NEW MICROWAVE BANDSTOP FILTER USING LUMPED AND TRANSVERSAL NETWORK

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ABSTRACT

A new approach for microwave bandstop filters design using the conventional lumped and transversal filtering network is presented. The applicability of the proposed design method is demonstrated with an experimental circuit of a 1.1-GHz bandstop filter of 2.5% bandwidth with a 55dB notch rejection.

1. INTRODUCTION

Traditional use of microwave lumped and transversal filtering architecture has been mainly applied in bandpass filter design [1]-[3]. More recently, Borjack et al. also demonstrated the applicability of this architecture to the optical signal shaping [4]. However, no emphasis has been placed on high selectivity bandstop (notch) filter based on this structure. The bandstop filter produces a sharp signal rejection spike at a specified frequency that is important for modern communication receivers to minimize interference in dense communication environments. Several techniques/architectures to implement notch filters have been proposed over the years by Bell et al. [5]-[8]. In this paper, the capability of the traditional lumped and transversal filtering structure is explored and used in the implementation of an experimental bandstop filter with the center frequency at 1.1GHz. A 2.5% bandwidth for a minimum rejection of 55dB was achieved. Besides this introductory section, this paper encompasses three additional sections. Section 2 presents the proposed bandstop filter design whilst the section 3 verifies the addressed design by testing an experimental bandstop filter. Finally, the conclusion is drawn in section 4.

2. BANDSTOP FILTER DESIGN

Fig. 1 shows the traditional lumped and transversal bandpass filter structure. This filter is obtained by designing the Nth order LC low-pass filter with a cut-off frequency at the bandpass filter upper band-edge whilst the Nth order high-pass cut-off frequency is equal to the passband lower frequency values.

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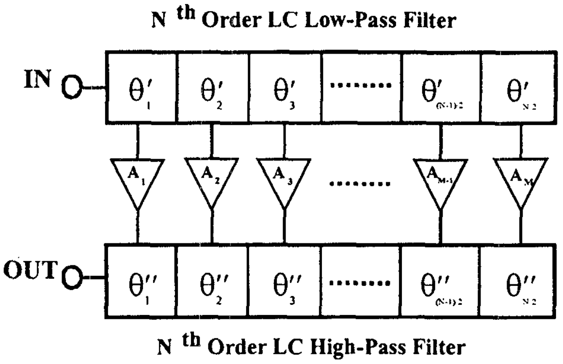

Figure 1. Microwave lumped and transversal bandpass filter.

The transversal elements gains (A_m m=1...M) are introduced to sharpen the bandedges rejection and to reduce the load effect of the high-pass filter on the low-pass filter. Fig. 1 also depicts the phase delay θ'_k and phase advance θ''_k (k =1...N/2) obtained by each passive section of the filter (2nd order low-pass or high-pass respectively) [2]. Three arrangements of this bandpass filter can be identified:

- *Equal phase θ'_k, θ''_k and unequal gain A_m;*
- *Unequal phase θ'_k, θ''_k and equal gain A_m;*
- *Unequal phase θ'_k, θ''_k and unequal gain A_m.*

Contrary to the above mentioned bandpass filter design, a bandstop response can be easily obtained by designing the Nth order LC low-pass filter having the cut-off frequency at the bandstop filter lower bandedge whilst the Nth order high-pass cut-off frequency is equal to the stopband upper values. For an easy MESFET selection and characterization when MMIC implementation is the goal, unequal phase θ'_k, θ''_k and equal gain A_m arrangement is the best choice for the proposed bandstop filter design. As an example, Fig. 2 presents a bandstop filter that comprises two sub filter sections denoted as I and II. The Y-matrix of the sub-filter section II using an ideal FET in common source (VCCS-g_m) is given by Eq.(1).

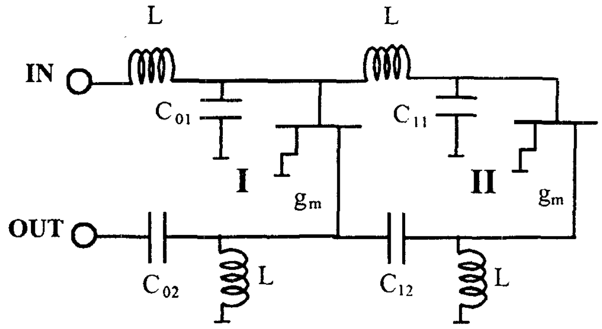

Figure 2. Designed microwave lumped and transversal bandstop filter.

$$Y_{II} = \begin{bmatrix} \dfrac{sC_{11}}{1+s^2LC_{11}} & 0 \\ \dfrac{g_m s^2 LC_{12}}{(1+s^2LC_{11})(1+s^2LC_{12})} & \dfrac{sC_{12}}{(1+s^2LC_{12})} \end{bmatrix} \quad (1)$$

Similar computation can be performed for the sub-filter section I. Therefore the filter's parameter S_{21} can be obtained as follows:

$$S_{21} = \frac{-2LC_{02}Z_0g_m s^2\left[(L^2C_{11}C_{12})s^4 + (LC_{11} + 2LC_{12})s^2 + 1\right]}{a_0s^8 + a_1s^7 + a_2s^6 + a_3s^5 + a_4s^4 + a_5s^3 + a_6s^2 + a_7s + a_8} \quad (2)$$

where

$$a_0 = L^4C_{01}C_{02}C_{11}C_{12}$$

$$a_1 = 3Z_0L^3C_{01}C_{02}C_{11}C_{12}$$

$$a_2 = L^3C_{01}C_{02}C_{11} + L^3C_{01}C_{02}C_{12} + 2L^3C_{01}C_{11}C_{12} + 2L^3C_{02}C_{11}C_{12} + 2Z_0^2L^2C_{01}C_{02}C_{11}C_{12}$$

$$a_3 = Z_0(2L^2C_{01}C_{02}C_{11} + 3L^2C_{01}C_{02}C_{12} + 2L^2C_{01}C_{11}C_{12} + 5L^2C_{02}C_{11}C_{12})$$

$$a_4 = L^2C_{01}C_{02} + L^2C_{01}C_{11} + 2L^2C_{02}C_{11} + Z_0^2LC_{01}C_{02}C_{11} + 2L^2C_{01}C_{12} + L^2C_{02}C_{12} + 2Z_0^2LC_{01}C_{02}C_{12} + 4L^2LC_{11}C_{12} + 2Z_0^2LC_{02}C_{11}C_{12}$$

$$a_5 = Z_0(2LC_{01}C_{02} + LC_{01}C_{11} + 3LC_{02}C_{11} + 2LC_{01}C_{12} + 2LC_{02}C_{12} + 2LC_{11}C_{12})$$

$$a_6 = LC_{01} + LC_{02} + Z_0^2C_{01}C_{02} + 2LC_{11} + Z_0^2C_{02}C_{11} + 2LC_{12}$$

$$a_7 = Z_0(C_{01} + C_{02} + C_{11})$$

$$a_8 = 1$$

It is obvious from Eq.(2) that the zeros of S_{21} are only determined by the section II passive components, and independent of the MESFET transconductance. Also, S_{21} poles are independent of the MESFETs.

3. EXPERIMENTAL FILTER EXAMPLE

In order to illustrate the usefulness of the proposed bandstop filter design, a filter prototype @1.1GHz was realized, using two sections (LC low-pass/high-pass) and two general-purpose discrete GaAs FET amplifiers as transversal elements as depicted in Fig. 2. Due to the parasitic elements of the filter, after a first approximation design of the LC filter, according to the above referred cut-off frequencies, a final design was obtained by a simple computer linear optimization. The GaAs FETs were biased with $V_{DS} = 1.5V$ and $I_D = 40mA$ and all the inductors values were fixed to a small value (3.3nH) in order to simplify future MMIC implementation. Experimental and simulated results are presented in Fig. 3. The filter transmission parameter S_{21} was measured in a 50-Ω system with ±1dB error in the 0.5 - 2-GHz band. From Fig. 3, it is noticed that the designed 1.1-GHz bandstop filter has a bandwidth of 25MHz or 180 MHz for a rejection better than 55dB or 3dB below the passband respectively.

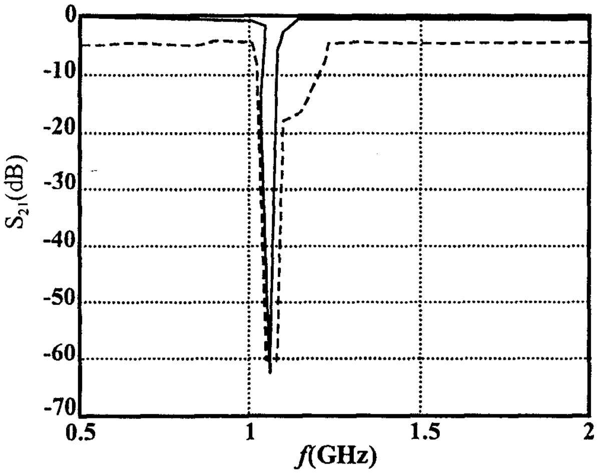

Figure 3. The simulated (-) and experimental (--) transmission characteristics of the prototype bandstop filter.

4. CONCLUSIONS

In this paper, a new microwave bandstop filter design approach is presented and experimentally demonstrated by an L-band notch filter. The experimental results show that a 55dB notch with 2.5% bandwidth can be obtained with a conventional microwave lumped and transversal filter structure. This result is important not only for the integration of this type of circuit with monolithic technology on modern communication systems but also to show the possibility of extending the low frequency transversal filtering technique to a microwave bandstop filter design.

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