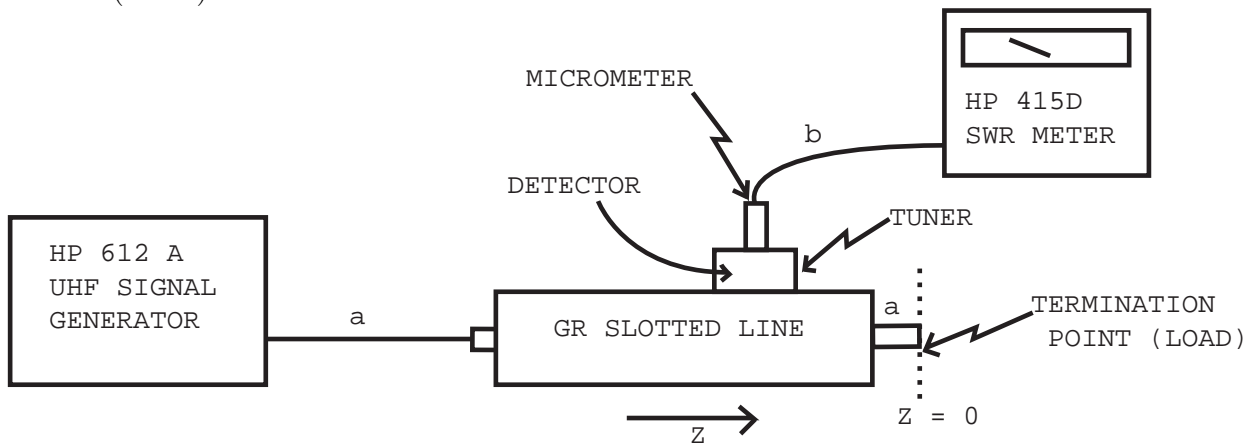


EECS 117A Demonstration 2 Microwave Measurement Instruments

NAME _____

Introduction. Please review the general sinusoidal wave concepts in Secs. 3.1–3.9 of Inan & Inan. Note carefully Section 3.3. In this demonstration you will learn how to use a “50 ohm” slotted line, crystal detector, and standing wave ratio meter to obtain the wavelength λ and voltage standing wave ratio S on a coaxial transmission line. In a later demonstration you will use these techniques to measure and control impedances and reflection coefficients on a microwave transmission system.

The apparatus used is shown below. The slotted line is a (rigid) continuation of the coaxial transmission lines “a” connected at each end. It has a thin slot in its outer conductor, cut along z . A probe rides within (but not touching) the slot to sample the transmission line voltage. The probe can be moved along z , and can also be moved into and out of the slot by means of a micrometer. The probe is connected to a crystal (diode) detector that converts the time-varying microwave voltage to dc. The dc voltage is measured using the standing wave ratio (SWR) meter.



Suppose a sinusoidal voltage wave

$$v_+(t) = \text{Re} [V_+ e^{j(\omega t - \beta z)}] \quad (1)$$

travels from the RF generator through the slotted line and is incident on a load (resistor, capacitor etc.) at $z = 0$. Here V_+ is the amplitude (generally a complex number) of the wave, $\omega = 2\pi f$ and $\beta = 2\pi/\lambda$, where f (in Hz) is the frequency, and λ (in meters) is the wavelength. In general, a reflected sinusoidal voltage wave

$$v_-(t) = \text{Re} [V_- e^{j(\omega t + \beta z)}] \quad (2)$$

is excited at the load and travels back through the slotted line toward the generator. The two waves interfere, such that the total voltage $v(t) = v_+ + v_-$ displays a series of maxima,

$$V_{max} = |V_+| + |V_-|, \quad (3)$$

and minima,

$$V_{min} = |V_+| - |V_-|, \quad (4)$$

with successive maximum and minimum values separated in z by a distance $\lambda/4$. The voltage standing wave ratio S is defined as

$$S = V_{max}/V_{min} \quad (5).$$

The crystal (Schottky-barrier diode) detector can be moved along z and samples a small fraction of the total slotted line voltage $v(t)$. For powers below $10 \mu\text{W}$ reaching the detector, the detector is a “square law” device, meaning that the dc output voltage V_b at b is proportional to the (time average of the) square of the slotted line voltage $v(t)$

$$V_b(z) = C \langle v^2(z, t) \rangle, \quad (6)$$

where $\langle \rangle$ denotes an average over a period $T = 2\pi/\omega$. The SWR meter expects this and is calibrated accordingly. The constant of proportionality C does not matter, since only voltage ratios are measured. It is common in microwave measurements to give the voltage standing wave ratio in decibels (dB):

$$S(\text{in dB}) = 20 \log_{10}(V_{max}/V_{min}). \quad (7)$$

Operation of HP 415D SWR Meter:

1. SWR meter settings: AC power, 200 k Ω Xtal, Coarse and fine gain controls at 3 o'clock, range switch at 20 dB, expand switch at NORM.
2. Move the detector along z to find the maximum voltage.
3. Rotate the tuner on the detector to maximize the SWR signal.
4. Withdraw the detector probe until the SWR meter reads “1” (third scale from the top) or “0 dB” (bottom scale) on the 20 dB range. The power reaching the detector is now small enough that the detector is a “good” square law device.
5. Vary the coarse and vernier gain so that the meter reads exactly $S = 1$ [$S(\text{dB}) = 0$] at the position of the maximum voltage.
6. Move the detector probe to the position of the nearest voltage minimum. Read S or $S(\text{dB})$ directly if $S(\text{dB}) \leq 10$ dB.
7. If $S(\text{dB}) > 10$ dB, then increase the meter sensitivity 10 dB (clockwise one notch) with the range switch. Read $S(\text{dB})$ and add 10 dB to your reading.
8. If $S(\text{dB}) > 20$ dB, then increase the range by 20 dB, read $S(\text{dB})$ and add 20 dB, etc.

Procedure: Set the RF signal generator to a frequency $f = 750$ MHz, 100% modulation at 1000 Hz, and 10 dBm (decibels above one milliwatt) output power. Connect the short circuit to the termination point.

1. Determine the wavelength λ along the line by measuring the distance between the two successive voltage minima locations z_1 and z_2 nearest the termination. Compare λ with the free space wavelength c/f , where $c = 3 \times 10^8$ m/s.

$$z_1 = \text{_____ cm.} \quad z_2 = \text{_____ cm.}$$

$$\lambda = \text{_____ cm.} \quad c/f = \text{_____ cm.}$$

2. Determine (as best you can) the voltage standing wave ratio for the short circuit. Compare to the theoretical value $V_- = -V_+$.

$$S = \text{_____} . \quad S(\text{dB}) = \text{_____ dB.}$$

$$S(\text{theory}) = \text{_____} . \quad S(\text{theory, dB}) = \text{_____ dB.}$$

3. Repeat parts 1 and 2, connecting the 25Ω resistor to the termination point. The theoretical value is found using $V_- = -V_+/3$.

$$\lambda = \text{_____ cm.}$$

$$S = \text{_____} . \quad S(\text{dB}) = \text{_____ dB.}$$

$$S(\text{theory}) = \text{_____} . \quad S(\text{theory, dB}) = \text{_____ dB.}$$

4. Repeat part 2 only, connecting the 50Ω resistor to the termination point. In this case, $V_- = 0$ (no reflected wave), which is generally desired in a microwave transmission system.