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RECONFIGURATION AND REPROGRAMMING OF THE  
BASEBAND LEVEL BY SOFTWARE DEFINED RADIO FOR  
WIMAX AND UMTS MULTI-STANDARDS TERMINALS

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January 2007

Technical Report # DIT-07-043



# **Reconfiguration and reprogramming of the baseband level by Software Defined Radio for WiMAX and UMTS multi-standards terminals**

**Abstract** – Emerging standards in the area of mobile services, such as Worldwide Interoperability for Microwave Access (WiMAX) and Universal Mobile Telecommunication System (UMTS), require new capabilities from mobile devices. As a result, these devices should be aware of how to download and correctly install particular software. For this purpose, the Software Define Radio (SDR) technology is used at present. SDR allows co-existence of different independent standards, protocols, and services. This signal processing approach is broadly spreading given that reprogramming and reconfiguring of mobile devices is of great importance. Due to the availability of SDR in the device architecture, a user can update and replace necessary services without changing the hardware. This work presents a new approach to adaptation of WiMAX and UMTS to the mobile terminals on the basis of SDR. We propose the original implementation of the signal processing phase which will be able to dynamically support incoming signals of different standards.

**Keywords** – Software Defined Radio, multi-standards systems, reconfiguration and reprogramming of the structure, the baseband level.

## **1 Introduction**

The major part of current research work in the wireless communication technologies focuses on providing many varied services and maintaining the high bit rate. The possibility to be reachable in any place and at anytime has also become much demanded. That is why the greatest companies try to find possible solutions to satisfy these requirements. To this end, there is a need to devise the structure which will be able to support the possibility to retune mobile terminals according to the reception signal. Existing approaches assume that a user should purchase a new device for each standard, because most of them have their own specification of frequencies range, modulations, coding scheme, and access to the environment. Therefore, the mobile operator has to provide support for all wireless systems separately. To resolve this problem, the Software Defined Radio (SDR) technology comes in handy. This idea was proposed by J. Minolta in [8].

SDR allows for reconfiguration and reprogramming of the system by using only software commands. These commands help to build the required architecture of the transceiver. Thus, SDR will play the key role when new communication technologies will appear. SDR is the mechanism supporting rebuilding of the system according to the request [10]. The work of SDR includes digital conversion of the hardware and the software, downloading of the necessary software from the network and installation. All these steps do not require any skills and efforts from the user.

The usage of new standards, such as WiMAX in Internet family and UMTS in telephony family, are spreading everywhere. Customers want to have all advantages of the novel technologies and vendors should conform to these requirements. This aspiration leads to examination of the possibility to realize at least two standards over one common element base, which will be handled and rebuilt by SDR [3].

In our work, we propose the new approach to handling and governing signal processing for two standards, more specifically, WiMAX and UMTS. The structural level of our development includes the baseband level of the transceiver architecture. We present the structure of SDR module which arranges the DSP module. This work will be realised in SystemC.

The rest of the paper is structured as follows. Section 2 describes the State-of-the-Art in the problem area, discussing new standards, technologies and services, the particular attention is drawn to

the multi-standard systems, and the motivation for adapting SDR is provided. Section 3 sketches main research directions and objectives of the present work. Finally, Section 4 presents the preliminary results obtained to the moment.

## 2 State-of-The-Art

### 2.1 New technologies, standards, and services

The current situation of Internet technologies and cellular systems demonstrates that the end users require a high quality connection while maintaining a high data rate anywhere and anytime. That is why companies try to find the new solution for both urban and rural areas. Also the end users are interested in having all possible applications, e.g. high quality video, audio, data format file. This is one of reasons why big companies constantly track appearance of new technologies to improve the quality of service and provide advanced services to their costumers.

The WiMAX technology connects local networks with the wide world [11]. It makes possible for costumer to be online with high data rate connection and does not lose access to Internet over different zones of coverage. This is the new standard suggested by the WiMAX Forum. This system unifies different devices from various companies. WiMAX is a type of wireless connection, and for this reason requires less time to build a network, more flexibility and simplest way to achieve scalability. The development of WiMAX is very popular among the customers who are not satisfied by the quality of the wire connection or in the situations when the digital subscriber line could not be defined.

WiMAX standard promises followings:

- a wideband access in that case when we can not apply xDSL connection;
- a solution to the Last mile problem;
- easy creation of the connection for large number of users at the same time;
- transmission of audio-, video- and multimedia format files with a high bit rate;
- access to worldwide Internet system anywhere and anytime;
- non-line-of-sight capability;
- roaming for mobile users;
- broadband wireless access for huge number of user for short time period (for example internet access during the conference in hotel);

WiMAX consists of specifications: 802.16, 802.16a, 802.16e and 802.16d [13]. The choice of configuration depends on needs. The specification 802.16a provides connection for fixed customers opposite 802.16e is for mobile network, i.e. mobile handset, PDA, and laptop with embedded, wireless system. Basing on [1], we could define favourable parameters of 802.16e for the physical layer.

UMTS is one of standards are created by European Telecommunications Standards Institute (ETSI) for 3G deployment in Europe. The current situation at the mobile scene obliges firms to find new ways of the realization for the satisfaction of growing end-user needs. The cellular standards are trying to increase the number of services such as voice call, video-telephony, video/audio broadcasting; mobile TV, receiving and transmission of video from one mobile phone to another one, web browsing, mobile office, services based on user location, maps and guidebooks, GPS, mobile e-commerce, payment of tickets, mobile Internet, etc [9]. UMTS has worldwide cover and high data rate 2 Mbps with regard to previous communication cellular standards such as GSM, GPRS, EDGE.

Existing 2G mobile systems support voice services like base. Parameters of data transmission are limited by slow-speed services (< 75 Kbps) with low QoS, which cannot satisfy the requirements for multimedia and other modern applications. These requirements can be solved by 3G networks, which promises high data rate for fixed end-user (2 Mbps), for pedestrian user (384 Kbps) and for moving user with speed more than 120 km/h (144 Kbps).

The key requirement of UMTS infrastructure is that it should maintain the interoperability with GSM networks for systems and the architecture upgrade. The upgrading of layer structure will be

occurred since UMTS works with expanded spectrum of modulation's types and with another access to the environment. There are three directions of investigation: at technical, network and service levels. Each of these includes features of integration, and the most importantly all of them have to evolve together or otherwise there are no good chances to reach satisfying results. For us the technical area should stay more perspective and interesting for the development.

## 2.2 Multi-standards systems

Recent developments in the telecommunication market aim to satisfy increasing needs in data transmission in different format such as sms, mms, voice, video, audio, etc. and providing such services as e-mail, web-browsing, e-commerce, etc. Therefore, new standards emerge on the communication scene in different directions. Most of them do not overlap each other and cannot be combined. In this sense gigantic companies have been searching a new solution for to allow the co-existence of different protocols, standards, modes, and frequency bands in a single device. There are three mechanisms of the different family combinations:

- the tight coupling architecture (TCA);
- the loose coupling architecture (LCA);
- no coupling architecture (NCA).

The structure is built depending on the relations between the Internet network and the cellular network. Three architectures (TCA, LCA and NCA) are broadly spreading, because they allow for the seamless connection. The seamless network requires the support of such features as: integrated authentication, integrated billing, roaming, terminal mobility, and service mobility [2].

TCA is the structure of interworking connection between different protocols. It is based on the telephone core network which is independent from type of wireless interface. In other words, usually the mobile terminal is active only when it is located inside the coverage zone of the hotspot. This device has to support a dual mode, i.e. it maintain the seamless connection using the radio area update technique, which is a part of the core mobility management procedure for the cellular network. Therefore, the handover from the cellular network to the Internet wireless network is defined as handover between two private cells. This technique was approved for GPRS/WLAN user equipment and supplies such benefits as:

- the provision of smooth switching from one network to another without loss of service;
- the adaptation of reuse of GPRS authentication, authorization and accounting model;
- WLAN uses the GPRS infrastructure (achieved by implementation GPRS as core network);
- WLAN subscriber has the permission for interception;
- the high security level is achieved by using GPRS authentication and ciphering for WLAN;
- for both cells there are used the same provisioning and customer care;

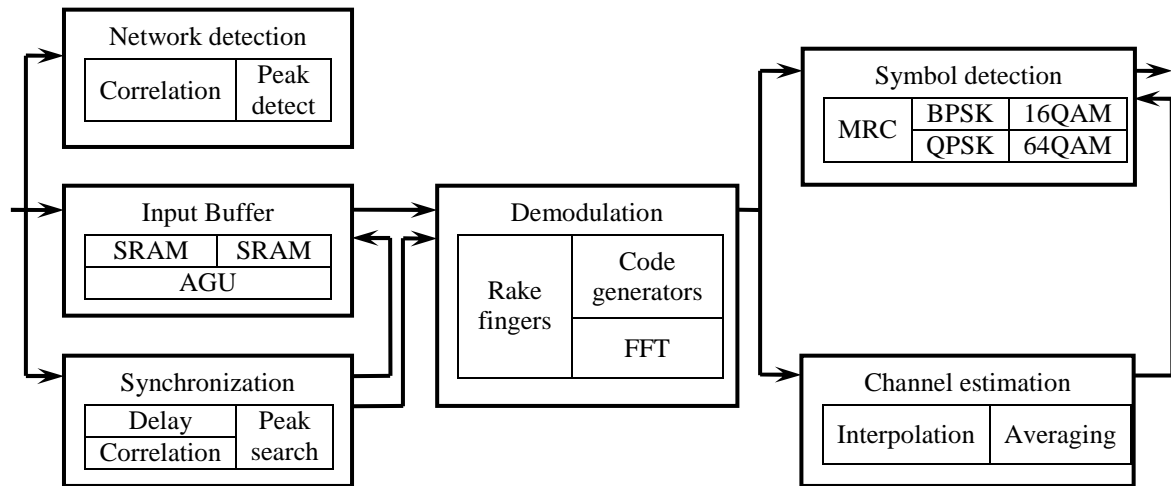
TCA is characterized by such drawbacks as the impossibility to support a lot of high-bit-rate users, which is caused by the implementation of WLAN traffic over the GPRS core network. Also TCA cannot support legacy of WLAN terminals. In this approach, author underlined the use of the Quorum scheduling algorithm for overlapping channels and handles the channel synchronization. In this case, the system cannot be rebuilt when the new software is required. The physical layer of this structure can provide only those application and services which are included in the GSM and WLAN protocols. These two standards cannot be active simultaneously because each of them makes interferences to another one. Therefore, they are not flexible according to reconfiguring and reprogramming.

In the LCA, WLAN data traffic moves directly to the operator's IP network. It means that in this structure the cellular technology is not integrated into WLAN network. LCA is characterized by the following features:

- the SIM-based authentication for both cells can be applied in order to amplify access to the operator's services;

- support of the integrated billing;
- roaming is permitted for all types of WLAN.

The common physical layer architecture for the baseband level of dual-mode receiver is depicted in Figure 1. As we can see, in this design it is not possible to reconfigure the system since signal processing blocks with similar functionalities are merged into the single modules.



**Figure 1.** The architecture for the dual-mode baseband level [4]; MRC is Maximal Ratio Combining, AGU is Address Computation Unit, FFT is Fast Fourier Transform.

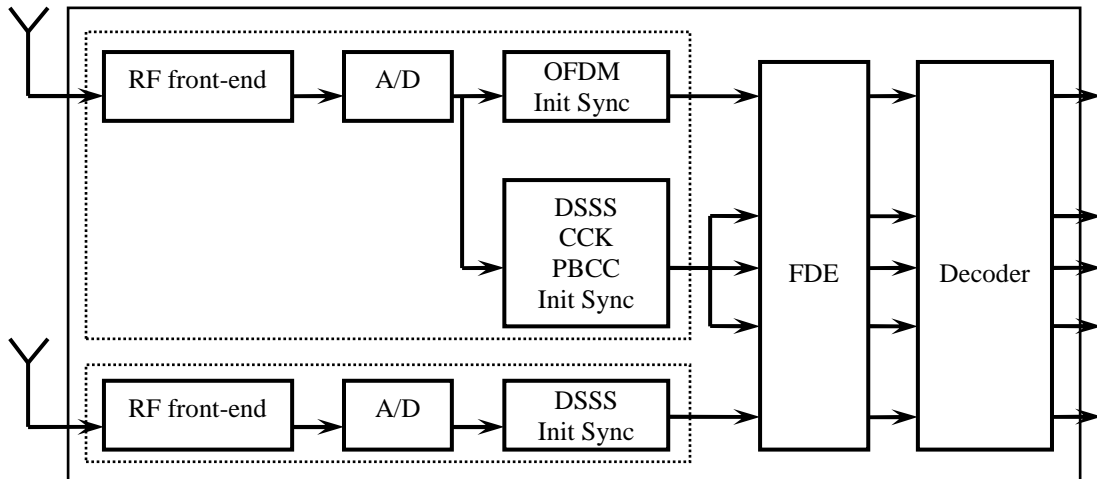
All cases of seamless switching described above cannot provide flexible architecture of the user terminal (UT) and, hence, do not allow to reconfigure the system smoothly. Since the UT has strong hardware architecture and software supply, we cannot expect that the UT will be able to install the new hardware or software when it is necessary to upgrade or update the system respectively.

For multi-standard and multi-mode receiver architecture, the solution described in [6], can be applied. The approach is to implement of developed protocol in Wireless technology and cellular technology. The emerging standards such as 802.11g and UMTS have their own benefits, which are presented in Table 1.

**Table 1.** Main parameters for emerging standards UMTS and 802.11g

Parameter/Technology	UMTS	Wi-Fi (802.11g)
Range	Depends on cell coverage	< 100 m
User number	Up to hundred thousands	< hundreds
QoS	Audio/video streaming Video telephony	Multimedia without guarantee
Data rate, Mbps	< 2	< 54
Mobility	High	Low
Access to environment	WCDMA	CSMA-CD/CA
PHY layer/modulation	DSSS/ BPSK, QPSK	DSSS, OFDM/ BPSK, QPSK, 16QAM, 64QAM

The researchers have developed the idea about implementation of minimum mean-square error (MMSE) frequency-domain (FD) block linear equaliser (BLE). Inasmuch as for UMTS the Rake receiver and Direct Sequence Spread Spectrum (DSSS) techniques are used and three different mechanisms (depends on type of modes, e.g. Orthogonal Frequency Division Multiplexing, Complementary Code Keying, DSSS) are represented for WLAN structure; the idea was to share frequency Domain Equalizer and also next chain of signal processing. The block diagram of the receiver part for MMSE FD BLE is presented in Figure 2. The purpose was a possibility to apply the Fast Fourier Transform-based architecture which includes the adapted overlap-add technique.



**Figure 2.** The general structure of MMSE FD BLE receiver part for Multi-Mode Multi-Standard receiver for WLAN/Cellular UT [6].

Also in this approach, the physical layer of the structure is strongly tied and cannot be reconfigured if some update occurs in the wireless network. In cases where UT should be reprogrammed and reconfigured against the required services or protocols, the best solution is provided by the SDR technique.

### 2.3 SDR adaptation

Improvements of previous standard and services appear each year. The user would like to have the advantages provided by these modernizations inside his or her equipment and avoid buying a new device. Moreover, vendors cannot quickly adjust all the equipment to support the new technology [15]. The new era of 4G telecommunication devices presumes integration of various standards, applications and system architectures on a single terminal. For this reason, SDR will play the important role for emerging technologies [16], because it can change the functional system by downloading and installing the required software instead of replacing the hardware.

The main goals of SDR structure are:

- replacement of as many as possible analog parts of the transceiver by providing the digital architecture;
- realization of a large number of tasks by means of specific software implementation, while allowing for easy software installation and removal.

Today a lot of research work is devoted to replacement of the analog parts of UTs by the digital ones. Most of the new technologies adapt SDR for switching between different users. Some other approaches consider SDR as an effective means for switching between communication protocols [12] or for data transfer [17].

In [14], the realization of SDR for 2G and 3G standards was described. Nonetheless, the proposed structure of the cordless system is based on the common signal processing structure. Main foci of this work were telephone standards of different frequencies, access into environment, and the number of carriers. They were convinced that it is possible to combine different air interfaces by the SDR tuning. For this purpose, the authors determined the sets of parameters for different standards handled by SDR.

## 3 Research Directions and Objectives

The application of SDR is opening numbers of opportunities to retune the system according to derivable data [5]. In our case of SDR application we will work with the baseband level in the main

architecture of the transceiver, which is beginning/finishing after/before ADC/DAC. Current way of the signal processing such as DSP and FPGA allows to consider SDR like a part of the transceiver structure. This part should control and arrange questions connected with order of data passing, e.g. for the receiver chain of WiMAX it is following: decimation filter → automatic frequency control → 2048 points Fast Fourier Transform → channel estimation and correlation → demapping → deinterleaving → decoder.

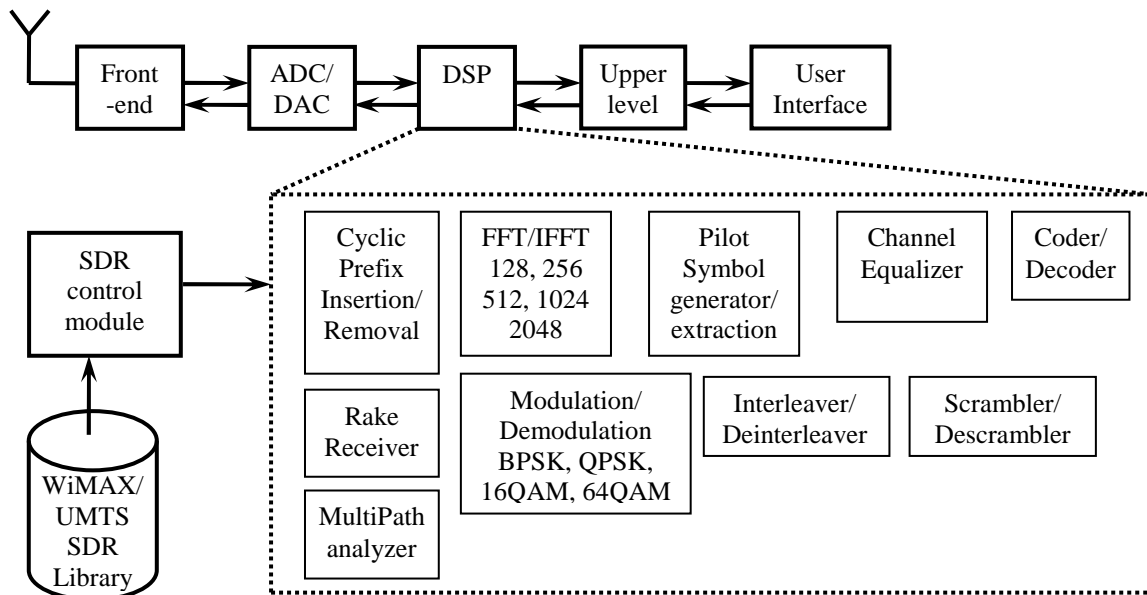
Today WiMAX has become spread widely in the whole world because it has following advantages depicted in Table 2.

**Table 2.** Main characteristics of WiMAX mobile system for 802.16e standard

Parameter/Technology	WiMAX(802.16e)
Range	Less 50 km
User number	Up to hundred thousands
QoS	Multimedia
Data rate, Mbps	< 75, depends on speed of MT
Mobility	Medium
Access to environment	OFDMA
PHY layer/modulation	OFDM2048/ BPSK, QPSK, 16QAM, 64QAM

On the other hand the cellular wireless systems are not losing Internet coverage. By the new technology such as UMTS, the mobile device can transmit/receive both voice, video, audio and provide access to Internet. In this sense, we can say that WiMAX and UMTS can be competitors. However, we have found solution allowing them to co-exist together exploiting the fact that their strong features can complement each other.

The most useful structure for our purpose is the SDR architecture. It includes both WiMAX and UMTS, and can control and reconfigure the system if necessary [4]. In order to achieve better performances for WiMAX as well as for UMTS, we propose the new design of the baseband physical layer for mobile devices based on commanding by the SDR control module. The block scheme of PHY for the signal processing is depicted on Figure 3.

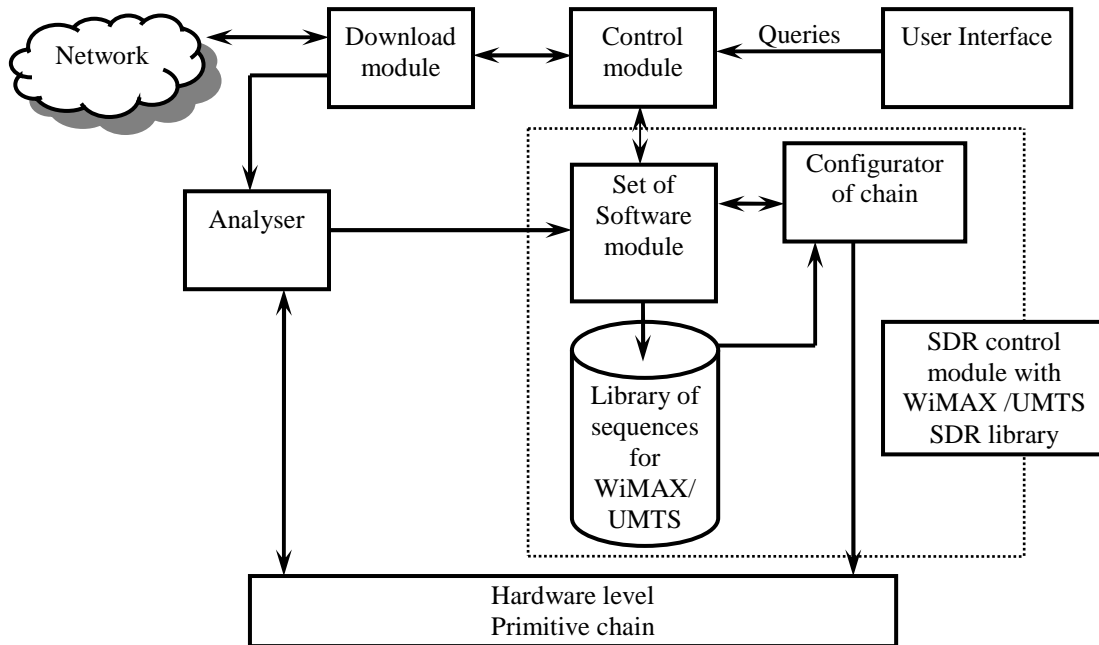


**Figure 3.** The block scheme for the transceiver based on SDR modules in the baseband level.

There are different schemes of the signal processing for WiMAX and UMTS at the baseband level. And we will apply the SDR for to reconfigure and to reprogram the DSP. The special sequent chains of processed blocks are built by the SDR modules which are included in the WiMAX/UMTS



SDR library. Then, the SDR library is loaded into DSP. The main principle of the work of the SDR modules and the SDR library is illustrated in Figure 4.



**Figure 4.** The block scheme of detailed work of SDR module and SDR library.

By the user's query, the control module sends a simple request containing the application parameters to the network and then receives the information about the design settings necessary to download these services. After analyzer sends required parameters to the Set of Software modules, that connects with the Library of sequences. Inside of this library the commands, described main and particular function of signal processing, are stored. Then some set of these functions is sent to Configurator of chain. It builds the correct order of the executed processing and to communicate to the hardware level, which provide the element base. And then the UT starts to work according to established parameters. This scheme is described by algorithms consisted of appointed functions.

The primary objectives of this work are the possibility to realize the proper algorithm in the particular environment, such as SystemC. This software allows simulation of the connection for few different signal processing systems. The SystemC is also basis for the creation of the specific code which is using for the programming of the hardware. It will help to test our system in the real-time architecture. As it is following from aforesaid we have to write the some code for each standard with all details and it is not easy. The global goals of the work are:

- Development of the SDR library for different functional parts of signal processing;
- Obtaining sets of function for description of system behaviour;
- Development of the control panel for whole process;
- Design and implement it for WiMAX/UMTS system;
- Improvement of this architecture for future implementation;
- Implement the test case for multi-standards system based on SDR library and for WiMAX/UMTS systems.

#### 4 What has been done so far

The research problem posed in the present PhD thesis proposal is to design the structure of the baseband level of the user equipment transceiver for the multi-standards system. Thus far, to realise this purpose, the following steps have been fulfilled:

- The analysis of the existing technologies is completed and the perspective directions in the providing of the wireless and the cellular connections for macro-cells were singled out. For the urban and rural area WiMAX and UMTS are more robust and perspective techniques. Each of them can supplement each other in different aspects and different areas;
- The SDR structure was accepted as the base of co-existence two different standards in the UT;
- The scheme of SDR processing was proposed (Figure 4). This way describes the signal processing for the SDR module and how it can govern the system above the hardware level;
- The framework of the algorithm was written. It includes the specific description of basic files with main parameters such as a coding, a spreading, a scrambling, FFT, channel estimation and correlation, etc.

The base procedures of the algorithm were denoted in the SystemC. This software allows to describe different types of signal processing in the context of the entire system. Also the SystemC is intended for the real-time hardware implementation. That software can be useful in the future experiences with the hardware.

The further work includes: the working out in details for the different types of the signal processing for both WiMAX and UMTS cases. The description of SDR library will be created. It has to include the procedures of main and particular functions. These functions describe the behaviour of the WiMAX/UMTS system in each possible case of the signal processing. Those cases are depending on outside factors of the environment such as the distance between the UT and the base station, the number of distortions, and etc. All mentioned components of our system will be joined together and their work will be implemented in the real hardware device. Then the checking of the chosen way must be done, and after it improvements and revisions will be applied.

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