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A COMPUTER AIDED ACCURATE ADJUSTMENT OF CELLULAR RADIO RF FILTERS

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ABSTRACT

An accurate and speedy tuning algorithm of cellular radio filters is presented. From measured performance, a computer instructs you how much to trim the dielectric resonators. To reduce the optimization error and secure the good convergence, analytical considerations are taken to derive the proper expression of a resonator equivalent circuit. By using this method, it took a beginner only 5 minutes to adjust a five-resonator-filter.

INTRODUCTION

Recently, cellular radio communication has become popular, and the number of mobile stations is increasing rapidly. In these equipment, dielectric resonator filters are widely used. And the adjustment of the filter requires intensive know-how so that only an expert can tune it.

This report describes a computer aided adjustment method which gives you the information about which resonator and how much to trim. In previous papers, Atia and Williams described a measurement procedure of couplings between electrical cavities[1] and Williams et al. extended their work to an automatic measurement technique with a desk-top computer[2]. However, they do not give the information about resonance frequency of each resonator which is most important for adjustment. In their procedures, prior to the measurement of coupling parameters, each resonator has to be tuned step by step keeping all yet untuned resonators shorted.

Since the filter performance follows a complex function of a lot of parameter values which are difficult to be estimated accurately by experiments, computer aided tuning has seemed to be not accurate enough to be used practically. So far, little has been reported on this subject.

In this method, different from [2], the conventional equivalent circuit is used, and the resonance frequencies of resonators can be obtained in the tuning process. The influence with parameter estimation errors were examined by computer simulation.

TUNING ALGORITHM

Tuning is done by the following steps.

step 1: Measure the performance of the filter under tuning.

step 2: Evaluate the parameters in the equivalent circuit by optimization procedure.

step 3: Compare the parameters with required ones to obtain the discrepancy for trimming information.

step 4: Trim the resonators to adjust the resonance frequencies.

step 5: Repeat the procedure from step 1 to step 4, for fine tuning.

To obtain the element values in the equivalent circuit of Fig.1, optimization technique modified from the Razor

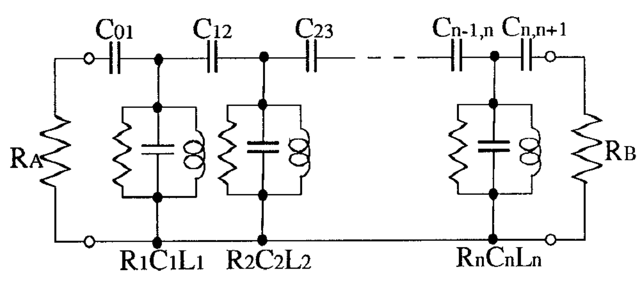

Fig.1. Equivalent circuit of the filter

Search[3] is used. In the optimization process, the objective function H is defined as

$$H = \Sigma|S11_m - S11_e| + \Sigma|S21_m - S21_e| \qquad (1)$$

where S11 and S21 are the S-parameters, and subscripts m and e refer to those measured and estimated in the equivalent circuit. The objective function is the function of resonator resonance frequencies and coupling capacitances. The summation is taken at the specified several frequencies. The number of frequencies is chosen to be large enough so that the objective function should avoid a local minima and the parameters obtained are well-converged. Furthermore, the number and the spacing of the frequencies can be determined after some trials depending on the structure of the filter.

In order to reduce computing time, optimization process has short-cut routine. Practically, at a manufacturing site, only frequency adjustment of resonators might be needed. In this case, all parameters are evaluated at the first optimization, and for the second optimization, only the resonance frequencies are changed keeping all other structural parameters unchanged.

RESONANT CIRCUIT SYNTHESIS

In the structural parameter finding process, admittance slope parameters and Q factors of resonators must be given as fixed values. So, before running the tuning algorithm, those values in Fig.2 are determined by measurements.

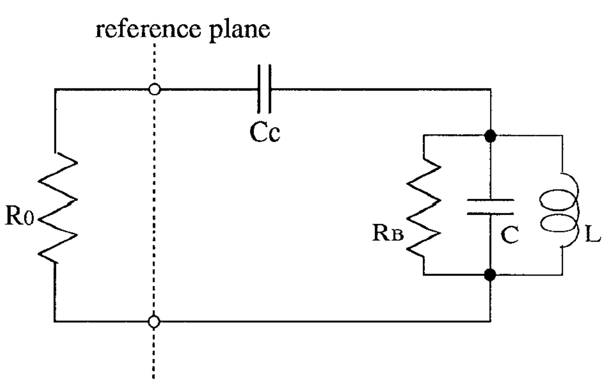

Fig.2. Equivalent expression of a resonator

However, since there is no good way to put hypothetical reference plane at the right place, it is difficult to get accurate values of admittance slope parameter by the method reported previously[4]. Now a new measurement idea will be discussed by analyzing the circuit.

The input impedance Z of the resonant circuit in Fig.2 is given by

$$\mathrm{Real}\,(Z) = \frac{\frac{1}{R_B}}{\left(\frac{1}{R_B}\right)^2 + \left(\omega C - \frac{1}{\omega L}\right)^2} \qquad (2)$$

$$\mathrm{Imag}\,(Z) = -\frac{\left(\omega C - \frac{1}{\omega L}\right)}{\left(\frac{1}{R_B}\right)^2 + \left(\omega C - \frac{1}{\omega L}\right)^2} - \frac{1}{\omega C_c}. \qquad (3)$$

From (2) and (3), admittance slope parameter can be calculated, only if the reference plane is correctly placed.

Fig.3 shows the calculated results of admittance slope parameter variation in terms of the relative position of reference plane. A slope parameter is calculated from measured impedance of a resonator. Each curve corresponds to the calculated value with a different coupling capacitance. Because these curves are measured for the identical resonator, the cross point gives the exact value for the admittance slope parameter, and at the same time the exact position of the reference plane is determined from the information of a network analyzer readout.

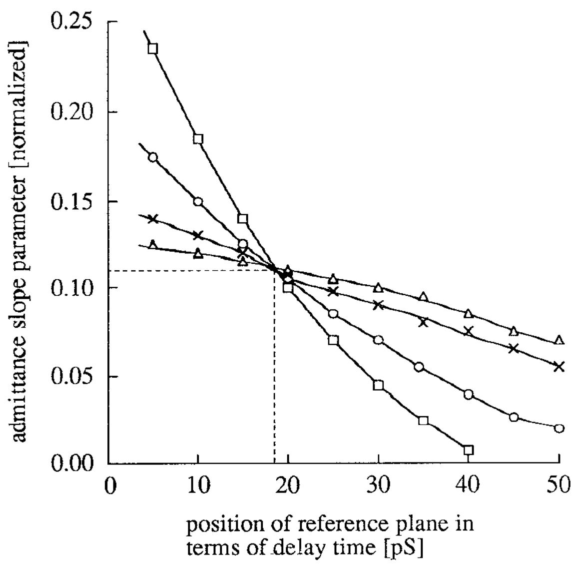

Fig.3. Calculated results of admittance slope parameter variation

ERROR ESTIMATION

The values of admittance slope parameters and Q factors, which are used to calculate $S11_e$ and $S21_e$ in (1), are obtained by the foregoing measurement of the resonant circuit. The results of the optimization in the tuning step would include some error, because those values are fixed and a slightly different from the true ones due to the measurement error. By computer simulation, the influence of these discrepancies are examined for admittance slope parameters of ±1% and ±5% measurement error and for Q factors of ±10% and ±20% measurement error, respectively. All the calculations were executed for the cases of combinations of ±1% offset of resonance frequency. For a five-resonator-filter, simulation results show that 5% error of the admittance slope parameter or 20% error of the Q factor causes maximum 0.05% error of the frequency estimation and 6% error of the capacitance estimation. Those accuracies are enough for practical use.

EXPERIMENTAL RESULTS

Experimental results demonstrate the excellent performance of the procedure presented here. The filter used in this experiment consists of five short-circuited quarter-wavelength dielectric resonators with printed coupling capacitances. Fig.4 shows the performance of the filter before tuning. Fig.5 shows the message from a computer which gives you the instruction of how much to trim the resonator. Trimming information is shown as normalized frequencies. Following the instruction, we

first step
f(1) :f(2) :f(3) :f(4) :f(5)
1.016 1.003 0.995 1.005 1.003

next step ?
f(1) :f(2) :f(3) :f(4) :f(5)
0.999 1.001 0.999 1.001 1.003

next step ?
f(1) :f(2) :f(3) :f(4) :f(5)
0.999 1.000 0.999 1.000 1.001

next step ?
f(1) :f(2) :f(3) :f(4) :f(5)
1.000 1.000 1.000 1.000 1.000

Fig.5. Tuning instruction from a computer

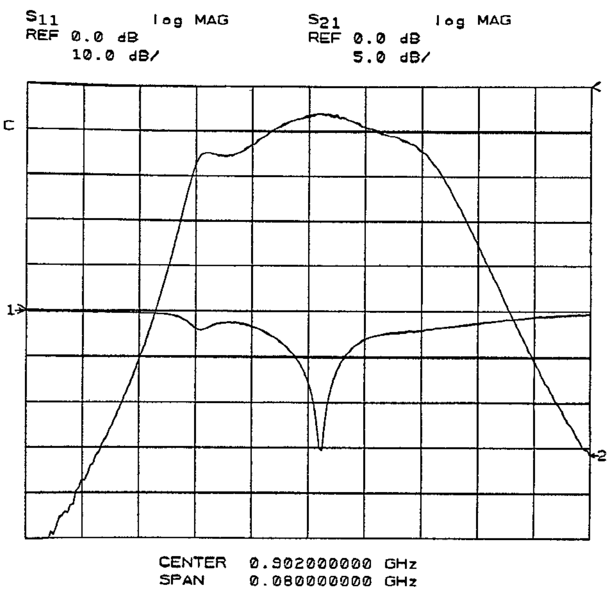

Fig.4. Performance of the filter before tuning

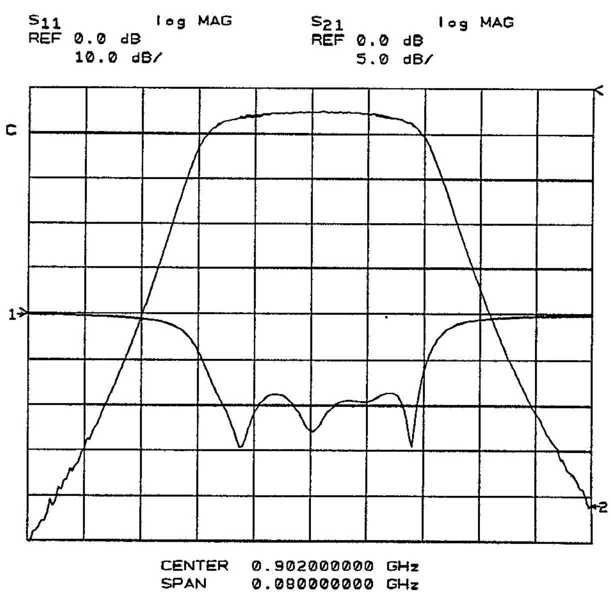

Fig.6. Final performance of the filter

trimmed the resonators until all the resonance frequencies become equal to desired ones. By this method, it is possible to tune all the resonators at the same consecutive period. Fig.6 shows the final performance of the filter. The optimization process repeated about 4 times to obtain final performance. The total tuning time is about 5 minutes.

CONCLUSION

An accurate and speedy tuning algorithm of cellular radio filters based on performance simulation of circuit network and optimization process is presented. From measured performance of an untuned sample, the amount of adjustment to be tuned was calculated. The experimental results for a five-resonator-filter showed the great advantage of this method, which reduced the tuning time from several hours to 5 minutes. A reference table of the relation between a trimming amount and a frequency change prepared in the program would reduce the computation time even more.

REFERENCES

[1]A.E.Atia and A.E.Williams,"Measurements of Intercavity Couplings, " IEEE Trans. Microwave Theory Tech., vol. MTT-23, pp.519-522, June 1975.

[2]A.E.Williams, R.G.Egri, and R.R.Johnson,"Automatic Measurement of Filter Coupling Parameters," 1983 IEEE MTT-S International Microwave Symposium Digest, pp.418-420.

[3]J.W.Bandler and P.A.Macdonald, "Optimization of Microwave Networks by Razor Search, " IEEE Trans. Microwave Theory Tech., vol. MTT-17, pp.552-562, August 1969.

[4]D.Kajfez and E.J.Hwan, "Q-Factor Measurement with Network Analyzer," IEEE Trans. Microwave Theory Tech., vol. MTT-32, pp.666-670, July 1984.