LABORATORY WORKBOOK
For the Course

COMMUNICATION SYSTEM

(TC-307)

Instructor Name:

Student Name:

Roll Number: **Batch:**

Semester: **Year:**

Department:

Department of Telecommunications Engineering
NED University of Engineering & Technology

LABORATORY WORKBOOK
For The Course
COMMUNICATION SYSTEMS
(TC-307)

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The Board of Studies Department of Telecommunications Engineering

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LAB SESSION 01

OBJECTIVE:

To examine the main parameters of an AM signal. To check the operation of an Amplitude modulator.

EQUIPMENT REQUIRED:

Amplitude Modulation Work board 53-130 which comprises the following blocks:

- Signal Generation
- Modulation
- Filters
- Demodulation

THEORY:

Modulation:

The modulation is simply a method of combining two different signals and is used in the transmitter section of a communication system. The two signals that are used are the information signal and the carrier signal. The information signal is the signal that is to be transmitted and received and is sometimes referred to as the intelligent signal. The carrier signal allows the information signal to be transmitted efficiently through the transmission media. The carrier signal is normally generated by an oscillator and has a constant frequency and amplitude. The information signal that is fed into the transmitter modifies the carrier signal.

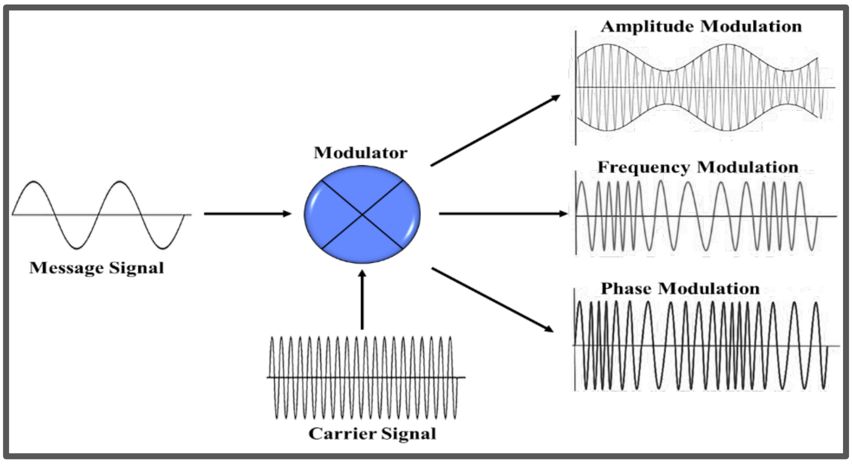

Figure 1.1 Modulation Techniques

Amplitude Modulation:

It is the simplest form of signal processing in which the carrier amplitude is simply changed according to the amplitude of the information signal, hence the name Amplitude Modulation. When the information signal's amplitude is increased the carrier signal's amplitude is increased and when the information signal's amplitude is decreased the carrier signal's amplitude is decreased. In other words, the ENVELOPE of the carrier signal's amplitude contains the information signal.

Modulation Mathematics:

The equation of a sinusoidal voltage waveform is given by: $\boldsymbol{v = V_{max} sin(\omega_t + \emptyset)}$,where:

- v is the instantaneous voltage
- Vmax is the maximum voltage amplitude
- ω is the angular frequency
- Ø is the phase

Amplitude modulation uses variations in amplitude (Vmax) to convey information. The wave whose amplitude is being varied is called the carrier wave. The signal doing the variation is called the modulating signal. For simplicity, suppose both carrier wave and modulating signal are sinusoidal, i.e., $v_c = V_c \sin \omega_c t$ (c denotes carrier) and $v_m = V_m \sin \omega_m t$ (m denotes modulation).

We want the modulating signal to vary carrier amplitude, Vc, so that:

$$v_c = [V_c + V_m \sin \omega_m t] \sin \omega_c t$$

where $[V_c + V_m \sin \omega_m t]$ is the new, varying carrier amplitude. Expanding this equation gives:

$$v_c = V_c \sin\omega_c t + V_m \sin \omega_c t \sin \omega_m t]$$

Now:

$$v_c = V_c [\sin\omega_c t + m \sin \omega_c t \sin \omega_m t]$$

where m= Vm/Vc and is called the modulation index

$$\sin \omega_c t \sin \omega_m t = \frac{1}{2} [\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t]$$

so, from the previous equation, we can express vc as:

$$v_c = V_c \sin\omega_c t + m \frac{V_c}{2} \cos(\omega_c - \omega_m)t - m \frac{V_c}{2} \cos(\omega_c + \omega_m)t$$

This expression for vc has three terms:

1. The original carrier waveform, at frequency ωc, containing no variations and thus carrying no information.
2. A component at frequency (ωc - ωm) whose amplitude is proportional to the modulation index. This is called the **Lower Side Frequency**.
3. A component at frequency (ωc + ωm) whose amplitude is proportional to the modulation index. This is called the **Upper Side Frequency**.

It is the upper and lower side frequencies which carry the information. This is shown by the fact that only their terms include the modulation index m. Because of this, the amplitudes of the side frequencies vary in proportion to that of the modulation signal.

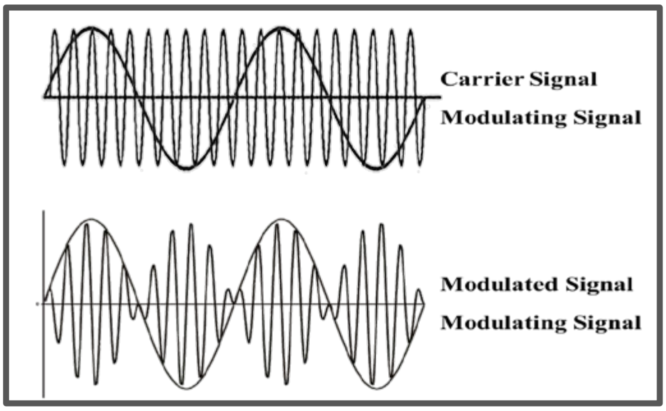

Figure 1.2 Amplitude Modulation

Sidebands:

If the modulating signal is a more complex waveform, for instance an audio voltage from a speech amplifier, there will be many side frequencies present in the total waveform. This gives rise to components 2 and 3 in the last equation being bands of frequencies, known as sidebands. Hence, we have the upper sideband and the lower sideband, together with the carrier. Clearly, for a given carrier amplitude there are limits for the size of the modulating signal; the minimum must give zero carrier, the maximum gives twice the unmodulated carrier amplitude. If these limits are exceeded, the modulated signal cannot be recovered without distortion and the carrier is said to be over-modulated.

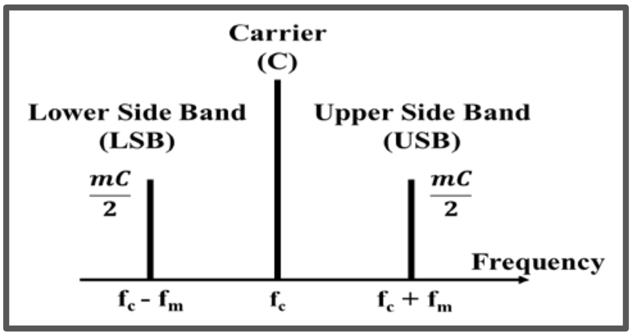

Figure 1.3 Frequency Spectrum of AM Signal

Experimental Determination of the Modulation Index:

This is most easily done by measuring the maximum and minimum values which the instantaneous amplitude of the carrier reaches. Let us call these x and y. Taking our previous equation:

$$v_c = V_c\,[sin\omega_c t + \; m \sin\omega_c t \sin\omega_m t]$$

and re-arranging it yet again, we can express vc as:

$$\mathrm{v}_c = V_c\; sin\omega_c t[1 + \; m \sin\omega_m t]$$

so that the instantaneous amplitude of the carrier is:

$$V_c\,[1 + m\;\sin\omega_m t]$$

Since $\sin\omega_m t$ can vary between +1 and - 1,

$$x = V_c\,(1 + m\,) \text{ and } y = V_c\,(1 - m\,)$$

To get the value of modulation index m from x and y, we eliminate Vc between these equations by division, giving:

$$\frac{y}{x} = \frac{1 - m}{1 + m}$$

Solving for **m** gives:

$$m = \frac{x - y}{x + y} = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

PROCEDURE:

In this practical the hardware is configured as shown in Figure 1.4.

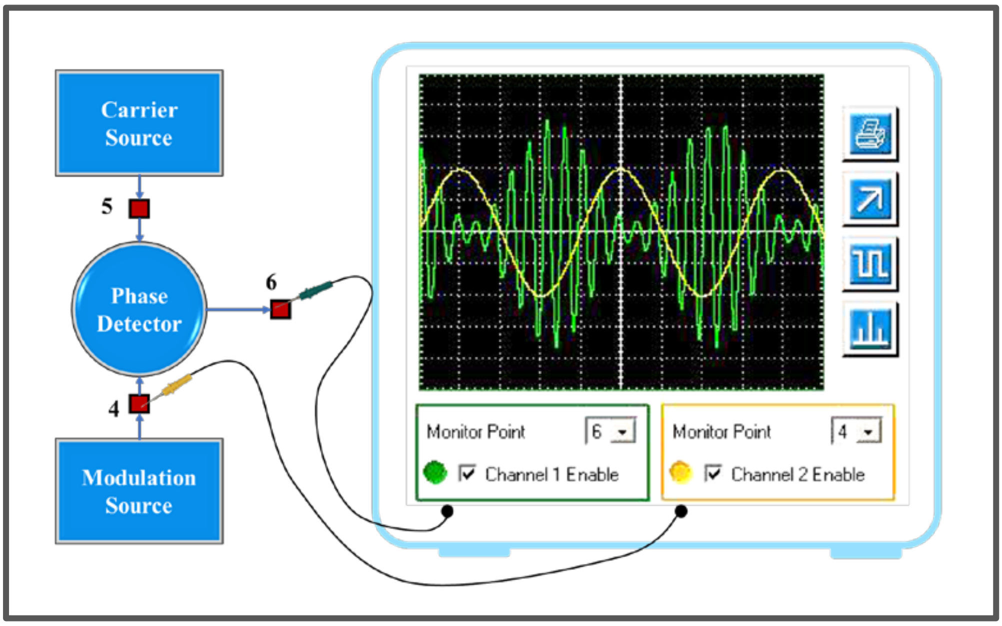

Figure 1.4 Experiment Setup

Set the ***carrier level*** to maximum. Set ***modulation level*** to zero. Observe the signals at all monitoring points. Write your observations.

Now increase the ***modulation level*** and observe at monitor point 6.

Increase the ***modulation level*** until the carrier amplitude just reaches zero on negative modulation peaks. This is 100% modulation. Observe the signals at all the monitoring points both with the oscilloscope and the spectrum analyzer at various modulation levels.

Also, with a fixed modulation level try adjusting the ***carrier level***.

WAVEFORMS/SPECTRUM:

Modulation Level	**Modulated Waveform at Test-Point 6**	**Frequency Spectrum at Test-Point 6**
Zero		

Under Modulation (50%)		
Exact Modulation (100%)		
Over Modulation (>100%)		

RESULTS:

F/OBEM 01/04/00

NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: Communication System (TC-307)

Laboratory Session No. 01 Date: ______________________

Psychomotor Domain Assessment Rubric-Level P2					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment identification Sensory skill to ***identify*** equipment and/or its component for a lab work	Not able to identify the equipment	--	--	--	Able to identify equipment as well as its components
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor’s Signature with Date:	

LAB SESSION 02

OBJECTIVES:

To check the operation of the balanced amplitude modulator with suppressed carrier.

EQUIPMENT REQUIRED:

Amplitude Modulation Work board 53-130 which comprises the following blocks:

- Signal Generation
- Modulation
- Filters
- Demodulation

PRE-LAB THEORY:

Double sideband suppressed carrier modulation:

In AM modulation, two-third of the transmitted power appears in the carrier which itself conveys no information. The real information is contained within the sidebands. One way to overcome this problem is simply to suppress the carrier. Since the carrier does not provide any useful information, there is no reason why it must be transmitted. By suppressing the carrier, the resulting signal is simply the upper and lower sidebands. Such a signal is referred to as a double-sideband suppressed carrier (DSB-SC or DSB) signal. Double sideband suppressed carrier modulation is simply a special case of AM with no carrier. A circuit called balanced modulator generates double sideband suppressed carrier signals as shown in Fig. 2.1.

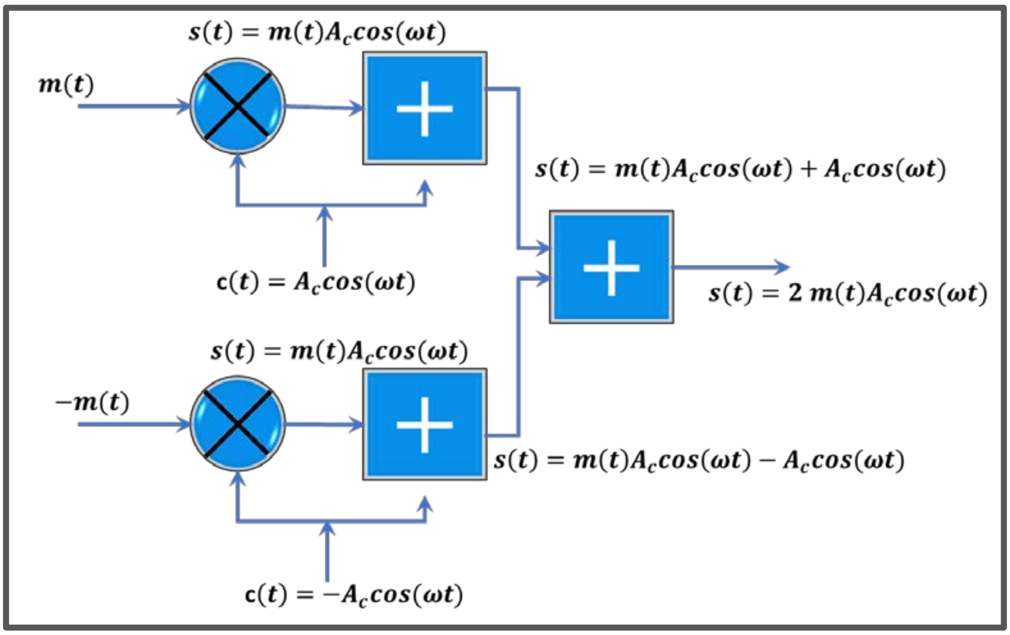

Figure 2.1 DSBSC Signal's Generation

In the theory for the Amplitude Modulation with Full Carrier assignment, it was established that the output signal of the AM Modulator circuit is:

$$\mathbf{v}_c = V_c \, sin\omega_c t + m\frac{V_c}{2}\cos(\omega_c - \omega_m)\, t - \; m\frac{V_c}{2}\cos(\omega_c + \omega_m)\, t$$

In DSB suppressed carrier modulation, the carrier term Vc sin ωc t is suppressed, leaving just:

$$\mathbf{v}_c = m\tfrac{V_c}{2}\cos(\omega_c - \omega_m)\, t - \; m\tfrac{V_c}{2}\cos(\omega_c + \omega_m)\, t \text{ as the modulated signal.}$$

The two cosine terms represent the lower and upper sidebands respectively. The frequency spectrum of DSB-

SC is shown in Fig. 2.2, while time domain representation of DSB-SC is illustrated in Fig. 2.3.

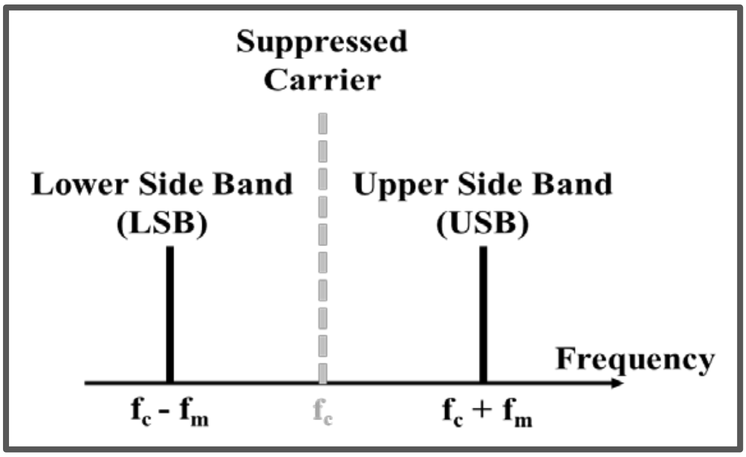

Figure 2.2 DSBSC Spectrum

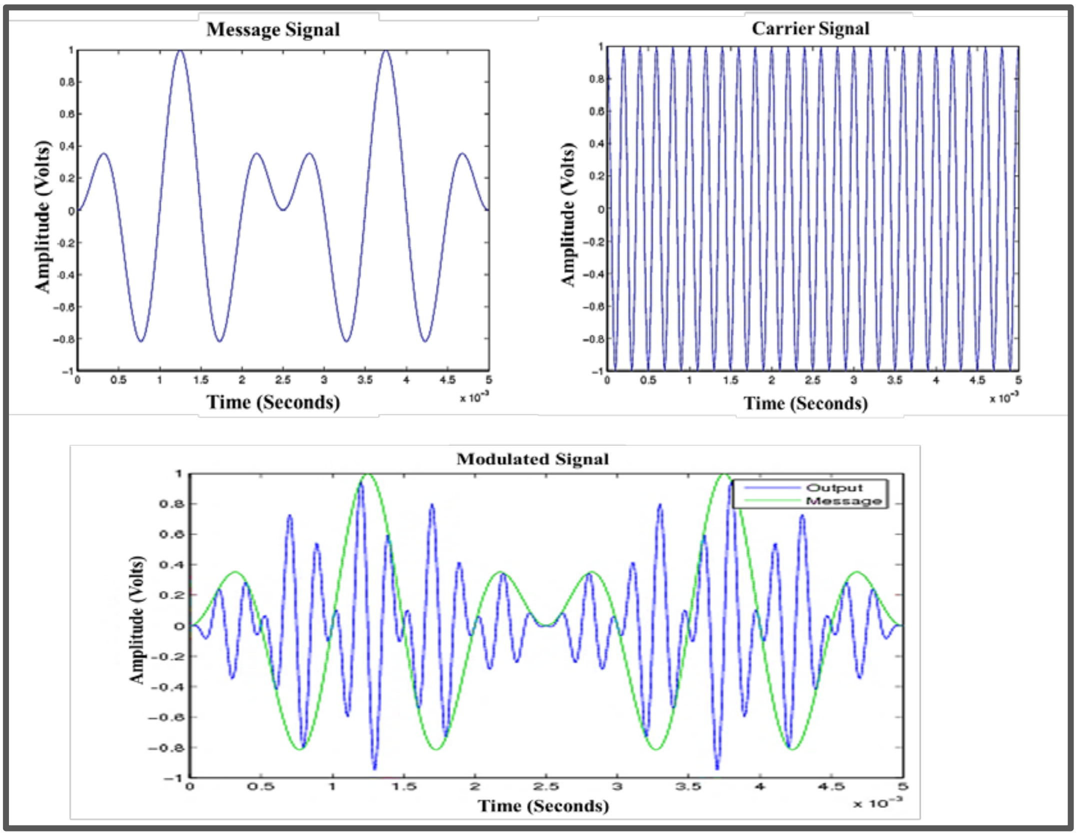

Figure 2.3 Time domain illustration of DSB-SC

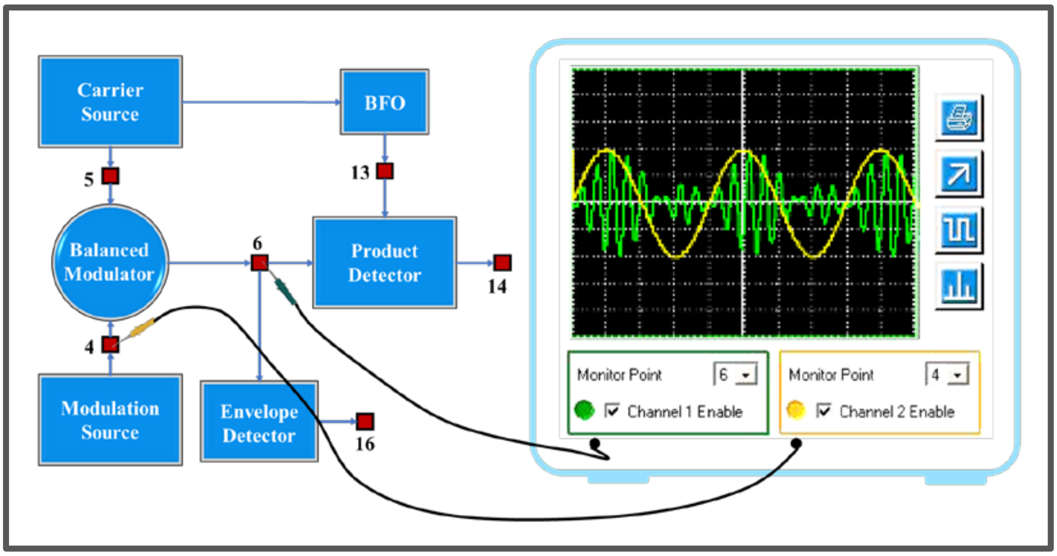

Figure 2.4 Experiment Setup

PROCEDURE:

Use the oscilloscope and spectrum analyzer to examine the signals at monitor point **4** and monitor point **5**. Set the ***carrier balance*** to mid-scale. Note that they are the same as for simple AM. Now examine at monitor point **6** and observe the wave shape.

Use the spectrum analyzer to observe that there are two sidebands but no carrier. Record your observations:

Adjust the ***carrier balance*** and observe the effect on carrier amplitude

Adjust ***modulation level*** and ***carrier level*** and observe the effects

RESULTS:

F/OBEM 01/04/00

NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: TC-307 (Communication Systems)

Laboratory Session No. 02 Date: ______________________

Psychomotor Domain Assessment Rubric-Level P2

Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment identification Sensory skill to ***identify*** equipment and/or its component for a lab work	Not able to identify the equipment	--	--	--	Able to identify equipment as well as its components
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 03

OBJECTIVES:

To examine the main parameters of the single sideband modulation and to check the use of filters to generate the SSB.

EQUIPMENT REQUIRED:

Amplitude Modulation Work board 53-130 which comprises the following blocks:

- Signal Generation
- Modulation
- Filters
- Demodulation

PRE-LAB THEORY:

Single sideband modulation:

A modulation technique in which only one sideband out of the two is transmitted is known as Single Side band transmission. In double sideband transmission, the basic information is transmitted twice once in each sideband. Therefore, transmitting both signals is redundant. The information can be transmitted through one sideband by further suppressing the one sideband. The generated signal is termed as single sideband suppressed carrier.

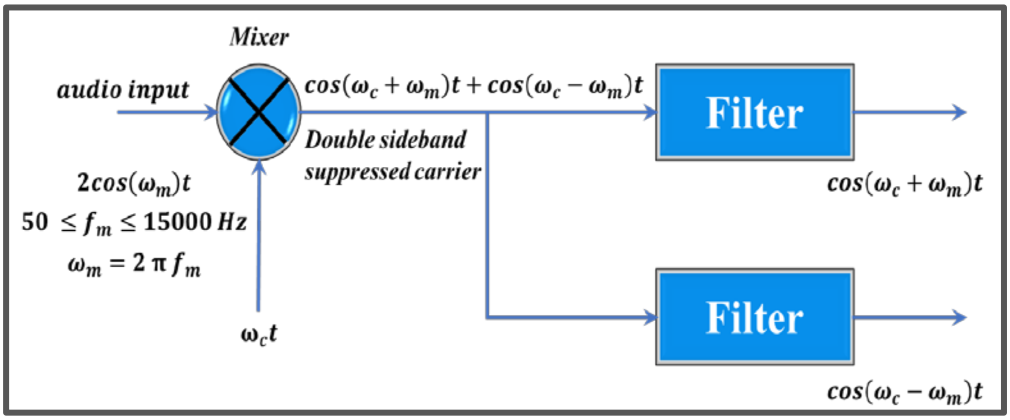


Figure 3.1 Generation of SSB signal

Generating SSB:

The generator in the practical is a balanced modulator, producing DSB, followed by a bandpass filter for the required sideband. There are other methods, but this filter method is the simplest to understand and is in very common usage in communication systems. It may be necessary for the bandpass filter to have a very good shape factor because, at normal carrier and audio frequencies, the upper and lower sidebands are quite close in frequency.

Another consideration is that the sideband filter should offer significant attenuation to the carrier, so that the balanced modulator need not be so accurately balanced. In practice the balanced modulator might provide 30dB of carrier suppression and the filter a further 10dB. The other sideband would normally be about 30 to 40dB down on the wanted one. In order to achieve this, the SSB filter has several poles and is, in most cases a ceramic filter or crystal filter. Various filters are commercially available with different specifications depending on the application.

In the practical, a high modulating frequency is used, so one can see clearly the relationship between the various frequency components. This means that the filter specification can be relaxed and here a single tuned circuit is used. Separate filters are provided for upper and lower sidebands and the means is provided to monitor the output of both.

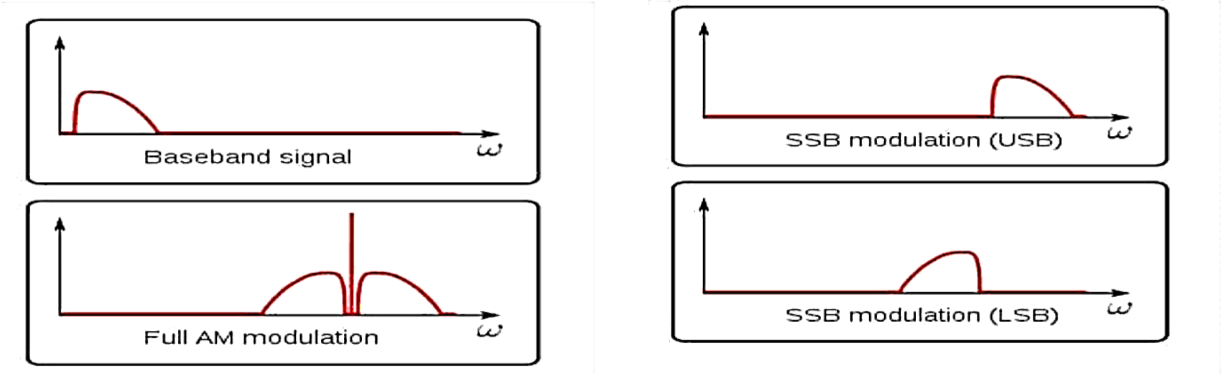
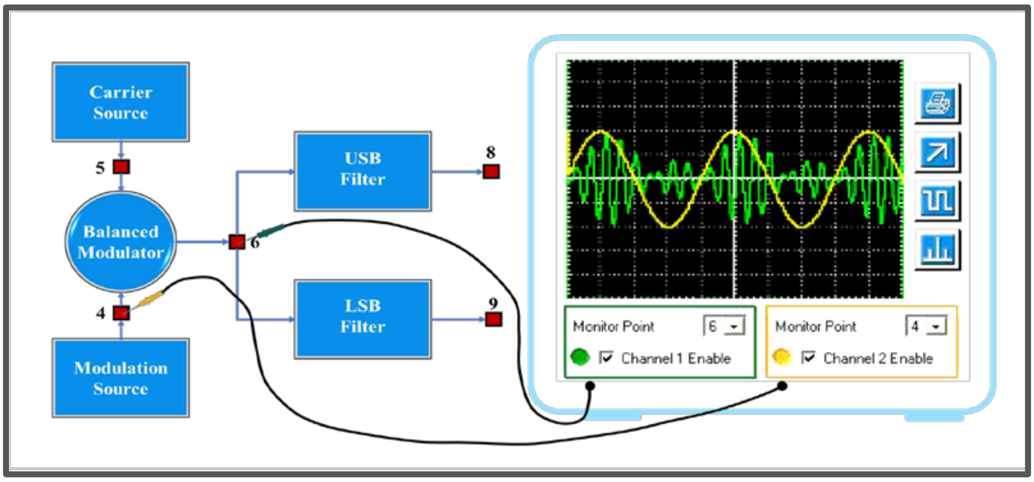


Figure 3.2 Frequency Spectrum Representations Upper or Lower Sideband

There is no reason why one sideband gives better results than the other, but general practice seems to favor the upper sideband. One convention is that with carrier frequencies below 10 MHz the lower sideband should be used, but this is not always the case. Consequently, various pieces of communication equipment must be able to deal with both.

PROCEDURE:



Monitor Point 6
● ☑ Channel 1 Enable

Monitor Point 4
● ☑ Channel 2 Enable

Figure 3.3 Experiment Setup

Use the spectrum analyzer and oscilloscope to observe at monitor point **6**. Note that the signal is DSB. Adjust the ***carrier balance*** as before.

Use the spectrum analyzer and oscilloscope to observe at monitor point **8**.

Use the spectrum analyzer and oscilloscope to observe at monitor point **9**.

RESULTS:

NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: TC-307 (Communication Systems)

Laboratory Session No. 03 Date: ______________________

Psychomotor Domain Assessment Rubric-Level P2					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment identification Sensory skill to ***identify*** equipment and/or its component for a lab work	Not able to identify the equipment	--	--	--	Able to identify equipment as well as its components
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 04

OBJECTIVE:

To investigate the demodulation of an AM signal with an Envelope Detector.

EQUIPMENT REQUIRED:

Amplitude Modulation Work board 53-130 which comprises the following blocks:

- Signal Generation
- Modulation
- Filters
- Demodulation

PRE-LAB THEORY:

The purpose of any detector or demodulator is to recover the original modulating signal with the minimum of distortion and interference. The simplest way of dealing with an AM signal is to use a simple half- wave rectifier circuit. If the signal were simply passed through a diode to a resistive load, the output would be a series of half-cycle pulses at carrier frequency. So, the diode is followed by a filter, typically a capacitor and resistor in parallel.

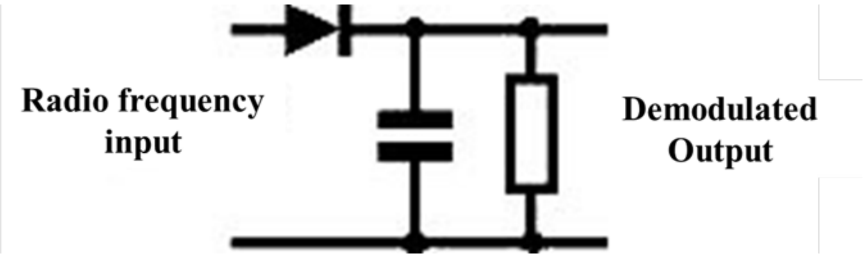

Figure 4.1 Envelope Detector Circuit

The capacitor is charged by the diode almost to the peak value of the carrier cycles and the output therefore follows the envelope of the amplitude modulation. Hence the term “envelope detector”.
The time constant of the RC network is very important because if it is too short the output will contain a large component at carrier frequency. However, if it is too long it will filter out a significant amount of the required demodulated output.

In this practical the output of the AM generator that is fed to an envelope detector. The output can be monitored and compared with the original modulation source. The time constant of the filter following the detector can be adjusted. This filter is often called a post-detection filter. It also introduces a phase shift between the original signal and the output.

PROCEDURE:

Obtain an AM modulated signal from an AM modulator and apply it to the input of the envelope detector. Here the signal from the amplitude modulator from the AM Signal generator is demodulated using an envelope detector.

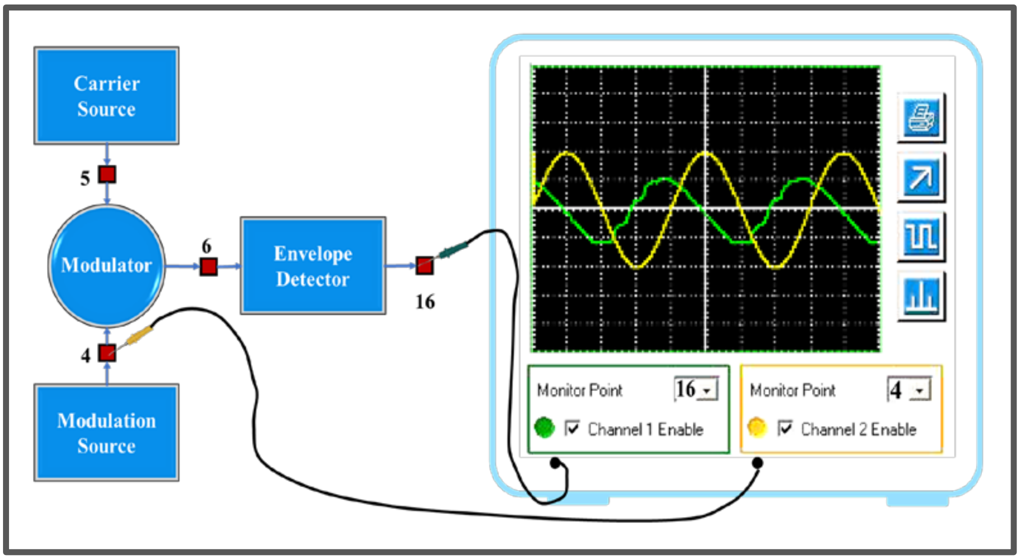

Figure 4.2 Experiment Setup

Use the oscilloscope to monitor the detector output **16** and adjust the time constant. If it's too less and too large what will happen? Also state the reason.

Use the spectrum analyzer to observe the carrier spectral components. Record your observations:

Compare the original modulating signal with the detector output in both shape and phase at various time constants using the oscilloscope. Record your observations.

RESULTS:

F/OBEM 01/04/00

NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: TC-307 (Communication Systems)

Laboratory Session No. 04 Date: _______________________

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Remarks	
Instructor's Signature with Date:	

LAB SESSION 05

OBJECTIVE:

To observe the operation of Product Detector

EQUIPMENT REQUIRED:

Amplitude Modulation Work board 53-130 which comprises the following blocks:

- Signal Generation
- Modulator
- Filters
- Demodulator

PRE-LAB THEORY:

Product detector has certain advantages over the simple envelope detector but at the expense of some complexity. It is not often used for Amplitude Modulation but is the only type of detector that will demodulate the suppressed carrier amplitude. It is important to appreciate that a product detector will demodulate all forms of AM.

Product Detector:

If the AM signal is mixed with (i.e., modulated by) a frequency equal to that of its carrier, the two sidebands are mixed down to the original modulating frequency and the carrier appears as a dc level. The mathematics of the process shows that this will only happen if the mixing frequency is equal not only in frequency to that of the carrier, but also in phase, i.e., the two signals are synchronous. This is why a product detector when used for AM is sometimes called a synchronous detector. For AM, the effect is very similar to a full-wave rectifier rather than the half-wave of the envelope detector.

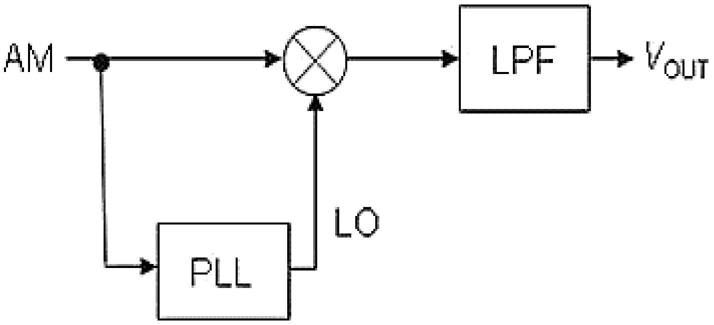

Figure 5.1 Block Diagram of Product Detector

The output still needs a post-detection filter to remove the residual ripple, but this time the ripple is at twice the carrier frequency and is therefore further away from the modulation and hence easier to remove. In general terms the product detector gives less distortion, partly because it uses both positive and negative peaks of the carrier.

Generating the Mixing Frequency:

This is produced by an oscillator which is usually referred to as a Beat Frequency Oscillator or BFO. This is because it is not at the same frequency as the carrier the output of the product detector. It works on a frequency equal to the difference between of the two, which is called a beat frequency. (You will be able to see this when you adjust the BFO for synchronism).

As previously described, it is vital that the BFO be synchronized to the carrier. In practice this is achieved with a special recovery circuit but here for simplicity a sample of the carrier is fed directly to the BFO and when the free running frequency of the BFO is near to that of the carrier it locks into synchronism.

PROCEDURE:

Follow required procedure to obtain product detector demodulating AM output.
The oscilloscope shows its input at ***monitor point 6***, which is the output of the same modulator as before. Monitor the BFO output with the oscilloscope and use the ***BFO*** frequency control to lock it to the carrier. This will be indicated by a stationary ***TRACE***.

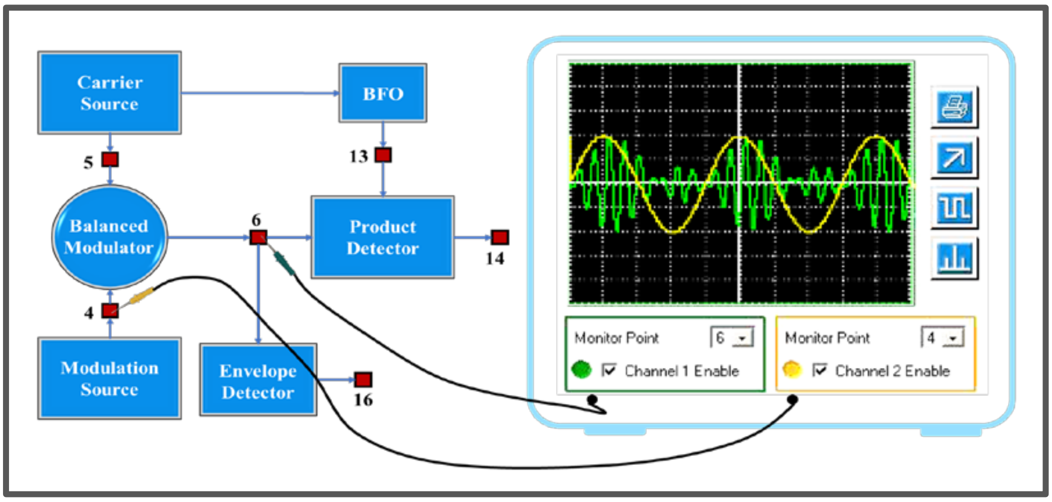

Figure 5.2 Experiment Setup

Use the oscilloscope to look at the output of the detector and compare it with original modulating signal.

Use the spectrum analyzer to confirm this.

Monitor the detector output with the oscilloscope, unlock the BFO with the ***BFO frequency*** control and observe the result. Repeat whilst using spectrum analyzer. Record your observations:

RESULTS:

F/OBEM 01/04/00

NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: TC-307 (Communication Systems)

Laboratory Session No. 05 Date: ________________________

Psychomotor Domain Assessment Rubric-Level P2					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment identification Sensory skill to ***identify*** equipment and/or its component for a lab work	Not able to identify the equipment	--	--	--	Able to identify equipment as well as its components
Equipment Use Sensory skills to ***demonstrate*** the use of the equipment for the lab work	Doesn't demonstrate the use of equipment	Slightly demonstrates the use of equipment	Somewhat demonstrates the use of equipment	Moderately demonstrates the use of equipment	Fully demonstrates the use of equipment
Procedural Skills ***Displays*** skills to act upon sequence of steps in lab work	Not able to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work	Able to fully understand lab work procedure and perform lab work
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Group Work ***Contributes*** in a group based lab work	Doesn't participate and contribute	Slightly participates and contributes	Somewhat participates and contributes	Moderately participates and contributes	Fully participates and contributes

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 06

OBJECTIVE:

To investigate the demodulation of SSB signals using Product/ Synchronous detection.

EQUIPMENT REQUIRED:

Amplitude Modulation Work board 53-130 which comprises the following blocks:

- Signal Generation
- Modulation
- Filters
- Demodulation

PRE-LAB THEORY:

Single sideband demodulation:

In the double sideband suppressed carrier practical, we saw how DSB is demodulated using the BFO to reinsert the carrier. In the case of DSB, the BFO must be in phase with the original carrier or the process will not work correctly. Since SSB is transmitted without a carrier it is not surprising that a similar method is employed.

The main difference is that, for SSB, the BFO need not be in phase with the carrier. It does need to be at the same frequency but even a small error in the frequency results only in a small error in the frequency of the demodulated output. This means that in non-critical applications, such as speech, a small overall frequency error does not make the system useless. The effect on speech is to raise or lower the tone of the voice, which within limits does not reduce intelligibility.

The fact that the BFO need not be locked, greatly simplifies the design of the receiver, and makes SSB one of the most powerful techniques for transmitting audio frequencies over radio links with its narrow bandwidth and efficient use of available transmitter power.

In the practical, you can use both upper and lower sidebands and see that with the BFO set correctly, near to the original carrier frequency, even though the two sidebands are at different frequencies the demodulated output is the same. You can also see that changing the BFO frequency causes the demodulated output to change in frequency by a similar amount.

PROCEDURE:

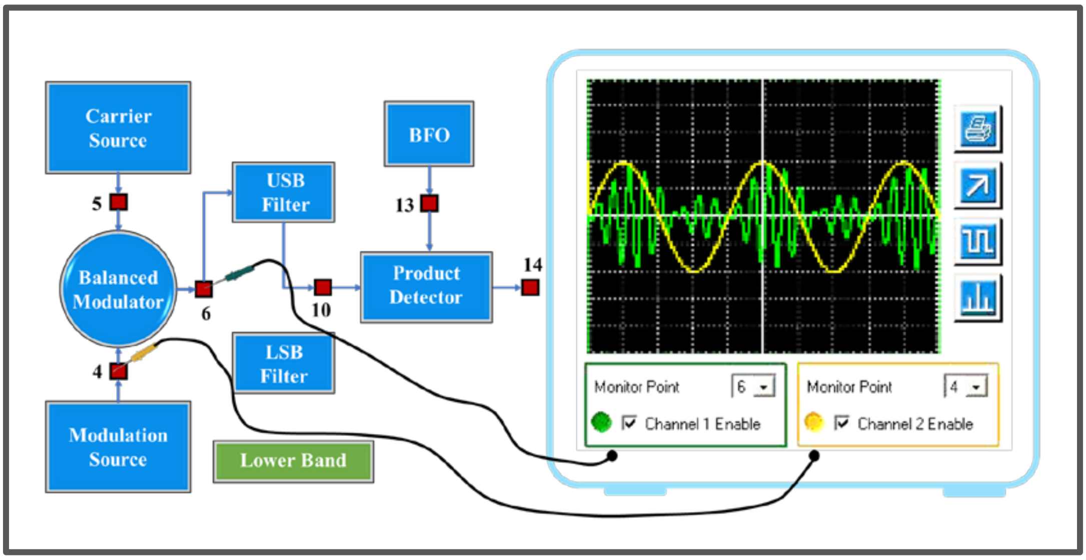

Figure 6.1 Experiment Setup

Monitor at monitor point **6**, and observe the DSB signal.

Move to monitor point **10** and note the upper sideband signal.

Change to lower sideband (by pressing the button) and note the lower sideband signal.

Use either the oscilloscope or analyzer to set the ***BFO*** frequency to that of the carrier, by monitoring at monitor point **13.**

Now monitor at point **14** and compare the output with the modulation input.

RESULTS:

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NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: TC-307 (Communication Systems)

Laboratory Session No. 06 Date: ______________________

Psychomotor Domain Assessment Rubric-Level P2					
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor’s Signature with Date:	

LAB SESSION 07

OBJECTIVES:

To observe the characteristics of a Frequency Modulated wave in Time Domain and Frequency Domain.

EQUIPMENT REQUIRED:

- Feedback-Teknikit Console 92-300
- Pentium 4 or equivalent computer available in lab

PRE-LAB THEORY:

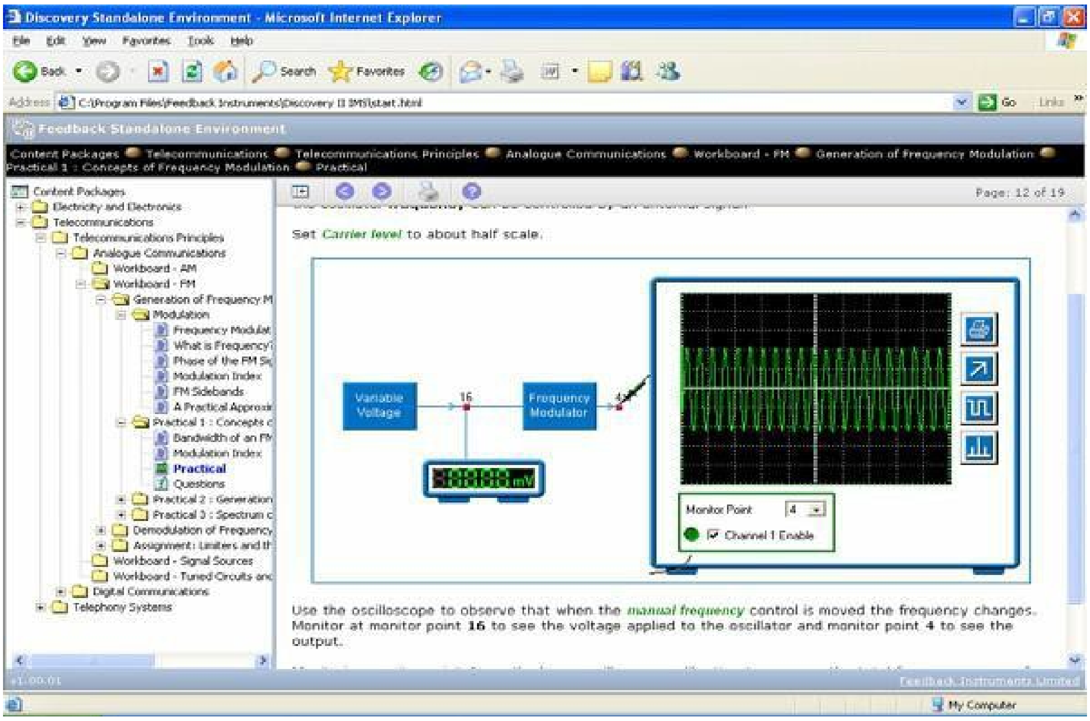
Frequency Modulation Generation:

The circuits used to generate a frequency modulation must vary the frequency of a high frequency carrier signal as a function of the amplitude of low frequency signal (modulation signal). In practice there are two main methods used to generate FM:

- **Direct method:** A tank circuit is used in which the reactance of one of the elements of the resonant circuit depends on the modulating voltage. The most common device with variable reactance is the Varactor or Varicap. This is a particular diode and its capacitance varies according to the reverse bias voltage applied across it. The frequency of the carrier is established with Automatic Frequency Control (AFC) circuits or Phase Lock Loop (PLL).
- **Indirect method:** The FM is obtained in this case by a Phase modulation, after the modulating signal has been integrated. In the phase modulator the carrier can be generated by a quartz oscillator, and so its frequency stabilization is easier.

PROCEDURE:

Set Carrier level to about half scale (0.8 Vp-p). Monitor point 16 shows us the DC input voltage and monitor point 4 shows the output carrier which is frequency modulated. Figure 7.1 shows the output signal when input voltage is 0 V.

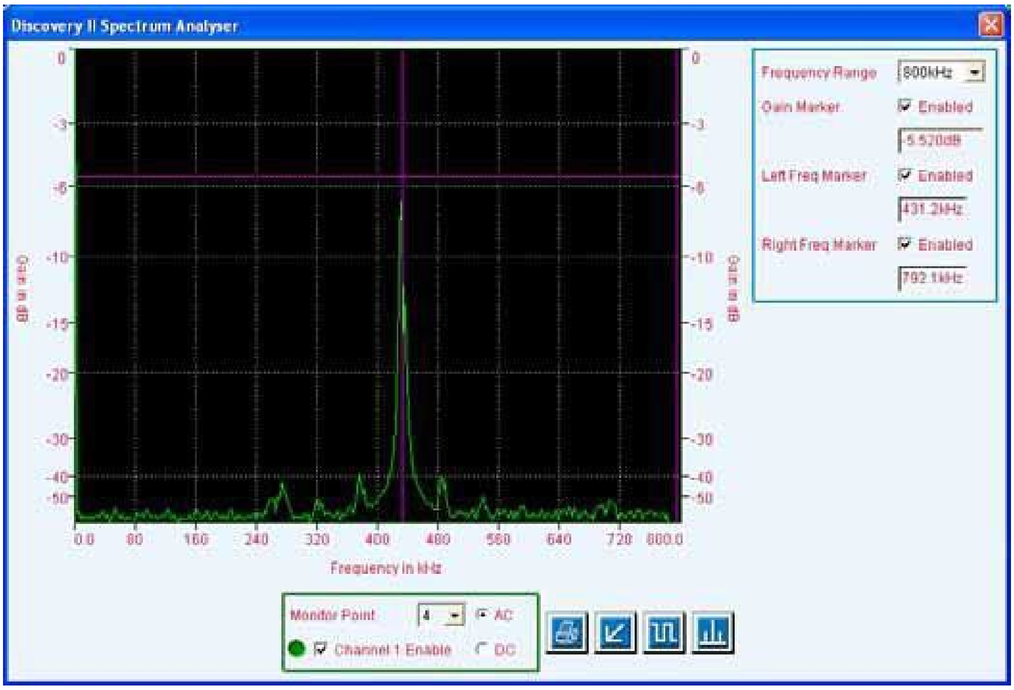


Set Carrier level to about half scale.

Use the oscilloscope to observe that when the *manual frequency* control is moved the frequency changes. Monitor at monitor point **16** to see the voltage applied to the oscillator and monitor point **4** to see the output.

Figure 7.1 Experiment Setup

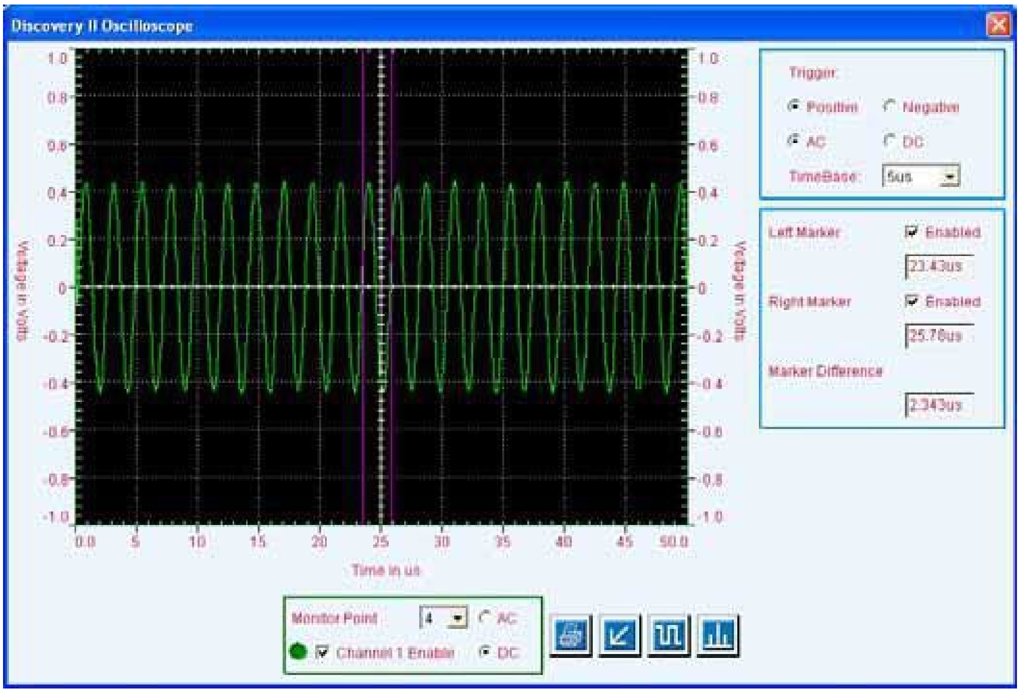
The Frequency corresponding to a zero-input voltage is best observed by the spectrum analyzer as shown in figure 7.2. The left marker of the spectrum analyzer is utilized to measure the signal frequency.



Frequency Range: 800kHz
Gain Marker: ☑ Enabled
-5.520dB
Left Freq Marker: ☑ Enabled
431.2kHz
Right Freq Marker: ☑ Enabled
792.1kHz
Monitor Point: 4
● AC ○ DC
● ☑ Channel 1 Enable

Figure 7.2: Spectrum analyzer output

A tedious way to measure the output signal frequency is by observing the signal in time domain. We take the inverse of the pulse time duration which is measured with the help of the left and right scope markers- Figure 7.3. Note, that the spectrum analyzer method is a bit more accurate.



Trigger:
● Positive ○ Negative
● AC ○ DC
TimeBase: 5us
Left Marker: ☑ Enabled
23.43us
Right Marker: ☑ Enabled
25.78us
Marker Difference
2.343us
Monitor Point: 4
○ AC ● DC
● ☑ Channel 1 Enable

Figure 7.3: Oscilloscope output

OBSERVATIONS:

Set the carrier amplitude such that it is 2 divisions above and below the x-axis (approximately 0.8 Vp-p). Fill in the table below for DC input voltage vs. output carrier frequency. Plot a graph using the values you recorded in the table.

Input Voltage (V)	Output Frequency (Oscilloscope) Hz	Output Frequency (Spectrum Analyzer) Hz

RESULT:

F/OBEM 01/04/00

NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: TC-307 (Communication Systems)

Laboratory Session No. 07 Date: ______________________

Psychomotor Domain Assessment Rubric-Level P2					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment identification Sensory skill to ***identify*** equipment and/or its component for a lab work	Not able to identify the equipment	--	--	--	Able to identify equipment as well as its components
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor’s Signature with Date:	

LAB SESSION 08

OBJECTIVE:

To analyze the Spectrum of an FM Signal with a Large Modulation Index.

EQUIPMENT REQUIRED:

- Frequency Modulation 53-140 module
- Oscilloscope

PRE-LAB THEORY:

This is a simple practical where the frequency modulator is connected to the spectrum analyzer. The carrier frequency has been reduced to about 5 kHz so, since the maximum deviation is the same; the modulation index is much greater.

The bandwidth is:

$$B = 2 (Fd+Fm)$$

Where B is the bandwidth, Fd the deviation and Fm is the bandwidth of the modulation.

So, if Fm is small compared with Fd, i.e., the modulation index is large, then

$$B = 2 Fd$$

On the analyzer the spectrum appears to be continuous but, it is made up of a large number of sidebands spaced at 5 kHz intervals from the carrier up to Fd.

This practical simply shows how with a large modulation index the bandwidth is determined almost exclusively by the deviation.

PROCEDURE:

1. In this practical the modulation frequency has been set to 5 kHz. This means that the modulation index can be very high.
2. This enables you to see that under these conditions the bandwidth of an FM signal is almost equal to twice the deviation.
3. Set ***Carrier level*** to about half scale.
4. Turn the 5 kHz level up and down and observe the bandwidth changing. Note that the bandwidth is almost proportional to the deviation.

OBSERVATIONS:

RESULT:

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NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: TC-307 (Communication Systems)

Laboratory Session No. 08 Date: ________________________

Psychomotor Domain Assessment Rubric-Level P2

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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor’s Signature with Date:	

LAB SESSION 09

OBJECTIVE:

To carry out FM demodulation using quadrature detector.

EQUIPMENT REQUIRED:

Frequency modulation work board 53-140 which comprises the following blocks

- Signal generation
- Modulator
- Limiter
- Quadrative demodulator
- VCO
- Phase comparator

PRE-LAB THEORY:

The purpose of an FM demodulator is to return the modulating signal to baseband. Since, in FM, the instantaneous frequency is proportional to the modulating signal, all that is needed is a circuit block which produces a voltage proportional to the input frequency. This is not quite as simple as it sounds. Another way is to turn the FM to phase modulation and then use a phase detector. This is a very common technique and is the basis of the Quadrature Detector.

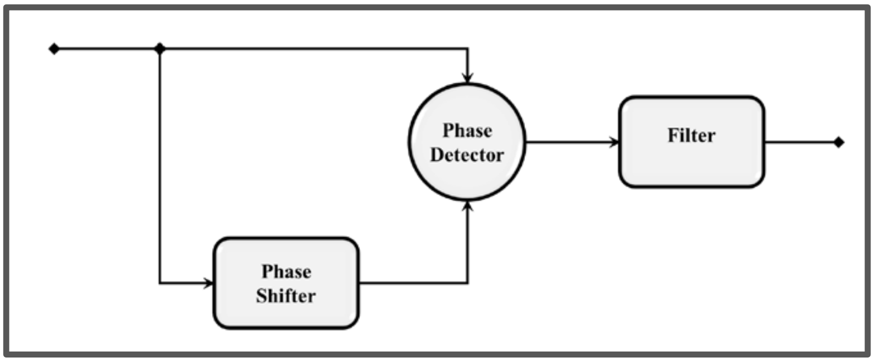

Figure 9.1 Block diagram of a Quadrature detector

The quadrature detector splits the incoming FM signal into two paths. One path is connected directly to one input of a phase detector. The other path contains a simple network which shifts the phase of the signal in proportion to its frequency deviation.

A minor complication is that most phase detectors produce their mean output for 90 degrees phase difference between the input signals. This is the required condition when the FM signal is at its center frequency, so an additional constant 90-degree phase shift is added to one of the paths. When unmodulated, the two inputs to the phase detector are at 90 degrees apart, or in quadrature; hence the name of the detector.
This constant phase shift is usually added by means of a simple inductor. The output of the phase detector still contains a large component at twice the carrier frequency and the detector is usually followed by a filter that passes the baseband but not the carrier.
Quadrature detectors are used extensively in domestic FM radios and in a lot of communications equipment.

In this practical, the same modulator is used as in the Generation of Frequency Modulation assignment. The modulation is a sine wave so that the signal can be followed through the circuit.

PROCEDURE:

This practical shows a quadrature detector working. Monitor at 9 and observe the FM signal at different settings of modulation level. Note the two signals at the inputs of the phase detector 9 and 11. Set the modulation level to about half scale.

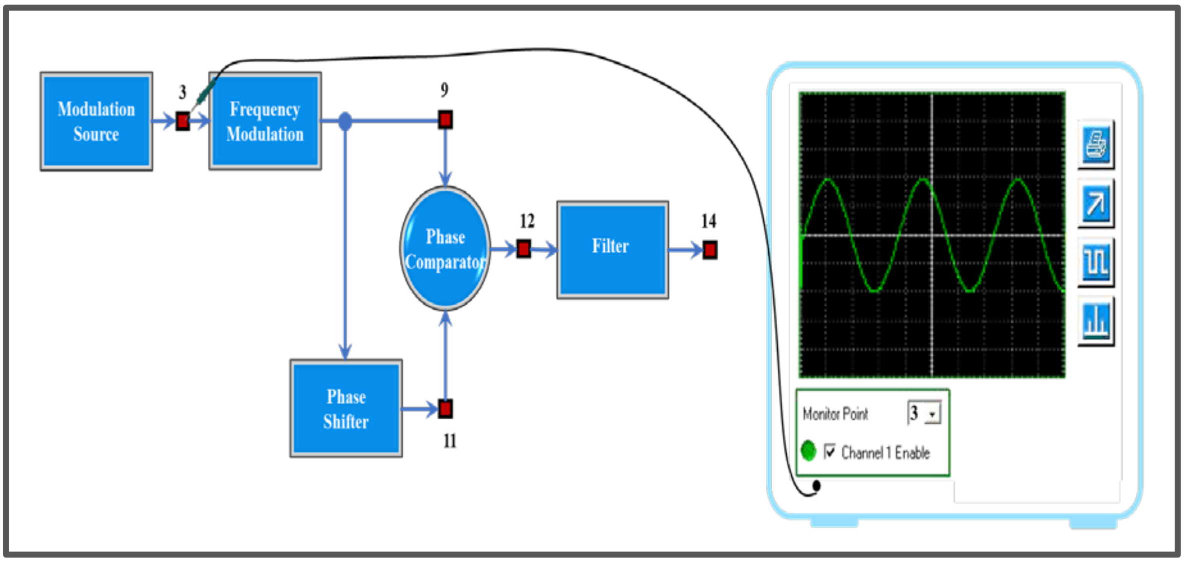

Figure 9.2 Experiment Setup

OBSERVATIONS:

Fc= fm= Vc= Vm=

Waveforms and Frequency Spectrum at:

Observation Point	Waveform	Frequency Spectrum
Point 9		
Point 11		
Point 12		
Point 14		

RESULT:

F/OBEM 01/04/00

NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: TC-307 (Communication Systems)

Laboratory Session No. 09 Date: ______________________

Psychomotor Domain Assessment Rubric-Level P2					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor’s Signature with Date:	

LAB SESSION 10

OBJECTIVE:

To carry out FM demodulation using PLL detector.

EQUIPMENT REQUIRED:

Frequency modulation work board 53-140 which comprises the following blocks

- Signal generation
- Modulator
- Limiter
- Quadrative demodulator
- VCO
- Phase comparator

PRE-LAB THEORY:

This practical introduces the phase locked loop (or PLL) demodulator. This type of detector offers some advantages over the quadrature detector when the signal to noise ratio is poor. Before trying to understand how a PLL can demodulate an FM signal it is necessary to understand what a PLL is. The concept is of an oscillator synchronized in phase to an external signal source using a feedback loop. As frequency is the same thing as rate of change of phase, once the phase of the local oscillator is synchronized to the external signal, the frequencies are automatically made identical

A phase locked loop consists of three main blocks:

1. An oscillator, the frequency of which is controlled by an external voltage or current source. A voltage-controlled oscillator or VCO is used in this assignment.
2. A phase detector, which compares the phase of the oscillator with that of the external signal.
3. A filter, which smoothes the output from the detector to provide the control signal to the VCO, adjusting its frequency to reduce the phase difference.

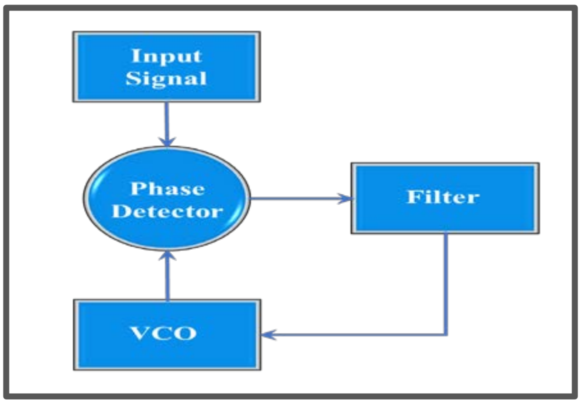


Figure 10.1 Block diagram of a phase locked loop (PLL)

Operation of a PLL:

Imagine an incoming signal at a constant frequency within the range of the VCO. Its phase is compared with that of the VCO and a voltage produced that alters the VCO frequency. The phase of the VCO therefore starts changing relative to the incoming signal, until eventually the phases match. Once they are equal, the control signal goes to zero and the system settles into equilibrium. Any drift of the VCO will be corrected by the control voltage which again appears. The two signals are said to be phase locked.
A filter is used in the control loop to keep the system stable and limit the maximum rate of change of oscillator frequency. This whole description is a very simplified view, and the parameters that set the filter characteristics are very complex. An important factor in the design is the time before the two signals become locked.

Phase locked loops are used extensively in communications systems where it is necessary to produce a reference oscillator in phase with an incoming signal, also in special signal sources called frequency synthesizers

The PLL as an FM Detector:

Suppose that there was a PLL locked onto an incoming carrier which was unmodulated. The VCO would be at the same frequency as the carrier and the VCO control voltage would be constant. If the carrier were to change in frequency the VCO would follow the change by means of a change in control voltage. So, the VCO control voltage varies with the carrier frequency, and if the carrier were frequency modulated the modulation would appear superimposed on the VCO control voltage. When a post-detection filter is added to the simple PLL to remove all the frequency components above the maximum modulating frequency we now have a PLL FM detector.

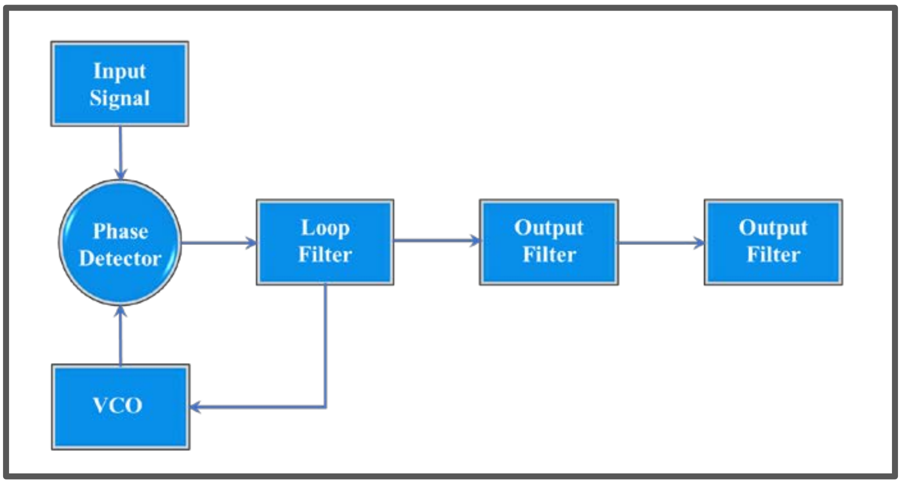
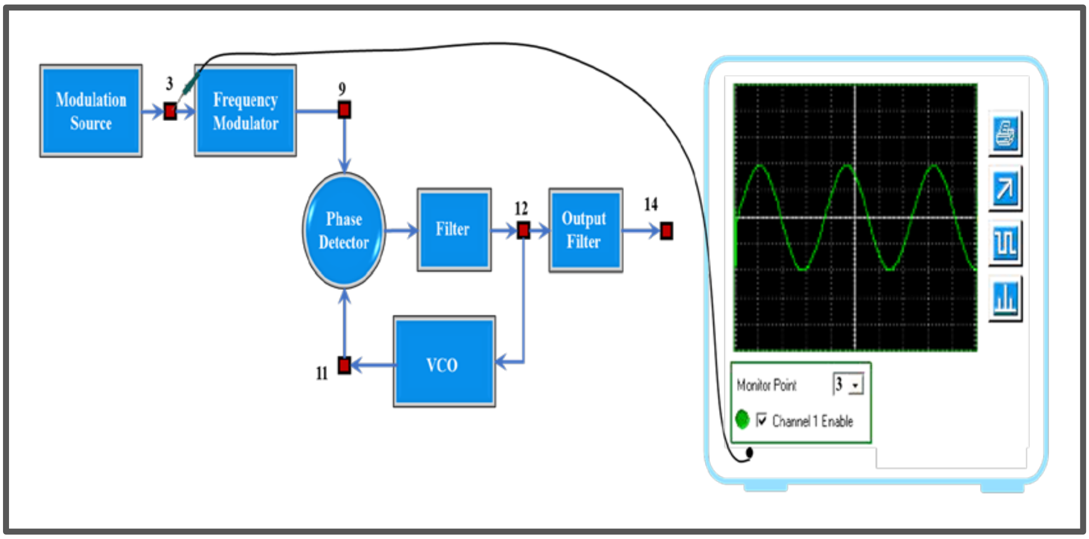


Figure 10.2 PLL working as an FM Detector

PROCEDURE:



Monitor Point 3

☑ Channel 1 Enable

Figure 10.3 Experiment Setup

In this practical we will see a PLL detector demodulating the same FM signal. The PLL is used when the ability to demodulate in the presence of noise is important. The distortion produced by this type of detector is determined mainly by the linearity of the VCO but this is often less important in noisy applications.

This practical shows a phase lock loop detector working. Monitor at **9** and observe the FM signal at different settings of modulation level. Examine the two signals at the input of the phase detector at **9** and the tracking

VCO at **11**. Set carrier level to maximum. Observe the signal at the phase detector output **12** and then after the post detection filter at **14**.

OBSERVATIONS:

Fc= fm= Vc= Vm=

Waveforms and Frequency Spectrum at:

Observation Point	Waveform	Frequency Spectrum
Point 9		
Point 11		
Point 12		
Point 14		

RESULT:

F/OBEM 01/04/00

NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: TC-307 (Communication Systems)

Laboratory Session No. 10 Date: ______________________

Psychomotor Domain Assessment Rubric-Level P2					
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor’s Signature with Date:	

LAB SESSION 11

OBJECTIVE:

To study the effects of a limiter and noise on the performance of PLL detector

EQUIPMENT REQUIRED:

Frequency modulation work board 53-140 which comprises the following blocks

- Signal generation
- Modulator
- Limiter
- Quadrative demodulator
- VCO
- Phase comparator

PRE-LAB THEORY:

Effect of Limiter:

If the received signal is large enough, the PLL will lock the local oscillator phase to that of the received signal. Doubling the signal amplitude will not alter this situation, so will not affect the output signal. To this extent the PLL removes unwanted amplitude modulation of the received signal.

If the signal is small and the deviation is large, the phase detector cannot give enough output to move the VCO over a large enough range to track the deviation. This can be shown in the practical by reducing the carrier amplitude with no limiter in operation. Failure to track over the whole range of deviation shows as a distortion of the output signal. For small enough signals, the PLL fails to lock altogether.

The addition of a limiter means that the phase detector in the PLL has a constant amplitude signal to deal with. The gain of the phase lock control loop is therefore maintained as the signal level changes.

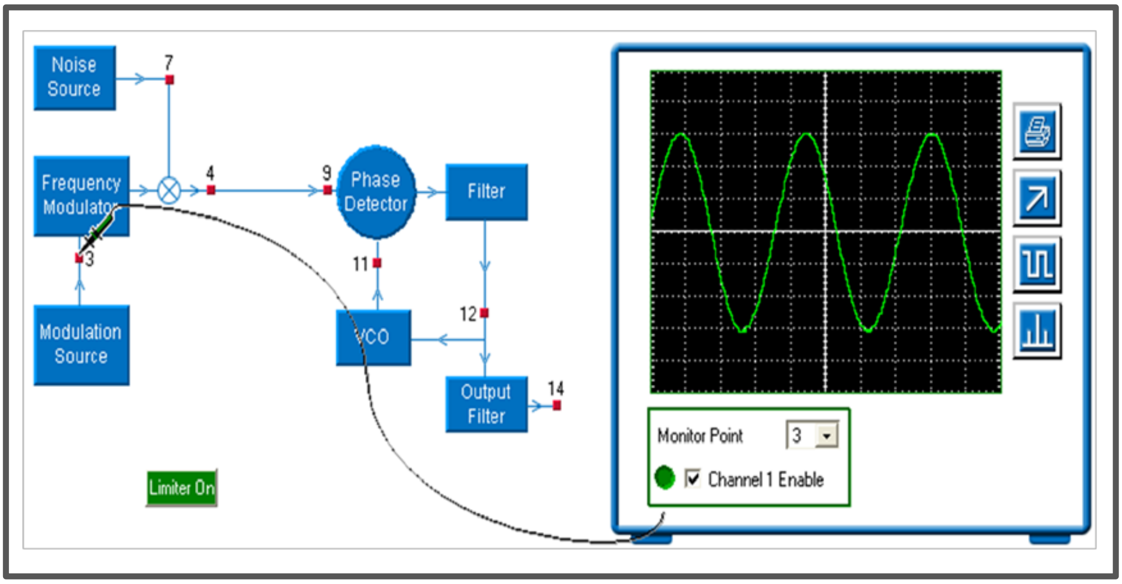
Effect of Noise:

Noise on the received signal causes both amplitude and phase changes. When a limiter is placed in the circuit, the amplitude changes are removed from the PLL input.

The principal effect on the PLL is that as the input signal tends to zero amplitude, there remains an adequate amplitude of signal to drive the phase lock loop. This continues to track the phase of the noisy received signal effectively, and with minimum error caused by noise amplitude variations.

Of course, the limiter cannot produce a signal from nothing, so as the carrier amplitude into the limiter falls, the noise from the limiter increases. This noise is faithfully detected by the PLL and degrades the output signal. This problem is due to fundamental noise problems and not due to any failing of the detector itself.

PROCEDURE:



Monitor Point 3

☑ Channel 1 Enable

Figure 11.1 Experiment Setup

Effect of Limiter:

Start with the limiter out (this is the default). Set the ***Carrier level*** and ***Modulation level*** to maximum. Set the Noise level to minimum. Observe at **14** that the demodulator is working correctly.

Reduce the ***carrier level*** and observe the output. Note that the detector loses track of the signal below a certain level, causing distortion of the detector output.

Also note that, when the modulation level is reduced, the carrier can be reduced further without distortion.

Now use the ***Limiter Button*** to switch in the limiter and repeat the tests. Note that the detector continues to work at much lower carrier levels. Use the other monitoring points to see how the system is operating.

Effect of Noise:

Set the ***Carrier level*** and ***Modulation level*** to maximum. The limiter should not be in use. Increase the ***Noise level*** and observe that the output becomes noisy.

Decrease the signal/noise ratio (SNR) further by reducing the ***carrier level*** until the signal becomes unrecognizable.

Now switch in the limiter using the ***Limiter Button***. Note that the detector keeps working at lower SNR when the limiter is in use.

RESULT:

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NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: TC-307 (Communication Systems)

Laboratory Session No. 11 Date: ______________________

Psychomotor Domain Assessment Rubric-Level P2

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Procedural Skills ***Displays*** skills to act upon sequence of steps in lab work	Not able to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work	Able to fully understand lab work procedure and perform lab work
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Equipment Handling ***Equipment care*** during the use	Doesn’t handle equipment with required care	Rarely handles equipment with required care	Occasionally handles equipment with required care	Often handles equipment with required care	Handles equipment with required care
Group Work ***Contributes*** in a group based lab work	Doesn't participate and contribute	Slightly participates and contributes	Somewhat participates and contributes	Moderately participates and contributes	Fully participates and contributes

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor’s Signature with Date:	

LAB SESSION 12

OBJECTIVES:

To examine the functioning of natural and flat sampling PAM modulator

EQUIPMENT REQUIRED:

- Module T20A
- Powers Supply
- Oscilloscope

PRE-LAB THEORY:

PAM:

A PAM signal is a sampling signal made up by a series of pulses whose amplitude is proportional to analog signal amplitude. Sampling can be of normal & flat type. Flat sampling results in distortion of reconstructed signal as τ pulse duration increases. This sampling is used in PCM system.

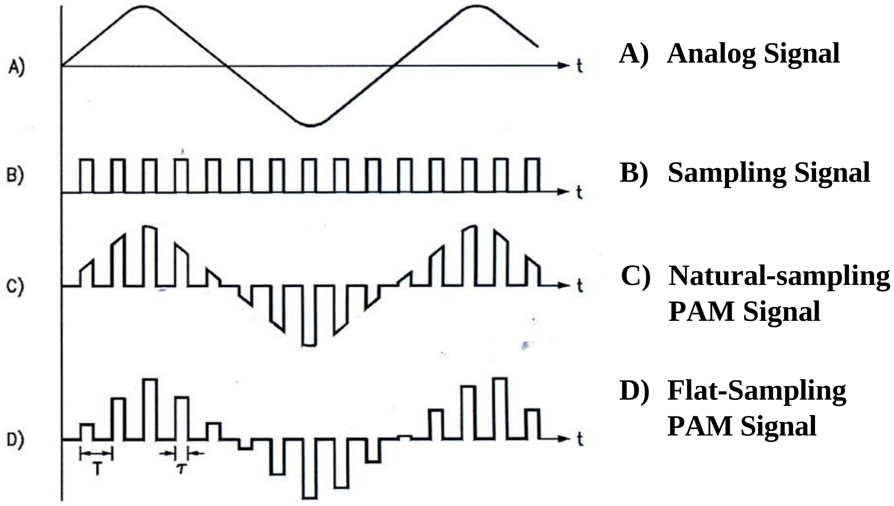


Figure 12.1 Natural & Flat Sampling PAM Signal

PAM modulator:

In Natural sampling block diagram mounted in model have an input analog signal that passes through a 3.5 kHz low pass filter which eliminates aliasing effect when sampling frequency is 8 or 12 kHz, then the signal goes to sampler. Sampling frequency in timing section can be selected at 4, 8, 12 kHz. Sampling pulse width is determined by pulse generator section.

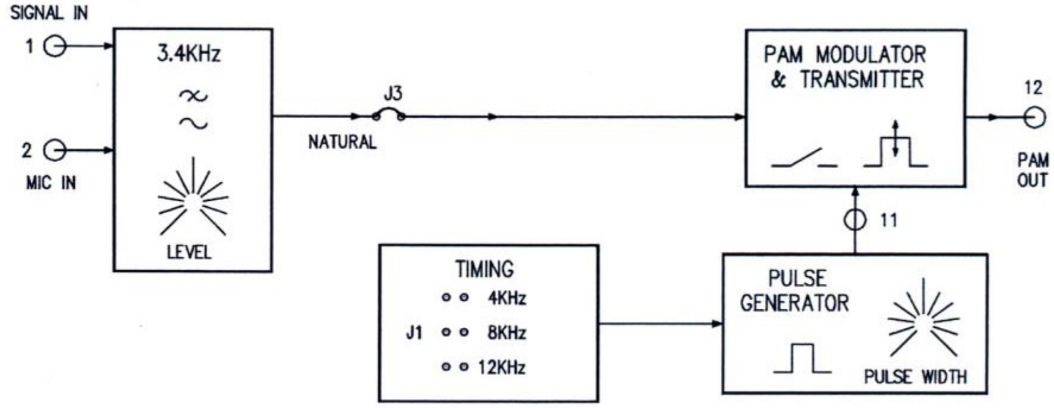


Figure 12.2 Natural-sampling PAM Modulator

In Flat sampling as compared with natural sampling modulator, a sample & hold circuit is added which fixes the output signal amplitude to keep it steady on the input value recorded in sampling. Sampler produces flat peak pulses whose width is proportional to analog signal width.

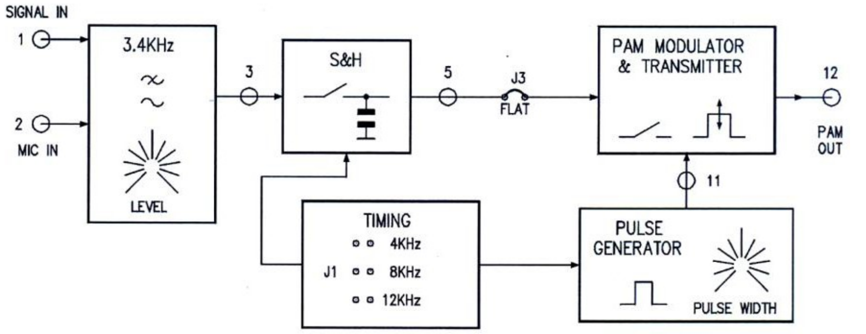
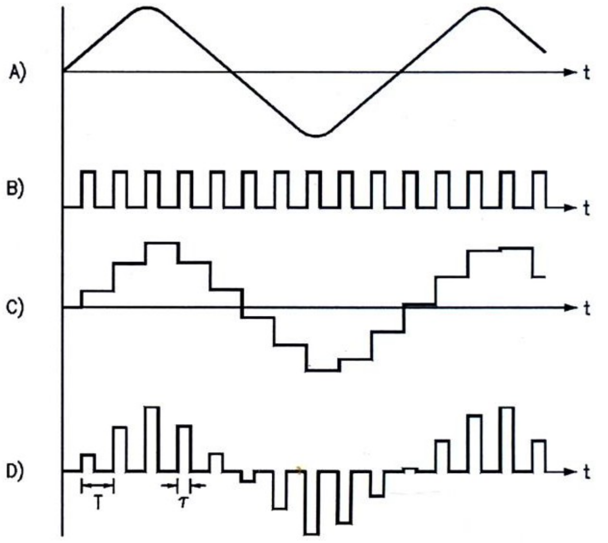


Figure 12.3 Flat-sampling PAM Modulator



A) Analog Signal

B) Sampling Signal

C) Sample & Hold Output

D) Flat-Sampling PAM Signal

Figure 12.4 Flat-sampling PAM Signal

PROCEDURE & OBSERVATIONS:

Natural sampling

1. Supply ±12V power & carryout following pre-settings:
   Timing: J1=8 kHz, j3= natural sampling, pulse generator: completely turn pulse width clockwise
2. Connect TP13 to TP3 and check input analog signal of 1kHz at TP13.

3. Check that PAM signal at TP12 is formed by train of pulses having amplitude that reflects analog signal waveform.

4. Connect oscilloscope to the output of pulse generator at TP11 and check that sampling pulses tally with PAM signal at TP12.
5. Change sampling pulse width & observe corresponding variation of PAM signal and write the result.

Flat sampling

1. Now short J3 = flat sampling w/o changing previous settings.
2. Examine again waveform of input signal TP13, sample & hold output signal TP5 & of S/H sampling pulses TP4.
3. Notice that signal is sampled at the beginning of sampling pulse & its amplitude is kept steady until next pulse. A step signal is obtained which approximates input analog signal.
4. Examine waveform at output of pulse generator at TP11 & output PAM signal TP12.
5. Notice that PAM pulse shows constant amplitude over their whole duration.

6. Change sampling pulse width & observe corresponding variation of PAM signal.

RESULT:

F/OBEM 01/04/00

NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: TC-307 (Communication Systems)

Laboratory Session No. 12 Date: ______________________

Psychomotor Domain Assessment Rubric-Level P2

Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment identification Sensory skill to ***identify*** equipment and/or its component for a lab work	Not able to identify the equipment	--	--	--	Able to identify equipment as well as its components
Equipment Use Sensory skills to ***demonstrate*** the use of the equipment for the lab work	Doesn't demonstrate the use of equipment	Slightly demonstrates the use of equipment	Somewhat demonstrates the use of equipment	Moderately demonstrates the use of equipment	Fully demonstrates the use of equipment
Procedural Skills ***Displays*** skills to act upon sequence of steps in lab work	Not able to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work	Able to fully understand lab work procedure and perform lab work
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Group Work ***Contributes*** in a group based lab work	Doesn't participate and contribute	Slightly participates and contributes	Somewhat participates and contributes	Moderately participates and contributes	Fully participates and contributes

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor’s Signature with Date	

LAB SESSION 13

Open Ended Lab

OBJECTIVES:

1. **Design and implement an AM modulator and demodulator using a breadboard/Veroboard.**
    - Circuit must be able to successfully transmit and receive a message
    - Use of modulator and demodulator IC is not allowed
    - The circuit must contain test points to visualize waveforms as seen in earlier lab sessions

2. **Prepare a lab report that must include but is not limited to following information:**
    - Introduction
    - Circuit diagram
    - Calculations for circuit design
    - Waveforms at different test points of circuit
    - Observations
    - Discussion

OUTCOMES:

After completion of this OEL, students must be able to comprehend:

- Basic theory of AM modulation and associated waveforms
- Design considerations and analysis for AM modulation circuit
- Effect of various electronic components on AM modulation
- Basic theory of AM demodulation and associated waveforms
- Design considerations and analysis for AM demodulation circuit
- Effect of various electronic components on AM demodulation

F/OBEM 01/18/00

NED University of Engineering & Technology
Department of Telecommunications Engineering
Course Code & Title: TC-307 Communication Systems
Assessment Rubric for OEL

Criterion	**Level of Attainment**				
	Below Average (0)	**Average (1)**	**Good (2)**	**Very Good (3)**	**Excellent (4)**
Problem understanding and analysis	Unable to understand the task completely	Can explain basic theory but unable to understand the task	Understands the problem fairly but unable to analyze it	Understands the problem completely and somewhat able to analyze it	Understands the problem completely and able to analyze it
Design Consideration	Unable to produce any circuit design	Has design of the circuit but with fundamental flaws	Has design of the circuit but unable to customize it according to the task	Has customized design of the circuit but unable to explain it	Has customized design of the circuit with complete understanding
Implementation	Unable to implement the circuit on breadboard/ Veroboard	Incomplete circuit is implemented which is not working	Half of the circuit is implemented which is working	Complete circuit is implemented but has minor issues in the resulting waveforms	Complete circuit is implemented producing the desired results
Presentation and Project understanding	Unable to present and explain the project completely	Slightly able explain and present the project	Somewhat able to explain and present the project	Moderately able to explain and present the project	Explains and presents the project completely
Project Report	Unable to submit the report	Report is submitted but is incomplete and does not follow the prescribed format	Report is submitted and somewhat follows the prescribed format with major portions missing	Report is submitted and somewhat follows the prescribed format with few portions missing	Complete report with proper format is submitted

Student's Name: ____ Roll No.: ____________

Total Score = ___________________________

Instructor's Signature: ____________________