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Using Lightning as a HF Signal-of-Opportunity to Produce Ionograms

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1 Extended Abstract

Real-time, localized specification of the bottom-side ionosphere is needed to understand the propagation of radio waves used in radio communication and radar systems. Ionograms, which describe the ionospheric electron density as a function of height, are traditionally produced by ionosondes or digital ionosondes (digisondes). Digisondes work by transmitting pulses, while stepping through the mid frequency (MF) and high frequency (HF) bands (usually 1-25 MHz). These signals are reflected from the ionosphere and the digisonde receiver listens for the delayed echoes. The group time delay between the emitted and return signal, as a function of frequency, is used to produce a profile of the electron density as function of height (i.e. an ionogram).

We present a novel technique for replicating this process by observing the ionospheric reflection of HF (3-30MHz) and very high frequency (VHF; 30-300 MHz) emission from lightning. The stepped leader breakdown process preceeding a single lightning strike (both cloud-to-cloud and cloud-to-ground) produces hundreds of short ($\sim$10 μs), broad-band radio bursts through the HF and VHF bands [1]. While most of the emission propagates freely away from earth, the portion of the spectrum below the peak plasma frequency of the ionosphere will be reflected back to earth, similar to the radiated signals from a digisonde. The impulsive nature of the bursts makes them ideal signals-of-opportunity as their short duration translates into fine range resolution. Using the Long Wavelength Array - Sevilleta (LWA-SV) radio telescope, we have demonstrated that we can use the impulsive emissions from lightning to produce digisonde quality ionograms.

For nearby lightning, LWA-SV can observe both the direct line of sight and the delayed ionospheric reflection. Figure 1 shows a comparison of the direct line of sight at 74 MHz and the delayed ionospheric reflection seen below 10 MHz for a handful of pulses from a lightning event. The times of arrival of these two paths provide enough information to produce ionograms with high SNR, and we can better our accuracy by leveraging the localization capabilities of existing VHF lightning detectors such as the Lightning Mapping Array [2]. This technique allows us to specify the ionosphere in many more directions and on much shorter time scales than a digisonde, thus opening a new avenue for exploration of the ionosphere without the need of a transmitter.

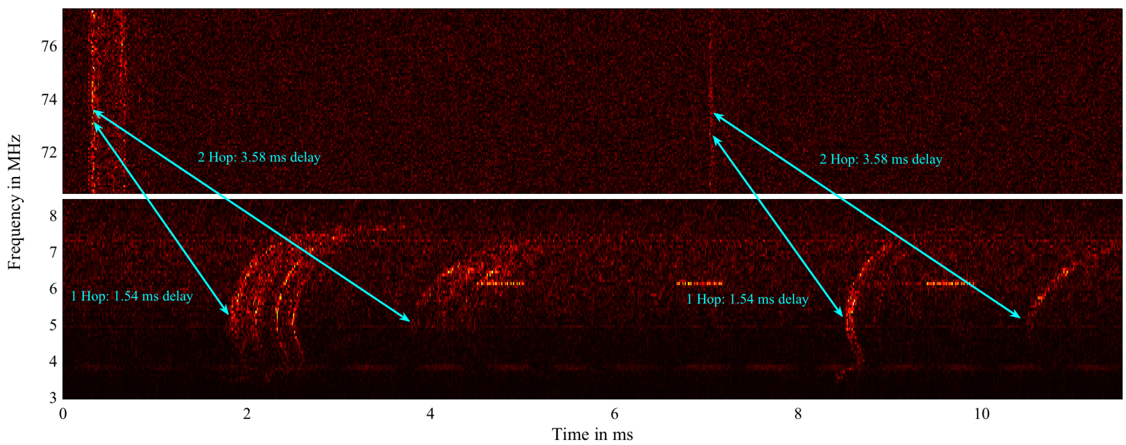

Figure 1. A handful of broad-band pulses measured using LWA-SV. Top panel shows the direct line of sight signal coming straight from the lightning to LWA-SV measured from 70 - 78 MHz. The bottom panel shows the delayed and dispersed ionospheric reflections of the same pulses measured from 3 - 8 MHz

References

[1] D. E. Proctor, “VHF Radio Pictures of Lightning Flashes to Ground”, *JGR*, **86**, 1981, pp. 4041-4071

[2] C. T. Rhodes, X.-M. Shao, P.R. Krehbiel, R.J. Thomas, and C.O. Hayenga, “Observations of Lightning Phenomena Using Radio Interferometry”, *JGR*, **99**, 1994, pp.13059-13082