SCP-RPSC TECHNOLOGY IN THE FEEDER LINES OF THE LEO,S COMMUNICATION SYSTEMS

Veselin Demirev

Faculty of Communications and Communication Technologies,
TU – Sofia, "Kl. Ohridsky" blvd. N8, 1756 – Sofia, Bulgaria,
Phone 3592-965-26-60, E-mail: demirev_v@tu-sofia.bg

Abstract

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. 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 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.

A new principle to realize the receiving satellite ground systems antennas - SCP was proposed by the author several years ago. The same approach - RPSC was investigated in transmit mode. The unique properties of the SCP-RPSC approach will give a new support for the future broadband LEO,s communication systems in the service feeder lines, intersatellite and interorbit 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. A review of the possible advantages, supported by a critical analysis, is given too.

The conclusion is that the practical SCP-RPSC principles implementations in the feeder lines, intersatellite and interorbit lines will change the existing paradigm in the LEO and mixed LEO-GEO satellite communication business. Many of the existing problems of the proposed LEO, MEO and GEO satellite systems, dealing with the service lines as frequency and orbital resource sharing, beam pointing, station keeping characteristics, beam shadowing, etc., will be solved successfully.

1. Introduction

A new principle to realize the receiving satellite ground systems antennas (Spatial Correlation Processing - SCP) was proposed in [1, 2, 3]. The same approach (Random Phase Spread Coding - RPSC) was investigated in transmit mode [4, 5]. Possible applications of SCP-RPSC technology in quasi-Geostationary satellite (GEO,s) systems [6], broadband High Altitude Platform Systems (HAPS) [7] and telemedicine [8] were reported by the author too. The listed areas of SCP-RPSC applications are in the field of the subscriber lines and terminals, were the low price and the abilities for mass production are of main interest. The unique properties of the SCP-RPSC approach will give a new support for the future broadband Low Earth Orbit satellite (LEO,s) communication systems in the service fee-

der lines domain. The possible applications of the SCP-RPSC technology in the feeder lines of several different types LEO,s constellations, using microwave frequency bands, are considered in the report.

2. The main LEO,s communication systems architectures

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 [9]. 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.1, 2 and 3 shows a set of several possible Satellite-Personal Communication Network (S-PCN) architectures as identified by European Telecommunications Standards Institute (ETSI), concentrating on the use of LEO,s, which in some cases interwork with GEO,s. Here, a global coverage scenario is assumed, whereby a particular gateway is only able to communicate with a satellite providing coverage to one of the parties involved in establishing the mobile call. In this case, mobile-to-mobile calls are considered. Establishing a call between a fixed user and a mobile would require the mobile to form a connection with an appropriately located gateway.

In option A in Fig.1 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. This option is used by the existing CDMA LEO,s system ***Global Star***.

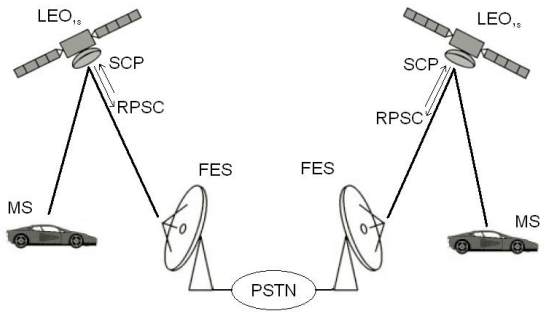

Figure 1. The satellite system architecture option A

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. 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.

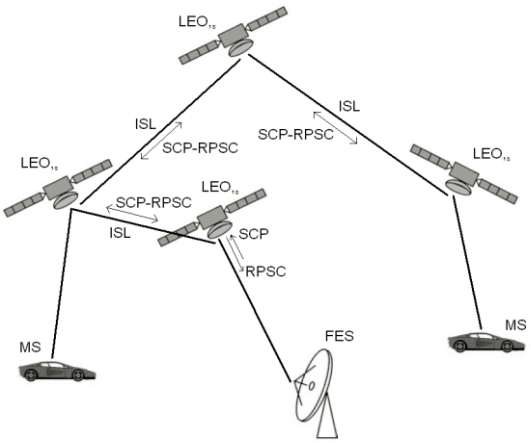

Figure 2. The satellite system architecture option B

Option B in Fig.2 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. A mobile-to-mobile call may have delays of varying duration depending on the route chosen through the ISL backbone. This option is used by the famous ***Iridium*** LEO,s system.

The main problem of the existing ISL technology, used by ***Iridium***, deals with the precise pointing of the narrow microwave antenna beams (the used frequencies are in 23 GHz band) and the need of tracking techniques to support the ISL work. It imposes very strong limitations over station keeping characteristics – about 2 km in cross-track, 5,7 km in-track and 4,7 km in radial direction [10]. The option A problems of the FES-satellite feeder lines, mentioned above, exist here too.

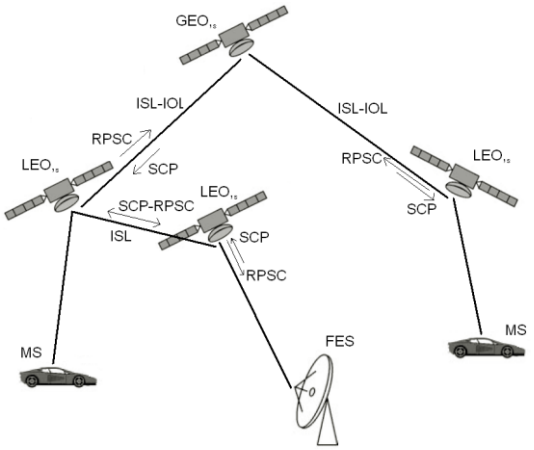

Figure 3. The satellite system architecture option C

In the final option C in Fig.3, 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 (IOL) (ISL-IOL) via a data relay geostationary satellite is employed. In this configuration, the GEO satellite is directly accessed by an LEO,s. To the above mentioned problems of the LEO,s feeder lines and ISL we should add the similar problems of the pointing of the IOL narrow antenna beams of the mobile LEO satellites to the fixed GEO satellite positions.

3. Proposals for SCP-RPSC Technology Implementations in LEO,s feeder lines

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.

A. Option A

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:

SCP (up-link FES-LEO,s):

- 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.

RPSC (down-link LEO,s-FES):

- Providing full duplex system with one simple and cheap transmit-receive antenna.
- 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 LEO,s. Several FES, equipped with the same SCP receivers and providing space diversity, receive them. The knowledge of the receiving FES positions for the transmitting LEO,s is not necessary.
- Close situated LEO,s could communicate with FES, using the same frequency channel without interference. The isolation between the LEO,s will be provided by their specific random phase spread coding, due to their specific random design.

B. Option B

SCP-RPSC feeder lines FES-LEO,s: the same as option A.
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.
- LEO,s constellations with random orbits could be implemented instead the existing deterministic LEO,s orbits with their specific problems.

C. Option C

SCP-RPSC feeder lines FES-LEO,s: the same as option A.
SCP-RPSC ISL feeder lines: the same as option B.
LEO,s-GEO,s IOL feeder lines:

The LEO,s omnidirectional antennas of the LEO,s – GEO,s IOL can be replaced with SCP (down-link) and RPSC (up-link) with the following benefits:

SCP (down-link GEO,s-LEO,s).

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

RPSC (up-link LEO,s-GEO,s).

- Providing full duplex system with one simple and cheap transmit-receive antenna.
- The transmitted random poly-phase spread signals will not cause significant harmful interference to the conventional GEO,s, 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 above the LEO,s. Several GEO,s, equipped with the same SCP receivers and providing space diversity, receive them. The knowledge of the recei-

ving GEO,s positions for the transmitting LEO,s is not necessary.

4. 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 phased array antennas with electronic scanning. According to the author of the paper it will rise series of new problems, as follows:

- The radiation hazard of the space environment is very high for the electronic components of the unprotected active phased array antennas. It is not dangerous for the simple and passive Radial Line Slot Antennas (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. Phased array in this band are unpractible, which is not the same for random RLSA, used in SCP-RPSC technology.

5. Conclusion

The practical SCP-RPSC principles implementations in the feeder lines, intersatellite and interorbit lines will change the existing paradigm in the LEO and mixed LEO-GEO satellite communication business. Many of the existing problems of the proposed LEO, MEO and GEO satellite systems, dealing with the service lines as frequency and orbital resource sharing, beam pointing, station keeping characteristics, beam shadowing, etc., will be solved successfully.

References

[1] V. Demirev, "SCP technology – the new challenge in broadband satellite communications", *ICEST,04 Conference Proceedings,* pp.159-162, Bitola, Macedonia, 2004.

[2] V. Demirev, A. Efremov, "SCP-CDMA GSO,s system proposal", *ICEST,04 Conference Proceedings,* pp.163-166, Bitola, Macedonia, 2004.

[3] V. Demirev, "The Probability Theory with Application in SCP Technology", *ICEST,04 Conference Proceedings,* pp. 167-168, Bitola, Macedonia, 2004 .

[4] V. Demirev, "Radiocommunication method and system with poly-phase spreading", *Bulgarian Patent Office applicant report,* N 106819/ 13.06.02.

[5] V. Demirev, "Review of SCP-RPSC technology", *ICEST,05 Conference Proceedings*, vol. 2, pp.630-633, Nis, Serbia and Montenegro, 2005.

[6] R. Markov, V. Demirev, "Application of SCP technology in quasi-GEO satellite systems", *ICEST,05 Proceedings of Papers,* Nis, Serbia and Montenegro, vol. 2, pp.519-521, June 29-July 1, 2005.

[7] В. Демирев, М. Николова, "Приложение на технологията SCP-RPSC в широколентови HAPS", *Телеком,06,* Варна, 2006 г.

[8] V. Demirev, "Broadband satellite SCP-RPSC communications – the new chance for the telemedicine", *CEMA,06,* Sofia, 2006.

[9] R. Sheriff, Y. Fun Hu, *Mobile Satellite Communication Networks*, John Wiley & Sons, 2001.

[10] D. Roddy, *Satellite Communications*, McGraw-Hill, 1996.