The New Technique for Calculating the Ionospheric Phase Advance and the Mapping Function for TEC Built on the Basis of NeQuick Model of the Ionosphere

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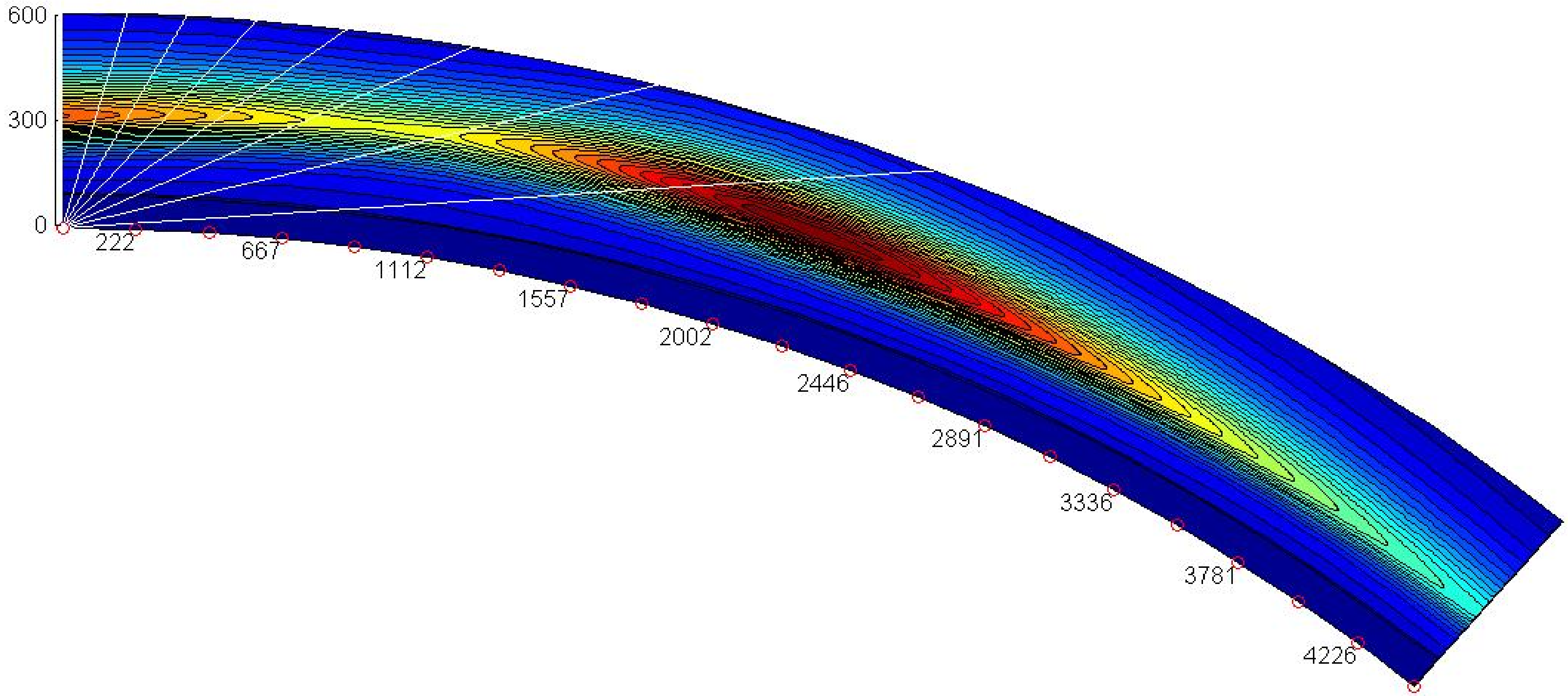
BSS2016, Trieste, Italy



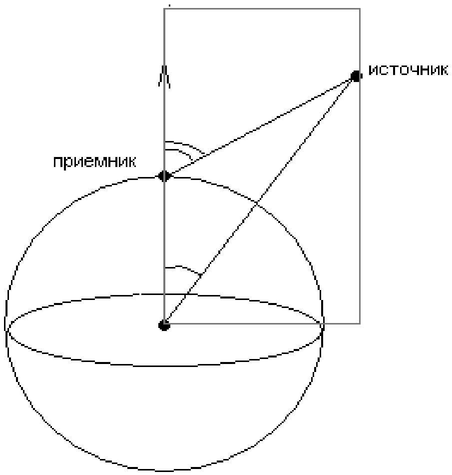
The NeQuick model generated distribution of the electron density in the meridian plain of propagation (40^o E) to the south from a satellite for July, UT=12, R_{12}=100. The ray paths of propagation correspond to the different latitudes of the satellite with 10^0 steps starting from 12^0 to 72^0

$$\nabla\varepsilon\left(r,\vartheta,\varphi\right)=\frac{1}{h_r}\frac{\partial\varepsilon}{\partial r}\mathbf{e}_r+\frac{1}{h_\vartheta}\frac{\partial\varepsilon}{\partial\vartheta}\mathbf{e}_\vartheta+\frac{1}{h_\varphi}\frac{\partial\varepsilon}{\partial\varphi}\mathbf{e}_\varphi$$

- in ray path equations

$$\alpha_\vartheta=\frac{\dfrac{\Delta\varepsilon}{h_\vartheta\left(r\right)\Delta\vartheta}}{\dfrac{\Delta\varepsilon}{\Delta r}}=\frac{L_r}{L_\vartheta}<1,\quad \alpha_\varphi=\frac{\dfrac{\Delta\varepsilon}{h_\varphi\left(r,\vartheta\right)\Delta\varphi}}{\dfrac{\Delta\varepsilon}{\Delta r}}=\frac{L_r}{L_\varphi}<1.$$

$$\psi_{o,e}=\int_{R_e}^{R_s}\sqrt{\varepsilon_{o,e}\left(r,\theta_0\left(r\right)+\theta_1\left(r\right),\phi_1\left(r\right)\right)}\sqrt{1+h_\theta{}^2\left(\frac{d\theta_0}{dr}+\frac{d\theta_1}{dr}\right)^2+h_\phi{}^2\left(\frac{d\phi_1}{dr}\right)^2}\,dr.$$



$$\psi(\mathbf{r}) = \psi_0(\mathbf{r}) + \psi_1(\mathbf{r}) + \psi_2(\mathbf{r})$$

$$\psi_{0r}\left(\mathbf{r}(L)\right) = \int_{R_e}^{R_s} \sqrt{\varepsilon(r,\vartheta_r,0)} \sqrt{1 + {h_\vartheta}^2 \left(\frac{d\vartheta_0}{dr}\right)^2}\, dr$$

$$\psi_{1r}\left(\mathbf{r}(L)\right) = \int_{R_e}^{R_s} \sqrt{\varepsilon(r,\vartheta_r,0)} \sqrt{1 + {h_\vartheta}^2 \left(\frac{d\vartheta_0}{dr}\right)^2} \left(\frac{{h_\vartheta}^2 \frac{d\vartheta_0}{dr} \frac{d\vartheta_1}{dr}}{1 + {h_\vartheta}^2 \left(\frac{d\vartheta_0}{dr}\right)^2} + \frac{\left(\vartheta_0(r) - \vartheta_r\right)}{2\varepsilon} \frac{\partial \varepsilon(r,\vartheta,0)}{\partial \vartheta}\bigg|_{(r,\vartheta_{pp},0)} \right) dr$$

$\psi_2\left(\mathbf{r}(L)\right) < 10^{-5}\, m$ - in the worst case

Calculations of TEC

$$TEC = \frac{\left(\psi^{(1)} - \psi^{(2)}\right) f_1^{\,2} f_2^{\,2}}{40,311\left(f_1^{\,2} - f_2^{\,2}\right)}$$

$$\Delta TEC = \frac{f_1^{\,2} f_2^{\,2}}{40,311\left(f_1^{\,2} - f_2^{\,2}\right)}\left\{\left[\Delta_{sp}\left(f_1\right) - \Delta_{sp}\left(f_2\right)\right] + \left[\psi_1\left(f_1\right) - \psi_1\left(f_2\right)\right]\right\}$$

$$\Delta_{sp} = \int_{R_e}^{R_s}\left(\sqrt{\varepsilon\left(r,\vartheta_{pp},0\right)}\sqrt{1+h_\vartheta^2\left(\frac{d\vartheta_0}{dr}\right)^2} - \left(1-\frac{e^2 N\left(r,\vartheta_{00}\left(r\right),0\right)}{2m\varepsilon_0\omega^2}\right)\sqrt{1+h_\vartheta^2\left(\frac{d\vartheta_{00}}{dr}\right)^2}\right)dr$$

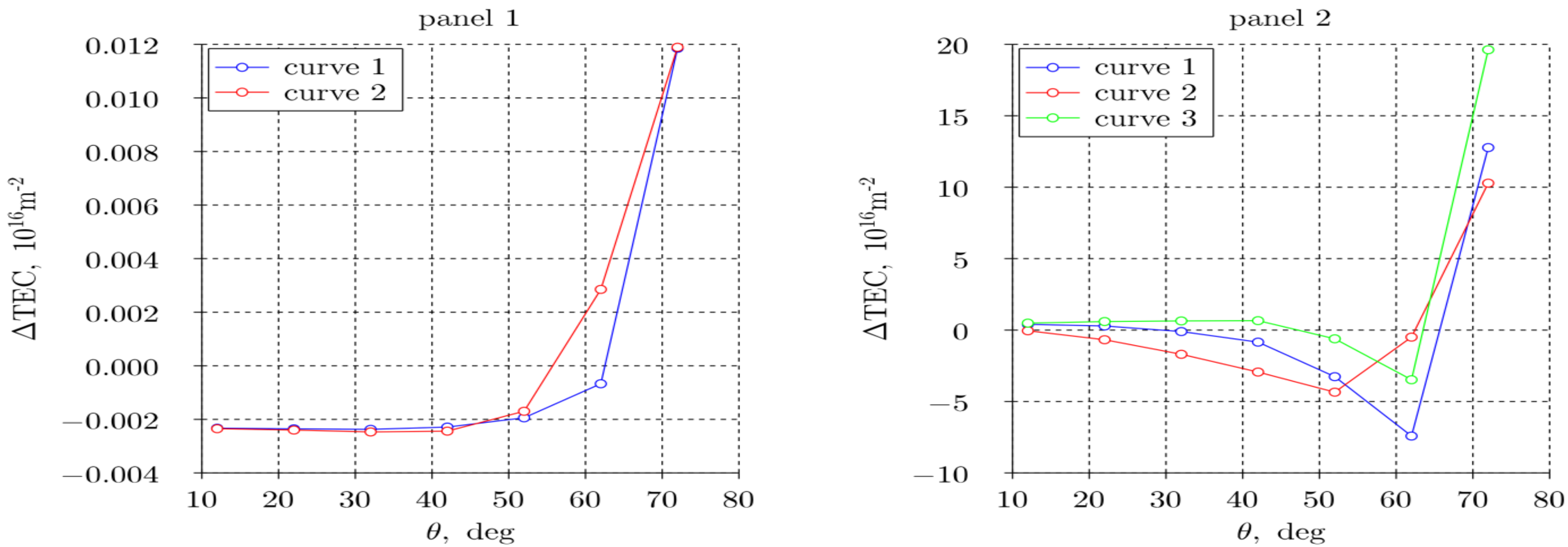


Figure 2. Results of calculation of TEC utilizing the new technique, and their comparison with the TECs directly generated by NeQuick model.

the blue curve 1 corresponds to the artificial spherically-layered ionosphere and the red one (curve 2) also takes account of the horizontal gradients to the artificial spherically –layered profile

The mapping function assessment in the form of the difference between the true values of the slant TEC and:

- spherically symmetric ionosphere at pierce point (blue curve 1);
- the same plus horizontal gradients at pierce point (red curve 2);
- standard cosine (green curve 3).

Conclusions

The technique for calculating the ionospheric phase advance on the transionospheric paths of propagation alternative to the traditionally used was presented. It was additionally validated by the numerical experiment, which directly reproduces the procedure of the TEC measurements in the duel-frequency mode of operation. The results of calculations very well fit those directly generated by the NeQuick model