Installation and Operation of the KC3EEY/W2NAF VLF Reception System

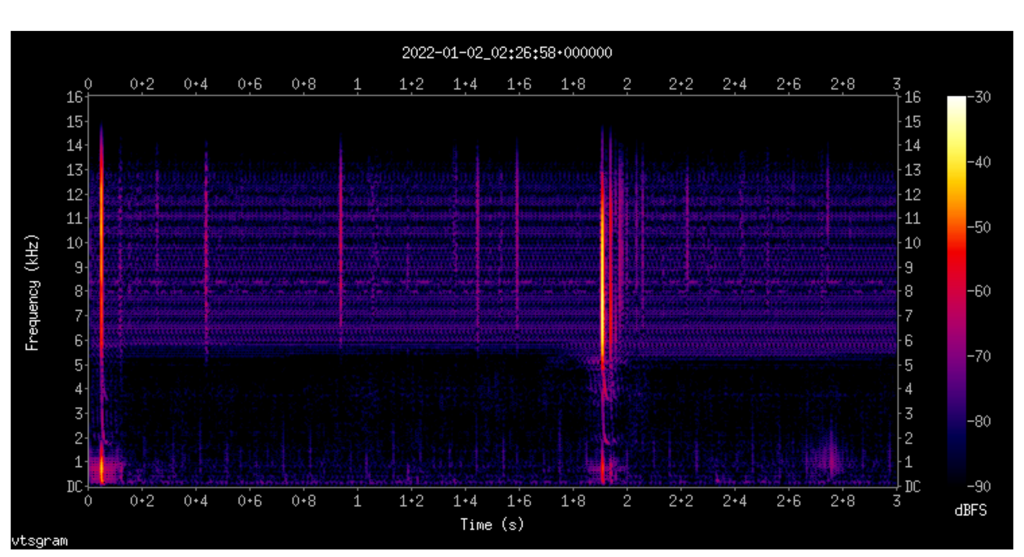
Jonathan Rizzo KC3EEY[1], Dr. Nathaniel Frissell W2NAF[2]

[1]HamSCI, [2]University of Scranton

Installation at the W2NAF/KC3EEY VLF Observatory

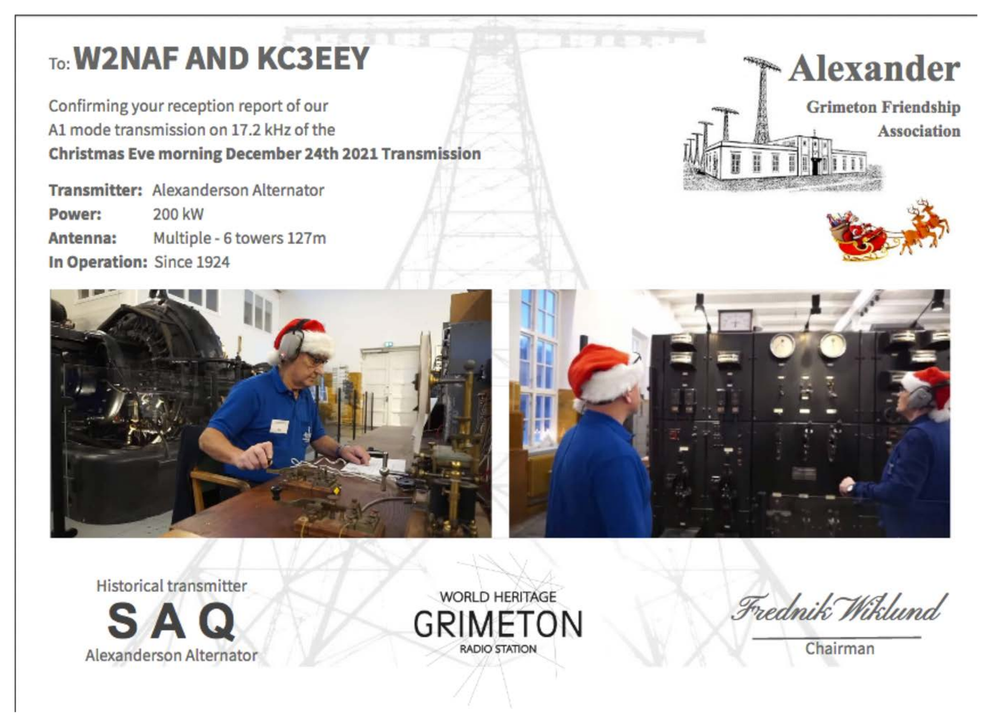
Installation of the VLF reception system consisted of trenching, laying conduit, and pulling the feedline through at the W2NAF KC3EEY VLF Observatory in Springbrook Township, PA, US. The VLF Active Antenna consists of an antenna element made of copper tape attached to a foam insert and a VLF preamp board encased in a PVC pipe. The feedline is a Cat 6 cable using two pairs, one for power delivery and one for signal. Inside the shack is a Raspberry Pi with Audio Injector Stereo soundcard and a GPS timing receiver. The signal is captured and GPS timestamped, then filtered and processed to detect natural radio events like sferics, tweeks, whistlers, chorus, and triggered emissions, as well as VLF transmitters and amateur VLF/ULF transmissions. For more information on this system, please see my HamSCI 2020 ePoster and presentation, *Using a PVC Pipe Antenna and a Raspberry Pi to Detect VLF Natural Radio.*

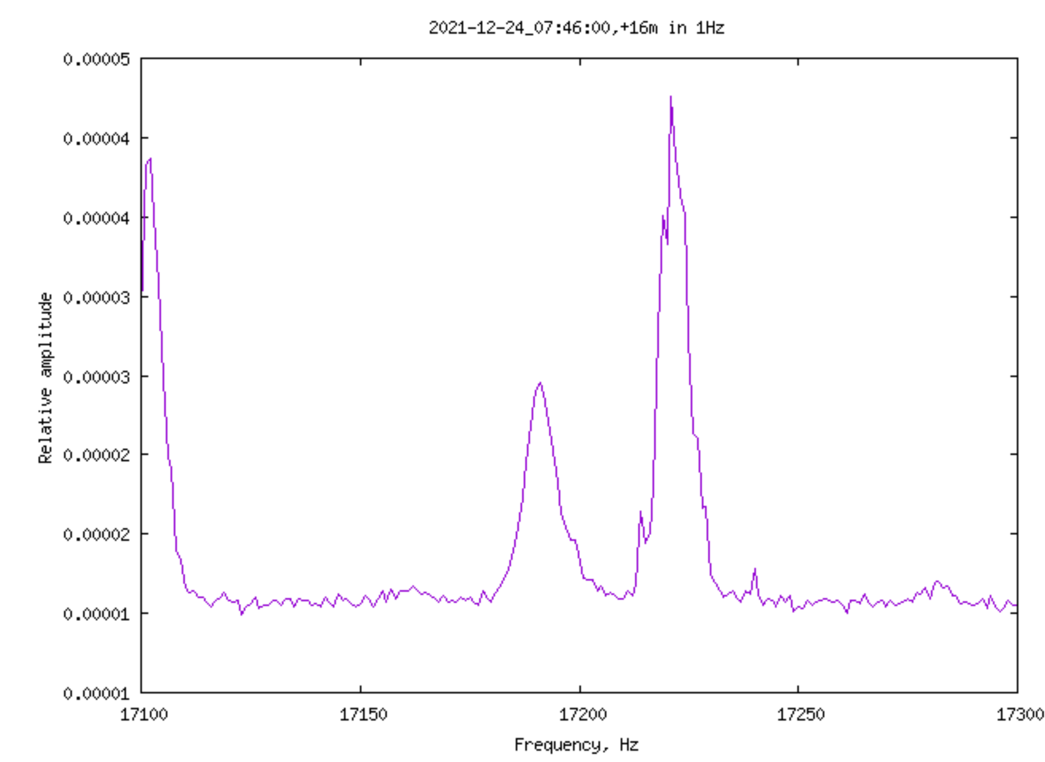
Natural Radio Events



Seen here are a type of natural radio emissions called tweeks captured with the VLF reception system in Springbrook Township, PA, US. Tweeks are sferics which have some of their frequency components dispersed by a scale of milliseconds, where the frequency dispersion occurs at the tweek resonant frequency of ~1.7 kHz, a resonant mode of the Earth-ionosphere waveguide. Tweeks propagate tens of thousands of miles and can be detected at night when the D layer disappears. This is a spectrogram created from recorded VLF spectrum captured on the VLF reception system. Notice some tweeks are multimode, where dispersion occurs on multiples of the tweek resonant frequency.

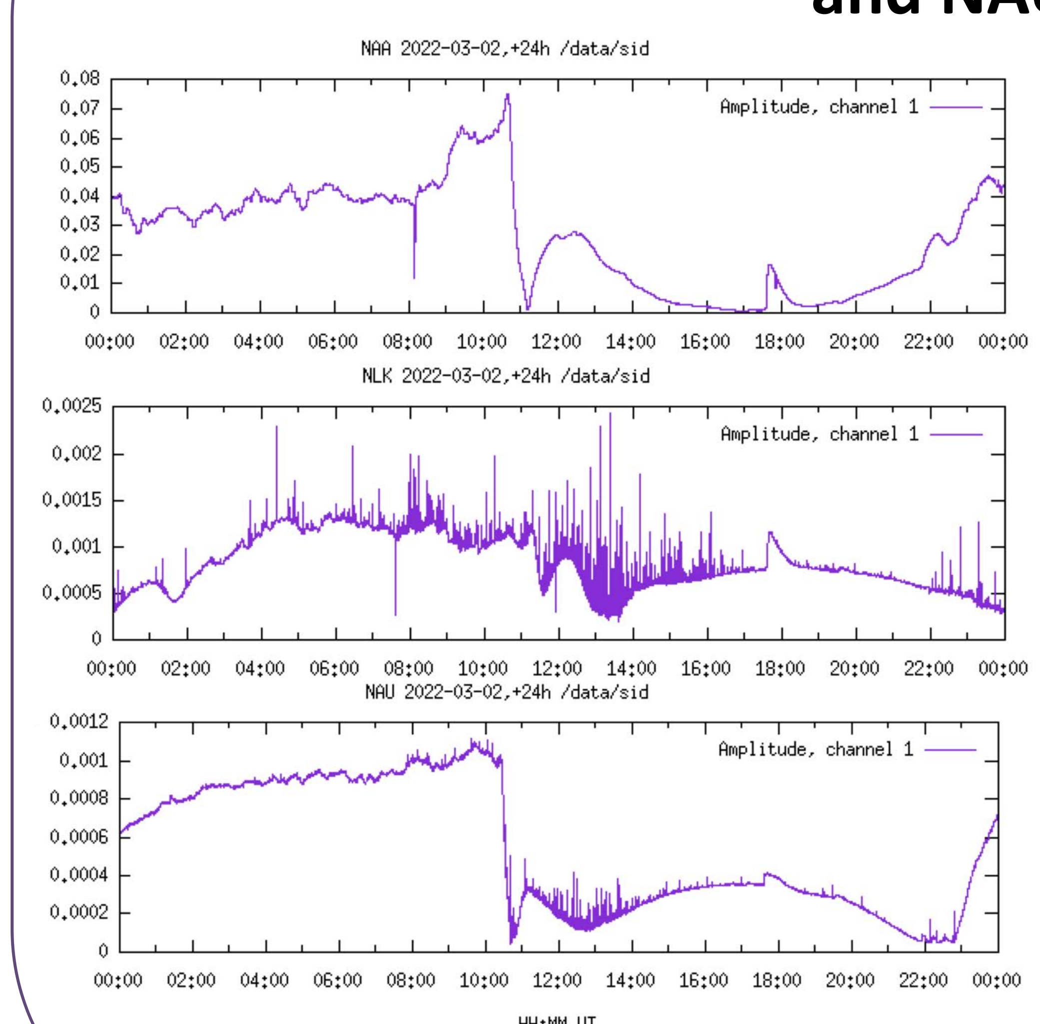
Reception of the SAQ 2021 Christmas Eve Transmission





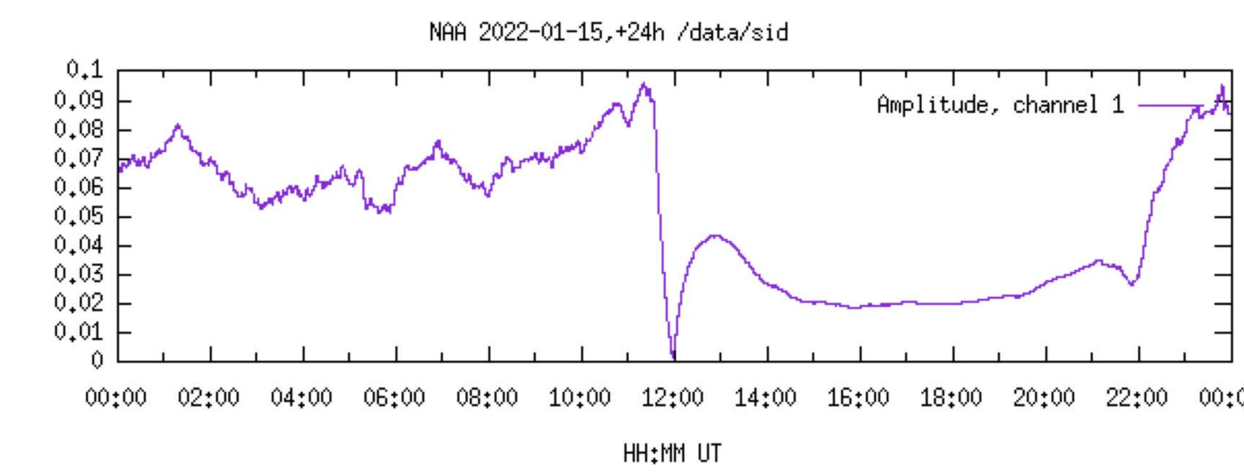
On December 24th, 2021, the Alexanderson Alternator was spun up for the annual Christmas Eve transmission from the SAQ VLF station in Grimeton, Sweden, at a frequency of 17.2 kHz. A QSO at Springbrook Township, PA, US was possible with the VLF reception system using signal processing. On the top right, a 200 kHz spectrum plot integrated over the duration of the whole transmission showing the power spectrum and a signal peak at ~17.150 kHz. Even with a peak of 3µ relative amplitudes above the noise floor, audible CW was able to be copied! Assuming a transmitter power of 3.1kW ERP based on LWPC modelling using a calibrated receiver at another location, it was estimated from LWPC modelling that received field strength at the antenna was 22 µV/m with VLF background noise at 8 µV/m in 1 Hz. After capturing, the spectrum was brick wall bandpass filtered, centered at the transmission frequency of 17.2 kHz and 1000 Hz wide, then downmixed to 500 Hz for audible copying. It was then fed through a Butterworth bandpass filter 20 Hz wide that made copying even easier. There was observed fading, but some of the message was able to be decoded! On the upper right image, a QSL card from the Alexanderson Association confirming QSO of the transmission!

Sudden Ionospheric Disturbance (SID) Event Observed on NAA, NLK, and NAU on 3/2/2022

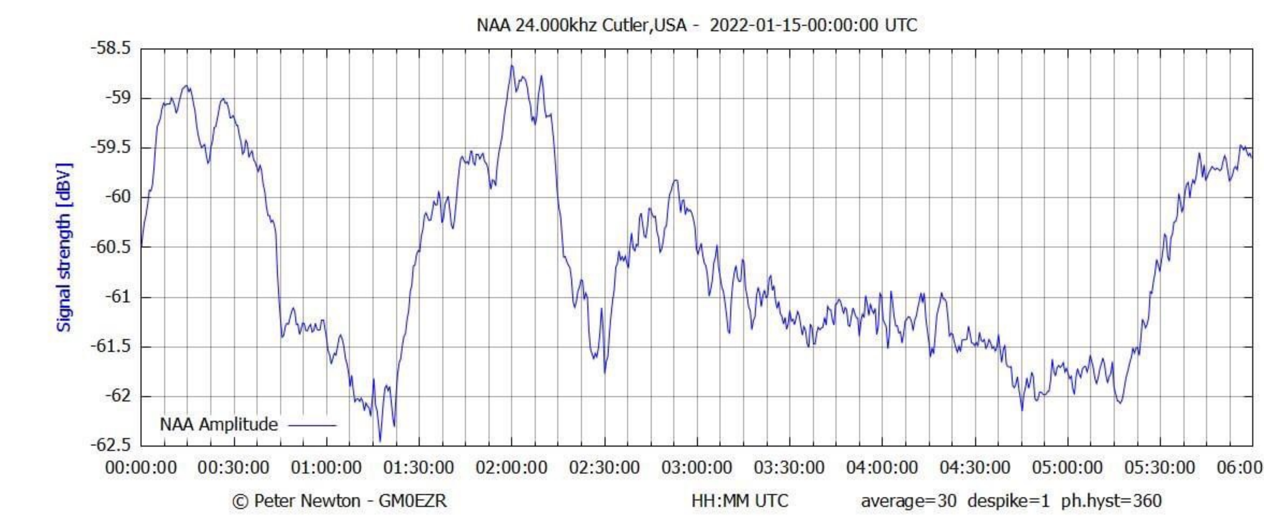


A Sudden Ionospheric Disturbance (SID) event was observed on three Navy VLF transmitters at the Springbrook Township, PA US location! SIDs occur because solar flares generate a sudden and intense burst of UV and X-Ray radiation which perturbates the dayside D and E layers of the ionosphere by creating an increase in ionization density. At VLF frequencies, this perturbation causes a sudden enhancement in propagation, usually within the time span of an hour. At HF, SIDs cause a diminishing of propagation. Gamma Ray Bursts (GRBs) from distant, extragalactic objects can also create an increase ionization density that also causes a sudden enhancement of propagation. Seen in the plots on the left are Navy VLF transmitters NAA at 24 kHz, NLK at 24.8 kHz and NAU at 40.8 kHz, a SID occurring shortly after 17:30 UT and lasting about an hour. Observed SIDs in VLF transmitters are propagation path-dependent, so this accounts for the variation in enhancement amplitude as seen in the plots. A characteristic of SIDs seen in VLF is the sudden propagation enhancement which often occurs in the span on 10 minutes or so. One way to verify a SID is to look at GOES X-Ray flux data. The peaks should match up temporally with the observed propagation enhancement, indicating a possible solar flare event occurred. The benefit to the VLF reception system is that many VLF transmitters can be observed with a single VLF antenna and preamp using vlfrx-tools software. vlfrx-tools has a utility called vtsid that can record amplitude and phase data of each VLF transmitter from inputted VLF spectrum data captured using the soundcard. It's so exciting capturing a SID on three different VLF transmitters from one location!

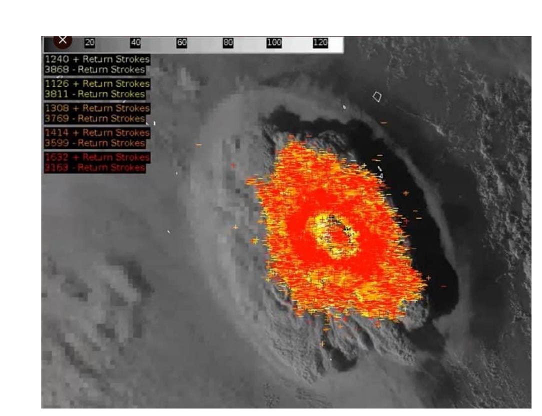
Possible Ionospheric Perturbation and Sudden Enhancement of Atmospherics (SEA) Event Caused by the 1/15/2022 Tonga Eruption

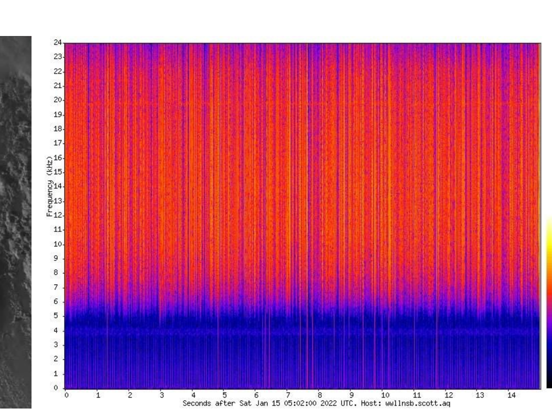


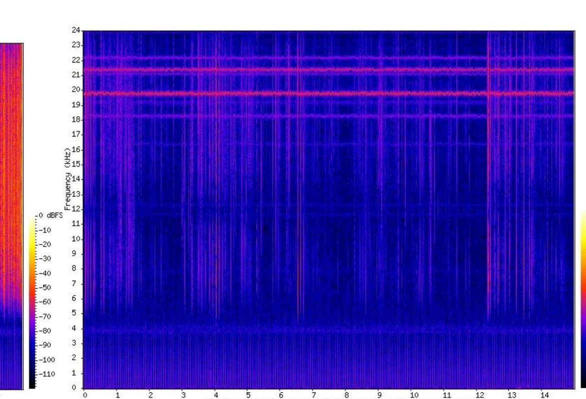
In this plot of NAA above captured at the Springbrook Township, PA, US, at 5:00 UT, a noticeable reduction in signal amplitude can be observed. This could be caused by either a Sudden Enhancement of Atmospherics or a perturbation of the ionosphere along the propagation path due to the eruption's pressure wave.



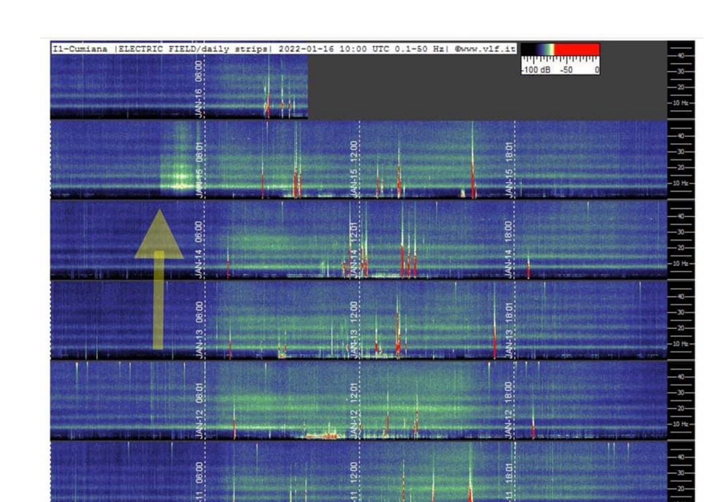
In this plot of NAA captured at Fife, Scotland by Peter Newton GM0EZR, the same reduction in amplitude can be observed at the same time.







In the image on the left (credit to @ChurchillWx), are a map of sferics superimposed over a visible satellite image. It's absolutely amazing that the ash cloud caused by the Tonga eruption generated an enormous amount of lightning! In the center (credit to the WWLLN receiver owner), a WWLLN spectrogram of the VLF spectrum in Scott Base, Antarctica, showing absolutely intense sferic activity at 5:00UT! On the right, in contrast, is the same spectrum only an hour before, showing a very small amount of sferic activity with mostly distant sferics.



The image on the left (credit to Renato Romero IK1QFK) are stacked spectrogram plots of the Schumann resonances, or the resonant modes of the Earth-ionosphere waveguide. These resonant modes are in constant excitation due to worldwide sferics. At around 5:00 UT as shown by the arrow, an intensity in excitation can be observed due to the SEA created by lightning from the Tonga eruption ash cloud.

In Gratitude:

I'd like to thank Dr. Nathaniel Frissell for hosting the VLF reception system at the W2NAF KC3EEY VLF Observatory. I'd like to thank Paul Nicholson for vlfrx-tools, his contributions to me, and the VLF community at large. I'd also like to thank those credited to the annotated images. The authors thank the support of NSF Grant AGS-2002278.