Lightning Scatter on 1296 MHz using MSK144[1]

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Some 50 lightening scattered signals were decoded using MSK144, over a 3-hour period, when a severe lightning storm passed between us on 13 February 2024. Such a severe storm is a very rare event at our latitudes and resulted in 544,000 lightning strikes[2] and power being lost to some 500,000 homes in Victoria[3]. The distance between us is 505 km and we ran 33 & 36 element single yagis with power levels of 120 and 50 watts. We were surprised that at this distance it was also possible to receive MSK144 decodes on aircraft scatter. However, we found it was possible, by replaying the files and examining the MSK144, Fast Graph window, to clearly identify the difference between both types of propagation. While at the time we completed three QSOs on 1296 MHz using MSK144, examination of the files shows that only one QSO was completely on lightning scatter and the other two were partly on aircraft scatter. Still, we can report the completion of a QSO using lightning scatter on 1296 MHz.

1. Background

The detection of lightning pings was fortuitous in that we were running tests on Q65-60B and we both noticed short and strong pings as if there was meteor scatter. While we did not think that meteor scatter would be the cause of these pings at 1296 MHz, we recalled reports of lightning scatter and decided to try MSK144. A subsequent search of the Web identified reports of lighting scatter by F6AGR[4] listening to a beacon at 648 km on 432 MHz and by ZS6BTE[5] listening to a UHF TV station at 550 km, but in neither case were messages involved. Wikipedia notes "Lightning scattering has sometimes been observed on VHF and UHF over distances of about 500 km"[6]. We have found no reports of lightning scatter QSOs but would be very interested in receiving reports of any complete QSOs on lightning scatter.

2. The Lightening Event

Fig 1 Shows extensive lighting flashes around the middle of our path (Yellow line), at the time of this event.

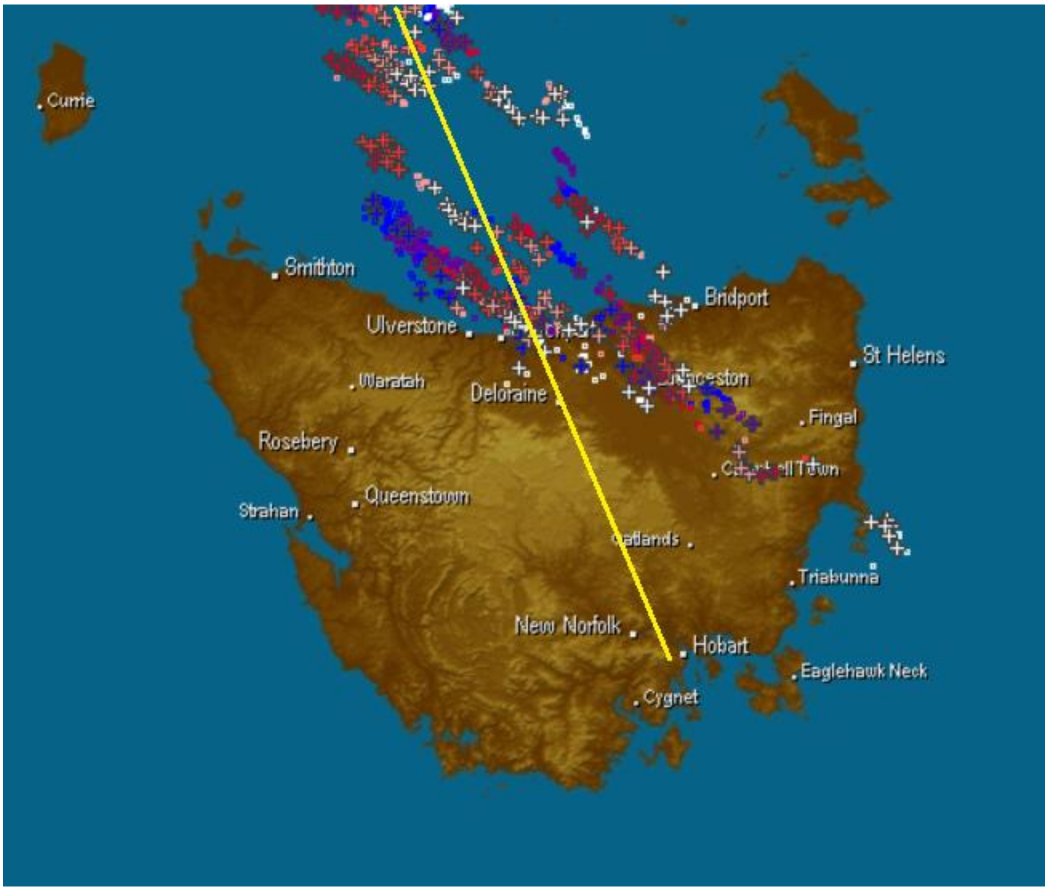

Fig 1: From Tasmania Radar/ Lightning Tracker[7]. We added the yellow line to show the path between us. VK3MAP slightly off the map at the top and VK7MO at the bottom near Hobart.

Fig 2 shows an example of decodes on moderate and strong lightning pings that decoded between 1 and 7 dB. The weakest lightning ping we decoded was at -2 dB. Fig 3 shows a strong aircraft scatter signal that gave two decodes at 11 and 12 dB. A set of files that can be decoded with the MSK144 program to show the difference between lightning pings and aircraft scatter decodes is at the link below:

https://shorturl.at/akEFL

By examining the MSK144 Fast Graphs for each of these files one can readily determine if a decode is due to lightning pings or aircraft scatter by the nature of the signal on the Fast Graph and the fact that lightening pings show on the Fast Graph at the same time as they decode.

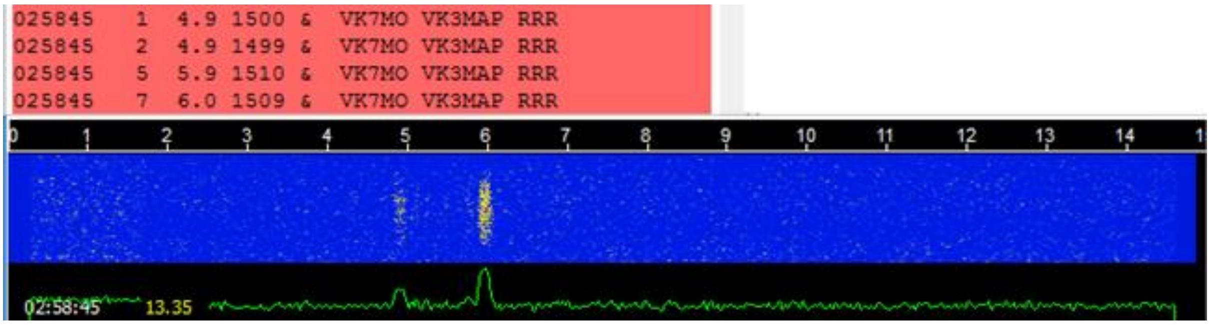

Fig 2: MSK144 Fast Graph window. The blue area shows frequency as vertical, time horizontal and the green spectrogram shows signal amplitude. Lighting pings decoded at 4.9/4.9 and 5.9/6.0 seconds.

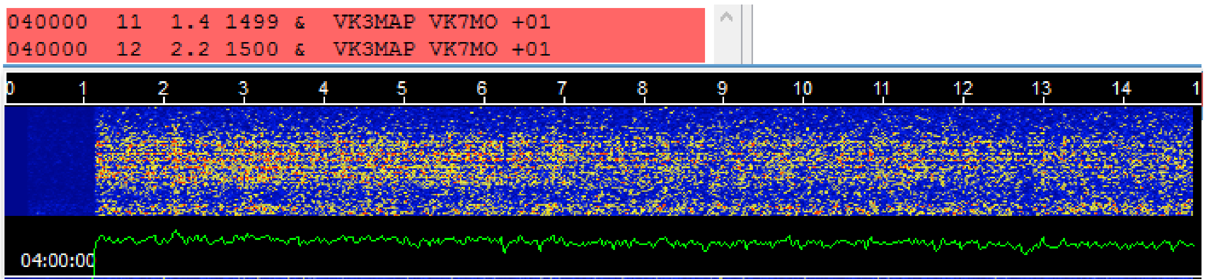

Fig 3: Strong aircraft scatter shows continuous signal fading gradually that decoded at 1.4 and 2.2 seconds.

3. Signal Levels on Lightning Pings and Aircraft Scatter Decodes

Fig 4 shows all decodes received in terms of reported signal level. They were differentiated between lightning pings and aircraft scatter by examining the relevant Fast Graphs for each decode. It is seen that the aircraft scatter decodes were present for only a short period of 3 minutes around 4:00 UTC when an aircraft flew close to along the path. There is a gap in the lightning decodes of about an hour which might relate to the fact that there were bands of lightning moving from West to East as shown in Fig 1.

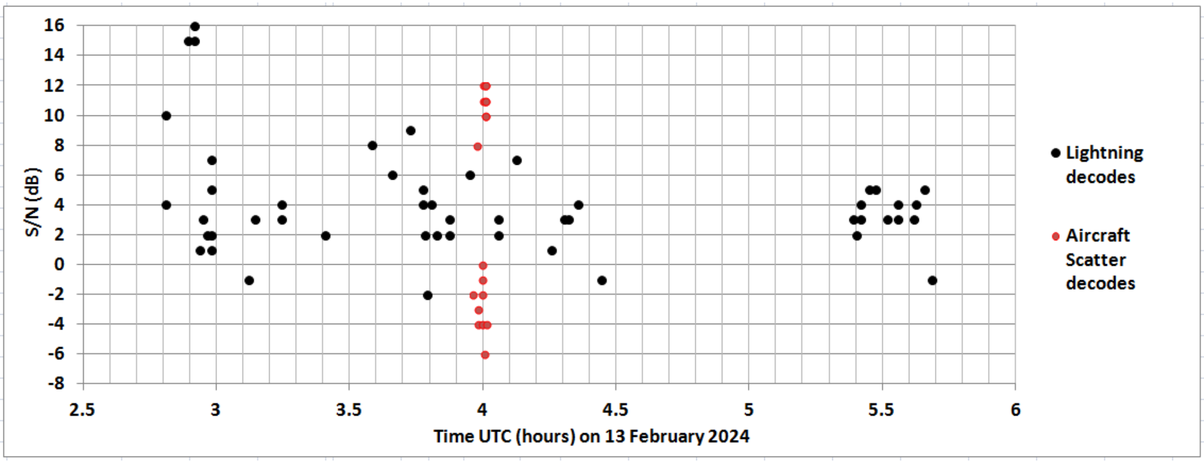

Fig 4: Signal levels as reported on MSK144 for all decodes in terms of time

4. Doppler Shifts on Lightning Pings and Aircraft Scatter Decodes

Both stations used GPS locking of IC-9700s (VK1XX and Leo Bodnar). We have found that with these systems the error does not exceed one Hz at 1296 MHz. Fig 5 shows the aircraft scatter decodes were much closer to the transmitted audio frequency of 1500 Hz with just a small drift due to Doppler. The lightning decodes show a much wider variation and on the first band of lightning a downward trend of around 35 Hz.

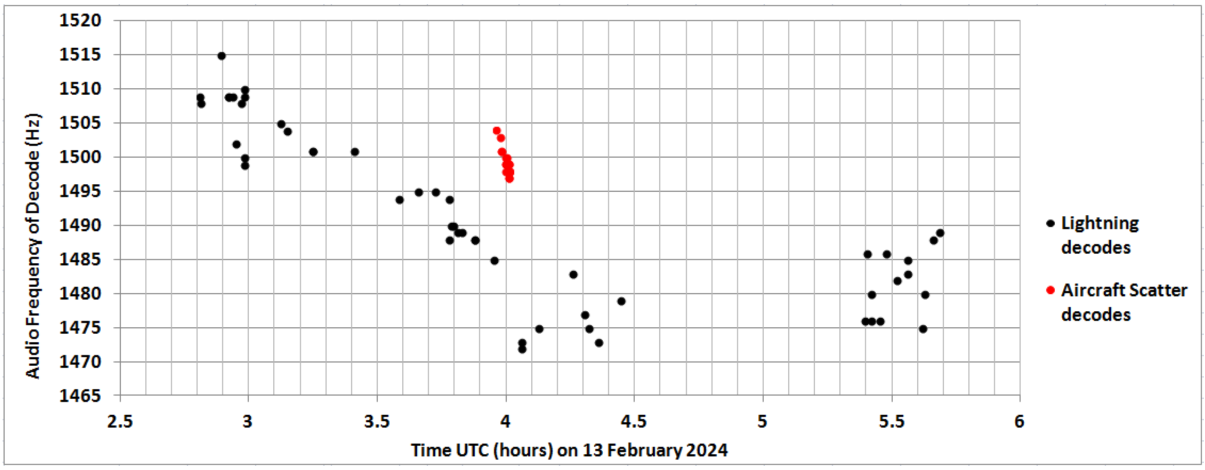

Fig 5: Shows how the audio frequency of decodes varied with time.

5. Completed QSO

Table 1 shows the exchange to complete a QSO. The QSO was completed to the RRR stage in just 10 minutes. VK3MAP did not start saving files until file 25600 so we do not have a file to confirm that the first decode of the QSO at 24830 was by lightning scatter. However, very fortunately, he did take a photograph of the Fast Graph for file 24830 to which he responded with a plus 10 dB report. The photograph confirms that this decode at 4.1 seconds at 10 dB was via lighting scatter. All other decodes necessary for the QSO, from file 25615 and later, can be confirmed as due to lightning pings from the files provided in Section 2.

Link below to photograph:

https://shorturl.at/pwVXY

24830	4	3.7	1509	&	VK3MAP	VK7MO	QE37
24830	10	4.1	1508	&	VK3MAP	VK7MO	QE37
25330	15	1.7	1515	&	VK3MAP	VK7MO	QE37
25500	15	1.1	1509	&	VK3MAP	VK7MO	QE37
25500	16	1.2	1509	&	VK3MAP	VK7MO	QE37
25615	1	9.6	1509	&	VK7MO	VK3MAP	10
25700	3	4.8	1502	&	VK3MAP	VK7MO	R+01

25800	2	3.3	1508	&	VK3MAP	VK7MO	R+01
25845	1	4.9	1500	&	VK7MO	VK3MAP	RRR
25845	2	4.9	1499	&	VK7MO	VK3MAP	RRR
25845	5	5.9	1510	&	VK7MO	VK3MAP	RRR
25845	7	6	1509	&	VK7MO	VK3MAP	RRR
30715	-1	3.6	1505	&	VK7MO	VK3MAP	RRR
30845	3	2.6	1504	&	VK7MO	VK3MAP	RRR
31445	3	7.1	1501	&	VK7MO	VK3MAP	RRR
31445	4	7.1	1501	&	VK7MO	VK3MAP	RRR
32430	2	5.3	1501	&	VK3MAP	VK7MO	73

Table 1: Decodes for Lightning Scatter QSO on 1296 MHz

6. 144 MHz Attempt

At the same time as we received lightning pings on 1296 MHz, we also attempted QSOs on 144 MHz with MSK144. Some 17 decodes where achieved due mainly to tropo scatter and possibly meteor scatter pings. When we compared these decodes with the lightning decodes on 1296 MHz there was no correlation between the time of decodes on both bands suggesting that lightning scatter is not effective at 2 metres, at least over this distance with our equipment.

A possible explanation as to why 1296 MHz is better is to consider lightning scatter as analogous to aircraft forward scatter as been analyzed by VK7MO[8]. The forward scatter gain is inversely proportional to wavelength squared, Siegel[9], giving 18 dB gain at 1296 MHz, explaining why 1296 MHz is much better. F6AGR advises “A lightning flash ionized channel can be several kilometers long, with a diameter being a few centimeters in size” and that ”80 % of the flashes are of cloud-cloud type”. Thus, most lightning flashes will be horizontal as compared to ground strikes that are generally visible below the clouds. A significant advantage of the very narrow lightning channel in a horizontal cloud-to-cloud strike is that it is much smaller than a wavelength in the vertical dimension and produces a very wide forward scatter lobe (near omni-directional) in the vertical dimension on both bands. Thus the 18 dB gain at 1296 MHz does not reduce at the scatter angles of several degrees as necessary to cope with earth curvature. This is in contrast to aircraft scatter where much of the vertical dimension of the aircraft is many wavelengths and produces a narrow forward scatter vertical lobe and results in a reduction of the gain with frequency at typical scattering angles. The downside of the very long horizontal dimension of the lighting strike is that this produces an extremely narrow forward scatter lobe in the horizontal dimension (at 1296 MHz around 0.003 of a degree for a one km long lightning strike) and thus very few lightning strikes are exactly in line to produce propagation in the direction of the receiver.

As the forward scatter lobe at 2 meters is nine times wider, we should pick up nine times more lightning pings but the fact that they are 18 dB weaker explains why they did not decode. If we were to go higher in frequency the pings should be even stronger but there will be less of them, suggesting that 1296 MHz is close to optimum for lightning scatter.

6. Attempt when lightning not present

We have attempted to see if anything equivalent to a lightning ping might occur when no lightning is present on the lightning tracker but nothing at all was detected in a few hours of testing. This is added evidence that these decodes are due to lightning.

7. Duration of lightning Pings

Visual examination of the pings that decoded on the fast graph shows all were in the range 0.1 to 0.3 seconds with most nearer 0.1 seconds. This is not inconsistent with advice by F6AGR [5] that "a single lightning ping can last several hundred milliseconds" and ZS6BTE [6] that the duration can be can be 0.1 to 0.6 seconds. ZS6BTE indicated the noise from the direct lighting pulse can last for 30 microseconds. We could not detect such noise bursts prior to decodable lightning pings.

8. Concluding Comments and Remarks

- We are confident that we achieved 50 lightning scatter decodes and one QSO at 1296 MHz.
- We used 15 second periods and auto sequencing to respond quickly enough.
- If aircraft are present, it will be difficult to confirm that a QSO is completely via lightning scatter until files are subsequently decoded.
- The durations of lightning pings between 0.1 and 0.3 seconds are ideally suited to MSK144.
- We are somewhat surprised that no corresponding pings were detected on 2 metres but conclude that 1296 MHz is a better band. Even if lightning pings can be detected on 2 metres it will be difficult to discern them from meteor pings.
- We think 1296 MHz is probably the optimum band for lightning scatter.
- It is unlikely we will come across a similar event at our latitudes but we will look out for any lightning events now we know what to look for. Stations in the tropics should have a much better chance of seeing such events.

9. References

[1] Steven J. Franke, K9AN and Joseph H. Taylor, K1JT "The MSK144 Protocol for Meteor-Scatter Communication" (QEX, September/October, 2017, pp. 8-14)

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[3] The Guardian 13 February 2024 "*Half a million Victorian homes without electricity*"

[4] Jean-L Rault, F6AGR, "*Lightning Scatter: a faint and rare mode of propagation*" VHF Communications 2/2005, https://hal.science/hal-00638547/document

[5] Ian Roberts, ZS6BTE "*VHF-UHF Propagation by Lightning Flash*"
https://www.qsl.net/zs6bte/VHF-UHF%20Lightning%20Flash%20Communications.htm

[6] Wikipedia https://en.wikipedia.org/wiki/Non-line-of-sight_propagation

[7] Tasmania Radar/Lightning Tracker https://www.farmonlineweather.com.au/radar/tas

[8] Rex Moncur, VK7MO, "*Aircraft Enhancement – some Insights from Bistatic Radar Theory*", Proc. GippsTech 2000, pp 1-19, CQ VHF magazine in the Fall 2003 Edition, also available at: https://w3sz.com/vk7mo_2000.pdf

[9] Siegel, K.M., "*Bistatic Radars and Forward Scattering*", Proc. 1958 Natl. Conf. on Aero. Electronics, Dayton Ohio, pp 286-90.