Wideband Bandstop filter with Sub-Harmonic Stubs

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Abstract: The performance of a wideband bandstop transmission line filter employing a series overlay inductor over two stubs resonating at respectively one half and one quarter of the centre frequency, is described. The structure contributes seven transmission zeros to the stopband and the performance compares to that of a Cauer filter. The structure has the advantage of having impedance levels that are readily realizable.

Introduction: Various ways have been employed to increase the rate of cutoff for wideband filters to obtain true or pseudo-elliptic responses. [1] – [5].

A completely novel approach to the realization of transmission zeros at real frequencies is introduced in [6], where a sub-harmonic stub is employed to contribute two zeros in the stopband of a bandstop filter. This principle is extended to two subharmonic stubs providing transmission zeros on either side of the passband of a bandpass filter in [7]. In this paper, a wideband bandstop filter is described that has three stubs, of which two are sub-harmonic, resonating in its stopband, contributing a total of seven transmission zeros because of the choice of harmonic lengths.

Filter Structure and Performance: The Sub-Harmonic Stub (SHS) microstrip filter is shown schematically in Fig. 1.

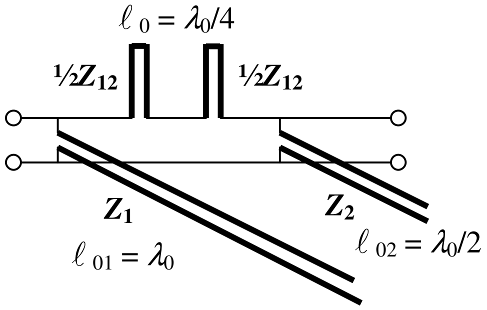

Fig. 1. Schematic construction of SHS bandstop filter

Shunt stub Z_1 resonates at one quarter of the filter centre frequency f_0, with $\ell_1 = \lambda_0$. The stub Z_2 resonates at $f_2 = f_0/2$, with a length of $\ell_2 = \lambda_0/2$, while two series connected series shorted stubs $½Z_{12}$, each resonate at f_0, length $\ell_0 = \lambda_0/4$. Defining $f_1 = f_0/4$, Z_1 contributes transmission zeros at f_1, $3f_1$, $5f_1$ and $7f_1$; Z_2 contributes zeros at $2f_1$, and $6f_1$, while Z_{12} contributes a zero at $4f_1$. This gives a total of seven transmission zeros in the stopband, which then lie evenly spaced between f_1 and $7f_1$, centered at $4f_1 = f_0$, as shown in Fig. 2.

Fig. 2 also shows the calculated transmission and reflection responses for a filter with centre frequency $f_{0,}$ in which values of $Z_1 = 43\Omega$, $Z_2 = 18\Omega$, and $Z_{12} = 168\Omega$ were chosen. Also shown in the figure are the S_{11} and S_{21} responses for a third order Cauer filter designated C350, $\Theta = 47$ [8], scaled to the same bandwidth as the SHS filter.

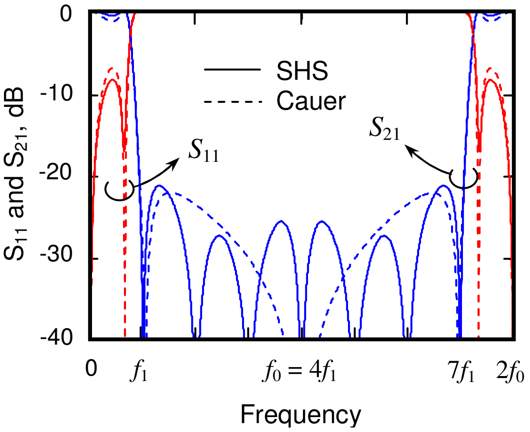

Fig. 2. Theoretical response of SHS filter compared to a third order Cauer filter.

The Cauer filter would be extremely difficult to realize as an etched structure because of extreme impedance values. The impedance values were chosen purely for ease of manufacture in the proof of principle demonstrator, and represent approximately the limit of selectivity, $0.41/f_0$ dB/MHz, (f_0 in GHz) that can be readily realized. Increasing the value of Z_{12} increases both the passband and stopband insertion loss. With $Z_{12} = 350\ \Omega$, $S_{11} = -15$ dB and $S_{21} = -30$ dB can be obtained, with a selectivity of $0.28/f_0$ dB/MHz. Suitable stub impedances are readily obtained through repeated analysis.

Construction: The physical construction of the filter is shown in Fig. 3.

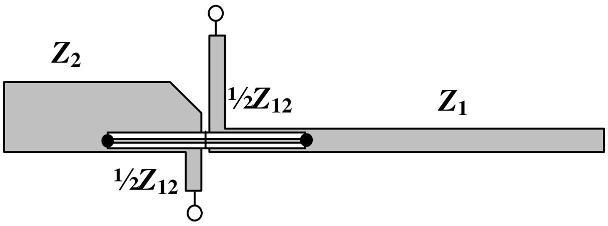

Fig. 3. SHS filter physical layout.

The stubs Z_1 and Z_2 are etched on a RT Duroid 5880 board with a dielectric thickness of 1.57 mm, relative dielectric constant of 2.2 and loss tangent $\delta = 0.0009$. The series stub Z_{12} was constructed as two series overlay shorted stubs each of $\frac{1}{2}Z_{12} = 84\ \Omega$ on RT Duroid 5880, in the form of a 5 mm wide strip bearing the copper track. The stubs $\frac{1}{2}Z_{12}$ are shorted to the upper metal of the stubs Z_1 and Z_2, forming in effect internal series stubs. Stub detail is shown in Fig. 4.

Measured Results: The measured insertion loss and return loss of the SHS filter is shown in Fig. 5, and shows very good agreement between mesured and calculated results. Because the filter was realized in microstrip, the dispersion differs for the different linewidths, varying from 18 mm for the 18 Ω line to 6 mm for the 43 Ω line and 2 mm for the 83 Ω lines. Consequently, the nulls that should have been visible theoretically are filled in.

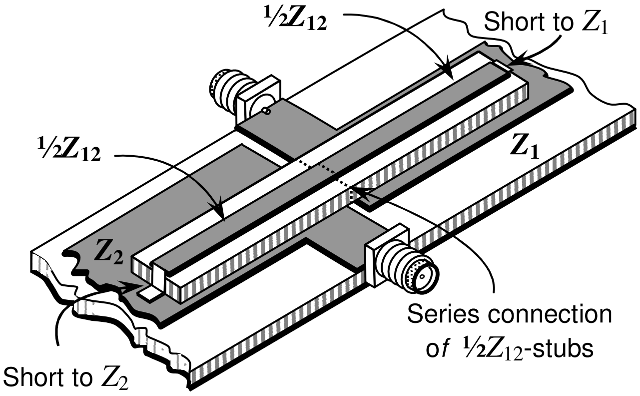

Fig. 4. Overlay shorted stub detail.

Conclusion: The sub-harmonic resonant stub filter exhibits a wide stopband that would compare well with an elliptic function filter, but is much simpler to construct. The usefulness of the sub-harmonic stub approach is illustrated. Practical bandwidths are of the order of 180%, and the filter is suited to pseudo-lowpass applications.

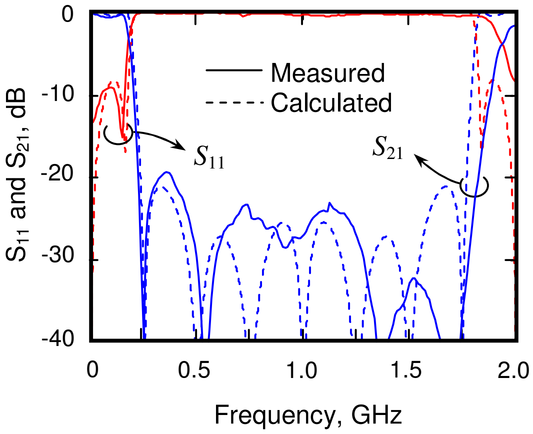

Fig. 5. Comparison of measured and calculated reflection and transmission response for the prototype SHS bandstop filter.

References

[1] Shaman, H., and Hong, J.-S.: ‘Wideband bandstop filter with crosscoupling’, *IEEE Trans. Microw. Theory Tech.*, 2007, **55**, (7), pp. 1780–1785

[2] Mandal, M.K., and Mondal, P.: ‘Design of sharp-rejection, compact, wideband bandstop filters’, *IET Microw. Antennas Propag.*, 2008, **2**, (7), pp. 389–393.

[3] Divyabramham, K., Mandal, M.K., and Sanyal, S.: ‘Sharp-rejection wideband bandstop filters’, *IEEE Microw. Wirel. Compon. Lett.*, 2008, **18**, (10), pp. 662–664.

[4] A. Sánchez-Soriano, G. Torregrosa-Penalva, and E. Bronchalo, “Compact Wideband Bandstop Filter With Four Transmission Zeros”, *IEEE Microw. Wirel. Compon. Lett.*, 2010, **20**, (6), pp. 313-315.

[5] Velidi, K., Guntupalli, A.B., and Sanyal, S.: ‘Sharp-rejection ultra-wide bandstop filters’, *IEEE Microw. Wirel. Compon. Lett.*, 2009, **19**, (8), pp. 503–505 .
[6] Malherbe, J.A.G., and Reid, C., “Double Resonant Stub Bandstop Filter with Pseudo-Elliptic Response”, *Electron. Lett.*, 2010, **46**, (7), pp. 508-509.
[7] J.A.G. Malherbe, “Pseudo-Elliptic Bandpass Filter with Sub-Harmonic Stubs”, *Electron. Lett.*, 2011, **47**, (3), pp. 196 – 198.
[8] Saal, R.: ‘Handbook of filter design’ (AEG-Telefunken, Berlin, 1979).

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