Potential science opportunities for HamSCI in Antarctica

G. W. Perry[1] (KD2SAK) and N. A. Frissell[2] (W2NAF)

1 - Center for Solar-Terrestrial Research, New Jersey Institute of Technology
2 - Department of Physics and Engineering, University of Scranton

Corresponding author: G. W. Perry — gperry@njit.edu

HamSCI 2022

INTRODUCTION

- Antarctica has been home to a multitude of science experiments which have used RF to study the unique natural environment.
- Remote sensing techniques using the HF portion of the band have a rich history in the region and are still used today.
- A strong focus has been placed on studying transcontinental HF propagation characteristics and conditions.
  - These studies are important for optimizing HF-based remote sensing techniques as well as communications.
  - Less attention has been paid to intercontinental HF propagation conditions.

MOTIVATION

- What are the potential science cases for HamSCI activities in Antarctica?
  - In particular, what are the potential science cases for studying space weather effects in the region using HF signals of opportunity?

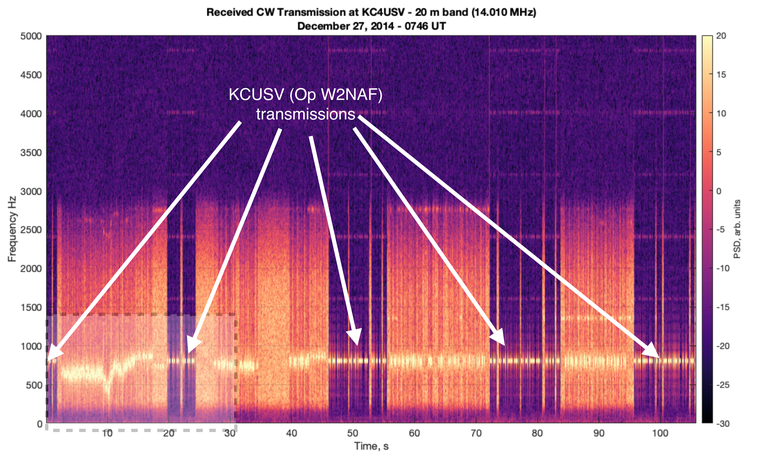


Figure 1: 20 m (14.010 MHz) communications captured at McMurdo Station (KC4USV) on December 27, 2014. Outgoing transmissions are coherent and at a constant frequency while incoming transmissions are dispersed and show strong variability, especially in the first 30 seconds (highlighted).

KC4USV OBSERVATIONS

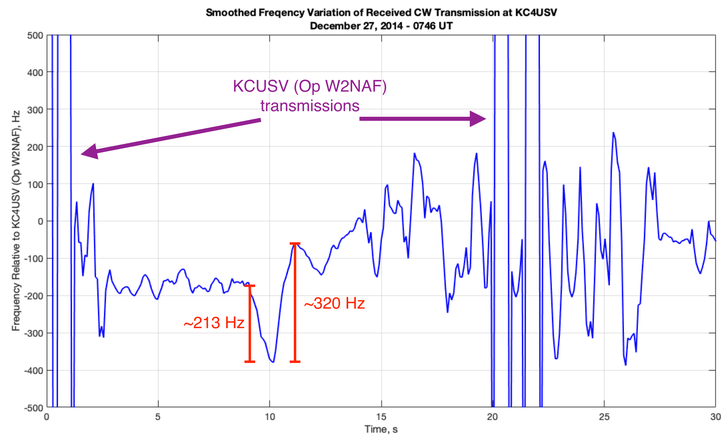


Figure 2: The peak received frequency captured at McMurdo Station on December 27, 2014 (the first 30 seconds of Figure 1), smoothed using Savitzky-Golay filter with a 0.92 s long window.

$$\Delta f = \frac{-1}{\lambda}\left[\int_{A(t)}^{B(t)} \frac{\partial n}{\partial t} ds + \frac{\partial B(t)}{\partial t} n(B) - \frac{\partial A(t)}{\partial t} n(A)\right] \quad (1)$$

- Equation (1) from Ponomarenko et al. (2009) describes the Doppler frequency shift between transmitter *A* and receiver *B*.
  - First term in square brackets describes temporal variation of index of refraction *n* (a function of plasma density along ray path).
  - The other two terms describe the motion of the transmitter/receivers.
- Strong temporal variations in the index of refraction (first term) is responsible for strong frequency variations.
  - Otherwise either receiver/transmitter would need to be moving 1000s m/s.
  - Receiver (B) definitely stationary; likely the case for transmitter (A) as well.
  - Culprit could be auroral precipitation along the ray path.
  - This mechanism has been proposed to explain similar signatures observed in HF radar data, e.g., Scoular et al. (2013).
  - This method only had temporal resolution of the order of minutes.

HF NUMERICAL RAY TRACING

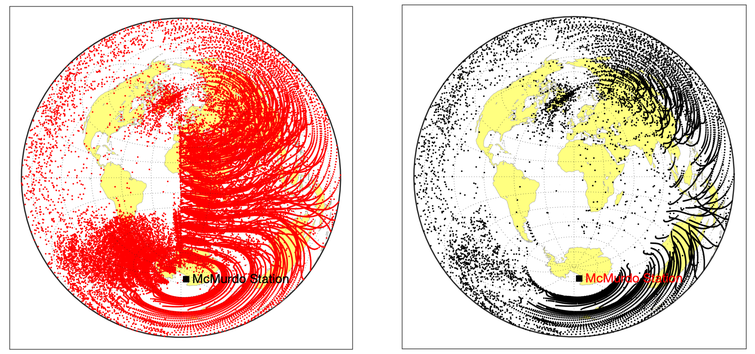
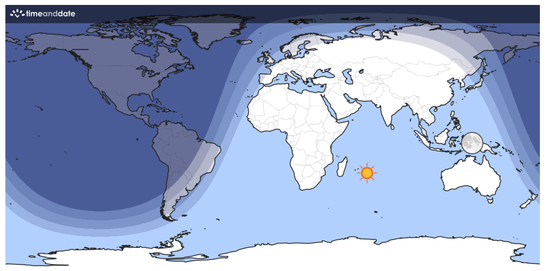


Figure 3: PHARLAP numerical ray trace simulation with foot-points of all rays included (red, left) and only rays with foot-points outside of 60°S (black, right). All rays originate at McMurdo Station.

Day/Night Terminator
07:46 UT - December 27, 2014



- Figure 2 shows foot-points of HF rays simulated in PHARLAP, a numerical ray tracer (Cervera & Harris, 2014).
  - 3-89° elevation in 0.87° increments; 0-360° in 0.72° increments at 14.010 MHz with IRI ionosphere.
- The absorptive properties of the Antarctic Ice/Snow to HF radio wave, we can constrain the likely origins of intercontinental HF radio waves shown in Figures 1 and 2.

CONCLUSIONS

- Antarctica offers a rich variety of science opportunities for HamSCI.
- The deployment of a passive HF receiver at McMurdo should be considered to study the space weather effects on intercontinental HF radio wave communications and propagation.
- The absorptive effects of the Antarctic ice allows one to constrain the geolocation of incident HF signals.

New Jersey Institute of Technology

REFERENCES

Cervera, M. A., & Harris, T. J. (2014). Modeling ionospheric disturbance features in quasi-vertically incident ionograms using 3-D magnetoionic ray tracing and atmospheric gravity waves. Journal of Geophysical Research: Space Physics, 119(1), 431–440. https://doi.org/10.1002/2013JA019247

Ponomarenko, P. V., St-Maurice, J.-P., Waters, C. L., Gillies, R. G., & Koustov, A. V. (2009). Refractive index effects on the scatter volume location and Doppler velocity estimates of ionospheric HF backscatter echoes. *Annales Geophysicae*, *27*(11), 4207–4219. https://doi.org/10.5194/angeo-27-4207-2009

Scoular, G., Ponomarenko, P. V., & St.-Maurice, J. P. (2013). A new type of Doppler velocity fluctuations in HF ground scatter from the polar cap. *Geophysical Research Letters*, *40*(19), 4992–4997. https://doi.org/10.1002/grl.50960