SCP-RPSC - the key technology in the next generation steerable lines for satellite communications

Veselin B. Demirev

A retrospective review of the author research, dealing with possible applications of SCP-RPSC technology in the next generation steerable lines for satellite communications, is given in this report. The analysis shows that there is very wide area of different SCP-RPSC applications in satellite communications where it is necessary: to direct a narrow beam over a sector angle and give coverage like a sector antenna; to obtain high antenna gain and thus to reduce power and amplification requirements on radios; to narrow the antenna beam width in order to reduce multipath propagation problems; to create complex and dynamically re-configurable radio networks exhibiting high spectrum efficiency; to reuse the frequencies and timeslots in different directions; to obtain secure and reliable satellite communications, resistive to the enemy active jamming, as well as to use "multiple spot beams" approach from unstable or mobile communication platforms at microwaves.

SCP-RPSC – базисна технология в новите поколения сканиращи линии за спътникови комуникации (Веселин Б. Демирев). *В доклада авторът е представил ретроспективен преглед на изследователската си работа в областта на приложението на технологията SCP-RPSC в следващите генерации спътникови комуникации. Специално внимание е обърнато на системите, използващи сканиращи антенни лъчи. Анализът показва извънредно широката област на приложение на технологията SCP-RPSC в спътниковите комуникации, когато е необходимо: насочване на тесен лъч в определен ъглов сектор и осигуряване на покритие, подобно на това на секторна антена; реализиране на голям коефициент на усилване на антенната система с оглед намаляване мощностите на излъчваните сигнали; елиминиране на проблемите, свързани с многолъчевото разпространение на радиовълните; създаване на комплексни и динамично преконфигуеми радио мрежи с висока спектрална ефективност; координиране на сканирането на антенния лъч с оглед преизползване на честотно орбиталния ресурс и времевите интервали в различните направления; елиминиране на ефектите, свързани с пространствена нестабилност или движение на спътниковата комуникационна платформа в сантиметровия и милиметровия диапазон на радиовълните, както и реализиране на надеждни и засекретени спътникови комуникации, устойчиви на активно радиопротиводействие.*

Introduction

Satellites have been successfully serving the traditional markets i.e. telephony and broadcasting, covering large geographical areas using single beam transmission [1]. There is a great demand for fixed and mobile two-way broadband access over large geographical areas not served by telecommunication infrastructure. Satellite broadband is expected to serve as a "local-loop" in such areas. Satellite telecommunication technology has the potential to accelerate the availability of high-speed Internet services in developing countries, land-locked and island nations, as well as in mobile platforms. There is a close link between the availability of a large-scale broadband infrastructure and the provision of public education, health and trade services, on-line access to e-government, e-trade information and in flight connectivity.

One of the biggest technical problems of the broadband satellite is the way of access to the satellite segment, particular the used antenna systems. The need to reuse the orthogonal polarizations, to track Low Earth Orbiting Satellites (LEO,s) or High Altitude Platforms (HAPS), to select one of several Geo Stationary Orbit Satellites (GEO,s) positions, as well as the requirements for two way broadband mobile communications at low price and mass market production leads to unsolved by traditional antennas problems. Their solution could be based on Electronically Steerable Antennas (ESA) [2]. 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 of 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, cancelling the above mentioned ESA drawbacks, was proposed by the author [3], [4], [5]. The name of the new technical solution is Spatial Correlation Processing – Random Phase Spread Coding (SCP-RPSC).

A retrospective review of the research, dealing with possible applications of SCP-RPSC technology in the next generation steerable lines for satellite communications, is given in the report with the main bibliography for details.

SCP-RPSC in the steerable satellite feeder lines of the onboard public access broadband communications

Introduction in the satellite on-board communications

Recently there has been an increase in the use of Fixed-Satellite Service (FSS) networks by Earth Stations mounted On Mobile Platforms (ESOMPs) to provide telecommunications services to aircrafts, ships, trains and other vehicles using both the C- and Ku-band. As the demand for these systems evolves, service providers are turning to other FSS bands, in particular Ka-band, to meet this growing need [6, 7]. The architecture of Ku band GEO broadband on-board system Mowgly is shown in fig.1.

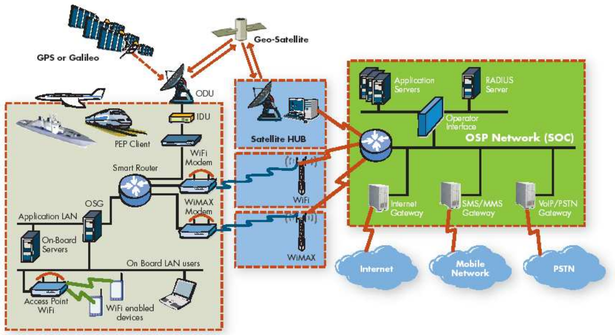

Fig. 1. Architecture of the on-board Ku band satellite system Mowgly.

To address potential interference with other co-frequency GEO FSS networks, ESOMPs should comply with the same constraints, such as off-axis EIRP limits, as those for other FSS earth stations. Such limits would be determined by both the inter-system satellite coordination agreements and the limits in the ETSI standards. In considering aggregate interference levels, it should be noted that there is no evidence that FSS systems, supporting ESOMPs, will have more spot beams or better frequency reuse than other FSS systems, thus by applying existing FSS rules the same level of protection will be provided to neighbouring satellite networks as is currently the case. Hence, from the perspective of potential uplink interference to other satellite networks, these requirements will ensure that such earth stations are essentially equivalent to stationary FSS earth stations.

The design, coordination and operation of ESOMPs should be such that the interference levels, generated by such earth stations, account for the following factors:

- Mis-pointing of the earth station antenna;
- Variations in the antenna pattern of the earth station antenna;
- Variations in the transmit power from the earth station.

ESOMP,s that use closed loop tracking of the satellite signal need to employ an algorithm that is resistant to capturing and tracking adjacent satellite signals. Such earth stations must be designed and operated such that they immediately inhibit transmission when they detect that unintended satellite tracking has occurred or is about to occur. Such earth stations must also immediately inhibit transmission when their mis-pointing would result in off-axis EIRP levels in the direction of neighbouring satellite networks above those of other specific and/or typical FSS earth stations operating in compliance with Recommendation ITU R S.524 or with any other limits coordinated with neighbouring satellite networks. These earth stations also need to be self-monitoring and, should harmful interference to FSS networks be detected, must automatically mute any transmissions.

The tracking of a satellite independently of mobile motion is an essential function for directional antenna systems, used by ESOMPs. The tracking function needs two capabilities – beam steering and tracking control [3].

On the other hand the tasks, performed by the ESOMP,s satellite tracking system, include satellite acquisition and automatic tracking. The acquisition system acquires the desired satellite by moving the antenna around the expected position of the satellite. Automatic tracking is initiated only after the received signal strength due to the beacon signal transmitted by the satellite is above a certain threshold value, which allows the tracking receiver to lock to the beacon. The automatic tracking ensures continuous tracking of the satellite. The main disadvantages of the most popular closed loop tracking methods when used in ESOMP,s are:

- The use of satellite signals as essential factor. This is because received signal levels from satellites are not stable because of the severe propagation environment, due to fading, blocking and shadowing;
- Long acquisition time period during the starting procedures, which is in order of one minute in real Ku band systems and several minutes in Ka band systems. The same acquisition time is needed after the loose of the signal due to blocking in urban environment;
- The listed methods can be used for tracking of only one communication satellite. In some cases, where very high reliability is necessary, the space diversity approach should be used. It includes simultaneous communications and tracking of several satellites.

The SCP-RPSC approach in the satellite on-board communications

The listed drawbacks of satellite tracking ESOMP,s methods could be successfully solved by the SCP-RPSC approach [7], [8], [9], [10]. According to the basic SCP principle, the cooperative satellite is chosen for communications by means of the corresponding synchronized Pseudo-Noise (PN) code, using the well-known Code Division Multiple Access (CDMA) approach. This specific SCP-RPSC feature should be taken in the first place when short acquisition time of the ESOMP,s systems is of great importance. Code synchronization consists of two steps, acquisition and tracking [7]. The most widely used algorithm for code acquisition is the so-called serial search strategy. Here the phase of the local code is changed step by step, in equal increments, resulting in serial search of the code delay uncertainty region until the synchro position is found. For each value of the phase of the local sequence, a correlation between the input signal and the local signal replica is formed and compared to a threshold. A high value of the correlation (above the threshold) indicates the synchro position. The acquisition time period is reduced in the modern CDMA systems by well-developed methods of parallel and combined search up to several tenths milliseconds. It is incomparable small with the acquisition time of the classical methods, used in Ku and Ka frequency bands.

The theory of code tracking in the modern CDMA systems is very well developed too. Similar to acquisition procedures, it is made by software and does not need multichannel RF coherent receiver as it is in classical monopulse tracking. SCP-RPSC gives the possibility of simultaneous tracking of several cooperative satellites, insuring space diversity.

Another very important issue in the field of microwave ESOMP,s is the Doppler effect. It was proven in [10] that it cancels in SCP-RPSC systems due to the correlation of the information and pilot signals, suffering in identical way by the Doppler shift.

SCP-RPSC in the steerable inter satellite and inter orbit feeder lines

Introduction in the LEO satellite mobile feeder lines

The space segment of the future global satellite systems for broadband communications can be designed in a number of ways, depending on the orbital type of the satellites and the payload technology available on board [11]. The use of different satellite orbits to provide complementary services, each optimised for the particular orbital type, is certainly feasible. Satellites can be used to connect with each other, through the use of Inter- Satellite Links (ISL) or Inter-Orbit Links (IOL), which when combined with on-board routing facilities, can be used to form a network in the sky. Fig. 2, 3 and 4 show a set of several possible Satellite-Personal Communication Network (S-PCN) architectures as identified by ETSI, concentrating on the use of LEO,s, which in some cases interwork with GEO,s. The same satellite architectures could be used for the developing of the future global satellite systems for broadband communications.

In option A in fig.2 transparent transponders are used in the space segment and the network relies on the ground segment Fixed Earth Stations (FES) to connect gateways. Satellites do not have the capability to perform ISLs.

The main problems of the FES-satellite feeder lines deal with the pointing of the high gain satellite antennas to the tracking FES antennas because of LEO,s continuous relative movement to the earth. For this reason low gain omnidirectional antennas are used in the LEO satellites at the moment. It leads to low feeder lines link margins and poor frequency reuse capabilities.

Option B in fig.3 uses ISLs to establish links with other satellites within the same orbital configuration. The ground segment may still perform some network functions, but the need for FES is reduced.

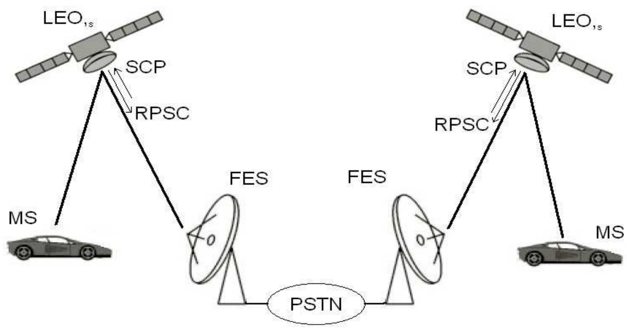

Fig. 2. The satellite system architecture option A.

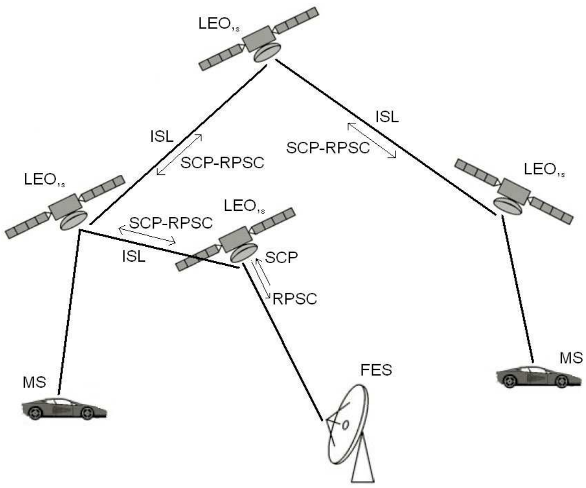

Fig. 3. The satellite system architecture option B.

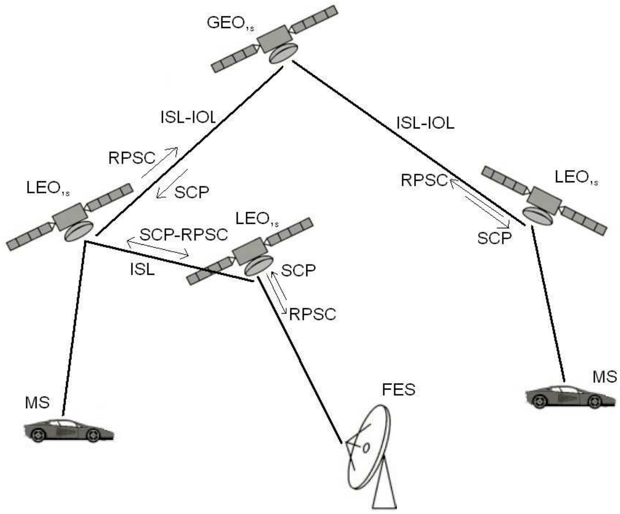

Fig. 4. The satellite system architecture option C.

In the final option in fig.4, a two-tier satellite network is formed through the use of a hybrid constellation. Interconnection between LEO satellites is established through ISL, as in the previous case, and inter-satellite inter-orbit links (ISL-IOL) via a data relay GSO satellite is employed. In this configuration, the GEO satellite is directly accessed by an LEO,s.

SCP-RPSC approach in the steerable feeder lines of the LEO,s communication systems

The unique properties of the SCP-RPSC technology could be very useful if it will be implemented in the feeder lines, ISL and IOL of the future LEO satellite communication networks. In the analysis below the considered options A, B and C are discussed from SCP-RPSC technology implementation point of view [12].

In option A (fig.2) the existing satellite omnidirectional antennas of the satellite-FES feeder lines can be replaced with SCP (up-link) and RPSC (down-link) with the following benefits:

In the up-links FES-LEO,s (SCP approach):

- The LEO,s receiving antenna systems will be omnidirectional for the cooperative FES, but with high figure of merit G/T;
- The different FES and polarizations could be selected simply by the use of specific allocated PN-codes;
- Soft handover between different FES is feasible because of the LEO,s movement and multiple beam forming properties of the SCP technology;
- Space diversity scheme: one LEO,s – several FES with possible frequency reuse is feasible too.

In the down-links LEO,s-FES (RPSC approach):

- Providing full duplex system with one simple and cheap transmit-receive antenna (particularly in Ku band where up and down link frequencies are relatively close);
- The transmitted random poly-phase spread signals will not cause significant harmful interference to the conventional FES, using the same frequency channels. The interference will be similar to that, caused by the sidelobes of a phased antenna array with random inter elements spacing;
- The transmitted random poly-phase spread signals are uniformly radiated in the space below the LEOs. Several FES, equipped with the same SCP receivers and providing space diversity, receive them. The knowledge of the receiving FES positions for the transmitting LEOs is not necessary.

In option B (fig.3) the SCP-RPSC feeder lines FES-LEOs are the same as in option A. In the SCP-RPSC ISL feeder lines the existing directional antennas of the ISL feeder lines can be replaced with SCP (both directions) and RPSC (both directions) with the following benefits:

- The virtual electronic scanning of the LEO,s ISL antenna patterns, typical for SCP-RPSC technology, will reduce significantly the limitations over station keeping characteristics and increase the satellite system reliability;
- LEOs constellations with random orbits could be implemented instead the existing deterministic LEO,s orbits with their specific problems.

In option C (fig.4) the SCP-RPSC feeder lines FES-LEOs are the same as in option A. The SCP-RPSC ISL feeder lines are the same as in option B. In LEOs-GEOs IOL feeder lines the LEOs omnidirectional antennas can be replaced with SCP (down-link) and RPSC (up-link) with the following benefits:

In the down-links GEOs-LEOs (SCP approach):

- The LEO,s receiving antenna system will be omnidirectional for the cooperative GEO,s, but with high figure of merit G/T;
- The different GEOs and polarizations could be selected simply by the use of specific allocated PN-codes;
- Soft handover between different GEOs is feasible because of the LEOs movement and multiple beam forming properties of the SCP technology;
- Space diversity scheme: one LEOs – several GEO,s with possible frequency reuse is feasible too.

In the up-links LEOs-GEOs (RPSC approach):

- Providing full duplex system with one simple and cheap transmit-receive antenna in Ku band;
- The transmitted random poly-phase spread signals will not cause significant harmful interference to the conventional GEO,s, using the same frequency channels;
- The transmitted random poly-phase spread signals are uniformly radiated in the space above the LEOs. The knowledge of the receiving GEOs positions for the transmitting LEOs is not necessary.

Phased array antennas with electronic scanning – problems in space environment

Some of the above mentioned existing problems of the LEO,s feeder lines antennas could be solved by means of ESA. It will raise series of new problems, as follows:

- The radiation hazard of the space environment is very high for the electronic components of the unprotected active ESA. It is not dangerous for the simple and passive Random Phased Radial Line Slot Antennas (RP-RLSA), used by SCP-RPSC technology.
- The temperature variations of the outer parts of LEO,s, where the antennas are situated, are in order of 400 deg. Very dangerous for active antennas too!
- The lack of the gases and humidity attenuations in space environment make the choice of W-frequency band very attractive. ESA in this band are unpractical, which is not the same for RP-RLSA, used in SCP-RPSC approach.

SCP-RPSC approach in the steerable feeder lines of Solar Powered Satellite systems

One of the most important use of satellite technologies in the future will be in Solar Power Satellites (SPS). The concept of generating solar power in space for wireless transmission to receivers on the ground has been discussed in details during the last four decades. The next wave of SPS proposals and ideas will come as a result of the recent developments in the field of the broadband satellite communication and information technologies. They will support the practical implementations of SPS systems in the real life. Several related but distinct architectural approaches to the problem of space solar power were identified as a part of a "Fresh Look" study. This includes:

- Low Earth Orbit (LEO) constellations of SPS with relatively low frequency power transmission;
- Middle Earth Orbit (MEO) constellations of 5 SPS satellites with relatively low to intermediate frequency power transmission;
- LEO power generation with higher orbit Power Relay Satellites (PRS) in MEO or GEO with a range of potential frequencies for power transmission;
- Small scale GEO SPS with high frequency power transmission;
- Large scale GEO SPS with various potential frequencies for power transmission;
- Extremely large scale systems involving multiple SPS and PRS with various potential frequencies for power transmission in LEO, MEO and GEO.

All of the above listed sophisticated SPS systems will need broadband wireless communications for telemetry and control purposes among the different parts of their architectures. Another important problem of the future SPS systems will be the transmission of video and telemetric information among SPS mounting robots (SPS mobile terminals- MT) and satellite or ground based control centres (SPS base stations - BS).

One of the biggest technical problems of the future SPS broadband mobile communications will be the SPS MT and BS antenna systems. The need to change the polarisation, to select one of several SPS MT or BS positions, as well as the requirements for mobile communications in the heavy space environment, high reliability and low price leads to unsolved by traditional antennas problems. The unique properties of the SCP-RPSC approach will give a new support for the future SPS mobile broadband communication systems [13].

SCP-RPSC in the backbone of the terrestrial base stations for mobile communications and IP LAN

There are attempts of some Internet providers to build new networks of MEO satellites with steerable Ka-band beams to provide lower-cost, fiber-grade access for cellular backhaul and IP backbone trunking in traditionally underserved areas [14]. The main O3b network parameters and architecture are presented in the report. Information concerning the satellite constellation and orbit, satellite and ground antenna beam steering, as well as inter-satellite handover procedures are given in the report too.

The possible applications of SCP-RPSC technology in O3b MEO satellite system is discussed in the report [15]. If this approach is used in the ground segment, the following new capabilities will improve the system work:

- Soft handoff between Setting Satellite (SS) and Rising Satellites (RS) with a single and cheap antenna system without mechanical movement, mounted not only on FES, but on ESOMP,s too (fig.5);
- Space diversity, giving the opportunities for simultaneous communications with more than one O3b satellite;
- Frequency sharing with GEO satellite communication systems;
- The system knowledge for the spatial distribution of the O3b satellites is not necessary;
- Proposed by the author new mobile access to the satellite segment named Random Phase Spread Coding Multiple Access (RPSC-MA) [16] is possible to be used in order to increase the O3b satellite segment capacity;
- Protection of satellite constellation against space terrorism by means of RPSC-MA is feasible too.

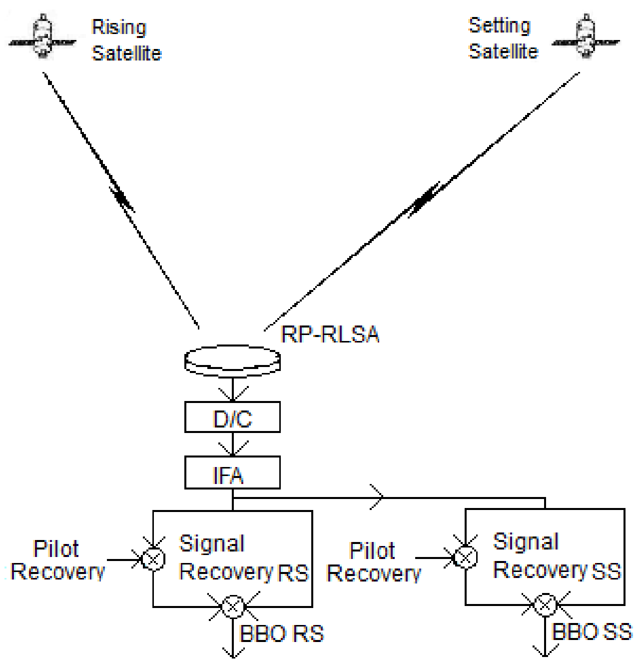

Fig.5. System architecture of a SCP based receiving earth station, ensuring soft handoff between SS and RS satellites.

According to the published information, the obtained maximum RLSA gain is about 40 dB. The FES and ESOMPs of the proposed MEO system will need higher antenna gains. In such cases it is possible to use SCP based receiving earth station, ensuring increased gain by means of several individual SCP receiver units and Signal Adding at Baseband (SCP-SAB), as it is shown in fig. 6.

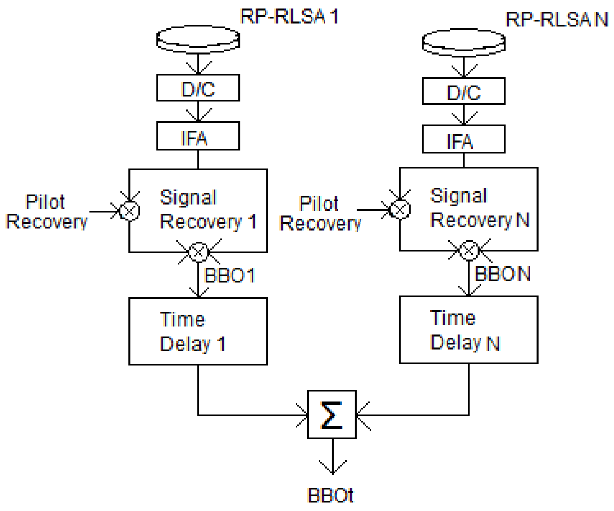

Fig.6. System architecture of a SCP-SAB receiving earth station.

SCP-RPSC in Global Navigation Satellite Systems

Historically, the Global Navigation Satellite Services (GNSS) have been delivered through the use of satellites transmitting in L-band. 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 on-board 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 (frequencies between 11 and 14 GHz) is an ideal candidate to offer error frees GNSS. An analysis of the possibilities to create new GNSS, working in Ku–band, is given in the reports [17], [18]. SCP approach is proposed as solution of the existing antenna problems. The possible advantages of such kind systems are discussed.

A possible architecture of a SCP based GNSS is shown in fig. 7.

The signals from different navigation satellites (Sat.1….Sat.M) are received by a RP RLSA, down converted and separated by means of coarse code recovery circuits (C1, C2,…CM recovery). The sum of the output signals is Gaussian random with Rayleigh distribution. It is strong correlated with the sum of the precise code signals (P1, P2….PM), coming from the corresponding satellites. The outputs of the P-codes recovery units are used for pseudo range navigation measurements in convenient way.

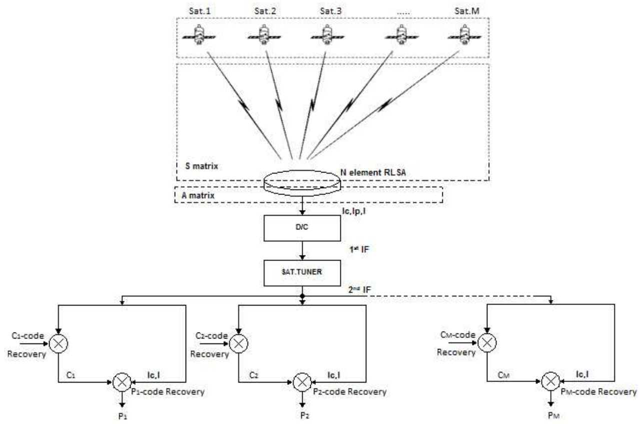

Fig. 7. Architecture of the proposed SCP GNSS.

The advantages of GNSS in Ku-band are:

- Improving the fade margin of GNSS in Ku-band;
- Significant reduction of ionosphere propagation errors;
- Better isolation among signals of the different satellites;
- Better pseudo-satellite compatibility;
- Better anti-jamming properties;
- Better anti multi-path propagation properties.

Conclusions

A retrospective review of the author research, dealing with possible applications of SCP-RPSC technology in the next generation steerable lines for satellite communications, is given in the report as follows:

- SCP-RPSC in the steerable satellite feeder lines of the on-board public access broadband communications;
- SCP-RPSC approach in the steerable feeder lines of the LEO,s Communication Systems;
- SCP-RPSC approach in the steerable feeder lines of Solar Powered Satellite systems;
- SCP-RPSC in the backbone of the terrestrial base stations for mobile communications and IP LAN,s;
- SCP-RPSC in Global Navigation Satellite Systems.

The analysis, given in the report, shows very wide area of the different SCP-RPSC applications in satellite communications, when it is necessary to:

- Direct a narrow beam over a sector angle and give coverage like a sector antenna;
- Obtain high antenna gain and thus to reduce power and amplification requirements on radios;
- Narrow the antenna beam width in order to reduce multipath propagation problems;
- Create complex and dynamically re-configurable radio networks exhibiting high spectrum efficiency;
- Reuse the frequencies and timeslots in different directions;
- Obtain secure and reliable satellite communications, resistive to the enemy active jamming;
- Use "multiple spot beams" approach from unstable or mobile communication platform at microwaves.

The practical SCP-RPSC principles implementations will drastically change the existing paradigm in the satellite communication steering lines in general. Many of the existing problems of the proposed satellite systems, using steering lines, will be solved successfully.

REFERENCES

[1] Mehrotra, R. Regulation of global broadband satellite communications. ITU Report, 2011.

[2] Technical report TR 101 938. ETSI V1.2.1 (2002-06).

[3] Demirev, V. Spatial correlation processing - the new approach in the broadband satellite tracking systems. Journal of Electrical and Control Engineering, Volume 3, No5, 2013, pp. 55-64.

[4] Demirev, V. Some important parameters of the spatial correlation processing technology. Journal of Electrical and Control Engineering, Volume 3, N 5, 2013, pp. 49-54.

[5] Demirev, V. Random phase spread coding – the new way to communicate with noise signals at microwaves. Journal of Electrical and Control Engineering, Volume 4, N 2, 2014, pp. 1-9.

[6] The use of earth stations on mobile platforms operating with GSO satellite networks in the frequency range 17.3-20.2 GHz and 27.5-30.0 GHz. ECC report 184, 2013.

[7] Demirev, V. Recent trends and future developments of vehicle mounted satellite tracking communications systems. Proceedings of CEMA, 13, Sofia, Bulgaria, 2013, pp. 66-69.

[8] Demirev, V. Application of SCP-RPSC technology in the broadband mobile satellite system MOWGLY. Proceedings of the National conference Telecom,08, St. Constantine - Varna, Bulgaria, 2008, pp. 121-126.

[9] Demirev, V. Application of SCP-RPSC technology in the broadband aeronautical satellite services. Proceedings of Bultrans, 10, Sozopol, Bulgaria, 2010, pp. 34-37.

[10] Demirev, V. Study of Doppler effect in SCP-RPSC aeronautical satellite communications. Proceedings of Bultrans, 2012, September, 2012, Sozopol, Bulgaria, pp. 71-75.

[11] Sheriff, R., Y. Fun Hu. Mobile satellite communication networks. John Wiley & Sons, 2001.

[12] Demirev, V. SCP-RPSC technology in the feeder lines of the LEO,s communication systems. Proceedings of CEMA,07 conference, Sofia, Bulgaria, 2007, pp. 1-5.

[13] Demirev, V. Application of SCP-RPSC mobile communications in SPS technology. Proceedings of ISRSSP, Sofia, Bulgaria, 2007, pp. 129-132 .

[14] iDirect's interoperability with O3b's MEO satellite system: A closer look", Internet, March 2009.

[15] Demirev, V. Application of SCP-RPSC technology in satellite MEO system O 3 b. Proceedings of the National conference Telecom,11, Sofia, Bulgaria, 2009.

[16] Demirev, V. Random phase spread coding multiple access - the new competitor of CDMA in the broadband wireless networks. Journal of Applied Electromagnetism, vol.13, Number 1, June 2011, Athens, Greece, pp. 26-32.

[17] Demirev, V. Application of SCP technology in global navigation satellite systems. Proceedings of Bultrans, 2011, Sozopol, Bulgaria, pp. 47-50.

[18] Demirev, V. Application of SCP technology in global navigation satellite systems. Proceedings of CEMA, 12, Athens, Greece, 2012, pp. 61-63.

This paper is an extension of work originally reported in the national conference with international participation "Telecom 2016", Sofia, Bulgaria, 2016.

Assos. Prof. Veselin Demirev *received MS degree in Radio-engineering, Higher Institute of Electrical and Mechanical Engineering (now Technical University – Sofia, TU-S) with a specialization in the fields of microwaves, antennas and radar (1971) and PhD degree in TU-S with thesis on "Radar signal processing antennas" (1981). He graduated a course in "Land mobile communications", USTTI & Motorola, USA (1994); course in "Spectrum management", ITU (1997); courses in "Satellite Earth Station maintenance" and "Satellite System Engineering", the Cable & Wireless College, Coventry, UK (1997). He is Associate Professor in Faculty of Communications, TU-S. His main scientific interests include Broadband mobile satellite and terrestrial communications; Radar and navigation systems; Signal processing antennas and Spread spectrum systems. He has about 100 scientific reports and papers, 15 patents and is author and co-author of 3 books (in Bulgarian).*

tel. 0887-526-936; e-mail: demirev_v@tu-sofia.bg

Received on: 31.08.2016