Modeling Voltage Level Data for Geospace Sensors

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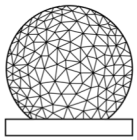
MIT Haystack Observatory



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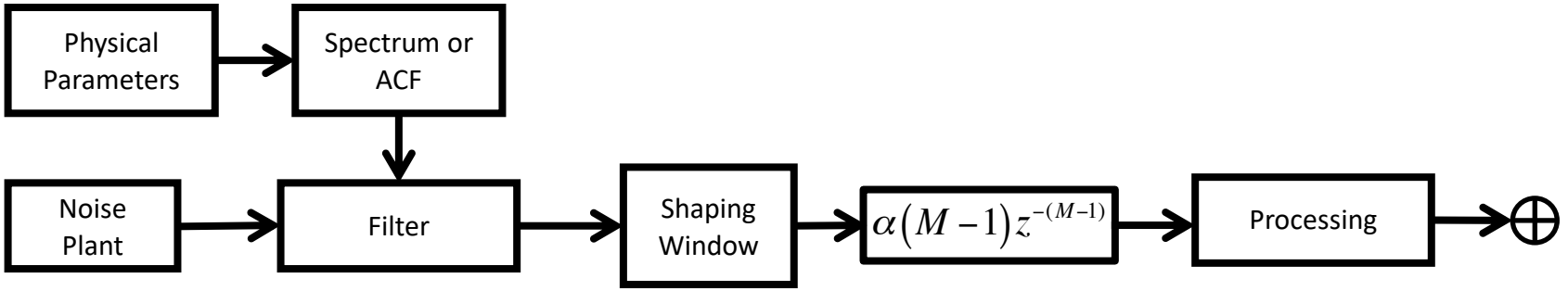
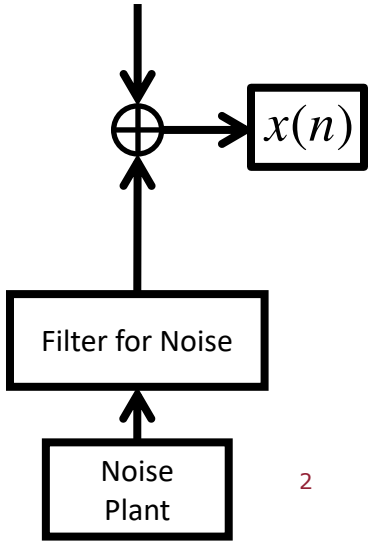
Creating Voltage Data



- Many applications are looking at second order statistics.
- Can create data with AWGN and shape data
- "Spectrum or ACF" block translation from physical parameter space



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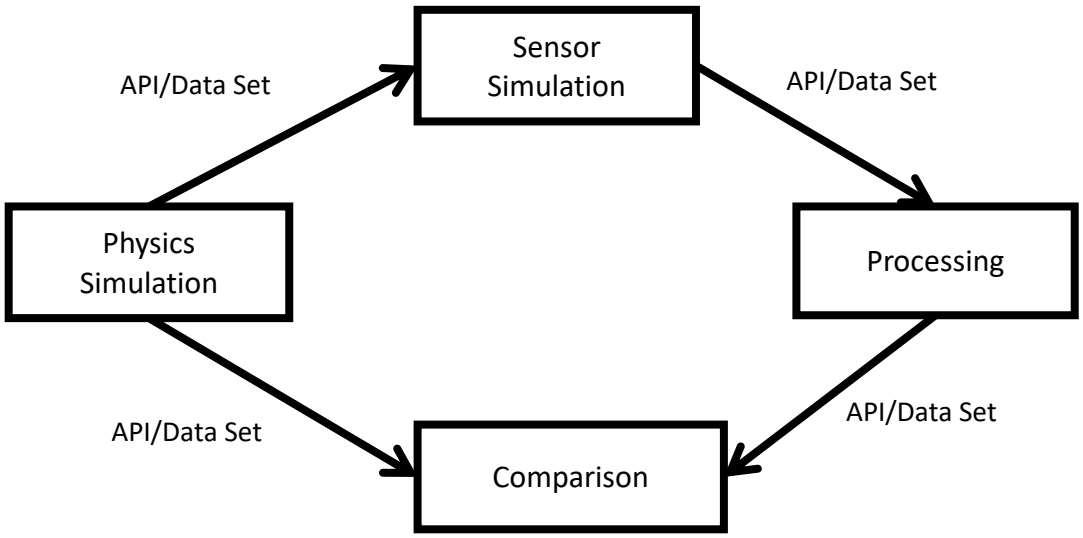
Software Setup



- Each block is its own code base
- Separate codebases increase utility
- Pieces can be reused for different applications

- Repository examples
  - https://github.com/jswoboda/ISRSpectrum
  - https://github.com/jswoboda/SimISR
  - https://github.com/MITHaystack/digital_rf

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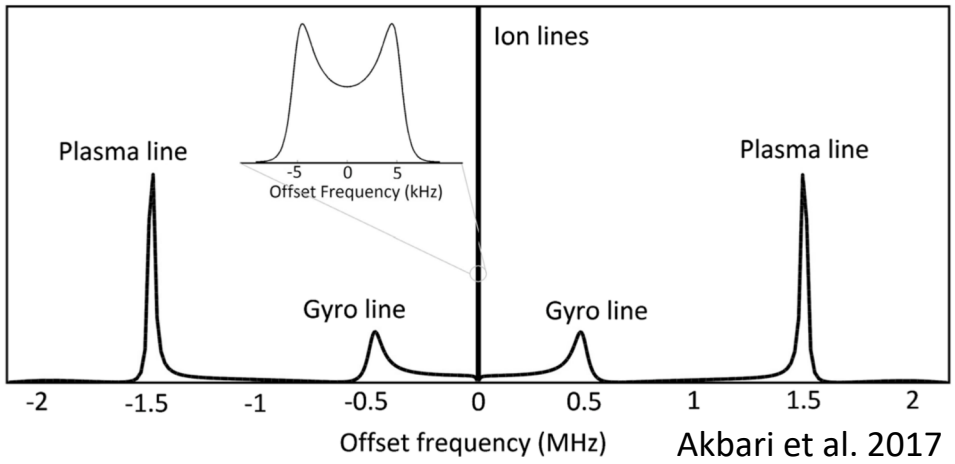
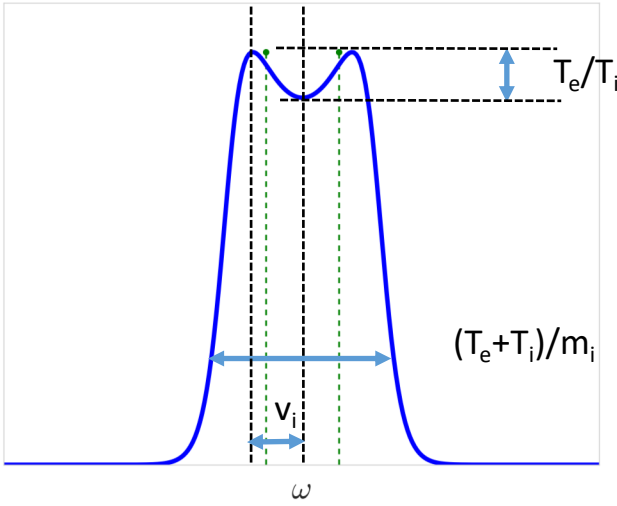
IS Spectrum



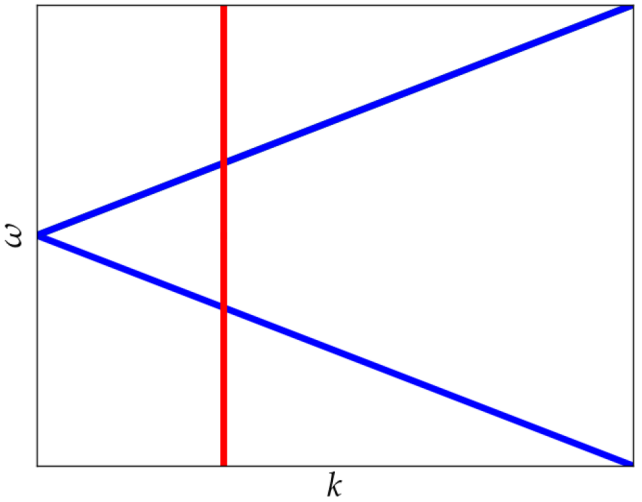
Akbari et al. 2017



$$\omega = k\sqrt{\frac{k_b T_e + k_b \gamma_i T_i}{M}}$$

Chen (2006)

Ion Acoustic Wave Dispersion Relation



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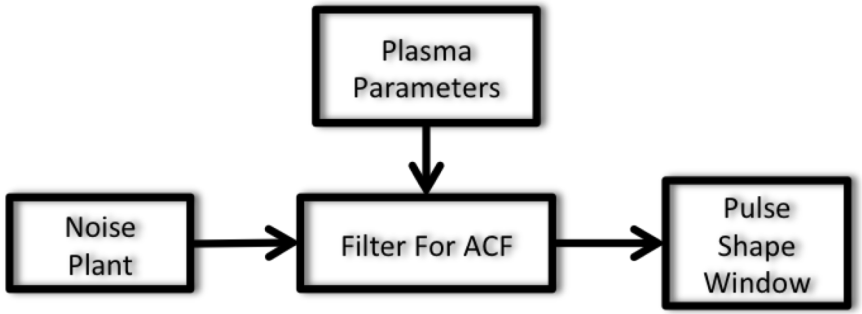
SimISR

- Radar simulation composed of noise plant filter systems



- Filter creation method

$$H_m(z) = \frac{G}{1 - \sum_{l=1}^{L} a_l z^{-l}}$$

Rabiner et al. 2010

$$G = \sqrt{\sum_{l=0}^{L} -a_l R_m(l)}$$

$$\begin{bmatrix} R_m(0) & R_m(L-1) & \cdots & R_m(1) \\ R_m(1) & R_m(0) & \cdots & R_m(2) \\ \vdots & & \ddots & \vdots \\ R_m(L-1) & R_m(L-2) & \cdots & R_m(0) \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_L \end{bmatrix} = \begin{bmatrix} R_m(1) \\ R_m(2) \\ \vdots \\ R_m(L) \end{bmatrix}$$

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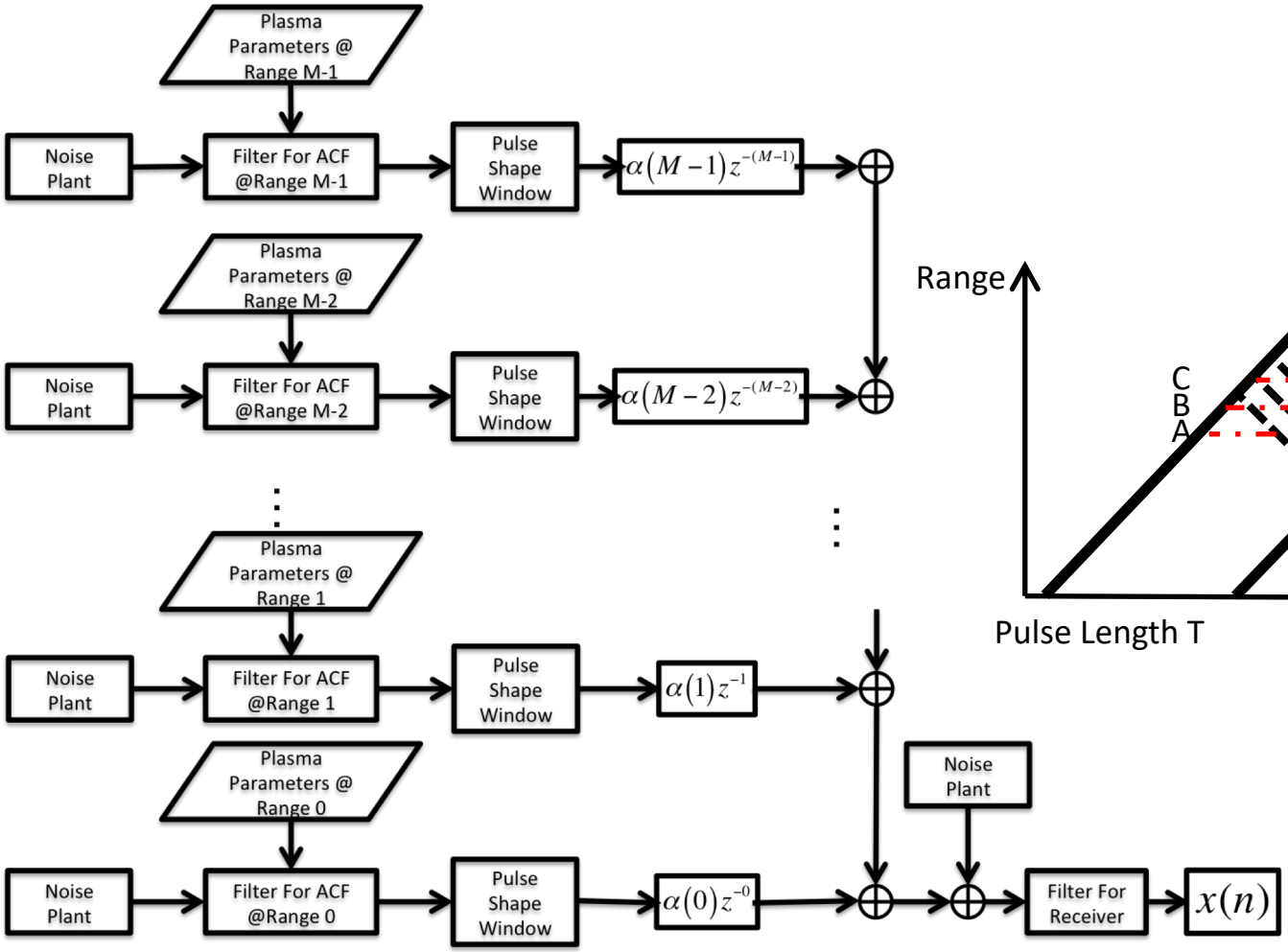
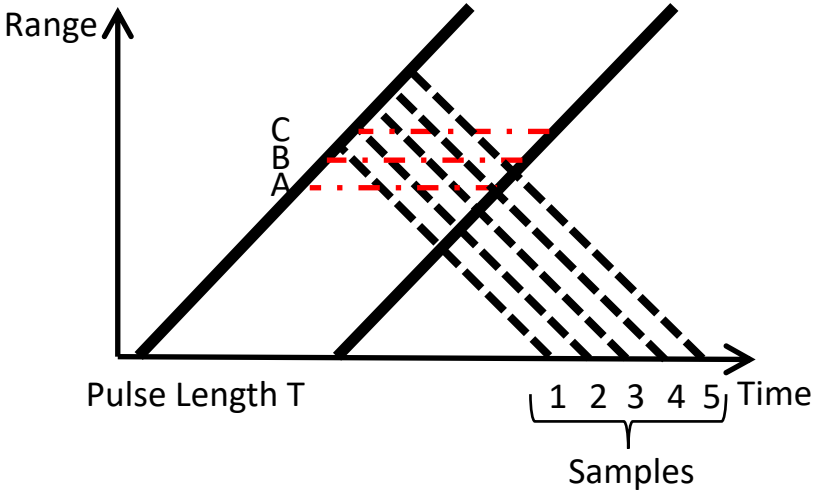
SimISR





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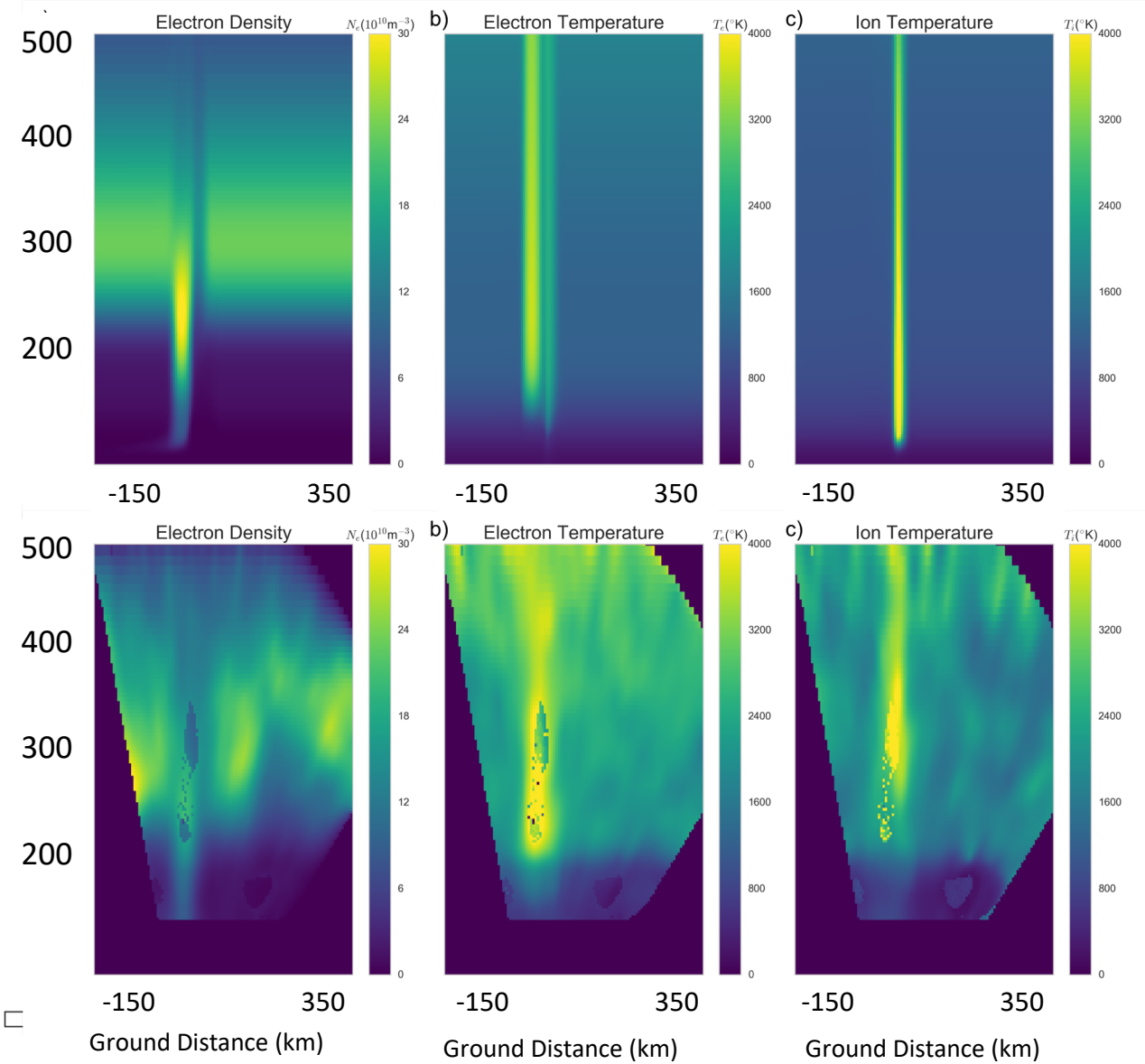
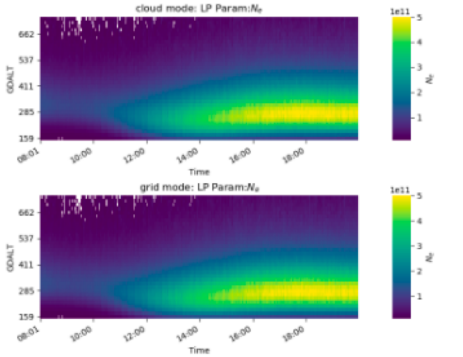
Simulation Inversion



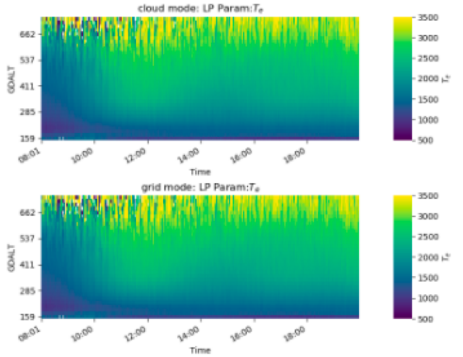
- Evacuation in electron density is visible but enhancement is reduced
- Enhancements are more noticeable than before.

Processing Chain Comparison Using SimVSR

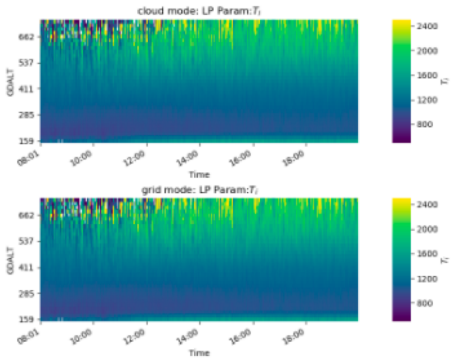
Long Pulse Data



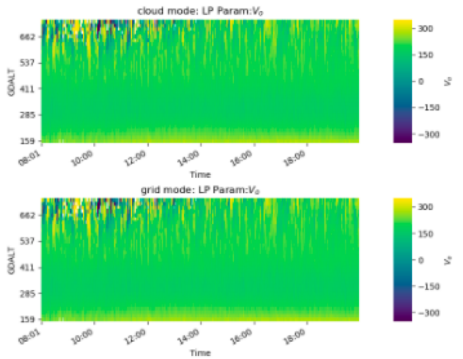
(a) N_e for long pulse



(b) T_e for long pulse

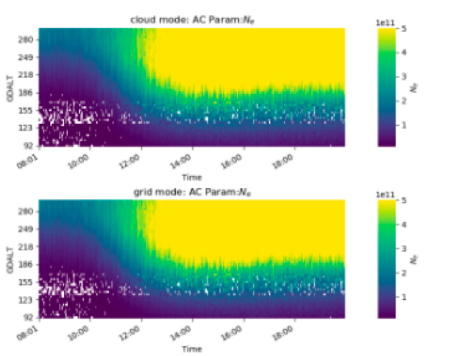


(c) T_i for long pulse

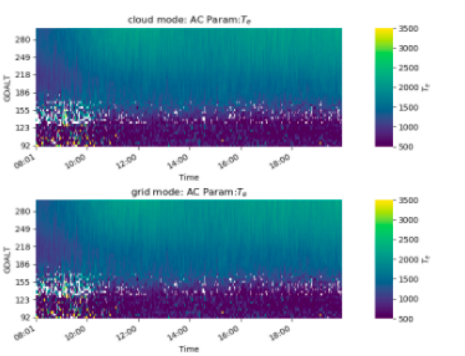


(d) V_o for long pulse

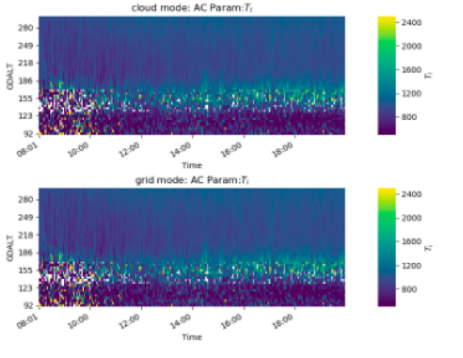
Alternating Code Data



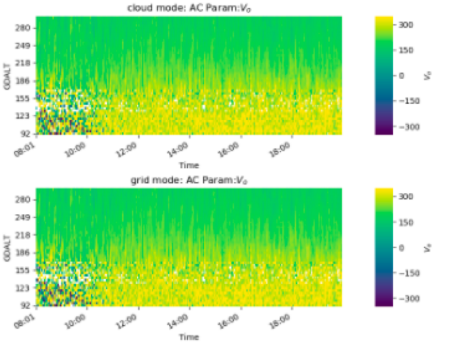
(a) N_e for Alternating Code



(b) T_e for Alternating Code



(c) T_i for Alternating Code



(d) V_o for Alternating Code

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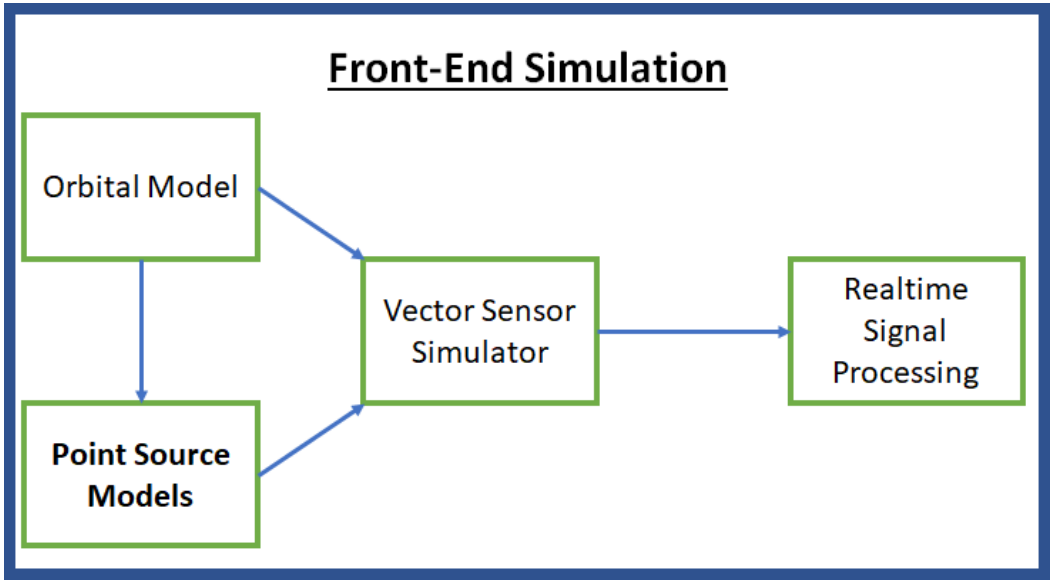
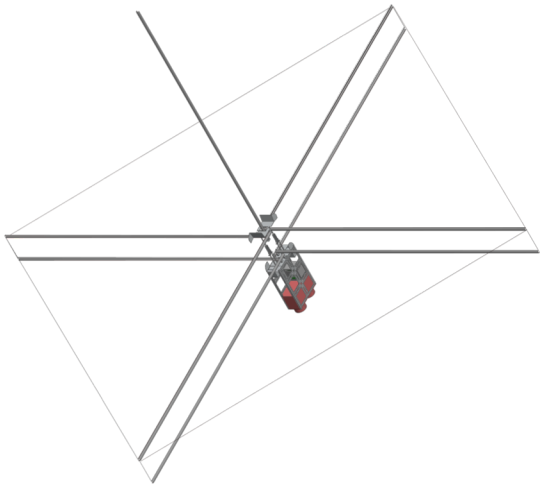
AEROVISTA Simulation Ecosystem

- Full model data creation
  - Orbit model
  - Point source model to determine signal parameters
  - Real-time signal processing is modelled





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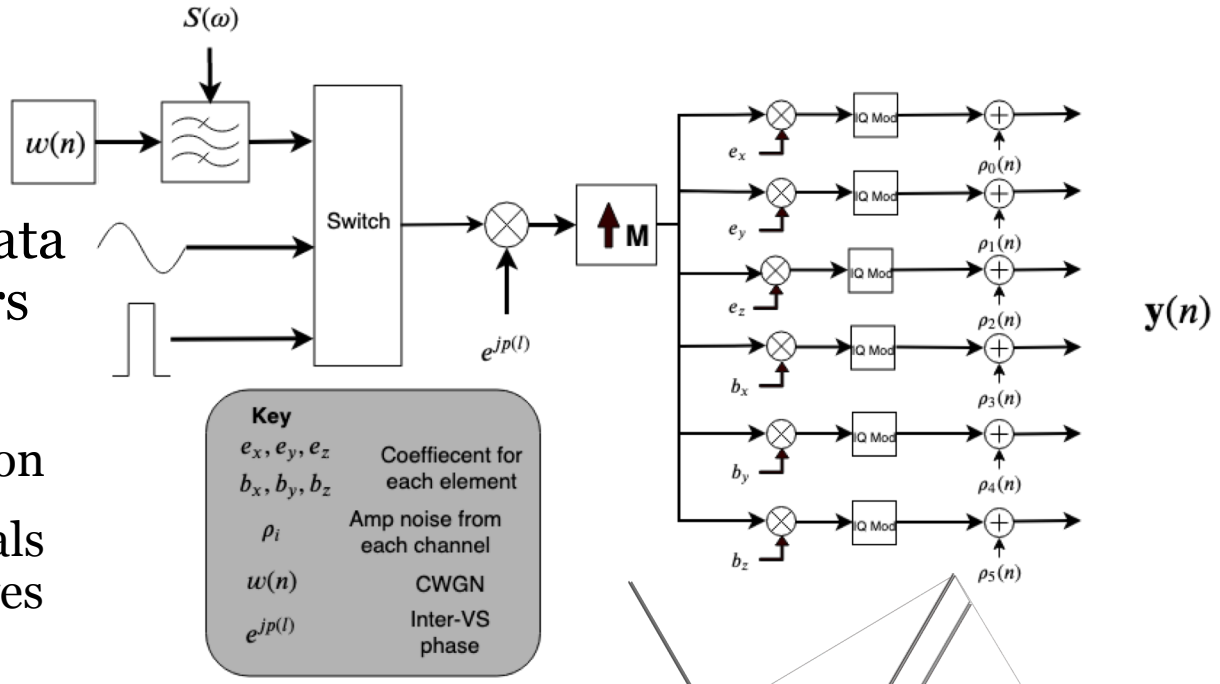
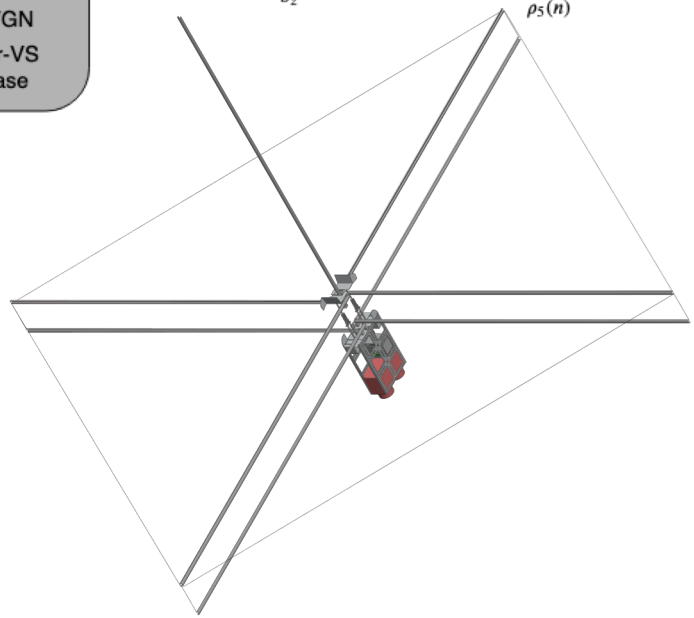
SimVSR

- Creates voltage level data given signal parameters
  - Position of source
  - Spectrum of emission
  - Can inject test signals i.e. pulses, sine waves





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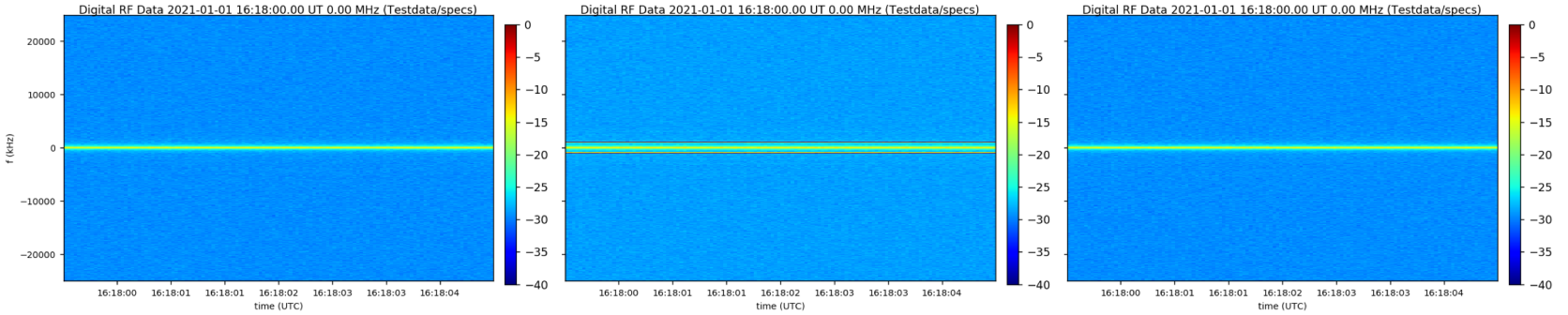
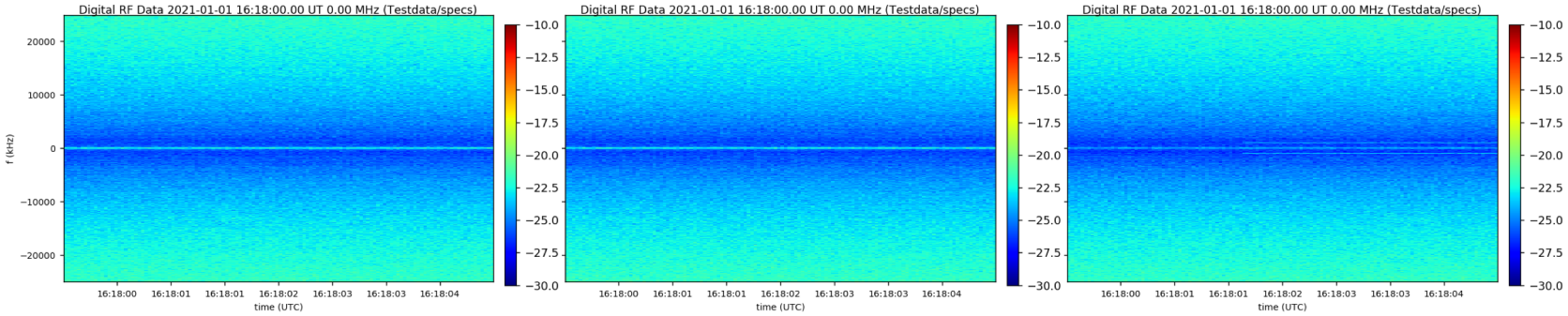
Example SimVSR Data

X Component | Y Component | Z Component

E Field



B Field



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Future

- SimISR
  - Need to update GitHub repository with Digital RF and better configuration setup.
  - Allow for download through anaconda (ISRSpectrum now supported)
  - Break out processing code to separate repository

- SimVSR
  - Create more simulated data for AEROVISTA processing chain.
  - Possibly augment for other vector sensor applications.

References

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