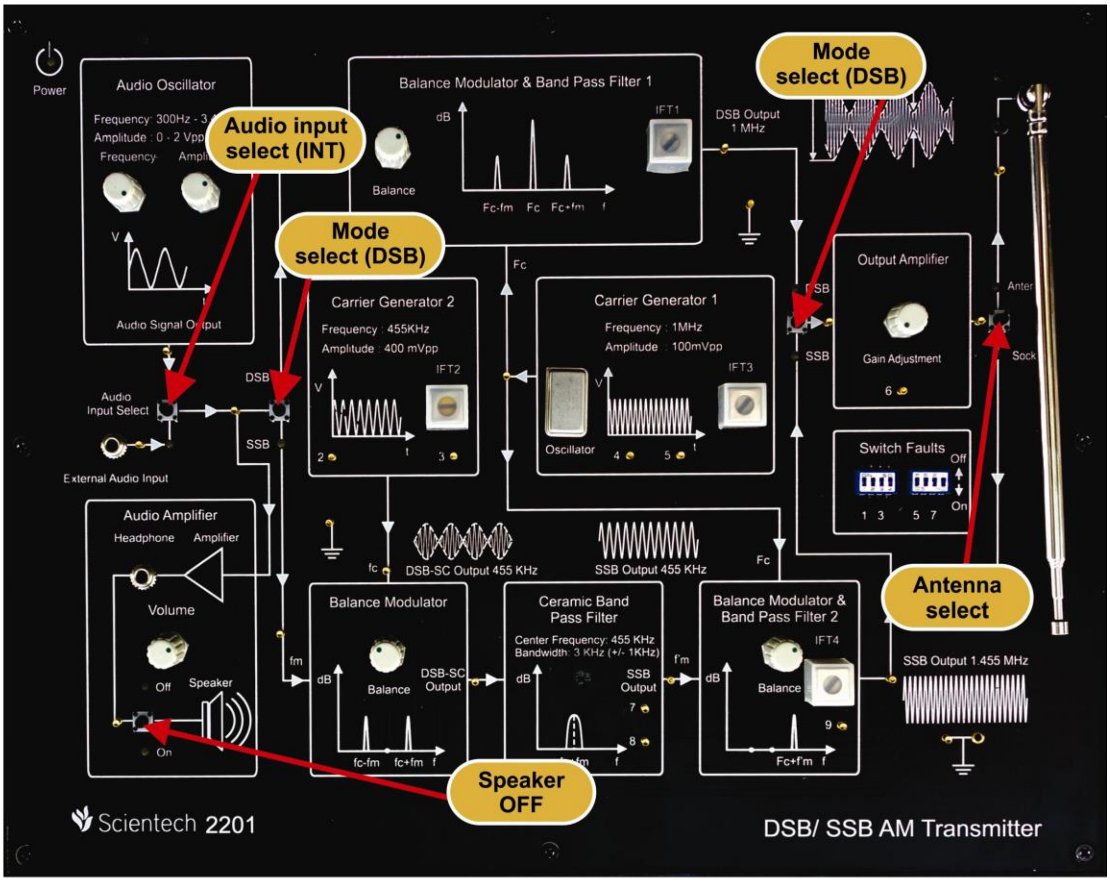


Figure 1.1

2. Turn on power to the **Scientech 2201** board.

3. Observe the output of 'Audio Oscillator' block at 'Audio Signal Output' test point on Oscilloscope (Fig. 1.2). Amplitude and Frequency of this audio signal can be varied using the respective Amplitude and Frequency control pots. The amplitude varies from 0 to 2vpp approx and frequency varies from 300Hz to 3 KHz approx.

   This is the audio frequency sine wave which will use as modulating signal input to Balanced Modulator and Band Pass Circuit 1.

   [CH1(Y) – 0.5V; Time base – 0.1 mS]

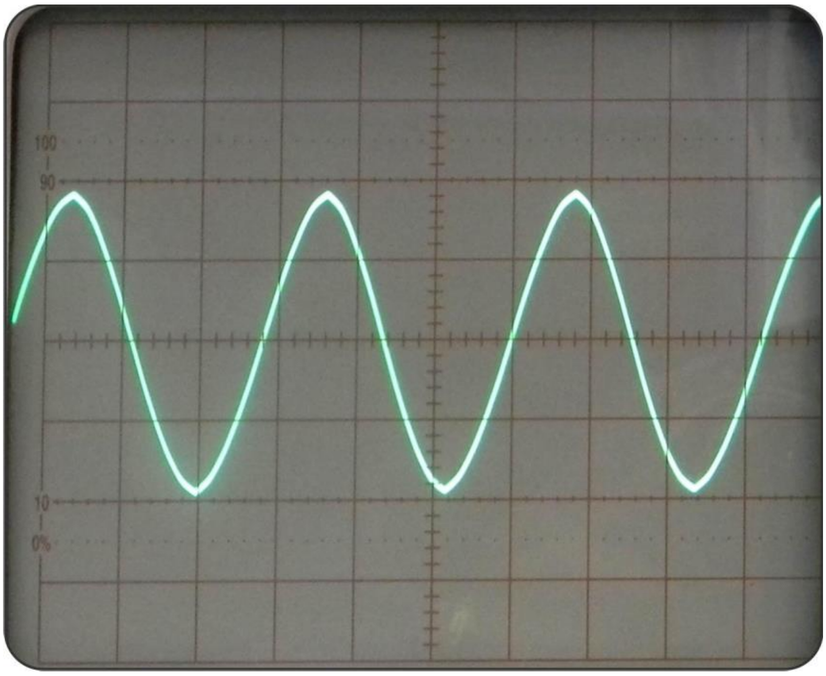


Figure 1.2

4. 1 MHz Crystal Oscillator Block generates a sine wave of 1 MHz frequency and 120mV pp amplitude approx, which is used as a carrier input to Balance Modulator and Band Pass Filter Circuit 1. Observe the carrier waveform at output test point on Oscilloscope. [CH1(Y) – 10mV; Time base – 1 uS]

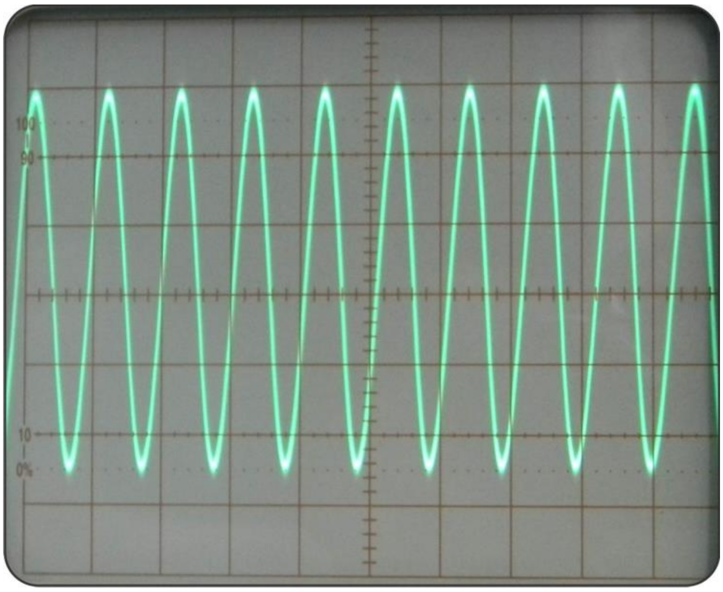


Figure 1.3

5. Balanced Modulator and Band Pass Filter Circuit 1 use to perform ‘Double Side Band Amplitude Modulation’. Balance pot is used to vary the depth of modulation AM waveform. Initially turn the pot to its maximum position and observe the DSB AM output on Oscilloscope together with the modulating Audio Signal output l at Trigger the Oscilloscope on the Audio signal output.

   The output from the balanced modulator & band pass filter circuit 1 block is a double-sideband. AM waveform, which has been formed by amplitude-modulating the 1MHz carrier sinewave with the audio-frequency sinewave from the audio oscillator.

   [CH1(Y) – 1V; CH2(X) – 0.2V Time base – 0.1 mS]

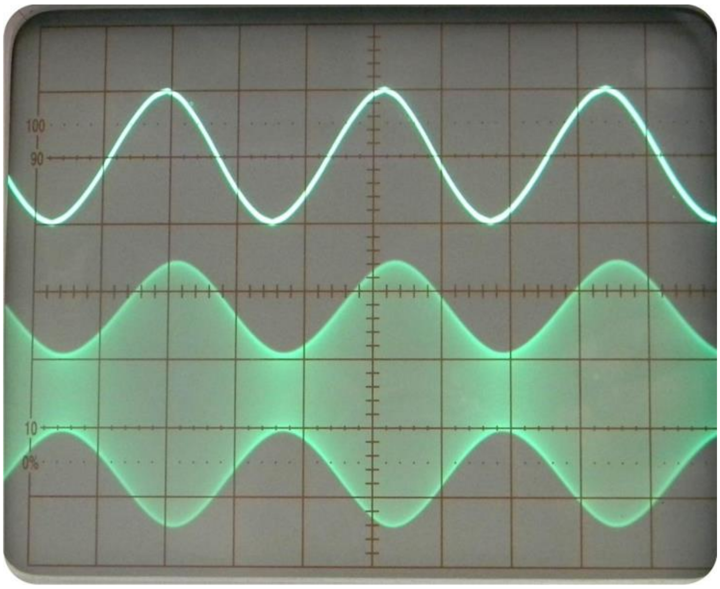


Figure 1.4

The frequency spectrum of this AM waveform is as shown below in Figure 1.5, where *fm* is the frequency of the audio modulating signal.

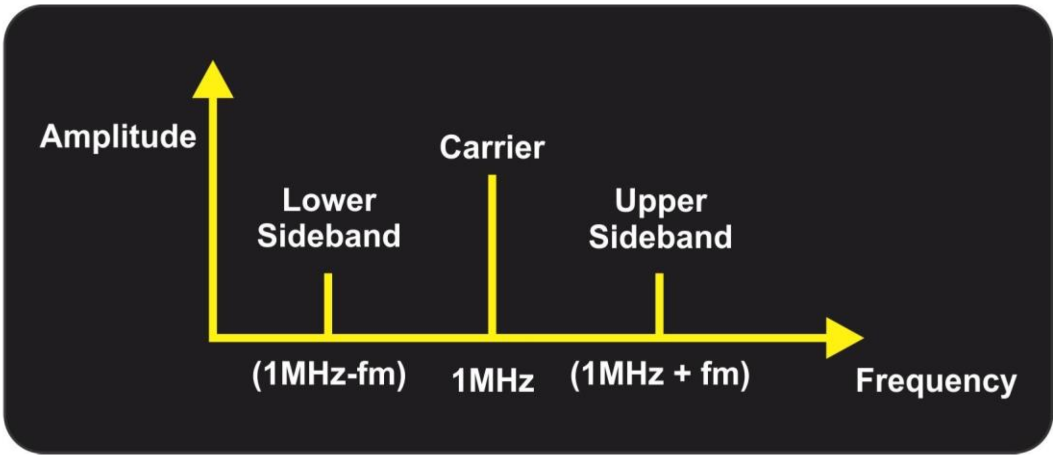


Figure 1.5

6. To determine the depth of modulation, measure the maximum amplitude (Vmax) and the minimum amplitude (V min) of the AM waveform, and use the following formula:

$$\text{Percentage Modulation} = \frac{\text{Vmax} - \text{Vmin}}{\text{Vmax} + \text{Vmin}} \text{ X } 100\%$$

   Where V max and V min are the maximum and minimum amplitudes shown in Figure 1.4.

7. Now vary the frequency of the modulating audio signal by varying the frequency pot of audio oscillator block and observe the effect on AM waveform. The frequency of envelop also varies with respect to the modulating audio signal frequency.

8. Now vary the amplitude of the modulating audio signal by varying the amplitude pot in the audio oscillator block and observe the effect on AM waveform. The amplitude of two sidebands can be reduced to zero by reducing the amplitude of the modulating audio signal to zero. Do this by turning the amplitude pot to its MIN position, and note that the signal at the output of Balanced modulator & Band pass filter 1 becomes an un-modulated sine wave of frequency 1 MHz, indicating that only the carrier component now remains.

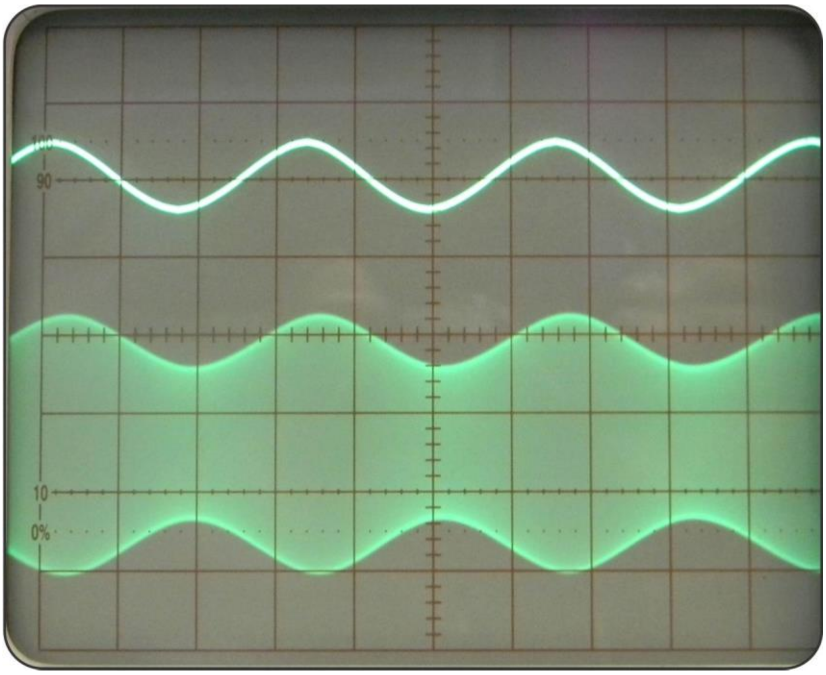


Figure 1.6

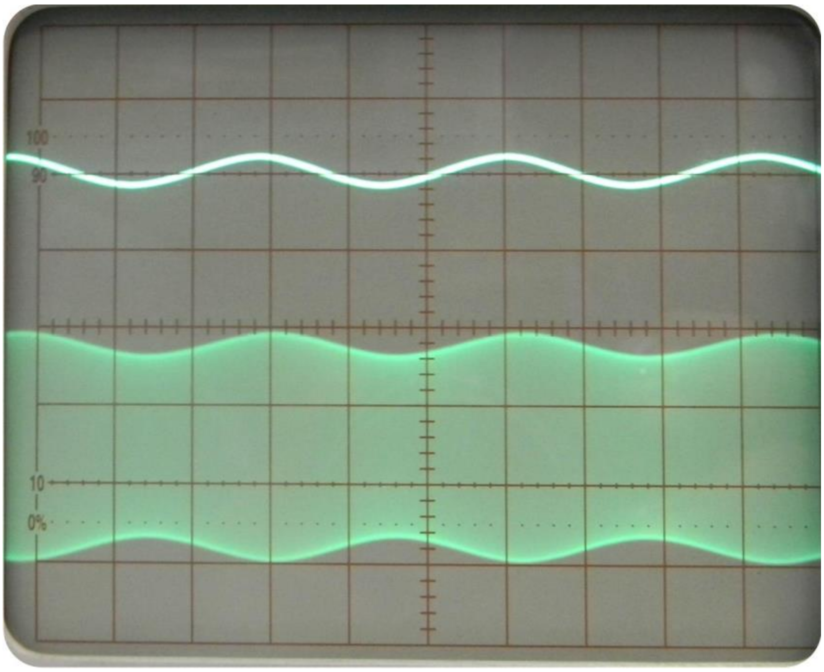


Figure 1.7

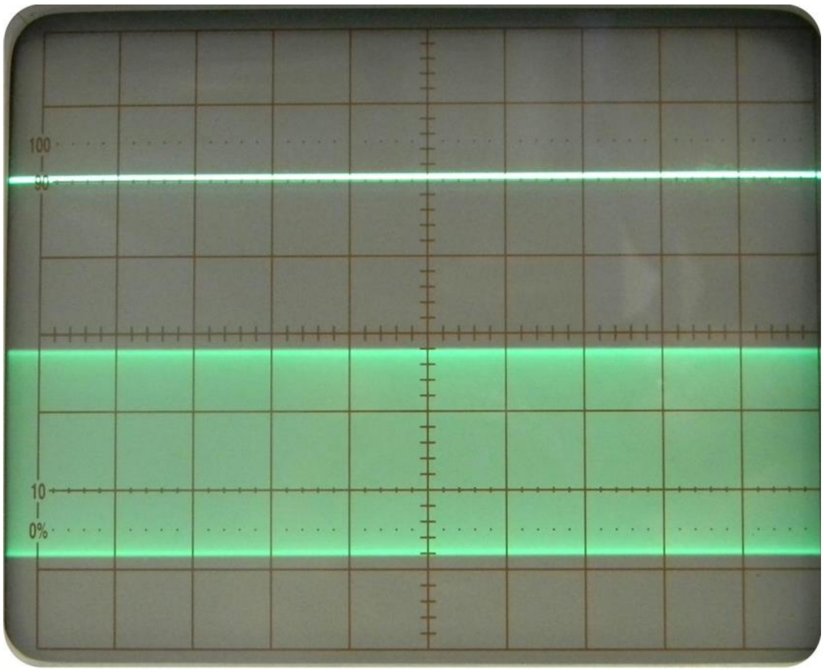


Figure 1.8

9. Now turn the amplitude pot of modulating audio signal to its maximum position and observe the DSB AM waveform at the output of Balanced Modulator & Band pass filter 1 by varying the 'Balance' pot to see the effect of change of depth of modulation.

   [CH1(Y) – 1V; CH2(X) – 0.2V Time base – 0.1 mS]

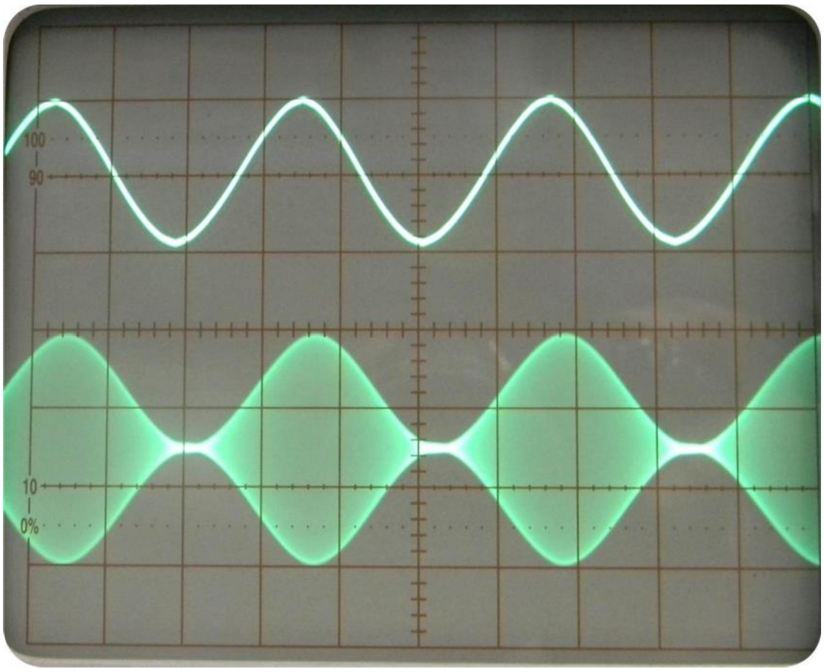


Figure 1.9

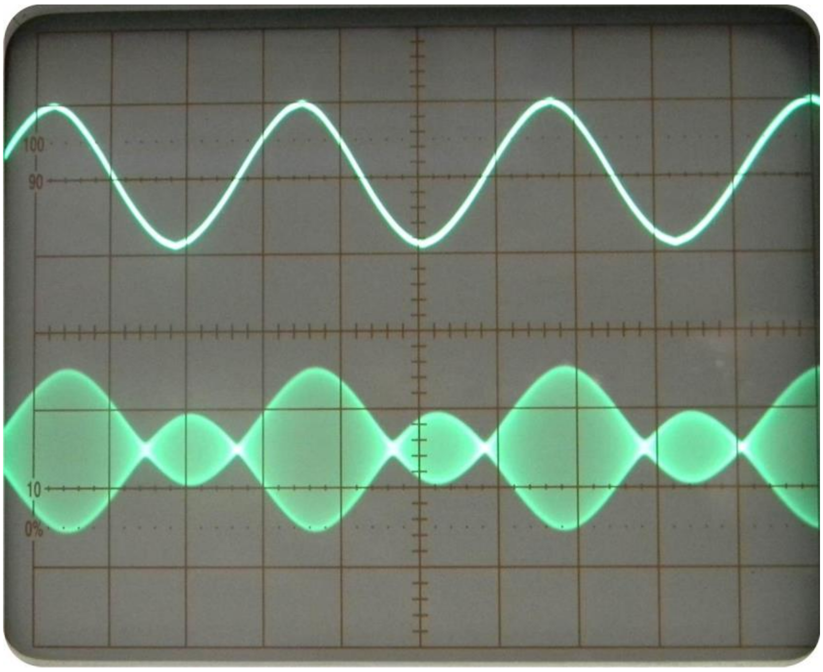


Figure 1.10

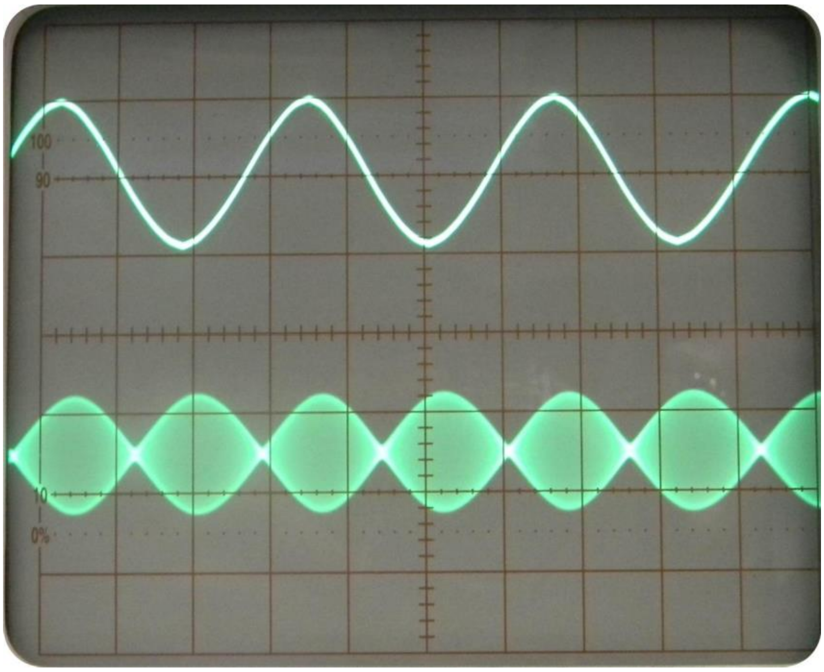


Figure 1.11

10. Observe the output of the ‘Output Amplifier block , together with the modulating Audio signal output, triggering the scope with the audio signal. Note that the DSBSC waveform appears, amplified slightly at the Output Amplifier, as we will see later, it is the output amplifier's output signal which will be transmitted to the receiver.

11. By using the microphone, the human voice can be used as the modulating signal, instead of using **Scientech 2201**'s audio oscillator block.

    Connect the module's output to the external audio input on the **Scientech 2201** board, and put the audio input select switch in the ext position.

    The input signal to the audio input module may be taken from an external microphone or from a cassette recorder, by choosing the appropriate switch setting on the module.

    Refer the user manual for the audio input module, for further details.

Experiment 2

Part 1

Objective:

To calculate modulation index of DSB wave by trapezoidal pattern

Procedure:

1. Ensure that the following initial conditions exist on the board.

   a. Audio input select switch should be in INT position to select onboard generated audio signal as a modulating signal.

   b. Mode switch in DSB position to connect the DSB signal to Output Amplifier section.

   c. Output amplifier's gain potentiometer in full clockwise position for maximum amplification.

   d. Speakers switch in OFF position.

2. Turn on power to the **Scientech 2201** board.

3. Set the amplitude and frequency of the audio signal to its maximum position using the respective Amplitude and Frequency control pots.

   This is the audio frequency sine wave is the modulating signal input to Balanced Modulator and Band Pass Circuit 1 with 1 MHz carrier input from 1 MHz Crystal oscillator block.

4. Balanced Modulator and Band Pass Filter Circuit 1 generate 'Double Side Band Amplitude Modulation'. Balance pot is used to vary the depth of modulation AM waveform. Initially turn the pot to its maximum position.

   The output from the balanced modulator & band pass filter circuit 1 block is a Double-Sideband. AM waveform, which has been formed by amplitude-modulating the 1MHz carrier sine wave with the audio-frequency sine wave from the audio oscillator.

5. To determine the depth of modulation, measure the maximum amplitude (Vmax) and the minimum amplitude (V min) of the AM waveform, and use the following formula:

$$\text{Percentage Modulation} = \frac{\text{Vmax} - \text{Vmin}}{\text{Vmax} + \text{Vmin}} \text{ X } 100\%$$

   Where Vmax and Vmin are the maximum and minimum amplitudes shown in figure 2.1.

   [CH1(Y) – 1V; CH2(X) – 0.2V Time base – 0.1 mS]

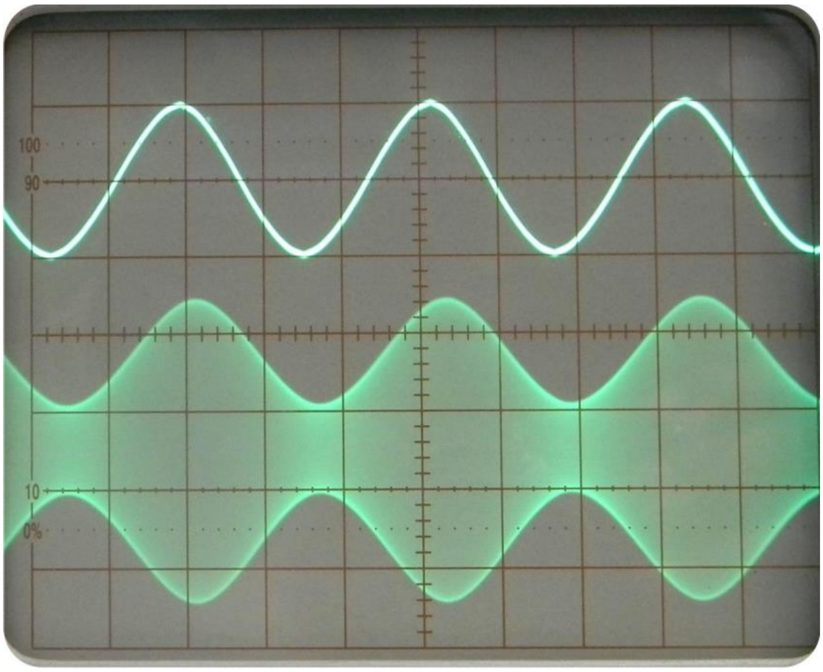


Figure 2.1

6. Now connect modulated waveform to the CH1(Y) input of the Oscilloscope and the modulating audio signal to the CH2(X) input of the Oscilloscope.

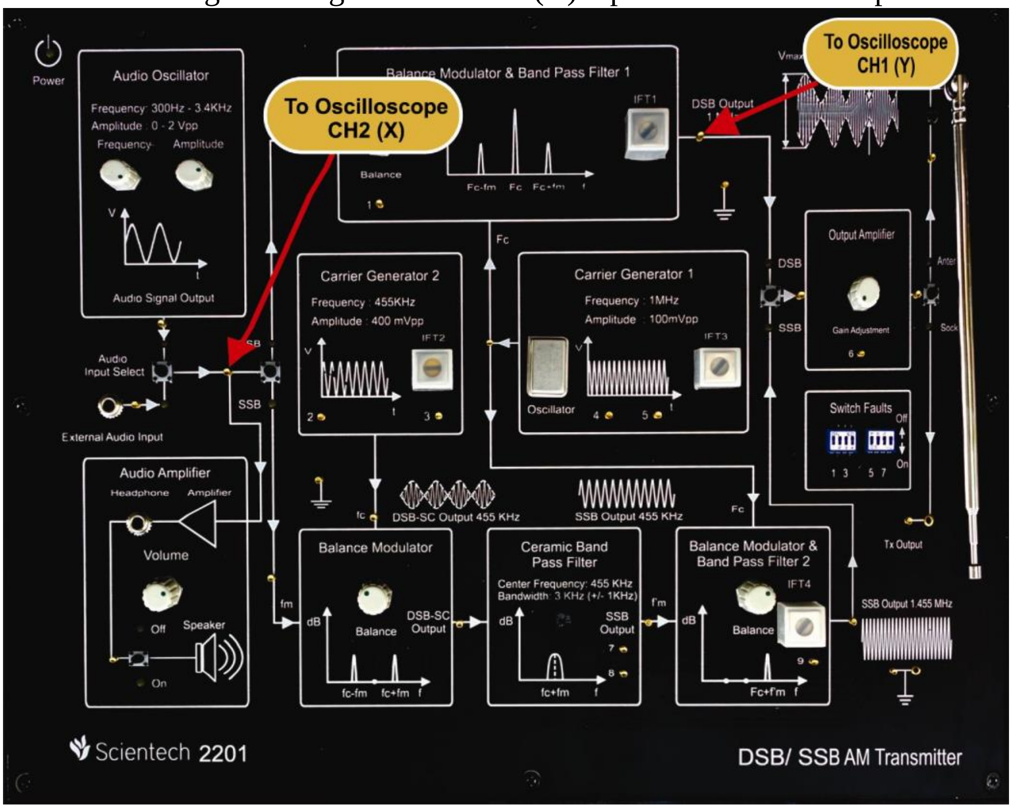


Figure 2.2

7. Press the XY switch, you will observe the waveform similar to the one given below:
[CH1(Y) – 0.2V; CH2(X) – 0.5V Time base – 0.1 mS]

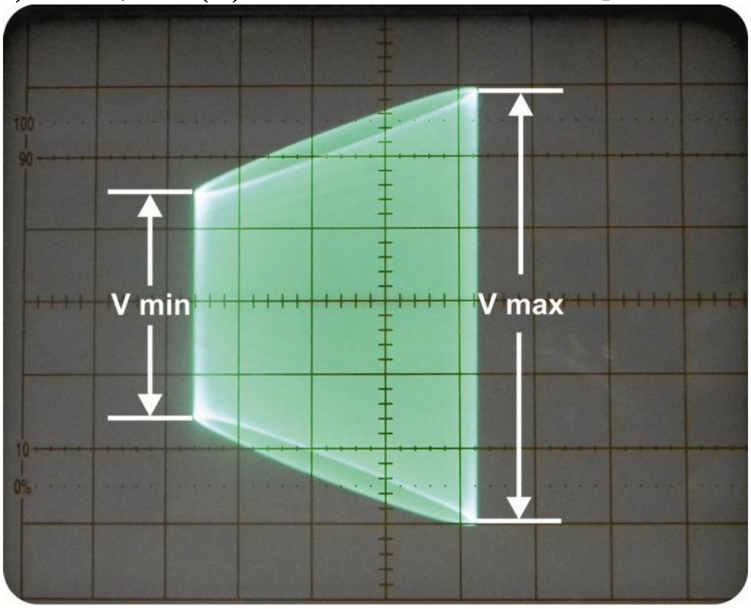
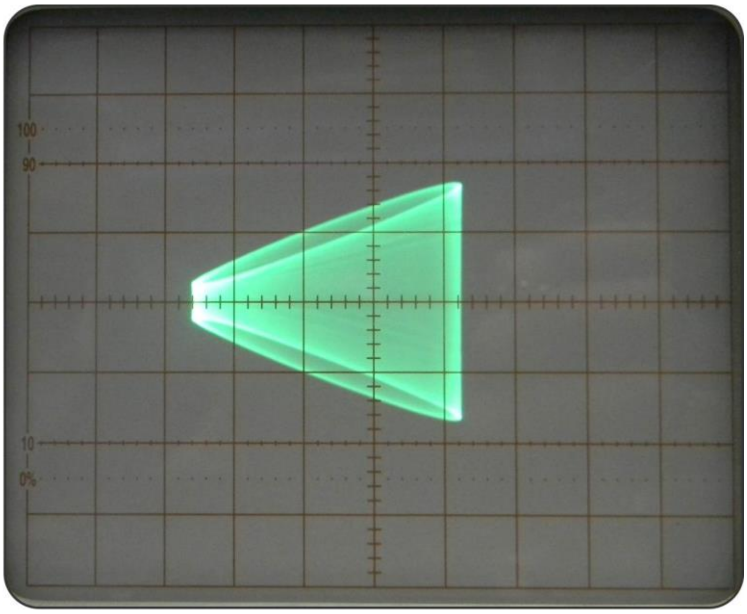


Figure 2.3

Calculate the modulation index by substituting in the formula

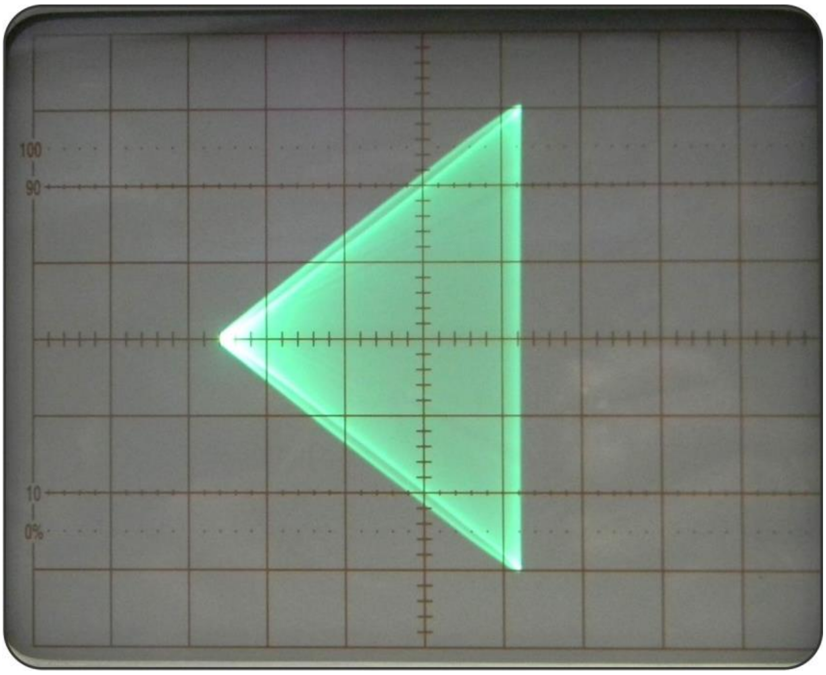
$$\text{Percentage Modulation} = \frac{\text{V max - V min}}{\text{V max + V min}} \text{ X } 100\%$$

8. Some common trapezoidal patterns for different modulation indices are as shown:



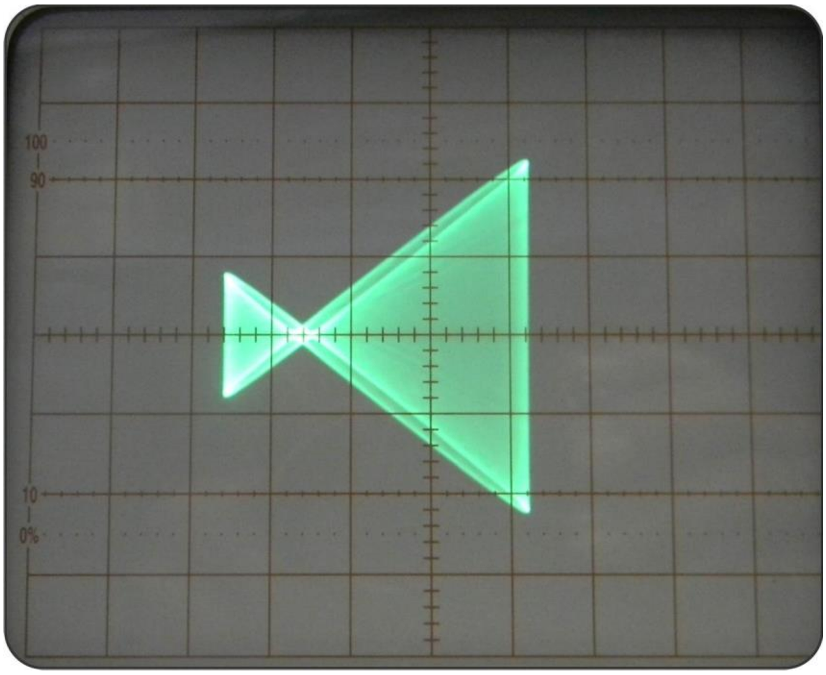
m<1

Figure 2.4



m=1

Figure 2.5



m>1

Figure 2.6

Experiment 1

Part 3

Objective:

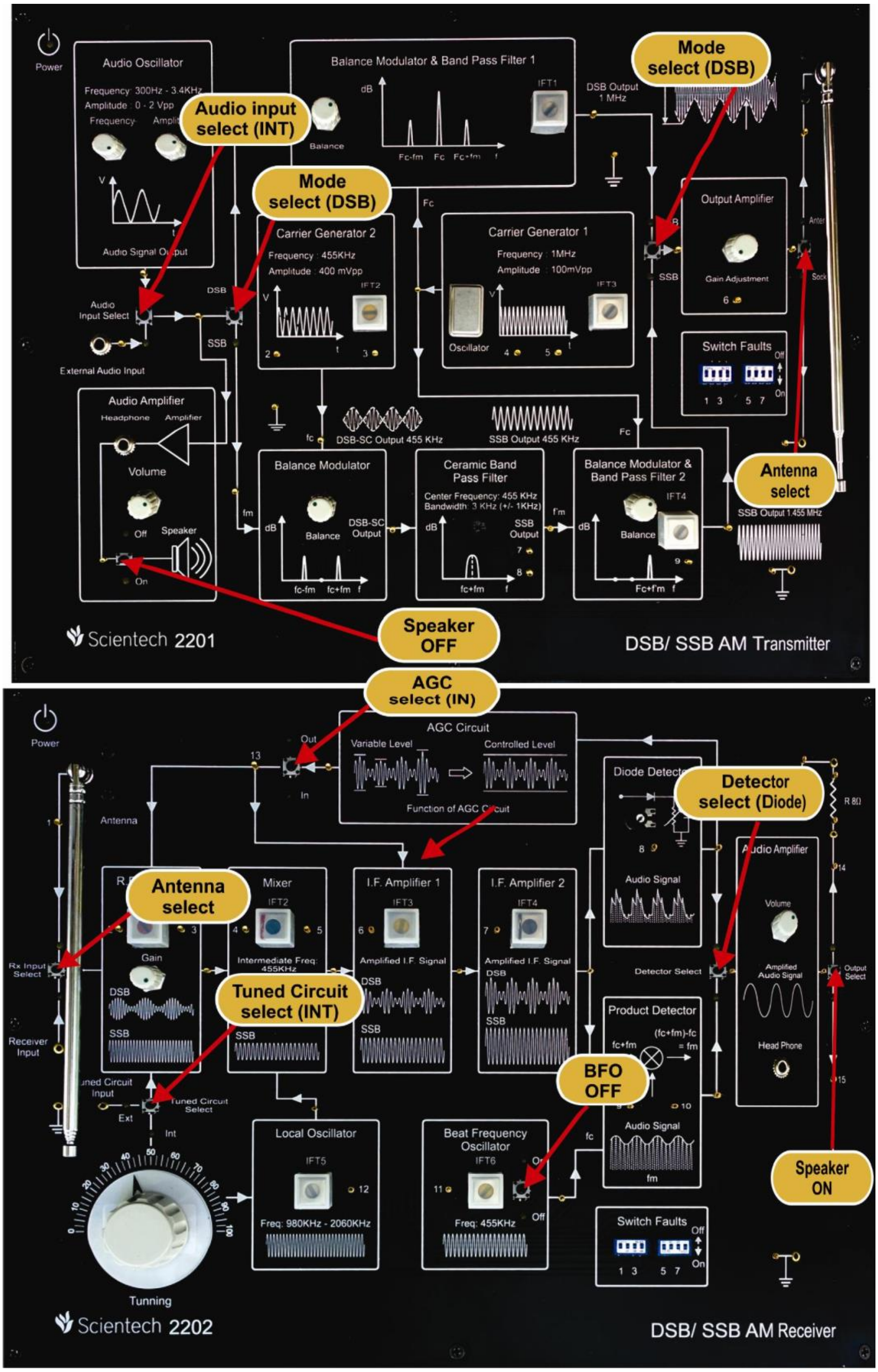
Double Sideband AM Reception and study of Diode detector

Procedure:

This experiment investigates the reception and demodulation of AM waveforms by the **Scientech 2201/ Scientech 2202** module. Both AM broadcast signals, and AM transmissions from **Scientech 2201**, will be examined, and the operation of automatic gain control at the receiver will be investigated.

To avoid unnecessary loading of monitored signals, X10 Oscilloscope probes should be used throughout this experiment.

1. Position the **Scientech 2201 & Scientech 2202** modules, with the **Scientech 2201** board on the left, and a gap of about three inches between them.
2. Ensure that the following initial conditions exist on the **Scientech 2201** board.
   a. Audio oscillator's amplitude pot in fully clockwise position.
   b. Audio input select switch in INT position.
   c. Balance pot in balanced modulator & band pass filter circuit 1 block, in full clockwise position;
   d. Mode switch in DSB position.
   e. Output amplifier's gain pot in full clockwise position.
   f. TX output select switch in ANT position:
   g. Audio amplifier's volume pot in fully counter-clockwise position.
   h. 'Speaker' switch in ON position.
   i. On-board antenna in vertical position, and fully extended.
3. Ensure that the following initial conditions exist on the **Scientech 2202** board:
   a. RX input select switch in ANT position.
   b. R.F. amplifier's tuned circuit select switch in 'INT' position.
   c. R.F. amplifier's gain pot in fully clock-wise position;
   d. AGC switch in 'IN' position.
   e. Detector switch in 'Diode' position.
   f. Audio amplifier's volume pot in fully counter-clockwise position.
   g. 'Speaker' switch in ON position.
   h. Beat frequency oscillator switch in OFF position.
   i. On-board antenna in vertical position, and fully extended.



Audio input select (INT)
Mode select (DSB)
Mode select (DSB)
Antenna select
Speaker OFF
Scientech 2201
DSB/ SSB AM Transmitter
AGC select (IN)
Detector select (Diode)
Antenna select
Tuned Circuit select (INT)
BFO OFF
Speaker ON
Scientech 2202
DSB/ SSB AM Receiver

Figure 3.0

4. Turn on power to the modules.

5. On the **Scientech 2201** module, examine the transmitter's output signal, together with the audio modulating Audio signal.

   [CH1(Y) – 1V; CH2(X) – 0.2V Time base – 0.1 mS]

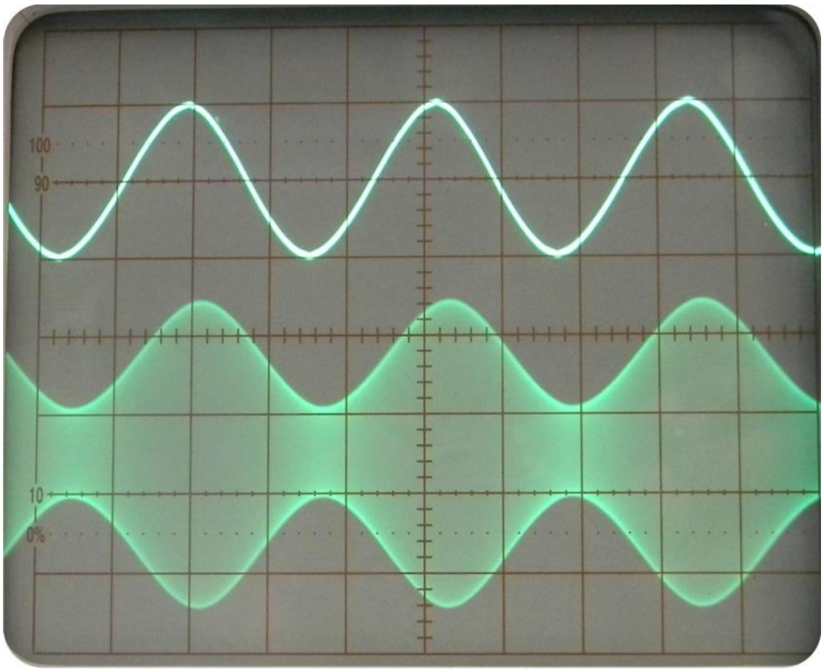


Figure 3.1

   Since **Scientech 2201** TX output select switch is in the ANT position, the AM signal at the output is fed to the transmitter's antenna. Prove this by touching **Scientech 2201**'s antenna, and nothing that the loading caused by your hand reduces the amplitude of the AM waveform at the output.

6. On the **Scientech 2201** module, turn the volume pot (in the audio amplifier block) clockwise, until you can hear the tone of the audio oscillator’s output signal, from the loudspeaker on the board.

   Note: If desired, headphones may be used instead of the loudspeaker on the board. To use the headphones, simply plug the headphone jack into the audio amplifier block's headphones socket, and put the speaker switch in the OFF position. The volume from the headphones is still controlled by the block's volume pot. Turn the volume pot to the full counter-clockwise (minimum volume) position.

7. On the **Scientech 2202** receiver, adjust the volume pot so that the receiver's output can be clearly heard. Then adjust the receiver's tuning dial until the tone generated at the transmitter is also clearly audible at the receiver (this should be when the tuning dial is set to about 55-65 and adjust the receiver's volume pot until the tone is at a comfortable level.

   Note: *If desired, headphones (supplied with the module) may be used instead of the on-board loudspeaker. To use the headphones, simply plug the headphone jack into the audio amplifier block's headphones socket, and adjust controlled block's volume pot.*

8. Check that you are tuned into the transmitter's output signal, by varying **Scientech 2201**'s frequency pot in the audio oscillator block, and nothing that the tone generated by the receiver changes.

   [CH1(Y) – 1V; CH2(X) – 2V Time base – 0.1 mS]

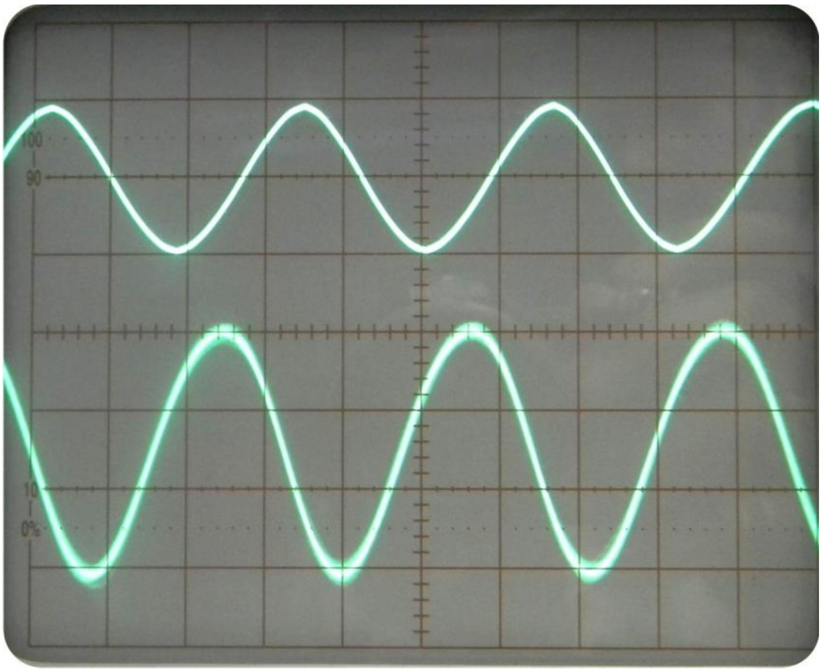
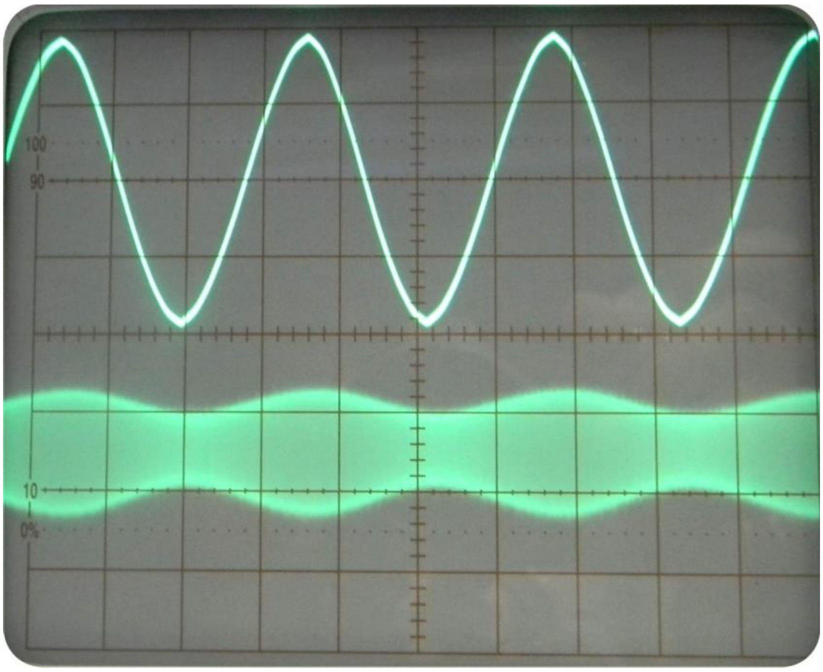


Figure 3.2

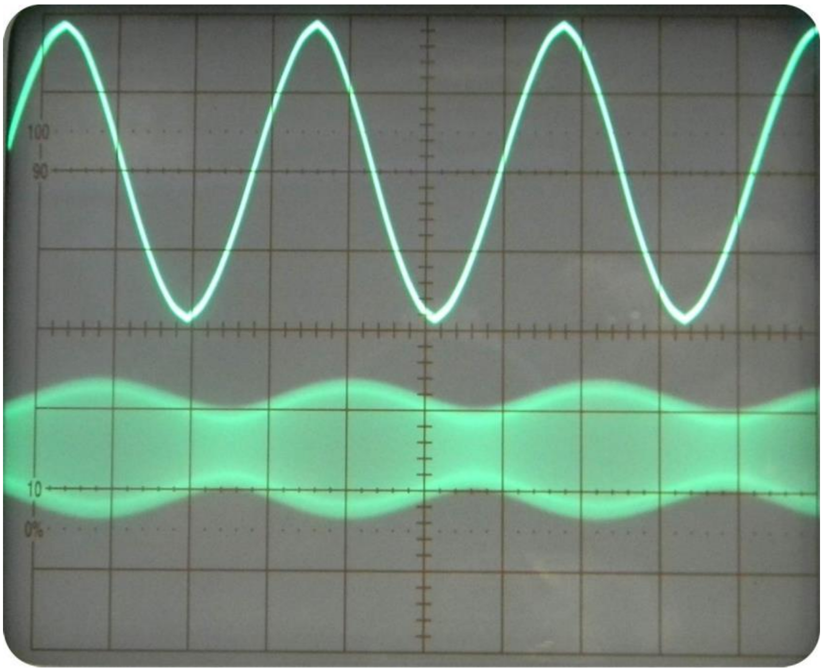
The **Scientech 2201/2252** receiver is now tuned into AM signal generated by the **Scientech 2201** transmitter. Briefly check that the waveforms, at the outputs of the following receiver blocks, are as expected:

[CH1(Y) – 0.5V; CH2(X) – 0.1V Time base – 0.1 mS]



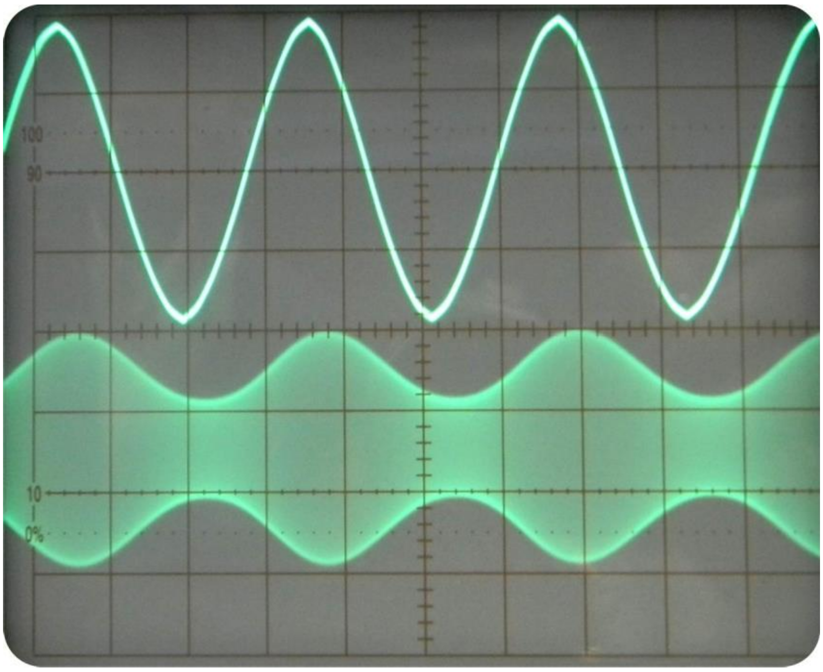
R. F. Amplifier output

Figure 3.3



Mixer output

Figure 3.4



I.F. Amplifier 1 output

Figure 3.5

[CH1(Y) – 0.5V; CH2(X) – 0.5V Time base – 0.1 mS]

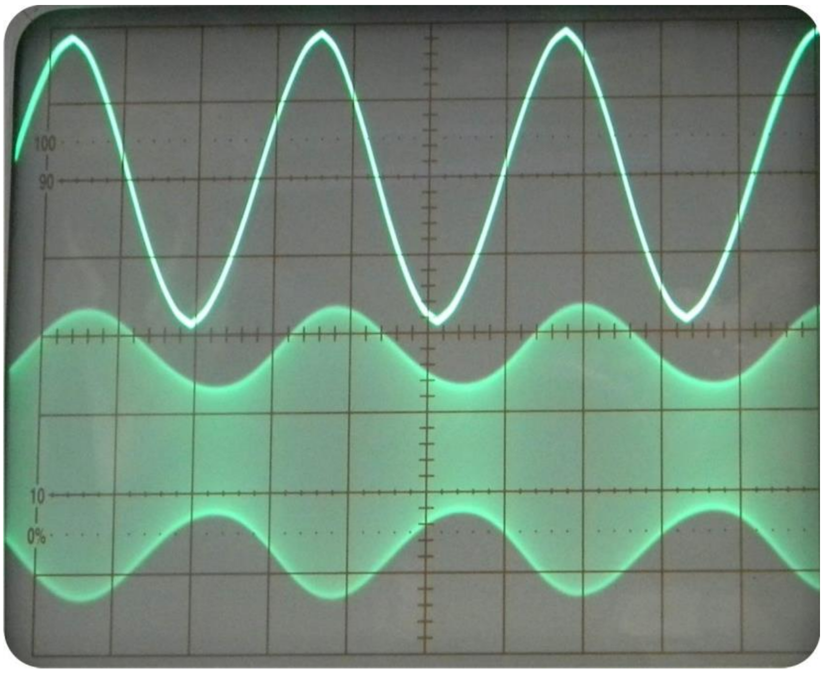
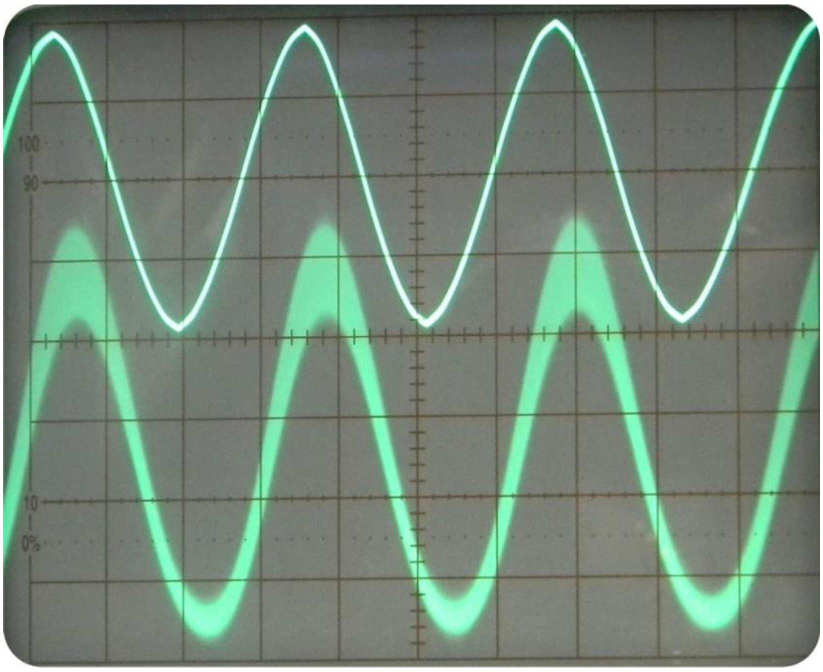


Figure 3.6

I.F. Amplifier 2 output

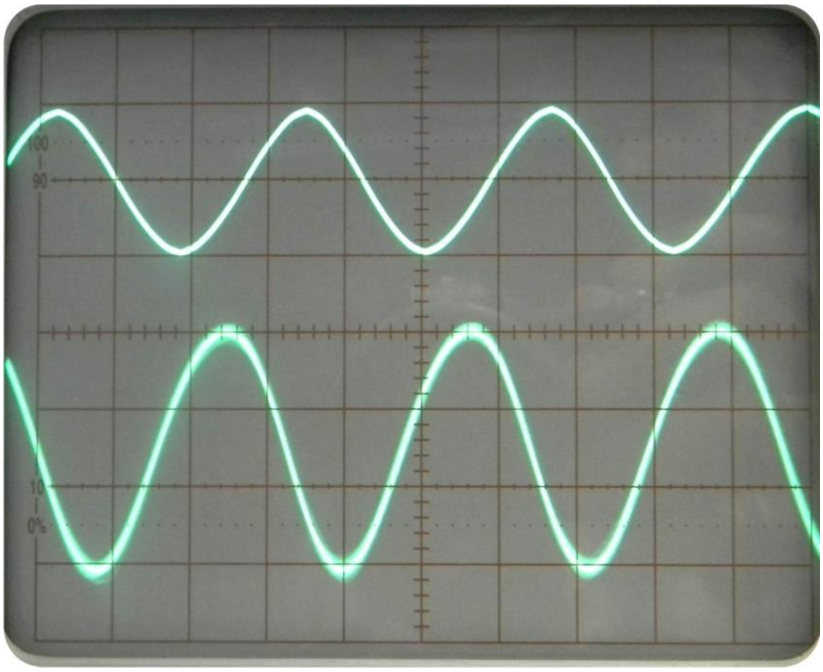
[CH1(Y) – 0.5V; CH2(X) – 0.2V Time base – 0.1 mS]



Diode Detector output

Figure 3.7

[CH1(Y) – 1V; CH2(X) – 2V Time base – 0.1 mS]



Audio Amplifier output

Figure 3.8

9. The first stage or 'front end' of the **Scientech 2202** AM receiver is the R.F amplifier stage. This is a wide -bandwidth tuned amplifier stage, which is tuned into the wanted station by means of the tuning dial.

Once it has been tuned into the wanted station, the R.F. amplifier, having little selectivity, will not only amplify, but also those frequencies that are close to the wanted frequency. As we will see later, these nearby frequencies will be removed by subsequent stages of the receiver, to leave only the wanted signal. Examine the envelope of the signal at the R.F. amplifier's output , with an a.c. - coupled Oscilloscope channel. Note that:

a. The amplifier's output signal is very small in amplitude (a few tens of millivolts at the most). This is because one stage of amplification is not sufficient to bring the signal's amplitude up to a reasonable level.

b. Only a very small amount of amplitude modulation can be detected, if any. This is because there are many unwanted frequencies getting through to the amplifier output, which tend to 'drown out' the wanted AM Signal.

You may notice that the waveform itself drifts up and down on the scope display, indicating that the waveform's average level is changing. This is due to the operation of the AGC circuit, which will be explained later.

10. The next stage of the receiver is the mixer stage, which mixes the R.F. amplifier's output with the output of a local oscillator. The Frequency of the local oscillator is also tuned by means of the tuning dial, and is arranged so that its frequency is always 455 KHz above the signal frequency that the R.F. amplifier is tuned to. This fixed frequency difference is always present, irrespective of the position of the tuning dial, and is known as the intermediate frequency (IF for short). This frequency relationship is shown below, for some arbitrary position of the tuning dial.

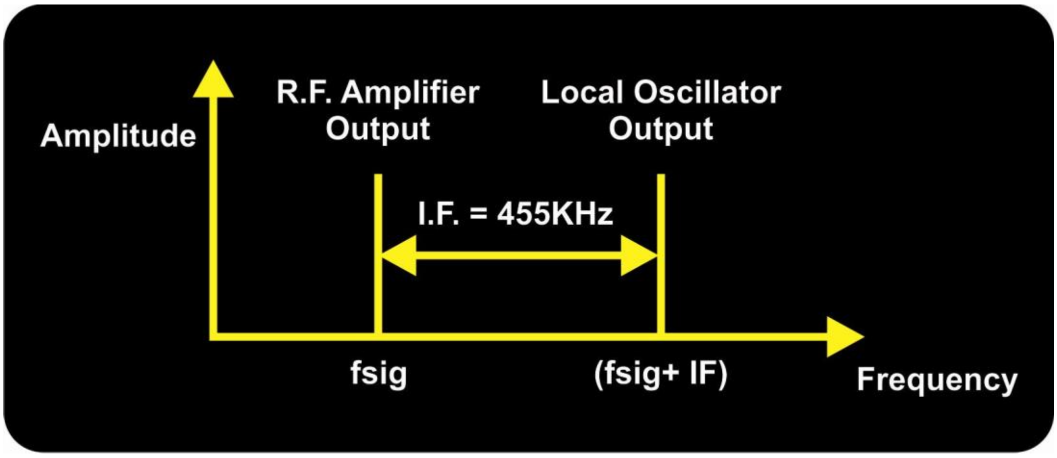


Figure 3.9

Observe the output of the local oscillator block, and check that its frequency varies as the tuning dial is turned. Re-time the receiver to a radio station.

11. The operation of the mixer stage is basically to shift the wanted signal down to the IF frequency, irrespective of the position of the tuning dial. This is achieved in two stages.

a. By mixing the local oscillator's output sinewave with the output from the R.F. amplifier block. This produces three frequency components:

The local oscillator frequency = (f sig + IF)

The sum of the original two frequencies, f sum = (2 f sig + IF)

The difference between the original two frequencies,

f diff = (f sig + IF - f sig) = IF

These there frequency components are shown in Figure 3.10.

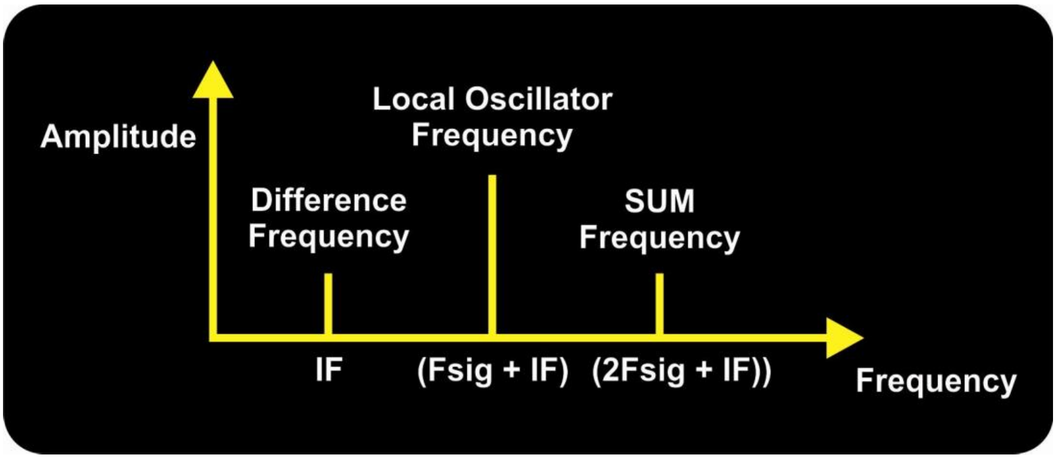


Figure 3.10

b. By strongly attenuating all components. except the difference frequency, IF this is done by putting a narrow-bandwidth band pass filter on the mixer's output.

The end result of this process is that the carrier frequency of the selected AM station is shifted down to 455 KHz (the IF Frequency), and the sidebands of the AM signal are now either side of 455 KHz.

12. Note that, since the mixer's band pass filter is not highly selective, it will not completely remove the local oscillators and sum frequency components from the mixer's output. This is the case particularly with the local oscillator component, which is much larger in amplitude than the sum and difference components.

Observe the output of the mixer block with an a.c. coupled Oscilloscope channel, and note that the main frequency component present changes as the tuning dial is turned. This is the local oscillator component, which still dominates the mixer's output, in spite of being attenuated by the mixer's band pass filter.

13. What we need to do now is to preferentially amplify frequencies around 455 KHz, without amplifying the higher-frequency local oscillator and SUM components.

This selective amplification is achieved by using two IF amplifier stages, IF amplifier 1 and IF amplifier 2, which are designed to amplify strongly a narrow band of frequencies around 455 KHz, without amplifying frequencies on either side of this narrow band.

These IF amplifiers are basically tuned amplifiers which have been pre-tuned to the IF frequency-they have a bandwidth just wide enough to amplify the 455 KHz carrier and the AM sidebands either side of it. Any frequencies outside this narrow frequency band will not be amplified.

Observe the output of IF amplifier 1 with an a.c.-coupled Oscilloscope channel, and note that:

a. The overall amplitude of the signal is much larger than the signal amplitude at the mixer's output, indicating that voltage amplification has occurred.

b. The dominant component of the signal is now at 455 KHz, irrespective of any particular station you have tuned into. This implies that the wanted signal, at the IF frequency, has been amplified to a level where it dominates over the unwanted components.

c. The envelope of the signal is modulated in amplitude, according to the sound information being transmitted by the station you have tuned into.

14. Observe the output of IF amplifier 2 with an a.c.-coupled Oscilloscope channel, noting that the amplitude of the signal has been further amplified by this second IF amplitude of the signal has been further amplified by this second IF amplifier stage.

IF amplifier 2 has once again preferentially amplified signals around the IF frequency (455 KHz), so that:

a. The unwanted local oscillator and sum components from the mixer are now so small in comparison, that they can be ignored totally,

b. Frequencies close to the I F frequency, which are due to stations close to the wanted station, are also strongly attenuated.

The resulting signal at the output of IF amplifier 2 is therefore composed almost entirely of a 455 KHz carrier, and the A.M. sidebands either side of it carrying the wanted audio information.

15. The next step is extract this audio information from the amplitude variations of the signal at the output of IF amplifier 2. This operation is performed by the Diode Detector block, whose output follows the changes in the amplitude of the signal at its input.

To see how this works, examine the output of the Diode Detector block, together with the output from. IF amplifier 2. Note that the signal at the diode detector's output:

- Follows the amplitude variations of the incoming signal as required:
- Contains some ripple at the IF frequency of 455 KHz, and
- The signal has a positive DC offset, equal to half the average peak to peak amplitude of the incoming signal. We will see how we make use of this offset later on, when we look at automatic gain control (AGC).

16. Vary the preset R45 in the diode detector block while observing the output of diode detector.
17. You can see the variations in the detected output when you change the RC time constant of the filter formed by R45 and C32.
18. The final stage of the receiver is the audio amplifier block contains a simple low-pass filter which passes only audio frequencies, and removes the high- frequency ripple from the diode detector's output signal. This filtered audio signal is applied to the input of an audio power amplifier, which drives on board loudspeaker (and the headphones, if these are used). The final result is the sound you are listening to!

    The audio signal which drives the loudspeaker can be monitored at Audio amplifier output (providing that the audio amplifier block's volume pot is not in its minimum volume position). Compare this signal with that at the diode detector's output , and note how the audio amplifier block's low pass filter has 'cleaned up' the audio signal.

    You may notice that the output from the audio amplifier block is inverted with respect to the signal at the output of the diode detector this inversion is performed by the audio power amplifier IC, and in no way affects the sound produced by the receiver.

19. By using the microphone, the human voice can be used as transmitter's audio modulating signal, instead of using **Scientech 2201'**s audio oscillator block. Use DSB and not DSBSC.

    Connect the microphone’s output to the external audio input on the **Scientech 2201** board, and put the audio input select switch in the EXT position.

    Note: *If more than one* **Scientech 2201** *transmitter/receiver system is in use at one time, it is possible that there may be interference between nearby transmitters if antenna propagation is used. To eliminate this problem, use a cable between each transmitter/receiver pair, connecting it between* **Scientech 2201**'*s TX output socket and* **Scientech 2201/Scientech 2202**'*s RX input socket. If you do this, make sure that the transmitter's TX output select switch, and the receiver's RX input select switch, are both in the SKT position, then follow the steps below as though antenna propagation were being used.*

Experiment 2
Part 1

Receiver Characteristics

The important characteristics of receivers are sensitivity, selectivity, & fidelity described as follows:

Sensitivity:

The sensitivity of radio receiver is that characteristic which determines the minimum strength of signal input capable of causing a desired value of signal output. Therefore, expressing in terms of voltage or power, sensitivity can be defined as the minimum voltage or power at the receiver input for causing a standard output.

In case of amplitude-modulation broadcast receivers, the definition of sensitivity has been standardized as "amplitude of carrier voltage modulated 30% at 400 cycles, which when applied to the receiver input terminals through a standard dummy antenna will develop an output of 0.5 watt in a resistance load of appropriate value substituted for the loud speaker" .

Selectivity:

The selectivity of a radio receiver is that characteristic which determines the extent to which it is capable of differentiating between the desired signal and signal of other frequencies.

Fidelity:

This is defined as the degree with which a system accurately reproduces at its output the essential characteristics of signals which is impressed upon its input.

Determination of receiver characteristics:

A laboratory method for the measurement of receiver characteristics is shown in Figure 51. We use here an artificial signal to represent the voltage that is induced in the receiving antenna. This artificial signal is applied through 'dummy' antenna, which in association antenna with which the receiver is to be used. Substituting the resistance load of proper value for the loudspeaker and measuring the audio frequency power determine the receiver output.

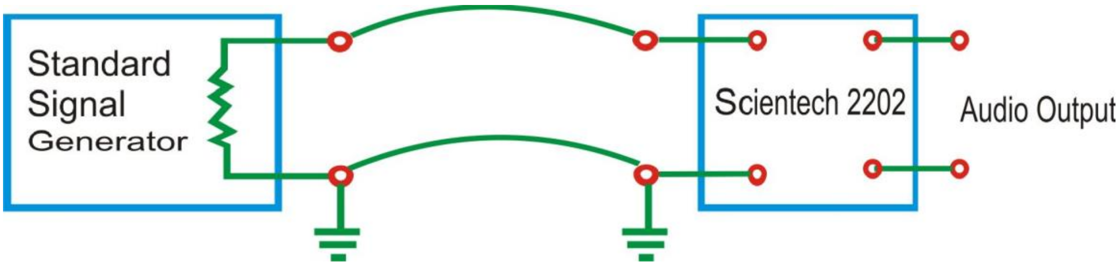


Figure 51

Sensitivity:

Sensitivity is a determined by impressing different RF voltages in series with a standard dummy antenna and adjusting the intensity of input voltage until standard outputs obtained at resonance for various carrier frequencies. Sensitivity is expressed in microvolt. A sensitivity curve is shown in Figure 52.

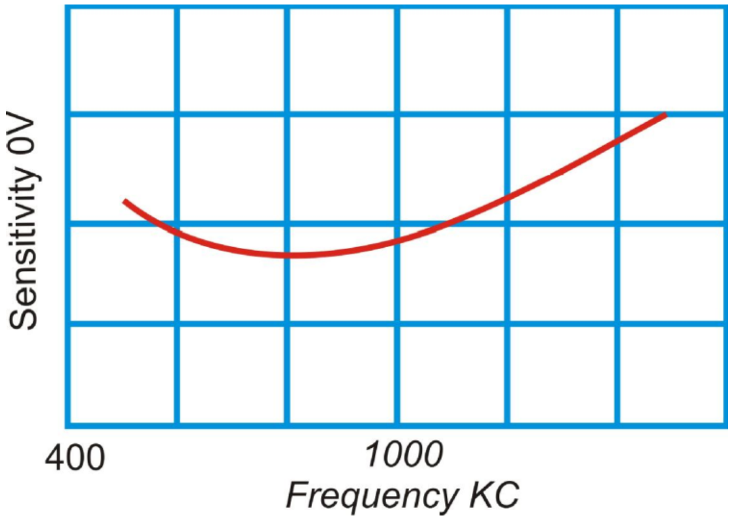


Figure 52

Selectivity:

Selectivity is expressed in the form of a curve that give the carrier signal strength with standard modulation that is required to produce the standard test output plotted as a function off resonance of the test signal.

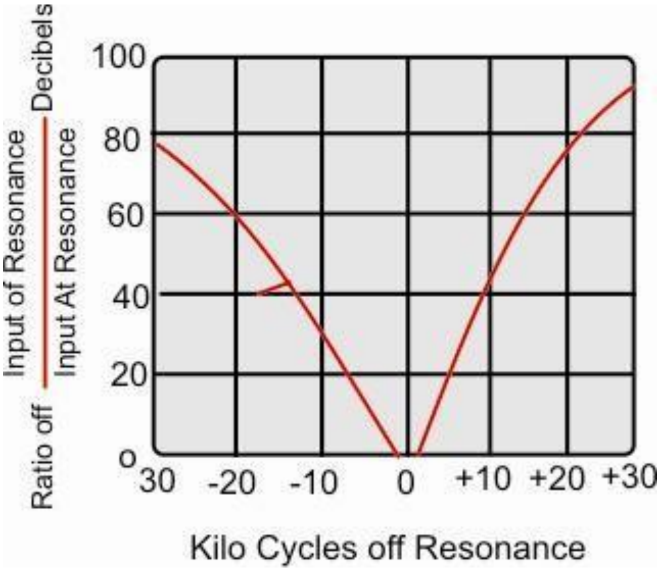


Figure 53

The receiver is tuned to the desired frequency and manual volume control is set for maximum value. At standard modulation, the signal generator is set at the resonant frequency of the receiver. The carrier output of the signal generator is varied until the standard test output is obtained. At the same tuning of receiver, the frequency of signal generator is varied above and below the frequency to which the receiver is tuned. For every frequency, the signal generator voltage, applied to the receiver input, is adjusted to give the standard test output from the receiver. The data are plotted in Figure 53.

Fidelity:

Fidelity is the term expressing the behavior of receiver output with modulation frequency of input voltage. To obtain a fidelity curve, the carrier frequency of the signal generator adjusted to resonance with the receiver, standard 400 cycles modulation is applied, the signal generator carrier level is set at a convenient arbitrary level and the manual volume control of the receiver is adjusted to give the standard test output. The modulation frequency is then varied over the audio range, keeping degree of modulation constant. A graph is then plotted in the ratio of actual output in volts to the output at 400 c/s against modulation frequency as shown in Figure 54

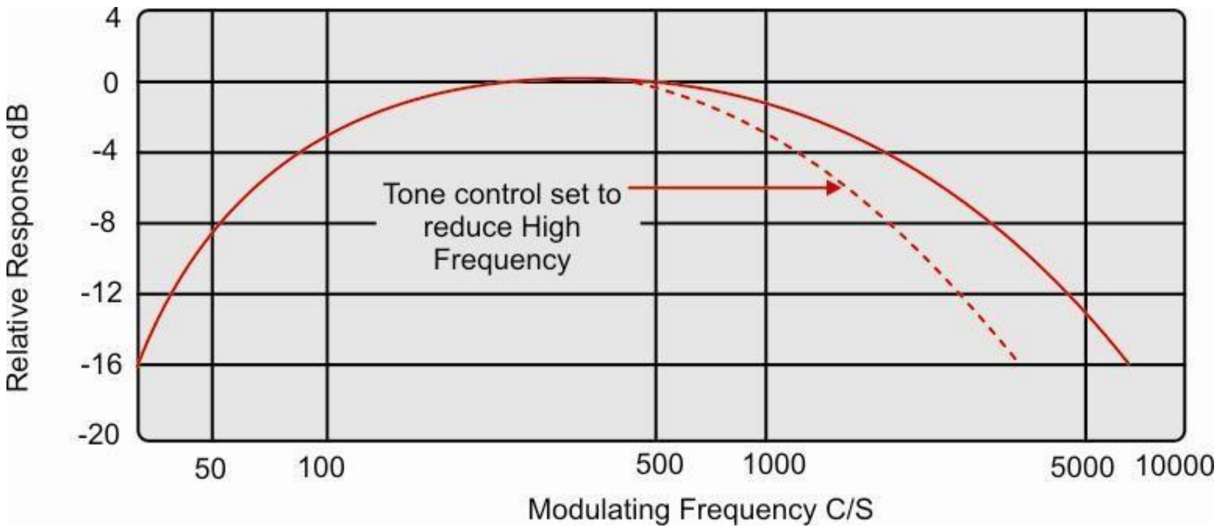


Figure 54

Experiment 2
Part 1

Objective:
To plot selectivity curve for radio receiver

Procedure:

1. Setting on **Scientech 2202**
   a. Set the detector in diode mode.
   b. AGC on.
   c. Set the volume control full clockwise.
2. Apply AM signal with 400 Hz modulating frequency and 30% modulation taken from AM generator into Rx input socket.
3. Set the input carrier frequency to suitable value that lies within the AM band (525 KHz - 1600 KHz). Also set signal level to 100mV.
4. Tune the Receiver using tuning control. Also adjust gain potentiometer provided in R.F. amplifier section of **Scientech 2202** so as to get unclipped demodulated signal at detector's output (output of audio amplifier).
5. Note the voltage level at receiver's final output stage i.e. audio amplifier's output on CRO (voltage at resonance (Vr)).
6. Now gradually offset the carrier frequency in suitable steps of 5 KHz or 10 KHz below and above the frequency adjusted in step 2 without changing the tuning of receiver while maintaining the input signal level.
7. Now record the signal level at output of audio amplifier for different input carrier frequency, on CRO (i.e. voltage off resonance (Vi))
8. Tabulate the readings as under:

Carrier Frequency	Output Voltage	Ratio = 20 log (Vi / Vr) dB

9. P
lot the curve between ratio and carrier frequency.

Experiment 2

Part 1

Objective:
To plot sensitivity curve for radio receiver

Procedure:

1. Setting on **Scientech 2202:**
   - **a.** Set the detector in diode mode.
   - **b.** AGC on.
   - **c.** Set the volume control fully clockwise.
2. Apply AM signal, with 400Hz modulating signal and 30% modulation, taken from AM generator into Rx input socket.
3. Set the input carrier frequency so as to lie within the AM Band (525 KHz-1600 KHz). Also tune the detector to that carrier frequency using tuning control.(You will hear atone)
4. Set the input AM level to 100mV. Also adjust the gain potentiometer provided in R.F. amplifier section of **Scientech 2202** so as to get unclipped demodulated signal at detectors output.
5. Record input carrier frequency & signal level at the final output stage i.e. output of audio amplifier (observed on CRO).
6. Change the input carrier frequency & also tune the receiver to that frequency & repeat step 4.
7. Tabulate the collected readings as under:

Carrier frequency	Output (pp)

8. Plot the graph between carrier frequency & output level.

Experiment 2
Part 3

Objective:
To plot fidelity curve for radio receiver.

Procedure:

1. Setting on **Scientech 2202:**
   a. Set the detector in diode mode.
   b. AGC on.
   c. Set the volume control fully clockwise.
2. Apply AM signal of 100mV with 400Hz modulating signal and 30% modulation, into Rx input.
3. Select a suitable carrier frequency that lies within AM Band (525 KHz - 1600 KHz). Tune the **Scientech 2202** receiver to that frequency using tuning control. Also adjust gain potentiometer provided in R.F. amplifier section so as to get unclipped demodulated signal at detector's output.
4. Note the demodulated signal level (Vr) at the final output stage i.e. output of audio amplifier (on CRO) for the applied AM signal with 400Hz modulating signal.
5. Now vary the modulating signal frequency over audio range (300 Hz-3 KHz) in suitable steps say 100Hz. Note the corresponding output level (Vi) at the output of audio amplifier (on CRO).
6. Tabulate readings as under:

Carrier frequency	Modulating frequency	Output Voltage

Relative response = 20 log (Vi / Vr) dB

7. Plot the graph between modulating frequency and relative response.

Scientech 2201 switched faults:

This section lists the faults on the **Scientech 2201** and **Scientech 2202** modules.

There are 8 faults switches on each modules.

1. Fault prevents the 1MHz oscillator from oscillating, by disconnecting the tuned circuits primary winding from the + 12volts supply.
2. Fault disables the output of the balanced modulator & bandpass filter circuit 1 block to become a double-sideband suppressed carrier (DSBSC) signal, irrespective of the position of the block's balance pot. The fault disconnects the balance pots slider from the - 12 volt supply.
3. Fault cause the output frequency from the balanced modulator & bandpass filter circuit 1 block to become a double-sideband suppressed carrier (DSBSC) signal, irrespective of the position of the block's balance pot. The fault disconnects the balance pots slider from the - 12volt supply.
4. Fault cause the output frequency from the audio oscillator block to drop to 150Hz, irrespective of the block's frequency pot position. The fault disconnects the 56K resistor, in the frequency pots divider chain, from 0 volts, so that the FM sweep input to the 8038 (pin 8) is pulled up to + 12 volts.
5. Fault stops the 455 KHz oscillator, by shorting out the 18K resistor the transistor's base bias chain. This cause the bias on the transistor's base to drop to 0 volts.
6. Fault prevents the carrier component at the output of the balanced modulator block from being 'balanced out' by the block's balance pot, so that a DSBSC waveform cannot be obtained output of Ceramic band pass filter. This is achieved by shorting the 'SIG-' pin of the 1496 (pin 4) to 0 volts.
7. Fault shorts together the input and output of the ceramic filter in the ceramic bandpass filter block, allowing both sidebands of the balanced modulator block's output signal to reach to next section.
8. Fault disables the output of the balanced modulator & bandpass filter circuit 2 block, by shorting the bias input (pin 5) of the 1496 to 0 volts.

Scientech 2202 switched faults:

1. Fault disable the R.F. amplifier block, by open-circuiting the transistor's base bias chain. This cause the bias voltage on the transistor's base to drop to o volts.
2. Fault disable the output from the mixer block, by open - circuiting the 1 K emitter resistor of the modulating transistor.
3. Open-circuit fault stops the local oscillator from working, by removing the bias voltage from the transistor's base.
4. Open-circuit fault disables the output from the diode detector block by removing the D.C. bias from the diode's anode.
5. Fault disables the output from IF amplifier 1 block, by shorting the transistor's emitter to the +12 volts supply.
6. Fault disable the product detector block, by shorting the base of the block's output transistor to 0volts.
7. Fault shorts to 0 volts the AGC control input to the R F amplifier and IF amplifier 1 blocks, disabling both blocks.
8. Fault shorts the inverting input (pin 2) of the audio amplifier block's LM 386 power amplifier IC to 0 volts, so that there is no audio output from the block