COMPUTER-AIDED FILTER ALIGNMENT AND DIAGNOSIS

Herbert L. Thal, Jr.
Valley Forge Space Center
General Electric Co.
Box 8555
Philadelphia, PA 19101

ABSTRACT

The cavity resonant frequencies and coupling values of a wide range of band-pass filters, band-reject filters, and equalizers have been determined in situ by computer-adjusting an analytic model to fit the scattering parameters measured on an automatic network analyzer.

Summary

Equivalent circuit models of various types of filters have been programmed with element optimization routines. These programs have been incorporated into the software library of an automatic network analyzer (Hewlett-Packard #8542). When ANA measurements are taken on a filter, these programs adjust the circuit element values to obtain a best-fit to the experimental scattering parameters over a specified frequency range. Different combinations of S_{11}, S_{22} and S_{12} may be utilized as appropriate. The resulting element values are then compared with the desired ones. Since each element in a suitably constructed equivalent circuit corresponds to some physical portion of the actual filter, the changes required to converge to the nominal response are evident.

A six pole TE_{011} elliptic filter is used to illustrate this technique. Figure 1 shows the experimental transmission and reflection losses (i. e. the reciprocals of $|S_{12}|$ and $|S_{11}|$ in decibels) with relatively severe detuning of some cavities. Each curve is computer-drawn from 101 data points taken at 1 MHz intervals. For filters with this narrow a bandwidth a discrete element circuit is adequate. Each resonator is represented by series RLC elements with arbitrary magnetic coupling between any specified resonators. The mutual inductances and cavity capacitances are varied to match the measured response. Figure 2 shows the printout of the coupling values and cavity resonant frequencies determined by the fitting procedure using scattering parameters at 34 of the measured frequencies. The mutual inductive coupling values are expressed in terms of the resonant frequency splitting (MHz) that would occur for the respective cavity-pair if all other cavities were detuned; a negative sign indicates coupling of the opposite sense. Figure 3 gives analytic responses obtained from these values.

Since the tuning plunger sensitivity is known, each plunger may be turned the amount required to yield the desired synchronous frequency. The coupling values can be adjusted in the same manner although for this particular filter, such changes would require a machining operation. Figure 4 shows the responses after retuning. Figure 5 gives the new circuit parameters from the fitting procedure. Note that the repeatability of the coupling values, which were not changed, is good even though the filter was removed and the analyzer was recalibrated between the two runs. Figure 6 shows the reconstructed responses. The unloaded Q is determined semi-automatically by repeating the fitting procedure with different values and selecting the one that yields the best fit; the unloaded Q for this filter is 20,000.

This technique has been used on many Chebyshev and elliptic filters with up to 13 poles in single-, dual-, and higher-order-mode realizations. It has been used for band reject filters and for aligning the frequencies and nulling the spurious cross-coupling in directionally-coupled equalizer stages as well. It has also been used as a synthesis tool by determining the circuit parameters corresponding to a response generated, for example, from a pole-zero pattern. In addition to providing a convenient method for diagnosing and correcting coupling and tuning errors in filters, this procedure provides an indication of the accuracy of the experimental data and the adequacy of the analytic models thereby increasing confidence in system designs and simulations which are based on these same models.

Acknowledgment

The author wishes to acknowledge the contributions of George Ditty to the design and testing of the experimental model.

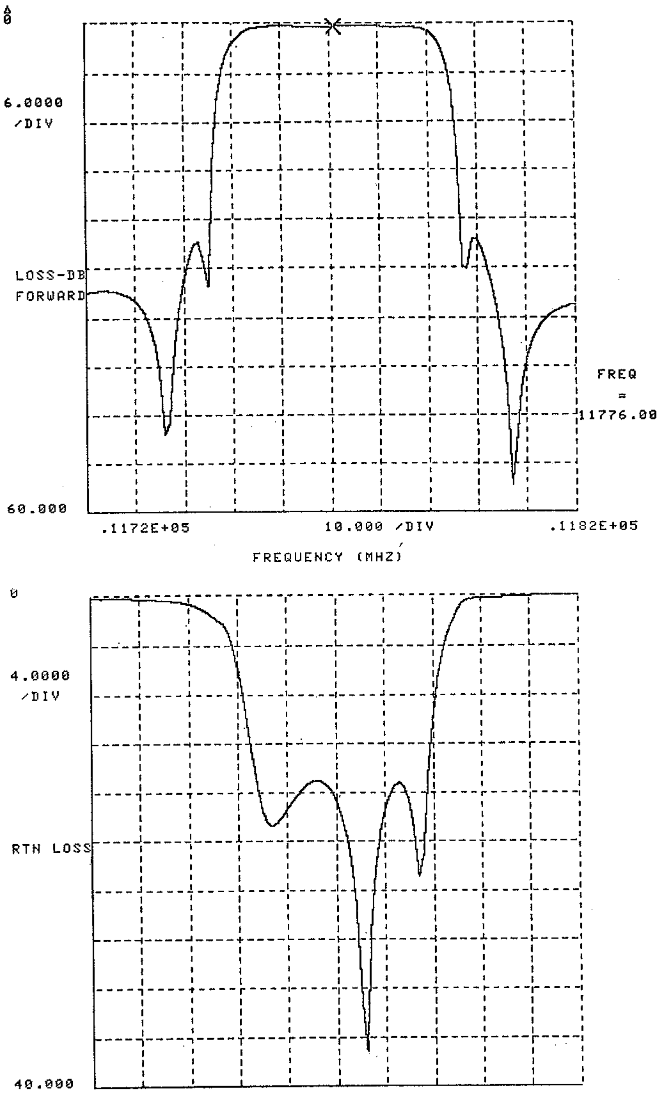

Figure 1 - Experimental Insertion and Return Loss for Misaligned Filter.

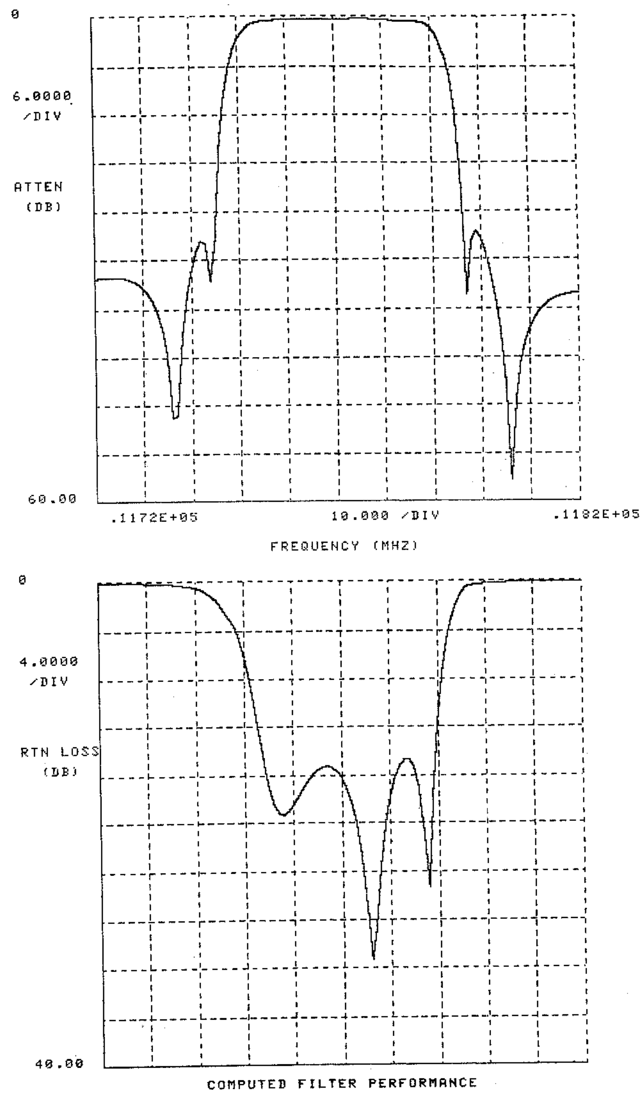

Figure 3 - Computed Response using Values from Figure 2.

			COUPLING	FREQ(MHZ)
1	0	1	42.0094	11775.2
2	1	2	35.5747	11779.2
3	2	3	21.5797	11781.5
4	3	4	36.9634	11769.9
5	4	5	22.0643	11772.9
6	5	6	36.3145	11770.7
7	6	7	41.4987	
8	2	5	-17.4086	
9	1	6	4.6906	
Q1,Q2		280.3	283.8	
REF PLANES(CM)			.226	.224

Figure 2 - Coupling Values and Frequencies from Fitting Procedure using Data of Figure 1.

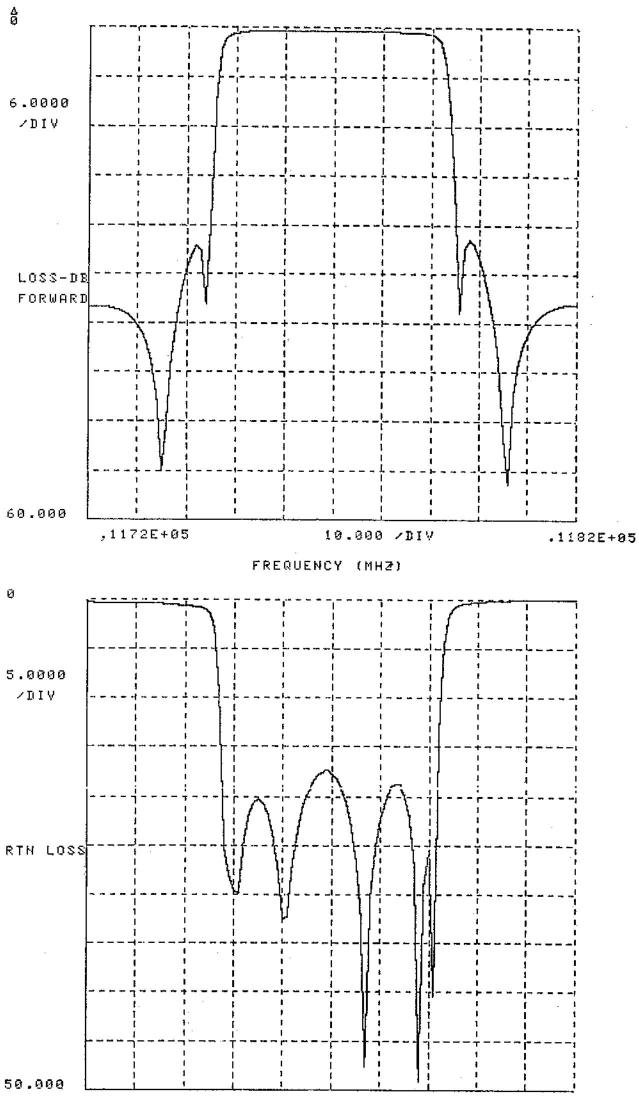

Figure 4 - Experimental Insertion and Return Loss for Aligned Filter.

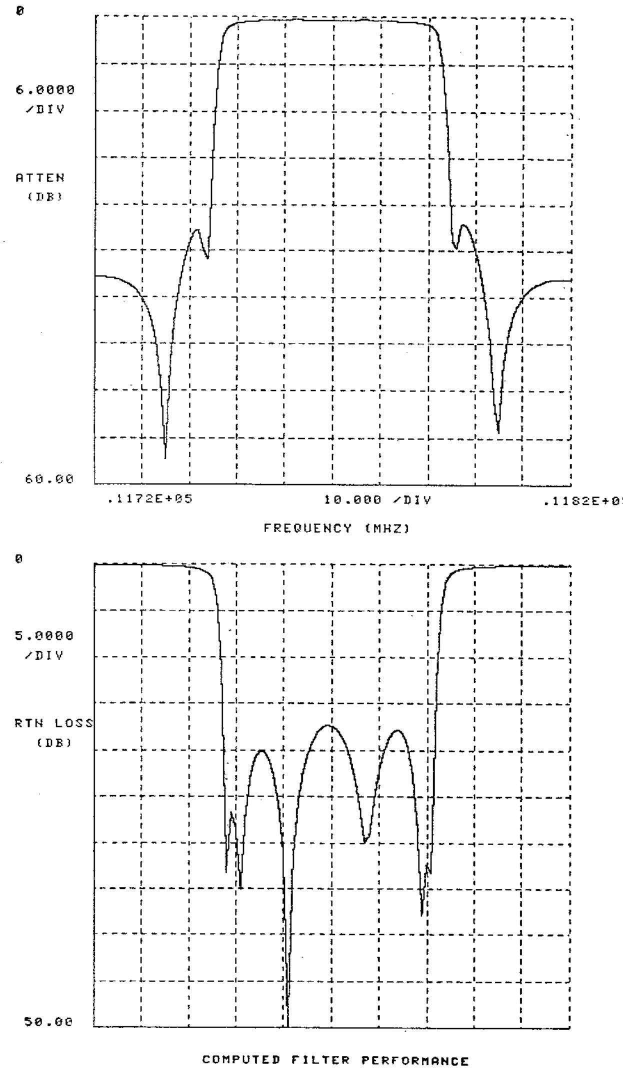

Figure 6 - Computed Response using Values from Figure 5.

			COUPLING	FREQ(MHZ)
1	0	1	41.6189	11774.5
2	1	2	35.7938	11774.5
3	2	3	21.5838	11774.7
4	3	4	37.1143	11774.3
5	4	5	21.9198	11774.7
6	5	6	36.2753	11774.2
7	6	7	41.3547	
8	2	5	-17.3375	
9	1	6	4.5901	
Q1,Q2		282.9	284.7	
REF PLANES(CM)			.226	.222

Figure 5 - Coupling Values and Frequencies from Fitting Procedure using Data of Figure 4.