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Comparison Decrement Method for Microwave Resonator Q Measurements

IVAN KNEPPO

***Abstract*—The sensitivity of resonator quality-factor measurements using the decrement method can be improved by the comparison of the decay curve of a measured resonator with that of a reference standard resonator. The decay curves are compared using the integral of the function given as difference between decay curves. The comparison method, to be proposed, also has the advantage that the calibration of neither time base nor power scale is needed. Some results of the experimental verification are presented.**

I. INTRODUCTION

The decrement method of measuring Q of a microwave resonator is a well-known and useful measuring method, especially if the resonator quality is high. Accuracy can be quite high, 0.5 percent [1]. However, in such a case when a small change of Q ought to be measured, e.g., cavity perturbation measurements of small loss tangents, or loss tangents smaller than the uncertainty due to the inaccuracy of the measurement method, the obtained results are neither reproducible nor satisfactory.

One way to enhance the sensitivity of the decrement-measuring set to the change of measured variables is to compare the decay curve of the measured resonator with that of a calibrated reference standard resonator.

II. THEORY

The method, to be proposed, is based on processing the difference between the square-law detector output voltages of the reference resonator

$$u_R(t)=\beta_R P_{OR}\exp(-\omega_{OR}t/Q_{LR}) \tag{1}$$

and that of the measured resonator

$$u_M(t)=\beta_M P_{OM}\exp(-\omega_{0M}t/Q_{LM}) \tag{2}$$

i.e.,

$$u_D(t)=u_M(t)-u_R(t). \tag{3}$$

If both microwave detectors are paired $\beta_M=\beta_R$, and the initial values of the resonator's output power and resonant frequencies are equal, $P_{OM}=P_{OR}$ and $\omega_{OM}=\omega_{OR}$, respectively, then, consequently, $u_D(t)$ has the form

$$u_D(t)=\beta_R P_{OR}[\exp(-\omega_{OR}t/Q_{LM})-\exp(-\omega_{OR}t/Q_{LR})] \tag{4}$$

where Q_{LM} and Q_{LR} are the loaded Q's of the measured and reference resonator, respectively. Integrating $u_D(t)$ and $u_R(t)$ over interval $\langle 0,\infty)$ we obtain

$$\iota_D=\int_0^\infty u_D(t)\,dt=\beta_R P_{OR}(Q_{LM}-Q_{LR})/\omega_{OR} \tag{5}$$

$$\iota_R=\int_0^\infty u_R(t)\,dt=\beta_R P_{OR}Q_{LR}/\omega_{OR}. \tag{6}$$

Dividing (5) by (6) we obtain the final expression

$$\iota_D/\iota_R=(Q_{LM}-Q_{LR})/Q_{LR} \tag{7}$$

which is very convenient for computing the unknown Q_{LM} on the basis of measured ratio ι_D/ι_R and previously known Q_{LR}.

III. PROCEDURE

The arrangement for measuring Q by comparison of decay curves is shown in Fig. 1. Microwave power from the pulse modulated source is divided into two equal portions, one for measured and one for reference resonator energization. Output voltages from detectors are fed to the inputs of the differential preamplifier of the sampling oscilloscope. The measurement is initiated with tuning the reference resonator onto the frequency of the microwave generator output, and recording the resonator decay power curve $u_R(t)$. The variable attenuator inserted into reference tract and the differential preamplifier gain are set in such a manner that the record optimally covers the whole area of the CRT screen and the value A_1 of the preamplifier gain is recorded. Secondly, the measured resonator is also tuned to the generator wave frequency as indicated by the lowering of the transient response, and the attenuator in the measuring tract is set to zeroing the transient response at $t=0$. The final $u_D(t)$ is recorded and the gain of the differential preamplifier should be increased to the value A_2 in order to obtain a good resolvable record again. The measurement process is completed by the measurement of the area under $u_R(t)$ and $u_D(t)$ with the use of a polar planimeter and computing Q_{LM} according to the formula

$$Q_{LM}=Q_{LR}[1+\iota_D/(K\iota_R)] \tag{8}$$

where $K=A_2/A_1$. In practice, we integrate over a finite interval instead of the theoretically assumed $\langle 0,\infty)$, requiring that the

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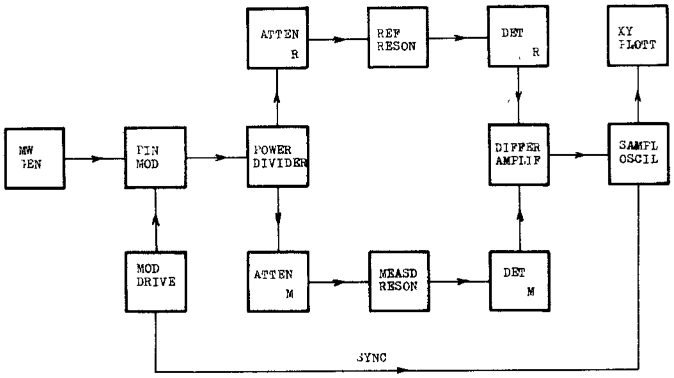

Fig. 1. Arrangement for the comparison decrement measuring of Q.

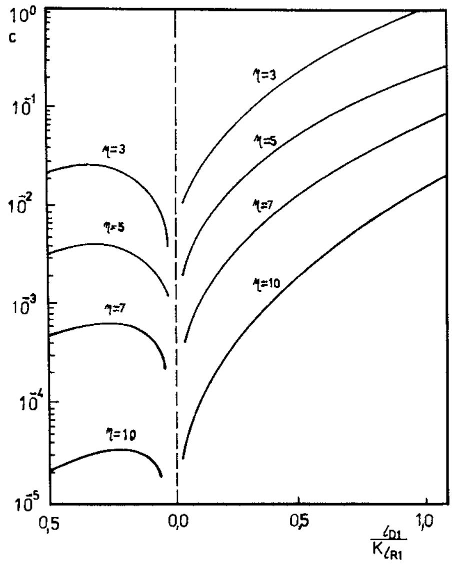

Fig. 2. Correction factor c as a function of $\iota_{D1}/(K\iota_{R1})$ Parameter $\eta = t_1\omega_{OR}/Q_{LR}$. For $\iota_{D1}/(K\iota_{R1}) < 0$, the correction factor is negative.

resulting error be eliminated using the corrected formula

$$Q_{LM} = Q_{LR}[1 + \iota_{D1}/(K\iota_{R1}) + c] \quad (9)$$

instead of (8). The index 1 is used to indicate integration over the finite interval $\langle 0, t_1 \rangle$ and c is the correction factor (see Fig. 2). The correction is negligible for large integration intervals

$$t_1 > 7Q_{LR}/\omega_{OR}$$

and small differences in resonators Q's

$$-0.5 < \iota_{D1}/(K\iota_{R1}) < +0.3.$$

If the integration interval is small

$$t_1 < 5Q_{LR}/\omega_{OR}$$

it is better to calculate Q_{LM} solving equation

$$Q_{LM}[1 - \exp(-\eta Q_{LR}/Q_{LM})] - Q_{LR}[1 + \iota_{D1}/(K\iota_{R1})][1 - \exp(-\eta)] = 0$$

where

$$\eta = t_1\omega_{OR}/Q_{LR}.$$

IV. Results

The described method was verified experimentally and the Q_L of three microwave-cavity X-band resonators was measured. The obtained results show a good reproducibility of better than 0.2 percent (see Table I), and high sensitivity of the comparison measuring set to change of Q_{LM}. The accuracy of measuring the value of Q_{LM} is limited by the accuracy of the reference resonator calibration, however, and is by no means as good as the reproducibility. The proposed method is advantageous even in such cases when a small change of Q is to be measured rather than its value.

TABLE I
Measured Values of Q of X-Band Cavity Resonators

Q_{LR} = 12 375 ±691† η = 3

RES No	$\frac{\iota_{D1}}{K\iota_{R1}}$	Q_{LM1} *	Q_{LM} **	Q_{LA} ***
0161	0,20338 ±0,00211	14 892 ±26	15 592 ±36	15 202 ±397
0335	0,23840 ±0,00260	15 325 ±32	16 200 ±45	16 565 ±943
EX 3	-0,34972 ±0, 00112	8 047 ±14	7 709 ±13	7 849 ±348

* from equation /8/, assuming finite interval $\langle 0, t_1 \rangle$
** from eq. /10/
*** measured by the absolute decrement method
† standard deviation of Q_{LR} is not included in the Q_{LM1} and Q_{LM} deviations

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A 94-GHz Diode-Based Single Six-Port Reflectometer

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Abstract—**This paper describes design considerations and gives measurement results for a single six-port reflectometer constructed from WR-10 waveguide with silicon Schottky diode detectors. Tradeoffs between various types of power detectors are discussed along with criteria for six-port junction design. The merits of two calibration procedures are compared. Measurements at 94 GHz indicate good agreement between expected and experimental values of q-points and of a sliding mismatch with nominal 0.1 reflection coefficient.**

I. Introduction

Recently there has been a renewed interest in 94-GHz radar systems because of their combined advantages of small size, high resolution, and all weather visibility. If these systems are to satisfactorily progress from paper design to production, there must also be a parallel development of fast and accurate measurements. The natural trend has been to evolve millimeter-wave

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