Station Report: A new ionosonde at Boulder

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Abstract

This brief station report announces that a new generation of fully digital ionosonde is located at the Boulder, Colorado ionosonde station. The Vertical Incidence Pulsed Ionospheric Radar is now installed and undergoing testing and alignment. The first ionograms indicate high quality data. Raw ionogram and graphical browse products are available online.

1 Instrument

In November 2008, the ionosonde station at Boulder, Colorado, USA $(40°N, 105°W)$ became the host of a new generation of ionosonde. The ionosonde hardware is the Vertical Incidence Pulsed Ionospheric Radar (VIPIR) developed and built by Scion Associates. Figure 1 is a photograph of the Boulder VIPIR equipment. The top of the image shows the Receiver, Reference, Exciter, Front End and Balun. A high speed USB hub, Control Computer and UPS are below. The 4kW solid state transmitter is shared with the recently refurbished Digisonde 256 and is not shown.

The VIPIR is a fully digital frequency agile radar that operates between 0.3 and 25 MHz. It features 8 digital receivers and a digital transmit exciter. Extremely high performance analog receive electronics and a 4kW solid state amplifier provide interface to the real world. A full description of the hardware is beyond the scope of this brief report, but is provided by Grubb et. al. at ftp://ftp.ngdc.noaa.gov/ionosonde/documentation/NewHFRadar-VIPIR.pdf

The VIPIR is the follow-on of the NOAA HF radar, which inspired the development and testing of the Dynasonde ionospheric measurement concepts. In addition to Dynasonde modes of operation, the VIPIR provides numerous other possible modes of operation. We are just beginning to explore the options.

The first successful, proof-of-concept operation of this hardware at Boulder dates to a brief interval in May 2006. Since that time, the radar has been developed into a stable and flexible scientific instrument. It is now ready for routine and experimental observations.

2 Field Site

The Boulder field site is a challenging place to operate an ionosonde. The facility is small, about 100x150 meters and oddly shaped. The delta transmit antennas run through the middle of the field, the ionosonde shelter is near the middle of the site, and there are chain link fences near the borders. Border power and telephone lines were recently buried, which has improved the situation slightly. Figure 2 shows the Boulder field site.

The ionosondes are located in the collection of 3 buildings near the center of the photograph. The bottom portion of the transmitting antenna tower is near and to the right of the buildings. Digisonde receive antennas are dark loops with white legs, while VIPIR antennas are mounted on dark, 3m tall vertical wooden timbers. The actual antennas cannot be clearly seen on this photograph. Receive antennas from both the VIPIR and the Digisonde must share and tolerate these obstacles, including each other.

Being close to the city of Boulder, the ionosonde field site also features very strong interference from local AM broadcasters in the 500-1600 kHz band, especially during the daytime hours.

All these factors make Boulder a difficult station to take research quality data.

3 Ionogram Images

Ionogram images in this report are generated from the raw data files, with relatively simple processing and reduction of the raw data into an ionogram. Phase coherent summation is used to compute Ordinary and eXtraordinary receive antenna beams. Incoherent power averaging is used to combine data from the same nominal frequency. The ionograms are plotted on a linear frequency scale in spite of the data being log spaced.

Figure 3 is a “First Light” measurement from Boulder. Figure 4 is a daytime ionogram showing interesting dynamics at the peak of the F layer and in the middle of the E layer. Figure 5 shows a brief interval of F-region spreading, possibly due to the dynamics observed in Figure 4. The ionogram images show that signal to noise ratios of 40 to 50 dB are obtained in some portions of the ionogram.

The bottom dozen or so range gates contain a calibration pulse that is injected into the front end of the receive antenna amplifiers in order to provide a continuous phase performance reference for the system.

Ground clutter is also evident, at narrow bands of frequencies, extending to ranges as large as 50 km.

4 Raw Data

These ionograms are ‘B-mode’ measurements, intended to be compatible with the Dynasonde21© software, but application of the data are not limited to that analysis method.

The nominal frequencies are from 1 to 10 MHz with a logarithmic frequency step of 0.5%. Nominal frequencies are taken in a group or ‘ramp’ of 4, and ramp is repeated a total of 4 times for a ‘block’ of data. At each nominal frequency, a pulse set or ‘pulset’ sequence of 8 pulses are transmitted, with a pattern of a few kHz frequency offsets. The details of these setting are programmable and are indicated in each raw data file.

The VIPIR provides full 16 bit raw In-phase and Quadrature data for all 8 receivers, range gates and frequencies, in a binary file format with the filename extension ‘.RIQ’ for ‘Raw Inphase & Quadrature’. These raw data are voluminous, about 250MB for each B-mode measurement. A useful level of compression, about 60%, is obtained by using the ‘bzip2’ lossless compression algorithm. Compressed data files are provided online.

The data files include extensive meta-data about the instrument, field site and settings used for each measurement. These data files, and graphical browse products similar to those presented here, are available from the US National Oceanographic and Atmospheric Administration National Geophysical Data Center (NOAA/NGDC). The URSI station code for this instrument is BD840 and the data are hosted at ftp://ftp.ngdc.noaa.gov/ionosonde/data/BD840/

Management of the large raw data files is non-trivial. Present bandwidth limitation to the facility prevent real time transfer of these files, although ionogram images are small enough to be moved in real time. Raw data files will be archived by NOAA/NGDC and made available online as resources permit.

5 Software

The author has FORTRAN-95 software to decode the VIPIR raw data files, which is available by request to the author by email Terry.Bullett@noaa.gov or a telephone call to 01-303-497-4788. This software also describes the format of the VIPIR data files, to aid the development of your own decoding and analysis software.

6 Future Observations

The VIPIR and Digisonde at Boulder share an amplifier and transmit antenna, so they cannot be run simultaneously, but can alternate their use of the shared assets. The recently refurbished Digisonde is in good maintenance condition and routine operation is intended for the foreseeable future. This will provide continuity and consistency of real time observations from this location, and will occupy time slots of 5 minutes, starting at 0, 15, 30 and 45 minutes of every hour. The remainder of the time is available to the VIPIR for routine or experimental observations.

7 Acknowledgements

The development of a new ionosonde is a large effort, for which the author can only take partial credit. The following people and institutions were vital to the success of this effort.

- Robert Livingston and Richard Grubb, for their VIPIR design and development effort.
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- NASA Sounding Rocket Program for supplementary R&D support.
- NOAA National Geophysical Data Center for material support and use of the Boulder Ionosonde Station.
- Bill Wright and Nikolay Zabotin, for their scientific inspiration to pursue the development of a new generation ionosonde.

8 Figures

Figure 1: Boulder VIPIR, November 2008

Figure 2: Boulder Ionosonde Station, March 2006

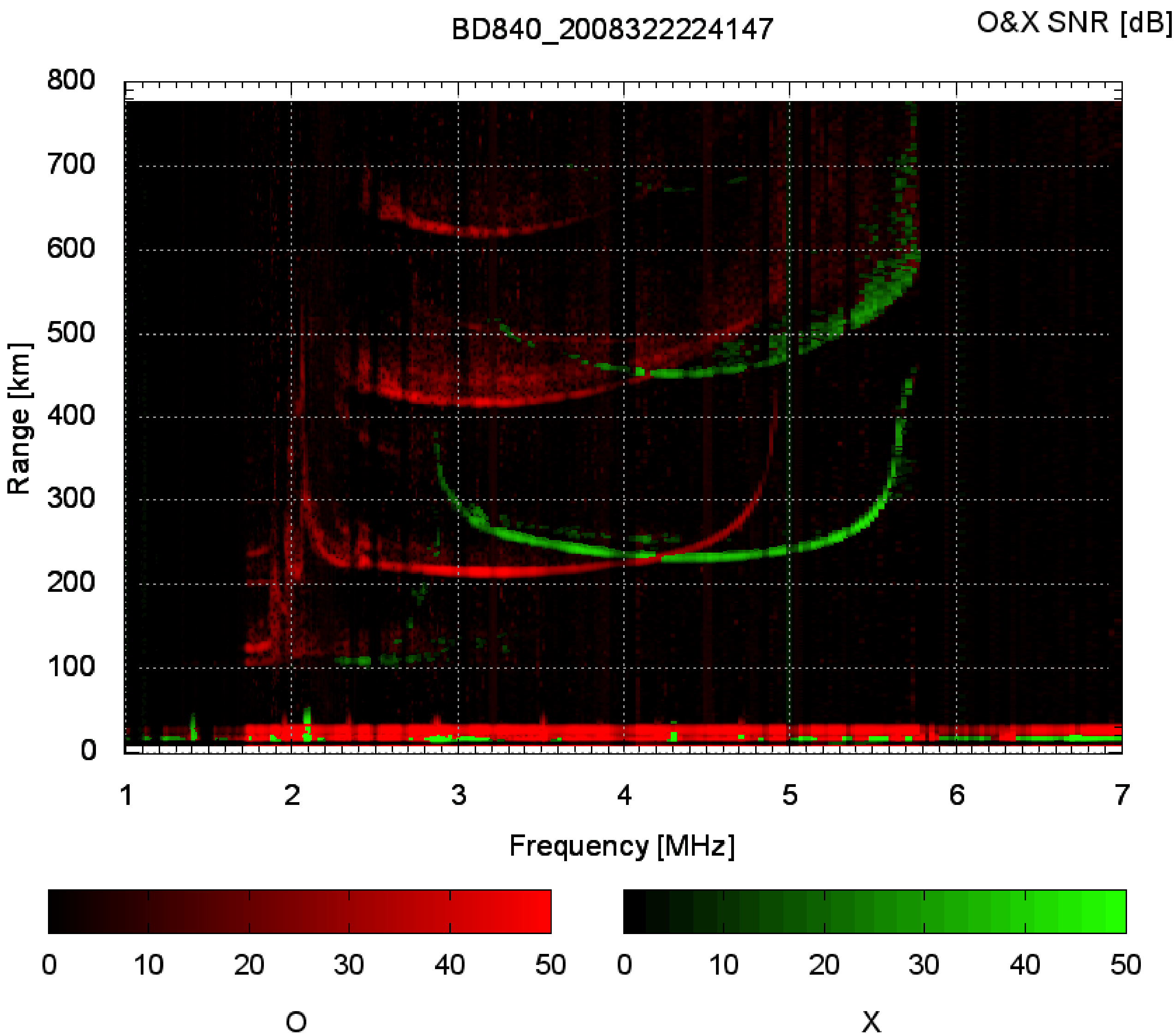

Figure 3: Boulder VIPIR First Ionogram, from 17Nov08 at 15:42LT.Signal to Noise Ratio (SNR) is plotted for O (red) and X (green) polarized signals.

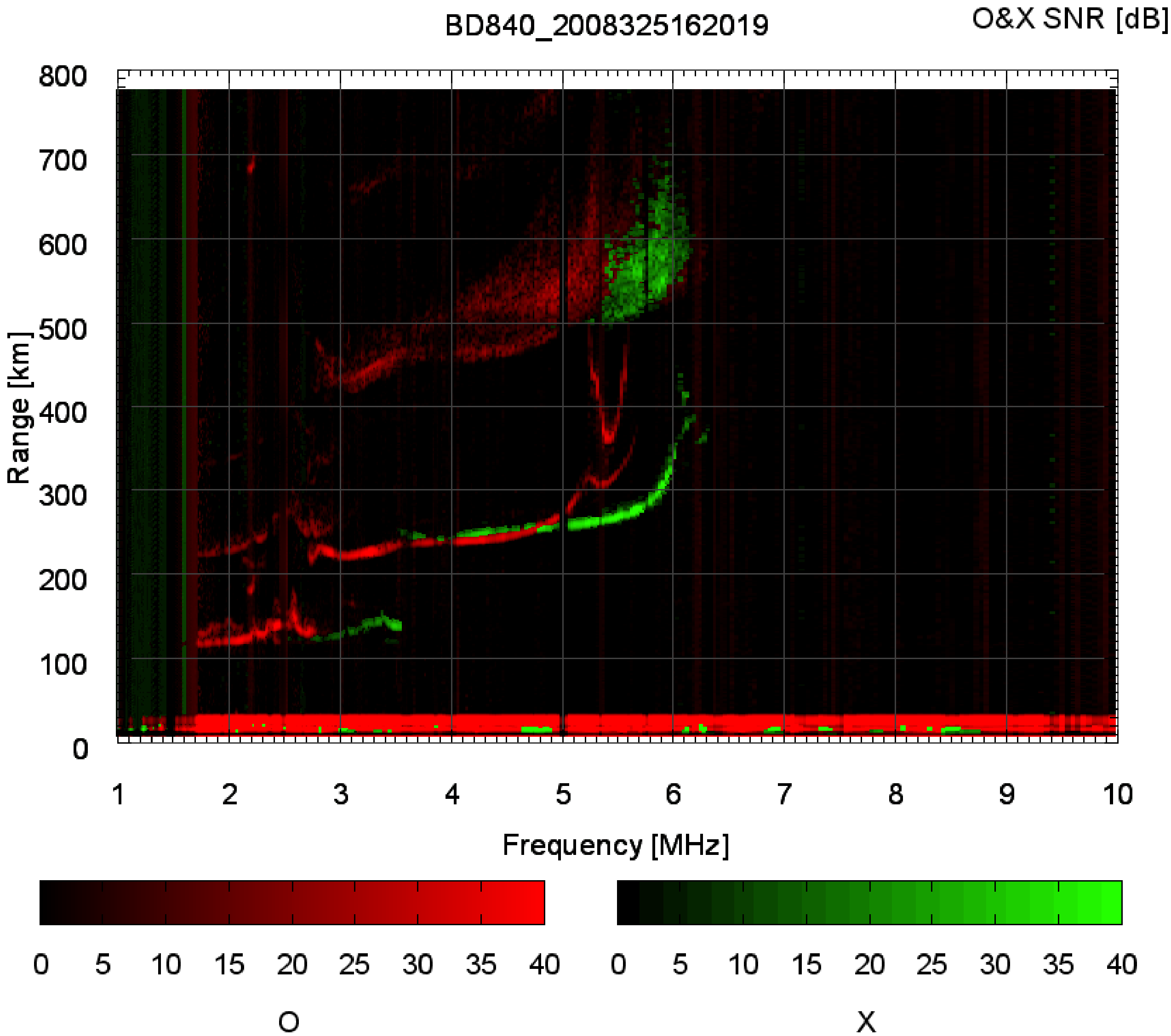

Figure 4: Boulder VIPIR daytime ionogram (20Nov08, 09:20LT) indicating E and F layer dynamics.

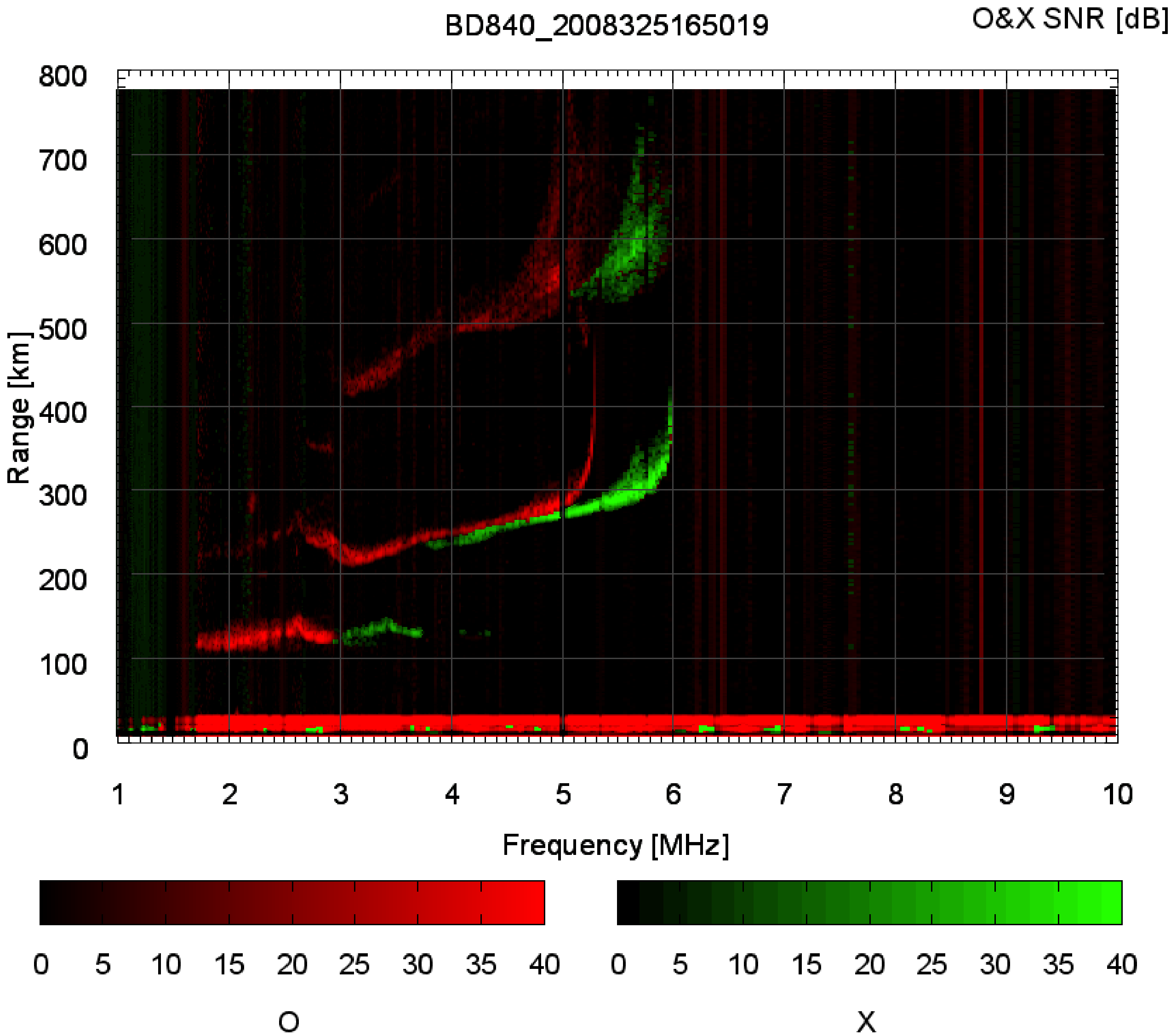

Figure 5: Boulder VIPIR ionogram (20Nov08, 09:50LT) with localized spreading in the F trace cusp.