Antenna Pointing Subsystem Conscan Implementation

R. Tappan
DSN Data Systems Development Section

The software of the computer that drives the tracking antennas in the DSN has been modified to improve the pointing accuracy for tracking operations at X-band frequencies. The change implemented an improved model for atmospheric refraction correction and added a software tracking option that corrects any remaining pointing errors. The software tracking option that was added measures the actual pointing error and corrects the antenna position accordingly. This option will be discussed.

The computer program that drives the 26-meter and the 64-meter antennas in the DSN has been updated to improve its performance. The improvement was obtained by revising the model used for atmospheric refraction correction, changing the method used to compute the ephemeris, and adding an option to use the computer as part of a closed loop tracking system.

The 26- and 64-meter parabolic antennas used in the DSN are driven in two axes by hydraulic servo systems that may be operated either manually or under computer control.

The computer program has three modes of operation that may be used to track a target.

The star track mode accepts inputs of right ascension and declination, and tracks the target at a sidereal rate.

The planetary mode requires three inputs of right ascension and declination. A quadratic equation is fitted to the three points and evaluated to determine the ephemeris.

The tape drive mode reads sets of time-tagged coordinates from paper tape. A quadratic equation is least squares fitted to four points and the program tracks between points 2 and 3.

Each of these modes has an option of using a method of conical scanning (conscan) as part of a closed-loop tracking system to improve the accuracy with which the antenna tracks the target. The option requires the addition of an analog to digital (A-D) converter to the hardware. The converters have been installed in the 64-meter stations to assist in X-band tracking operations.

Conscan adds corrections to the antenna position that maximize the received signal level. The corrections added are small, but they are important for operations at X-band frequencies where the narrow beam width causes the received signal to be reduced by one decibel for a pointing error of 0.011 degree.

Conscan imposes a circular scan pattern on the path of an antenna that is tracking a target. The circular scan pattern is generated by adding a sinusoidal signal to the servo error signal of the hour angle (HA) axis, and a consinusoidal signal to the declination (DEC) axis. The period and radius of the scan pattern are entered by the operator prior to the start of the conscan operation.

$$HA = R^{*}SIN\,(SCNANG)$$

$$DEC = R^{*}COS\,(SCNANG)$$

where R is the radius of the scan in degrees, and $SCNANG$ is the scan angle.

If the radio-frequency (RF) boresight of the receiving system is not pointing directly at the target, the scan will produce a small sinusoidal variation in the received signal power as the antenna sweeps toward the signal source and back again. The rate of the sinusoid is the scan period. The phase with respect to the scan rotation is determined by the direction of the pointing error, and the amplitude is proportional to the angular deviation from the source. The amplitude proportionality constant, the gain, is also an operator input. The received signal is monitored by an A-D converter that can be switched to sample either the automatic gain control (AGC) voltage of the receiver for tracking the coherent signal from the spacecraft, or the voltage of a radiometer for tracking noncoherent (noise) sources.

The pointing error that exists for each axis is recovered from the A-D converter samples by correlating them with the scan drive of the axis, suitably offset in phase to account for the mechanical and electrical delays in the receiving system.

$$HA \text{ correlation} = SIG^{*}SIN\,(SCNANG - LPS)$$

$$DEC \text{ correlation} = SIG^{*}COS\,(SCNANG - LPS)$$

where SIG is the A-D converter sample, $SCNANG$ is the scan angle associated with the A-D converter sample, and LPS is the phase delay in the receiving system.

The correlations are summed for one complete scan period and scaled to become the angular corrections that are required to move the RF boresight back to the target.

The gain is selected to cause a fraction of the required correction to be made at the end of each scan period to minimize positioning errors due to noise on the A-D converter samples. The radius is selected to cause an acceptable signal loss when the pointing error has been reduced to zero. Typically, for X-band operations, a radius of 0.011 degree would be selected for the initial scan, causing a signal loss of one decibel. The radius would then be changed to 0.004 degree (the 0.1-dB point) after several scans had reduced the pointing error. The period selected is one that corrects the pointing angle as frequently as is necessary and avoids synchronization with a periodically fluctuating signal from the target, as might occur when tracking spin stabilized spacecraft. Normally used periods range from 60 to 120 seconds.