ON THE COEXISTENCE OF SATELLITE-UMTS AND GALILEO WITH SDR RECEIVER

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ABSTRACT

In the last years, the tendency to have a reconfigurable receiver able to offer more than one service at the same time is growing. The receiver must be able, in general, to treat together different signals (i.e. in terms of bandwidth, modulation, received power) without any augmentation of costs of the mobile terminal. The purpose of this paper is to analyse an integration method for positioning and third generation mobile radio communication systems by means of SDR (software defined radio) technology.
In general, the application of this technology introduces implementation problems especially due to the Analog to Digital Converter.
For the study two system have been considered: the first one is Galileo, the future European positioning system, and the second one is S-UMTS. The common characteristics (both are DSSS-CDMA) and the software radio technology make the integration possible without an increase of the number of components of the receiver. The integration method proposed in this paper, allows one to appraise the possibility of building a receiver able to offer services of mobile radio communication and of satellite navigation.

1. INTRODUCTION

In the last years, the tendency to have a reconfigurable receiver able to offer more than one service at the same time is growing. The receiver must be able, in general, to treat together different signals (i.e. in terms of bandwidth, modulation, received power) without any augmentation of costs of the mobile terminal.

A possible solution to solve this problem is given by Software Defined Radio. In this case a unique hardware platform with different software libraries can be used to have e reprogrammeble and reconfigurable system.

The SDR can be defined [2] as a radio system with software able to control different modulation techniques, narrow and wide-band operations, safety of communications and satisfy technical characteristics and functionality of the actual and future standard.
In general, the most important characteristics of the Software Radio technology are the following:

- flexible architecture, controlled and programmable via software.
- Possibility to substitute the radio functionality with digital elaboration
- Possibility of dynamic reconfigurability (with software download)
- Possibility of multimode and multistandard terminal
- Possibility to realise and modify by software carrier, bandwidth, modulation , radio researches and, in particular, user applications.

The first domain of SDR implementations was related to military applications. SPEAKeasy [7] is a successful implementation of an adaptable SDR modem platform, characterised by an open architecture. In [8], the software implementation of a GSM base station is considered.

Analogue studies are produced now for terrestrial UMTS SDR implementations.

From the SDR commercial component side, a fully programmable Spread Spectrum transceiver is supplied by SIRIUS corporation (Belgium), who recently launched on the market some wireless modem products based on DSP and software radio technologies (see e.g. DATASAT™ system [9]). The transmission is performed over the ISM band at 2.4 GHz (2.4-2.4385 GHz), characterized by programmable spreading factor, programmable modulation, and channel coding. Some studies concerning the possibility to the application of software radio concepts in the context of GPS systems. For example in [10] a software radio architecture for GNSS is proposed. In particular, major attention is devoted to testing of novel signal processing techniques for signal acquisition and tracking.

Some studies concerning the possibility to build terminal where there is a coexistence between more navigation standards. [11], proposed a software architecture receiver, flexible and modular in order to be reconfigured for employing it with GLONASS and GPS systems.

In[12], a reconfigurable receiver by means of software radio techniques for GPS is presented.

The fundamental concept in the proposed system is to develop a receiver that can be used both to the communication and to the satellite navigation

Concerning to navigation systems, in this paper, GPS software techniques will be shown. Furthermore, for radio mobile communications, consolidated SDR methods will be analysed. The common characteristics of these application field allow a possible integration in an unique receiver .

As an example, a method of integration of positioning services and cellular communications will be described, based on pseudonoise sequences properties, making possible to build a receiver able to offer radio mobile communication and satellite navigation services. The studied and examined system has the objective to make the most critical component of the SDR receiver, the analog to digital converter, more realizable because made the bitrate properties less strong and allowed to reorganize the converter required.

For this study S-UMTS and the Galileo systems, the future European positioning system, have been considered. The common characteristics (both are DSSS-CDMA) and the software radio technology make possible the integration without an increase of the receiver components. Moreover, the modality FDD/W-CDMA on the downlink channel for the transmission of the S-UMTS signal and the signal on the E6 band for the Galileo system have been considered.

The aim of implement the subsystems through software rather than hardware needs that the analog to digital converter is near to the antenna. In this case, the most critical component of the system is really the analog-to-digital converter because at its input they will be had signals with elevated dynamic frequency.

The goal of the proposed method is to permit the most critical component of the SDR receiver, i.e. the analog-to-digital converter, in a less critical situation by reducing the sample frequency of the converter. In fact, by overlapping the two signals at the stadium of radio frequency through superetherodyne conversion, the bandwidth of the overall signal (Galileo+UMTS) is reduced.

The overlap of the two signals can carries out degradations due to the cross-interference between two signals (Galileo, with wide bandwidth and low power and S-UMTS, smaller bandwidth but elevated power with respect to Galileo).

2. SOFTWARE DEFINED RADIO PROBLEMS AND CHARACTERISTICS

A fundamental characteristic of the reconfigurable users terminals is to reveal, identify and control the radio access technologies with the purpose to allow users to access the available services.

In future, this kind of technologies will allow the receiver to be able to pass from a service to another offering the best available service. (in terms of economic cost, or of performances, or of other parameters) [1].

Reconfigurable terminals allow the receiver to adapt the necessity of the user by downloading software in dynamic or static way. The first way (dynamic) allows to make available services without the necessity of load the whole software but only that is useful. The second one (static) allows to update, integrate or change the system; the integration between various services is, in fact, often complex and susceptible of improvements in time.

The use of DSP devices, instead of devoted hardware ones, can allow the implementation of the base band receiver functions by software, i.e. coding, modulation, equalization and impulse shape.

Furthermore the system can be reprogrammed to be compatible with different standards.

Besides systems DSP reprogrammabile components can be used, for example FPGA (Field Programmable Gate Arrays) or ASIC (Application Specific Integrated Circuits), formed by an array of blocks each containing logical blocks and interconnections to connect them, and generic processors.

The SDR systems, therefore, should have a common platform, adaptable to each radio interface simply changing the software [4].

The system reprogrammability allows the development of reconfigurable radio systems, of networks able to autonomously update reconfigurable users terminals (RUT Reconfigurable User Terminal).

These last ones can be considered as programmable radio transceiver because the user terminal is able to adapt dynamically to the user necessities.

The SDR technology developments will allow to realize a terminal with [5]:

- adaptable characteristics: the possibility to change applications, services and functionality of the terminal to offer to the user the demand service according to the capacity of the used terminal
- possibility of use in different communication standard: it will allow to have an only terminal with the possibility to connect to different nets
- capacity to evolve on the base on the user needs

2.1. Analog to Digital converter problems

On the other side, the most important problem in this technology is given by the ADC (Analog to Digital converter); this is a fundamental block in the SDR terminals [3]. This component have to face great bandwidth and dynamic variation. The ADC dynamic variation increase with the growth of the bit number and the oversampling ratio, i.e. the relationship between the sampling rate and the received signal spectrum band.

A compromise between the sampling rate and resolution, i.e. the bit number for each sample to the ADC output, is necessary; in fact, more the sampling rate is high more the resolution is low. Currently the technology allows to reach 1Gsample/s with resolution of 6-8 bits, 100Msample/s with 10 bits and 50Ksample/s with 16 bits. The available bit number couldn't be enough in case of signals with an elevated dynamic variation, for example the GSM.

The ideal system is not yet realizable; in fact, especially in the portable systems, low dissipation, dimensions, complexity and weight are need; a super-heterodyne system is therefore used in which the radio frequency and the intermediate frequency sections are totally analogical, while the digital component is present only in the base band part. The output data flow of the ADC is the input to a PDC (programmable downconverter); this brings the received signal in base band, extracts the channels and adapts the sampling.

3. SATELLITE UMTS

The satellite component of UMTS (S-UMTS) will play an important role in providing worldwide access to UMTS services. Because satellite systems have the advantage of fast deployment, flexible use, and global coverage, satellites are able to provide telecommunication services in areas where terrestrial networks are economically or technically not feasible, such as the rural areas.

As is known, the 3GPP T-UMTS proposal encompasses two operating modes: W-CDMA, associated with frequency division duplex (FDD), and TD-CDMA, associated with time division duplex (TDD). The two operating modes were adapted to the satellite environment, which resulted in the two proposals identified: as Satellite W-CDMA (SW-CDMA) and Satellite Wideband Code and Time Division Multiple Access (SW-CTDMA) [14]. For what concerns SW-CTDMA, it may be a suitable solution for regional systems adopting geostationary or elliptical orbits when the terminal peak effective radiated power (EIRP) can be relatively large. More details can be found in [15]. SW-CDMA represents an adaptation of the T-UMTS WCDMA proposal [16]. As the T-UMTS specifications are still evolving, the discussion mainly refers to the T-UMTS RTT specifications at the time of approval by ITU.

Table 1 lists some key technical parameters of the SW-CDMA radio interface [14][15].

SW-CDMA is based on wide-band direct-sequence CDMA technology, with a basic chip rate of 3.84Mchip/s and a half rate option at 1.92Mchip/s, which may be more suitable in a multi-operator environment where bandwidth limitations may arise. SW-CDMA uses FDD and has a flexible carrier spacing of 4.4-5.0MHz with a carrier raster of 200 kHz.

Multiple access scheme	WCDMA
Duplex scheme	FDD
Chip rate	3.84Mchip/s
Carrier spacing	4.4-5.0MHz (200 kHz raster)
Modulation type	QPSK

Table 1 SW-CDMA physical layer characteristics

The physical layer offers services to higher layer. These services are denoted as transport channels. A transport channel is defined on the basis of the data transferred over the air interface. The transport channels can be classified into two main groups:

Dedicated channels, using inherent addressing of User Equipment (UE);

Common channels, using explicit addressing of UE, if needed.

Various kinds of transport channels can be found [14][16]. To each transport channel, there is a corresponding transport format (TF) set, determining the possible mappings, encoding, interleaving, etc, of a particular transport channel. The physical layer takes in charge the conversion of transport channels into physical signals to be sent on air.

An example of channel allocation for three different operators is proposed in Figure 1 [17].

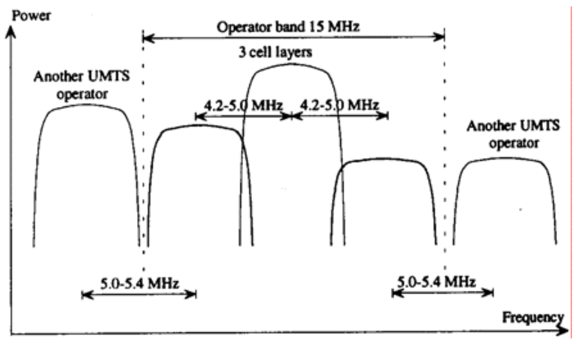

Figure 1 UMTS channel frequency allocation

In our work the UMTS channels are distributed in the same manner as depicted in figure 1 and in particular a different number of channels on each carrier is considered [16].

4. GALILEO

The Galileo system, like the GPS one, is composed by a constellation of MEO satellites that transmits the information using the CDMA technique as a multi user transmission technique. The system offers a multitude of services, some of those are public (OAS, CAS) and some are private (GAS). At this time, the system definition phase is not yet finished, but there are some hypothetical scenarios of the Galileo system.

One of those is the scenario named "European standalone scenario (termed "reference scenario" before WRC2000) that comprises the frequency bands E5, E6, E2, E1 and C [13].

In this scenario, limited in this paper to the band E6, the Galileo signal is composed by one carrier frequency modulated by spread spectrum codes and a QPSK modulated data signal. The pseudonoise codes are Gold sequences [3], like the C/A code in the GPS system, with chip rate of 20.46 Mchip/s and length of 8184. The data message has a bit-rate of 125 bps. The modulation is a QPSK like modulation, where the in-phase signal carries the data message and the quadrature signal is used as pilot signal without signal message.

The received power of the Galileo signal is assumed, like the GPS one [18], at a level of –159.6 dBw.

The received signal is sent to an Intermediate Frequency (IF) demodulator and then to synchronization module, that performs a correlation process with one locally regenerated code replica in order to perform the coarse signal acquisition. The general receiver architecture can be seen in Figure 2.

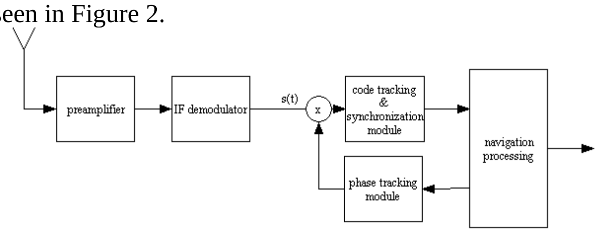

Figure 2 General receiver architecture

In a Galileo receiver realization two different solutions can be developed, classical hardware receiver or more innovative software systems.

After a analog elaboration of the RF signal and in the Intermediate frequency the signal is converted with a ADC and the following steps are digital.

According to the receiver these operations are realized with specialized hardware or with software solution. In the first case a higher velocity, useful in real time solutions, can be reached. In the second case a reprogrammabile receiver can be developed. Moreover the software radio receivers works on data in real time systems, as the classical hardware solutions.

This second case is considered in the studied method.

A software solution of a GNSS receiver have a lot of advantages in comparison with a traditional receiver. Beyond the possibility to reconfigurate in a dynamic manner, this type of solution is useful to employ better acquisition techniques according to the received signal. These advantages have a cost due to the limit of the available hardware.

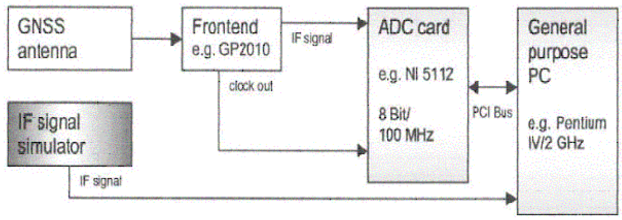

Figure 3 A proposed software receiver [13]

In this case to avoid the problems due to a very wide band a downsampling is proposed [13]. In the considered case, instead, a method useful also to integrate different systems, S-UMTS and Galileo, is proposed.

5. PROPOSED METHOD

In general, the SDR approach consists in the deployment of software modules instead of hardware ones. To allow this approach the analog part of the receiver must be the less possible. Also, the most critical part is yielded on the analog/digital converter that converts the analog signal in the digital one [21].

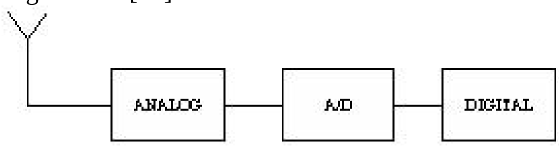

Figure 4 ideal software radio receiver

This component must be dimensioned depending on the signal characteristics: the greater signal bandwidth the more bits the A/D must convert. Furthermore the cost of this module is dependent on its speed.

From the receiver point of view, the bandwidth of the signal sensed by the antenna can be drawn as shown in Figure 5.

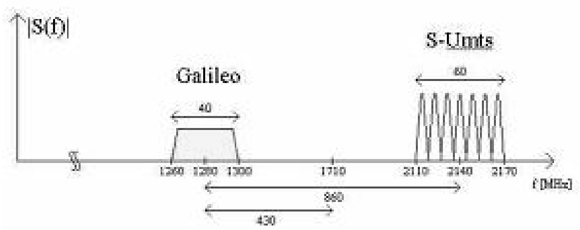

Figure 5 bandwidths of the two standards

Due to the huge distance among the frequencies of the two standards a conventional supereterodina receiver cannot have great performances, in fact, the bandwidth of the overall signal after the demodulation at the carrier frequency of 1280 MHz is 890 MHz. In this situation, choosing a A/D that use 3 bits at the Nyquist rate, the core speed of the A/D converter must be 5200 MHz.

Alternate approach are proposed in order to reduce the bandwidth of the incoming signal, for example the GAUSS receiver, by using to demodulation stages, allows to have a core speed of the A/D converter [19] less than 5200 MHz.

The proposed approach permits to use a A/D converter with a lower core speed.

In fact, by using a demodulation stage at carrier frequency of 1710MHz the intermediate frequency of the UMTS signal is 430 MHz and in the same carrier frequency is placed, also, a replica of the Galileo signal. Figure 6 shows the complete overlapping of the two signals.

In order to reduce the signal bandwidth, a further demodulation stage is used to down-convert the Intermediate frequency of 70 MHz (the same of GPS receivers) [20]

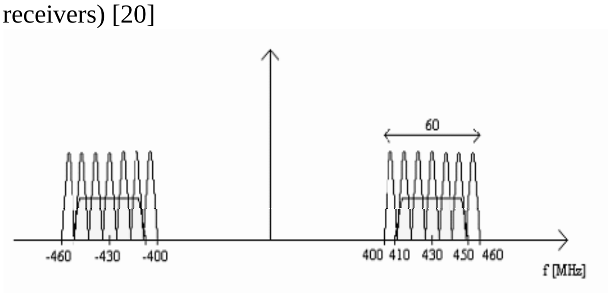

Figure 6 signals overlapping after the demodulation stage

In this case the signal bandwidth at the input of the A/D converter is 100MHz, see Figure 7.

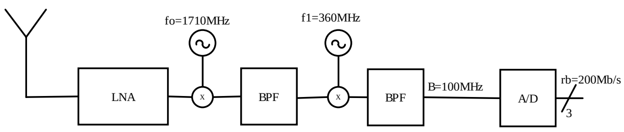

Figure 7 down-conversion analog module

The two BPFs are designed to avoid image frequency components of the downconverted signals.

Following the same calculation done before the A/D converter core speed is 600MHz.

This approach allows the use of a cheaper analog to digital converter, but, on the other hand, the interference caused by the overlapping of different signal can disrupt the capability of the signal.

6. RESULTS

In order to demonstrate the effectiveness of the proposed approach a simulation environment has been set up. For this purpose the whole Galileo transceiver system has been simulated, as well as the UMTS transmitter, by using MATLAB™ SIMULINK™ 6.0 environment,

In this paper the attention is focused in the BER of the UMTS receiver when the Galileo signal is assumed as a noise source.

The simulations are done using low pass equivalent signals [22] and assuming:

- four satellites in view for the Galileo system;
- AWGN channel;
- UMTS transmission from LEO satellites

The simulation are done by assuming the UMTS transmission power of 3KW [16] and varying the UMTS channels. In the considered case there is the presence of a unique S-UMTS satellite; no interference by other UMTS transmitters has been considered.

The UMTS system transmits three different bit stream, one with bitrate of 16Kb/s and two with bit rate of 8Kb/s.

The tests have been performed analyzing different S-UMTS channels; in fact on the considered bandwidth 12 different channels can be present. In the following part the distinction between the channels is given by the distance of the frequency carrier from the central frequency. The considered space is of 5MHz.

In the following figures the focus is on a single UMTS channel; the BER is given compared to variation of C/N_0.

In Figure 8 the case of channels with distance from the central frequency of 7,5MHz is shown. The Figure 9 shows the case of external channels with distance of 27,5MHz.

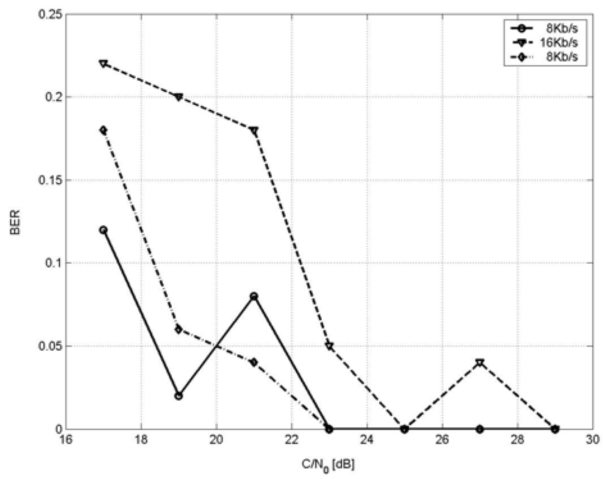

Figure 8 BER in case of central channels (7,5MHZ from the central frequency)

In both plots an expected behavior, by theoretical and logical analysis, is shown; in fact the channel with higher bit rate (16Kb/s) has a BER greater of the others (8Kb/s). More in particular, with these plots, the difference of two channels characterised by the presence or by the absence of Galileo interference are shown.

In Figure 8 the case of channels in the middle of the UMTS assigned spectrum is given. These channels, in the proposed method, are entirely overlapped to the Galileo band. On the contrary, the Figure 9 shows the case of external channels; in these case the Galileo signal is not present.

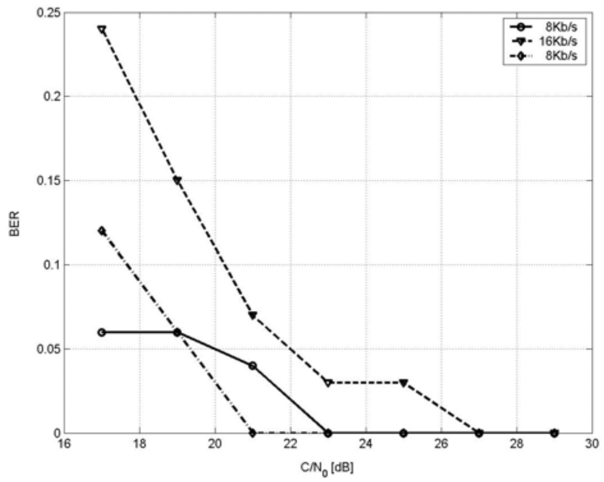

Figure 9 BER in case of external channels (27,5MHZ from the central frequency)

The channels suffer of a similar disturbance, only a more careful analysis shows that the central frequencies - i.e. the frequencies in which a complete overlap of Galileo and S-UMTS is present – are a BER greater. However this difference in performance is minimum. This fact, present on all the S-UMTS channels, allows to validate the proposed method.

7. CONCLUSIONS

In this paper, a method to integrate positioning and cellular services is presented. This method permits to model an A/D converter with less stringent properties . The achieved results shows that the integration of UMTS and Galileo services is a traversable method. Moreover that the S-UMTS performances are not reduced by the presence of a Galileo signals. Future works will deal with the study of possible methods to recognised the transmission standard present on the channel.

11. REFERENCES

[1] E. Buracchini, “The Software Radio Concept”, *IEEE Communication Magazine*, No. 9, Settembre 2000, pp. 138-143

[2] J. Mitola, “The Software Radio Architecture”, *IEEE Comunication Magazine,* Maggio 1995

[3] T.Hantschel, M. Hencker, G. Fettweis, “The digital Front-End of Software Radio Terminals”, *IEEE Personal Communication,* August 1999, pp. 6-12

[4] D. ZgonJanin, K. Mitrevski, “Software Radio:Principles and Overview”

[5] M. Mehta, N. Drew, G.Vardouilias, N.Greco, C. Niedermeir, “Reconfigurable Terminals: An Overview of Architectural Solutions”, *IEEE Communication Magazin*, August 2001, pp. 82-89

[6] Alison Brown, Kenn Gold, Mark Nylund, “A GPS Software Application for Embedding in Software Definable Radios”, *Proceedings of 13th Virginia Tech Symposium on Wireless Personal Communications*, June 4-6, 2003.

[7] P. G. Cook, W. Bosner, “Architectural Overview of the SPEAKeasy System”, *IEEE Journal on Selected areas in Communications,* Vol. 17, No. 4, April 1999.

[8] T. Turletti, H.J. Bentzen, D. Tennenhouse, “Towards the Software Realization of a GSM Base Station”, *IEEE Journal on Selected Areas in Communications*, Vol. 18, No. 4, April 1999, pp. 603-612.

[9] *“DataSat™ technical information”*, edited by SIRIUS corporation (B), http available at:www.siriuscomm.com

[10] D. Avagnina, A. Gramazio, M. Dumville, P. Mulassano, “Software-radio approach to the design of GNSS receivers” NAVITEC 2001, Noordwijk, The Netherlands, 10-12 December 2001

[11] A Jovancevic, A. Brown, S Ganguly, M. Kirchner, S. Zigic, “Flexible software navigation receiver”, NAVITEC 2001, Noordwijk, The Netherlands, 10-12 December 2001.

[12] F. Mulassano, F. Dovis, D. Avagnina, A.Gramazio, “REGAL: a reconfigurable receiver for GPS and GALILEO”, *GNSS* 2001, Sevilla, Spain, 8-11 May 2001.

[13] Thor,Normark, Ståhlberg-A High-Performance Real-Time GNSS Software Receiver and its Role in Evaluating Various Commercial Front End ASICs-ION GPS 2002

[14] D. Boudreau, G. Caire, G. E. Corazza, R. De Gaudenzi, G. Gallinaro, M. Luglio, R. Lyons, J R. Garcia, A. Vernucci, H. Widmer, “Wide-Band CDMA for the UMTS/IMT 2000 Satellite Component”, *IEEE Trans on Veh. Tech*. Vol. 51, No 2 March 2002.

[15] Report ETSI TS 101 851-3.

[16] Report ETSI TS 101 851-1.

[17] R. Prasad, W. Mohr, W. Konhauser, *“Third generation mobile communication systems”*, Artech House Publishers, 2000.

[18] J. Benedicto et al., “Understanding Galileo. GalileoSat: ESA’s Proposal*”, Galileo’s World*, autumn 2000, pp. 28-37.

[19] G. Mocci, A. Di Fazio, F. De Piccoli, F. Six, A. Vernucci “The GAUSS (Galileo and UMTS Synergetic System) User Terminal”, NAVITEC 2001, Noordwijk, The Netherlands, 10-12 December 2001

[20] B. W. Parkinson, *“Global Positioning System: Theory and Applications”*, Vol. I, American Institute of Aeronautics and Astronautics, Inc., 1996

[21] J. Mitola III, *“Software Radio Architecture”*, Wiley: 2000

[22] M. C. Jeruchim et al., *“Simulation of Communication Systems: Modelling, Methodology, and Techniques”*, Kluwer academic, 2000, pp.75-83.

