Department of Telecommunications Engineering
NED University of Engineering & Technology

LABORATORY WORKBOOK

For the Course

ANTENNA AND MICROWAVE ENGINEERING (TC-313)

Instructor Name: _____

Student Name: _____

Roll Number: _____ **Batch:** _____

Semester: _____ **Year:** _____

Department: _____

LABORATORY WORK BOOK

For The Course

ANTENNA AND MICROWAVE ENGINEERING

(TC-313)

Prepared By:

Ms. Nida Nasir

Revised By:

Dr. Uzma Afsheen (Assistant Professor)

Reviewed By:
Dr. Hira Marium (Assistant Professor)

Approved By:

The Board of Studies of Department of Telecommunications Engineering

INTRODUCTION

Antenna & Microwave Engineering Practical Workbook covers a variety of experiments that are designed to aid students in their profession and theory. The practical are very beneficial to students and will help them in having a core knowledge and understanding of the subject. The practical covered in this manual give more than a basic introduction to students. They cover a variety of topics which include antennas, transmission lines and microwave waveguides. A practical exposure to such equipment is necessary as it builds on the theory taught to students. The practical are based on modern trainers that incorporate a variety of functions to demonstrate to students the principles of Antenna & Microwave Engineering techniques. The students will develop a profound interest in this course which will facilitate them whether it is in future professional work or higher studies.

CONTENTS

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11		By the use of the slotted line, • Determine the unknown frequency • Determine the Voltage Standing Wave Ratio (VSWR) and Reflection Coefficient.	52	3	
12		By use of slotted waveguide • Observe how the load impedance affects the VSWR. • Determine when a waveguide is properly terminated	58	3	
13		To determine the unknown load impedance attached to a waveguide (Open Ended Lab)	63	3	

LAB SESSION 01

OBJECT:-
To investigate the properties a dipole antenna in free space

EQUIPMENT:-
Antenna Lab hardware
Discovery Software
Dipole elements
Yagi boom

THEORY:

Antenna: An antenna is a transducer designed to transmit or receive radio waves which are a class of electromagnetic waves. In other words, antennas convert radio frequency electrical currents into electromagnetic waves and vice versa. Antennas are used in systems such as radio and television broadcasting, point-to-point radio communication, wireless LAN, radar, and space exploration. Antennas usually work in air or outer space, but can also be operated under water or even through soil and rocks at certain frequencies for short distances. Physically, an antenna is an arrangement of conductors that generate a radiating electromagnetic field in response to an applied alternating voltage and the associated alternating electric current, or can be placed in an electromagnetic field so that the field will induce an alternating current in the antenna and a voltage between its terminals.

Simple Dipole Antenna: The simplest form of antenna is called the d*ipole*. This is a conductor that is divided in the middle and is connected at this point to a feeder (or feed line). This feeder then connects the antenna to the receiver, or transmitter. Feeders come is many forms. The most commonly used is coaxial cable. This is the type of feeder used in this trainer.
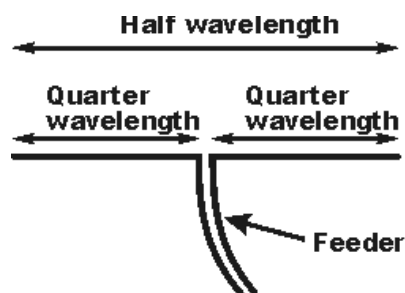
Figure 1

Generally, the dipole is considered to be Omni-directional in the plane perpendicular to the axis of the antenna, but it has deep nulls in the directions of the axis.
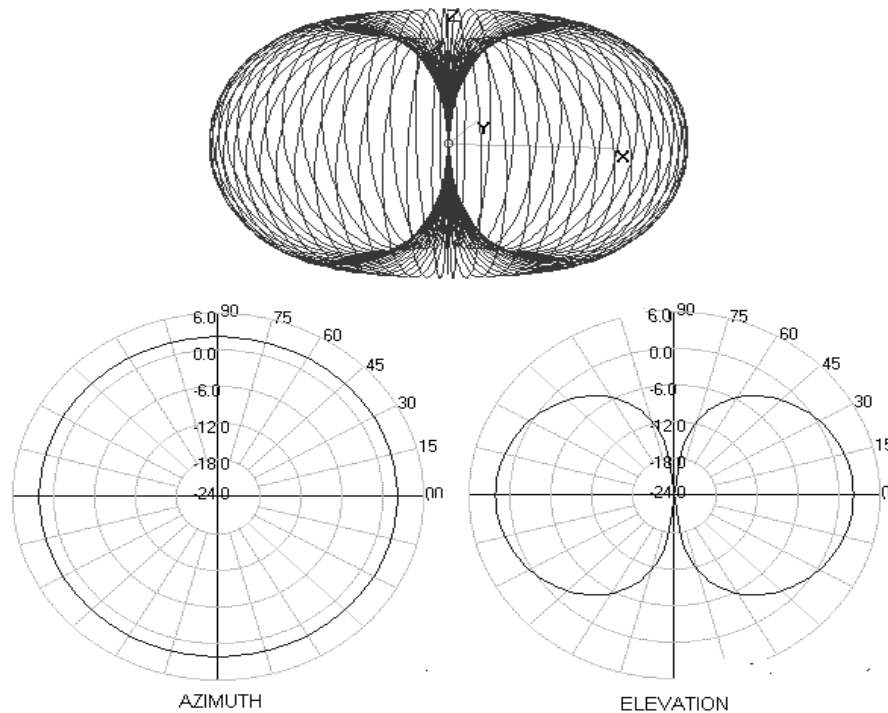
Figure 2

PRE LAB TASK:

1. Discuss Dipole Antenna Characteristics:
- Frequency Vs. Length
- Radiation Pattern and Gain.
- Feeder Line
2. Write Common applications of Dipole Antenna.

PROCEDURE:

1. Identify one of the antenna Boom Assemblies and mount it on top of the Generator Tower.
2. Ensure that all of the elements are removed, except for the dipole.
3. Examine the dipole element, you will see that the ends are extendible. Adjust the dipole length so that it is 5cm either side of the centre.
4. Ensure that the Motor Enable switch is off and then switch on the trainer.
5. Launch signal strength vs. angle 2D polar graph and immediately switch on the motor enable.
6. Ensure that the Receiver and Generator antennas are aligned with each other and that the spacing between them is about one meter.
7. Acquire a new plot at 1500MHz.
8. Observe the polar plot.

OBSERVATIONS:

1. Does the dipole antenna have the same response in all directions in the azimuth (horizontal) plane?

   _____

2. In which direction(s) is the response a maximum?

   _____

3. In which direction(s) is the response a minimum?

   _____

RESULT:

F/OBEM 01/05/00

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Psychomotor Domain Assessment Rubric-Level P3					
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	0	1	2	3	4
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 2

OBJECT:-

- To investigate the properties of a system comprising a dipole and a parasitic element.
- Understand the terms 'driven element', 'reflector', 'director'
- To know the form of a YAGI antenna and examine TWO element Yagi.
- To see how gain and directivity increase as number of elements increase

EQUIPMENT:-

Antenna Lab hardware
Discovery Software
Dipole elements
Yagi boom

THEORY:-

Antenna: An antenna is a transducer designed to transmit or receive radio waves which are a class of electromagnetic waves. In other words, antennas convert radio frequency electrical currents into electromagnetic waves and vice versa. Antennas are used in systems such as radio and television broadcasting, point-to-point radio communication, wireless LAN, radar, and space exploration. Antennas usually work in air or outer space, but can also be operated under water or even through soil and rocks at certain frequencies for short distances.

Physically, an antenna is an arrangement of conductors that generate a radiating electromagnetic field in response to an applied alternating voltage and the associated alternating electric current, or can be placed in an electromagnetic field so that the field will induce an alternating current in the antenna and a voltage between its terminals.

Yagi Uda Antenna: An antenna with a driven element and one, or more, parasitic element is generally known as a "yagi", after on of its inventors (Yagi and Uda).

With the length of the second dipole (the un-driven or **"Parasitic"** element) shorter then the driven dipole (the driven element) the direction of maximum radiation is from the driven element towards the parasitic element. In this case, the parasitic element is called the "**director**".

With the length of the second dipole longer than the driven dipole the direction of maximum radiation is from the parasitic element towards the driven element. In the case, the parasitic element is called the "**reflector".**

Simple 3-element Yagi With Support Boom

Figure 1

Figure 2

PRE-LAB TASKS:

1. Why do we require Arrays? Give Reasons.

2. Discuss different types of Antenna Arrays

3. How are BEAMWIDTH, DIRECTIVITY and GAIN related?

PROCEDURE & OBSEVATIONS:

1. Identify one of the Yagi Boom Assemblies and mount it on top of the Generator Tower.
2. Ensure that all of the elements are removed, except for the dipole.
3. Ensure that the Motor Enable switch is off and then switch on the trainer.
4. Launch signal strength vs. angle 2D polar graph and immediately switch on the motor enable.
5. Ensure that the Receiver and Generator antennas are aligned with each other and that the spacing between them is about one meter.
6. Set the dipole length to 10cm.
7. Acquire a new plot at 1500MHz. Observe the polar plot.
8. Identify one of the other undriven dipole antenna element.
9. Move the driven dipole forward on the boom by about 2.5 cm and mount a second undriven dipole element behind the first at a spacing of about 5 cm.
10. Set the undriven length to 10 cm.
11. Acquire a second new plot at 1500 MHz.

Has the polar pattern changed by adding the second element?

12. Change the spacing to 2.5cm and acquire a third new plot at 1500 MHz

What changes has the alteration in spacing made to the gain and directivity?

_____

CHANGING THE LENGTH OF THE PARASITIC ELEMENT:

13. Launch new signal strength vs. angle 2D polar graph window.
14. Acquire a new plot at 1500 MHz.
15. Extend the length of the un-driven element to 11cm.
16. Acquire a second new plot at 1500 MHz.
17. Reduce the length of the un-driven element to 8cm.
18. Acquire a third new plot at 1500MHz.

What changes has the alteration in length made to the gain and directivity?

_____

RESULT:

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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 03

OBJECT:-

- To investigate the properties of a system comprising a dipole and a parasitic element.
- Understand the terms 'driven element', 'reflector', 'director'
- To know the form of a YAGI antenna and examine MULTI element Yagi.
- To see how gain and directivity increase as element numbers increase

EQUIPMENT:-

Antenna Lab hardware
Discovery Software
Dipole elements
Yagi boom

THEORY:-

Antenna: An antenna is a transducer designed to transmit or receive radio waves which are a class of electromagnetic waves. In other words, antennas convert radio frequency electrical currents into electromagnetic waves and vice versa. Antennas are used in systems such as radio and television broadcasting, point-to-point radio communication, wireless LAN, radar, and space exploration. Antennas usually work in air or outer space, but can also be operated under water or even through soil and rocks at certain frequencies for short distances.

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With the length of the second dipole (the un-driven or **"Parasitic"** element) shorter than the driven dipole (the driven element) the direction of maximum radiation is from the driven element towards the parasitic element. In this case, the parasitic element is called the "**director**".

With the length of the second dipole longer than the driven dipole the direction of maximum radiation is from the parasitic element towards the driven element. In the case, the parasitic element is called the "**reflector".**

Simple 3-element Yagi With Support Boom

Figure 1

8 Elements Yagi-Uda

Figure 2

PRE-LAB TASKS:

1. Why do we require Arrays? Give Reasons.

2. Discuss different types of Antenna Arrays

3. How are BEAMWIDTH, DIRECTIVITY and GAIN related?

PROCEDURE & OBSEVATIONS:

1. Identify one of the Yagi Boom Assemblies and mount it on top of the Generator Tower.
2. Ensure that all of the elements are removed, except for the dipole.
3. Ensure that the Motor Enable switch is off and then switch on the trainer.
4. Launch signal strength vs. angle 2D polar graph and immediately switch on the motor enable.
5. Ensure that the Receiver and Generator antennas are aligned with each other and that the spacing between them is about one meter.
6. Set the dipole length to 10cm.
7. You have already acquired a plot at 1500MHz for TWO element Yagi in the previous lab. Now,

ADD A SECOND REFLECTOR:

8. Mount the driven dipole on the boom forward from the axis of rotation by about 2.5cm and mount a second un-driven dipole element behind the first, at a spacing of about 5cm.
9. Set the dipole length to 10cm and the un-driven dipole length to 11cm
10. Acquire a new plot at 1500MHz.
11. Observe the polar plot

Is there any significant difference between the two plots?

_____

12. Mount a second parasitic element about 5cm from the first parasitic reflector and adjust its length to 11cm.

13. Acquire a second new plot at 1500MHz. Observe the polar plot.
14. Change the spacing between the two reflectors and acquire a third new plot at 1500MHz.

Is there any significant difference between the plots, now?

_____

You will find that the addition of a second reflector has little effect on the gain and directivity of the antenna, irrespective of the spacing between the two reflectors.

ADDING DIRECTORS:

15. Remove the second reflector element from the boom
16. Launch new signal strength vs. angle 2D polar graph window.
17. Acquire a new plot at 1500 MHz. Observe the polar plot.
18. Mount a parasitic element about 5cm in front of the driven Element and adjust its length to 8.5cm
19. Acquire a second new plot at 1500 MHz, Observe the polar plot.

Is there any significant difference between the two plots?

_____

20. Move the director to about 2.5 cm in front of the driven element.
21. Acquire a third new plot at 1500 MHz, Observe the polar plot.

How does the new plot compare with the previous two?

_____

22. Launch signal strength vs. angle 2d polar graph window.
23. Acquire a new plot at 1500 MHz.
24. Add a second director 5 cm in front of the second.
25. Acquire a second new plot at 1500 MHz.
26. Add a third director 5 cm in front of the second.
27. Acquire a third new plot at 1500 MHz
28. Add a fourth director 5 cm in front of the third.
29**.** Acquire a fourth new plot at 1500 MHz.

How do the gains and directivities compare?

_____

30. Launch signal strength vs. angle 2D polar graph window.
31. Acquire a new plot at 1500 MHz.
32. Move the reflector to 2.5 cm behind the driven element. Acquire a second new plot at 1500 MHz.

Does the driven element – reflector spacing has much effect on the gain or directivity of the antenna?

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RESULT:

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- 17 -

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NED University of Engineering & Technology
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 04

OBJECT:

• Understand the terms 'baying' and 'stacking' as applied to antennas.
• To investigate stacked and bayed Yagi antennas.
• To compare their performance with a single Yagi.

EQUIPMENT:

Antenna Lab hardware
Discovery Software
6 element log periodic antenna

THEORY:

Yagi antennas may be used side-by-side, or one on top of another to give greater gain or directivity. This is referred to as baying, or stacking the antennas, respectively.
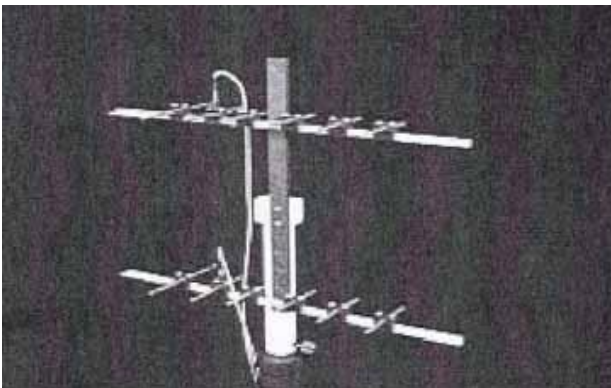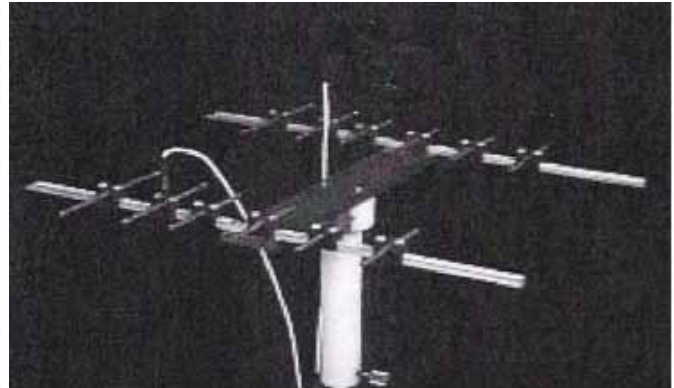

Figure 1

Figure 2

PRE-LAB TASK:

1. Which configuration of the two appears better than the other and why?

PROCEDURE & OBSERVATIONS:

Baying Two Yagis:

1. Connected up the hardware of *Antenna Lab.*
2. Loaded the Discovery software.
3. Loaded the NEC-Win software
4. Ensure that a Yagi Boom Assembly is mounted on the Generator Tower.

5. Building up a 6 element Yagi. The dimensions of this are:

	Length(cm)	Spacing
Reflector	11	5cm behind driven element
Driven element	10	Zero (reference)
Director 1	8.5	2.5 cm in front of DE
Director 2	8.5	5 cm in front of D1
Director 3	8.5	5 cm in front of D2
Director 4	8.5	5 cm in front of D3

6. Plot the polar response at 1500 MHz
7. Without disturbing the elements too much, remove the antenna from the Generator Tower Identify the Yagi Bay base assembly (the broad grey plastic strip with tapped holes) and mount this centrally on the Generator Tower.
8. Mount the 6 element Yagi onto the Yagi Bay base assembly at three holes from the centre Assemble an identical 6 element Yagi on the other Yagi Boom Assembly and mount this on the Yagi Bay base assembly at three hole the other side of the centre, ensuring that the two Yagis are pointing in the same direction (towards the Receiver Tower).
9. Identify the 2-Way Combiner and the two 183mm cables.
10. Connect the two 183mm cables to the adjacent connectors on the Combiner and their other ends to the two 6 element Yagis.
11. Connect the cable from the Generator Tower to the remaining connector on the Combiner
12. Acquire a new plot for the two bayed antennas onto the same graph as that for the single 6 element Yagi.
13. Reverse the driven element on one of the Yagis and acquire a third plot

Does reversing the driven element make much difference to the polar pattern for the two bayed Yagis?

_____

How does the directivity of the two bayed Yagis compare with the single Yagi plot (with the driven element the correct way round)?

_____

How does the forward gain of the two bayed Yagis compare with the single Yagi plot (with the driven element the correct way round)?

_____

Now, move the two Yagis to the outer sets of holes on the Yagi Bay base assembly. Ensure that you keep the driven elements the same way round as you had before to give the correct phasing. Superimpose a plot for this assembly.

How do the directivity and forward gain of the wider spaced Yagis compare with the close spaced Yagis?

_____

Stacking Two Yagis:

1. Identify the Yagi Stack base assembly (the narrow grey plastic strip with tapped holes) and mount this on the side of the Generator Tower.
2. Mount the 6 element Yagi onto the Yagi Stack base assembly at one set of holes above the centre.
3. Plot the polar response at 1500 MHz.
4. Mount the other 6 element Yagi on the Yagi Stack base assembly at the uppermost set of holes, ensuring that the two Yagis are pointing in the same direction (towards the Receiver Tower)
5. Identify the 2-Way Combiner and the two 183mm coaxial cables.
6. Connect the two 183mm cables to the adjacent connectors on the Combiner and their other ends to the two 6 element Yagis.
7. Connect the cable from the Generator Tower to the remaining connector on the Combiner.
8. Superimpose the polar plot for the two stacked antennas onto that for the single 6 element Yagi.
9. Reverse the driven element on one of the Yagis and superimpose a third plot
10. Change the position of the lower Yagi to the bottom set of holes on the Yagi Stack base assembly. Ensure that the driven elements are correctly phased and superimpose a fourth polar plot.

How does the directivity of the different configurations compare?

_____

How does the forward gain of the stacked Yagis compare with the single Yagi?

_____

How does the forward gain of the stacked Yagis change when the driven element phasing is incorrect?

_____

RESULT:

F/OBEM 01/05/00

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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 05

OBJECT:

• Be familiar with the DISH form of antenna.
• To investigate the gain and directivity of the dish antenna.
• Appreciate the advantages and disadvantages of a dish antenna as compared with a Yagi.

EQUIPMENT:

Antenna Lab hardware
Discovery Software
Parabolic Dish reflector
Dipole (10cm)
Yagi boom
Ground plane reflector

THEORY:

A dish can be thought of as a passive reflector that focuses the energy from a source into one direction, much like a parabolic mirror focuses light. However, to perform as efficiently as an optical reflector, a dish needs to be in excess of ten wavelengths in diameter for the frequency being used. This is very often not the case in practice, due to physical size constraints. A horn antenna is often used to, launch or capture energy from a dish reflector. Although this is quite common, a simple dipole is often used to perform the same task. The dish set-up with *Antenna Lab* is one that uses a dipole at, or close to, the focus of a 60cm parabolic dish.
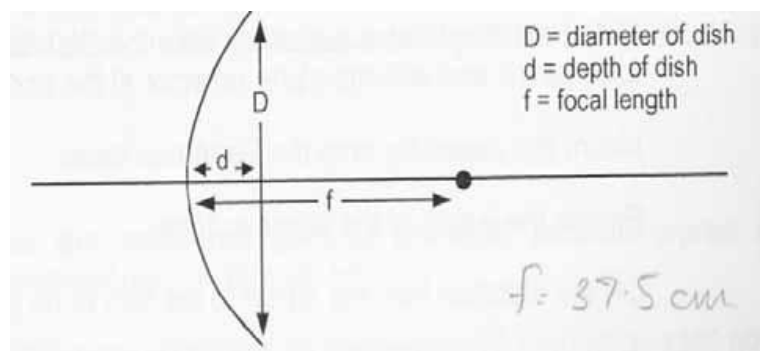

Figure 1

The dimensions for a dish are shown in figure. The focal length for a parabolic dish is given by

$$f = D^2 / 16d$$

The gain of a dish is given by:

$$G = 4\pi ac / \lambda 2$$

Where, 'G' is the gain, 'a' is the area of the dish, 'c' is the dish efficiency and 'λ' is the wavelength. Note that this is dB_i, your measured gain will be dB_i. For the dish with *Antenna Lab* at 1500 MHz the efficiency is about 0.5, f=37.5cm, D=57.4cm and d=5.5cm
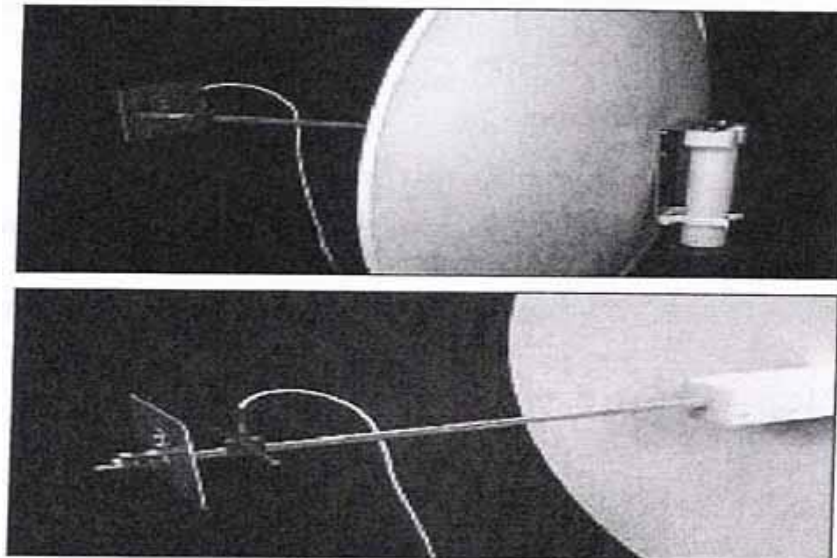
Figure 2

PRE-LAB TASKS:

1. What is Parabola? Why its geometry makes it suitable to be used as Antenna Reflector?

2. Describe different methods of feeding Parabolic Reflector.

PROCEDURE & OBSERVATIONS:

1. Connect the hardware of *Antenna Lab* s described in the Operators Manual.
2. Load the Discovery software as described in the Operators Manual.
3. Mount the Yagi Boom Assembly on top of the Generator Tower and place the dipole at the centre, directly above the tower
4. Set the length of the dipole to 10cm
5. Do not connect up the coaxial cable to the dipole
6. Launch new signal strength vs. angle 2D polar graph.
7. Because the dish is a physically large structure, the speed of rotation of the system must be lowered for this Assignment. From the menu select Tools, then change, Motor Speed. Select a value of approximately 60 % and click OK.
8. Now, connect up the cable.
9. Plot the polar response of the dipole at 1500 MHz
10. Remove the Yagi Boom assembly from the tower.

11. Identify the Dish Antenna
12. Mount the Yagi Boom assembly onto the Dish and position the dipole towards the end with the plane reflector at the end of the boom.
13. Mount this assembly onto the Generator tower
14. Ensure the length of the dipole is 10cm.
15. Set the distance from the dipole to the dish to be 38cm.

16. Set the plane reflector 5cm in front of the dipole (Farther from the dish).
17. Superimpose a new plot to observe the response of the dish at 1500 MHz.

Does the dish antenna have gain over the dipole at 1500 MHz?

_____

Does the dish antenna have directivity at 1500 MHz?

_____

Does the measured gain of the dish antenna agree with the theoretical gain at 1500 MHz?

_____

18. Superimpose polar plots for frequencies of 1200 MHz, and 1300 MHz 1400 MHz on the 1500 MHz one.

 Does this dish Antenna have directivity over this range of frequencies?

_____

19. Superimpose polar plots for frequencies of 1600 MHz and 1800 MHz on the 1500 MHz one.

 Does the dish antenna have gain over this range of frequencies?

_____

20. Increase the spacing to 6 cm and superimpose another new plot

Does the response change significantly?

_____

21. Reduce the distance from the dipole to the dish by 1 cm whilst maintaining the spacing of the plane reflector from the dipole of 5 cm and superimpose a second 1500 MHz polar plot.

22. Reduce the distance from the dipole to the dish by another 1cm whilst maintaining the spacing of the plain reflector from the dipole of 5cm and superimpose another 1500MHz plot.

Does the response change significantly?

_____

23. Try for other distance and reflector spacing

Is the response of the dish antenna critically dependant on the spacing?

_____

RESULT:

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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 06

OBJECT:

- Be familiar with the Log Periodic form of antenna
- To investigate the gain, and directivity of the log Periodic antenna over a wide frequency range.
- Appreciate the advantages and disadvantages of a log periodic Antenna as compared with a Yagi.

EQUIPMENT:

Antenna Lab hardware
Discovery Software
5 element log periodic Antenna
Directional coupler

THEORY:

The Yagi antennas that you have been investigating are inherently narrow-bandwidth antennas. The relatively small range of frequencies over which the VSWR is below 2:1 has demonstrated this. The log periodic antenna is a design that attempts to cover a much wider bandwidth. With a Yagi all of the elements are active on the operating frequency. With a log periodic antenna only a number of the elements will be active on any one frequency, the actual elements that are active changes as the frequency is changed. The role of active elements is passed from the longer to the shorter elements as the frequency increases. View of the assembly required for this assignment.
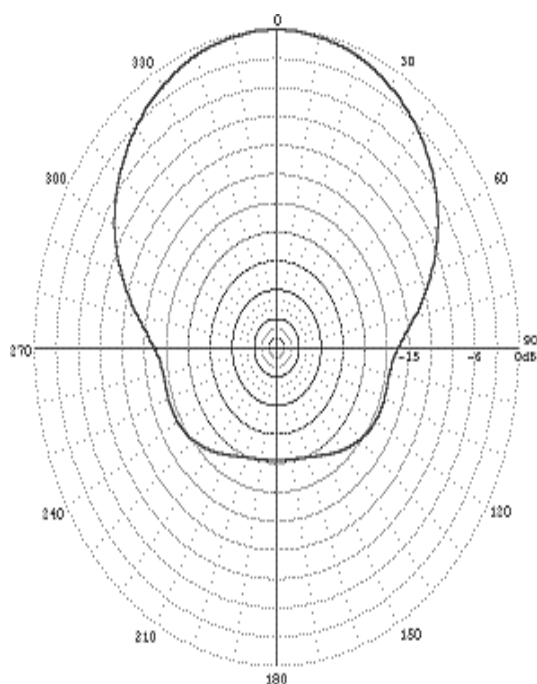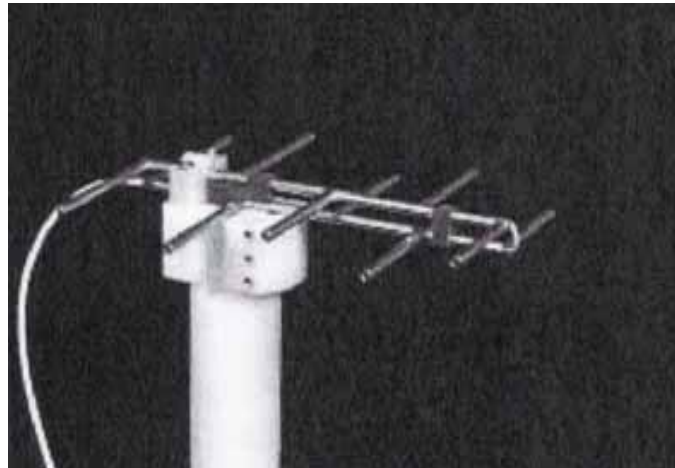

Figure 1

Figure 2

PRE-LAB TASKS:

We say that "a log-periodic antenna (LP, also known as a log-periodic array) is a **broadband**, multi-element, **unidirectional**, **narrow-beam antenna** that has impedance and radiation characteristics that are regularly repetitive as a logarithmic function of the **excitation frequency**. The individual components are often dipoles, as in a log-periodic dipole array (LPDA). Log-periodic antennas are designed to be **self-similar** and are thus also **fractal antenna arrays.**

Define each of the terms (6) (in bold letters).

PROCEDURE & OBSERVATIONS:

1. Connect up the hardware of Antenna
2. Load the Discovery software
3. Mount the Yagi boom assembly on top of the generator tower and Position the dipole at the center, directly above the tower.
4. Set the length of the dipole to 10cm
5. Plot the polar response of the dipole at 1500 MHz.
6. Remove the Yagi boom assembly from the tower
7. Identify the 5 elements log periodic Antenna with its feeder cable.
8. Mount this antenna on the Generator tower and connect the cable.
9. Superimpose the response for this antenna at 1500MHz.

Does the log periodic antenna have gain over the dipole at 1500 MHz?

Does the log periodic antenna have directivity at 1500 MHz?

10. Using a new graph window, plot the polar response for 1500 MHz again
11. Superimpose polar plots for frequency of 1200 MHz, 1300MHz and 1400MHz on the 1500MHz one.

Does the log periodic antenna have gain over this range of frequencies?

Does the log periodic antenna have directivity at over this range of frequencies?

12. Restart and plot the response for 1500 MHz again.
13. Superimpose polar plots for frequency of 1600 MHz, 1700 MHz and 1800 MHz on the 1500 MHz one.

What happens to the gain of the log periodic antenna over this range of frequencies?
What changes has the alteration in spacing made to the gain and directivity?

CHANGING THE LENGTH OF THE PARASITIC ELEMENT:

1. Launch new signal strength vs. angle 2D polar graph window.
2. Acquire a new plot at 1500 MHz.
3. Extend the length of the un-driven element to 11cm.
4. Acquire a second new plot at 1500 MHz.
5. Reduce the length of the un-driven element to 8cm.
6. Acquire a third new plot at 1500MHz.

What changes has the alteration in length made to the gain and directivity?

RESULT:

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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 07

OBJECT:

Identification of different waveguide components.

EQUIPMENT:

Wave-Guide (mod.MW-2 I mod.MW-3)
WG/COAX adapter (mod.MW·1)
Slotted Line (mod.MW-5)
BNC-SMA detector (mod. MW-4)
Coaxial Attenuator (mod.MW-23)
Matched Load Termination (mod.MW-9)
Short-Circuit (mod.MW-10)
Variable Attenuator (mod.MW-6)

THEORY:

There are many components designed for operation at microwave frequencies. Some of these used in our laboratory experiments are:

WG/COAX adapter (mod.MW·1):
The Wave-guide to Coaxial adapter or "WG to Coax" is used to convert the electromagnetic field (E-H) present in the wave-guide into electrical signal in the coaxial cable. Obviously its function is performed in both directions, so also from electrical signal to electromagnetic field. See *Figure 1*. The commonly available adapters are set for the excitation of the electrical fields inside the wave-guide: this occurs introducing a conductor inside the guide (*Figure 2*), at a distance of λg/4 (λg is the wave-length in the guide) from the rear side, so that the reflected and the incident waves are in phase. Even the height X is about λg/4 and each component is singularly matched for the best performances. Our adaptor is Coaxial cable kind: SMA-female, VSWR: 1.25 max.

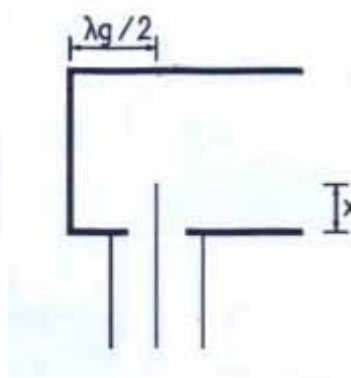| Figure 1 | Figure 2 |

Wave-Guide (mod.MW-2 I mod.MW-3):

The "wave-guide" is more properly called "WG Straight section". It is used as a transmission line and there are rigid or flexible versions of different kind, that enable the transferring of the

electromagnetic field inside it. Important characteristics are low loss and VSWR. Our system uses three rigid and straight ones with the following characteristics, Figure 3.

Figure 3

Slotted Line (mod.MW-5) :

It is a device used to detect the standing wave inside the guide (*Figure 4*). The Detector (mod.MW-4) must be used and is screwed on the upper part of the trailer that slides along the slot of the wave-guide. The voltage provided by the detector is proportional to the amplitude of the standing wave in the different positions along the line
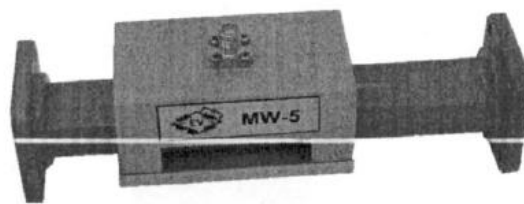
Figure 4

BNC-SMA detector (mod. MW-4):

Inside, the detector is characterized by the following components
   • Input RF matching impedance DC Return
   • RF by-pass capacitor
   • Detector diode (with negative polarity)
The input of the detector is designed to match the signal that is to be analyzed on 50 Ohm. The DC output is commonly called Video output. See *Figure 5*.

Figure 5

Coaxial Attenuator (mod.MW-23):
The coaxial attenuator is a passive component inserted into a metal container (*Figure 6*). The input and the output use the SMA coaxial connector and are matched on 50ohm. Its function is to attenuate the level of the RF signal to the input of 20dB. In particular, 20 dB corresponds to
Attenuation equal to:
   • 100 times in power, and
   • 10 times in voltage

If the attenuator is used, e.g., across the output of an amplifier stage, the total output level after the attenuator will be reduced of 20 dB, if it is expressed in dBm (measurement unit of the power referred to 1mW) as well as in dB J.l (measurement unit of the voltage referred to IJ.lV).

The attenuator is used when in presence of strong signals that could damage the next circuit, saturate the states of a receiver or a meter or when it is necessary for the signal level to be inside a fixed level range.

Figure 6

Matched Load Termination (mod.MW-9):

The termination or fictitious load is a device absorbing the RF power without causing reflections (*Figure 7*). It consists of a WG straight section of wave-guide closed in short-circuit, with absorbing material (for the RF) that starts from the short-circuit and restricts to the open side.

The particular shape with triangular section enables the gradual and complete absorption of the incident power to prevent reflections. Important characteristic is the low VSWR.
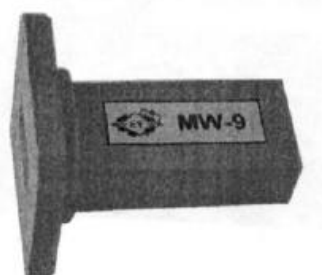
Figure 7

Short-Circuit (mod.MW-10):

It is short-circuit termination for wave-guide. It uses the completely closed standard flange that causes the complete reflection of the whole incident RF signal. See *Figure 8.*
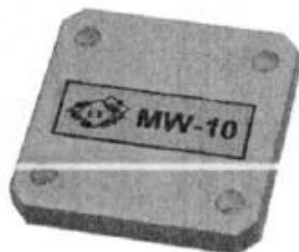
Figure 8

Variable Attenuator (mod.MW-6):

It consists of a "WG straight section" where a plate is mounted in the central part and the intensity of the electrical field is maximum. The depth of insertion of the plate is adjustable and the introduced attenuation varies consequently. See *Figure 9.* The attenuation level can be adjusted from 0.5dB to roughly 30dB. VSWR is around 1.20.

Figure 9

OBSERVATION & RESULTS:

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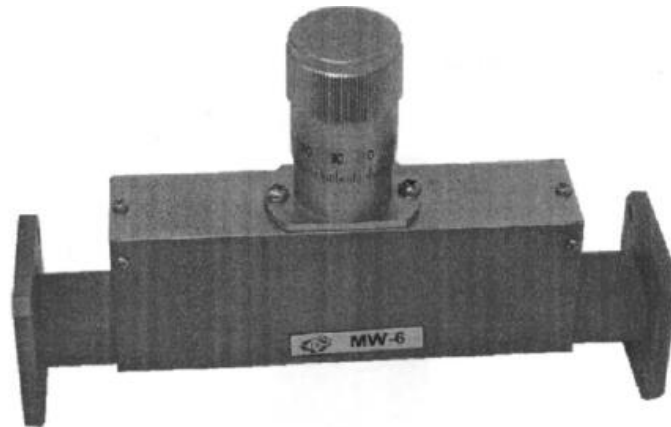| Psychomotor Domain Assessment Rubric-Level P3					
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 08

OBJECT:

Determination of Insertion loss in a waveguide communication system.

EQUIPMENT:

1 Transmitter Module MW-TX.
1 Up Converter unit module MW-UC.
1 VSWR/LEVEL meter unit module MW-MT.
2 Waveguide modules MW-3.
2 WG/Coax Adapter Module MW-1.
1 Fixed attenuator module MW-8.
1 Fixed attenuator module MW-7.
1 20db Co-axial attenuator module MW-23.
1 slotted line module MW-5.
1 Detector module MW-4.
1 Short circuit module MW-10.
2 Low support modules MW-21.
2 SMA-SMA coaxial cables.
1 BNC-BNC coaxial cable.
1 cable with 2 mm plug.

THEORY:

All waveguide components have a particular power loss value. It is a loss that can be wished or not, and in particular we define:
- • Insertion Loss as a not wished loss due to the design and quality characteristics of the component.
- • Attenuation a wished, fixed or variable, loss depending on the design characteristics of the component.

Components introducing an insertion loss are:
- • Directional couplers.
- • Frequency meters.
- • Impedance adapters.
- • Slotted lines with probes inserted.
- • Components with impedance mismatching.
- • Components not perfectly coupled.

The typical components introducing attenuation are:
- • Fixed attenuators.
- • Variable attenuators
- • Load terminations (absorbing the complementary power).

The attenuation or insertion loss A of a component of the transmission system is calculated with the following formula:

$$A_{dB} = 10 \log \left[\frac{P_{in}}{P_{out}} \right]$$

where,
P_{in} = input power
P_{out} = output power

$$P_{dBm} = 10 \log \left[\frac{P}{1mW} \right]$$

where,
P_{dBm} = signal power expressed in dBm.
P = signal power expressed in mW.

PRE-LAB TASKS:

1.   Define Insertion Loss in a Waveguide.

2.   What are the causes of Insertion Loss? And how it can be avoided?

PROCEDURE:

1.   Carry out the wiring between the units as shown in Figure 1.
2.   Set the transmitter unit in the following operating mode:
        SW1 = 1
        SW2 = 1
        SW3 = Direct
        Level = -25
3.   Set the meter unit in the following operating mode:
        SW1 = 200mV
        SW2 = OFF
4.   Power the two units using the start up switch set on the rear side.
5.   Increase the signal level using the level command to get full scale of the instrument. This calibration operation provides the power reference level.
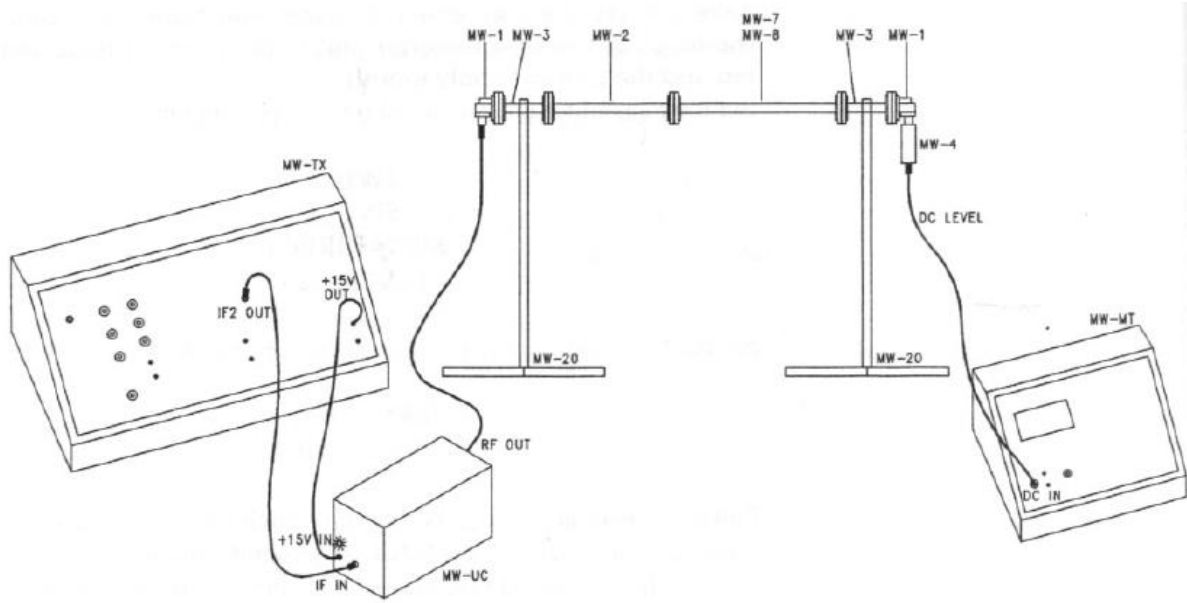
Figure 1

OBSERVATION:

RESULT:

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Department of Telecommunications Engineering
Course Code and Title: TC-313 Antenna and Microwave Engineering
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 9

OBJECT:

• To describe the characteristics of the horn antenna.
• To carry out gain measurements using method of comparison.

EQUIPMENT:

1 Transmitter unit mod.MW-TX
1 Up-Converter unit mod. MW-UC
1 VSWR/LEVEL meter unit mod. MW-MT
2 WG/ Coax adapters mod.MW-1
1 15db-Horn Antenna mod. MW-15
2 10db- Horn antennas mod. MW-16
1 Variable attenuator mod.MW-6
1 Fixed attenuator mod. MW8
2 Wave-guides mod. MW-3
1 Turn table with slide mod. MW-22
1 Detector mod. MW-4
2 High supports mod.
2 SMA-SMA coaxial cables
1 BNC- BNC coaxial cable
1 Cable with 2 mm-plugs
1 Multimeter.

THEORY:

The horn antennas consist in a wave-guide enlarging in the shape of a horn that a can be pyramid, sectorial or conical kind. The gain G of the horn antenna depends on the ratio between the surface of the horn opening and the working wave-length, and can be increased by enlarging the same horn. The gain of horn antennas for practical use is however limited generally to a maximum of about 20dB.

The horn antennas are used alone, or in combination with parabolic reflector. In this second case, the horn antenna constitutes the so called **feeder** while the parabolic reflector is used to increase the directivity and gain of the set. The radiation diagram of horn antennas depends on the gain and the shape of the same antenna. Figure shows the shape of the main lobes in the planes E and H of a trapezoidal horn antenna and two sectorial horn antennas. Note that in the sartorial antenna the main lobe is narrower in the plane in which the opening is smaller.
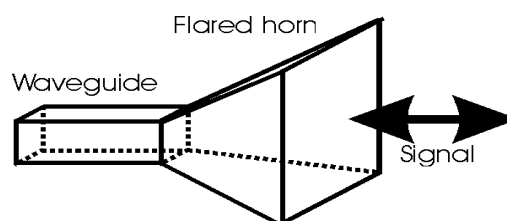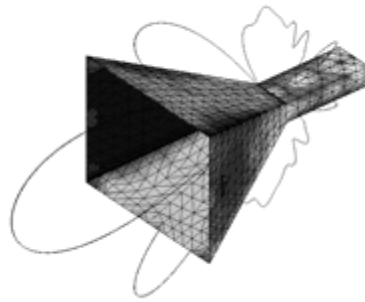

Figure 1

Figure 2

The theoretical gain **G** of a horn antenna is provided by the following relation:

$$G = \frac{10A}{\lambda_o^{\,2}} \cong \frac{6.4A}{\lambda_o^{\,2}}$$

λ_g = wave-length in guide
λ_o = wave-length in free space
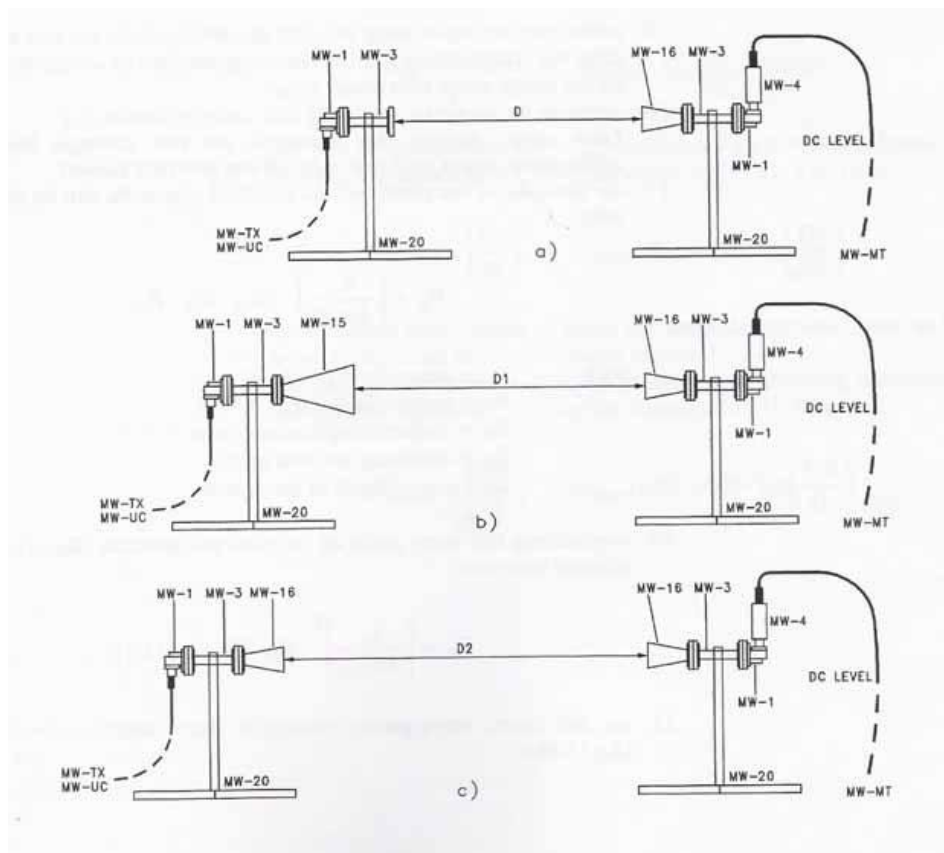A = surface (**a, b**) of the horn antenna opening.

Figure 3

PRE-LAB TASKS:

1. What is horn antenna?

2. How it is fed?

3. What are its applications?

PROCEDURE:

Calculation of the gain of the horn antennas

1. Measure the sides **a** and **b** of the opening of the horn antenna MW-16
2. Calculator the gain **G** of the antenna at the frequency of 10.7 GHz, using the formula. A value is obtained near the nominal one:

$$G = \frac{10A}{\lambda_o^2} \cong \frac{6.4A}{\lambda_o^2}$$

Where λ_g = wave-length in guide
λ_o = wave-length in free space
A = surface (**a** $\times$ **b)** of the horn antenna opening.

3. Carry out the same calculation for the horn antenna MW-15.

Measurement of the gain – Method of comparison:

Consider to use an open guide as isotropic antenna. The behavior of the open guide is actually like one of an isotropic antenna, but it is sufficient to describe and use the measurement method.
Carry out the wiring as indicated in *figure 1* between the units.

4. Consider that the presence of metal surface can cause unwanted reflections, so they can alter the result of the exercise. Take care of the connection between the transmitter unit and the input of the up converter unit. (Side in which are the led and the power supply input).
5. Set the transmitter unit in the following operating mode:
<div align="center">

SW1=1
SW2=1
SW3=DIRECT
LEVEL= to half
</div>

6. Set the meter unit in the following operation mode:
<div align="center">

SW =1
SW2 = ON
</div>

7. Set the ends of the guide MW-3 at a distance D of about 20 cm from the receiving antenna.
8. Power the two units using the start up switch set on the rear side.

9. Align the transmitting and receiving station to obtain the reading on the meter at maximum value.
10. Calibrate the meter to obtain the full scale indication.
11. Take care during the exercise do not change the meter calibration again of the level of the emitted power.
12. The formula of the power of the received signal PR can be simplified with

$$PR = \left[\frac{\lambda o}{4\pi D}\right]^2 G_W . G_R . P_T .$$

Where P_T = transmitted power, P_R = received power,
G_W = transmitted antenna gain, G_R = receiving antenna gain and
λo = wave length in free space.

13. Considering the open guide as an isotropic antenna ($G_w=1$), the last relation becomes

$$PR = \left[\frac{\lambda o}{4\pi D}\right]^2 G_R . P_T . \qquad (1)$$

14. On the open wave guide mount a horn antenna mod MW-15.
15. Move the receiving station away until the meter gives the same reading seen before which will be obtained at new the distance D1.In this situation the same power P R of the last case is received, but at a different distance. The formula becomes:

$$PR = \left[\frac{\lambda o}{4\pi D1}\right]^2 G_{MW15} . G_R . P_T . \qquad (2)$$

16. Change the antenna MW-15 with the antenna MW-16.
17. Move the receiving station away until the meter gives the same reading seen before (1) that will be obtained at new distance D2 in this situation the same power PR of the last cases is received but at a different distance, the formula becomes:

$$PR = \left[\frac{\lambda o}{4\pi D2}\right]^2 G_{MW16} . G_R . P_T . \qquad (3)$$

18. The gain of antenna MW-15 is calculated by dividing member by member the equation (2) by the equation (1):
19.

$$G\,MW15 = [D1/D]\,2 \qquad G\,MW15\ (dB) = 20\log[D1/D]$$

The obtained result shifts of some dB from the nominal gain, as the open guide is not an ideal isotropic antenna!

20. The gain of antenna MW-16 is calculated by dividing member by the member the equation (3) by the equation (1)
21.

$$G\,MW16 = [D2/D]^2 \qquad GMW16\ (dB) = 20.\log[D2/D]$$

OBSERVATIONS & CALCULATIONS:

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RESULT:

TC-313 Antenna and Microwave Engineering
NED University of Engineering and Technology- Department of Telecommunications Engineering

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F/OBEM 01/05/00

NED University of Engineering & Technology
Department of Telecommunications Engineering
Course Code and Title: TC-313 Antenna and Microwave Engineering
Laboratory Session No. _____   Date: _____

Psychomotor Domain Assessment Rubric-Level P3					
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Equipment Use Sensory skills to *demonstrate* the use of the equipment for the lab work.	Doesn't demonstrate the use of equipment.	Slightly demonstrates the use of equipment.	Somewhat demonstrates the use of equipment.	Moderately demon strates the use of equipment.	Fully demonstrates the use of equipment.
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 10

OBJECT:

Measurement of the gain of **HORN** Antenna – using Method of the two antennas

EQUIPMENT:

1 Transmitter unit mod.MW-TX
1 Up-Converter unit mod. MW-UC
1 VSWR/LEVEL meter unit mod. MW-MT
2 WG/ Coax adapters mod.MW-1
1 15Db-Horn Antenna mod. MW-15
2 10Db- Horn antennas mod. MW-16
1 Variable attenuator mod.MW-6
1 Fixed attenuator mod. MW8
2 Wave-guides mod. MW-3
1 Turn table with slide mod. MW-22
1 Detector mod. MW-4
2 High supports mod.
2 SMA-SMA coaxial cables
1 BNC- BNC coaxial cable
1 Cable with 2 mm-plugs
1 Multimeter

THEORY:

Use two identical antennas as shown in figure. If **Gx** is the gain of each, from the formula of the received power **P_R** (FRIIS equation) we get:

$$G^2 x = \left[\frac{4\pi D}{\lambda_o}\right]^2 \frac{P_R}{P_T}$$

Where,
P_T = transmitted power
D = distance between antennas
P_R = received power
λ_o = wave-length in free space

PROCEDURE:

1. Set the Meter unit in the following operating mode:
$$SW1 = 100mV$$
$$SW2 = ON$$
2. Two horn antennas mod.MW-16 are used
3. Carry out the wiring as indicated in *Figure 1* between the units

4. Set a distance D of 100cm between the antennas opening
5. Power the two units using the start up switch set on the rear side
6. Align the transmitting and the receiving stations to get the maximum reading on the meter
7. Calibrate the meter so to obtain, e.g., the indication 0.2 and about 2.2m V with the multimeter.
8. The gain GMW16 of antenna is calculated using (1)

$$G^2 MW16 = \left[\frac{4\pi D}{\lambda_o}\right]^2 \frac{P_R}{P_T}$$

9. The ratio PR / PT can be evaluated as follows: remove the two antennas mod.MW -16 and connect the two sections between them via the variable attenuator mod. MW-16 as in figure. Adjust the attenuator up to obtain the same reading seen before (0.2) on the meter and about 2.2m V with the multimeter (that corresponds to -25dBm) Change the variable attenuator with the fixed one, mod.MW-8 and read the indication with the voltmeter, e.g. 166m V (that corresponds to -2dBm). Considering the fixed attenuator, the received level is 4dBm (= -2dBm + 6dB). The ratio corresponds to the inserted attenuation, so equal to 29dB (=4dBm - (-25dBm)).
10. The last formula of the gain GMW16 becomes:

$$G^2 MW16 = 10 \log \left[\frac{4\pi D}{\lambda_o}\right] - \frac{A_{db}}{2}$$

Where AdB = attenuation introduced by the variable attenuator
D= 100 cm

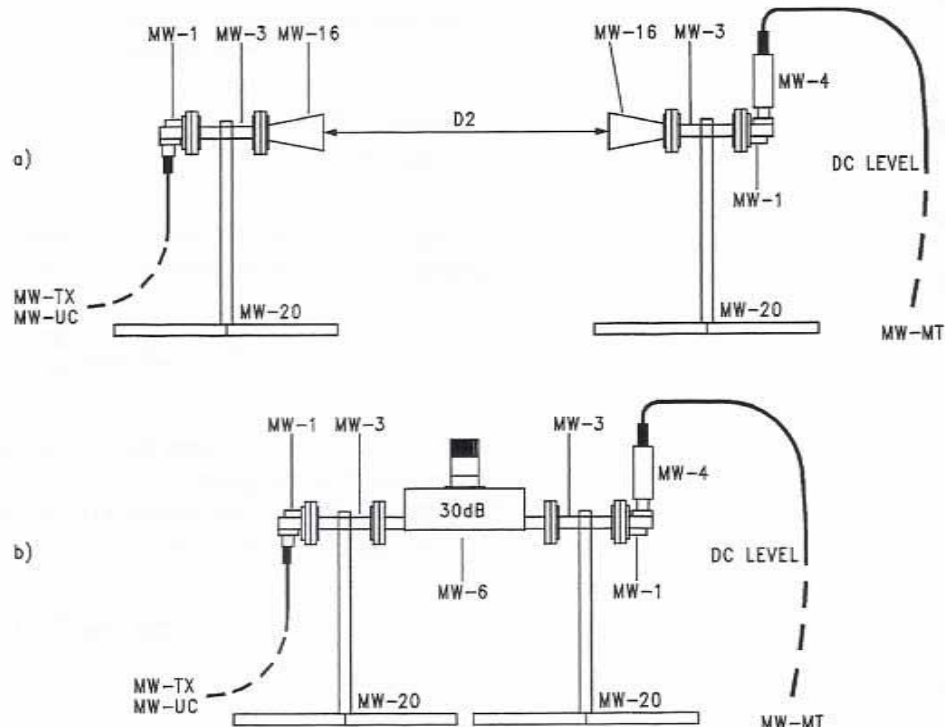11. Calculate the gain of the antenna under measurement

Figure 1

OBSERVATIONS & CALCULATIONS:

RESULT:

F/OBEM 01/05/00

NED University of Engineering & Technology
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 11

OBJECT:

By the use of the slotted line,
- To determine the unknown frequency
- To determine the Voltage Standing Wave Ratio (VSWR) and Reflection Coefficient.

EQUIPMENT:

Transmitter Mod MW-TX,
One slotted line MW-5.
Loads of different values (OC, SC, 75Ω, 50Ω, 100Ω)
RF cable (Z_o=75Ω)
Voltmeter

THEORY:

When power is applied to transmission line voltage & current appear. If Z_L=Z_o, load absorbs all power & none is reflected. If Z_L in not equal to Z_o, some power is absorbed & rest is reflected. We have one set of Voltage & Current waves traveling towards load & a reflected set traveling back to generator. These sets of traveling waves, in opposite directions, set up an interference pattern called **Standing waves.** Maxima (antinodes) & minima (node) of Voltage & Current at fixed positions.

The slotted line is used to measure voltage and current on the various sections of a coaxial line, as by the slot you can enter the electrical fields between the two connectors constituting the coaxial line.
In presence of standing wave, the voltage (or current) maximum and minimum value can bee seen, the distance between a maximum and the adjacent is equal to one fourth the wave length, the speed factor of the line is equal to 1 because the dielectric is air. Once the speed factor is known, by measuring the distance between two minima and multiplying it by two, it is possible to obtain the frequency of the signal applied to the slotted line, if this is unknown.

The standing wave ratio (SWR) is equal to the ratio to maximum to the minimum value; in fact, on the maximum the direct and reflected wave value (of voltage and current) are added and on the minimum are subtracted. If the reflected wave does not exist, voltage and current keep constant along all line and their ratio is equal to the characteristic impedance Zo; the SWR is equal to l. such a line is called a line.
The output power of the generator, tuned to the lowest frequencies (for example 701.5 MHz), must be regulated to the maximum, connect the output of generator to the slotted line with 75 Ω cables, I m long, connect 75Ω to the other end of the slotted line: the line is thus terminated on its characteristic impedance.
If the machining is perfect, by moving the probes along the slotted line the signal amplitude will keep almost constant any way there may be variations which are due to the connectors or to slight variation of the probes alignment. Change the termination of 75Ω with a 50Ω and measure the voltage along the line it has stronger minimum and maximum values than last ones.

Check if the distance between minimum and maximum is equal to ¼ the wavelength, in other words by varying the frequency and repeating measurement, you can observe how the distance between max and min is longer or shorter if you decrease or increase the frequency; repeat the exercise with termination of 100 ohm.

Note that, with the help of slotted line, you can distinguish if the load is greater or smaller than the characteristic impedance of the line, In fact, with 100 ohm the voltage minimum is at ¼ wave length from the load, while on the load there is a maximum; with 50 ohm, the voltage minimum is on the load.

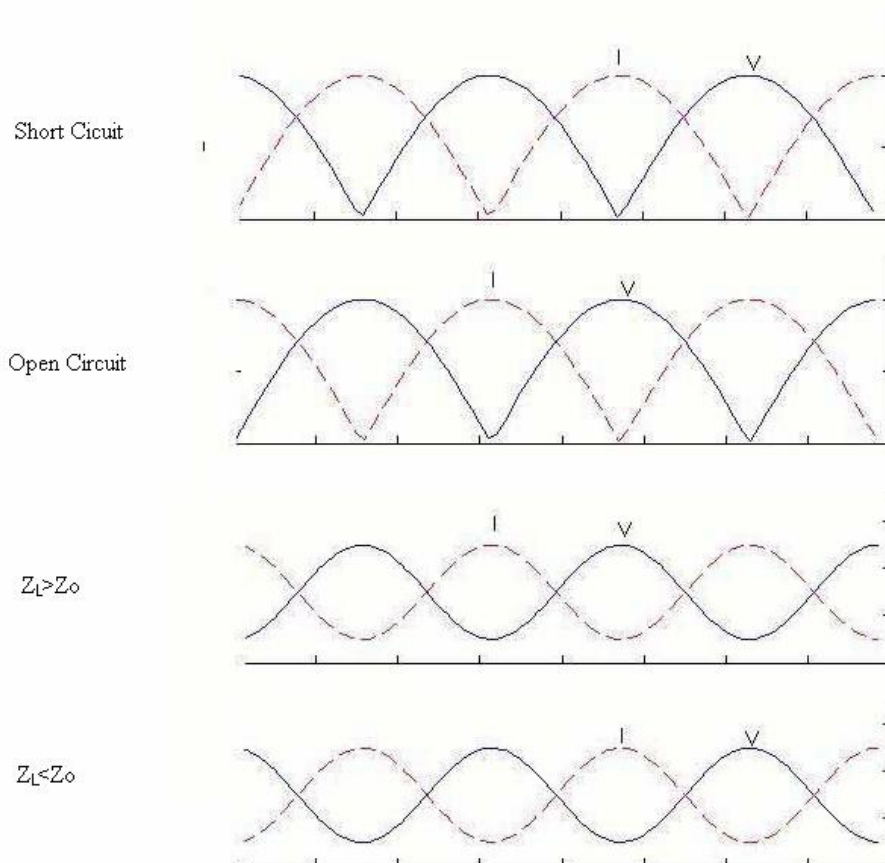The standing wave patterns for different loads are:

Figure 1

PRE-LAB TASKS:

1. Define Characteristic Impedance of Transmission Line.
2. Differentiate Balanced and Unbalanced Transmission line.
3. Draw RF Equivalent circuit for transmission line.
4. Discuss different types of losses in Transmission Lines.

PROCEDURE:

1. Connect the generator (transmitter) to the slotted line through RF cable.
2. Terminate the line by attaching a load (Z_L) on other end of line.
3. Insert probes of voltmeter in the slots provided on the trailer of the slotted line.
4. Turn on the generator and excite the cable with RF waves
5. Move the trailer on the slotted line. Positions of maximum & minimum voltage appear alternately on the slotted line.
6. Note down the max & min values of voltage
7. Also note down the positions of the voltage minima and voltage maxima on the scale
8. Determine VSWR by the following formula:

Measured VSWR =Vmax/Vmin

9. Determine the calculated VSWR by the formula:

$$VSWR = \frac{1+\Gamma}{1-\Gamma}$$

Where, $$\Gamma = \frac{Z_L - Z_o}{Z_L + Z_o}$$

10. Calculate the unknown frequency with the help of the following formula.

$$f = c/\lambda$$

$\lambda/2$= distance between consecutive maxima and minima

11. Repeat same procedure for different loads (Z_L).

OBSERVATIONS:

Frequency of incident wave=

Z_L	V_{max}	V_{min}	VSWR (Measured)	VSWR (Calculated)

Distance of First minima or maxima from load(d1) cm	Distance of second minima or maxima from load(d2) cm	Calculated frequency MHz

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CALCULATIONS:

RESULT:

F/OBEM 01/05/00

NED University of Engineering & Technology
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

LAB SESSION 12

OBJECT:

By use of slotted waveguide
- • To observe how the load impedance affects the VSWR.
- • To determine when a waveguide is properly terminated

EQUIPMENT:

1 Transmitter Module MW-TX.
1 Up Converter unit module MW-UC.
1 VSWR/LEVEL meter unit module MW-MT.
1 Waveguide module MW-3.
2 WG/Coax Adapter Module MW-1.
1 Fixed attenuator module MW-8.
1 20db Co-axial attenuator module MW-23.
1 slotted line module MW-5.
1 Detector module MW-4.
1 Short circuit module MW-10.
2 Low support modules MW-21.
2 SMA-SMA coaxial cables.
1 BNC-BNC coaxial cable.
1 cable with 2 mm plug.

THEORY:

Consider a transmitter line with characteristic impedance $\mathbf{Z_o}$ connected to a load impedance $\mathbf{Z_L}$. If $\mathbf{Z_L}$ is different from $\mathbf{Z_o}$ there is a mismatch between load and line. In this case, not all the power reaches the line end in the load, but part of it returns to the same line (and so to the generator). Along the line Standing Wave are created, resulting from the sum of the incident wave traveling along the line to the load and the reflected wave coming back and moving away from the load. Along the line there are **loops** (maxima) and **nodes** (minima) of voltage and current in fixed positions, the maxima and minima are separated by $\lambda_o / 2$ and a maxima of voltage corresponds to a minima of current and vice versa.

PRE-LAB TASKS:

1. State advantages of waveguides over transmission line.
2. Discuss different modes that propagate through a Waveguide.

PROCEDURE:

1. Carry out wiring between the units as indicated in *Figure*. Take care of the connection between the transmitter unit and the input of the UP- converter unit (the side in which there are the led and the power supply input.)

SW1=1
SW2=1
SW3=DIRECT
LEVEL= -25

2. Set the meter unit in the following operating mode:

SW1=100mV
SW2=ON

3. Power the two units using the startup switch set on the rear side.
4. Move the trailer of the slotted guide to the unknown impedance (adapter plus attenuator).
5. Note that the values expressed during the exercise could be different as the impedance is not ideal.
6. Move the trailer and note the position of the first minimum ($\mathbf{D}_m1$).
7. Move the trailer and note the position of the first maximum ($\mathbf{D}_m1$) and calibrate the instrument to the maximum indication.
8. Move the trailer and note the position of the second minimum $\mathbf{D}_m2$ and measure the VSWR on the instrument.
9. If $\lambda_\mathbf{g}/\mathbf{2}$ is equal to the distance between the two minimum values, calculate $\lambda_\mathbf{g}$ that will be equal to about 4 cm.
10. Change the adapter and coaxial attenuator with the short circuit.
11. Move the trailer and find the new first minimum value, next to the last ($\mathbf{D}_s$).
12. Check again the measurement of $\lambda_g/2$.
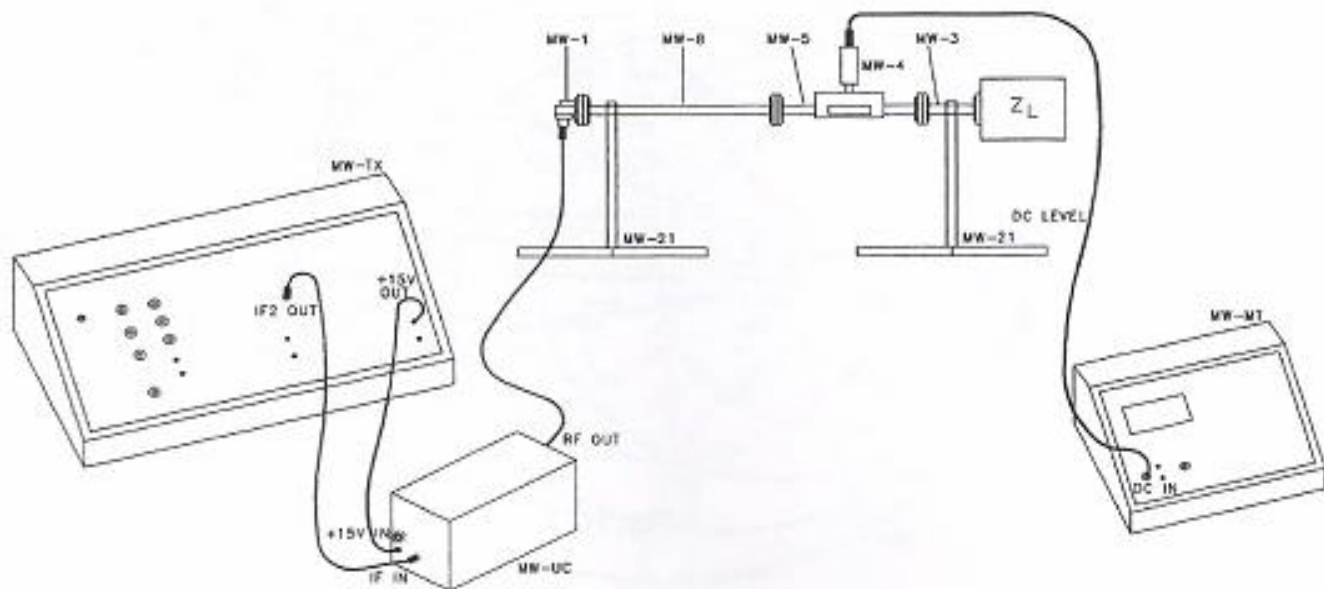13. Repeat for different types of load (Z_L).

Figure 1

OBSERVATIONS & CALCULATIONS:

Dimensions of the waveguide a=_____ cm; b=_____cm
Mode of Propagation=_____

Frequency of Operation=_____GHz
Wavelength in free space =_____cm
Cut off frequency of waveguide=_____GHz
Cut off wavelength =2a=_____cm

TERMINATIONS	D_m1	D_m2	$\lambda_g=2(Dm2-Dm1)$	V_{max}	V_{min}	VSWR
OC						
SC						
HORN ANTENNA MW-16						
MATCHED LOAD						

RESULT:

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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

OPEN ENDED LAB

OBJECT:

Determine the unknown load impedance attached to a waveguide (Open Ended Lab)

INSTRUCTIONS AND REQUIREMENTS:

- Use the hardware in the Lab
- Choose any unknown load and waveguide module, clearly mention the module number
- Give step by step procedure
- Clearly show all calculations
- Justification of the method used

- F/OBEM 01/05/00

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Remarks	
Instructor's Signature with Date:	