DSN Inherent Accuracy Project

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The objectives and organization of the DSN Inherent Accuracy Project, and the technical work performed by the project, are described. Current work (reported in the three following articles) is introduced and summarized.

I. Description

The DSN Inherent Accuracy Project was formally established by the DSN Executive Committee in July 1965. The objectives of the project are:

(1) Determination (and verification) of the inherent accuracy of the DSN as a radio navigation instrument for lunar and planetary missions.

(2) Formulation of designs and plans for refining this accuracy to its practical limits.

Achievement of these goals is the joint responsibility of the Telecommunications and Mission Analysis Divisions of JPL. To this end, regular monthly meetings are held to coordinate and initiate relevant activities. The project leader and his assistant (from the Mission Analysis and Telecommunications Divisions, respectively) report to the DSN Executive Committee, and are authorized to task project members to (1) conduct analyses of proposed experiments, (2) prepare reports on current work, and (3) write descriptions of proposed experiments. The project is further authorized to deal directly with those flight projects using the DSN regarding data-gathering procedures that bear on inherent accuracy.

The various data types and tracking modes provided by the DSIF in support of lunar and planetary missions are discussed in Ref. 1. Technical work directly related to the Inherent Accuracy Project is presented in Ref. 2 and in subsequent Space Programs Summary (*The Deep Space Network*) volumes, and is continued in the three following articles.

For most upcoming planetary missions, such as *Mariner* Mars 1971, the tightest bounds on the allowable errors for a number of parameters arise from the navigational accuracy requirements during encounter support. In particular, encounter navigational accuracy is most sensitive to error sources that cause a diurnal signature on the radio tracking data (Ref. 3). These sources of error are of two classes: (1) those parameters that define the locations of the DSS in inertial space, and (2) those phenomena that directly affect the DSS tracking data. The first category includes the locations of the DSS with respect to earth's crust; Universal Time (UT1); polar motion (the motion of the earth's crust with respect to the spin axis); precession and nutation (orientation of the earth's spin axis with respect to inertial space); and the ephemerides of the earth, moon, and target body. Of these, uncertainties in the first three are currently the major limitations to the encounter support of navigation accuracy.

The dominant sources of error in the second category are those affecting the tracking data directly. These include frequency system instability, electrical phase path variations (through both the spacecraft and the DSS), and the transmission media (the troposphere and the charged particles in the ionosphere and space plasma).

II. Current Work

The three following articles are concerned with the effect of the transmission media on the radio metric data. The first article (MacDoran, et al) discusses an interesting result obtained with the differenced range versus integrated doppler (DRVID) technique during the *Mariner* Mars 1969 mission. This technique takes advantage of the fact that charged particles affect range increments obtained from the accumulated doppler count, and those obtained from differencing range measurements, by a nearly equal but opposite amount; i.e., the effect advances the phase velocity (doppler) and retards the group velocity (ranging). Thus, DRVID can be used to calibrate tracking data to obtain the effect of charged particles. DRVID was first tried during the *Lunar Orbiter* and *Mariner V* missions, and although these attempts were not successful in obtaining the desired calibration information for the tracking data, they did succeed in identifying problem areas that masked the effects of the charged particles. Subsequently, the recent effort during *Mariner* Mars 1969 (Refs. 4 and 5) has yielded encouraging results. In fact, not only has the calibration of radio metric data proved possible with DRVID, but as explained by MacDoran, et al, DRVID has been used to probe the solar corona during the superior conjunctions of the *Mariner VI* and *VII* spacecraft. It has been possible to establish a correspondence between plasma fluctuations in the radio raypath and McMath regions on the solar surface. Estimates of electron densities a factor of four larger than the normal ambient condition and scale sizes from 6×10^4 to 2×10^6 km have been made for plasma clouds transiting the radio path.

The next two articles (Miller, et al; Winn and Leavitt) discuss tropospheric refraction. Currently, doppler residuals at lower elevation angles generally show systematic behavior such that it has become common practice to delete all data taken below elevation angles of 10 or 15 deg from the orbit determination solutions. This is unfortunate, because there are indications (Ref. 3) that this low elevation data is particularly desirable for inclusion in the orbit determination process. It is felt that the systematic lower elevation angle doppler residuals are due to inadequacies in the ability to correct for the transmission media—in particular, the troposphere—and a serious effort is being made to correct this situation.

One approach is to use a separate exponential refractivity profile for both the wet and the dry component instead of the single profile model presently used. Further, instead of representing the ray trace results from these profiles by an empirical formula, they will be more accurately represented in the orbit determination software in tabular form. However, neither the wet nor the dry refractivity profile is invariant so the tropospheric calibration error caused by assuming a nominal refractivity profile, as opposed to the actual profile, was examined (Miller, et al). For reasonable profile variations, it was found that the error in the tropospheric range correction obtained by using the nominal profile will be less than 0.5 m down to a 5-deg elevation angle, which is within the acceptable limits for support of the *Mariner* Mars 1971 mission during real-time operations. This allows a table of tropospheric corrections versus elevation angle for a nominal refractivity profile to be stored in the orbit determination software, and the tropospheric corrections to the radio metric tracking data are obtained by scaling the contents of this table by the zenith tropospheric range correction. Consequently, a considerable simplification is realized over having to perform raypath tracings for each tracking pass during the *Mariner* Mars 1971 mission.

The scaling factor must still be determined for each tracking pass. Possible ways of doing this include the use of radiosonde data to compute the zenith range correction or including the scaling factor as a "solve for" parameter during the orbit determination process itself. An analytical investigation of this later technique was reported by Ondrasik (Ref. 6), while Winn and Leavitt attempt to accomplish this by processing tracking data obtained from *Surveyor* spacecraft after they had landed on the moon. This is a preliminary study and the charged particle corrections—notably, those due to the ionosphere which have a diurnal signature—have not been removed from the tracking data. Nevertheless, where systematic errors in the doppler residuals are visible below a 25-deg elevation angle, solving for the tropospheric scaling factor—on a tracking pass by tracking pass basis—removes the signature at elevation angles above 15 deg, and reduces the second moment of the doppler residuals by 80%.

References

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