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 in-
clude 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 inte-
grated doppler (DRVID) technique during the Mariner
Mars 1969 mission. This technique takes advantage of the
fact that charged particles affect range increments ob-
tained 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 in-
formation for the tracking data, they did succeed in identify-
ing 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 re-
sults. 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 $6 \times 10^4$ to $2 \times 10^4$ 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 resid-
uals 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 inclu-
sion 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 trans-
mision media—in particular, the troposphere—and a seri-
ous effort is being made to correct this situation.

One approach is to use a separate exponential refrac-
tivity profile for both the wet and the dry component
instead of the single profile model presently used. Fur-
ther, instead of representing the ray trace results from
these profiles by an empirical formula, they will be more
accurately represented in the orbit determination soft-
ware in tabular form. However, neither the wet nor the
dry refractivity profile is invariant so the tropospheric
calibration error caused by assuming a nominal refrac-
tivity profile, as opposed to the actual profile, was ex-
amined (Miller, et al). For reasonable profile variations,
it was found that the error in the tropospheric range cor-
rection 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 cor-
rections to the radio metric tracking data are obtained by
scaling the contents of this table by the zenith tropo-
spheric 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 correc-
tion or including the scaling factor as a "solve for" para-
meter during the orbit determination process itself. An
analytical investigation of this later technique was re-
ported 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 fac-
tor—one a tracking pass by tracking pass basis—removes
the signature at elevation angles above 15 deg, and re-
duces the second moment of the doppler residuals by 80%.
References


