L-RESONATOR BANDSTOP FILTERS

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ABSTRACT

A design procedure is presented for TEM narrow bandstop filters using L resonators, which are intermediate of the gap- and parallel-coupled resonators typically used, having parallel coupling only over a portion of the resonator length and a grounded end in either the coupled or stub portion of the resonator.

INTRODUCTION

In the two most common configurations for TEM narrow bandstop filters (Figure 1), a transmission line is coupled to a cascade of grounded resonators by either end (capacitive) gaps [1] or by full-length parallel (commensurate-line) couplings [2]. Both filter configurations are typically used to realize conventional, e.g. Chebyshev, responses with all resonant frequencies the same and nominal (at resonance) spacing between resonators of 90 degrees.

In the filter presented here (Figure 2), the resonators are intermediate of those two approaches, each having parallel coupling over a portion of the resonator length (less than 90 degrees nominal), a shunt stub, and an uncoupled line to provide additional electrical length between resonators as required. The grounded end may be in either the coupled or stub portion of the resonator, and either type is referred to as the "L resonator." Coupled and stub line lengths can be an arbitrarily chosen with some limitations, and can vary between resonators.

Using this approach, the selection of design parameters is greatly increased. The filter designer can incorporate other criteria such as imposed dimensional limitations, power handling, tuning access, etc. more readily into the final design with the increased flexibility and choices allowed by L resonators. As with filters using resonators with end gaps, those with L resonators can be designed to meet a general bandstop filter response having different resonant frequencies and spacings [3], including an elliptic function response.

EQUIVALENT CIRCUITS

Figure 3 shows the equivalent circuits (Table VII.3 in [4]) for the coupled line pair consisting of a through line with input and output ports, and a coupled line with either a short or open at one end, and an arbitrary termination at the other. The coupled line with a short results in a unit element and a series connection of the termination in parallel with a commensurate inductor; the coupled line with an open results in a unit element and a shunt connection of the termination in series with a commensurate capacitor.

A series or shunt bandstop L resonator will be created by replacing the arbitrary termination with a stub which represents a transmission-line capacitor or inductor, respectively, having a nominal electrical length of less than 90 degrees at resonance. Note however that the stub length does not have to be commensurate with the coupled line pair; in one extreme (electrical length approaches zero) it would be a lumped element. If circumstances require that both ends of the L resonator be shorts or opens, the

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stub portion could be lengthened to between 90 and 180 degrees.

DESIGN EXAMPLE

Equating reactances and reactance slopes at resonance, the design of a shunt-connected L resonator can be obtained from a denormalized highpass prototype resonator (Figure 4); the fractional bandwidth $w_p = bw/f_p$, where bw is the equiripple passband width and f_p is the loss pole frequency. Choosing nominal, but arbitrary, lengths of 30 degrees for the coupled lines and 60 degrees for the stubs, a five-resonator elliptic-function bandstop filter with a center frequency of 2 GHz, 40 dB minimum stopband width of 20 MHz, and 1.1 SWR equiripple passband width of 33.78 MHz has a theoretical response (Figure 5) which is close to that of the highpass prototype. The design is summarized in Table I.

Similar results may be obtained for series connected L resonators. By reducing the free design parameters, symmetric coupled sections ($y_{22} = y_{11}$) or other configurations can be obtained. With the appropriate layout, a bandstop filter can also be constructed with both shunt and series connected resonators.

ACKNOWLEDGEMENT

Thanks are due Dr. Ralph Levy for his awareness of the earliest English language publication [4] containing the equivalent circuits (Figure 3).

REFERENCES

[1] L. Young, G. L. Matthaei, and E. M. T. Jones, "Microwave band-stop filters with narrow stop bands," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-10, pp. 416-427, Nov. 1962.

[2] R. J. Wenzel, "Exact design of TEM microwave networks using quarter-wave lines," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-12, pp. 94-111, Jan. 1964.

[3] H. C. Bell, "Narrow bandstop filters," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-39, pp. 2188-2191, Dec. 1991.

[4] N. Saito, "Coupled-line filters," in *Microwave Filters and Circuits*, Ed. A. Matsumoto. New York: Academic Press, 1970, pp. 179-224.

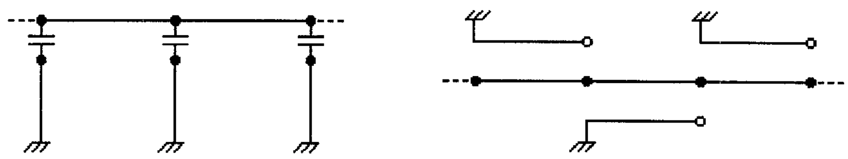
TABLE I

Five-Resonator Elliptic-Function Bandstop Filter

Center Frequency: 2 Ghz
Stopband: 40 dB min, 20 Mhz wide
Passband: 1.1 SWR max, 33.78 Mhz wide

Terminations, Uncoupled Lines: $R = Z_{hp} = 50\ \Omega$
Coupled Lines: $\theta_1 = 30$ deg
Stubs: $\theta_2 = 60$ deg, $Z_2 = 75\ \Omega$

Resonator	θ_{hp} (deg)	f_p (MHz)	y_{11} (S)	y_{12} (S)	y_{22} (S)
1	>30	1990.398	0.02050	0.00259	0.01357
2	70.75	1993.712	0.02124	0.00409	0.01349
3	83.67	2000.000	0.02141	0.00433	0.01333
4	96.33	2006.288	0.02124	0.00405	0.01318
5	109.25	2009.602	0.02050	0.00255	0.01310



(a) (b)

Figure 1. Bandstop filters with (a) capacitive couplings and (b) parallel couplings.

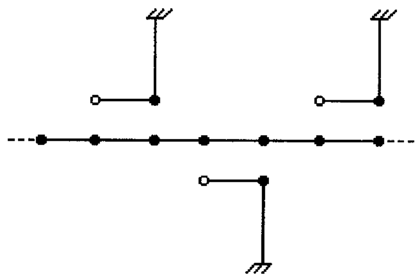
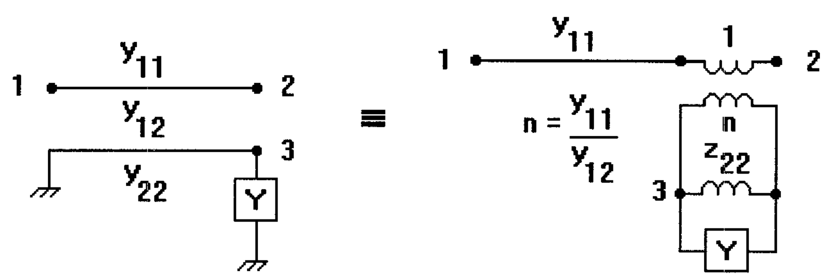
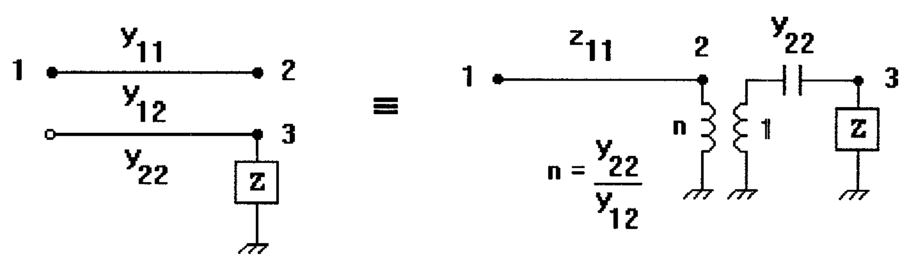


Figure 2. Bandstop filter with L resonators.

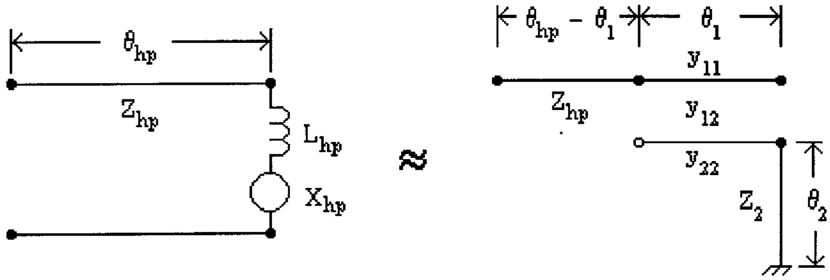


(a)



(b)

Figure 3. Equivalent circuits for (a) series connection and (b) shunt connection.



$$n^2 = \frac{\cot(\theta_2)}{\frac{\theta_1}{\sin(2\cdot\theta_1)} + \frac{\theta_2}{\sin(2\cdot\theta_2)}} \cdot \frac{L_{hp}}{Z_2} \cdot \frac{1}{w_p} \qquad z_{11} = \frac{y_{22}}{\Delta y} = Z_{hp}$$

$$y_{22} = \frac{\cot(\theta_1)\cdot\cot(\theta_2)}{Z_2} \qquad y_{12} = \frac{y_{22}}{n} \qquad y_{11} = \frac{1}{Z_{hp}} + \frac{y_{12}}{n}$$

Figure 4. Shunt-connected L resonator design from highpass prototype.

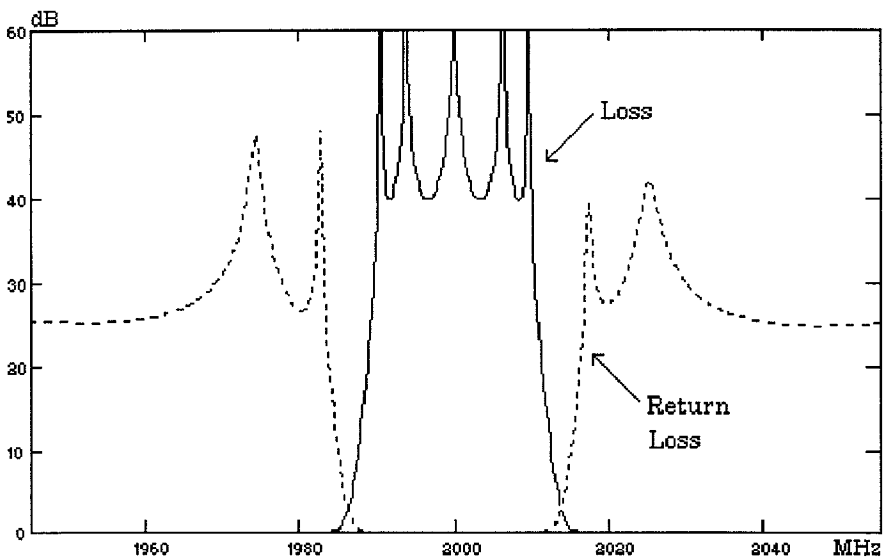


Figure 5. Theoretical loss and return loss of L-resonator bandstop filter, Table I.