



## Precise Time Synchronisation and Ranging in Nano-Satellite Swarms

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Precise time synchronization and ranging is very important for a variety of scientific experiments with more than two nano-satellites: For synthetic aperture radar (SAR) applications, for example, the radar signal phase (which corresponds to a synchronized time) as well as the location must be known on each satellite forming synthetic antenna. Also multi-static radar systems, MIMO radar systems or radio tomography applications will take advantage from highly accurate synchronization and position determination.

We propose a method for synchronizing the time as well as measuring the distance between nano-satellites very precisely by utilizing mm-wave radio links. This approach can also be used for time synchronization of more than two satellites and accordingly determining the precise relative location of nano-satellites in space. The time synchronization signal is modulated onto a mm-wave carrier. In the simplest form it is a harmonic sinusoidal signal with a frequency in the MHz range.

The distance is measured with a frequency sweep or short pulse modulated onto a different carrier frequency. The sweep or pulse transmission start is synchronized to the received time synchronization. The time synchronization transmitter receives the pulse/sweep signal and can calculate the (double) time of flight for both signals. This measurement can be easily converted to the distance.

The use of a mm-wave carrier leads to small antennas and the free space loss linked to the high frequency reduces non line of sight echoes. It also allows a high sweep/pulse bandwidth enabling superior ranging accuracy. Additionally, there is also less electromagnetic interference probability since telemetry and scientific applications typically do not use mm-wave frequencies.

Since the system is working full-duplex the time synchronization can be performed continuously and coherently. Up to now the required semiconductor processes did not achieve enough gain/bandwidth to realize this concept at frequencies above 60GHz in a small, cost effective and low power integrated circuit. But with the state of the art (commercial available) SiGe and p-HEMPT GaAs semiconductor processes it becomes possible to implement this concept even at 300GHz in a small MMIC or hybrid circuit.