Antennas with electronic beam steering in earth observation applications

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In the recent decades, space communication has gained an important role in earth observation applications because of its abilities to establish an efficient communication link between a ground station and a ground terminal located in a place without any developed infrastructure. This communication system consists of a ground station, satellites and ground terminals. The efficient functioning of such a system depends mainly on the satellites. This is the most costly and vulnerable part of the system. The design of the satellites requires a lot of effort and can benefit considerably from incorporating the most recent progress in the different used technologies.

LEO (Low Earth Orbit) satellites for earth observation fly on altitudes from 200 km to 2000 km. Their orbital periods vary from 30 minutes to 30 hours. Due to constant movements of the satellite with regard to the ground station or ground terminals dedicated specifications can be imposed on the antenna system to keep the communication link as efficient as possible. There are different types of antennas used on LEO satellites depending on available space and the application targeted. A straightforward way to obtain a better communication link is sending high power. However, in a point to point link between two antennas, it is a waste of power to send a signal in directions other than the direction of the receiver (satellite, ground station or terminal). In satellites the available power is very limited because the weight of solar cells has to be kept at a minimum. By using a directional antenna even on one side of the communication link, the total link budget is improved considerably. Hence, the use of directional antennas is preferable. In many cases, the exact position of the receiver or transmitter on the Earth is not known. In this case on the satellite, antennas with an isoflux radiation pattern can be used. An ideal isoflux condition consists in sending equal power density to every point of the illuminated earth area. The communication link budget can be improved further by using more directional antennas. The narrower the beam width, the more power is sent to the sector where the receiver antenna is located. The drawback of these antennas is that they must be pointed accurately in the direction of the receiving antenna. This pointing needs a special steering mechanism. The most widely used directional antennas are reflectors of different types. The direct steering of the main beam is performed mechanically. Once a system like this is installed on a satellite, it will suffer from vibrations caused by rotation of the reflector or its primary feeder. This vibration deteriorates the accuracy and efficiency of the whole system. For large satellites, large reflectors with multiple beam feeders without mechanical scanning can be used. Although indeed used in telecommunications, in earth observation this system is not always the most appropriate.

An alternative to mechanical beam steering is electronic beam steering [1]. In this case, the antenna array is composed of several elements, each of them can be controlled electronically. A short overview of widely used topologies for electronic beam steering will be given. These topologies include antenna arrays constructed using Butler matrices or RF phase-shifters. The common characteristic of these arrays is that they are based on electronic beam steering using RF components. These RF components ensure necessary phase shift between the adjacent elements in the array. Although these arrays are used in practice, they are meanwhile very expensive in manufacturing due to the high cost of RF components.

A promising technique, developed in the framework of the so-called KULSAT project, is quite different from RF electronic beam steering. Here received signals are decomposed into two I and Q Base Band (BB) orthogonal signals. Both signals are processed and after weighted summing result in the signal with desired phase shift. The advantage is that the processing is done with analog devices. This means that the beam can be continuously scanned. Another advantage is that the analog devices used in the processing are much cheaper than RF components. Moreover, they are widely available.

This technique is one of the possibilities for the future satellite carrying the IS-HS mission. The design of the whole system, including the RF part on the satellite, with signal processing and ground terminal is performed by the Katholieke Universiteit Leuven, Belgium, and the University of Stellenbosch, South Africa. In contrast to the original KULSAT array, the design is performed using mostly space qualified components. They have to satisfy the very strong requirements for space applications, in order to survive high vibrations during the launch and hostile space environments during operation. More detailed information on the designed system will be given in the full paper.

[1] Balanis C.A., *Antenna Theory: Analysis and Design*, Wiley, 1997