Lab Assignment No.1

Introduction Of Different Equipment Used In The Lab With Diagrams And With A Block Diagram Of Full Apparatus.

Klystron power supply:

Scientific Microwave manufactures two type of power supplies for the microwave benches in X-Band. Klystron Power Supply For the klystron based microwave bench. Klystron power supply generates required beam and repeller voltage for the X-Band klystron tube like 2K25. It is very stable and contains the short circuit protection circuit. Also it has amplitude and frequency modulation circuits for the generation of 1 KHz square wave and the saw tooth wave.

Specifications:

Voltage Range: 200-450 V continuously Variable

Current: 50mA Max

Regulation: Better than 0.5% for 10% variation in the mains supply voltage

Ripple: Less than 5 mV rms

Repeller supply Voltage Range: 10V to 270 V DC Continuously variable with respect to klystron cathode

Regulation: 0.25% for 10% variation in the mains supply voltage

Heater Supply: 6.3 V DC (Regulated)

Modulation:

Square Wave: Max. Amplitude: + 110 V peak to peak Freq.: 500 Hz-2000Hz Amplitude and frequency continuously variable

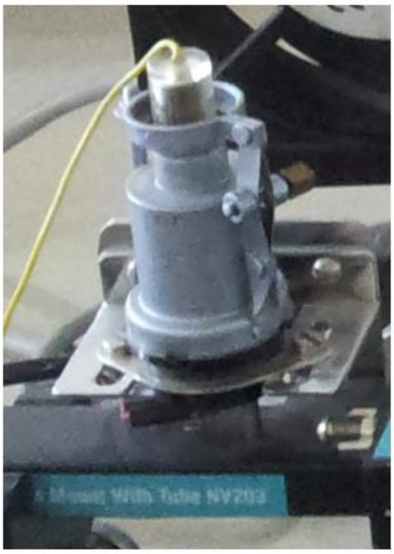
Sawtooth: Amplitude: -60 V max. peak to peak Freq.: 50 Hz-150 Hz Amplitude and frequency continuously variable

Operating Voltage: 230V 10%, 50 Hz, A.C.

Klystron power supply generates voltage required for driving the reflex klystron tubes like 2k25. It is absolutely stable, regulated and short circuit protected power supply. It has built in facility of squire wave and saw tooth generators, for amplitude and frequency modulation. Specifications: Operationg Voltage - 230V+/- 10, 50Hz AC Beam supply - Voltage:200-300V continuously variable; Current: 50mA max.; Regulation: better than 0.5%.

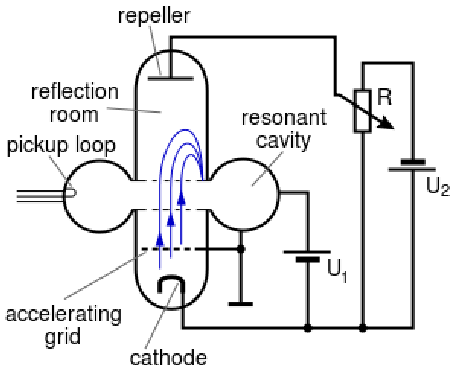
Reflex klystron Tube:

In the reflex klystron (also known as a 'Sutton' klystron after its inventor, Robert Sutton), the electron beam passes through a single resonant cavity. The electrons are fired into one end of the tube by an electron gun. After passing through the resonant cavity they are reflected by a negatively charged reflector electrode for another pass through the cavity, where they are then collected.



The electron beam is velocity modulated when it first passes through the cavity. The formation of electron bunches takes place in the drift space between the reflector and the cavity. The voltage on the reflector must be adjusted so that the bunching is at a maximum as the electron beam re-enters the resonant cavity, thus ensuring a maximum of energy is transferred from the electron beam to the RF oscillations in the cavity. The reflector voltage may be varied slightly from the optimum value, which results in some loss of output power, but also in a variation in frequency. This effect is used to good advantage for automatic frequency control in receivers, and in frequency modulation for transmitters. The level of modulation applied for transmission is small enough that the power output essentially remains constant. At regions far from the optimum voltage, no oscillations are obtained at all.

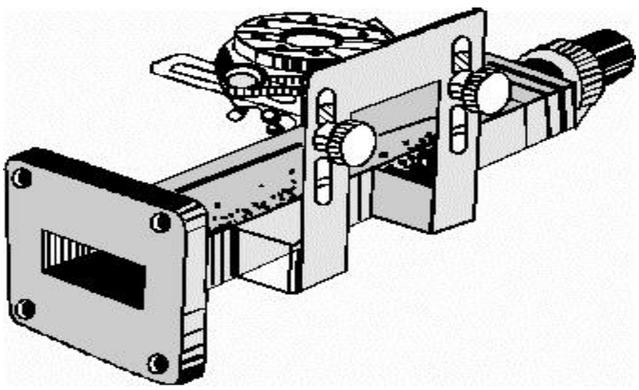
There are often several regions of reflector voltage where the reflex klystron will oscillate; these are referred to as modes. The electronic tuning range of the reflex klystron is usually referred to as the variation in frequency between half power points—the points in the oscillating mode where the power output is half the maximum output in the mode.



Klystron Mount:

It is a waveguide of suitable length having octal base on the broad wall of the waveguide for mounting the klystron tube. It consists of movable short at one end of the waveguide to direct the microwave energy generated by the klystron tube. A small hole located exactly at the center of the broad wall of the waveguide is used to put the coupling pin of the tube as the electric field vector of EM energy is maximum at the center only. The maximum power transfer can be achieved by tuning of the movable plunger.

We are engaged in offering our valuable customers a wide array of Klystron Mounts. The offered range is highly required in market for different experiments and laboratory work. These klystron mounts are appreciated by customer for its attributes like optimum finish and higher functional life. Along with this, these products are ideal for performing microwave experiments.



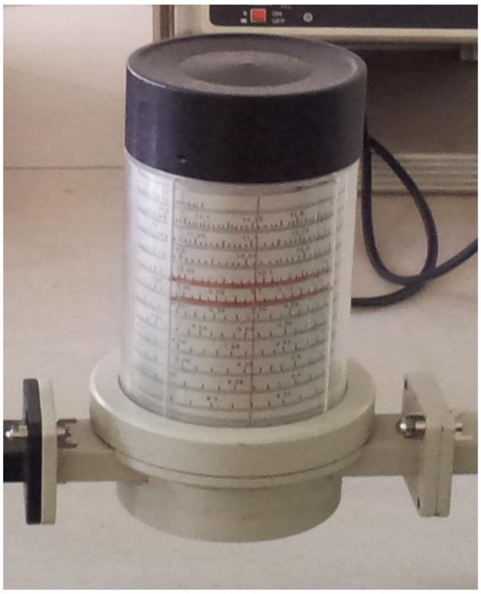
Isolator:

An isolator is a two-port device that transmits microwave or radio frequency power in one direction only. It is used to shield equipment on its input side, from the effects of conditions on its output side; for example, to prevent a microwave source being detuned by a mismatched load.

An RF isolator is a two-port ferromagnetic passive device which is used to protect other RF components from excessive signal reflection. Isolators are common place in laboratory applications to separate a device under test (DUT) from sensitive signal sources. An RF circulator is a three-port ferromagnetic passive device used to control the direction of signal flow in a circuit and is a very effective, low-cost alternative to expensive cavity duplexers in base station and in-building mesh networks.

Frequency meter:

The tunable wavemeter with an L/C circuit was one of the earliest instruments for RF frequency measurements. As usable frequencies increased, the tuneable cavity was discovered.



Many firms made microwave frequency meters with tuneable cavities; as ever, HP led the way in combining electronic and mechanical ingenuity. It's not difficult to see why these meters acquired the nickname of "gumball machine". The black ring on the top is turned to rotate the dial and simultaneously move a piston up and down an internal cavity; both piston and cavity are silver-plated. The piston and its bearings and the cavity bore are so accurately machined that there is no contact between piston and cavity. The meter was inserted in the line under test and a detector was also connected; tuning to resonance produced a power "dip" of 0.6 -1 dB and the frequency was read from the scale. The 536A measures frequencies in the range of 940 MHz to 4.2 GHz. The spiral scale is, in total, about 15 feet long. A pair of red divider strips runs in a spiral groove as the dial rotates and the frequency is read between the strips on a cursor line. Here the frequency is close to 2 GHz.

Tunable probe:

An electronically tuned microwave wafer probe using varactor diodes as tuning elements has been fabricated. This probe can be used for the acquisition of the noise parameters of active devices. A complete set of algorithms has been installed in a simple computer program to allow these measurements to be performed automatically.

The probe may be used to generate wafer maps of noise parameters, which are useful for the development of low-noise device processes, and in the monitoring of the performance of low-noise integrated circuits.

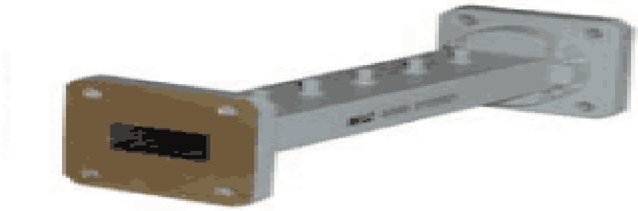
Tunable probes are very useful devices to measure the SWR and Impedances. Tunable probe is consists of a crystal detector and a small wire antenna in coaxial housing. Its depth of penetration into the slotted section is variable.

Waveguide:

Depending on the frequency, waveguides can be constructed from either conductive or dielectric materials. Generally, the lower the frequency to be passed the larger the waveguide is. For example the natural waveguide the earth forms given by the dimensions between the conductive ionosphere and the ground as well as the circumference at the median altitude of the Earth is resonant at 7.83 Hz. This is also known as Schumann resonance. Waveguides can also be less than a millimeter in width. An example might be those that are used in extremely high frequency (EHF) communications.

A dielectric waveguide employs a solid dielectric rod rather than a hollow pipe. An optical fibre is a dielectric guide designed to work at optical frequencies. Transmission lines such as microstrip, coplanar waveguide, stripline or coaxial cable may also be considered to be waveguides.

The electromagnetic waves in a (metal-pipe) waveguide may be imagined as travelling down the guide in a zig-zag path, being repeatedly reflected between opposite walls of the guide. For the particular case of rectangular waveguide, it is possible to base an exact analysis on this view. Propagation in a dielectric waveguide may be viewed in the same way, with the waves confined to the dielectric by total internal reflection at its surface. Some structures, such as non-radiative dielectric waveguides and the Goubau line, use both metal walls and dielectric surfaces to confine the wave.



VSWR meter:

The SWR meter or VSWR (voltage standing wave ratio) meter measures the standing wave ratio in a transmission line. The meter can be used to indicate the degree of mismatch between a transmission line and its load (usually a radio antenna), or evaluate the effectiveness of impedance matching efforts.

Directional couplers:

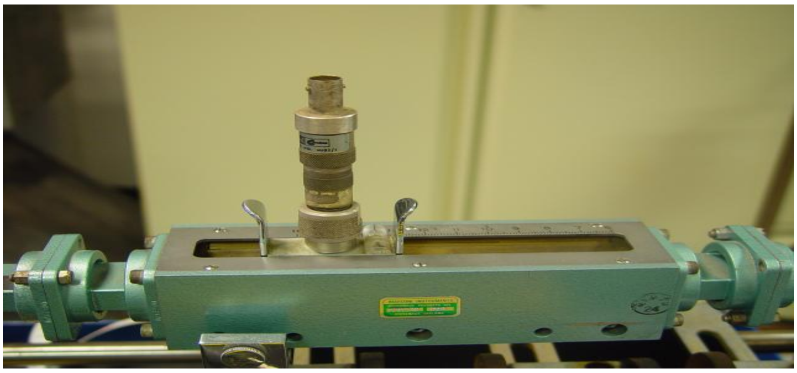
Directional couplers are most frequently constructed from two coupled transmission lines set close enough together such that energy passing through one is coupled to the other. This technique is favoured at the microwave frequencies the devices are commonly employed with.

However, lumped component devices are also possible at lower frequencies. Also at microwave frequencies, particularly the higher bands, waveguide designs can be used. Many of these waveguide couplers correspond to one of the conducting transmission line designs, but there are also types that are unique to waveguide.

Directional couplers and power dividers have many applications, these include; providing a signal sample for measurement or monitoring, feedback, combining feeds to and from antennae, antenna beam forming, providing taps for cable distributed systems such as cable TV, and separating transmitted and received signals on telephone lines.

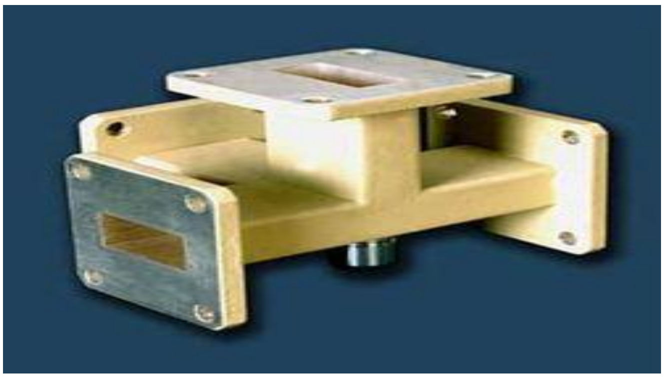
Slotted Section:

Slotted Section consists of a precision waveguide slotted line and the probe carriage. The wavelength slotted line, comprise of an accurately machined section of waveguide in which a small longitudinal slot has been cut which is a basic means for monitoring wave –patterns inside the waveguide system. Such data may be transformed into impedance of the terminal load of unknown system of components, percent of transmitted power, degree of antenna-match and other characteristics of waveguide. A precision built probe carriage has a centimeter-scale with a vernier reading of 0.1mm least count. Frequency range 8.2 to 12.4 GHz Max. residual VSWR 1.01. Total Vernier travel 15cm typical.



Tees:

A magic tee (or magic T or hybrid tee) is a hybrid or 3 dB coupler used in microwave systems. It is an alternative to the rat-race coupler. In contrast to the rat-race, the three-dimensional structure of the magic tee makes it less readily constructed in planar technologies such as microstrip or stripline. To function correctly, the magic tee must incorporate an internal matching structure. This structure typically consists of a post inside the H-plane tee and an inductive iris inside the E-plane limb, though many alternative structures have been proposed. Dependence on the matching structure means that the magic tee will only work over a limited frequency band.



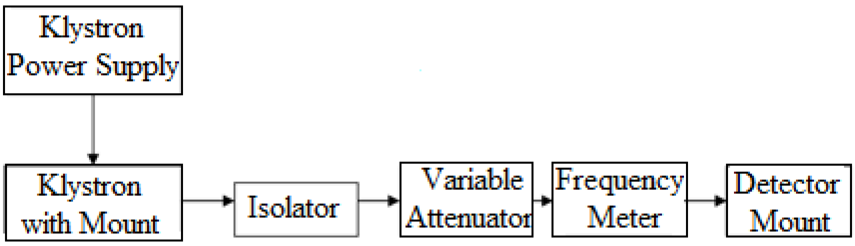
Lab Assignment No.2

To Study The Output Characteristics V/S Repellant Voltage Of The Reflex Klystron Tube

Apparatus:

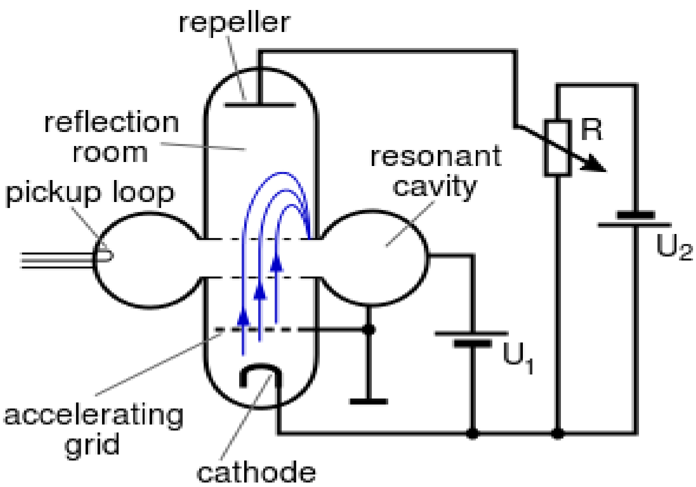
Klystron Power Supply, Klystron with mount, Isolator, Frequency meter, Variable Attenuator.

Block Diagram:



Three power sources are required for reflex klystron operation:

Filament power, Positive resonator voltage often referred to as beam voltage used to accelerate the electrons through the grid gap of the resonant cavity, and negative repeller voltage used to turn the electron beam around.



Observations and Calculations:

Beam Voltage = 306v

Beam Current = 32mA

Input Power = 9.792 W

O/P V (-v)	O/P I	O/P Pwr	Efficiency
58	10 micro	580	0.005
60	50	300	0.003
62	150	9300	0.0958
64	200	12800	0.131
66	225	14850	0.0153
70	240	16800	0.173
72	230	16560	0.17
74	200	14800	0.152
76	170	12290	0.126
78	90	7020	0.072
80	10	800	0.008

Questions

1) Write down the uses of Reflex Klystron.

Reflex Klystron uses as:

- As power output tubes.
- As power oscillator.
- The reflex klystron has been the most used source of microwave power in laboratory applications.
- Radar receivers.
- Local oscillator in microwave receivers.
- Signal source in microwave generator of variable frequency.
- Portable microwave links.
- Pump oscillator in parametric amplifier.

2) What is the difference between two cavity Klystron and Reflex Klystron?

2 cavity Klystron:

A klystron uses special cavities which modulate the electric field around the axis the tube. In the middle of these cavities, there is a grid allowing the electrons to pass. The first cavity together with the first coupling device is called a "buncher", while the second cavity with its coupling device is called a "catcher".

Reflex Klystron:

The reflex klystron contains a reflector plate, referred to as the repeller, instead of the output cavity used in other types of klystrons.

3) What is the benefits of Multi cavity Klystron?

Multi cavity Klystron:

Klystron amplification, power output, and efficiency can be greatly improved by the addition of intermediate cavities between the input and output cavities of the basic klystron. Additional cavities serve to velocity-modulate the electron beam and produce an increase in the energy available at the output.

4) What is the relationship between repeller voltage and output power?

From graph, we can easily estimate that on increasing the repeller voltage, firstly, output power gradually increases and after a certain voltage, it is gradually decreases to zero value.

5) What are the types of linear beam tubes?

There are two types of linear beam tubes.

Klystron Travelling wave tube

6) Explain clearly bunching and velocity modulation.

Velocity modulation:

The modulation in velocity of a beam of electrons or ions caused by passing the beam through a high-frequency electric field, as in a cavity resonator.

Bunching:

The flow of electrons from cathode to anode of a velocity-modulated tube as a succession of electron groups rather than as a continuous stream.

7) **What is Magnetron? Write difference between Magnetron and Klystron.**

Magnetron:

A microwave tube in which electrons generated from a heated cathode are affected by magnetic and electric fields in such a way as to produce microwave radiation used in radar and in microwave ovens.

Differences:

Klystron	**Magnetron**
Electrons are formed into a beam that is velocity modulated by the input waveform to produce microwave energy.	Electrons are emitted from cathode and interact with an electric field and a strong magnetic field to generate the microwave energy.
Consists of four parts: o beam source (electron gun or cathode) o Buncher (velocity modulating unit) o Accelerator o Catcher (beam stop)	Consists of four parts: o Anode o Filament/cathode o Antenna o Magnets

8) What are the applications of Magnetron?

It is used in following devices.

- Microwave Oven
- Radar
- Jam Opponents

9) What is the effect of debunching of electrons in higher modes?

Debunching is simply the spreading out of the electron bunches before they reach electrostatic fields across the cavity grid.

In higher modes of operation the electron bunches are formed more slowly. They are more likely to be affected by debunching because of mutual repulsion between the negatively charged electrons. The long drift time in the higher modes allows more time for this electron interaction and, as a result, the effects of debunching are more severe. The mutual repulsion changes the relative velocity between the electrons in the bunches and causes the bunches to spread out.

10) Write down the types and operation of travelling wave tubes.

Travelling wave tubes:

Traveling-wave tube (TWT) is a specialized vacuum tube that is used in electronics to amplify radio frequency (RF) signals to high power, usually as part of an electronic assembly known as a traveling-wave tube amplifier.

Types:

- Coupled cavity TWTs
- Helix TWTs
- Bifilar Contra-Wound and Ring-Bar TWTs

Operation:

- The passage of the microwave signal down the helix produces electric and magnetic fields that will interact with the electron beam.
- The electromagnetic field produced by the helix causes the electrons to be speeded up and slowed down, this produces velocity modulation of the beam which produces density modulation.
- Density modulation causes bunches of electrons to group together one wavelength apart and. These bunch of electrons travel down the length of the tube toward the collector.
- The passage of the microwave signal down the helix produces electric and magnetic fields that will interact with the electron beam.
- The electromagnetic field produced by the helix causes the electrons to be speeded up and slowed down, this produces velocity modulation of the beam which produces density modulation.
- Density modulation causes bunches of electrons to group together one wavelength apart and. These bunch of electrons travel down the length of the tube toward the collector.

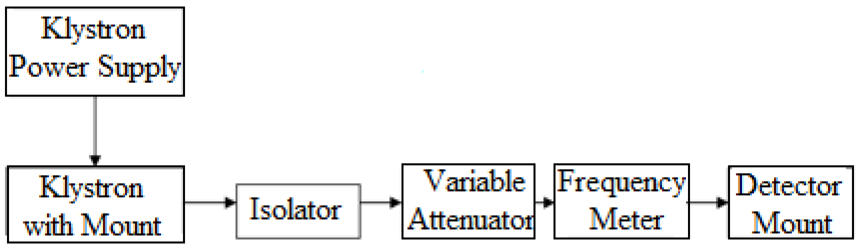
Lab Assignment No.3

To Study The Different Modes Of Operation Of Reflex Klystron And Plot A Graph Between Repeller Voltage And Output Power.

Apparatus:

Klystron Power Supply, Klystron with mount, Isolator, Frequency meter, Variable Attenuator.

Block Diagram:



Observations and Calculations:

Beam voltage: 314v

Beam current: 32mA

Input power: 10W

Mode 3:

Voltage	current	power	efficiency
16	0	0	0
17	90	1530	0.153
18	75	1350	0.135
19	60	1200	0.12
20	50	1050	0.105
21	40	880	0.008
22	35	805	0.00805
23	25	600	0.006
24	15	375	0.00375
25	10	260	0.0026
26	0	0	0

Mode 2:

Voltage	current	power	efficiency
32	0	0	0
33	20	320	0.0032
34	70	660	0.0066
35	110	2380	0.0238
36	140	3850	0.0385
37	145	5040	0.0504
38	150	5365	0.0536
39	150	5700	0.057
40	150	5850	0.0585
41	150	6000	0.06
42	130	6150	0.0615
43	115	5460	0.0546
44	100	4945	0.04945
45	70	3150	0.0315

46	30	1380	0.0138
47	20	940	0.0094
48	0	0	0

Mode 1:

Voltage	current	Power	Efficiency
59	65	2795	0.02795
60	140	8400	0.084
61	180	10980	0.1098
62	210	13020	0.1302
63	230	14490	0.1449
64	235	15240	0.1524
65	260	16300	0.163
66	260	17160	0.1716
67	270	18090	0.1809
68	270	18360	0.1836
69	275	18900	0.189
70	270	18815	0.18815
71	265	18720	0.1872
72	260	18250	0.1825
73	250	17230	0.1723
74	235	15000	0.15
75	200	12540	0.01254
76	165	11550	0.1155
77	150	6240	0.0624
78	80	790	0.0079
79	0	0	0

Questions

1) Write down the methods of measuring microwave frequency.

There are following methods:

- Slotted-Line Frequency Measurements
- Prescaler Frequency Measurements
- Resonant Cavity Frequency Measurements

Frequency Measurement Methods Compared Slotted-line frequency measurements are sometimes cumbersome and often give less accurate results when compared to prescaler frequency measurements. High-Q Resonant cavities usually provide very accurate results, on the order of ±0.1% of Accuracy.

2) Explain the operation of the absorption type wave meter.

Absorption type wave meter:

The simplified illustration of an absorption wave meter consists of a pickup coil, a fixed capacitor, a lamp, a variable capacitor, and a calibrated dial. When the wave meter's components are at resonance, maximum current flows in the loop, illuminating the lamp to maximum brilliance. The calibrated dial setting is converted to a frequency by means of a chart, or graph, in the instruction manual. If the lamp glows very brightly, the wave meter should be coupled more loosely to the circuit. For greatest accuracy, the wave meter should be coupled so that its indicator lamp provides only a faint glow when tuned to the resonant frequency.

3) What is meant by mechanical tuning of Reflex Klystron?

Mechanical tuning:

Variation in frequency of resonance of cavity by varying its dimension by a mechanical method like adjusting screws is called as mechanical tuning. Klystron can be mechanically tuned over a wide range of frequency. It is achieved by the adjusting the cavity within the evacuated envelope by means of a flexible diaphragm. The number of tuning cycles may be limited to avoid damage to the diaphragm.

4) How the frequency tuning range is related to mode number?

There are often several regions of reflector voltage where the reflex klystron will oscillate; these are referred to as modes. The electronic tuning range of the reflex klystron is usually referred to as the variation in frequency between half power points—the points in the oscillating mode where the power output is half the maximum output in the mode.

High stability in the output frequency is achieved by operating the Reflex Klystron at high beam voltage.

5) In which order modes, the performance of the Reflex Klystron is considered good?

Modes in following order is considered good:

1^{st}, 2^{nd}, 3^{rd} and so on.

6) Comment on observation, how efficiency is related to mode number?

On the basis of readings which I have taken while performing the experiment, it is clearly concluded that for 1^{st} mode, efficiency is higher than for 2^{nd} mode and so on.

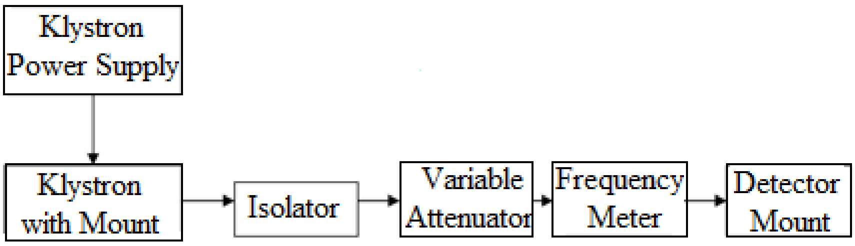
Lab Assignment No.4

To Observe The Frequency Vs Repeller Voltage Characteristics Of Reflex Klystron

Apparatus:

Klystron Power Supply, Klystron with mount, Isolator, Frequency meter, Variable Attenuator.

Block Diagram:



Frequency Meter:

Absorption wave meter:

- Used to change the size of cavity by the movement of planger.
- Resonant frequency changes for each setting of planger.
- At resonance the power is absorbed within the cavity causing a dip in output power.
- Change in frequency is higher in higher mode (Electric Frequency Tunning)

Mechanical Tunning:

Changing the frequency of operation of Reflex Klystron by changing the size of cavity.

Repeller voltage	Frequency
-17	9.89
-20	9.555
-22	9.565
-24	9.585
-34	9.865
-37	9.92
-40	9.56
-43	9.95
-45	9.59
-48	9.62
-58	9.86
-61	9.525
-63	9.915
-65	9.925
-68	9.945
-72	9.58
-75	9.59
-77	9.65
-78	9.63

Questions

1) **Salient feature of 2k25 Reflex Klystron.**

Heater Voltage = 6.3 v ± 8%

Heater Current = 0.44 A

D.C Resonator Voltage (max.) = 330 v

D.C Resonator Current (max.) = 37mA

D.C Repeller Voltage (max.) = -400 v

Voltage B/W heater & cathode = 50 v

2) **Write down the methods of measuring microwave frequency.**

There are following methods:

- Frequency counter method
- Wavelength measurement method
- Wave meter method

Frequency counters designed for radio frequencies (RF) are also common and operate on the same principles as lower frequency counters. For microwave frequencies, many designs use a high-speed prescaler to bring the signal frequency down to a point where normal digital circuitry can operate. Microwave frequency counters can currently measure frequencies up to almost 100 GHz. Above these frequencies the signal to be measured is combined in a mixer with the signal from a local oscillator, producing a signal at the difference frequency, which is low enough to be measured directly.

In Wavelength method, From the relation λ = c / f between wavelength λ, speed *c*, and frequency *f*, the wavelength of a wave motion can be calculated if the speed is known and its frequency is measured. The ease and accuracy of electronic counting and timing make frequency measurement the most precise of all physical measurements. This method of wavelength determination is thus one of the most accurate, but only if the speed (phase velocity) is known. Unless otherwise specified, it is general practice to quote the wavelength of an electromagnetic wave as the free-space value λ_0, given by the equation below.

$$\lambda_0 = \frac{c_0}{f}$$

A wave meter is one of the earliest devices used to measure resonant frequency. It is an adjustable resonant circuit provided with a calibration that gives resonant frequency in terms of setting of tuning adjustment. Wave meters are used to measure frequency when the higher accuracy of standard is not required, and where simplicity and portability is important.

3) Comment on observation, how efficiency is related to mode number?

On the basis of readings which I have taken while performing the experiment, it is clearly concluded that for 1st mode, efficiency is higher than for 2nd mode and so on.

4) How the frequency tuning range of Reflex Klystron is related to mode number?

There are often several regions of reflector voltage where the reflex klystron will oscillate; these are referred to as modes. The electronic tuning range of the reflex klystron is usually referred to as the variation in frequency between half power points—the points in the oscillating mode where the power output is half the maximum output in the mode.

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Modes in following order is considered good:

1st, 2nd, 3rd and so on.

7) **What is meant by mechanical tuning of Reflex Klystron?**

Mechanical tuning:

Variation in frequency of resonance of cavity by varying its dimension by a mechanical method like adjusting screws is called as mechanical tuning.

Klystron can be mechanically tuned over a wide range of frequency. It is achieved by the adjusting the cavity within the evacuated envelope by means of a flexible diaphragm. The number of tuning cycles may be limited to avoid damage to the diaphragm.

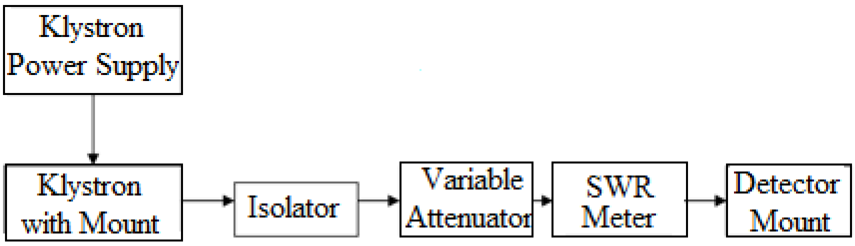
Lab Assignment No.5

To Study The Variable Attenuators Their Calibration & Measurement Of Frequency Sensitivity

Apparatus:

Klystron Power Supply, Klystron with mount, Isolator, SWR meter, Variable Attenuator.

Block Diagram:



Attenuators are linear passive or active networks or devices such that attenuate electrical or microwave signals, such as voltages or currents, in a system by a pre-determined ratio. They may be in the form of transmission line strip line or wave guide components. Attenuation is usually expressed as the ratio of input power to output power.

In Decibels:

$$\text{Attenuation (A)} = 10\log_{10}(P_{in}/P_{out}) = 20\log_{10}(V_{in}/V_{out})$$

Observations and Calculations:

Repeller Voltage	Micrometer Reading	SWR meter Reading In Db
-32	8.01	0.75
	7.04	1
	6.005	1.3
	5.01	1.6
	5	1.68
-43	9.025	0.1
	8.00	0.3
	7.00	0.5
	6.00	0.85
	5.00	1.4
-57	8.01	0.7
	7.00	0.9
	5.045	1
	5.00	1.35
	4.00	1.8

Questions

1) Discuss the reading obtained in observation table.

By observing table, we noticed that increasing the value of variable attenuator values of SWR in dB decreases at constant repeller voltage.

The same thing happened in different modes of Reflex Klystron tube.

2) What are the important performance parameters of attenuators?

Accuracy

Impedance match

Attenuation Step size

Dynamic range

Supply voltage

3) Identify the practical use of attenuators and explain them?

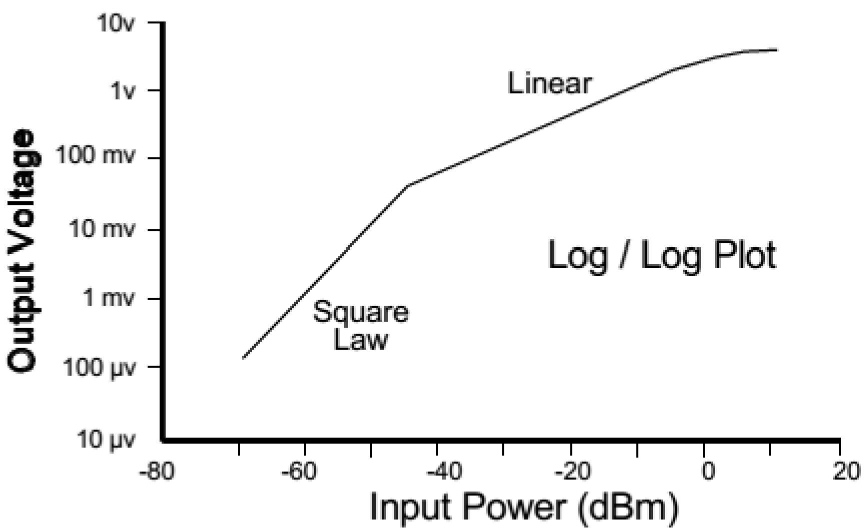
An attenuator is a passive microwave component which, when inserted in the signal path of a system, reduces the signal by a specified amount. They normally possess a low VSWR which makes them ideal for reducing load VSWR in order to reduce measurement uncertainties. They are sometimes used simply to absorb power, either to reduce it to a measurable level, or in the case of receivers to establish an exact level to prevent overload of following stages.

Fixed attenuators in circuits are used to lower voltage, dissipate power, and to improve impedance matching. In measuring signals, attenuator pads or adapters are used to lower the amplitude of the signal a known amount to enable measurements, or to protect the measuring device from signal levels that might damage it. Attenuators are also used to 'match' impedance by lowering apparent SWR

4) Square law detector and impact of too much inserted power

A detector is used in receiver circuits to recognize the presence of signals. Typically a diode or similar device is used as a detector. Since this type of detector is unable to distinguish frequency, they may be preceded by a narrow band-pass filter.

In the square law region, the output voltage V is proportional to the square of the input voltage Vi , thus V o is proportional to the input power.



When input power is greater, then response will be linear

Linear Detector

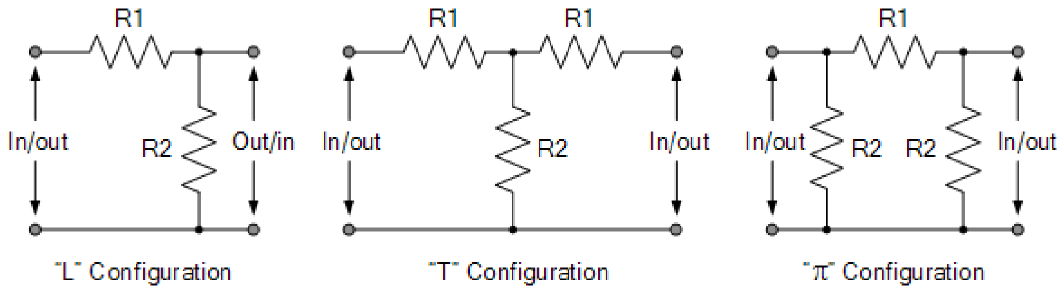
In the linear detection region, the output voltage is given by:

$$V_o = mV_i$$

Where m is the constant of proportionality.

5) What are the different technologies for inserting attenuators in microwave circuits?

There are many ways in which resistors can be arranged in attenuator circuits with the Potential Divider Circuit being the simplest type of passive attenuator circuit. The potential or voltage divider circuit is generally known as an "L-pad" attenuator because its circuit diagram resembles that of an inverted "L". But there are other common types of attenuator network as well such as the "T-pad" attenuator and the "Pi-pad" (π) attenuator depending upon how you connect together the resistive components. These three common attenuator types are shown below:



Lab Assignment No.6

To Determine The Frequency And Wavelength In A Rectangular Wave Guide Working On TE01 Mode

Theory:

A transverse mode of a beam of electromagnetic radiation is a particular electromagnetic field pattern of radiation measured in a plane perpendicular to the propagation direction of the beam.

- **Transverse Electric (TE) Modes:**

  No electric field in the direction of propagation. These are sometimes called H modes because there is only a magnetic field along the direction of propagation. H is the conventional symbol for magnetic field.

- **Transverse Magnetic (TM) Modes:**

  No magnetic field in the direction of propagation. These are sometimes called E modes because there is only an electric field along the direction of propagation.

$$\lambda_g = 2\,(d_1 - d_2)$$

$$1/\lambda_o = (1/\lambda_g + 1/\lambda_c)^{1/2}$$

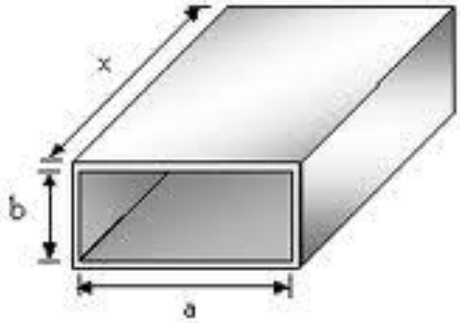
λ_o = free space wavelength

λ_g = wave guide wavelength

λ_c = cutoff wavelength

$c = \lambda f$

$\lambda_c = 2a/m$



Calculations:

d_2 = 13.5mm d_1 = 13.8mm

d_2 = 12.9mm d_1 = 13.3mm.

$\lambda_g = 2(d_1 - d_2)$ $\lambda_g = 2(d_1 - d_2)$

$\lambda_g = 2(13.8 - 13.5)$ $\lambda_g = 2(13.3 - 12.9)$

$\lambda_g = 0.6$mm $\lambda_g = 0.8$mm

$\lambda_c = 2a$ $\lambda_c = 2a$

$\lambda_c = 2 * 2.286$mm $\lambda_c = 2 * 2.286$mm

$\lambda_c = 45.72$mm $\lambda_c = 45.72$mm

$1/\lambda_o = (1/\lambda_g^2 + /\lambda_c^2)$ $1/\lambda_o = (1/\lambda_g^2 + 1/\lambda_c^2)$

$\lambda_o = 0.045$mm $\lambda_o = 0.045$mm

$f = c / \lambda = 6.6$GHz $f = c / \lambda = 6.6$GHz

Questions

1. **What are elliptical and reentrant waveguides? Explain their merits.**

Elliptical waveguide:

Microwave radio links rely on the efficient transmission of RF energy between the radio equipment and the antenna at each site in the network. At frequencies above 2GHz, waveguides have lower attenuation than coaxial cables, and are deployed as standard practice unless 'integrated antennas' can be used. Radio Frequency Systems' FLEXWELL elliptical waveguides are available in a wide selection of frequency bands from 3 to 40GHz. FLEXWELL is offered in three versions: standard, premium (low VSWR) and 'overmoded' (low attenuation). FLEXWELL standard waveguide is recommended for low and medium capacity radio relay systems, while premium elliptical waveguide is recommended for high capacity radio systems.

Over moded waveguide is used when long distances or restricted power budgets call for lower than normal attenuation. This is achieved at particular frequency bands by operating the waveguide above the cut-off frequency of higher-order modes. The effect of this is to introduce additional modes and energy into the waveguide.

2. **What is meant by dielectric losses in waveguides, how are they different from air filled guides?**

Dielectric losses:

Dielectric losses are also lower in waveguides than in two-wire and coaxial transmission lines. Dielectric losses in two-wire and coaxial lines are caused by the heating of the insulation between the conductors. The insulation behaves as the dielectric of a capacitor formed by the two wires of the transmission line. A voltage potential across the two wires causes heating of the dielectric and results in a power loss. In practical applications, the actual breakdown of the insulation between the conductors of a transmission line is more frequently a problem than is the dielectric loss.

Dielectric waveguide:

A waveguide that consists of a dielectric material surrounded by another dielectric material, such as air, glass, or plastic, with a lower refractive index.

An example of a dielectric waveguide is an optical. A metallic waveguide filled with a dielectric material is not a dielectric waveguide.

Air filled waveguide:

A waveguide in which air is filled as medium is called air filled waveguide.

3. **Compare Waveguide and Transmission Line from point of view of frequency limitations, attenuation Power handling capacity & spurious radiations.**

Transmission Line:

- Two or more conductors separated by some insulating medium.
- Normal operating mode is the TEM or quasi-TEM mode can support TE and TM modes but these modes are typically undesirable.
- No cutoff frequency for the TEM mode. Transmission lines can transmit signals from DC up to high frequency.
- Significant signal attenuation at high frequencies due to conductor and dielectric losses.

- Small cross-section transmission lines like coaxial cables can only transmit low power levels due to the relatively high fields concentrated at specific locations within the device field levels are limited by dielectric breakdown.
- Large cross-section transmission lines like power transmission lines can transmit high power levels.

Waveguide:

- Metal waveguides are typically one enclosed conductor filled with an insulating medium (rectangular, circular) while a dielectric waveguide consists of multiple dielectrics.
- Operating modes are TE or TM modes & cannot support a TEM mode.
- Must operate the waveguide at a frequency above the respective TE or TM mode cutoff frequency for that mode to propagate.
- Lower signal attenuation at high frequencies than transmission lines.
- Metal waveguides can transmit high power levels. The fields of the propagating wave are spread more uniformly over a larger cross-sectional area than the small cross-section transmission line.
- Large cross-section low frequency waveguides are impractical due to large size and high cost.

4. **Explain impedance matching phenomena using stub tuners?**

A single-stub transmission line impedance matching network is composed of a short circuited section of transmission line placed along the main signal line. The short circuited section provides an equivalent shunt susceptance. This short circuited section is an attached perpendicular to the main line. The construction of the short circuited section is similar to the main line. The load impedance Z_L can be matched to the characteristic impedance of the transmission line Z_O using either a specified length of single short or open circuit stub placed a specified distance from the load.

Lab Assignment No.7

To Measure The VSWR & Reflection Coefficient Of Rectangular Waveguide

Theory:

In telecommunications, Reflections occur as a result of discontinuities, such as an imperfection in an otherwise uniform transmission line, or when a transmission line is terminated with other than its characteristic impedance.

The reflection coefficient Γ is defined thus:

$$\Gamma = \frac{V_r}{V_f}.$$

Γ is a complex number that describes both the magnitude and the phase shift of the reflection.

Standing wave ratio (SWR) is the ratio of the amplitude of a partial standing wave at an antinode (maximum) to the amplitude at an adjacent node (minimum), in an electrical transmission line.

The SWR is usually defined as a voltage ratio called the VSWR, for voltage standing wave ratio.

The voltage component of a standing wave in a uniform transmission line consists of the forward wave with amplitude V_f superimposed on the reflected wave with amplitude V_r.

SWR = Measure of mismatch between load and transmission line.

$$VSWR = \lambda_g / (\pi (d_1 - d_2))$$

$$\lambda_g = 2(d_1 - d_2)$$

Calculations:

d1 = 12.3	**d2 = 10.1**	**d1 - d2 = 2.2**
d1 = 14.4	**d2 = 12.3**	**d1 - d2 = 2.1**

$\lambda_g = 2\ (2.2) = 4.4$

VSWR = 4.4 / (π * 2.2) = 0.636
VSWR = 4.2 / (π * 2.1) = 0.636

Questions

1. **Explain the operation and application of VSWR meter?**

The SWR meter or VSWR (voltage standing wave ratio) meter measures the standing wave ratio in a transmission line.

Application:

The meter can be used to indicate the degree of mismatch between a transmission line and its load usually a radio antenna, or evaluate the effectiveness of matching efforts.

2. **Search the web for Hazards of exposure of a personnel to electromagnetic radiation. Does the penetration of microwave depend upon the dielectric constant of the body?**

Electromagnetic radiation can be classified into two types, ionizing radiation and non-ionizing radiation, based on its capability of ionizing atoms and breaking chemical bonds.

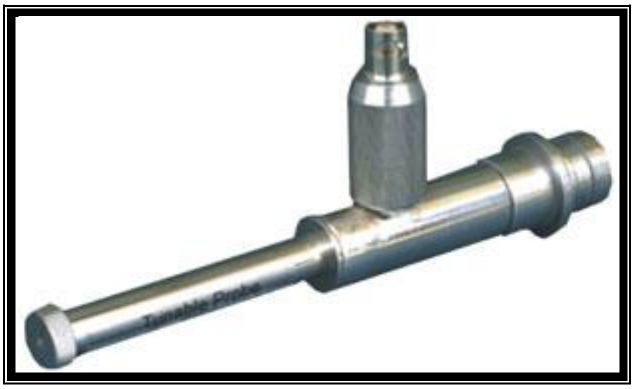
The best understood biological effect of electromagnetic fields is to cause dielectric heating. For example, touching or standing around an antenna while a high-power transmitter is in operation can cause severe burns. This heating effect varies with the power and the frequency of the electromagnetic energy.

There is also possibility that week electric and magnetic fields from high power transmission lines may affect biological cellular processes at the cell nucleus. Biological substances such as brain, blood, bone, muscle, fat behave as conductive dielectrics, the microwave energy directed onto body may be scattered, reflected or absorbed depending upon field strength, the frequency, dimension of body and the electric properties of tissues. The absorbed microwave energy produces molecular vibration and convert this energy into heat. This heat rises the body temperature and may damage biological substances permanently.

3. **Explain the operation of Tunable probe and slotted line carriage?**

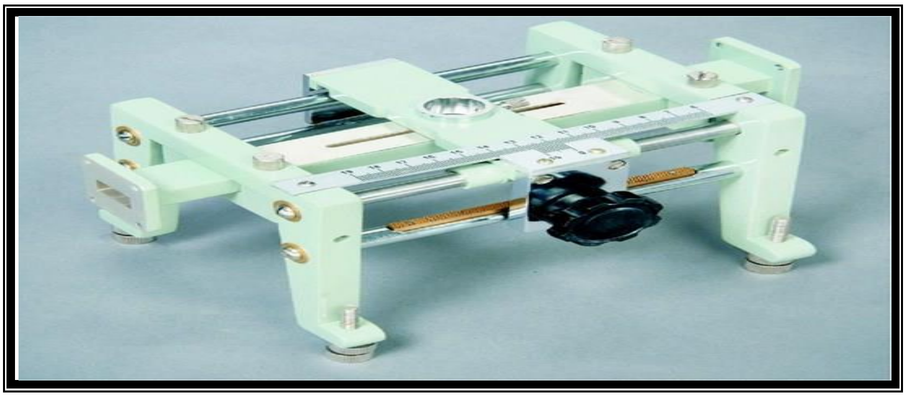
Tunable probe:

Tunable probes are very useful devices to measure the SWR and Impedances. Tunable probe is consists of a crystal detector and a small wire antenna in coaxial housing. Its depth of penetration into the slotted section is variable.



Slotted line carriage:

A slotted line carriage contains a coaxial E-field. When penetrates inside a rectangular waveguide slotted section or a coaxial slotted line section from the outer wall and is able to transverse a longitudinal narrow slot. The longitudinal slot is cut along the center of the waveguides broad wall or along the outer conductor of the coaxial lone over a length of 2-3 wavelengths where the electric current on the wall does not have any transverse component. The slot should be narrow enough to avoid any distortion in the original field inside the waveguide.



4. **Power is the energy dissipated or stored per unit time, search for the operation of sensors used in microwave power measurement like bolometer sensor, schottky barrier diodes and thermocouples?**

Bolometer sensor:

A bolometer is a device for measuring the power of incident electromagnetic radiation via the heating of a material with a temperature-dependent electrical. Bolometers are directly sensitive to the energy left inside the absorber. For this reason they can be used not only for ionizing particles and photons, but also for non-ionizing particles, any sort of radiation, and even to search for unknown forms of mass or energy like dark matter this lack of discrimination can also be a shortcoming. The most sensitive bolometers are very slow to reset (i.e., return to thermal equilibrium with the environment). On the other hand, compared to more conventional particle detectors, they are extremely efficient in energy resolution and in sensitivity. They are also known as thermal detectors.

Schottky barrier diodes:

Scotty barriers, with their lower junction voltage, find application where a device better approximating an ideal diode is desired. They are also used in conjunction with normal diodes and transistors, where their lower junction voltage is used for circuit protection among other things.

Because one of the materials in a Schottky diode is a metal, lower resistance devices are often possible. In addition, the fact that only one type of doping is needed may greatly simplify fabrication. And because of their majority carrier conduction mechanism, Schottky diodes can achieve greater switching speeds than p-n junction diodes, making them appropriate to rectify high frequency signals.

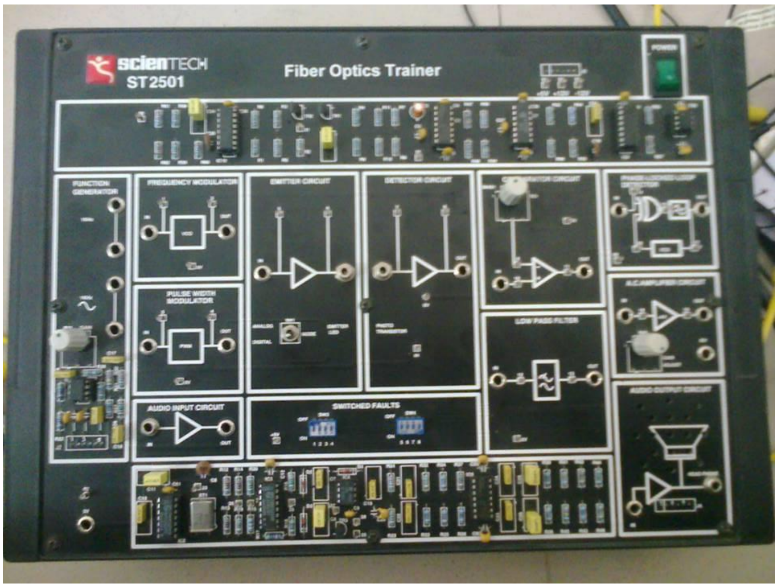
Thermocouples:

A thermocouple consists of two conductors of different materials (usually metal alloys) that produce a voltage in the vicinity of the point where the two conductors are in contact. The voltage produced is dependent on, but not necessarily proportional to, the difference of temperature of the junction to other parts of those conductors. Thermocouples are a widely used type of temperature sensor for measurement and control and can also be used to convert a temperature gradient into electricity. Commercial thermocouples are inexpensive, interchangeable, are supplied with standard connectors, and can measure a wide range of temperatures. In contrast to most other methods of temperature measurement, thermocouples are self powered and require no external form of excitation. The main limitation with thermocouples is accuracy; system errors of less than one degree Celsius (°C) can be difficult to achieve.

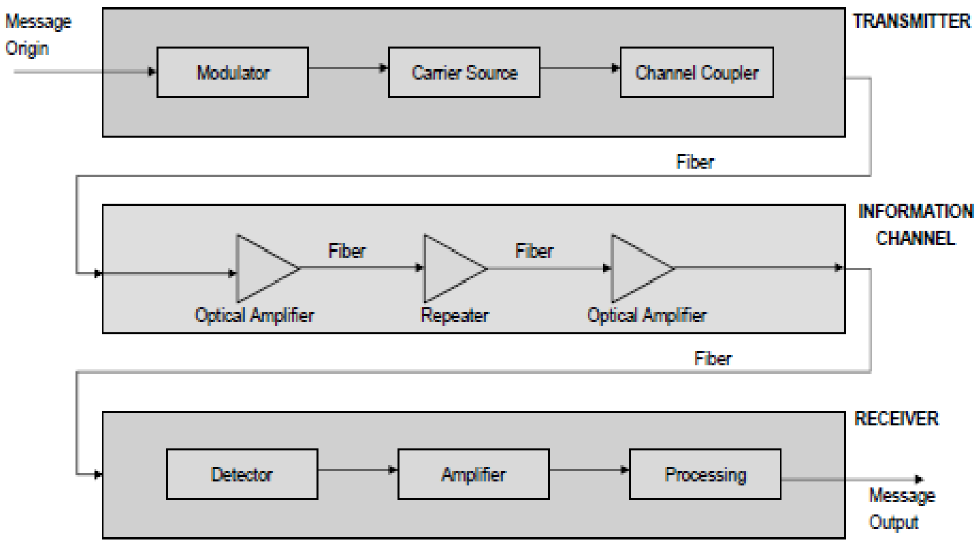
Lab Assignment No.8

To Study The Fiber Optic, Analogue Link And Study The Relationship Between The Input And Output Received Signal

Apparatus:



Block Diagram:



Theory:

An optical fiber is a flexible, transparent fiber made of high quality extruded glass or plastic, slightly thicker than a human hair. It can function as a waveguide to transmit light between the two ends of the fiber. Power over Fiber optic cables can also work to deliver an electric current for low power electric devices. The field of applied science and engineering concerned with the design and application of optical fibers is known as fiber optics.

Questions

1. **What is meant by index profile?**

For an optical fiber, a step-index profile is a refractive index profile characterized by a uniform refractive index within the core and a sharp decrease in refractive index at the core-cladding interface so that the cladding is of a lower refractive index. The step-index profile corresponds to a power-law index profile with the profile parameter approaching infinity. The step-index profile is used in most single-mode fibers and some multimode fibers.

A step-index fiber is characterized by the core and cladding refractive indices n_1 and n_2 and the core and cladding radii a and b.

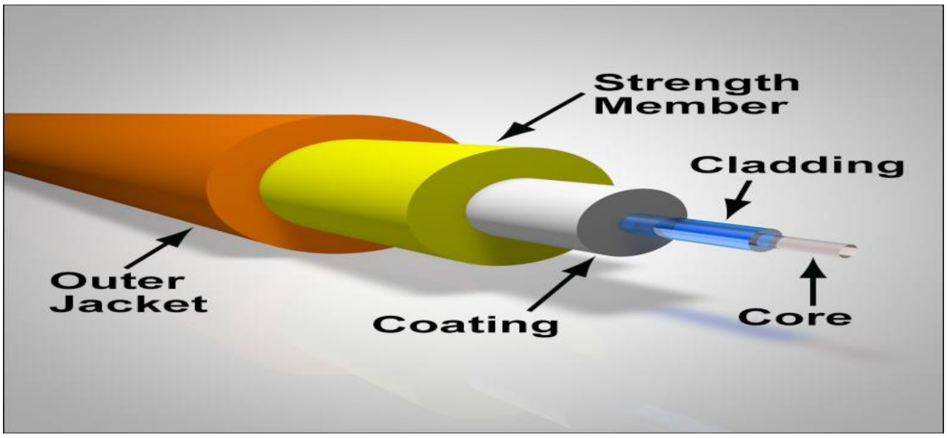
The fractional refractive-index change

$$\triangle = \frac{n_1 - n_2}{n_1} \ll 1$$

The value of n_1 is typically between 1.44 and 1.46,

and $\triangle$ is typically between 0.001 and 0.02.

Step-index optical fiber is generally made by doping high-purity fused silica glass (SiO_2) with different concentrations of materials like titanium, germanium, or boron.



2. What are the characteristics of multimode fiber?

Multi-mode optical fiber is a type of optical fiber mostly used for communication over short distances, such as within a building or on a campus.

Typical multimode links have data rates of 10 Mbit/s to 10 Gbit/s over link lengths of up to 600 meters (2000 feet) — more than sufficient for the majority of premises applications.

Multi-mode fibers are described by their core and cladding diameters. Thus, 62.5/125 µm multi-mode fiber has a core size of 62.5 micrometres (µm) and a cladding diameter of 125 µm. The transition between the core and cladding can be sharp, which is called a step-index profile, or a gradual transition, which is called a graded-index profile. The two types have different dispersion characteristics and thus different effective propagation distance. Multi-mode fibers may be constructed with either graded or step index profile.

3. **What is fiber optics?**

An optical fiber is a flexible, transparent fiber made of high quality extruded glass or plastic, slightly thicker than a human hair. It can function as a waveguide to transmit light between the two ends of the fiber. Power over Fiber optic cables can also work to deliver an electric current for low power electric devices. The field of applied science and engineering concerned with the design and application of optical fibers is known as fiber optics.

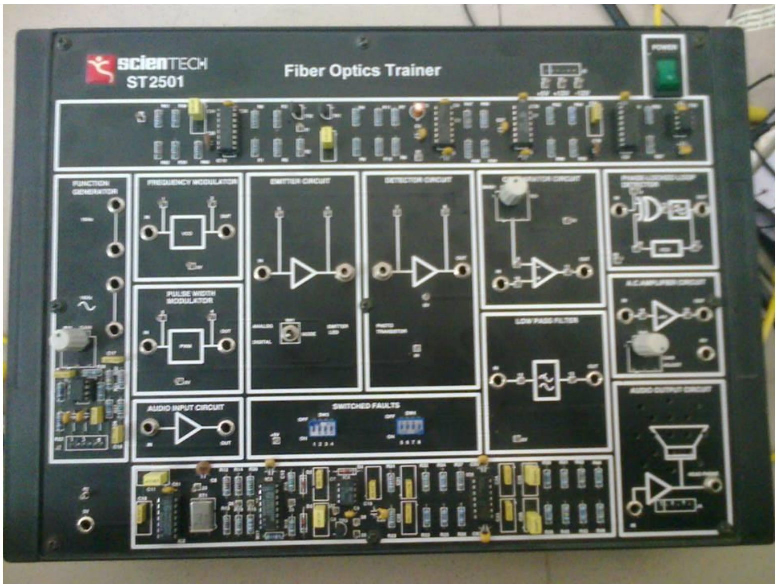
Optical fibers are widely used in fiber-optic communications, which permits transmission over longer distances and at higher bandwidths than other forms of communication. Fibers are used instead of metal wires because signals travel along them with less loss and are also immune to electromagnetic interference. Fibers are also used for illumination, and are wrapped in bundles so that they may be used to carry images, thus allowing viewing in confined spaces. Specially designed fibers are used for a variety of other applications, including sensors and fiber lasers.

Optical fibers typically include a transparent core surrounded by a transparent cladding material with a lower index of refraction. Light is kept in the core by total internal reflection. This causes the fiber to act as a waveguide. Fibers that support many propagation paths or transverse modes are called multi-mode fibers (MMF), while those that only support a single mode are called single-mode fibers (SMF). Multi-mode fibers generally have a wider core diameter, and are used for short-distance communication links and for applications where high power must be transmitted. Single-mode fibers are used for most communication links longer than 1,000 meters (3,300 ft).

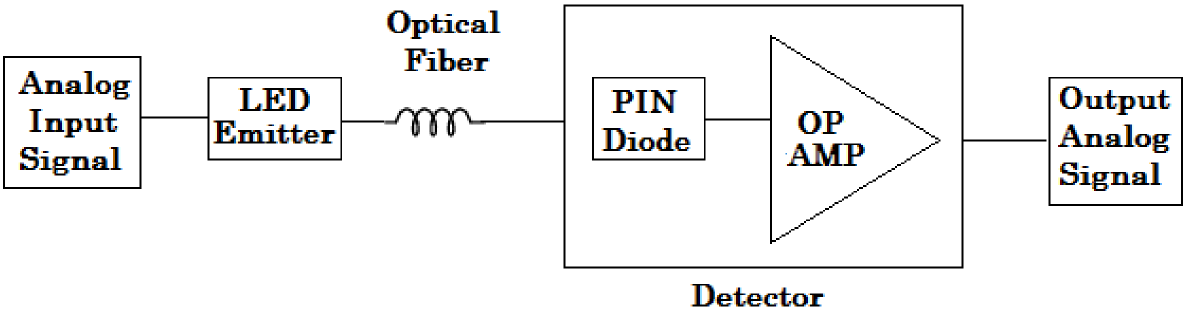
Lab Assignment No.9

To Obtain The Intensity Modulation Of Analog Signal Transmit It Over A Fiber Optical Link & Demodulate The Same At Receiver End To Retrieve The Original Signal

Apparatus:



Block Diagram:



Questions

1. **What is the function of transmitter, optical fiber & Receiver?**

The most commonly used optical transmitters are semiconductor devices such as light-emitting diodes and laser diodes. The difference between LEDs and laser diodes is that LEDs produce incoherent light, while laser diodes produce coherent light.

In its simplest form, an LED is a forward-biased p-n junction, emitting light through spontaneous emission, a phenomenon referred to as electro luminescence. The emitted light is incoherent with a relatively wide spectral width of 30-60 nm.

LED light transmission is also inefficient, with only about 1% of input power, or about 100 microwatts, LEDs are suitable primarily for local-area-network applications with bit rates of 10-100 Mbit/s and transmission distances of a few kilometers.

A semiconductor laser emits light through stimulated emission rather than spontaneous emission, which results in high output power (~100 mW) as well as other benefits related to the nature of coherent light. The output of a laser is relatively directional, allowing high coupling efficiency (~50 %) into single-mode fiber. The narrow spectral width also allows for high bit rates since it reduces the effect of chromatic dispersion. Furthermore, semiconductor lasers can be modulated directly at high frequencies because of short recombination time.

The main component of an optical receiver is a photodetector, which converts light into electricity using the photoelectric effect. The primary photodetectors for telecommunications are made from Indium gallium arsenide The photodetector is typically a semiconductor-based photodiode.

Several types of photodiodes include p-n photodiodes, p-i-n photodiodes, and avalanche photodiodes. Metal-semiconductor-metal (MSM) photodetectors are also used due to their suitability for circuit integration in regenerators and wavelength-division multiplexers.

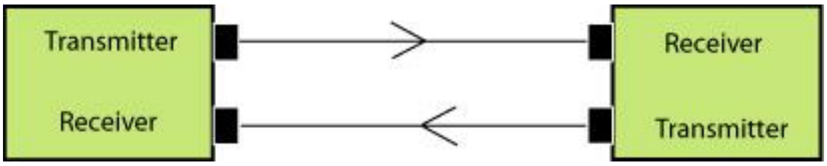
Optical-electrical converters are typically coupled with a transimpedance amplifier and a limiting amplifier to produce a digital signal in the electrical domain from the incoming optical signal, which may be attenuated and distorted while passing through the channel.

An optical fiber cable consists of a core, cladding, and a buffer, in which the cladding guides the light along the core by using the method of total internal reflection.

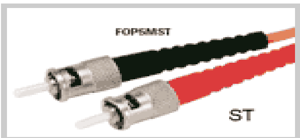
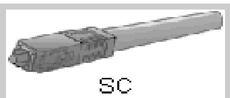
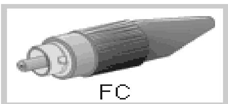
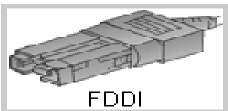
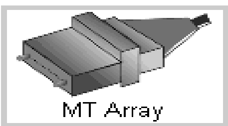
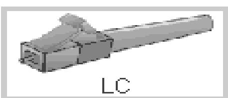
Connecting two optical fibers is done by fusion splicing or mechanical splicing and requires special skills and interconnection technology due to the microscopic precision required to align the fiber cores.

Two main types of optical fiber used in optic communications include multi-mode optical fibers and single-mode optical fibers. A multi-mode optical fiber has a larger core ($\geq$ 50 micrometers), allowing less precise, cheaper transmitters and receivers to connect to it as well as cheaper connectors. However, a multi-mode fiber introduces multimode distortion, which often limits the bandwidth and length of the link.

2. **Where optical fiber links can be used?**



Fiber optic links work by sending optical signals over fiber. Fiber optic transmission systems all use data links that work similar to the diagram shown above. Each fiber link consists of a transmitter on one end of a fiber and a receiver on the other end. Most systems operate by transmitting in one direction on one fiber and in the reverse direction on another fiber for full duplex operation. Transmitters are semiconductor LEDs or lasers and receivers are semiconductor photodetectors.

	Used in inter/intra building, security, Navy and industrial applications (also used with some B&B Electronics products)
 	Used in data communications and telecommunications applications (also used with some B&B Electronics products)
	Used in data communications and telecommunications applications
	Used in some fiber optic networks
 	Used where high density interconnections are required

3. Intensity Modulation of analog signal in fiber optics

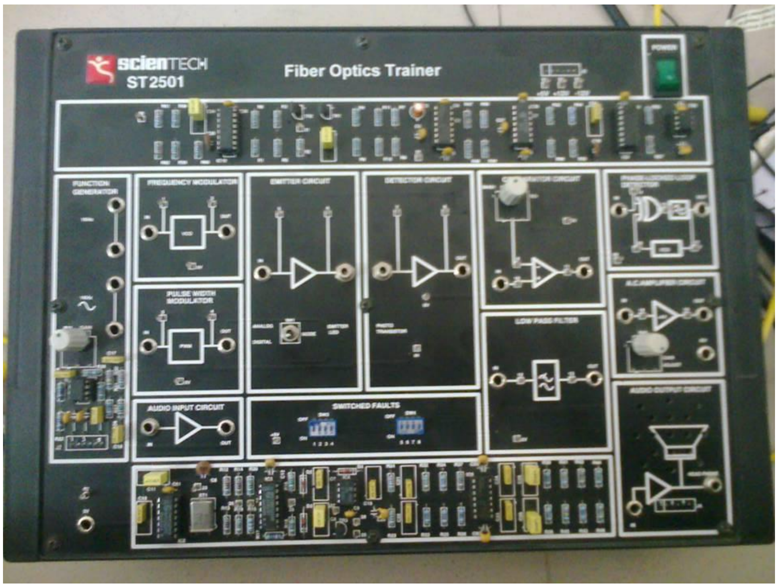
In fiber optic communications systems, modulation in which the optical power output of a source is varied in accordance with some characteristic of the modulating signal, i.e., the baseband signal or the information-bearing signal. Common abbreviation IM.

In intensity modulation, there are no discrete upper and lower sidebands in the usually understood sense of these terms. However, the output of an optical source does have a spectral width. The envelope of the modulated optical signal is an analog of the modulating signal in that the instantaneous power of the envelope is an analog of the characteristic of interest in the modulating signal. Recovery of the modulating signal usually is by direct detection rather than by heterodyning as in radio receivers. If coherent light is used, detection can be accomplished by heterodyning.

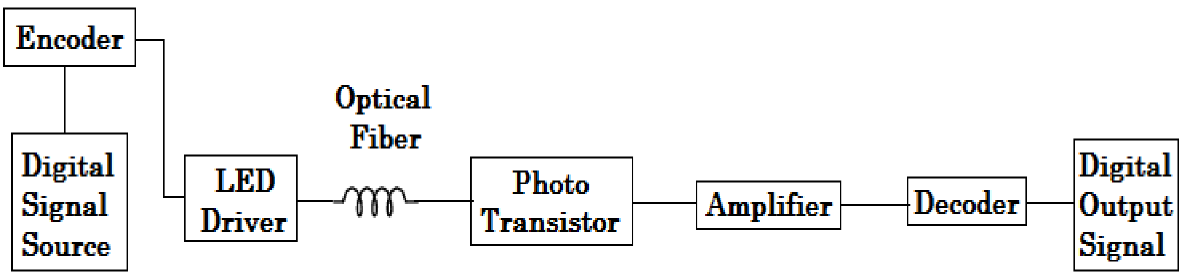
Lab Assignment No.10

To Obtain The Intensity Modulation Of Digital Signal Transmit It Over A Fiber Optical Link & Demodulate The Same At Receiver End To Retrieve The Original Signal

Apparatus:



Block Diagram:



Questions

1. What is the function of laser Encoder , decoder and Comparator?

A laser incremental encoder with autofocus operation is proposed. In the encoder, an optical read head focuses three laser beams upon a disk with a scaling grating. The scaling grating is a reflection grating for which the height difference between adjacent pixels is one quarter of the wavelength of the laser.

Each of the two laser beams is focused onto one of the two sections of the reflective grating, whereby the pitch of the grating can be detected by inter ferometric reflection. The third beam acts to provide autofocus and is reflected from a smooth part between the two sections of the reflective grating. Therefore the encoder is less sensitive to the gap between the optical read head and the scaling grating, and no precision adjustment is required.

A decoder takes input from an attached laser scanner decodes it then transmits the collected data to its host.

The basic concept of the comparator is that a part is affixed to a stage, a light source shines on it, and the resulting shadow image of the part is magnified with lenses and bounced by mirrors, to be projected on the back of a screen for magnified viewing, pretty much just like our overhead projector example.

Based on the known magnification of the lenses, measurements of the part can be made directly off the screen, using (traditionally) a screen overlay or crosshairs as the reference point for projected points or edges. The operator centers a feature of interest on the crosshairs, records a point, then moves the image and records another point.

2. How the modulated signal is detected?

Detection methods for digitally modulated optical signals are classified most logically using traditional distinctions.

In non coherent detection, only the presence or absence of energy is ascertained, and no phase information is recovered. We consider non coherent detection of M-level intensity modulation, referred to as M-ary pulse-amplitude modulation (M-PAM).

In differentially coherent detection, the phase in one symbol is compared to the phase in the previous symbol. We consider differentially coherent detection of M-ary differential phase-shift keying (M-DPSK).

In coherent detection, a signal is detected using a carrier phase reference generated at the receiver. We consider coherent detection of M-ary phase-shift keying (M-PSK) or M-ary quadrature-amplitude modulation (M-QAM)

Table 1. Classification of detection techniques.

Detection Technique	Heterodyne or Homodyne Implementation	Direct Detection Implementation	Modulation Techniques Considered	Class of Technique
Noncoherent	Envelope detection	Direct detection	PAM	Asynchronous
Differentially coherent	Delay-and-multiply detection	Interferometric detection	DPSK	
Coherent	Coherent detection	—	PSK, QAM	Synchronous

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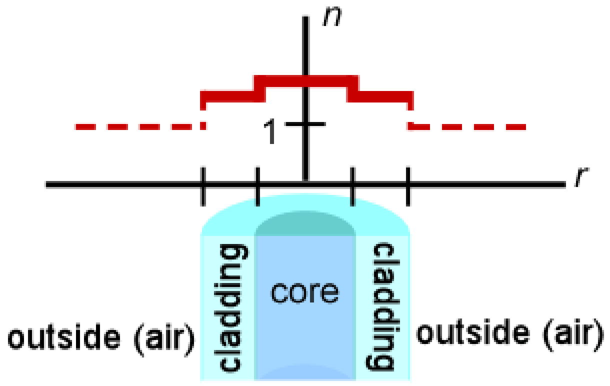
In intensity modulation, there are no discrete upper and lower sidebands in the usually understood sense of these terms. However, the output of an optical source does have a spectral width. The envelope of the modulated optical signal is an analog of the modulating signal in that the instantaneous power of the envelope is an analog of the characteristic of interest in the modulating signal. Recovery of the modulating signal usually is by direct detection rather than by heterodyning as in radio receivers. If coherent light is used, detection can be accomplished by heterodyning.

4. What is step index fiber & how propagation losses are measured?

For an optical fiber, a step-index profile is a refractive index profile characterized by a uniform refractive index within the core and a sharp decrease in refractive index at the core-cladding interface so that the cladding is of a lower refractive index. The step-index profile corresponds to a power-law index profile with the profile parameter approaching infinity. The step-index profile is used in most single-mode fibers and some multimode fibers.

A step-index fiber is characterized by the core and cladding refractive indices n_1 and n_2 and the core and cladding radii a and b

All plastic fibers are limited to very short paths by their high propagation losses.
Path lengths are usually less than a few tens of meters.
Large acceptance angles improve coupling efficiency.



Attenuation is the opposite of amplification, and is normal when a signal is sent from one point to another. If the signal attenuates too much, it becomes unintelligible, which is why most networks require repeaters at regular intervals. Attenuation is measured in decibels.

All fiber cabling has losses from absorption and back reflection of the light caused by impurities in the glass. Attenuation is a function of wavelength and needs to be specified or measured at the wavelength in use.