Receiving Meteor Reflections Using Low band DTV Transmitter Pilot Carriers

By Dennis Condron – K0LGI

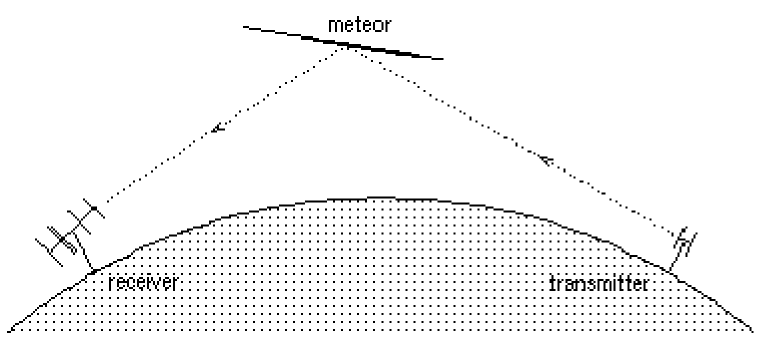
What is this about ?

Are you interested in the possibility of monitoring earth detected asteroids such as 2012 DA14 near earth flyby or the one that struck the atmosphere on the morning of February 15th over the city of Chelyabinsk Russia recently where it became a meteor that exploded causing personal injuries and property damage?

As unlikely as that may be, it does bring about an interesting question. Just how can one observe something similar but not as massive as those objects using modest radio equipment and what does it takes to do that?

There are far more typical smaller alien debris events that occur daily which are arriving as meteors that are also easily radio detectable. Hundreds if not more occur each day are observable by radio forward scatter methods.

The hobby of receiving radio reflections from meteors arriving within the earth's outer atmosphere that often create an ionized path that allows some reflected radio signals to be propagated a considerable distance from an operating transmitter signal origin to a typical user receiver.



Drawing from: International Meteor Organization Introduction to Forward Scattering Radio Techniques

During most major meteor shower events that occur during a typical year there often occurs an exceptional high number of meteors that are observed visually and by radio. There are also continuing but lessor meteor ionization trails occurring each day of the year.

Less daily meteor numbers usually occur in the later afternoon and early evening hours, with the prevalence of higher occurrences during the remaining hours, with a preference being the local early morning hours.

This propagation mode has been known historically for many decades by radio experimenters; hams included and are currently use in by the US government, military, and commercial entities. The frequencies used are varied as is the intended purpose.

A Present Day Working Forward Meteor Scatter System

A well-known and historically significant example of the practical use of meteor propagated signaling is the SNOtel (SNOpack TELemetry) system operated by the National Research Conservation Service and the SCAN (Soil Climate Analysis Network) master transmitters that are located in several states including Idaho, Utah, Missouri, Ohio, Mississippi and Alaska that are used to provide a signal source that is somewhat lower than DTV channels 2 through 6 for meteor reflections that are located mainly in the 30-50 MHz band. These dedicated low band VHF systems operate primarily for the purpose of collecting a variety of weather related data including, snowpack, and soil moisture from remote measuring sites throughout the US.

Below: A Previous SNOtel Master Station Site Location – Utah

This picture is of the previous Ogden Utah Master station site that has since been removed in 2010 and relocated to the nearby Utah Dugway Proving Grounds location.

[Note the numerous multi element Yagi antennas that are used for connecting to US Western states SNOtel remote data transmission sites. There are eight receiving antennas and one transmit antenna at this site for nearly complete western US coverage]

The SNOtel-SCAN master station transmitting sites obtain multiple weather related datasets from several hundred remote locations throughout the US by interrogating them by use of its signal and have been in continuous use for several decades.

How can I do it ?

All that is required for basic meteor return monitoring by radio is actually very strait forward, but is dependent on having a suitable receiver, antenna, and a reliable signal source that will illuminate the meteors ionized path from the far upper earth atmosphere back to the receiver. This is called forward scatter where a medium (the meteor ionized trail) is exposed to a suitable existing RF signal and detected by a remote receiver located elsewhere.

One of the more prolific signal sources for RF illumination of meteor trails in the US and elsewhere, are DTV television stations that also operate continuously and provide a high power and constant reliable source of low band channels 2 – 6 VHF signals that cover a major part of the United States. They operate on what is generally considered to be in the lower VHF TV band segment and maximize the meteor trail reflection characteristics with their proven resulting performance and reliability that is very useful for meteor detection using these lower VHF frequencies.

In the past, and in some locations currently in Mexico and Canada, the US television transmission standards incorporated a considerable differing modulation technique using AM modulation for the video and FM for the audio segment. This required two separate carriers to be effective called the intercarrier system. In that modulation technique, referring to the video carrier, it was located above a channel band lower edge by 1.250 MHz and the FM carrier was 4.5 MHz above it.

At that time when analog television was predominant, the video carrier of operating lower band VHF TV stations had been used as a signal source for monitoring meteor returns via forward scatter quite successfully. It continues to some extent in the US border regions near Canada and Mexico where some analog TV stations continue to operate there. If one is located near an existing analog TV transmitter, it can be used also for meteor detection as well.

Today, a modern digital television DTV channel 2 station for example, transmits a pilot carrier that is approximately .309 MHz above the lower edge channel assignment (54-60 MHz). As an example, the DTV 2 transmitter sends out a pilot carrier at 54.309 MHz. Likewise, a DTV 3 transmitter provides a pilot carrier at 60.309 MHz. These are the most desired DTV frequencies that are used for radio meteor monitoring in addition to channels 4-6 if there are no other lower DTV channel available near your area.

For technical and reference purposes, the actual calculation method used to determine the television DTV pilot carrier frequency is stated as:

A DTV pilot carrier is *approximately* 309 kHz above the lower channel edge. This is obtained by taking the bandwidth of the DTV signal -- 5,381.1189 kHz (the Nyquist frequency difference or one half the symbol clock frequency of 10,762.2378 kHz) -- and centering it in the 6 MHz TV channel. Subtracting 5,381.1189 kHz from 6,000 kHz leaves 618.881119 kHz. Half of that is **309.440559 kHz**, the precise, standard pilot offset above the lower channel edge.

There are exceptions to this rule where adjacent channel or on channel interference issues exist and are explained in Doug Lung’s credit reference at the end of this article.

Reflected meteor reception occurs at an atmospheric height of approximately 50 to 80 miles are common. Exact meteor detection range will vary considerably dependent on the receiving end overall sensitivity, DTV transmitter power and antenna pattern, external ambient noise level present, including meteor size, height, meteor path location, it’s orientation and reflected signal levels from it.

It is not uncommon to see aircraft reflections also dependent on the aircraft position and size or RCS (Radar Cross Section). The typical meteor position for optimum detection is usually considered to be near the midpoint between the transmitter and receiver location, however it is not unusual that it can occur also near the transmitting or receive location. The resulting trace indicated on the Argo software that is covered later, will show a longer duration image left by an aircraft largely due to the much slower velocity than what a typical meteor leaves and will indicate the actual Doppler shift returned from the it as well as from meteors if present also. Aircraft returns are ~ 1/200 the velocity of most meteors.

The range that DTV pilot carriers are effective for meteor reflected return signal paths is highly variable from ~ 200 to over 600 miles from the DTV signal source typically. There have been times when experiencing enhanced lower atmospheric propagation conditions; even further opportunities may exist extending the range even farther. Sporadic E propagation and lightning of course tend to reduce the detectable range generally due to the higher levels of undesired noise and high signal levels from the DTV pilot carrier itself that will increase receiver AGC action and therefore masking the weaker but desired meteor path return.

What does it take to do it ?

The detection method commonly known as forward backscatter from the object whether of a meteor or aircraft is very straight forward and within the capability of a very modest setup consisting of a communications type SSB receiver and antenna that covers the desired frequency range. In this application, it requires a unit capable of receiving from 54 to 83 MHz to receive the pilot carriers located at 54.309, 60.309, 66.309 76.309, and 82.309 MHz.

For a complete listing of operating channels 2 and 3 in the US, Canada and Mexico including DTV and analog stations, see the FCC reference links included in the credits section.

[Note that there are no television channel assignments between 72 -76 MHz due to an older Industrial Scientific Medical (ISM) band, including airport marker beacon operations at 75 MHz.]

This configuration would be adequate for most to begin receiving stronger meteor returns audibly, but with the addition of a PC and some additional software designed for very low signal levels, will dramatically enhance the experience and provide a very good record of intercepts along with a better understanding of meteor reflected trail signal propagation modes.

The first consideration is the receiver used to hear these mysterious sounds generated by incoming meteors. A good unit that has a SSB voice bandwidth mode is necessary as it will provide the reference from which the resulting sounds will be heard and analyzed when using the low level signal recording PC software mentioned previously.

Good receiver sensitivity, frequency accuracy and stability are required for consistent, repeatable results. USB (upper sideband) detection mode is typically used. A line level output of the receiver to the PC input is desirable, but is not essential for use with the software used for recording and analysis. If a line level output is not available, a means of attenuating the speaker output level may be required to reduce drive levels to the PC software. If a SDR receiver is used, it can also be selected under the appropriate sound card for the Argo input under the Setup tab.

The receiver antenna preference is a Yagi designed and constructed for a particular DTV channel operating frequency that can be rotated toward the nearest selected DTV transmitter. There are some commonly available VHF only television antennas that can be used also. For DTV 2 transmitters, an amateur 6 meter band Yagi can be used if retuned slightly to the higher frequency end of that band. It could be a simple two element unit or more that will improve the end result by an increase in signal levels. A good starting point is to use a horizontal correctly tuned dipole to see if the received signal is strong enough for use as is, then decide if a higher gain antenna such as a Yagi is needed to optimize reception.

It is desirable to use low loss coaxial cable for this project, however for cost reduction reasons, some versions of good quality, fully shielded 75Ω coax used for CATV can also be used at this frequency and is readily available almost anywhere. F to BNC connector adapters are also usually available at modest cost to adapt to the more commonly used BNC antenna and receiver connections. Some electronic part suppliers also include CATV cable type BNC connectors for direct receiver connection possibilities at a modest cost including proper installation tools.

To see much weaker meteor returns that often are not heard at all but can be seen clearly using FFT software on the receiver because of the typical 2 - 3 kHz bandwidth used in SSB mode, there is available a free program that can be run on a Windows PC OS called Argo that will provide a better detection method and record meteor returns visually for later analysis or for record keeping on the PC. It is highly recommended for this application.

Argo has several setup options for keeping a log of received signals that are sent for record keeping on the PC of meteor intercepts. It is easy to setup and use to see extremely weak signals that often occur from some smaller meteor returns by using very narrow FFT bandwidths that can be set to less than 1 Hz. Additionally, Argo is relatively resistant to impulses noise such as lightning bursts and other short term noise sources. Argo V1 build 143 can be downloaded by clicking on **Argo** at: http://www.weaksignals.com/

To begin listening and looking for meteor activity, select a DTV pilot carrier frequency for radio detected meteors using the FCC information from above, connecting the correct antenna to the SSB mode receiver, usually set for USB in this case, and listen with the receiver set to 1KHz below the pilot carrier after enabling the Argo software loaded and connected to the PC unit line level audio input. Make sure the Argo software is also centered for display of the ~940 Hz signal from the receiver.

A typical Argo starting point setup for this use is as follows:

SETUP: Line In, Auto Run, **MODE**: QRSS 3 or 10, **SPEED**: Normal, **PALLETE**: User choice

FTP UPLOAD: For file transfer uploading only

Although there is no official manual for setting up the Argo parameters for use, with some use of it over time, it will become more obvious of its usefulness and of its capabilities to observe very weak signals not normally detected audibly.

After pressing the Argo Start button you should also see time ticks at the lower part of the Argo chart. Adjustment of the sliding Sensitivity and Contrast controls are user selectable and are dependent on optimum audio levels settings of the receiver output level.

If the receiver is accurately set as in this demonstration example to 54.3085 MHz USB, you should start seeing and hearing a meteor returns if they are strong enough and also see them displayed by Argo on the PC at ~940 Hz, the meteor return signals from the selected channel (in this case it is channel 2) DTV pilot carrier. Some meteor returns can and often do have a return frequency that is several, usually 10's of Hz, away from the pilot carrier frequency due to Doppler shift, but can easily been seen using Argo.

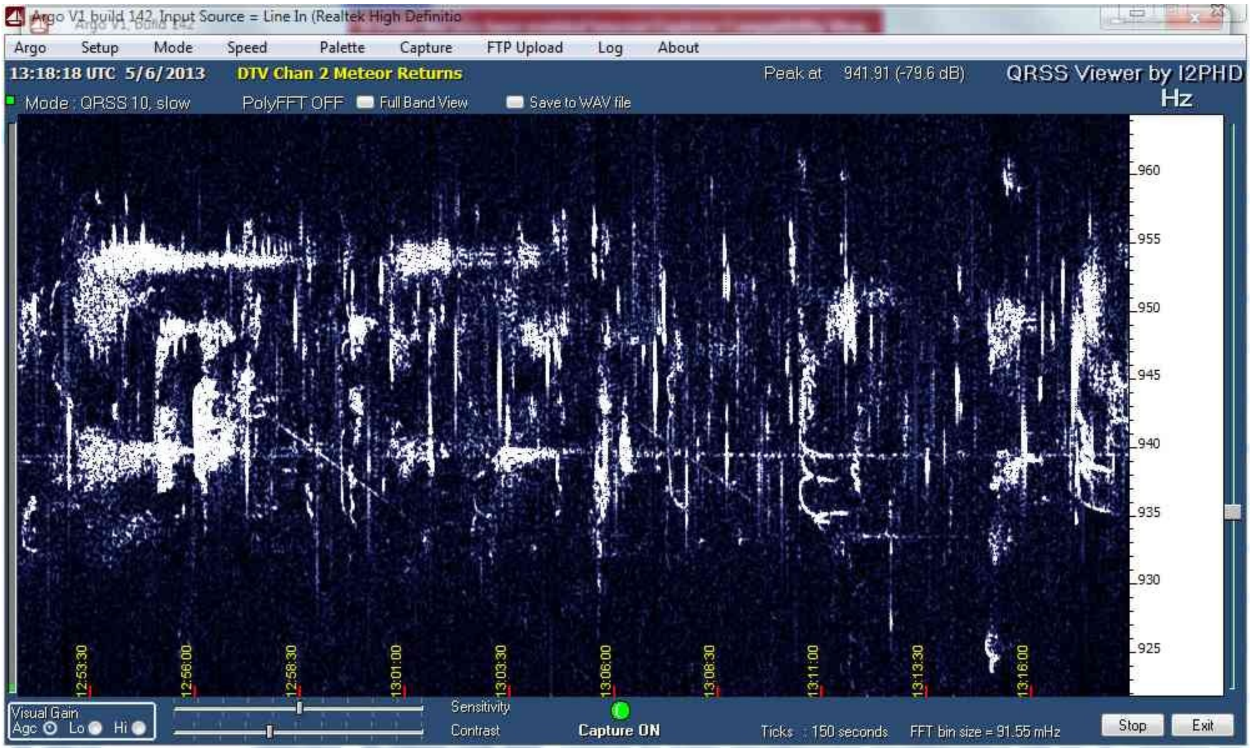
Larger meteor breakups or groups of smaller meteors can produce a considerably wider return signal noted using Argo, and at the same time the sound it produces is different also compared to a single, more typical singular meteor return.

Click here for an audio example of a Geminid meteor shower return: http://science1.nasa.gov/media/medialibrary/1998/12/20/ast22dec98_1_resources/geminidecho.wav

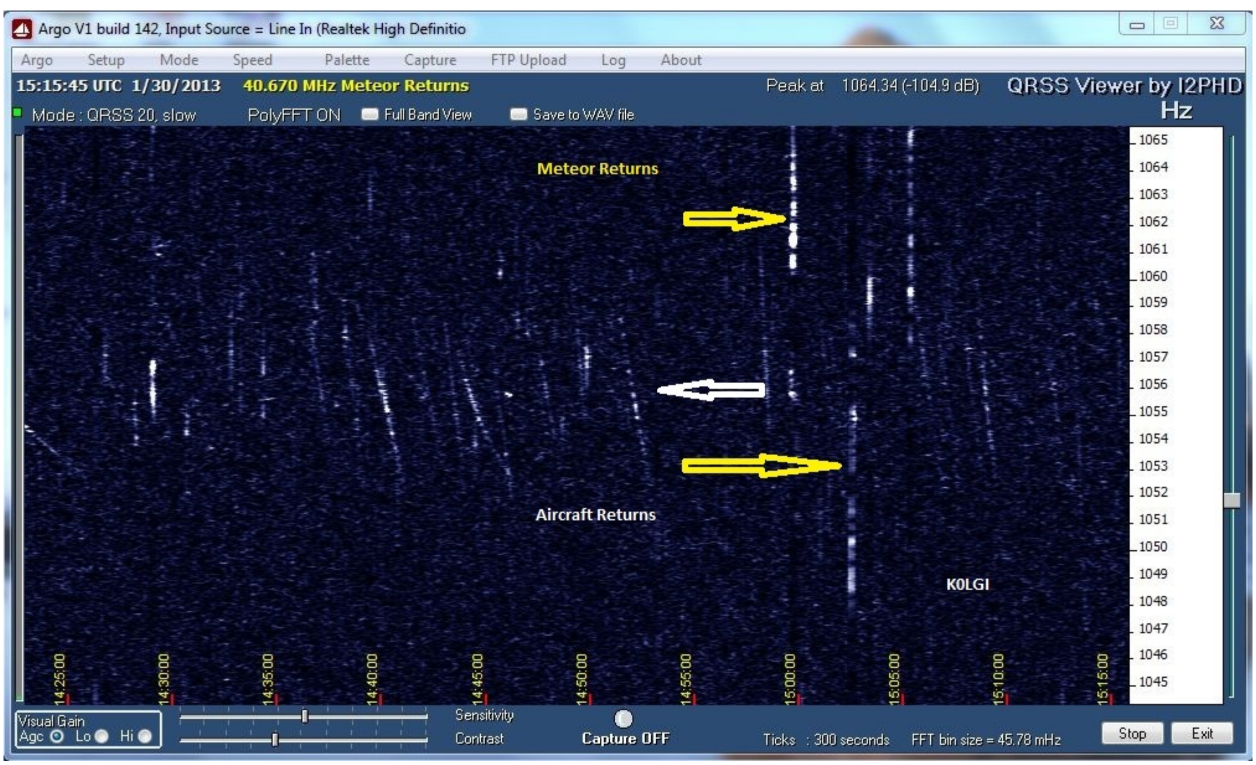
During major meteor showers there are substantial increases in meteor events that can be easily received. For more detail on when these will occur, it is suggested a review of American Meteor Society's Meteor Activity Outlook at http://www.amsmeteors.org/articles/ for updates and other useful information content.

Show me some examples !

May 06, 2013 DTV Channel 2 Meteor Returns



Below: ARGO image example indicating both meteor and aircraft returns as received on 40.670 MHz



Where can I find out more ?

To see more of what is being done in radio monitoring of meteors, check out Stan Nelsons, KB5VL Meteor Monitoring website at http://www.roswellmeteor.com/default.htm or join the Google RadioMeteors Group for the latest radio meteor observations and discussion at https://groups.google.com/forum/?fromgroups#!forum/radiometeors.

Also, read more related content included in the references below for more complete information than is presented in this article.

Enjoy the fascinating sights and sounds of radio detected meteors !

Dennis Condron - K0LGI

Credits and references:

http://www.amsmeteors.org/radio/amsfaq-r.txt - Christian Steyaert

http://www.amsmeteors.org/radio/ams203.txt - James Richardson

http://www.amsmeteors.org/ams-programs/radio-observing/ - James Richardson

http://www.amsmeteors.org/radio/scatter_notes.txt - James Richardson and Dr. David Meisel

http://www.imo.net/radio/intro Introduction to Forward Scattering

http://science1.nasa.gov/science-news/science-at-nasa/1998/ast22dec98_1/

Tony Tolsdorf, USDA Hydrologist Portland, OR – SNOtel-SCAN System Information

Stan Nelson, KB5VL – July 2013 Monitoring Times SNOtel –SCAN Article

Alberto di Bene, I2PHD - ARGO software developer

US-Canada-Mexico Channel 2 FCC Station Listing (Includes digital and analog)

http://transition.fcc.gov/fcc-bin/tvq?state=&call=&arn=&city=&chan=02&cha2=02&serv=&type=0&facid=&list=2&dist=&dlat2=&mlat2=&slat2=&dlon2=&mlon2=&slon2=&size=9

US-Canada-Mexico Channel 3 FCC Station Listing (Includes digital and analog)

http://transition.fcc.gov/fcc-bin/tvq?state=&call=&arn=&city=&chan=03&cha2=03&serv=&type=0&facid=&list=0&dist=&dlat2=&mlat2=&slat2=&dlon2=&mlon2=&slon2=&size=9

http://earthsignals.com/add_CGC/RF_Column_77_Jul_98.pdf - Doug Lung - Pilot Carrier Calculation Detail

Additional Radio Meteor Related Reference Source Links

http://www.roswellmeteor.com/default.htm

http://spaceweather.com/

http://spaceweatherradio.com/index.php?PHPSESSID=ma9t8j632kt9svpu9aqbipfih4

https://groups.google.com/forum/?fromgroups#!forum/radiometeors

http://www.amsmeteors.org/ams-programs/radio-observing/

http://www.amsmeteors.org/radio/amsfaq-r.txt

http://www.amsmeteors.org/radio/ams203.txt

http://www.amsmeteors.org/audio/index.html

http://www.amsmeteors.org/radio/poplar.html

http://www.amsmeteors.org/radio/scatter_notes.txt

http://www.tvcomm.co.uk/radio/

http://radio.meteor.free.fr/us/main.html

https://groups.google.com/forum/?fromgroups#!aboutgroup/sara-list

http://www.radio-electronics.com/info/propagation/meteor-scatter-burst-communications/basics-tutorial.php

http://ea4eoz.blogspot.fr/search/label/Radioastronomy

http://www.kolumbus.fi/oh5iy/msobs/msobs.html

http://www.qsl.net/dk3xt/ms.htm

http://www.youtube.com/watch?v=xgrxQdRrCRE&feature=plcp

http://www.globalsecurity.org/space/library/report/1990/JJP.htm

https://sites.google.com/site/sjwamback/highfrequencymeteorscatterradioastronomy

http://www.rcallen.com/doppler.htm

http://www.dtic.mil/dtic/tr/fulltext/u2/a198848.pdf

http://meteor.uwo.ca/research/radar/cmor_intro.html

http://www.qsl.net/g0isw/g0iswms.htm

http://www.salsburg.com/NAVSPASUR/

http://web.archive.org/web/20060712014151/http://www.k4gfg.us/navspasur/toc.html

http://www.fas.org/spp/military/program/track/spasur_at.htm

http://www.df5ai.net/ArticlesDL/NAVSPASUR/NavSpaSur.html

http://www.k5kj.net/meteor.htm

http://www.nasa.gov/offices/meo/outreach/forward_scatter_detail_prt.htm

http://www.britastro.org/radio/projects/An_SDR_Radio_Telescope.pdf

http://science1.nasa.gov/science-news/science-at-nasa/1998/ast22dec98_1/

http://www.imo.net/radio

http://mysite.verizon.net/jkelly/meteor/meteor.htm

http://www.youtube.com/watch?v=kPU188fekmg

http://www.ehow.com/how_6523147_bounce-radio-signals-off-meteors.html

