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Turning Nuisances in Satellite Navigation into Signals-of-Opportunity for Remote Sensing of Ionosphere, Troposphere, and Earth Surface

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GPS/GNSS has impacted nearly every aspect of our modern society. Yet, it relies on extremely low power signals traversing a vast space to reach receivers on the Earth surface. Numerous nuisance factors interfere with the signals along their propagation paths, including ionospheric plasma, moisture in the lower troposphere, and multipath reflections from the Earth surface. Understanding these effects on navigation signals is the prerequisite for developing robust navigation technologies. Moreover, these effects enable satellite navigation signals to function as signals-of-opportunity for low cost, distributed, passive sensing of the signal propagation environment. Developing technologies that enable studies of the effects of the space and local environments on satellite navigation signals and to mitigate these effects to ensure availability, accuracy, and reliability of position, navigation, and timing solutions are my areas of interest.

In this presentation, I will share the unusual journey that led me to this interdisciplinary research destination. With an educational background in physics and radio engineering, pursuing graduate research in incoherent scatter radar (ISR) probing of the ionosphere seemed to be a natural path to take when I arrived in the US in the mid-1980's. The powerful beams of the Arecibo ISR shed light on the structure and formation mechanisms of the ionospheric irregularities in the mid-latitudes. To gain a global view of the ionospheric dynamics, I joined the research team that built the High-Resolution Doppler Imager (HRDI) onboard the Upper Atmosphere Research Satellite (UARS) at the University of Michigan as a postdoc. Following the exciting publication of the first global mesospheric wind field pattern observed by HRDI, my career as an ionospheric scientist came to an abrupt stop as I began an 8-year journey as a full-time mother to raise two children. Ten years after I left the ionospheric research community, I found an opportunity to reinvent myself as a GNSS receiver engineer to develop technologies for navigation in challenging urban environments and on highly dynamic platforms where the signals are weak and multipath reflections are abundant. It turns out that these challenges are like those experienced by GNSS signals traversing ionospheric irregularities. The GNSS navigation receiver technologies that I developed can be applied to mitigate ionospheric effects and became a powerful, distributed, passive sensing technique for ionosphere monitoring.

But the ionosphere is not the only nuisance factor that impacts high accuracy and robust GNSS solutions. Moisture in the lower troposphere, multipath reflections and scattering from foliage and structures, intentional and unintentional radio frequency interferences, satellite orbit and clock errors, and low-cost GNSS receiver hardware limitations are all elements that challenge the integrity of navigation solutions. Yet, the very existence of these challenging factors enables sensing of the sources that create them. Today, thousands of GNSS receivers are distributed worldwide to monitor the ionosphere and meteorological weather parameters and to detect and potentially enable early warning of earthquake and other large scale natural hazard events. Airborne and spaceborne GNSS radio occultation (RO) systems are becoming a major contributor to weather data, and GNSS reflectometry (GNSS-R) systems have demonstrated capability to map ocean wind speed, sea ice age and anomalies, land surface water content, and even river slopes. These high impact applications were not part of the original plan for GPS.

I want to conclude my presentation to encourage early career researchers to be not afraid of taking bold steps to embrace and explore new subjects, new ideas, and to dream up new applications.