RECENT TRENDS AND FUTURE DEVELOPMENTS OF VEHICLE MOUNTED SATELLITE TRACKING COMMUNICATIONS SYSTEMS

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Abstract

Earth Stations mounted On Mobile Platforms are currently a strong growth market, driven chiefly by major projects to deploy vast regional or world-wide networks. One of the biggest technical problems here is the antenna system. The tracking of a satellite independently of mobile motion is an essential function for directional antenna systems in Ku and Ka frequency bands. The tracking function needs two capabilities – beam steering and tracking control.

Analytical review of the beam steering and tracking control methods, used in Earth Stations mounted On Mobile Platforms, is given in the report. The advantages and disadvantages of the Mechanical steering and Electronic steering methods, as well as the closed and open loop methods for tracking control are given too.

The proposed review of tracking antenna methods shows that the solving of tracking Earth Stations mounted On Mobile Platforms problems needs entirely new approach. The aim of this paper is to analyze the new technical proposal, named Spatial Correlation Processing, from satellite tracking techniques point of view. Special attention is given to the reasons for obtaining a very short acquisition time period during the starting procedures. Proposal for parallel code acquisition procedures is given too.

1. INTRODUCTION

The growing satellite communications market makes it more and more difficult to assign frequency resources in the commonly used frequency bands at 4-6 GHz and 11-14 GHz. Thus, frequency bands above 17 GHz are of increasing interest for future satellite communication links. Ka band satellite broadband applications present a number of advantages and some drawbacks in comparison with other broadband solutions, their suitability depending on the environment considered. For example, in rural and other isolated areas, where fibre links could be very expensive, satellite Ka band can be used to overcome first-mile connectivity gaps [1]. Improvements in Ka band technology include amongst others:

- Systems employ narrow “spot beams” rather than a single coverage area over a region. A far more efficient use of the available bandwidth resulting in a higher throughput and a much lower transmission cost per Mbytes. The contracted and planned Ka band satellites will use multiple tens and up to several hundreds of spot beams for broadband access systems. Spot beam apertures of less than 0.3° and advanced beam pointing error correction techniques are foreseen.
- High satellite Equivalent Isotropic Radiated Power (EIRP) and Figure of Merit (G/T) will allow to accommodate small-size user antennas (e.g. down to about 40 cm diameter dish) compatible with requirements on transportability.
- Improved spectrum efficiency in particular due to multispot frequency re-use.

Ka band satellite broadband services currently enable diverse applications such as:

- Internet: Provisioning of broadband access to small and medium enterprise, households as well as individuals in low density populated areas (more than 50% of European territory).
- Information & Entertainment: Broadcasting high quality of service (QOS) TV in high definition or even 3D format as well as emerging interactive broadcast services.
- Broadband service to mobile platforms such as aircrafts, ships, cars and trains.
- Business continuity: Provisioning of high QoS as well as reliable and dependable private communication networks for real time exchange of critical information between geographically distributed entities;
- Disaster management: Surveillance of critical or dangerous assets as well environ-

mental monitoring with data collection from sensors deployed in remote areas.
- National and international security domain.
- Feeder links for satellite data relay systems.

Satellite broadband services with advanced Ka band multi-beam antenna and payload technologies will be able to deliver up to 100 Mbps peak data rates on the downlink and up to 20 Mbps peak data rates on the uplink. Hence, satellite broadband can be qualified as a complementary Next Generation Access technology.

2. 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

Recently there has been an increase in the use of Fixed-Satellite Service (FSS) networks by Earth Stations mounted On Mobile Platforms (ESOMP,s) 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 [2].

Advances in satellite antenna technology, particularly the development of stabilised antennas capable of maintaining a high degree of pointing accuracy even on rapidly moving platforms, have already allowed the development of mobile terminals with very stable pointing characteristics. The pointing accuracy performance of systems currently either in production or under development for use in Ka-band is equal to or better than that currently achieved by Ku-band systems operating on mobile platforms. These mobile terminals are designed to operate in the same interference environment and comply with same regulatory constraints as those for typical uncoordinated FSS earth stations. Ka-band satellite networks with mobile terminals are expected to be operated in Europe from early 2013.

To address potential interference with other co-frequency Geo Stationary Orbit (GSO) FSS networks, ESOMP,s 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 standard. In considering aggregate interference levels, it should be noted that there is no evidence that FSS systems, supporting ESOMP,s, 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 neighboring satellite networks as is currently the case. Hence, from the perspective of potential up-link 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 EIRP 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.

3. EARTH STATION ANTENNA BEAM STEERING AND TRACKING METHODS

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

There are two types of beam steering methods. The first is mechanical steering, which physically directs the antenna to the satellite. The second is electronic steering, which directs the antenna beam by electronic scanning. A typical example of electronic steering is achieved through a phased array antenna. The main features of the two types of methods are listed below:

- Mechanical steering

Advantages: Technically easy to fabricate; Wide beam coverage; Good axial ratios in wide beam coverage.

Disadvantages: Low reliability; Low-speed beam scanning; Large in volume and heavy; Very high cost (in order of several thousands US $).

- Electronic steering

Advantages: Light and low profile; High-speed beam scanning; High reliability.

Disadvantages: Technically difficult to fabricate; Narrow beam coverage, Narrow frequency working band; Poor axial ratios in wide scanned coverage; Excessive feeder loss; Extremely high cost (in order of hundred thousands US $).

There are also two methods to control tracking. The first is the closed loop method, which uses a signal from the satellite to search for and maintain in satellite direction. The second method is the open loop method, which does not use signals from a satellite. It uses compasses and rate sensors and is not applicable for ESOMP,s in Ku and Ka frequency bands, where high gain narrow beam antenna systems are used.

The tasks, performed by the ESOMP,s satellite tracking system, include satellite acquisition and automatic tracking [4]. 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. Figure 1 shows the generalized block schematic arrangement of the closed loop satellite tracking system. The ESOMP,s antenna makes use of the beacon signal to track itself to the desired positions in both azimuth and elevation. The auto track receiver derives the tracking correction data that is used to drive the antenna. The tracking techniques are classified on the basis of the methodology used to generate angular errors. Commonly used tracking techniques include Sequential Lobing, Conical Scan and Monopulse Tracking.

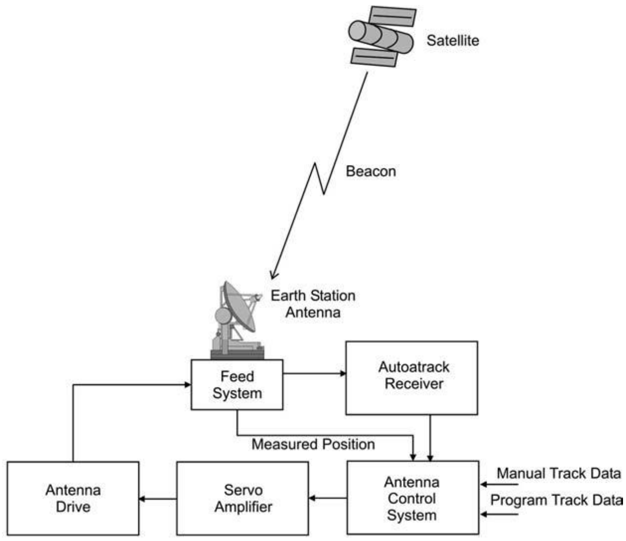

Figure 1. Block schematic arrangement of closed loop satellite tracking systems with mechanical steering

The main disadvantages of the above listed 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 only one communication satellite. In some cases, where very high reliability is necessary, the space diversity approach is used. It includes simultaneous communications and tracking of several satellites.

4. THE SCP-RPSC APPROACH

The listed review of satellite tracking ESOMP,s methods shows that the solving of their main problems needs entirely new approach, proposed by the author ten years ago [5,6,7]. The name of the new proposal is SCP-RPSC (Spatial Correlation Processing – Random Phase Spread Coding) technology.

The SCP system objectives solve simultaneous the problems of antenna beam steering and closed-loop satellite tracking. SCP system could be defined as virtually electronic steering and multiple satellites closed-loop tracking system. The SCP approach is base for the later developed Random Phase Spread Coding (RPSC, or SCP,transmit) approach, as well as for the RPSC-Multiple Access techniques.

The possibilities of SCP-RPSC approach to solve the regulatory ESOMP,s problems in Ku band were reported by the author in [8]. The same advantages could be declared for the SCP-RPSC systems in Ka band, as well as the additional advantages from acquisition and tracking point of view.

The SCP system architecture is shown in fig. 2, where 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). This specific SCP-RPSC feature should be 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 [9].

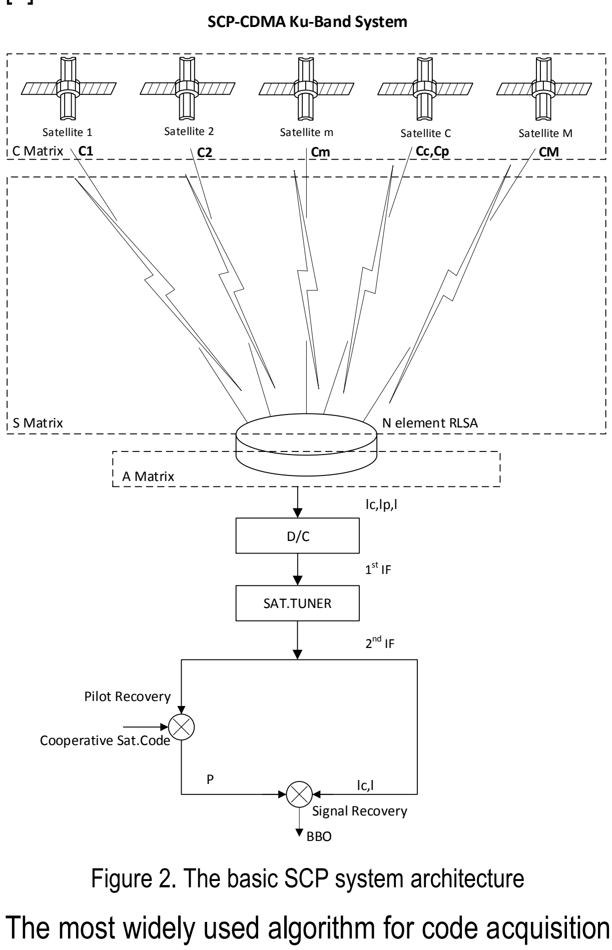

Figure 2. The basic SCP system architecture

The most widely used algorithm for code acquisition is the so-colled 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 with the acquisition time of the above mentioned, used in Ku and Ka frequency bands, classical methods.

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. This approach gives the possibility of simultaneous tracking of several cooperative satellites, insuring space diversity.

5. CONCLUSION

The recent and future developments of satellite communications in Ku and Ka frequency bands for fixed and mobile users will lead to new extremely important possibilities for the human mankind. They will improve quality of life of billion people. Very important part of this development is the practical implementation of the proposed by the author SCP-RPSC approach.

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