D-REGION ABSORPTION USING THE DIGISONDE: NORMAL AND SOLAR FLARE

LDI
LOWELL DIGISONDE INTERNATIONAL

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XIV INTERNATIONAL GIRO FORUM · 20–23 MAY

OUTLINE

- DIGISONDE POWER CALIBRATION PROCESS
- BOULDER DIGISONDE CALIBRATION
- NON-ABSORPTION LOSSES
  - FOCUSING GAIN
  - F-LAYER REFLECTIVITY
- D-REGION PHYSICS
- HF ABSORPTION
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  - SOLAR X-RAY FLARES
- SUMMARY

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CALIBRATION PROCESS
Friis Formula for Received Power

$$P_R(f) = \frac{P_T G_T G_R(f) \lambda^2}{(4\pi)^2 h^2} \frac{1}{L(f)}$$

System calibration was carried out using only nighttime data. This was no D-region absorption and therefore *L(f) = 1*

Then solving for the Digisonde system parameters:

$$P_T G_T G_R(f) = \frac{(4\pi)^2 h^2}{\lambda^2} P_R$$

Where λ is known and the Digisonde measures P_R and *h* (true height).

CALIBRATION and LOSSES

After completing the system calibration it is then possible to solve the Friis equation for the loss term using the sounder measurements

$$L(f) = \frac{\left[P_T G_T G_R(f)\right]\lambda^2}{(4\pi)^2 h^2 P_R(f)}$$

Where the loss term includes the following contributions:

$$L(f) = L_{absorption}(f) + L_{focusing} + L_{reflectivity} \quad (dB)$$

OBJECTIVE

We are investigating D-region absorption which is primarily a daytime phenomena. This absorption depends on the electron density and electron collision frequency along the ray path at altitudes between 60 and 90 km. Then from the measured absorption and using D-region models it becomes possible to investigate the production and distribution of electrons at these altitudes.

Under quiet conditions the D-region electrons are produced by both UV and visible solar radiation during the daytime. Solar X-ray flares enhance the density of electrons and increase the HF radio wave absorption.

We show that Digisonde sounding makes very sensitive absorption measurements because lower frequencies are used compared to the riometer (30 MHz) technique. Absorption typically varies inversely with square of the frequency. The actual exponent can be determined by analysis of the absorption data.

ABSORPTION INDEX

$$E(r) = E_o e^{j(\omega t - \vec{k}\ \vec{r})} = E_o e^{j\omega t}\, e^{-j\vec{k}\ \vec{r}}$$

$$where\ k = k_o n \quad and \quad k_o = \frac{2\pi}{\lambda_o}$$

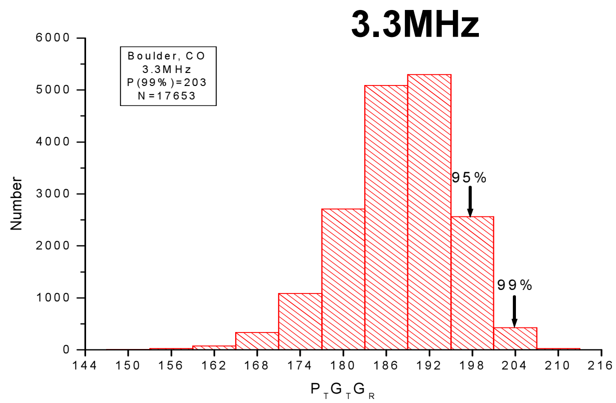
$$E = E_o e^{-jk_o \mu r}\, e^{-\chi k_o r}$$

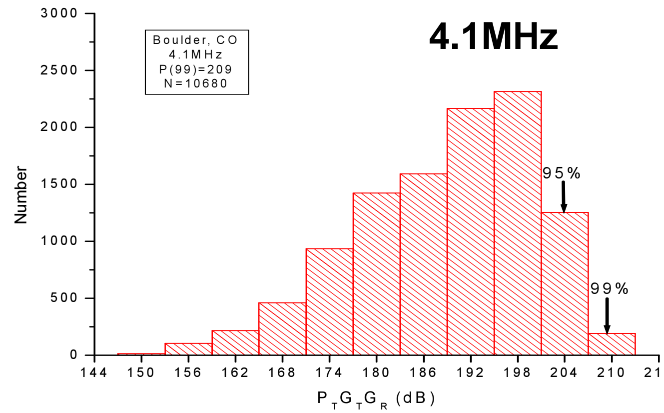
Loss term → $e^{-\chi k_o r}$; Loss term → $\kappa = \chi k_o$

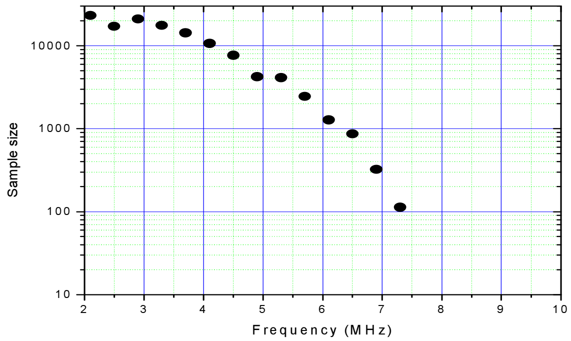
$$\kappa = \int_{\substack{ray\\path}} \frac{N_e(z)\nu(z)}{(\omega \pm \omega_H)^2 + \nu(z)^2}\, dr$$

BOULDER, CO. DIGISONDE CALIBRATION

BOULDER DIGISONDE CALIBRATION







Nighttime data

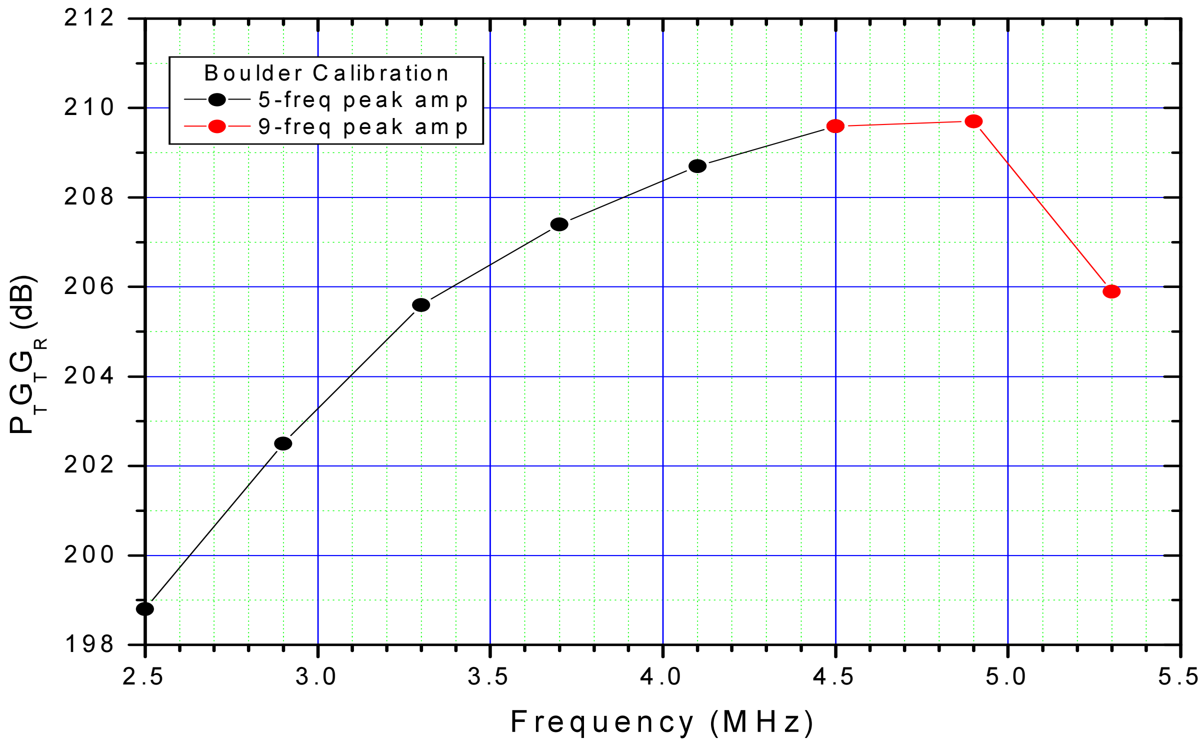
Frequency step = 400kHz (2.1MHz)

May, June July and Aug. 2005 (~120 days)

2000 LT to 0500 LT/ 15 min ionograms

9 frequencies/frequency (f ± 50,100,150 200kHz)

BOULDER SOUNDER CALIBRATION
2.5MHz to 5.3MHz



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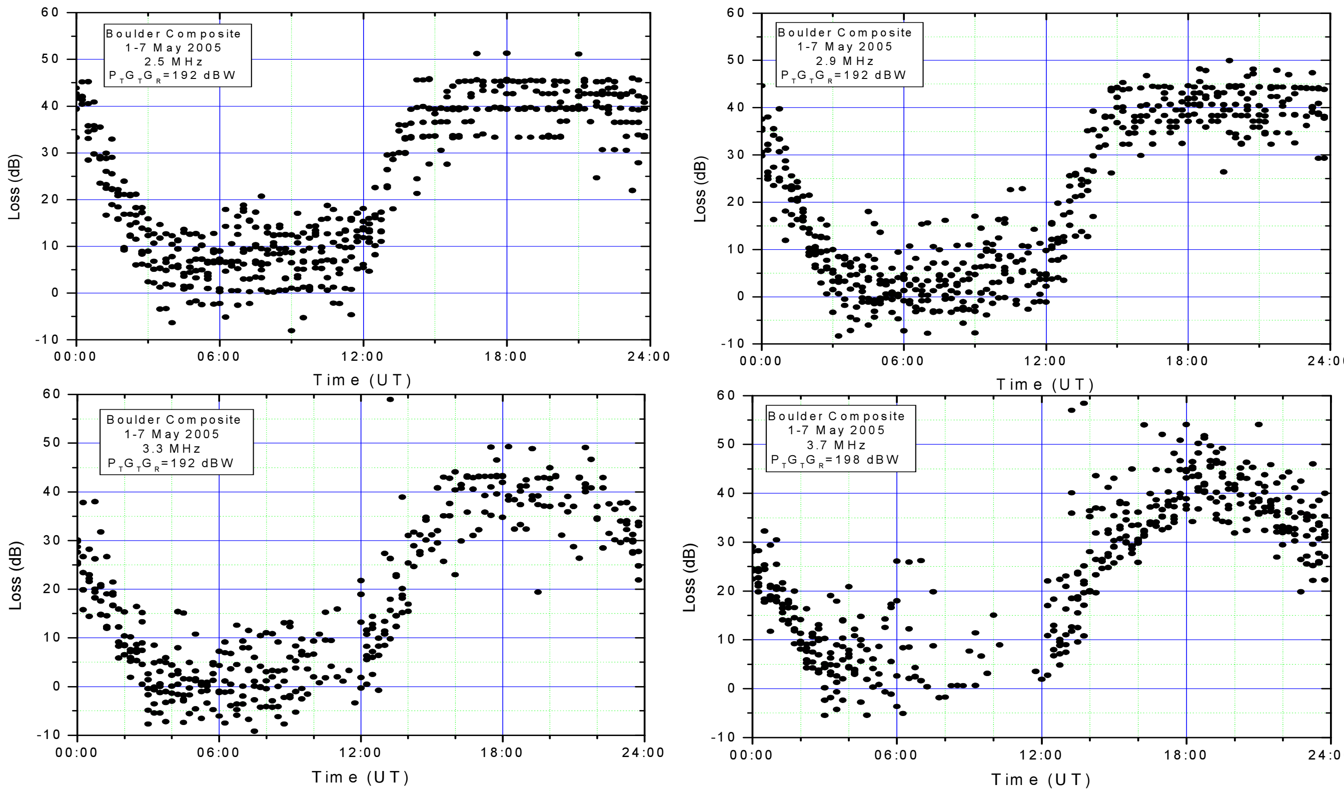
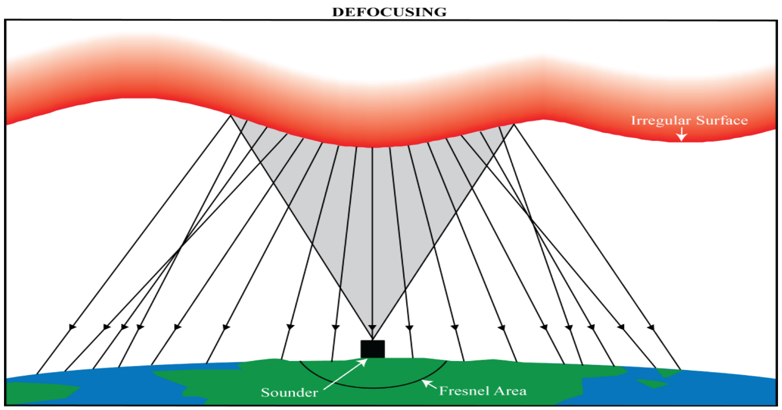
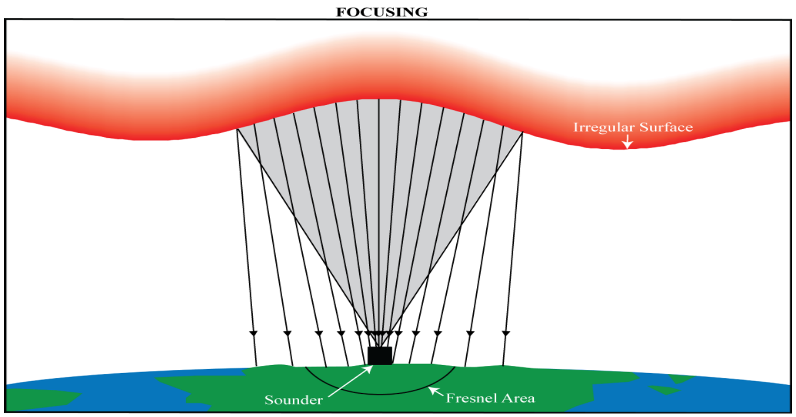
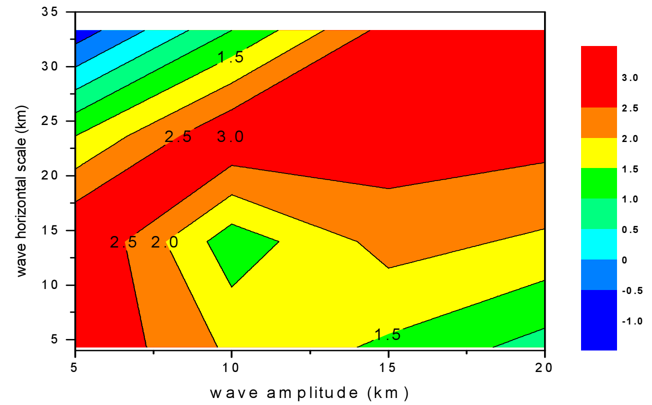
HF ABSORPTION (dB)
2.5, 2.9, 3.3 and 3.7MHz
1 – 7 May 2005



IONOSPHERIC FOCUSING GAIN







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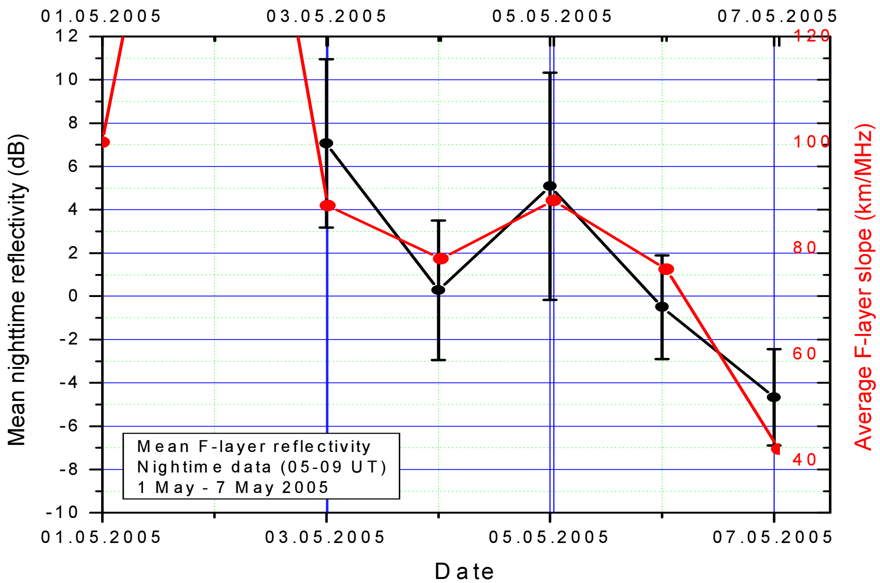
REFLECTIVITY LOSSES and EPSTEIN LAYER



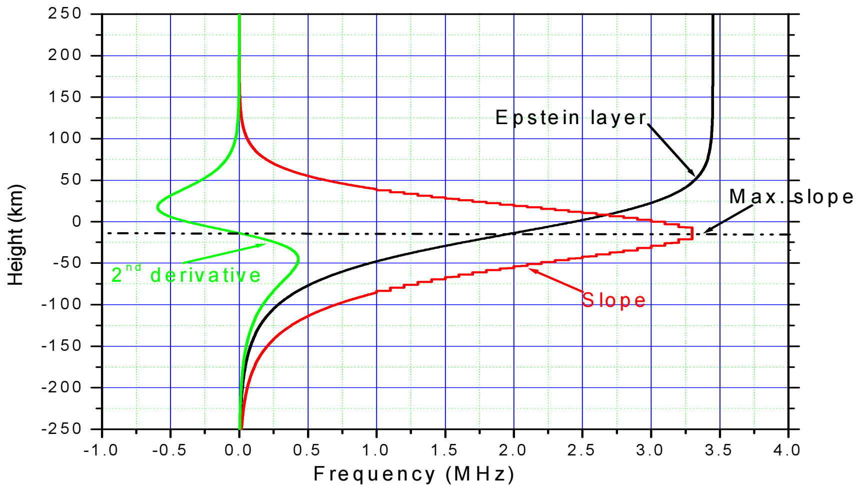
This plot compares the average nighttime loss with the average slope of the F-layer during the same night. The high degree of correlation suggested that the reflectivity of the F-layer was related to the shape of the F-region at the particular time.

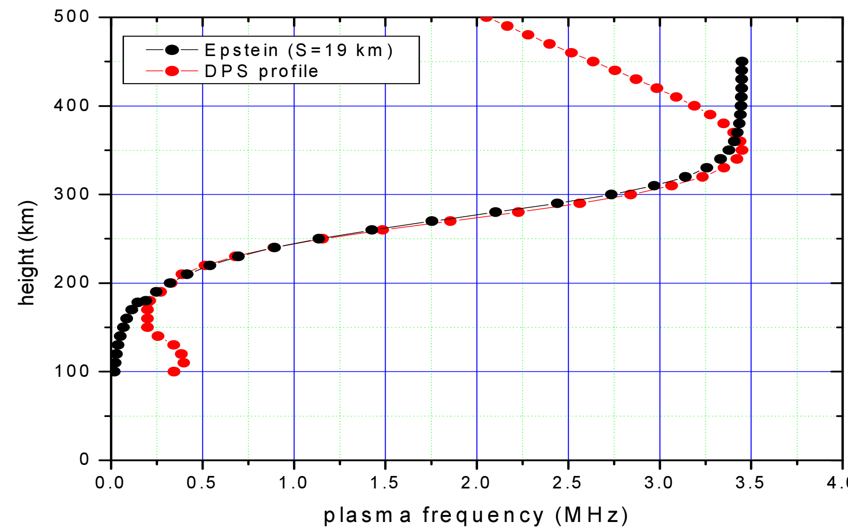
There is one F-layer model for which it is possible to calculate the reflectivity and that is the Epstein layer given as:

$$f_p(z) = foF \left[\frac{\exp\left(\frac{z - z_o}{S}\right)}{1 + \exp\left(\frac{z - z_o}{S}\right)} \right]^{\frac{1}{2}}$$

EPSTEIN LAYER

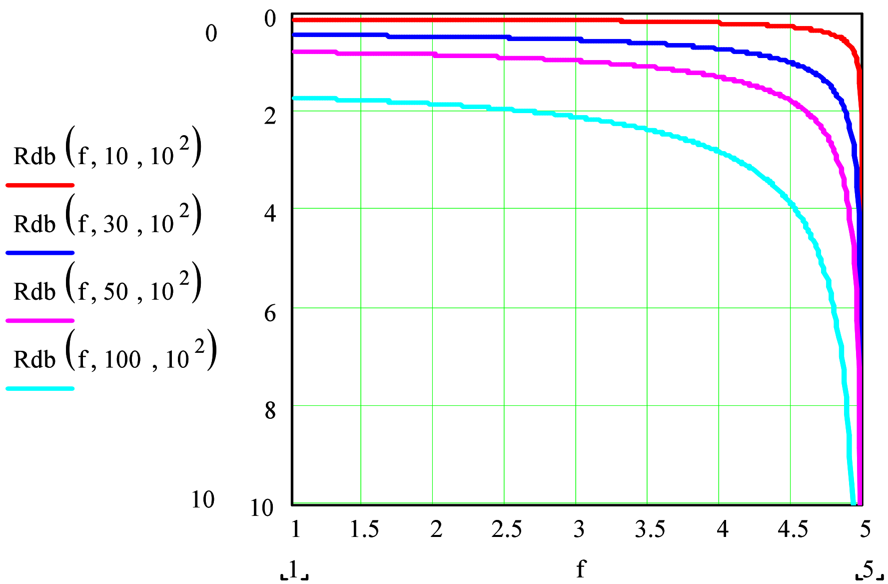
The Digisonde profile was used to determine the maximum slope and the height at which it occurred. These two parameters were used to determine the Epstein profile that best fit the measured true height profile.





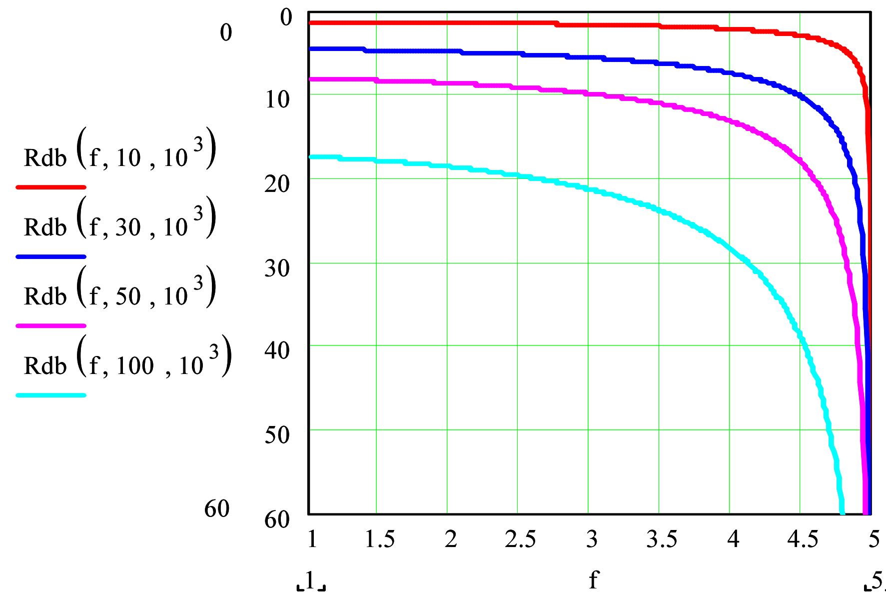
BUDDEN/RAWER REFLECTION COEFFICIENT FOR THE EPSTEIN LAYER

Low collision frequency



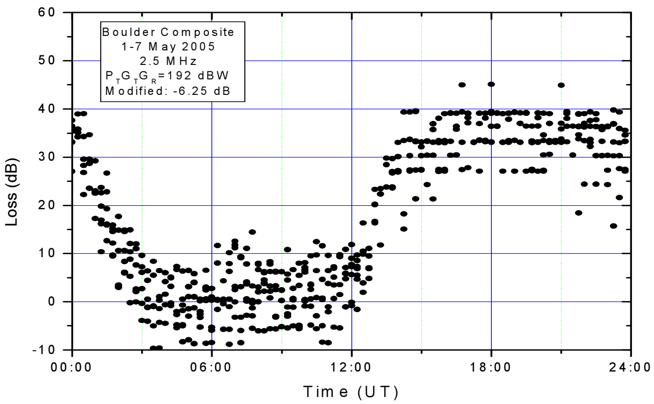
$\nu_{en} = 100\ s^{-1}$

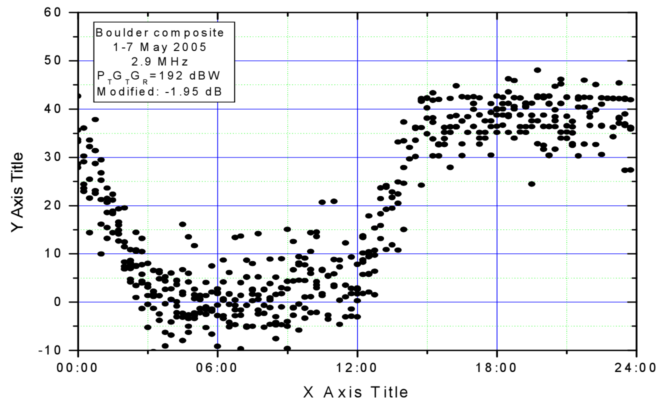
Higher collision frequency



$\nu_{en} = 1000\ s^{-1}$

REFLECTIVITY and FOCUSING CORRECTED ABSORPTION



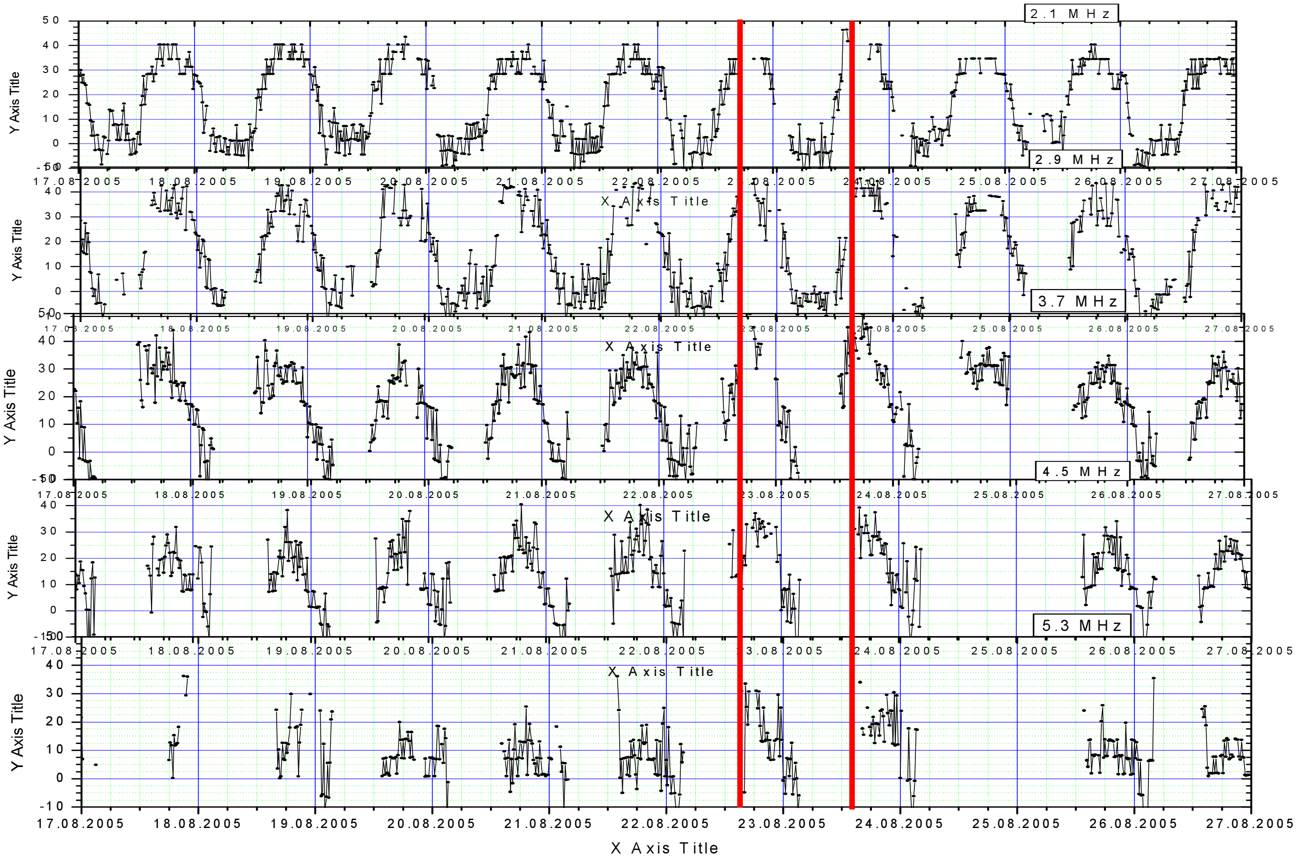


SUMMARY

- WE NOW HAVE A METHOD USING THE DIGISONDE TO MEASURE THE DAILY D-REGION ABSORPTION OVER A FREQUENCY RANGE FROM 2MHz TO 7MHz. THE ACTUAL RANGE WILL DEPEND ON THE SOUNDER LOCATION.
- THIS ANALYSIS CAN BE USED TO INVESTIGATE THE DAILY VARIATIONS IN D-REGION ABSORPTION AS IT RELATES TO SOLAR ACTIVITY IN TERMS OF CHANGING X-RAY FLUX.
- THESE ABSORPTION DATA CAN BE USED TO PREDICT LOSSES ON HF RADIOWAVE COMMUNICATION PATHS IN THE VICINITY OF THE SOUNDER.

Absorption (dB) – Boulder Co.

Aug. 17 – 27, 2005



Red lines indicate two M-class solar flares on:

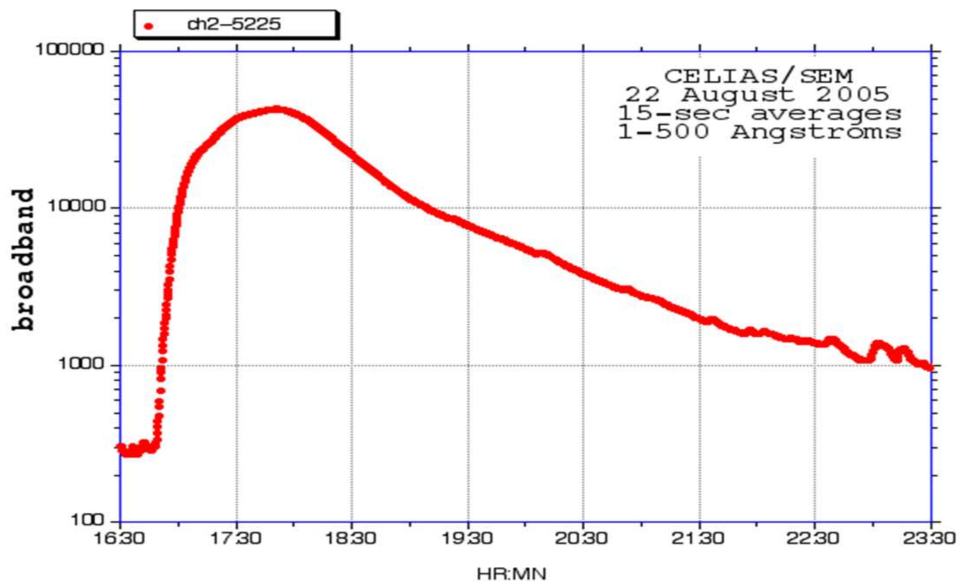
22 Aug. 2005 – 1646UT

23 Aug. 2005 – 1419UT

X-RAY FLUX
1-8 Angstrom

22 Aug. 2005, 1727UT
M class
Flux = 5.6 x 10E-5 W/m2

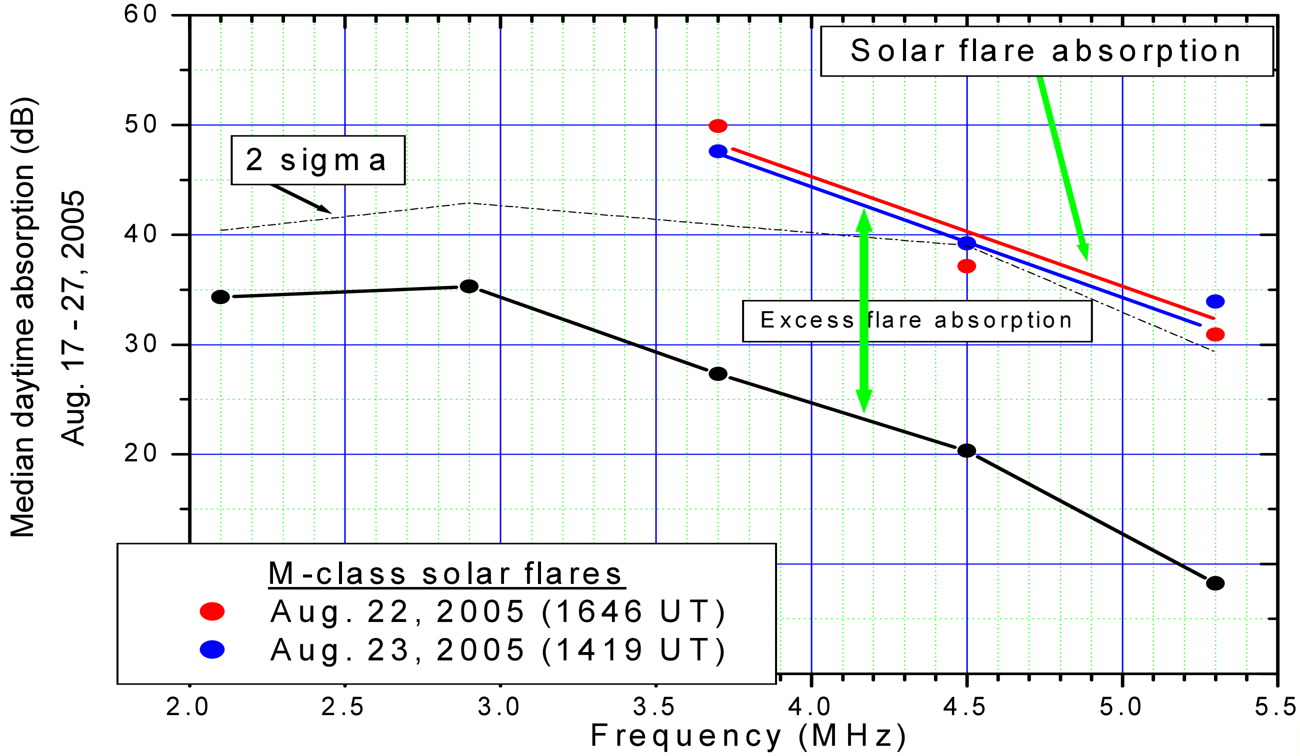
23 Aug. 2005, 1444UT
M class
Flux = 2.7 x 10E-5 W/m2



Background and Solar Flare Absorption

Boulder, CO

17 – 27 Aug. 2005



SUMMARY

With a calibrated Digisonde system it has been possible to measure diurnal variation of D-region absorption and the additional absorption produced by solar X-ray flares. A natural follow up to this work is the modeling of the D-region using these absorption data sets.