The Model of Mars Radio Ranging. W. Z. Zhang[1] and J. S. Ping[2], [1]Beijing Normal University, Xinjiekouwai Street, No 19, Beijing, China. Contact:wenzhaozhang@bnu.edu.cn; [2]Key Lab. of Lunar and Deep Space Exploration Research, National Astronomical Observatory of CAS, Datun Rd. 20A, Beijing, China, Contact:jsping@bao.ac.cn.

Introduction: Since the beginning of the last century 60's, people began to launch a probe to carry out the Mars exploration program. Many domestic and foreign research institutions have begun to launch a broad and in-depth research work around Mars exploration. Non manned Mars exploration mission Exo-Mars, which carried out by ESA and NASA, is expected to be launched in 2018. It will give us a new opportunity to study Mars.

Mars radio ranging is based on the Mars lander and ground radio equipment system. The theoretical model gives the geometric relations and basic principles of measurement. It takes into account the vast majority of correction factors in the distance measurement between Mars and Earth, and discusses the effect of the various corrections on the distance measurement while the theoretical distance precision reaching 0.1 mm. The research on the high precision theoretical model can be used as auxiliary means of Mars missions. The compare of theoretical model and real measurement also can help to correct the parameters of the Atmosphere model and Martian gravity field.

Basic principles and Geometric model:

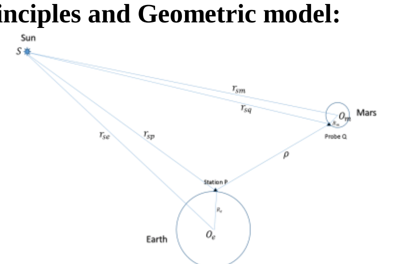

Figure 1 Geometric model

Suppose a radio signal is transmitted from the ground station to the mars probe. t_f is the transmission time, and t_b is the forwarding time, and then the signal vector from ground to mars probe is:

$$\overrightarrow{\rho_{em}} = \overrightarrow{r_{sq}}(t_b) - \overrightarrow{r_{sp}}(t_f)$$

And then,

$$\overrightarrow{r_{sq}}(t_b) = \overrightarrow{r_{sm}}(t_b) + [C]\overrightarrow{R_m}(t_b)$$

$$\overrightarrow{r_{sp}}(t_f) = \overrightarrow{r_{se}}(t_f) + [P][N][R][W][B]\overrightarrow{R_e}(t_f)$$

[C] is the rotation matrix of mars fixed coordinate system to inertial principal axis reference system, and [P] is the rotation matrix of precession of the equinoxes, and [N] is the rotation matrix of nutation, and [R] is the rotation matrix of earth rotation, and [W] is the rotation matrix of pole shifting, and [B] is the rotation matrix of epoch bias constant.

The signal transmission time is τ:

$$\tau = \frac{\rho_{em} + \Delta\rho}{c}$$

$$t_b = t_f + \tau$$

Δρ is the distance change caused by the interference factor, and c is the speed of light.

The distance of ground station and the mars probe can be got by the iteration below:

$$t_b^1 = t_f + \tau_0$$

$$t_b^n = t_f + \frac{\left|\overrightarrow{r_{sq}}(t_b^{\,n-1}) - \overrightarrow{r_{sp}}(t_f)\right| + \Delta\rho}{c}$$

Considered the precision of 0.1 mm, the condition for the end of the iteration is set to：

$$\left|t_b^{\,n} - t_b^{\,n-1}\right| < 10^{-13} s$$

Corrections of the Distance: It is the theory of the distance measurement of Mars above, but in practical application, the theoretical distance is affected by many kinds of external interference factors. And so, it needs to be modified in high precision model.

The factors is including:

1. Shapiro effect correction[1]
2. Atmospheric refraction correction[2][3]
3. Ionospheric delay correction
4. plasma delay correction
5. thermal noise of instrument and equipment
6. the earth's tidal action
7. Martian atmosphere and ionosphere correction

References:

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