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Position Measurement and Synchronization for Space-borne Ultra-long Wavelength Radio Array

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In radio astronomy, the Ultra-Long Wavelengths (ULW) regime (wavelength longer than 10 m), remaining as the last virtually unexplored window of the electromagnetic spectrum, has been drawing more and more studies due to its potentially significant science outcomes. However, the opaqueness of the Earth's ionosphere, ionospheric distortion and artificial radio frequency interference (RFI) make the space-borne radio telescope to be the only resolution for ULW radio observations. For a space-based radio array, all the satellites should be synchronized, and their positions should be known to keep the signal coherence between satellites, though these requirements are lower at ULW band. In the Ref. [1] [2], the microwave link has been used to achieve the ranging and synchronization, and the star sensor camera has been employed to determine the direction of baseline vector between different satellites. These technologies do resolve the problems of antenna position and clock synchronization, however, extra instruments are required to carry out the measurements, which will increase unavoidably the weight, the power, and the cost, etc. In this work, we proposed a passive measuring method to implement the relative position measurement and the synchronization between different satellites.

At the ULW band, an omnidirectional antenna (e.g. tripole) onboard a satellite is usually adopted to be the basic receiving element, which make it capable to observe the radio sources in different directions simultaneously. As we know the flux of radio source has a negative exponent relation with the frequency, it is easy to find several strong radio sources in the whole sky that could be used to calibrate the ULW radio array. In the ULW radio observations, the radio emissions from these strong sources will be always in the signals sensed by each antenna. In principle, they will arrive at each antenna with different time delays, which are determined by the direction of radio source, the relative positions and the clock differences of the satellites. Using the fringe searching technologies like convolution, the time delays between each pair of satellites can be obtained for different radio sources. To describe the relative position of two satellites, three parameters are required at least including the distance, elevation and azimuth angles. Another parameter can be used to represent the clock difference. Since the directions of the radio sources are known in the sky. We could build an equation set including four relations between the time delays and the four unknown parameters. By solving this equation set, the relative position parameters and the clock difference parameter will be obtained.

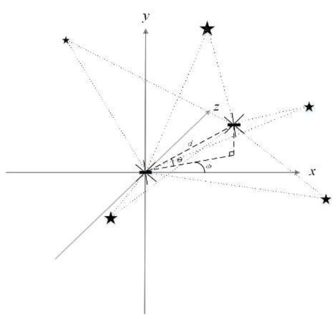

Figure 1. Schematic view of observing multi radio sources with space-borne ULW radio interferometer.

Studies show that using the proposed method in this work the satellite relative position can be measured with the accuracies of sub-meter in distance and one tenth of degree in angle. The clocks can be synchronized to the nanosecond level. As a passive measuring methods, it is quite competitive and cost-effective for a space-borne ULW radio array mission.

References

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