A Multitaper Model for Quiet Voltage in Relative Ionospheric Opacity Meters

GlobalSIP 2019: Hardware and Real-Time Implementations

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13/11/2019

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   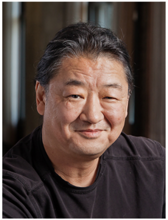

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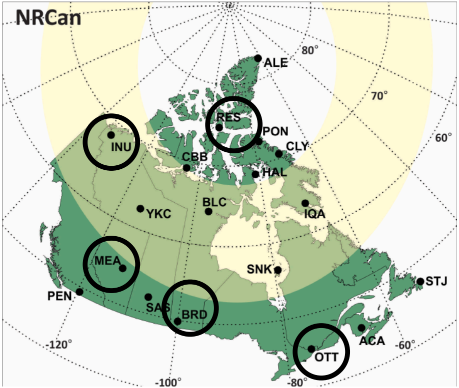
Outline

High-latitude HF Communication

- High-latitude HF communication
  - Industry, operators of critical infrastructure.
  - Ionospheric transport.
-
- Absorption events
  - Solar ionization $\rightarrow$ attenuation.
-
- Relative ionospheric opacity meters (riometers)
  - Real-time absorption monitoring.

The Canadian Riometer Array (CRA) [1]

- Canadian Space Weather Forecast Centre (CSWFC).
- Geospace Observatory Riometer Network (University of Calgary).

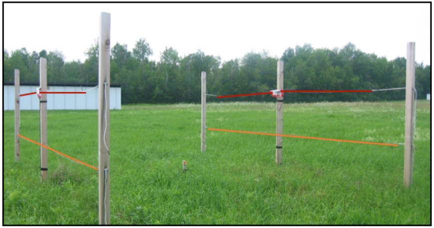


[1] "HF Radio Propagation"

The Ottawa Riometer

- Radio-wave opacity of the D-region.
- Accepts 30.0 ± 0.1 MHz frequencies, and reads at 60 sps.

Antenna

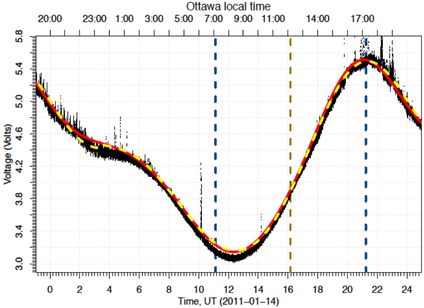


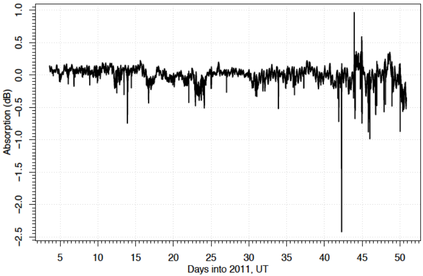
Riometer

Danskin, Canadian Solar Workshop presentation, 2014

Outline

Quiet Voltages





- Measured absorption $\propto \log_{10}\{$**voltage**$\}$ - $\log_{10}\{$**quiet voltage**$\}$.

Updating Algorithms

- **The Problem:**
  How to reconstruct the quiet voltage in real time?
-
- **Solutions:**

Algorithm	**Derivatives**[2]	**Quantile**[3]	**Fourier**[4]
Duration	1h	1min	1min
Portability	3/3	1/3	2/3

[2] University of Calgary, Spanswick, 2005
[3] Canadian Space Weather Forecast Centre
[4] Drevin & Stoker, 2003

Outline

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Portability

- **Question**:
  Does riometer voltage contain a stable periodic element?
-
- **Task**:
  Find harmonic components stable over space and time.

Portability - Stable, periodic element

- ***k*'th DFT: Complex-Gaussian model (Thomson, 1982)**

$$Y_k(f_m) = y_k^{(QDC)}(f_m) + Y_k^{(RES)}(f_m),$$

- **Harmonic components:**

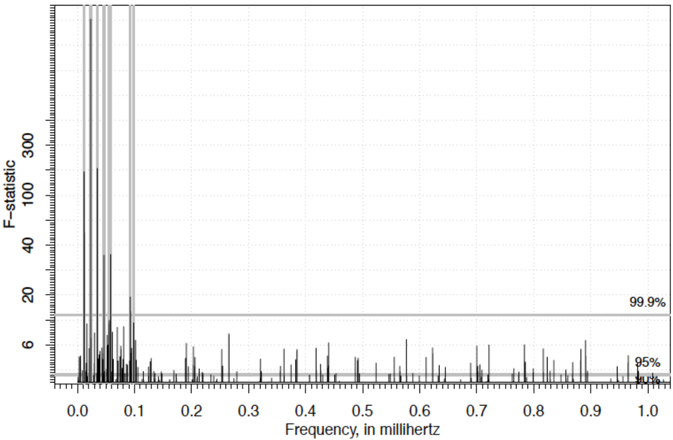
$$y_k^{(QDC)}(f_m) = \begin{cases} x^{(l)} V_k(0), & f_m = f^{(l)} \\ 0, & f_m \neq f^{(l)} \end{cases}$$

- **Reconstruction**

$$\hat{x}_n^{(QDC)} = \sum_{l=1}^{L} \hat{x}^{(l)} \exp\left(i2\pi \hat{f}^{(l)} n \right).$$

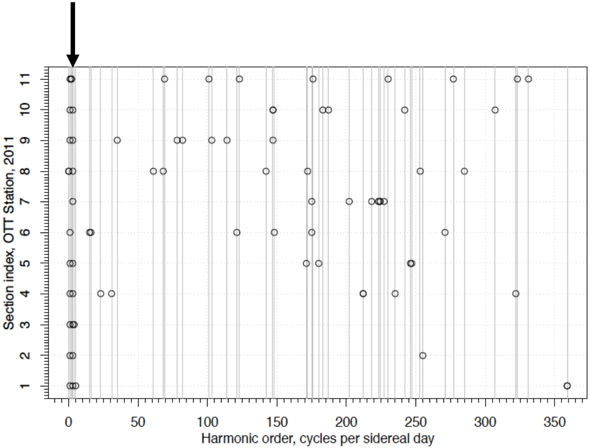
Portability - Determining L

$$\hat{x}_n^{(QDC)} = \sum_{l=1}^{L} \hat{x}^{(l)} \exp\left(i2\pi \hat{f}^{(l)} n\right)$$



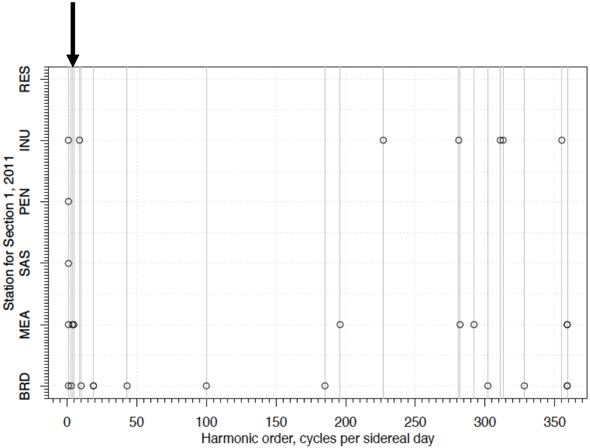
Portability - Different Times

$$\hat{x}_n^{(QDC)} = \sum_{l=1}^{L} \hat{x}^{(l)} \exp\left(i2\pi \hat{f}^{(l)} n\right)$$



Portability - Different Stations

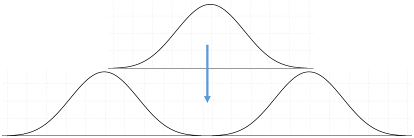
$$\hat{x}_n^{(QDC)} = \sum_{l=1}^{L} \hat{x}^{(l)} \exp\left(i 2\pi \hat{f}^{(l)} n\right)$$

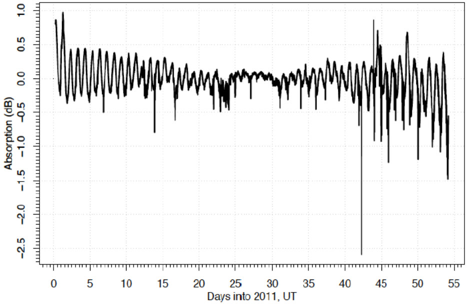


Outline

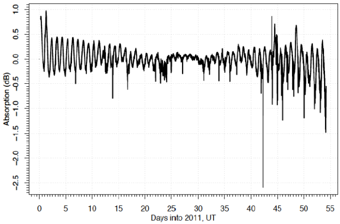
Implementation - Section Overlap

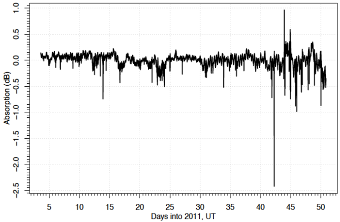
$$\log_{10}\left(\hat{X}_n^{(QDC)}\right) - \log_{10}(x_n)$$





Implementation - Section Overlap





Conclusions and Future Directions

- $<$1h of training.
-
- Less sensitive to outliers.
-
- Portable.
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- Section-overlap algorithm:
  - 10 min cleaning.
  - 2$\times$ faster than full-record reconstruction.
  - Better reconstruction at record ends.
-
- Build a user interface for the realtime monitoring.

Acknowledgments

- Dr. Donald Danskin (NRCan)
- Dr. Emma Spanswick (University of Calgary)
- Dr. Eric Donovan (University of Calgary)
- NSERC; CANSSI; Bonneyville Power Authority; Queen's University.

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