Introduction

SCIENTECH Antenna Trainer. ST2261: is a student friendly trainer kit for studying characteristics of different antennas. The trainer is designed so that students can take the readings and plot the polar plots themselves, thus understanding the subject thoroughly. They can even stop & repeat the readings in between if needed.

All the antennas are made by high conducting rods with chrome finish for long durability and mounted on the glass epoxy PCB for easy mounting and dismounting.

Areas of Experimentation and Study :

- Polar plot & Polarization of various Antennas
- Wave Modulation and Demodulation
- Antenna Gain
- Antenna Beam Width
- Element Current Study
- Front Back Ratio Study
- Antenna Matching
- SWR Measurement
- Antenna Radiation with Distance.

$G = e_{cd} D,$ $e_{cd} = \frac{R_r}{R_r + R_L}$

$D = \frac{U}{U_0} = 4\pi \frac{U}{P_{rad}}$.

rad intens. $U = \frac{P_{rad}}{4\pi} = r^2 S$.

Rad. densi. $S = \frac{P_{rad}}{4\pi r^2}$.

Features

- **Self Contained Simple and Student Friendly Trainer.**
- **Low Cost.**
- **Hands on set-up for measuring and plotting radiation patterns of 20 different Antennas.**
- **On board RF & Tone Generators.**
- **Antenna Matching Stub.**
- **Characteristics and SWR Measurement**
- **Transmitting and Receiving levels observed On Built- in Meters.**
- **Functional Block indicated On- board Mimics.**
- **Built in DC Power Supply.**
- **Fully Documented Operating Manual and Polar Charts with each Trainer.**
- **Text book named 'Antennas' by J. Kraus with each Trainer.**
- **"Antenna kit" for fabricating Special Antenna.**
- **Compact Design.**
- **Lightweight.**

e. small $C < \frac{\lambda}{10}$; large $C \approx \lambda$.

Technical Specifications

RF Generator	:	750 MHz approximately (on board adjustable with level display)
Modulation Generator	:	1 KHz approximately (On board with level adjust for modulation)
Directional Coupler	:	Forward & Reverse (On board selectable)
Matching Stub	:	Slide Stub
Antenna Rotation	:	0-360 Degrees, Resolution 1 Degree Transmitting & Receiver masts provided
Receiving antenna	:	Folded Dipole with reflector
Detector Display	:	On board level adjustable meter
Power Supply	:	230V ±10%, 50Hz
Power Consumption	:	3VA (approximately)
Interconnections	:	BNC
Dimensions (Main Unit)	:	385×285×75mm
Weight	:	3.5 Kgs. approximately

Trainer Description

The trainer consists of :

- Main Unit
- Transmitting Mast
- Receiving Mast
- RF Detector
- Accessories Case containing Antennas (22 types)
- Matching Stub
- Other Accessories

The main unit is designed for desk top use with screen print on front panel showing trainer mimic diagram. See figure 1

The main unit consists of :

- RF Generator
- Modulation Generator
- Directional Coupler

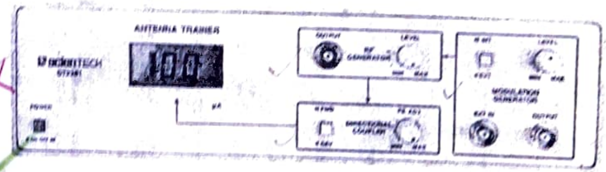


Figure 1

+ differma, simple, and folded.

RF Generator :

Delivers a test signal to feed the antennas under test. The RF Generator operates at a frequency of 750 MHz approximately. The reason being reduced size for antennas. The higher is the frequency, the smaller is the size of the antennas and the size of the trainer as a whole. This gives the advantage of a handiest operation of the system on a test desk of a laboratory.

The RF generator features the following :

1. Knob adjustable output power level.
2. Facilities to match different loads.
3. Modulating input (AM) which can be used with the on board modulation generator.
4. Capability to stand indefinitely even heavily mismatched output (short or open). In extreme cases the generator stops oscillations and latches up in protection. Normal operation is restored by taking the level knob to zero or switch off the power and again switch on.

Modulation generator :

This provides amplitude adjustable sine wave (approximately 2Vpp, 1 KHz) for modulation of the RF generator.

Directional coupler :

This allows separate metering of power flowing in the forward direction (generator to antenna) and the reverse direction (antenna to generator). This is used during the experiments as an aid to match the generator to the load and also as a means to measure the *Standing Wave Ratio* in the transmission line to the antennas.

Matching stub :

This is a trunk of the transmission line, which is given separately provided with a slide cursor shortening the line at presetable length from the other end (input).

RF Detector :

This is used to detect and measure the radiation pattern of the antennas under study. (See figure 2.)

The features of the detector are the following :

1. Completely passive instruments.
2. Adapter (+9V) is given for DPM (Digital panel meter).
3. The table top RF Detector can be directly connected to receiving mast by using a BNC to BNC cable of 25" long. See the figure 4 for set up.
4. Detector antenna is consists of a folded dipole antenna as receiving element and a reflector to reduce possible disturbance to the measurement due to reflection of waves from objects and laboratory walls behind the detector.
5. Display readings can be adjusted by varying 'Level' knob.

Signal Demodulator : Received RF modulated signal is demodulated by a diode detector and the demodulated signal is available at red and black sockets of the Detector to connect external measuring instruments (Oscilloscope).

RF Detector

Figure 2

Transmitting mast :

The transmitting mast consists of base and stand. The stand is attached to the base, and the transmitting antenna is connected on the top of the stand. RF OUT of the main unit is connected to the female BNC socket of the stand by using a BNC to BNC cable of 25" long. The mast has a Goniometer on the base. Goniometer is a circular scale graduated in 360 degrees. The stand of the mast has a graduated reference index mark for matching the Goniometer scale (See figure 3).

Installation of Transmitting Mast

Figure 3

Receiving mast :

This consists of base and stand. The stand is attached to the Base and the Detector antenna is connected to the top of the stand. The RF Detector is connected to the other female BNC socket of the stand using a BNC to BNC cable of 25" long. (See figure 4)

In order to detect vertically polarized waves, Detector antenna can be mounted vertically by using 'L' shaped BNC (male to female) at the top of the receiving mast.

Antenna current sensor :

This is used to measure the current in the antenna element. For details see manual

Installation of Receiving Mast & RF Detector

Figure 4

see page 20

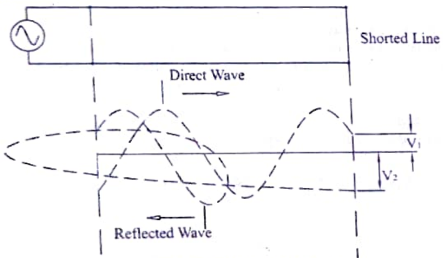
Basic Antenna Concept

This section is a concise review of some important theory aspects concerned by the operation of this trainer. This discussion does mean to be exhaustive but just serve as a guide to help student to relate what he has learned in his theory course to the hardware he is facing.

Transmission lines :

Transmission lines are used to convey energy from a source (generator) to a load. The generators are sine wave voltage sources. The sine wave voltage applied to the line input determines a sine wave current in it. The ensemble of the sine wave voltage and sine wave current is generally called a wave.

The wave propagates along the line. The concept of a wave travelling from the source through the line is in harmony with the idea of energy flowing from the generator to the load. We now suppose that our transmission line, instead of being infinitely long, is cut and shorted at a certain length.



Direct and Reflected Voltage Waves in a Shorted Line

Figure 5

Short-circuit is a no-power-draining load (Ohm's law), therefore the energy incident on short-circuit must go somewhere.

The only way the energy may go from the short circuit is to come back along the line, or be reflected. To do this the short must evidently be capable to generate a voltage equalling in modulus and opposed in phase with the incident voltage.

This concept allows us to draw the pattern of the reflected wave given the pattern of the incident one. It simply is the incident pattern reverted.

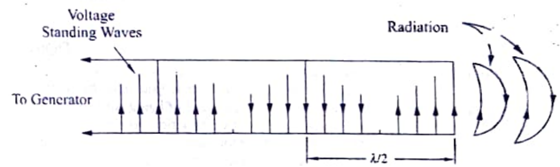
We can extend our narrative, non-mathematical reasoning on the line to the cases where the line is open instead of shorted and then terminated with a generic load. The conclusions will be that there are stationery waves in all cases except when the line is infinitely long and when the line is matched i.e. terminated on a load equalled to the

characteristic impedance of the line. The characteristic impedance is a parameter depending on the physical nature and construction characteristics of the line.

When a line is terminated on a matched load, there is no reflected wave, therefore the energy transfer from the line to the load (which are in our cases antennas), is maximized.

Radiation Mechanism and Evolution of Dipole

Consider the open-circuited transmission line of Figure 6. It is seen that the waves travelling forward and reverse combine to form a standing-wave pattern on the line, with a voltage anti- node at the open-circuited point, but not all the forward energy is reflected by the open circuit.



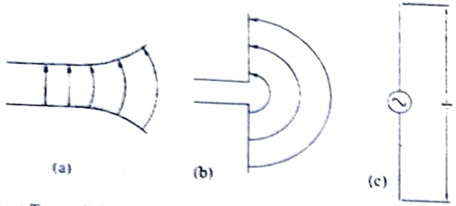
Radiation from transmission line

Figure 6

As shown, a small portion of the electromagnetic energy escapes from the system and is thus radiated. This occurs because the lines of force, travelling towards the open circuit, are required to undergo a complete phase reversal when they reach it. Not all of them are able to do this, because they posses the equivalent of mechanical inertia, and thus some do escape. It must be added that the proportion, of waves escaping the system to those remaining is very small, for two reasons.

First, if we consider the surrounding space as the load for the transmission line, we see that a mismatch exists, and thus very little power is dissipated in this "load". Second, since the two wires are close together, it is apparent that the radiation from one tip will just about cancel that from the other. This is because they are of opposite polarities and at a distance apart that is tiny compared to a wavelength. Conversely, this is also the reason why low-frequency parallel-wire transmission lines do not radiate.

The cure for this problem seems to be an "enlargement" of the open circuit, i.e. spreading of the two wires, as in Figure 7. There is now less likelihood of cancellation of radiation from the two wire tips. By the same token, the radiating transmission line is now better coupled to the surrounding space. This is another way of saying that more power will be "dissipated" in the surrounding space, i.e. radiated. Moreover, because of the spreading out, waves travelling along the line find it more difficult to undergo the phase reversal at the end. Thus everything points to an increase in radiation.



(a) Opened out Transmission Line (b) Conductor Line (c) Half Wave Dipole

Evolution of Dipole

Figure 7

The radiation efficiency of this system is improved even more when the two wires are bent so as to be in the same line as in Figure 6. The electric (and also the magnetic) field is now fully coupled to the surrounding space, instead of being confined between the two wires, and the maximum possible amount of radiation results. This type of radiator is called a dipole. When the total length of the two wires is a half-wavelength, the antenna is called a half-wave dipole. It has the form indicated in Figure 7, and now even greater radiation occurs. The reason for this increase is that the half-wave dipole may be regarded as having the same basic properties (for the point of view of impedance particularly) as a similar length of transmission line. Accordingly, we have the antenna behaving as a piece of quarter-wave transmission line bent out and open-circuited at the far end. This result in the high impedance at the far ends of the antenna reflected as low impedance at the end connected to the main transmission line. This in turn, means that a large current will flow at the input to the half-wave dipole, and efficient radiation will take place.

Standing Wave Ratio

The Standing Wave Ratio (SWR) is defined as the ratio between maximum and minimum values of voltage (and current) along the line. Figure 8 shows the SWR pattern along a line with a mismatched load and helps understanding the definition of SWR. The SWR is an index of the mismatch existing between the load and the line feeding it. The SWR equals 1 in the perfectly-matched case, impossible to reach in practice, and tends to reach very high values (infinity) for lines shorted or open. In practice SWR values in the range 1.4 to 2 are to be considered a good matching condition in an antenna system, while rather larger values are acceptable with our trainer. This is because unlike large power systems where the design aim is maximum power transfer, in a trainer system the aim is in handiest operability and simple construction.

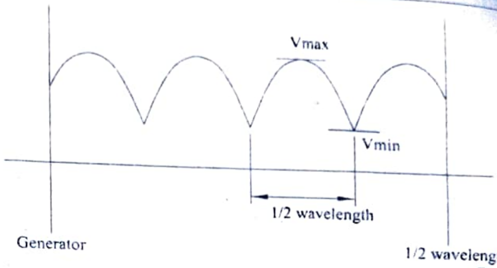


Figure 8

Directional Coupler

To sense the direction of power travel, as well as the amount of power, is sensing device must have diodes as circuit elements.

The directional coupler of Figure 9 consists of two line trunks placed alongside a main transmission line carrying energy from generator to antenna. The power travelling from input to output of the device will cause induced voltages in the upper and lower loops. In the lower one the voltage will build across the sensing devices thanks to the forward conducting diode, while this will not happen in the upper loop. As for the power travelling from load to generator, the situation is reverted the upper loop will sense, the lower one will not.

Therefore the device of Figure 9 allows separate metering of direct and reverse power.

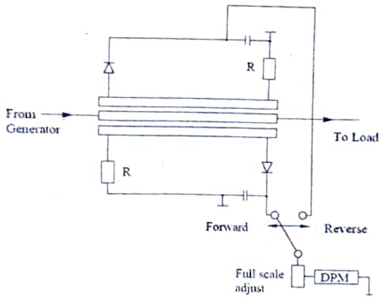


Figure 9

The practical procedure to use the directional coupler to measure the SWR is the following.

- Turn on the transmitter
- Place the switch of the SWR meter on FORWARD and note the reading. You can also adjust the Level for full-scale display (e.g. you set it at 100 in the case of our trainer. Adjust RF Level if needed)
- Switch the meter to REVERSE. Note the reading. Calculate the SWR by the formula.

$$SWR = \frac{FOR + REV}{FOR - REV} \quad \text{or} \quad \frac{100 + REV}{100 - REV}$$

Antenna Matching

Let's consider a short-circuited transmission line having length ¼ of the wavelength of the signal impressed by the generator.

At the shorted end there will be a null voltage and a maximum current while at the other end (Generator side), there will be opposite situation of maximum voltage and zero current. The line therefore appears to the generator as infinite impedance, since no current is drawn.

Let's now consider another line, half wavelength long, shorted at the end opposed to that of the generator.

The junction point of the generator to the line will be a zero-voltage, maximum current point. The impedance of the line, as "seen" from the generator, shall be a short circuit (zero impedance).

In all the intermediate cases of a line having length between ¼ and ½ wavelengths, the generator shall see impedance between zero and infinity. Going on further with the same reasoning we find out that for shorted lines ¼ wavelength long to zero length, the impedance goes again from infinity zero.

Since our line is loss less, the impedance must be purely reactive and if we consider the pattern of the current together to that of the voltage, we soon find out that in the ½ to ¼wavelength interval the impedance goes from 0 to infinite and is capacitive, while in the ¼ wavelength to zero length interval the impedance goes from infinite to zero and is inductive.

All this leads us to think of a very handy way to match the impedance seen from the generator by placing in parallel to the mismatched load a trunk of shorted line of a proper length. See Figure 10. These devices are generally called *Matching Stubs*.

Rdam
1.5.2.4

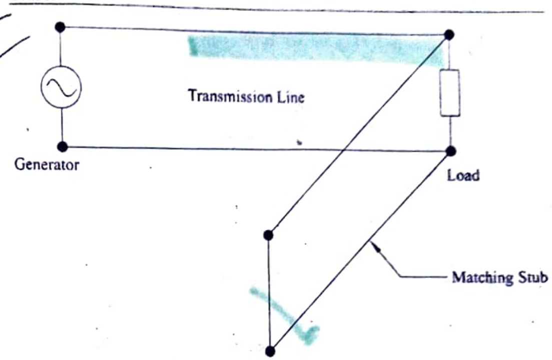


Figure 10

An adjustable length matching stub can be adjusted to have a reactive impedance equal in modulus and opposed sign of a mismatched load, in order to cancel its reactive component and make it appear to the line as purely resistive.

Types of Antennas :

Antennas can be broadly classified by the directions in which they radiate or receive electromagnetic radiation. They can be isotropic, omni directional or directional.

An isotropic antenna is a hypothetical antenna that radiates uniformly in all directions so that the electric field at any point on a sphere (with the antenna at its centre) has the same magnitude. Such radiation cannot be realized in practice since in order to radiate uniformly in all directions an isotropic antenna would have to be a point source. The nearest equivalent to an isotropic antenna is a Hertzian dipole.

The Hertzian dipole is the name given to a dipole, which is very small, compared to its wavelength that is about one-hundredths of the wavelength at its operating frequency; even in this case its pattern is not truly isotropic.

An omni (-) directional antenna radiates uniformly in one plane. Examples of omni directional antennas are Monopoles, Dipoles etc. The radiation of a vertical dipole is uniform in the horizontal plane and in the vertical plane.

A directional antenna radiates most of is power in one particular direction. Examples of directional antennas are Yagi UDA, Log-Periodic, and Helical.

Important Characteristics of Antenna

An antenna is chosen for a particular application according to its main physical and electrical characteristics. Further, an antenna must perform in a desired manner for the particular application. An antenna can be characterised by the following factors, not all are applicable to all types of antenna. Most of the characteristics mentioned below can be studied using this trainer.

- Radiation resistance.
- Radiation pattern
- Beam width
- Bandwidth
- Gain of main lobe.
- Position and magnitude of side lobes Front to back ratio.
- Aperture
- The polarisation of the electric field.

There are two principal planes in which the antenna characteristics are measured. These are the horizontal and vertical planes for land based antennas. Some characteristics such as beam width and side lobes are the same in both planes for symmetrical antennas such as helical and reflectors. Other characteristics such as gain on bore-sight (i.e. where the azimuth and the elevation planes intersect) can only have a single value. In general, for unsymmetrical antennas the characteristics are different in the two principal planes.

Radiation Resistance

We can consider an antenna as a load that terminates the transmission line that feeds it. In the ideal case this load will have impedance which is purely resistive, that is, the load will not have any reactive component, such as an inductance or capacitance. In practice, the impedance of an antenna is made up of a self-impedance and mutual impedance. The self-impedance is the impedance that would be measured at the terminals of the antenna when it is in free space, given no other antennas or reflecting objects in the vicinity. The mutual impedance accounts for the coupling between the antenna and any other source. When the antenna is sufficiently isolated from other objects, this mutual impedance tends to zero. On the other hand, in some antennas such as the Yagi array the operation depends on the mutual coupling between the driven element and the other parasitic passive elements.

When the antenna has the same impedance as the transmission line that feeds it, the antenna is said to be matched on the line. When this occurs, maximum power is transferred from the transmission line to the antenna. In general the impedance of the antenna is not the same as that of the transmission line. When the transmission line has purely resistive impedance and the antenna has impedance that contains a different resistive value as well as a reactive part, the optimum transfer of power can be achieved via the use of tuning circuits between the transmission line and the antenna. In general, these circuits consist of an LC circuit in which the capacitance of the capacitor is altered in order to provide the maximum transfer of power.

In this trainer Antenna match tuning capacitor does this.

Graphical representation of the radiation properties as a function of space coordinates.

Radiation Pattern

The antenna is a reciprocal device, means it radiates or receives electromagnetic energy in the same way. Thus, although the radiation pattern is identified with an antenna that is transmitting power, the same properties would apply to the antenna even, if it was receiving power. Any difference between the received and radiated powers can be attributed to the difference between the feed networks and the equipment associated with the receiver and transmitter. The antenna radiates the greatest amount of power along its bore sight and also receives power most efficiently in this direction.

The radiation pattern of an antenna is peculiar to the type of antenna and its electrical characteristics as well as its physical dimensions. It is measured at a constant distance in the far field. The radiation pattern of an antenna is usually plotted in terms of relative power. The power at bore sight, that is at the position of maximum radiated power, is usually plotted at 0 degrees; thus, the power in all other positions appears as a negative value. In other words, the radiated power is normalised to the power at bore sight. The main reason for using dB instead of linear power is that the power at the nulls is often of the order of 10,000 times less than the power on the bore sight, which means that the scales would have to be very large in order to cover the whole range of power values.

For the convenience of the students to plot the polar graph the readings are plotted after converting them in to dB. A conversion chart is provided in this manual. Also the procedure for normalizing the readings is also given at the end of this manual. The student can choose any procedure for drawing the polar plot.

The radiation pattern is usually measured in the two principal planes, namely, the azimuth and the elevation planes. The radiated / received dB is plotted against the angle that is made with the bore sight direction. If the antenna is not physically symmetrical about each of its principal planes, then one can also expect its radiation pattern in these planes to be unsymmetrical. The radiation pattern can be plotted using the Polar or the Rectangular / Cartesian Co-ordinates.

Polar Plots

In a Polar Plot the angles are plotted radially from the bore sight and the levels (dBμV/ dBμA) are plotted along the radius. The angles may be selected at any convenient interval. However 5 degrees or 10 degrees may be chosen. Choosing of 1 degree is also possible in the trainer but this does not serve any special purpose because the readings will not change much and will consume more time. The polar plot gives a pictorial representation of the radiation pattern of the antenna and is easier to visualise than the rectangular plots. The student will easily understand the polar plot drawn by them.

$10 \log_{10}(M/A)$ dB

Beam width and Gain of main lobe

The beam width of an antenna is commonly defined in two ways. The most well known definition is the -3dB or half-power beam width, but the 10dB beam width is also used, especially for antennas with very narrow beams. The -3dB or half-power beam width of an antenna is taken as the width in degrees at the points on either side of the main beam where the radiated level is 3dB lower than the maximum lobe value. The -10dB value is taken as the width in degrees on either side of the main beam where the radiated level is 10dB lower than the maximum lobe value. The IEEE definition of gain of an antenna relates to the power radiated by the antenna to that radiated by an isotropic antenna (that radiates equally in all directions) and is quoted as a linear ratio or in decibels referred to an isotropic (dBi, i: for isotropic). When we say that the gain of an antenna is, for instance, 20dBi (100 in linear terms) we mean that an isotropic antenna would have to radiate 100 times more power to give the same intensity at the same distance as that particular directional antenna.

The radiation pattern of an antenna shows the power on the boresight as 0dB and the power in other directions as negative values. The gain in all directions is plotted relative to the gain on boresight. In order to find the absolute gain in any direction the gain on boresight must be known. If this gain is expressed in decibels, (as is normally the case) then this value can simply be added to the gain at any point to give the absolute gain. The absolute gain on boresight is measured by comparison with a standard gain antenna, which functions as a reference antenna whose gain is calculated or measured with a high degree of accuracy.

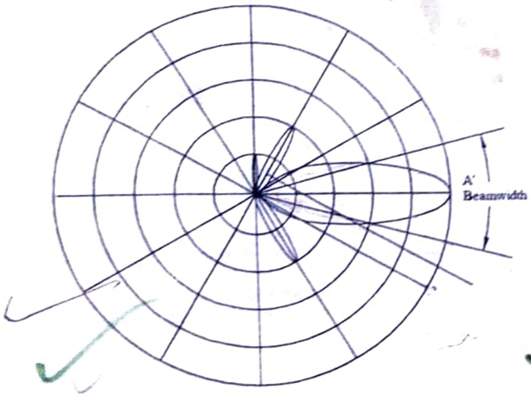


Figure 11

see 25

Position and Magnitude of Side Lobes

The side level is usually quoted as the level below the bore sight gain. Strictly all peaks on either side of the main lobe are side lobes. However, in practice only the "near-in" lobes, those, which are adjacent on either side of the boresight maxima, are referred to as side lobes. Their amplitude and angle are easily measured using the Polar Plot. For an antenna that is symmetrical about its main axis, the radiation pattern is in general also symmetrical. Thus, the level of the side lobes on opposite sides of the main beam would be the same. The average value is taken where the two side lobes are different. The absolute level of the side lobes can only calculated if the absolute bore sight gain is known.

Bandwidth → for viva

The bandwidth of an antenna is a measure of its ability to radiate or receive different frequencies. It refers to the frequency range over which operation is satisfactory and is generally taken between the half power points in the direction of maximum radiation. The bandwidth is the range of frequencies that the antenna can receive (or radiate) with a power efficiency of 50% (0.5) or more or a voltage efficiency of 70.7% (that is -3dB points). The operating frequency range is specified by quoting the upper and lower frequencies, but the bandwidth is often quoted as a relative value. Bandwidth is commonly expressed in one of the two ways;

1. As percentage or,
2. As a fraction or multiple of an octave (An octave is a band of frequencies between one frequency and the frequency that is double or half the first frequency; for instance, we have an octave between 400 MHz and 800 MHz). When it is expressed as a percentage bandwidth, its centre frequency should be quoted and the percentage expressed in octaves, its lower and upper frequency should be also quoted.

Front to Back Ratio

The front-to-back ratio is a measure of the ability of a directional antenna to concentrate the beam in the required forward direction. *In linear terms, it is defined as the ratio of the maximum power in the main beam (bore sight) to that in the back lobe.* It is usually expressed in decibels, as the difference between the level on bore sight and at 180 degrees off bore sight. If this difference is say 35dB then the front-to-back ratio of the antenna is 35dB; in linear terms it would mean that the level of the back lobe is 3,162 times less than the level of the bore sight.

$20 \log_{10} \left(\frac{M}{N}\right)$

$\frac{\text{main}}{\text{back}}$

Aperture / Capture Area

In simple words aperture or capture area of antenna is the effective receiving area of the antenna and may be calculated from the power received and it's comparison with the power density of the signal being received.

If

S = power density of the wave in Watts / sq meter

A = capture area of the antenna

P = Total power absorbed by the antenna

Then $P = S\,A$ Watts or $A = P/S$

The aperture size can be defined in two ways; either in terms of actual physical size in meters, or in terms of wavelength. For instance, if we say that an antenna has an aperture of two wavelengths, then its actual size depends on its operating frequency. At a frequency of 1 GHz, the physical aperture would be 60cms, whereas at 10GHz it would be only 6cms. It is more meaningful to refer to an antenna size in terms of its operating wavelength when the antenna is narrow band or single frequency because its beam width and gain are directly related to the aperture in terms of its operating wavelength. In this case we have to calculate its wavelength to find its physical dimensions. However, in the case of broadband antennas, its physical size is more appropriate because there is a range of operating frequencies.

The aperture of an antenna governs the size of its beam width. In general, the larger the aperture, the narrower the beam width, and the higher is the gain at a given frequency.

Polarisation of Electric Field

Polarisation is used almost exclusively to describe the shape and orientation of the locus of the extremity of the electric field vector as it varies with time at a fixed point in space. This locus could be a straight line, an ellipse or a circle.

In the case of linear polarisation, the electric field varies in sinusoidal manner in one plane. When this plane is vertical it is called vertical polarisation. When this plane is horizontal, it is called horizontal polarisation. The electric field can also be polarised in any other angle between 0 and 90 degree to the horizontal. In general the only other commonly used angle is 45 degrees, which is known as the slant polarisation.

The polarisation of a receiving antenna must match that of the incident radiation in order to detect the maximum field. If the angles are not the same, only those components which are parallel to the Plane of incident polarisation will detect. If we have a vertically polarized antenna and the incident radiation is slant Polarised the magnitude of its component in the vertical Plane will be reduced by a factor cosine 45 degrees.

Experiment 1

Objective :

Arranging the trainer and performing the functional checks

Procedure :

Main unit :

- Place the main unit on the table and connect power cord.
- RF Generator : Adjust Level Potentiometer to middle position.
- Modulation Generator : Select switch to 'INT' position and adjust Level Potentiometer to middle position.
- Directional Coupler : Select the switch to 'FWD' position and adjust FS ADJ Potentiometer to middle position.

1. Install Transmitting mast, place it beside the main unit and connect it to the main unit's 'RF OUT' using a BNC to BNC cable of 25" long.
2. Install Receiving mast and keep it at some distance from the Transmitter mast.
3. Place RF detector Unit beside the Receiving mast and connect it to the Receiving mast using a BNC to BNC cable of 25" long (see figure 13).
4. Keep the base of Transmitting mast such that the '0'degree position of Goniometer should be directed towards the RF Detector and also align the marker of the mast with '0' degree position.
5. Install Detector Antenna on the Receiving mast. Keep its direction towards the Transmitting mast by rotating it in counter clockwise direction.
6. Install folded Dipole Antenna on the Transmitting mast. Keep its direction towards the Receiving mast by rotating it in counter clockwise direction.
7. Switch on the main unit and check the Display in DPM of Directional Coupler. It will show some reading according to its level knob at starting.
8. Connect a +9V Adapter to the RF Detector unit, Switch it on and keep the Level knob at middle position. It will show some reading according to its level knob at starting. (In case of over loading, reduce it by level Potentiometer of RF detector)
9. Now vary the FS Adjust Potentiometer of Directional Coupler to make the display reading 100 Micro Amp and then adjust the Level of RF detector to show the ¾ reading of the main unit's display.
10. Rotate the transmitting Antenna between 0-360 degrees and observe the display at RF Detector. The variation in reading indicates that the transmitter and receiver are working and radiation pattern is formed.

The unit is ready for further experiments.

JS 332
See 29

Important Note :

Following action can be taken to get the optimum radiations at RF Detector.

Adjustment for Antenna match :

If necessary, the adjustment for Antenna match may be required to optimize maximum radiations from different Antennas. However this can be done by rotating the trimmer gently with the aligner. This trimmer is given on the top surface of the unit.

Adjustment of Level of RF Generator :

In case of low reading (for Low gain antennas), set the RF Level Potentiometer of main unit to maximum position. Also the reading of DPM of Directional Coupler can be set to 50 Micro Amp for these antennas and then adjust the Level of RF detector to show the ¾ reading of the main unit's display.

Adjustment of distance :

The distance between Transmitting mast and Receiving mast may be adjusted for receiving optimum radiations at RF Detector.

Plotting the Polar Graph :

Now to plot the Polar Graph for the Transmitting Antenna, start taking the readings at the interval of 5 or 10 degrees and note the reading of RF Detector's display.

Convert the noted Micro Amp readings into dB, with the help of the conversion chart given at the end of this work book and plot the polar graph for degrees of rotation of antenna against readings in dB.

Plotting the Polar Graph for Normalized reading :

One can also plot the polar graph against normalized readings of RF Detector. The procedure to convert the Micro Amp in to normalize reading is given as follows:

Consider the maximum reading say N (When the RF Detector receives maximum radiations) as 0 dB.

Let say it is N=50 Micro Amp,

Convert next reading taken at the interval (5 or 10 degrees) say N1 by the following formula:

$$\boxed{\ln N1 / N = \text{reading in dB}}$$

Let take N1=40 Micro Amp,

$\ln (40/50) = -0.22$ dB

Follow the same procedure for the further readings thus the generalized formula will be:

প্রশ্ন করলে জানাবার হয় 10log (μA) বা 20log (μA) dB

↳ এদের করলে good হয়।

-ve আসলে যে pointer plot করবনা

$$\boxed{\ln Nx / N = \text{readings in dB}}$$

Plot the radiation pattern of antenna with the new dB readings as usual.

1. Calculate the following with the help this graph
   - Beam width.
   - Front / Back ratio.
   - Directive gain of antenna.

   To calculate the above from the graph, please refer to figure 12 and proceed as follows.

Beam width :

Look for main lobe. Draw bore sight maxima line AA' Mark -3 dB from maximum on the bore sight line point B. Draw an arc of radius AB This arc will intersect main lobe at C & D. Measure angle CAD This angle is - 3 dB beam width. Similarly calculate -10 dB beam width.

Front to back ratio :

Look for the main lobe. Draw bore sight maxima line AA' Look for back lobe if any (At 180°) If no back lobe, then,

$$\text{Front to back ratio} = \frac{AA'}{1}\ \text{dB}$$

If back lobe is present then, measure AE, where E is the maximum of back lobe.

$$\text{Front to back ratio} = \frac{AA'}{AE}\ \text{dB}$$

Gain of antenna :

$$G = \frac{\text{Maximum radiation intensity}}{\text{Maximum radiation intensity from a ref antenna (isotropic antenna) with same power input}}$$

Since, we cannot have an ideal isotropic antenna we presume here that its maximum radiation intensity is 1dB and is 100% efficient. Under this assumption Gain of antenna (or Directional Gain of antenna) is

$$G = \frac{AA'\ \text{dB}}{1}$$

folded এর → RR বেশি, BW বেশি

Yagi's element বাড়লে বেশি smooth।

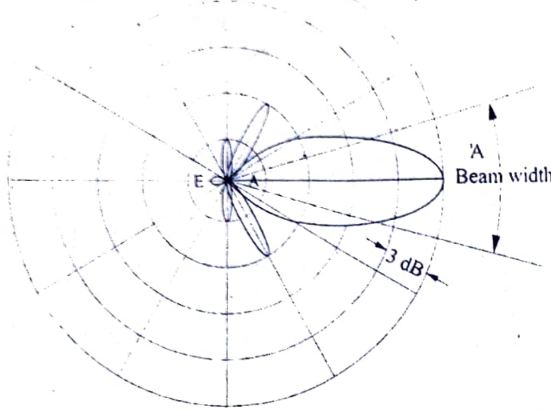
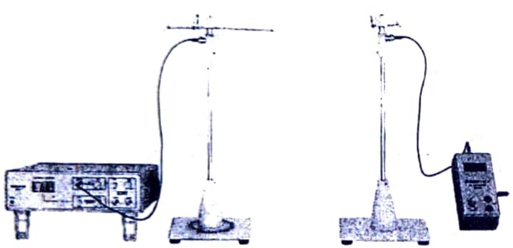


Figure 12



Set up Arrangements of Antenna Trainer

Figure 13

dipole ant. is a half wavelength made of wire. Two conductors length λ/4.

Experiment 2

Objective :

Study of Simple Dipole (λ/2) Antenna

A simple Dipole is the simplest form of antenna having 2 poles each of length (λ/2). The nominal impedance of this antenna is 73Ω. The actual value departs from this due to construction constraints, such on non-zero diameter rods, presence of BNC connector body and the antenna mast. The effect of all this are partially corrected by a "Y match" arrangement connection. See Figure 14.

The radiation pattern of simple Dipole (λ/2) is uniform in forward & reverse direction. The polarisation is horizontal. The typical radiation pattern of this antenna is given in Figure 15.

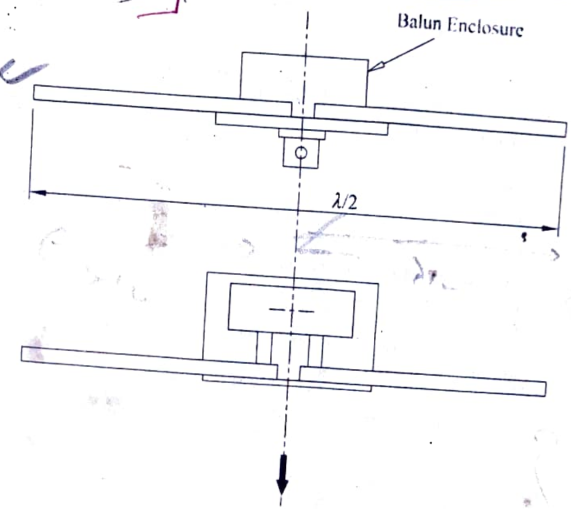


Figure 14

Procedure :

1. Mount simple dipole (λ/2) on the top of the transmitting mast
2. Arrange the Set up as per procedure given in Experiment 1 and draw the polar graph.

See 40

270 90

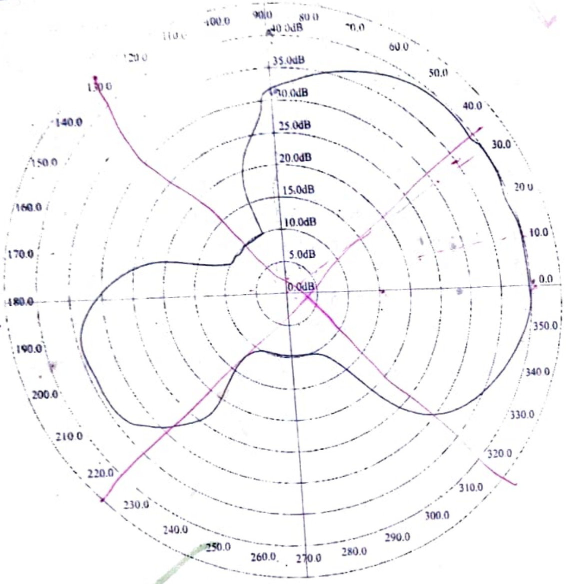


Figure 15

Practical ⊕ Idea

dB = 10 log(

10 log(μA)

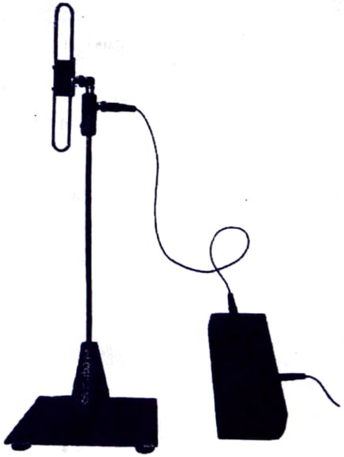
Experiment 3

Objective :

To perform Polarisation Test

Procedure :

1. Arrange the Set up as per procedure given in Experiment 1
2. Connect the 'L' shape BNC on the top of the Receiving Antenna mast and mount the detector Antenna vertically. (See figure 16.)
3. Since, we have changed the plane of receiving antenna to vertical keeping transmitting antenna still in the horizontal plane that detector antenna receives practically no signal.
4. Rotate the transmitting antenna from 0 to 360° gradually and observe that the receiving antenna received practically no signal or very less signal.
5. Repeat this with other horizontally polarised antennas.
6. Check with vertically polarised antennas.



Vertically Mounted Detector Antenna

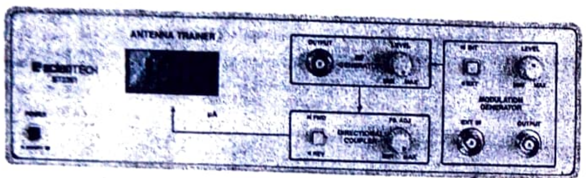
Figure 16

Experiment 4

Objective :
To perform Modulation Test

Procedure :

1. As the Modulation Switch is in 'INT' Position, it will select internally generated Sine wave (1 KHz, 300mV) to modulate with the RF signal at 'RF OUT'.
2. Observe demodulated output signal at the out terminals of RF detector with the help of oscilloscope probe. It should be sine wave of low amplitude and slightly distorted but indicating that this information signal (sine wave) was transmitted & received by the antennas.
3. The frequency Potentiometer can be tuned finely to get the proper shape of the Detector Signal.



Main Unit

Figure 17

signal

Experiment 5

Objective :
Study of variation in the radiation strength at a given distance from the antenna

The detector will show a higher strength when it is nearer to the transmitting antenna and shall reduce gradually with increasing distance.

Procedure :

1. Mount Folded dipole (λ/2) antenna on the top of the transmitting mast
2. Arrange the Set up as per procedure given in Experiment 1.
3. Keep the RF detector at a distance of approximately 1 ft. from the transmitting antenna and align it. Adjust level of RF Generator & Detector so that the reading should be ¾ of the main units reading.
4. Note the above reading for 1 ft. distance.
5. Shift the detector and keep it 2 ft. away from the Transmitting Antenna.
6. Note the reading for 2 ft. distance.
7. Similarly take the readings for 3, 4, 5 ft.
8. Plot a graph of reading with distance and see whether it is linear or non-linear. Same experiment can be done with other antennas.

Experiment 6

Objective :

Study of the Reciprocity theorem for antennas

Procedure :

1. Mount Yagi-UDA 3-E folded dipole antenna at the transmitting end, and 5-E folded dipole antenna at the receiving end. (any two antenna can be taken but keeping in mind that both should be of same polarization)
2. Take the radiation pattern for 3E folded dipole yagi antenna.
3. Take the radiation pattern for 3E folded dipole yagi antennas.
4. Now interchanging the transmitting & receiving side antennas.
5. Take the radiation pattern for 5E folded dipole Antenna.
6. You will get the same nature of radiation patterns. It proves the reciprocity theorem.

Note : The facility of changing the antenna at detector side is given for above experiments and to measure the characteristic of low power Antenna because in detector Antenna only a folded dipole element and reflector is present. So if we connect 3E folded dipole or 5E folded dipole antenna, receiving current gets increased.

Experiment 7

Objective :

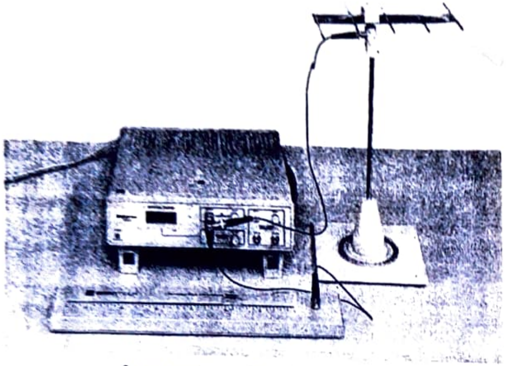
To practice how to use the matching stub provided with this trainer

Matching Stub : Please read the text given in the theory portion of this manual.

A matching stub is a piece of transmission line which is normally short circuited at the far end. Stub has an input admittance which a pure susceptance and it is used to tune the susceptance component of the line admittance. Stubs are particularly used at higher frequencies for variety of loads.

Matching procedure :

1. Mount folded dipole antenna on the top of the transmitting mast and keep the setup ready as per Experiment 1.
2. Now disconnect the BNC cable and connect a BNC to BNC male adapter and 'BNC-Tee' to the RF OUT of main unit.
3. Now connect one end of 'BNC–Tee' to transmitting mast using BNC to BNC cable of 25" long and other end to the Matching stub's input using BNC to BNC cable of 18" long. (See Figure 18)
4. Keep the stub knob at '0' of the Matching scale. You will observe that the reading on the Detector has already gone down with the connection of the matching stub.
5. Now keep the Directional coupler switch to 'REV' position.
6. Start moving Stub knob from right to left slowly, and observe the reading on meter of the main unit. You will observe that the meter has maxima and minima at some points. The maxima indicate that the reverse power is maximum and line is mismatched. Choose the minimum point while going from right to left. This position indicates that the line is matched



Setup Arrangement for Matching Stub

Figure 18

Experiment 8

Objective :
SWR Measurement

Please read the theory of SWR given in the earlier pages of this workbook. The SWR is the index of mismatch existing between the load and the feeding line. In the previous experiment, we have tried to match the line by matching stub and adjusting it to the minimum display in the RF position of the meter. This position is already the position of minimum reverse power.

1. Note this reading in µA, on main unit
2. Turn the switch to FWD. This gives the reading of the forward power.
3. The SWR can be calculated as under

$$SWR = \frac{FWD+REV}{FWD-REV}$$

If, you adjust the FS level to 100 then,

$$SWR = \frac{100+REV}{100-REV}$$

Experiment 9

Objective :

Antenna current sensor

This is used to measure the current in the antenna. This device consists of a sensing loop with rectifying diode and capacitor. See Figure 19 When the sensor is placed in the neighbourhood of a radiating antenna element, a part of the varying magnetic flux will cross the sensing loop and develop along its voltage. This voltage, rectified and smoothened by a capacitor, will appear as a DC (or modulated DC if you are transmitting an AM modulated wave.)

Note the Following :

1. For representing precisely the current flowing along a radiating antenna element, the loop should be as small as possible, down to approximate a point like device. The signal voltage developed in the loop is however proportional the magnetic flux crossing it i.e. to its section. This implies that in order to have easy to measure signal values, the loop must not be too small.
2. The actual size of the sensor is a trade off between the two requirements above.
3. The E component of the wave radiated by the antenna also interferes with the sensor. For the case of a radiating rod without other active or passive element near by, nor obstacles to the wave propagation, the E field can be depicted as a vector orthogonal placed to the axis of the radiating rod. The E components induce voltage contributions in the loop sensor arms and cable connections. The contributions however have opposed signs and should balance out if the sensor is held orthogonal to the rod and if the connection cable is made to leave the sensor straight and orthogonal.
4. Any object in the space surrounding an antenna will perturb the field distribution, in a manner that is generally difficult to predict except for rare, very simple cases. The current sensor behaves like such a perturbation object and therefore should not be used when field measurement or other propagation experiment are in course.

Not with standing the severe limitation in the use of the current sensor, this instrument is didactically useful, since it demonstrates in an immediately perceivable manner the current and field pattern of radiating antennas.

Procedure :

1. Connect a Simple dipole $\lambda/2$ antenna on the top of the transmitting mast.
2. Make the unit ready as per the procedure given in Experiment1.
3. Now connect the current sensor near the feeding point of the antenna.
4. Connect a DC Voltmeter at the other end of the Antenna current sensor and note down the voltage across the resistance. (See Figure 19)
5. Now move the sensor little away from the feeding point and again note the voltage.
6. Repeat the above procedure till the end point of the element, and you will find that the voltage decreases as we move away from the feeding point.
7. Now connect a 5 E simple dipole antenna to the Transmitting mast and connect the current sensor to the 'Active Element' of this antenna and note the voltage reading.
8. Now shift the sensor to the next element i.e. director of the antenna .Again note the reading.
9. Repeat the above steps till the last element of the antenna. Note down the readings and you will find that the voltage decreases as we move away from the active element due to less flux linkages with the elements.

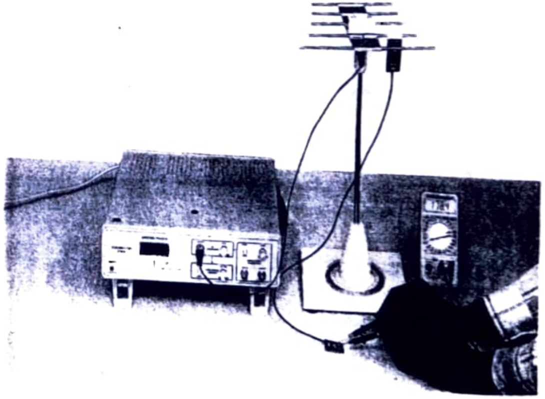


Figure 19

Mounted vertically on the ground.

the actual figure depends on height above ground.

Experiment 10

the feed point impedance is ½ of dipole or 36Ω.

Objective :

Study of Simple Dipole λ/4 Antenna (monopole)

Procedure :

1. Mount simple dipole (λ/4) antenna on the top of the transmitting mast.
2. Arrange the Set up as per procedure given in Experiment 1 and draw the polar graph.

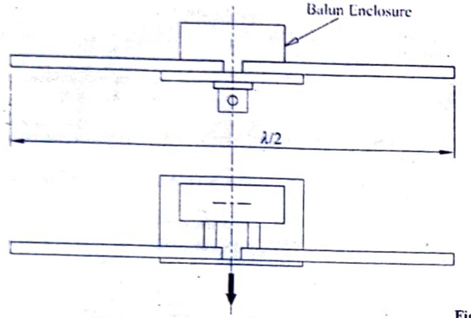


Figure 20

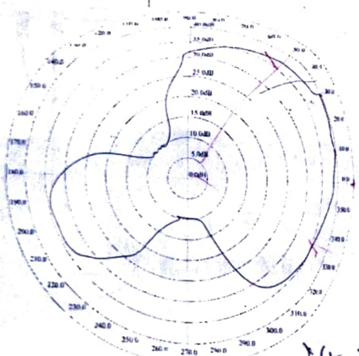


Figure 21

Experiment 11

Objective :

Study of Folded Dipole λ/2 Antenna

Compared to a simple dipole this antenna has a substantially higher radiation resistance (nominally, approximately 300Ω) for the presence of the folded arm. See Figure 22. The actual impedance is derived from rod diameter and distance from centre shape of the end bends, the presence of the BNC connector & balun etc. The typical radiation pattern in horizontal plane for this antenna appears like for the case of simple dipole as in previous experiment.

The polarisation is horizontal. The typical radiation pattern of folded dipole is given in Figure 23 for experimentation proceeds as follows.

Procedure :

Mount folded Dipole (λ/2) antenna on the transmitting mast and follow steps as per experiment no 2 and plot graph of this antenna

1. Mount Folded dipole (λ/2) antenna on the top of the transmitting mast
2. Arrange the Set up as per procedure given in Experiment 1 and draw the polar graph

* Good directional pattern characteristics
* Good matching to co-axial line.

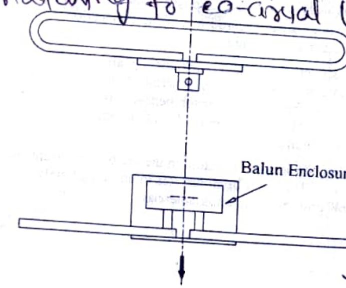


Figure 22

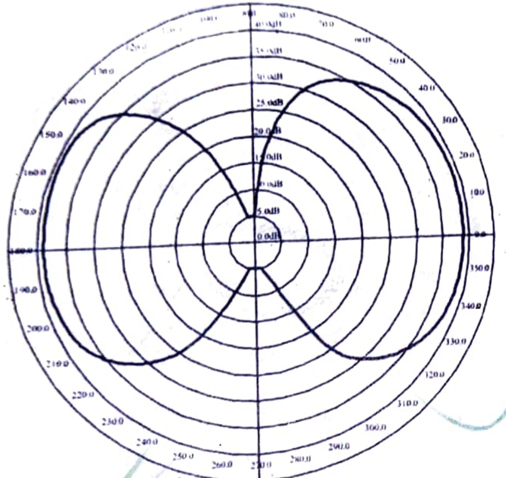


Figure 23

Yagi uda: Is a directional antenna, consists of dipole or folded antenna. High directional. No. of directors increases → not gain increased but better control of o/p patt. over wide freq. range.

3-30 MHz; VHF - 30-300 MHz, 300-3000 MHz.
end fire array.

Experiment 12

Objective :

Study of Yagi -UDA 3 element folded dipole has one active element, 1 reflector 1 director

Procedure :

1. Mount Yagi-UDA 3 element folded dipole Antenna on the top of the transmitting mast.
2. Arrange the Set up as per procedure given in Experiment 1 and draw the polar graph. Typical radiation pattern is shown in Figure 25.

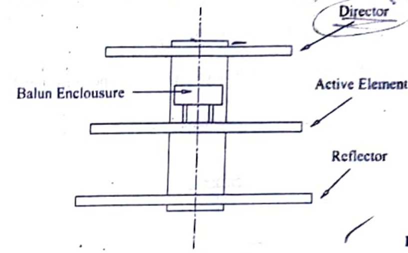


Figure 24

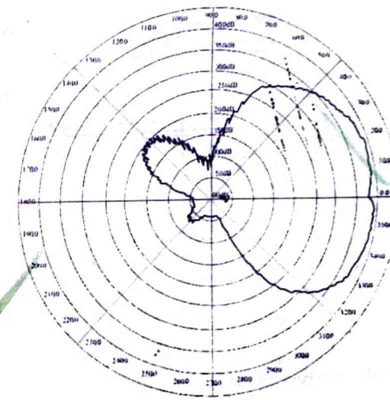


Figure 25

Experiment 13

Objective :

Study of Yagi-UDA 5 element folded dipole

The theoretical impedance of this antenna is 75Ω. This is a very important antenna for unidirectional transmission and widely used in TV reception. See Figure 26. Yagi-UDA Antenna with folded or non-folded dipoles are widely used antennas Behind the dipole they have a reflectors and in front they have directors 1-3-5-7-9, etc.

The typical radiation pattern of this antenna is shown in Figure 27. The polarisation is horizontal.

Procedure :

1. Mount Yagi-UDA 5 element folded dipole Antenna on the top of the transmitting mast.
2. Arrange the Set up as per procedure given in Experiment 1 and draw the polar graph.

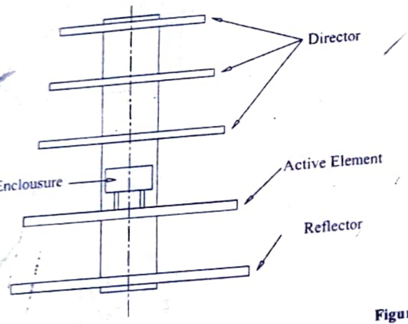


Figure 26

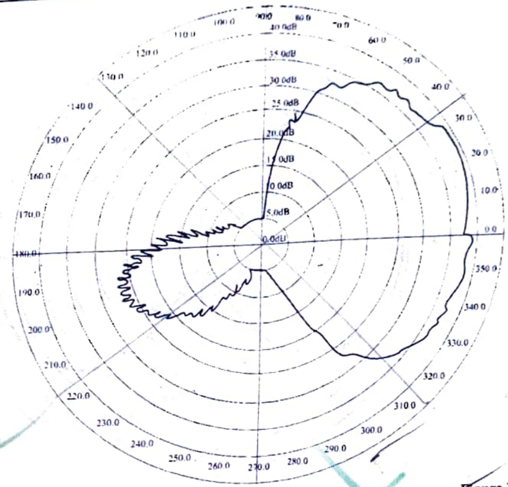


Figure 27

Experiment 14 (difference between previous?)

Objective :
Study of Yagi-UDA 5 element simple dipole

Procedure :

1. Mount Yagi-UDA 5 element simple dipole Antenna on the top of the transmitting mast
2. Arrange the Set up as per procedure given in Experiment 1 and draw the polar graph. Typical radiation pattern is shown in figure 29.

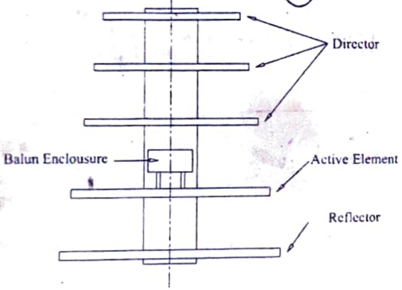


Figure 28

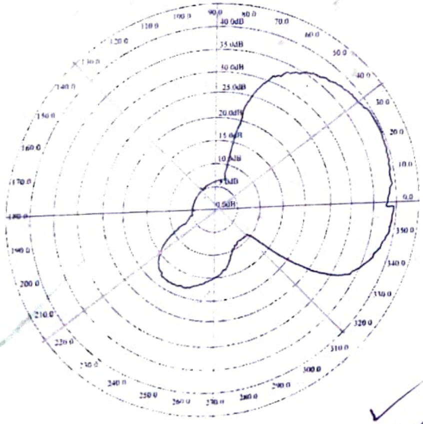


Figure 29

Experiment 15

Objective :
Study of Yagi-UDA 7 element simple dipole

Procedure :

1. Mount Yagi-UDA 7 element simple dipole Antenna on the top of the transmitting mast
2. Arrange the Set up as per procedure given in Experiment 1 and draw the polar graph. Typical radiation pattern is shown in figure 31.

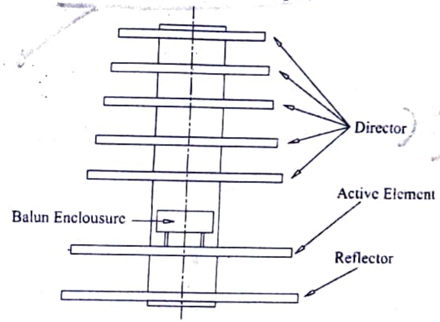


Figure 30