# TELECOMMUNICATION SYSTEMS

Sinusoidal signals or pulse series are used as carrier signals in telecommunication systems. Telecommunication systems are divided into two main groups based on this characteristic of the carrier. These are;

**1.** Analog telecommunication systems where carrier and data signal are sinusoidal signals.
**2.** Digital telecommunication systems where carrier or data signal are pulse series.

Analog telecommunication is discussed in Section 2. Digital telecommunication will be examined in the next sections.

# ANALOG TELECOMMUNICATION (AM)

It is a telecommunication system where the carrier signal is sinusoidal. Sine wave as a formula;

$v = V.\sin(2\pi F + \theta)$ or
$i = I.\sin(2\pi F + \theta)$

In the formula;
$v$ - Instantaneous voltage changing in time (**Volt**)
V – Voltage peak value (**Volt**)
F - Frequency (**Hz**)
$\theta$ - Phase angle (**Degree**)
i – Instantaneous current changing in time (**Ampere**)
I – Current peak value (**Ampere**)

If you pay attention, there are three changing parameters in the equation such as V or $v$ (**amplitude**), F (**frequency**) and $\theta$ (**angle**). Whichever parameter of the carrier signal the data signal is changing at the modulator level, the modulation that is made is called by the name of that parameter. Accordingly, analog telecommunication modulation types are;

1. **Amplitude** modulation (**AM**)
2. Frequency modulation (**FM**)
3. Phase modulation (**PM**)

As we already know, the highest frequency carrier of the signals used in telecommunication systems is (**Fc**) signal. In our experiment set, carrier signal frequencies are made low as much as possible for easy follow up in the oscilloscope screen. Despite of this, it is very difficult to see varying signals in normal oscilloscopes. Therefore it is necessary that in the experiments at least 2x40MHz double channel memory (**storage**) oscilloscope is used.

# EXPERIMENT: 2.1
# EXAMINATION OF AMPLITUDE MODULATION (AM)

## PREPARATION DATA

Changing of amplitude of the carrier signal based on the data signal is called amplitude modulation. When the carrier signal and data signal are applied to the amplitude modulator simultaneously, three separate signals are obtained.

**1.** Carrier signal (**Fc**)
**2.** Carrier signal + Data signal (**Fc+Fm**)
**3.** Carrier signal – Data signal (**Fc–Fm**)

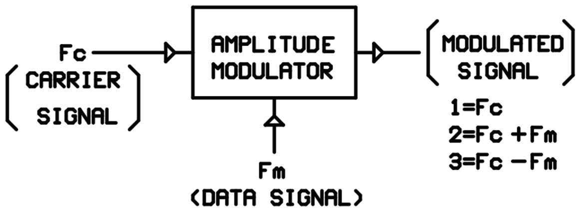



**Figure 2.1.1**

(**Fc+Fm**) signal obtained at the output of the amplitude modulator is called upper side band and (**Fc-Fm**) signal is called lower side band. Data signal is present in both side bands. The two edge bands' characteristics are the same other than their frequencies. The region covered by the modulated signal at the frequency axial is called band width. This value is the region remaining between the two side bands. In Figure 2.1.2, band width in the frequency spectrum is shown.

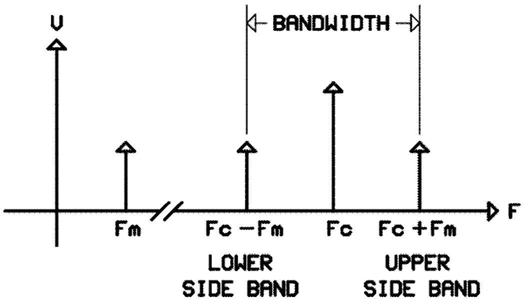



**Figure 2.1.2**

As it is clear, band width is twice as much as data signal. This value is 3KHz for telephone telecommunication and 5KHz for radio telecommunication.

The greatest amplitude among the signals that are obtained as a result of the modulation process is the carrier signal. The carrier signal doesn't have any data. Therefore, data signal can be transmitted without carrier signal is sent. Thus, power is spent minimally and efficiency improves. This method is called **Double Side Band** (DSB) modulation. The carrier is pressed and eliminated in the double side band modulation. Bottom and top side bands are sent. Other than the bottom and top side band frequencies, one of the side bands is sent and data transmission can be made since they have the same characteristics. This method is called **Single Side Band** (SSB) modulation. In the single side band modulation, one of the carrier signal and side bands is pressed and eliminated. When amplitude modulation is made, and if the carrier signal, data signal and obtained modulated signal are examined in an oscilloscope, the signs in Figure 2.1.3 are obtained.

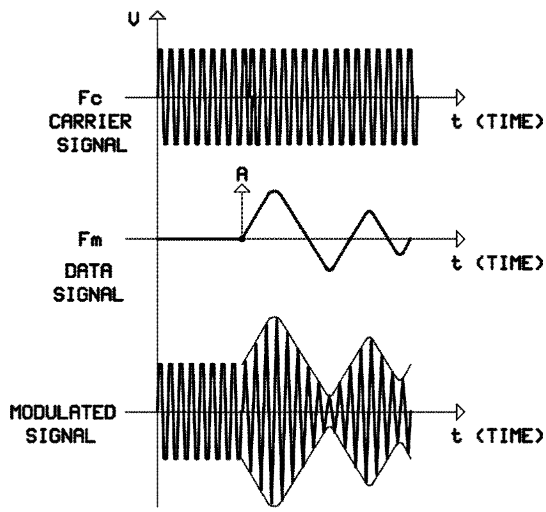



**Figure 2.1.3**

**Carrier signal:** Its amplitude and frequency don't change. It is the signal carrier with the greatest amplitude and frequency in the system.

**Data signal:** Electrical signal that is heard by human ear or image seen by human eye.

**Modulated signal:** Figure 2.1.3 shows the state of the three signs at the same **"t"** time. There is no data signal until the A point at the time axis. Up to this point, modulated signal carrier is the same as the signal. This means that at the zero points of the data signal, the shape of the modulated signal is the same as that of the carrier signal. When the modulated signal is sent when there is no data signal within the modulated signal, this increases the power loss of the system. This method is the conventional amplitude modulation. Although the power loss is great, classic amplitude modulation is used a lot. As the amplitude of the data signal increases in a positive direction, modulated signal increases in the positive and negative regions as much as the sum of the carrier signal's and data signal's amplitudes. At the point where data signal is zero, for a moment modulated signal becomes the same as the carrier signal. When the data signal is at the negative region, the modulated signal's amplitude decreases. This decrease is as much as the subtractions of the data signal amplitude from the carrier signal amplitude.

This decrease is seen as symmetrical at the positive and negative region of the modulated signal again. This change in the signal with amplitude modulation is called modulation envelope. As it is shown in Figure 2.1.4, the modulated signal has two envelopes. These are called upper side envelope in the positive region, and lower side envelope in the negative region.

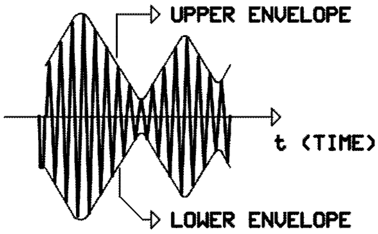



**Figure 2.1.4**

## MODULATION FACTOR

In telecommunication with amplitude modulation, for a noise-free telecommunication, data signal amplitude and carrier signal amplitude should be compatible. This accord is achieved by the mathematical calculation of modulation factor. Modulation factor is shown with an **"m"**. For a quality telecommunication, modulation factor must be approximately m=30%. Data signal's amplitude changes modulation percentage. This change is directly proportional. Modulation factor as a formula;

$$\%m = \frac{e\max - e\min}{e\max + e\min} .100$$

In the formula;
**emax:** Maximum amplitude of the modulated signal from peak to peak
**emin:** Minimum amplitude of the modulated signal from peak to peak

Measurement of modulation percentage is easily made by using an oscilloscope. Maximum and minimum points of the modulated signal are shown in Figure 2.1.5.

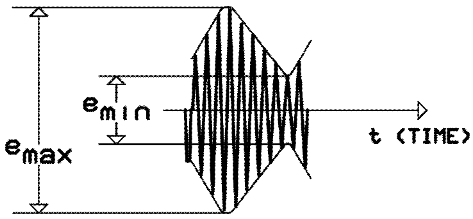



**Figure 2.1.5**

**Example:** From peak to peak maximum value of the modulated signal shown in the oscilloscope screen is 6V, and its minimum value from peak to peak is 2V. Calculate the maximum percentage.

$$\%m = \frac{e\max - e\min}{e\max + e\min}.100 = \frac{6-2}{6+2} = \frac{4}{8}.100$$

$$\%m = 50$$

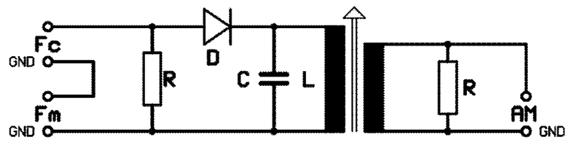



**Figure 2.1.6**

In Figure 2.1.6, the simplest amplitude modulator that is made of a germanium diode and tuned parallel resonance circuit is shown. The resonance frequency of parallel resonance circuit is 500KHz. By adjusting the inductor core, resonance frequency can be adjusted between 450KHz-550KHz. The carrier signal and data signal are connected to one another serially and the carrier signal amplitude is changed depending on the data signal. In our experiment module, modulation is examined by this simple circuit.

## EXPERIMENTAL PROCEDURE

Mount Y-0024/002 module to its place. Make the circuit connections as shown in Figure 2.1.7. (**Note: No power circuit is used in this experiment. RF oscillator and function generator are connected serially in the experiment.)**

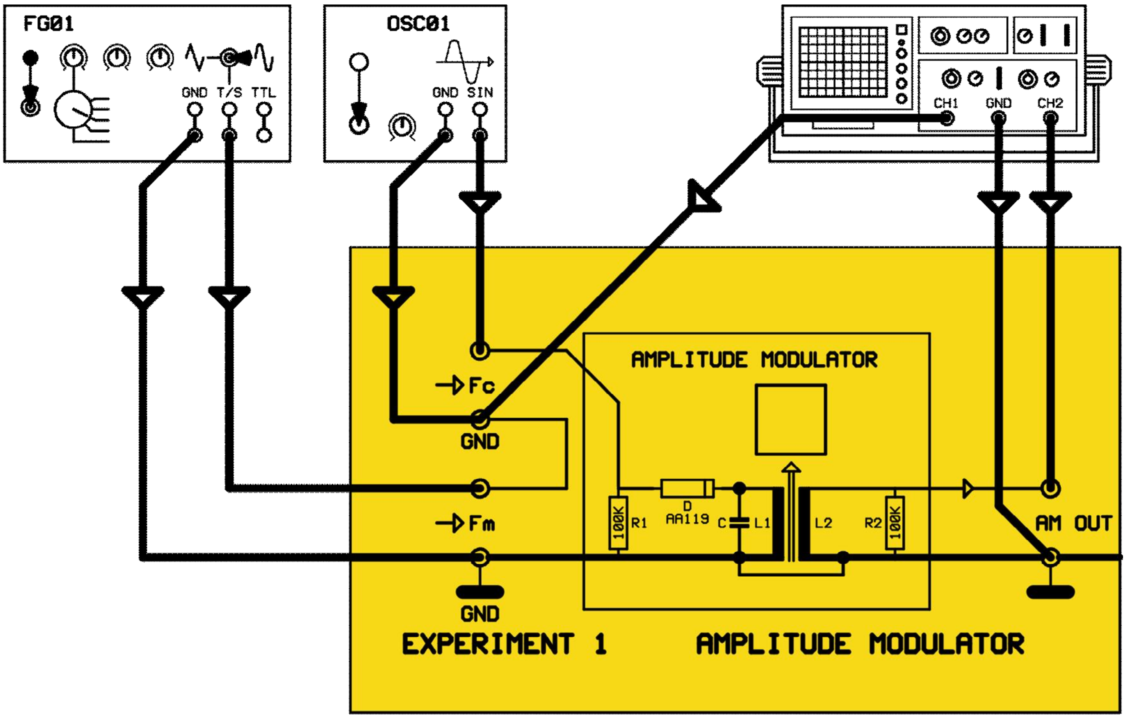
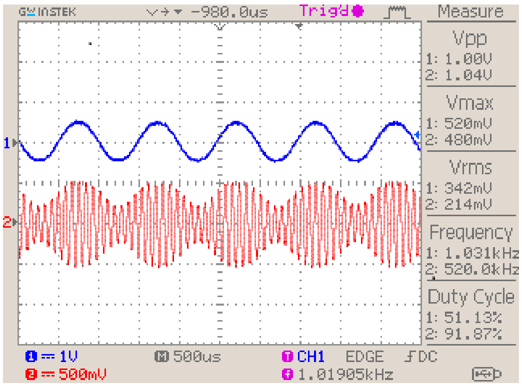



Figure 2.1.7

**1-** Adjust the amplitude (Fc) of output signal of OS1 RF oscillator to 5Vpp, output signal of function generator (Fm) to a sine wave, its frequency to 1KHz and its amplitude to 1Vpp. Observe the output signal in the oscilloscope. Adjust the inductor core and obtain maximum amplitude. Draw the amplitude of this signal. Define the signal.




*Output signal is an amplitude modulated signal.*

**2-** Increase the output signal (Fm) frequency of function generator until 2KHz. As doing this process, what is the change in the modulated output signal like?

*The same change is observed in the data signal (Fm) of the modulated output signal's upper side envelope, and again the same change is observed of the modulated signal's lower side envelope symmetrically.*

**3-** Adjust the output signal (Fm) frequency of the function generator to 1KHz. This time increase the amplitude of the sign slowly to 2Vpp. As this process is carried out, what is the change like in the modulated output signal?

*Modulation percentage is changing in the modulated output signal.*

**4-** Adjust the function generator's output signal (Fm) frequency to 1KHz, and its amplitude to 1Vpp. Calculate the modulation percentage.

*emin 0.6Vpp , emax 1.0Vpp*

$$\%m = \frac{e\max - e\min}{e\max + e\min} = \frac{1.0 - 0.6}{1.0 + 0.6}.100 = \frac{0.4}{1.6}.100$$

$$\%m = 25$$

**5-** Make the amplitude of the data signal zero. What is the sign at the output? Interpret this situation.

*The signal at the output is the carrier signal. This is the worst aspect of the classical amplitude modulation. When there is no data signal, power is exerted in the system.*

# EXPERIMENT: 2.2
## EXAMINATION OF AMPLITUDE DEMODULATION (AM)

### PREPARATION DATA

Separation of data signal from the modulated signal is called demodulation or sensing. The circuits where this process is carried out are called demodulators or detectors. Demodulation of amplitude modulation can be made in synchronized and asynchronous systems. In the synchronous system, demodulation process is carried out at the receiver by the signs coming from the transmitter synchronously. An example to synchronous systems is multiplication detector, switched detector, PLL detector (**PLL Phase Locked Loop**). The synchronous system is a widely used system with the least number of components. An example to this system is the diode detector and transistor detector. In our experiment set, diode detector was examined.

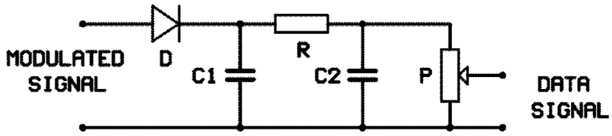



**Figure 2.2.1**

Figure 2.2.1 shows a diode detector. These circuits are also called envelope detectors. The D diode in the circuit does the verifying process. It passes positive or negative alternations of the modulated signal depending on the direction of polarization. C1, C2 capacitors and R resistor ($\pi$) are low pass filters. As the high frequency components of the signal that is corrected over the diode are transmitted to the ground by means of the filter, it is corrected by the charge-discharge of the envelope capacitors at the peak. C1 capacitor does this process effectively. C2 capacitor completes the process. Time coefficient in the filter circuit (T=R.C) must be greater than the period of the carrier signal, and it must be smaller than the period of the data signal. As the P potentiometer transmits the data signal that is obtained again to the sound frequency amplifier, it is used for adjusting the amplitude.

When the demodulation process is examined by an oscilloscope, the signs in Figure 2.2.2 are observed.

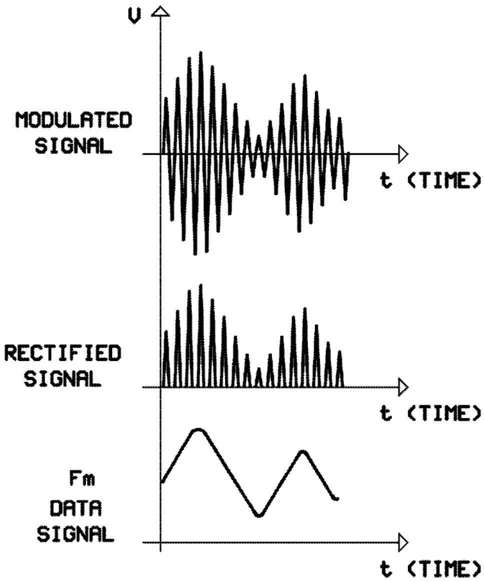



**Figure 2.2.2**

The sign that is obtained at the diode output is only the positive alternations of the modulated signal. C1 and C2 capacitors must be in the circuit in order to see this signal. If C1 and C2 capacitors are connected to the circuit, the envelope is completed at the peaks of the signal and data signal is obtained again.

## EXPERIMENTAL PROCEDURE

Mount Y-0024/002 module to its place. Make the circuit connections as shown in Figure 2.2.3.

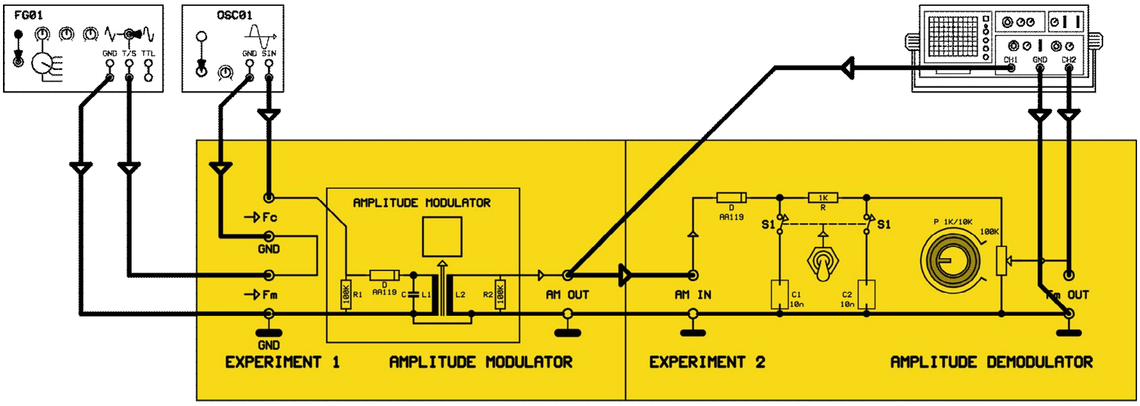
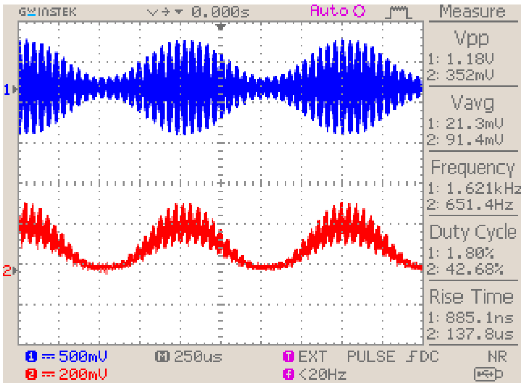



**Figure 2.2.3**

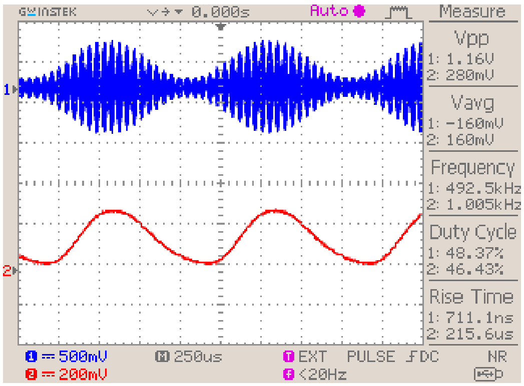
Apply Fc=500KHz, Vpp=5V and Fm=1KHz, Vpp=1V sign sign to the amplitude modulator in Experiment 2.1. Adjust the **"L"** inductor and obtain the most amplitude. In the amplitude demodulation experiment, use this amplitude modulated signal that you obtained.

**1.** Adjust the potentiometer to the maximum (**mid-point is above**) state, and S1 **switch** to the on position (**switch pin is below**). Compare the input and output signals.




*The input modulated signal is a modulated signal with only positive alternations even though the output signal has unseen sections on the time axis.*

**2.** Turn off the S1 switch. Define the input and output signals in this situation.




*The input sign is a modulated signal again. Output signal is the data signal.*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**3.** Compare the data signal located at the positive and negative envelope of the modulated signal and the data signal that is obtained as a result of demodulation in terms of frequency and amplitude.

*The data signal located at the positive envelope of the modulated signal and the data signal at the output is the same in terms of frequency. The data signal at the negative envelope of the modulated signal and the data signal at the output is symmetrical to one another.*

**4.** Change the frequency and amplitude of the data signal at the input. What is the reaction of this data signal that you obtained again at the output to this change?

*The data signal that is obtained at the output is changing in accord with the changes at the input the same way.*

# EXPERIMENT: 2.3
## EXAMINATION OF AMPLITUDE MODULATION (DSB)

### PREPARATION DATA

When there is no modulation in the amplitude modulated signal, the carrier is transmitted. The power that is exerted in the carrier is about two third (66%) of the system power. As we already know, there is no data in the carrier signal. When there is no data signal and if the carrier signal is not transmitted, system efficiency improves.

This process is achieved by making **double side band (DSB)** modulation with its carrier suppressed. Double side band pressed circuits with amplitude modulation are generally complicated and have many peripheral components.

Today, integrated circuits that are generated to use in telecommunication are used. MC1496 integration is a double balanced modulator and demodulator integration that generates an output signal in proportion with the multiplication of the input signals (Fc and Fm) and also able to do traditional amplitude modulation. MC1496 integration can do carrier suppressing very well (**65 dB**), enable adjustable gain and signal, and has balanced inputs and outputs.

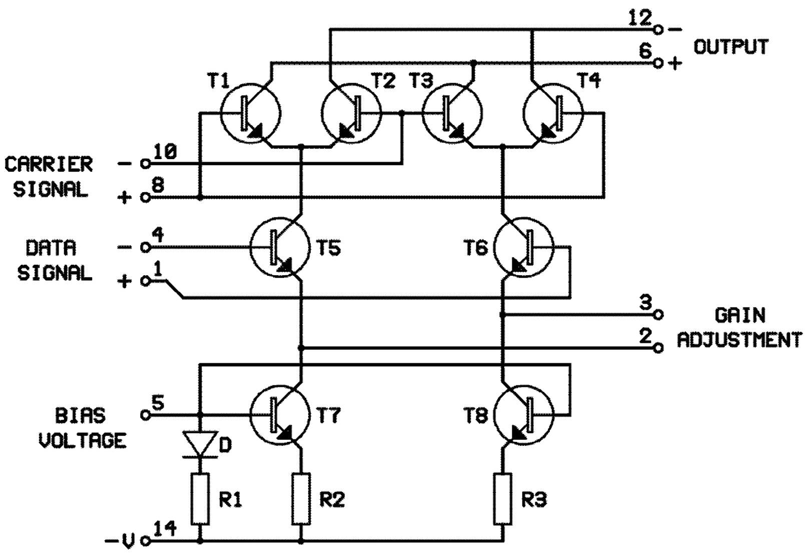



**Figure 2.3.1**

Figure 2.3.1 shows the integral structure of MC1496. D1 diode R1, R2, R3 resistors and T7, T8 transistors enable the DC polarization of T5 and T6 transistors. T5 and T6 transistors enable input difference combination of the difference amplifier which is cross connected and formed by T1, T2, T3, T4 transistors. A resistant to be mounted between the pin number 2 and 3 controls the gain of a balanced modulator. By a resistor to be mounted between pin no. 5 and ground (GND), the size of the polarization current that is necessary for the amplifier is adjusted. The DC level at pin no. 1 and 4 balances the pre voltages of the difference amplifiers and this balance suppresses the carrier signal (Fc). Pin no. 6 and 12 are the output pins of the side bands.

MC1496 integrate has two separate types of production namely metal sheathed and plastic sheathed.

İnput voltage level of the carrier is very important in the carrier pressing process. The integrated cannot do the required switching processes in the carrier signs that have low voltage level. In this case, the carrier is not pressed well and the lost power increases. MC1496 integration is designed according to RMS 60mV sine input signal. The optimum carrier frequency is 500KHz and near it. MC1496 does the suppressing process the best at these frequency values.

When DSB sign with the carrier suppressed and having an amplitude modulation is examined in an oscilloscope, it is seen as shown in Figure 2.3.2.

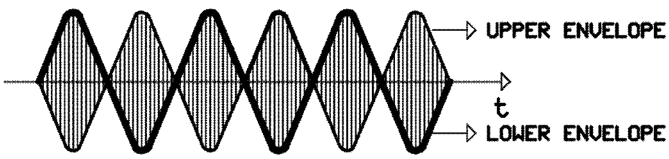



**Figure 2.3.2**

It is clear that the upper and lower envelopes that carry the data signal are coinciding. In spectrum analyzer, the sign with a classic amplitude modulation and the spectrum of DSB sign with its carrier pressed and an amplitude modulation is shown in Figure 2.3.3.

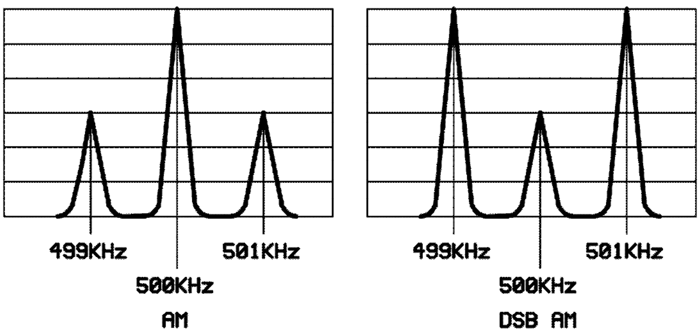



**Figure 2.3.3**

In both modulations, the carrier signal and data signal have the same characteristics. In classic amplitude modulation, the carrier signal amplitude is twice as much as the side band amplitudes. Lost power is great in the system. The situation is just the opposite in DSB sign with an amplitude modulation. Power loss is scarce in the system.

## EXPERIMENTAL PROCEDURE

Mount Y-0024/002 module into its place. Make the circuit connections as shown in Figure 2.3.4. Apply power to the circuit.

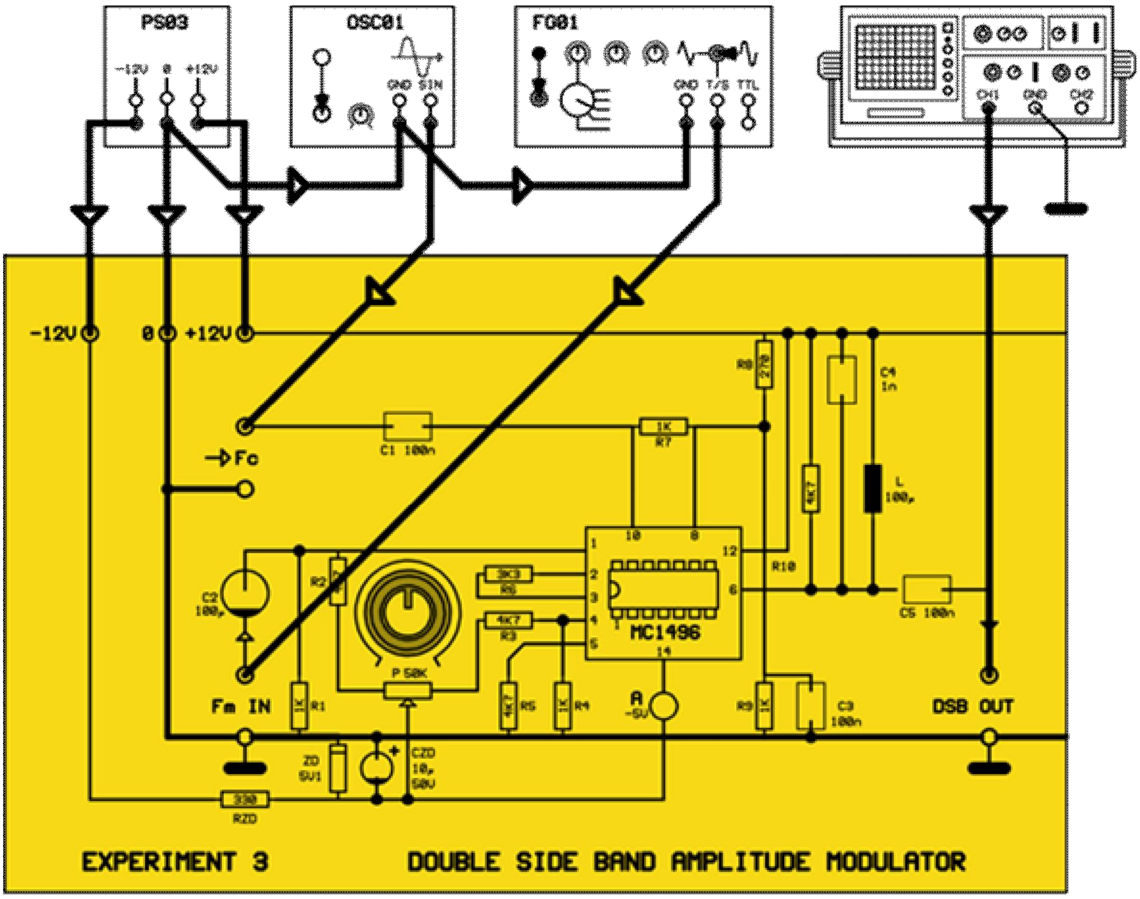
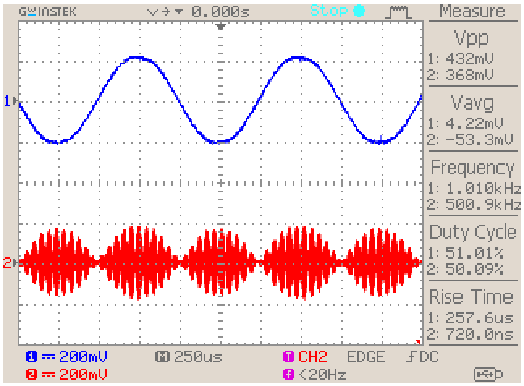



**Figure 2.3.4**

**1.** Adjust the output signal (Fc) amplitude of OS1 RF oscillator 1Vpp, output signal of the function generator (Fm) a sine wave, its frequency 1KHz and its amplitude 400 mVpp. Obtain a DSB sign by a P potentiometer.



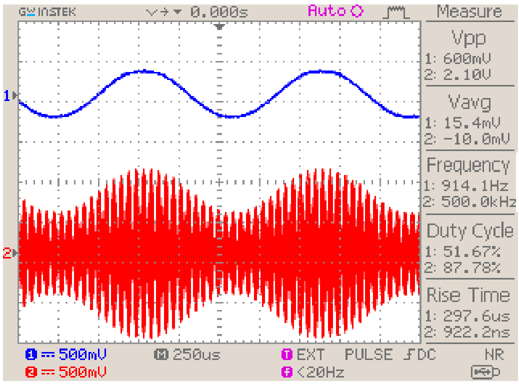

**2.** Adjust the amplitude of the data signal 0 (zero). Write down the change in DSB modulated signal.

*There is no sign left at the output. This means that when there is no data signal, there is no carrier sign either. In other words, when there is no data signal, the carrier signal is pressed.*

**3.** Adjust the amplitude of the data signal in turn 600mV, 800mV. Examine the output signal for each situation in oscilloscope. What can be said about this situation?

*When data signal is applied to the circuit, DSB modulated signal is obtained. When amplitude of the data signal is increased, amplitude of the modulated signal at the output increases as well.*

**4.** Adjust the input signal's amplitude as 600 mVpp. Adjust P potentiometer slowly to the right completely or to the left completely. Write down the change in the output signal and interpret.




*Output signal is turned into the situation of conventional modulated modulation. It means that DSB modulation and classic amplitude modulation can be made by MC1496 integration. The process shows this.*

# EXPERIMENT: 2.4
## AN EXAMINATION OF AMPLITUDE DEMODULATION (DSB)

The signals with double side band amplitude modulation (**DSBGM**) are demodulated by using balanced modulators generally. MC1496 balanced modulator integration is used as a demodulator by making little change in the circuit elements.

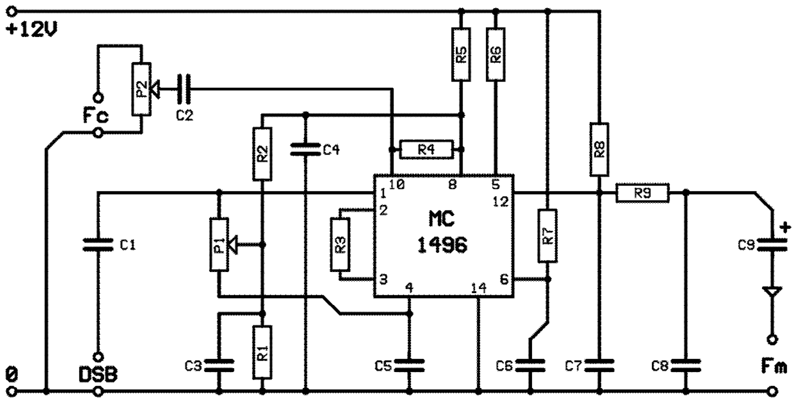



**Figure 2.4.1**

The multiplication demodulator is shown in Figure 2.4.1. The output signal is taken from pin no. 12 of MC1496 integration. P1 potentiometer controls the amplitude of the amplitude modulated signal, and P2 potentiometer controls the amplitude of the carrier signal. C7, C8 capacitors and R9 resistor are low pass filters that are used to eliminate undesired harmonic signals. C9 capacitor suppresses the DC offset coming from the demodulator. Figure 2.4.2 show the input and output signals for the same **"t"** moment.

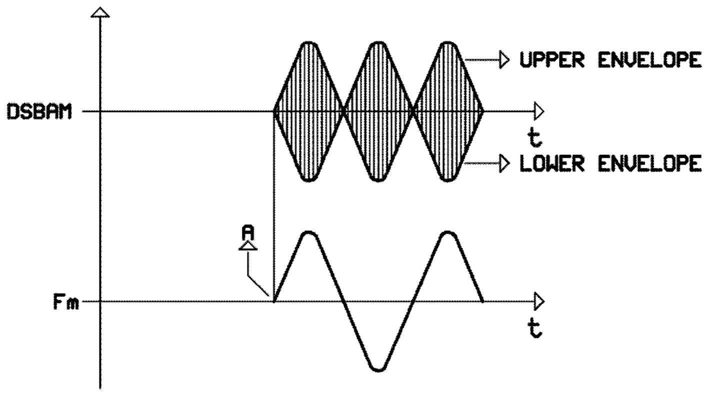



**Figure 2.4.2**

As it is shown in Figure 2.4.2, there is no carrier signal on the time axis until point **"A"**. There is no data signal up until this point either.

The demodulators that are made by using balanced modulators have good performances however they have complex circuitry. In addition, synchronization is necessary between the carrier signal and amplitude modulation in terms of frequency and phase angle. Otherwise, there are distortions in the output signal. Therefore P1 and P2 potentiometers should be adjusted well for obtaining a high quality output signal.

## EXPERIMENTAL PROCEDURE:

Mount Y-0024/002 module to its place. Make the circuit connections as shown in Figure 2.4.3. Apply energy to the circuit.

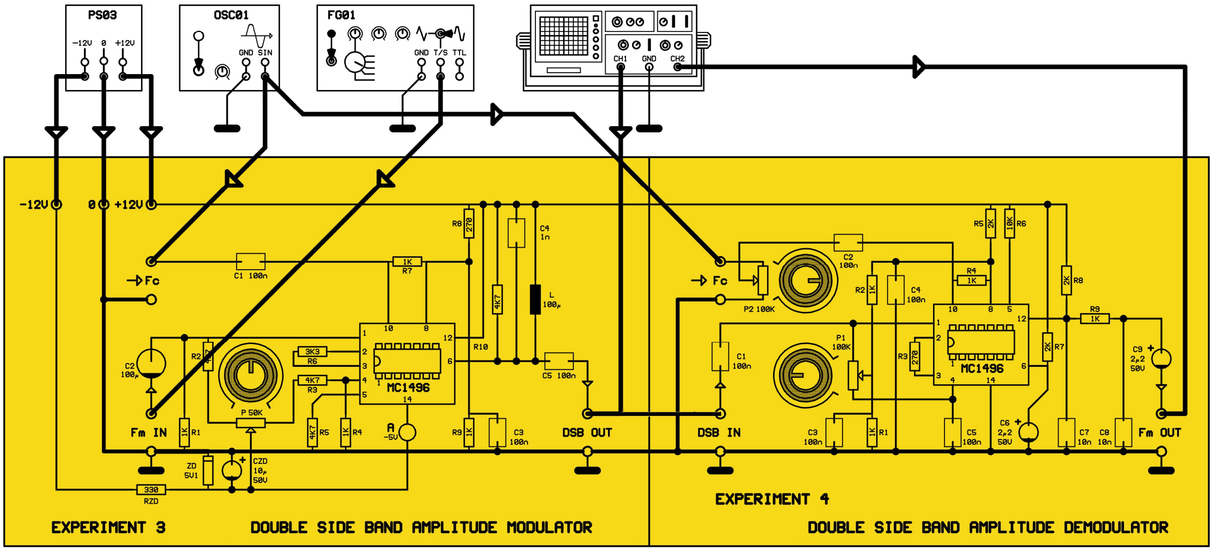
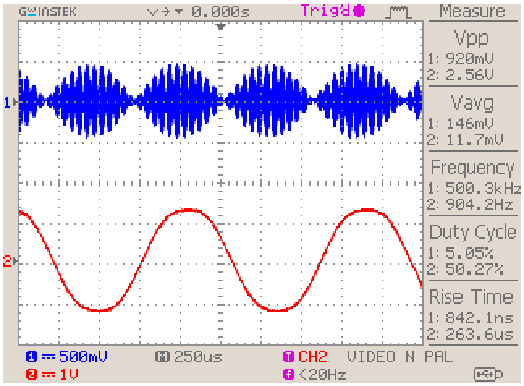



**Figure 2.4.3**

In this experiment, the sign with double side band amplitude modulation is the output signal of the amplitude modulator in experiment 2.3. Apply to experiment 2.3 circuit, the carrier sign Fc=500KHz-1Vpp, data signal Fm=1KHz-1Vpp. Obtain the sign with DSB modulation at the output end of the modulator by a P potentiometer at the modulators.

**1-** Adjust P1 and P2 potentiometers, obtain the data signal (**Fm**). What are the functions of P1 and P2 potentiometers?




*P1 potentiometer adjusts the amplitude of the data signal and P2 potentiometer adjusts the amplitude of the carrier signal. When there is phase and frequency synchronization between the two signals, data signal is obtained.*

**2-** Repeat the experiment by changing the amplitude and frequency of the data signal.