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Modified RF Lumped and Transversal Filter

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Abstract

This paper presents a novel RF lumped and transversal filter structure with the special emphasis on image rejection. The proposed filter is based on the traditional lumped and transversal filtering architecture parallel with a *Transversal Tuned Amplifier* (TTA). By this new filter, some transmission zeros may be introduced to improve selectivity and to reject the unwanted signal's. An experimental filter designed at the center frequency of 148MHz with 3MHz 3dB BW, two zeros 44dB@129MHz and 48dB@169MHz for image rejection is used to verify the filter usefulness.

1. INTRODUCTION

Traditional RF/microwave lumped and transversal bandpass filtering technique has been established for more than two decades both in discrete and MMIC implementations [1]-[4]. The main drawback of this filter to be used in the modern communication systems is its intrinsic wide bandwidth characteristics [5]. This laggard will be indeed the main lingering doubt of its usage in the narrow-band and high dynamic range frond end filter design even it has good noise performance [6]. Recent investigations have been mainly placed on its circuitry similarity between traditional distributed amplifier used in optical signal shaping as addressed by Borjak *et al.* [7] and higher selectivity by architecture modifications as reported by Rauscher *et al.* [4],[5]. However, no emphasis has been placed on this filter image rejection characteristics. In fact, the modern transceiver's mixing process always accepts the unwanted signal's and so it is of paramount importance to have some filter to eliminate these interfered signal's.

In this paper, a new architecture modification of the traditional lumped and transversal filter is presented. By this filter, its signal rejection capability is explored in terms of the parallel connection of a tuned amplifier (in fact, a single transversal section) to the transversal element in order to obtain transmission zeros in the passband proximity. Also, a prototype filter centered @148MHz with 2% 3dB BW is designed and tested to demonstrate its usefulness. There are three additional sections in this paper besides the introductory section, section 2 will address the proposed modified RF lumped and transversal filter and then its experimental verification is demonstrated in section 3. The conclusion is drawn in section 4.

2. MODIFIED RF LUMPED AND TRANSVERSAL FILTER DESIGN

Fig. 1 shows the traditional lumped and transversal filter, where A_i (i=1...M) are gains [4].

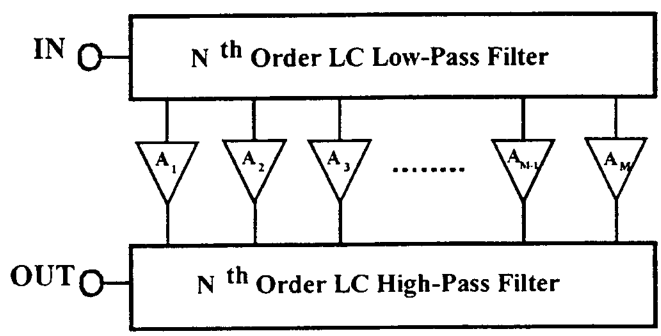

Fig. 1 Traditional lumped and transversal bandpass filter.

In order to ease the filter analysis, a modular approach is adopted as depicted in Fig. 2. It represents a traditional lumped and transversal bandpass filter having three modular sections. In order to implement future MMIC active filter with ease, equal MESFETs and equal inductors configuration is used. Therefore, these three sub filter sections are similar and can be denoted as three Transversal Tuned Amplifiers (TTA), i.e. sub filter section I, II and III, connected in cascade format.

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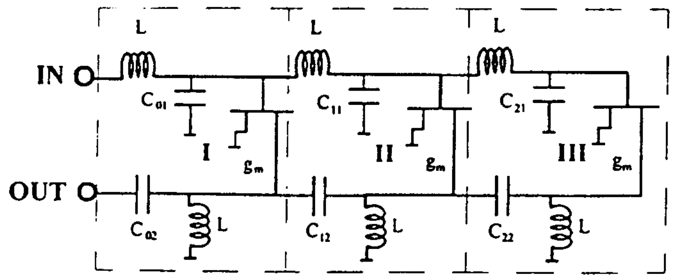

Fig. 2 Traditional lumped and transversal bandpass filter modular representation.

For an arbitrary section of the above filter, the ideal FET common source (VCCS-gm) is used [4] (see Fig. 3). This common source FET Y-matrix can be given in Eq. (1).

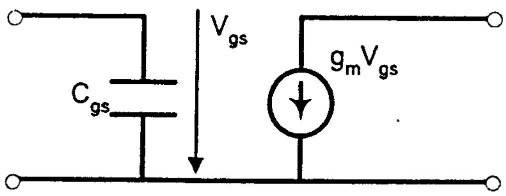

Fig. 3 Ideal common source FET equivalent circuit.

$$Y_{FET} = \begin{bmatrix} sC_{gs} & 0 \\ g_m & 0 \end{bmatrix} \qquad (1)$$

In this paper, the new filter is depicted in Fig. 4, where a TTA is connected to the first transversal element in order to introduce the transmission zeros. By using Eq. (1), the corresponding Y-matrix of the section III TTA is given in Eq. (2).

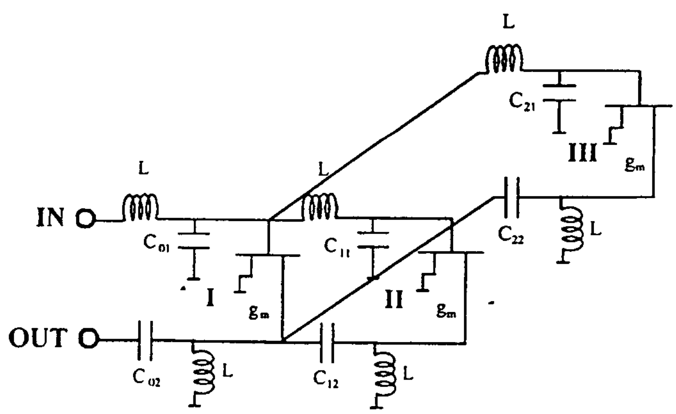

Fig. 4 Modified lumped and transversal filter.

$$Y = \begin{bmatrix} \dfrac{sC_{21}}{1+s^2LC_{21}} & 0 \\ \dfrac{g_m s^2 LC_{22}}{(1+s^2LC_{21})(1+s^2LC_{22})} & \dfrac{sC_{22}}{(1+s^2LC_{22})} \end{bmatrix} \qquad (2)$$

After some calculation, the zeros of filter's S_{21} can be derived as follows:

$$\begin{aligned} &s^2LC_{22}(1+s^2LC_{11})(1+s^2LC_{12})+ \\ &s^2LC_{12}(1+s^2LC_{21})(1+s^2LC_{22})+ \\ &(1+s^2LC_{11})(1+s^2LC_{12})(1+s^2LC_{21})(1+s^2LC_{22})=0 \end{aligned} \qquad (3)$$

From Eq. (3), it is obvious that the filter's zeros are only dependent on section II and III TTAs. By changing these lumped elements in sections II and III, it is possible to obtain some zeros in the desired image frequencies.

3. EXPERIMENTAL FILTER CHARACTERISATIONS

In order to illustrate the usefulness of the proposed filter design, a filter prototype centered @148MHz was implemented using the circuitry diagram as shown in Fig. 4. Three general purpose discrete GaAs FETs were used and biased with V_{DS}=3V and I_D=20mA. The experimental filter result is depicted in Fig. 5. Form these measured transmission S_{21} values, 148-MHz bandpass filter has a bandwidth of 3MHz and two zeros of 44dB@129MHz and 48dB@169MHz located in the passband proximity. By these zeros, it confirms the possibility of implementing the transmission zeros by the passband filter design. Also, this filter has more than 40dB rejection @20MHz apart from passband edges.

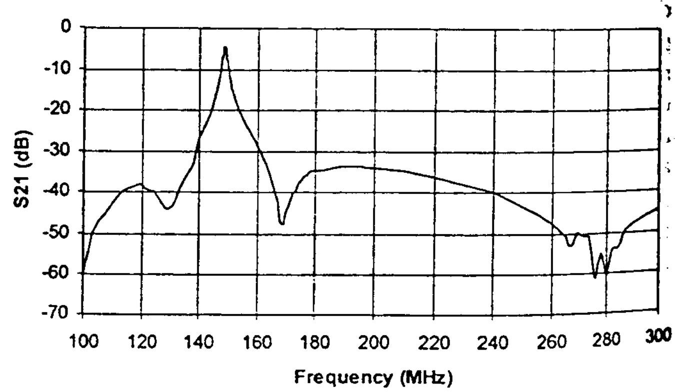

Fig. 5 Experimental characterization of the proposed filter.

4. CONCLUSIONS

A modified lumped and transversal filter is proposed and experimentally demonstrated by a prototype bandpass filter of 148-MHz as center frequency, 3MHz as 3dB BW and two zeros at 129-MHz and 169-MHz. It is anticipated that this structure can extend the traditional lumped and transversal filter architecture for the narrow band RF front end image rejection filter design.

V. REFERENCES

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