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WØASP

Radio Meteor Detector

Building a radio meteor detector can be quite simple for the average radio amateur and not very expensive. A 6m receiver and antenna is enough. A scientific quality instrument can be built for under $1000.   You do not need a radio license to do this, because it is receive-only. In addition to meteors, you will likely detect sporadic-E, aircraft, satellites other strange signals.

First, let's set the stage with some terminology. A meteriod is a chunk of rock out in space orbiting the sun, with mass and velocity and subject to gravitation as described by Newton's equations just like the Earth and the Moon. Most meteroids are comet dust, traveling at the high velocity of their source comet. That same chunk of rock, as it starts to enter the Earth's atmosphere, heats up due to atmospheric friction and burns away leaving behind a trail of hot particles in a process called Ablation.   Think of the heat shield on the Apollo missions. The ablated material is hot enough to emit visible light. During this brief period, the meteroid has become a meteor. If that same chunk of rock hits the ground, what is left of the rock is a meteorite. In astronomy, both optical and radio, we are viewing the brief meteor stage of life.

The frictional heat and ablation causes the outer surface of the meteor to vaporize, and then ionize as there is enough heat energy to strip off an electron from the atoms of iron, magnesium and calcium that are common constituents of the meteor. So in addition to the bright streak of light you see, there is a longer lasting trail of plasma left behind at heights of about 100 km or 60 miles above ground. This plasma is an excellent reflector and scatterer of radio energy. And because of the physics of the ionosphere, the meteor plasma can hang around for several seconds to minutes, unlike the visible meteor trail, leaving a nice radio reflector in space. These same plasma processes are responsible for the radio blackout for re-entering spaceships. A cloud of plasma forms during reentry which disturbs radio waves coming and going, prohibiting communication to the reentry vehicle.

The meteor plasma trail is also large compared to the visual signature, so a very small meteoroid, about grain of sand size, with an optical signature too faint to see, will still make a radio-detectable plasma trail. For this reason, radio counts of meteors are often hundreds to thousands of times more than those of optical observations. And the radio techniques work in the daytime and under clouds. So we radio astronomers don't have to stay up all night, but we never get any time off…. We do, however, have bad weather. Thunderstorms, especially those with circulation that tend to form tornadoes, are full of very energetic lightning discharges that emit radio noise knows as sferics in the VHF frequency band. This noise effectively blinds the radio instrument.

The Colorado Astronomy net starts at 7PM MDT, which is the absolute worst time of day for radio meteors. The best time of day is 7AM. Why? Think of bugs on a windshield. The meteoroids out there are like a cloud of bugs out there in space, following their orbital paths around the sun. The Earth, in it's orbit around the Sun, sweeps through these clouds of meteoroids, like a car driving through a cloud of bugs. In the morning, our overhead sky is the windshield and points in the direction of Earth's orbit, thus sweeping up more meteoroids, even catching some of the slow ones. The evening sky is our rear window and the meteoroids have to be traveling much faster to catch up with us. Noon and midnight are neutral 'side window' periods.

Professional scientists measure meteors with a meteor scatter radar. This is a megawatt class radar usually around 50 MHz, that transmits and receives echoes from meteor trails. The radar can give range, location duration and motion of the meteor trail. These traces serve as 'smoke trails' in the lower ionosphere to measure temperature, pressure and winds at 100 km altitude.

In this application, we use the powerful transmitters from over-the-horizon television transmitters in the lower VHF band, Channels 2 to 6, at frequencies of 54-88 MHz. This technique is called bi-static radar. These TV stations have a very powerful carrier or pilot tone that is about 310 kHz above the bottom of the allocated band and about 20 dB over the modulated signal. And they are always on. Some stations have licensed power levels well over 10 kW.

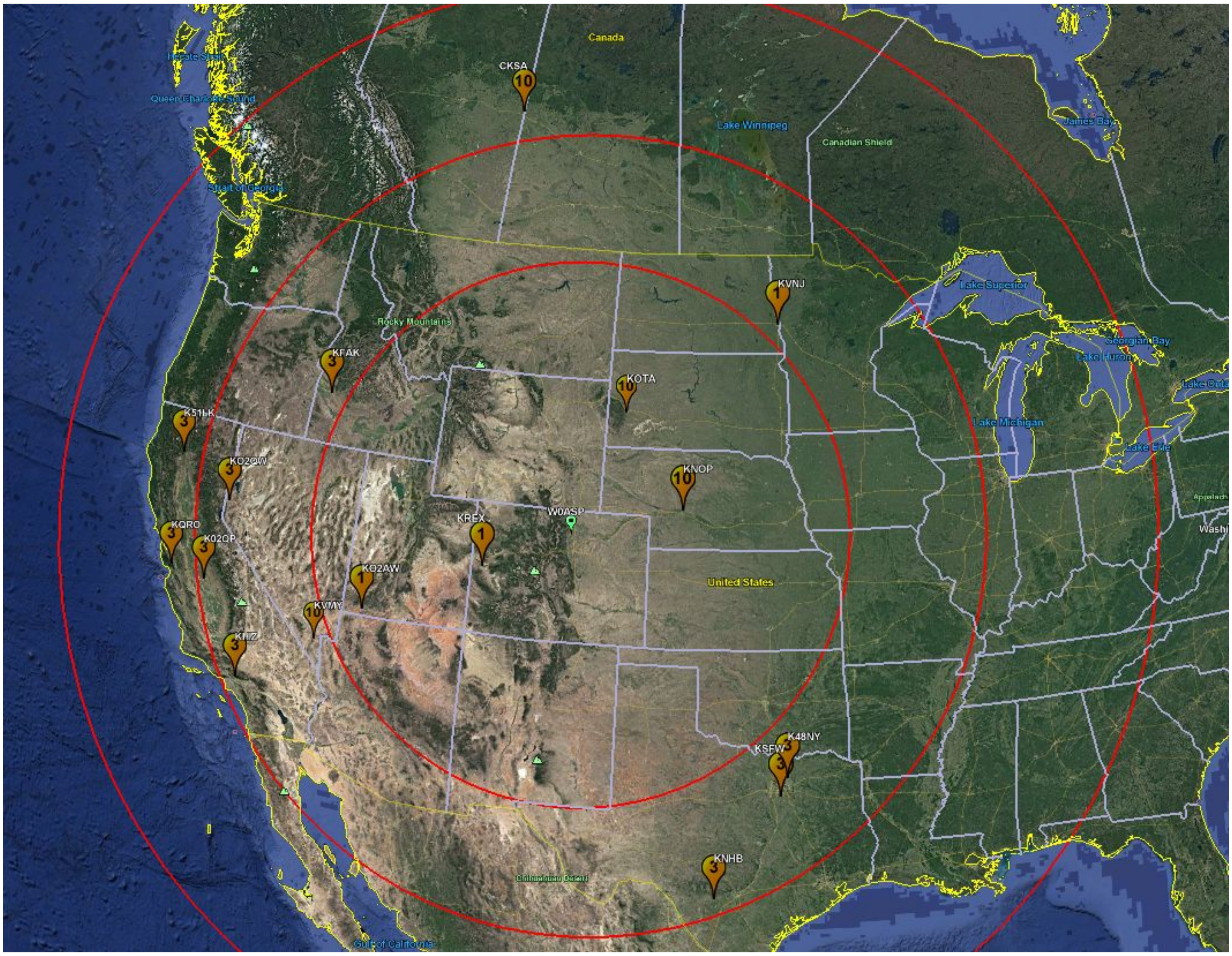

Figure 1: Google Earth image of meteor scatter geometry from Northern Colorado. The red circles are ground ranges for reflections at 100 km at elevation values of 10, 5 and 0 degrees. The pins are data taken from the FCC database include station location, call sign, and approximate power level. 1 means about 1 kW, 3 is about 3 kW, 10 is 10kW or above. The author has Google Earth KML files for western US stations on channels 2,3,4,5, and 6 available by request.

Because the stations we choose are well beyond line of sight, we get very little direct propagation. However, when an object such as an aircraft or meteor plasma trail are somewhere between us and the distant transmitter, there is an open propagation path. This is the ‘ping’ that we hear on the radio. Longer, more complex tones are associated with larger, faster meteors making larger and more complex plasma trails or the interference pattern between multiple transmitters reflecting from the same plasma trail.

Here is what I use to detect meteor scatter.

- TV Antenna – Must cover the Lower VHF TV band, Radio channels 2-6. You may already have one on the roof. I use a new Channel Master CM5020 ($200, Amazon). Don't forget a mast and tripod ($75,Amazon). I also use a medium duty rotor (CM-9521HD, $200) but this is entirely optional. A 6m antenna, horizontal or vertical also works

- Preamp – Essential to overcome cable loss and help the receiver noise figure. I use Channel Master CM-7778 ($65, Amazon) (3 dB NF)

- Cable – You need 75 ohm TV cable (RG6 or RG11), probably a couple hundred feet, and F type connectors.

- Receiver – Modern Software Defined Radios work very well. There are cheap SDR dongles RTL such as the NooElec R820T2 ($25, Amazon) but receivers such as the Airspy ($180) or SDRPlay ($200) will perform much better.

- Timing: Most TV stations use precise frequency standards for their signal generation. By using a GPS disciplined oscillator ($200, Leo Bodnar Electronics, UK) I can measure precise frequency differences over long periods of time. This helps with Transmitter ID, which is a difficult task. Small frequency differences in the pilot tone are unique to each station, but TV stations are reluctant to reveal this information.

- An amateur radio operator most likely has all of the equipment needed. A receiver that tunes the 6m ham band (50-54 MHz) will likely tune to the Channel 2 carrier frequency, 54.308 USB) but most will not tune into the other lower VHF television channels (60-88MHz). This and a good 6m antenna will let you listen, but to get a better appreciation, a computer with a waterfall display is recommended. You need an interface from the radio to the sound card in the computer. Usually this is just an audio cable.

- Computer – Just about any throw-away second-hand laptop built within the last 8 years or so will work. The computations necessary are not all that intense. And running Windows XP, 7 or 10.

- Software – You need (1) Software that works with your receiver ; (2) VBCABLE virtual audio driver, and SpectrumLab to see the data. All $FREE.

- Operation – Set your radio to Upper SideBand (USB) at least 3 kHz bandwidth.
- Tune your radio to:
  - Ch2 – 54.308 MHz
  - Ch3 – 60.308 MHz
  - Ch4 – 66.308 MHz
  - Ch5 – 72.308 MHz
  - Ch6 – 82.308 MHz.

Channels 2, 5 and 6 have transmitters in Colorado, which cause us to see all of the aircraft in the Denver area. This is especially true if you view the meteor trails on a waterfall diagram such as Spectrum Lab. Channel 3 has at least one distant transmitter. I have had the best luck on Channel 4, with the nearest station being Lincoln, Nebraska. There are 3 others I have no ID on yet. The FCC is actively working to eliminate this by licensing a Channel 4 station near Fredrick, CO. Any day now I can be wiped out. This is precisely why radio astronomers have to live in the exact middle of nowhere.

After setting up your equipment, Listen for the pings. These can be heard almost every day, not just during meteor showers. Small chunks of rock like sand make these short 1-2 second pings. Bigger pea sized rocks make longer life pings of a few minutes. Fist size chunks of rock make pings for 20 minutes or so. The longer the ping, generally the bigger the rock. A good fireball can make a plasma trail that lasts an hour.

Here are some examples that I have previously recorded.
A 1 minute small meteor
http://www.ki0ar.com/Meteor_1.mp3
A 10 minute long meteor. Note the fading pattern in the tone due to multiple reflections from the trail
http://www.ki0ar.com/Meteor_Long.mp3

As a ham, I use these data to detect sporadic-E openings on 6m. When the pings of meteors turn into a continuous strong signal, that means there is Strong Scatter Sporadic-E in the region between you and the transmitter and 6m is likely to be open to somewhere in that direction.

At Little Thompson Observatory in Berthoud, we use meteor scatter to provide our visitors something to see when it is cloudy. It is also an outreach to the visually impaired. These observers often hear things in the data that I do not. And it is interactive enough for short attention span elementary school children to learn something.

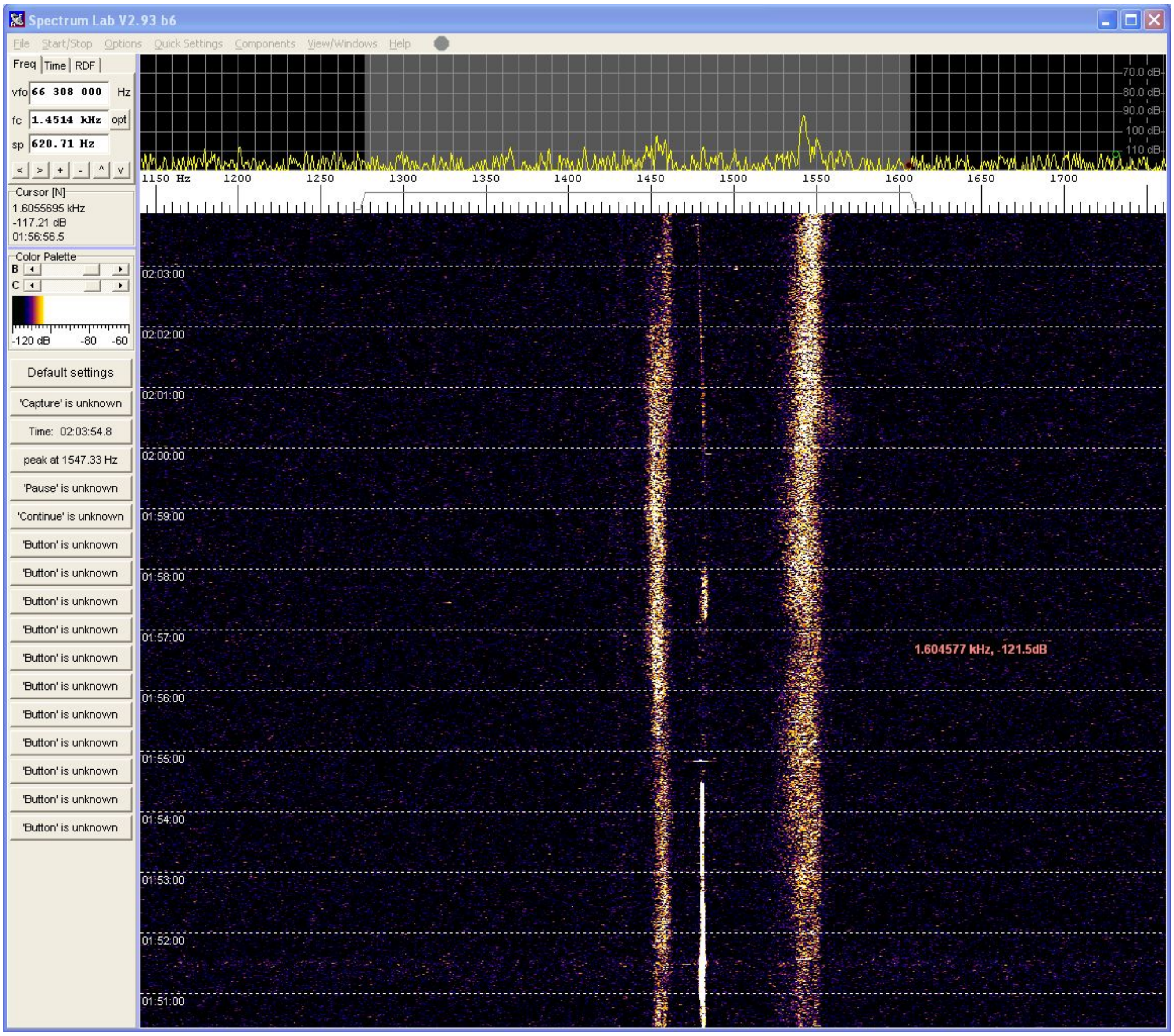

Figure 2: Waterfall from Spectrum Lab software at W0ASP observatory. Note the 3 vertical lines are different transmitters on the Channel 4. Two trails show complicated, diffuse echoes. The center trail is smooth. likely a sporadic-E layer, which fades in and out.

Good Luck,
Terry Bullett
tbullett@skybeam.com
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