Study of Navigation Error and Pattern Group Delay in GPS Satellite Antennas

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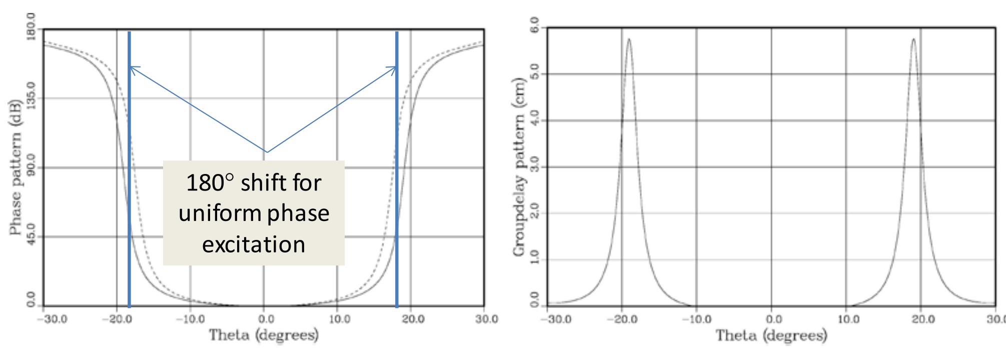
In the global positioning system GPS the 3D location of a ground user is determined based on pseudorange (all users) and carrier phase (high accuracy users) measurements from 4 or more satellites. The satellite position and clock offset are transmitted with the L-band signal from each satellite, enabling the ground receiver to determine its own position. The pseudorange measurement is based on the difference in signal time T between the satellites and ground receiver. Any group delay variation $\tau = d\varphi/d\omega$ along the signal path will affect this time and cause navigation error unless it is compensated for.

It can be shown that an antenna with uniform phase over the aperture radiates a pattern with constant and zero group delay $\tau(\theta,\phi)$ relative to boresight. Any deviation from constant phase excitation results in varying group delay vs. (θ,ϕ), in particular around the pattern nulls. This is illustrated with an example in Fig. 1.



a. **b.**

Figure 1: Predicted radiation patterns of a 3λ aperture with uniform amplitude distribution. **a.** Phase patterns for two different frequencies separated by 8% **b.** Group delay pattern predicted from the phase patterns (solid curve) in **a**.

For some antennas it may be possible to find a best fit "group delay center" that results in an approximate flat group delay pattern if the antenna is rotated around this point. The group delay center could be explained physically as the point from where the energy emanates, and can be expressed in a constant ϕ cut as

$$z_{ph} = \frac{\varphi_{\max}(\theta)}{360\,(1-\cos\theta)}\lambda_0$$

$$z_\tau = \frac{dz_{ph}}{df} f_0 \approx \frac{d\varphi_{\max}(\theta)}{df}\frac{c}{360\,(1-\cos\theta)} = \frac{\tau(\theta)}{1-\cos\theta}, \quad c = f_0\lambda_0$$

where z_{ph} and z_τ are phase zenter and group delay center, respectively, φ_{max} and $d\varphi_{max}$ are maximum phase and maximum differential phase, respectively, over angle θ, and f_0 and λ_0 are the operational frequency and wavelength, respectively.

Navigation error increases with increasing group delay variation. The paper will also show computed group delay patterns from shaped phased array beams, demonstrating that spatial group delay can vary significantly for large antennas with shaped beams.