Observations on the Stopband Performance of Tapped Line Filters

Robert J. Wenzel and Daniel G. Swanson, Jr.*

Wenzel / Erlinger Associates, a Subsidiary of Bartley R.F. Systems Inc., Agoura Hills, CA 91301
*Bartley R.F. Systems Inc., Amesbury, MA 01913

Abstract — **Current circuit based models for filters with tapped line inputs are shown to be accurate for predicting passband performance and inaccurate for predicting stopband performance. EM field-solver computations are shown to be capable of accurate performance predictions in both the passband and stopband. Significant differences in stopband performance are shown to be possible with different types of input/output coupling.**

I. Introduction

The first analytical design procedures for interdigital and combline filters used transformer or redundant line input configurations [1]-[2]. The advantages of a tapped line input were discussed and outlined in [3]. Although designs were more compact using the tapped line approach, the analytical theory was simpler and more accurate with the redundant line approach, especially if filter bandwidth was wide. The tapped line equivalent circuit given by Cristal [4] made analytic solutions (approximate or with use of numerical optimization) possible and very accurate (from a passband viewpoint) for filters of arbitrary bandwidth. The majority of combline and interdigital filters built over the last thirty years have used the tapped line approach.

Using the circuit model of [4] for a tapped line input structure, the equivalent circuit (Fig. 1) of a tapped line combline filter is of cascade form with multiple transmission zeros above the passband. Such a circuit predicts a very deep and wide upper stopband response. However, using the multiple coupled line equivalent circuit of Sato-Cristal [5] (Fig. 2) one sees two coupled line arrays in parallel, with transmission zeros that are certainly not at the same frequencies as for the cascade circuit obtained using the tapped line model.

II. Circuit Model Analysis

To test the two circuit models, an N = 5 combline filter (Fig. 3) with about 40% bandwidth and cover capacitive loading was designed using CLD [6]. This program uses the tapped cascade circuit model and empirically derived resonator spacing correction factors for obtaining desired filter bandwidth.

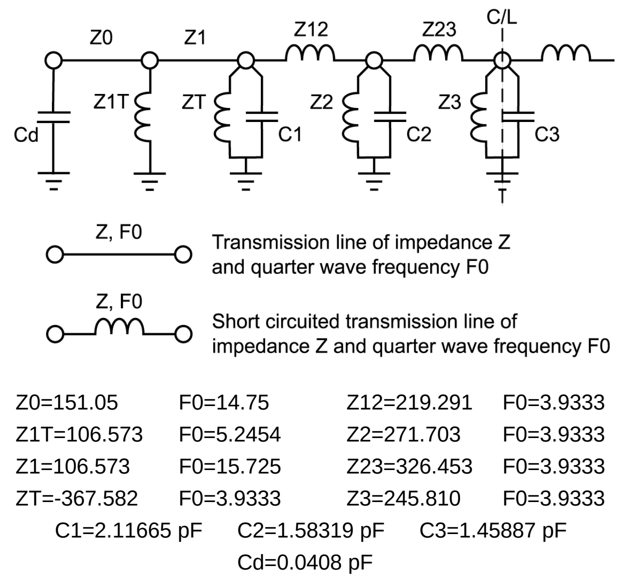

Fig. 1. Combline tapped line cascade equivalent circuit from Cristal [4]. Element values are for the N=5 experimental hardware.

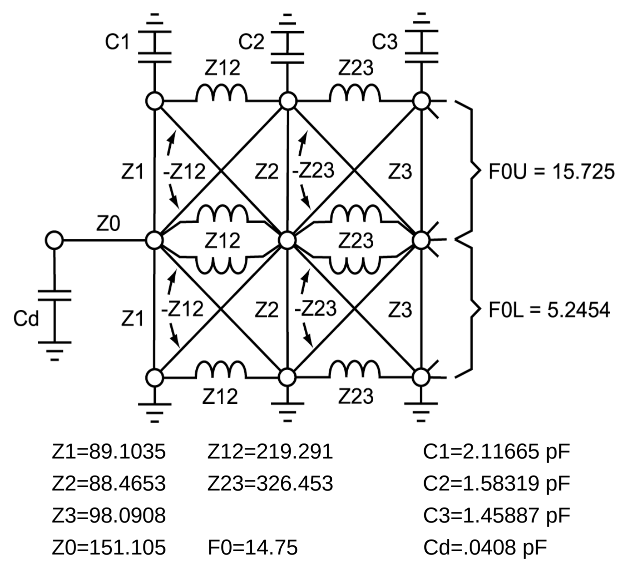

Fig. 2. Combline tapped line equivalent circuit from Sato-Cristal [5]. Element values are for the N=5 experimental hardware.

0-7803-6540-2/01/$10.00 (C) 2001 IEEE

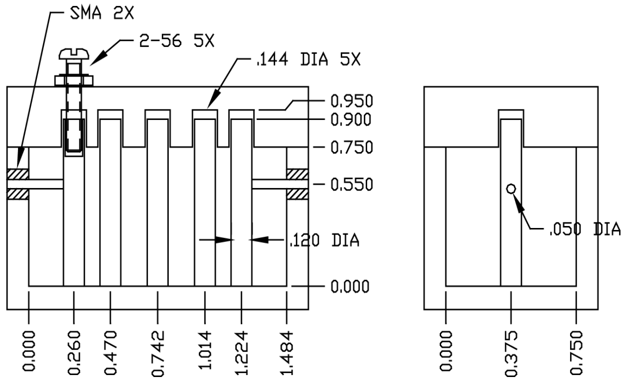

Fig. 3. Dimensions (inches) of N=5 experimental hardware. The 21 dB equal ripple bandwidth is 1.178 to 1.814 GHz.

The equivalent circuit was then converted to the Sato-Cristal model. The analyzed response of both circuits is shown in Fig. 4. Both circuit models give virtually identical passband response, but substantially different stopband response. The tapped line circuit model shows the deep stopband associated with the transmission zeros of the cascade equivalent circuit, while the Sato-Cristal modeling shows a more moderate near flat level of stopband rejection, with a close in transmission zero on the high side of the passband.

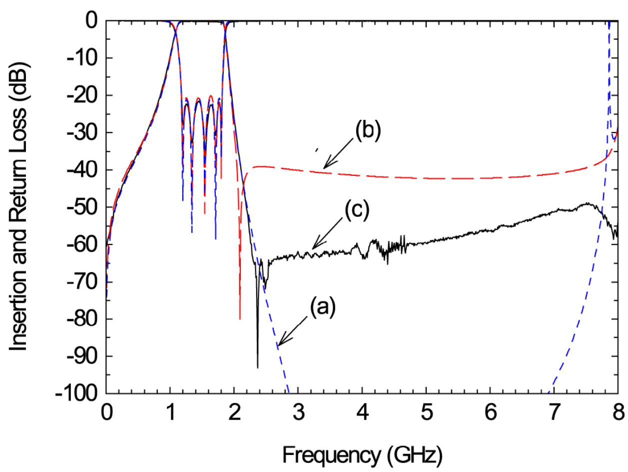

Fig. 4. Comparison of responses: (a) computed using Cristal tap circuit, (b) computed using Sato-Cristal circuit and (c) measured response of experimental hardware.

Experimental hardware for the design above was built and tested, with the results as shown in Fig. 4. The only modification required to obtain equal ripple passband performance at the design bandwidth was to lower the design tap position by .012 inch. Note that while neither circuit model predicts the exact physical tap location for equal ripple performance, the predicted value of 0.562 inch is very close to the correct value.

The measured results have the characteristics of the Sato-Cristal modeling, but differ by about 20 dB in stopband level. An explanation of the 20 dB stopband difference was investigated by (a) varying the input tap line position, (b) including non-adjacent resonator coupling in the circuit model, and (c) making sure that the filter was tuned with no interstage coupling screws. None of the above had any noticeable effect on the calculated or measured stopband performance. The initial model and experiments were conducted more than fifteen years ago, and no theoretically derived circuit based model has been found that can accurately predict the measured stopband response.

III. EM Field-Solver Analysis

Recently, the above problem has been re-visited using EM field-solvers [7]-[8] and the multiport analysis and tuning technique described in [9].

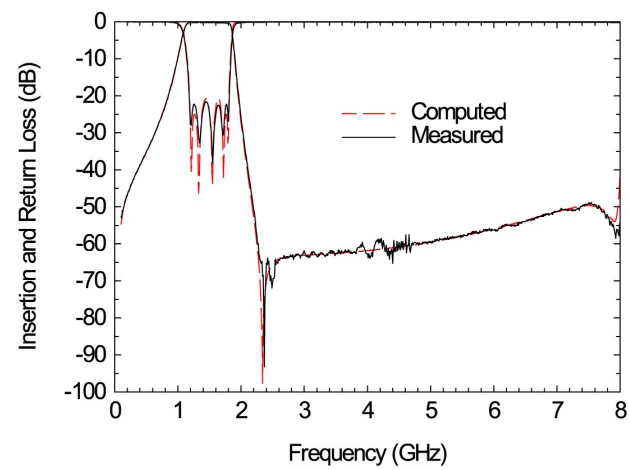

Fig. 5. Comparison of measured response and field-solver computation.

Using the resonator and tap line dimensions of the experimental model described above, the computed field-solver passband and stopband results are compared with the measured results in Fig. 5 and are seen to be nearly identical. The total solution time for the tuned filter response on the field-solver was 13 minutes on an 850 MHz Pentium PC. The measured results are from a recently constructed second model and duplicate the results of the fifteen-year-old model.

V. Conclusion

The above results confirm that circuit models based on tapped line cascade circuits and Sato-Cristal multiple couple line models are (with the exception of exact tap position) capable of accurately predicting passband performance but are incapable of accurately predicting stopband performance. The effects are of greatest practical significance in low order filters of the type commonly used in many systems and sub-systems.

Stopband performance when redundant combline and interdigital type input lines are used has also been investigated, and computed results for these configurations will be presented in the final paper. While tapped line circuits are simpler and more compact than redundant line circuits; they can result in significant reduction in achievable stopband rejection.

REFERENCES

[1] G. L. Matthaei, "Interdigital band-pass filters," *IEEE Trans. Microwave Theory and Tech.*, vol. MTT-10, no. 6, pp. 479-491, November 1962.

[2] G. L. Matthaei, "Comb-line bandpass filters of narrow or moderate bandwidth," Microwave Journal, vol. 6, pp. 82-91, August 1963.

[3] M. Dishal, "A simple design procedure for small percentage bandwidth round-rod interdigital filters (Correspondence)," *IEEE Trans. Microwave Theory and Tech.*, vol. MTT-13, no. 5, pp. 696-698, September 1965.

[4] E. G. Cristal, "Tapped-line coupled transmission lines with applications to interdigital and combline filters," *IEEE Trans. Microwave Theory and Tech.*, vol. MTT-23, no. 12, pp. 1007-1012, December 1975

[5] R. Sato and E. G. Cristal, "Simplified analysis of coupled transmission-line networks," *IEEE Trans. Microwave Theory and Tech.*, vol. MTT-18, no. 3, pp. 122-131, March 1970.

[6] CLD – Combline Design Ver. 3.0, Bartley R.F. Systems, Amesbury, MA.

[7] Agilent HFSS Ver. 5.6, Agilent EEsof EDA, Santa Rosa, CA.

[8] Ansoft HFSS Ver. 7.0, Ansoft Corporation, Pittsburgh, PA.

[9] D. G. Swanson and R. J. Wenzel, "Fast analysis and optimization of coupled line filters using FEM," *2001 IEEE MTT-S Int. Microwave Symp. Dig.*, May 2001.

0-7803-6540-2/01/$10.00 (C) 2001 IEEE