Observing Meteors using GB3MBA

GB3MBA is the UK meteor beacon located at the Sherwood Observatory of the Mansfield and Sutton Astronomical Society. It's construction, by volunteers, was funded by the Radio Society of Great Britain and its running costs are supported by the British Astronomical Association.

The beacon transmits a CW signal vertically up using circular polarisation to illuminate the region where meteors entering the earth's atmosphere burn up briefly creating ionisation reflective to radio. This occurs at an an altitude of 80 to 100km. The beacon “illuminates” a region with a diameter of about 400km centred on its location near Mansfield.

Anyone within about 1200km of Mansfield and having a suitable receiver and antenna can receive echoes from meteors entering the illuminated region and use these to count and study meteor events.

Receiver Requirements

In principle, any receiver covering the required frequency of 50.408MHz, connected to a suitable antenna can be used to receive meteor echoes. Those within about 400km of the beacon can expect to see reflections from aircraft too but these are easily distinguished from meteor events. Other, naturally occurring phenomena within the ionosphere can also cause reflections which can be observed at even greater distances from the beacon but again, with some care the observer can distinguish these from meteor events. Meteor echoes will be detectable up to about 1200km from the beacon depending on the performance of the receiver and antenna. As with most aspects of radio astronomy, man-made interference can be a problem so before investing too much time and money it is wise to conduct some simple tests at your location to see whether the local noise level is acceptable. See “Noise and Interference” for more information on assessing your local interference level.

While a conventional receiver can be used, a Software Defined Radio is a better option and if starting from scratch this will be cheaper too. A conventional receiver should be tuned to 50.407MHz, 1KHz below the beacon frequency, and using Upper Side Band (USB) will produce an audio signal centred on 1KHz which can be displayed on an audio spectrogram such as Spectran to study the size and “shape” of the echoes.

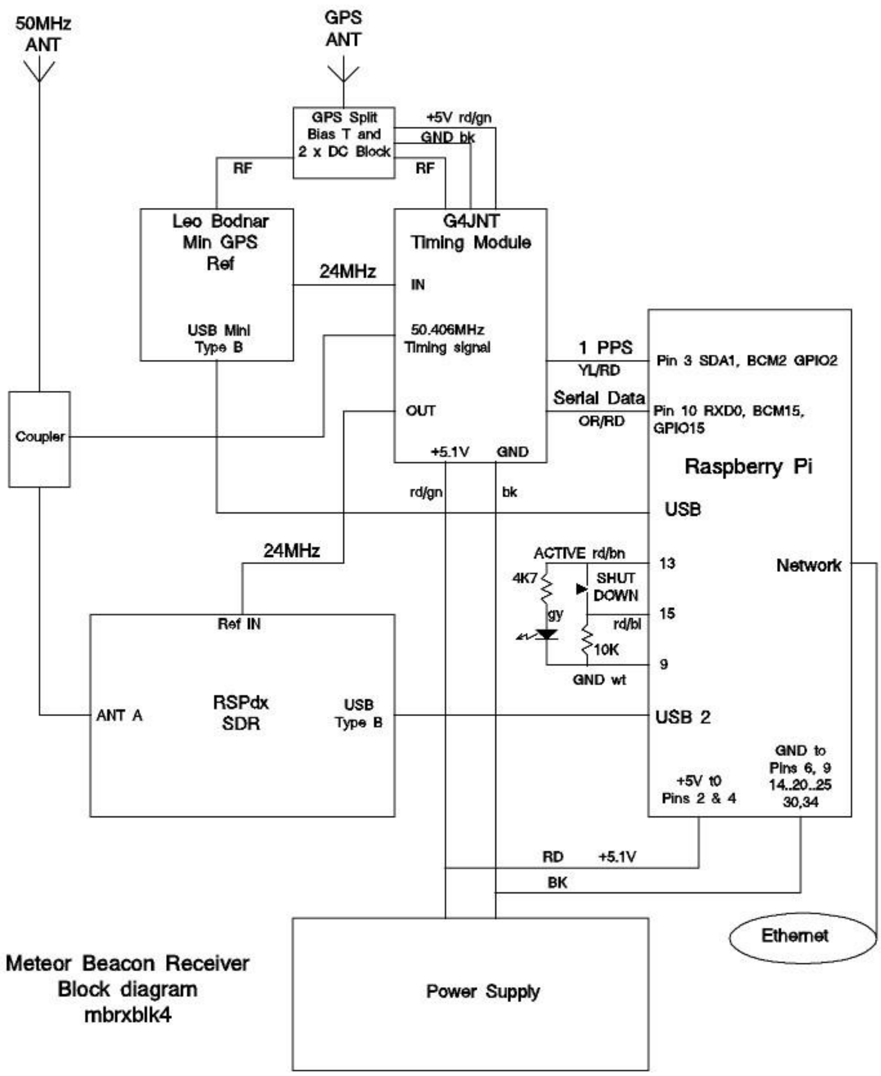
The best solution however is to use a Software Defined Radio together with software to display the spectrum and having a waterfall display (See Screenshot 1).

There are many SDRs available on the market and many software packages to support them. An important part of this project is to develop a network of receivers accessible to all. After we have built and deployed the first few receivers, we will publish the design and it is hoped that others will build their own receivers and join them into the network. Whilst for casual observations almost any receiver will do, to join the network receivers will have to conform to our standard and be deployed to suitable, radio quiet locations with power and internet access. Those without suitable locations will be able to access our network of receivers to make their own useful observations.

Our design is based on the RSPdx from SDR play and these notes will focus on how this receiver can be used, initially using SDR Console as the display, to make very useful initial observations which will contribute to the project. When the network is developed, users will in principle, be able to use any suitable software to record, display and analyse echoes from GB3MBA as received by our network of receivers. Once you start making detailed observations and want accurate measurements of Doppler shift it becomes necessary to provide a precision frequency reference. The RSPdx has the ability to accept a 24.00000MHz reference and this can be provided by a [Mini Precision GPS Reference Clock](). See Fig 1.

Fig 1 Receiver Block Diagram - DRAFT

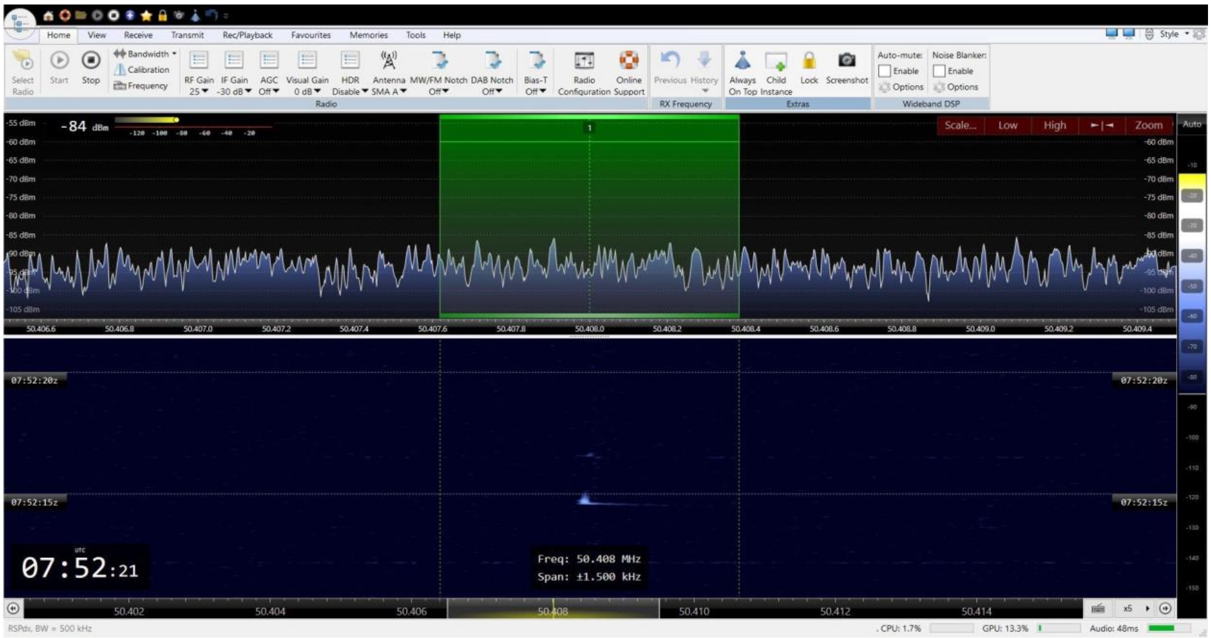
Fig 1 shows a block diagram of the receiver we are developing as at February 2023. It features an RSPdx Software Defined Radio along with a Raspberry Pi controller and web interface. It also includes a GPS sub system which provides a precision frequency reference to the RSPdx and precision timing pulses that will be used later in this project to accurately correlate recordings of meteor events viewed from different locations



But to get started with a system that will be able to join the network, all you need is an RSPdx, a suitable antenna and a PC. Using SDR console you will be able to check your location for local noise, position your antenna for best results and see your first echoes from GB3MBA. See screenshot 1. Visit the Resources – Documents section of the website for further information.

Screenshot 1

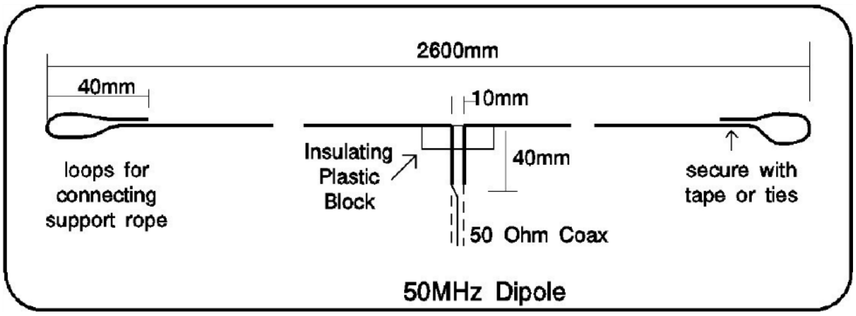
Screenshot 1 shows an echo from the ionised trail of a meteor probably no bigger than a grain of sand. The vertical line is a direct signal from the beacon which you will see if you are within about 200km of it or if there are favourable propagation conditions. SDR Console allows you to view, display and record meteor events. Later in this project you will be able to use your own receiver or those in the network to display, record and analyse meteor echoes using the audio I/Q data that they will make available. But for initial evaluation and some of the tests recommended in this document SDR Console, which is available free here SDR Console download



Antennas

If you are within about 200km of the beacon, you can get started with a simple wire dipole. See Fig 2.

Fig 2 A wire Dipole for 50.408MhzScreenShot 1



Try positioning the antenna away from noise sources and if the direct signal from the beacon is strong try placing the antenna end on to the direction of the beacon where there is a null in the dipole's doughnut shaped radiation pattern.

A popular choice of antenna is the Moxon type see Photo 1. This is more compact and robust than a 2 element Yagi antenna and has an exceptionally high front to back ratio which can be useful to null out local noise sources. This can be constructed from wire and plastic water pipe for just a few pounds see Building a moxon antenna or can be purchased from Wimo Antennas Photo below If you want to make your own more robust version like the Wimo one using aluminium tube the Moxon Rectangle Calculator by AC6LA does all the maths for you see Moxon Rectangle Calculator.

A Moxon Antenna

These antennas have a useful gain and a very high front to back ratio which can be used to null out local noise sources.

Within 200-400km of the beacon you can expect to see aircraft reflections in addition to meteor echoes. From 400km to about 1200km echoes from meteors and from other phenomena that occur in the ionosphere such as Sproradic E will be observed. You will learn to distinguish between meteor echoes and these unwanted ones if you follow these notes.

Directional antennas such as the Moxon, should be pointed up, towards the point 100km above the beacon. Close to the beacon your receive antenna should be pointed vertically up.

Try different configurations to find out what works best for you by “nulling” out the direct signal and / or interference.

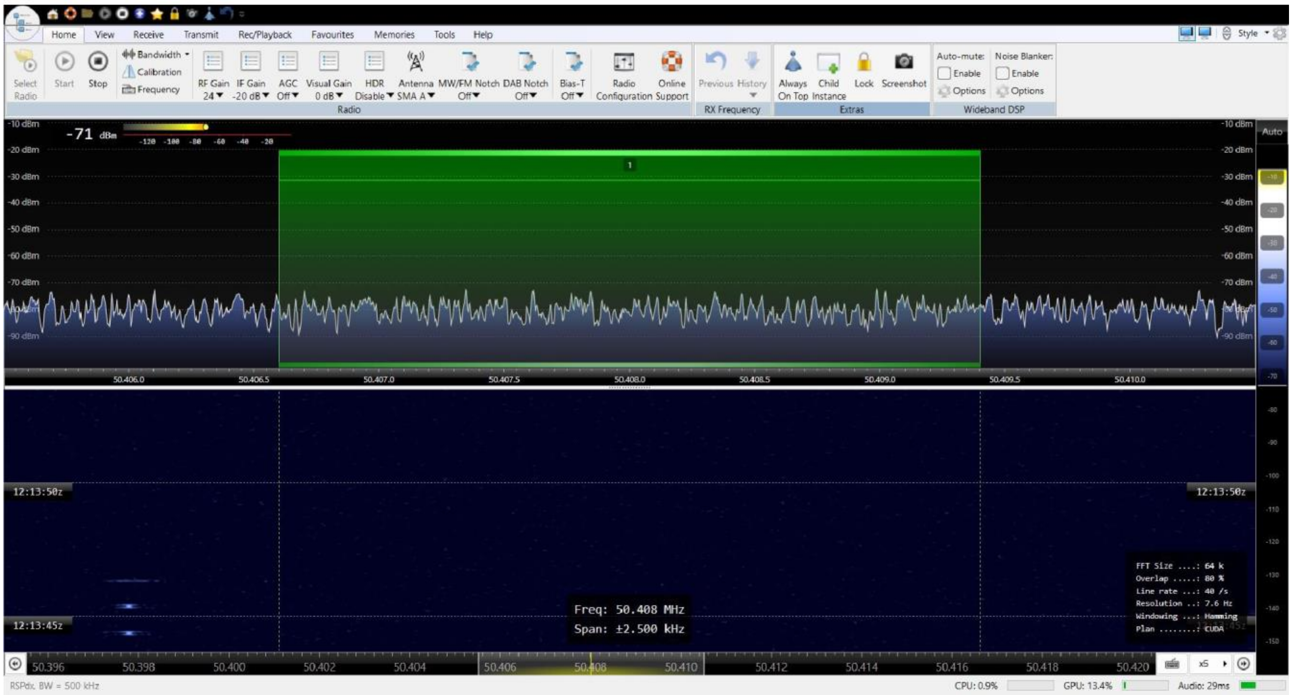
If you are located more than about 400km from the beacon an antenna with more gain may be helpful such as a 3 or 4 element Yagi.

Noise and interference

Man made noise and interference is the bane of all radio astronomers. If you are lucky enough to live in a radio quiet rural area or one where the interference is minimal you will have few problems. It is useful to asses your local noise level before you spend too much time, money and effort. This can be done with any SDR using SDR SDR Console to compare the “noise Floor” with antenna connected to that with the antenna replaced by a 50 Ohm load as described here.

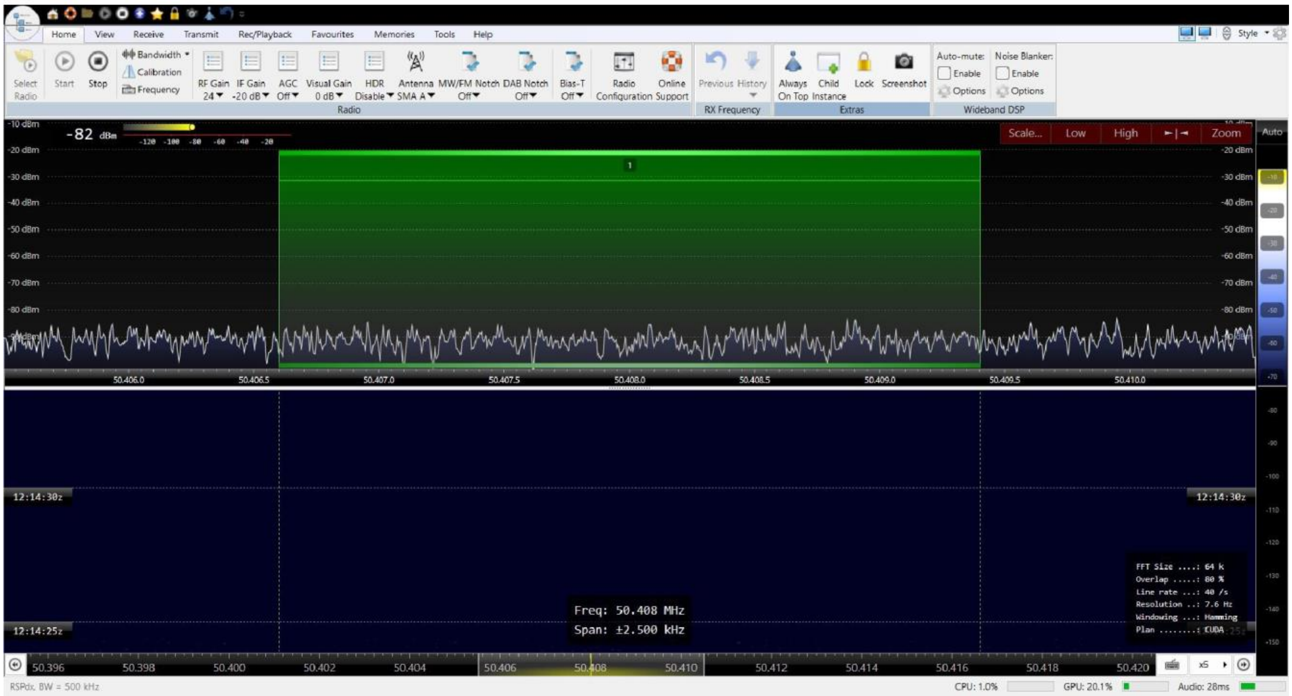
Screenshot 2

Screenshot 2 shows the situation with the antenna connected. Note there must be no signals in the receiver passband, highlighted in green, so the signal level indicator, upper left, is showing the noise floor. -71dB in this case. This is a relative rather than an absolute level.



Screenshot 3 with antenna replaced by a 50 Ohm resistor

With antenna replaced with a 50 Ohm resistor the noise floor has dropped to -82dB indicating that the noise increases by 11dB with the antenna connected. Don't worry about the absolute levels as these can be a function of the various gain settings you have set and other factors. Also note that for all observations of meteor echoes the automatic gain control (AGC) should be turned OFF. If you cannot reduce this change in noise floor to about 15dB or less, your location may be too noisy for useful observations although you my still see some stronger echoes. If your noise level is high the first thing to try to reduce it is to reposition the antenna to get it as far away from the noise source as possible and to use its directional properties to null out the noise source. Ideally the antenna should point upwards to a point 100km above the beacon. This may also help to reduce noise. If your local noise level is too high you can always use our [live stream](#) which can also be useful to assess how well your own receiver and antenna are working.

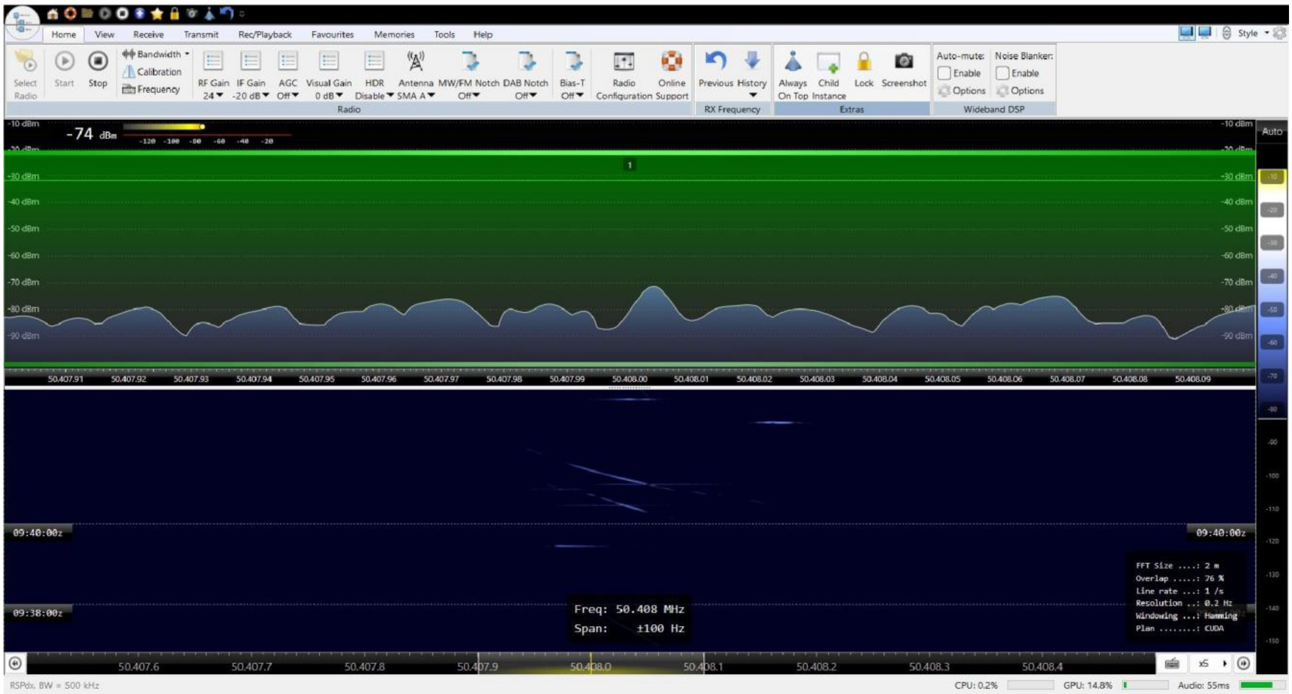


Making observations

Once you have established that you can receive meteor echoes from the GB3MBA beacon you will need to consider how to display them.   For simple meteor counts, a slow waterfall display with a narrow frequency span is adequate.

Screenshot 4

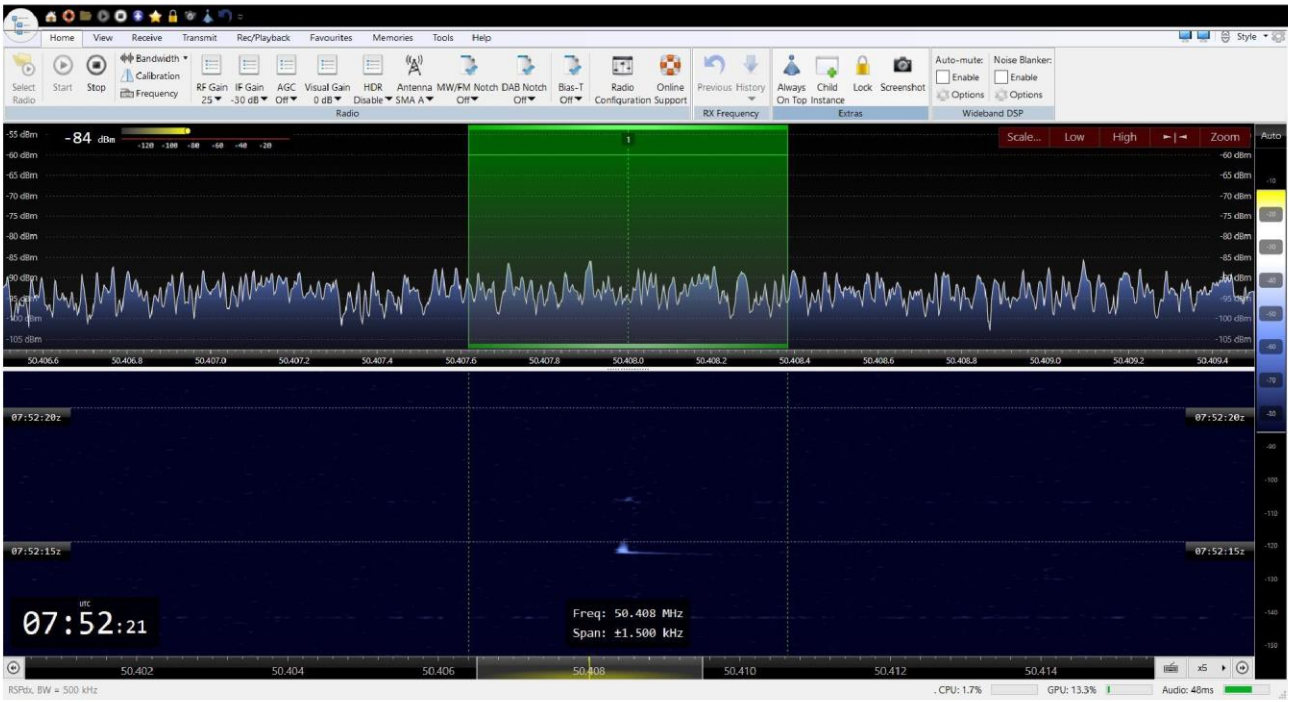
Screenshot 4 shows such a display. Note that the vertical time span of the waterfall lasts about 5 minutes, and the frequency span is +/-100Hz. The diagonal lines are aircraft reflections with the slowly changing Doppler shift. The horizontal lines are meteor echoes. This kind of display is fine for counting meteors, but it lacks resolution of individual meteor events. It's advantages are that you only need to look at it every 5 minutes or so to count meteors. For detailed observations of individual meteor events a faster waterfall with a wider frequency span is necessary.



Screenshot 5

Screenshot 5 shows a display featuring a faster waterfall of about 10 seconds duration and larger frequency span of +/-1.5KHz in this example. This does mean that the observer has to concentrate on the display in much the same way that a conventional optical meteor observer has to concentrate on the sky. If you blink you could miss a meteor event. But much more detail is visible with this format allowing more detailed analysis. SDR Console enables you to capture screenshots and to make recordings that you can watch later and exchange with others. The slightly sloping line at the foot of this echo from a small meteor, is from the highly ionised trail of the meteor as it burns up. It exhibits rapidly changing Doppler shift due to the reflection path length changing as the meteor moves across the sky and decelerates. In this case the echo frequency changes by about 200Hz in just a few 10s of milliseconds. This is not easy to see with the slow, narrow bandwidth displays such as Screenshot 4. Using a display with this waterfall speed and frequency span allows us to gather much more information. The echo is not from the meteor itself, at this 6m wavelength its radar cross section is far too small to produce an echo. The reflection is from the thin highly ionised trail following the meteor as it burns up. As electrons quickly recombine, this wirelike structure will be quite short and appear as a rapidly moving “point” source. The brighter patch with little Doppler shift is clearly static or almost static. This is the “Tail Echo” as it stretches out behind the “head” on the waterfall. Tail echoes sometimes have a small Doppler shift of 0-50Hz which is due to wind at the ionised region.

The presence of a “head echo” confirms that we are viewing a meteor (or space debris) event. Other ionospheric phenomena such as sporadic E can give rise to echoes which will not feature a head echo and could otherwise be confused with meteor echoes.



Science Objectives

Details of the projects science objectives can be found at:- https://ukmeteorbeacon.org/Scienceobjectives

Some additional detail we wish to collect, and study include: -

Brightness and extent of Doppler shift of the head echo. Note that “Head echoes” are most probably directional so not all observers of a particular event will see one.

Brightness, Doppler shift, spectral spread and duration of tail echoes.

Head echoes are from a thin, short, wirelike structure they may be directional and polarised. This is an area of particular interest.

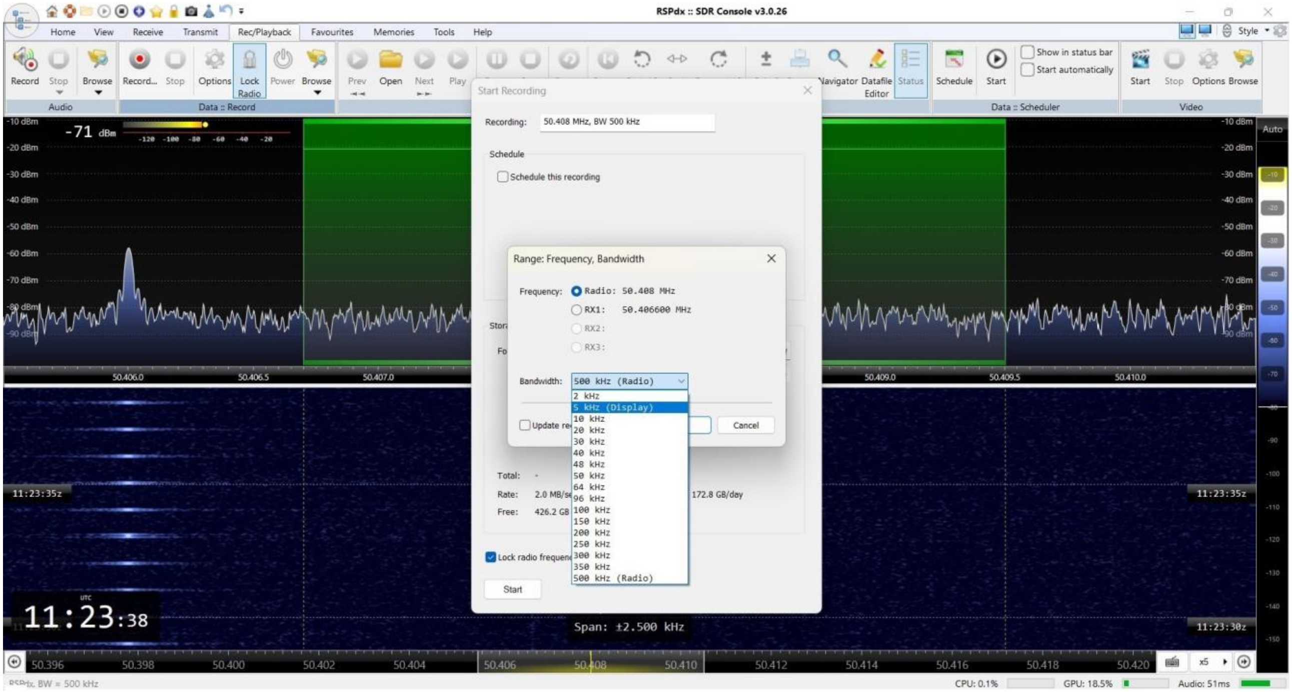
Later in the project we plan to use observation of precise Doppler shift at an instant, viewed from multiple directions, to calculate the location, trajectory and radiant of meteor events. Also it should be possible to establish the altitude at which maximum ablation occurs and / or where tail echoes form.

Example Observations

While our network of receivers is being developed and deployed useful observations can be made using your own receiver together with software such as SDR Console and that is what I have used to produce the examples I show here. SDR Console is free (but please make a donation to its author if you use it)

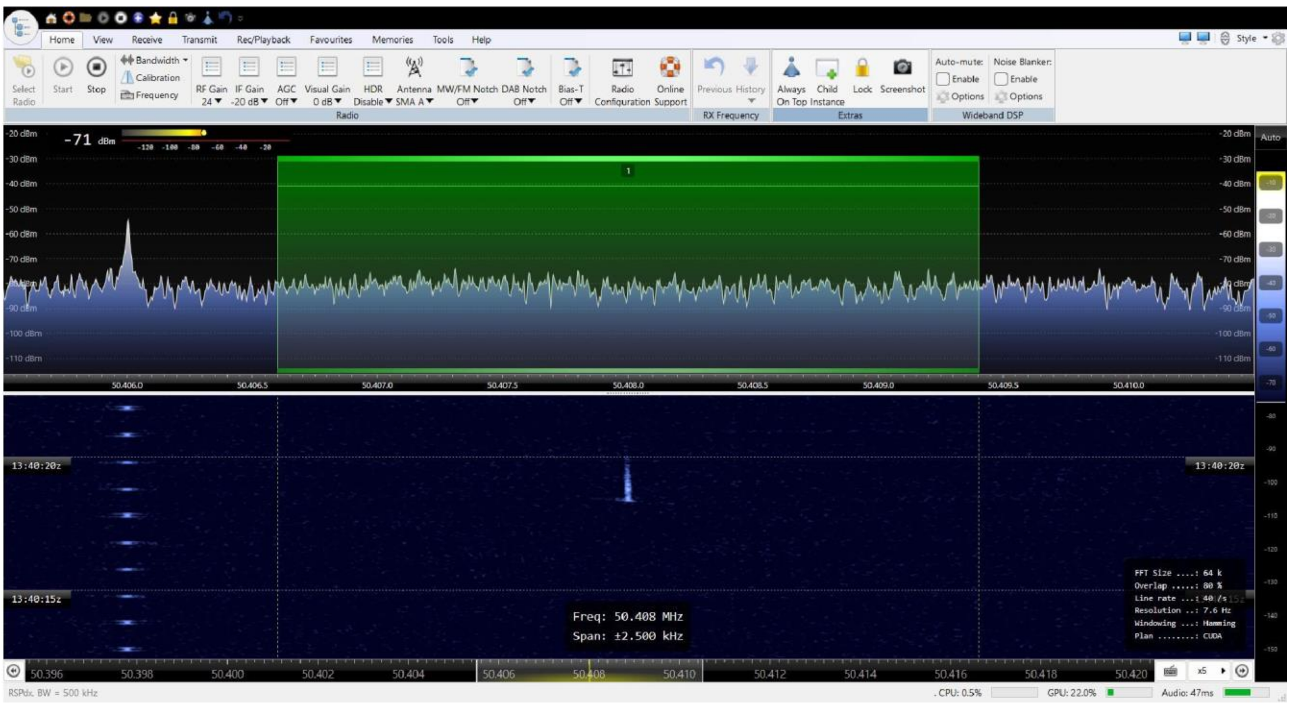
Screenshots with the high resolution, fast waterfall (say 10 seconds maximum) and wide span (say +/- 2.5KHz) will be very helpful. SDR Console can also make useful compact recordings by setting the range to “Display” the span you have set. See Screenshot 6.

Screenshot 6



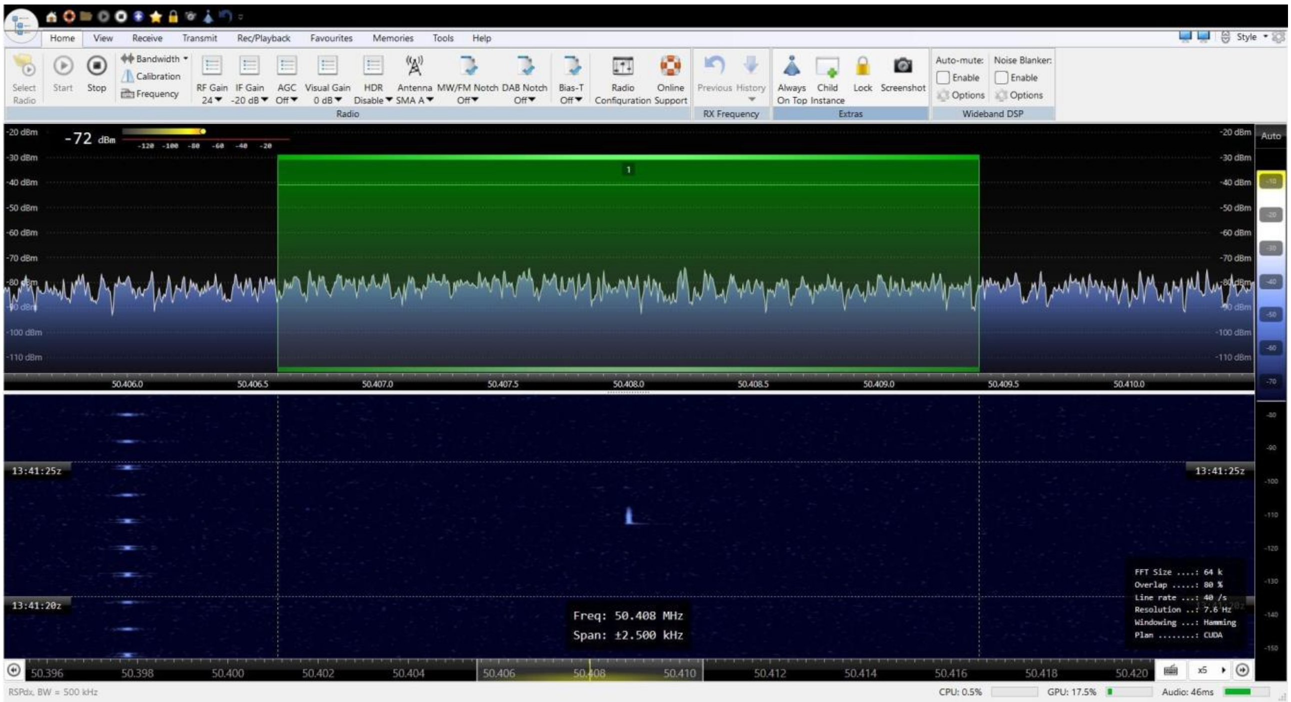
Screenshot 2023-02-06-13:41:22

Most but not all Meteor echoes viewed with this resolution show the characteristic “head echo” with rapidly changing Doppler shift.



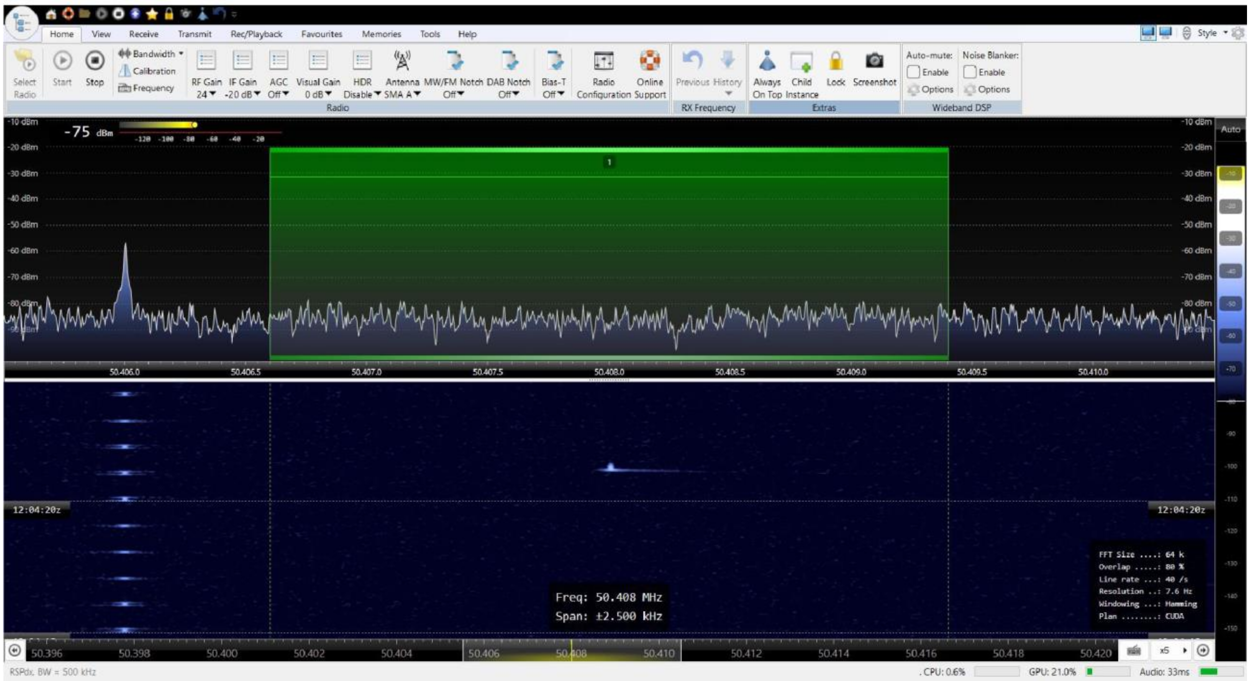
Screenshot 2023-02-06-13:41:27

A typical echo from a small meteor featuring head and tail echoes.



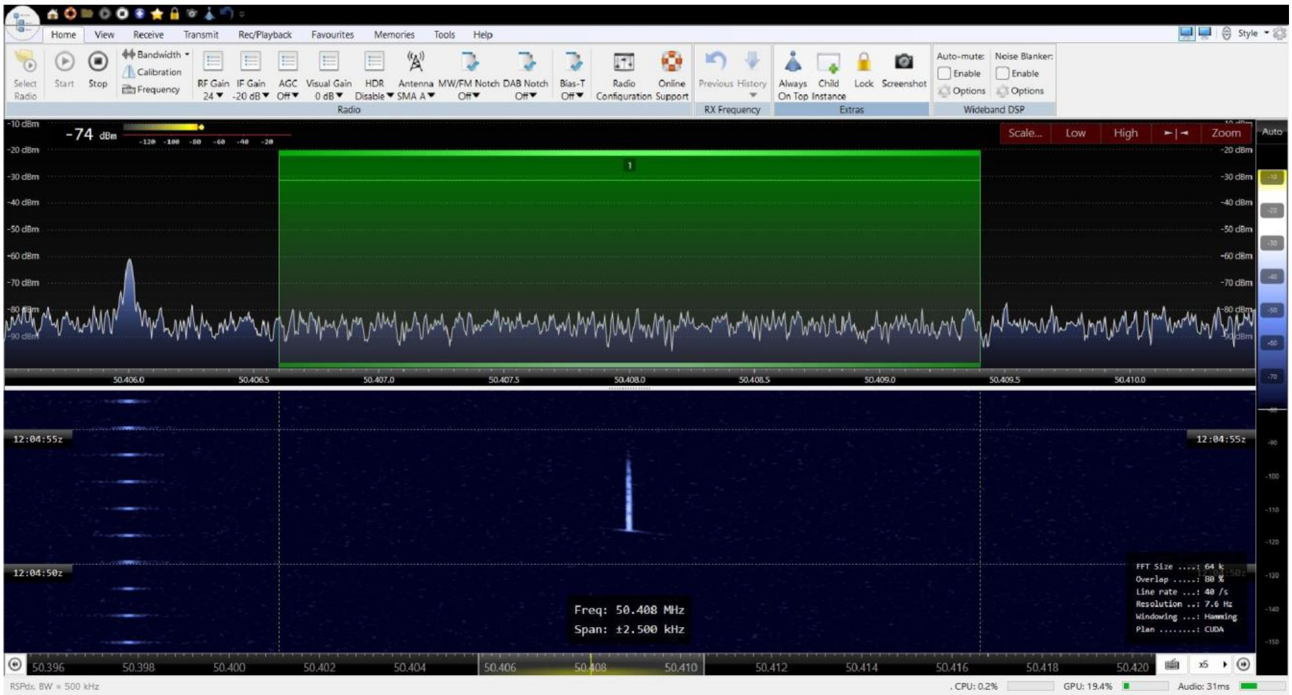
Screenshot 2023-01-26-12:04:24

A fairly typical echo from a small meteor. The head echo starts with a positive Doppler shift of about 350Hz suggesting that the path from beacon transmitter to meteor to receiver was closing at about 2000m/s at the start of the trace. The meteor could be travelling much faster of course



Screenshot 2022-12-26-16:38:54

A clear head echo with the tail echo forming later and the head echo continuing substantially unchanged. The meteor did NOT explode! The tail echo lasts for 3 or more seconds.



Screenshot 2023-01-26-12:04:56

This echo is viewed with +/-100Hz span and slow time base. There appear to be two tail echoes the longer lasting one formed first with slight positive Doppler and the smaller one forms later with slight negative Doppler suggesting that the meteor has passed through a region with wind shear. Note the aircraft reflections, the sloping lines exhibiting slow changing Doppler