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MICROSATELLITE NAVIGATION SYSTEM DESIGN BASED ON 21-CENTIMETER SPECTRAL LINE

Abstract

21-centimeter spectral line, also named as hydrogen line, is a celestial phenomenon in radio astronomy which has strong flux density as spectral line. This natural phenomenon is triggered by the change in the energy state of neutral hydrogen atoms. As the result, the electromagnetic radiation is at the precise frequency of 1420405751.76670.0009Hz which is equivalent to the vacuum wavelength of 21.1061140542 cm in free space. According to its super stability in the radiation frequency, it has been regarded as a promising source for future spacecraft navigation.

This paper was to introduce the principle of microsatellite navigation based on 21-centimeter spectral line and the instrumental design of the on-board navigation receiver. The essence of this idea was to measure the Doppler velocities of the spacecraft with respect to the 21cm spectral line source. From the analysis of the Doppler frequency shift, the relative velocity between the source and the observer could be derived. The velocity integral can estimate the position, which can be enhanced with a Kalman filter. The similar processes in the three dimensions would enable the prediction of the satellite's position in the space, if no less than three 21-centimeter spectral line sources can be simultaneously observed.

Also, this paper proposed a front-end design of the navigation receiver for the micro satellite navigation. There have been two main requirements to design the receiver: (1)Signal amplification and denoising: at least 30dB gain would be provided from the antenna to the Analog-digital converter. (2) Beam forming: digital beam forming technique can be used to carry on the digital weighting to the antenna array and control the antenna beam to fulfill different observation directions. In this case, the receiver can observe more than one radiation source.

Based on this analysis, this paper proposed a receiver design with 37 basic modules aligned in hexagon, and each module consisted in a micro-patch antenna, a two stage low noise amplifier, a phase shifter and a mixer. The numerical simulation showed that the system performance in the hexagon alignment can implement the beam scanning from -45 degree to 45 degree using 6 bits and provide a system gain of 31.7dB.