Active Feedback Amplifier Approach For Microwave Filter

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Abstract

In this paper, a novel microwave active filter based on the traditional lumped and transversal filter architecture is presented. This new filter adopts an active feedback amplifier topology in order to provide higher selectivity. Also, an alternative filter synthesis is derived from this topology for the conventional lumped and transversal filter. In order to demonstrate its usefulness, a L-band active filter is designed at GSM1800 center frequency- 1.8GHz with 30MHz 3-dB BW and evaluated in terms of computer simulation. These simulated results demonstrate that the proposed filter architecture has superior performance when compared with the traditional lumped and transversal filter.

1. Introduction

The microwave active filter development has about 20 years [1] and it is of paramount importance for the present mobile communication applications because of its compactness and ease of monolithic integration. The main drawback of the active filter is its low Q and noise laggards when compared to its counterpart - hybrid filter (like the SAW filters for example [2]).

Current challenges in monolithic filter investigation either in MESFET or CMOS technology is related with achievements in terms of higher filter selectivity. Therefore, new filter implementations have been reported during a considerable period of time including, for example, structures using negative resistance techniques, operational amplifiers, pre-distorted, transversal and also recursive filters [3-6]. Amongst them, the lumped and transversal active filter with m transversal sections, as shown in Fig.1 (where A_i is transversal gain, i=1...m), has the advantage of using lumped elements to obtain not only the required phase shifts but also to achieve the overall filter response. The transversal element in each transversal section (A_i) is then used to sharpen the band-edges rejections in order to provide higher selectivity. Some new developments of this type of filter has been reported in recent years [2,7]. One of the main filter design difficulties is its high synthesis complexity due to the intrinsic transversal structure. However, this design complexity consideration is not yet highly emphasized in recent research results. In this paper, a basic lumped and transversal filter structure is proposed

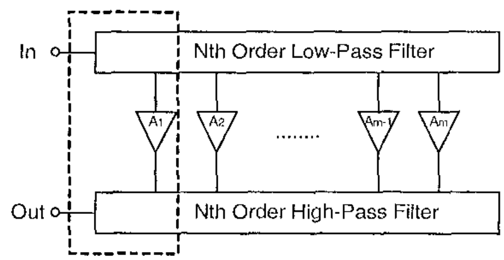

Fig. 1 Traditional lumped and transversal filter

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in section 2 based on an alternative active feedback amplifier topology [8,9] for the simplification of the synthesis design procedure. Using this new topology, the filter will include a new active feedback amplifier circuit. In section 3, to demonstrate the superior performance of this architecture, a L-band active filter is designed and compared with the traditional lumped and transversal structure using computer simulation.

2. NEW MICROWAVE ACTIVE FILTER

To simplify, we will present a traditional lumped and transversal filter circuit that can be implemented, for example, by the section (Fig. 2) within the dashed line of Fig. 1 whilst its alternative active feedback amplifier representation is then depicted in Fig. 3.

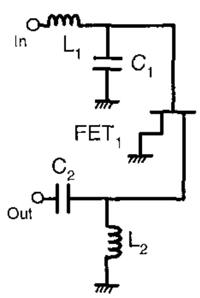

Fig. 2 Single lumped and transversal section.

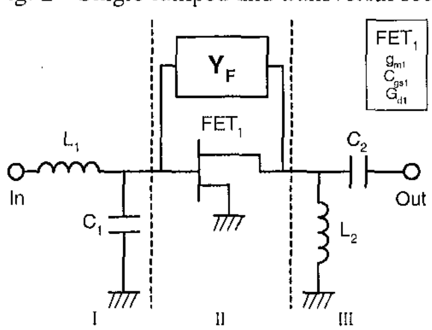

Fig. 3 Alternative feedback amplifier representation of active filter.

Through this representation, section 1 in Fig. 3 will implement a low-pass filter with input signal matching. Similarly, a high-pass filter with output matching can be obtained by the circuit of section 3. Finally, the function of the middle section 2 will be described next.

Assuming the ideal equivalent circuit of the common source FET as shown in Fig. 4 and its corresponding Y-matrix given by Eq.(1),

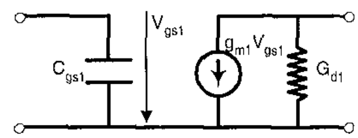

Fig. 4 Ideal equivalent circuit of the common source amplifier FET_1.

$$Y_{FET1} = \begin{bmatrix} sC_{gs1} & 0 \\ g_{m1} & G_{d1} \end{bmatrix} \qquad (1)$$

the symbolized parallel component Y_F is

$$Y_F = \frac{1}{Y_o}\begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \qquad (2)$$

Based on these equations, the section 2 S-parameter S_{21} can be derived as:

$$S_{21} = \frac{-2Y_o(g_{m1}Y_o + Y_{21})Y_o}{(Y_{11} + sC_{gs1}Y_o + Y_oY_o)(Y_{22} + G_{d1}Y_o + Y_oY_o)} \qquad (3)$$

where

$$Y_o = \frac{1}{Z_o} = \frac{1}{50\Omega}$$

g_{m1} is the transconductance of FET_1

C_{gs1} is the gate-source capacitance of FET_1

G_{d1} is the drain conductance of FET_1

Therefore, the synthesis of the traditional lumped and transversal filter can now be analysed in terms of Y_F. For example, in the case of two transversal sections of the traditional lumped and transversal filter, Y_F (circuit shown in Fig. 5) and S_{21} can be given by Eqs.(4) and (5), respectively.

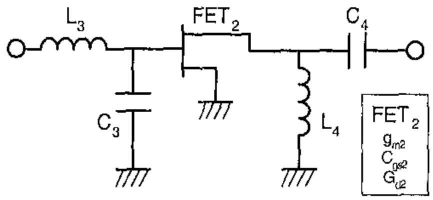

Fig. 5 Two-section traditional lumped and transversal filter's Y_F circuitry.

$$Y_F = \frac{1}{Y'_n}\begin{bmatrix} Y'_{11} & Y'_{12} \\ Y'_{21} & Y'_{22} \end{bmatrix} \tag{4}$$

$$S^t_{21} = -\frac{2Y_o(g_{m1}Y'_n + Y'_{21})Y'_n}{(Y'_{11} + sC_{gs1}Y'_n + Y_oY'_n)(Y'_{22} + G_{d1}Y'_n + Y_oY'_n)} = \frac{N^t(s)}{M^t(s)} \tag{5}$$

where

$$Y'_{11} = s^3C_4L_4(C_3 + C_{gs2}) + s^2G_{d2}L_4(C_3 + C_{gs2}) + s(C_3 + C_{gs2})$$

$$Y'_{12} = 0$$

$$Y'_{21} = -s^2C_4g_{m2}L_4$$

$$Y'_{22} = s^4G_{d2}L_3L_4(C_3 + C_{gs2}) \quad s^3C_4L_3(C_3 + C_{gs2}) + s^2G_{d2}L_4 + sC_4$$

$$Y'_n = s^4C_4L_3L_4(C_3 + C_{gs2}) + s^3G_{d2}L_3L_4(C_3 + C_{gs2}) + s^2(C_3L_3 + C_4L_4 + C_{gs2}L_3) + sG_{d2}L_4 + 1$$

In this paper, a novel filter structure is proposed based on the change of this common source FET by an active feedback amplifier circuit [9], as depicted in Fig. 6, which will allow a better performance of the whole filter.

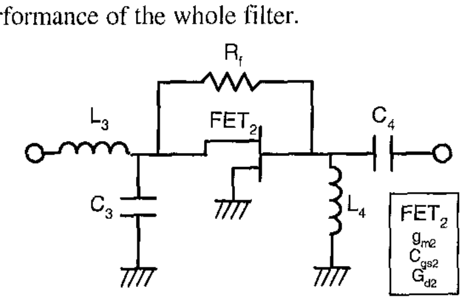

Fig. 6 Proposed active feedback amplifier circuitry.

Based on the above, similar analysis of the circuit can be made in terms of the corresponding Y_F and S_{21} parameters as presented in Eqs.(6) and (7), respectively:

$$Y_F = \frac{1}{Y^a_n}\begin{bmatrix} Y^a_{11} & Y^a_{12} \\ Y^a_{21} & Y^a_{22} \end{bmatrix} \tag{6}$$

$$S^a_{21} = -\frac{2Y_o(g_{m1}Y^a_n + Y^a_{21})Y^a_n}{(Y^a_{11} + sC_{gs1}Y^a_n + Y_oY^a_n)(Y^a_{22} + G_{d1}Y^a_n + Y_oY^a_n)} = \frac{N^a(s)}{M^a(s)} \tag{7}$$

where

$$Y^a_{11} = s^3C_3L_4R_f(C_4 + C_{gs2}) + s^2L_4(C_{gs2}G_{d2}R_f + C_4 + C_4G_{d2}R_f + C_3) + s(g_{m2}L_4 + G_{d2}L_4 + C_3R_f) + (1 + G_dR_f)$$

$$Y^a_{12} = s^2C_4L_4(g_{m2}R_f - 1)$$

$$Y^a_{21} = -s^2C_4L_4$$

$$Y^a_{22} = s^5C_3C_4C_{gs2}L_3L_4R_f + s^4C_4L_3L_4(C_{gs2} + C_{gs2}G_{d2}R_f + C_3) + s^3C_4(C_{gs2}L_4R_f + g_{m2}L_3L_4 + G_{d2}L_3L_4 + C_3L_3R_f) + s^2C_4(L_3 + L_4 + G_{d2}L_2R_f) + sC_4R_f$$

$$Y^a_n = s^4C_3L_3L_4R_f(C_4 + C_{gs2}) + s^3L_3L_4(C_{gs2} + C_{gs2}G_{d2}R_f + C_4 + C_4G_{d2}R_f + C_3) + s^2(C_4L_4R_f + C_{gs2}L_4R_f + g_{m2}L_3L_4 + G_{d2}L_3L_4 + C_3L_3R_f) + s(L_3 + L_4 + L_3G_{d2}R_f) + R_f$$

The above $M^t(s)$ (Eq. 5) will be independent of the g_{m2} but $M^a(s)$ (Eq. 7) is not only a function of g_{m2} but also of R_f. This means that the proposed filter may have additional degree of freedom allowing the control of the values of g_{m2} and R_f. When the active feedback amplifier circuitry is biased at the pinch-off voltage, $g_{m2} = 0$, S_{21} is maximized and that will be true also for R_f.

3. Simulation Results

In order to demonstrate the proposed structure, two L-band active filters have been designed @1.8GHz. The first one is the traditional lumped and transversal filter with two transversal sections (Fig. 5) whilst the second one is the new filter (Fig. 6). These two filters have both been simulated, using the linear and nonlinear simulation package like [10], with the same SMD components (the value of the inductor and capacitor are 50nH and 30pF respectively, the feedback resistance is in the order of 10Ω). Also, the conventional discrete GaAs FET was used and biased @ V_{DS} = 3.5V and I_D = 30mA [11].

Fig. 7 shows the S_{21} responses of these two filters. The new filter presents 20dB band-edges rejections 100MHz apart from the centre frequency. Moreover, being the 3-dB BW close to 30MHz. These performances are considerably superior than that of the two-section traditional lumped and transversal filter.

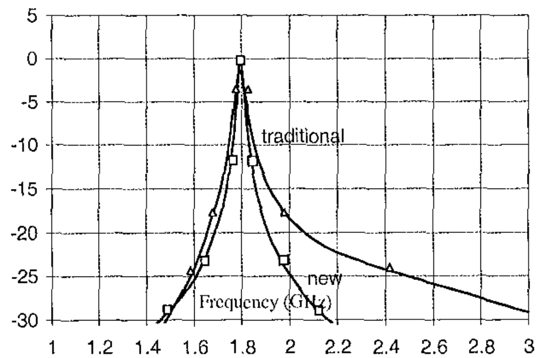

Fig. 7 Transmission responses (S_{21}) of the new band-pass filter □ and the traditional lumped and transversal band-pass filter Δ.

4. Conclusions

In this paper, a novel microwave filter using an active feedback amplifier approach is proposed and simulated at a center frequency of 1.8GHz with 30MHz 3-dB BW. By comparison of simulation results, it is shown the better performance of the new filter structure when compared with the traditional lumped and transversal filter. Through this new approach, the traditional lumped and transversal filter synthesis is presented by means of the paramenter Y_F. This approach may also facilitate the complete m-sections filter design and synthesis in the future. Also, it can be predicted that a future monolithic implementation in either GaAs MESFET or CMOS technology will achieve significant results for microwave filtering.

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