Keo Scientific RIOMETER

The Keo Scientific Riometer

A RIOMETER (Relative Ionospheric Opacity METER) is an instrument used to quantify the amount of electromagnetic wave ionospheric absorption in the atmosphere. As the name implies, a riometer measures the "opacity" of the ionosphere to radio noise emanating from distant stars and galaxies. In the absence of any ionospheric absorption, this radio noise, averaged over a sufficiently long periods of time, forms a quiet-day curve (QDC). Increased ionization in the Earth's ionosphere will cause absorption of radio signals and thus a departure from the QDC. The difference between the QDC and the riometer signal is an indicator of the amount of absorption. The first riometer was developed in the mid 1950s by scientists at the University of Alaska who were studying the effect of auroral particle precipitation on radio wave propagation.

Commercially-produced riometers in the last three decades have largely been of the analog-servo variety, with nearly all of them produced by La Jolla Sciences, Inc. While the approach taken by the La Jolla on their excellent systems was in the past state-of-the-art, the techniques embodied in the design come from a pre-ubiquitous-computing era. In effect, the servo-mechanism may be considered a crude "analog computer" implementing a very simple, narrowly-focused algorithm.

The emergence of relatively inexpensive DSP techniques in the 1980s suggests that the 1950s-era servo design could reasonably have been re-visited at that time, but never was.

Five years in the making, Keo Scientific's riometer may be considered a 'next-generation' riometer.

In backyard and small-instrument radio astronomy, the most common instrument configurations for riometry, continuum astronomy or low-sensitivity solar observations are the *Dicke radiometer* and the *phase switched interferometer.* We are employing SDR-based alternatives to these systems. Our RF front-end is simple, and small, and has only enough gain to drive our RF sampler, thus reducing inherent gain fluctuations. Furthermore, our front-end is temperature stabilized, thus reducing further instability to negligible levels, even for fine-structure absorption studies.

A purely-analog design makes many aspects extremely difficult and often expensive to implement, including frequency and bandwidth agility. The modern RF environment, however, is utterly-hostile to the type of science that riometers are trying to address. Even in the so-called protected sections of the RF spectrum, narrow-band RFI is an ongoing problem that can render-useless a large numbers of scientific observations. By leveraging recent innovations in RF technology, we have produced a riometer that is agile and robust, meeting all of the requirements of radio-based ionospheric science in the noisy modern world.

Our unique approach means that new features can be implemented entirely as software updates that can be installed remotely, a benefit not enjoyed by traditional analog riometers.

Specifications

- Multi-frequency: Four "sky" channel
- Frequency agile: Each of 4 channels tunable anywhere between 24MHz and 1700MHz. This is overkill for Riometers, but it speaks to the flexibility and capability of the approach employed.
- Dual-reference channels, averaged together to cover the frequency range of the Riometer.
- Temperature-controlled reference source: Provides excellent stability equal or better than Ryle-Vonberg or Dicke-Switched radiometers.
- Reference temperature, monitored in real-time, and calibration parameters adjusted accordingly in real time.
- Noise figure: < 3dB.

- Dynamic range in detector: Better than 50dB. Conventional diode detectors have very limited dynamic range, so their use in environments where one wants high dynamic range (such as in deep absorption events) tends to be problematic. The Keo Scientific riometer does not suffer from such limitations.
- Gain stability: 0.012dB in eight hours (verified). This is approximately a factor of 20 better than what is needed for measuring both the QDC, and "typical" absorption events. **However, such good stability enables one to reliably observe more subtle absorption events, where it is very possible that cutting-edge science may be hiding.**
- Digital design, with digital receivers in environmentally shielded enclosure right up at the antenna. This avoids stability-reducing feed-line re-radiation.
- User-variable detector bandwidth, from 10 kHz to 200kHz (or 800kHz on a more-capable computer).
- Out-of-band rejection: Better than 60dB. One may also take advantage of flexible bandwidth "trimming" to get away from narrowband RFI.
- Antenna: A custom designed variant of LWA "blade" antenna for uniform, broad, frequency response.
- Frequency accuracy: 1PPM.

Notes

- This multi-frequency riometer gives the end-user the ability to select operating frequencies and detector bandwidth on-the-fly. This is a vast advantage over traditional riometers. The multi-frequency approach gives one the ability to select "frequencies of opportunity" apart from the "official" frequencies often used for riometers. If, say, 300kHz around 33.123MHz, is found to be never-occupied at a given site, then one may elect to use it. As everything is defined in software it is straightforward to provide a "Mapping Out" Mode for the riometer, wherein it spends a week mapping out the frequency ranges that aren't apparently in use in any meaningful way, at the deployment site, and then settles down and uses these.
- Because nearly all of the signal-processing is done in software, there's tremendous down-stream flexibility available as upgrades/add-ons don't typically require swapping of RF hardware.
- Through software, this Riometer can also be turned into a scanning spectral riometer (as opposed to a wide band FFT spectral riometer) - using a hybrid approach of "stitching" multiple FFTs (one from each receiver) together to form a real-time spectral estimate. I.e., one may span about 1.5MHz of bandwidth on each receiver at any given instant, so one could cover 25 to 45MHz very quickly, and get a "near real-time" spectral estimate over the entire riometry band.
- By using a different receiver that is able to be made phase-coherent over significant bandwidth, a phased-array of such riometers can be constructed ("imaging riometer").