APPLICATION OF SCP TECHNOLOGY IN GLOBAL NAVIGATION SATELLITE SYSTEMS

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Abstract

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 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. The possible transport applications require a much greater accuracy than normally in L-band because of the ionosphere propagation effects.

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

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

1. INTRODUCTION

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 (frequencies between 11 and 14 GHz, out of which 2+2 GHz assigned to satellite use) 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 the report. SCP technology [1,6] is proposed as solution of the existing antenna problems. The possible advantages of such kind systems are discussed.

2. SCP GNSS SYSTEM ARCHITECTURE

A possible architecture of a SCP based GNSS is shown in fig.1. The signals from different navigation satellites (Sat.1….Sat.M) are received by a random phased Radial Line Slot Antenna (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. In fig. 2 the frequency spectrum of the navigation signals in the proposed SCP-GNSS is shown.

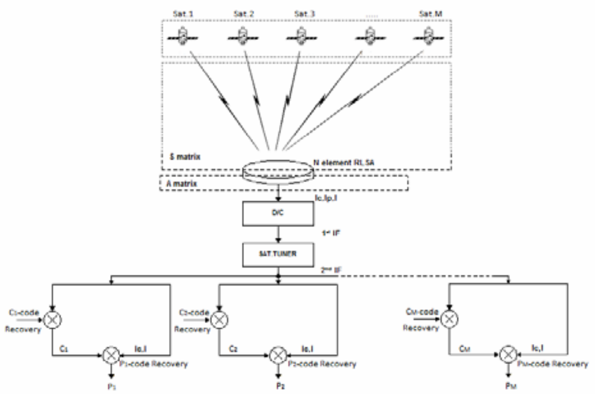

Figure 1. Architecture of the proposed SCP GNSS

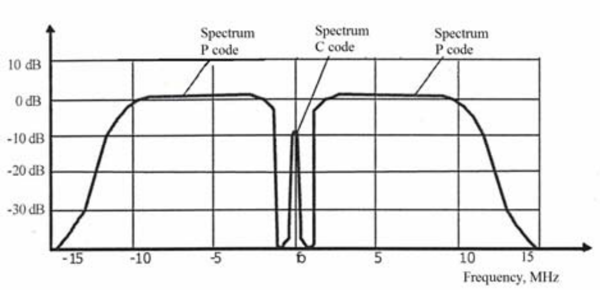

Figure 2. Frequency spectrum of the navigation signals in a SCP GNSS

3. ADVANTAGES OF GNSS IN KU-BAND

3.1. Improving the fade margin of GNSS in Ku-band

A basic parameter of the satellite communications channels is the Carrier to Noise Density Ratio [2]:

$$C/N_0 = C/kT_s = C/T_s + 228{,}6 \text{ (dBHz)}, \quad (1)$$

where:

$$C/T_s = EIRP - L + G_r/T_s \text{ (dBW/K)}, \quad (2)$$

where *EIRP* is the Equivalent Isotropically Radiated Power of the transmitter site, L –propagation losses and G_r is the gain of the receiving antenna,

$$L = L_0 + L_{add} \quad \text{(dB)}, \quad (3)$$

where L_0 are the Free Space Path Losses,

$$L_o = 20\lg R + 20\lg f + 92{,}45 \text{(dB)}, \quad (4)$$

and L_{add} are the additional losses in the atmosphere and hydrosphere, *f* is the frequency in GHz, and *R* is the distance between the ground station and the satellite in km.

Bearing in mind eq. 1, 2, 3 and 4, it is possible to compare different GNSS on the basis the parameter C/N_0.

L- band:

- The used antennas are semi omni directional in order simultaneous receiving of navigationnal signals from all visible satellites. Antenna gain is about 3 dB.
- L_{add} =2 dB in heavy rain.

Ku-band:

- By means of SCP technology [1], it is possible to develop antenna system with 36 dBi gain and diameter about 60 cm, with several virtual beams directed towards different navigation satellites. The antenna dimensions are suitable for proper antenna mounting over cars, boats, planes or trains roofs.
- The additional losses, due to heavy rain conditions, are in order of 10 dB. The increase of the free space losses will be in order of 8,8 dB.

The common increase of the propagation losses due to the use of Ku-band will be about 17 dB. On the contrary, due to the much higher antenna gain, the parameter C/N_0 will be about 14 dB higher. The result will be drastically decrease of the thermal noise User-Equivalent Range Error (UERE), which is now about 11,1 м [3, fig. 5.10].

3.2. Drastically reduce of the ionosphere propagation errors

One of the main source of UERE are the propagation effects in the Earth Ionosphere. They are result of the Sun activity and often they are unpredictable. The root mean square Ionosphere delays UERE in normal activity is equal to 9,9 м, but in the case of high sun activity and low satellite elevation it could reach even 50 м [3]. There are many ways to reduce these kinds of errors, but all of them suffer from different disadvantages.

The frequency dispersion of the root mean square Ionosphere delays UERE could be approximated with $1/f^2$. The transfer of GNSS frequencies from *L* to *Ku* –band will lead to about 50 times decrease of this error, which will delete the importance of Ionosphere delays UERE over satellite navigation systems.

3.3. Improving the GNSS system parameters due to the directivity of the SCP virtual antenna patterns

- better isolation among signals of the different satellites
- better pseudo-satellite compatibility
- better anti-jamming properties

In particular GNSS applications the down-links will be well protected from jamming, coming from the side-lobes of the Spatial Cross-Correlation Function (SCCF), an important parameter of the SCP technology. The level of the side-lobes will be very low (in order of -25, -30 dB). It leads to good protection rations of SCP down-links against ground based terrorist jamming.

- better anti multi-path propagation properties.

One of the main reason for navigation errors in GNSS are the reflected signals (fig. 3), causing s.c. multi-path errors. In some cases UERE, due to multi-path, can reach 12,6 м [4,5]. In a SCP-GNSS the down-links are well protected from multi-path reflections, coming from the low side-lobes of the SCCF.

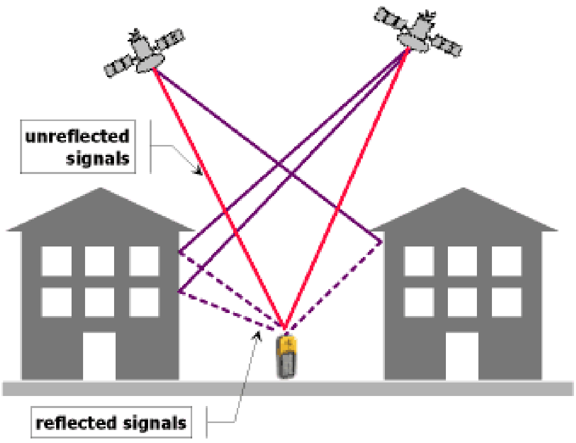

Figure 3. Multi-path of GNSS signals in urban environment

4. CONCLUSION

The preliminary analysis of the possible transition from L to Ku-band of the future high accuracy GNSS, based on SCP technology, gives good first results and impressions. In the future this possibility should be studied in details, based on funded research projects.

Referencies

[1] В. Демирев, Мобилни и Персонални Спътникови Комуникации, Изд. ТУ-София, 2010.
[2] G.Gordon, W. Morgan, Principles of Communications Satellites, John Willey&Sons, 1993.
[3] M.Grewal, L. Weill, A. Andrews, Global Positioning Systems, Inertial Navigation and Integration, Wiley, 2001.
[4] E. Kaplan, Understanding GPS – Principles and Applications, Artech House, 1996.
[5] Error analysis for the Global Positioning System, Wikipedia, Internet.
[6] В. Демирев, "Приложение на технологията SCP в системите за спътникова навигация", Трудове на Бултранс, 2011, стр. 47-50, Септември, 2011, Созопол.