1 INTRODUCTION

The purpose of this note is to report on some experiments conducted in January 2012 to detect meteor echoes from a site near Bristol in the UK, using the BRAMS transmitter operated by the Belgian Institute for Space Aeronomy[1].

Previous work had been carried out by the author using the French GRAVES transmitter on 143.050MHz [2]. The BRAMS system operates at a much lower frequency of 49.97MHz and offered an opportunity to compare the general form of meteor and other echoes received at the two frequencies.

There were a number of reasons for wishing to observe meteor echoes using the BRAMS transmitter:

- The Graves Tx is located in central France and energy is beamed southward. This means that meteor echoes are seen from events over southern France – and these cannot be observed visually in the UK.
- The desire is to try to have a meteor scatter radar system that could be used at sites in the southern UK to enable simultaneous visual and radar observations to be made. This required a transmitter that was nearer to the southern UK than Graves.
- To compare the types of echoes obtainable at these two very different frequencies - almost a factor of three apart. The lower frequency was thought to be more suited to reflecting energy from meteor trails.
- In view of the difference in frequency, the Doppler shift from meteor trails would be considerably lower from the BRAMS radar and it would be interesting to see what detail could be recovered from the lower Doppler shift data.

This article describes in brief the BRAMS transmitter, discusses the design of a suitable receive antenna and shows examples of some of the hundreds of echoes recorded. Finally we offer some conclusions and suggestions regarding the use of the BRAMS system.

2 BRAMS TRANSMITTER

BRAMS (Belgian RAdio Meteor Stations) is a set of radio receiving stations using forward scattering techniques to study the meteoroid population. The project is coordinated by the Belgian Institute for Space Aeronomy (BISA), in the frame of the Solar-Terrestrial Centre of Excellence (STCE). Most stations will be run by Belgian radio amateurs or groups of amateur astronomers. Two dedicated beacons located in Ieper (Western Belgium) and Dourbes (Southern Belgium) act as transmitters.

In September 2010, the Institute installed a beacon at the Geophysical Centre of Dourbes which belongs to the Royal Meteorological Institute of Belgium (RMI). Coordinates are: latitude=50,0972° N, longitude= 4,5847° E. It emits a CW circularly polarized signal at a frequency of 49.97 MHz with a constant power of 150W.

The geometry of the meteor radar formed by the BRAMS transmitter in Belgium and the receiving station near Bristol in the UK is shown in Figure 1.

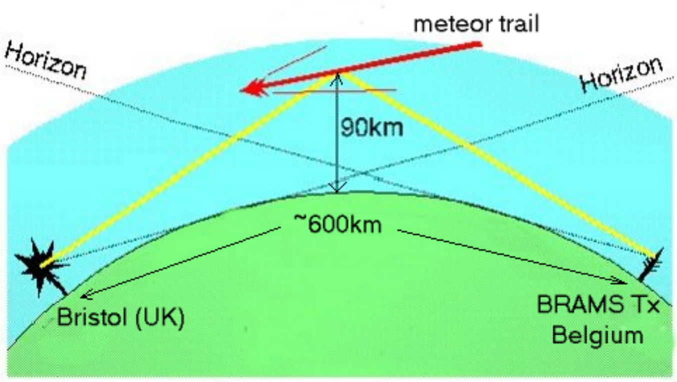


Figure 1 Geometry of BRAMS / Bristol Meteor Scatter Radar

The location of the Tx & Rx are shown on the map in Figure 2. The measured distance between the two is 574km.

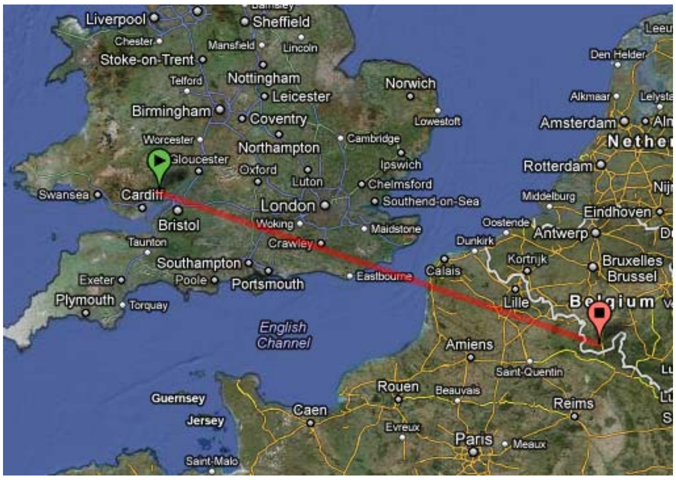


Figure 2 Distance from BRAMS to Bristol is 574km

The network of receiving stations in Belgium is shown in Figure 3. The Tx location is marked in red. With so many receivers, it is possible for the Belgian Institute to accurately calculate the track of the meteor trails.

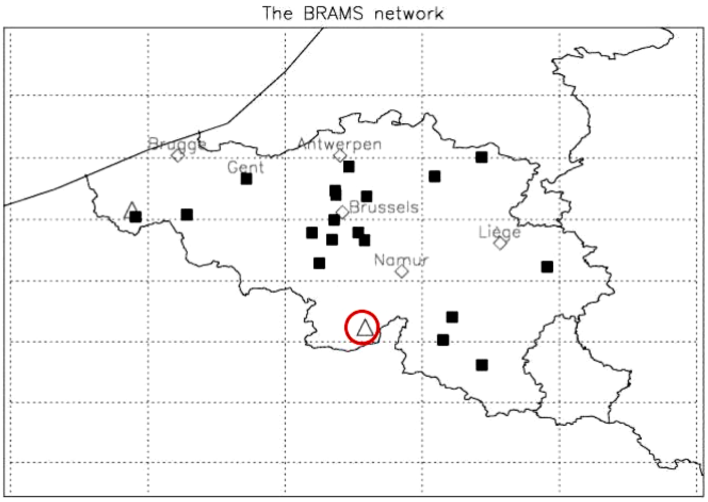


Figure 3 The BRAMS receiving network

The system has had a recent upgrade to the Tx antenna to incorporate an 8m x 8m ground plane as shown in Figure 4. This improved the upward beaming of the signal as shown in Figure 5.

Figure 4 The BRAMS Tx antenna with improved ground plane

The BRAMS Tx calculated antenna beam has been plotted in polar form in Figure 6 and shows that very little signal is transmitted along the horizontal. This is good for an observer at extreme range (e.g. Bristol) as no background signal can be detected and clear ‘pings’ are heard when a meteor is present in the beam projected high over Belgium. However the consequence of this is that it may not be possible to clearly visually observe trails over Belgium from the location in Bristol – and correlation between Radar and visual sightings may not be very good.

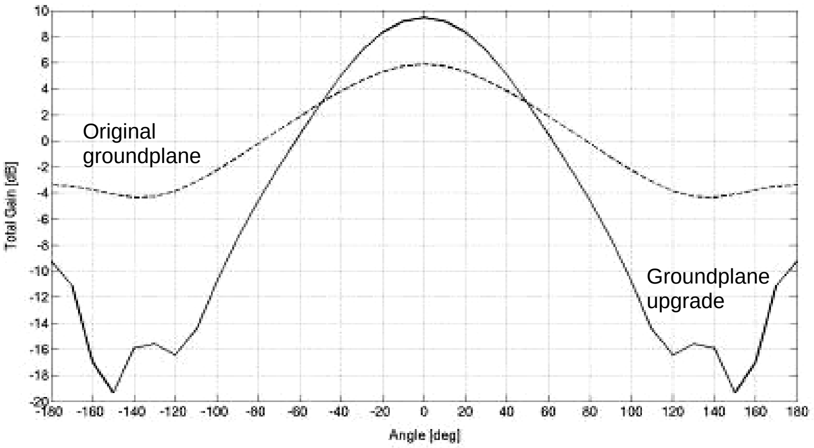


Figure 5   BRAMS Tx Antenna plot (Calculated)

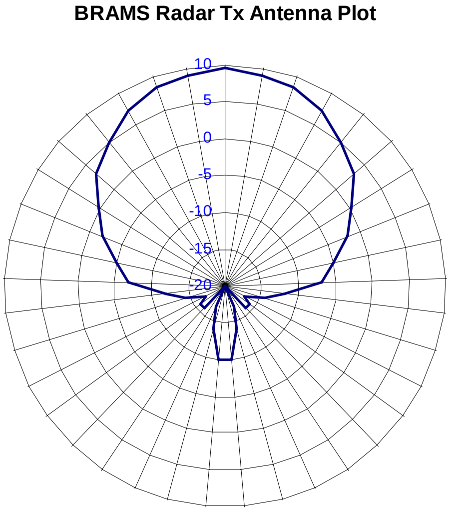


Figure 6 BRAMS Tx Antenna Polar Plot (Calculated)

Figure 7 shows the arrangement of the Tx antenna elements and other equipment.

Figure 7   Antenna Elements & Tx Equipment

3 50MHz RECEIVE ANTENNA

The antenna used to receive the BRAMS signal was very largely based on the design for a 50MHz (6m band) amateur radio design developed by D.A.Reid PA3HBB / G0BZF[3].

It was published by the Radio Society of Great Britain in the November 1997 issue of the Society magazine - Radio Communication ©. (The paper can be found on the internet at reference 3).

The design appeared to be just what was required for use in these experiments with the BRAMS meteor radar – only small adaptations have been made in some of the constructional details.

Reid[3] gives his priorities that the design has to fulfil as:

- Boom length of not more that 2m
- Reasonable gain
- Low cost
- Ability to dismantle easily, for transportation
- Easy assembly with the minimum of tools
- Easy and quick tune-up
- Lightweight

These are exactly what are needed for a portable Radar receiving station that can be driven around the countryside to meetings and demonstrations etc.

My dimensioned diagram – based on the paper - is given in Figure 8. In the version of the antenna used for these meteor experiments the elements are made from 15mm diameter lightweight metal tubing and each element is a single length. Even the driven element is a continuous tube thanks to the Gamma match arrangement that is described later.

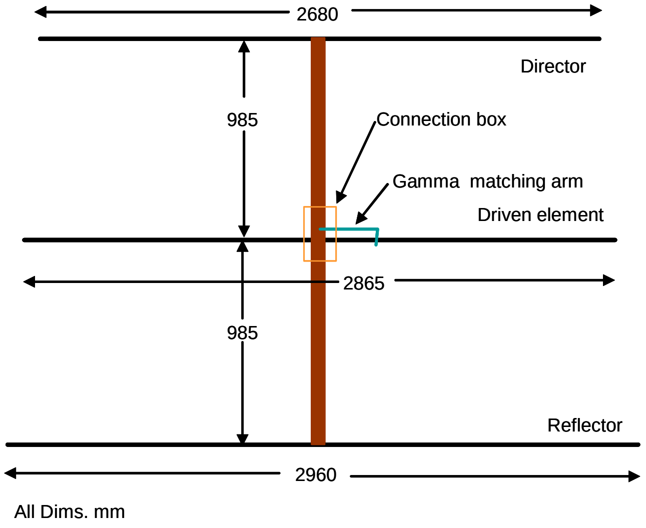


Figure 8 50MHz 3 Element Yagi Antenna (After Reid)

15mm diameter tubing was selected so that cheap plastic water pipe spring clips could be used to hold the elements firmly. The tubes can be simply snapped into place and the antenna assembled in seconds. See detail in Figure 9.

Figure 9 Snap-on plastic clips

All three elements are held to the varnished wooden boom in this way.

The important part of this design by D.A.Reid is the Gamma connection of the coaxial cable to the active element.

The gamma-match connection (which is a special case of the T-match, and thus a particular case of the folded dipole) is employed as a broadband matching technique to feed a dipole from a mismatched coaxial line [4]. The inner gamma rod, usually with smaller radius, is connected to a coaxial line at one end and is tapped at one location to the active element.

The tap point is set at a distance ‘x’ from the driven element centre. The gamma match and dipole are separated from each other by a small distance ‘y’. A capacitor, the purpose of which is to resonate the circuit and balance the line, is placed at the feed point of the gamma rod. See Figure 10. Further detail can be found by inspecting Figure 9.21 from the book Antenna Theory by Balanis [5].

Reference 4 gives a MATLAB program for a gamma-match connection and is designed to calculate the values of ‘x’ and C, which are, respectively, the length of the gamma rod and the capacitance of the capacitor at the junction of the transmission line and the gamma rod.

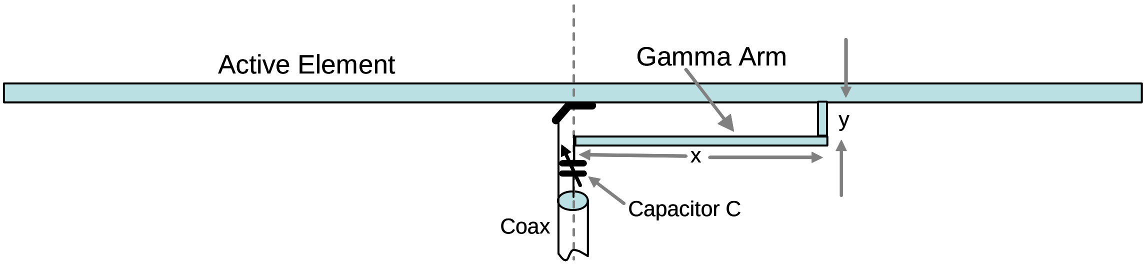


Figure 10 Gamma Connection

The detail of the construction of the Gamma connection can be seen in Figure 11. The gamma arm is 320mm long and made from 10mm dia tube. A single threaded rod is used to clamp the gamma arm, connecting piece and driven element together, ensuring a good electrical connection and strong mechanical joint.

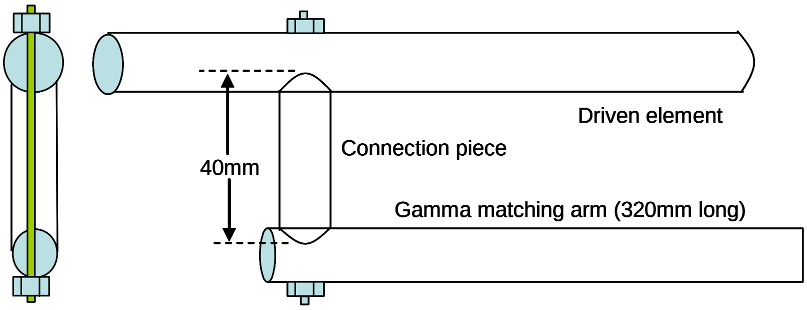


Figure 11 Detail of Gamma arm assembly

At the other end of the gamma arm, at the centre of the driven element, the coaxial cable (usually 50 Ω) is connected as shown in Figure 12. Note that the gamma arm can be positioned to either side of the centre of the driven element – in this figure it is shown on the right hand side.

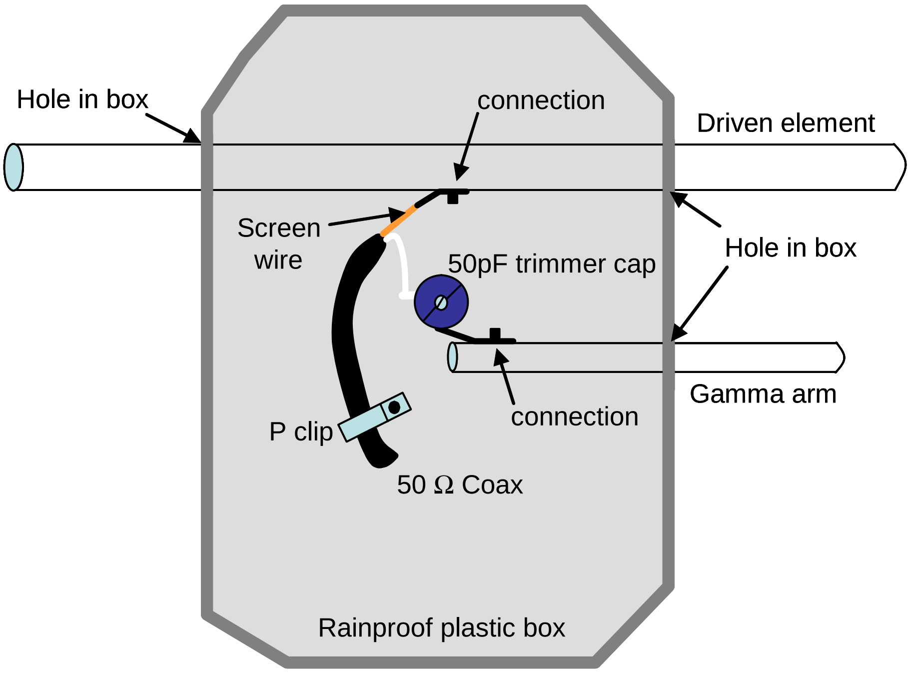


Figure 12 Detail of Coaxial connection and Capacitor

A variable capacitor is used to connect the coax inner to the gamma arm, as this allows the antenna performance to be optimised by trimming to the correct value.

The whole connection is mounted in a rainproof plastic box with the tubes projecting through the sides and sealed and supported with epoxy glue as shown in Figure 13.

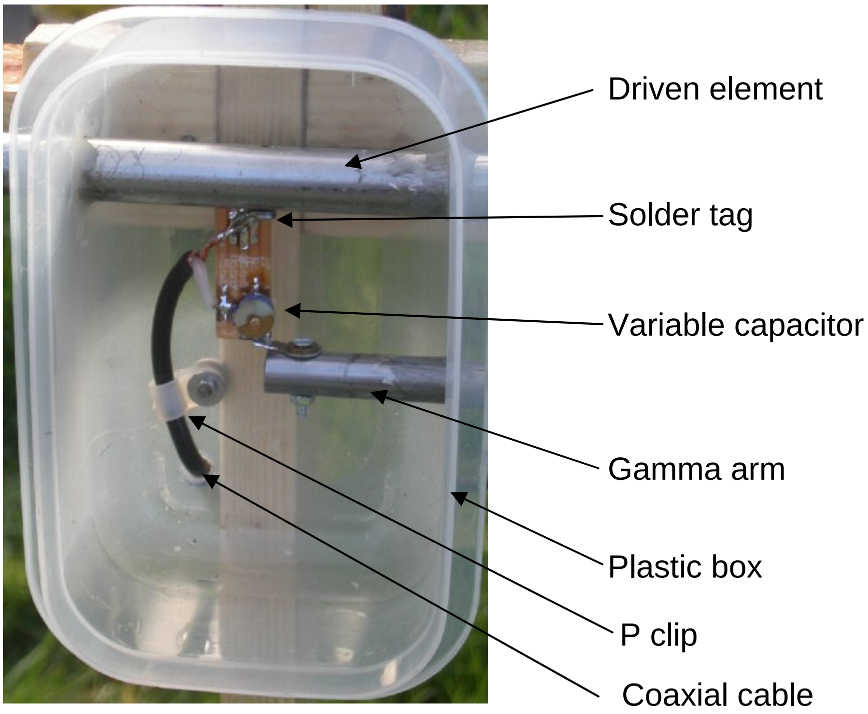


Figure 13   Connection Assembly

The finished item can be seen in Figure 14. The whole of the driven element assembly simply slots into the plastic clips mounted on the wooden support beam.

Figure 14   The finished driven element assembly

In order to have the ability to tilt the antenna upwards, a quadrant plate with four pre-set angles is fitted to the boom and the main vertical support member that connects with the 50mm diameter metal mast. When attempting to detect echoes from the BRAMS transmitter in Belgium, the antenna needs to point to the horizon and the elevation quadrant is not required. However it is hoped to use this antenna to detect meteors over the UK – if a suitable CW transmitter can be found - and the ability to tilt the antenna upward will be useful.

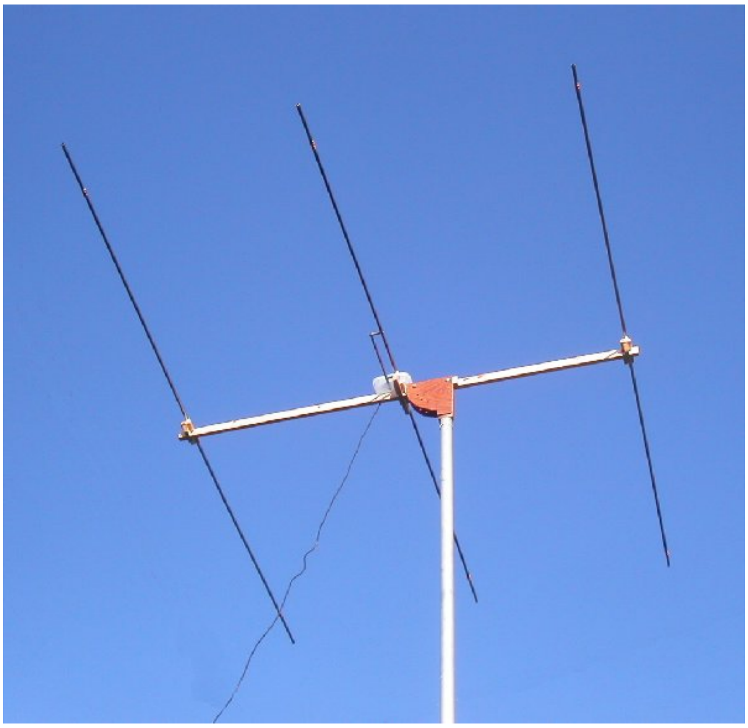


Figure 15   The completed Receive Antenna

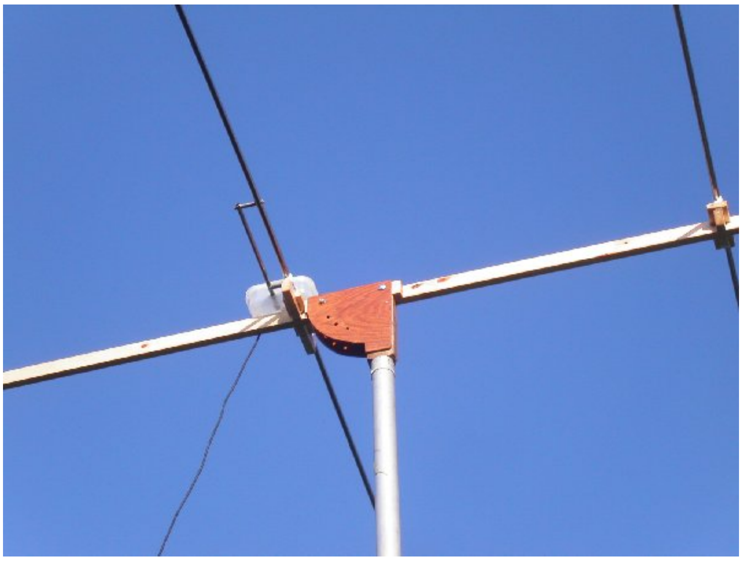


Figure 16   Detail of the Quadrant Plate

4 ECHOES RECEIVED AT 49.97MHz from BRAMS

4.1 Single Under-dense Echoes

Most meteor trail echoes are short and result from the formation of under-dense ionisation trails [6 7]. These short echoes appear to have no significant Doppler shift and therefore appear as 'spots' on a velocity v time plot. The line of sight (LOS) velocity is proportional to the frequency produced by an SSB demodulator in the receiver. The ICOM –R7000 receiver used in these experiments is shown in Figure 17 and the frequency was tuned to just above the radar frequency of 49.97MHz. This results in an audio detection tone of ~ 800Hz or 1.6kHz, being equivalent to a zero velocity return in the two sets of experimental examples given below. (The higher frequency enables the 'Spectrum Lab'[9] analyser to operate with higher frequency resolution.)

Figure 18 shows a typical 'spot' echo from an under-dense meteor trail. The echo is better than 20 dB higher than the background noise. The echo colour is related to the signal intensity.

Figure 17 Icom R7000 receiver with SSB demodulation

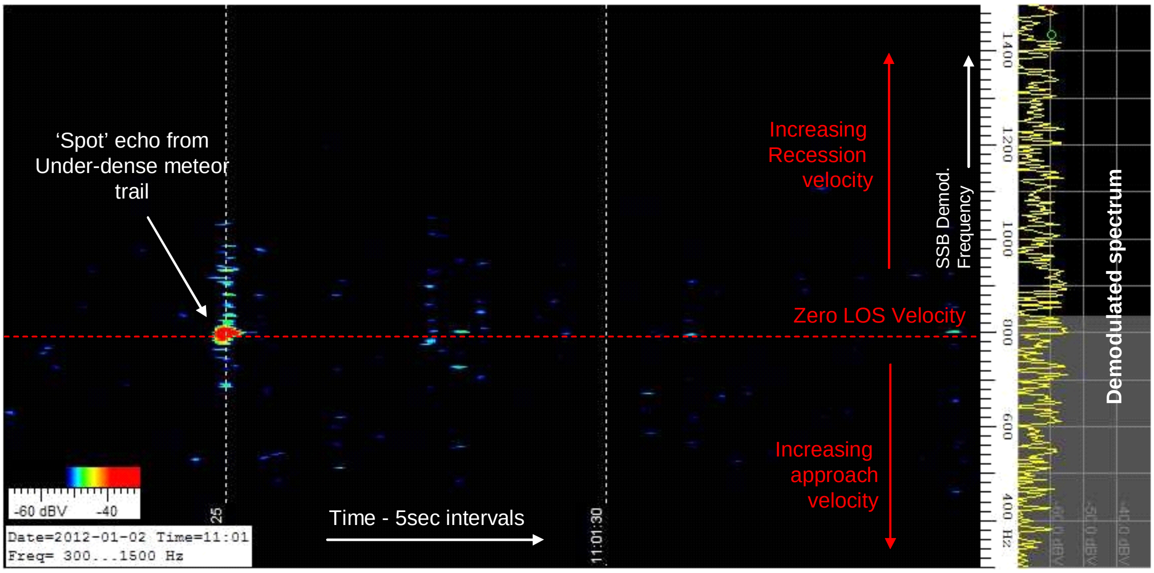


Figure 18 Typical frequency / time waterfall plot of an under-dense echo

Figure 19 shows three ‘spot’ echoes being received within about 10 seconds. It may be noticed that faint signals occur above and below the bright echo spot and seem to be related to the strength of the echo. It is not known if this is a real physical effect or an instrument artefact and will be the subject of further study.

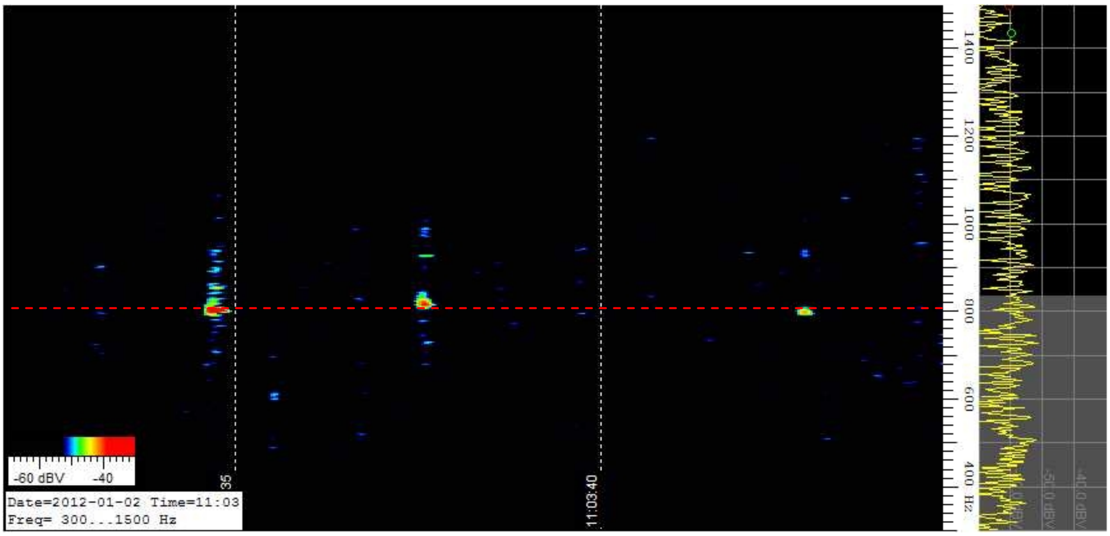


Figure 19 Multiple under-dense echoes

These results were obtained on the 2nd of January 2012 during the build up to the peak of the Quadrantid meteor shower on the 3rd to 4th of the month. On average the system was detecting 60 to 80 echoes per hour.

4.2 Longer low-velocity echoes

Whilst most of the echoes were the short ‘spot’ type shown above, some lasted longer – up to a few seconds – and are thought to arise from over-dense meteor trails[6][7]. An example can be seen in Figure 20. The echo lasts for about 2 seconds and the intense echo head is accompanied by noise similar to that observed for the ‘spot’ echoes.

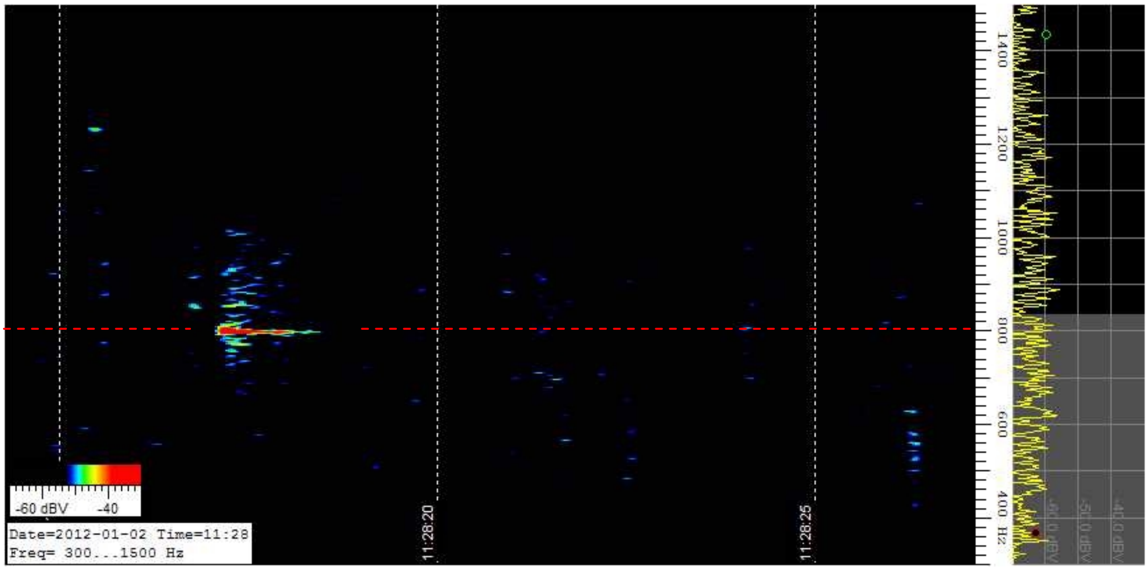


Figure 20 Longer lasting echo from over-dense trail

Two further examples of echoes lasting a few seconds are shown in Figures 21 and 22. In both cases the intense part of the echo is accompanied by noise at demodulated frequencies close to that of the echo. It will be important to understand what causes this noise and to determine if it is a real phenomenon associated with the meteor trail formation or is generated in the receiver.

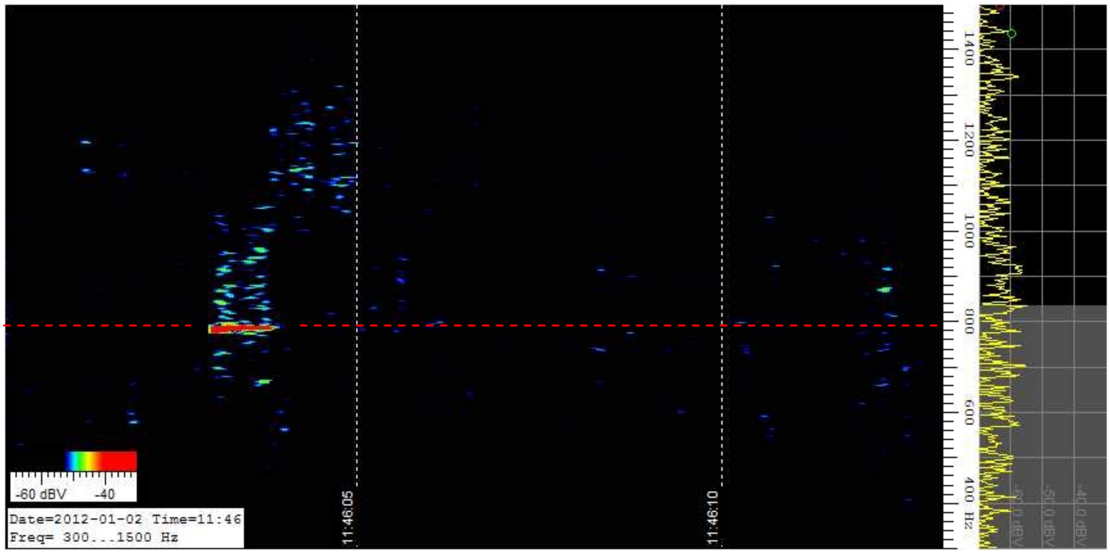


Figure 21 An example of an echo lasting a few seconds

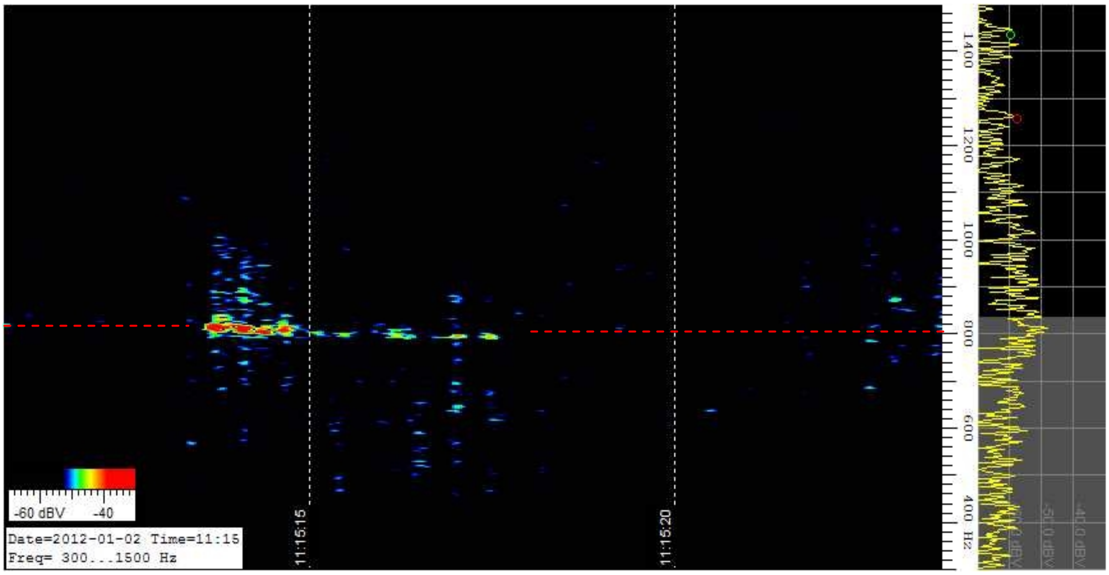


Figure 22 An example of an echo with small bursts and a long tail

4.3 Raised Noise levels on echoes

The observation of raised broadband noise levels associated with echoes is puzzling as this is not seen on the results obtained with the Graves Radar[2 8]. It is important to understand if observation at 49.97MHz using the BRAMS radar can reveal something about the meteor trail generation that is not seen at 143.050MHz with the Graves system. Figure 23 shows a good example of how the noise seems to maximise at the start of each intense segment of the echo. This could indicate that the noise is produced in the receiver – perhaps related to the operation of the AGC . If this was the case however, one might expect to see noise *diminish* at the start of a strong signal rather than increase.

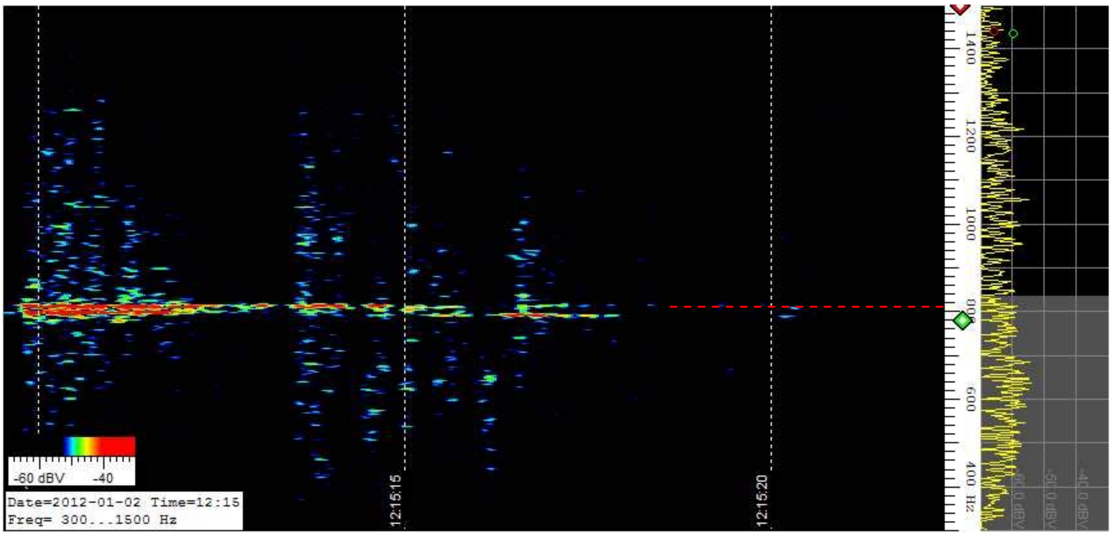


Figure 23 Noise bursts associated with intense parts of the echo

4.4 Echoes from aircraft

A number of echoes were received from aircraft. These can last 20 to 30 seconds and with the frequency / velocity resolution used in these waterfall plots they appear to have little LOS velocity as depicted in Figure 24.

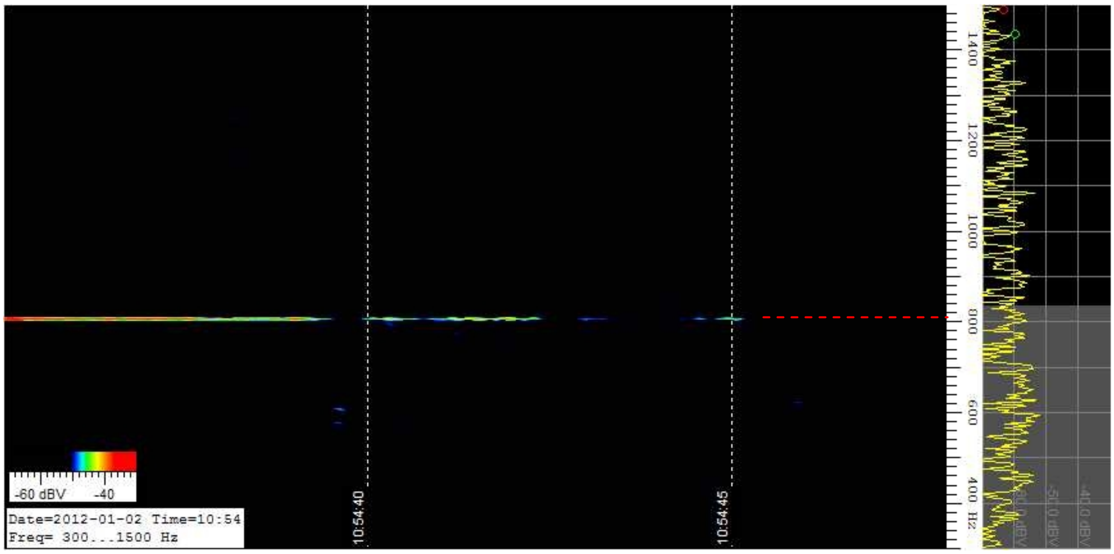


Figure 24 Persistent echo from an aircraft

Another example of a rather more broken echo from an aircraft is shown in Figure 25.

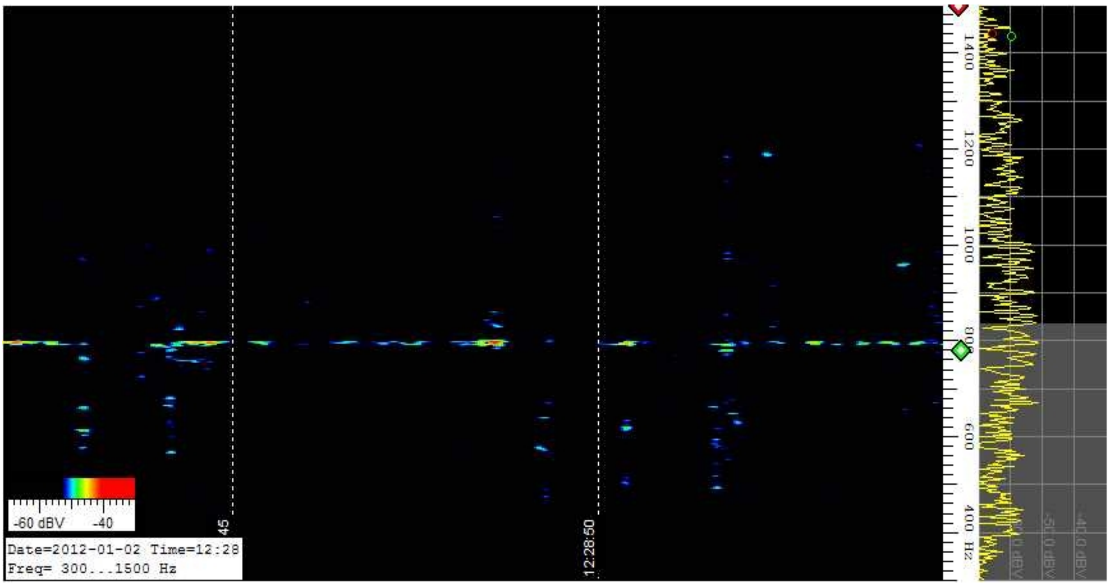


Figure 25 A long, intermittent echo from an aircraft

4.5 Fast decelerating echoes & 'Hooks'

This type of echo has been seen repeatedly using the Graves system. These echoes start with near vertical traces – sometimes followed by a horizontal section - indicating a long lived stationary trail. The steep part of the trace probably results from an ionised trail that is rapidly decelerating as the meteor loses energy through interaction with the atmosphere at 90km and below. Using 49.97Mhz from the BRAMS radar, the Doppler shift from the LOS velocity of the trail is less than that from the Graves system on 143.050MHz, but it can still be seen clearly in Figure 26.

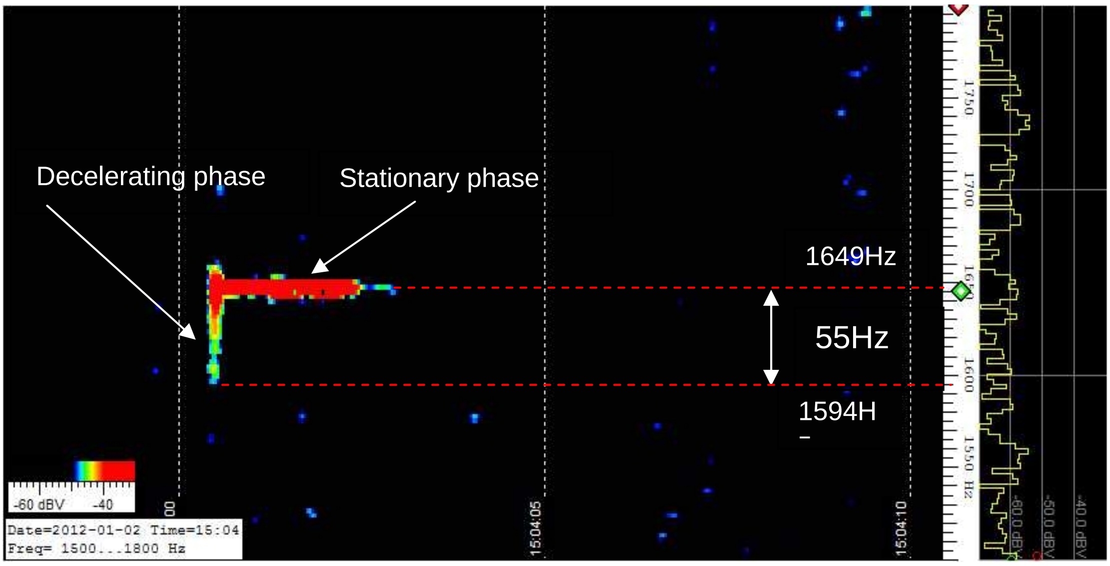


Figure 26 Decelerating meteor forming a 'Hook' shape

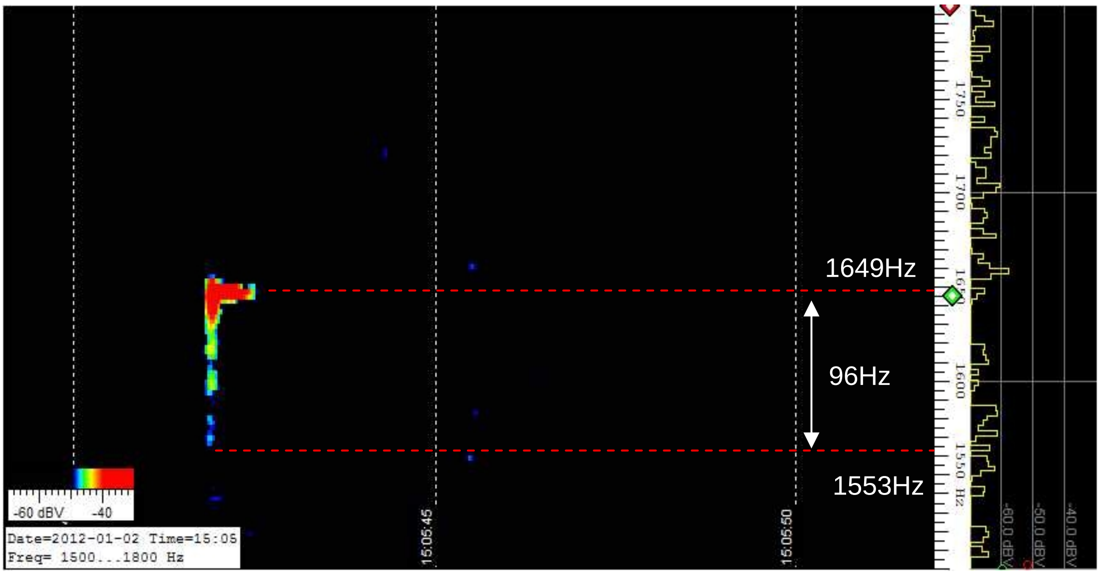
In this example the Doppler shift of the fastest part of the echo is only 55Hz. If we use the formula below we see that the echo only starts to be dense enough to detect with this system when the meteor velocity has reduced to 330m/s.

$$\Delta f/F = v/c \qquad \text{Eqn. 1}$$

Where Δf = the Doppler shift in Hz
F = the Radar frequency in Hz
V = the LOS velocity in m/s
C = speed of light ($3\text{x}10^8$ m/s)

The ideas expressed here about the causes of these meteor echo traces are conjecture and need substantiating or modifying by conducting further research. Ideas and comments from readers are welcome – including directing the author to existing work that explains the properties of these echo traces. (Contact dmradast@hotmail.co.uk).

A second example with higher Doppler shift, but with a shorter duration stationary component, is shown in Figure 27. The highest LOS velocity detectable on this trace is 576m/s.

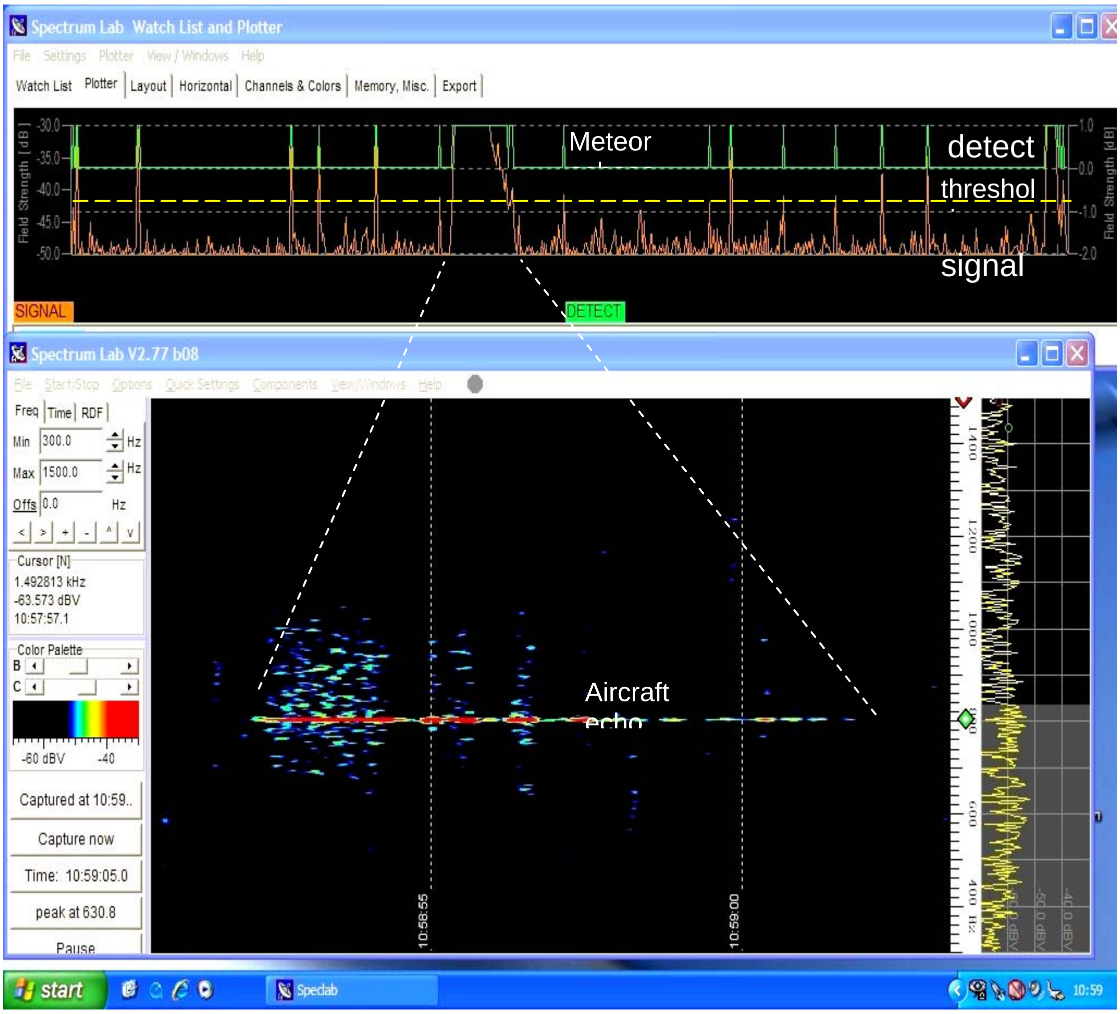


Date=2012-01-02 Time=15:05
Freq= 1500...1800 Hz

Figure 27 A second example of a 'hook' meteor echo

4.6 Echo rate achieved

The Spectrum Lab software [9] can be configured to automatically detect an echo signal. The 'conditional action' feature can be used to detect a signal that exceeds a nominated threshold, at which point the 'screen capture' macro is invoked to store the waterfall plot. The operating screen contains the waterfall plot (with the spectrum on the right side) and the 'Watch List' graphs that show the signal and the detected echoes along a time base of several minutes. This can be seen in Figure 28.



Min 300.0 Hz
Max 1500.0 Hz
Offs 0.0 Hz
Cursor [N]
1.492813 kHz
-63.573 dBV
10:57:57.1
Captured at 10:59..
Time: 10:59:05.0
peak at 630.8

Figure 28 Spectrum Lab screen showing automatic echo detection

A long aircraft echo has been recorded on the waterfall plot and in the watch list graph at the top of the screen. The short detection spikes (green trace) are due to meteors and sometimes interference. Any interference can be distinguished from meteor echoes by inspection of the waterfall plots recorded for each ‘detection spike’.

The rate of echo detections varies considerably from minute to minute and hour to hour. The greatest rate of detection is usually at dawn [10] , due to the position on the Earth where the radar is located having a maximum velocity by a combination of the orbital and rotational velocities. The average detection rate over any specified period can be determined by counting the ‘detection spikes’ (green spikes) using Microsoft EXCEL, for example.

During these experiments with the BRAMS radar on 2/1/2012 at a time when the Quadrantid shower was building up to its maximum on the 3/4/1/2012, the average detection rate was about 80/ hour. Most of the echoes were single ‘spot’ echoes from under-dense meteor trails.

5 CONCLUSIONS

In this section there are some observations and conclusions that can be drawn from this brief experiment using the BRAMS Belgian radar to detect meteors.

- It is possible to detect meteors using the BRAMS transmitter with receivers located in the south west of the UK. Reasonable signal strengths can be obtained resulting in typical echoes being 20dB above background noise.
- A three element Yagi antenna can be constructed quite cheaply that provides suitable gain and directionality for meteor observations at 50MHz.
- A low noise head amplifier[11] is useful at the mast head if more than 20m of coaxial cable connects the antenna to the receiver.
- A standard communications receiver with an SSB demodulator can be used to receive the signals and convert them to audio tones in the range 500Hz to 1.5kHz - depending on the receiver tuning.
- Several types of meteor echoes have been detected. Most of them are short ‘spot’ echoes from under-dense meteor trails. A small fraction (around 10%) are longer, lasting a few seconds and are generated by over-dense meteor ionisation trails .
- Aircraft are easily detected and produce long echoes lasting up to 30 seconds.
- Occasionally ‘hook’ type echoes are received that are composed of a clear Doppler shifted section during deceleration and a longer static section before the echo fades away.
- All these types of echoes have previously been seen using the Graves Radar at the higher frequency of 143.050MHz. In general there is more definition of features in the ‘Graves echoes’, as the signal-to-noise ratio is better and any Doppler shifts are about three times as large as those derived from the BRAMS system operating at 50 MHz.
- One feature that is different is the bursts of broadband noise that accompany almost all the BRAMS echoes. This has not been seen in the Graves results. It is not clear at present what causes this effect. If it arises in the receiver it is a nuisance and may be difficult to eliminate. If it is real and is associated with the formation of the meteor trail, it is interesting and worth further exploration to understand its cause.
- Using the BRAMS radar it may be possible to correlate radar and visual observation of meteors over the southern UK. Such an experiment might attract visual observers of meteors to take part.

REFERENCES

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5 Balanis Antenna Theory: Analysis and Design, 3rd Edition Wiley Publications

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7 www.imo.net/radio/reflection

8 Graves echo results www.britastro.org/radio

9 Spectrum Lab www.qsl.net/dl4yhf/spectra1.html

10 Diurnal variation of echo rate Section 8.2 of:
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11 Minicircuits LNA ZX60-33LN
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