SPATIAL CORRELATED RADIOCOMMUNICATION TECHNOLOGIES - THE BULGARIAN CONTRIBUTION FOR A BETTER WORLD

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***Abstract**: Radiocommunication is among technology's biggest contributions to mankind. It involves the transmission of information over a distance without help of wires, cables or any other forms of electrical conductors. On the other hand radiocommunication suffers some disadvantages. The growth of wireless network has enabled us to use personal devices anywhere and anytime. This has helped mankind to improve in every field of life but this has led many threats as well: Radio network has led to many security threats to mankind; Radio network could be jammed easy by the terrorists, enemies ets.; Radio frequency spectrum is limited natural resource; Frequency sharing among different radio systems and users is difficult task. This report represents in brief the authors efforts to solve above mentioned problems. The used common term is "spatial correlation technologies", in particular Spatial Correlation Processing (SCP) – Random Phase Spread Coding (RPSC) and Spatial Correlated – Code Division Multiple Access (SC-CDMA). **It is shown in the report too that the practical implementation of SCP-RPSC and SC-CDMA principles and technologies will solve many global telecommunication problems.** The results of this 20 years long research activity will be a very strong Bulgarian contribution and way to a better world for the human mankind.*

Keywords: SPATIAL CORRELATION PROCESSING, RANDOM PHASE SPREAD CODING, SPATIAL CORRELATED CDMA.

1. Introduction

Radiocommunication is among technology's biggest contributions to mankind. It involves the transmission of information over a distance without help of wires, cables or any other forms of electrical conductors. The transmitted distance can be anywhere between a few meters and thousands of kilometers. Some of the devices used for radiocommunication are cordless telephones, mobiles, GPS units, wireless computer parts, and satellite television.

The recent economic crisis shows the crucial role of efficient and productive use of limited natural resources, such as biomass, biosphere, mineral resources, and water to stimulate sustainable economic development. Climate change has been labelled as the "defining challenge of our time". Its impact is already evident and will intensify over time if left unaddressed. There is overwhelming scientific evidence, that climate change will threaten economic growth, long term prosperity and social welfare of practically all countries, as well as the very survival of the most vulnerable populations. The Information and Communication Technologies (ICTs) and radiocommunications in particular are essential tools in the combat against climate change [1]. Areas foreseen in this context include: continued observations and long-term monitoring of solar activity to improve our knowledge and understanding of the influence of the electromagnetic radiation from the sun on Earth´s environment, including climate; continued observations to characterize changes in the atmosphere, oceans, and land surface, and the use of such information for climate change modelling; and continued observations of the change in the ozone layer and its effects on the environment and human health. Land cover change assessment and understanding of its dynamics are recognized as essential requirements for sustainable management of natural resources, environmental protection, food security, climate change and humanitarian programmes. Terrestrial and satellite radiocommunication systems contribute to the monitoring of carbon emissions, the changing of ice in polar caps and glaciers, and temperature changes. Another key aspect is the application of modern radiocommunication system's to increase productivity, optimize energy consumption and reduce transportation costs leading to reduced levels of CO_2 emissions.

Radiocommunication has the following advantages:

- Communication has enhanced to convey the information quickly to the consumers;
- Working professionals can work and access Internet anywhere and anytime without carrying cables or wires wherever they go. This also helps to complete the work anywhere on time and improves the productivity;
- Doctors, workers and other professionals working in remote areas can be in touch with medical centers through wireless communication;
- Urgent situation can be alerted through wireless communication. The affected regions can be provided help and support with the help of these alerts through radiocommunication;
- Wireless networks are much cheaper to install and maintain.

On the other hand radiocommunication suffers some disadvantages. The growth of wireless network has enabled us to use personal devices anywhere and anytime. This has helped mankind to improve in every field of life but this has led many threats as well.

- Radio network has led to many security threats to mankind. It is very easy for the hackers to grab the wireless signals that are spread in the air. It is very important to secure the wireless network so that the information cannot be exploited by the unauthorized users;
- Radio network could be jammed easy by the terrorists, enemies ets. This also increases the risk to lose information;
- Radio frequency spectrum is limited natural resource. Frequency sharing among different radio systems and users is difficult task.

This paper represents in brief the author efforts to solve some of the above mentioned problems in the last 20 years. The common used term is "spatial correlation technologies', in particular Spatial Correlation Processing (SCP) – Random Phase Spread Coding (RPSC) and Spatial Correlated – Code Division Multiple Access (SC-CDMA).

2. SCP Technology

The main objectives of the SCP technology [3,4] are:

- To receive one or more radio signals coming from one or several spatially distributed signal sources (satellites, base stations), insuring high gain of the antenna systems and using fixed or mobile receiving terminals, equipped with SCP signal processing equipment;
- To ensure spatial selectivity high enough to cancel the same frequency channel interference, coming from different space directions, using simple one channel receiver.

The objectives stated above are achieved by a patented by the author method for radio communications, which proposes application of additional pilot signal transmitted in the band of information signals and available in the receiver by CDMA. The SCP receiver terminal is equipped with antenna array with random phase aperture excitation. The phase shifts among the signals, coming from the antenna elements, are random at the antenna output, regardless of the information source direction. These random phase spread signals correlate with the recovered pilot signal, phase spread in the same manner, in a signal recovery unit. The result of the correlation process between pilot and information signals is the recovered information signal at base band.

The main features of the SCP approach are:

- Simple, cheap and flat passive antenna, suitable for mass production;
- One channel convenient microwave receiver with simple signal processing;
- Omni directional for the cooperative signal source, but with high figure of merit G/T;
- Selection of the different signal sources and polarizations by PN-codes;
- Applications in existing Digital Video Broadcasting – Satellite (DVB-S) systems with minor modifications of the ground transmitters, compatible with the existing satellite transponders;
- Multi-beam and soft handover features.

3. RPSC Technology

Reliability and availability of real time communications are imperative in the context of wireless communication services. A popular technique used in this scenario is Spread Spectrum (SS). A new principle to create broadband SS systems was proposed and patented by the author [5]. It is based on transmission of broadband microwave signals in the open space by means of multi element random phased antenna arrays. The sum of the different element signals in a given point in the space has Gaussian probability distribution and noise like properties. The sums in the different directions of the space are not correlated each other. In such way the proposed principle solves simultaneous the problems of spreading and beam forming of the future sophisticated microwave terrestrial and satellite communication systems with fixed and mobile applications.

The main features of the RPSC technology, when it is used in the up-links of the satellite communication links, additionally include:

- Omnidirectivity for the cooperative satellite, but high equivalent (at base-band) Equivalent Isotropic Radiated Power (EIRP);
- Selection of different terminals and polarizations by Pseudo-Noise (PN) codes;
- Soft handover and virtual multi-beam features;
- The coherent demodulation by means of pilots (specific property of SCP technology), cancelling the Doppler shift and the phase jitter, introduced by local oscillators in the satellite system;
- Compatibility with the existing bent-pipe satellite transponders;
- RPSC up-link protection against jamming, coming even from points, close situated to the earth stations;
- The knowledge of the receiving satellite positions for the transmitting equipment is not necessary;
- The SCP-RPSC approach is a breakthrough technology, leading to unpredictable increase of the frequency reuse factor in satellite and terrestrial wideband networks. Close situated subscriber terminals could communicate with base stations, using the same frequency channel without interference. The isolation between the terminals is provided by their specific random phase spread coding.

4. SC-CDMA technology

One of the main objectives of the Satellite Personal Communication Networks (S-PCN) is to complement terrestrial mobile networks by providing analogous services in areas where satellite technology is more effective and economic. It can be achieved by the provision of dual-mode user equipment which communicates with both the satellite and terrestrial mobile networks so that when users roam outside of the terrestrial coverage, their requested services can still be supported via the satellite segment. An important topic in this field of research are the Connection Transference Schemes (CTS) with Soft Handover (SH). SH maintains the call connection through the old link until a new link is firmly established. SH is always associated with diversity (satellite - terrestrial or satellite – satellite). With soft handover, the service will not be interrupted since the old connection is still used for communication during the handover procedures. As a result, seamless handover can be achieved. The CDMA radio-access approach is particular suitable to realize seamless SH in the Integrated Satellite-Terrestrial Network Scenario.

A new approach, named Space Correlated Unique –Pseudo Noise (SC U-PN) codes, was proposed by the author [6]. It is particular useful as SS radio access technology in the mobile broadband communication and radar systems with integrated terrestrial - satellite positioning. The principles of U-PN codes generation, as well as the basic methods of their acquisition and tracking were reported too. SC-CDMA principle of operation uses several space distributed sources of radio-signals. They are phase modulated by appropriate PN-codes. The Mobile Stations (MS) receive these signals by means of the well known CDMA technology. For this purpose the same PN-codes are generated and synchronized in MS receivers. The *sum(mod2)* of these codes creates a new code, which we named U (Unique)-PN code. This code is used for spreading the information, transmitted by the MS. Similar approaches are used for generation of the Base Station (BS) U-PN codes.

5. SCP, RPSC and SC-CDMA Applications

5.1. Digital Video Broadcasting - Satellite (DVB-S)

A proposal for SCP-CDMA Geo Stationary Orbit (GSO) satellite system, suitable for DVB-S communications in Ku-band for fixed and mobile terminals, is given in [3]. The proposed algorithm for system parameters evaluation, based on link budget calculations, gives good results – Figure of merit (G/T) better than 14 dBi/K for 60 cm antenna diameter at very low prize (in order of several $). Similar proposal for quasi GSO satellites at elliptical polar orbits is given too.

GSO systems provide fixed and mobile communications, as well as TV broadcasting services since 1964. Nevertheless, they still suffer some problems, as follows:

- The amount of the already existing systems limits the frequency and orbital resources in the most desired frequency bands, for example the Ku band.
- The low elevation angles in the high latitude regions hampers the reception in urban areas and rough terrains. Mobile reception using horizontal antennas mounted over mobile platforms is just impossible.

An appropriate decision of the above mentioned problems is the use of satellite systems on high elliptic eccentricity polar orbits, known as Quasi-GSO [3]. The active zone of the satellites here is in the apogee, when the relative satellite -Earth velocity is low.

The application of the above-mentioned Quasi-GSO systems encounters several specific problems:

- It requires the use of high gain tracking antennas;
- The ground terminals should know the exact angle coordinates to the active satellites. This requirement puts hard restrictions on the orbital Quasi-GSO satellites parameters;
- The need of soft handover between the satellites. When mechanical scanning tracking antennas are used, two antennas are needed at least;
- The relative movement between the Earth and the satellites leads to high Doppler shift of the information signals.

The application of the SCP technology in GSO systems requires specific approaches. In the case of fixed reception the antenna should be mounted vertically on the wall, looking to the chosen GSO satellite. In the case of mobile reception it should be mounted horizontally on the roof of the vehicle. In Quasi-GSO the antenna should be in horizontal position in both mobile and fixed reception. Soft handovers among different Quasi-GSO satellites is possible due to the ability of SCP technology for multi-beam reception, using several correlators, each one for the different satellite. The result is:

- Ability for soft hand-off between the satellites using single antenna aperture.
- Space diversity, which allows reception of the same information from several satellites, leading to increased reliability in urban and rough terrain areas.
- The collective systems in trains, aircrafts or ships allow the receiving of different TV programs from several satellites by means of a single antenna system.
- Another advantage of SCP technology in Quasi-GSO is the lack of Doppler shift problems; being the same for the pilot signal and the information one in the process of correlation it is compensated.

To summarize the stated above we can say that for fixed reception from GSO,s it is possible to use the conventional parabolic antennas, while for the Quasi-GSO systems that is inapplicable. The only reasonable solution for them is SCP.

5.2. Space Links

5.2.1.Inter Satellite Links (ISL)

The space segment of the future global satellite systems for broadband communications can be designed in number of ways, depending on the orbital type of the satellites and the payload technology available on board. The use of different satellite orbits to provide complementary services, each optimized for the particular orbital type, is certainly feasible. Satellites can be used to connect with each other and the ground networks, through the use of Feeder Lines, Inter-Satellite Links or Inter-Orbit Links, which when combined with on-board routing facilities, can be used to form a network in the sky. The unique properties of the SCP-RPSC approach will give a new support for the future broadband Low Earth Orbits (LEO,s) communication systems in the service feeder lines, inter-satellite and inter-orbit lines domain. The possible applications of the SCP-RPSC technology in these microwave lines of several different types LEO,s constellations are considered in the report [5].

5.2.2. Feeder Lines for cellular backhaul and IP backbone trunking

There is a great interest in the satellite society for new networks on Medium Earth Orbit (MEO) satellites, using steerable Ka-band beams to provide lower-cost, fiber-grade access for cellular backhaul and IP backbone trunking in traditionally underserved areas. A possible solution of the above mentioned system is based on Electronically Steerable Antennas (ESA). Their benefits include:

- An ESA can direct a narrow beam over a sector angle and give coverage like a sector antenna;
- The narrow beam corresponds to a high antenna gain and thus reduces power and amplification requirements on radios;
- The narrow beam width reduces multipath propagation problems;
- Complex and dynamically re-configurable radio networks can be created exhibiting high spectrum efficiency;
- If the steering of antennas is coordinated it potentially enables the reuse of frequencies and timeslots in different directions;
- The used until now "multiple spot beams" approach is not effective when there is instability or motion of the communication platform. It is due to the necessity of permanent handover among the different spot beams. The ESA approach is good solution in such cases.

The drawbacks of the ESA include:

- There is an increase of complexity in the antenna;
- There will be losses in the RF-electronics in the antenna which lowers the antenna efficiency;
- The use of non-linear devices in the antenna will demand that spectrum issues be addressed;
- The existing ESA designs have only one steering beam. In the case of mobile or unstable platforms we need several hundred independently steering and isolated each other antenna beams.

A new solution for these MEO satellite systems, cancelling the ESA drawbacks, could be SCP-RPSC approach [5].

5.3. High Altitude Platform Systems

A new radio technology to realize the last mile access to the broadband fixed networks, named High Altitude Platform Systems (HAPS), is discussed in report [5]. Such a mode of service delivery offers advantages as coverage can be rapidly set-up over any location and can be just as easily removed or relocated; high elevation angles can be achieved to the mobile users; efficient frequency re-use schemes can be employed to maximize network capacity; the round-trip delay is relatively short; the cost is considerably less than terrestrial or satellite counterparts. The goal of the report is to discuss the possibilities and the advantages of the implementation of SCP-RPSC technology in HAPS feeder lines, as well as in the fixed and mobile terminal communications.

5.4.WIMAX

In [5] the possibilities and advantages of the implementation of SCP-RPSC technologies in *Wi-MAX* communications are discussed. The implementation of these technologies in subscriber terminals is discussed first. After that the possible base station applications are treated too. The applications of SCP-RPSC technologies simultaneous at base station and terminal stations are feasible, but they will need additional research and investigations.

5.5. Aeronautical Mobile Satellite Service (AMSS)

Recent evolutions in the context of AMSS have changed the landscape and the role of the different systems that allow aircrafts to maintain a link with the ground while in flight. The increase in capacity needed to support the growth of worldwide air traffic and the need for increased communication safety are driving a transition from voice-centric procedures aided by slow data link connections to data-centric control applications executed on higher capacity communication systems. These future data links have to fulfill very stringent performance requirements. Indeed, the nature of the information they carry which is bound to become the first mean of air traffic control make their availability critical to the safety of air transportation in the future. Satellite communication systems have many differentiating arguments when compared to terrestrial solutions. Indeed, while the deployment costs of terrestrial systems can be sustainable in high-density areas, their use in low-density remote areas is much less interesting. In high-density areas, satellite could also be useful either as a primary mean of communication or as a secondary one in order to improve the overall communication system's availability. A satellite system, by nature, is able to cover large regions of the earth and can thus provide a cost effective solution to the coverage of both high and low density areas such as oceanic regions where reliable terrestrial coverage is nonexistent. The use of Ku and Ka frequency bands for AMSS leads to unsolved until now problems, which could be solved successfully by SCP-RPSC approach [5].

5.6. Global Navigation Satellite Systems (GNSS)

Historically, the Global Navigation Satellite Services (GNSS) have been delivered through the use of satellites transmitting in L-band (out of which only a few tens of MHz are assigned to GNSS use from regulatory authorities). Targeted to military navigations at first, these services have evolved towards hundreds of civil applications, some of them (for example railway transport) with great accuracy. The use of L-band gives important benefits, such as small onboard antenna size and little or no attenuation due to rain. However, the amount of L-band available, and more specifically the portion allocated to GNSS, is limited. Moreover, frequency reuse due to different orbital slots is extremely limited. The possible transport applications require a much greater accuracy than normally in L-band because of the ionosphere propagation effects. To definitely overcome the problems due to the L-band, the only choice is to move GNSS to a higher frequency band. Ku-band is an ideal candidate to offer error free GNSS.

An analysis of the possibilities to create new GNSS, working in *Ku* –band, is given in [5]. SCP technology is proposed as solution of the possible antenna problems. The possible advantages of such kind systems are discussed, as follows:

- Improving the fade margin of GNSS in Ku-band.
- Drastically decreasing of ionosphere propagation errors.
- Improving the GNSS system parameters due to directivity of the SCP virtual antenna pattern – better isolation among different satellite PN-codes, better Pseudo-satellite Compatibility, better anti-jamming and multi-path propagation properties.

5.7. Integrated Terrestrial-Satellite Personal Communication Networks EMI SC-CDMA system

Proposal of a realistic SC-CDMA system, based on the existing navigation GPS system, is given in [5]. It was named EMI A&B (Enhanced Mobile Information, variants A & B).

The system consists of satellite and earth segments, as follows:

- Earth segment, including subscriber mobile terminals (MS), terrestrial base stations (BS), as well as earth Gate Way Stations (GWS);
- Satellite segment, including LEO satellite base stations and satellite based sources of PN signals (GPS).

The possible frequency allocations for the different parts of the system are as follows:

- 2 GHz – terminal up-link SC-CDMA;
- 2,2 GHz – terminal down-link SC-CDMA;
- 1,6 GHz – GPS signals, used as satellite based sources of PN signals;
- 12 GHz down-link, 14 GHz up-link of Non Geostationary Orbit – Fixed Satellite Service (N-GSO-FSS) technology for the feeder lines of isolated BS without access to terrestrial telecommunication infrastructure;
- 18 GHz up-link, 11 GHz down-link, NGSO-MSS technology for the LEO,s feeder lines.

The distances among different elements of EMI A&B are important and they are as follows:

- *R* – distance between MS and BS;
- *Ri bs* – distance between BS and the i-th GPS satellite;
- *Ri bs leo,s* – distance between a LEO,s and the i-th GPS satellite;
- *Ri ms* – distance between MS and i-th GPS satellite.

In principle in a static SC-CDMA system the generated U-PN codes will repeat in the time due to the repetition character of the primery PN codes. When several LEO or MEO satellites (as it is in GPS) are used as primary PN code sources, their phases will change fast due to their relative fast speeds (in order of several kilometers per second). The result will be generating of pure noise like U-PN codes with very good and unambiguity auto and crosscorrelation functions.

6.Conclusion

The conclusion is that the practical implementation of SCP-RPSC and SC-CDMA principles and technologies will solve many global telecommunication problems. The results of this 20 years long research activity will be a very strong Bulgarian contribution and will lead to a better world for the human mankind.

Referencies

[1]. Rancy, F., Radiocommunications and Climate Change, ITU-R Information page, 2012.

[2]. Demirev, V., Spatial Correlation Processing – the New Approach in the Broadband Satellite Tracking Systems, Journal of Electrical and Control Engineering, Vol.3, N 5, 2013, pp. 55-64.

[3]. Demirev, V., Some Important Parameters of the Spatial Correlation Processing Technology, Journal of Electrical and Control Engineering, V.3, N 5, 2013, pp. 49-54.

[4]. Demirev, V., Random Phase Spread Coding – the New Way to Communicate with Noise Signals at Microwaves, Journal of Electrical and Control Engineering,V.4, N 2, 2014, pp. 1-9.

[5]. Demirev, V., SCP-RPSC – the Key Technology for the Next Generation Microwave Communication Systems, Machines, Technologies, Materials, N 6, 2015, pp. 13-16.

[6]. Demirev, V., Space Correlated U-PN Codes – a Possible Solution for the New Microwave Communication and Radar Systems, Machines, Technologies, Materials, N 6, 2015, pp.17-20.