Karadeniz Technical University
Faculty of Engineering
Department of Electrical and Electronics Engineering
Microwave Laboratory

MICROWAVE POWER MEASUREMENT

Preliminary Information :

At microwave frequencies, it is generally not feasible to measure voltage and current directly. Therefore, indirect methods are used for power measurement. In this experiment, a microwave power bridge will be used.

When microwave energy is absorbed by a material, it is converted into heat, causing a temperature increase. If the material has a physical property that changes with temperature, this change can be used to measure the microwave power.

A "bolometer" is an element used for this purpose, utilizing the change in resistance with temperature. The two common types of bolometers are the "barretter," which is a thin metallic film, and the "thermistor," which is a piece of semiconductor material. The thermistor is more robust and sensitive than the barretter, but its resistance change with temperature is non-linear (Figure 1).

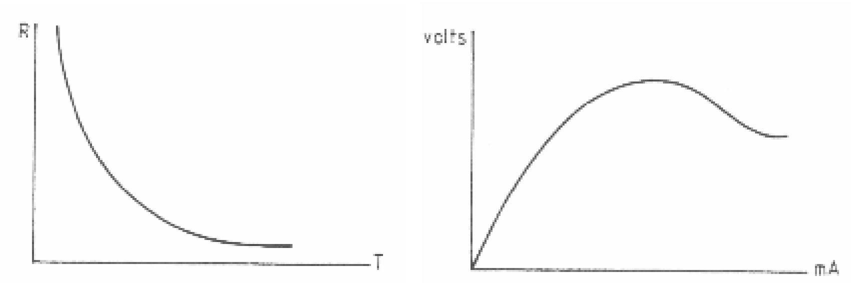

Figure 1: (a) Resistance-temperature and (b) voltage-current characteristics of a thermistor

The circuit used for power measurement is a bridge, as shown in Figure 2. The bolometer is placed in one arm of a Wheatstone bridge. Before applying microwave power, the bridge is balanced with a bias signal. When microwave power is applied to the bolometer, the bridge becomes unbalanced (as the bolometer heats up, its resistance decreases). To re-balance the bridge, the bias signal is reduced. The amount of reduced bias power is equal to the applied microwave power.

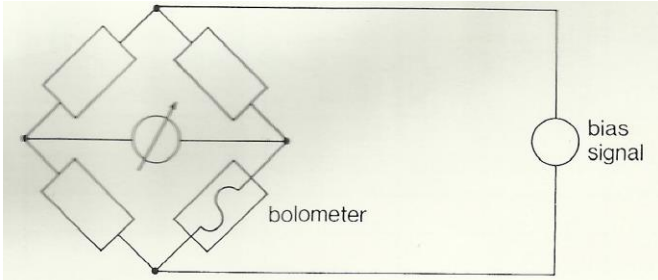

Figure 2: A simple power bridge circuit with a bolometer

Two concepts frequently used in describing system and component characteristics are "average power" and "peak power." The power of an unmodulated sine wave (continuous-wave, CW) from a microwave signal generator is P_o (Figure 3a). If this signal is periodically switched, a pulsed signal is obtained (Figure 3b). The power measured during the pulse duration is called the peak power and is equal to the continuous-wave power P_o. The power averaged over the modulation period T is the average power.

$$P_{average} = P_{peak} \cdot \frac{\tau}{T}$$

Here, 1/T is the pulse repetition frequency.

$\frac{\tau}{T}$: Pulse duration-to-period rate

For example, if a Klystron microwave power source has a peak power of 10 kW with a pulse duration of 0.2μs and a pulse repetition frequency of 1000 Hz, the average power is:

$$P_{average} = 10.10^3 . \frac{0,2.10^{-6}}{1/1000} = 2\ \mathrm{W}$$

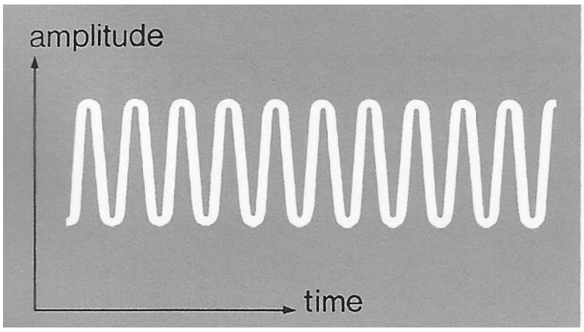

Figure 3a: Continuous-wave (CW) signal

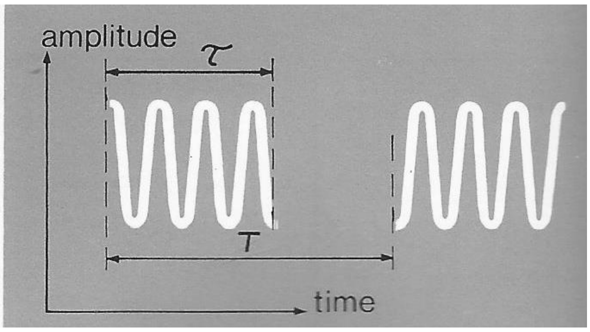

Figure 3b: Pulsed signal

The PM7841 model power meter to be used in this experiment is a self-balancing bridge. The bias signal is both a DC signal and a 15 kHz low-frequency (LF) signal (Figure 4).

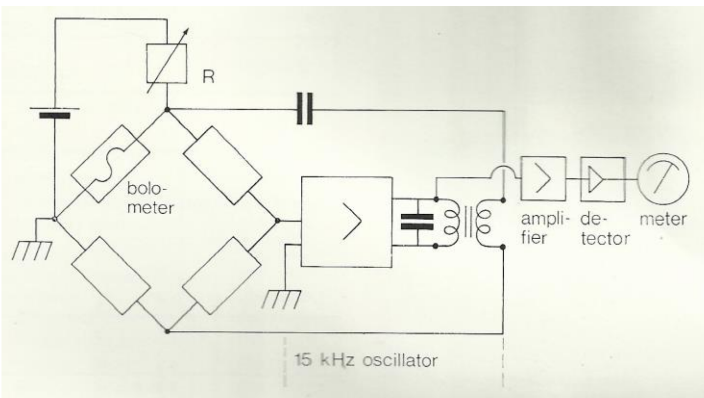

Figure 4: Simplified diagram of the PM7841 power meter

The bridge is zeroed with the DC bias using the variable resistor R. When the power meter is zeroed, the applied LF power is 1.2 times the power indicated by the full-scale deflection. For example, if the power meter is zeroed on the 1 mW (0 dBm) range, the applied LF power is 1.2 mW. When the power meter reads 1 mW, the amount of reduced LF power is 1 mW, and the remaining LF power is 0.2 mW. The factor of 1.2 is chosen to ensure that the balancing circuits operate at a suitable power level.

The PM7841 power meter can be used with both negative temperature coefficient bolometers (thermistors) and positive temperature coefficient bolometers (barretters). The PM7201X model thermistor element to be used in the experiment is in a tunable waveguide structure. When making measurements, this element must be tuned for very low reflection. Otherwise, the reflected power will affect the accuracy of the measurement.

Experimental Procedure:

1 General Procedures

1.1 Set up the experimental apparatus as shown in Figure 5. (Do not turn on the microwave oscillator's power supply yet).

1.2 Since the thermistor in the PM7201X has a negative temperature coefficient, set the switch on the back of the power meter to the "NEG" position.

1.3 Select the "100 Ω" resistance value position on the back of the power meter.

1.4 Press the 1 mW button on the power meter.

1.5 Using the coaxial T-connector and cables, connect the power meter and oscilloscope to the thermistor mount and turn them both on. Set the oscilloscope to horizontal: 50 µs/div, vertical: 0.2 V/div.

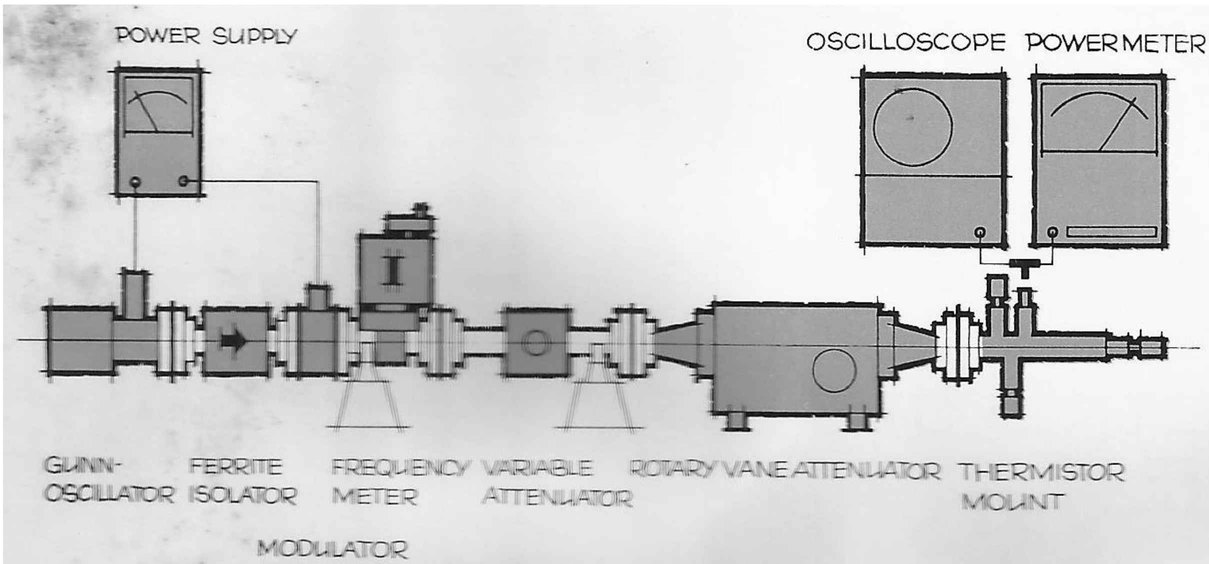

Figure 5: Experimental setup for microwave power measurement

2. LF and Microwave CW Power

2.1 Zero the power meter using the "coarse" and "fine" knobs on the front.
2.2 When the power meter reads zero, read the peak-to-peak voltage from the oscilloscope and record it in Table 1.
2.3 Calculate the RMS value of the voltage using the formula $V_{rms}=V_{p-p}/2\sqrt{2}$ and record it in Table 1.
2.4 Calculate the LF power in the thermistor using the formula $P_{LF}=V^2_{rms}/100$ and record it in Table 1.
2.5 Compare this with the theoretical value of 1.2 x 1 mW.
2.6 Set the variable attenuator's attenuation to approximately 10 dB and the rotary vane attenuator's attenuation to 0 dB.
2.7 Turn on the oscillator's power supply (set its voltage to -8.5 V) and adjust its frequency to approximately 9 GHz.
2.8 Observing the power meter, adjust the variable attenuator to obtain a deflection.
2.9 Tuning the thermistor mount for minimum reflection: First, pull the two side arms (looking up and down) outwards. Move the end piston to a position that gives the maximum deflection on the power meter. Slowly push the two side arms inwards to maximize the deflection and readjust the piston. When the maximum deflection is achieved, the power reflected by the thermistor element is at its minimum.
2.10 Adjust the variable attenuator to read 1 mW on the power meter.
2.11 Increase the oscilloscope's sensitivity and read the peak-to-peak voltage, recording it in Table 1.
2.12 Calculate the LF power as in steps 2.3-2.4 and record it in Table 1.
2.13 Compare the result with the theoretical value of (1.2 - 1) mW = 0.2 mW.

Table 1: LF and Microwave CW Power

Powermeter Deviation	V_{p-p}	V_{rms}	P_{LF}
0 mW			
1 mW			

3. Modulated Signal

3.1 Turn off the oscillator's power supply or increase the variable attenuator's setting to a value like 60 dB. Check that the power meter reads zero; readjust if necessary.
3.2 Turn on the oscillator's power supply or adjust the attenuation to obtain a 1 mW reading on the power meter. Record this value in Table 2.
3.3 Modulate the microwave signal with a 1 kHz square wave. To do this, connect the 1 kHz square wave generator on the bench to the modulator with a coaxial cable and turn it on.
3.4 Read the deflection on the power meter and record it in Table 2.
3.5 Calculate the theoretical value and record it in Table 2. Compare this result with the result from step 3.4 (Assume the duty cycle of the square wave signal is 50%. You can determine this ratio by connecting the square wave generator to the oscilloscope).

Table 2: Modulated Signal

Reading from Power Meter		Calculated Square Wave Power
CW-Signal	Square Wave Signal	