Inferring ratio of negative ion to electron concentration in D region by using Arecibo Incoherent Scatter Radar

UNIVERSITY OF WASHINGTON
ELECTRICAL ENGINEERING

Marcos Inonan, John Sahr

Department of Electrical Engineering, University of Washington

Introduction

A new experiment has been implemented at Arecibo's Incoherent Scatter Radar to study D region parameters. This poster analyzes the width of the ISR spectra to estimate the ratio of negative ion to electron concentration, which appear as the result of collisions between electrons and neutrals. The spectra was fitted by using three models (Folded Lorentzian, folded Gaussian and folded Voigt functions) and each width was compared with the theoretical width that was calculated with plasma parameters from the IRI model.

Additionally, an analysis of resulting ISR spectra has been made. Considering that the ISR spectra is obtained after a long incoherent integration, a combination of median/mean integration was applied in order to eliminate the outliers (echoes caused by airplanes or human interference) that could distort the spectra.

Theoretical Model

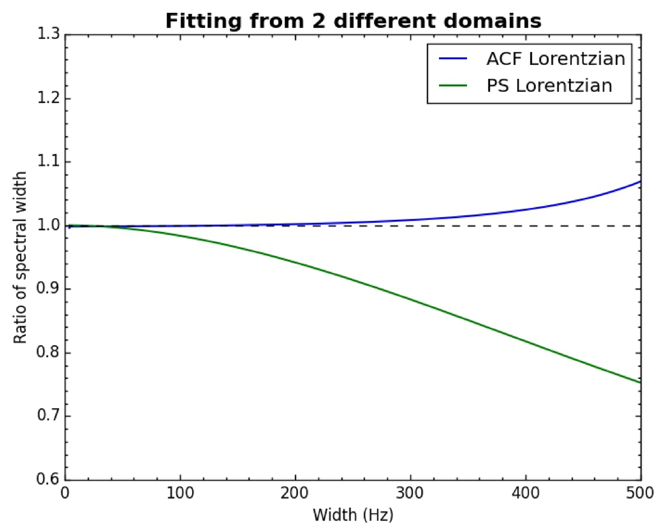
LORENTZIAN

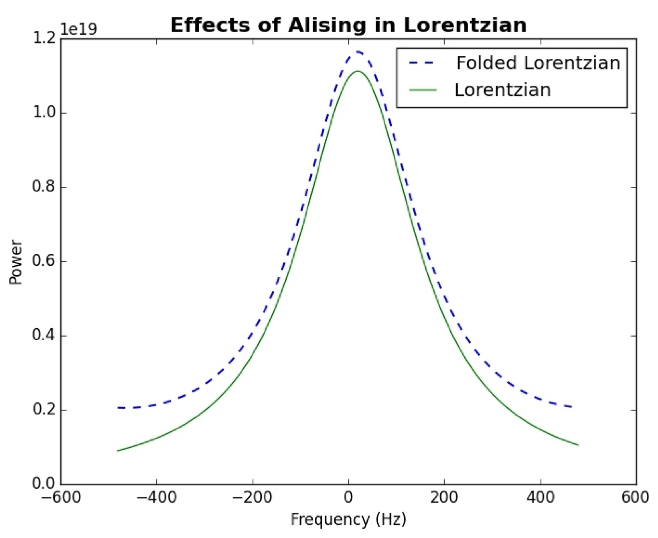
PS

$$S(f) = \frac{1}{\pi}\frac{A_0 W}{\left(1+\left(\frac{f-D}{W}\right)^2\right)} + B$$

ACF

$$R(\tau) = A_0 \exp(-W|\tau|)\exp(iD\tau) + B\delta[0]$$





VOIGT

PS

$$S(f) = A_0\frac{Re[w(z)]}{\sqrt{2\pi\sigma^2}} + B$$

$Re[w(z)]$ Faddeeva function

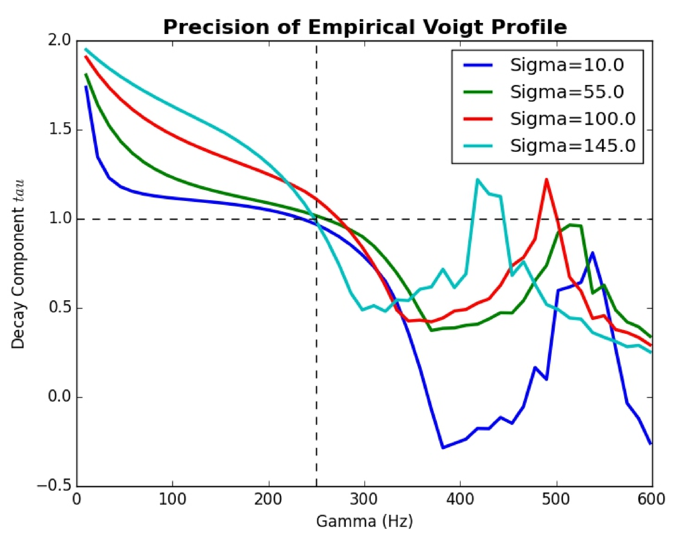
$$z = \frac{f-D+iW}{\sqrt{2}\sigma}$$

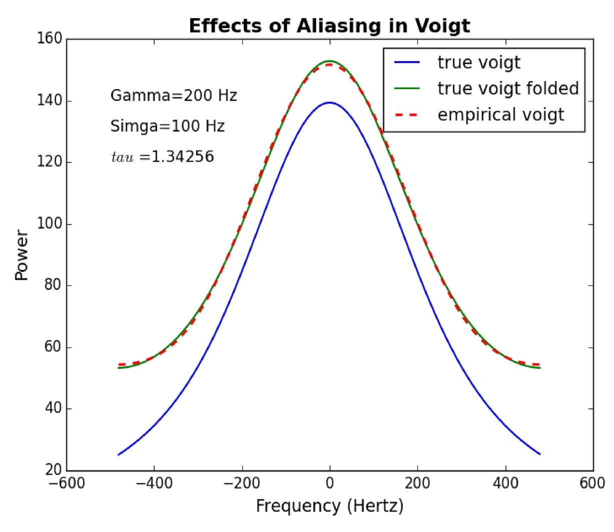
ACF

$$R(\tau) = A_0 \exp\left(-W|\tau| - \frac{1}{2}\sigma^2\tau^2\right)\exp(i2\pi\tau D) + B\delta[0]$$

ACF (empirical)

$$R(\tau) = A_0 \exp\left(-\left|\frac{\tau}{\tau_e}\right|^{n_\tau}\right)\exp(i2\pi\tau D) + B\delta[0]$$





Where

- A Power of the spectrum
- f is the frequency variable,
- B is the offset
- W is the width of the spectrum
- D is the Doppler shift for the center frequency
- τ_e is the spectral width
- n_τ is the "decay exponent" determines the spectral shape. When $n_\tau = 2$ Gaussian, $n_\tau = 1$ Lorentzian,

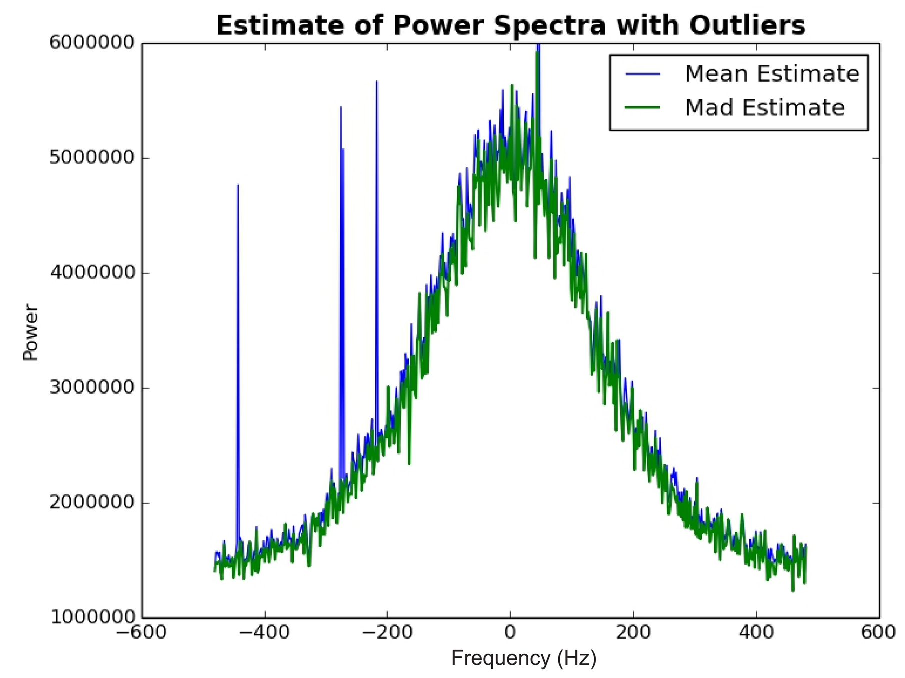
Experiment Setup

Parameter	Value	Units
Inter pulse Period (IPP)	1.040 (156)	ms (km)
Pulse width	52 (7.8)	μs (km)
Duty cycle	5%	
Code	Barker 13	bits
Sampling rate	500	kHz
Range resolution	0.3	km
Initial range	48	km
Number of samples per Ipp	250	
Final range	123	km
Transmiited peak power	2.5	MW

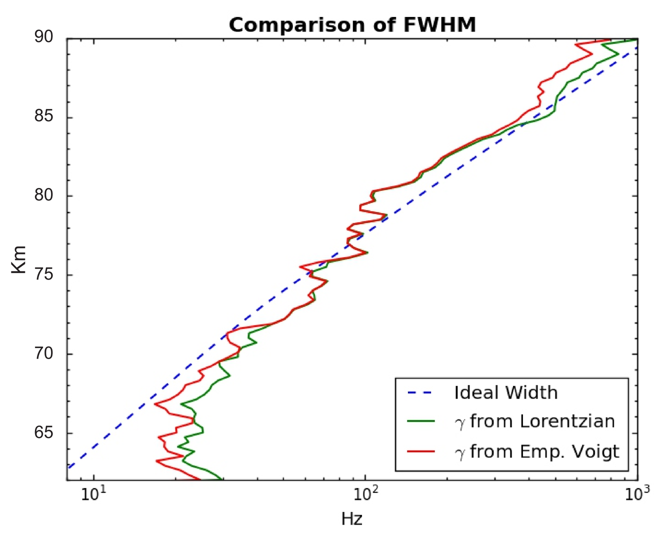
Outliers

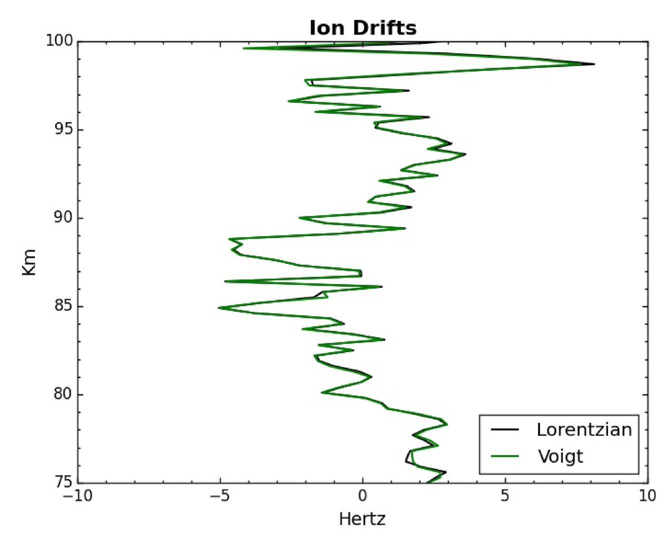
$$MAD(x) = Med\{|\mathbf{x} - Med(\mathbf{x})|\}$$

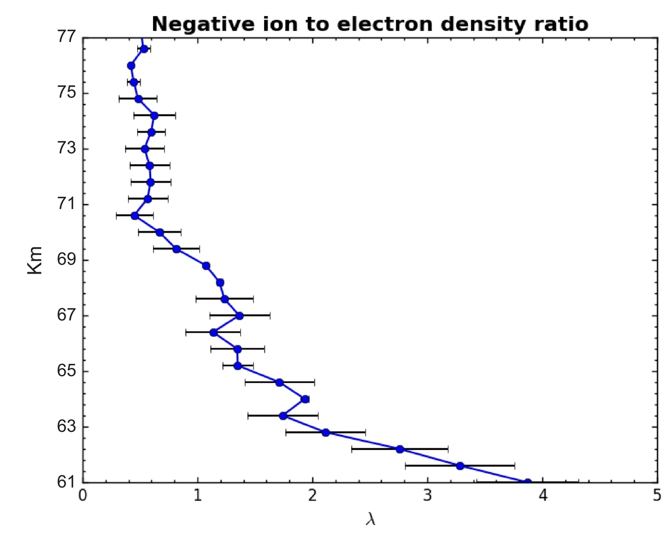
$$MADN(x) = \frac{MAD(x)}{0.6745}$$

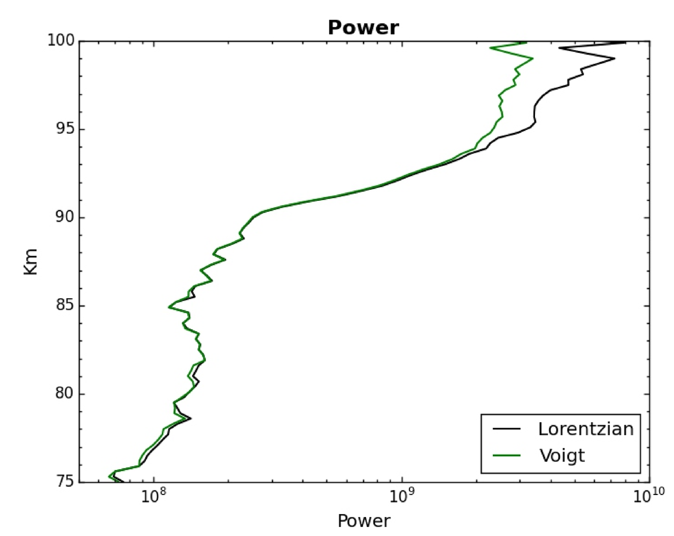


Fitting process









$$W = CT\frac{((1+\lambda)+\alpha^2/2)}{\nu_{in} m_i (1+\alpha^2)}$$

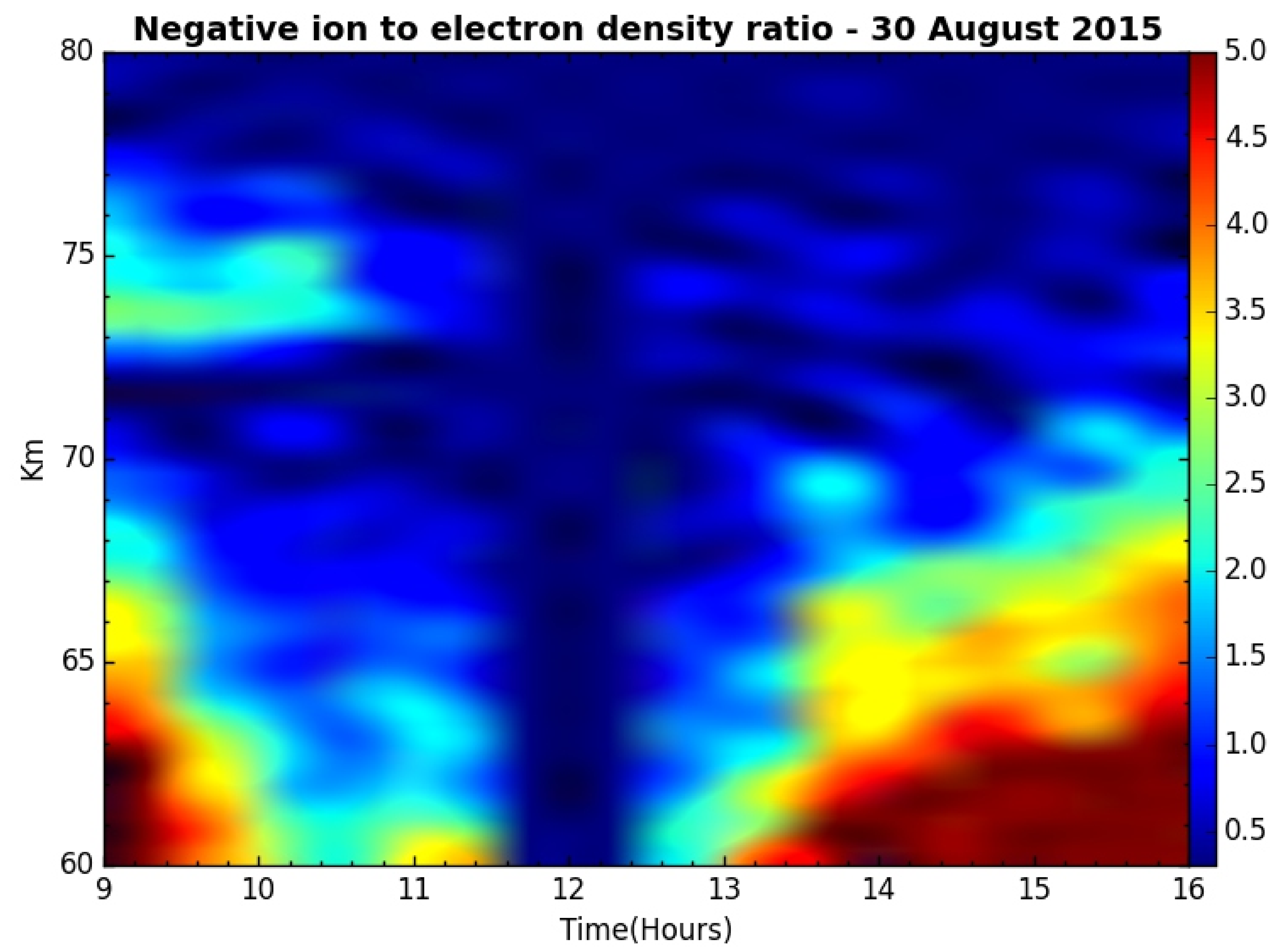
$$\alpha = \frac{4\pi\lambda_D}{\lambda_R}$$

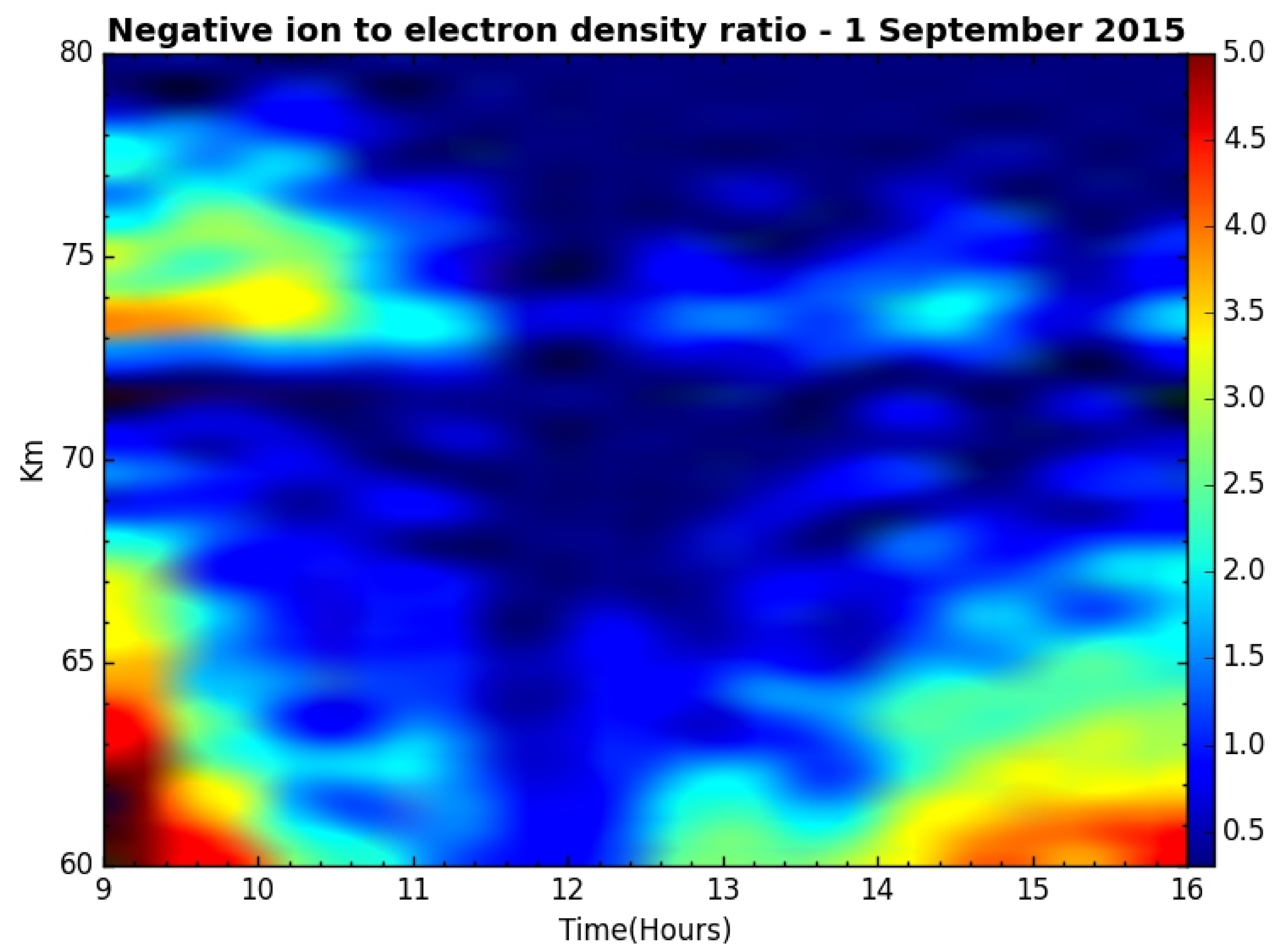
$$C = 32\pi\frac{K_B}{\lambda_R^2}$$

Where

- ν_{in} is the ion-neutral collision frequency,
- m_i is the mass of positive ion,
- K_B is the Boltzman constant,
- T is the ion/electron temperature.
- λ_R is the radar wavelength
- λ is the ratio of negative ion to electron density
- λ_D is the Debye length

Results





Conclusions

- MAD is an efficient method to detect outliers which allow to compute the sample mean more precisely.
- The presence of negative ions exists in D region, they become important below 70 Km. However, during morning hours they are significant between 73-77 Km.
- Presence of atmospheric turbulence deforms the shape the spectrum from Lorentzian to Voigt. In order to overcome the difficulties of fitting a Voigt profile, an empirical Voigt was used as alternative that provides a better fit.
- The empirical Voigt profile offers a close approximation to a folded Voigt. The advantage of this model is that its parameters are nearly orthogonal which robust the fitting process since their partial derivatives are uncorrelated.