SLOTTED LINE MEASUREMENTS

Objective: To familiarize with the measurement technique using slotted line.

a) Measurement of standing wave distribution on a slotted line, with short circuit and open circuit termination.
b) Measurement of guide wavelength and determination of operating frequency.
c) Measurement of high VSWR by double minimum method.
d) Measurement of low VSWR by nodal shift method.

Theory

a) **Standing Wave Distribution:** If a transmission lines is terminated in an independence not equal to its characteristic impedance, the termination is said to be 'not matched' to the line. Waves traveling down the line are partially or wholly reflected from the termination. Total reflection occurs when the terminal impedance is not dissipative, i.e. a short, open or reactive termination. Standing waves are the result of two wave trains of equal wavelength incident and reflected along the line in opposite directions.

b) **Frequency and wavelength:** The distance between successive minima of a standing wave pattern determines the half wavelength $(\lambda g/2)$ on the line. In the case of a waveguide slotted line operated in IE_{10} mode the guide wavelength λg is related to the free space wavelength λo by the equation.

$$\lambda_g = \frac{\lambda_o}{[1-(\frac{\lambda_o}{2a})^2]^{1/2}} \qquad (1)$$

where 'a' is the larger internal dimension of the guide.

c) **High VSWR by Double Minimum Method:** The voltage standing wave ratio of a transmission line terminated in a load is defined as,

$$VSWR = \frac{V_{\max}}{V_{\min}} \qquad (2)$$

where $v_{\max}$ and $v_{\min}$ are the voltage at the maxima and minima of voltage standing wave distribution. When the VSWR is high (≥ 5), the standing wave pattern will have a high maxima and low minima. Since the square law characteristics of a crystal detector is limited to low power, an error is introduced if $v_{\max}$ is measured directly. This difficulty can be avoided by using the 'double minimum method' in which measurements are take on the standing wave pattern near the voltage minimum. The procedure consists of first finding the value of voltage minima. Next two positions about the position of $v_{\max}$ are found at which the output voltage is twice the minimum value. If the detector response is square law, VSWR is given by

$$VSWR = [1 + \frac{1}{\sin^2(\frac{\pi d}{\lambda_g})}]^{1/2} \qquad (3)$$

where λg is the guide wavelength and d is the distance between the two points where the voltage is $2v_{\min}$.

d) **Low VSWR by Nodal Shift Method:** This method is for measuring low VSWR caused by small reflections due to transitions, etc. for example, consider two different transmission lines connected together through a lossless coupling network (fig.1). The output guide joining the lossless structure is connected to a sliding short circuit. The voltage standing wave pattern which results in the input guide will possess nodes dependent on the position of the short circuit. Let AA' correspond to voltage node in the input guide, when BB' corresponds to a voltage

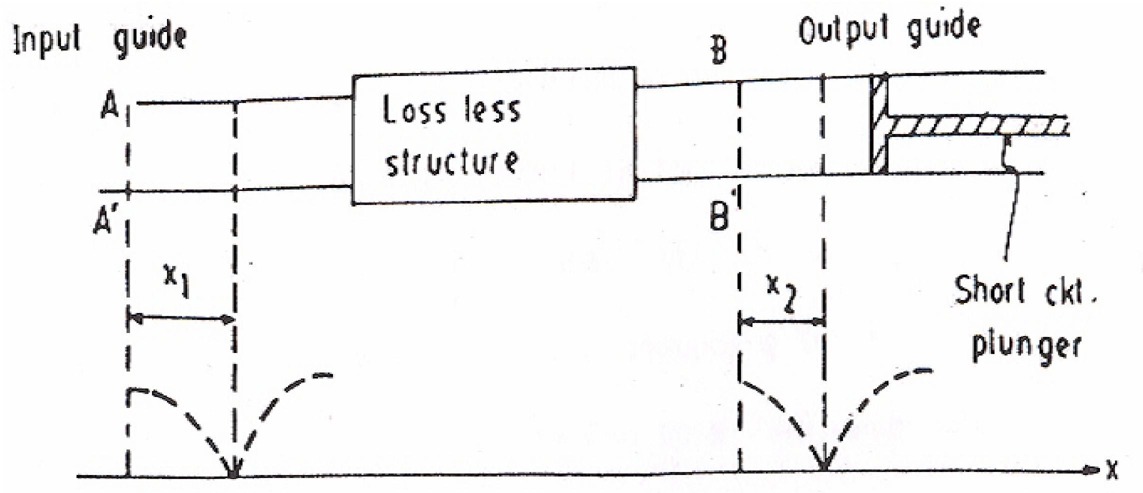


Fig.1. Nodal shift method

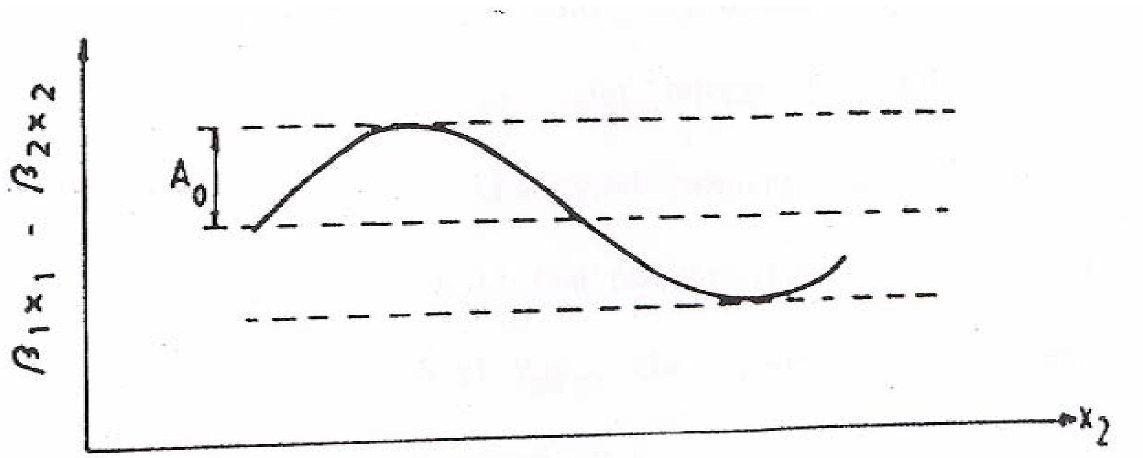


Fig 2. Typical plot of Nodal shift method data

node in the output guide. Now, if the shorting plunger is moved, the corresponding voltage node located at AA' also shifts. Referring to Fig.1, the electrical distances $B_1 \times x_1$ and $B_2 \times x_2$ corresponding to the node shift are measured with respect to the arbitrary reference pianes AA' and BB'.

A plot of $(B_1 \times x_1 - B_2 \times x_2) vs\ x_2$ is shown fig.2 A_o is the amplitude of the curve, the VSWR of the lossless structure under matched conditions is given by.

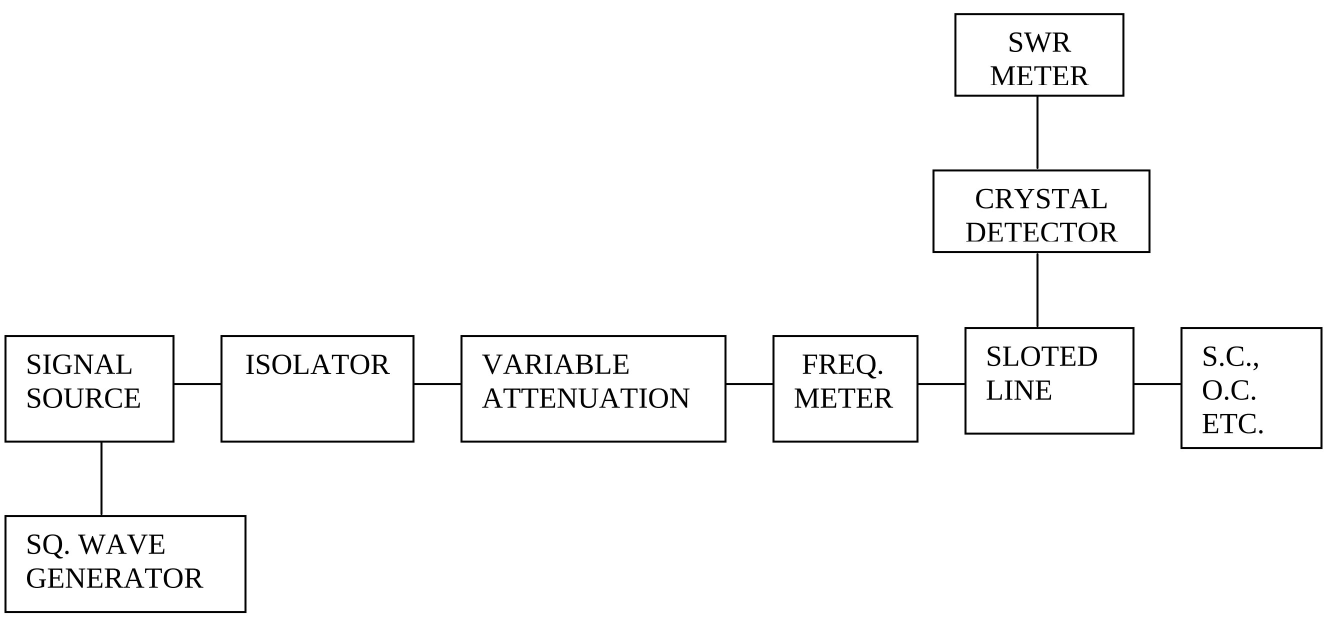
$$VSWR = \frac{1 + \sin A_O}{1 - \sin A_O} \qquad (4)$$

Procedure

A block diagram of the experimental set up is shown in figure. The source may be a square wave modulated Klystron or a Gunn oscillator. The slotted line probe carriage carries an electric probe to sample the electric field inside the slotted line. The voltage induced in this probe is proportional to the probe depth. This voltage is applied to the crystal detector having square law response. The crystal output corresponding to the modulation frequency (generally 1 KHz) is fed to a VSWR meter which is essentially a tuned, amplifier.

Since the amplifier is linear, the meter response is linear on the linear scale, and hence the reading is proportional to power. On the 'VSWR reading scale' the scale is laid out so that if the pointer is set to full scale when the probe is at v_{max}, the VSWR may be read directly when the probe is moved to v_{min}.

Since the crystal has a square law characteristic only for small powers, the amplifier should be set at almost full gain so that as small a power as possible gives full scale reading on the meter.



(a) Measurement of standing wave distribution:

1. Energize the source and apply square wave modulation. First terminate the slotted line with a short-circuit termination. Move the slotted line probe to a position of voltage maximum in the standing pattern.
2. Tune the probe for maximum sensitivity by adjusting the tuning plunger on the slotted line. Adjust the probe.
3. Measure the standing wave pattern by moving the probe carriage along the slotted line section.
4. Repeat for open circuit termination.

(b) Measurement of guide wavelength and operating frequency.

1. Measure $\lambda_g / 2$ by noting the distance between successive minima in the standing wave pattern. Calculate frequency. Compare with the frequency measured by a wavemeter.

(c) Measurement of high VSWR:

1. With the load connected to the end of the slotted line; located a position of $v_{\min}$ on the slotted line. Adjust the VSWR meter gain to some reference value say 3 db.
2. Move the probe along the slotted line on either side of $v_{\min}$ so that the reading is 3 db below the reference i.e. 0 db. Record the probe positions and obtain the distance between the two. Determine the VSWR using equation (3)

(d) Measurement of low VSWR:

1. Terminate the output guide by a matched load. Locate a position of $v_{\max}$ on the input guide (A, A’).
2. Terminate the output guide by a short. Move the short until a voltage minimum appears at AA’. The position of short in the output guide forms the reference plan BB’.
3. Move the shorting plunger by a short distance (x_2) and note shift in the position of voltage minimum on the input line (x_1).
4. Plot $(B_1 x_1 - B_2 x_2) vs\, x_2$. If $B_1 - B_2$, then

   $(B_1 x_1 - B_2 x_2)$ can be replaced by $(x_1 - x_2)$.

5. Determine the amplitude A_0 from the curve and VSWR from equation (4)

DISCUSSIONS

1. Why the lot is cut in the centre of the waveguide not off centre?
2. What types of errors are introduced in measurement due to finite probe depth and a slot in a waveguide.
3. Why detector is required to have a square law response? If it has response proportional to the cube of the input what correction you will need to apply.
4. Why the Klystron/gunn source is square wave modulated at end frequency range?
5. If the excitation of the waveguide is changed to TE_{mn} mode, can we continue with this set up? What will be the effect of multimode in measurement?

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