Sounding the Ionosphere with Signals of Opportunity in the High-Frequency (HF) Band

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The explosion of commercial off-the-shelf (COTS) education- and consumer-grade hardware supporting software-defined radio (SDR) over the past two decades has revolutionized many aspects of radio science, bringing the cost and calibration of traditionally complex receiver hardware within the grasp of even advanced amateur experimenters. Transmission has now become the limiter of access in many cases, particularly through spectrum management and licensing considerations. Fortunately, several classes of signals endemic to the HF band lend themselves to processing for ionospheric characteristics: time and frequency standard broadcasters, surface-wave oceanographic radars, amateur radio transmissions, and ionospheric sounders.

This presentation is a tour of these signals of opportunity and techniques for collecting and processing them into ionospheric characteristics, with emphasis on distributed receivers collecting on a small number (four or fewer) of coherent channels. Receiving techniques will be discussed for near-vertical ("quasi-vertical") incidence skywave (NVIS or QVI), long-distance oblique soundings, and transionospheric sounding. Soundings will be demonstrated from space-based, ground-based, and maritime platforms.

Binary, Doppler, delay, cone angle of arrival, and polarization observations will be exploited, depending on the signal type and capability of the collector. Each of these techniques conveys different, but not always "orthogonal," information about the ionospheric skywave channel. The information content of each datum will be discussed with respect to the implications for inverting the local or regional ionosphere from the observations. More importantly than inverting the full ionosphere, some of these techniques are sensitive indicators of ionospheric irregularities, structures, and instabilities, that might otherwise be difficult to study due to limited geographic coverage with larger, more exquisite instrumentation.