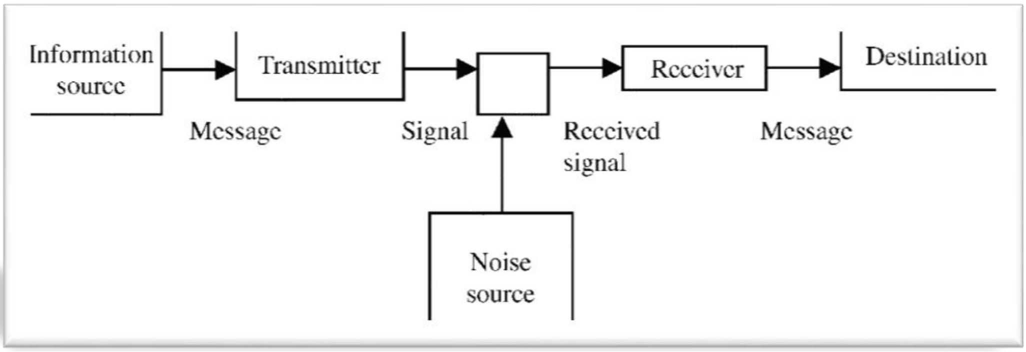
LAB Assignment No. 1:
INTRODUCTION TO BASIC ELEMENTS OF COMMUNICATION SYSTEM

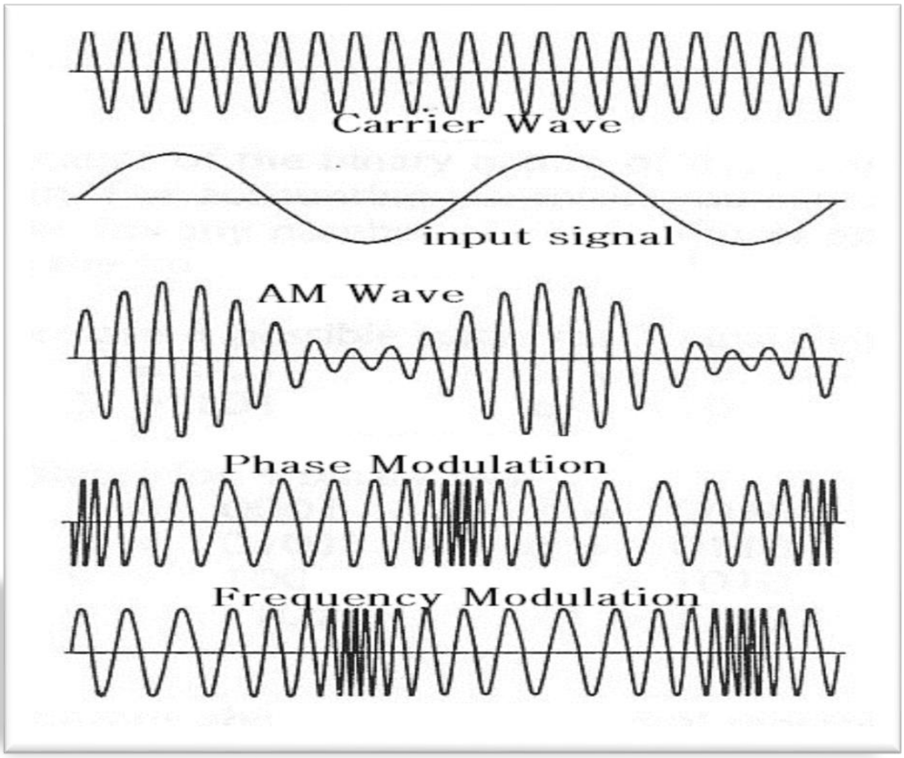
A communications system is a collection of individual communications networks usually capable of interconnection and interoperation to form an integrated whole.

In electronics and telecommunications, modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal which typically contains information to be transmitted.

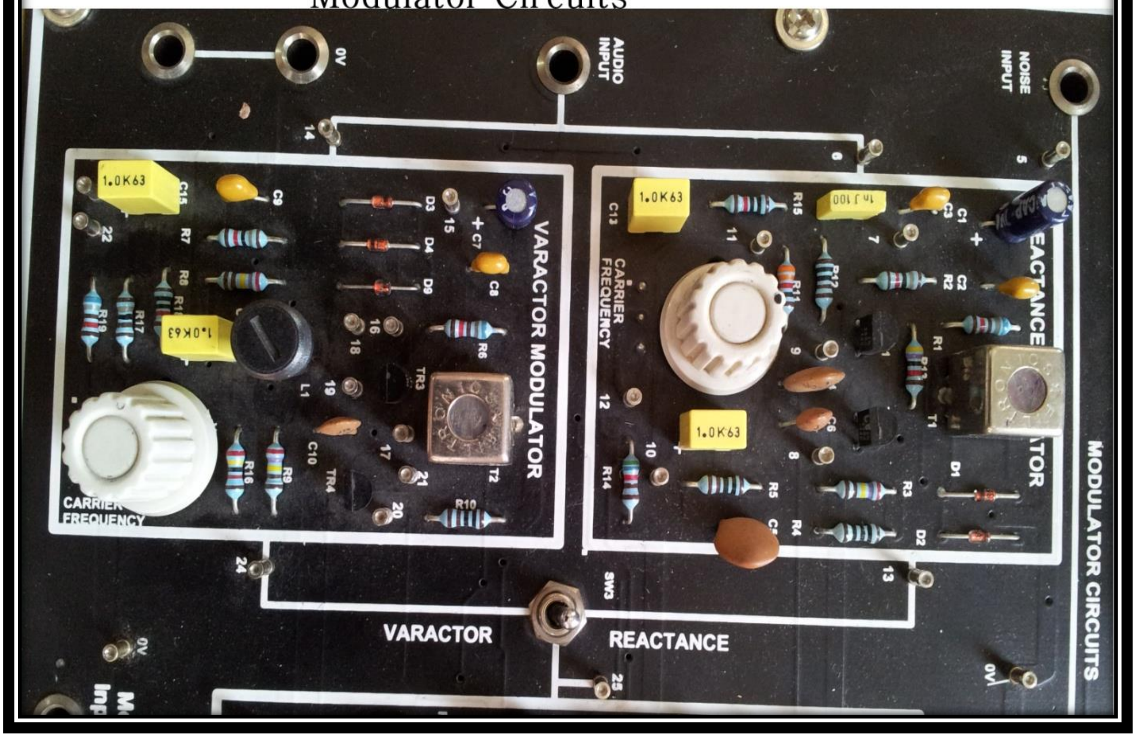


The three key parameters of a periodic waveform are its amplitude ("volume"), its phase ("timing") and its frequency ("pitch"). Any of these properties can be modified in accordance with a low frequency signal to obtain the modulated signal. Typically a high-frequency sinusoid waveform is used as carrier signal, but a square wave pulse train may also be used.

In radio communications, cable TV systems or the public switched telephone network for instance, electrical signals can only be transferred over a limited frequency spectrum, with specific non-zero lower and upper cutoff frequencies.



A device that performs modulation is known as a modulator and a device that performs the inverse operation of modulation is known as a demodulator sometimes detector or demod. A device that can do both operations is a modem. “Mo” from modulator and “Dem” from demodulator.



Modulator Circuits

The aim of digital modulation is to transfer a digital bit stream over an analog bandpass channel, for example over the public switched telephone network where a bandpass filter limits the frequency range to between 300 and 3400 Hz, or over a limited radio frequency band.

The aim of analog modulation is to transfer an analog baseband or lowpass signal, for example an audio signal or TV signal, over an analog bandpass channel at a different frequency, for example over a limited radio frequency band or a cable TV network channel.

In telecommunications and signal processing, frequency modulation (FM) conveys information over a carrier wave by varying its instantaneous frequency. This contrasts with amplitude modulation, in which the amplitude of the carrier is varied while its frequency remains constant.

In analog applications, the difference between the instantaneous and the base frequency of the carrier is directly proportional to the instantaneous value of the input-signal amplitude. Digital data can be sent by shifting the carrier's frequency among a range of settings, a technique known as frequency-shift keying (FSK).

Frequency modulation is known as phase modulation when the carrier phase modulation is the time integral of the FM signal. FM is widely used for broadcasting music and speech, two-way radio systems, magnetic tape-recording systems and some video-transmission systems. In radio systems, frequency modulation with sufficient bandwidth provides an advantage in cancelling naturally-occurring noise.

Advantages of modulation are the ease of radiation of electromagnetic energy allowing antenna sizes to be reasonable and simultaneous transmission of several signals over the same channel.

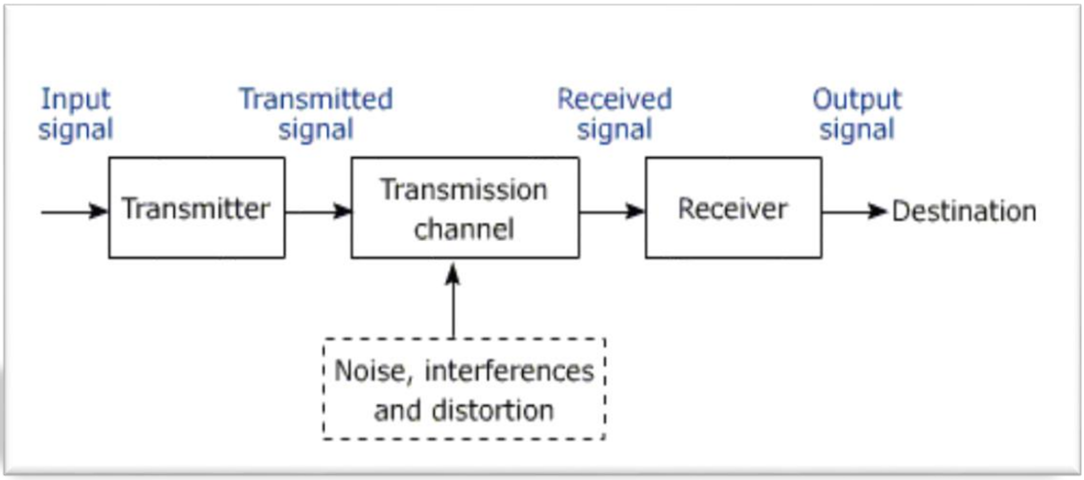
Communicating data from one location to another requires some form of pathway or medium. These pathways, called communication channels.

In telecommunications and computer networking, a communication channel, or channel, refers either to a physical transmission medium such as a wire, or to a logical connection over a multiplexed medium such as a radio channel.

Two types of media: cable i.e. twisted-pair wire, cable, and fiber-optic cable; and broadcast i.e. microwave, satellite, radio, and infrared are used as a channel.

Cable or wire line media use physical wires of cables to transmit data and information. Twisted-pair wire and coaxial cables are made of copper, and fiber-optic cable is made of glass.

A channel is used to convey an information signal, for example a digital bit stream, from one or several senders or transmitters to one or several receivers. A channel has a certain capacity for transmitting information, often measured by its bandwidth in Hz or its data rate in bits per second.



LAB Assignment No. 2:

TO STUDY THE FREQUENCY MODULATION BY USING VARACTOR MODULATOR

APPARATUS:

Oscilloscope Trainer

Power supply Connecting leads

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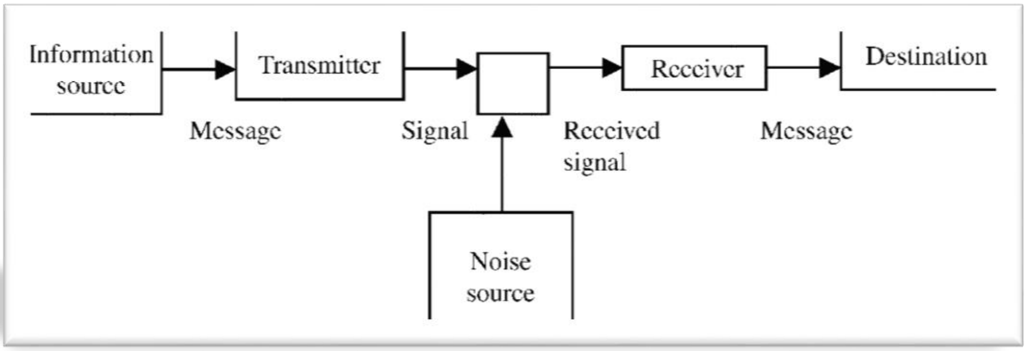

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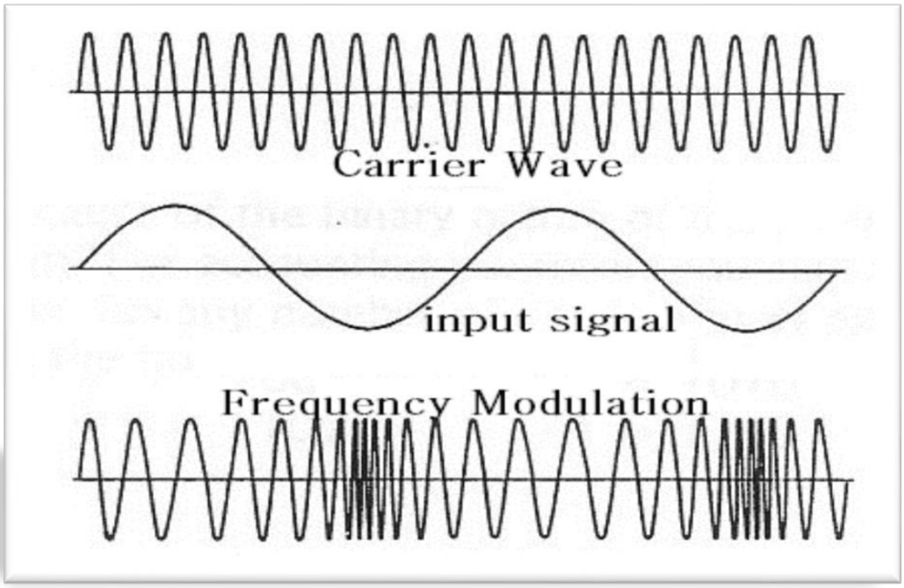

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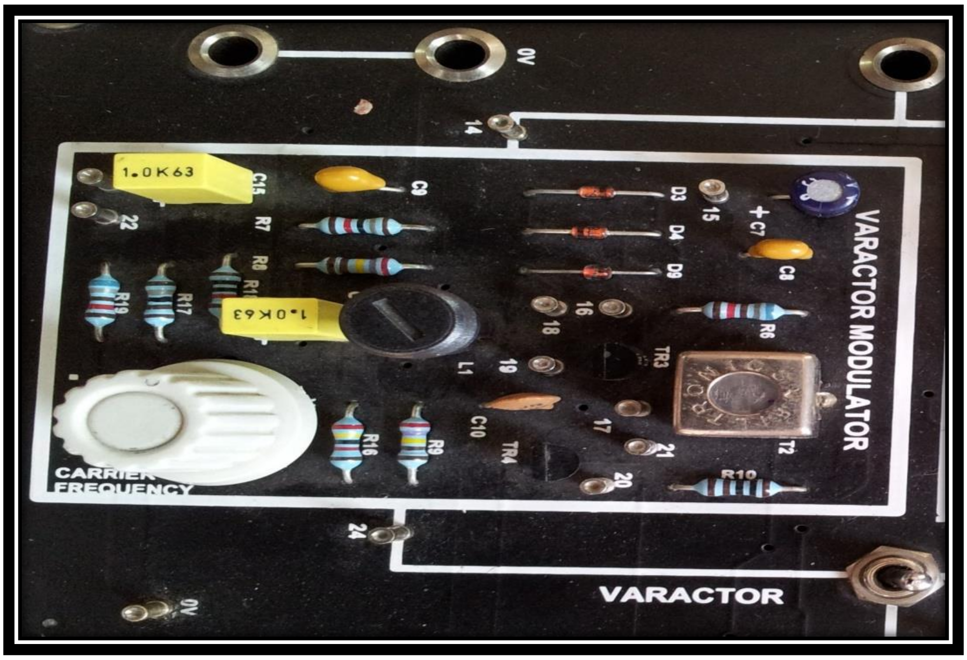
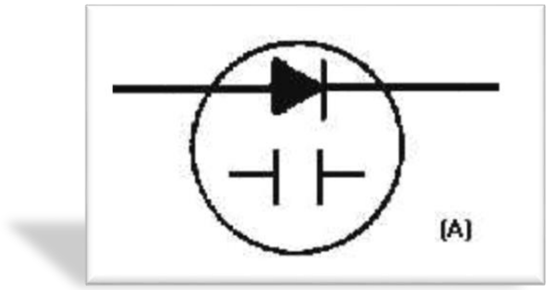
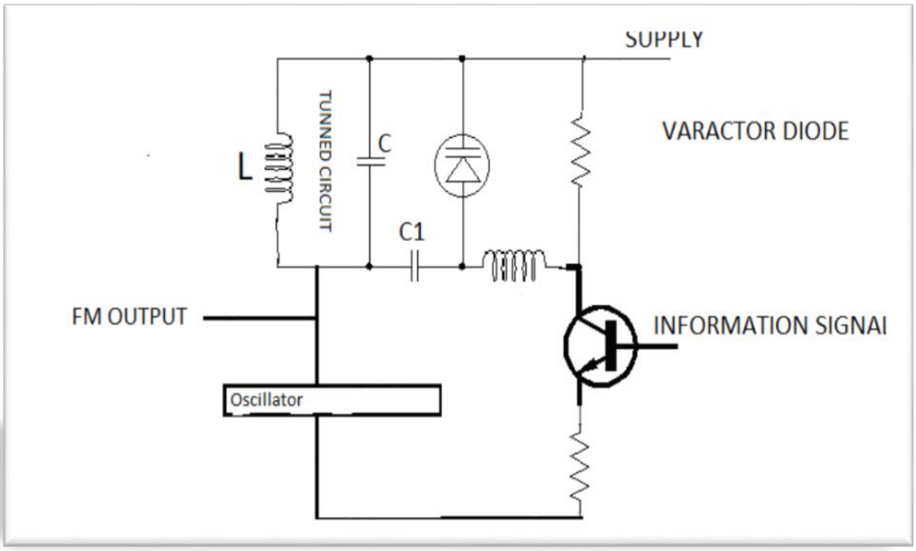
The varactor is simply a diode, or pn junction, that is designed to have a certain amount of capacitance between junctions.



Varactors are operated in a reverse-biased state. No current flows, but since the thickness of the depletion zone varies with the applied bias voltage, the capacitance of the diode can be made to vary. Generally, the depletion region thickness is proportional to the square root of the applied voltage; capacitance is inversely proportional to the depletion region thickness. Thus, the capacitance is inversely proportional to the square root of applied voltage.

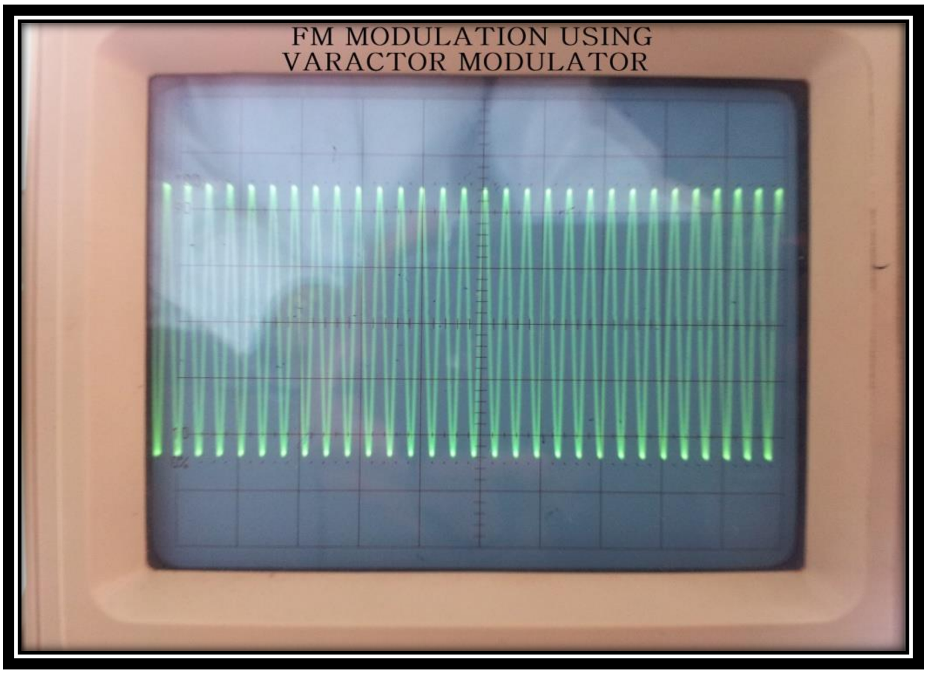


All diodes exhibit this phenomenon to some degree, but varactor diodes are manufactured specifically to exploit this effect and increase the capacitance and thus the range of variability, whereas most ordinary diode fabrication strives to minimize the capacitance.



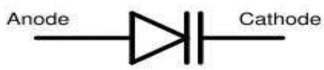
Generally the use of a varicap diode in a circuit requires connecting it to a tuned circuit, usually in parallel with any existing capacitance or inductance. Because a DC voltage must be applied reverse bias across the varicap to alter its capacitance, this must be blocked from entering the tuned circuit. This is accomplished by placing a DC blocking capacitor with a capacitance about 100 times greater than the maximum capacitance of the varicap diode in series with it and applying the DC from a high impedance source to the node between the varicap cathode and the blocking capacitor.

The capacitance of a varactor, as with regular capacitors, is determined by the area of the capacitor plates and the distance between the plates. The depletion region in the varactor is the dielectric and is located between the p and n elements, which serve as the plates. Capacitance is varied in the varactor by varying the reverse bias which controls the thickness of the depletion region. The varactor is so designed that the change in capacitance is linear with the change in the applied voltage. This is a special design characteristic of the varactor diode. The varactor must not be forward biased because it cannot tolerate much current flow. Proper circuit design prevents the application of forward bias.



What is varactor diode? Explain its operation n characteristics? How it helps to work as a V/F convertor for FM generation.

Varactor diodes, also called varicaps, are semiconductor devices that behave like variable capacitors. When reverse-biased, they have a capacitance that varies with an applied voltage. They are most often used in devices that require electronic tuning, such as radios.



The capacitance of a varactor decreases when the reverse-voltage gets larger. They are usually placed in parallel with an inductor in order to form a resonant frequency circuit. When the reverse voltage changes, so does the resonant frequency, which is why varactors may be substituted for mechanically tuned capacitors.

Varactor diodes are commonly found in communication equipment where electronic tuning is a necessity. They are an important component of radio frequency or RF applications.

What are advantages and disadvantages of FM?

ADVANTAGES:-

1. The amplitude of FM wave remains constant. This makes FM more immune to noise due to variations in amplitude of FM waveform which can be eliminated in FM receivers by amplitude limiters
2. Improved signal to noise ratio (about 25dB).
3. Less radiated power.
4. Well defined service areas for given transmitter power.

DISADVANTAGES:-

1. Much more Bandwidth as much as 20 times as much.
2. More complicated receiver and transmitter.

What is meant by capture effect? how does it help FM signal to have better reception?

The capture effect is a phenomenon associated with FM reception in which only the stronger of two signals at, or near, the same frequency will be demodulated. The capture effect is defined as the complete suppression of the weaker signal at the receiver limiter if it has one where the weaker signal is not amplified, but attenuated. When both signals are nearly equal in strength, or are fading independently, the receiver may switch from one to the other and exhibit picket fencing.

What is frequency deviation?

The variation of carrier frequency is known as the frequency deviation and for very-high-frequency broadcasting it can reach ± 75 kilohertz. The greater the frequency deviation the greater is the effective modulation. Though theoretically its maximum value need not be limited to 75 kilohertz, any increase beyond this value requires a wider channel, which adds to the cost of reception.

What is VCO and its purpose on the FM trainer in the lab?

The variation of carrier frequency is known as the frequency deviation**,** and for very-high-frequency broadcasting it can reach ± 75 kilohertz. The greater the **frequency deviation** the greater is the effective modulation. Though theoretically its maximum value need not be limited to 75 kilohertz, any increase beyond this value requires a wider channel, which adds to the cost of reception.

A voltage-controlled oscillator or VCO is an electronic oscillator designed to be controlled in oscillation frequency by a voltage input. The frequency of oscillation is varied by the applied DC voltage, while modulating signals may also be fed into the VCO to cause frequency modulation (FM).

Is FM better to overcome small interfaces as compared to AM? How?

FM is better to overcome small interferences as compared to AM because in FM smaller geographical interference are between neighboring stations, So lesser distortion. Frequency modulated wave is less susceptible to intereferences from buildings, traffic etc which provides improved signal to noise ratio (about 25dB) w.r.t. to man made interference. Waves at higher frequencies can carry more data than the waves at low frequency. Well defined service areas for given transmitter power. On the other hand Signal of AM is not stronger than FM when it propagate to obstacle only one sideband of AM transmits Information Signal, So it loss power on other sideband and Carrier. Noise mixes AM Signal in amplitude when it propagates in free space that it make difficult to recover Original Signal at receiver.

Define pre emphasis and de emphasis in FM?

In processing electronic audio signals, **pre-emphasis** refers to a system process designed to increase (within a frequency band) the magnitude of some (usually higher) frequencies with respect to the magnitude of other (usually lower) frequencies in order to improve the overall signal-to-noise ratio by minimizing the adverse effects of such phenomena as attenuation distortion or saturation of recording media in subsequent parts of the system.

In telecommunication, de-emphasis is the complement of pre-emphasis, in the anti noise system called emphasis. Emphasis is a system process designed to decrease, (within a band of frequencies), the magnitude of some (usually higher) frequencies with respect to the magnitude of other (usually lower) frequencies in order to improve the overall signal-to-noise ratio by minimizing the adverse effects of such phenomena as attenuation differences or saturation of recording media in subsequent parts of the system.

Can PDE be used in AM for signal quality improvement or nor? Explain shortly?

We could use PDE in AM broadcasting to improve the output SNR but in practice, however this is not done for several reasons.

1. Firstly the output noise amplitude in FM is constant with frequency and does not change linearly as in FM. Hence de-emphasis does not yield such a dramatic improvement in AM.
2. Secondly introduction of PDE would necessitate modifications in receiver already in use.
3. Third, increasing high frequency component amplitudes (pre-emphasis) would increase interferences with adjacent stations. Moreover an increase in deviation ratio at high frequencies would make detector design more difficult.

LAB Assignment No. 3:

TO STUDY THE FREQUENCY MODULATION BY USING REACTANCE MODULATOR

APPARATUS:

Oscilloscope Trainer

Power supply Connecting leads

THEORY:

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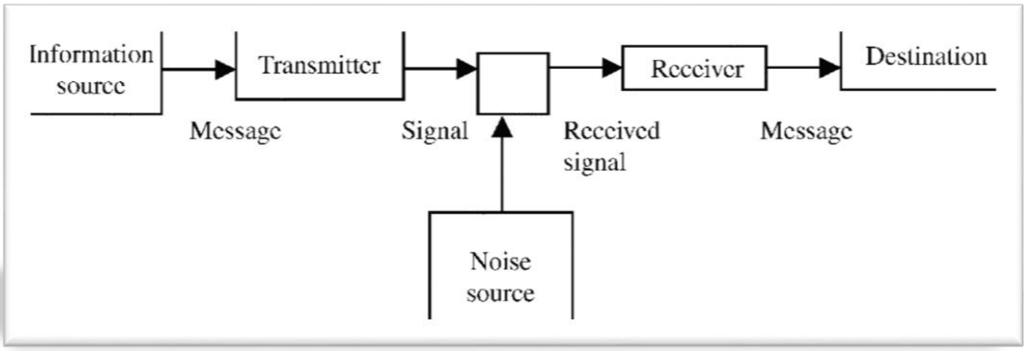

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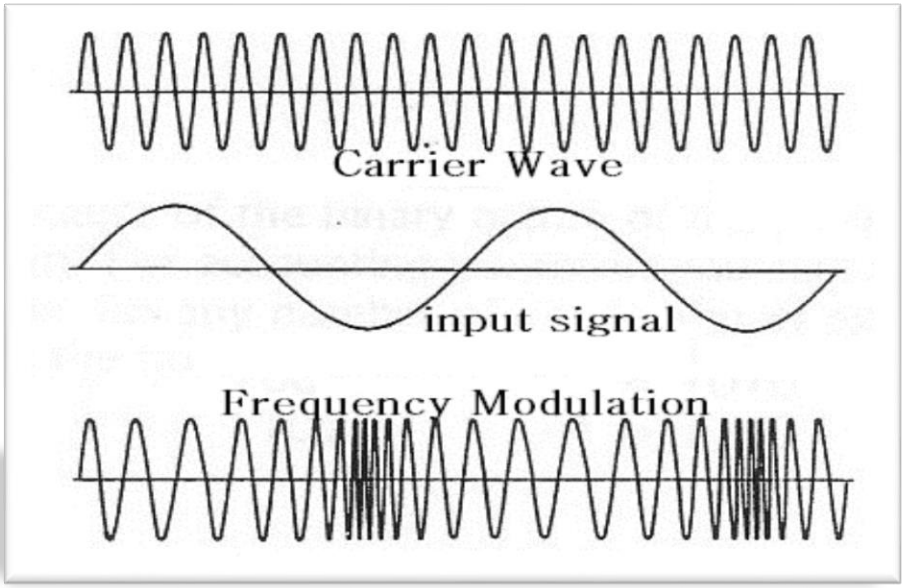

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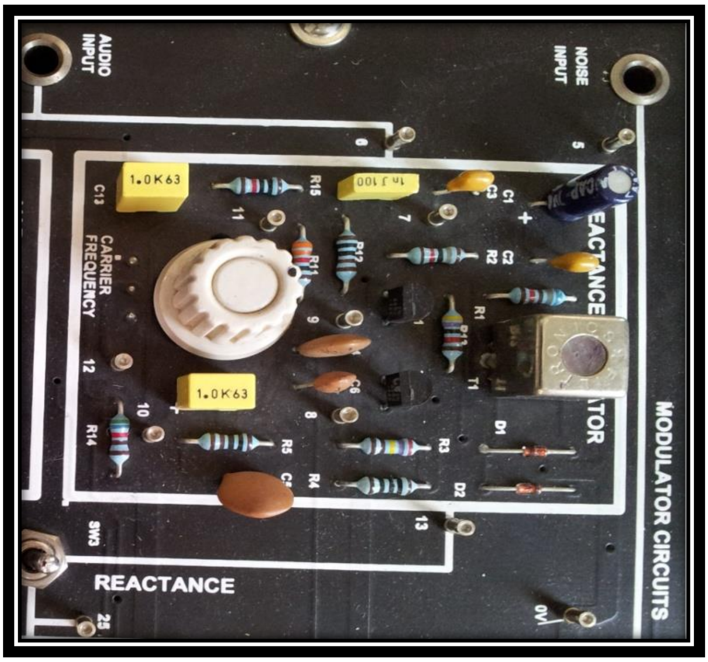
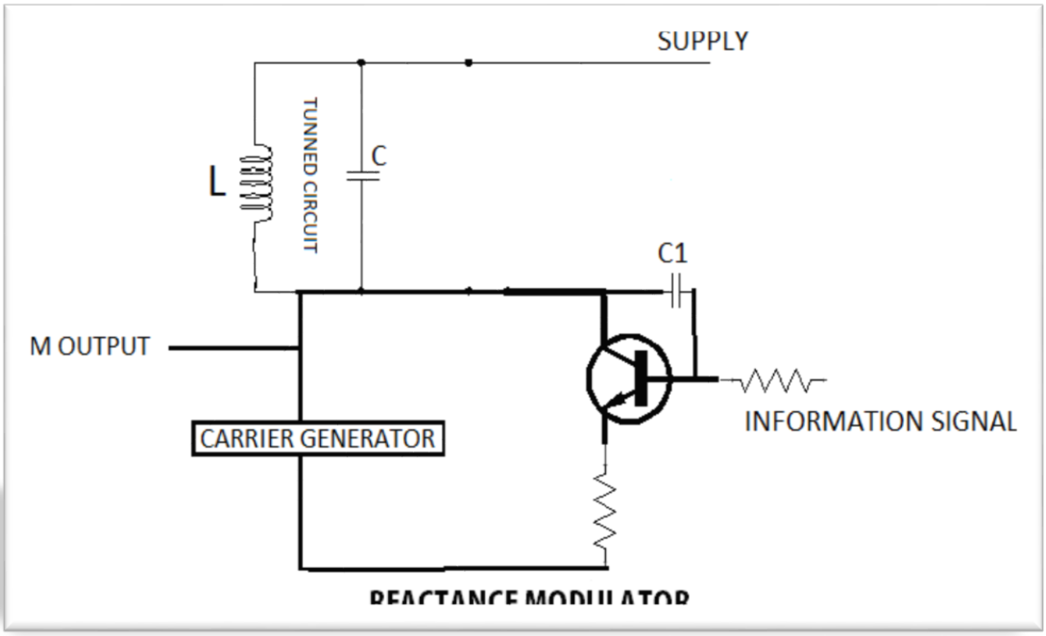
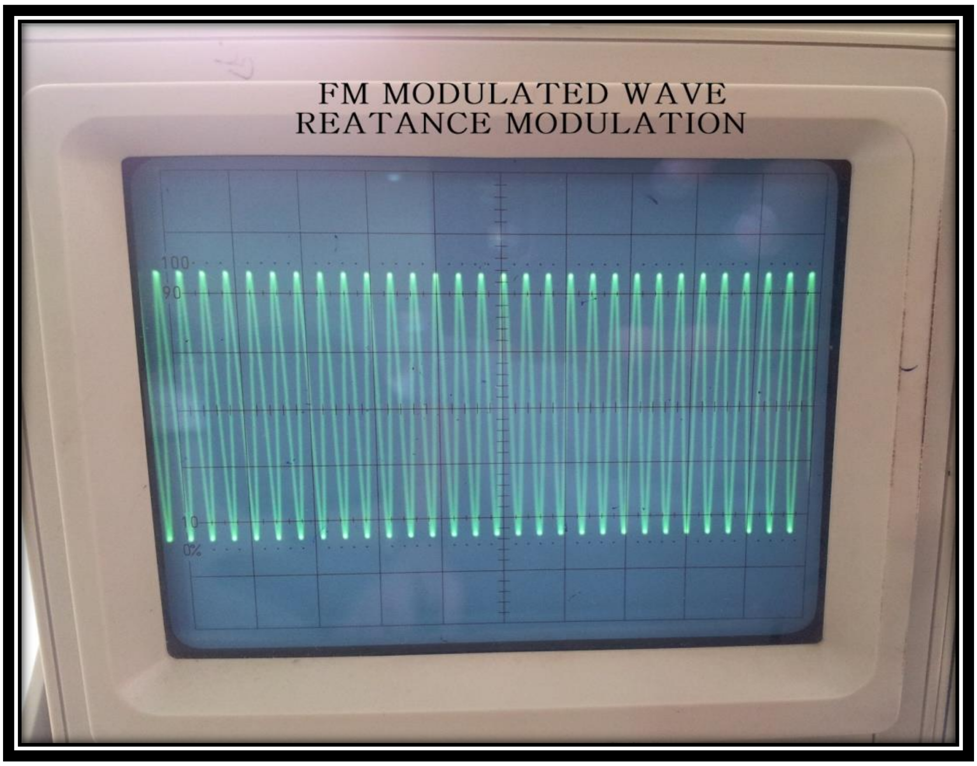
The reactance modulator is a very popular means of FM generation. The reactance modulator is an amplifier designed so that its input impedance has a reactance that varies as a function of the amplitude of the applied input voltage-modulating signal.



A reactance modulator changes the frequency of the tank circuit of the oscillator by changing its reactance. This is accomplished by a combination of a resistor, a condenser, and a vacuum tube the modulator connected across the tank circuit of the oscillator, and so adjusted as to act as a variable inductance or capacitance.



The information signal is applied at the base of transistor through a resistor. The capacitor is also attached to it. The capacitor and resistor provides 90 phase shift between the oscillator voltage and current. The change in information signal change the value of this capacitance. The change in capacitance causes to change the frequency of carries signal.



How many methods exist for generation of FM signal? How do they differ from each other?

There are two methods:

1. DIRECT FM GENERATION.
2. INDIRECT FM GENERATION.

DIRECT FM GENERATION:

The simplest method for generating FM directly is to vary the frequency of an oscillator. A capacitance microphone or a varactor diode may be used as part of the oscillator’s frequency determining network. The capacitor microphone’s capacitance varies in response to the intensity of the sound waves striking it, making the oscillator’s frequency vary as the amplitude of the sound varies. The varactor diode's capacitance depends on the voltage across it. Audio signals placed across the diode cause its capacitance to change, which in turn, causes the frequency of the oscillator to vary.

Indirect FM:

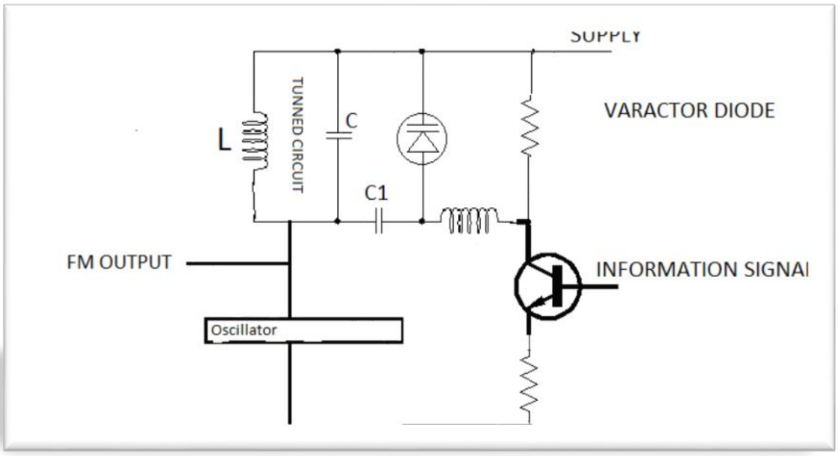
While it is not possible to vary the frequency of a crystal oscillator directly, it is possible to vary its phase. The resulting PM signal can be used to create FM. An audio signal is passed through a pre emphasis network and then an integrator, a special network whose output is the time integral of the input signal. The pre emphasized integrated signal is used to phase modulate a crystal oscillator. Mathematically, it can be shown that PM using the integral of the audio signal is identical to FM using the audio signal itself. In this way an FM signal is generated.An FM station is authorized to operate at 90.9 MHz, with maximum deviation of 75 KHz. The FM signal is generated with an Armstrong modulator whose output is 500 KHz with a deviation of 15.432 Hz. The modulator output is applied to 3 triplers and a doubler to obtain a frequency of 81 MHz and a deviation of 2.5 KHz. The 81 MHz signal is mixed with a 77.97 MHz signal to produce a 3.03 MHz signal whose deviation is still 2.5 KHz. This signal is fed through a doubler, tripler and quintupler to multiply the carrier to 90.9 MHz and the deviation to 75 KHz.

What is the range of FM commercially used for communication?

A frequency range of 88khz to108mhz for FM broadcasting, with a separation of 200khz between adjacent stations and a peak frequency deviation of 75khz.

Explain the operation of reactance modulator?

A reactance modulator changes the frequency of the tank circuit of the oscillator by changing its reactance. This is accomplished by a combination of a resistor, a condenser, and a vacuum tube (the modulator) connected across the tank circuit of the oscillator and so adjusted as to act as a variable inductance or capacitance. The net result is to change the resonant frequency of the LC circuit.



Which method is used commercially for FM generation and what are its merits and demerits?

Advantages:

Relatively high-frequency deviations and modulation indices are easily obtained because the oscillator are inherently unstable.

1. It gives noiseless reception.
2. The operating range is quite large.
3. It gives high fidelity reception.
4. The efficiency of transmission is very large.

Disadvantages:

Relatively unstable LC oscillators must be used to produce the carrier frequency which prohibits using crystal oscillators. Requires the addition of some form of automatic frequency control circuitry to maintain the carrier frequency.

1. Requires more complicated demodulator

2. Sidebands extend to infinity either side: The sidebands for an FM transmission theoretically extend out to infinity. To limit the bandwidth of the transmission, filters are used, and these introduce some distortion of the signal.

Write advantages of FM over AM.?

ADVATNAGES:

1. Lesser distortion. Frequency modulated wave is less susceptible to intereferences from buildings, traffic etc which provides improved signal to noise ratio (about 25dB) w.r.t. to man made interference.
2. Waves at higher frequencies can carry more data than the waves at low frequency.
3. Smaller geographical interference between neighboring stations.
4. Less radiated power.
5. Well defined service areas for given transmitter power.

DISADVANTAGE:

1. Since attenuation is directly proportional to frequency, so FM suffers more attenuation than AM signal.
2. FM signals propagate as line-of-sight phenomenon, so if there is a large hill between transmitter and receiver, the receiver will not receive any signal. AM signals, on the other hand, are at low frequencies which are

reflected back by ionospehere and thus, using sky-wave-propagation phenomenon, can travel farther distances. FM waves penetrate ionosphere and are not refracted back.

3. Complicated receiver and transmitter.
4. Much more Bandwidth (as much as 20 times as much).

Search for other uses of FM apart from commercial communication.

FM is used at audio frequencies to synthesize sound. This technique, known as FM synthesis, was popularized by early digital synthesizers and became a standard feature for several generations of personal computer sound cards.

MAGNETIC TAPE STORAGE

FM is also used at intermediate frequencies by all analog VCR systems, including VHS, to record both the luminance (black and white) and the chrominance portions of the video signal. FM is the only feasible method of recording video to and retrieving video from Magnetic tape without extreme distortion,

Can exchange of Bandwidth with SNR be possible with AM or FM, and upto which extent?

It is possible to exchange SNR with the bandwidth of transmission. FM or AM effects such an exchange. The amount of modulation controls the exchange of SNR and the transmission bandwith.

SNR = Sp (signal power) / Np (noise power)

As a high frequency signal has more no. of bits per sample of the signal, it requires large bandwidth to transmit that signal.so, above relationship shows that a high value of SNR has high power signal, which has high frequency also and it takes more bandwidth.

LAB Assignment No. 4:

TO STUDY THE OPERATION OF DEMODULATION OF FM SIGNAL BY USING QUADRATURE DETECTOR

APPARATUS:

Oscilloscope Trainer

Power supply Connecting leads

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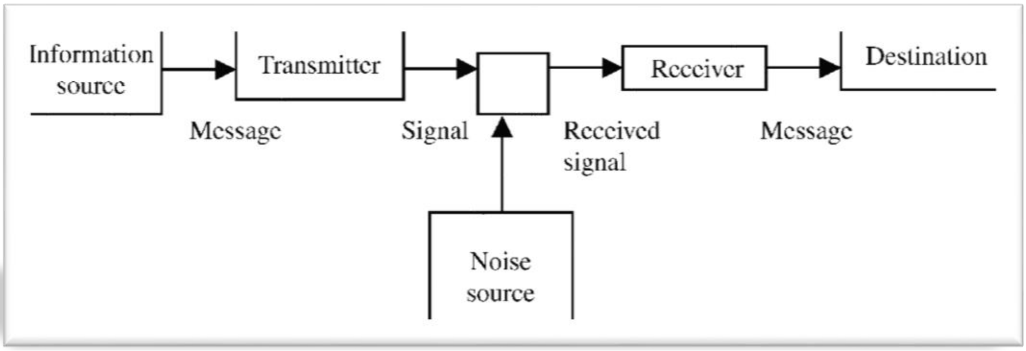

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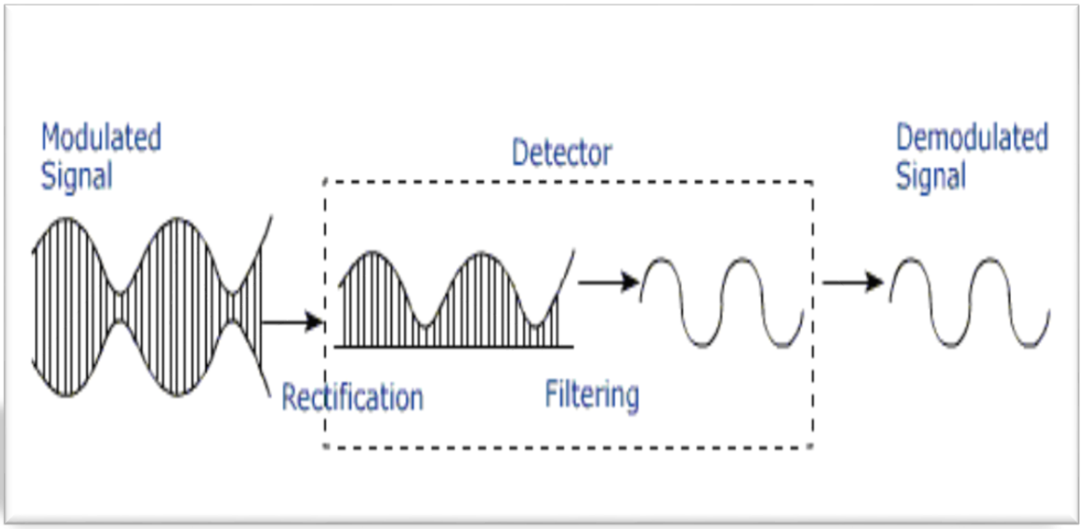
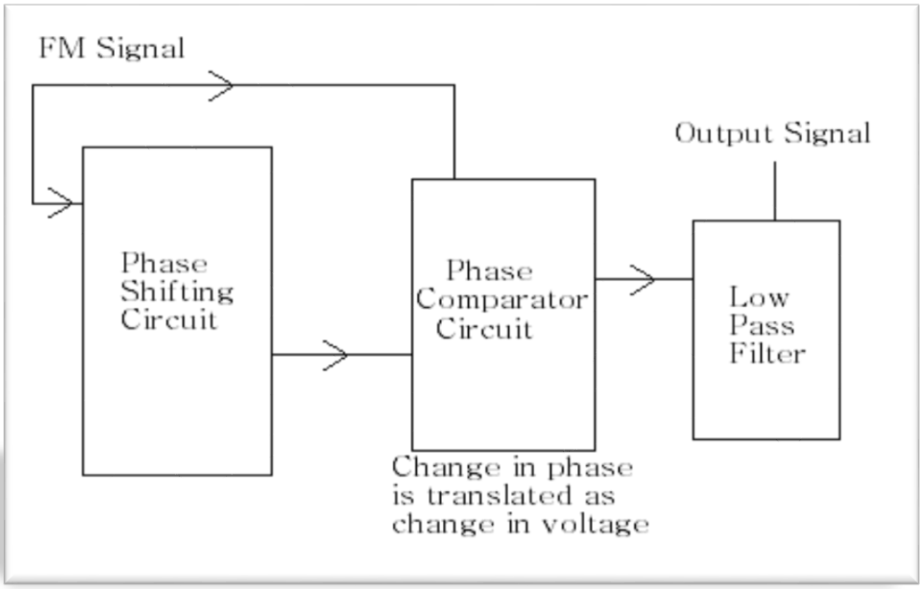
There are several ways of demodulation depending on how parameters of the base-band signal are transmitted in the carrier signal, such as amplitude, frequency or phase. For example, for a signal modulated with a linear modulation, like AM (Amplitude Modulation), we can use a synchronous detector. On the other hand, for a signal modulated with an angular modulation, we must use an FM (Frequency Modulation) demodulator or a PM (Phase Modulation) demodulator.



Demodulation is the act of extracting the original information-bearing signal from a modulated carrier wave. A demodulator is an electronic circuit or computer program in a software-defined radio that is used to recover the information content from the modulated carrier wave.

In an FM signal, the modulation is the deviation of a carrier from its nominal frequency. The conventional method to demodulate this signal is to convert frequency deviation to phase and detect the change of phase.

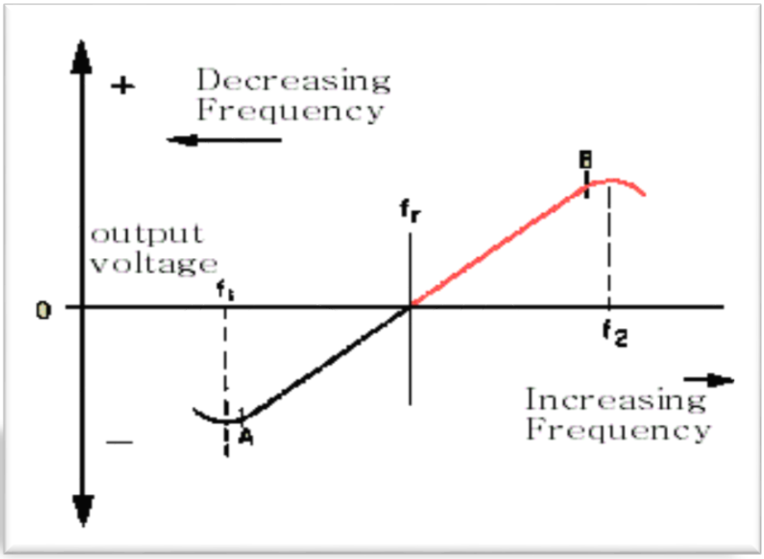


Rules for the degree of phase shift:

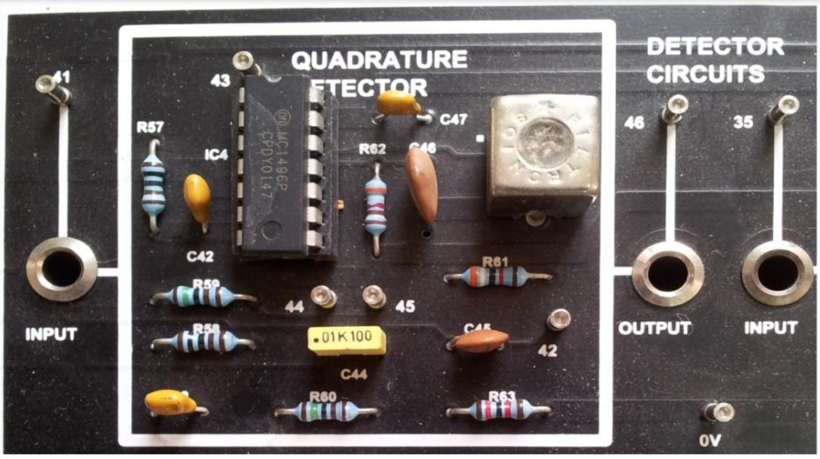
1. If the carrier is un-modulated, phase shift is 90^0.
2. If the carrier increases in frequency, phase shift is less than90^0.
3. If the carrier decreases in frequency, phase shift is greater than90^0.

Rules for phase comparator circuit:

1. If phase shift is 90^0, No change in output voltage.
2. Phase shift less than 90^0, results in increase in voltage level.
3. Phase shift greater than 90^0, results in decrease in voltage level.



A quadrature demodulator for FM signals consists out of two parts; A frequency dependent phase shift network and a phase detector. Two signals are considered to be in phase quadrature when their phase difference is exactly 90°.



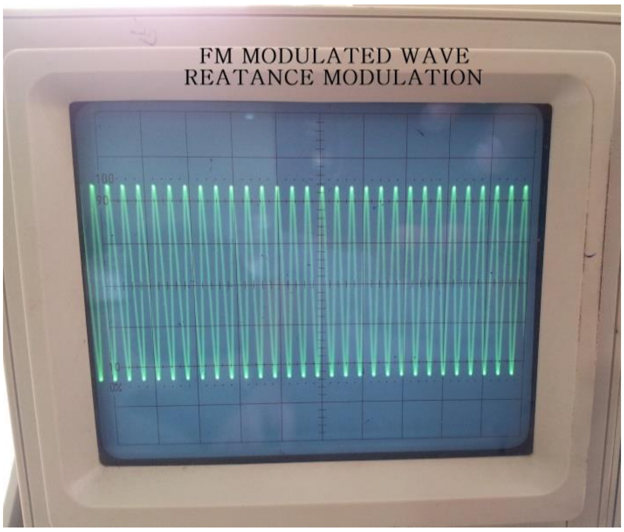
Quadrature Detector

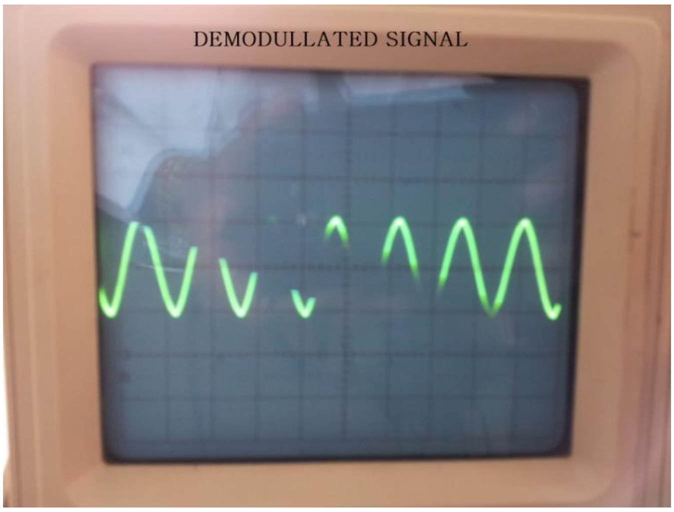
A quadrature detector splits the signal, that is to be demodulated, up into two signals. The first signal remains unchanged and is applied to the input of a phase detector. The second signals is passed through a capacitor. The capacitor will create a 90° phase shift. The phase shifted signal is then applied to a frequency dependent phase shifter, a LC tank circuit. If the LC tank circuits center frequency equals the signals frequency, it imposes a further phase shift of 0° on the signal. Therefore the overall phase difference will remain 90°.

If the signals frequency does vary from the LC circuits center frequency, the LC tank will further shift the phase of the signal from the capacitor, so that the signal's total phase shift will be the sum of the 90° shift, that's imposed by the capacitor, and the additional positive or negative phase change that is imposed by the LC tank circuit. If the frequency increases, the phase shift of the LC circuit decreases and vice versa. Therefore, the overall phase difference decreases as the frequency increases and vice versa.

Low Pass Filter

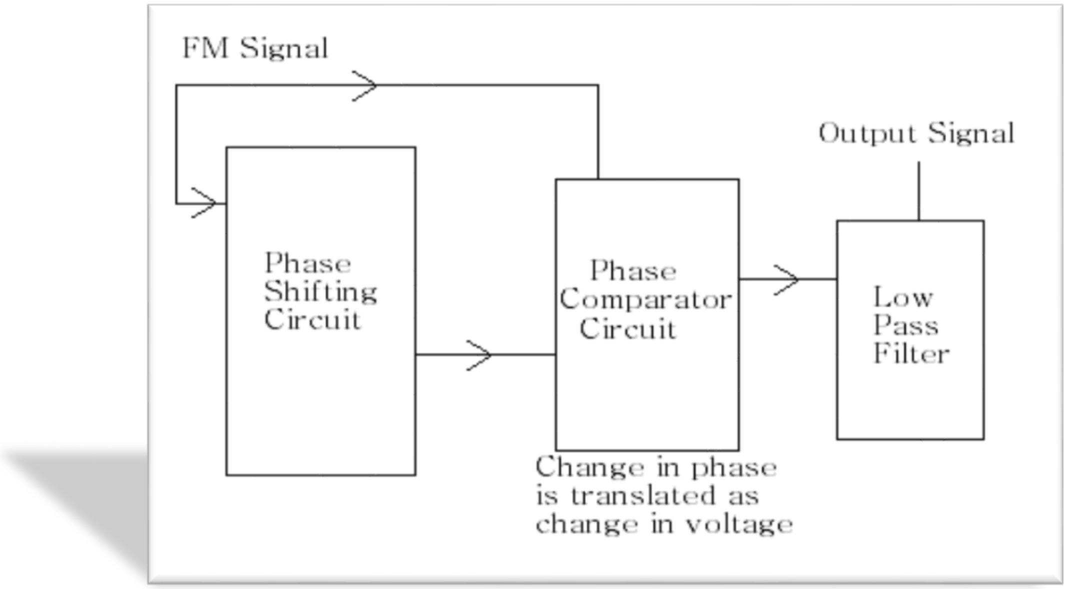
If the the original signal and the phase shifted signal are applied to the input of a phase detector, the modulation signal can be recovered easily.





Explain the operation of quadrature demodulator with the help of block diagram and circuit.

The method of FM demodulation for integrated circuits is quadrature demodulator that uses a phase shift network and a phase detector. The phase detector compares the phase of the IF signal (v1) to v2, the signal generated by passing v1 through a phase shift network. This phase shift network includes an LC tank (L, Rp, and Cp) and a series reactance (Cs). The network gives a frequency-sensitive 90° phase shift at the center frequency. The output of the multiplier (Io) is filtered, which results in a DC level that changes as the input frequency changes.



What is difference between phase modulation and frequency modulation? How can you generate a PM wave through FM and a FM wave through PM?

In telecommunications and signal processing, frequency modulation (FM) conveys information over a carrier wave by varying its instantaneous frequency. This contrasts with amplitude modulation, in which the amplitude of the carrier is varied while its frequency remains constant.

In analog applications, the difference between the instantaneous and the base frequency of the carrier is directly proportional to the instantaneous value of the input-signal amplitude. Phase modulation (PM) is a form of modulation that represents information as variations in the instantaneous phase of a carrier wave. Modification in phase according to low frequency will give phase modulation.

The reason PM is better is because in PM and FM there can be non-zero energy produced at 0 Hz, which in FM will produce a shift in pitch if the FM wave is used again as a modulator, however in PM the DC component will only produce a phase shift. Another reason PM is better is that the modulation index (which determines the number of sidebands produced and which in normal FM is calculated as the modulator amplitude divided by frequency of modulator) is not dependent on the frequency of the modulator; it is always equal to the amplitude of the modulator in radians.

What is a Hard Limiter Circuit? Why used in F.M.?

Hard limiting ("clipping") is a limiting action in which there is

(a) Over the permitted dynamic range, negligible variation in the expected characteristic of the output signal, and

(b) A steady-state signal, at the maximum permitted level, for the duration of each period when the output would otherwise be required to exceed the permitted dynamic range in order to correspond to the transfer function of the device.

What is a filter also explain the function of the LPF as the last stage of FM receiver?

A digital filter is just a filter that operates on digital signals, such as sound represented inside a computer. It is a computation which takes one sequence of numbers (the input signal) and produces a new sequence of numbers (the filtered output signal). It is important to realize that a digital filter can do anything that a real-world filter can do. That is, all the filters alluded to above can be simulated to an arbitrary degree of precision digitally. Thus, a digital filter is only a formula for going from one digital signal to another. It may exist as an equation on paper.

What is a phase comparator and how it helps to demodulate FM wave in the trainer circuit?

A comparator that accepts two radio-frequency input signals of the same frequency and provides two video outputs which are proportional, respectively, to the sine and cosine of the phase difference between the two inputs. A phase detector is a frequency mixer or analog multiplier circuit that generates a voltage signal which represents the difference in phase between two signal inputs. It is an essential element of the phase-locked loop (PLL). Detecting phase differences is very important in many applications, such as motor control, radar and telecommunicationsystems, servo mechanisms, and demodulators. A circuit, a charge pump, or a logic circuit consisting of flip-flops. When a phase detector that's based on logic gates is used in a PLL, it can quickly force the VCO to synchronize with an input signal, even when the frequency of the input signal differs substantially from the initial frequency of the VCO. Such phase detectors also have other desirable properties, such as better accuracy when there are only small phase differences between the two signals being compared.

Transmission and Reception Area for FM is small, Comment with reasons?

The primary path of the space wave is directly from the transmitting antenna to the receiving antenna. So, the receiving antenna must be located within the radio horizon of the transmitting antenna. Although space waves suffer little ground attenuation, they nevertheless are susceptible to fading.

This is because space waves actually follow two paths of different lengths (direct path and ground-reflected path) to the receiving site and, therefore, may arrive in or out of phase. If these two component waves are received in phase, the result is a reinforced or stronger signal. Alternately, if they are received out of phase, they tend to cancel one another, which results in a weak or fading signal. The process of communication involves the transmission of information from one location to another.It is only the characteristics of the carrier wave which determine how the signal will propagate over any significant distance.

What is meant by Space waves and Ground reflected waves, which mode of transmission media is used by them?

Radio waves in the VLF band propagate in a ground, or surface wave. The wave is connected at one end to the surface of the earth and to the ionosphere at the other. The ionosphere is the region above the troposphere (where the air is), from about 50 to 250 miles above the earth. It is a collection of ions, which are atoms that have some of their electrons stripped off leaving two or more electrically charged objects. The sun's rays cause the ions to form which slowly recombine. The propagation of radio waves in the presence of ions is drastically different than in air, which is why the ionosphere plays an important role in most modes of propagation. Ground waves travel between two limits, the earth and the ionosphere, which acts like a duct. Since the duct curves with the earth, the ground wave will follow. Therefore very long range propagation is possible using ground waves.

What is meant by Line of Sight for FM?

FM signals propagate as line-of-sight phenomenon, so if there is a large hill between transmitter and receiver, the receiver will not receive any signal. AM signals, on the other hand, are at low frequencies which are reflected back by ionospehere and thus, using sky-wave-propagation phenomenon, can travel farther distances. FM waves penetrate ionosphere and are not refracted back.

What is ionosphere and troposphere? How do they help in transmission and reception of radio waves?

IONOSPHERE The ionosphere extends upward from about 31.1 miles (50 km) to a height of about 250 miles (402 km). It contains four cloud-like layers of electrically charged ions, which enable radio waves to be propagated to great distances around the Earth. This is the most important region of the atmosphere for long distance point-to-point communications.

TROPOSPHERE The troposphere is the portion of the Earth's atmosphere that extends from the surface of the Earth to a height of about 3.7 miles (6 km) at the North Pole or the South Pole and 11.2 miles (18 km) at the equator. Virtually all weather phenomena take place in the troposphere. The temperature in this region decreases rapidly with altitude, clouds form, and there may be much turbulence because of variations in temperature, density, and pressure. These conditions have a great effect on the propagation of radio waves.

LAB Assignment No. 5:

TO STUDY SIGNAL SAMPLING AND RECONSTRUCTION TECHNIQUES ALONG WITH NYQUIST CRITERION AND ALIASING

APPARATUS:

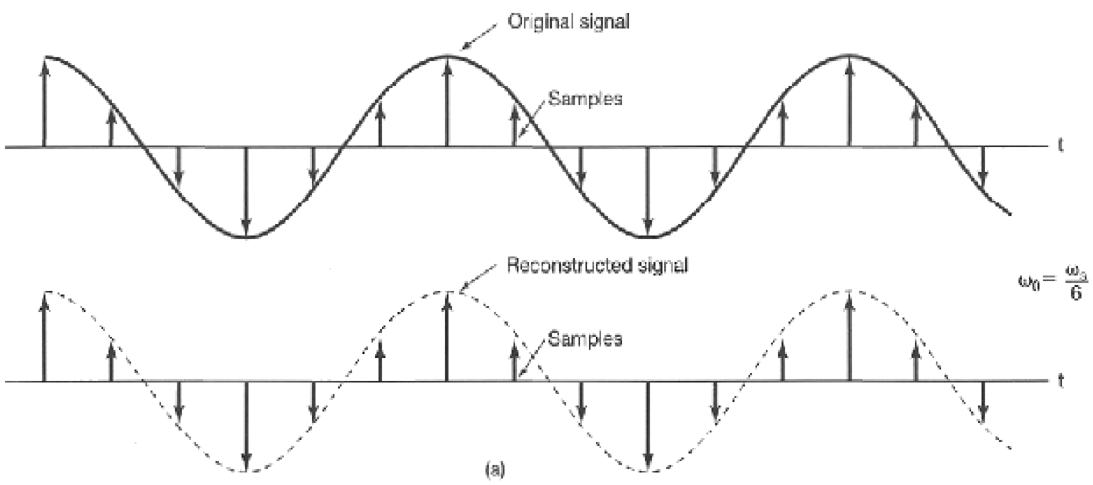
Oscilloscope Trainer

Power supply Connecting leads

THEORY:

A communications system is a collection of individual communications networks usually capable of interconnection and interoperation to form an integrated whole.

Sampling is the reduction of a continuous signal to a discrete signal. A common example is the conversion of a sound wave, a continuous-time signal to a sequence of samples, a discrete-time signal.



(a)

The Nyquist Stability Criteria is a test for system stability, Nyquist Criteria can tell us things about the frequency characteristics of the system. For instance, some systems with constant gain might be stable for low-frequency inputs, but become unstable for high-frequency inputs. Also, the Nyquist Criteria can tell us things about the phase of the input signals, the time-shift of the system, and other important information.

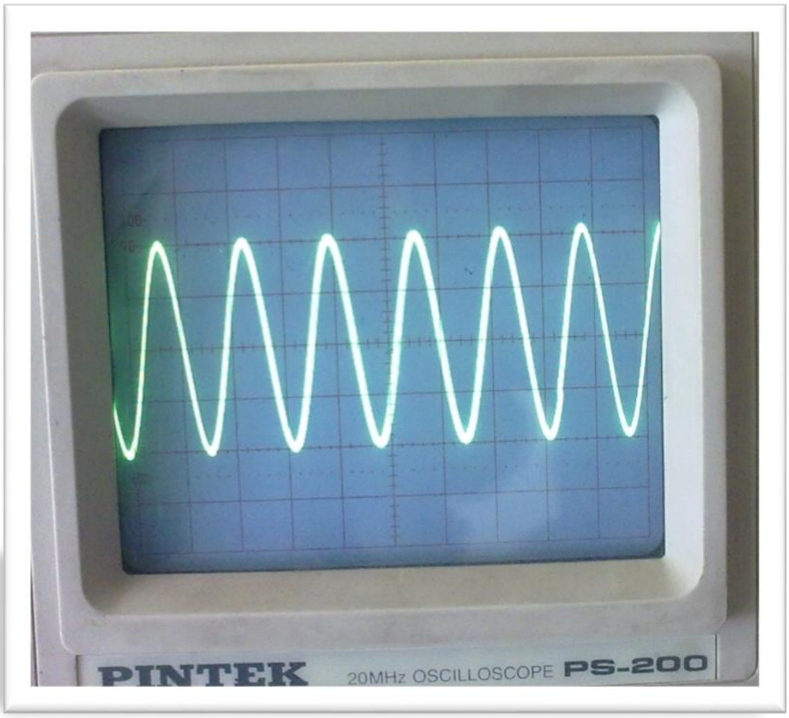


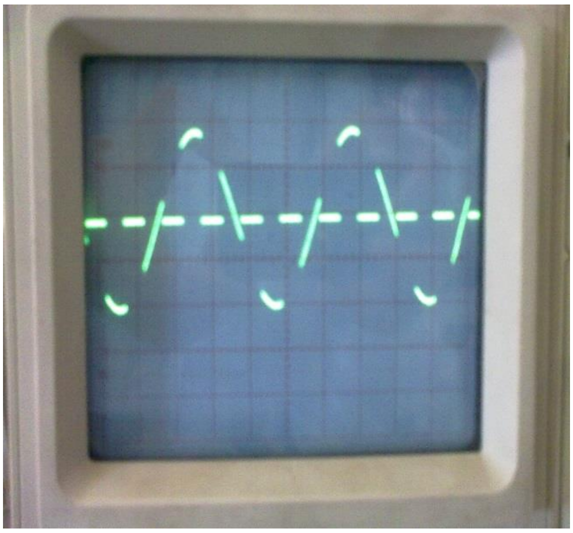
Figure 1 input signal

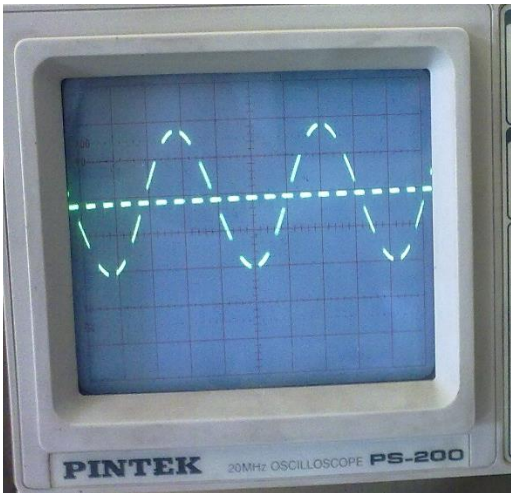
When the condition $f_s/2 > f$ is met for the highest frequency component of the original signal, then it is met for all the frequency components, a condition known as the Nyquist criterion

$$N = Z - P$$

- N is the number of encirclements of the (-1, 0) point.
- Z is the number of zeros of the characteristic equation.
- P is the number of poles of the open-loop characteristic equation.

With this equation stated, we can now state the **Nyquist Stability**





Aliasing is a common problem in digital media processing applications. Aliasing is an effect of violating the Nyquist-Shannon-Sampling-Theory. During sampling the base band spectrum of the sampled signal is mirrored to every multifold of the sampling frequency. These mirrored spectra are called alias. If the signal spectrum reaches farther than half the sampling frequency base band spectrum and aliases touch each other and the base band spectrum gets superimposed by the first alias spectrum. The easiest way to prevent aliasing is the application of a steep sloped low-pass filter with half the sampling frequency before the conversion.

In signal processing and related disciplines, aliasing refers to an effect that causes different signals to become indistinguishable when sampled. It also refers to the distortion or artifact that results when the signal reconstructed from samples is different from the original continuous signal.

Explain following terms clearly

Sampling Nyquist criteria Aliasing Reconstruction

Sampling is the reduction of a continuous signal to a discrete signal. A common example is the conversion of a sound wave a continuous-time signal to a sequence of samples a discrete-time signal.

The Nyquist Stability Criteria is a test for system stability, Nyquist Criteria can tell us things about the frequency characteristics of the system. For instance, some systems with constant gain might be stable for low-frequency inputs, but become unstable for high-frequency inputs. Also, the Nyquist Criteria can tell us things about the phase of the input signals, the time-shift of the system, and other important information

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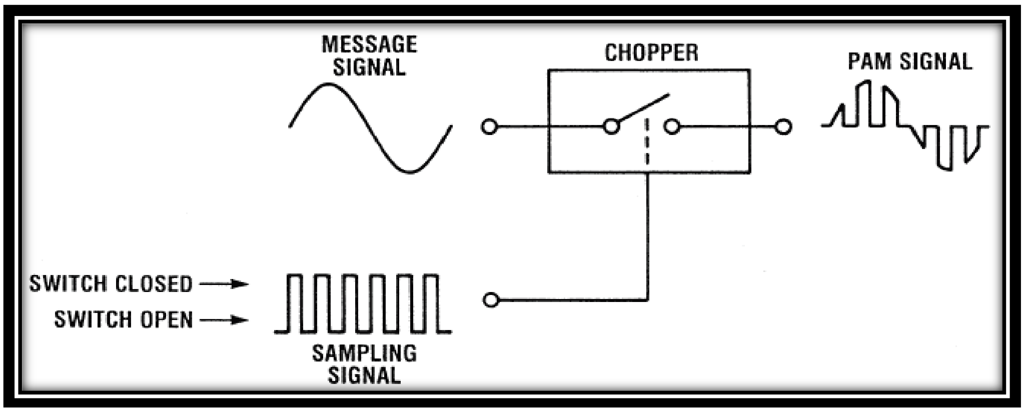
In signal processing and related disciplines, aliasing refers to an effect that causes different signals to become indistinguishable or *aliases* of one another when sampled. It also refers to the distortion or artifact that results when the signal reconstructed from samples is different from the original continuous signal.

Reconstruction is the process of creating an analog voltage or current from samples. A digital-to-analog converter takes a series of binary numbers and recreates the voltage or current level that corresponds to that binary number. Then this signal is filtered by a low pass filter. This process is analogous to interpolating between points on a graph, but it can be shown that under certain conditions the original analog signal can be reconstructed exactly from its samples. Unfortunately, the conditions for exact reconstruction cannot be achieved in practice, and so in practice the reconstruction is an approximation to the original analog signal.

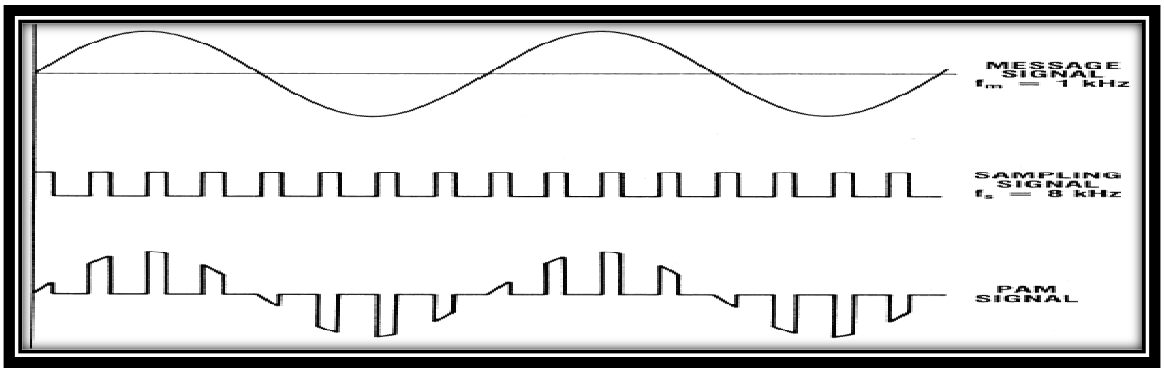
What is an electronic switch how it can be used in sampling?

A PAM signal is generated by using a pulse train, called the sampling signal or clock signal to operate an electronic switch or "chopper". This produces samples of the analog message signal, as shown in Figure.



Natural sampling – generation of PAM signals

The switch is closed for the duration of each pulse allowing the message signal at that sampling time to become part of the output. The switch is open for the remainder of each sampling period making the output zero. This type of sampling is called natural sampling.



How does the duty cycle of the sampling or switching signal affects the reconstruction?

As the sampling frequency is increased, the reconstructed output is less distorted and almost original signal is reconstructed For a sampling frequency of 4KHz, only 4 samples of the 1KHz signal are taken, whereas that for a sampling frequency of 8KHz, 8 samples of 1 KHz signal is taken. Hence, as the number of samples taken of the signal increases, the distortion of the reconstructed signal decreases. Moreover as the duty cycle increases, the sampling time, i.e., the time period over which the signal information is obtained, is more. Hence the reconstructed Signal Amplitude approaches that of the original signal.

When we increase the sampling frequency the signal reconstructed is better why? Up to which limit the increase in frequency turns out to be feasible?

As we increase the sampling frequency the signal reconstructed is better because the distortion of the reconstructed signal decreases as per the Nyquist Criterion at least two samples are required for the reconstruction of the signal. If the Nyquist Criterion is not satisfied, or if the signal is not band limited, then spectral overlap, called "aliasing" occurs, causing higher frequencies to show up at lower frequencies in the recovered signal, and specially in voice transmission intelligibility is seriously degraded Thus, universally for the voice band (300Hz to 3000Hz), the sampling frequency used is 8KHz, which satisfies the Nyquist Criterion.

Give different types of A/D converter? How does an A/D Converter work?

In analog-to-digital converter (ADC) accepts an analog input-a voltage or a current-and converts it to a digital value that can be read by a microprocessor. Figure 1shows a simple voltage-input ADC. This hypothetical part has two inputs: a reference and the signal to be measured. It has one output, an 8-bit digital word that represents the input value. The reference voltage is the maximum value that the ADC can convert. Our example 8-bit ADC can convert values from 0V to the reference voltage. This voltage range is divided into 256 values, or steps. The size of the step is given by:

$$V_{ref}/256$$

Where V_{ref} is the reference voltage. The step size of the converter defines the converter's resolution. For a 5V reference, the step size is:

$$5V/256 = 0.0195V \text{ or } 19.5Mv$$

What is folding frequency? How can aliasing be avoided?

The **Nyquist frequency**, named after the Swedish-American engineer Harry Nyquist or the Nyquist–Shannon sampling theorem, is half the sampling frequency of a discrete signal processing system. It is sometimes known as the **folding frequency** of a sampling system

The Nyquist frequency should not be confused with the *Nyquist rate*, which is the lower bound of the sampling frequency that satisfies the Nyquist sampling criterion for a given signal or family of signals. This lower bound is twice the bandwidth or maximum component frequency of the signal. *Nyquist rate*, as commonly used with respect to sampling, is a property of a continuous-time signal, not of a system, whereas *Nyquist frequency* is a property of a discrete-time system, not of a signal. The domain of the signals does not have to be time, though that is common, leading to Nyquist frequency in hertz; for example, an image sampling system has a Nyquist frequency expressed in units such as cycles per meter.

What is the disadvantage of sampling rate higher than the Nyquist Rate?

When a signal is sampled at rate higher than the Nyquist rate ($F_s > 2B$).This yields a signal with repetitions with a finite band gap between successive cycles. We can recover this signal using a low pass filter with a gradual cut off characteristic, but even in this case, the filter gain is required to be zero beyond the first cycle which is impossible. It shows that when sampling rate is higher than the Nyquist rate then it is impossible to recover a band limited signal exactly from its samples.