The imaging of the ionosphere based on the spaceborne SAR

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In this report the feasibility of the reconstruction of the ionosphere based on the spaceborne SAR image with intense point target is proposed theoretically. The SAR provides high-resolution images by coherently processing the signals returned from the ground. Perturbations of the ionosphere propagation cause phase change of the SAR signal. In the distorted SAR signal the information of the ionosphere can be carried and it provides the possibilities of imaging of the ionosphere.

The signal with an intense point target of known reflection coefficient among the SAR image can be obtained by the PGA (Phase Gradient Arithmetic) where the information of signal reflection coefficient during the ionosphere propagation is included. The reflection coefficient of vertical propagating wave satisfies equation

$$\frac{dr}{dz} = j2kr_{-}\frac{d\Gamma}{dz}$$

Considering the ionosphere of dielectric $q(k,z) = 1 - \frac{\omega_p^2(z)}{k^2c^2}$, this equation becomes a Riccati equation

$$\frac{dr}{dz} = j2kr\left[1 - \frac{\omega_p^2\left(z\right)}{2c^2}\cdot\frac{1}{k^2}\right] - \frac{1-r^2}{4k^2c^2}\left[1 + \frac{\omega_p^2\left(z\right)}{k^2c^2}\right]\cdot\frac{d\left[\omega_p^2\left(z\right)\right]}{dz}$$

Introduced variation x by $z = \int\limits_0^x \frac{\omega_p^2(t)}{c^2}dt = \int\limits_0^x N\left(t\right)dt$ for numerical stability, above equation change as

$$\frac{dr\left(x\right)}{dx} = j2kr\left(x\right)N\left(x\right)\left[1 - \frac{N\left(x\right)}{2k^2}\right] - \frac{1-r^2\left(x\right)}{4k^2}\left[1 + \frac{N\left(x\right)}{k^2}\right]\cdot\frac{dN\left(x\right)}{dx}$$

The inversion of the ionosphere can be realized through this equation by using the Newton-Kantorovich method.