Application of SCP technology in Quasi-GEO satellite systems

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Abstract – **In this paper a brief overview of the Quasi-GEO satellite systems is given; and the possible application of SCP technology in these systems. Afterwards is paid attention to the difficulties experienced, and the ways they are handled. Finally a model system analysis for a SCP system working on Quasi-GEO is given.**

Keywords – **SCP, Quasi-GEO, application**

I. INTRODUCTION

Geostationary systems provide fixed and mobile communications, as well as TV broadcasting services since 1964. They still suffer some problems as:

- 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 hamper the reception in urban areas and/or rough terrain. Mobile reception using horizontal antennas mounted over mobile platforms is just impossible.

II. QUASI-GEO SATELLITE SYSTEMS

An appropriate decision of the afore-mentioned problems is the use of satellite systems on high elliptic eccentricity polar orbits, known as Quasi-GEO. The active zone of the satellites is in the apogee, when the relative satellite -Earth velocity is low. Three systems of this type are being proposed – the American Virtual GEO system [1], [4], The Russian “Centaur”, [2], [3] and the Japanese Quasi-Zenith Satellite System - QZSS [5], [6].

In fig.1 the satellite constellation configuration is displayed. The parameters of this orbit are:

Major axis – 20281 km, Apogee – 27300 km, Perigee – 525 km, Eccentricity – 0.66, Inclination – 63 degrees, Period – 8 h.

The advantages of the Quasi-GEO systems over standard GSO are obvious:

Quasi-GEO provides high elevation angles in high latitudes areas. In graph. 1 [3] the elevation angles for some of the largest cities in the world, both for Quasi-GEO and GSO are compared.

- Quasi-GEO allows frequency reuse of overcrowded GSO frequency bands, i.e. Ku band. In fig. 2 the active zones of GSO and Virtual GEO systems are shown. It is obvious that the minimum angle separation between satellites of both types is about 40 degrees. It allows simultaneous use of Ku band for both systems by the ground terminals with highly directed antennas (s.c. SDMA - Space Division Multiple Access).

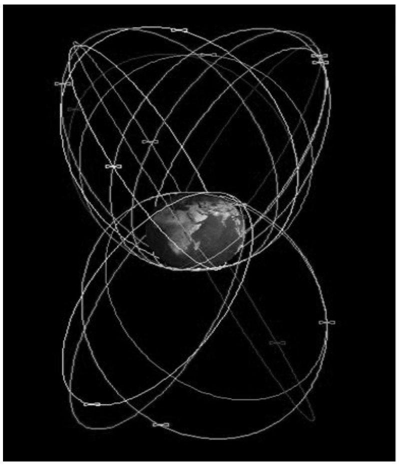
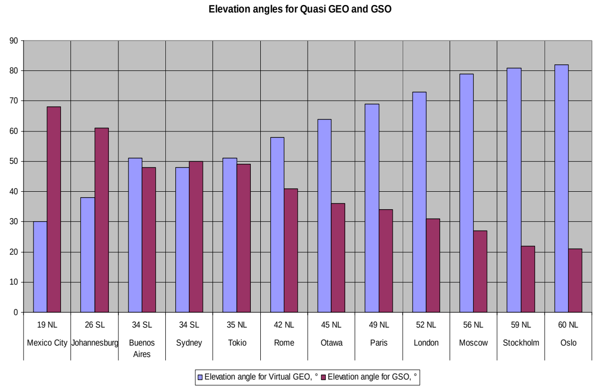


Fig. 1. The satellite constellation of Virtual GEO [4]



Graph. 1. Elevation angles for Quasi GEO and GSO

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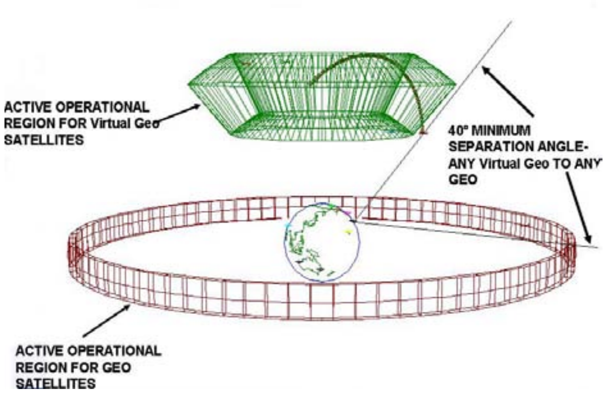

Fig.2. Comparison between Virtual GEO and GSO operational regions [4]

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

- It requires the use of high gain tracking antennas.
- The ground terminals need the exact angle coordinates of the active satellites. This requirement puts hard restrictions on the orbital Quasi-GEO satellites parameters.
- The need of soft hand-off 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.

III. THE SCP TECHNOLOGY – AN APPROPRIATE DECISION FOR QUASI-GEO

In [8] a new radio technology was proposed – SCP, which stands for Spatial Correlation Processing. It allows the receiving of one or more radio signals, coming from one or several spatially distributed sources (satellites) and insures high gain of the antenna system. Its high spatial selectivity cancels the same frequency channel interference, coming from different space directions. The above stated objectives are achieved by means of additional pilot signal, transmitted in the band of information signals and available in the receiver by CDMA (Code Division Multiple Access) techniques. The SCP receiver terminal is equipped with antenna array with random phase aperture excitation. The phase shifts of the signals, coming from different antenna elements, are random at the antenna output regardless of the information source direction. These phase spread signals correlate with the recovered pilot signal, phase spread in the same manner. The result of the correlation process is the recovered information signal at base band. The signals, coming from other satellites, will propagate in different random environment. Their phase spreads will be different from these of the chosen pilot and will not correlate during the signal processing. This lack of correlation ensures the spatial and polarization selectivity of the SCP system.

The SCP technology allows virtual scanning of one or several antenna beams, with high gain and space selectivity. It is a unique technology and a revolutionary step in the development of the next generation satellite communications.

The application of the SCP technology in GSO, s 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-GEO the antenna should be in horizontal position in both mobile and fixed reception.

Another advantage of the SCP technology is the ability 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-GEO 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 while using fixed reception from GSO, s it is possible to use the conventional parabolic antennas, while for the Quasi-GEO systems that is inapplicable. The only reasonable solution for them is SCP.

IV. SYSTEM ANALYSIS OF SCP QUASI-GEO SATELLITE SYSTEM

The system analysis of SCP Quasi-GEO system could be made using the mathematical model, developed in [8] for SCP GSO's system. The specific approach here is that the link equation is defined for one array antenna element. Afterwards the received signal-to-noise ratio is multiplied by the number of the antenna array elements. The following assumptions are made:

- The antenna pattern of a single radiator is omnidirectional
- The gain for a single radiator is G_S =1,6 dBi
- The link equation is used in a simplified form [9]

The parameters for a Quasi-GEO system are as follows:

- EIRP = 56.4 dBW
- S = 42 000 km – the maximum distance to a Quasi-GEO
- f = 12 GHz (λ = 2.5 cm)
- Free space path loss; L = 206.5 dB
- R = 20 MB/s (information signal rate) and
- Rc = 1.23 MCh/s (pilot signal chip rate)
- Receiver noise figure F = 1 dB and antenna noise temperature T_A = 50 grad. K
- L_{add} = 5 dB – (additional losses)
- N = 4800 (number of elements in 80 cm antenna array) => N [dB] = 36.8
- L_{pol} = 3 dB – polarization losses

Calculated:

- Figure of merit per slot $G/T_S = G_S - 10\lg T_S$ =1.6 - 20.88= - 19.28 dBi/grad. K
- Energy per bit over power noise density per antenna element: $E_b/N_o(ips) = EIRP - L - L_{add} + G_S - 10\lg T_S + 228.6 - 10\lg R - L_{pol}$ = - 20.08 dB
- Carrier power per element: $C(ips) = EIRP - L - L_{add} + G_S$ = -153.5 dBW

The multiplying of the pilot and information signals of an element in the correlator and the following low-pass filtering is a process of a coherent demodulation. The result is N in-phase components at base band, which sum is the demodulated information signal. Bearing in mind the fact, that the signal-to-noise ration for the pilot signal is at about 20 dB higher than the one for the information signal, the total

(Eb/No)t=N(Eb/No)ips, (Eb/No)t [dB] = N [dB] + (Eb/No) [dB]ips = 16.72 dB

The total figure of merit for the system will be (G/T)[dB]=N[dB]+ (G/T)per slot[dBi/grad.K] = 36.8 –19.28 = 17.52 dBi/grad.K

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