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# Multi Standard Reconfigurable Receiver Architecture for Wireless Systems

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**Abstract:** ***The existence of a large number of wireless standards motivates the investigation of a multi-standard wireless receiver architecture that uses the same hardware in meeting performance requirements. This paper presents an architecture of a reconfigurable receiver operating in both Low-IF and Zero-IF modes for GSM-1800 and UMTS-2100 wireless standards. The reconfigurability in the RF front-end part is achieved by a reconfigurable filter based on a dual mode resonator with the possibility of using MEMS switches to tune the center frequency and the bandwidth of the preselect filter. System-level analysis and derivation of block-level specification for the specified standards are developed to design the receiver. Simulation results for both system-level analysis of the reconfigurable receiver and circuit design of the reconfigurable filter are presented and discussed.***

**Keywords:** multi-standard receiver; reconfigurable dual mode resonator filter; system performance simulation

## 1. Introduction

The simultaneous need for global roaming and all-in-one wireless phones has resulted in a demand for handsets capable of receiving multiple standards and satisfying the modern requirements of the wireless devices such as low cost, high integration and high performance [1].

In order to accommodate these different wireless standards, and to meet the modern requirements, suitable receiver architectures and reconfigurable filters should be designed.The Low-IF and Zero-IF architectures meet these modern requirements, despite having some problems such as DC offset and Image rejection [2].

The reconfigurable filter offers the possibility of choosing the desired frequency band of different standards. This kind of filter should offer size reduction, high selectivity and should be easy to be fabricated and integrated with the receiver printed circuit board.

The recent advance in designing dual-mode microstrip resonators using RF MEMS switches offers the possibility of designing reconfigurable filters that meet the previous requirements [3].

However, in this paper we propose to use one RF-FE block and dual mode resonators as reconfigurable filters to deal with different standards. The reconfigurability of the filter is achieved by simulating the use of MEMS switches. This solution is characterized by size reduction, high selectivity and it is easy to be implemented and integrated in microstrip technology.

In this context, we present the design and analysis of the proposed RF front-end receiver. First, a brief summary of the two wireless standards and the overall receiver specifications required for each standard are provided. The proposed Low-IF Zero-IF receiver is then examined, and an outline of the reconfigurable dual mode resonator filter with the possibility of using MEMS switches and other components used in the receiver are presented. A system-level simulation results are also presented and discussed to valid the design of the proposed receiver architecture.

## 2. The Reconfigurable RF Front-End (RF-FE) Receiver

Our work, about the design of a reconfigurable RF-FE receiver, has been the subject of many papers and dissertations around the world ([1], [2] and [4 - 6]). In this paragraph we present our motivation to do this work, and its novelty when compared to others.

The Zero-IF and Low-IF architectures are more suitable for high integration level [2]. Choosing the suitable architecture (Zero-IF or Low-IF) for the suitable standard is essential in order to improve the receiver performance.

Generally, a dual standard operation is enabled through two separated parallel receiver chains (Figure 1), which is obviously not cost-efficient solution, in addition to increase the size [4].

To overcome this problem some solutions were developed. One of these solutions consists of using a silicon varactor-tuned band pass filter (BPF) in connection with a tunable six-port demodulator to design a reconfigurable direct conversion receiver front end for GSM and WLAN bands (1.9 and 2.4 GHz). The tunable demodulator is composed of a tunable six port junction in connection with four RF power detectors [5]. Although this BPF offers high selectivity, it requires using two different sets of supply voltage and the insertion loss degrades as varactor capacitance increases due to the mismatch and varactor diode equivalent series resistances [5].

Another solution proposed the use of a dual behavioral resonator (DBR) topology to design an electrical tunable filter able to switch between UMTS, WiFi and LTE reception bands.

The DBR topology is based on the parallel association of two stubs which gives a band pass response. For controlling central frequency and bandwidth independently, varicap diodes are implemented at the end of each stub [6].

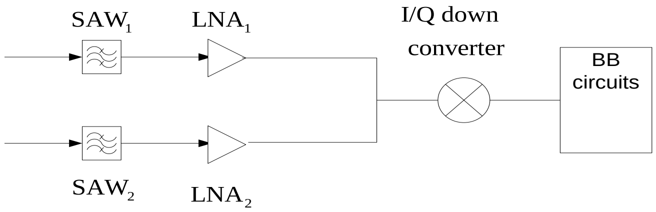



**Figure 1:** Classical approach for dual standard RF front-ends

Micro-Electro Mechanical Systems (MEMS) switches facilitate building reconfigurable filter to cope with different standards, and to obtain good performance [3]. Then we can design multi-standard receiver without increasing its size or cost.

We find in [4] an example of using RF MEMS switches to design a reconfigurable FBAR filter for multi-standard RF receiver front-end. Although this filter offers unique advantages such as high frequency operation and high quality factor, the technology FBAR may not be available everywhere and easy to fabricate.

However, in this paper we propose to use one RF-FE block, instead of two separated parallel receiver chains, and dual mode resonators as reconfigurable filters to deal with different standards. The reconfigurability of the filter is achieved by simulating the use of MEMS switches. This solution is characterized by size reduction, high selectivity and it is easy to be implemented and integrated in microstrip technology.

## 3. GSM1800 and UMTS 2100 Standards

Table 1 shows the receiver frequency bands of GSM-1800 and UMTS-2100. UMTS-2100 has a channel of 5MHz bandwidth while GSM-1800 has a 200 KHz channel bandwidth.

**Table 1:** Receiver frequency bands for GSM-1800 and UMTS-2100.

| Standard | Downlink Rx frequency band (MHz) |
|---|---|
| GSM-1800 | 1805 to 1880 |
| UMTS-2100 | 2110 to 2170 |

The two standards have different specifications named as minimum performance requirements [7], [8]. These requirements specify mainly the receiver sensitivity, inter-modulation characteristics, adjacent and alternate channel selectivity, blocking characteristics, and spurious emission.

From these different standards specifications we derive a set of specifications valid for the two standards by selecting the most stringent requirements of each parameter. Table 2 shows the common specifications of the multi-standard receiver to be able to work with the two standards.

**Table 2:** Required specifications of the multi-standard receiver

| | |
|---|---|
| Noise Figure (dB) | < 7.2 |
| $IIP_2$ Mixer (dBm) | ≥ 35 |
| $IIP_3$ (dBm) | ≥ -14.7 |
| Image rejection (dB) | ≥ 30 |
| Blocking characteristics | designed receiver must satisfy blocking characteristics defined in [7] and [8]. |

## 4. Low-IF/Zero-IF Multi-Standard Receiver Architecture

It is preferable to use Zero-IF architecture when dealing with systems that have wide channel bandwidth like UMTS-2100, because removing DC offset by using DC notch filter or AC coupling will not cause a significant damage [1]. The narrow channel bandwidth in GSM-1800 makes this architecture unattractive due to removal significant part of the signal when removing DC offset. Thus, using Zero-IF architecture is suitable for UMTS-2100 while using Low-IF architecture will be more suitable for GSM-1800[1].

The Low-IF architecture is similar to the Zero-IF architecture, except that there is an AC coupling or DC notch in the Zero-IF to remove the DC offset. And there is an image rejection circuit in Low-IF to drop out the image signal.

In order to reduce size and cost, we will design a common RF-FE receiver that can be configured to operate as Zero-IF for UMTS-2100 and Low-IF for GSM-1800. This can be achieved using for example digital dual quadrature converter in the digital base band block of the Low IF receiver to cope with the image rejection. Moreover, we will drop the AC coupling or DC notch filter from the Zero-IF architecture, The DC canceller will be achieved by means of I/Q down converter, as we will see in section (V). Figure 2 shows the architecture of the proposed receiver. This architecture is based on high-dynamic analog-to-digital converter (ADC). It helps to relax the restrictions on the automatic gain control system (AGC) which is concentrated on the RF amplifiers. By using fixed and low gain baseband amplifiers, this architecture may have less I and Q mismatch and DC offset issue [9].

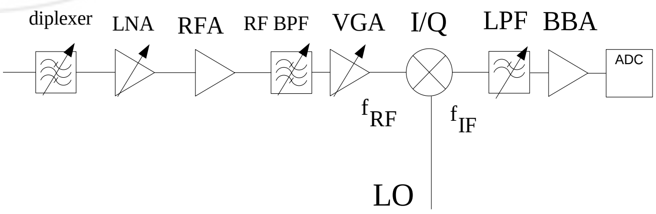



**Figure 2:** The architecture of the proposed receiver

## 5. RF-FE Building Blocks design

### 5.1 Reconfigurable dual mode resonators

The filters based on dual mode resonators are designed to be reconfigurable. The reconfigurabilty consists of tuning their center frequency and bandwidth to achieve multi-band selection according to the two standards.

Recently, dual-mode microstrip resonators have been increasingly used for designing reconfigurable microwave filters. They have the advantages of ease of fabrication and integration, low loss, and high selectivity in addition to low cost [3].

Dual mode resonators have symmetric structure (it's a ring in our case) and support two orthogonal degenerate modes of resonance. By inserting a perturbation (cut for example) into the structure of the resonator, the two modes are coupled and tuned to perform a resonant filter [3].

The bandwidth of the filter could be changed by adjusting the dimensions of its perturbation element, while tuning its center frequency could be accomplished by changing the center radius of the ring.

Usually, RF switches are used to achieve geometric tuning, so they can be used to change the dimensions of the cut and the center radius of the ring. Nowadays, RF MEMS switches are considered as a suitable choice to achieve fine tuning, because of their small size, simple circuit model, zero power consumption and low insertion loss [3].

In this work two filters have been simulated to represent the changing cut size and center radius instead of implementing RF MEMS switches (which are considered as an ideal short-circuit). Figure 3 shows these two filters.

Figure 4 shows simulation results for these filters using an electromagnetic simulator. The insertion loss ($|S21|_{dB}$) and reflection coefficient ($|S11|_{dB}$) of the filters are shown.

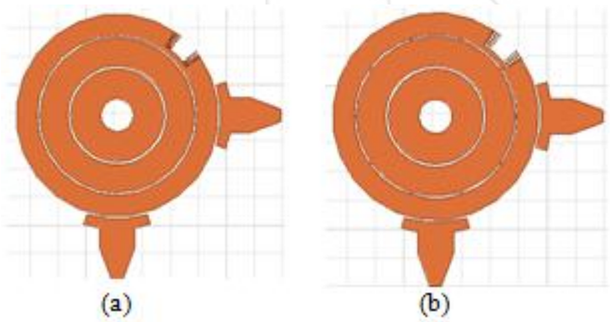
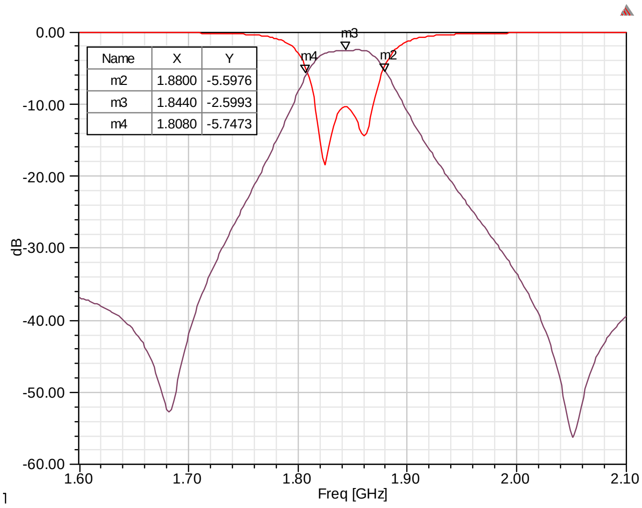
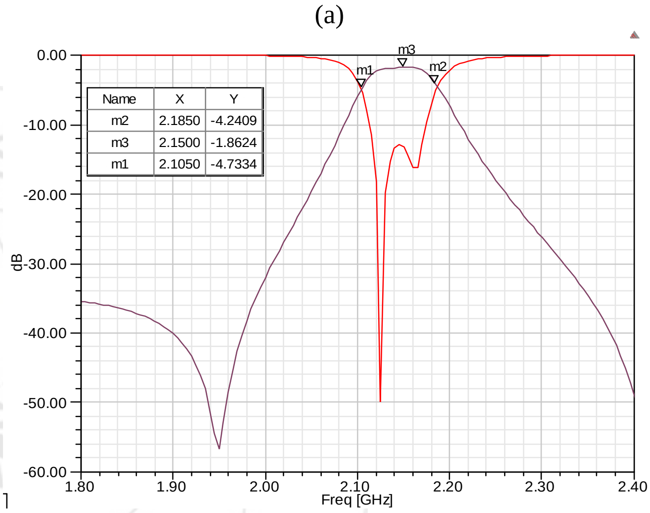



**Figure 3:**Layout of the two designed filters with substrate of$h$= 3.06 mm, $\varepsilon_r = 3.58$ and tanδ=0.0035, (a) the center frequency and bandwidth agree with GSM-1800, (b) the center frequency and bandwidth agree with UMTS-2100.




(a)




(b)

**Figure 4:**$|S11|_{dB}$ and $|S21|_{dB}$ simulation results of the designed filter. (a) GSM-1800filter. (b) UMTS-2100filter.

## 5.2 RF and Baseband Blocks of the Receiver

Both diplexer and RF BPF are designed to be reconfigurable filter with dual mode resonators to achieve high selectivity against transmission leakage and other interferers.

ADC plays an important role in this design. Because of its large dynamic range (80 dB or 13 bits), low order baseband LPF and fixed-gain baseband amplifiers could be used. The dynamic range of the AGC system could be relaxed to only 53dB in spite of the required dynamic range for the designed receiver is about 100 dB (with margin).

Low noise amplifier (LNA) and variable gain amplifier (VGA) form the AGC system. The 53 dB dynamic range is resulting from the two gain-stepped LNA and the one gain-stepped VGA. This configuration makes AGC system simple and efficient.

The characteristics of the I/Q down converter affect directly the performance of the receiver. It should have a suitable second order intercept point $IIP_2$ (more than 35 dBm as specified in table 2) since I/Q down converter dominates the second order distortion in Zero-IF architecture [9]. The I/Q down converter should offer enough isolation between its ports to reduce signal leakages. In our design, the DC canceller is achieved by the I/Q down converter which offer this ability by means of a signal control coming from digital domain.

Table 3 shows the characteristics of the different amplifiers and I/Q down converter forming the RFFE of the receiver.

Low pass filter (LPF) form the channel filter in both Zero-IF and Low-IF. Since the bandwidth of the channel in GSM-1800 and in UMTS-2100 is different, the cutoff frequency of the LPF should be tunable to obtain 200 kHz for Low_IF case and 2.5 MHz for Zero-IF. An active fourth order chebyshev filter is employed in both I and Q channels, where Figure 5 shows the first 2nd order stage of this filter. Switches (SW) are used totune thecutoff frequency.

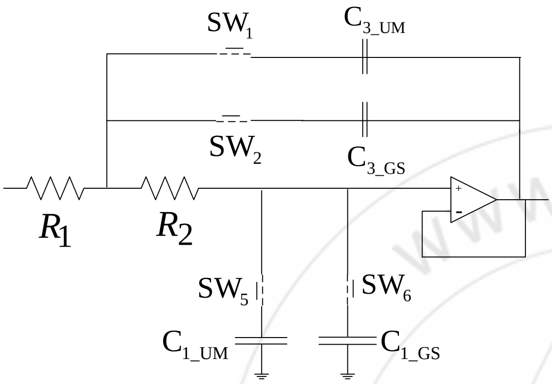



**Figure 5:** First 2nd order stage of 4th order chebyshevtunable LPF filter.

**Table 3:** Specifications of amplifiers and I/Q Mixer of the RFFE receiver

| | LNA | VGA | RFA | BB_A | Mixer |
|---|---|---|---|---|---|
| High gain (dB) | 11 | 10 | | | |
| $NF_{Low\_gain}$ (dB) | 2.5 | 30 | | | |
| $IIP_{3\_Low\_gain}$ (dBm) | 25 | 59 | | | |
| Mid gain (dB) | 2 | | 15 | 36 | 2.5 |
| $NF_{Mid\_gain}$ (dB) | 8 | | 4 | 28 | 12.7 |
| $IIP_{3\_Mid\_gain}$ (dBm) | 27.5 | | 12 | 20 | 25.7 |
| Low gain (dB) | -12 | -20 | | | |
| $NF_{High\_gain}$ (dB) | 21 | 4.5 | | | |
| $IIP_{3\_High\_gain}$ (dBm) | 28 | 29 | | | |
| $IIP_2$ (dBm) | | | | | 60 |
| RF / LO Isolation (dB) | | | | | 58 |

## 6. Simulation Results

The simulation results for GSM-1800 are presented and compared to the minimum requirements defined by the GSM-1800 standard.

Figure 6 shows the building receiver, the assigned values to the components' parameters are the same as the real ones to make the simulation closer to the reality. The simulation results include noise figure, third order input intercept point, sensitivity and blocking characteristics.

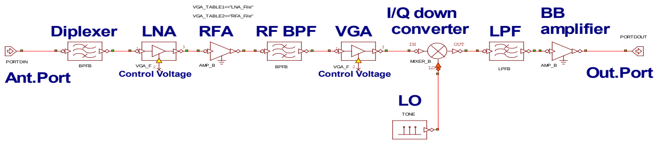



**Figure 6:** Block diagram of the simulated receiverwith RF and Baseband Blocks of real specifications.

### 6.1 Noise Figure

From table 2, the noise figure of the receiver should be less than 7.2 dB. Figure 7 shows that noise figure $NF$ of the designed receiver is 5.7 dB, which means that the design has a margin of about 1.5 dB.

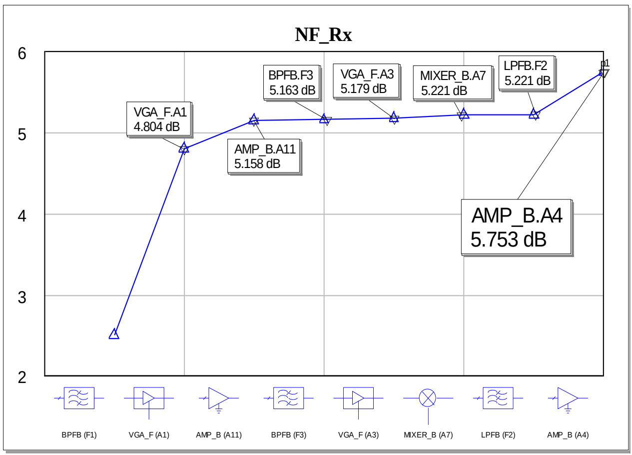



**Figure7:** Simulated $NF$ of the receiver with real components' parameters.

### 6.2 Third order input intercept point

The resulting third order input intercept point $IIP_3$ of the simulated receiver using real components' parameters is shown in Figure8.The total $IIP_3 = -14.23$ dBm satisfy the required $IIP_3 = -14.7$ dBm from table 2. The margin is only about 0.5 dB, this is because the gain in the RF block is forced to be high to cope with the low sensitivity defined in UMTS-2100 standard to be -117 dBm [8].

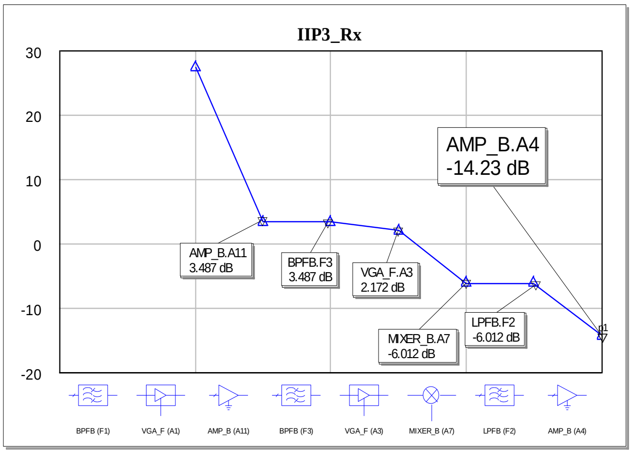



**Figure 8:** Simulated $IIP_3$ of the receiver with real components' parameters.

### 6.3 Sensitivity

The sensitivity of a wireless mobile receiver is defined as the weakest RF signal power that can be processed to develop a minimum signal-to-noise ratio for achieving a required bit error rate ($BER$) by the system [9]. GSM-1800 standard defines the sensitivity as $-102$ dBm for $BER = 10^{-3}$. For $CNR_{min} = 8$ dB which meets the specified value of $BER$[5], the result of simulation of receiver sensitivity is shown in Figure9.

The sensitivity of the designed receiverusing real components' parameters is -104.7 dBm; which means that a design margin of about 2.7 dB is obtained.

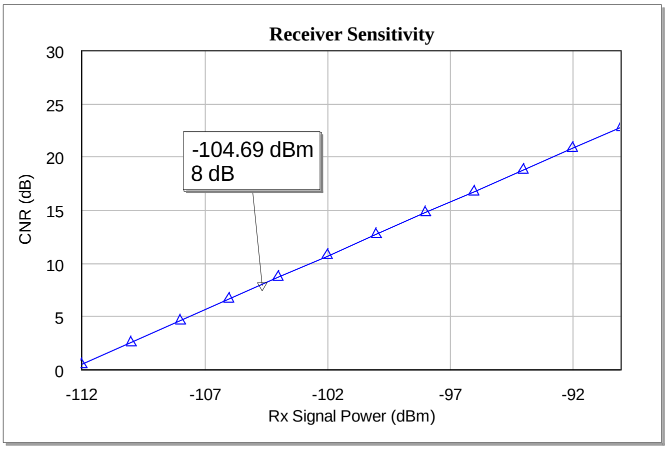



**Figure 9:** Simulated sensitivityof the receiver with real components' parameters.

### 6.4 Blocking characteristics

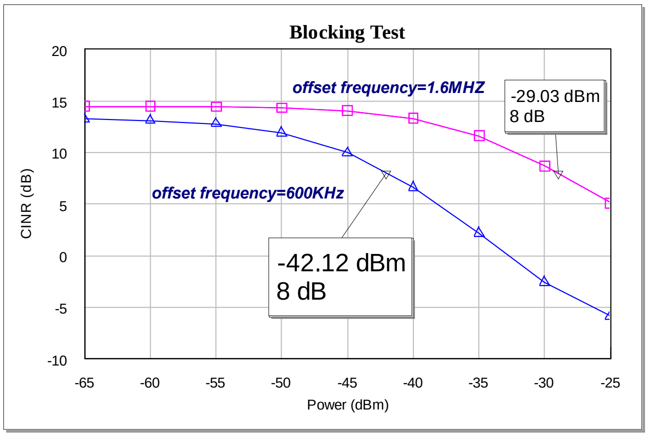
Blocking characteristics of a receiver are mainly determined by theadjacent/alternate channelselectivity of the receiver and the phase noise and spurs of synthesizers usedas local oscillators of the receiver.

The blocking requirements set by the standard are shown in table 4, for a desired signal level of -99 dBm at the input of the receiver [8].

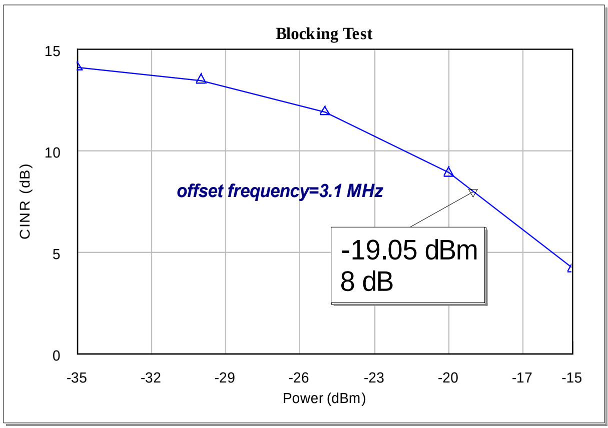
**Table 4:** GSM blocking requirements

| Offset Frequency (MHz) | Allowed I_blocking (dBm) |
|---|---|
| 0.6-1.6 MHz | -43 |
| 1.6-3.0 MHz | -33 |
| >3 MHz | -26 |

The results of simulationof blocking characteristics ofthe receiver with real components' parameters are shown in Figure 10.




(a)




(b)

**Figure10:** Simulation results of blocking characteristics for defined offset frequencies. (a) 0.6 MHz and 1.6 MHz, (b) 3.1 MHz.

Figure 10 shows that the proposed receiver architecture meets the blocking requirements defined in table 4 with good margin.

## 7. Conclusion

A dual-standard front-end RF receiver based on reconfigurable dual mode microstrip band pass filter has been designed. The architecture of the receiver is reconfigurable, operating in low-IF one for GSM-1800 and zero-IF for UMTS-2100.

System-level analysis allowed the derivation of block-level specifications concerning receiver sensitivity, noise performance, intermodulation distortion, and blocking characteristics for the specified standards. Then real components have been chosen to design the receiver.

Based on the analysis of the simulation results for The reconfigurable filter

The simulation of the proposed band pass filter and outline of the other components are presented. Finally a simulation of the whole system has shown that the proposed design meets the requirements defined for the GSM-1800 and UMTS-2100 standards.

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**Khaled Yazbek** received the B.S., M.S., and PhD. degrees in Electrical Engineering from ENSERG, INPG and University Paris XI in 1987, 1989, 1994, respectively. During 1994-2015, he was lecturer and researcher in Communications Department at Higher Institute for Applied Sciences and Technology (HIAST). During 2008-2011, he was Deputy Director (Vice Dean) for Scientific Affairs and Research at HIAST.He teaches microwave engineering, antennas and wave propagation for wireless applications, RF engineering, RF and microwave system design and analysis. He is Founder and member of the organizing committee and permanent participant in Summer University since foundation in 1997. Universities and Institutes from France, Lebanon, Palestine, Jordan, Iraq, and Syria are involved, with the sponsoring of the Regional Office of UNESCO for Education in the Arab States.The main objective of the Summer University is to integrate tools and academic programs (software and hardware) already used in the industry in the university teaching curricula. Other objectives are first to allow instructors and trainers coming from different universities to meet in order to deepen and complete their knowledge in specific fields of technology, and second to offer a framework for participants to exchange their vocational and educational experiences and to establish friendship relations with one another that may be useful for future cooperation.