RELATIONSHIP BETWEEN λ_g and λ_a

Objective: To provide the relation

$$\frac{1}{\lambda_g^2} - \frac{1}{\lambda_a^2} = \frac{1}{(2a)^2}$$

where λ_a is the wavelength in free space, λ_g is the wavelength in waveguide and ‘a’ is he broad dimension of the waveguide.

List of Equipment

1. Microwave source with square wave modulation
2. Isolator
3. Variable attenuator
4. Crystal detector
5. VSWR Meter
6. Ferrite Isolator
7. Horn antenna
8. Reflecting sheet

Theory:

The best way to prove this relationship is to measure λ_g and λ_a and then plot the values of $(1/\lambda_a)^2$ against the corresponding values of $(1/\lambda_g)^2$. This should result in a straight line graph which cuts the $(1/\lambda_a)^2$ axis at a value equal to $(1/2a)^2$. If this graph allows the determination of a value of width of the broad wall of the guide which agrees with the actual value as measured by Calipers then this surely is a proof of the validity of the relationship expressed in the above equation.

To measure the waveguide wavelength, λ_g, standing waves are produced by improperly terminating the waveguide. Secondly, the radiation is allowed to leave the waveguide and the wavelength of the standing wave in free space (λ_a) is compared with the wavelength in the waveguide (λ_g). To produce standing wave in the waveguide and in the air, a horn is attached to the waveguide and a sheet of metal is placed a certain

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distance way from the horn. The electromagnetic radiation will then leave the waveguide via the horn into the air. It will be reflected from the sheet of metal and produce a standing wave between the horn and the sheet with a wavelength, λ_a. As the reflected wave will re-enter the waveguide there will be a standing wave produced in the waveguide but with a wavelength λ_g.

If the sheet is moved relative to the horn keeping its plane at right angles to the axis of the waveguide the standing wave will move. Therefore, the signal at the stationary probe of the standing wave detector will vary as the standing wave moves past it. The distance moved by the sheet to repeat the output on the meter (i.e. to have the probe at the ext corresponding position on the standing wave) is half a free pace wavelength $\lambda_a/2$. The voltage of the sanding wave must always be at a minimum at the sheet because it is a good conductor. Consequently, moving the sheet moves the pattern. Therefore, when the sheet has moved a distance $\lambda_a/2$, the voltage at the stationary probe of the standing wave detector will be repeated. A measurement of the amount of movement of the sheet determines $\lambda_a/2$ at particular frequency.

To determine the guide wavelength $\lambda_g/2$ at the same frequency all that is necessary is to keep the sheet still and move the standing wave detector probe. The pattern will remain stationary and the probe will explore that pattern in the waveguide which repeats every half guide wavelength $\lambda_g/2$. Recording, the distance between two adjacent minima on the scale of the standing wave detector will give $\lambda_g/2$.

Now knowing $\lambda_g/2$ and $\lambda_a/2$ at one frequency, these values are recorded and the whole experiment is repeated at a new frequency. This procedure is repeated for measurement at a number of frequencies. The values of $(1/\lambda_g)^2$ and $(1/\lambda_a)^2$ for each frequency are plotted and from the intersection of the graph with the $1/\lambda_a^2$ axis a value of the inside broad dimension of the waveguide can be obtained, and compared with the measured value.

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Procedure:

1. The experimental arrangement to be made is shown in Fig.1

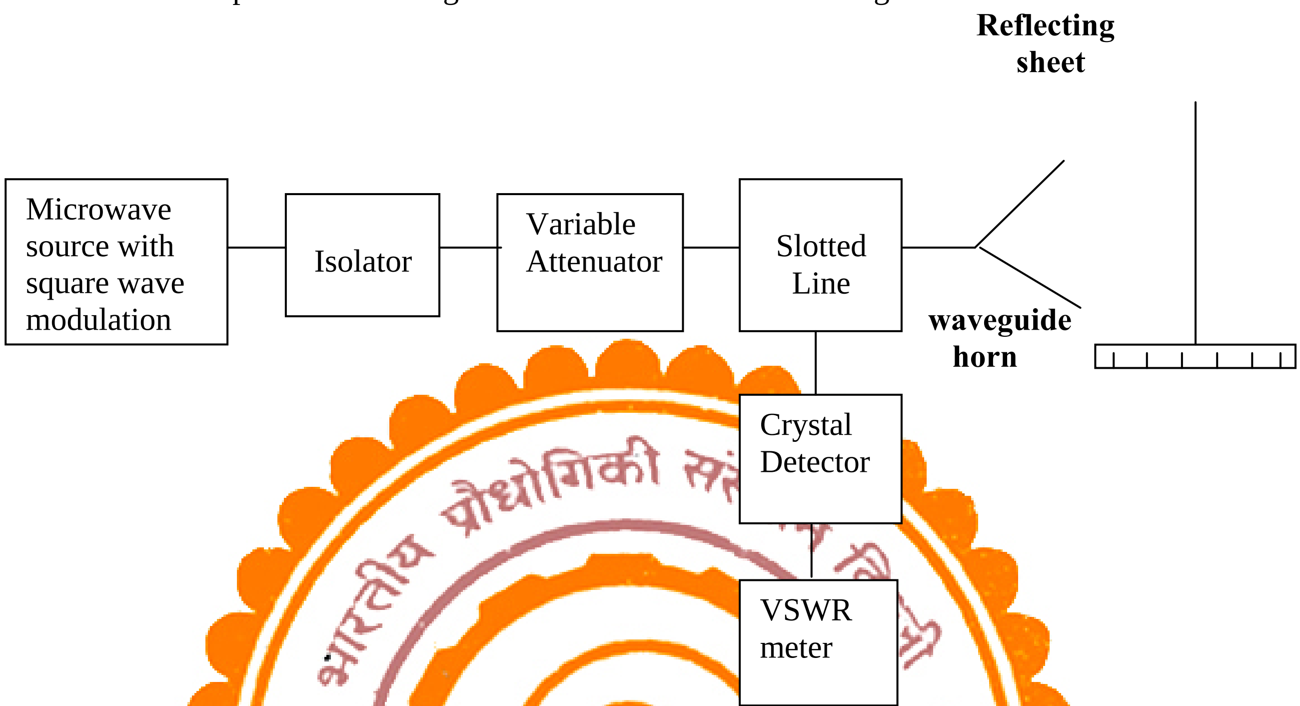

Fig.1 Experimental arrangement for measuring λ_g and λ_a

2. Microwave signal generator is turned on and set at, say 9 GHz. The frequency may be measured using the wavemeter and its calibration chart.
3. The metal sheet is placed about 20 cms. from the waveguide horn.
4. Leaving the slotted-line probe fixed in one position, slowly move the metal sheet towards the horn until the probe output is a minimum. Do this 2-3 times and mark an average location of the sheet corresponding to the minimum output. Let the distance of the sheet at this location be x_1 cm from some reference point along the normal to the sheet (towards the horn). Now, gradually move the sheet towards the horn till a minimum output reading, as before, is obtained. Let the sheet now be at a distance x_2 cms from the reference. Similarly, for successive minima, x_3, x_4 etc. can be noted. So, at this frequency

$$\frac{\lambda_a}{2} = x_1 - x_2 = x_3 - x_4 = \frac{x_4 - x_1}{3} \text{ etc.}$$

5. Leaving the sheet fixed in this position, move the probe in the slotted line and obtains $\lambda_g / 2$ as the separation between successive minima. Record these values of frequency, λ_a and λ_g in table.
6. Change the frequency in small steps, say 200 MHz. Measure the corresponding λ_a and λ_g. Do this to cover a frequency range of, say, 9-11 GHz.
7. Plot a graph of $\frac{1}{\lambda_g}2$ (y-axis) vs. $\frac{1}{\lambda_a}2$ (x-axis). The intersection of the graph with x-axis equals $1/(2a)^2$, enabling one to arrive at an estimate of a. This estimate may be compared with the actual value.

Discussions:

1. Why metal sheet is used? What effect does it produce?
2. Why horn antenna is used? Can we use any other antenna?
3. What do you mean by guided wavelength?

References

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