Federal Urdu University of Arts, Science & Technology

LAB MANUAL

SEVENTH SEMESTER
MICROWAVE THEORY & TECHNIQUE

TELECOMMUNICATION LAB
DEPARTMENT OF ELECTRICAL ENGINEERING

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          Dean Electrical Department
## CONTENTS

<table>
<thead>
<tr>
<th>Exp No</th>
<th>List of Experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>INTRODUCTION TO MICROWAVE DEVICES TRAINER</td>
</tr>
<tr>
<td>2</td>
<td>GUNN OSCILLATOR</td>
</tr>
<tr>
<td>3</td>
<td>FREQUENCY SENSITIVITY OF GUNN OSCILLATOR</td>
</tr>
<tr>
<td>4</td>
<td>TO STUDY THE GUNN OSCILLATOR FOR SQUARE WAVE MODULATION</td>
</tr>
<tr>
<td>5</td>
<td>THE MATCHING STUB</td>
</tr>
<tr>
<td>6</td>
<td>STANDING WAVE RATIO SWR MEASUREMENT</td>
</tr>
<tr>
<td>7</td>
<td>LOAD IMPEDENCE</td>
</tr>
<tr>
<td>8</td>
<td>INTRODUCTION TO ANTENNA TRAINER</td>
</tr>
<tr>
<td>9</td>
<td>BASIC SETUP</td>
</tr>
<tr>
<td>10</td>
<td>GENERATOR ADJUSTMENT</td>
</tr>
<tr>
<td>11</td>
<td>RADIATION POLAR DIAGRAMS</td>
</tr>
<tr>
<td>12</td>
<td>HORIZONTAL END-FED ANTENNA (ZEPPELIN ANTENNA)</td>
</tr>
<tr>
<td>13</td>
<td>LOOP ANTENNA</td>
</tr>
<tr>
<td>14</td>
<td>YAGI-UDA ANTENNA</td>
</tr>
<tr>
<td>15</td>
<td>VERTICAL END-FED ANTENNA</td>
</tr>
<tr>
<td>16</td>
<td>SLOT ANTENNA</td>
</tr>
</tbody>
</table>
EXPERIMENT NO - 1

INTRODUCTION TO MICROWAVE DEVICES TRAINER

OBJECTIVE:

- To understand the Gunn oscillator
- To analyze frequency, guide wavelength & free space wavelength.
- To measure the SWR.
- To measure impedance of load.

THEORY:

OMEGA TYPE ES – 502 uses gun oscillator with its gun power supply and pin modulator as a microwave signal source along with other standard high quality components VSWR meter, enables to perform under mentioned experiments in the laboratory. The wave guide components are based on rectangular waveguide equipped with rectangular flange.

FEATURES:

The complete experimental setup consists of the following items:

- Gunn power supply.
- Gunn oscillator.
- PIN modulator.
- Isolator.
- Frequency meter.
- Variable meter.
- Variable Attenuator.
- Slotted section with probe carriage.
- Tunable probe.
- Detectors mount.
- Moveable short.
- Matched termination.
- VSWR meter, solid state.
- Waveguide stands
- Slide screw tuners.
Describe the following components in detail as discussed in the lab:

1. **Gunn power supply:**

2. **Gunn oscillator:**

3. **PIN modulator:**

4. **Isolator:**

5. **Frequency meter:**
6. Variable Attenuator:

7. Slotted section with probe carriage:

8. VSWR meter, solid state:

COMMENTS:

Teacher’s Signature: __________________. Date: ________________.

Teacher’s Name: Engr Saqib Riaz.
EXPERIMENT NO - 2

GUNN OSCILLATOR

OBJECTIVE:

- To obtain the knowledge on the theory and the operation of the Gunn oscillator. Also understand the characteristics of Gunn Diode.

CONSTRUCTION OF GUNN DIODE:

The construction of Gunn diode is shown in figure 1 and figure 2. The figure is self explanatory.
TYPICAL CHARACTERISTICS:

It typically used a 10 – 12V supply with typical bias current of 250mA giving a continuous wave power of 25 mW in the X-band.

- CW power - 25mW to 250mW X band (5-15 GHz).  
  100 mW at 18-26.5 GHz.  
  40mW at 26.5-40 GHz.
- Pulsed power - 5W (5-12 GHz).
- Efficiency 2% to 12% (at 1.5W CW to 50 mW CW).

GUNN DIODE AMPLIFIER:

Gunn diode with negative characteristics can be used as an amplifier (similar to tunnel diode) but are not very popular. Gunn diode amplifiers available have been able to give the following performance characteristics.

- Power - 1W at frequency between 4 and 16 GHZ.
- Gain band width product - 10dB
- Average Gain - 1-12 db
- Noise figure - 15 dB

GUNN OSCILLATOR:

Gunn diode oscillator normally consists of a resonant cavity, an arrangement for coupling diode to the cavity; a circuit for biasing the diode and a mechanism to couple the RF power the diode and a mechanism to couple the RF power from the cavity to the external circuit/load. A coaxial cavity or rectangular waveguide cavity are commonly used.
THEORY:

The Gunn oscillator is based on negative differential conductivity effect in bulk semiconductor which has two conduction bands minima separated by an energy gap. A domains disturbance at the cathode gives rise to high field region which travels towards the anode, when this high field domain reaches the anode, it disappears and another domain is formed at the cathode and starts moving towards anode and so on. The time required for domain to travel from cathode to anode gives oscillation frequency. In a Gunn oscillator, the Gunn diode is placed in a resonant cavity in this case the oscillation frequency is determined by cavity dimensions than by diode itself. Although Gunn oscillator can be amplitude modulated with the bias voltage. We have used separate PIN modulator through PIN diode for square wave modulation. A measure of the square wave modulation capability is the modulation depth i.e., the output between ‘ON’ and ‘OFF’ state.

CO-AXIAL CAVITY BASED:

The circuit using co-axial cavity has the Gunn diode mounted at one end of the cavity and is in continuation with the central conductor of the co-axial line. The output is taken using a inductively or capacitively coupled probe. The length of the cavity determines the frequency of oscillation. The location of the coupling loop or probe within the resonator determines the load impedance presented to the Gunn diode. Heat sink conducts away the heat due to power dissipation of the device. The circuit has an advantage that it can be easily fabricated but low Q of co-axial resonator and oscillations at harmonics of the desired frequency are disadvantages.

WAVEGUIDE CAVITY BASED:

The circuit using waveguide cavity is more popular, consisting of a simple waveguide section separated from the output waveguide by an iris. The Gunn diode is mounted in a post across the narrow dimension in the centre of the waveguide. The rectangular cavity operates in the TE10 mode. The diode post acts as a large inductive susceptance and the iris is also inductive. Hence the resonant frequency is lower than that for which the length $l$ is $\lambda g / 2$. The dielectric tuning rod is used to adjust the frequency mechanically. Sapphire dielectric rod is commonly employed.
PROCEDURE:

1. Set the components and equipments as required.
2. Initially set the variable attenuator for maximum attenuation.
3. Keep the control knob of Gunn power supply as below;
   - Meter switch – OFF
   - Gunn bias knob – fully anti clock wise
   - Pin bias knob – fully anti clock wise
   - Pin mod frequency – any position

4. Keep the control knob of VSWR meter as below;
   - Meter switch – normal
   - Input switch – low impedance
   - Range db switch – 50db
   - Gain control knob – fully clockwise

5. Set the micrometer of Gunn oscillator for required frequency of operation.
6. ‘ON’ the Gunn power supply and VSWR meter.

SCHEMATIC:
VOLTAGE-CURRENT CHARACTERISTICS:

1. Turn the meter switch of Gunn power supply to voltage position.
2. Measure the Gunn diode current corresponding to the various voltage controlled by Gunn bias knob through the panel meter and meter switch.
3. Set the variable attenuator to 10dB.
4. Do not exceed the bias voltage above 9 volts.
5. Plot the voltage and current readings.
6. Measure the threshold voltage switch which corresponds to maximum current.

<table>
<thead>
<tr>
<th>VOLTAGE (V)</th>
<th>CURRENT (mA)</th>
<th>POWER (mA)</th>
<th>POWER in (dBm)</th>
<th>ATTENUATOR (dB)</th>
<th>GUNN DIODE OUTPUT (dBm)</th>
<th>GUNN DIODE OUTPUT (mW)</th>
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<td>0</td>
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Supply Voltage vs Current Characteristics

Supply Voltage vs Output Power Characteristics
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Teacher’s Signature: _________________. Date: _________________.

Teacher’s Name: Engr Saqib Riaz.
EXPERIMENT NO - 3

FREQUENCY SENSITIVITY OF GUNN OSCILLATOR

OBJECTIVE:

The main purpose of this lab is to study the Gunn oscillator for output power and frequency as a function of BIOS voltage

PROCEDURE:

Following steps are to be considered;

- Turn the meter switch of Gunn power supply to voltage position.
- Increase the Gunn bias control Knob.
- Rotate PIN bias knob to around maximum position.
- Tune the output in the VSWR meter through frequency control knob of modulation.
- If necessary change the range dB switch of VSWR meter to higher or lower dB position to get deflection on VSWR meter. Any level can be set through variable attenuator and gain control knob of VSWR meter.
- Measure the frequency by frequency meter and detune it.
- Reduce the Gunn bias voltage in the interval of 0.5V to 1.0V and note down corresponding reading of output as VSWR meter and frequency by frequency meter.
- Use the reading to draw the power V/s voltage curve & frequency V/s voltage and plot the graph.

SCHEMATIC:

Make the table for different values of frequency and bias voltage and sketch the graph
TABLE:

<table>
<thead>
<tr>
<th>Voltage (V)</th>
<th>Frequency (GHz)</th>
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Supply Voltage vs Frequency
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Teacher’s Signature: ___________________  Date: ___________________.

Teacher’s Name: Engr Saqib Riaz.
EXPERIMENT NO - 4

TO STUDY THE GUNN OSCILLATOR FOR SQUARE WAVE MODULATION

OBJECTIVE:

The main purpose of this lab is to study the Gunn oscillator for square wave modulation and calculating the modulation depth.

PROCEDURE:

- Keep the meter switch of the gunn supply to volt position and rotate the gunn bias voltage slowly so that the panel meter reads 9 volts.
- Tune the pin modulator bias voltage and frequency knob for max. Output.
- Coincide the bottom of square wave in oscilloscope to some reference level and note down the micrometer reading of variable attenuator.
- Now with the help of variable attenuator coincide the top of square wave to the same reference level and note down the micrometer reading.
- Connect VSWR to detector mount and note down the DB reading in VSWR meter for both the micrometer reading of the variable attenuator.
- The difference of both db readings of vswr meter gives the modulation depth of PIN modulator.

TABLE:

<table>
<thead>
<tr>
<th>Attenuation (dB)</th>
<th>Output (Vp-p)</th>
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Teacher’s Signature: _______________. Date: ________________.

Teacher’s Name: Engr Saqib Riaz.
EXPERIMENT NO - 5

INTRODUCTION TO TRANSMISSION LINE TRAINER

OBJECTIVE:

- To understand the various parameters in Transmission Line.

Trainer Description:

In the telecommunication field transmission lines are used to
convey the signals from one point to another point. The line properties become very
important especially in multi-channel system. Transmission line trainer is a unique design
for experimenting various properties of the line. The trainer provides basic concept of
coaxial line and includes devices and accessories to conduct the experiment.

1. Test Generator:

2. Transmission Line:

3. Impedance Matching Resistor:
EXPERIMENT NO - 6

MEASURING THE CHARACTERISTICS OF A LINE

OBJECTIVE:

• To understand the basic properties of the coaxial cable used in transmission line.

THEORY:

The coaxial-line used for the transmission of electromagnetic waves consist of an external conductor of cylindrical shape, with an inner conductor arranged along the axis of the former. The two conductors are separated by dielectric material of suitable features.

PROCEDURE:

1. Fig shows the modalities for the measurement to be performed.

2. Make connections as in Diagram.

3. Both the inductance and the ohmic resistance of the line are measured in series by short-circuiting end of the line and connecting the measuring instruments to the start of the line. The capacitance and the conductance are measured in parallel by operating on the open line.

4. The resistance R and the conductance G can be measured with an ohmmeter or DMM. For the conductance to be measured an is required which is able to perform resistance measurements with a range greater than 100MΩ.

5. For the measurement of series inductance L and the parallel capacitance C, a LCR meter or measuring bridge is required. The results of these measurements give values of R, L, C and G referred to the cable length that, in our case, is of 100 meters.
$Z_0$ can be measured by using the following formula:

$$Z_0 = \sqrt{\frac{L}{C}}$$

<table>
<thead>
<tr>
<th>Length</th>
<th>Resistance</th>
<th>Inductance</th>
<th>Capacitance</th>
<th>Impedance</th>
</tr>
</thead>
<tbody>
<tr>
<td>50m</td>
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<td></td>
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<tr>
<td>100m</td>
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COMMENTS:

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Teacher’s Signature: _________________. Date: _________________.

Teacher’s Name: **Engr Saqib Riaz**.
EXPERIMENT NO - 7
MEASURING THE ATTENUATION OF A LINE

OBJECTIVE:

• To analyze the input & output signal of the transmission line and also to calculate the attenuation of the line.

PROCEDURE:

1. Adjust Ri & RL for 18E and 68E respectively with the help of DMM.
2. Make the connection as shown in the figure.

3. Set the sin-wave frequency to approximately 100 KHz and voltage level to 0.4 V p-p.
4. Oscilloscope CH1 shows applied input and CH2 shows output.
5. Measure the signal level at input, and at 25m, 50m, 75m & 100m.
6. Now calculate the attenuations in dB at various lengths by the formula given below:

   \[ a = 20 \log \frac{V2}{V1} \]

7. Tabulate as under.
TABLE:

<table>
<thead>
<tr>
<th>Length (m)</th>
<th>Input Voltage (V1)</th>
<th>Output Voltage (V2)</th>
<th>Attenuation (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25m</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>50m</td>
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<td></td>
<td></td>
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<tr>
<td>75m</td>
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<tr>
<td>100m</td>
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Teacher’s Signature: ___________________. Date: ___________________.

Teacher’s Name: Engr Saqib Riaz.
EXPERIMENT NO - 8
MEASURING THE INPUT IMPEDENCE OF THE LINE

OBJECTIVE:
• To analyze the effect of input impedance on the output.

PROCEDURE:
1. Adjust $R_I$ & $R_L$ for 18E and 68E respectively with the help of DMM.
2. Make the connection as shown in the figure.
3. A 1E resistance in series between the generator and the transmission line as shown allows to measure the value of I/P current.
4. Set the I/P at 1Vp-p and freq 100 KHz of sin-wave (both measurement on CRO)
5. Take readings of $V_{in}$ and $V_{m}$ (across 1E) on oscilloscope.
6. Calculate the input impedance according to the following formula:
   $$Z_{in} = \frac{V_{in}}{I} = \frac{V_{in}}{V_{m}} \times 1E$$
7. Change the frequency to 1MHz and note the values of $V_{in}$ & $V_{m}$ at this frequency.

TABLE WITH LOAD:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>$V_{in}$</th>
<th>$V_{m}$</th>
<th>$Z_{in}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 KHz</td>
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<tr>
<td>1 MHz</td>
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</tbody>
</table>
**TABLE FOR OPEN CIRCUIT:**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Vin</th>
<th>Vm</th>
<th>Zin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 KHz</td>
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<td>1 MHz</td>
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</table>

**TABLE FOR SHORT CIRCUIT:**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Vin</th>
<th>Vm</th>
<th>Zin</th>
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<tr>
<td>1 KHz</td>
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<td>1 MHz</td>
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Teacher’s Signature: __________________. Date: ________________.

Teacher’s Name: **Engr Saqib Riaz.**
EXPERIMENT NO - 9

FREQUENCY CHARACTERISTICS OF THE LINE

OBJECTIVE:

• To analyze the effect of frequency of the input signal on the output.

PROCEDURE:

1. Adjust R_I & R_L for 18E and 68E respectively with the help of DMM.
2. Make the connection as shown in the figure.

3. Set the oscilloscope to 0.1 V/div for both the channels.
4. Adjust the sin generator for an O/P of 0.2 Vp-p (2 div. deflection on ch I) and at frequency 40KHz
5. At this point ch I is reading 2 div. deflection and channel II is reading 1.6 div. (this is due to fix attenuation of the line)
6. Now, vary the frequency of generator gradually keeping the input amplitude constant (observe ch I and maintain 2 div. deflection by adjusting AMP VAR control) till the waveform at the end of 100m line falls to -3dB (1.4 div of ch II on the oscilloscope). Note, this frequency on the oscilloscope. This frequency is known as the cut-off frequency.
### TABLE:

<table>
<thead>
<tr>
<th>Frequency of Input</th>
<th>Vin p-p</th>
<th>Vout p-p</th>
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<tbody>
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Teacher’s Signature: ________________ .  Date: ___________________ .

Teacher’s Name: **Engr Saqib Riaz**.
EXPERIMENT NO - 10

INTRODUCTION TO ANTENNA TRAINER

OBJECTIVE:

• To get familiar with the Antenna Trainer & its components.

Trainer Description:

The trainer consists of a main cabinet and a case containing the antennas, accessories and parts required to perform the experiment. The main cabinet is designed for desk-top use, made of aluminium with silkscreen printing on the front face showing block diagram and unit interconnections.

1. Power Supply:

2. RF Generator:

3. Test Tone Generator:
4. Directional Coupler:

5. Power Meter:

6. Slot Line/Matching Stub:

6. Protractor:
EXPERIMENT NO - 11
RF GENERATOR & MATCHING STUB

OBJECTIVE:

- To familiarize with meaning and use of the adjustments and control points of the generator.
- The scope of this experiment is to practice on how to use the slot-line/matching stub provided on the trainer.

PROCEDURE (a):

Following steps are to be considered;

- Detector mounted vertically on its supporting arm placed 1.5mm away from the transmitting antenna.
- Mount the folded dipole on top.
- Align the main axis of the transmitting antenna with the detector.
- Turn the FS adjustment knob of the FWD/REV power meter to minimum, and then switch the power ON.
- Adjust the level knob of the detector to max and the RF level knob of the transmitter to have a ½ scale reading on the detector meter.

RF LEVEL:

This potentiometer controls the power supply voltage applied to the transistor working as an oscillator inside the generator, thus controlling the amplitude and power of the resulting RF signal. The level can be adjusted from approx. 20% to 100%.

OUTPUT FREQUENCY:

The transistor oscillator of the RF generator works on base emitter feedback and the operating frequency is determined by a microstrip line provided with a capacitive trimmer to adjust its resonance frequency. Find the adjustment screw driver provided with the trainer amongst the accessories. While observing the detector indication moves the FREQ. ADJ. screw in one direction and then the other.

Observe the following:

- There is a point of maximum receiver indication corresponding to the resonance condition of the generator to the external circuit.
- There are two limits in the position of the screw outside which the generator abruptly stops of weakens.
- Never over tighten the adjustment screw in a clockwise direction.
- A stopping block is provided internally, however in extreme cases the block might be overwhelmed and the regulating screw could fall inside the cabinet.

**OUTPUT Z:**

This is another trimmer placed on the output of the oscillator, whose function is to adjust to some extent the output impedance of the generator to the load. Keep an eye to the indication of the detector and gently move the screw core in one direction and then the other to peak the signal. The trimmer has more effect on the needle deflection than the preceding one. In addition to maximizing power transfer from the generator. This trimmer has also a secondary effect of slightly moving the operating frequency. Re-adjustment of the first trimmer is therefore required after peaking the second.

**ANTENNA MATCH:**

This trimmer is not actually part of the generator, since it is placed at the output of the directional coupler; however its function is being mentioned here for the sake of a complete view of the adjustments allowed. This trimmer can be adjusted to compensate the reactive components of the antenna and its feeding line. Try this control by proceeding as with the other two trimmers. The best setting expected for this trimmer, since the folded is being used, is towards an “unscrewed” position. Different settings would obviously be required for other antennas.

**TABLE:**

<table>
<thead>
<tr>
<th>Minimum Output</th>
<th>Maximum Output</th>
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**COMMENTS:**

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PROCEDURE (b):

Prepare the equipment as already described in the preceding Worksheet: detector placed in its supporting arm, 1.5m away from the transmitting antenna. Antenna mast placed on the protractor.

Find the BNC “T” amongst the accessories and place it on top of the mast. Mount the folded dipole on top and plug the BNC-BNC coax cable on the third port of the BNC “T”.

Plug the other end of the coax cable into the input socket of the line.

Bend the cable so that it leaves the mast at 90° and in a direction opposite to the receiver. This is to minimize disturbance to the wave propagation from transmitter to receiver.

Turn ON the power and align the transmitting and receiving antennas. Notice how the detector indication is lower compared to the case of Worksheet No. 2. This is because the BNC “T”, the cable, the shorted stub are obviously far from being lossless items, and also because of the random initial setting of the stub carriage.

Move the slide carriage of the slotted line slowly from one end to the other and observe the indication of the meter of the directional coupler waving from a maximum to a minimum indication. The meter of the detector also does the same.

Record the positions of maximums and minimums and also the corresponding meter deviations.

Note that the amplitude of the max. points near the line input are higher than near the far end. This is because of losses (and radiation) in the line.

Repeat with the FWD/REV selector on FWD recording the new positions of maximums and minimums. Notice that maximums and minimums are now less evident than in the preceding case.

Match the patterns for the FWD and REV cases: for slide positions near the input end, a max. in FWD corresponds quite well to a min. in REV. This is the point of best matching for the antenna being studied. Obviously the results are more evident using other types of antennas than the folded dipole, since this antenna was used to adjust the generator. Try the same experiment with, for instance, the simple dipole.
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<th>Distance (cm)</th>
<th>Deflector Meter Reading (uA)</th>
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Teacher’s Signature: _________________.     Date: ___________________.

Teacher’s Name: **Engr Saqib Riaz**.
EXPERIMENT NO - 12

RADIATION POLAR DIAGRAM OF FOLDED DIPOLE ANTENNA

OBJECTIVE:

- To use antennas as a transmitting device, trying out its matching characteristics and recording its radiation pattern
- To familiarize with folded dipole antenna and their different characteristics.
- How to draw the radiation pattern of folded dipole.

PROCEDURE:

Following are the steps for recording a radiation pattern;

- The principle of the procedure is to rotate the transmitting antenna with respect to the detector and measure the relative power levels at each angular point chosen.
- The detector should be placed at a fixed distance from the transmitter.
- Align the axis of the transmitting and receiving antennas and place the receiver approx. 0.8 to 1.5m away, same height of the transmitting one.
- Choose a convenient protractor graduation as a “ZERO” reference point.
- For high gain antennas, the distance might have to be increased to 3 or 4 m. if this is impractical in the laboratory, reduce the RF transmission level.
- Try the knob of the receiver fully clockwise.
- Raise the level knob on the generator to obtain a large deflection of the detector instrument.
- If the instrument goes full scale move the detector some distance away or reduce the RF level knob.
- The actual effect of reflections from any object in the testing area is the generation of a more or less evident deformation of the radiation pattern of the antenna.
- Record the level indication of the detector meter at this “ZERO” reference point.
- Rotate the transmitting antenna by a chosen number of degrees.
- Again record the detector meter indication and the angular position of the transmitting antenna.
- Repeat this experiment for complete 360° of the antenna.
- At this stage, have a table of results containing relative power levels with respect to the power level at the “ZERO” position.
- At this point the relative power values can be plotted against the angle in a polar diagram.
- An alternative method is to convert the relative power values in decibels(dB) and use the dB values to construct the plot using the formula;

\[ A_{db} = 20 \log_{10} A \]
**FOLDED DIPOLE:**

Compared to the simple dipole, this antenna has a substantially higher radiation resistance due to the presence of the folded arm. The actual impedance deviates due to the rod diameter and distance, the shape of the end bends, the presence of the BNC connector and balun etc. The typical radiation pattern in the horizontal plane for this antenna appears similar to that of the simple dipole. The polarization is horizontal.
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<th>ANGLE DEGREE</th>
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Teacher’s Name: Engr Saqib Riaz.
EXPERIMENT NO - 13

HORIZONTAL END-FED ANTENNA
(ZEPPELIN ANTENNA)

OBJECTIVE:

- To introduce with horizontal end-fed antenna.
- About the radiation pattern of horizontal end-fed antenna.

THEORY:

The model of horizontal End fed antenna induced in the trainer consists of a piece of brass rod with a tubular sleeve, allowing effective length of the antenna to be varied. The matching device is a step-up single-loop transformer.

Zeppelin Antenna:

This antenna was developed in the beginning of this century to be used on the Zeppelin German Aerostat where the shape constraints did not leave too many choices. The original Zepp consisted of a wire, fed at one end by a balanced line, pulled from the nose to the tail of the aerostat. This Antenna performed well on shortwave, at wavelengths equal to sub-multiples of the antenna length.

Hertz Antenna:

This is another generic name for horizontal wire antenna having a length that is a multiple of the half-wavelength of the signal frequency. This wire is fed at one end by another piece of wire having the same characteristics the horizontal one, whose function is to transform the antenna impedance.

Random Antennas:

Another name for any horizontal fed piece of wire, regardless of its length. These Antennas are brought to resonance by adjustable LC elements on the feed line.
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Teacher’s Name: Engr Saqib Riaz.
EXPERIMENT NO - 14

LOOP ANTENNA

OBJECTIVE:

- To introduce with loop antenna.
- About the radiation pattern of loop antenna.

DESCRIPTION:

These antennas consist of single or multiple loop arrangements. The total loop perimeter is generally one half-wavelength long or multiples of it. In the basic configuration the antenna has rather low impedance so that it can be used only for reception due to matching efficiency. The Loop Antenna of this trainer has its input impedance raised to adequate levels by the appropriately setting the loop perimeter. This antenna normally has a horizontal polarization; however a vertically polarized component may appear in the case of mismatching between the generator and the antenna.

FIG. 22 – OUTLINE OF THE LOOP ANTENNA (A) AND RADIATION DIAGRAM (B)
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Teacher’s Signature: _________________. Date: ___________________.

Teacher’s Name: Engr Saqib Riaz.