SATELLITE AND SPACE COMMUNICATIONS **SSC**

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SSC Newsletter **Vol. 19, No. 1, June 2009**

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The Satellite and Space Communications (SSC) Committee is a volunteer group actively involved in advancing satellite and space communication technologies within the IEEE. This committee is approved by the IEEE Communications Society and is governed by the constitution and bylaws of the IEEE as well as the other twenty-three Technical Committees in the Society. The committee belongs to the Technical Committee Clusters of Communication/Signal Processing (C/SP).

SATELLITE & SPACE

- JOIN US -

All conference attendees are welcome to join us in the SSC Committee meeting.

Location: Konferenz 7&8
Convention Center

Date: Monday, June 15, 2009

Time: 7:30 – 9:30

Future SSC Meetings

Nov.-Dec. 2009, Honolulu, U.S.A
May 2010, Capetown, South Africa
Dec. 2010, Miami, FL, U.S.A.

ICC2009 SSC Committee Activities

Wireless Communication Symposium
WCS-P1: Topics in Transmission Technologies
Room: Poster Area 1
Time: Mon, 15 Jun, 10:50 am - 12:20 pm

Wireless Networking Symposium
WN-P1: Relays, Gateways, and Satellite Systems
Room: Poster Area 2
Time: Wed, 17 Jun, 9:00 am - 10:30 am

HOW TO JOIN SSC COMMITTEE AND MAILING LIST

If you like to join SSC Technical Committee: Please send your name and e-mail address to the SSC Secretary, optionally include your mail address, telephone and fax numbers.
If you like to join SSC Mailing List: Instructions on how to subscribe/unsubscribe are available at http://lists.scnl.dist.unige.it/listinfo/ssc.

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MESSAGE FROM THE CHAIR

Prof. Takaya Yamazato

Welcome to the nineteenth issue of the Satellite and Space Communications newsletter. The goal of the Satellite and Space Communication (SSC) Technical Committee (TC) is to develop, organize and distribute technical information in the area of the satellite and space communications. The engineers and professionals from universities, government and research originations throughout the Globe participate as members and officers of this committee. At the moment, we have 158 members and 58 associate members. All conference attendees are welcome to attend and those who are attending the SSC TC meeting for the first time will automatically become a member of the TC. Please join us to discuss mutual topics of interest in this important field in communications technology. The meeting agenda and other information about SSC TC activities and operation can be found at the TC web page:
http://www.comsoc.org/socstr/org/operation/techcom/ssc/index.html

I would like to thank our vice chair, Dr. Tarik Taleb, for editing the SSC newsletter and our secretary, Dr. Igor Bisio, for SSC web page and membership information updates. Concerning the technical activities, we have endorsed ICC2009 Wireless Networking Symposia (co-chair, Dr. Mario Marchese) and Wireless Communication Symposia (co-chair, Dr. Takaya Yamazato). Dr. Claudio Sacchi takes a lead as a co-chair of Selected Areas in Communications, and Dr. Sastri Kota and Dr. Tarik Taleb are co-chairs of Wireless Networking Symposium, IEEE Globecom 2009 (30 Nov. - 4 Dec. 2009, Honolulu, Hawaii, USA). For ICC2010 (23-27 May 2010, Cape town, South Africa), the SSC is endorsing the SAC Symposium and Dr. Tarik Taleb is a co-chair and for Globecom2010 (5-10 Dec. 2010, Miami, Florida, USA), Dr. Takaya Yamazato is a co-chair of Other Selected Areas in Communications Symposia. TC representatives for ICC2011 (5 - 9 June 2011, Kyoto, Japan) and Globecom2011 will be decided at the next SSC meeting. At the moment, my name is on the list for ICC2011. We have also endorsed SPECTS 2009, IWSSC 2009, TELSIKS 2009, WCNC 2010, WCSP 2010, Array 2010, ICT 2010, ICSOS 2011. For details, please check the following pages or SSC web site.

By the way, the endorsement approval process of a conference sponsorship application has been changed. It is now decided by the TC chairs, not by the cluster chairs. TAC Vice President, Dr. Andrzej Jajszczyk, wrote the email dated on April 25, 2009 that "it was decided to suppress the positions of Cluster Chairs, as their role in the conference approval process has been diminished by distributing this responsibility among Technical Committee Chairs. The Cluster Chair positions are suppressed immediately." For ComSoc sponsorship approval, the event must have the endorsement of a ComSoc TC. This means that the scope of the technical program falls within the TC's scope, that there is a quality, independent peer review process for paper selection, and that three members of the ComSoc TC will be active members of the event's TPC. For more detail, please visit:
http://ww2.comsoc.org/drupal/conferences/Event-Sponsorship.
In addition, I ask to add a link from the conference web page to SSC web page to the endorsed conference TPC. I hope this will help our membership development.

The nomination for our next award for Distinguished Contribution to Satellite Communications is due shortly (15th August, 2009). All members are encouraged to consider this important event to nominate anyone who they know with a good contribution to the satellite research. Finally, I would like to thank all members for their support. Without your help, we could not organize any conference or review any paper. I look forward to work with you in other occasions toward enhancing the knowledge in the field of mobile communications in general and of satellite communications in particular.

Prof. Takaya Yamazato, Chair
Satellite and Space Communications
Technical Committee

SCANNING THE WORLD

Prof. Fotini-Niovi Pavlidou

The IEEE Globecom08 Workshop on Aerial and Space Platforms was organized for the first time in the context of this conference. Since the scientific community dealing with this topic is small and well connected internationally the workshop has been publicized mainly through mailing lists created through local relevant events. The presentations selected, around 12, have been solicited by invitation but they were gone through a review process. Thus a good range of topics were covered and the participation was quite international.

The attendance reached the number of 14 people and the discussion was quite interesting for the whole day of the workshop. Some interesting issues which have been intensively discussed are the joint investigation of aerial and space platforms and the importance of the regulatory activities.

The presentations can be found on the workshop page: http://newton.ee.auth.gr/aerial_space/

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FORTHCOMING GLOBECOM AND ICC CONFERENCES

COSPONSORING / RELATED CONFERENCES AND WORKSHOPS

MILCOM 2009

October 16- 21, 2009, Boston, MA, USA

http://www.milcom.org/

MILCOM 2009 is soliciting both unclassified and classified papers (up to DoD Secret) relevant to communications and information processing system technologies and capabilities that address the 21st century challenges of National Defense, Homeland Security, Disaster Response and Interoperability as summarized above. Industry, academic and government organizations from both the US and countries around the globe are invited and encouraged to participate.

GLOBECOM 2009

November 30-December 4, 2009, Honolulu, Hawaii, USA

http://www.ieee-globecom.org/2009

The theme of the IEEE GLOBECOM 2009 conference is "Riding the Wave to Global Connectivity," the conference covers the entire range of communications technologies, offering in-depth information on the latest developments in voice, data, image, and multimedia.

ICC 2010

May 23-27, 2010, Capetown, South Africa.

http://www.comsoc.org/confs/icc/2010/index.html

The IEEE Communications Society will, in 2010 being holding its flagship International Communications Conference (ICC) in Cape Town, South Africa. This will be the first time that ICC has been held in Africa and with Cape Town being voted one of the most beautiful cities in the World, this promises to be an exceptional conference.

Conference participants will have a wide range of exciting options to add to their conference tour: hikes up the famous Table Mountain; whale watching; tours of the Cape Winelands, Robben Island and even CapePoint where two oceans meet. The FIFA World Cup Soccer tournament, held all around South Africa starts just after the conference ends.

CONFERENCES CALENDAR

CONFERENCE	DATE & LOCATION	INFORMATION
SPECTS 2009 International Symposium on Performance Evaluation of Computer and Telecommunication Systems	July 13-16, 2009, Istanbul, Turkey	http://atc.udg.edu/SPECTS2009/
SPACOMM 2009 The First International Conference on Advances in Satellite and Space Communications	July 20-25, 2009, Colmar, France	http://www.iaria.org/conferences2009/SPACOMM09.html
IWSSC 2009 2009 International Workshop on Satellite and Space Communications	10-11 September 2009, Siena, Italy	http://iwssc09.dii.unisi.it/
Ka and Broadband Communications Conference	23-25 September 2009, Sardinia, Italy	http://www.kaconf.org/
TELSIKS 2009 International Conference on Telecommunications in Modern Satellite, Cable and Broadcasting Services	October 7-9, 2009 Niš, Serbia	http://www.telsiks.org.yu/
WCNC 2010 IEEE Wireless Communications & Networking Conference	April 18-21, 2010 Sydney, Australia	http://www.ieee-wcnc.org/
PSATS 2010 2nd International Conference on Personal Satellite Services	Feb 4-6, 2010 Rome, Italy	http://www.psats.eu/
WCSP 2010 International Conference on Wireless Communications and Signal Processing	November 13-15, 2009 Nanjing, China	www.ic-wcsp.org
Array 2010 IEEE International Symposium on Phased Array Systems & Technology	October 12-15, 2010 Boston, MA, USA	www.array2010.org
ICT 2010 17th International Conference on Telecommunications	April 4-7, 2010 Doha, Qatar	www.qu.edu.qa/ict2010
ICSOS 2011 International Conference on Space Optical Systems and Applications	May 2011 Los Angeles, CA, USA	Web Site not yet available

To all SSC members: If your postal address, telephone or fax numbers have changed, please update them with the committee secretary. You can review our current records on our web page at http://www.comsoc.org/~ssc/.

Applicability of Wireless Terrestrial Technologies to Satellite Communications

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Abstract — **Fixed broadband satellite communications involve challenges at every layer of the protocol stack. However, physical layer technologies for satellite communications are not developing as fast as for wireless terrestrial communications. In this perspective article, transmission technologies borrowed from the wireless terrestrial field (i.e. UWB and OFDM) are proposed as possible solutions for increasing channel data rate, system capacity and spectrum utilization. Challenges related to their applications and open research areas are identified.**

Index Terms — **UWB, OFDM, satellite communications, unlicensed spectrum, spectral efficiency, RF impairments, circuit complexity.**

I. Introduction

While terrestrial wireless networks often witness a breakthrough in the development of communications technologies, satellite communications technologies are quite stationary in their progress. Consider the new standard for Digital Video Broadcasting via Satellite, i.e. DVB-S2 [1]. This new standard has small incremental innovations with respect to the older DVB-S. The main innovations are: introduction of Low Density Parity Check (LDPC) codes and the possibility of using Adaptive Modulation and Coding (AMC). On the other hand, wireless terrestrial technologies experienced several radical changes. Some of the most important technology trends in wireless terrestrial communications are represented by Ultra Wideband (UWB) and Orthogonal Frequency Division Multiplexing (OFDM). Some attempts to apply those techniques to satellite communications have been made, but they are far from becoming consolidated technologies in the satellite world. Obviously satellite and terrestrial communications systems have different requirements and constraints and not all the techniques that are attractive in terrestrial systems are attractive in satellite systems. However, more often their application to satellite systems would require just some modifications and enhancements and even if they have interesting advantages, they need much more time to become a consolidated technology in the satellite scenario.

It is not easy to justify the different development speed between satellite and wireless terrestrial communications technologies. From the Authors point of view, the main cause is the different level of system reliability required by satellite and wireless terrestrial systems. The high cost of a satellite system and the impossibility to upgrade or repair a satellite lead to the exploitation of only well tested technologies with the minimization of risks. Moreover, the strict space qualification process contributes to limit useable technologies. Furthermore, the resources of a satellite payload such as memory, complexity and energy consumption are limited. However, it should be considered that complexity, memory size and energy consumption of a set-top box can be much higher than that of a mobile wireless device such as a mobile phone or a wireless card for a notebook. This higher resource availability allows to implement a broader set of technologies.

The objective of the research on new technologies analyzed in this paper is to increase channel data rate, system capacity and spectrum utilization.

In this perspective article, we propose the use of terrestrial communications technologies such as UWB and OFDM for fixed communications between ground terminals and Geostationary Earth Orbit (GEO) satellites, considering the different characteristics of satellite fixed channels with respect to terrestrial mobile channels: more severe Radio Frequency (RF) circuit impairments and negligible multipath.

The objective of this article is to draw the perspective use of some of the key technologies of current wireless systems in satellite communications, outlining advantages, needed modifications and thus identifying new research areas.

The paper is organized as follows. Section II proposes the use of UWB technologies in satellite communications and discusses possible advantages. In Section III OFDM is proposed as a possible solution to improve the spectral efficiency. Finally conclusions are drawn in Section IV.

II. UWB for Satellite Communications

A. UWB FOR WIRELESS TERRESTRIAL COMMUNICATIONS

UWB is a terrestrial communication technology for transmitting information free of license over a very large bandwidth without interfering with narrowband licensed systems and is typically concerned with short range terrestrial communications. The reason for applying UWB only to short range wireless applications is a consequence of the limitations to the radiated power. Essentially, UWB devices are allowed to interfere with existing systems, ideally at a low enough power level that existing services would not experience performance degradation. The operation of UWB devices in tandem with existing users is a significantly different approach to spectral efficiency than achieving the highest possible data rates in a channel with precisely defined bandwidths.

On September 1, 1998, the FCC issued a Notice of Inquiry pertaining to the revision of Part 15 rules to allow the unlicensed use of UWB devices. The FCC defines UWB as a signal with either a fractional bandwidth of 20% of the center frequency or 500 MHz (when the center frequency is above 6 GHz). The formula proposed by the FCC commission for calculating the fractional bandwidth is $2(f_H - f_L)/(f_H + f_L)$ where f_H represents the upper frequency of the -10 dB emission point and f_L represents the lower frequency limit of the -10 dB emission point. Therefore, the definition of UWB is only concerned with bandwidth, but not with emission power, and hence, UWB communications technologies can also be used in licensed systems if a large bandwidth would be available.

The key benefits of UWB can be summarized as follows:

1. unlicensed use;
2. low equipment complexity and cost;
3. multipath immunity;
4. ranging and communication at the same time;
5. low probability of intercept;
6. low power consumption.

A primary driving application of UWB communications is a high rate Wireless Personal Area Network (WPAN) confined to a small coverage area (less than 10 m of radius). Another important application is in distributed sensor communications or low rate WPANs. However, some of the key benefits of UWB can also be exploited for satellite communications.

We propose two solutions to allow the use of UWB technologies in satellite communications: to reshape the emission limits to allow license-free satellite UWB communication or to move to frequency bands higher than the Ka band, i.e. Q/V and W bands, where ultra-wide portions of band are available to be allocated for licensed use.

B. ADVANTAGES IN TERMS OF CAPABILITY TO SHARE THE FREQUENCY SPECTRUM

Unlicensed or license-free spectrum simply means a spectrum band that has rules pre-defined for both the hardware and deployment methods of the radio in such a manner that interference is mitigated by the technical rules defined for the bands rather than it being restricted for use by only one entity through a spectrum licensing approach.

The limit imposed by the FCC to the radiated power of UWB systems does not depend on the system characteristics, but are applied to any kind of mobile or fixed UWB communications system. This is in general a conservative method since it is not possible to control the location of a terrestrial system (especially mobile systems) and, hence, it is not possible to control the distance of a UWB terrestrial license free system from a terrestrial licensed communications system. However, this is not true for satellite systems and in particular for GEO satellites where the position with respect to any terrestrial system is fixed and known. This characteristic allows to compute the minimum distance between a satellite and a terrestrial communications system so that the maximum power received by a terrestrial system is known. Therefore, it is possible to apply different power emission constraints to satellite UWB systems with respect to terrestrial UWB systems.

In imaginary satellite systems employing UWB communication technologies, if the power transmitted from the satellite to the Earth is at the same level as terrestrial UWB devices, the received signal on the Earth is very low, and reliable communication is impossible. However, if the power spectral density of signals transmitted by UWB satellites on the Earth's surface is assumed to be greater than that of terrestrial UWB transmitters, then transmission at high data rate is possible.

Furthermore, for fixed satellite services, the level of interference between different satellite systems depends on the relative spacing between satellites, the directivity of the antennas and eventually the processing gain of the transmission technique. Highly directional aperture antennas allow several broadcasting satellites to share the same spectrum in a given coverage area. In this case, new communication channels can be added without an assignment of new frequencies to the existing satellite communications services and without license.

Few studies of using UWB signals on satellite communication links are available [2-3] and a very rich area of research is opened.

In [2] a satellite modem supporting 800-Mbps Quadrature Phase Shift Keying (QPSK) in a single 650-MHz Ka-band channel was demonstrated. This experiment remains the record of demonstrated UWB systems as defined by the FCC.

The first and unique attempt to study the performance of UWB signals over satellite links with the limitations imposed on terrestrial UWB systems is reported in [3]. Authors show that it is possible to achieve a data rate of 236 Mbps by limiting the power spectral density of the signal received on Earth to a signal level lower than the level imposed for a terrestrial UWB device, and by using a multi-band UWB transmission scheme.

To this respect, the study of the interference with terrestrial systems is a key point. Many other points should be analyzed in this area: which band is more suitable for allocating the license-exempt spectrum for satellite UWB communications services? How much interference is generated to other satellite systems at orbits near or below the considered one?

It should be demonstrated whether sufficient transmission speed (>1 Gbps) is obtained or not by satellite UWB communications with a transmission power compliant with future satellite UWB power limitations. In fact, regulations in step with modern developments, have to adapt to permit future satellite UWB systems. The arrival of the technology should reshape the concepts of spectrum management to allow modern satellite UWB technology. Finally, it is needed to standardize license-free UWB on satellite links so that the satellite maximum Effective Isotropic Radiated Power (EIRP) is increased with respect to the maximum EIRP for terrestrial links.

In the case we do not aim to deploy unlicensed satellite systems and, hence, there is no need to meet the power constraints of UWB systems, the exploitation of UWB signals is still interesting from the system performance point of view. In fact, novel UWB signals can be effectively exploited on saturated power amplifiers typical of satellite systems and can increase the performance of classical modulation methods.

For licensed UWB satellite systems, advantages in terms of lower circuit complexity and lower sensitivity to RF impairments are discussed below. To this respect, the ultimate goal of using UWB transmissions is to increase the channel data rate and the system capacity with respect to standard transmission techniques which are more sensitive to RF impairments and require more complex circuitry.

C. ADVANTAGES IN TERMS OF LOWER CIRCUIT COMPLEXITY

While communications technologies used by current satellite systems are quite standard and simple, the circuit required for the implementation of these transmission techniques are quite complex.

One of the main characteristics of satellite communications is the need to transmit signals at high power so that the signal received on the ground has enough power for a correct reception. Therefore one of the most important element of the RF transmission chain is the power amplifier.

Despite recent advances in microwave solid state power amplifiers, tube amplifiers such as Traveling-Wave Tubes (TWTs) and klystrons still provide the best combination of power output, power efficiency and bandwidth.

Power amplifiers can be categorized into Continuous Wave (CW) amplifiers or pulsed amplifiers. CW amplifiers are amplifiers designed to handle continuous waveforms, while pulsed amplifiers are designed to handle pulse signals. A pulsed amplifier produces high RF power for short durations for a duty cycle of less than 10%. Because pulsed amplifiers run cooler, they often can provide higher power and efficiency compared to similar CW amplifiers.

CW and pulsed amplifiers can be used in carrier-based UWB and impulse-based UWB respectively.

In impulse-based UWB communications, pulses of very short duration (typically in the order of sub-nanosecond) are transmitted. Because of very narrow pulses the spectrum of the signal reaches several GHz of bandwidth. Impulse-based UWB is a carrier-less transmission and, hence, the implementation of this technique is very simple and cost effective since no mixers and local oscillators are required. On the other hand, high speed D/A and A/D converters are needed for the digital processing of the signals. In impulse-based UWB multiple access can be provided by means of Time Hopping (TH) or Direct Sequence (DS) Code Division Multiple Access (CDMA) techniques. Pulsed amplifiers with high output power are typically designed for pulse radar and are effectively applicable to low duty cycle signals such as impulse-based UWB signals. However, for very short pulses, it is needed to consider the bandwidth of the amplifier, so that it maintains the pulse shape.

Carrier-based UWB communications use traditional heterodyning architectures and can be realized as either single band or multi-band. Carrier-based UWB has better spectral control properties with respect to impulse-based UWB. An example of carrier-based UWB is the Multi-Band (MB) OFDM scheme which is based on frequency-hopped PSK/QAM OFDM modulation. Basically, MB-OFDM is a low-complexity radio technology implemented by means of Fast Fourier Transforms (FFT). By using the QPSK constellation the resolution of A/D and D/A can be reduced. Furthermore, increasing the spacing between sub-carriers relaxes the phase noise requirement of OFDM technology and improves the synchronization errors.

As previously mentioned, UWB satellite communications could be a very interesting field of research at “beyond Ka-band” frequencies (i.e.: Q/V and W bands). In this frequency range, UWB satellite transmission power will not be constrained by previously described emission limits, being the RF “beyond Ka-band” spectrum almost free. The very narrow EHF (Extremely High Frequency) beams could also decrease interference problems.

As a matter of fact, “beyond Ka-band” satellite communication is limited by present technology (in particular Tx front-end power generation); in case of the use of UWB pulsed signals, these problems can be faced considering the consolidated state of the art space technology related to W-band satellite radar for cloud profiling (see CloudSat Mission [4]). In particular wideband space qualified EIK (Extended Interaction Klystron) radar pulsed amplifiers could be modified (decreasing pulse width and increasing pulse repetition frequency) to be used for UWB EHF broadband communications [5].

D. ADVANTAGES IN TERMS OF LOWER SENSITIVITY TO RF IMPAIRMENTS

UWB transmission technologies can demonstrate a lower sensitivity to RF impairments such as: High Power Amplifier (HPA) non-linearity, phase noise, I/Q imbalance.

Some innovative UWB pulse shaping, as Prolate Spheroidal Wave Functions (PSWF) waveforms, can provide RF modulated signals characterized by a near-optimal compromise between spectral compactness and envelope compactness. Therefore, the effect of nonlinear distortions can be drastically reduced, while maintaining a spectral efficiency rather similar to bandwidth-limited raised cosine waveforms. In [6] authors simulated a W-band satellite communication PHY-layer based on PSWF waveforms, evaluating effects of linear, nonlinear distortions and phase noise on link performances. PSWF demonstrated their favorable characteristics in the presence of nonlinear distortion with an evident performance gain improvement with respect to the raised cosine, providing an improved service availability with better net payload rates.

A further example of UWB technology that can be effectively exploited in satellite communications is the Frequency Modulation Ultra WideBand (FM-UWB) scheme [7]. FM-UWB is a constant-envelope UWB communication scheme which uses low modulation index Frequency Shift Keying (FSK) followed by high-modulation index analog FM to achieve the wide bandwidth. This approach has two attractive properties for satellite communications: very low complexity of implementation and low sensitivity to HPA nonlinearities.

Finally, low sensitivity to RF impairments can be achieved by using impulse-based UWB, where phase noise and I/Q imbalance are not an issue.

III. OFDM

Orthogonal frequency Domain Multiplexing (OFDM) has become a very popular transmission technique for wireless communications for two main reasons: a) it offers a lower complexity solution (in terms of receiver computational load and hence on the hardware receiver architecture) than current single carrier systems to the problem of performance degradation over severely frequency selective channels, such as wireless channels for very high speed communications (several tens of Mbps); b) it potentially offers good spectral efficiency. OFDM has been adopted as physical layer scheme for important broadband wireless interface standards, such as IEEE 802.11/WiFi, IEEE 802.16/WiMAX, as well as Digital Video Broadcasting-Terrestrial (DVB-T) [8], [9]. On the other hand, the application of this transmission technique has been considered unfit for satellite communications. An OFDM signal is characterized by high amplitude fluctuations that produce large Peak-to-Average-Power-Ratio (PAPRs). This makes OFDM sensitive to non-linear distortion caused by transmitter's power amplifiers, which is one of the critical factor to be considered when dealing with satellite systems. However, recently it has been proved that the adoption of strong channel coding techniques in conjunction with the use of non linear distortion compensation techniques can lead to satisfactory performance even when operating close to amplifier saturation [10], [11]. The use of OFDM for satellite communication is attracting interest mainly for the following reasons:

a) in fixed broadband communications, even if there is negligible multipath, its high spectral efficiency is attractive;

b) OFDM could be efficiently used in order to reduce overall satellite payload receiver complexity (considering a regenerative architecture);

c) in case of a strong channelized payload architecture, the analysis of an innovative channelization architecture, based on the OFDM principle could be a very interesting research field;

d) in some hybrid terrestrial-satellite communications scenario where the terrestrial part uses an OFDM-based air interface, the use of the same technique for the satellite component would reduce the complexity of the terminal.

The latter reason has motivated the adoption of OFDM for the novel standard DVB-SH, with proper modifications and enhancement with respect to the DVB-H OFDM air interface. DVB-SH is a broadcast standard for delivering multimedia services over hybrid satellite/terrestrial networks to a variety of small mobile and fixed terminals with compact antennas and very limited directivity such as handheld devices. OFDM has been also recently applied to military communications. In particular, it has been chosen as physical layer in the Joint Tactical Radio System (JTRS) Wide-Band Networking Waveform (WNW) to support network centric operations [12]. OFDM modulation has recently been explored in JTEO's research efforts for identifying the optimal air-interface for MILSATCOM networks through Wideband Global SATCOM (WGS) systems. In all these applications, one critical issue that remains is the high PAPR and hence, low power efficiency. PAPR reductions techniques have been extensively studied and can be applied to satellite communications. However, one breakthrough in the utilization of OFDM in satellite communications is represented by the novel concept of Constant Envelope OFDM (CE-OFDM) [13]. CE-OFDM transforms the OFDM signal, by way of phase modulation, to a signal designed for efficient power amplification. At the receiver, the inverse transformation—phase demodulation—is applied prior to the conventional OFDM demodulator. The phase modulation transform results in 0 dB PAPR constant envelope signals. It is demonstrated that uncoded CE-OFDM exploits multipath diversity. CE-OFDM is shown to compare favorably to conventional OFDM in multipath fading channels when the impact of nonlinear power amplification is taken into account. On the other hand, it is now well known that the same advantages of multicarrier communications, can be achieved by cyclic-prefixed single carrier systems with Frequency Domain Equalization (FDE). It is also worth noting that the Long Term Evolution (LTE) standard, which represents the evolution of wireless communications towards 4G, foresees an OFDM-based multiple access scheme, such as OFDMA, for the downlink and the Interleaved FDMA (IFDMA), which is a Single Carrier scheme with FDE (SC-FDE), for the uplink. SC-FDE systems have performance close to the ones of a multicarrier system but much lower PAPR, which makes the user terminal more power efficient. Therefore, for the same reasoning, this transmission scheme could be a better candidate for satellite communications with respect to OFDM itself, having also the advantage of being compatible with OFDM based transmitter/receiver as it foresees the introduction of the cyclic prefix and the equalization is performed in the frequency domain. In [14] a first attempt to evaluate the performance of an air interface similar to the uplink of the LTE-standard has been performed with the objective to identify proper modifications and parameters optimization for the satellite scenario.

Finally, we should consider that future broadband satellite systems are going to work at frequency bands above 40 GHz (Q/V bands but eventually W-bands). This communication scenario is also in favor of SC-FDE transmissions rather than OFDM. Some works have already outlined how SC-FDE are less sensitive to RF impairment than OFDM and they can be applied to high frequency bands communications in a more efficient way [15].

IV. CONCLUSION

The final aim of this article is to identify new research areas in fixed satellite communications adopting technologies well developed for wireless terrestrial communications.

In this article the use of UWB and OFDM technologies are proposed for fixed satellite communications with the aim to improve channel data rate, system capacity and spectrum utilization.

In fact, UWB could allow unlicensed satellite systems by means of permissive un-assigned airwave use within emission limits implicitly defined by the future regulations. However, it must be verified that interference and power limitations do not limit the success of license free UWB satellite communications.

On the other hand, UWB can be also used in licensed satellite EHF communications without any power constraint. This will not increase spectrum utilization but could be an advantage in terms of lower circuit complexity and lower sensitivity to RF impairments, and, hence improving the channel data rate.

OFDM satellite communications could be an attractive solution for three reasons: increasing the spectral efficiency of fixed satellite communications, reducing overall satellite receiver complexity, decreasing the complexity of integration between satellite and terrestrial mobile communications systems. However, SC-FDE systems can offer the same advantages of multicarrier systems while noticeably reducing their drawbacks over satellite. Therefore, Authors believe that the use of SC-FDE transmissions in satellite systems represents an interesting research area.

REFERENCES

[1] Digital Video Broadcasting (DVB), Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications, ETSI EN 302 307, v1.1.2, 2006.

[2] S. Vaughn, R. Sorace, “Demonstration of the TDRS Ka-band transponder”, in Proc. 2000 IEEE Military Communications Conference, vol. 2, Los Angeles, CA, pp. 1055–1065, Oct. 2000.

[3] Yoshio Kunisawa, Hiroyasu Ishikawa, Hisato Iwai, Hideyuki Shinonaga, “Satellite Communications using Ultra Wideband (UWB) Signals”, Proceedings of the International Symposium on Advanced Radio Technologies (ISART 2004), March 2-4, 2004.

[4] S. Tanelli, S. L. Durden, E. Im, K. S. Pak, D. G. Reinke, P. Partain, J. M. Haynes, R. T. Marchand, “CloudSat's Cloud Profiling Radar After Two Years in Orbit: Performance, Calibration, and Processing”, IEEE Transactions on Geoscience and Remote Sensing, vol. 46, Issue 11, Part. 1, pp. 3560–3573, November 2008.

[5] P. Horoyski, D. Berry, B. Steer, “A 2 GHz Bandwidth, High Power W-Band Extended Interaction Klystron”, IEEE International Vacuum Electronics Conference, 15-17 May, 2007.

[6] C. Sacchi, T. Rossi, M. Menapace, F. Granelli, “Utilization of UWB Transmission Techniques for Broadband Satellite Connections Operating in W-band”, IEEE Globecom 2008 – IEEE Workshop/EHF – AEROCOMM - Exploitation of Higher Frequency Bands in Broadband Aerospace Communications, New Orleans, LA, USA, November 30 – December 4, 2008.

[7] John F.M. Gerrits, Michiel H.L. Kouwenhoven, Paul R. van der Meer, John R. Farserotu, John R. Long, “Principles and Limitations of Ultra Wideband FM Communications Systems”, EURASIP Journal on Applied Signal Processing, Special Issue on UWB-State of the Art, Volume 2005, Number 3, pp. 382 - 396, March 2005.

[8] I. Koffman, et al., “Broadband Wireless Access Solutions Based on OFDM Access in IEEE 802.16”, IEEE Communications Magazine, Vol. 40, No. 4, pp. 96-103, April 2002.

[9] X. D. Yang, et al., “Performance Analysis of the OFDM Scheme in DVB-T”, The 6th IEEE Circuits and Systems Symposium on Emerging Technologies, Vol. 2, No. 31, pp. 489-492, 2004.

[10] S. Cioni, G.E. Corazza, M. Neri, A. Vanelli-Coralli, “On the Use of OFDM Radio Interface for Satellite Digital Multimedia Broadcasting Systems”, International Journal of Satellite Communications and Networking, John Wiley & Sons, vol. 24, no. 2, pp. 153-167, March/April 2006.

[11] S. Cioni, G.E. Corazza, M. Neri, A. Vanelli-Coralli, “OFDM vs. HSDPA Comparison for Satellite Digital Multimedia Broadcasting Systems”, IEEE Globecom Conference 2005, St. Louis (Missouri), vol. 5, pp. 2922-2926, 28 November - 2 December, 2005.

[12] A. Baddeley, “Going Forward with JTRS,” Military Information Technology”, Vol. 9, No. 7, September 21, 2005.

[13] S. C. Thompson, A. U. Ahmed, J. G. Proakis, J. R. Zeidler, M. J. Geile, “Constat Envelope OFDM”, IEEE Trans. On Commun. Vol. 56, no. 8. August 2008, pp. 1300-1312.

[14] E. Re, E. Cianca, M. Ruggieri, “MSS Physical Layer for PPDR Communications”, accepted in European Wireless Technology conference EuWIT09, Rome, Sept. 2009.

[15] Chia-Chin Chong, Kiyoshi Hamaguchi, Peter F. M. Smulders, Su-Khiong Yong, “Millimeter- Wave Wireless Communication Systems: Theory and Applications”, EURASIP Journal on Wireless Communications and Networking, Volume 2007