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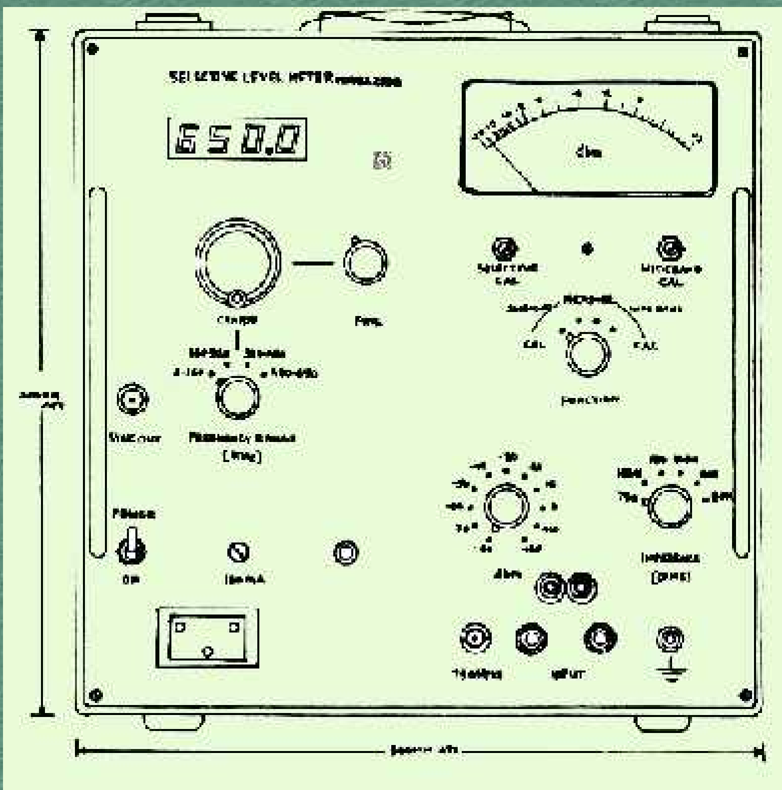
MEASURING INSTRUMENTS



Indian Railways Institute of
Signal Engineering and Telecommunications
SECUNDERABAD - 500 017

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INDIAN RAILWAYS INSTITUTE OF SIGNAL ENGINEERING & TELECOMMUNICATIONS, SECUNDERABAD - 500 017

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MEASURING INSTRUMENTS

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CHAPTER-1

INTRODUCTION TO MEASURING INSTRUMENTS

1.0 GENERAL

The term measuring instrument is commonly used to describe a measurement system, whether it contains only one or many elements. A measuring system exists to provide information about the physical value of some variable being measured. In simple cases, the system can consist of only a single unit that gives an output reading or signal according to the magnitude of the unknown variable applied to it.

Fig.1.1 Typical block diagram of a measuring instrument

The first element in any measuring system is the primary sensor; this gives an output that is a function of the measurand (the input applied to it). For most but not all sensors, this function is at least approximately linear. The second stage is a variable conversion element. It is needed where the output variable of a primary transducer is in an inconvenient form and has to be converted to a more convenient form. For example the resistance change cannot be easily measured and so it is converted to a change in voltage by a bridge circuit. In some cases, the primary sensor and variable conversion element are combined, and the combination is known as a transducer.

The next element in a measurement system is the point where the measured signal is utilized. In some cases, this element is omitted altogether because the measurement is used as part of an automatic control scheme, and the transmitted signal is fed directly into the control system. In other cases, this element in the measurement system takes the form either of a signal presentation unit or of a signal-recording unit.

These take many forms according to the requirements of the particular measurement application, and the range of possible units is applied to the display system.

1.1 Types of Measuring Instruments

Measuring instruments are classified as

- Indicating
- Recording
- Integrating

Indicating instruments are those, which indicate the magnitude of a quantity, being measured.

Recording instruments give a continuous record of the quantity being measured, on paper roll extending over selected period of time.

Integrating instruments give the total amount of energy over a period of time. The summation is the product of time and an electrical quantity.

Today irrespective of type of meter, all are classified as analog and digital meters.

1.2 Analog and Digital instruments

An analog instrument gives an output that varies continuously as the quantity being measured changes. The output can have an infinite number of values within the range that the instrument is designed to measure.

A digital instrument has an output that varies in discrete steps and so can only have a finite number of values.

1.3 GENERAL INSTRUMENTS

The instruments which are most commonly used in telecommunication systems are volt meter, ammeter and an ohm meter.

The above said meters integrated into one unit are called as multi meters.

The basic principle of operation of an analog meter is of moving coil meters based on galvanometer sensors. An analog multimeter has a core function of current-to-display conversion.

1.3.1 Moving Coil Meters

The design of a voltmeter, ammeter or ohmmeter begins with a current-sensitive element. Though most modern meters have solid state digital readouts, the physics is more readily demonstrated with a moving coil current detector called a galvanometer. Since the modifications of the current sensor are compact, it is practical to have all three functions in a single instrument with multiple ranges of sensitivity. Schematically, a single range "multimeter" might be designed as shown in fig. 1.2

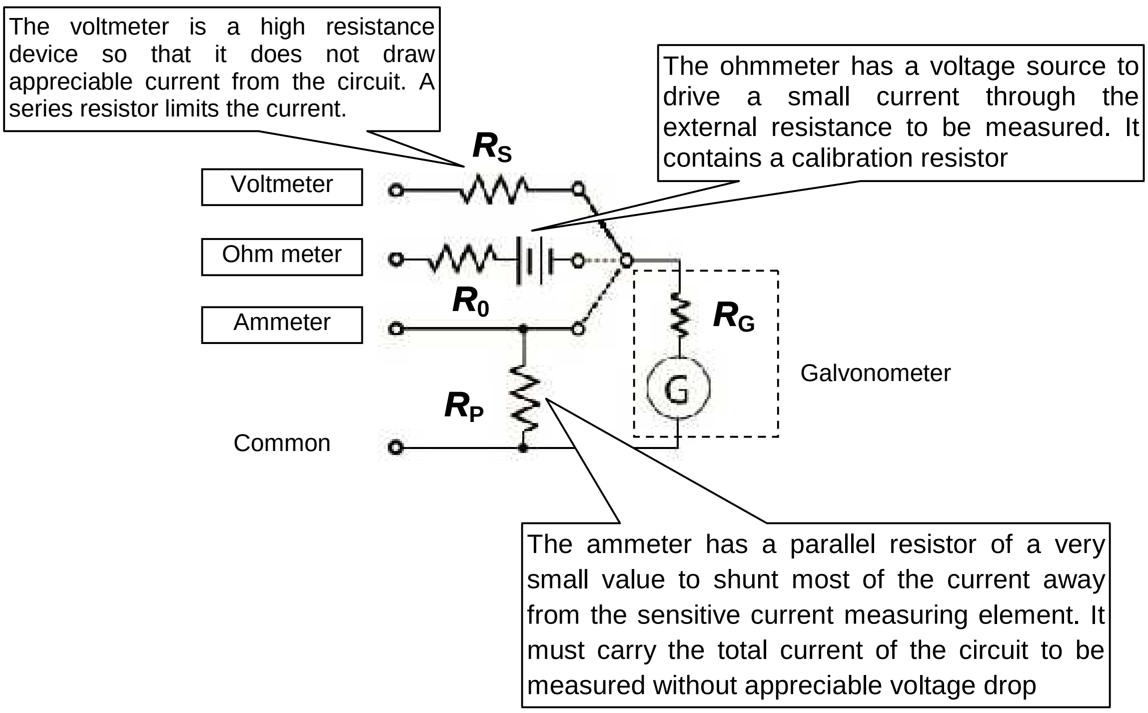

Fig.1.2 Schematic diagram of a moving coil analog multimeter

A current through the coil of a d'Arsonval movement creates a magnetic field that deflects a rotating, pivoted permanent magnet with an attached needle and a restoring spring. Needle deflection is proportional to the current. The range of applied currents is very narrow, such as 0-50 microamperes, and is adjusted to the signal under test by building a resistor network inside the meter box and choosing the combination to be used for each scale with a switch of some type. Overall accuracy is directly proportional to the accuracy of the resistors. For resistance testing, a battery inside the box provides a current source, and the needle is zeroed by shorting the test leads together and adjusting a built-in series potentiometer until the needle reads zero ohms (actually set to full scale). Adding the resistor under test reduces the current, in a logarithmic way that can be read on a reversed (zero on the right) and very nonlinear scale.

1.3.2 Voltmeter/Ammeter Measurements

A **voltmeter** is an instrument used for measuring the electrical potential difference between two points in an electric circuit i.e, it measures the change in voltage between two points in an electric circuit and therefore, it must be connected in parallel with the portion of the circuit on which the measurement is made.

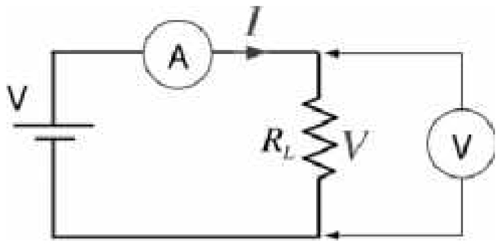

Fig 1.3 schematic diagram for voltage and current measurement

A moving coil galvanometer can be used as a voltmeter by inserting a resistor in series with the instrument. It employs a small coil of fine wire suspended in a strong magnetic field. When an electric current is applied, the galvanometer's indicator rotates and compresses a small spring. The angular rotation is proportional to the current through the coil. For use as a voltmeter, a series resistance is added so that the angular rotation becomes proportional to the applied voltage. Moving-coil instruments with a permanent - magnet field respond only to direct current.

An **ammeter** is an instrument for measuring the electric current in amperes in a branch of an electric circuit. It must be placed in series with the branch, and must have very low resistance to avoid significant alteration of the current it is to measure.

One of the design objectives of the instrument is to disturb the circuit as little as possible and so the instrument should draw a minimum of current to operate. This is achieved by using a sensitive ammeter or micro ammeter in series with a high resistance. The sensitivity of such a meter can be expressed as "ohms per volt", the number of ohms resistance in the meter circuit divided by the full scale measured value. For example a meter with sensitivity of 1000 ohms per volt would draw 1 milli ampere at full scale voltage; if the full scale was 200 volts, the resistance at the instrument's terminals would be 200,000 ohms and at full scale the meter would draw 1 milli ampere from the circuit under test.

For multi-range instruments, the input resistance varies as the instrument is switched to different ranges.

1.3.3 Ohmmeter

An **Ohm meter** is an instrument to measure resistance in ohms. It supplies a constant voltage to the resistance to be measured and measures the current through it. That current is inversely proportional to the resistance according to Ohm's law, so it has a non-linear scale.

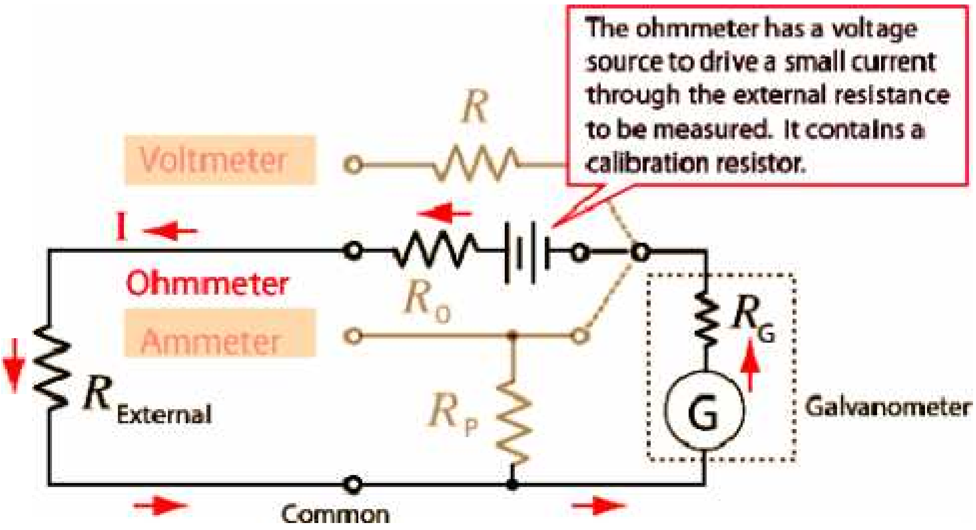

Fig1.4 Schematic for resistance measurement

1.4 Digital Multimeter- Principle of Operation

All types of digital meters are basically modified forms of the digital voltmeter (DVM) irrespective of the quantity that they are designed to measure. Digital meters designed to measure quantities other than voltage are in fact digital voltmeters that contain appropriate electrical circuits to convert current or resistance measurement signals into voltage signals. Digital multimeters are also essentially digital voltmeters that contain several conversion circuits, thus allowing the measurement of voltage, current and resistance within one instrument.

Digital meters have been developed to satisfy a need for higher measurement accuracies and a faster speed of response to voltage changes than can be achieved with analogue instruments. They are technically superior to analogue meters in almost every respect.

The input voltage, current or ohm signals are conditioned by the function and selector switches to produce and output DC voltage between 0 and +199mV. If the input signal is 100VDC, it is reduced to 100mV DC by selecting a 1000:1 divider. If the input is 100VAC, then after the divider it is processed by the AC converter to produce 100mVDC. If current is to be read, it is converted to a DC voltage via internal shunt resistors. For resistance measurements, an internal voltage source supplies the necessary 0-199mV voltage to be fed to the input.

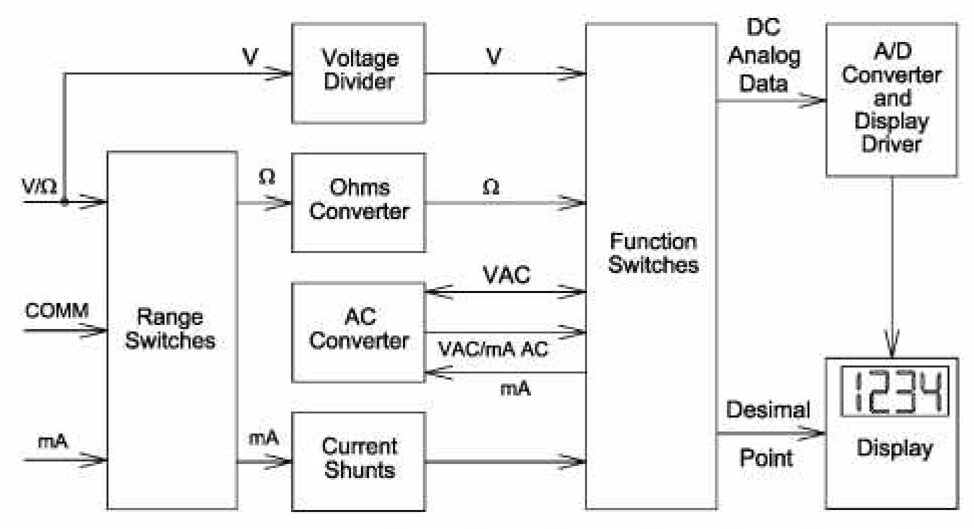

Fig1.5 Typical block diagram of a digital multimeter

The output of the function switch is fed to an A/D (analog to digital) converter. Here the DC voltage amplitude is changed into a digital format. The resulting signals are processed in the decoders to light the appropriate LCD segment. Timing for the overall operation of the A/D converter is derived from an external oscillator whose frequency is selected to be 40 kHz. In the function switch, this frequency is divided by four before it clocks the decade counters. It is further divided to form the three convert-cycle phases. The final readout is clocked at about three readings per second.

Digitized measurements data is presented to the display as four decoded digits (seven segments) plus polarity. Decimal point position on the display is determined by the selector switch setting

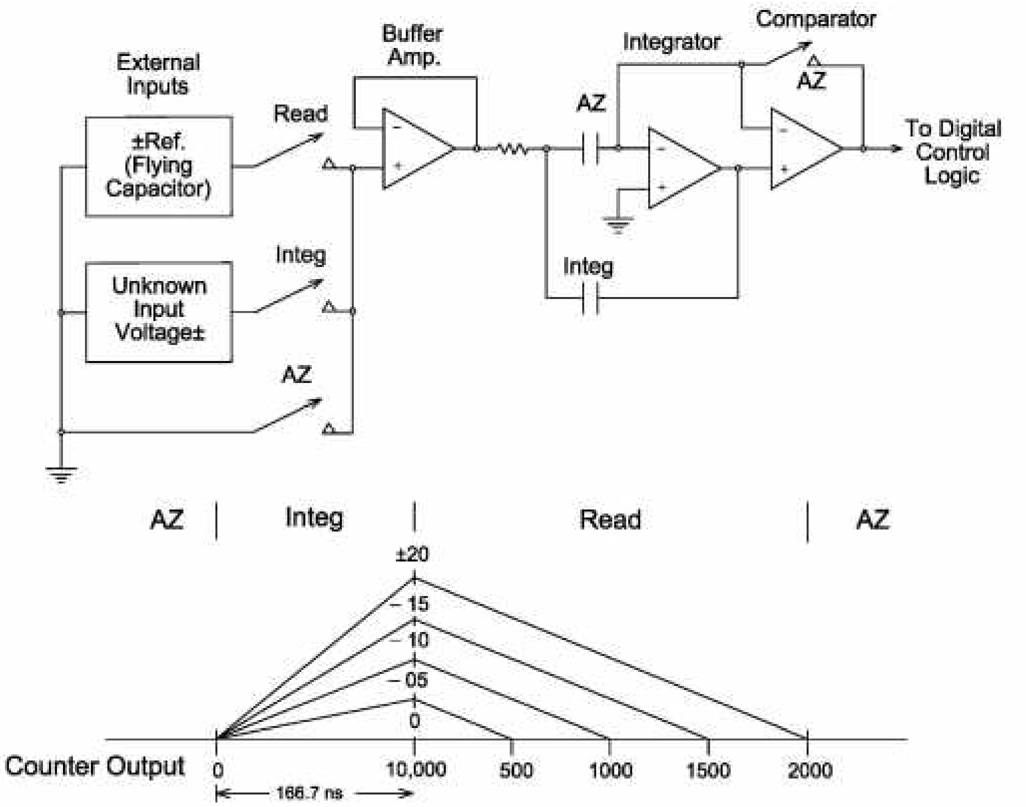

Fig1.6 Simplified circuit diagram of the analog portion of the A/D converter

A simplified circuit diagram of the analog portion of the A/D converter is shown in Figure 1.6. Each of the switches shown represents analog gates which are operated by the digital section of the A/D converter. Basic timing for switch operation is keyed by an external oscillator. The conversion process is continuously repeated.

Any given measurement cycle performed by the A/D converter can be divided into three consecutive time periods: **auto zero (AZ), integrate (INTEG) and READ**. Both auto zero and integrate are fixed time periods. A counter determines the length of both time periods by providing an overflow at the end of every 1,000 clock pulses. The read period is a variable time, which is proportional to the unknown input voltage. The value of the voltage is determined by counting the number of clock pulses that occur during the read period.

During auto zero, a ground reference is applied as an input to the A/D converter. Under ideal conditions the output of the comparator would also go to zero. However, input-offset-voltage errors accumulate in the amplifier loop, and appear at the comparator output as an error voltage. This error is impressed across the AZ capacitor where it is stored for the remainder of the measurement cycle. The stored level is used to provide offset voltage correction during the integrate and read periods. The integrate period begins at the end of the auto zero period. As the period begins, the AZ switch opens and the INTEG switch closes. This applies the unknown input voltage to the input of the A/D converter. The voltage is buffered and passed on to the integrator to determine the charge rate (slope) on the INTEG capacitor. At the end of the fixed integrate period, the capacitor is charged to a level proportional to the unknown input voltage. This voltage is translated to a digital indication by discharging the capacitor at a fixed rate during the read period, and counting the number of clock pulses that occur before it returns to the original auto zero level. As the read period begins, the INTEG switch opens and the read switch closes. This applies a known reference voltage to the input of the A/D converter. The polarity of this voltage is automatically selected to be opposite that of unknown input voltage, thus causing the INTEG capacitor to discharge as fixed rate (slope). When the charge is equal to the initial starting point (auto zero level), the read period is ended. Since the discharge slope is fixed during the read period, the time required is proportional to the unknown input voltage. The auto zero period and thus a new measurement cycle begins at the end of the read period. At the same time, the counter is released for operation by transferring its contents (previous measurement value) to a series of latches. This stored stat is then decoded and buffered before being used for driving the LCD display.

Note that there are 3- and 4-digit (and more) DMMs, plus 3-1/2, 3-3/4, 4-1/2, etc. A 3-1/2 digit meter reads 000-999 plus 1000 to 1999. Since this is twice as high as a 3-digit meter can read, it is arbitrarily called a 3-1/2 digit. A seven-segment display for this only needs the two segments that make up a "1" to perform this function. A 3-3/4 digit meter reads 000-3999, doubling the range again, but saving only one segment compared to a full 4-digit display. One could define a 3-7/8 digit meter as extending to 7999, and use a regular 4-digit display, but this is not normally done, since you are practically at the next level but probably have to charge less for it.

1.4.1 VOLTAGE MEASUREMENT

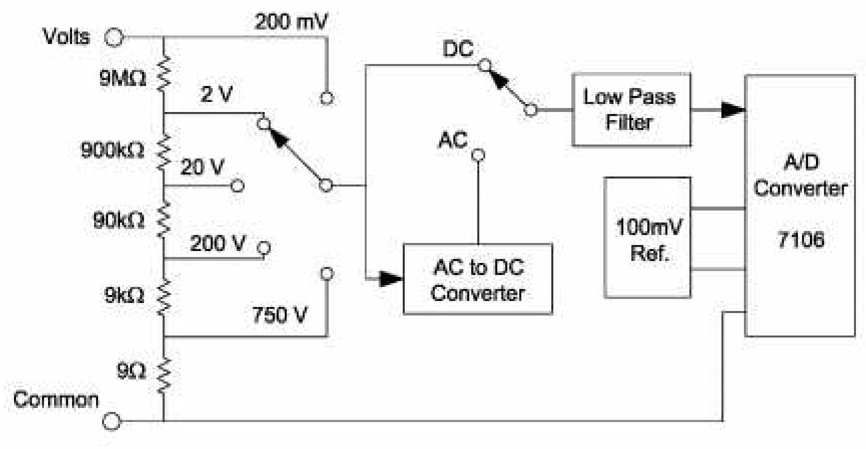

Fig1.7 Simplified Voltage Measurement Diagram

The input divider resistors add up 10MΩ with each step being a division of 10. The divider output should be within –0.199 to +0.199V or the overload indicator will function. If the AC function is selected, the divider output is AC coupled to a full wave rectifier and the DC output is calibrated to equal the rms level of the AC input.

1.4.2 CURRENT MEASUREMENT

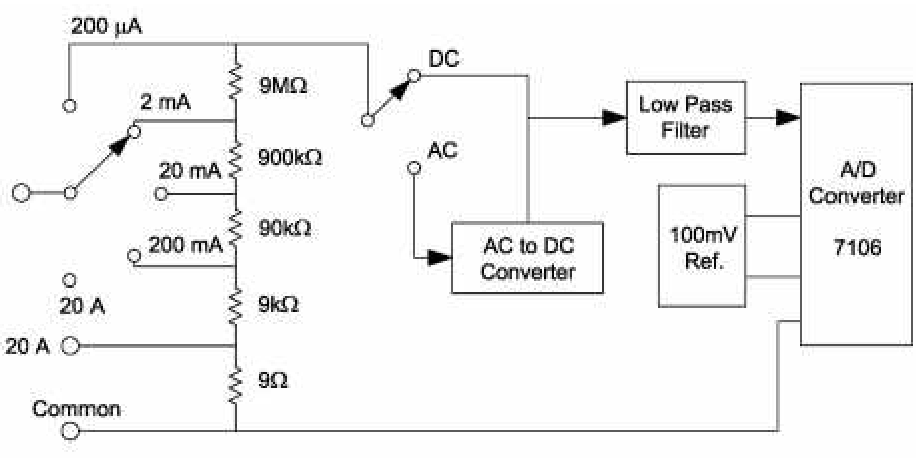

Fig1.8 Simplified Current Measurement Diagram

Figure 1.8 shows a simplified diagram of the current measurement positions. Internal shunt resistors convert the current to between –0.199 to and 0.199V which is then processed in the IC to light the appropriate LCD segments. If the current is AC in nature, the AC converter changes it to the equivalent DC value.

1.4.3 RESISTANCE MEASUREMENTS

A simple series circuit is formed by the voltage source, a reference resistor from the voltage divider (selected by range switches), and the external unknown resistor. The ratio of the two resistors is equal to the ratio of their respective voltage drops. Therefore, since the value of one resistor is known, the value of the second can be determined by using the voltage drop across the known resistor as a reference. This determination is made directly by the A/D converter

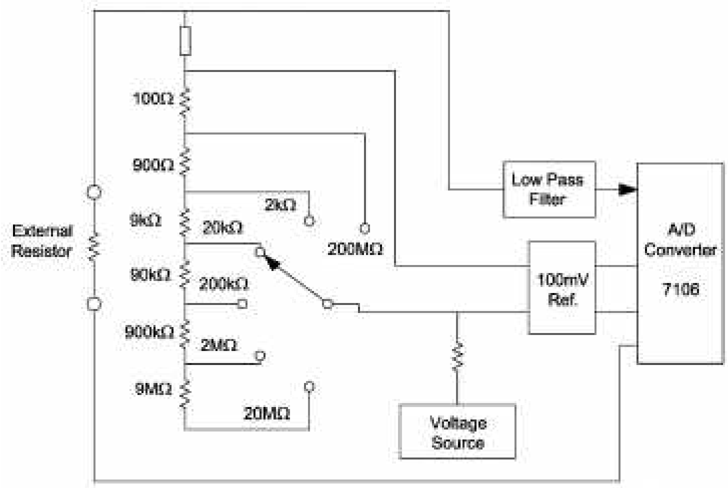

Fig1.9 Simplified Resistance Measurement Diagram

1.5 ESSENTIAL QUALITIES OF A GOOD METER

SENSITIVITY: Refers to the smallest value of the physical property that is detectable.

RESOLUTION: Smallest change in a physical property that causes a change in the Sensory output.

For example, human can detect loudness variations of about 1dB, while a sound level Meter may detect changes as small as 0.001dB.

RANGE: The range or span of an instrument defines the minimum and maximum values of a quantity that the instrument is designed to measure.

LINEARITY: It is normally desirable that the output reading of an instrument is linearly proportional to the quantity being measured. Specifies how sensitivity varies range. For example, we can usually hear frequencies between 20Hz and 20 KHz, our hearing is most sensitivity to loudness variation at frequencies from 0.3KHz to 5KHz.

PRECISION: Refers to the reproducibility or repeatability of an observation.

The terms **repeatability and reproducibility** mean approximately the same but are applied in different contexts as given below.

Repeatability describes the closeness of output readings when the same input is applied repetitively over a short period of time, with the same measurement conditions, same instrument and observer, same location and same conditions of use maintained throughout.

Reproducibility describes the closeness of output readings for the same input when there are changes in the method of measurement, observer, measuring instrument, location, conditions of use and time of measurement.

Both terms thus describe the spread of output readings for the same input. This spread is referred to as repeatability if the measurement conditions are constant and as reproducibility if the measurement conditions vary.

LAG AND SETTING TIME: Refers to the amount of time that lapses between the initiation of an observation and the final output of information.

1.6 Errors during the measurement process

Errors in measurement systems can be divided into those that arise during the measurement process and those that arise due to later corruption of the measurement signal by induced noise during transfer of the signal from the point of measurement to some other point.

It is extremely important in any measurement system to reduce errors to the minimum possible level and then to quantify the maximum remaining error that may exist in any instrument output reading. However, in many cases, there is a further complication that the final output from a measurement system is calculated by combining together two or more measurements of separate physical variables. In this case, special consideration must also be given to determining how the calculated error levels in each separate measurement should be combined together to give the best estimate of the most likely error magnitude in the calculated output quantity.

Errors arising during the measurement process can be divided into two groups, known as **systematic errors and random errors.**

1.6.1 Systematic errors describe errors in the output readings of a measurement system that are consistently on one side of the correct reading, i.e. either all the errors are positive or they are all negative. Two major sources of systematic errors are system disturbance during measurement and the effect of environmental changes (modifying inputs)

1.6.1.1 Sources of systematic error

Systematic errors in the output of many instruments are due to factors inherent in the manufacture of the instrument arising out of tolerances in the components of the instrument. They can also arise due to wear in instrument components over a period of time. In other cases, systematic errors are introduced either by the effect of environmental disturbances or through the disturbance of the measured system by the act of measurement

System disturbance due to measurement

Disturbance of the measured system by the act of measurement is a common source of systematic error.

Measurements in electric circuits

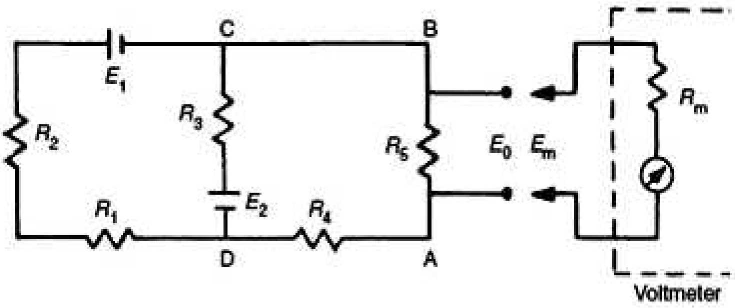

Fig1.10 Analysis of circuit loading: a circuit in which the voltage across *R*5 is to be measured

In analyzing system disturbance during measurements in electric circuits, Th´evenin's theorem is often of great assistance. For instance, consider the circuit shown in Fig.1.10. in which the voltage across resistor R5 is to be measured by a voltmeter with resistance Rm. Here, Rm acts as a shunt resistance across R5, decreasing the resistance between points AB and so disturbing the circuit. Therefore, the voltage Em measured by the meter is not the value of the voltage E0 that existed prior to measurement. The extent of the disturbance can be assessed by calculating the open circuit voltage E0 and comparing it with Em.

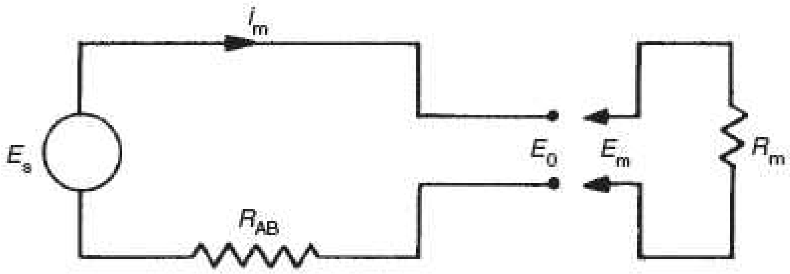

Fig1 .11 equivalent circuit by The´ venin's theorem

Th´evenin's theorem allows the circuit of Figure 10. comprising two voltage sources and five resistors to be replaced by an equivalent circuit containing a single resistance and one voltage source, as shown in Figure 1.11.

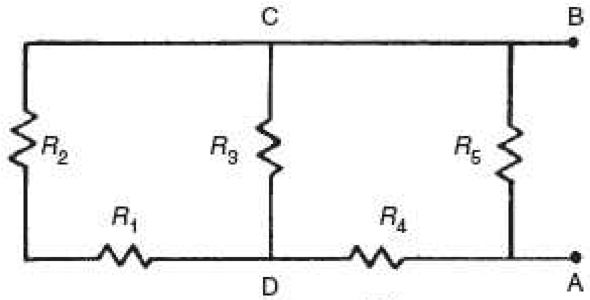

Fig1.12 The circuit used to find the equivalent single resistance *R* AB.

For the purpose of defining the equivalent single resistance of a circuit by Th´evenin's theorem, all voltage sources are represented just by their internal resistance, which can be approximated to zero, as shown in Figure1.12. Analysis proceeds by calculating the equivalent resistances of sections of the circuit and building these up until the required equivalent resistance of the whole of the circuit is obtained. Starting at C and D, the circuit to the left of C and D consists of a series pair of resistances (R1 and R2) in parallel with R3, and the equivalent resistance can be written as

$$\frac{1}{R_{CD}} = \frac{1}{R_1 + R_2} + \frac{1}{R_3} \text{ or } R_{CD} = \frac{(R_1 + R_2)R_3}{R_1 + R_2 + R_3}$$

Moving now to A and B, the circuit to the left consists of a pair of series resistances (R_{CD} and R4) in parallel with R5. The equivalent circuit resistance R_{AB} can thus be written as:

$$\frac{1}{R_{AB}} = \frac{1}{R_{CD} + R_4} + \frac{1}{R_5} \quad \text{or} \quad R_{AB} = \frac{(R_4 + R_{CD})R_5}{R_4 + R_{CD} + R_5}$$

Substituting for R_{CD} using the expression derived previously, we obtain:

$$R_{AB} = \frac{\left[\frac{(R_1+R_2)R_3}{R_1+R_2+R_3}+R_4\right]R_5}{\frac{(R_1+R_2)R_3}{R_1+R_2+R_3}+R_4+R_5}$$

Defining I as the current flowing in the circuit when the measuring instrument is connected to it, we can write:

$$I = \frac{E_0}{R_{AB}+R_m},$$

And the voltage measured by the meter is then given by:

$$E_m = \frac{R_m E_0}{R_{AB}+R_m}.$$

In the absence of the measuring instrument and its resistance Rm, the voltage across AB would be the equivalent circuit voltage source whose value is E_0. The effect of measurement is therefore to reduce the voltage across AB by the ratio given by:

$$\frac{E_m}{E_0} = \frac{R_m}{R_{AB}+R_m}$$

It is thus obvious that as Rm gets larger, the ratio Em/E0 gets closer to unity, showing that the design strategy should be, to make Rm as high as possible to minimize disturbance of the measured system. (Note that we did not calculate the value of E0, since this is not required in quantifying the effect of Rm.)

1.6.1.2 Random errors are perturbations (disturbance) of the measurement either side of the true value caused by random and unpredictable effects, such that positive errors and negative errors occur in approximately equal numbers for a series of measurements made of the same quantity. Such perturbations are mainly small, but large perturbations occur from time to time unpredictably. Random errors often arise when measurements are taken by human observation of an analogue meter, especially where this involves interpolation between scale points. Electrical noise can also be a source of random errors. To a large extent, random errors can be overcome by taking the same measurement a number of times and extracting a value by averaging or other statistical techniques. However, any quantification of the measurement value and statement of error bounds remains a statistical quantity.

Finally, a word must be said about the distinction between systematic and random errors. Error sources in the measurement system must be examined carefully to determine what type of error is present, systematic or random, and to apply the appropriate treatment. In the case of manual data measurements, a human observer may make a different observation at each attempt, but it is often reasonable to assume that the errors are random and that the mean of these readings is likely to be close to the correct value. However, this is only true as long as the human observer is not introducing a parallax-induced systematic error as well by persistently reading the position of a needle against the scale of an analogue meter from one side rather than from directly above. In that case, correction would have to be made for this systematic error (bias) in the measurements before statistical techniques were applied to reduce the effect of random errors.

1.6.2 Calibration of measuring sensors and instruments

1.6.2.1 Principles of calibration

Calibration consists of comparing the output of the instrument or sensor under test against the output of an instrument of known accuracy when the same input (the measured quantity) is applied to both instruments. This procedure is carried out for a range of inputs covering the whole measurement range of the instrument or sensor.

Calibration ensures that the measuring accuracy of all instruments and sensors used in a measurement system is known over the whole measurement range, provided that the calibrated instruments and sensors are used in environmental conditions that are the same as those under which they were calibrated

All instruments suffer drift in their characteristics, and the rate at which this happens depends on many factors, such as the environmental conditions in which instruments are used and the frequency of their use. Thus, errors due to instruments being out of calibration can usually be rectified by increasing the frequency of recalibration.

1.6.2.2 Calibration chain and traceability

The calibration facilities provided within the instrumentation department of a company provide the first link in the calibration chain. Instruments used for calibration at this level are known as working standards. As such working standard instruments are kept by the instrumentation department of a company solely for calibration duties, and for no other purpose, then it can be assumed that they will maintain their accuracy over a reasonable period of time because use-related deterioration in accuracy is largely eliminated

The instrument used for calibrating working standard instruments is known as a secondary reference standard. This must obviously be a very well-engineered instrument that gives high accuracy and is stabilized against drift in its performance with time. When the working standard instrument has been calibrated by an authorized standards laboratory, a calibration certificate will be issued. This will contain at least the following information.

- the identification of the equipment calibrated
- the calibration results obtained
- the measurement uncertainty
- any use limitations on the equipment calibrated
- the date of calibration
- the authority under which the certificate is issued.

The establishment of a company Standards Laboratory to provide a calibration facility of the required quality is economically viable only in the case of very large companies where large numbers of instruments need to be calibrated across several factories. In the case of small to medium size companies, the cost of buying and maintaining such equipment is not justified. Instead, they would normally use the calibration service provided by various companies that specialize in offering a Standards Laboratory.

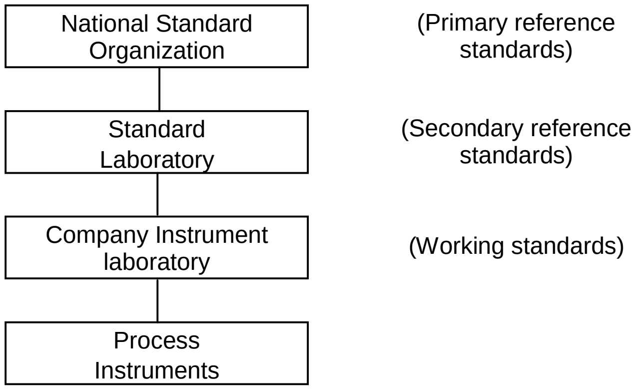

Fig1.13 Instrument calibration chain.

What these specialist calibration companies effectively do is to share out the high cost of providing this highly accurate but infrequently used calibration service over a large number of companies. Such Standards Laboratories are closely monitored by National Standards Organizations.

1.6.2.3. Calibration records

An essential element in the maintenance of measurement systems and the operation of calibration procedures is the provision of full documentation. This must give a full description of the measurement requirements throughout the workplace, the instruments used, and the calibration system and procedures operated. Individual calibration records for each instrument must be included within this. This documentation is a necessary part of the quality manual, although it may physically exist as a separate volume if this is more convenient. An overriding constraint on the style in which the documentation is presented is that it should be simple and easy to read.

The starting point in the documentation must be a statement of what measurement limits have been defined for each measurement system documented. Such limits are established by balancing the costs of improved accuracy against customer requirements, and also with regard to what overall quality level has been specified in the quality manual.

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<tr><td>Calibration date</td><td colspan="2">Calibration results</td><td>Calibrated by</td></tr>
<tr><td></td><td colspan="2"></td><td></td></tr>
</table>

Table 1. Typical format for instrument record sheets

1.7 Some of the measuring units related to telecommunication systems:

1.7.1 Decibel: In April 2003, the International Committee for Weights and Measures (CIPM) considered a recommendation for the decibel's inclusion in the International System of Units (SI), but decided not to adopt the decibel as an SI unit. However, the decibel is recognized by other international bodies such as the International Electro technical Commission (IEC). The IEC permits the use of the decibel with field quantities as well as power and this recommendation is followed by many national standards bodies.

In electronics, the decibel is often used to express power or amplitudes logarithmic ratios (gains), in preference to arithmetic ratios or percentages. One advantage is that the total decibel gain of a series of components (such as amplifiers and attenuators) can be calculated simply by summing the decibel gains of the individual components. Similarly, in telecommunications, decibels are used to account for the gains and losses of a signal from a transmitter to a receiver through some medium (free space, wave guides, coax, fiber optics, etc.) using a link budget.

A decibel (dB) is one tenth of a bel (B), i.e. 1B = 10dB. The bel is the logarithm of the ratio of two power quantities of 10:1, and for two field quantities in the ratio $\sqrt{10} : 1$.

A field quantity is a quantity such as voltage, current, sound pressure, electric field strength, velocity and charge density, the square of which in linear systems is proportional to power.

The calculation of the ratio in decibels varies depending on whether the quantity being measured is a power quantity or a field quantity.

When referring to measurements of power or intensity, a ratio can be expressed in decibels by evaluating ten times the base-10 logarithm of the ratio of the measured quantity to the reference level. Thus, the ratio of a power value P_1 to another power value P_0 is represented by L_{dB}, that ratio expressed in decibels, which is calculated using the formula:

$$L_{\mathrm{dB}} = 10 \log_{10}\left(\frac{P_1}{P_0}\right)$$

P_1 and P_0 must measure the same type of quantity, and have the same units before calculating the ratio. If $P_1 = P_0$ in the above equation, then $L_{dB} = 0$. If P_1 is greater than P_0 then L_{dB} is positive; if P_1 is less than P_0 then L_{dB} is negative.

Similarly, in electrical circuits, dissipated power is typically proportional to the square of voltage or current when the impedance is held constant. Taking voltage as an example, this leads to the equation:

$$G_{\mathrm{dB}} = 20 \log_{10}\left(\frac{V_1}{V_0}\right)$$

where V_1 is the voltage being measured, V_0 is a specified reference voltage, and G_{dB} is the power gain expressed in decibels.

1.7.2 Common reference levels and corresponding units with respect to decibel

1.7.2.1 Absolute and relative decibel measurements

Although decibel measurements are always relative to a reference level, if the numerical value of that reference is explicitly and exactly stated, then the decibel measurement is called an "absolute" measurement, in the sense that the exact value of the measured quantity can be recovered using the formula given earlier. For example, since dBm indicates power measurement relative to 1 milliwatt, 0 dBm means no change from 1 mW. Thus, 0 dBm is the power level corresponding to a power of exactly 1 mW. 3 dBm means 3 dB greater than 0 dBm.

If the numerical value of the reference is not explicitly stated, as in the dB gain of an amplifier, then the decibel measurement is purely relative.

1.7.3 Absolute measurements

Power

dBm or dBmW

dB(1 mW) – power measurement relative to 1 milliwatt. X dBm = X dBW + 30.

dBW

dB(1 W) – similar to dBm, except the reference level is 1 watt.

0 dBW = +30 dBm;

−30 dBW = 0 dBm;

XdBW = XdBm − 30.

Voltage: Since the decibel is defined with respect to power not amplitude, conversions of voltage ratios to decibels must square the amplitude

dBV

dB(1 VRMS) – voltage relative to 1 volt, regardless of impedance.

dBu or dBv

dB(0.775 VRMS) – voltage relative to 0.775 volts. Originally dBv, it was changed to dBu to avoid confusion with dBV. The "v" comes from "volt", while "u" comes from "unloaded". dBu can be used regardless of impedance, but is derived from a 600 Ω load dissipating 0 dBm (1 mW).

dBmV

dB(1 mVRMS) – voltage relative to 1 millivolt. Widely used in cable television networks, where the nominal strength of a single TV signal at the receiver terminals is about 0 dBmV. Cable TV uses 75 Ω coaxial cable, so 0 dBmV corresponds to −78.75 dBW (−48.75 dBm) or ~13 nW.

dBμV or dBuV

dB(1 μVRMS) – voltage relative to 1 microvolt. Widely used in television and aerial amplifier specifications. 60 dBμV = 0 dBmV.

1.7.4 Acoustics

Probably the most common usage of "decibels" in reference to sound loudness is dB SPL, referenced to the nominal threshold of human hearing:

dB(SPL): dB (sound pressure level) – for sound in air and other gases, relative to 20 micropascals (μPa) = 2×10^{-5} Pa, the quietest sound a human can hear. This is roughly the sound of a mosquito flying 3 meters away. This is often abbreviated to just "dB", which gives some the erroneous notion that "dB" is an absolute unit by itself. For sound in water and other liquids, a reference pressure of 1 μPa is used.

dB(PA): dB – relative to 1 Pa, often used in telecommunications.

dB SIL : dB sound intensity level – relative to 10^{-12} W/m^2, which is roughly the threshold of human hearing in air.

dB SWL: dB sound power level – relative to 10^{-12} W.

dB(A), dB(B), and dB(C)

These symbols are often used to denote the use of different weighting filters, used to approximate the human ear's response to sound, although the measurement is still in dB (SPL). These measurements usually refer to noise and noisome effects on humans and animals, and are in widespread use in the industry with regard to noise control issues, regulations and environmental standards.

1.7.5 Radio power, energy and field strength

dBc: relative to carrier—in telecommunications, this indicates the relative levels of noise or sideband peak power, compared with the carrier power.

dB(J) – energy relative to 1 joule. 1 joule = 1 watt per hertz, so power spectral density can be expressed in dBJ.

1.7.6 Antenna measurements

dBi: dB(isotropic) – the forward gain of an antenna compared with the hypothetical isotropic antenna, which uniformly distributes energy in all directions. Linear polarization of the EM field is assumed unless noted otherwise.

dBd: dB(dipole) – the forward gain of an antenna compared with a half-wave dipole antenna. 0 dBd = 2.15 dBi

dBiC: dB(isotropic circular) – the forward gain of an antenna compared to a circularly polarized isotropic antenna. There is no fixed conversion rule between dBiC and dBi, as it depends on the receiving antenna and the field polarization.

dBq: dB(quarter wave) – the forward gain of an antenna compared to a quarter wavelength whip. Rarely used, except in some marketing material. 0 dBq = −0.85 dBi

dBFS or dBfs: dB(full scale) – the amplitude of a signal (usually audio) compared with the maximum which a device can handle before clipping occurs. In digital systems, 0 dBFS (peak) would equal the highest level (number) the processor is capable of representing. Measured values are always negative or zero, since they are less than the maximum or full-scale. Full-scale is typically defined as the power level of a full-scale sinusoid, though some systems will have extra headroom for peaks above the nominal full scale.

dB-Hz: dB(hertz) – bandwidth relative to 1 Hz. E.g., 20 dB-Hz corresponds to a bandwidth of 100 Hz. Commonly used in link budget calculations. Also used in carrier-to-noise-density ratio (not to be confused with carrier-to-noise ratio, in dB).

dBov or dBO: dB(overload) – the amplitude of a signal (usually audio) compared with the maximum which a device can handle before clipping occurs. Similar to dBFS, but also applicable to analog systems.

dBr: dB(relative) – simply a relative difference from something else, which is made apparent in context. The difference of a filter's response to nominal levels, for instance.

dBrn : dB above reference noise.

Objective:

1. In analog meters, ---------------------- is basically a primary sensor.
2. Primary sensors and conversion unit combined are termed as ----------------.
3. A sensitive micro ammeter has a very high resistance in ----------------.
4. Unit for measuring sensitivity is ---------------------.
5. Digital meters have greater accuracy and faster -------------------------.
6. Conversion unit of a digital meter is ------------------- converter.
7. Principal of A/D conversion is basically a ------------------- circuit.
8. Three cycles used by A/D converter, for measurements are ------, --------, -----------.
9. Value of a variable is detected by the slope of charging on -----------------.
10. I/C no 7106 is a basic--------------------.
11. Calibration of working standard equipment's is done with--------------------equipments.
12. --------------- is a logarithmic ratio of powers.

Subjective:

1. What are the elements that constitute a measuring instrument?
2. Why " d "Arsonval movement is important for analog voltmeters ?
3. Define Sensitivity. How is FSD related to it?
4. Explain the advantage of using high input impedance meters?
5. Draw and explain with blocks a Digital Multi meter.
6. Explain the significance of Analog to Digital converter in a digital instrument.
7. What are the essential qualities of a good instrument?
8. Explain the importance of calibration of measuring instruments.
9. Which are the most used measuring units in telecommunication systems? Mention any five absolute and relative measuring units

CHAPTER-2

OUTDOOR (FIELD) MEASURING INSTRUMENTS

2.0 GENERAL

The outdoor (field) measuring instruments used in telecommunication systems are generally on underground copper cables of various types, overhead (ACSR) lines and systems.

Various types of measurements taken periodically on the above said systems, during installation and maintenance are classified as-

i. Insulation resistance
ii. Route tracing
iii. Fault locating
iv. Earth resistance
v. Transmission losses

For the above said measurements, the measuring instruments used are megger, cable route tracer, cable fault locator, earth tester and transmission measuring set respectively.

2.1. INSULATION RESISTANCE MEASUREMENT

The purpose to check insulation resistance of underground cables: The insulation is used to separate the conductors bunched in a unit to prevent short circuit between two conductors in a pair or between conductors of one pair with the conductor any other pair in the unit or core in the cable. The insulation is used as SHEATH to separate the insulated conductors from being corroded or eroded in soil. The insulation is being used for marking / identifying the pair or conductor in the unit and in the cable as a whole for that matter. The insulating material is used for preventing the grounding or earthing of the conductors and also used for preventing the corrosion of armoring.

2.1.1 THE GENERAL TYPES OF CABLE FAULTS:-

1. Earth fault: When the insulation between the earth and the conductor in the cable becomes very low.
2. Low insulation fault.: When the insulation between conductors in the cable or between the pairs or between pair and earth falls below a prescribed limit (normally 0.5 meg ohm) This may be due to entry of moisture or due to failure of wire insulation.
3. Disconnection Fault: When the Conductor is cut then the fault is called break fault or is called High Resistance fault when High Resistance is introduced in the circuit.
4. Short Circuit Fault: When the resistance between the wires or between the conductors becomes very low even without any loop in the circuit on the pairs. This is also called contact fault.
5. Foreign potential :The existence of potential, even when the circuit is idle or isolated from the potential of exchange

Badly insulated circuits can create leakage current. Generally, insulation resistance measurements are done between each conductor and the earth and between various conductors.

2.2 MEGGER

The megger is a portable instrument used to measure insulation resistance of cables and/or overhead lines. Meggers are available in 100V dc, 500Vdc ranges.

2.2.1 Principle of operation: The megger is basically an ohm meter used to measure a high resistance. The megger consists of a hand-driven DC generator and a direct reading ohm meter. A simplified circuit diagram of the instrument is shown in Fig. 2.1

The moving element of the ohm meter consists of two coils, A and B, the control coil and the deflecting coil which are rigidly mounted to a pivoted central shaft and are free to rotate over a C-shaped core (C on Figure). These coils are connected by means of flexible leads. The moving element may point in any meter position when the generator is not in operation.

As current provided by the hand-driven generator flows through Coil B, the coil will tend to set itself at right angles to the field of the permanent magnet. With the test terminals open, giving an infinite resistance, no current flows in Coil A. Thereby, Coil B will govern the motion of the rotating element, causing it to move to the extreme counter-clockwise position, which is marked as infinite resistance.

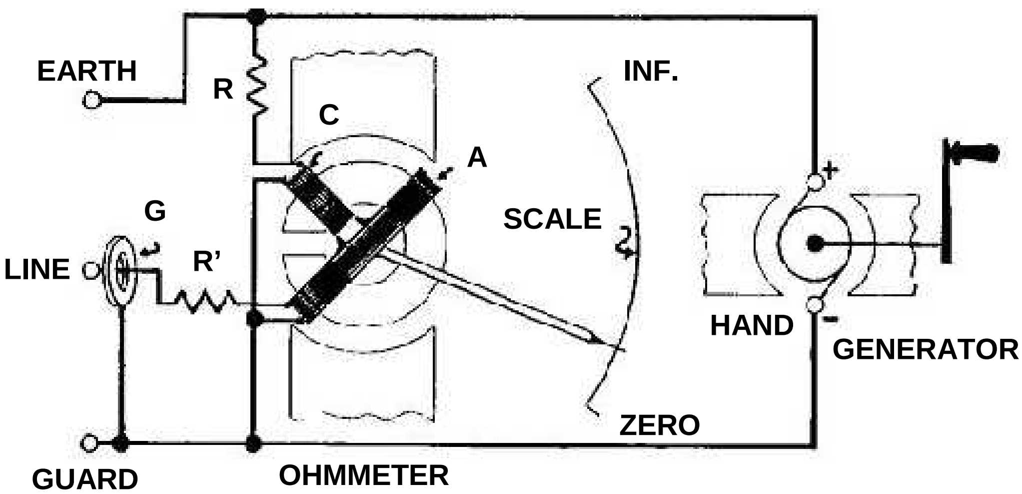

Fig.2.1 Simple Megger schematic diagram

Coil A is wound in a manner to produce a clockwise torque on the moving element. With the terminals marked "line" and "earth" shorted, giving a zero resistance, the current flow through the Coil A is sufficient to produce enough torque to overcome the torque of Coil B. The pointer then moves to the extreme clockwise position, which is marked as zero resistance. Resistance (R^{l}) will protect Coil A from excessive current flow in this condition.

When an unknown resistance is connected across the test terminals, line and earth, the opposing torques of Coils A and B balance each other so that the instrument pointer comes to rest at some point on the scale. The scale is calibrated such that the pointer directly indicates the value of resistance being measured.

The other types of megger instruments used today are provided with internal DC source available and can directly read the values of resistance through digital display.

2.3 CABLE ROUTE TRACER

Cable route tracer is a widely used instrument for maintenance of underground tele-communication cables. It is helpful in tracing the path or route through which the cable has been laid and is extremely useful for utility mapping i.e preparing maps of underground cables & to provide ready reference to cater to emergencies. The features include, to trace route of the buried cable, measurement of depth of lay of cable, identification of particular cable from bunch of telecom cables, ground survey. Its use avoids indiscriminate digging and damage to public properties due to random excavation

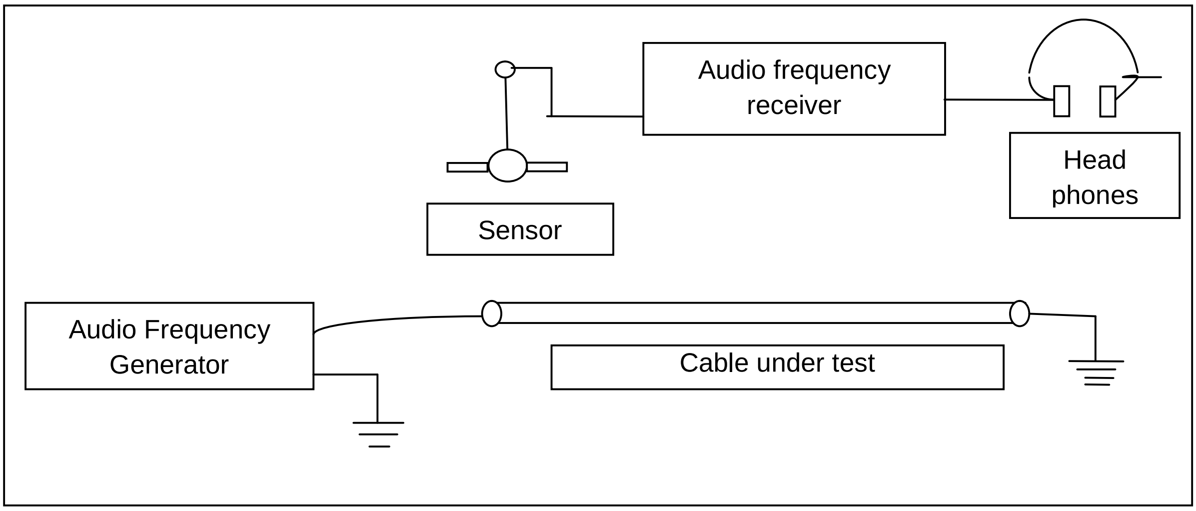

Fig.2.2 Setup of cable route tracing equipment

2.3.1 PRINCIPLE OF OPERATION FOR ROUTE TRACING

The system consists of an Audio Frequency generator, Audio Frequency Receiver, Universal Search Coil, Transmitter Coil, Cable Identification Probe and Headphones

The transmitter of the cable route tracer injects an A.F. signal into the cable which generates an electromagnetic field around it. This field is concentric to the cable & is present over the entire length. The presence of this field (in turn the cable) is detected by a highly selective and sensitive receiver with a search coil.

Sensor block is a Search coil that collects the induced electromagnetic signal and feeds it to the input circuit of a receiver. The sensor (antenna) is swivel-mounted for operation in vertical, horizontal or 45^0 mode used to calculate depth. The receiver provides audible and visual indication of detected signal strength

The receiver can be used to trace lines using either peaks (detection of the maximum signal) or nulls (detection of the minimum, or zero signals).

Over a healthy cable, audio frequency signal will attenuate gradually. However, if there is a fault (impedance change) attenuation of audio signal will vary, depending upon nature of fault. This method is used for fault finding. More than one frequency are used in practice, hence the receiver is having a switching circuit to select a particular frequency.(Usually three operating frequencies 480Hz,1450Hz and 9820Hz are used)

The three methods of coupling the injected signal to the cable under test are:

(i) **Galvanic coupling method (With earth as return conductor)**

In this method one terminal of generator output is connected to the conductor. The other output terminal is returned to earth by means of earth spike. The far end of the conductor should also be connected to earth as shown in fig.2.3

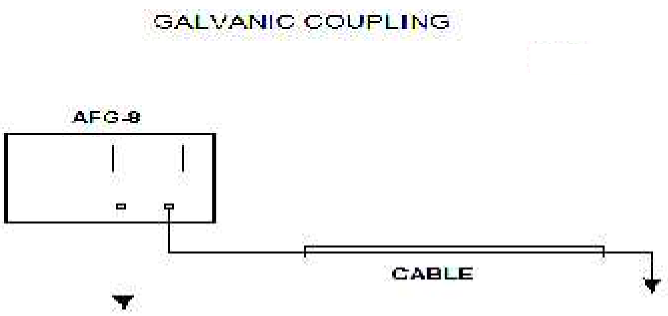

Figure 2.3 Galvanic coupling method

(ii) **Capacitive coupling method:** This method is mainly used when near end of the cable is available and the far end is not accessible. This method of coupling gives measurable radiated signal from cable for a limited distance.

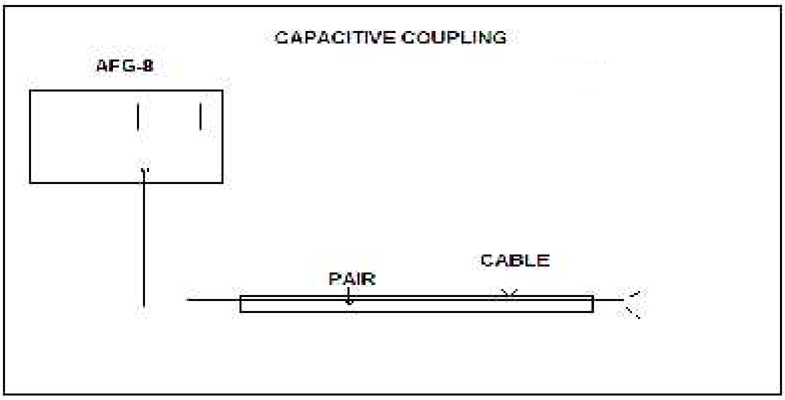

Figure 2.4 capacitive coupling method

(iii) **Inductive Coupling method:** If disconnection to cable is not possible, then inductive method of coupling has to be selected. This method is also useful when access for connection above ground surface is not available, especially useful to test route where other end of the cable is not available.

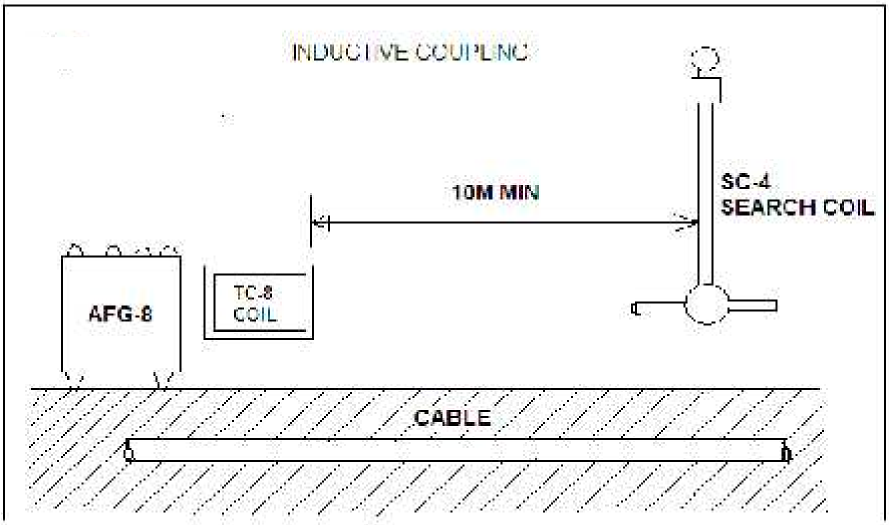

Figure 2.5 Inductive Coupling method

2.4 CABLE FAULT LOCATOR

A cable fault locator is used to mainly locate low insulation and contact faults in UG cables. This instrument can also be used to measure distance to fault in case of clear open faults using pulse reflection principles.

Cable Fault Locators are commonly used for in-place testing of very long cable runs, where it is impractical to dig up or remove cable. They are indispensable for preventive maintenance of telecommunication lines, as they can reveal growing resistance levels on joints and connectors as they corrode, and increasing insulation leakage as it degrades and absorbs moisture long before either leads to catastrophic failures. Using a cable fault locator, it is possible to pinpoint a fault.

The different types of measurements used by a cable fault locator in U/G telecom cables are following –

- To locate low insulation faults
- To detect open and short faults (distance of fault)
- For measuring insulation resistance
- For measuring foreign voltage on cables

Cable Fault Locators are operated in two methods

1. Pulse Echo Method
2. Time Domain Reflectometry (TDR)

2.4.1 Pulse Echo Method: In this method, a low voltage short duration pulse is injected in the cable and time taken by the pulse to travel to the point, where changes in insulation occur, and the reflected back energy is measured. Limitation of this method is, only short circuit faults can be located. It is essentially a high frequency AC pulsed signal generator that is used as a source, and for fault localization pulse echo techniques is used. A defined pulse is transmitted on the cable pair under test. The pulse travels along the pair length at a fixed velocity of propagation depending on the dielectric of the cable. A part of the pulse energy reflects back from the point where the characteristics impedance of cable changes due to fault occurrences. The time taken by the pulse to reach the faulty location and return to the source multiplied by the velocity of propagation gives twice the distance to fault. This is computed internally and distance to fault is displayed directly in meters. The typical timing pulses are 80ns.250ns, 800ns and 1800ns respectively for 0.3 KM, 1 KM, 3 KM and 10KM.

The faulty distance can be calculated by the formula-

D= (V/2)T

Where D= Distance to fault in meters
V= velocity of propagation
T= time taken in seconds

2.4.2 Time Domain Reflectometry (TDR): A TDR transmits a short rise time pulse along the conductor. If the conductor is of a uniform impedance and properly terminated, the entire transmitted pulse will be absorbed in the far-end termination and no signal will be reflected toward the TDR. Any impedance discontinuities will cause some of the incident signal to be sent back towards the source. Increases in the impedance create a reflection that reinforces the original pulse whilst decreases in the impedance create a reflection that opposes the original pulse. The resulting reflected pulse that is measured at the output/input to the TDR is displayed or plotted as a function of time and, because the speed of signal propagation is almost constant for a given transmission medium, can be read as a function of cable length. Because of this sensitivity to impedance variations, a TDR may be used to verify cable impedance characteristics

The amount of the reflected energy is a function of the condition at the end of the cable. In addition to the amount of energy, you can analyze the reflected signal waveform and timing details to get information on what kind of impedance mismatches can be seen on the cable and where they are located in the cable.

- If the cable is in an open condition the energy pulse reflected back is a significant portion of the injected signal in the same polarity as the injected pulse
- If the other end of the cable is shorted to ground or to the return cable, the energy reflected is in the opposite polarity to the injected signal.
- If the end of the cable is terminated into a resistor with a value matching the characteristic impedance of the cable, all of the injected energy will be absorbed by the terminating resistor and no reflection will be generated.
- If the end of the cable is terminated into a resistor with a value close to cable impedance but not exactly matching the characteristic impedance of the cable, most of the injected energy will be absorbed by the terminating resistor and a very low amplitude reflection will be generated.

2.5 DIGITAL EARTH RESISTANCE TESTER

Digital earth resistance tester is direct replacement of the conventional hand generator type universal earth tester. It is basically an Ohm meter designed for measurement of the resistance of earthing used in electrical equipment as well as for measurement of ground resistivity.

2.5.1 Operating principle: The instrument uses the four terminal method of measurement. A reversing d.c. test current is injected into the earth through terminals '**C1**' and '**C2**'. The potential developed across the earth is monitored with '**P1**' and '**P2**'. A three pole test is achieved by shorting terminals '**C1**' and '**P1'** together through an internal relay. At the beginning of a test, the control logic initiates a Potential spike resistance check, monitoring the input over-range detector for the result. The instrument auto ranges by the control logic monitoring the output of the over-range detector and switching the current source to a lower current output. The instrument also auto ranges if the high current loop resistance detector senses too much current for the preset range.

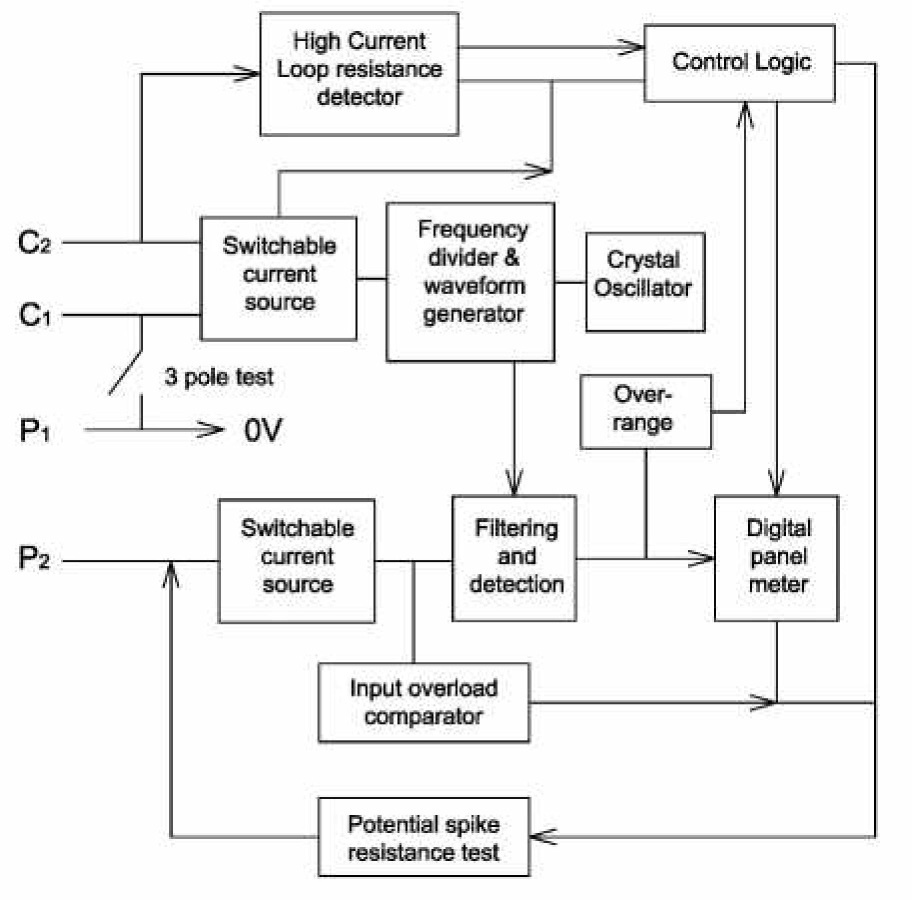

Fig 2.6 Typical Block diagram of digital earth tester

The instrument measuring circuitry is connected to terminals '**P1**' and '**P2**'. The voltage limiter and input buffer prevent damage to the instrument and loading of the resistance under test. Synchronous filtering and detection are used to recover the test signal from noisy environments followed by filtering and conversion to a reading by the digital panel meter. The test signal frequency is produced by dividing the frequency of a crystal oscillator. This is then passed through logic circuitry to produce the waveforms for synchronous filtering and detection.

Four electrodes ABCD are rods driven in the earth, the resistance of which is to be tested at a distance of 20m from each other as shown in fig.2.6

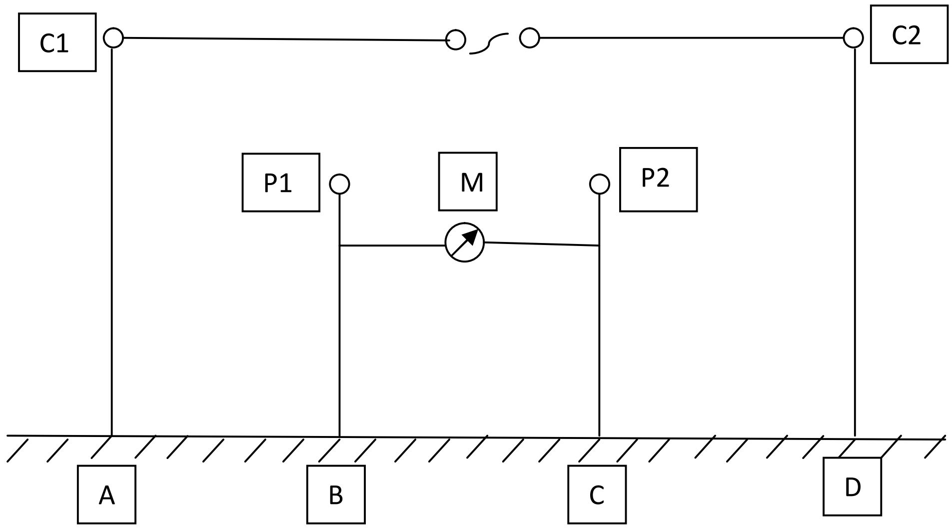

Fig.2.7 Measuring of earth resistance using 4- electrode method

AC signal is applied to electrodes A and D and voltage developed across electrodes B and C due to flow of current through the earth is measured by ammeter M. If the current is constant the voltage measured will be directly proportional to the earth resistance.

To eliminate the error due to other signals, the meter reading will be sampled at the same frequency as that of the applied signal. Accordingly the frequency selected is of an odd value around 72Hz thus eliminating any chances of errors due to harmonics of 50Hz.

The sampling is done by having an FET across the meter and switching the FET at the selected frequency only. The metering is also isolated from DC source.

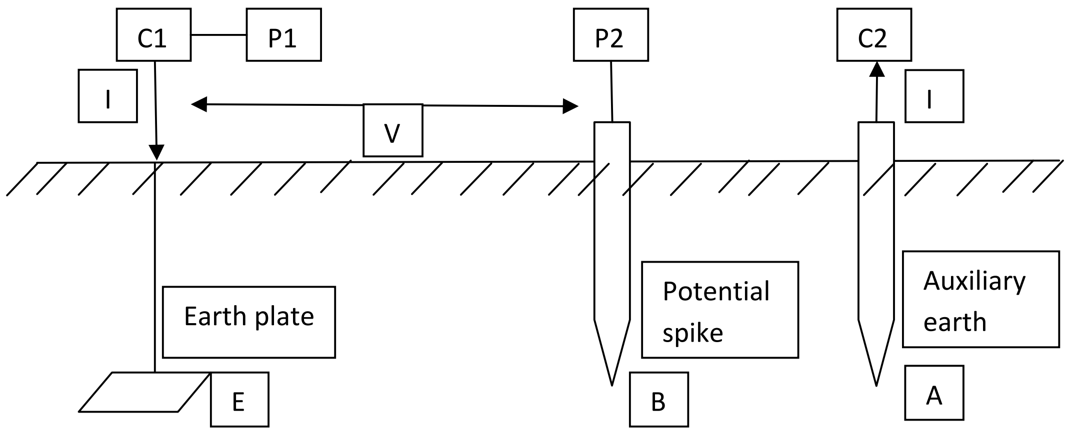

Fig.2.8 Measurement of effective earth resistance of earth by 3- electrodes

2.5.2 Measurement of effective earth resistance of earth electrodes

To find out resistance of earth connection three terminal methods is used. Current is passed through the plate E which is an earth plate to an auxiliary electrode A in the earth at a distance away from the plate C1. C1 and P1 are coupled.

A second auxiliary electrode B is inserted between E&A and the potential difference V between E and B is measured for a given current I. The resistance of earth connection is V/I.

To operate the instrument first turn on the range selector switch to 1000Ω position. The digital display will read zero. Connect the test leads as shown in fig. and press test switch; the LCD display will indicate the resistance. If the reading is too small the range selector switch may be turned to 10 Ω range.

After completion of testing, the selector knob should be turned to off position and the digits over the display will disappear.

2.6 Transmission Measuring Set (TMS)

Transmission Measuring Set is a compact instrument designed especially for maintenance of telecommunication lines in telephone exchanges & on the field. It is an accurate instrument with two in one facility of frequency oscillator & level meter. The level oscillator & level meter operate independently & hence can be used separately or can be combined to form a Voice Frequency level test set useful for measurements on communication lines, line-up testing and monitoring of communication facility.

2.6.1 Principle of operation: The TMSs are integrated level measuring set plus a signal generator. Having one fixed frequency sinusoidal output at 800Hz or 1000Hz or switchable variable frequency. The signal generator may be an RC timed unit or a synthesizer which provides superior accuracy and stability. The o/p is balanced and earth free, with source impedance between 600 and 1120 ohms. The transmission level being variable typically + 20 to –60 dB relative to a 0dBm output.

The input interface to the level measuring circuit is also balanced, by using either a transformer or a differential amplifier with a high common mode rejection, typically 80-90 dB. This active circuit more easily provides a high input impedance over a wide frequency band. The TMS is provided with a switched alternative of high impedance for “bridging“ measurement on balanced terminated transmission lines or selectable input terminations. Display of readings is available on both analog meter and digital display with auto ranging facility.

TM sets are used for the following measurements

1. Signal Levels.
2. Insertion Losses.
3. Transmission Losses
4. Return Losses.

2.6.2 Transmission Loss Measurement

The line resistance and electrostatic or electromagnetic couplings cause transmission loss occurring in telephone circuits. Transmission measuring set can measure transmission loss at the near and far end in telephone circuits

Measurement of Transmission Loss near End:

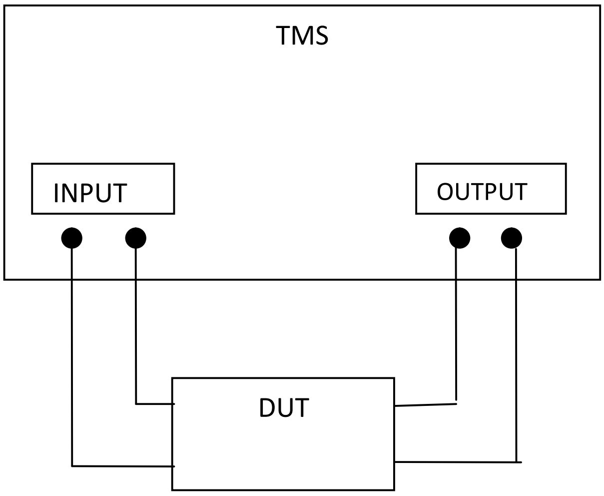

Fig 2.9 Measurement of Transmission Loss near End

Procedure:

- Connect the output of generator to the input of level meter with the supplied patch cord.
- Select the measuring frequency of 800 Hz by pressing the frequency selection switch.
- Select the measuring range from + 20 to – 60 dB.
- Select '0' dB level.
- Switch ON the instrument and give 3 minutes warm up time.
- Adjust the level 0 dB with the help of Trans level pot.
- Check 0 dB for all 12 spot frequencies & readjust the pot if required.
- Now instrument is ready to measure the transmission loss & connect the terminal with circuit as shown in Fig 2.9
- If the panel meter shows under or over range, then select next range. The panel meter wills directly gives the value of loss in the conductor pair under test.

Measurement of Transmission Loss Far End: For far end transmission loss, perform counter test at both ends facing telephone circuits. Therefore two instruments are required. The setting procedure of the instrument is same as in near end. Connect the instrument terminals to the circuit as shown in Fig 2.10.

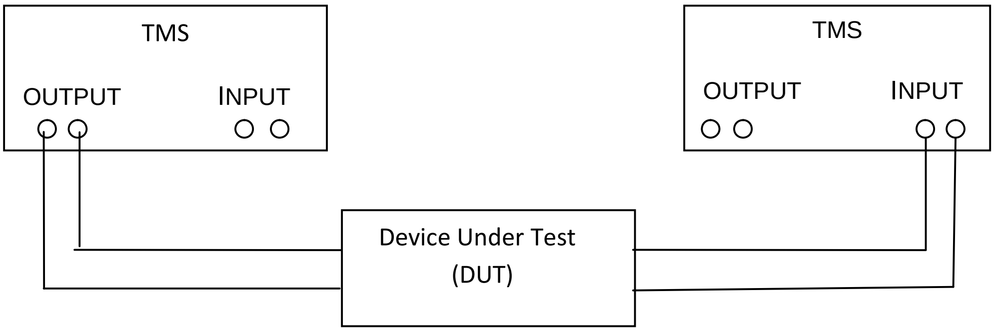

Fig 2.10 Measurement of transmission loss far end

2.6.3 Measurement of Return Losses

The amount of power which is reflected back to the source from an incorrectly terminated line is an important property called "Return Loss" and measurement of return loss can reveal line faults due to mismatching.

If the power transmitted by the source is P_T and the power reflected back is P_R, then the return loss is given by P_R divided by P_T.

Definition - The Return Loss of a line is the ratio of the power reflected back from the line to the power transmitted into the line.

Power can be reflected from mismatching at either end, but for lines of a reasonable length, the matching of the transmitter has more effect on the return loss than the matching of the receiver. This is because reflections from the far end are attenuated by the line before they arrive back at the transmitter. Often, high return loss is caused by changes in characteristic impedance at cable joints near to the transmitter

For maximum power transfer the return loss should be as small as possible. This means that the ratio P_R/P_T should be as small as possible. The return loss should be as large a negative number as possible. For example a return loss of -40dB is better than one of -20dB.

Return loss = $20 \log_{10} \Gamma$

Where $\Gamma = (Z_L - Z_S) / (Z_L + Z_S)$

Z_L = impedance towards load

Z_S = impedance towards source

Γ = Reflection coefficient

The procedure for this measurement is as follows:

- The line or system whose return loss is to be measured is connected to the terminals marked UNKNOWN at the rear panel of the TMS.
- The switch in the rear panel is switched to the corresponding position 600 Ω or 1120 Ω
- Switch on the instrument and select input and output impedance on line characteristic impedance (600 Ω & 1120 Ω).
- Connect a patch cord to short input and output terminal at front panel.
- Adjust 0dB reading with the help of Trans level. The frequency of measurement should be adjusted to 800 Hz. for normal measurements.
- Connect output terminals of front panel to output terminals of rear panel with the help of patch cord.
- Also connect INPUT terminals of front panel to input terminals of rear panel as shown in fig.2.11
- Note the reading on the panel meter after setting switch at proper range. If it is 600Ω lines for system measurement, add +6 dB to the panel meter reading to get the absolute value after addition in the return loss of the system.
  Ex. If panel meter reads – 47 dB, then return loss = - 47 + 6 = - 41 dB.

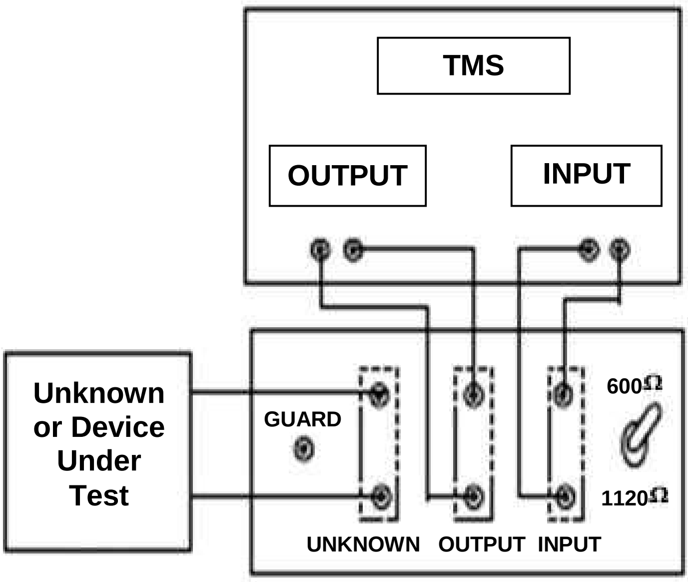

Fig.2.11 Measurement of Return Losses

- If it is 1120 Ω line for system measurement, convert panel meter reading dB to dBm by adding –2.71 dB first & then add + 6 dB in it.

  Ex: - If panel meter reading is obtained – 43 dB, then return loss is:

  -43 dB – 2.71 + 6 dB = - 45.71 dB + 6 dB. = - 39.71 dB.

2.6.4 Measurement of Insertion Loss: In telecommunications, insertion loss is the loss of signal power resulting from the insertion of a device in a transmission line.

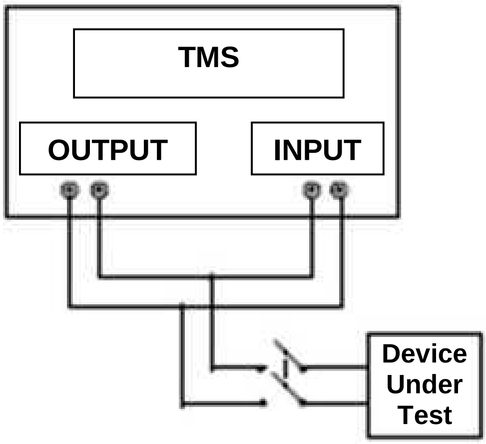

Fig.2.12 Measurement of Insertion Loss

- Select INPUT & OUTPUT impedance as required but should be both sides.
- Connect the output to the input.
- Select measuring range + 20 to – 20 dBm.
- Set 0-dBm levels.
- Insert device under test to close switch ‘S’ as shown in Fig 2.12

Objective:

1. Low insulation in circuits cause ----------------------currents.
2. Low current and --------------voltage is required for insulation test.
3. Megger is a true ----------------------- meter.
4. Sensor of a cable route tracer is a highly --------------and ----------- receiver.
5. Principle for cable fault location is basically ----------------------.
6. TDR is sensitive to ---------------------variations of the cable under test.
7. Digital earth resistance tester is the replacement of conventional----------
---------------- earth tester.
8. TMS is equipped with the facility to make measurements on both ------------ and ------------
----- modes.
9. Return loss is the consequence of fractional energy reflection due to ---------------------
10. **--------------------**is the loss of signal power resulting from the insertion of a device in a transmission line .

Subjective:

1. What are the different tests done on UG telecommunication cables?
2. What are the different faults on UG telecommunication cables, and how is Megger useful in testing them?
3. State the principle of Cable route tracing?
4. Explain how cable fault location can be done through Time Domain Reflectrometer method?
5. State the principle of Digital earth resistance tester?
6. Describe the method of measurement of earth resistance.
7. Explain how Transmission measuring sets are useful for testing voice frequency telephone systems? State different tests.
8. Differentiate between Return loss and Insertion loss

CHAPTER-3

MEASURING INSTUMENTS USED FOR MW AND ASSOCIATED SYSTEMS

3.0 GENERAL

In long distance communication system (MW), the voice frequency signal has to undergo different stages to reach a Microwave Radio. During transmission and reception of the VF signal, transformation from the multiplexing/demultiplexing to radio transmission and reception system, different measurements are required at different stages. The minimum required measuring instruments for maintenance are discussed in this chapter

3.1 SELECTIVE LEVEL OSCILLATOR (SLO)

Selective Level Oscillators are designed to meet the measurement requirements of FDM systems along with Selective Level Meters. SLOs are basically signal generators designed to work typically in the frequency range from few hertz to 1.5 MHz, for 120 or 300 channel carrier systems. The level oscillator is very much useful for on line selective measurements on a channel without disrupting the whole group along with selective meter. The SLO can be synchronized with SLMs to form a complete level measuring system.

Working principle: An automatic tuning circuit enables the oscillator and meter to be synchronous tuned making measurements with a common input and output frequency simple and rapid. The frequency determining circuit of the frequency generator is designed in such a way that set is tuned by a frequency locking facility in steps of 4 kHz, corresponding to the channel spacing of the FDM system under test. The set is tuned in 4 kHz steps to the desired FDM channel, the channel's carrier frequency appears on digital display.

The level oscillator uses one low frequency Voltage controlled oscillator whose frequency is typically 100 Hz +/-5 KHz and another oscillator whose frequency is high 1.0002 to 1.620 MHz These two oscillator signals are mixed in a modulator and the output frequency signal is passed through a low pass filter of 620 KHz to produce low frequency signal of 0.2 to 620 KHz. 1 MHz oscillator signal is controlled by an AGC circuit. The AGC circuit detects output of amplifier and buffer.

The output of the amplifier detected by meter circuit and indicated by meter within a range of –10 to +2 dBm. The final amplifier is followed by transformer attenuator to give output of +10 dBm to –60dBm. Digital counter indicates the output frequency. In case of Ext. Syncs. Position 1.0002 to 1.620 MHz signal from selective level meter is used. In this condition the output frequency of level oscillator is synchronized with selective level meter and the frequency can be changed by frequency 'Range' switch of SLM.

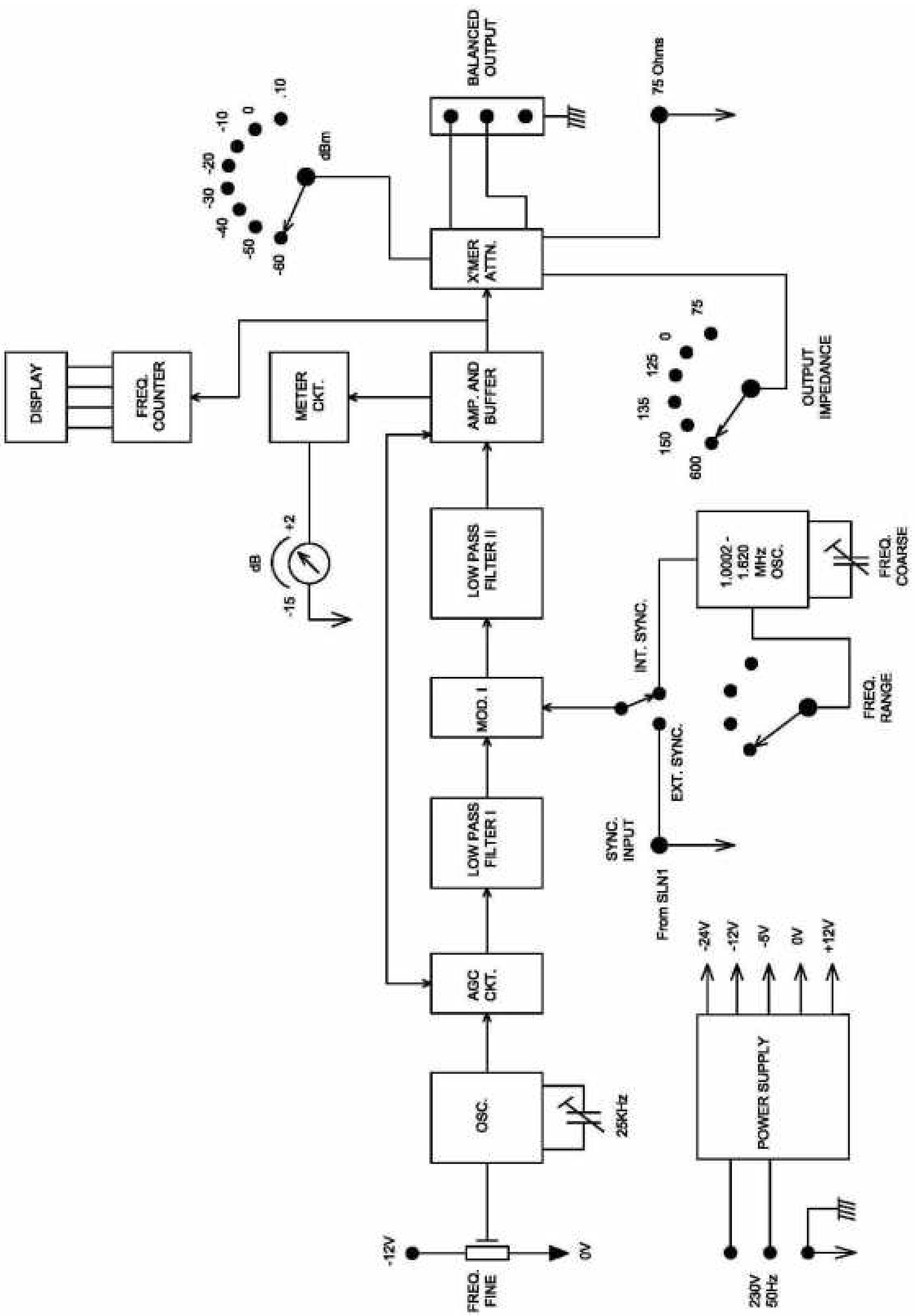

FIG.3.1 TYPICAL BLOCK DIAGRAM OF SELECTIVE LEVEL OSCILLATOR

3.2 SELECTIVE LEVEL METER (SLM)

Selective level measurements are universally used for the measurements of levels of pilots, channels, carrier leaks etc. on higher- order multiplexed signals. This may be used for monitoring overall system parameters.

3.2.1 Measurements in FDM system using SLM

1. **SSB measurements:** Selective measurement feature allows selective level measurement of a tone injected, into some carrier derived channel. Measurement can be taken at any point along the transmission path in respective frequency position without taking other channel out of service.
2. **Frequency response check:** Frequency response check can be measured in four ways
    a. From VF input to basic group output
    b. From VF input to VF output looped at basic group
    c. From local input to distant output
    d. Frequency response from basic group to basic super group
3. Pilot level measurement/carrier leak at any level up to super group
4. Intelligible cross talk can be measured by injecting a test tone on VF channel and taking measurements at group level

3.2.2 Principle of operation: Selective level meter as shown in fig 3.2 operates on the principle of a super heterodyne receiver, which can be tuned to the desired signal, with a gain that can be adjusted to bring the selected signal to a level with in the dynamic range of the detector**.**

The SLM used for the above said measurements are used in two modes. Wide band mode and selective band mode. A signal level encountered in a carrier system can be measured on wide band mode if the signal is the only one present on the band. For composite signals, measurements have to be made in selective mode. The frequency range for wide band mode is 200 Hz to 620 KHz and for selective mode 2 KHz to 620 KHz.

In selective measurement mode the input signal is applied via the balanced input transformer and attenuator to the input amplifier. Then the signal is passed through 620 KHz LPF and it is mixed with local oscillator frequency range of 1.002MHz to 1.620MHz. The mixer output is passed through 1MHz crystal filter and is mixed with MIX II with a local oscillator frequency of 998.5 KHz to produce 1.5 KHz IF. This is amplified and filtered. The signal is detected by switched gain IF amplifier, power detector and measured by meter circuit. The attenuator III provides power level switching for different impedances.

In wide band mode signal from the input amplifier is directly fed to the meter circuit to give wide band measurements.

3.2.3 Operating procedure: The selective measurements can be used in connection with level oscillator to form a complete level measurement system. The instrument must be checked for its calibration prior to any accurate measurements. For the calibration of the meter, the calibration potentiometers are to be adjusted with function switches in SELECTIVE position and WIDEBAND position to read the meter to 0 dBm.

The input terminals provided on the panel are balanced 75,125,150,600 ohms and HI input impedance. For 75 ohms unbalanced & HI input impedance BNC socket are to be selected accordingly. The selection of impedance value and frequency will also be chosen as per the application of measurement.

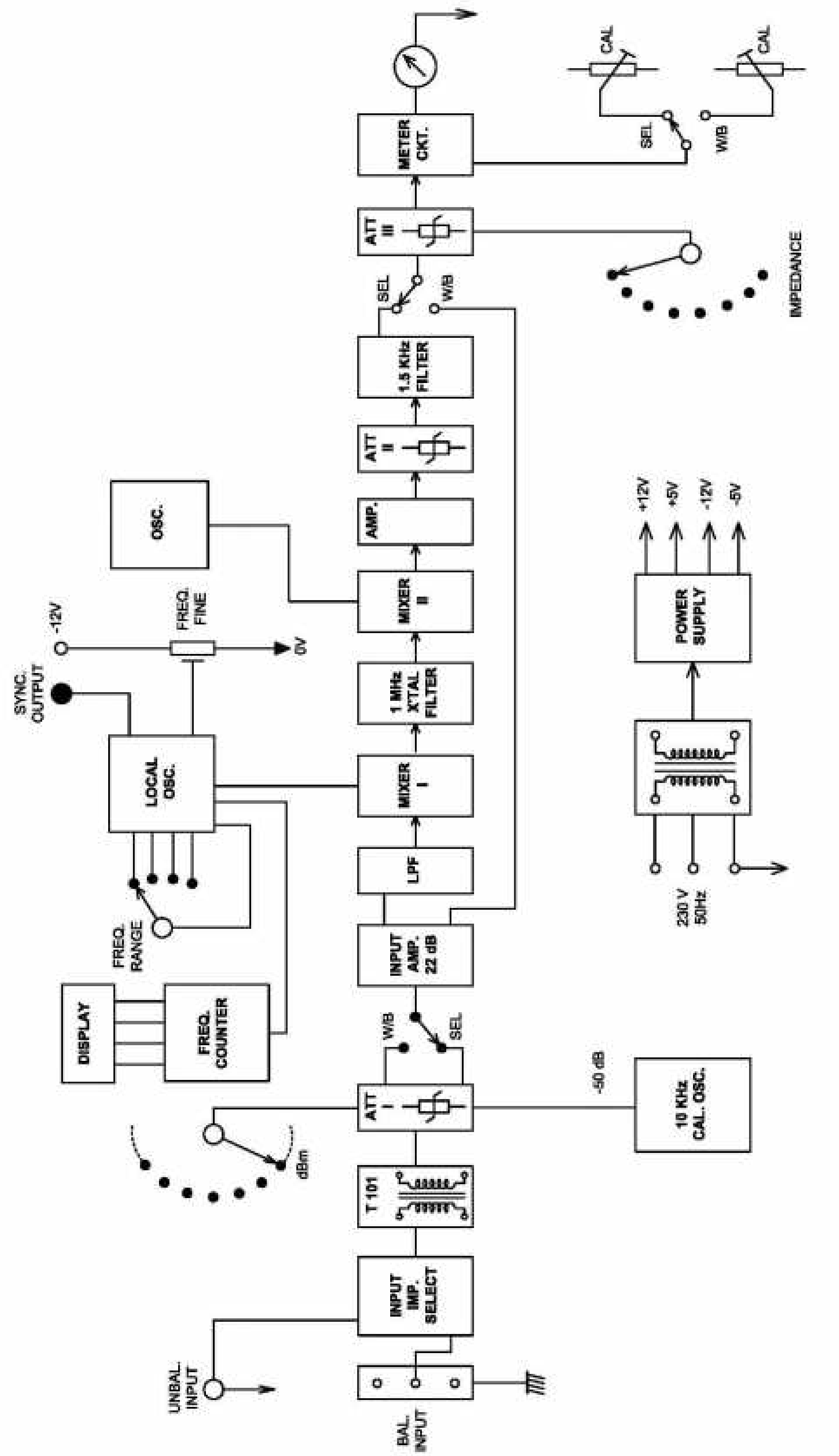

FIG.3.2 TYPICAL BLOCK DIAGRAM OF SELECTIVE LEVEL METER

3.3 FREQUENCY COUNTER

Frequency counter is an electronic instrument, or component of one, that is used for measuring frequency. Frequency is defined as the number of events of a particular sort occurring in a set period of time. Frequency counters usually measure the number of oscillations or pulses per second in a repetitive electronic signal or by counting the number of cycles in an electric signal during a preselected time interval. Frequency counters are used for direct measurement as low, medium and high unknown frequencies i.e. from dc to the giga-hertz range can be measured.

There are three different methods for the measurement of frequency.

1. Reciprocal method (10 Hz to 10 KHz).
2. Direct method (10KHz to 120 MHz)
3. Heterodyne method (120 MHz to 20 GHz)

Most frequency counters work by using a counter which accumulates the number of events occurring within a specific period of time. After a preset period (1 second, for example), the value in the counter is transferred to a display and the counter is reset to zero. If the event being measured repeats itself with sufficient stability and the frequency is considerably lower than that of the clock oscillator being used, the resolution of the measurement can be greatly improved by measuring the time required for an entire number of cycles, rather than counting the number of entire cycles observed for a pre-set duration (often referred to as the reciprocal technique). The internal oscillator which provides the time signals is called the time base, and must be calibrated very accurately.

Frequency counters designed for radio frequencies (RF) are also common and operate on the same principles as lower frequency counters. Often, they have more range before they overflow. For very high (microwave) frequencies, many designs use a high-speed prescaler to bring the signal frequency down (heterodyne method) to a point where normal digital circuitry can operate. The displays on such instruments take this into account so they still display the correct value. 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**.

3.3.1 General description of a frequency counter

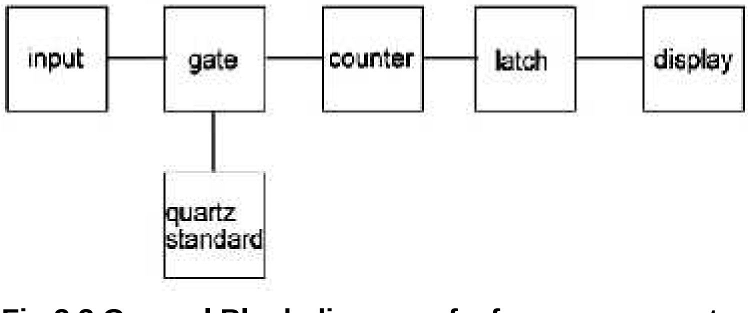

Fig.3.3 General Block diagram of a frequency counter

Input- Connect the signal to be measured to the frequency counter's input. The input may be any kind of wave form; the frequency counter conditions the signal and converts it to rectangular pulses, which are easily counted. The input will have a range of sensitivities depending on the model, typically from a few mill volts to a few volts peak-to-peak.

Gate- Before the signal is counted, it passes through a gate circuit. It's a precisely timed digital switch that is either open or closed. It has two main modes: frequency count and event count. Frequency count lets you measure the frequency of the input signal. In this case, the gate will open for a time period, passing the signal to the counter and letting the counts accumulate. For example, the gate may turn on for 1 second, so the counter counts pulses from your signal for that long. After 1 second, the gate closes and lets the counter display its result. Then it resets the count to 0 and opens again. Event count keeps the gate open, letting you count all the signal events you send to the counter. You can reset the count with a manual push-button switch or external pulse. Event counting lets you determine the total number of events occurring in an arbitrary time period, from seconds to weeks or longer.

Counter-The counter circuit has a set of divide-by-10 stages. The total number of stages is the number of display digits minus 1. The stages are chained together, so the first stage divides by 10, the next by 100 and so on. The counter outputs are used to drive the display.

Latch-The latch is a simple memory circuit that holds the last count. Typically, the counter will be counting for the current gate period, but the latch will have the results from the last count. When the current gate period is over, it resets the latch and gives it the latest count. This improves readability. Without the latch, you'd see a fluttering of numbers as the counter counts from 0 to your frequency every second. With the latch, you see only the actual frequency, with updates every second.

Display-The frequency counter's display is a set of decimal digits driven by the counter and latch. A typical frequency counter has six or seven digits. They may be seven-segment LED, LCD or other technology. In addition to showing the frequency count, the display may have indicators for mode, gate time or battery condition.

Quartz Standard- The frequency standard determines the accuracy of the gate. A typical standard is a quartz crystal in a heated chamber. Keeping it at a known temperature improves the counter's accuracy. If the crystal runs at a frequency of 100,000 hertz, a separate set of dividers reduces it to 1 pulse per second. A separate counter may divide it further to 1 pulse every 10 seconds. The longer the gate is open, the more precise the frequency measurement can be.

3.3.2 Operation of frequency counters using heterodyne principle: A high frequency measurement can be achieved using heterodyne down conversion of frequency, and this method is useful for frequencies up to 20GHz. In the fig. shown in dotted lines is the frequency down converter. As shown in the block diagram, fx is the unknown frequency to be measured applied to mixer. The time base signal is applied to the multiplier to produce a highly stable reference frequency as f_{in} is applied to harmonic generator to produce harmonics at a space of f_{in}.

One harmonic at a time is selected by the switch filter under microprocessor control and is mixed with an unknown frequency fx to produce a beat frequency $fx \pm K f_{in}$, where K is the harmonic number.

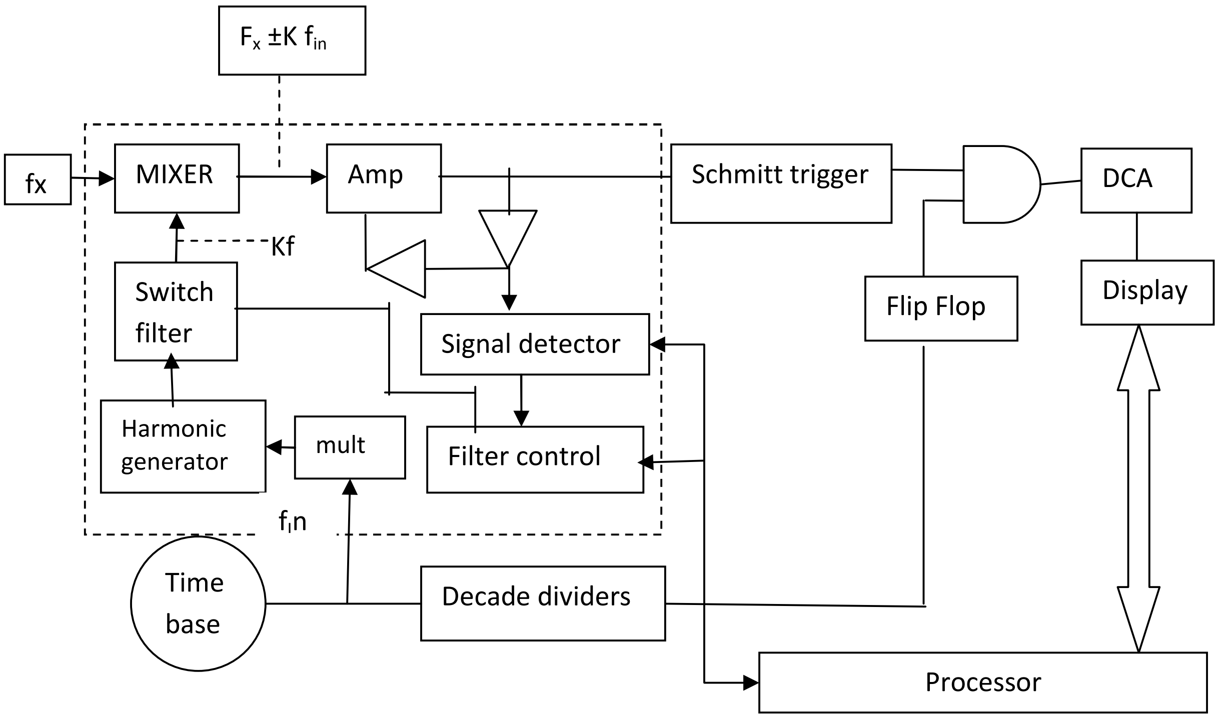

Fig 3.4 Block diagram of frequency counters using heterodyne principle

The microprocessor steps the filter through its range starting at K = 1, until a mixer output is obtained. The output from the mixer is amplified and passed to the signal detector, which signals the processor to stop and store the final value of K. The acquisition time for the counter which is the time required for the counter to reach correct value of K.

3.4 POWER METER

The importance of power

The output power level of a system or component is frequently the critical factor in the design, and ultimately the purchase and performance of almost all radio frequency and microwave equipment. The various measurements must be consistent within acceptable uncertainties. Secondly, measurement uncertainties cause ambiguities in the realizable performance of a transmitter because signal power level is so important to the overall system performance, it is also critical when specifying the components that build up the system. Each component of a signal chain must receive the proper signal level from the previous component and pass the proper level to the succeeding component.

By the term "signal level," the natural tendency might be to suggest measuring voltage instead of power. At low frequencies, below about 100 kHz, power is usually calculated from voltage measurements across assumed impedance. As the frequency increases, the impedance has large variations, so power measurements become more popular, and voltage or current are the calculated parameters.

At frequencies from about 30 MHz up through the optical spectrum, the direct measurement of power is more accurate and easier. Another example is in waveguide transmission configurations where voltage and current conditions are more difficult to define.

Power

The term "average power" is very popular and is used in specifying almost all RF and microwave systems. The terms "pulse power" and "peak envelope power" are more pertinent to radar and navigation systems.

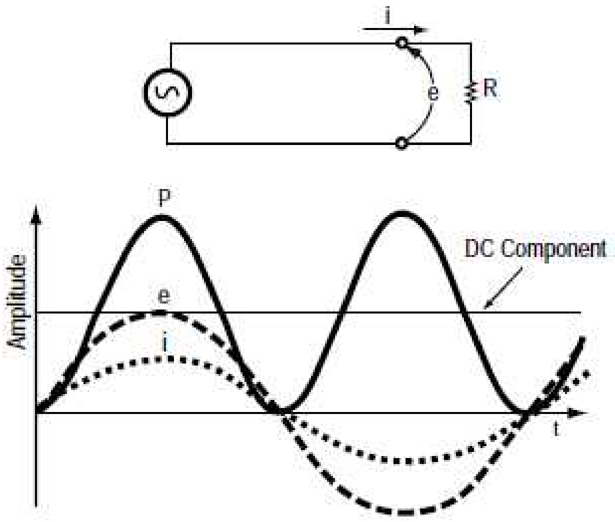

Fig.3.5

3.5 The product of voltage and current, P varies during the sinusoidal cycle.

In elementary theory, power is said to be the product of voltage and current. But for an AC voltage cycle, this product V x I varies during the cycle as shown by curve p in Figure 3.5, according to a 2f relationship. From that example, a sinusoidal generator produces a sinusoidal current as expected, but the product of voltage and current has a DC term as well as a component at twice the generator frequency. The word "power," as most commonly used, refers to that DC component of the power product.

The fundamental definition of power is energy per unit time. This corresponds with the definition of a watt as energy transfer at the rate of one joule per second. The important question to resolve is over what time is the energy transfer rate to be averaged when measuring or computing power?

From Figure3.5 it is clear that if a narrow time interval is shifted around within one cycle, varying answers for energy transfer rate are found. But at radio and microwave frequencies, such microscopic views of the voltage current product are not common. For this application, power is defined as the energy transfer per unit time averaged over many periods of the lowest frequency (RF or microwave) involved.

Average Power

Average power, like the other power terms to be defined, places further restrictions on the averaging time than just “many periods of the highest frequency.” Average power means that the energy transfer rate is to be averaged over many periods of the lowest frequency involved. For a continuous wave (CW) signal, the lowest frequency and highest frequency are the same, so average power and power are the same? For an amplitude modulated wave, the power must be averaged over many periods of the modulation component of the signal as well.

Average power, pulse power and peak envelope power all yield the same answer for a CW signal. Of all power measurements, average power is the most frequently measured because of convenient measurement equipment with highly accurate and traceable specifications. Pulse power and peak envelope power can often be calculated from an average power measurement by knowing the duty cycle. Average power measurements therefore occupy the greatest portion of this note

In microwave, power measurements are divided into three groups depending upon power level. These are low powers, which are less than 10mW; medium powers which are ranging from 10 mW to 1W and high powers, which are greater than 1W.

A microwave power meter consists of two parts, the power sensor which converts the MW power to some low frequency change of state and the low frequency circuitry provides an output reading corresponding to the change measured by the sensor.

Three methods of sensing power

There are three popular devices for sensing and measuring average power at RF and microwave frequencies. Each of the methods uses a different kind of device to convert the RF power to a measurable DC or low frequency signal.

The devices are the **thermistor, thermocouple and diode sensor**.

The general measurement technique for average power is to attach a properly calibrated sensor to the transmission line port at which the unknown power is to be measured. The output from the sensor is connected to an appropriate power meter. The RF power to the sensor is turned off and the power meter zeroed. This operation is often referred to as “zero setting” or “zeroing.” Power is then turned on. The sensor, reacting to the new input level, sends a signal to the power meter and the new meter reading is observed.

3.4.1 Thermistor Sensors

Bolo meters are power sensors that operate by changing resistance due to a change in temperature. The change in temperature results from converting RF or microwave energy into heat within the bolometric element. There are two principle types of bolometer, barretter and thermistors. A barretter is a thin wire that has a positive temperature coefficient of resistance. Thermistors are semiconductors with a negative temperature coefficient.

Thermistor elements are mounted in either coaxial or waveguide structures so they are compatible with common transmission line systems used at microwave and RF frequencies. The thermistor and its mounting must be designed to satisfy several important requirements so that the thermistor element will absorb as much of the power incident on the mount as possible.

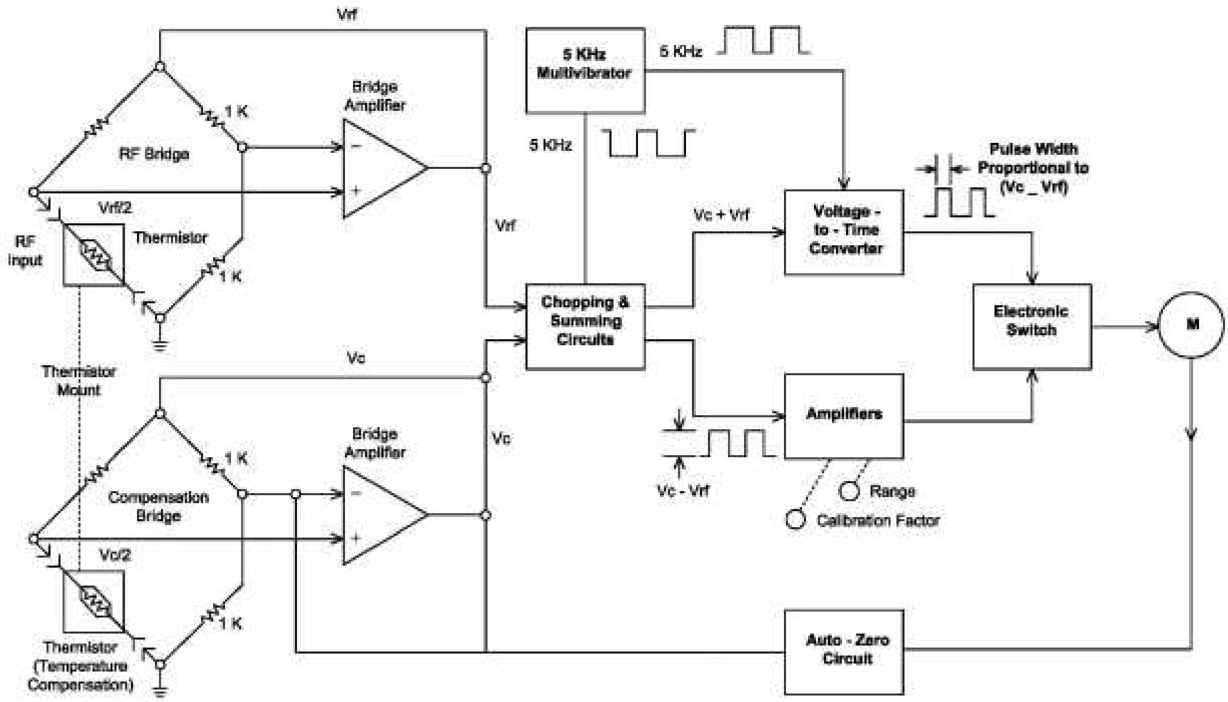

Fig.3.6 simplified diagram of power meter using thermistor

First, the sensor must present a good impedance match to the transmission line over the specified frequency range. The sensor must also have low resistive and dielectric losses within the mounting structure because only power that is dissipated in the thermistor element can be registered on the meter.

The principal parts of the meter as shown in Figure3.6 are two self-balancing bridges, the meter-logic section, and the auto-zero circuit. The RF bridge, which contains the detecting thermistor, is kept in balance by automatically varying the DC voltage Vrf, which drives that bridge. The compensating bridge, which contains the compensating thermistor, is kept in balance by automatically varying the DC voltage Vc, which drives that bridge. The power meter is initially zero-set (by pushing the zero-set button) with no applied RF power by making Vc equal to Vrfo (Vrfo means Vrf with zero RF power). After zero-setting, if ambient temperature variations change thermistor resistance, both bridge circuits respond by applying the same new voltage to maintain balance.

If RF power is applied to the detecting thermistor, Vrf decreases so that

$$P_{rf} = \frac{V_{rfo}^{\,2}}{4R} - \frac{V_{rf}^{\,2}}{4R} \qquad \text{eq-1}$$

Where Prf is the RF power applied and R is the value of the thermistor resistance at balance. But from zero-setting, Vrfo= Vc so that

$$P_{rf} = \frac{1}{4R}\ (V_c^{\,2} - V_{rf}^{\,2}) \qquad \text{eq-2}$$

Which can be written as

$$P_{rf} = \frac{1}{4R}\ (V_c - V_{rf})\ (V_c + V_{rf}) \qquad \text{eq-3}$$

The meter logic circuitry is designed to meter the voltage product shown in equation (eq-3). Ambient temperature changes cause Vc and Vrf to change so there is zero change to $(Vc)^2 - (Vrf)^2$ and therefore no change to the indicated Prf.

3.4.2 Thermocouple Sensors

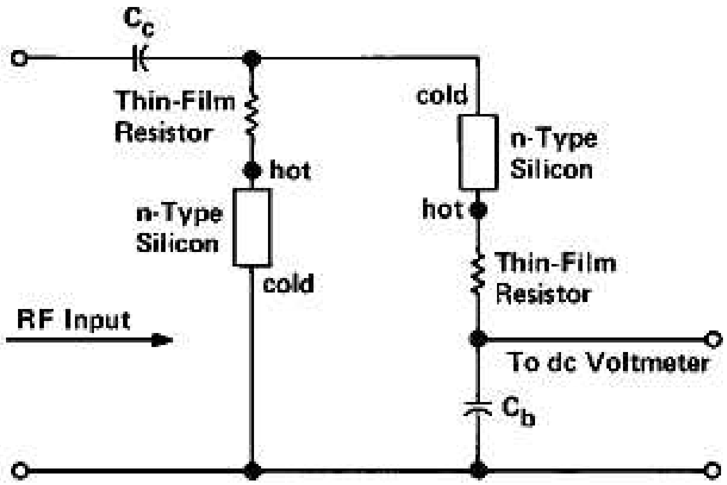

Fig.3.7 schematic diagram of thermocouple sensor

The power sensor contains two identical thermocouples on one chip, electrically connected as in Figure3.7. The thermocouples are connected in series as far as the DC voltmeter is concerned. For the RF input frequencies, the two thermocouples are in parallel, being driven through coupling capacitor Cc. Half the RF current flows through each thermocouple. Each thin-film resistor and the silicon in series with it has a total resistance of 100Ω. The two thermocouples in parallel form a 50 Ω termination to the RF transmission line.

The lower node of the left thermocouple is directly connected to ground and the lower node of the right thermocouple is at RF ground through bypass capacitor Cb. The DC voltages generated by the separate thermocouples add in series to form a higher DC output voltage. The principal advantage, however, of the two-thermocouple scheme is that both leads to the voltmeter are at RF ground; there is no need for an RF choke in the upper lead. If a choke were needed it would limit the frequency range of the sensor.

The principal characteristic of a thermocouple sensor for high frequency power measurement is its sensitivity in microvolts output per milliwatt of RF power input. The sensitivity is equal to the product of two other parameters of the thermocouple, the thermoelectric power and the thermal resistance. The thermoelectric power (not really a power but physics texts use that term) is the thermocouple output in microvolts per degree Celsius of temperature difference between the hot and cold junction.

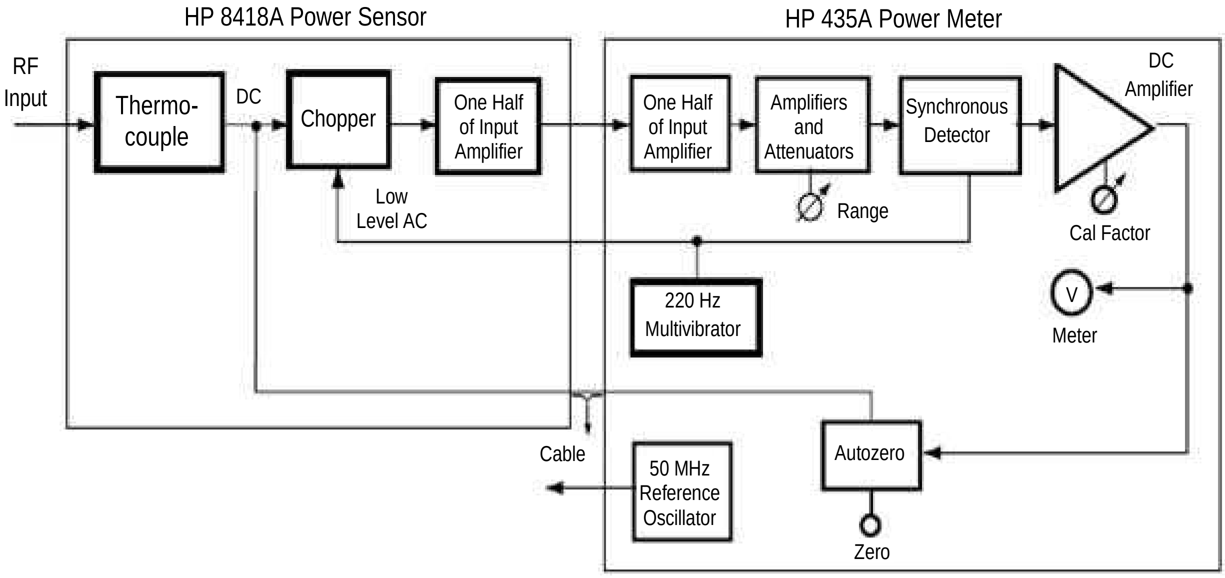

Fig.3.8 Block diagram of power meter using thermocouple sensor

Thermocouple sensor DC output is very low-level (approximately 160 nV for 1 microwatt applied power), so it is difficult to transmit in an ordinary flexible connection cable. This problem is multiplied if the user wants a long cable (25 feet and more) between the sensor and power meter. For this reason it was decided to include some low-level AC amplification circuitry in the power sensor, so only relatively high-level signals appear on the cable.

One practical way to handle such tiny DC voltages is to “chop” them to form a square wave, then amplify with an AC-coupled system. After appropriate amplification (some gain in the sensor, some in the meter), the signal is synchronously detected at the high-level AC. This produces a high-level DC signal which is then further processed to provide the measurement result. Figure 3.8 shows a simplified block diagram of the sensor/meter architecture.

The chopping frequency of 220 Hz was chosen as a result of several factors. Factors that dictate a high chopping frequency include lower 1/f noise and a larger possible bandwidth, and thereby faster step response. Limiting the chopping to a low frequency is the fact that small transition spikes from chopping inevitably get included with the main signal. These spikes are at just the proper rate to be integrated by the synchronous detector and masquerade as valid signals. The fewer spikes per second, the smaller this masquerading signal. However, since the spikes are also present during the zero-setting operation, and remain the same value during the measurement of a signal, the spikes are essentially removed from the meter indication by zero setting and cause no error. The spikes do, however, use up dynamic range of the amplifiers.

3.4.3 Diode Sensors

Rectifying diodes have long been used as detectors and for relative power measurements at microwave frequencies. The earliest diodes were used mostly for envelope detection and as nonlinear mixer components in super heterodyne receivers. For absolute power measurement, however, diode technology had been limited mainly to RF and low microwave frequencies.

Diode sensor principles

Diodes convert high frequency energy to DC by way of their rectification properties, which arise from their nonlinear current-voltage (i-v) characteristic. It might seem that an ordinary silicon p-n junction diode would, when suitably packaged, be a sensitive RF detector. However, p-n junctions have limited bandwidth. In addition, the silicon p-n junction, without bias, has extremely high impedance and will supply little detected power to a load. An RF signal would have to be quite large to drive the junction voltage up to 0.7 volts where significant current begins to flow. One alternative is to bias the diode to 0.7 volts, at which point it only takes a small RF signal to cause significant rectified current. This effort turns out to be fruitless, however, because the forward current bias gives rise to large amounts of noise and thermal drift. There is little, if any, improvement in the minimum power that can be metered.

Using Diodes for Sensing Power

Precision semiconductor fabrication processes for silicon allowed the Schottky diodes to achieve excellent repeatability, and, because the junction area was larger, they were more rugged. First use of such a low barrier Schottky diode (LBSD) for power sensing was introduced in 1975 as the power sensor.

As Gallium-Arsenide (GaAs) semiconductor material technology advanced in the 1980s, such devices exhibited superior performance over silicon in the microwave frequencies. A sophisticated diode fabrication process known as planar-doped-barrier (PDB) technology offered real advantages for power detection.

The new PDB sensor employed two diodes, fabricated on the same chip using MMIC (Microwave Monolithic Integrated Circuit) chip technology. The two diodes were deposited symmetrically about the center of a coplanar transmission line, and driven in a push-pull manner, for improved signal detection and cancellation of common-mode noise and thermal effects.

The construction is based on MMIC technology and combines the matching input pad, balanced PDB diodes, Field Effect Transistor (FET) choppers, integrated RF filter capacitors, and the line driving pre-amplifier. All of those components operate at such low signal levels that it was necessary to integrate them into a single thermal space on a surface-mount-technology PC board. Power sensor features a frequency range from 10 MHz to 18 GHz. To achieve the expanded dynamic range of 90 dB, the sensor/meter architecture depends on a data compensation algorithm which is calibrated and stored in an individual EEPROM in each sensor. The data algorithm stores information of three parameters, input power level vs frequency vs temperature for the range 10 MHz to 18 or 26.5 GHz and -70 to +20 dBm and 0 to 55° C.

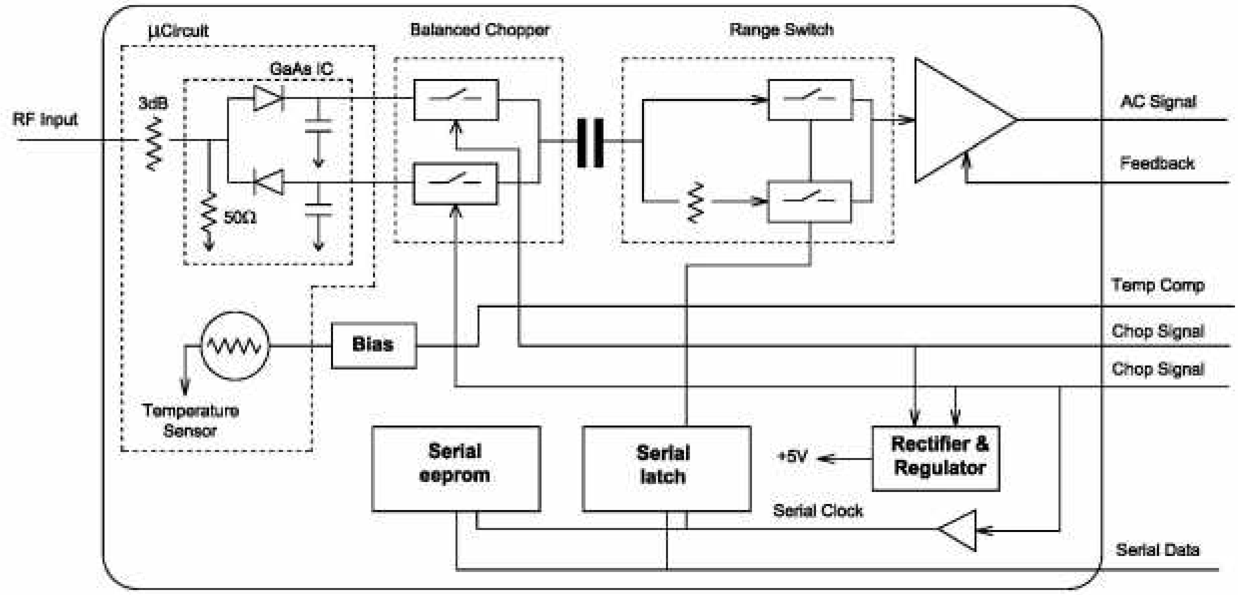

Fig.3.9 Schematic for MMIC power sensors

Power meter using MMIC power sensors:

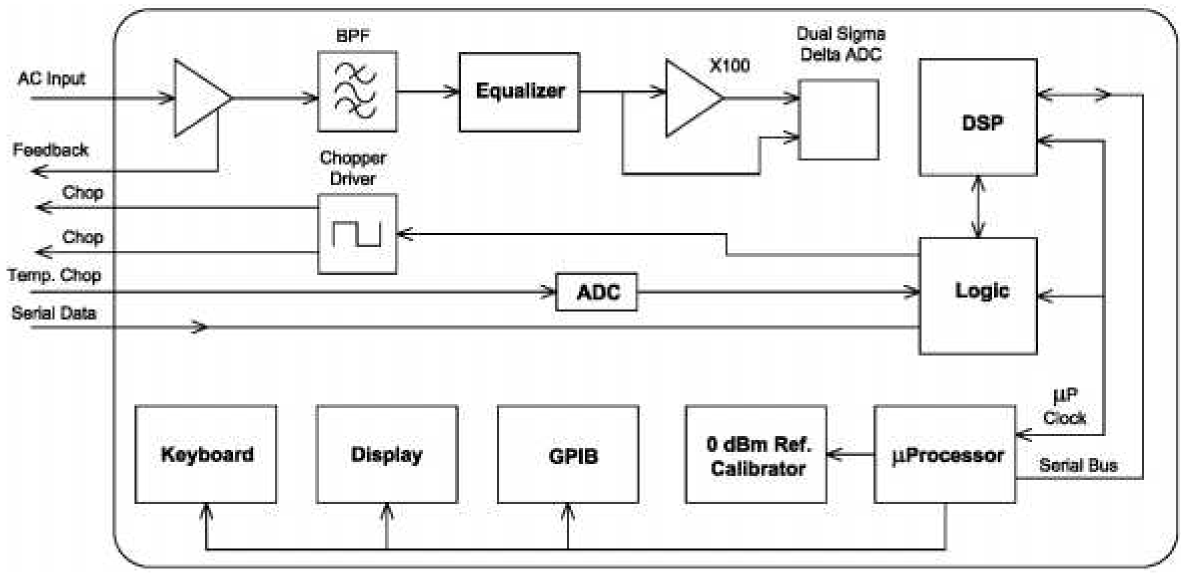

Fig3.10 Power meter using MMIC power sensors

The pre-amplified sensor output signal receives some early amplification, followed by some signal conditioning and filtering. The signal is then split, with one path receiving amplification. Both low and high-level chopped signals are applied to a dual ADC. A serial output from the ADC takes the sampled signals to the digital signal processor which is controlled by the main microprocessor. A differential drive signal, synchronized to the ADC sampling clock, is output to the sensor for its chopping function. The ADC provides a 20-bit data stream to the digital signal processor, which is under control of the main micro-processor. There is no range switching as in traditional power meters which maintain an analog signal path. Even the synchronous detection is performed by the ADC (analog to digital converter) and DSP (digital signal processesor) rather than use of a traditional synchronous detector.

Objective:

1. Selective level meter works on the principle of------------------ receiver.
2. SLM's can be used for selective and ---------------------measurements.
3. --------------------method is primarily used for frequency measurement in microwave range
4. .------------------------- circuit is an essential component for frequency counting device.
4. Latch is a simple memory circuit for holding the------------------------.
5. ------------------method of power measurement is accurate and easier at 30 MHz and above.
6. Power measurement in micro wave range refers to the -------------- power.
7. Under Bolo meter method of power measurement--------------sensors are used.
8. Thermocouple sensor is a composition of------------------and ----------------- hot and cold junction.
9. Diode sensors are GaAs based semiconductors fabricated by----------------- technology.

Subjective:

1. State the necessity of Selective level meter and oscillator for carrier and FDM systems.
2. Describe the principle of SLM, What are the tests that can be done with a SLM?
3. Draw and explain a basic frequency counter.
4. Why heterodyne type frequency counters are suitable for measuring MW frequencies up to 20 GHz?
5. What are the three methods of measuring power in RF and MW frequency range? Describe any one.

CHAPTER-4

MEASURING INSTRUMENTS USED IN OFC

4.0 Typical Fiber Optic Field Measurements

Why and where we have to use OFC measurements?

- Link Certification
  - Insertion loss
  - Length
- Troubleshooting
  - Equipment output power
  - Link insertion loss
  - Link continuity
  - Link fault-locating

The instruments which are mostly used in the field of OFC are

1. Visual Fault Locator
2. Optical power meter
3. OTDR

4.1 Visual Fault Locator

Visual fault locator (also called laser fault locator) is a handheld device using 650nm or 635nm visible laser source that emits a bright beam of laser light into a fiber, allowing the user to visually detect a fiber fault for up to 5 km.

With these fault locators you can easily isolate high losses and faults in optical fiber cables. The bright beam of 650nm or 635nm red light in a fiber allows you to see a break as a glowing or blinking red light

They can operate on multimode or single mode fibers independent of the transmission wavelength.

VFLs are designed to locate faults visually in single mode optical fiber cable

1. To locate breaks
2. To locate macro bends
3. To locate fault in connectors
4. To find end to end identification.

These devices typically couple 1mW of 650nm Laser light into the fiber core, allowing for instant identification of fiber breaks, micro or tight macro bending, even through tight buffered or un buffered.

Two versions are available: one with a universal port for 2.5mm ferrule connectors and one which includes an adapter that allows use with 1.25mm ferrule connectors

Applications include LAN, WAN, fiber data links, telephone and CATV.

4.2 OPTICAL POWER METER

For optical fiber loss measurement, the measurement with an optical power meter is made to determine how much attenuation (loss) the light emitted from a light source suffers, while it travels through a given length of fiber.

The devices required for optical power measurement are light source, optical sensor, optical power meter and FC-PC patch cord

4.2.1 LED/Laser light source:

Fiber light source is a test equipment to measure the loss of fiber cables; usually it is used with the fiber optic power meters.

The source of the photon energy may be a light-emitting or semiconductor laser diode, whose function is to produce light energy at a single wavelength. By turning the light source on and off quickly, streams of ones and zeros can be transmitted to form a digital communications channel.

The wavelength of the optical light source describes the frequency of the transmitted light wave (the longer the wavelength, the lower the light wave’s frequency) and has been selected to best match the transmission properties of recognized optical fiber types. The light source will be provided with an inbuilt optical attenuator, to vary the attenuation of the output level (typically 0 to 6db in 0.1 steps). The internal digital modulation frequency options is also provided in the source unit. The options may be 270Hz, 1 KHz and 2 KHz

Fiber optical light sources provide 1 to 4-wavelength output according to the specific requirements including the 650nm red source, 1310nm/1550nm wavelength for the single mode fiber and 850nm/1300nm wavelength for the multimode fiber.

In general, lasers transmitting over single mode fiber support the highest bandwidth and longest distance, while LEDs transmitting over larger diameter (62.5-µm) multimode fiber support the lowest bandwidth and shortest distances.

4.2.2 POWER METER

An optical power meter (OPM) is a device used to measure the energy in an optical signal. The term usually refers to a device for testing average power in fiber optic systems.

A typical OPM device consists of a calibrated sensor, display and measurement units. The sensor primarily consists of photodiode which is fit to measure appropriate range of wavelengths. On the display unit, measured optical power and the wavelength being measured is displayed. Depending on the set measurement wave on power meter, measured power can vary due to the calibration of the device. A traditional optical power meter responds to a broad spectrum of light. However, the calibration is wavelength dependent. This is not normally an issue, since the test wavelength is usually known; the user must set the meter to the correct test wavelength.

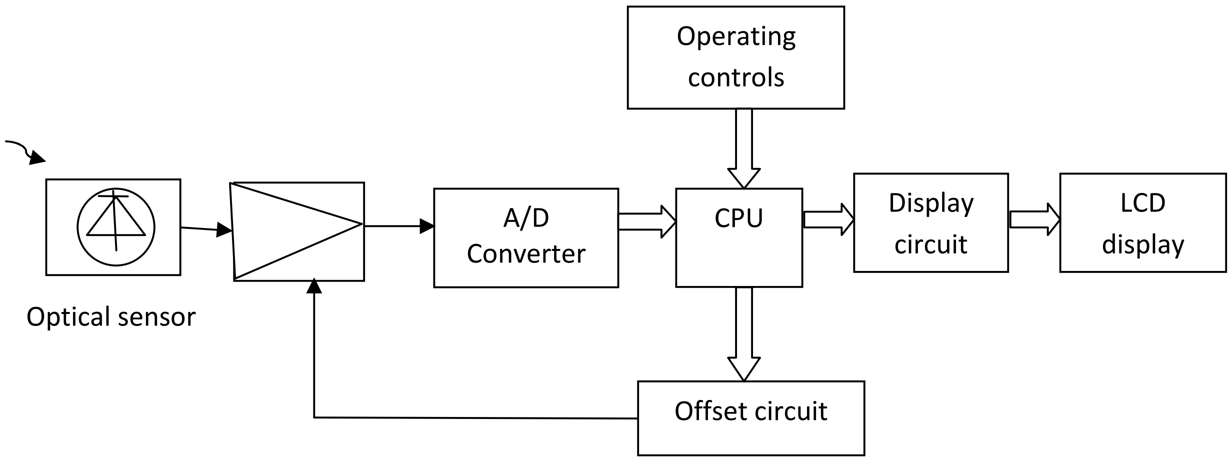

Fig.4.1 Typical Block diagram of optical power meter

An optical sensor is a device that converts light rays into electronic signals, it measures the physical quantity of light and translates it into a form read by the instrument. Usually, the optical sensor is part of a larger system integrating a measuring device, a source of light and the sensor itself. This is generally connected to an electrical trigger, which reacts to a change in the signal within the light sensor.

One of the features of an optical sensor is its ability to measure the changes from one or more light beams. This change is most often based around alterations to the intensity of the light. When a phase change occurs, the light sensor acts as a photoelectric trigger, either increasing or decreasing the electrical output, depending on the type of sensor.

The major semiconductor sensor types are Silicon (Si), Germanium (Ge) and Indium Gallium Arsenide (InGaAs). Additionally, these may be used with attenuating elements for high optical power testing or wavelength selective elements so they only respond to particular wavelengths. These all operate in a similar type of circuit. However in addition to their basic wavelength response characteristics, each one has some other particular characteristics. The sensor covers a wavelength range of 800 to 1700nm and the power range is -60 to + 3 dBm (1 nw to 2 mw).

An important part of an optical power meter sensor, is the fiber optic connector interface. Careful optical design is required to avoid significant accuracy problems when used with the wide variety of connectors typically encountered.

4.2.3 Optical power measurement:

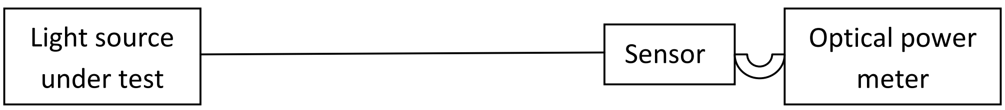

Fig 4.2 Typical connectivity diagram for optical power measurement

Measurement procedure:

By connecting the fiber under test as shown in the above figure,

- Select the continuous wave (CW) output on the LED source
- Select the wave length on the sensor
- Connect the sensor to the optical power meter
- Select the dBm mode on the power meter
- Connect patch cord between the output of optical source and the sensor and take the measurements

4.3 OPTICAL TIME DOMAIN REFLECTOMETER (OTDR)

OTDR (Optical Time Domain Reflectometer) is a measuring instrument for identifying optic fiber transmission features. The instrument is mainly used to measure attenuation of a whole optic fiber chain and provide attenuation details relating to length namely to detect, locate and measure any event in optic fiber chain (events refer to faults caused by splicing, connectors, and bending whose transmission change can be measured). Its non-destructive one-end connection and rapid measurement has made the OTDR an indispensable tool for manufacture, construction, and maintenance of optic fiber.

Information relating to distance is obtained through time information (that's the reason why there is "time Domain" in the name of OTDR). Fresnel reflection occurs at the boundary between two media of different (IOR) Index Of Refraction (for example, connections of faults, connectors, or optic fiber end). This reflection is used to locate the discontinuous points on optic fiber. The magnitude of reflection depends on the difference between IOR and the smoothness of boundary.

The OTDR measures the time difference between the outgoing pulse and the incoming back scattered pulses. An OTDR sends short pulses of light into a fiber. Light scattering occurs in the fiber due to discontinuities such as connectors, splices, bends and faults. An OTDR then detects and analyzes the backscattered signals. The signal strength is measured for specific intervals of time and is used to characterize events. This way OTDR can be characterized similar to optical radar.

An OTDR uses the effects of Rayleigh scattering and Fresnel reflection to measure the fiber condition, but the Fresnel reflection is tens of thousands of times greater in power level than the backscatter.

Rayleigh scattering occurs when a pulse travels down the fiber and small variations in the material, such as variations and discontinuities in the index of refraction, cause light to be scattered in all directions. However, the phenomenon of small amounts of light being reflected directly back toward the transmitter is called backscattering.

Fresnel reflections occur when the light traveling down the fiber encounters abrupt changes in material density that may occur at connections or breaks where an air gap exists. A very large quantity of light is reflected, as compared with the Rayleigh scattering. The strength of the reflection depends on the degree of change in the index of refraction. Fresnel reflections are only point events.

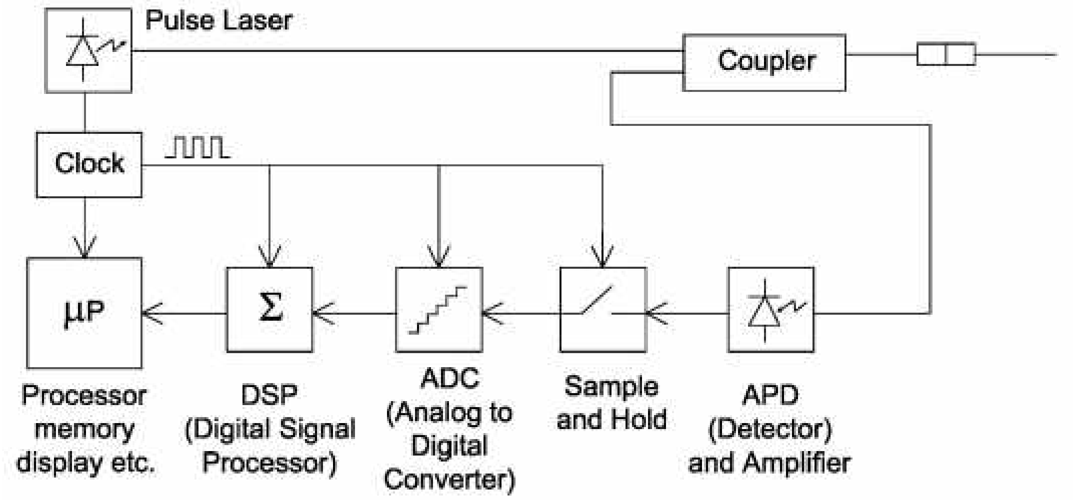

Fig. 4.3 Typical block diagram of an OTDR

The basic OTDR setup consists of a source laser, a coupler, a detector, a processor, a connector panel on the OTDR, a launch cable and the system under test.

The source laser, coupler, detector, and processor are all contained inside the OTDR. When a trace is shot, the source laser shoots pulses through the coupler then through the system via the launch cable. As light is scattered back to the OTDR, the light goes back through the coupler which redirects the light to the detector. The processor then analyzes the data received from the detector and constructs the trace.

The following measurements can be carried out with OTDR:

- Fiber Attenuation Characteristics (dB/km)
- Insertion Loss (Connector)
- Splice loss
- End to End Loss Measurements (Link loss) and
- Break point (fiber break)

4.3.1 Trace Analysis of OTDR

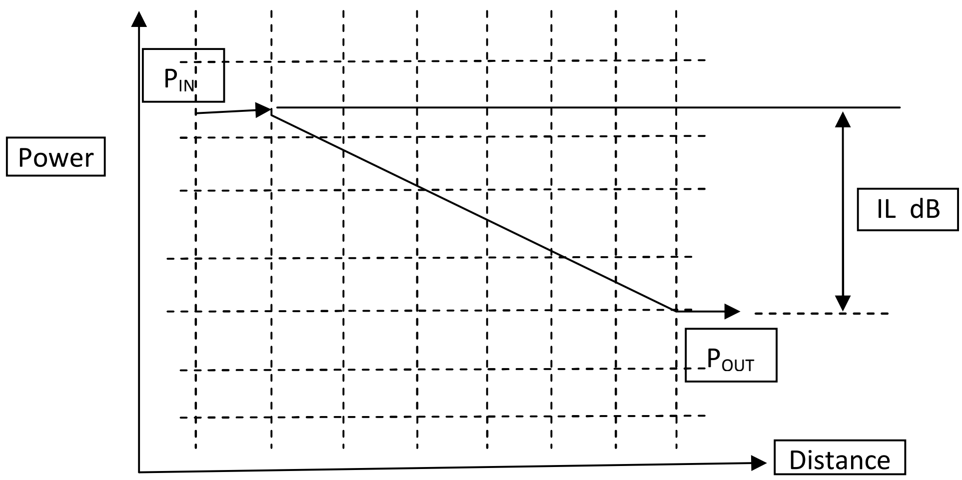

Fig 4.4 OTDR graph or "trace" of power vs. distance …

OTDR sends out a light pulse into connected optic fiber, and receive reflections of events and backward scattering power of pulse in time and converts sample times into distances. (Distance = Speed x Time). The y-axis is dB value of backward scattering power, and the x-axis is the distance. Insertion loss (IL) is the $P_{IN} - P_{OUT}$

Where P_{IN} is the power inserted into the fiber to be tested and P_{OUT} is the received power from the fiber end.

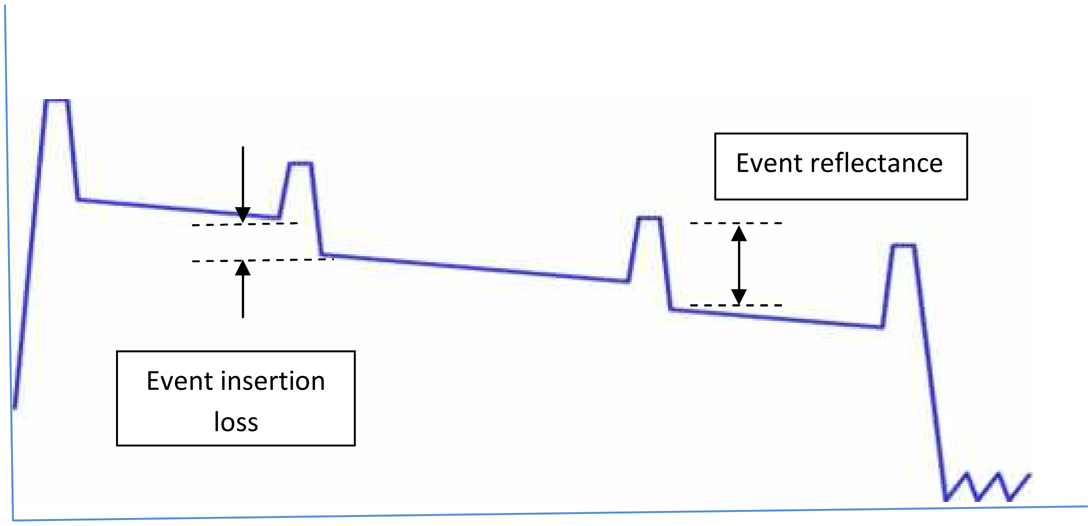

Fig 4.5 OTDR trace of events

4.3.2 Basic Definition and Classification of Events

Events refer to any abnormal points causing attenuation or sudden change of scattering power besides the normal scattering of optic fiber, which include all kinds of losses like bending, connections etc.

Events points displayed on LCD are abnormal points that cause traces to deviate from straight line. Events can be classified as reflection events and non-reflection events.

4.3.3 Reflection Events

When some pulse energy is scattered, reflection events happen. Reflection events occur at connectors. When reflection event occurs, peak shows on trace, as shown in Figure4.6

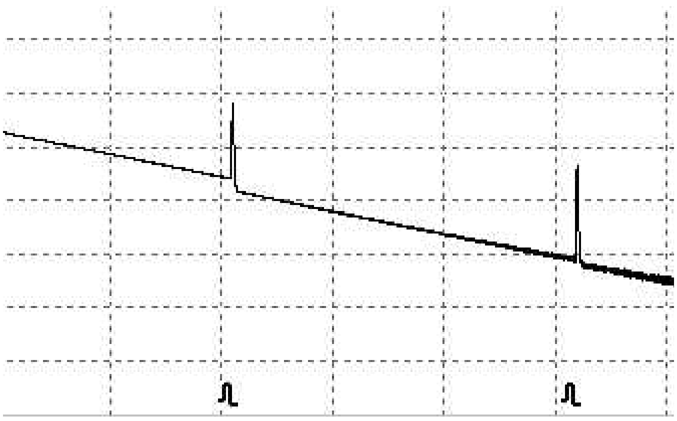

Fig 4.6 Reflection Event

4.3.4 Non-reflection Events

Non-reflection events happen at certain points(at splice) where there is some optic loss but no light scattering. When non-reflection event occurs, a power decline shows on trace, as in Figure 4.7

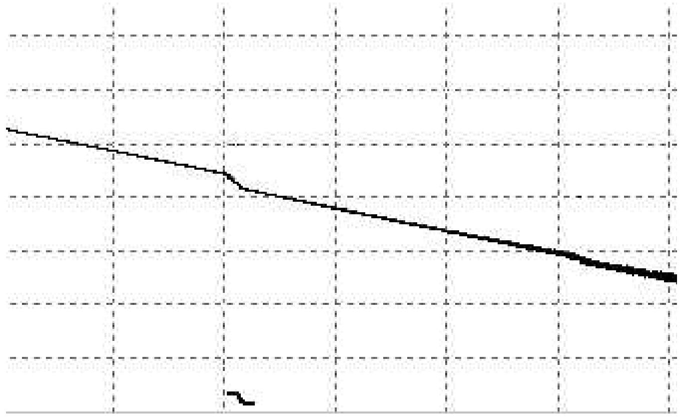

Fig 4.7 Non-reflection Event

4.3.5 OTDR Setup

OTDRs have four basic setup requirements

- Range/Resolution
- Wavelength
- Pulse Width
- Index of Refraction

Range is the selection of distance of fiber to be tested. Distance range will be typically 18, 36, 72,144 Km. In the horizontal axis (X- axis) of the trace will be Km/full scale.

Wavelength selection is depending upon requirement as 1310 nm or 1550nm. The selected wave length will be displayed on LCD.

Pulse Width is the width of the optical pulse from the OTDR reflected in a time frame. Long pulse widths are suitable for long distance measurements but then the dead zone will become wider and the connector for short intervals will disappear. On the other hand, short pulse widths can identify connectors of short intervals but it cannot make long distance measurements as the optical power will decrease. Pulse width will be expressed in µ seconds.

Index of Refraction enables the refractive index of the optical fiber to be set. The index range will be 1.4000 to 1.5999 in 0.0001 steps.

Objective:

1. Visual fault locator allows -------------observation of fiber cable faults as breaks, micro or macro bending.
2. VFL couples typically---------------micro watts of laser light into the fiber core.
3. Optical power source is used along with---------------------fiber optic power meter.
4. Optical sensors typically sense the power in the range -----------to ----------dBm in the wavelength range ----------------to ---------------- nm.
5. OTDR uses the effects of------------------------and ------------------ to measure the condition of fiber under test.
6. Fresnel reflections are ----------------times more powerful than Rayleighs scatter signals.
7. In OTDR the power level of the ------------------and ------------------ signal is sampled over time.

Subjective:

1. Write the utility of a Visual Fault Locator.
2. Draw and explain the block diagram of an Optical Power meter.
3. State the procedure of Optical power measurement.
4. Explain why OTDR is a indispensable tool for OF communication?
5. Draw and explain the principle of OTDR with a block diagram.
6. Why is OTDR told to be optical radar? What are the traces and events in the display of OTDR?
7. State the basic setup requirements needed before using an OTDR?

CHAPTER-5

ANALYZERS

5.0 GENERAL

An analyzer is a device that analyses given data. It examines in detail the structure of the given data and tries to find patterns and relationships between parts of the data. An analyser can be a piece of hardware or a software program running on a computer

5.1 Classification of analyzers

Analyzers are broadly classified as spectrum analyzers and network analyzers.

A spectrum analyzer or spectral analyzer is a device used to examine the spectral composition of some electrical, acoustic or optical waveform. It may also measure the power spectrum.

A spectrum analyzer displays signal amplitude (strength) as it varies by signal frequency. The frequency appears on the horizontal axis, and the amplitude is displayed on the vertical axis. To the casual observer, a spectrum analyzer looks like an oscilloscope and, in fact, some lab instruments can function either as oscilloscopes or spectrum analyzers.

A spectrum analyzer can also be used to determine whether or not a wireless transmitter is working according to defined standards for purity of emissions. Output signals at frequencies other than the intended communications frequency appear as vertical lines (pips) on the display. A spectrum analyzer can also be used to determine, by direct observation, the bandwidth of a digital or analog signal, because its analysis is frequency domain based.

A network analyzer (RF) is an instrument used to analyze the properties of electrical networks, especially those properties associated with the reflection and transmission of electrical signals known as scattering parameters (S-parameters).

A network analyzer (data communications) also called a protocol analyzer or packet analyzer is a combination of hardware and programming, or in some cases a stand-alone hardware device, that can be installed in a computer or network to enhance protection against malicious activity. Network analyzers can supplement firewalls, anti-virus programs and spyware detection programs.

5.2 SPECTRUM ANALYZERS

Spectrum analyzers are used primarily to display the spectrum of a radio frequency signal. It can also be used to make power and frequency measurements, although not as accurately as dedicated instruments

A spectrum analyzer display, like that of an oscilloscope has two axes. For the spectrum analyser the vertical axis displays level or amplitude, whereas the horizontal axis displays frequency. Therefore as the scan moves along the horizontal axis, the display shows the level of any signals at that particular frequency

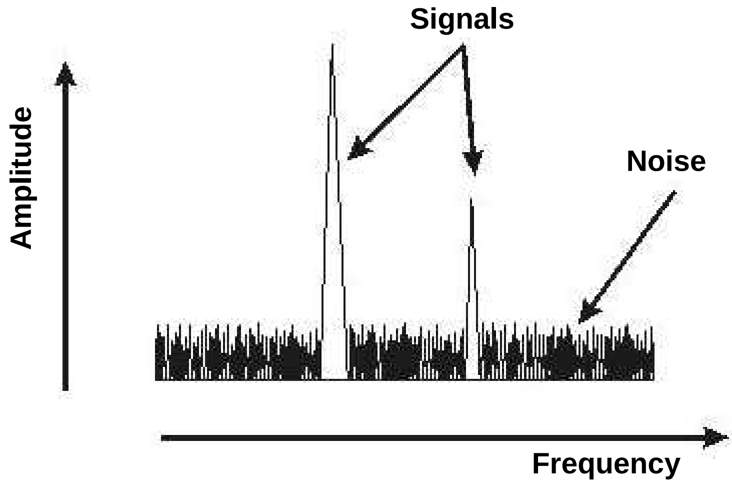

Fig 5.1 General format of the display on a spectrum analyzer

This means that the spectrum analyser, as the name indicates analyses the spectrum of a signal. It shows the relative levels of signals on different frequencies within the range of the particular sweep or scan. In view of the very large variations in signal level that are expected. These are calibrated in dB in line with many other measurements that made for signal amplitudes. The horizontal scale conversely is normally linear. This can be adjusted to cover the required range. The term span is used to give the complete calibrated range across the screen.

5.2.1 Types of spectrum analyser

Just as in the case of other instruments, there are a number of types of spectrum analyzer that can be seen in the manufacturers catalogues.

- **Swept or super heterodyne spectrum analysers*:*** The operation of the swept frequency spectrum analyzer is based on the use of the super heterodyne principle, sweeping the frequency that is analysed across the required band to produce a view of the signals with their relative strengths. This may be considered as the more traditional form of spectrum analyser, and it is the type that is most widely used.
- **Fast Fourier Transform, FFT analysers*:*** These spectrum analyzers use a form of Fourier transform known as a Fast Fourier Transform (FFT) converting the signals into a digital format for analysis digitally. These analysers are more expensive and often more specialised.

5.2.2 Swept or super heterodyne spectrum analyser

Super heterodyne spectrum analyzer technology also referred to as sweep or swept frequency spectrum analyzer technology is widely used within analyzers to make RF measurements. Super heterodyne or sweep analyzers offer very high levels of performance, especially when compared to what was available a few years ago. Typically today they make widespread use of digital signal processing techniques, the signals being converted into a digital format after the IF stage. This enables very flexible filtering to be offered along with a host of other useful facilities that would not be possible if only analogue techniques were employed

The swept spectrum analyser uses the same super heterodyne principle used in many radio receivers as the underlying principle on which its operation depends. The super heterodyne principle uses a mixer and a second, locally generated local oscillator signal to translate the frequency.

The mixing principle used in the spectrum analyzer operates in exactly the same manner as it does for a super heterodyne radio receiver. The signal entering the front end is translated to another frequency, typically lower in frequency. Using a fixed frequency filter in the intermediate frequency section of the equipment enables high performance filters to be used, and the analyzer or receiver input frequency can be changed by altering the frequency of the local oscillator signal entering the mixer.

Although the basic concept of the spectrum analyzer is exactly the same as the super heterodyne radio, the particular implementation differs slightly to enable it to perform its function as a spectrum analyzer.

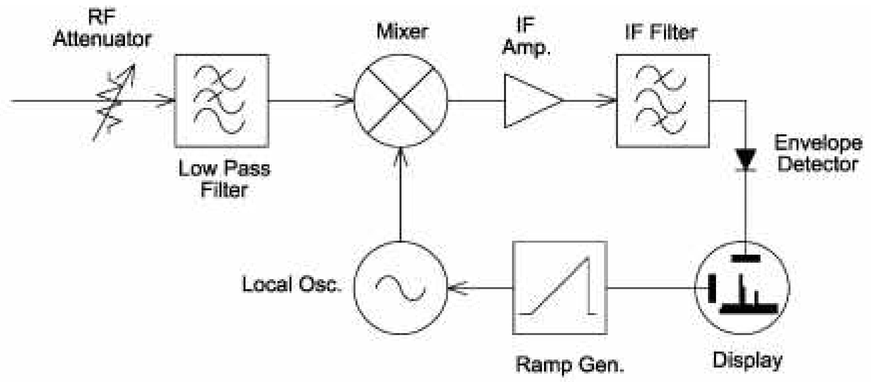

Fig 5.2 Super heterodyne or swept frequency spectrum analyzer block diagram

The frequency of the local oscillator governs the frequency of the signal that will pass through the intermediate frequency filter. This is swept in frequency so that it covers the required band. The sweep voltage used to control the frequency of the local oscillator also controls the sweep of the scan on the display. In this way the position of the scanned point on the screen relates to the position or frequency of the local oscillator and hence the frequency of the incoming signal. Also any signals passing through the filter are further amplified, detected and often compressed to create an output on a logarithmic scale and then passed to the display Y axis.

Advantages of the super heterodyne spectrum analyser

Able to operate over wide frequency range*:* Using the super heterodyne principle, this type of spectrum analyzer is able to operate up to very high frequencies - many extend their coverage to many GHz.

Wide bandwidth*:* Again as a result of the super heterodyne principle this type of spectrum analyzer is able to have very wide scan spans. These may extend to several GHz in one scan.

Not as expensive as other spectrum analyzer technologies: Although spectrum analyzers of all types are expensive, the FFT style ones are more expensive for a similar level of performance as a result of the high performance ADCs in the front end.

This means that for the same level of base performance, the super heterodyne or sweep spectrum analyzer is less expensive.

Disadvantages of the super heterodyne spectrum analyzer technology

Cannot measure phase*:* The super heterodyne or sweep spectrum analyzer is a scalar instrument and unable to measure phase - it can only measure the amplitude of signals on given frequencies.

Cannot measure transient events*:* FFT analyzer technology is able to sample over a short time and then process this to give the required display. In this way it is able to capture transient events. As the super heterodyne analyzer sweeps the bandwidth required, this takes longer and as a result it is unable to capture transient events effectively.

5.2.3 Fast Fourier Transform Spectrum analyzer

FFT analyzers find many uses, especially where phase or short term waveform capture and analysis are required. To capture a waveform digitally, this must be achieved using discrete values, both in terms of the values of samples taken, and the time intervals at which they are taken. As the time domain waveform is taken at time intervals, it is not possible for the data to be converted into the frequency domain using the standard Fourier transform. Instead a variant of the Fourier transform known as the Discrete Fourier Transform, DFT must be used. As the DFT uses discrete samples for the time domain waveform, this reflects into the frequency domain and results in the frequency domain being split into discrete frequency components of "bins." The number of frequency bins over a frequency band is the frequency resolution. To achieve greater resolution, a greater number of bins is needed, and hence in the time domain a large number of samples is required. As can be imagined, this results in a much greater level of computation, and therefore methods of reducing the amount of computation required is needed to ensure that the results are displayed in a timely fashion, although with today’s vastly increased level of processing power, this is less of a problem. To ease the processing required, a Fast Fourier Transform, FFT is used. This requires that the time domain waveform has the number of samples equal to a number which is an integral power of two.

The block diagram and topology of an FFT spectrum analyzer are different to that of the more usual super heterodyne or swept spectrum analyzer. In particular circuitry is required to enable the digital to analogue conversion to be made, and then for processing the signal as a Fast Fourier Transform. This means that the block diagram for the FFT spectrum analyzer is very different to that of the more familiar super heterodyne spectrum analyzer.

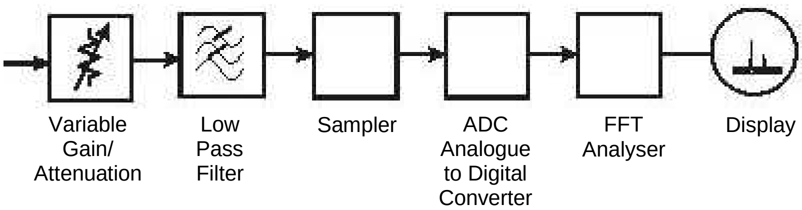

Fig.5.4 FFT Spectrum Analyser Block Diagram

FFT Spectrum Analyser Elements: The FFT spectrum analyzer can be considered to comprise of following blocks

Analogue front end attenuators/gain*:* The FFT analyzer requires attenuators of gain stages to ensure that the signal is at the right level for the analogue to digital conversion. If the signal level is too high, then clipping and distortion will occur, too low and the resolution of the ADC and noise become a problems. Matching the signal level to the ADC range ensures the optimum performance and maximises the resolution of the ADC.

Analogue low pass anti-aliasing filter*:* The signal is passed through an anti-aliasing filter. This is required because the rate at which points are taken by the sampling system within the FFT spectrum analyzer is particularly important. The waveform must be sampled at a sufficiently high rate. According to the Nyquist theorem a signal must be sampled at a rate equal to twice that of the highest frequency, and also any component whose frequency is higher than the Nyquist rate will appear in the measurement as a lower frequency component - a factor known as "aliasing". This results from, where the actual values of the higher rate fall when the samples are taken. To avoid aliasing a low pass filter is placed ahead of the sampler to remove any unwanted high frequency elements. This filter must have a cut-off frequency which is less than half the sampling rate, although typically to provide some margin, the low pass filter cut-off frequency is at highest 2.5 times less than the sampling rate of the FFT spectrum analyzer. In turn this determines the maximum frequency of operation of the FFT spectrum analyzer.

Sampling and analogue to digital conversion*:* In order to perform the analogue to digital conversion, two elements are required. The first is a sampler which takes samples at discrete time intervals - the sampling rate. The importance of this rate has been discussed above. The samples are then passed to an analogue to digital converter which produces the digital format for the samples that is required for the FFT analysis.

FFT analyzer*:* With the data from the sampler, which is in the time domain, this is then converted into the frequency domain by the FFT analyzer. This is then able to further process the data using digital signal processing techniques to analyze the data in the format required.

Display*:* With the power of processing it is possible to present the information for display in a variety of ways. Today's displays are very flexible and enable the information to be presented in formats that are easy to comprehend and reveal a variety of facets of the signal. The display elements of the FFT spectrum analyzer are therefore very important so that the information captured and processed can be suitably presented for the user.

Advantages of FFT spectrum analyzer technology

Fast capture of waveform*:* In view of the fact that the waveform is analysed digitally, the waveform can be captured in a relatively short time, and subsequently analysed. This short capture time can have many advantages.

Able to capture non-repetitive events*:* The short capture time means that the FFT analyzer can capture non-repetitive waveforms, giving them a capability not possible with other spectrum analyzers.

Able to analyse signal phase*:* As part of the signal capture process, data is gained which can be processed to reveal the phase of signals.

Disadvantages of the FFT spectrum analyzer technology

Frequency limitations*:* The main limit of the frequency and bandwidth of FFT spectrum analyzers is the analogue to digital converter, ADC that is used to convert the analogue signal into a digital format. While technology is improving this component still places a major limitation on the upper frequency limits or the bandwidth if a down-conversion stage is used.

Cost: The high level of performance required by the ADC means that this item is a very high cost item. In addition to all the other processing and display circuitry required, this results in the costs rising for these items.

5.3 Network analyser: Network analyzers are used mostly at high frequencies; operating in the range 9 kHz to 110 GHz. Special types of network analyzers can also cover lower frequency ranges down to 1 Hz. These network analyzers can be used for example for the stability analysis of open loops or for the measurement of audio and ultrasonic components. RF network analyser is used to measure the properties of RF devices.

The two main types of network analyzers are

- **Scalar Network Analyzer** (SNA) — measures amplitude properties only
- **Vector Network Analyzer** (VNA) — measures both amplitude and phase properties

An SNA is functionally identical to a spectrum analyzer in combination with a tracking generator

5.3.1 Generalized Network Analyzer

Here is a generalized block diagram of a network analyzer, showing the major signal-processing sections.

In order to measure the incident, reflected and transmitted signal, four sections are required:

- Source for stimulus
- Signal-separation devices
- Receivers that down convert and detect the signals
- Processor/display for calculating and reviewing the results

Description of network analyzer:

Source

The signal source supplies the stimulus for our stimulus-response test system. We can either sweep the frequency of the source or sweep its power level. Traditionally, network analyzers used a separate source. These sources were either based on open-loop voltage-controlled oscillators (VCOs) which were cheaper, or more expensive synthesized sweepers which provided higher performance, especially for measuring narrowband devices. Excessive phase noise on open-loop VCOs degrades measurement accuracy considerably when measuring narrowband components over small frequency spans. Most network analyzers today have integrated, synthesized sources, providing excellent frequency resolution and stability.

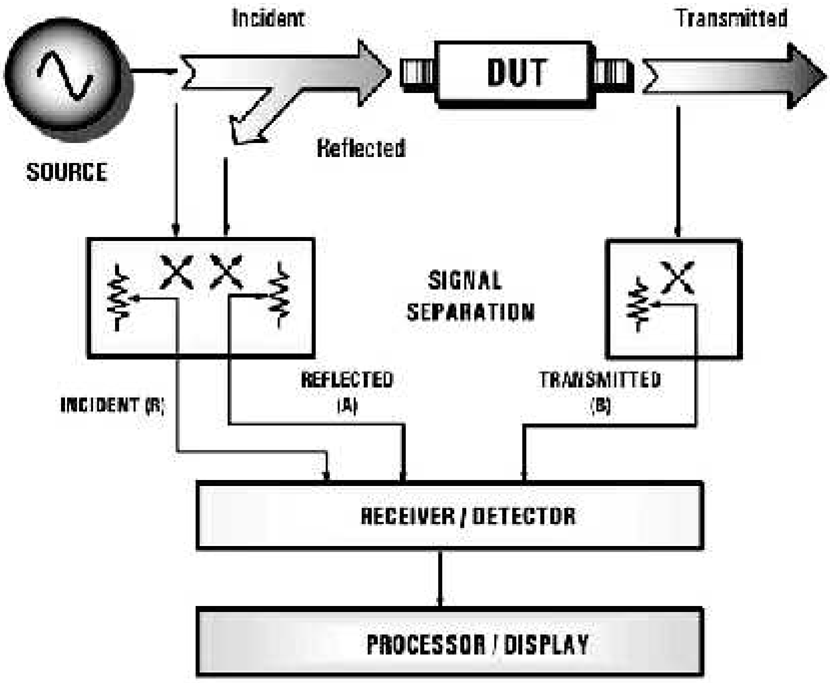

Fig.5.5 Generalized Network Analyzer Block Diagram

Signal Separation

The next major area is the signal separation block. The hardware used for this function is generally called the “test set”. The test set can be a separate box or integrated within the network analyzer.

There are two functions that signal-separation hardware must provide. The first is to measure a portion of the incident signal to provide a reference for ratioing. This can be done with splitters or directional couplers. Splitters are usually resistive. They are non-directional devices and can be very broadband. The trade-off is that they usually have 6 dB or more of loss in each arm. Directional couplers have very low insertion loss (through the main arm) and good isolation and directivity. They are generally used in microwave network analyzers, but their inherent high-pass response makes them unusable below 40 MHz or so.

The second function of the signal splitting hardware is to separate the incident (forward) and reflected (reverse) traveling waves at the input of DUT. Again, couplers are ideal in that they are directional, have low loss, and high reverse isolation. However, due to the difficulty of making truly broadband couplers, bridges are often used instead. Bridges work down to DC, but have more loss, resulting in less signal power delivered to the DUT.

Directivity

Unfortunately, real signal-separation devices are never perfect. For example, let's take a closer look at the actual performance of a 3-port directional coupler. Ideally, a signal traveling in the coupler's reverse direction will not appear at all at the coupled port. In reality, however, some energy does leak through to the coupled arm, as a result of finite isolation. One of the most important parameter for couplers is their directivity.

Directivity is a measure of a coupler's ability to separate signals flowing in opposite directions within the coupler. It can be thought of as the dynamic range available for reflection measurements.

Directivity can be defined as:

Directivity (dB) = Isolation (dB) - Forward Coupling Factor (dB) –
Loss (through-arm) (dB)

Detector Types

The next portion of the network analyzer is the signal detection block. There are two basic ways of providing signal detection in network analyzers. Diode detectors convert the RF signal level to a proportional DC level. If the stimulus signal is amplitude modulated, the diode strips the RF carrier from the modulation (this is called AC detection). Diode detection is inherently scalar, as phase information of the RF carrier is lost. The tuned receiver uses a local oscillator (LO) to mix the RF down to a lower "intermediate" frequency (IF). The LO is either locked to the RF or the IF signal so that the receivers in the network analyzer are always tuned to the RF signal present at the input. The IF signal is band pass filtered, which narrows the receiver bandwidth and greatly improves sensitivity and dynamic range. Modern analyzers use an analog-to-digital converter (ADC) and digital-signal processing (DSP) to extract magnitude and phase information from the IF signal. The tuned-receiver approach is used in vector network analyzers and spectrum analyzers.

Processor/Display

The last major block of hardware in the network analyzer is the display/processor section. This is where the reflection and transmission data is formatted in ways that make it easy to interpret the measurement results. Most network analyzers have similar features such as linear and logarithmic sweeps, linear and log formats, polar plots, Smith charts, etc. Other common features are trace markers, limit lines and pass/fail testing.

5.3.2 What is the Difference between Network and Spectrum Analyzers?

Now that we have seen some of the measurements that are commonly done with network and spectrum analyzers, it might be helpful to review the main differences between these instruments. Although they often both contain tuned receivers operating over similar frequency ranges, they are optimized for very different measurement applications. Network analyzers are used to measure components, devices, circuits and sub-assemblies. They contain both a source and multiple receivers, and generally display ratioed amplitude and phase information (frequency or power sweeps). A network analyzer is always looking at a **known** signal (in terms of frequency), since it is a stimulus response system. With network analyzers, it is harder to get an accurate trace on the display, but very easy to interpret the results. With vector-error correction, network analyzers provide much higher measurement accuracy than spectrum analyzers. Spectrum analyzers are most often used to measure signal characteristics such as carrier level, sidebands, harmonics, phase noise etc. on **unknown** signals. They are most commonly configured as a single channel receiver, without a source. Because of the flexibility needed to analyze signals, spectrum analyzers generally have a much wider range of IF bandwidths available than most network analyzers. Spectrum analyzers are often used with external sources for nonlinear stimulus/response testing. When combined with a tracking generator, spectrum analyzers can be used for scalar component testing (magnitude versus frequency, but no phase measurements). With spectrum analyzers, it is easy to get a trace on the display, but interpreting the results can be much more difficult than with a network analyzer.

5.4 NETWORK ANALYZER (Data communication)

Network analyzer (also known as a packet analyzer, protocol analyzer or sniffer) is a computer program or a piece of computer hardware that can intercept and log traffic passing over a digital network or part of a network. As data streams flow across the network, the sniffer captures each packet and, if needed, decodes and analyzes its content according to the appropriate specifications. A network analyzer is a combination of hardware and programming, or in some cases a stand-alone hardware device, that can be installed in a computer or network to enhance its utilization and protection against malicious activity.

5.4.1 Applications

In data communication, there is often need to observe and analyze, or even to simulate, the interactions between network devices interconnected by wide area networks (WANs)or local area networks(LANs) .Based on a uniform architecture with identical features and functions, they can be used flexibly for a wide variety of tasks, including analysis of network problems and detect network misuse by internal and external users.

- Monitor LAN/WAN bandwidth utilization as a function of time.
- Monitor network usage (including internal and external users and systems).

- Serve as primary data source for day-to-day network monitoring and management.
- Debug network protocol implementations.
- Verify internal control system effectiveness. (firewalls, access control, Web filter, Spam filter, proxy)
- Provide detailed statistics for current and recent activity on the network.
- Configure alarms for defined threats and search for specific data strings in packets.
- Create application-specific plug-ins and display all statistics on a user-friendly control panel.

5.4.2 BASIC INSTRUMENT ARCHITECTURE AND OPERATION

In order to understand the network analyzer, it is useful to have a basic understanding of how they work. The architecture of a LAN analyzer or a WAN analyzer is virtually identical.

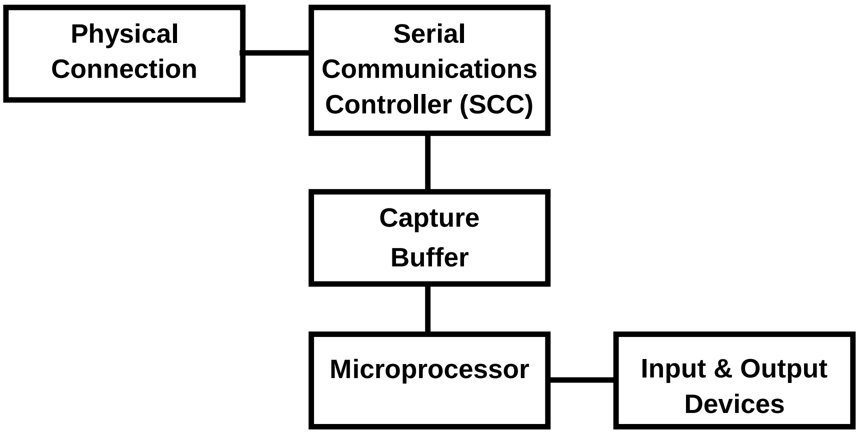

Fig.5.6 BLOCK DIAGRAM OF NETWORK ANALYSER

PHYSICAL INTERFACE: The physical interface provides the connection from the protocol analyzer to the data communication link under test. This block handles all the layer one analog conditioning, level sensing, level conversion, impedance matching etc. Manufacturers often add an additional feature such as a break out box to change interconnections for specific situations. Overall, the function of the physical interface block is to convert the signals found on a data communication link into digital signal that the protocol analyzer can interpret and to do this without disturbing the link under test.

SERIAL COMMUNICATION CONTROLLER: The serial communication controller (SCC) block provides the function of converting the serial digital data stream with its embedded synchronization from the physical interface into framed parallel bytes that can be processed by the protocol analyzer. Commonly, there is additional capability to filter for specific types of data as well as to trigger (or trap) and start or end the acquisition of data on specific information of interest. A filter serves the function of sorting the run time data to the protocol analyzer and of passing only that which is of interest for analysis or storage to avoid flooding the memory with data that are of no interest.

MICROPROCESSOR AND CAPTURE BUFFER

The microprocessor and the capture buffer serve to analyze and store the data as they come into the instrument. The combination of these two functional blocks has a great deal to do with the delivered performance of the protocol analyzer. In some architecture, data from the SCC are stored directly into the capture buffer and the processor then operates on the data to provide analysis. This method is appropriate for applications where the user needs to acquire limited amounts of high-speed data and keep the cost of the instrument's hardware low. The architecture tends to consume memory very quickly, resulting in a shallow effective capture size. On the other hand, if the processor first formats and adds information to the data before storing it into the buffer memory, it could be overrun by the speed of data.

INPUT AND OUTPUT DEVICE

The input and output block in the block diagram is simply the display, keyboard and local mass storage for the instrument. Presentation through the user interface is an important dimension for consideration. The tradeoff with this part of the instrument is usually one of simplicity of operation versus the versatility and flexibility afforded by it. Soft key assistance, use of graphic user interface and inclusion of a programming language to control the instrument are common implementations each with its own special value.

5.4.3 SET UP

On wired broadcast LANs, depending on the network structure (hub or switch), one can capture traffic on all or just parts of the network from a single machine within the network; however, there are some methods to avoid traffic narrowing by switches to gain access to traffic from other systems on the network (e.g. ARP spoofing). For network monitoring purposes it may also be desirable to monitor all data packets in a LAN by using a network switch with a so-called monitoring port, whose purpose is to mirror all packets passing through all ports of the switch when systems (computers) are connected to a switch port.

On wireless LANs, one can capture traffic on a particular channel. On wired broadcast and wireless LANs, to capture traffic other than uni cast traffic sent to the machine running the sniffer software, multicast traffic sent to a multicast group to which that machine is listening, and broadcast traffic, the network adapter being used to capture the traffic must be put into promiscuous mode; some sniffers support this, others don't. On wireless LANs, even if the adapter is in promiscuous mode, packets not for the service set for which the adapter is configured will usually be ignored. To see those packets, the adapter must be in monitor mode . Promiscuous *mode* is a configuration of a network card that makes the card pass all traffic it receives to the central processing unit rather than just frames addressed to it — a feature normally used for packet sniffing, and bridged networking for hardware virtualization

The captured information is decoded from raw digital form into a human-readable format that permits users of the protocol analyzer to easily review the exchanged information. Protocol analyzers vary in their abilities to display data in multiple views, automatically detect errors, determine the root causes of errors, generate timing diagrams etc.

Some protocol analyzers can also generate traffic and thus act as the reference device; these can act as protocol testers. Such testers generate protocol-correct traffic for functional testing, and may also have the ability to deliberately introduce errors to test for the DUT's ability to deal with error conditions. Network analyzers are not intended to replace firewalls, anti-virus programs, or spy ware detection programs. However, the use of a network analyzer in addition to other countermeasures can minimize the probability that an attack will occur, and can facilitate rapid response in the event an attack begins.

5.5 SDH/PDH Transmission Analyzer

The transmission analyzer is a graphic SDH/PDH measuring instrument designed for field use in analysis and maintenance of SDH/PDH lines to ensure quality connections across the entire access network and verify that the quality of network synchronization meets ITU-T standards by performing BER, Jitter and Wander measurements. It incorporates the most popular and advanced features for testing PDH (2, 34, 139 Mbit/s),T-carrier (1.5 and 45 Mbit/s), and SDH networks (52, 155, 622 Mbit/s and 2.5 Gbit/s).The transmission analyzer has optic and electric port to evaluate and analyse result according to ITU-TG.821, G.826, G.828, G.829, M.2100 and M.2101. It supports both in-service and out-of-service test applications.

5.5.1 In-service measurements (ISM): are based on the checking of errors in fixed bit or allowed patterns during the flow of data from the user (real traffic), as well as in the calculation of parity in pre defined data blocks, parity bit or line code violations, FAS or CRC errors. These measurements allow us to monitor the long term behavior of the network and carryout preventive maintenance.

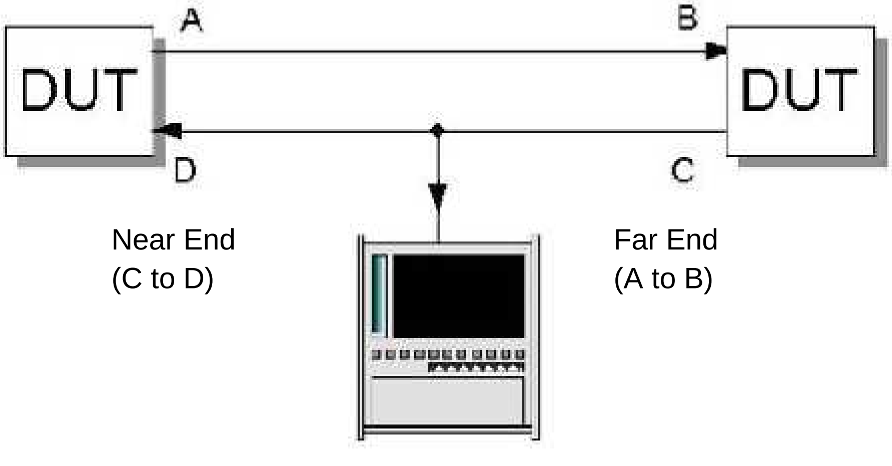

Fig.5.7 In-service monitoring setup

5.5.2 Out of service measurements (OOS): are made by substituting real traffic in a network for a known test pattern, usually a PRBS, the correct reception of which is checked in the distant end of the communication. These tests disrupt the traffic, but in turn they provide exact quality measurements, since the received signal is verified bit-by-bit against the transmitted test pattern.

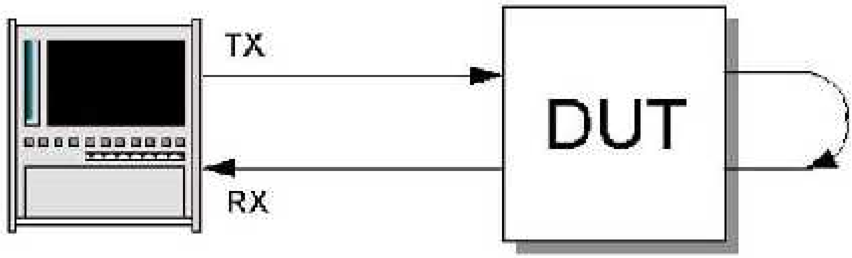

Fig.5.8 Out of service measurement setup

Today's analyzers come with a pre-installed demo version of test sequencer tool, which belongs to the CATS (CVI Application Test Sequences) family. CATS is a test automation software based on the popular National Instruments product "Lab Windows CVI Test Executive", and it may be used to make routine, consecutive test jobs as easy as the click of a mouse button in

- R&D
- Acceptance Testing
- Installation
- Troubleshooting

CATS usually run on a Windows PC and can control one or more test instruments in small Automatic Test Systems via the IEEE bus or other communication interfaces. Since the analyzer is a PC-based test instrument, provides a stand-alone application that runs on the instrument's internal PC. Hence, no external controller PC is needed to take full advantage of this test automation tool.

5.5.3 Virtual instruments

To allow the instrument to be operated simply and logically despite the large number of functions, a user interface was developed for the instruments that make use of virtual instruments. These VIs are designed so that each VI is assigned to a clearly defined task. By selecting specific VIs, customized applications (or tools) can be generated which are tailor-made for each particular measurement task.

The Application Manager is the starting point for each measurement. The various measurement windows for a measurement are selected and the maximum measurement duration is set here. The Analyzer represents a collection of several specialized measuring instruments, each of which fulfils a particular task. Each "instrument" is represented by a corresponding window. The test windows are therefore called "**V**irtual **I**nstruments" (VI). Depending on the measurement, various VIs are combined to make an application.

The following are the VIs for different applications

Application Manager Control and management of measurement applications
Signal Structure Configures the physical layer.
Anomaly/Defect Insertion Generates anomalies and defects for the physical layer including the “Transmission Convergence Sub layer
Anomaly/Defect Analyzer Analyzes anomalies and defects for the physical layer including the “Transmission Convergence Sub layer”.
Overhead Generator Edit physical frame overhead information. Used with SDH, SONET and PDH/ATM frames to G.832 (34 Mbit/s and 140 Mbit/s).
Overhead Analyzer Analyzes physical frame overhead information. Used with SDH, SONET and PDH/ATM frames to G.832 (34 Mbit/s and 140 Mbit/s).
Pointer Generator / Analyzer Generates and Analyzes SDH/SONET pointers.
PDH Generator/Analyzer Set and display physical frame overhead. Used with PDH frames.
Performance Analysis Performance analysis to G.821, G.826, M.2100, M.2101 and Bell core/ANSI.

These VIs have overall control of

· Measurement applications
· Measurement results generated using the applications
· Measurement sequence.

5.5.4 Performance Analysis by using SDH/PDH Transmission Analyzer:

Performance Analysis: These measurements are performed in order to determine the quality of a transmission path. The measurements are based on the corresponding ITU-T Recommendations of G.821, G.826, G.828, G.829, M.2100 and M.2101.

ITU-T G.826 evaluation: The G.826 analysis is separated into ISM (in-service measurement) and OOS (out of service measurement). OOS is mainly used for aligning newly set-up communications equipment. Unframed test signals are measured and block errors are evaluated. ISM, as the name implies, allows measurement while the system is operational.

This Recommendation defines error performance parameters and objectives for international digital paths which operate at or above the primary rate. The objectives given are independent of the physical network supporting the path. These paths may be based on a Plesiochronous Digital Hierarchy, Synchronous Digital Hierarchy or some other transport network such as cell-based This Recommendation is based upon a block-based measurement concept using error detection codes inherent to the path under test.

Anomalies: In-service anomaly conditions are used to determine the error performance of a PDH path when the path is not in a defect state. The two following categories of anomalies related to the incoming signal are defined:

a1 an errored frame alignment signal;

a2 an EB as indicated by an EDC

Defects: In-service defect conditions are used in the G.730 to G.750 series of Recommendations relevant to PDH multiplex equipment to determine the change of performance state which may occur on a path.

The three following categories of defects related to the incoming signal are defined:

d1 loss of signal;

d2 alarm indication signal;

d3 loss of frame alignment.

G.826 – Set of parameters and measurement criteria

Type Set of parameters Measurement criteria

ES An ES is observed when, during one second, at least one anomaly a1 or a2, or one defect d1 to d3 occurs

SES An SES is observed when, during one second, at least "x" anomalies a1 or a2, or one defect d1 to d3 occurs

BBE A BBE is observed when an anomaly a1 or a2 occurs in a block not being part of an SES

The following results are determined and displayed

Result	Explanation	
EB	Errored Blocks	Count of errored blocks
BBE	Background block errors	Errored blocks not in SES as a count and as an error rate
ES	Errored seconds	Errored seconds as a count and as an error rate
EFS	Error free seconds	Error free seconds as a count and as an error rate
SES	Severly Errored seconds	Severly Errored seconds as a count and as an error rate
UAS	Unavailable seconds	Unavailable seconds as a count and as an error rate
Verdict		Accepted/rejected:overall assessment of path quality
Path allocation		Path allocation setting

Table-1

The analysis provides separate results for the “NEAR END” and the “FAR END”. Put simply, this means that errors occurring directly in the path are analyzed as well as errors occurring in the return path which are indicated by a REI message. This allows both directions to be monitored without actually connecting to both. The “Verdict” box gives direct indication as to whether the communications path meets the requirements of the Recommendation or not.

Objective:

1. Spectrum analyzer is a ---------------------domain based device.
2. FFT spectrum analyzers are suitable for ----------------- applications.
3. ----------------principle of spectrum analyzers enables it to scan wide bandwidth.
4. RF Vector network analyzers measure both amplitude and -------------- properties.
5. The ----------------------time enables the FFT analyzer to analyze non repetitive wave forms.
6. ITU-T‘---------------evaluation reveals parameters and measurement criteria for PDH/SDH Transmission analyzers.
7. Data communication analysers are basically -------------and -------------- analyzers.
8. ---------------------- mode on network analyzers is a feature normally used for packet sniffing and bridged networking for hardware virtualization.

Subjective:

1. What are Analyzers? Classify the analyzers used in communication networks?
2. Draw and explain a super heterodyne type Spectrum analyzer.
3. What are the advantages of using FFT analyzers over Spectrum analyzers?
4. State what is a Network analyzer? Explain with a block diagram.
5. Differentiate between a Network analyzer and a Spectrum analyzer.
6. What is a Transmission analyzer? State the measurements taken using PDH/SDH Transmission analyzer.
7. How is a Network analyzer used in data communication different? State the tasks that can be done on data communication networks?
8. What are Virtual instrument? State its advantages in instrumentation.