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GLOBAL CLOCK SYNCHRONIZATION FOR A SATELLITE ARRAY IN SPACE

Abstract

In recent years, exciting science drivers have emerged in the ultra low frequency range of 0.3-30 MHz ranging from the epoch of re-ionization, exo-planets, ultra-high energy cosmic rays and studies of the astronomical dark ages. However, terrestrial observations at these frequencies are severely hampered by the ionospheric distortion and man-made interference. The Orbiting Low Frequency Antennas for Radio astronomy (OLFAR) is a Dutch funded program which aims to design and develop a detailed system concept for an array (> 50) of scalable autonomous nano satellites in space (well above the ionosphere) to be used as a scientific instrument for ultra low frequency observations. The satellites will be equipped with deploy-able antennas, in addition to sufficient processing and communication capabilities. All the (> 50) satellites with independent orbits, must be constrained within a virtual sphere of 100 km diameter, to synthesize a large aperture dish of similar dimensions. The OLFAR cluster could either orbit the moon, whilst sampling during the Earth-radio eclipse phase, or orbit the Earth-moon L2 point, sampling almost continuously or Earth-trailing and leading orbit. Furthermore, to alleviate single point of failure, the cluster of satellites will be a distributed system co-operating with each other, both for radio astronomy observations and communications, with minimal control from earth based ground stations. These requirements bring fundamental technological challenges for such a mission.

One of the key challenges for the coherent functioning of OLFAR cluster is synchronization. Each nano satellite will be equipped with a high quality Rubidium clock oscillator for accurate time stamping of observed data and for communication. However, despite the high standard, clocks are susceptible to both phase and frequency drifts which need to be corrected at regular intervals. In the OLFAR cluster, all satellite clocks must be resynchronized every half an hour, within accuracies of a few tens of nano seconds. This article discusses the clock requirements for radio astronomy in space and a study on feasible space qualified clocks which suit the OLFAR mission are presented, where Rubidium standard is shown to be an optimal solution. Furthermore, a novel network synchronization algorithm is proposed for jointly estimating both clock offsets and clock skews of all the independent satellite clocks. The algorithm exploits the two way communication between all nano satellites and is shown to be computationally less complex and yet efficient.