MEASUREMENT OF TRANSMISSION CAVITY QUALITY FACTORS

Frank M. Palka
Sperry Electronic Tube Division
Gainesville, Florida 32601

J. Robert Ashley
University of Colorado
Colorado Springs, Colorado 80907

Abstract

The high internal Q and the presence of two coupling ports greatly complicate the accurate determination of the Q and coupling factors for the transmission cavities used in the stabilization of microwave oscillators. Most signal sources used in microwave measurements do not have sufficient carrier stability to allow VSWR measurements on resonators with Q's greater than 10,000 and a dynamic or sweeping method is required. This paper uses a method based on readily available sweep oscillators. A system for proper termination of the "unused" port is described. The most significant advantage of the method is the small amount of time required to take and process the data.

Introduction

The transmission cavity (Fig. 1) used for the stabilization of microwave oscillators[1] is usually a TE_{01n} right circular cylindrical resonator with n ranging from 1 to 5 and the unloaded Q from 10,000 to 50,000. This high Q_0 and approximately critical coupling makes the measurement of quality and coupling factors by slotted lines very difficult unless an unusually stable signal source is used and a power meter used as a standing wave indicator. We have expanded a method previously given for one-port resonators[2] to quickly and accurately measure these high Q two-port resonators.

Definitions

The usual definitions[3] applied to a two-port cavity are:

Q_0 = unloaded Q of cavity

Q_{E1} = external Q of input circuit

Q_{E2} = external Q of output circuit

Q_{L1} = loaded Q of input circuit = $\dfrac{Q_0 Q_{E1}}{Q_0 + Q_{E1}}$

Q_{L2} = loaded Q of output circuit = $\dfrac{Q_0 Q_{E2}}{Q_0 + Q_{E2}}$

Q_{L12} = total loaded Q, losses in cavity, input circuit, and output circuit

Also

$\beta_1 = \dfrac{Q_0}{Q_{E1}}$ = standing wave ratio σ at resonance looking into input coupling with load disconnected from output circuit if $\beta_1 > 1$; otherwise $\sigma = 1/\beta_1$

$\beta_2 = \dfrac{Q_0}{Q_{E2}}$

$\gamma_1 = \dfrac{Q_{L2}}{Q_{E1}}$ = σ at resonance looking into input coupling with matched load connected to output circuit if $\gamma_1 > 1$; otherwise $\sigma = 1/\gamma_1$

$\gamma_1 = \dfrac{\beta_1}{1 + \beta_2}$

$\gamma_2 = \dfrac{Q_{L1}}{Q_{E2}}$

$\gamma_2 = \dfrac{\beta_2}{1 + \beta_1}$

where we have designated port 1 as the oscillator side of the resonator and port 2 as the output side. The coupling factors are typically $0.3 < \beta_2 < 0.7$ and $1.3 < \beta_1 < 1.7$.

Measurement Procedure

For our example, a TE_{015} stabilizing cavity is used to demonstrate the measurement procedure. For this cavity, the procedure is to first measure the output port (No. 2) with the input port terminated with a sliding short. The short is adjusted until the reflection at resonance is minimized. This position means that the losses at port 1 are nearly zero and for this condition β_2 and Q_0 are measured.

The microwave system of Fig. 2 is used on each port for measuring quality and coupling factors. The procedure for the output port 2 is:

1. The swept frequency signal generator is adjusted to sweep through resonance and far enough on each side to view the region where the reflection from the resonator is complete. If the resonator Q_0 is expected to be high (>5000) then the sweep rate should be slowed by a factor of 2 while carefully observing the trace. If the "depth of the dip" noticeably changed, the sweep rate is too high and must be lowered. If the trace did not change, the sweep can be set back at the higher rate to facilitate viewing the display. Then slide screw tuner No. 1 is adjusted so that the

incident wave signal shows no small dips or peaks near the test resonance.

2. Set the precision attenuator to zero and detune the wavemeter. Then adjust the incident wave attenuator to make the reference line go through the bottom of the resonator dip. (See Fig. 3a.)

3. Detune the test resonator and adjust the precision attenuator until the line from the reflected channel coincides with the line from the incident channel. This is a measurement of the reflection coefficient at resonance. Record the setting of the precision attenuator (2.7 dB for the example) and use this value with Fig. 4 to obtain another setting of the attenuator (1.1 dB) which will determine the half power bandwidth of the resonator.

4. Set the precision attenuator to this new attenuation value and adjust the forward wave channel reference line to coincide.

5. Retune the precision attenuator to zero dB and retune the test resonator. Measure the bandwidth f_1-f_2 of the resonator as shown in Fig. 3b. We have used the Δf calibration of the sweeper to calibrate the horizontal axis of the scope trace in MHz/cm (0.2 MHz/cm for this example). A simple measurement of length then gives f_2-f_1. For our example:

$$\Delta f = 0.2 \text{ MHz/cm} \times 1.05 \text{ cm} = 0.21 \text{ MHz}$$

Now calculate:

$$Q_L = \frac{f_o}{\Delta f} = \frac{9438}{0.21} = 45{,}000$$

6. Adjust the position and insertion of slide screw tuner No. 2 to make the cavity appear to be critically coupled; e.g., to minimize the signal reflected from the cavity at resonance. With the reference line at the same position as in step 4, measure the bandwidth again. (All we need here is to determine if bandwidth increased or decreased in comparison to that measured in step 5.) If the bandwidth increased, the resonator is undercoupled ($\beta < 1$).

In Fig. 3c, we see that the bandwidth increased and the resonator is undercoupled. From Fig. 4, $\beta = 0.17$, and

$$Q_o = (\beta + 1)\, Q_L = 52{,}600$$

$$Q_{ex} = \frac{Q_o}{\beta} = 310{,}000$$

The cavity is then reversed to measure the unknown coupling at port 1. Usually, it is more convenient to put a matched termination on port 2 and obtain the coupling factor γ_1 which is close to unity.

For the cavity of our example, Fig. 3d shows a bandwidth of 0.4 MHz which leads to a measured $Q_L = 23{,}600$, $\gamma_1 = 1.0$, $\beta_1 = (1 + \beta_2)\gamma_1 = 1.17$ and $Q_o = 51{,}200$.

Conclusion

The advantages of this procedure are the short data processing time and adequate accuracy. The measured cavity Q and measured[4] oscillator Q_x give excellent prediction of stabilizing factors.

References

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[2] Ashley, J. R. and Palka, F. M., "Reflection Coefficient Measurement of Microwave Resonator Q Factors," Microwave Journal, June 1971.

[3] Moreno, Theodore, Microwave Transmission Design Data, Dover, N.Y., 1948.

[4] Ashley, J. R. and Palka, F. M., "A Modulation Method for the Measurement of Microwave Oscillator Q," IEEE Trans. MTT, Vol. MTT-18, No. 11, pp. 1002-1004, Nov. 1970.

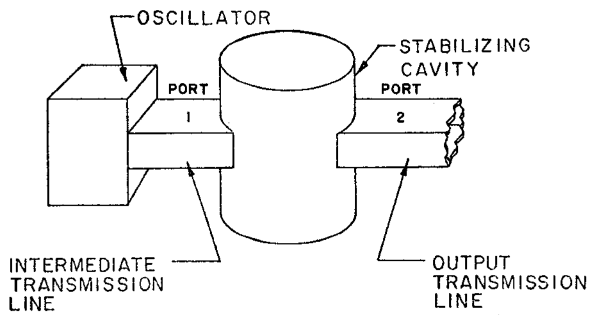


FIG. 1. Cavity Stabilized Oscillator System

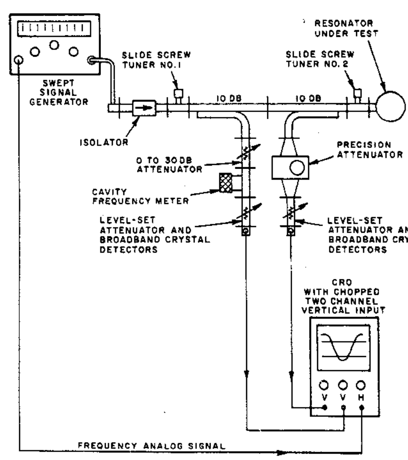
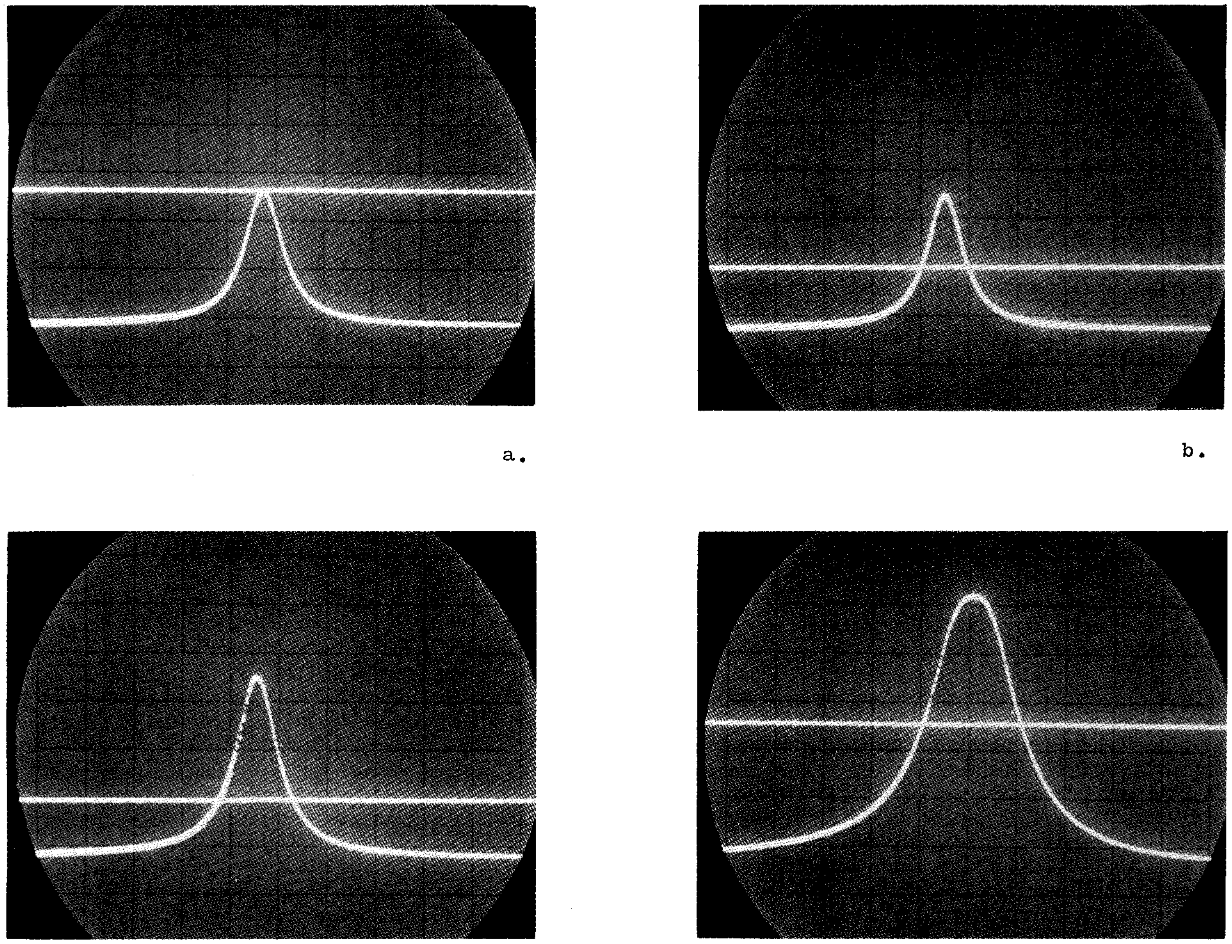


FIG. 2. Equipment Arrangement for Q Measurement



a. b. c. d.

FIG. 3. Oscilloscope Presentation of Q Data

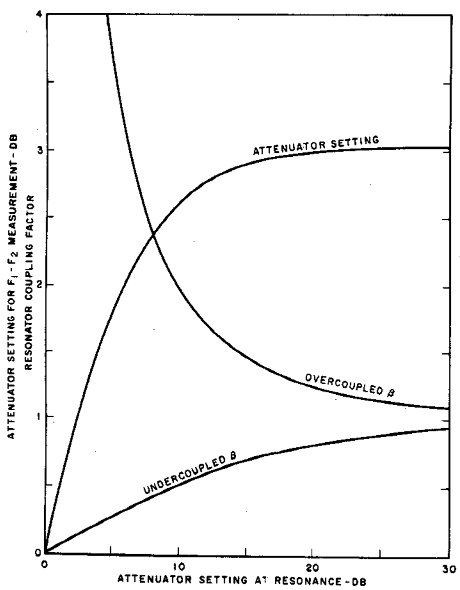


FIG. 4. Plot of Undercoupled and Overcoupled Beta, and Attenuator Setting vs. Attenuator Setting at Resonance