Aircraft Scatter Propagation on 10 GHz using JT65C

Results of initial Tests over a 624 km Path

By Rex Moncur VK7MO and David Smith VK3HZ

This is an initial report of our first tests of 10 GHz propagation that demonstrate that it is possible with small portable 10 GHz amateur stations to use aircraft scatter over relatively long paths using the digital mode JT65c. We think the keys to this success are GPS locking at both ends to ensure adequate frequency stability combined with careful alignment of the path of propagation with the aircraft flight path so as to reduce the rate of change of Doppler shift to levels that allow the use of JT65c. Somewhat to our surprise we found that unlike with aircraft scatter at VHF the signals often come in strong bursts of just a few seconds which opens up the possibility that a mode such as JT6M which is designed for meteor scatter might produce better results. We are unable to explain these short bursts with the existing models of aircraft scatter that work well at VHF.

Background

Aircraft scatter is widely used by Australian Amateurs on VHF to work distances of 400 km up to around 800 km. At VHF one can take advantage of the diffractive scatter lobe which forms a beam that is typically several degrees wide and gives gains of 20 dB or more. At 10 GHz the main diffractive scatter lobe is reduced to a small fraction of a degree and is too narrow to return to Earth and thus be useful. However, there are minor diffractive scatter lobes that should return to Earth even if these have much lower scatter gain. It is also possible that under some situations specula reflection from the aircraft could give useful signals particularly if sections of the aircraft act like Corner Reflectors to give gain. Thus while we did not expect the high scatter gains that occur at VHF we thought it may be possible to get useful propagation if we made up for the lower gains with the extra sensitivity of JT65 and the higher gain antennas that are practical at 10 GHz. The downsides are that JT65 even with AFC does not cope well with large rates of change of Doppler shift and high gain antennas are extremely difficult to align. The JT65C version was chosen on the basis that we thought it should cope better than JT65a and JT65b with large rates of change of Doppler shift although this may not be the case as all versions do the AFC process in the narrower 2.7 Hz bins . We also hoped that the rate of change of Doppler could be reduced by using a path that is closely aligned with that of the aircraft but this does still depend on the aircraft accurately flying along the path.

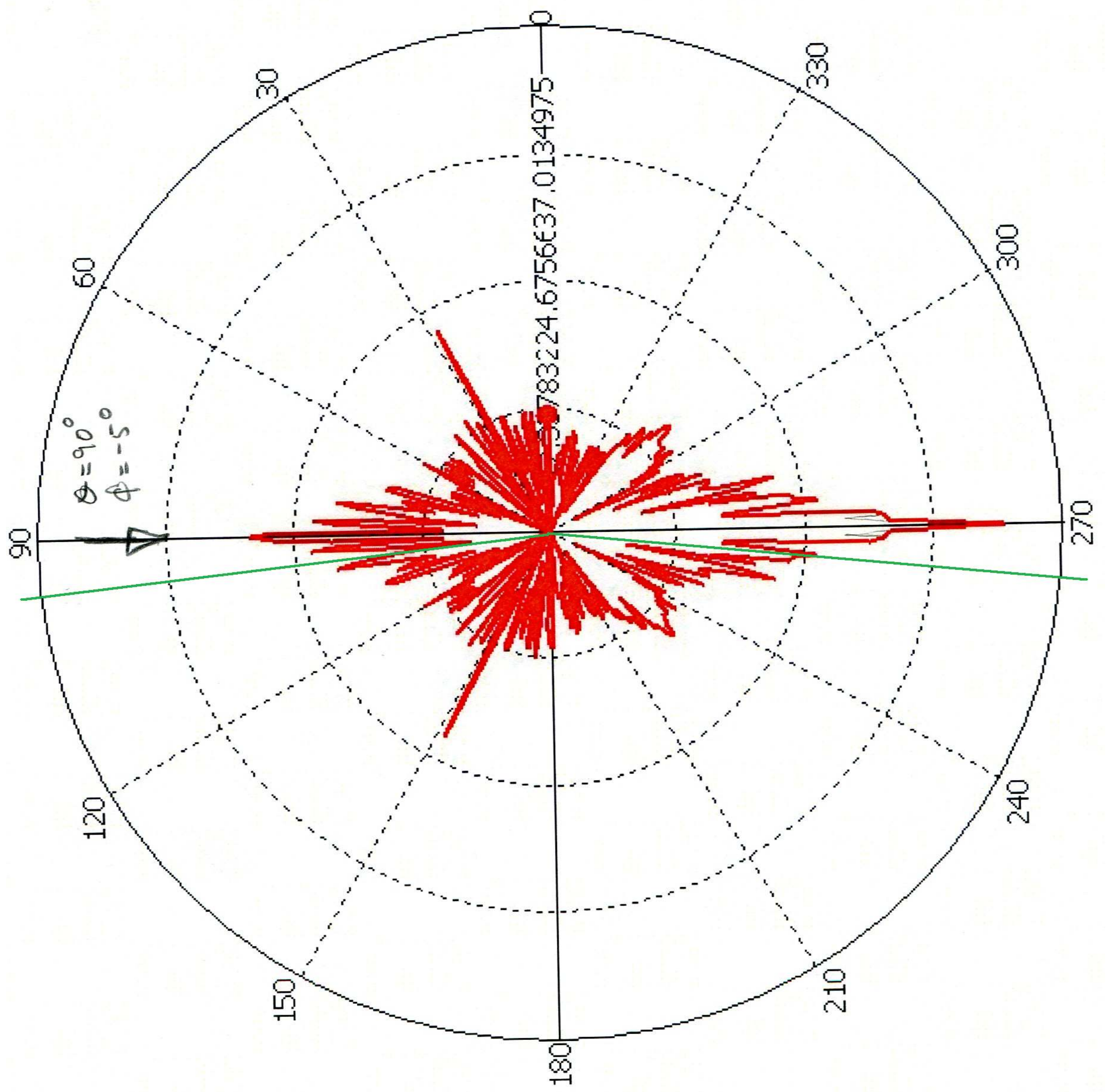

Figure 1 Scatter Pattern of an Aircraft at 1296 MHz

Figure 1 shows a modeled scatter pattern based roughly on a Boeing 737 at 1296 MHz that was produced by Andy Sayers VK2AES. It is indicative only as in this case it is a horizontal pattern based on the propagation coming to the aircraft 5 degrees below and looking at what is received 5 degrees below. In practice we really need such a pattern in the vertical plane which would then show the actual lobes for the green lines which represent the directions of propagation. Nevertheless for our purposes the diagram does give an indication of what is happening. In this case it is seen that the green line leaving the aircraft in the forward direction just below 270 degrees misses the main forward scatter lobe with its very high gain but does pick up the first minor lobe. Taking this indicative model further to 10 GHz the pattern would break up into many more lobes which would be much narrower and if the 10 Ghz signal did come from a lobe it is likely that rather than being the first minor lobe it will be the 8th or so minor lobe. One can then see that as the aircraft moves along the path the signal strength will vary as the various lobes come into play. Nevertheless, as the angles to the aircraft in our case only vary by a fraction of a degree we would not expect rapid variations. Ideally we need a detailed model of how each aircraft scatters at 10 GHz in the vertical plane so the above model and discussion is intended only to give some idea of what might be expected.

Equipment

VK7MO Mt Wellington: DB6NT transverter locked to a Fury GPS disciplined 10 MHz Oscillator. IC910-H as the IF on two metres which was also locked to the GSPDO at 30.2 MHz. 59x69 cm offset dish with a gain of approximately 34 dBi and a 3 dB beamwidth of 3.1 degrees. 10 Watt DB6NT PA and DB6NT LNA. Rifle scope and protractor for Azimuth alignment and inclinometer for elevation. Azimuth was set by aligning on a known target (the Bridgewater bridge at 358.9 degrees) and then moving against a protractor to the actual direction to VK3HZ as determined from Google Earth

VK3HZ Sunbury: Converted Qualcomm "Lambchop" transverter with remote DEMI 8W PA and DEMI preamp mounted on the 45 cm dish. IF is an FT-817 IF on 144 MHz. Both units are locked to a homebrew 10 MHz GPSDO. Aligned visually on a reference point determined from Google Earth and survey photos taken on a previous day. Elevation set using a digital level.

Path

The flight path of aircraft flying from Melbourne to Hobart is as shown on Figure 2.

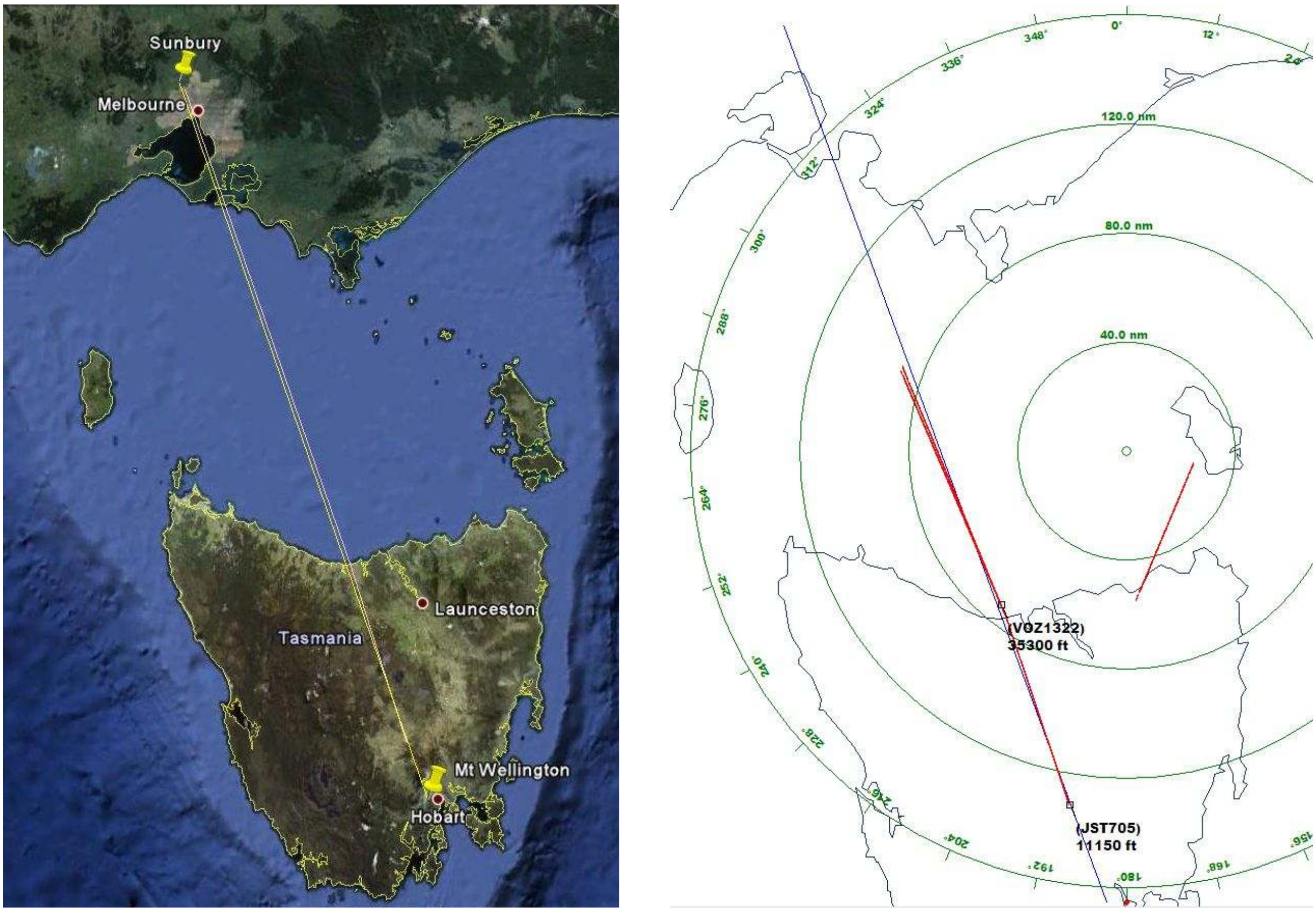

Figure 2: Path for 10 GHz Aircraft Scatter Tests

On the left of Figure 2, a Google Earth display shows the aircraft route of interest while on the right, an SBS-1 ADS-B receiver display shows the actual paths of the aircraft flying that route. As can be seen, depending on prevailing winds, the aircraft regularly take a path slightly to the west of the approved route. It turns out that Mt Wellington near Hobart is very close to in-line with the path and is sufficiently high that it can see an aircraft for over 400 km as demonstrated by the reception of ADS-B signals from the aircraft. At the Melbourne end the path goes over relatively low land with poor take-offs but starts to rise past the airport. A site was found near Sunbury that is in line with the slightly westerly path and has a reasonable take-off such that one can see the high rise building in the Melbourne CBD and ADS-B signals could be seen out to approximately 300 km. The total path length is 624 km giving a potential overlap of around 80 km which at typical Jet speeds of 600 km per hour represents about 10 minutes.

Aircraft for Tests

It was predicted that four aircraft would fly the path in around two hours that we had planned. The first and third would fly to Hobart and stay on the path for a longer period while the second and the fourth would fly to Launceston and depart from the path somewhat earlier.

Test Procedure

We started using JT65c in single tone mode which is produced by using the message @1270 in any of the TX boxes. This provides a continuous 1270 Hz tone for the duration of each 48 second transmission which is much easier to see on SpecJT and gives around 3 to 4 dB better signal reports. It also gives a better idea of the amount of Doppler. Once stable tones could be seen we changed to the standard JT65c procedure transmitting callsigns and grid locator. While the single tones were seen quite strongly at up to -20 dB on the WSJT scale at the VK7MO end only brief indications of a signal were seen by VK3HZ. Similarly while callsigns and grid locators were received for the last two flights at the VK7MO end only three syncs and no decodes were received at the VK3HZ end. At this time we cannot explain the reasons for the one way reception so we will focus on the results from the last two flights which give useful information on what is possible.

Results from Second Last flight – Melbourne to Hobart

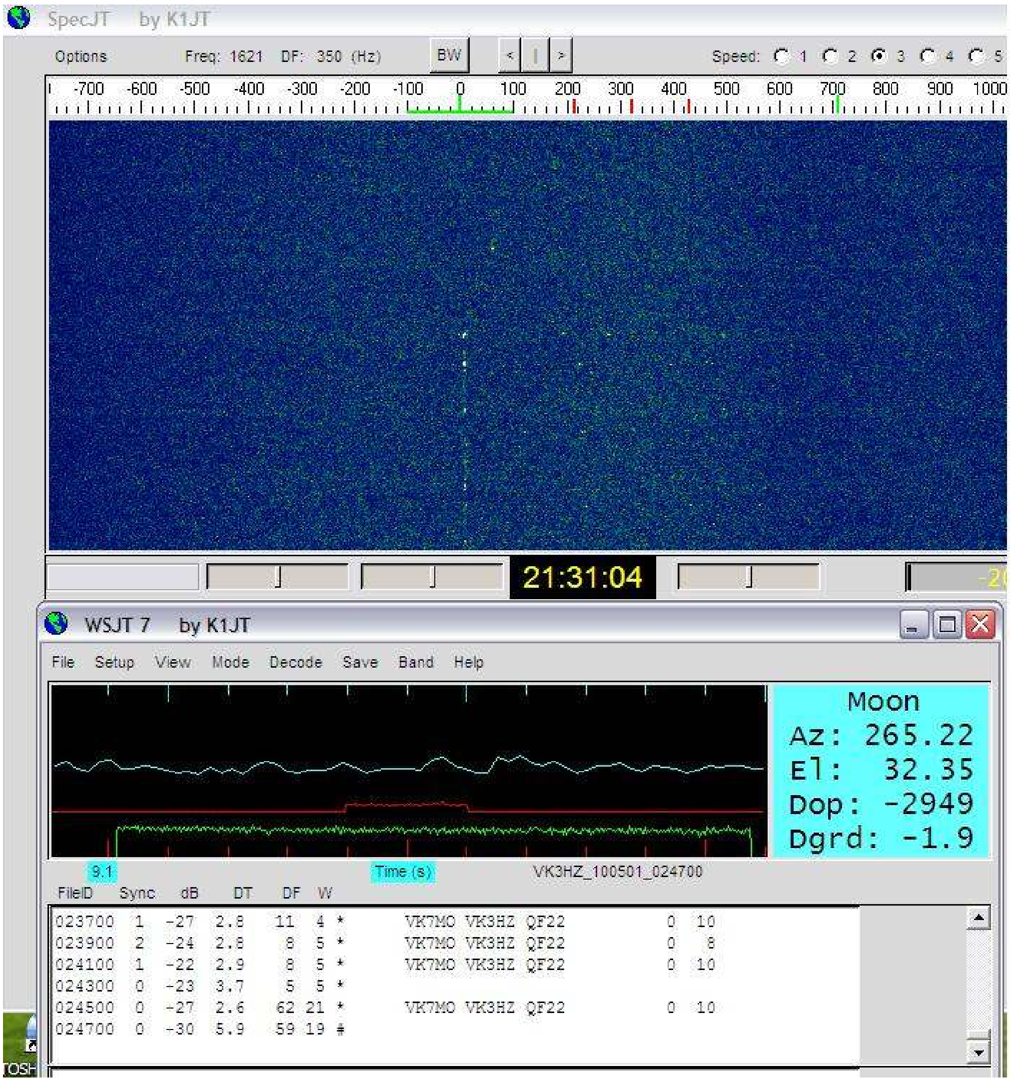

Figure 3: Shows the results from the second last flight

As is shown on Figure 3 four decodes were received over a ten minute period with signals ranging from -22 dB to -27 dB which gave decodes. Surprisingly nothing was decoded at 2243 when the reported signal level was -23 dB. Also of note is that none of the transmissions were decoded on the Koetter-Vardy decoder despite one being at -22 dB which would normally decode. The waterfall display from SpecJT was produced with the speed set to 3 which shows 5 to 6 decodes or almost the full 10 minute period that shows in the decode window. It is seen that the signal has some weak continuous periods but with short strong peaks almost like meteor pings. It is also seen on both the waterfall and the DF readings that while the signal was initially almost stable with W or drift readings of 4 or 5 Hz and the DF dropping from 11 to 5 Hz over 4 periods or 8 minutes the W reading later increased to 21 Hz and the DF to 62 Hz indicating a rapid change in frequency due presumably to Doppler. This would suggest that the aircraft changed direction.

Results from Last Flight – Melbourne to Launceston

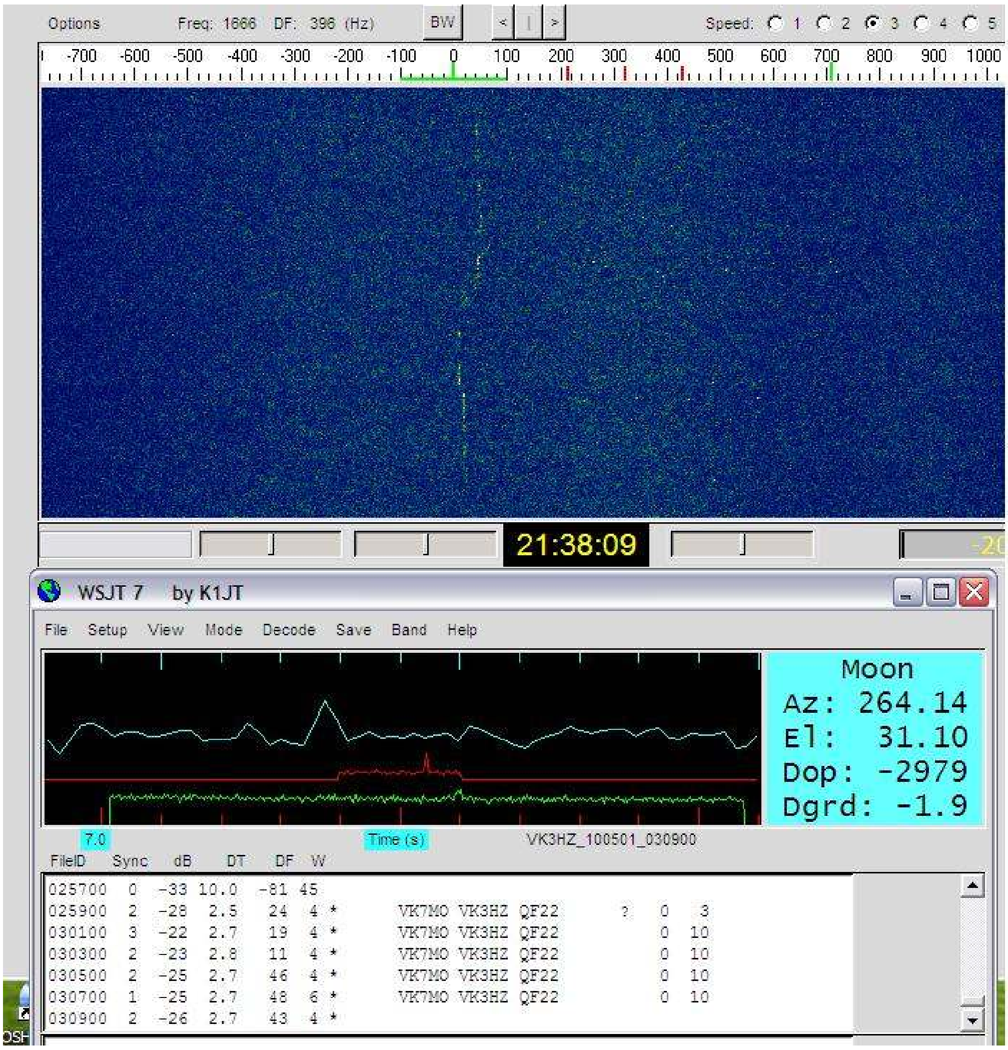

Figure 4: Shows results from last flight from Melbourne to Launceston

Again there were 5 decodes over 10 minutes with a slightly less stable but smaller overall Doppler shift as shown by the waterfall which covers almost the full period as shown in the decode window. Again there are no decodes on the Koetter-Vardy decoder even through Signal to Noise ratios of -22 dB and -23 dB are reported. There is again evidence of constant signals together with sharp peaks.

More Detailed Analysis of Results

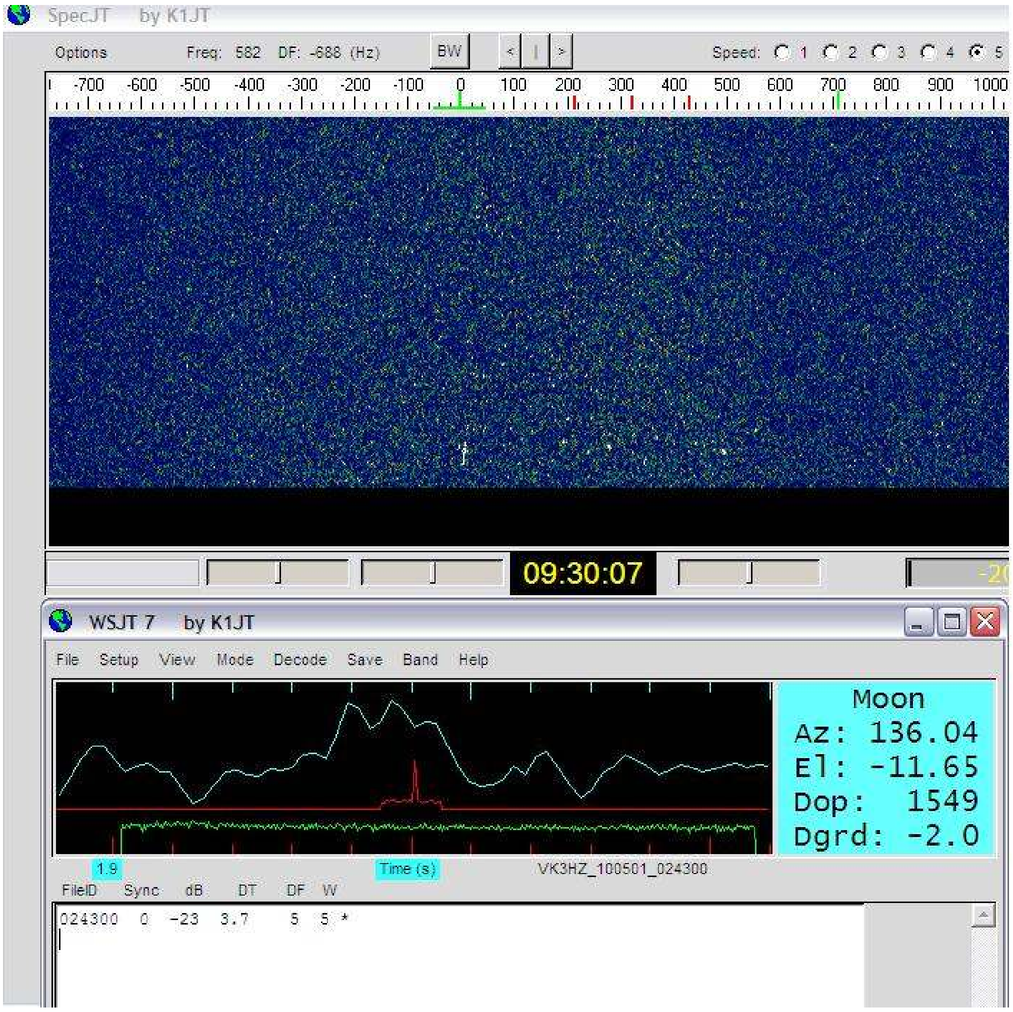

Figure 5: 024300 period at waterfall speed 5 to cover almost full waterfall

Figure 5 shows the full 48 second period of the decode attempt at 0243 which gave a -23 dB S/N but no decode. Inspection of the waterfall shows that signal was very strong for just a short period of about 4 seconds that produced this -23 dB signal. Other than this short period there are only a few areas of a faint trace that could indicate the presence of the signal at other times. One might expect that if the average signal over 48 seconds at -23 dB was the result of just 4 seconds then this 4 seconds must have been around 10 times as strong and thus reached around -13 dB. This leads to the thought that JT6M which is designed for short meteor scatter bursts might be more effective. JT6M should also cope better with Doppler shift. However, tests of JT6M show that for short bursts of a few seconds it requires about -10 dB signal level to give consistent decodes so it could also be on the margin – never-the-less this is well worth testing in future trials.

Given that JT65a repeats the message 5 times throughout a period it seems that the signal was just not strong enough for long enough to get enough signal to decode – even with the Deep Search decoder. It seems that the nature of aircraft scatter at 10 GHz giving such short bursts of signal probably explains why there are no Koetter-Vardy decodes even at signal levels of -22 and -23 dB.

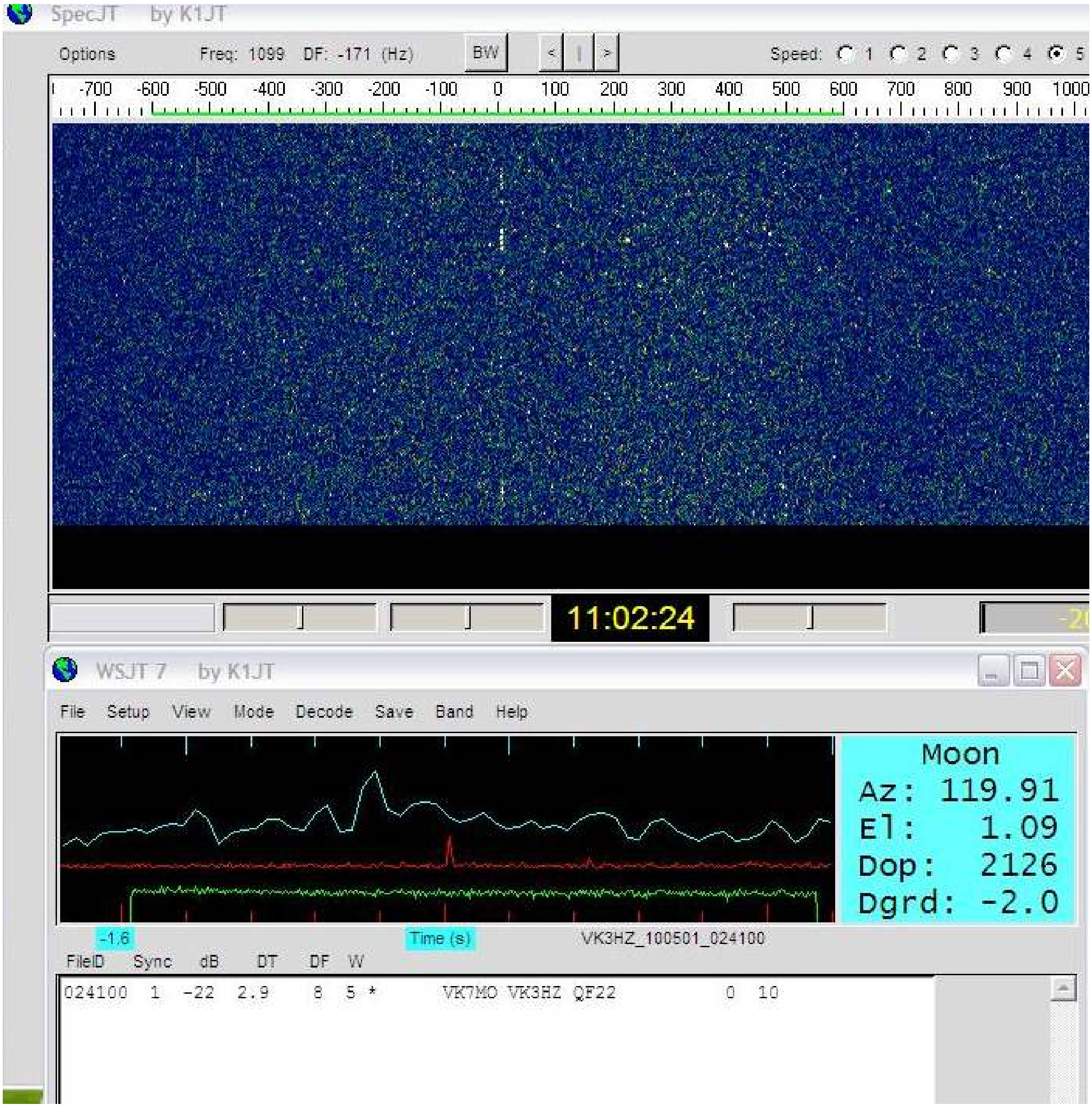

Figure 6: 024100 period at waterfall speed 5 to cover almost full waterfall

In the case of the period 024100 as shown in Figure 6 the waterfall shows three short periods of about 4 seconds which do decode at -24 dB.

In two of the above examples there were short bursts of strong signals for just a few seconds. It is hard to explain this in terms of the sort of modelled scatter pattern in Figure 1 as even if we extrapolate up to 10 GHz the angles do not change rapidly as the aircraft moves along the path – not more than a fraction of a degree. It therefore seems that a more detailed explanation of these short bursts is required and there is further interesting work to undertake. It would also be useful to measure the actual signal strengths of these short bursts and the wave files can be made available to anyone who would like to try such measurements.

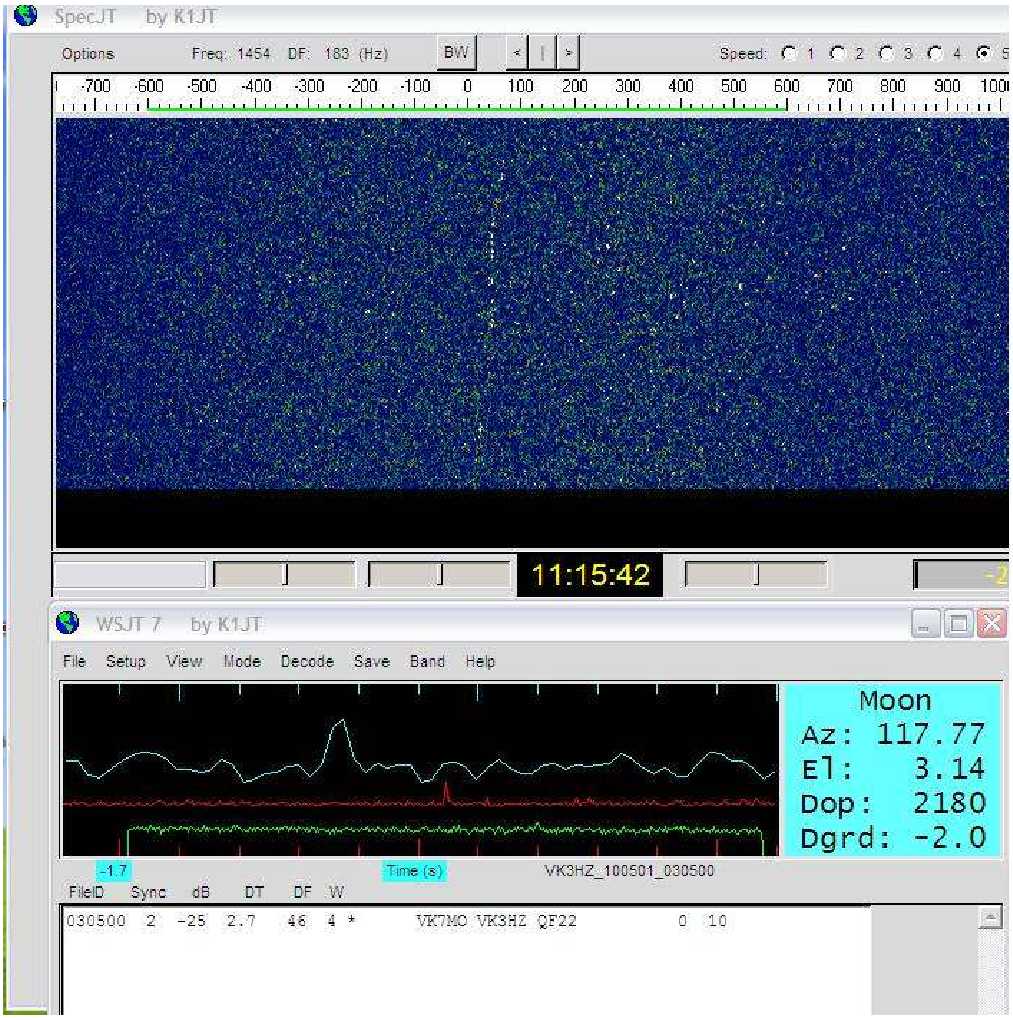

Figure 7: 030500 period at waterfall speed 5 to cover almost full waterfall

Period 030500 also decodes but shows a more even distribution of S/N without the sharp bursts of high signal as per the previous examples.

Discussion

While in this case decodes were only achieved one way the tests have demonstrated that it is possible to use aircraft scatter at 10 GHz using the digital mode JT65c.

It is seen that signals often vary rapidly on a scale of a few seconds. This would suggest that the perhaps some other mechanism is in play that is not picked up in our present models. One possibility is that small sections of the aircraft act as high gain reflectors and that the short bursts of signal relate to small changes in the attitude of the aircraft in a similar way as a windscreen of a car will flash sunlight. It is possible that a mode such as JT6M that is designed for the short bursts of meteor scatter might prove useful.

Clearly further tests are required to unravel exactly what it happening in the case of aircraft scatter at 10 GHz and develop appropriate models to explain it.