FORMULATION OF MICROWAVE LUMPED AND TUNED TRANSVERSAL FILTER

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Active filters have been successfully employed at low frequencies to realize accurate high-order frequency responses for many years. Recent development of microwave active filter leads to several major design approaches and they are negative resistance, pre-distorted, active inductor and transversal & recursive filtering. Amongst them, the synthesis of conventional lumped and transversal filter can be relaxed when the number of transversal elements is limited [1-4]. But the filter with limited transversal elements is mainly applicable to the wide band communication application as demonstrated by some examples in [2]. Accordingly, a new lumped and transversal filter structure with better selectivity but offering simple filter synthesis is introduced. Recall that in a conventional frequency-selective network – tuned amplifier; it is in effect bandpass filter. Skirt selectivity improvement can be obtained by replacing the transversal element by a tuned amplifier. An *L*-band prototype filter simulation results show that this new structure is not only effective for filter synthesis in general, but also applicable to narrow band filtering in the modern mobile communication system. The presented approach is to simplify filter synthesis formulating the conventional transversal element by a tuned ones as shown in Fig. 1 where each tuned transversal element is given in Fig. 2.

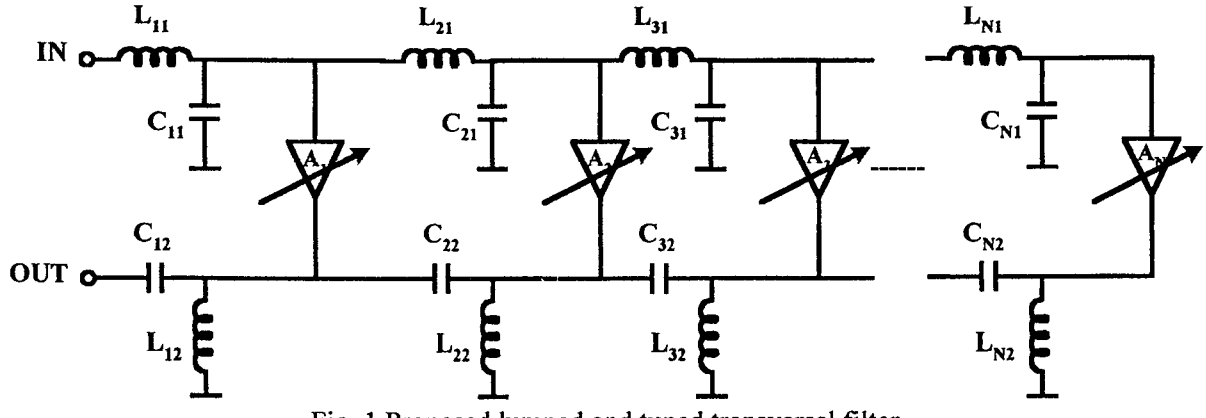
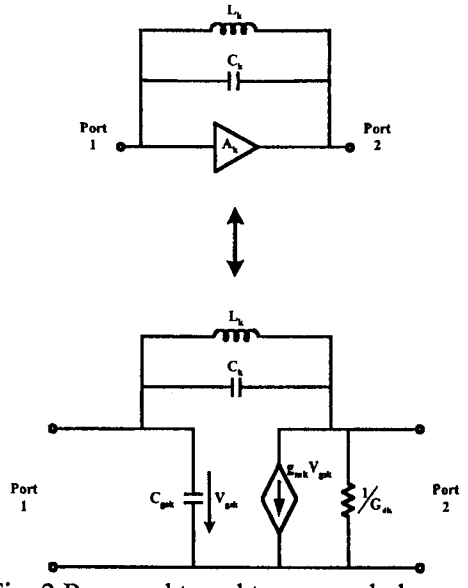


Fig. 1 Proposed lumped and tuned transversal filter.

With the formulation presented in Fig. 2, *S*-parameter's S_{21} of this proposed tuned transversal element is a fourth order function and also contributes two pairs of complex conjugate zeros. Applying it to the traditional lumped and transversal filter, we may also obtain better selectivity but with smaller number of transversal elements. In fact, the synthesis computation can be relaxed when the number of transversal element is limited. Specially, the proposed lumped and tuned transversal filter may allow to implement much selective filter with less number of transversal element.

In order to demonstrate the proposed structure's usefulness, an MMIC lumped and tuned transversal filter centered @1.54GHz is designed for a 0.5μm MESFET technology. In order to ease the discussion, two transversal sections filter is considered and the same MESFET is used in both transversal elements ($A_1 = A_2$). These two MESFETs are both biased with V_{GS} = 0V and V_{DS} = 3V. Standard spiral inductors (~8.9nH each) and polymide capacitors (~0.51pF each) are used. Mesa resistor of 50Ω is employed as the reference impedance. The traditional MMIC lumped and transversal filter with three transversal sections is also designed to compare with tuned filter performance.



$$S_{21} = \frac{2Z_0 s^2 \sum_{i=0}^{4} a_i s^i}{\sum_{j=0}^{4} b_j s^j} \quad (1)$$

where

$$a_0 = L_k$$
$$a_1 = -g_{mk} L_k^2$$
$$a_2 = C_k L_k^2$$
$$b_0 = 2Z_0$$
$$b_1 = 2L_k Z_0 - g_{mk} L_k Z_0^2 + G_{dk} L_k Z_0^2$$
$$b_2 = L_k^2 + G_{dk} L_k^2 Z_0 + C_{gsk} L_k Z_0^2 + 4C_k L_k Z_0^2$$
$$b_3 = C_{gsk} L_k^2 Z_0 + 2C_k L_k^2 Z_0 - C_k g_{mk} L_k^2 Z_0^2 + C_{gsk} G_{dk} L_k^2 Z_0^2$$
$$b_4 = C_{gsk} C_k L_k^2 Z_0^2 + 2C_k^2 L_k^2 Z_0^2$$

Fig. 2 Proposed tuned transversal element.

The predicted curves for these two filters are summarized in Fig. 3. Obviously, the proposed lumped and tuned transversal filter shows much better selectivity than that of the traditional ones. In fact, the new filter shows about one fifth bandwidth = 40MHz of that of traditional ones. This new filter also obtains a gain of 7.8dB at center frequency. But the new filter response has 20dB less attenuation apart from the passband edges than the conventional response. One may notice that there are four transmission zeros observed in the traditional transversal filter and they are simulated at –63dB@0.85GHz, –39dB@1.05GHz, –37dB@1.9GHz and –59dB@2.35GHz respectively. But there is no notable transmission zero observed in the proposed transversal filter.

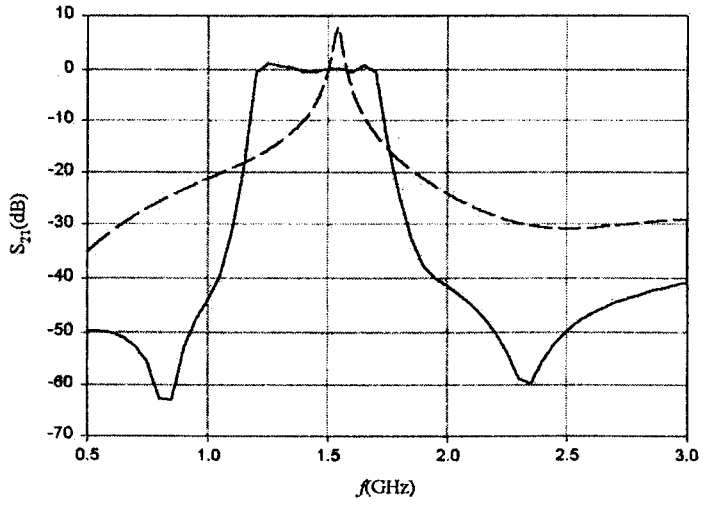


Fig. 3 S_{21} of microwave lumped & conventional (-) and tuned (--) transversal filters.

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[3] M. J. Schindler and Y. Tajima, "A novel MMIC active filter with lumped and transversal elements," *IEEE Trans. Microwave Theory Tech.*, vol. 37, pp. 2148-2153, Dec. 1989.

[4] K. W. Tam, P. Vitor and R. P. Martins, "MMIC active filter with tuned transversal element," *IEEE Trans. on Circuits and System II: Analog and Digital Signal Processing*, vol. 45, pp. 632-634, May 1998.