Modulation – Demodulation Software Radio

Can Earthquakes change and create Shortwave Propagation?

(A 4-year study of measuring background noise and propagation concludes that this is the case.)

Goups.io user group: https://groups.io/g/MDSRadio

MDSR website: http://users.skynet.be/myspace/mdsr

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1. Intro:

There is well-established scientific evidence (ref 1,2) that earthquakes cause changes in the ionosphere. Experimental results, reported here, support that conclusion by presenting recorded changes in the ambient noise level at shortwave frequencies during an earthquake.

Furthermore, recently published experimental results from Los Alamos National Laboratories (ref 3) for the Cascadia fault, and theoretical results (ref 4) predicting that sound waves carry inertial mass, show that tectonic effects can be detected prior to the release of an earthquake, contrary to the current scientific consensus (ref 5).

The RF-Seismograph recorded such an event on Nov 1st. The spikes and the signal dropouts that were recorded could not come from space, due to solar inactivity (see case study in article). It also caught the eye of the RF-Seismograph team and we went and investigated the phenomena. At the same time, while listening to the local news radio station, it was announced that there had been an earthquake, a M4.9, just north of Vancouver Island! The times of the quake and the measured spike matched in time!

Now, the RF-Seismograph team has been collaborating with USGS to find a correlation between HF propagation and earthquakes. USGS has provided us with a list that contained 171 M6+ earthquakes for the 4 years the RF-Seismograph has been collecting data.

We have recreated the data of the propagation and noise level measurements on days that had a M6+ earthquake and see how much of a change there was visible in our measurements. The findings will be discussed in the following pages.

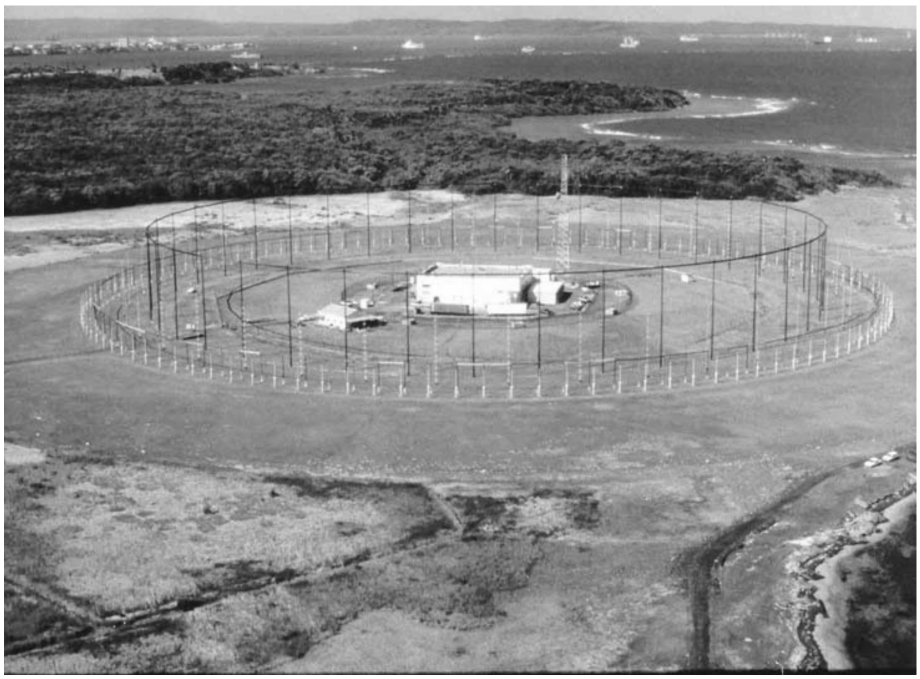
Using the RF-Seismograph, we are slowly starting to understand more on how the field lines that earthquakes create behave and change propagation. Considering the fact that there are over 1000 quakes (mostly small ones) every day, it becomes quite clear that earthquakes are responsible for a large part of propagation, especially on the lower bands and during solar minimum.

Note: The RF-Seismograph system was developed to measure and collect data on the changes in the ionosphere and radio propagation during the solar eclipse. It uses a shortwave radio and a multi-band vertical antenna to measure background noise and amateur radio transmissions. After the eclipse the team decided to leave the RF-Seismograph running, and now we are in the 4th year of operations. For more info on RF-Seismograph go to: http://users.skynet.be/myspace/mdsr/index.html

1. History of HF Monitoring

To monitor the HF background noise and to intercept radio signals is nothing new. It has been done by the military for a long time. They must have seen the same spikes, noise increases and propagation changes, but could not correlate the events with earthquake times. So most of the noise changes were considered to be unknowable or caused by the sun and ignored.

Fortunately, we now have the Internet. We can now easily call up information on earthquakes with an amazing detail and on a real time basis; thanks to USGS. The Internet made it possible for us to gather all the information and correlate the times of the earthquakes with the reception of signals and the interference caused by them.



Picture of the **AN/FRD-10** HF Monitoring Station, Galeta Island, Panama

Technical information

- **Country of origin:** United States
- **Introduced:** 1961
- **Type: Wullenweber antenna array**
- **Frequency:** Low Band 2 MHz - 9 MHz; High Band 9 MHz - 32 MHz
- **Inner Array Antenna radius:** 393.5 ft (119.9 m)
- **Inner Array Reflector radius:** 366 ft (112 m)
- **Outer Array Antenna radius:** 436.75 ft (133.12 m)
- **Outer Array Reflector radius:** 423.5 ft (129.1 m)
- **Range:** 3,200 nautical miles (5900 km)
- **Antenna Cost (1970)**: $900,000 ($5.81 million today)
- **Electronics Cost (1970):** $20 million ($129 million today)
- By combining multiple stations, a radio signal could be traced to a 100 km^2 area anywhere in the Atlantic or Pacific.

A total of 16 stations were built, 14 in the USA and US bases around the world, and 2 in Canada. The 2 located in Canada and the one in Puerto Rico are still in operation by remote control; the rest have been demolished.

2. How do Earthquakes create Electromagnetic Fields that change propagation?

The science on electromagnetic fields of earthquakes has been discussed for many years and excellent papers and books exist on this subject (see reference at the end). But geologists have never embraced this part of an earthquake, because it is dangerous and cumbersome to collect data on site. Most of their instruments are mechanical and need to be on location in remote, inaccessible parts of the planet to work properly.

The piezoelectric effect and micro-fractures are the main contributors of electromechanical processes during an earthquake. All of them have been confirmed in lab tests as valid physical processes that can create electricity using mechanical energy. When free electrons flow along the path of least resistance field lines are generated. Field lines are a part of electricity and do not exist on their own. Since all the processes must occur before the quake, it will be possible to measure the changes several hours before the quake releases.

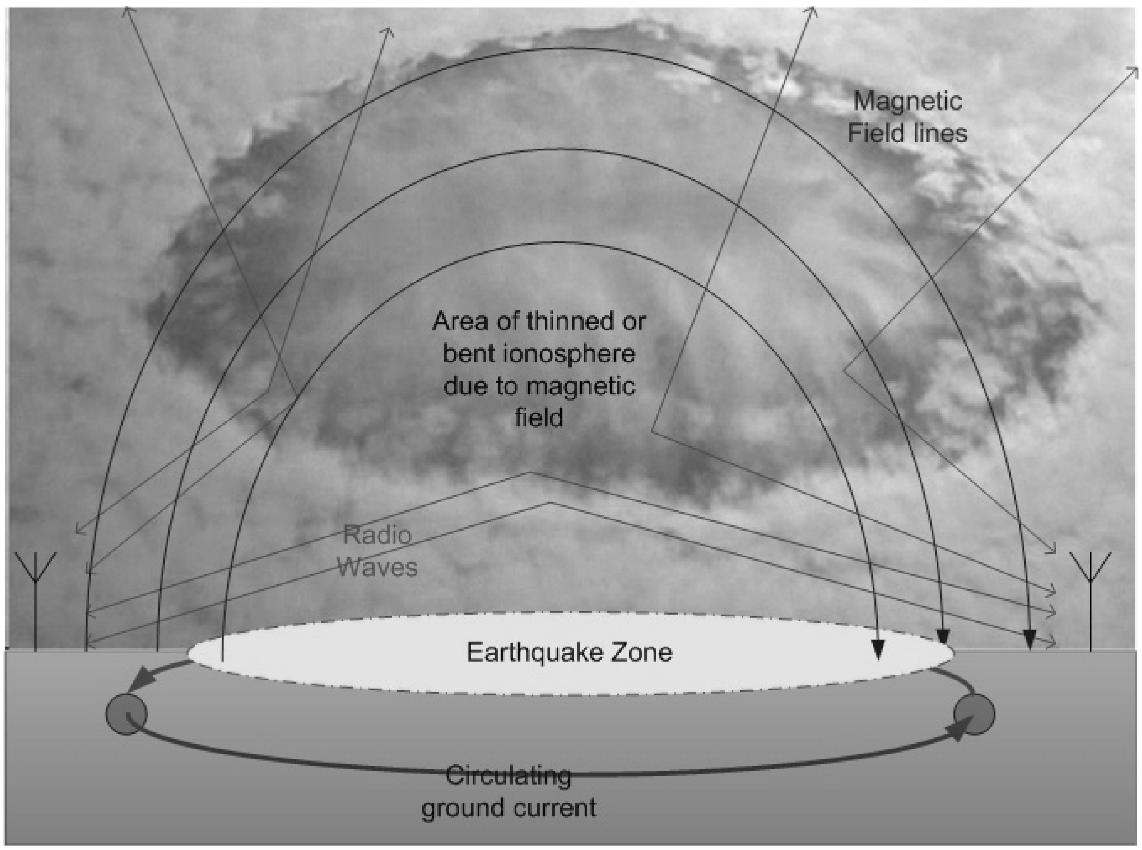
How does an earthquake build up before the actual release of mechanical vibration

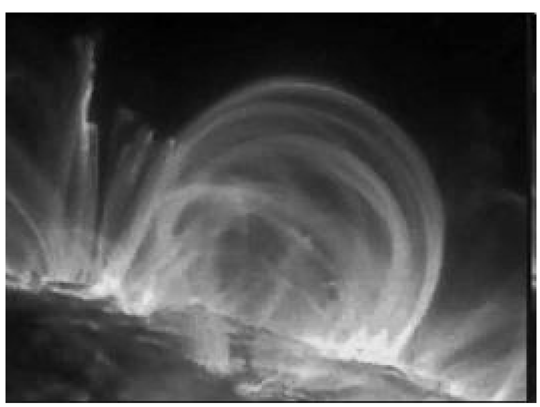
- Piezoelectric effect of rocks sliding and vibrating on top of each other.
- Micro-fractures of rocks releasing vast amounts of free electrons.
- Electrons move up towards the surface or sea-floor and circulate around the quake area.
- Electromagnetic fields start to emerge out of the earth crust and move upward towards the ionosphere.
- Since the ionosphere contains charged particles, the magnetic field interacts with the ions and creates a hole or a dome of charged particles, affecting radio waves passing through (see graphic below).
- For more information see Scientific American Oct. 2018: "Earthquakes in the Sky" and reference at the end.

3. Distortions of the Ionosphere by Earthquakes

The ionosphere is constantly morphing. Well understood is the impact of the solar wind and solar flux on the ionosphere and the earth's magnetic field. The 24 h day and night and seasonal changes are very well represented in models that we use every day to predict propagation.

The image below shows how magnetic field lines of an earthquake reach into the ionosphere and disturb or bend the layers, breaking existing radio paths or creating new ones. The signals which the RF Seismograph receives drop out, or new connections only last for a few hours while the quake is active.





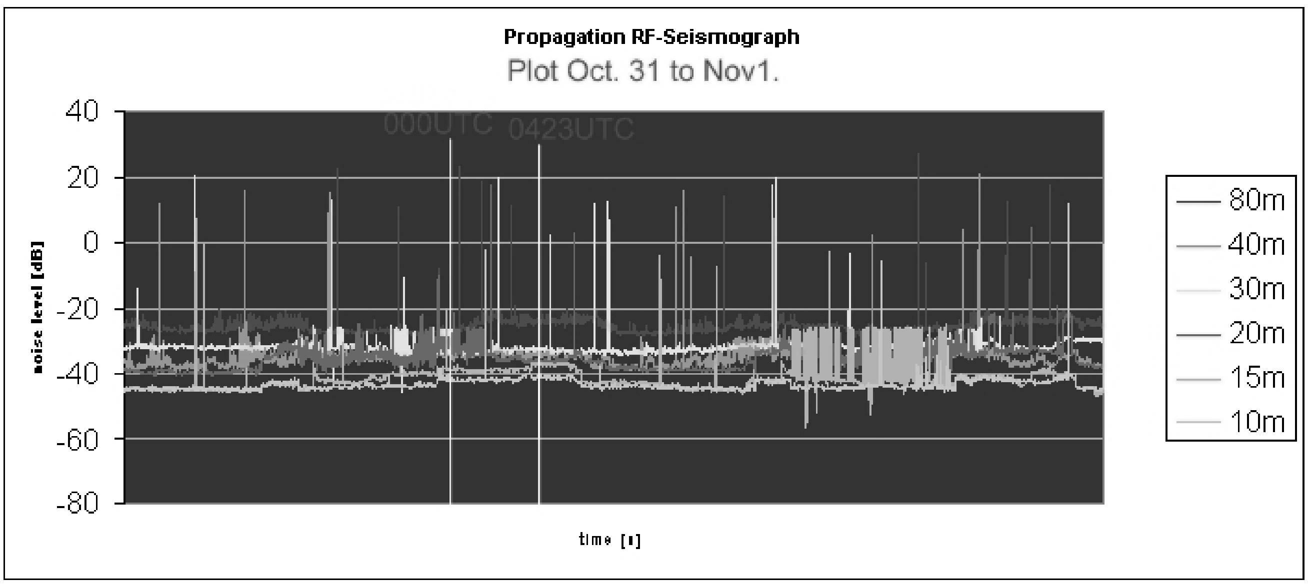
This can be seen as the equivalent of a magnetic field shooting out of the surface of the sun. Because of the hot plasma, the field lines are visible. This process on the sun is much more energetic than an earthquake here on earth, but the physics are the same.

5. **How are earthquakes** visible on the RF-Seismograph?

The different stages of the quake as seen by the RF-Seismograph

(Case study for M4.9 event, 256 km SW of Pt. Hardy, N-Vancouver Island, BC)

- Energy buildup – noise increases on 80 m (red) starting at 00:00 UTC.
- Disruption of 40 m, 30 m and 20 m bands – communication dropout (lines go flat).
- Quake releases at 04:23 UTC.
- The energy buildup and blackout continues after this quake for the same time the before the quake (2 h) for at total of 4 h.
- After the energy is released, the ionosphere starts to rebuild slowly and normal communication continues.



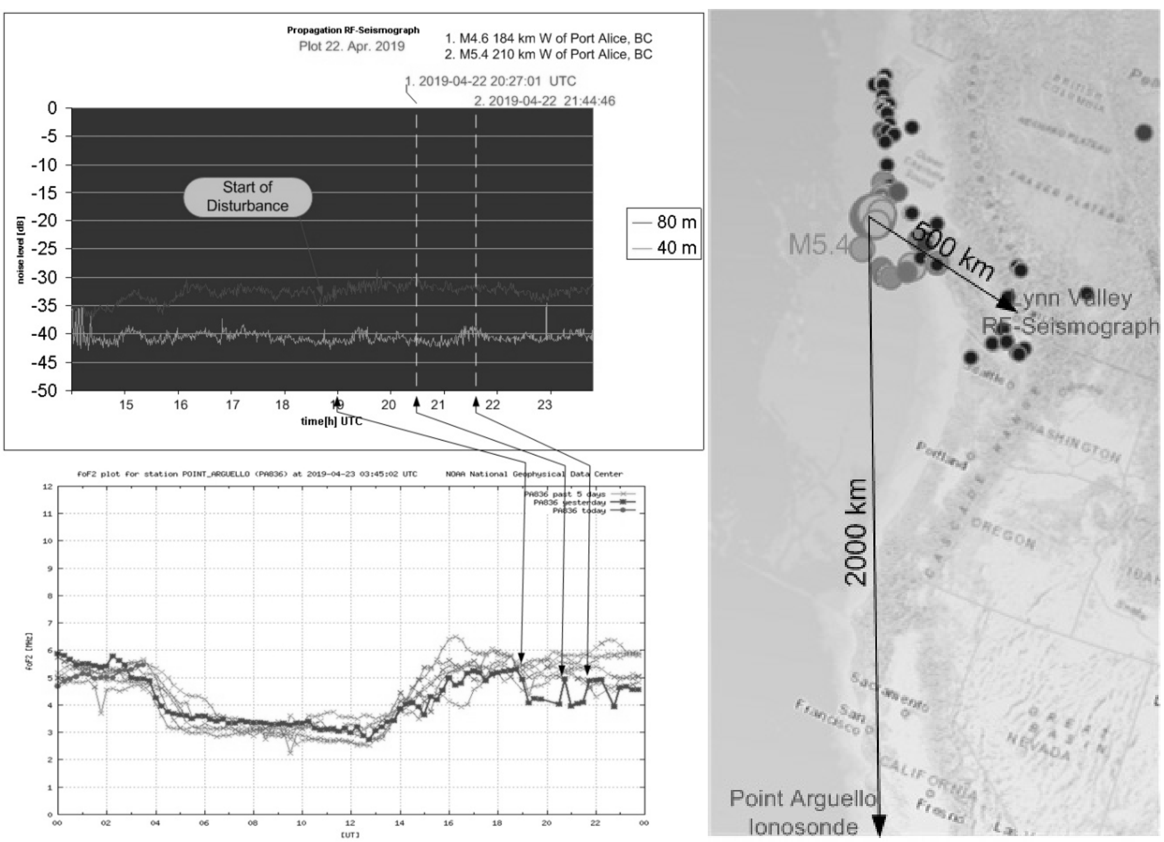
Note: The sharp vertical spikes are static crashes. They can also be produced by breaking field lines.

6. Comparison: RF-Seismograph vs. Ionosonde

The fault line north of Vancouver Island is very active. It releases medium-sized quakes multiple times per year. Usually there is one larger tremor with several aftershocks. Such a series of two earthquakes, within 1 h, have occurred in the Pacific, NW of Vancouver Island on 22nd April 2019. Both of them were picked up by the RF-Seismograph; the first one, on 80 m (top graph, top line) and second one on 40 m (top graph, bottom line). The Ionosonde at Arguello Pt. (lower graph, thick line) picks up the changes as well and even shows the individual quakes as spikes. Even though the Ionosonde and the RF-Seismograph measurements agree in this case, the Ionosonde network does not pick up quakes as easily as the RF-Seismograph.

There are three big difference between the RF-Seismograph and the Ionosonde

- The Ionosonde only measures in one direction vs. the RF-Seismograph, which will pick up any signal from any direction with its omnidirectional multiband antenna. The main focus of the RF-Seismograph antenna is on the horizon, except for 80 m which uses NVIS (Near Vertical Incident Skywave) propagation.
- The data capture time for each frequency is 7 s with and interval of every 52 s. The Ionosonde records changes in the ionosphere only every 15 minutes! The minimum frequency of an earthquake as described in "**Computation of seismograms and atmospheric oscillations"** (see ref. at the end) is 0.00368 and 0.0044 Hz, with two ground periods of 271 and 227 s. Both frequencies are too fast for the scan time of the Ionosonde network.



- The RF-Seismograph is passive and listens to all digital amateur traffic on the bands it scans. It works like an oblique Ionosonde with no fixed transmitter. The RF-Seismograph uses RX only and therefore does not need a license to operate.

RF-Seismograph - Lynn Valley (top graph)

- detects a disturbance starting at 19:00 UTC,
- measures a peak on 80 m when the first quake releases
- measures a peak on 40m before second quake

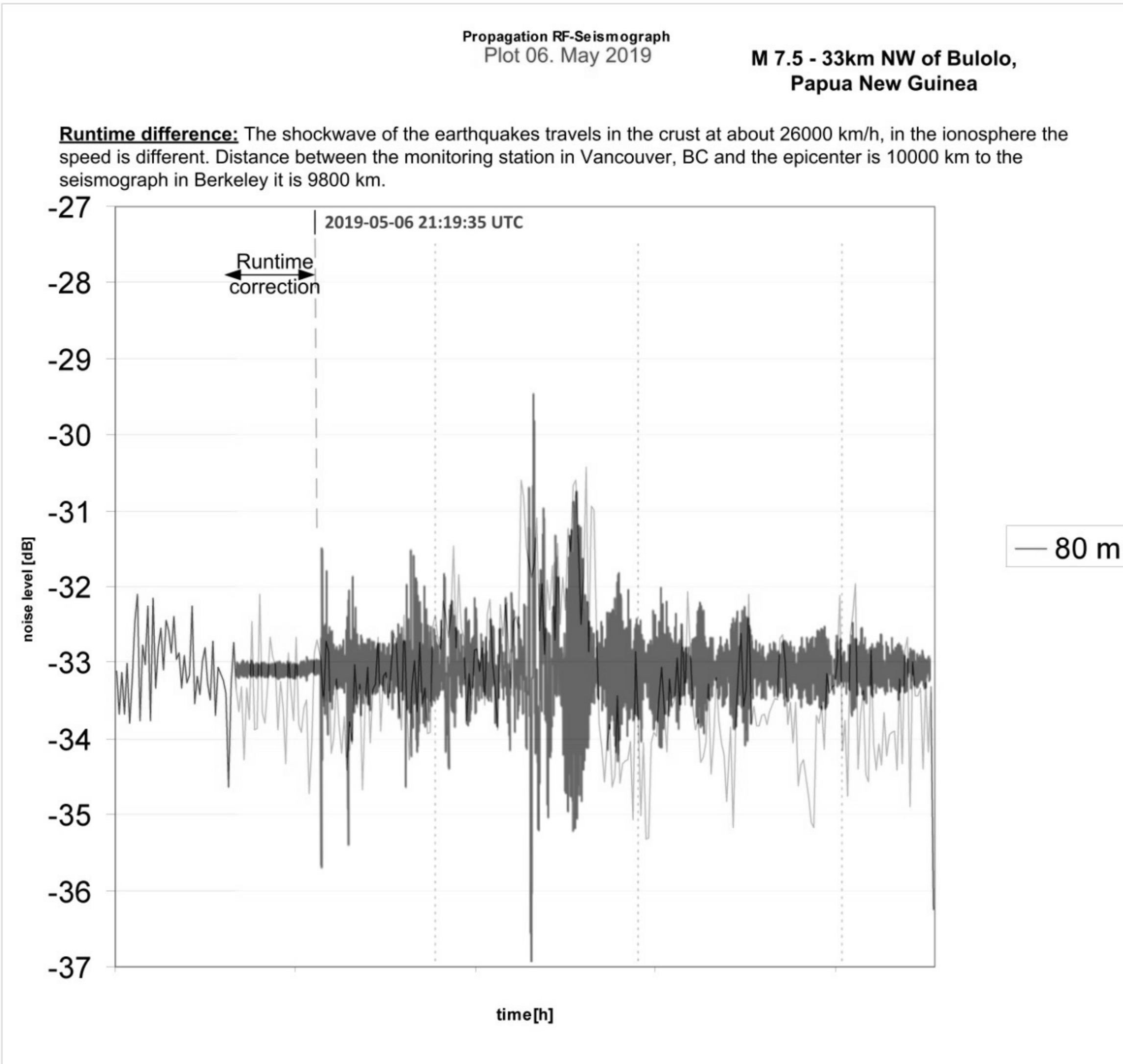
Ionosonde – Pt. Arguello (bottom graph)

- detects a drop in the foF2 frequency at 19:00 UTC
- measures a peak during the first quake
- measures prolonged peak during second quake

Note: one measurement only every 15 minutes

7. Comparison: RF-Seismograph vs. standard Seismograph

The USGS has a website where anyone can create their own seismogram (see ref. for details). This is how we recreated the black full wave graph of the M7.5 event that occurred in Papua New Guinea on 6th of May 2019. The RF-Seismograph also recorded this quake, and matching the two would proof that both were created by the same event.



- Earthquakes are very distinct and the wave energy released is like a finger print.
- The black graph is a full wave representation of the physical shock waves recorded by USGS.
- The red graph is the recording of the event on the RF-Seismograph (RMS) on 80 m. The main shockwave energy level and timing match the recording from USGS, confirming that both are caused by the same event.
- Since mantle shockwaves travel at different speed the events arrive at different times at the recording stations.
- Phasing distorts the outer pattern of the signals that travel over 10000 km in different media (crust vs. air).

8. The 4 Year Propagation vs. Earthquake Study

Why is it so difficult to prove that earthquakes have electromagnetic properties?

In previous studies the measurements were done on location, mostly using portable VHF radios with small antennas, and only one specific quake was measured at a time. This makes it very hard to 'catch the quake in the act'. It is also very dangerous and time consuming. If one stands right in the field dome and transmits VHF radio waves, they are at a steep angle to the field lines. The radio waves also penetrate the ionosphere perpendicularly. The ionosphere refracts VHF very poorly, making measurements difficult. In order to actually measure the effect on propagation with the RF-Seismograph, one has to be at least 500 km away from the quake and HF frequencies have to be used. This is necessary because we want to measure the radio signals that bounce back from the disturbed ionosphere.

Why is this study different?

Once we realized the very chaotic nature of earthquakes and linked this to the RF noise they generate (electromagnetic white wideband noise, from 0.0044 Hz into the VHF range), we understood why it is possible to study almost all earthquakes from one location (besides triangulation). By using HF and considering the fact that earthquakes can create RF signals that have several megawatts of power output (possible even more), they are easy to pick up on 80 m. By correlating the time of the quake with the spike on 80 m we can also verify the changes in propagation by the field lines as measured by the RF-Seismograph! The RF-Seismograph combines both events in one graph for easy verification.

- In all, 171 earthquakes were studied: All M6+ events from the beginning of our recording (Aug 2016) to today. Events were provided by USGS, and the quality of the data is high.
- 961 days of recorded data with 171 M6+ quakes amount to one major quake every 5.6 days. Approximately 17.3% of background noise is affected by these strong events. Since we only looked at 6+ events, we can conclude that a lot of the background noise we monitor is also created by smaller seismic events (and there are a lot more of these). If one looks at smaller quakes the (<M3.0) the earth really never stops shaking. There is a lot of energy even in small quakes and they are the major source of the rumble one hears when a HF rig is set to 160m or 80m. It would be interesting to take this experiment to a different planet or moon and see if this is actually the case.
- Only 15 quakes did not have RF noise associated with them.
- 1 day out of 961 was not recoverable due to data loss.
- In 26 cases the time of the disturbance did not match the time stated in the USGS report.
- In 122 quakes (72%) we were able to see a noise increase in the 80 m band either before, after and before and after the quake released. The "before and after" is the most common one. More analysis is needed.
- Introduction and Study of Earthquakes (also see also ref. at the end)
  http://www3.telus.net/public/bc237/MDSR/IntroductionRF-SeismographandEarthqakes.pdf
- The study is still continuing and we need your help to set up more monitoring stations.

9. How to store and search the data we have collected

The data storage is at the moment a simple text file utility. Every day the RF-Seismograph spits out one csv file that has 1661 lines of data. One record = 6 measurements every 52 s. At this moment there are about 1000 individual files. They are uploaded to the group on regular bases for backup and access of group members.

The data is accessible to all IO User group members – membership is free, so please join us! The data files are kept in the files section at our https://groups.io/g/MDSRadio group.

Sample Data:

Timestamp – *f* [kHz]	3576	7076	10138	14076	21076	28076
06-07-2016 23:56:12 [dB]	-38.59	-49.25	-47.87	-46.16	-51.56	-55.76
06-07-2016 23:57:04 [dB]	-37.61	-50.71	-48.69	-46.3	-51.47	-56.25
06-07-2016 23:57:56 [dB]	-38.21	-50.9	-47.52	-47.35	-51.3	-55.92
06-07-2016 23:58:52 [dB]	-39.3	-50.03	-47.52	-47.27	-50.16	-55.55

Note: The data collection times have deliberately been kept off the common 1 minute markers and are pseudo random to avoid synchronization bias with digital broadcast.

The future storage of data

We would like to see that all the data gets put into a SQL data base. So we are looking for volunteers who are willing to spend some time to get this set up. If you are interested in this please contact us.

Conclusion

Earthquakes are very hard to hear on the radio, but their effect on propagation is undeniable and easy to measure. Shortwave radio operators use the propagation created by earthquakes every day and do not know it! Most of us believe or have been lead to believe that this propagation comes from the sun, which is only a small part of the story. With earthquakes in the picture a new era of propagation research can begin and amateur radio operators are at the edge of new science, again!

Now we come to the big question: Is it possible to predict earthquakes and evacuate people before the event? With the provided measurements it seems that most quakes have a precursor noise level that could be detected and used to alarm a region. It will certainly add another useful tool to the measurements of earthquakes and it will create more certainty that a region is actually getting shaken to a level that causes damage and cost of life. Combined with regular seismographs, it could improve prediction, but clearing an area and then have nothing happen is the worst nightmare of any official; or even worse, after the all clear is given, disaster strikes!

References:

(ref 1) Philippe Lognonne, Eric Clevede, and Hiroo Kanamori, Geophys. J. Int.(1998) 135,338-406

http://www3.telus.net/public/bc237/MDSR/Atmosphere Osc.pdf

(ref 2) Juliette Artru, Thomas Farges and Philippe Lognonne, Geophys. J. Int (2004)158, 1067-1077

(ref 3) **https://twitter.com/LosAlamosNatLab/status/1111386164995321856?s=20**

(ref 4) Angelo Esposito, Rafael Krichvsky,and Alberto Nicolis, Phys. Rev. Lett, 122,084501(2019).

(ref 5) Robert J. Geller, David Jackson, Yan Kagan, and Francesco Mulargia, Science 14 March 1997; Vol 275, Issue 5306 pp. 1616 DOI:10.1126/science.275.5306.1616

Scientific American Oct. 2018: "Earthquakes in the Sky"

http://www.ep.sci.hokudai.ac.jp/~heki/pdf/Scientific_American_Vance2018.pdf

Earthquakes Canada: **http://www.earthquakescanada.ca**

U.S. Geological Survey: **https://www.usgs.gov/**

Sergey Pulinets, Kirill Boyarchuk, Ionospheric Precursors of Earthquakes, ISBN 3-540-20839-9 Springer Berlin Heidelberg New York

Northern California Earthquake Data Center (hosted by the Berkeley Seismo Lab)

http://ncedc.org/bdsn/make_seismogram.html

Access to Study for 2017, 2018 (2019 is part of 2018):

http://www3.telus.net/public/bc237/MDSR/Matches-RF-Seismograph and Seismic data for 2017.pdf

http://www3.telus.net/public/bc237/MDSR/Earthquakes visible with RF-Seismograph 2018.pdf

Support for the RF-Seismograph for Linux and Raspberry Pi**: https://groups.io/g/MDSRadio/**

Download MDSR software for PC from: **http://users.skynet.be/myspace/mdsr/**

Our SciStarter project can be found here: **https://scistarter.org/rf-seismograph**