Tunable CMOS RF Filter Design for New Generation of Mobile Communications 3GPP LTE

AHMED EL OUALKADI
Laboratoire de la Technologie de l'Information et de la Communication (LabTIC)
Université Abdelmalek Essaadi. Ecole Nationale des Sciences Appliquées de Tanger
ENSA de Tanger, Route Ziaten, BP 1818, Tanger
MOROCCO
ahmed.eloualkadi@ieee.org

Abstract: - This paper proposes the design of a tunable radiofrequency filter based on the switched capacitor techniques. This circuit, which can replace high-Q external passive filters, allows a high selectivity with a tunable center frequency range of 400 MHz [700-1100 MHz], with quality factor up than 1100. Implemented in 0.18 µm CMOS technology, this circuit is intended to be used for the next generation of mobile communications 3GPP LTE which requires a very high-Q characteristic.

Key-Words: - Tunable, CMOS, filter, radiofrequency, high-Q, 3GPP LTE

1 Introduction

The wireless broadband is one of the important issues in telecommunications for the next decade. Recently, 3GPP (3rd Generation Partnership Project) has standardized LTE (Long Term Evolution) as the future standard for mobile network fourth generation (4G). With this standard, manufacturers and operators seek to increase the data rate up to 100 Mbit/s for downlink (50 Mbit/s for uplink) [1]. It should reach a data rates closed to those available in the fixed telephony, with the qualification that the bandwidth is pooled among all users simultaneously present in the area. A key requirement in the LTE technology is the ability to use the available parts of the radio spectrum efficiently and flexibly. Moreover, the LTE technology should have a compatibility with existing networks such as GSM, CDMA and WCDMA [2]. For this reason, the LTE standard has more stringent requirements on linearity and noise level than previous mobile networks standards.

In this context, the development of high-performance RF circuits around the frequency of 700 MHz (band 12, 13 and 14) is a great need to provide mobile communication systems for 3GPP LTE [1-2]. The bandpass filter is most critical building blocks of a radio receiver. The aim of this work is to study the design feasibility of a new radiofrequency tunable filter integrated in CMOS technology for the new generation of mobile 3GPP LTE.

2 General Principle of the Filter

The behavior of the proposed filter can be explained by the theoretical approach of the 'N-path' switched capacitor filters. Several articles [5-6] have described this kind of filter. In [3] a simplified structure was proposed. This architecture (Fig. 1) has, under defined conditions, similar properties compared to the 'N-path' switched capacitor filters [7].

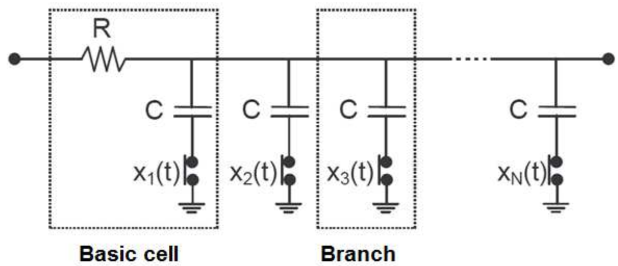

Fig.1. Classical topology of switched capacitor filter with N branches.

This classical architecture uses a first order RC low-pass filter as the basic cell. The N switches are successively closed with a switching period To during To/N. When the command signals of the switches are considered Dirac pulses δ(t) of a period of To = 1/Fo, the output signal S(f) can be expressed

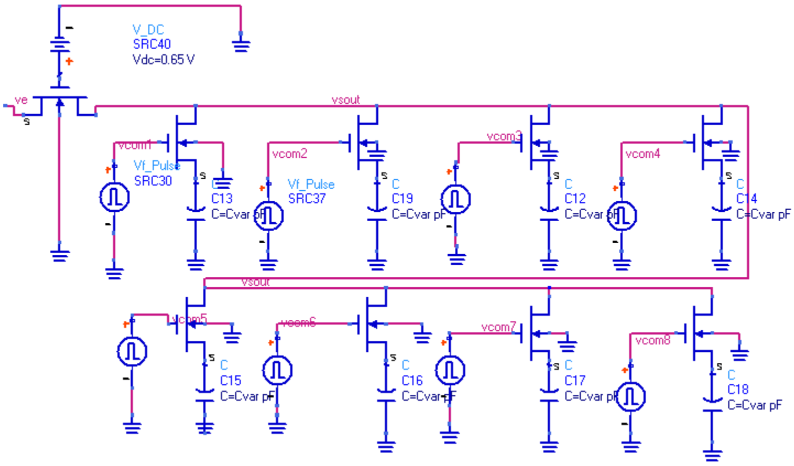

Fig.2. Proposed filter architecture

in the frequency domain according to the input signal e(t) as follows:

$$S(f) = H_S(f) \,.\, E_S(f) \qquad (1)$$

Where,

$$H_S(t) = \sum_{m=-\infty}^{+\infty} h(mTo).\exp(-2\pi\pi jfmTo)$$

With HS(t) is the Fourier transform of the impulse response of the basic cell sampled at the period T, and,

$$E_S(t) = \sum_{q=-\infty}^{+\infty} e(\frac{qTo}{N}).\exp(-2\pi jf\,\frac{qTo}{N})$$

With ES(t) is the Fourier transform of the input signal sampled at the period To/N.

Equation (1) shows that the transfer function Hs(f) of the classical switched-capacitor filter is the result of the transposition of the transfer function of the basic cell (first order RC low-pass filter) transposed around the center frequency (Fo = 1/To) and all of their harmonic components.

A voltage controlled oscillator (VCO) can be used for generating command signals. The VCO can be fully integrated with the filter. The advantage of having internal command signals is the ability to tune the center frequency of the filter.

Moreover, the quality factor of the filter (Fig. 1) can be expressed as Q = π N R C Fo [8], this relationship shows that the selectivity of the filter depends directly on the number of branches N and the value of input resistance, which is usually taken equal to 1 k allowing to have a good trade-off between selectivity and dynamic output.

3 Filter Architecture & Design

The major advantage of these kinds of filters is that they have high quality factors that allow them to be used in a receiver of the LTE standard, such as a passband filter instead of no tunable off-chip passive filters. Moreover, the center frequency of these filters is controlled by command signals which make them very promising for applications such as: multi-mode and multi-band radio receiver or Software-Defined Radios (SDR) communication systems where there is a strong need of tunable bandpass filters.

The architecture of the bandpass filter is presented in Fig. 2. The proposed filter is a comb with eight switched capacitor, the resistor in the input, presents in classical architecture, is replaced by a MOSFET biased in the ohmic region. According to the variation of Vgs, this resistance can take different values.

Simulations were performed to study the behavior of the transfer function of this architecture. The results of these simulations have shown identical behavior to that of the conventional structure of the switched capacitor filter (Fig.1) described above. The number of eight branches chosen for this study seems to be a good trade-off between the quality factor Q and the complexity of the implementation on chip.

Proposed the filter (Fig.2) can be used for clock recovery by filtering the harmonic components. It can also be used as a bandpass filter centered around the switching frequency Fo. This last application will be considered in this paper.

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The various compromises on the design of an original oscillator circuit assuring the command signals for this type of filter in the radio frequency band were presented in reference [9]. This command circuit is based on the association of a ring voltage controlled oscillator with "XOR" gates.

4 Results and Discussions

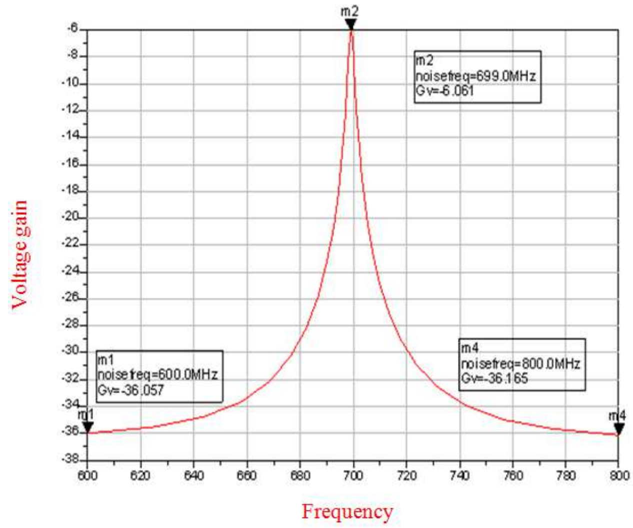
The filter is designed in 0.18 µm CMOS technology. Fig. 3 shows the voltage gain versus frequency for center frequencies of 700 MHz, 900 MHz and 1100 MHz.

All simulation results for center frequencies of 700 MHz and 1100 MHz are summarized in Table 1. The filter is very selective in frequency. A quality factor of 583.3 was obtained at 700 MHz, while the quality factor becomes equal to 1222 at 1100 MHz. The filter can be tuned between 700 MHz and 1100 MHz, which covers the majority of the bands of the LTE standard.

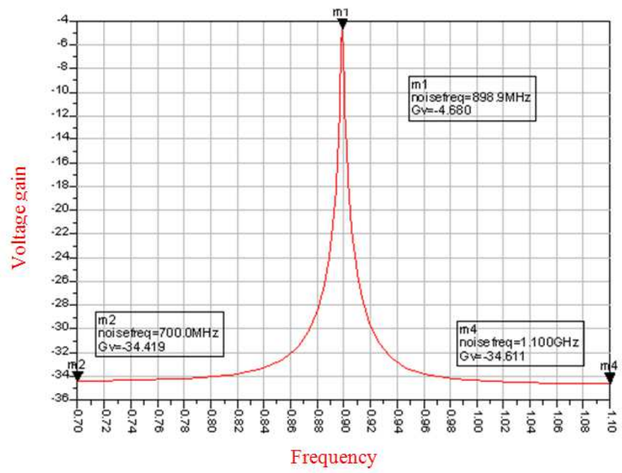
Thus, the proposed filter has interesting performances. This will make it an attractive alternative for off-chip passive filters in modern receivers based LTE.

4 Conclusion

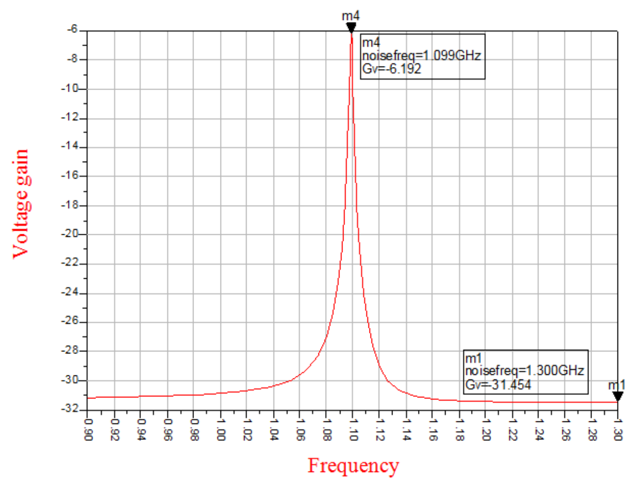
The work presented in this paper demonstrates the feasibility of a filter with a high quality factor tunable over a frequency band. This circuit, is designed in 0.18 µm CMOS technology, has several advantages. The filter is characterized by high quality factors and the ability to tune its center frequency over a frequency band of 400 MHz (from 700 MHz to 1100 MHz) with an insertion loss and a tolerable dynamic. This filter can be fully integrated which make it attractive to replace passive filters widely used in RF receivers. Thus, the results obtained show the feasibility of this filter to the receivers of the new generation of mobile 3GPP LTE.



(a) around 700 MHz.



(b) around 900 MHz.



(c) around 1100 MHz.

Fig.3. Gain versus frequency: (a) around 700 MHz (b) around 900 MHz and (c) around 1100 MHz

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Center frequency F_0 (MHz)	700	1100
-3 dB Bandwidth @ F_0 (MHz)	1.2	0.9
Quality factor	583.3	1222
Dynamic (dB)	30.10	25.26
Insertion loss @ F_0 (dB)	-6.06	-6.192

Table 1. Filter performances

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