PRACTICAL WORK BOOK
For The Course
TC-382 Antenna & Microwave Engineering

For

Third Year
(Telecommunications Engineering)

Name of Student:______________________________

Class:____________________ Batch :________________

Discipline:__________________________________

Class Roll No:____________ Examination Seat No: ___________

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PRACTICAL NO.1

OBJECT

By the use of the slotted line

a) To determine the unknown frequency
b) To determine the Voltage Standing Wave Ratio (VSWR) and Reflection Coefficient.

APPARATUS

Transmitter Mod MW-TX,
One slotted line MW-5.
Loads of different values (OC,SC,75Ω,50Ω,100Ω)
RF cable ($Zo=75\Omega$)
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 $Z_L \neq Z_O$, 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 occur at fixed positions.

The slotted line is used to measure voltage and current directly on the various sections of a coaxial line, as by the slot you can enter the electrical and magnetic 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 minimum is equal to one fourth the wave length; the speed factor of the line is equal to1 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 the 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 the line and their ratio is equal to the characteristic impedance Z_o; the SWR is equal to 1. Such a line is called a flat line.

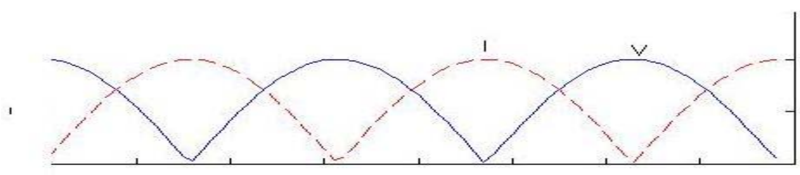
The output power of the generator, tuned to the lowest frequencies (for example 701.5 MHz), must be regulated to the maximum, connect the output of the generator to the slotted line with 75 Ω cable, 1 m long, connect 75 Ω to the other end of the slotted line: the line is thus terminated on its characteristic 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 75 Ω with a 50 Ω and measure the voltage along the line: it has stronger minimum and maximum values than the last ones.

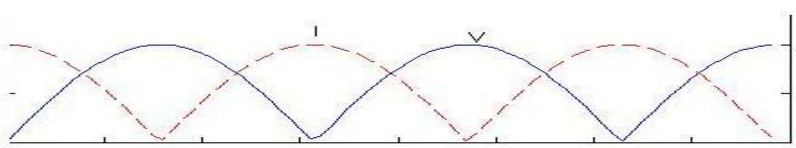
Check if the distance between minimum and maximum is equal to ¼ the wavelength, in other words by varying the frequency and repeating measurement, you can observe how the distance between max an min is longer or shorter if you decrease or increase the frequency repeat the exercise with termination of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

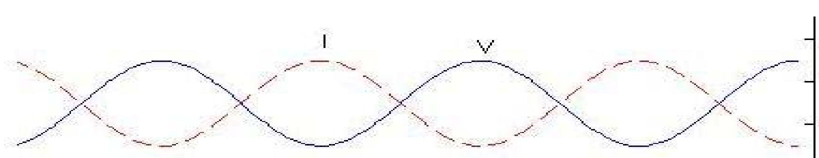
Short circuit



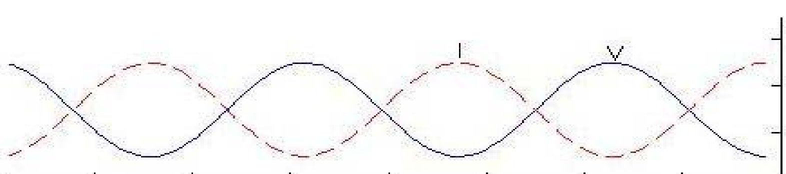
Open circuit



$Z_L > Z_O$



$Z_L < Z_O$



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= V_{max} / V_{min}

9. Determine the calculated VSWR by the formula:

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

   where $$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

10. Calculate the unknown frequency with the help of the following formula.
    $\lambda / 2$ =distance between consecutive V maxima or minima

$$f = c / \lambda$$

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 cms)	Distance of second minima (or maxima) from load (d2 cms)	Calculated frequency (MHz)

CALCULATIONS

RESULT

PRACTICAL NO 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 multi element yagi.
- To see how gain and directivity increase as element numbers increase.

APPARATUS

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 dipole antenna is simply two wires pointed in opposite directions arranged either horizontally or vertically, with one end of each wire connected to the radio and the other end hanging free in space. This is the simplest practical antenna and it is also used as reference model for other antennas. 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.

Yagi Uda Antenna
An antenna with a driven element and one, or more, parasitic element is generally know as a “yagi” , after on of its inventors (Mssrs 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**”

PROCEDURE

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 a 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.
8. Observe the polar plot.
9. Identify one of the other undriven dipole antenna element.
10. 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.
11. set the undriven length to 10 cm
12. acquire a second new plot at 1500 MHz

Has the polar pattern changed by adding the second element?

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13. 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?

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CHANGING THE LENGTH OF THE PARASITIC ELEMENT

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

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

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ADDING A SECOND REFLECTOR

20. 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.
21. Set the dipole length to 10cm and the un-driven dipole length to 11cm.
22. Acquire a new plot at 1500MHz.
23. Observe the polar plot.
24. Mount a second parasitic element about 5cm from the first parasitic reflector and adjust its length to 11cm.
25. Acquire a second new plot at 1500MHz.
26. Observe the polar plot.

Is there any significant difference between the two plots?

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27. 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

28. Remove the second reflector element from the boom.
29. Launch a new signal strength vs. angle 2D polar graph window.
30. Acquire a new plot at 1500 MHz.
31. Observe the polar plot
32. Mount a parasitic element about 5cm in front of the driven
33. element and adjust its length to 8.5cm.
34. Acquire a second new plot at 1500 MHz.
35. Observe the polar plot.

Is there any significant difference between the two plots?

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36. Move the director to about 2.5 cm in front of the driven element.
37. Acquire a third new plot at 1500 MHz
38. Observe the polar plot.

How does the new plot compare with the previous two?

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39. Launch another new signal strength vs. angle 2d polar graph window.
40. Acquire a new plot at 1500 MHz.
41. Add a second director 5 cm in front of the second.
42. Acquire a second new plot at 1500 MHz.
43. Add a third director 5 cm in front of the second.
44. Acquire a third new plot at 1500 MHz.
45. Add a fourth director 5 cm in front of the third.
46. Acquire a fourth new plot at 1500 MHz

How do the gains and directivities compare?

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47. Launch another new signal strength vs. angle 2D polar graph window.
48. Acquire a new plot at 1500 MHz.
49. 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 have much effect on the gain or directivity of the antenna?

RESULT

The addition of a second parasitic dipole element close to the driven dipole gives rise to a change in directivity and an increase in gain in a preferred direction. It also showed that the length of the parasitic element had an effect on the direction of maximum gain. If the parasitic element is the same length, or longer than the driven element the gain is in a direction from parasitic element to driven element. The parasitic element acts as a reflector. If the parasitic element is shorter than the driven element the gain is in a direction from driven element to parasitic element. The parasitic element acts as a director.

PRACTICAL NO 3

OBJECT

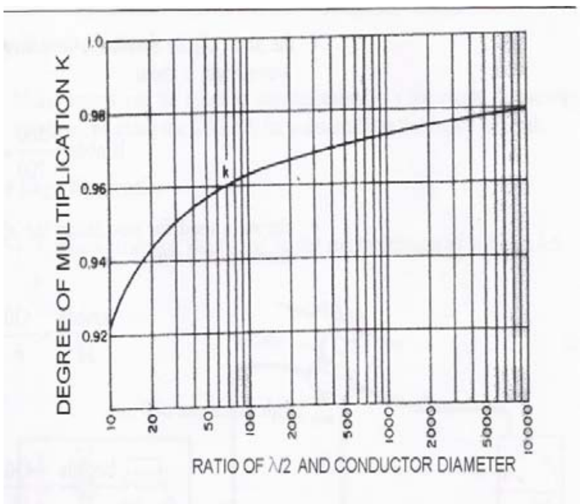
To study the effect of thickness of conductors upon the bandwidth of dipole.

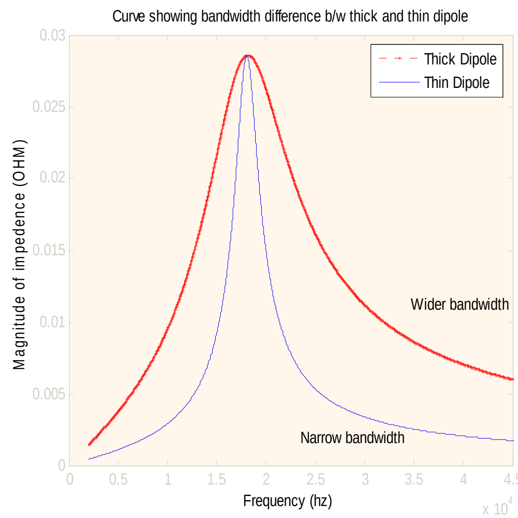
APPARATUS

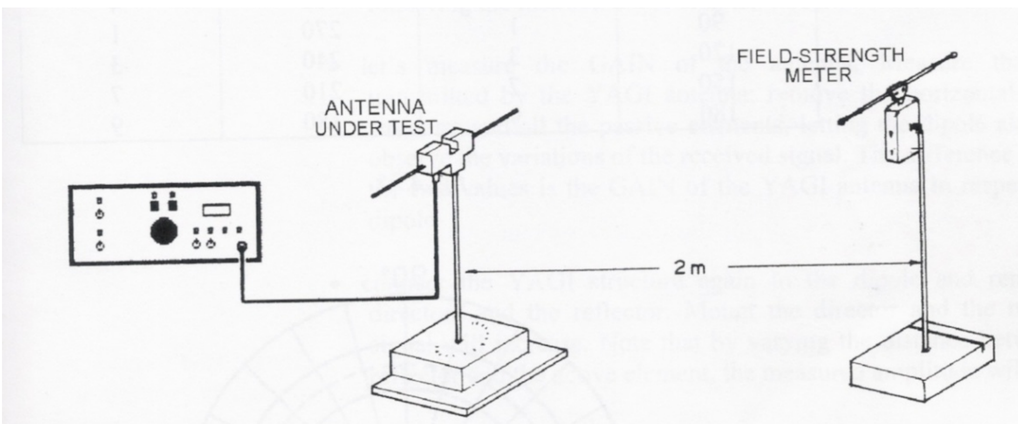
Electronica Veneta (turntable) with stand
Field meter SFM 1 EV
Microwave generator
75ohm coaxial cable
Basic dipole antenna short thick conductors (8mm)
Basic dipole antenna Short Thin dipole (3mm)

THEORY

Dipole:
It consists of two poles that are oppositely charged.
Dipole antenna:
The simple dipole is one of the basic antennas. It is an antenna with a center-fed driven element for transmitting or receiving radio frequency energy. This is the directed antenna i.e. radiations take place only forward or backward. Its characteristic impedance is 73Ω.
Half wave dipole:
Half wave dipole is an antenna formed by two conductors whose total length is half the wave length. In general radio engineering, the term dipole usually means a half-wave dipole (center-fed).
Thin and thick dipole
Theortically the dipole length must be half wave; this is true if the wavelength/conductor's dia ratio is infinite. Usually there is a shortening coefficient K (ranging from 0.9-0.99)according to which the half wavelength in free space must be multiplied by K in order to have the half wave dipole length, once the diameter of the conductor to be used is known.(refer fig)
Bandwidth:
The range of frequencies in which maximum reception is achieved.
Effect of thickness:
By increasing the conductor diameter in respect to the wavelength, the dipole characteristic impedance will increase too in respect to the value of 73Ω. On the other hand outside the center frequency range, the antenna reactance varies more slowly in a thick than in a thick antenna.
This means, with the same shifting in respect to the center frequency, the impedance of an antenna with larger diameter is more constant and consequently the SWR assumes lower values. Practically the **BANDWIDTH** is wider.







PROCEDURE

1. Construct a dipole with arms of 3mm diameter (short) and mount on the central support of the tuntable.
2. Set the antenna and instruments as shown in figure.
3. Set the generator to a determinate output level and to the center frequency of the antenna under test. 701.5 MHz for measurements with short (thick or thin dipole)
4. Adjust the dipole length and sensitivity of the meter to obtain the maximum reading (10^{th} LED glowing)

5. Now decrease the frequency up to the value such that the 10^{th} LED keeps on glowing. Note the value as f2.
6. Now increase the frequency up to the value such that the 10^{th} LED keeps on glowing. Note the value as f1.
7. Note down the difference between these two frequencies, this will be the bandwidth

8. Calculate the wavelength for the resonance frequency of around 700 MHz for short dipole using the formula $\lambda = c / f$
9. The ratio used for calculating the shortening coefficient is $\lambda / 2$
   where d=dia of conductor
11. From graph obtain a shortening coefficient K.
12. Calculate the physical length of Dipole and compare with the measured length.
    Physical length of half wavelength dipole= $\frac{\lambda}{2}$x K
13. Construct a dipole with arms of 8mm diameter (short).
14. Repeat the same procedure for thick dipole.

OBSERVATIONS & CALCULATIONS

Resonant frequency= MHz
$\lambda = c / f = 300/ \quad =$ cm
Measured length of short dipole thin= 220mm
Measured length of short thick dipole=195mm
THIIN dipole: d=
The ratio used for calculating the shortening coefficient is (with a dia of 3mm)
$\lambda / 2d =$K=
From graph we obtain a coefficient. of 0.960 for the thin dipole
Physical length of half wavelength dipole= $\frac{\lambda}{2}$x K=

f1(MHZ)	f2(MHZ)	BW=f1-f2(MHZ)

THICK dipole: d=
The ratio used for calculating the shortening coefficient is with a diameter of 8mm
$\lambda / 2d =$K=

f1(MHZ)	f2(MHZ)	BW=f1-f2(MHZ)

From graph we obtain a coefficient of 0.947 for thick dipole
Calculated physical length of half wavelength dipole= $\frac{\lambda}{2}$x K=
(These values refer to a dipole in air. Actually the dipole under consideration is not totally in air because for mechanical reasons, its internal part is in a dielectric. This slightly increases the resonance frequency.)

RESULT

With the same shifting in respect to the center frequency, the impedance of an antenna with larger diameter is more constant and consequently the SWR assumes lower values. Practically the **BANDWIDTH** is wider. In other words increasing the thickness of conductor has an effect upon the bandwidth of the dipole.

Thicker the conductor larger would be the bandwidth.

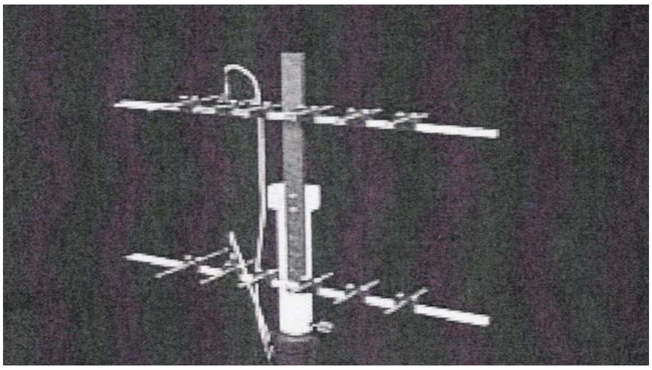
PRACTICAL NO 4

OBJECT

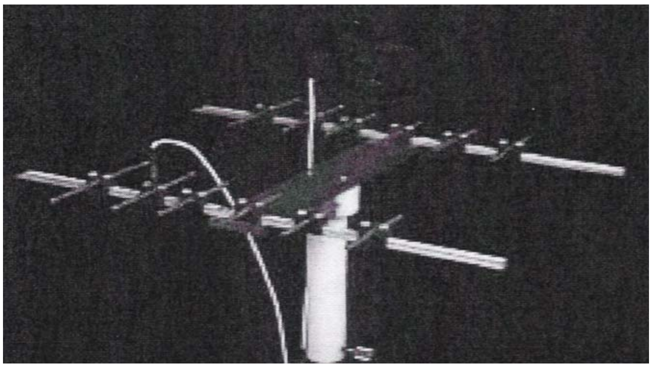
- Understand the terms ‘baying’ and ‘stacking’ as applied to antennas.
- To investigate stacked and bayed yagi antennas.
- To compare their performance with a single yagi.

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.



Stacked Yagi assembly



Bayed Yagi Assembly

PROCEDURE

(A) Baying Two Yagis

1. Connected up the hardware of *AntennaLab*.
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	**Spacing**
Reflector	11 cm	5cm behind driven element
Driven Element	10 cm	Zero (reference)

Director 1	8.5 cm	2.5 cm in front of DE
Director 2	8.5 cm	5 cm in front of D1
Director 3	8.5 cm	5 cm in front of D2
Director 4	8.5 cm	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.
8. Identify the Yagi Bay base assembly (the broad grey plastic strip with tapped holes) and mount this centrally on the Generator Tower.
9. Mount the 6 element yagi onto the Yagi Bay base assembly at three holes from the centre.
10. 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).
11. Identify the 2-Way Combiner and the two 183mm cables.
12. Connect the two 183mm cables to the adjacent connectors on the Combiner and their other ends to the two 6 element yagis.
13. Connect the cable from the Generator Tower to the remaining connector on the Combiner.
14. Acquire a new plot for the two bayed antennas onto the same graph as that for the single 6 element yagi.
15. Reverse the driven element on one of the yagis and acquire a third plot

OBSERVATIONS

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

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

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

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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?

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(B) 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.

OBSERVATIONS

How does the directivity of the different configurations compare?

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How does the forward gain of the stacked yagis compare with the single yagi?

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

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RESULT

PRACTICAL NO 5

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.

APPARATUS

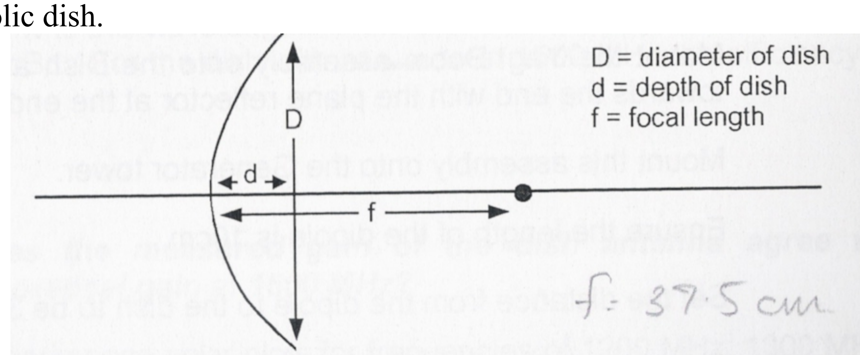
Antenna Lab hardware
Discovery Software
Parabolic Dish reflector
Dipole (10cm)
Yagi boom
Ground plane reflector

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.



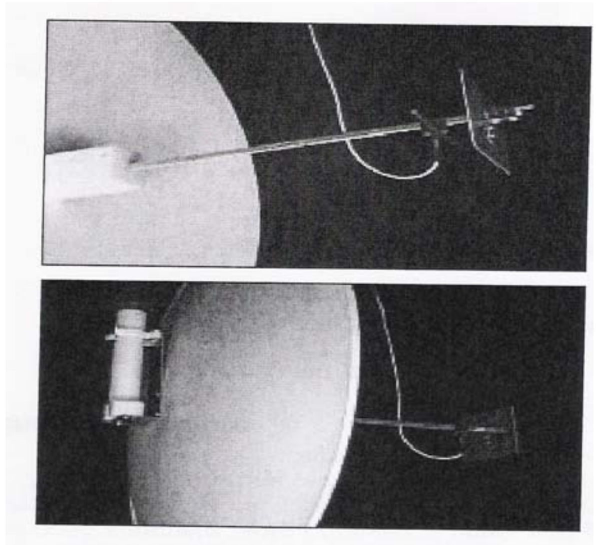
The dimensions for a dish are shown in figure. The focal length for a parabolic dish is given by

$$\mathbf{f=D^2/16d}$$

The gain of a dish is given by:

$$\mathbf{G = 4\pi a\epsilon/\lambda 2}$$

where G is the gain, a is the area of the dish, ϵ is the dish efficiency and λ is the wavelength. Note that this is dBi, your measured gain will be dBi.
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..



PROCEDURE & OBSERVATIONS

1. Connect the hardware of *Antenna Lab* as 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 a 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, Moter 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 (Further 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 the dish antenna have gain over this range of frequencies?

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?

Does this dish Antenna have directivity 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

For the frequencies used by Antenna Lab, the dish is not large enough to be very efficient, much of the radiation reflected by the plane reflector passes outside the rim of the dish. This is why the polar plots shows significant rear lobes-they would be much smaller if the dish were larger. However, it can be seen that the gain achievable with a dish is significantly greater than with any other type of antenna tested and that its directivity is high.

The performance of the dish is not greatly dependent on exact position of dipole and reflector.

Because of its advantages of high gain and directivity, the dish type of antenna is the most used from of antenna for high UHF and microwave applications.

PRACTICAL NO 6

OBJECT

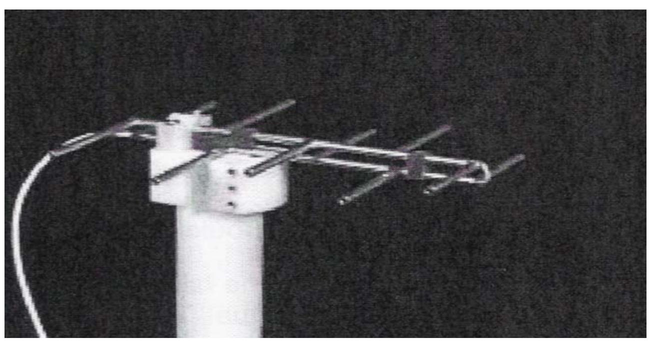
- Be familiar with the LOG PERIODIC form of antenna
- To investigate the gain, and directivity of the log Periodic antenna over a wide frequency range.
- Appreciate the advantages and disadvantages of a log periodic Antenna as compared with a yagi.

APPARATUS

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.



5 element Log Periodic Antenna

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?

____

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

____

14. Launch a return loss vs frequency graph window. Identify the directional coupler and connect it. Plot the VSWR(Return loss) vs frequency.

Is the VSWR response of the antenna greatly dependant on frequency?

____

RESULT:

The log periodic form of antenna sacrifices gain for bandwidth. However, as the frequency is changed other elements become active, thus maintaining the performance much more constant over a wide range of frequencies. The impedance, and thus the VSWR, is also more constant over the frequency range as compared to yagi.

PRACTICAL NO 7

OBJECT

(a) To describe the characteristics of the horn antenna.
(b) To carry out gain measurements using method of comparison.

APPARATUS

-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

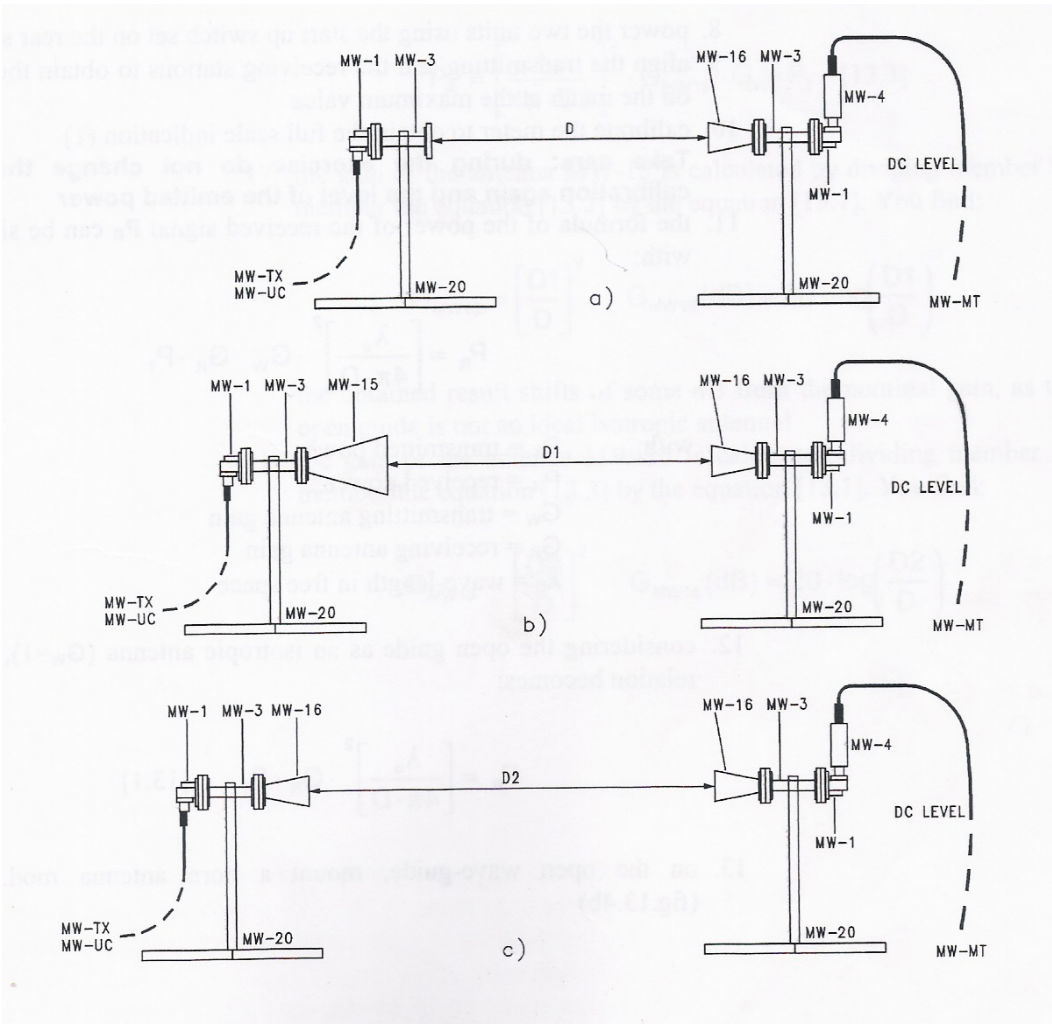
The horn antennas consist in a wave-guide enlarging in the shape of a horn that a can be pyramid, sectorial or conical kind.
The gain G of the horn antenna depends on the ratio between the surface of the horn opening and the working wave-length ,and can be increased by enlarging the same horn.
The gain 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 sactorial horn antennas.Note that in the sartorial antenna the main lobe is narrower in the plane in which the opening is smaller.

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

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

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



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 $\mathbf{G}_{dB}$ of the antenna at the frequency of 10.7 GHz, using the formula. A value is obtained near the nominal one:

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

where λg = wave-length in guide
λo = wave-length in free space
A = surface (**a** x **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.

4. Carry out the wiring as indicated in figure between the units.

Consider that the presence of metal surface can cause unwanted reflections, so they can alter the result of the exercise.Take care to 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:
   SW1=1
   SW2=1
   SW3=DIRECT
   LEVEL= to half
6. Set the meter unit in the following operation mode :
   SW =1
   SW2 = ON
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 unit 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 P_R can be simplified with

$$P_R = \left[\frac{\lambda_o}{4\pi D}\right]^2 G_w . G_R . P_T$$

where P_T = transmitted power
P_R = received power
G_w = transmitted antenna gain
G_R = receiving antenna gain
λ_o = wave length in free space.

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

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

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 the situation the same

power P_R of the last case is received, but at a different distance. The formula becomes

$$P_R = \left[\frac{\lambda_0}{4\pi D1}\right]^2 .G_{MW15}.G_R.P_T \qquad (2)$$

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 D2in this situation the same power P_R of the last cases is received but at a different distance, the formula becomes

$$P_R = \left[\frac{\lambda_0}{4\pi D2}\right]^2 .G_{MW16}.G_R.P_T \qquad (3)$$

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. $G_{MW16} = [\ D2/D]^2$ $\qquad$ G_{MW16} (dB) = 20. log [D2/D]

OBSERVATIONS & CALCULATIONS

RESULT:

PRACTICAL NO. 8

OBJECT

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

APPARATUS:

-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 **G_X** is the gain of each, from the formula of the received power **P_R** (FRIIS equation) we get**:**

$$G_X^2 = \left[\frac{4\pi D}{\lambda_0}\right]^2 \frac{P_R}{P_T}$$

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. 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)

$$G_{MW16}^2 = \left[\frac{4\pi D}{\lambda_0}\right]^2 \frac{P_R}{P_T}$$

9. The ratio P_R/P_T 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-6 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 P_R/P_T corresponds to the inserted attenuation, so equal to 29dB (=4dBm - (-25dBm)).
10. The last formula of the gain GMW16 becomes:

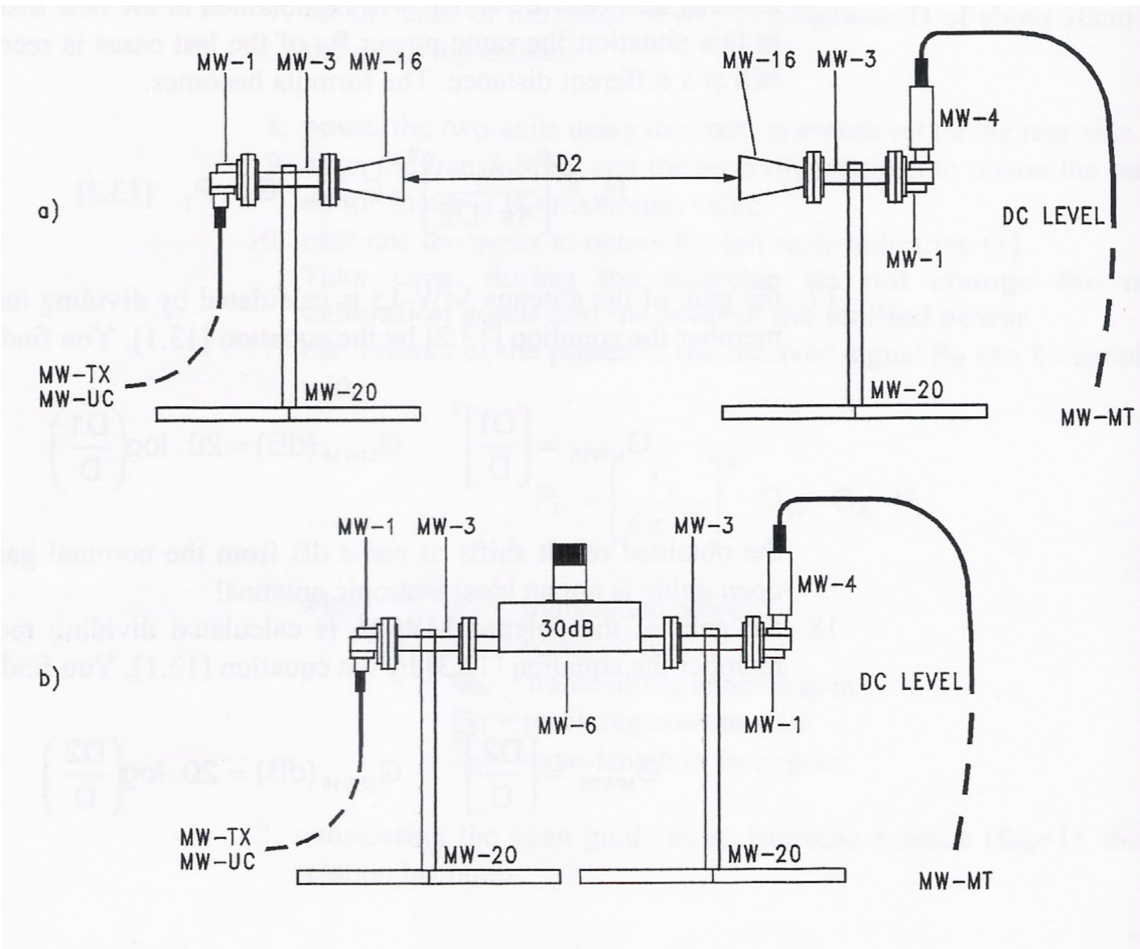
$$G_{MW16} = 10log\left[\frac{4\pi D}{\lambda_0}\right] - \frac{A_{dB}}{2}$$

Where A_{dB}=attenuation introduced by the variable attenuator

D= 100 cm

11. Calculate the gain of the antenna under measurement.

OBSERVATIONS & CALCULATIONS



RESULT

The gain of the antenna under measurement is found to be

PRACTICAL NO

OBJECT

a) To use a slotted waveguide to measure VSWR
b) To observe how the load impedance affects the VSWR
c) To determine when a waveguide is properly terminated
d) To measure an unknown impedance using the Smith Chart

APPARATUS

- 1 Transmitter unit module MW-TX
- 1 Up converter unit module MW-UC
- 1 VSWR/LEVEL meter unit module MW-MT
- 1 wave guide 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 mod 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 an 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 the so called STANDING WAVE creates, 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 so there are **loops** (maximum) and **nodes** (minimum) of voltage and current in fixed positions: the maximum and minimum are separated by $\lambda / 2$ and a maximum of voltage corresponds to a minimum of current and vice versa.

CO-EFFICENT OF REFLECTION

It can be given by the following relation ship

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

STANDING WAVE RATIO

We define as VSWR (voltage standing wave ratio) as the ratio between the maximum value and the minimum value of standing wave :

$$VSWR = \frac{V_{max}}{V_{min}}$$

RATIO BETWEEN VSWR AND Γ

The ratio between Γ and VSWR is the following

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

POWER SANDING WAVE RATIO

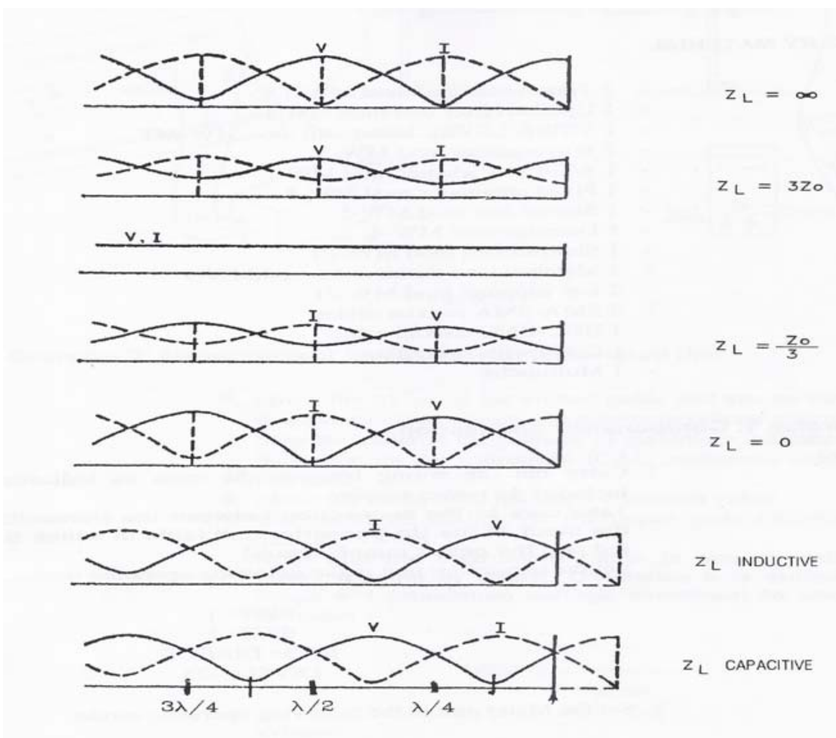
Power standing wave ratio:

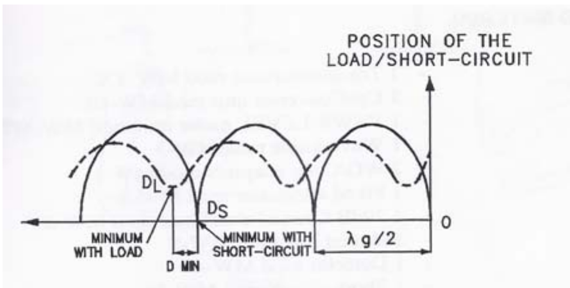
$$SWR = VSWR^2$$

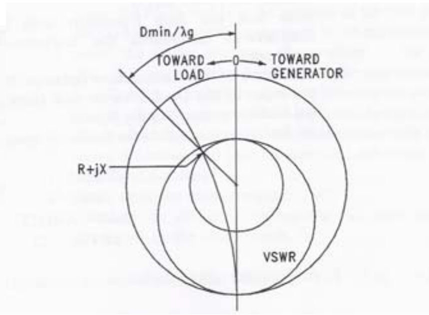
LINE WITH LOAD

In case of perfect matching between the line and load ($\mathbf{Z_o=Z_L}$) we have Γ =0 and **VSWR** = 1.Acceptable **VSWR** values are included between 1.1 and 2. Figure shows example of standing wave ratio for different load impedances note that

- when $\mathbf{Z_L} = \infty$ (open circuit); on the load there is maximum voltage and null current
- when $\mathbf{Z_L} = 0$ (short circuit); on the load there is null voltage and maximum current







CALCULATION OF AN UNKNOWN IMPEDANCE WITH THE SMITH CHART

Consider an unknown impedance $\mathbf{Z_L}$ connected to a line with impedance wave-guide $\mathbf{Z_o}$

The procedure to calculate $\mathbf{Z_L}$ is the following:

Connect the $\mathbf{Z_L}$ at the end of the line with the use a slotted line, calculate **VSWR**

Determine the position $\mathbf{D_L}$ as reference of a standing wave minimum

Remove $\mathbf{Z_L}$ and insert a short circuit

Measure the wave length in guide λg (measure the value λg /2 between two minimum or two maximum value of the standing wave) note the new position $\mathbf{D_S}$ of the minimum.

On the smith chart, plot the circle corresponding to the VSWR calculated in the last point 2.

Calculate the variation of the two minimum value found before expressed in fractions of wave length.

$$\mathbf{D_{min} = (D_L - D_S) / \lambda g}$$

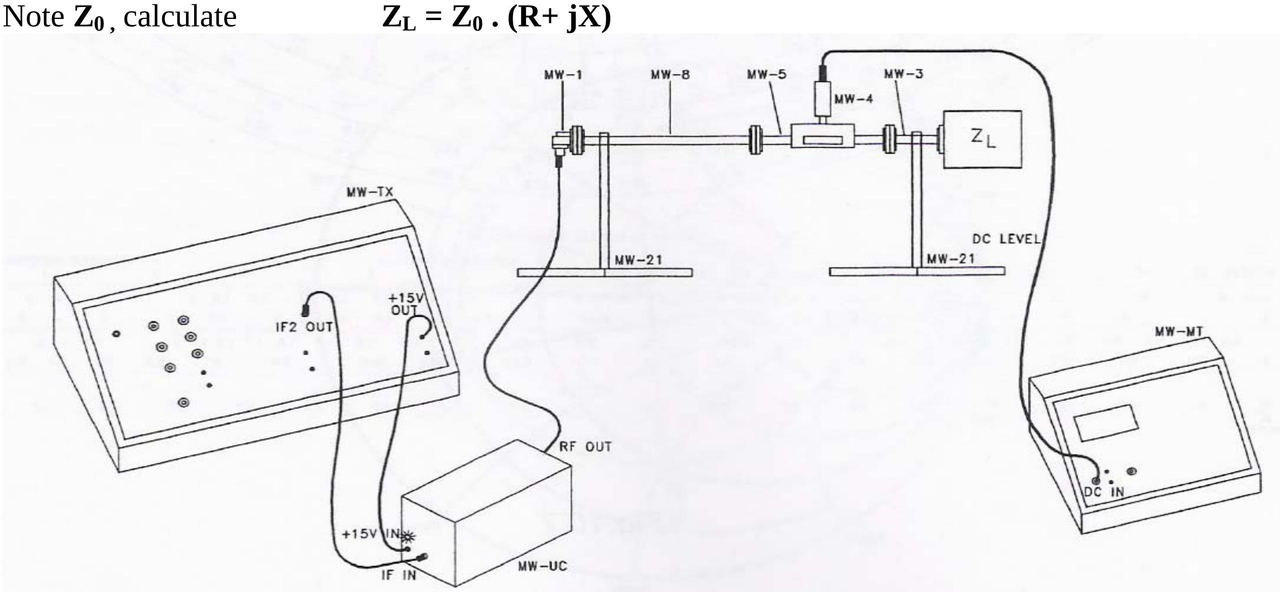
Move along the circumference of the smith chart with a quantity like the last value $\mathbf{D_{min}}$ clock wise, if the minimum value found with the load is moved toward the generator in respect to the minimum value found with the short circuit, vice versa on the contrary case.

Plot straight line between the determined point and the center of the smith chart

The standardized value **(** $\mathbf{Z_L / Z_0}$ **)** of the unknown impedance is read in the intersection point between the circle and the straight line:

$$\mathbf{Z_L/Z_0 = R + jX}$$

Note $\mathbf{Z_0}$, calculate $\mathbf{Z_L = Z_0 \cdot (R + jX)}$



PROCEDURE

1. Carry out wiring between the unit as indicated in figure.
   (note that the final transition with the coaxial attenuator module MW-23 represent the unknown load that is to be measured).
2. Take care to the connection between the transmitter unit and the input of the UP-converter unit (side in which there are the led and the power supply input!)
   SW1 =1
   SW2 = 1
   SW3 = Direct
   LEVEL = -25
3. Set the meter unit in the following operating mode:
   SW1 = 100 mV
   SW2= ON
4. Power the two units the start up switch set on the rear side

5. Move the trailer of the slotted guide to the unknown impedance (adapter plus attenuator)
6. Note that the values expressed during the exercise could be different as the impedance is not ideal
7. Move the trailer and note the position of the first minimum ($D_{m1} = D_L$)
8. Move the trailer and note the position of the first maximum (D_{M1}) and calibrate the instrument to the maximum indication.
9. Move the trailer and note the position of the second minimum D_{m2} and measure the VSWR on the instrument.
10. If **λg/2** is equal to the distance between the two minimum values,calculate **λg** that will be equal to about 4 cm.
11. Change the adapter and coaxial attenuator with the short circuit
12. Move the trailer and find the new first minimum value, next to the last (D_S)
13. Check again the measurement of **λg/2**
14. Calculate the distance between the two first minimum value as expressed by the formula

$$\mathbf{D_{min} = (D_L - D_S) / \lambda g}$$

15. On the smith chart plot, the circle corresponding to VSWR. Move the distance **D_{min}** towards generator from the short circuit point and draw a line from this new position to the center of smith chart.
16. The cross point B of SWR circle and line provides the normalized resistive and reactive component of the unknown impedance, read about
    R/Z_o
    X/Z_o
17. The impedance Zo is in this case the impedance of the wave guide that can be calculated with the following formula:

$$Zg = Z_o = \frac{120\,\pi}{\sqrt{1-(\frac{f_c}{f_0})^2}} = \frac{120\,\pi}{\sqrt{1-(\frac{\lambda_0}{\lambda_c})^2}}$$

where f_c = cut off frequency =c/**λc=** 7.870 GHz
f_o = frequency in free space

18. At the frequency of 10.7 GHz, λ_0 =2.8cm, calculate the used wave guide(**λc=2a=3.81cm)** characteristic impedance .
19. Calculate the values of R and X.

OBSERVATIONS & CALCULATIONS

Dimensions of the waveguide a=_______cm; b=________cm
Mode of propagation= TE_{10}
Frequency of operation=_________GHz
Characteristic impedance of waveguide=____________ohm
Wavelength in free space λ_0 =_________cm

Terminations	D_{M1}	D_{m1}	D_{m2}	**λg=** $2(D_{m2}-D_{m1})$	**V_{max}**	**V_{min}**	**VSWR**
unknown load							
short circuit	-						
matched load	-	-	-	-			

D_L =_________; $D_{S=}$__________

$D_{min} = (D_L - D_S) / \lambda g$

From smith chart: R/Z_o =__________;X/Z_o =_____________

$$Z_o = \frac{120\,\pi}{\sqrt{1-(\frac{f_c}{f_0})^2}} = \frac{120\,\pi}{\sqrt{1-(\frac{\lambda_0}{\lambda_c})^2}} =$$

R=________; X=_________

RESULT