Q-1

A SIMPLE EXPERIMENTAL TECHNIQUE FOR DETERMINING COUPLING BETWEEN DIELECTRIC RESONATORS

Jerry C. Brand

Motorola Inc., GEG
Scottsdale, Arizona

ABSTRACT

A method for determining the coupling coefficients between dielectric resonators (DR) is presented. Experimentally measured S-parameters are used to characterize a circuit model of the DR. The DR's resonant frequency is systematically altered with a sliding short in the desired filter configuration and measured. This data is combined with the DR model utilizing equivalent circuit techniques to determine the coupling coefficient.

MODEL DEVELOPMENT

Filters utilizing dielectric resonators (DR) are typically configured in a direct coupled manner [1]. This coupling is achieved through the external magnetic field of the DRs and is adjusted by varying the distance between the resonators. This type of filter construction requires knowledge of the coupling between the end resonators and the transmission line and between individual resonators as shown in Figure 1. The usual method of determining the coupling between resonators is to perform an insertion loss measurement with two resonators coupled together [2]. However, this measurement requires the movement of the DRs and this usually involves the machining or rearranging of the filter structure. This technique is not only a potentially destructive test but is time consuming and also prone to errors if the coupling for several different bandwidth filters are to be measured.

The basis for the experimental technique described herein involves the model of a DR, image theory, and the equivalent circuits of coupled resonators. The equivalent circuit of the DR resonant at a frequency f_o is the coupled parallel RLC network shown in Figure 2 with the impedance given by [3].

$$Z = \frac{2B}{1 + 2\,Q_u\,x} \qquad (1)$$

where Q_u is the unloaded quality factor of the DR, B is the coupling of the DR to the transmission line, and $x=(f-f_o)/f$. The equivalent circuit values of the L and C may then be calculated using equation (1), measured data for B and Q_u [3], and

$$f_o = \frac{1}{2\,\pi\sqrt{LC}} \qquad (2)$$

near the resonant frequency f_o. The calculated values from a typical DR are also shown in Figure 2. Figure 3 illustrates two equivalent circuits of a two resonator direct coupled filter.

The relationship between the two circuits is given by [4]

$$L_1=L_2 = \frac{L_a(L_m + L_c)}{L_a + L_m + L_c} \qquad (3)$$

and

$$M = \frac{L_a\,L_c}{L_a+L_m+L_c} \qquad (4)$$

The coupling coefficient k may then be determined by

$$k = \frac{M}{L_1} \qquad (5)$$

The components L_a and L_c are the resonant component L in equation (2). If one of the resonators is shorted out, the resonant frequency f_o will shift due to the inductive coupling of L_m. Since the capacitance of the resonator is unchanged, the inductor L_m is given by

$$L_m = \frac{L'\,L}{L- L'} \qquad (6)$$

where L' is the inductance required to resonate C at f_o. With this information, the circuit values L_1 and M and the coupling coefficient k may be calculated. The problem then arises how to physically perform a representation of these operations.

EXPERIMENTAL METHOD

The equivalent circuit of the resonator indicates that shorting at f_o will occur when the resonator is detuned. However, this will change the equivalent circuit of the resonator and may give false coupling results as well as limit the determination to one coupling value only. The alternative is to replace one resonator with a movable short. This configuration is shown in Figure 4 along with the image of the remaining resonator. This image of the DR allows the determination of the fields that would exist if two DRs were physically in place [5]. The transfer of energy does not take place since the model only represents a mathematical equivalent. Instead, the energy is reflected as if the image resonator was shorted causing a shift in the resonant frequency of the resonator. Thus, by moving the short to various positions and measuring the frequency shift from the isolated DR position (short removed), equations (2) through (6) are used to calculate the coupling coefficient versus resonator separation.

0149-645X/86/0000-0399$01.00

A sample measurement is illustrated in Figure 5 along with the calculated coupling based on Cohn's [1] technique. A three pole 15 MHz bandwidth filter designed from the sample data is shown in Figure 6 along with measured and predicted data. Reasonable agreement is indicated in both figures.

CONCLUSION

A method has been presented that allows experimental determination of the coupling between dielectric resonators without disturbing the filter structure and with minimal computation. A brief explanation of the equivalent circuits is presented and their relationship to the physical filter is related. Results of a coupling experiment are compared to calculated data and good agreement is shown. The coupling coefficients are then used to construct a sample filter with the measured and predicted results given. This work describes what is believed to be an original method for easily and accurately determining the coupling between dielectric resonators.

REFERENCES

[1] S.B. Cohn, "Microwave bandpass filters containing high dielectric resonators, "IEEE MTT-16, Apr. 1968, pp. 218-227.

[2] G. Matthaei, L. Young, and E.M.T. Jones, Microwave Filters, Impedance Matching Networks and Coupling Structures, New York, McGraw-Hill, 1964, pp. 663-668.

[3] A.P.S. Khanna, "Q Measurements on Dielectric Resonators," Microwaves and RF, January 1984, pp. 81-86.

[4] A. Zverev, Handbook of Filter Synthesis, New York, Wiley, 1967, p. 529.

[5] R. Harrington, Time-Harmonic Electromagnetic Fields, New York, McGraw-Hill, 1961, pp. 103-106.

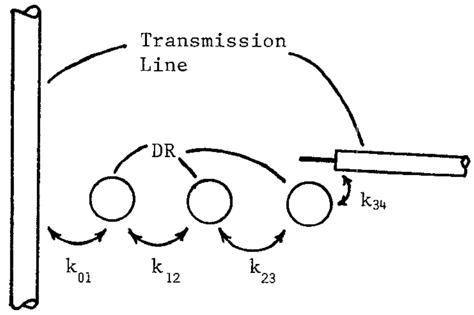

Figure 1. Filter coupling coefficients.

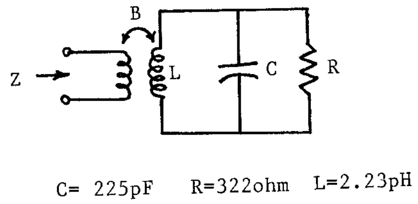

Figure 2. Equivalent circuit of the dielectric resonator.

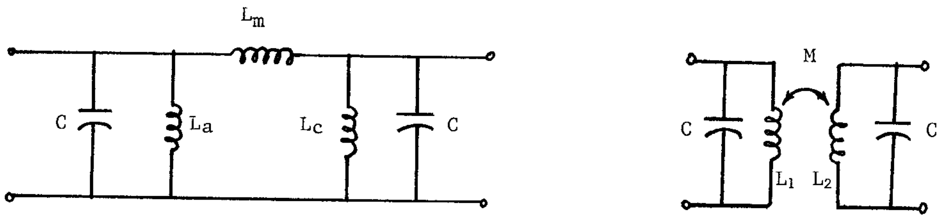

Figure 3. Two equivalent circuits of a pair of coupled resonators.

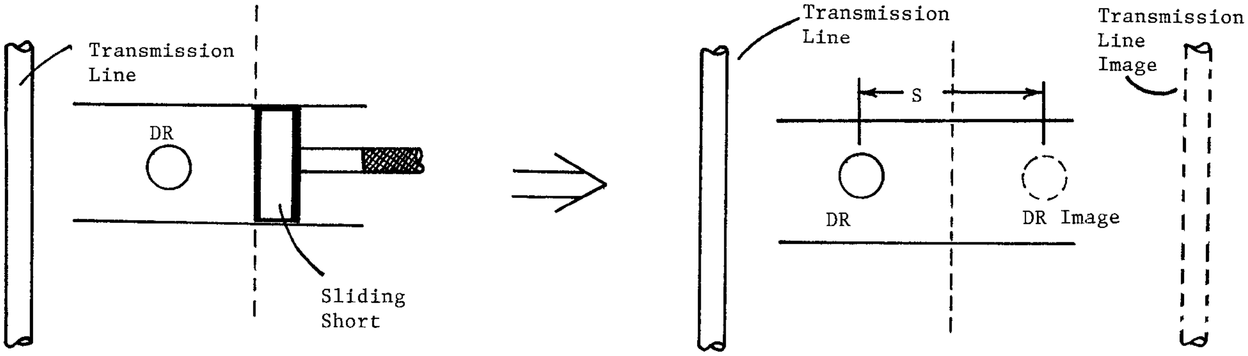

Figure 4. Measurement configuration and the equivalent image representation.

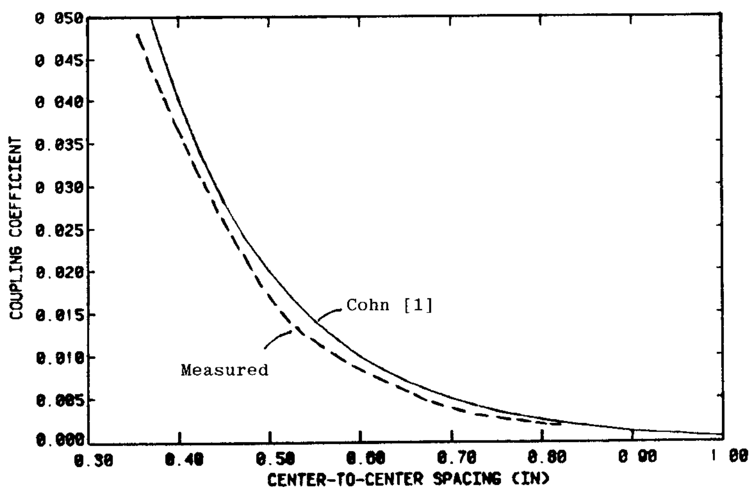

Figure 5. Comparison of the calculated [1] and experimental coupling coefficients.

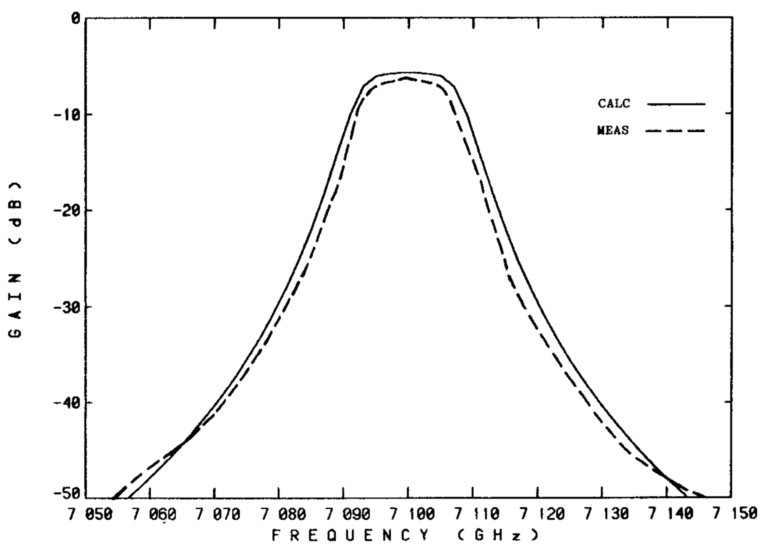

Figure 6. Calculated and measured response of three-pole, 0.5 dB ripple Chebyshev filter.