DETERMINING IONOSPHERIC TOTAL ELECTRON CONTENT IN USING SPACE VLBI

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ABSTRACT. For the first time, a new concept of space VLBI's application is presented, in which space VLBI technique is used to sound ionospheric electron content along the ray path.

1. INTRODUCTION

In 1990's, there are two space VLBI satellites to be launched into the Earth orbit, One is a Russion space VLBI mission called RADIOASTRON, the other is a Japanese space VLBI mission called VSOP. Although the main objective of both missions is for astrophysical research, they also provide potential applications in other fields, such as astometry, geodesy and satellite dynamics. In this paper, we will propose a new application of space VLBI, in which ground-space VLBI baselines dual frequency delay observation is used to sound ionospheric Total Electron Content (TEC). TEC is an important parameter in determining ionospheric effects on communication, space geodesy, radio astronomy, satellite and spacecraft navigation and orbit determination.

2. BASIC CONCEPT

Radio signal, which propagate from radio source to ground based VLBI station, will pass through the ionosphere, and cause an additional path delay. For ground VLBI baselines, the ionospheric effect is obtained in the difference of two path delay, it can not be absolutely evaluated for the TEC of each path. But for ground-space VLBI baselines, satellite is above the ionosphere,so no effect from source to satellite will appear. Therefore it is possible to determine the TEC absolutely along th direction of between the source to the ground station.
The first order term of the path delay is

$$\triangle\tau_{ion} = q/f^2 \tag{1}$$

$$q = cr_0Ne/2\pi \tag{2}$$

where, c is the speed of light in vacuum, r_0 is classical electron radius, Ne denotes the TEC

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between the source to the ground station.
Defined τ_1 and τ_2 as observed delays at dual frequencies f_1 and f_2 for ground-space VLBI baselines, we have

$$\tau_1 = \tau + q/f_1^2 \tag{3}$$

$$\tau_2 = \tau + q/f_2^2 \tag{4}$$

here τ is the time delay without ionospheric effect.
From equations (2) to (4), the TEC can be estimated by ($f_2 > f_1$)

$$Ne = 2\pi \triangle \tau / cr_0 (1/f_1^2 - 1/f_2^2) \tag{5}$$

$$\triangle\tau = \tau_1 - \tau_2 \tag{6}$$

3. ESTIMATION OF ACCURACY

From equation (5), TEC's sounding accuracy can be estimated by

$$\sigma_{Ne} = 2\pi f_1^2 \beta \sigma_{\triangle\tau} / cr_0 \approx 0.75 \times 10^7 f_1^2 \beta \sigma_{\triangle\tau} \tag{7}$$

$$\beta = (1 - f_1^2/f_2^2)^{-1} \tag{8}$$

$$\sigma_{\triangle\tau} = (\sigma_{\tau 1}^2 - \sigma_{\tau 2}^2)^{1/2} \tag{9}$$

The selection of observing frequencies will affect the accuracy of TEC directly, the covariance σ_{Ne} is in magnitude directly proportional to f_1^2 , in order to get the best sounding accuracy, the lowest frequency band of the VLBI satellite should be selected as f_1 , that is

RADIOASTRON	P-band	0.327 GHz
VSOP	L-band	1.700 GHz

β is called the error magnifing factor, when f_1 has been selected, it is in magnitude inverse proportional to f_2^2 , for RADIOASTRON and VSOP have $\beta \approx 1$. The additional delays, which are caused by the orbit error of VLBI satellite, atomsphere, instruments and so on, all have been eleminated from $\tau_1 - \tau_2$, so $\triangle\tau$ only includes the ionospheric path delay and random observational error $\sigma_{\triangle\tau}$.

Assumeτ_1 and τ_2 have same random error and are equal to 50ps, then the sounding accuracys of TEC, which are determined by RADIOASTRON and VSOP, can be estimated and listed in Table 1. Presently, the normal way of sounding TEC is the ionospheric sounding satellite, its accuracy is also listed in Table 1. It can be seen, in using space VLBI, the TEC's accuracy is more higher then the normal way's.

Table 1. TEC's sounding accuracy unit: *electrons*/m^2

sounding way	ionospheric satellite	RADIOASTRON	VSOP
$\sigma_{N\epsilon}$	$> 1.0 \times 10^{16}$	5.3×10^{13}	1.6×10^{15}

4. TIME AND SPACE RESOLUTIONS

There are two kinds of ionospheric sounding satellites: one is the synchronous satellite; another is the non-synchronous satellite. The first one can only sound TEC's time rate in a special space direction, the second one can only sound TEC's distribution along the satellites visibility arc. But in using space VLBI, through selecting the distribution of observed sources and adjusting observational programs, both TEC's rate and its distribution in the whole space can be sounded accuratly.

5. CONCLUSIONS

Space VLBI technique may become a new way of sounding TEC, with higher accuracy and better time-space resolutions. It provides a chance to model ionospheric effect successfully on space geodesy, radio astronomy and so on.

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