Using Fractional Clock-Period Delays in Telemetry Arraying

Special digital FIR filters help to increase accuracy.

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A set of special digital all-pass finite-impulse-response (FIR) filters produces phase shifts equivalent to delays that equal fractions of the sampling or clock period of a telemetry-data-processing system. These filters have been used to enhance the arraying of telemetry signals that have been received at multiple ground stations from spacecraft (see figure). Somewhat more specifically, these filters have been used to align, in the time domain, the telemetry-data sequences received by the various antennas, in order to maximize the signal-to-noise ratio of the composite telemetric signal obtained by summing the signals received by the antennas.

The term "arraying" in this context denotes a method of enhanced reception of telemetry signals in which several antennas are used to track a single spacecraft. Each antenna receives a signal that comprises a sum of telemetry data plus noise, and these sum data are sent to an arraying combiner for processing. Correlation is the means used to align the set of data from one antenna with that from another antenna. After the data from all the antennas have been aligned in the time domain, they are all added together, sample by sample. The desired result is (1) the coherent addition of the telemetry data to obtain an enhanced telemetry signal NS, where N is the number of antennas and S is an average telemetry signal received by one antenna; and (2) the addition of the uncorrelated noise components of the signals received by the various antennas to obtain a reduced (relative to the enhanced telemetry signal) noise signal of $N^{1/2}|V|$, where $|V|$ is a root-mean-square noise component of the signal received by an antenna.

It must be emphasized that in order to obtain the desired result, one must align the timing of the data sequences from the various antennas as precisely as possible. This translates to a need to delay the various signals by various time intervals that could be as small as a fraction of a clock period.

One can construct special digital FIR filters that exhibit linear phase as long as their coefficients are symmetric around their centers. A filter of this type can be made to be of an all-pass type such that it produces group delay, based on the length of the filter, equal to a whole number of clock periods if an odd number of coefficients are used. If an even number of coefficients are used, then the group delay can include half a clock period. By shifting the coefficients of such a filter to be slightly asymmetric, one can obtain a group delay that includes a fraction (not necessarily half) of a clock period.

This concept has been implemented through modification of the Parks-McLellan algorithm for generating equal-ripple FIR filters, in order to produce all pass filters with coefficients of varying asymmetry. This implementation has been found to yield filters that not only give the needed fractional-clock-period delays but also leave phases almost perfectly linear within the pass bands used for telemetry signals.

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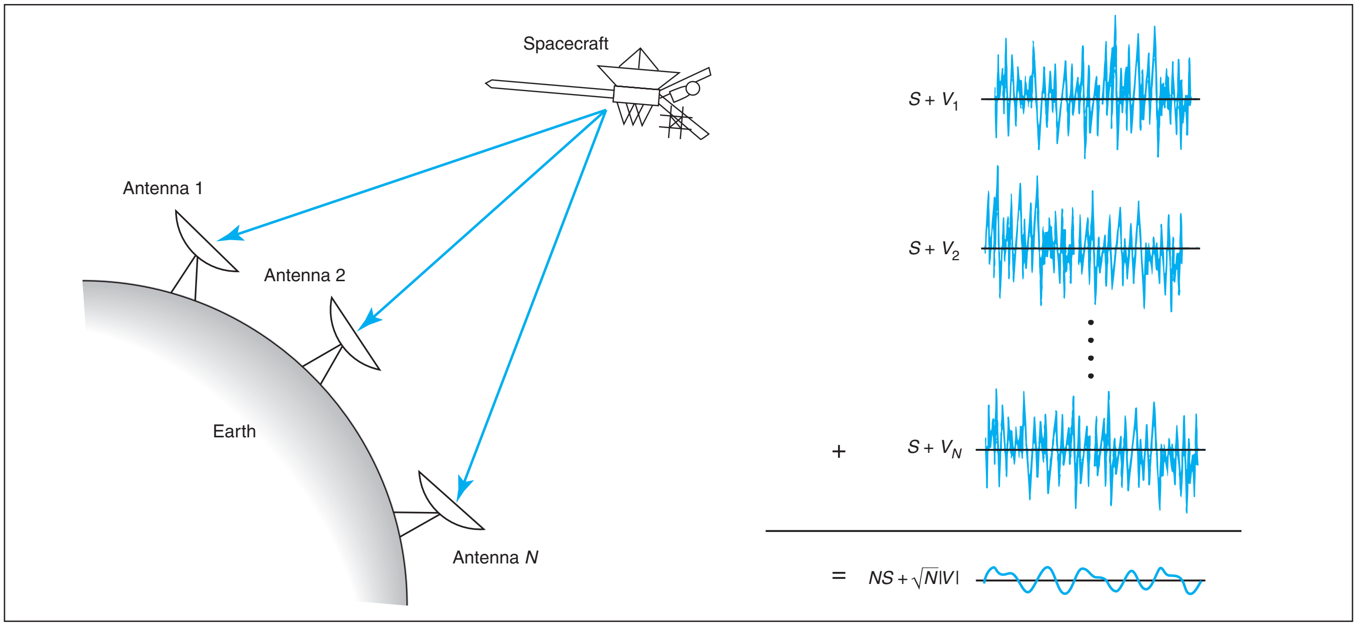

In **Spacecraft-Telemetry Arraying**, the telemetry signals plus noise received at multiple antennas are first aligned in time, then added to increase the signal-to-noise ratio.