ECE 435

Microwave Cavity Measurement

Latest revision: November 1999

Introduction

The basic objectives of this experiment are to make the following measurements and observations regarding the characteristics of microwave cavities:

1. Become familiar with techniques for measuring the resonant frequency and Q of a microwave cavity; in particular, the TM_{010} and TE_{111} circular cylinder cavity modes as well as the TE_{10p} rectangular cavity modes.
2. Observe the dependence of the cavity resonant frequency and Q upon the size, shape, mode type, wall conductor, and dielectric loading of the cavity resonator.
3. Measure the complex microwave permittivity (dielectric constant) of a dielectric material by using cavity perturbation techniques.
4. Observe the effect of cavity coupling on the shape of the cavity Q-curve and the resonant frequency of the microwave cavity.

The cavities to be studied in this experiment have resonant frequencies in the X-band (8.2 – 12.4 GHz) microwave frequency range.

The theoretical Q for TM_{010} cavity is given by

$$Q = \frac{\lambda}{\delta}\frac{2.405}{2\pi(1 + a/d)}$$

where δ is the skin depth of the cavity walls, λ is the wavelength in the cavity, a is the radius of the cavity, and d is the height of the cavity.

The complex permittivity of a dielectric rod can be determined by measuring the resonant frequency and cavity Q for the cases of no rod (unperturbed case) and with the rod fully inserted into the cavity (perturbed case). The equations relating the real part (ε') and imaginary part (ε'') of the complex permittivity are

$$\frac{\omega - \omega_0}{\omega_0} = -\frac{(\varepsilon' - 1)}{2}\left(\frac{b}{a}\right)^2\left[\frac{J_0^2(2.405b/a) + J_1^2(2.405b/a)}{J_1^2(2.405)}\right]$$

$$\frac{1}{Q} - \frac{1}{Q_0} = \varepsilon''\left(\frac{b}{a}\right)^2\left[\frac{J_0^2(2.405b/a) + J_1^2(2.405b/a)}{J_1^2(2.405)}\right]$$

where ω_0 and Q_0 are the values for the unperturbed case.

Procedure

1. Connect the HP8620C Sweep Oscillator, the Digitizing Oscilloscope, and the TM_{101} cavity (drum cavity) as shown in Figure 1. Set the Sweep Oscillator to sweep between 9.2 and 9.4 GHz.
2. Tune the detector for maximum output (e.g. set the standing wave in the shorted cavity so that the peak is at the detector).
3. Using the cavity data (a = 1.23 cm, air-filled), show that the theoretical resonant frequency is 9.3 GHz. Note that the actual measured frequency is slightly lower due the skin effect and the holes in the cavity walls.
4. Adjust the sweep oscillator frequency range so that only one cavity Q curve is displayed on the oscilloscope.
5. Using the cavity wavemeter, measure the resonant frequency and Q of the empty cavity where $Q = f_0 / B$ and B is the 3-dB bandwidth of the Q-curve. Use the program Progs/BenchLink program to capture the oscilloscope display and print it.
6. The cavity wavemeter is a resonant cavity connected to the X-band waveguide. The mode of oscillation utilized is the TE_{111} mode. Use the wavemeter pip to determine the resonant frequency and bandwidth of the Q-curve. Read the frequency from the wavemeter.
7. Insert a pyrex glass rod into the cavity parallel to its axis. Be very careful, since the rod will break quite easily. Locate the new resonant frequency (somewhere around 8.8 GHz) and measure its frequency and the Q of the loaded cavity.
8. Construct an aperture-coupled TE_{10p} mode rectangular cavity by connecting an adjustable short-circuit to the directional coupler with one of the brass circular aperture plates (the one marked 5 mm) placed between the short and the coupler connecting flanges. You now have formed a rectangular cavity of adjustable length. Adjust the Sweep Oscillator frequency to 9.5 GHz and vary the length of the cavity until the resonance is observed on the oscilloscope. Adjust the cavity attached to the detector to again establish a standing wave peak at the detector location. Which TE_{10p} mode are you observing? Print the Q-curve.
9. Insert various apertures and print the oscilloscope display of the resulting cavity Q-curve.

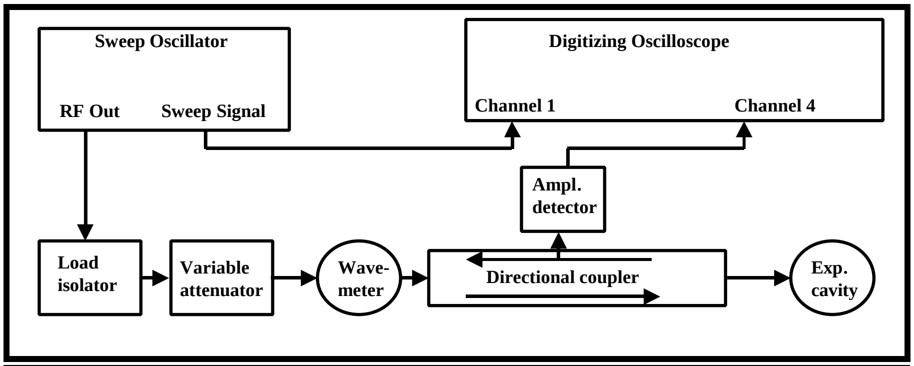

Figure 1. Experimental setup.

Report

In you report, you should minimally address the following questions.

1. Compare the theoretical Q to the measured Q.
2. Calculate the complex permittivity of the pyrex glass rod based on the unperturbed and perturbed resonant frequency and Q measurements. Note, a very careful measurement of the rod diameter is important for reasonable and accurate results. A small error in this dimension greatly alters the results obtained. Also note the conductivity of brass us 1.57 $x10^7$ mhos/meter.
3. Why does the insertion of a glass rod perturb the cavity's resonant frequency and Q?
4. What is the Q of the rectangular cavities with the 2.5mm, 5.0mm, and 10mm feed apertures?
5. Why does the feed aperture diameter affect the performance of the cavity?