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Reconciling Radar and Satellite Beacon Scintillation using the Inverse Diffraction Technique

Charles Carrano*[1], Keith Groves[1], Charles Rino[1], Paul Straus[2]

[1] Institute for Scientific Research, Boston College, Chestnut Hill, MA, USA (charles.carrano@bc.edu)
[2] Aerospace Corporation, El Segundo, California, USA

EXTENDED ABSTRACT

The inverse diffraction technique is a deterministic phase screen modeling approach for scaling observations of ionospheric scintillation from one carrier frequency to another (Carrano et al., 2012; Carrano et al., 2014). In this paper, we use the inverse diffraction technique to reconcile radar and beacon satellite observations of ionospheric scintillation along identical propagation paths. The data consist of ALTAIR radar tracks of the C/NOFS satellite acquired while a tri-band beacon (TBB) receiver monitored transmissions from the CERTO beacon onboard this same satellite. Both the ALTAIR and TBB instruments are co-located at Kwajalein Atoll on the island of Roi-Namur. The ALTAIR data reflects the effect of two-way propagation through the ionosphere, while the TBB data reflects the effects of one-way propagation. The purpose of this study is to see how well one can reconcile scintillation effects along identical one-way and two-way propagation paths in the presence of radar cross section (RCS) fluctuations and signal fading effects of non-ionospheric origin (antenna pattern and terrestrial multipath effects).

In addition to the ionospheric contribution, the shape of the satellite body induces random fluctuations in the ALTAIR RCS. Similarly, the antenna pattern and multipath reflections from the satellite body and the ground induce random fluctuations in the TBB signals. A spectral analysis of these data suggest that the period of these non-ionospheric fluctuations is longer than the Fresnel period associated with scintillation, and that a high-pass detrending filter is able to effectively isolate the ionospheric contribution from the body shape and antenna/multipath contributions. We used the detrended intensity and phase measurements from the ALTAIR UHF signal (422 MHz) to establish the electric field at the radar. We back-propagated this electric field in a sequence of steps to determine the Fresnel frequency which minimized the intensity variations. Once we found the field with minimal intensity variations, we extracted the phase and divided by 2 (which accounts for 2-way propagation). We used this phase as an equivalent phase-changing screen to simulate propagation conditions at the frequency of the ALTAIR VHF signal (158 MHz) and the CERTO beacon frequencies (150, 400, 1066 MHz). We computed S_4 and σ_φ for each simulated signal and compared these with the corresponding measurements. Figures 1 & 2 compare the predicted and measured scintillation statistics for the ALTAIR VHF signal at 158 MHz and the TBB signals at 150 MHz and 400 MHz.

The predictions of one-way S_4 for ALTAIR are accurate to within 0.1 S_4 unit. The predictions of one-way σ_φ for ALTAIR are also accurate to within 0.1 rad, except when the scattering is very strong (one-way $S_4 >> 1$). We have examined the ALTAIR VHF phase and have noted evidence of difficulty unwrapping the phase during these strong scatter periods. Hence, some of the discrepancy may be due to data processing limitations, rather than inaccuracy of the propagation calculations. Nearly all of the predictions of S_4 and σ_φ for the TBB are accurate to within 0.1 S4 unit and 0.1 rad, respectively.

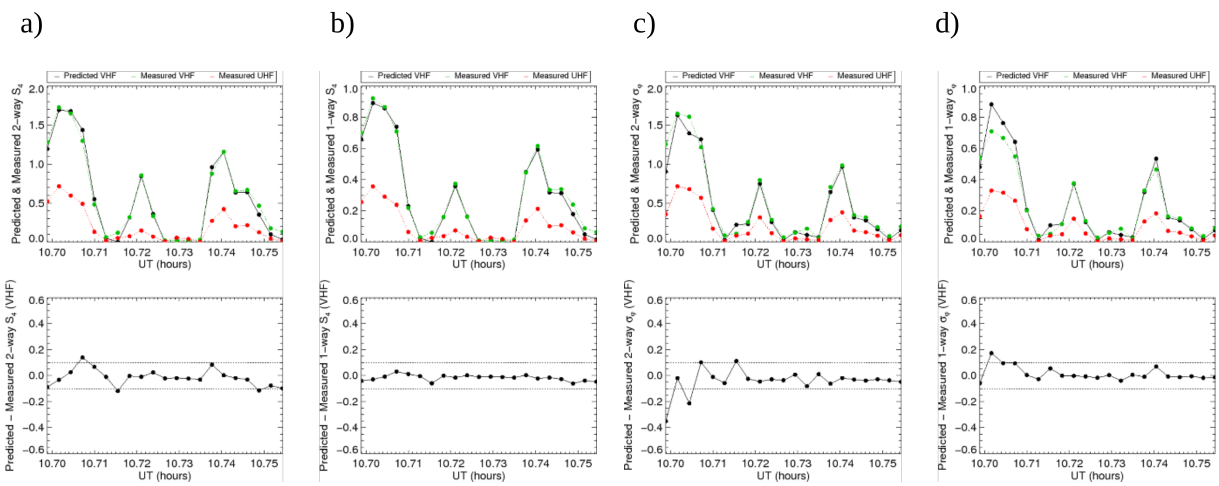

Figure 1. Predicted and measured scintillation statistics for ALTAIR: a) two-way S_4, b) one-way S_4, c) two-way σ_φ and d) one-way σ_φ. The top plots show results for the predicted VHF signal (black), the measured VHF signal (green), and the UHF signal (red) for reference. The bottom plots show the difference between predicted and measured values of the VHF S_4 and σ_φ.

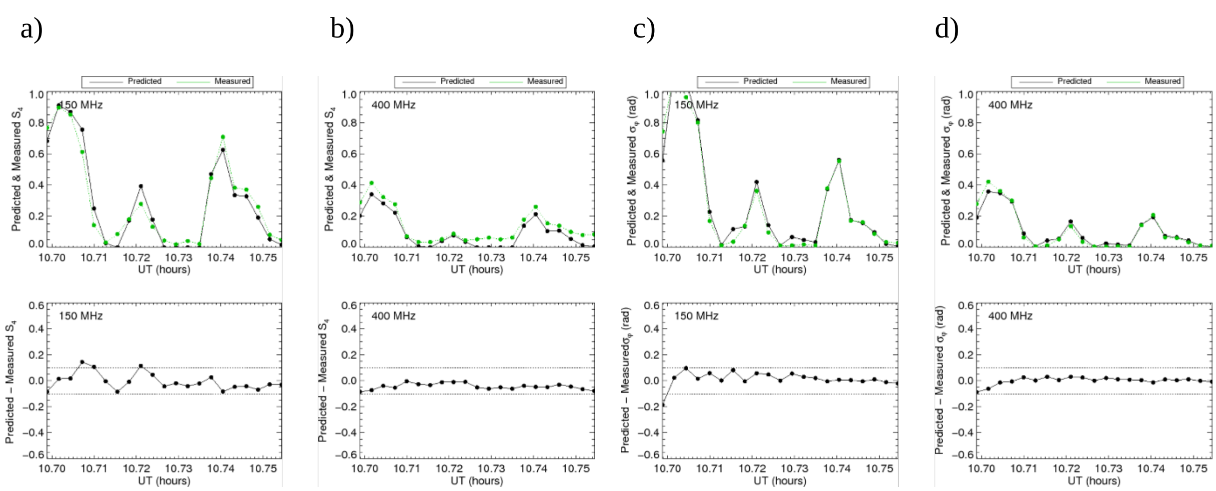

Figure 2. Predicted and measured scintillation statistics for the TBB: a) one-way S_4 at 150 MHz, b) one-way S_4 at 400 MHz, c) one-way σ_φ at 150 MHz, d) one-way σ_φ at 400 MHz. The top plots show results for the predicted (black) and measured (green) signals. The bottom plots show the difference between the predicted and measured values of S_4 and σ_φ.

Key words: Scintillation, ionospheric irregularities, diffraction, phase screen

References

Carrano, C., K. Groves, S. Delay, and P. Doherty (2014), An inverse diffraction technique for scaling measurements of ionospheric scintillations on the GPS L1, L2, and L5 carriers to other frequencies, Proc. 2014 Institute of Navigation ITM meeting, San Diego, CA, January 27-29, 2014.

Carrano, C., K. Groves, and R. Caton (2012), The effect of phase scintillations on the accuracy of phase screen simulation using deterministic screens derived from GPS and ALTAIR measurements, Radio Sci., 47, RS0L25, doi:10.1029/2011RS004958.