SCP RAKE RECEIVER – THE POSSIBLE SOLUTION OF N-LOS HAPS AND WIMAX MM-WAVE NETWORKS

Veselin Demirev

Radio Communications and Video Technologies Department, TU-Sofia, Kl. Ohridski blv. № 8, 1756-Sofia,
e-mail: demirev_v@tu-sofia.bg

Abstract

A new wireless technology, named SCP-RPSC, was proposed by the author several years ago to solve the antenna problems of mm-wave HAPS and WIMAX. The proposals deal with LOS mm wave propagation environment, which is accepted by the communication community as the only way to communicate in these frequency bands. However, in high building city environment most of the terminal links will be shadowed, which will need more and more new base stations. A possible solution is the NLOS mm-wave systems, working properly in high building city environment. The possibilities of SCP technology to create simultaneous several narrow virtual antenna beams could be a good solution of the problem, leading to effective use of the reflected beams by gathering the signals in phase at baseband.

To realize this idea in HAPS – WIMAX down links, the Rake-receiver principles are proposed in the report to recovery the pilot signals of the different multipath components. After that, by means of several signal recovery correlators, according to the basic SCP technology signal processing, several virtual high gain antenna beams, directed towards the different reflecting points, are created. In such way the reflected signals will be received with high antenna gain and will be better isolated each other. The received in such way different multipath signals should be delayed in proper way and summed in phase at baseband.

The procedure for the HAPS-WIMAX up-links, using RPSC approach, will be similar to the previous case. The Rake receiver for the different pilots multipath components will be situated at the base station site and the signal processing will be similar too.

Block-schemes of a SCP-RPSC HAPS or WIMAX system, based on the described above principles of operation, are given in the report. A description of the multipath propagation phenomena, typical for high buildings city propagation, is given too.

1. Introduction

A new wireless technology, named SCP-RPSC (Spatial Correlation Processing – Random Phase Spread Coding), was proposed by the author several years ago to solve the antenna problems of mm-wave HAPS (High Altitude Platform Systems) [1,2] and WIMAX (World Interoperability for Micro-wave Access) [3,4]. The proposals deal with LOS (Line Of Sight) mm-wave propagation environment, which is accepted by the communication community as the only way to communicate in these frequency bands. Possible applications of SCP-RPSC technology in HAPS LOS terminals are shown in fig. 1, in HAPS LOS base stations – in fig. 2, in HAPS feeder lines and inter HAP links – in fig. 3.

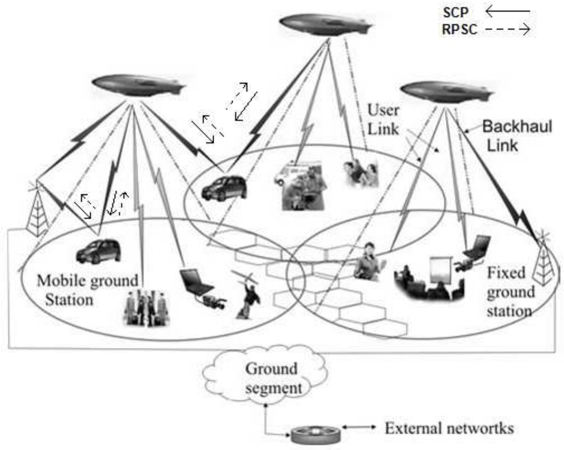

Figure 1. Possible applications of SCP-RPSC technology in HAPS LOS terminals

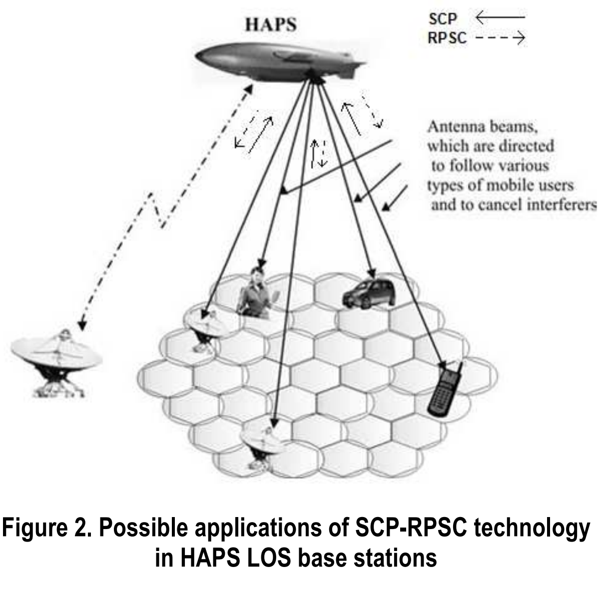

Figure 2. Possible applications of SCP-RPSC technology in HAPS LOS base stations

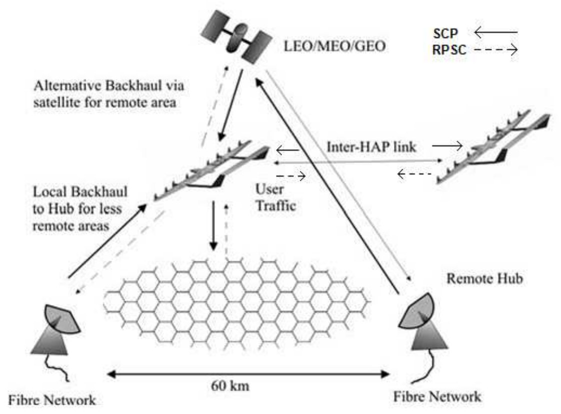

Figure 3. Possible applications of SCP-RPSC technology in HAPS feeder lines and inter HAP links

2. NLOS mm-wave HAPS and WIMAX systems

In high building city environment most of the terminal links will be shadowed, leading to necessity of more and more new earth and HAPS mounted base stations. Careful studies of the propagation phenomena at various operating frequencies for the case of HAPS based scenario, are given in [5,6]. In [5] the authors conclude, that LOS can be only guaranteed for large reception angles under the HAPS base station and the multipath effects will dominate in the most of the serviced area. Bearing in mind the roughness of the building walls, according to the Rayleigh criterion, the authors stated, that a typical wall may have reflection coefficient up to 98 % if the whole of the main beam is incident on the wall. According to the published data, for frequencies in the Ka-band the critical height is fairly small (0,2 cm), but for the IMT-2000, this critical height can be as much as 3,5 cm.

One of the best advantages of the famous CDMA technology is the ability to separate the different multipath components according to their time of arrival by means of multi-channel Rake receiver. CDMA is particular suitable for mobile low and medium speed wireless communications, but for broadband communications it is obviously unusable. A competing technology for this particular case was proposed by the author of this report, named RPSC-MA (Random Phase Spread Coding Multiple Access) [7].

For the reasons, mentioned above, the possibilities to create HAPS and WIMAX links in NLOS environment with SCP technology are of great importance. Another intuitive possible advantage, which should be studied in the future by the radio propagation community, is that the Rayleigh limitations could not be valid for the proposed system, because of the specific random phase spreading in the receiving SCP antenna array.

3. SCP technology in NLOS HAPS and WIMAX down links

One of the main advantages of SCP technology is the possibility to create simultaneous several narrow virtual antenna beams, represented by the SCCF (Spatial Cross-Correlation Functions). In satellite communications it gives the ability to the ground terminal for satellite space diversity and soft handover between different satellites. In our case the goal is the effective use of the reflected from the different buildings beams, gathering the energy of the multipath signals in phase at baseband (similar to the CDMA) – fig. 4.

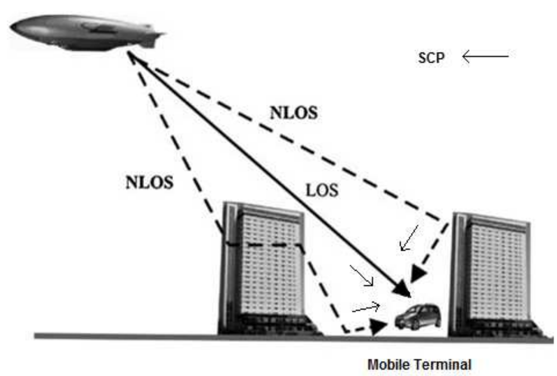

Figure 4. Possible applications of SCP-RPSC technology in HAPS mixed LOS and NLOS propagation environment

A block-scheme of a SCP Rake receiver for HAPS mixed LOS and NLOS propagation environment is shown in fig.5. Here a typical SCP receiver is used, but at low IF (Intermediate Frequency) several Rake channels are created. Each of them consists of pilot recovery unit and signal recovery unit. The pilot recovery units are fed by the used PN-code, properly time shifted according to the time offset of the different reflected signals. Each recovered pilot signal is sum of several thousands random phased signals (equal to the number of the antenna array elements). According to the CLT (Central Limit Theorem) such sum has Gaussian random distribution. In the signal recovery units the corresponding recovered pilots correlate with the spread in the same manner information signals, coming from the same reflecting points. The baseband output of the correlators are time delayed with the specific time delays:

$$\Delta t_1 = \frac{\Delta R_1}{c}; \quad \Delta t_2 = \frac{\Delta R_2}{c}; \quad \ldots\ldots \ \Delta t_n = \frac{\Delta R_n}{c};$$
$$\ldots\ldots\ \Delta t_N = \frac{\Delta R_N}{c} \qquad (1)$$

where:

$$\Delta R_1 = \max(R_{na} + R_{nb}) - (R_{1a} + R_{1b});$$
$$\Delta R_2 = \max(R_{na} + R_{nb}) - (R_{2a} + R_{2b});$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$\Delta R_N = \max(R_{na} + R_{nb}) - (R_{Na} + R_{Nb}), \qquad (2)$$

ΔR_{na} is the distance between the base station and n-th reflecting point, ΔR_{nb} is the distance between the n-th reflecting point and the terminal antenna and $\max(R_{na} + R_{nb})$ is the longest one way propagation trip base station – reflecting point – terminal antenna. For this finger channel the reflected beam is with maximum time delay and the introduced by the system additional time delay at baseband is zero.

The total baseband output signal of the proposed system is sum of the delayed signals of the different Rake fingers:

$$BBO_{total} = BBO_{LOS} + BBO_{NLOS1} + BBO_{NLOS2} + \\ + \ldots\ldots\ldots. + BBO_{NLOSn} + \ldots\ldots\ldots BBO_{NLOSN} \qquad (3)$$

The created in such manner several virtual high gain antenna beams are directed towards the different reflecting points. The reflected signals will be received with high antenna gain and will be well isolated each other (they will not be separated only by the autocorrelation function of the used spreading code as it is in the famous CDMA techniques). The angles among the different reflecting points toward the terminal antenna should be wider than the created virtual antenna beams (the beam-width of the SCCF). The SCCF is approximated with the equation (4) [8]:

$$F(\theta) = \frac{2J_1(2\pi a.\sin\theta/\lambda)}{2\pi a.\sin\theta/\lambda}, \qquad (4)$$

where J_1 is the Bessel function of first order and a is antenna array radius. For this particular case the first side-lobe level is -17,6 db and the half power beam-width $2\Delta\theta_{0,5}$ is:

$$2\Delta\theta_{0,5}(rad) = 1{,}02\lambda/2a \qquad (5)$$

An interesting problem, which should be investigated in details in the future, is the possible interference from signals, reflected by points, situated closer in angle than the SCCF beamwidth, but at different distance from the selected by the Rake receiver reflected points. The probability of such reflections is very small, but they can cause intersymbol interference.

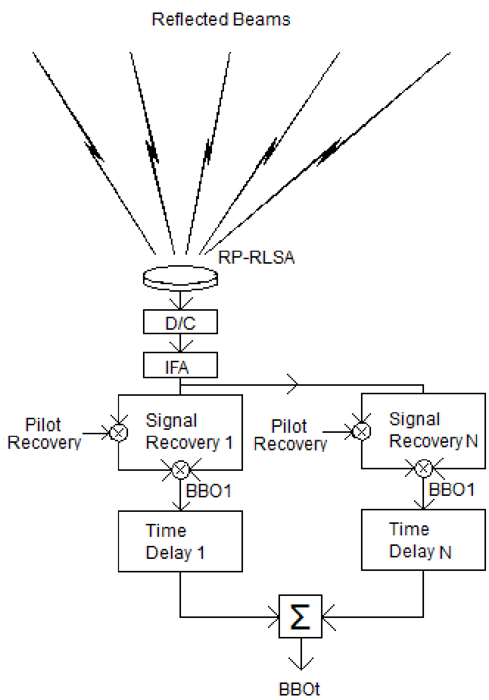

Figure 5. Block-scheme of SCP Rake receiver in HAPS mixed LOS and NLOS propagation environment

4. RPSC technology in NLOS HAPS and WIMAX up-links

The procedure for the HAPS-WIMAX up-links, using RPSC approach, will be similar to the previous case. The Rake receiver for the different pilots multipath components will be situated at the base station site and the signal processing will be similar too.

5. Conclusions

The magic properties of SCP-RPSC technology will help the HAPS and WIMAX millimeter wave antennas not only in LOS conditions, but in NLOS environment too. As a result high capacity reliable broadband wireless networks will appear soon on the market, solving the communication problems of the big cities in 21-st century.

References

[1] V. Demirev, M. Hikolova, "Application of the SCP-RPSC technology in broadband High Altitude Platform Systems", *Telecom,06*, Varna, 2006 (in Bulgarian).

[2] V. Demirev, "The basic characteristics of the SCP-RPSC HAPS systems", *Telecom,10*, Sofia, Bulgaria, 2010 (in Bulgarian).

[3] V. Demirev, "Application of SCP-RPSC Technology in Microwave Wi-Max Systems", *Telecom,07*, Varna, Bulgaria, 2007 (in Bulgarian*).*

[4] V. Demirev, "SCP-RPSC WI-MAX systems – the new approach for the next generation microwave access strategies", *Caspian Telecoms,08*, Istanbul, Turkey, 2008.

[5] A. Aragon-Zavala, J. Cuevas-Ruiz, J. Delgado-Penin, *High-Altitude Platforms for Wireless Communications,* Wiley, 2008.

[6] D. Grace, M. Mohorcic, *Broadband Communications via High Altitude Platforms*, Wiley, 2011.

[7] V. Demirev, "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), pp. 26-32*, Athens, Greece, 2011.

[8] V. Demirev, A. Efremov, "Some Important Parameters of the SCP Technology", Proceedings of XXXX International Conference on Information, Communication and Energy Systems and Technologies ICEST'05, pp.516-518, Nis, Serbia and Montenegro, 2005.