Small Dish Portable EME

By Rex Moncur, VK7MO

The keys to "Small dish Portable EME" are to:

- Use 10 GHz to get best system performance with small dishes.
- Use digital modes.
- Remove as many variables as possible (such as frequency, pointing and timing).
- Understand other variables such as libration spreading, lunar degradation, moon noise and absorption.
- Take advantage of "good" conditions, noting that there can be up to 10 dB and more variation between "good" and "poor" conditions.

Examples of what can be achieved at 10 GHz are:

- A four foot dish with 50 watts can work a similar station under most conditions.
- A two foot dish with 30 watts can work can work the larger home stations.

PROPOPAGATION LOSS

EME propagation loss increases by 20 dB for every 10 times increase in frequency such that:

144 MHz	253 dB
1296 MHz	271 dB
10,368 MHz	290 dB

37 dB more loss in going from 144 MHz to 10 GHz – so why go up in frequency?

ANTENNA GAIN

For the same size dish (or same capture area) the antenna gain goes up by 20 dB for every 10 times increase in frequency and thus fully compensates for the propagation losses. But as there are two antennas we gain 20 dB at each end for each 10 times increase in frequency. In the case of 144 to 10,368 MHz the overall gain is around 37 dB in going to 10 GHz. The result is we can use much smaller antennas that are suitable for portable operations. While 24 GHz provides another 7 dB antenna gain, it suffers from much higher atmospheric absorption, it is more difficult to generate useful power, has higher spreading and poorer receive noise figures - accordingly 10 GHz is considered the "sweet spot" for small dish portable EME.

TRANSMITTER POWER

In a portable situation it is difficult to generate more than about 50 watts at 10 GHz compared to much higher levels that can are generally used at lower frequencies - so in terms of overall system performance we don't get the full advantage of the higher antenna gain in going up to 10 GHz.

SYSTEM NOISE

In general system noise is lower at higher frequencies due to much lower external noise off-setting a small increase in the LNA noise figure. However, the higher gain and narrower beam-width of a 10

GHz antenna means it picks up more moon noise. For example, for a 10 foot dish receiving station this costs about 2 dB compared to only about 0.2 dB for a small 2 foot 6 inch dish. But even so 10 GHz is generally in front overall, in particular compared to the high noise levels in suburban environments at 144 MHz.

LUNAR DEGRADATION

As the moon moves around the Earth in an elliptical orbit its distance varies such that the propagation loss varies by up to 2.3 dB.

LIBRATION SPREADING

Lunar Libration spreads the signal in proportion to frequency and thus the effects of libration are 72 times worse at 10 GHz than 144 MHz. Typical spreading is around 100 Hz at 10 GHz and less than 1 Hz at 144 MHz. Spreading can, however, reach up to 200 Hz or more on 10 GHz and as shown in Fig 1 a change in spreading from 5 Hz to 200 Hz costs about 7 dB with the QRA64 mode.

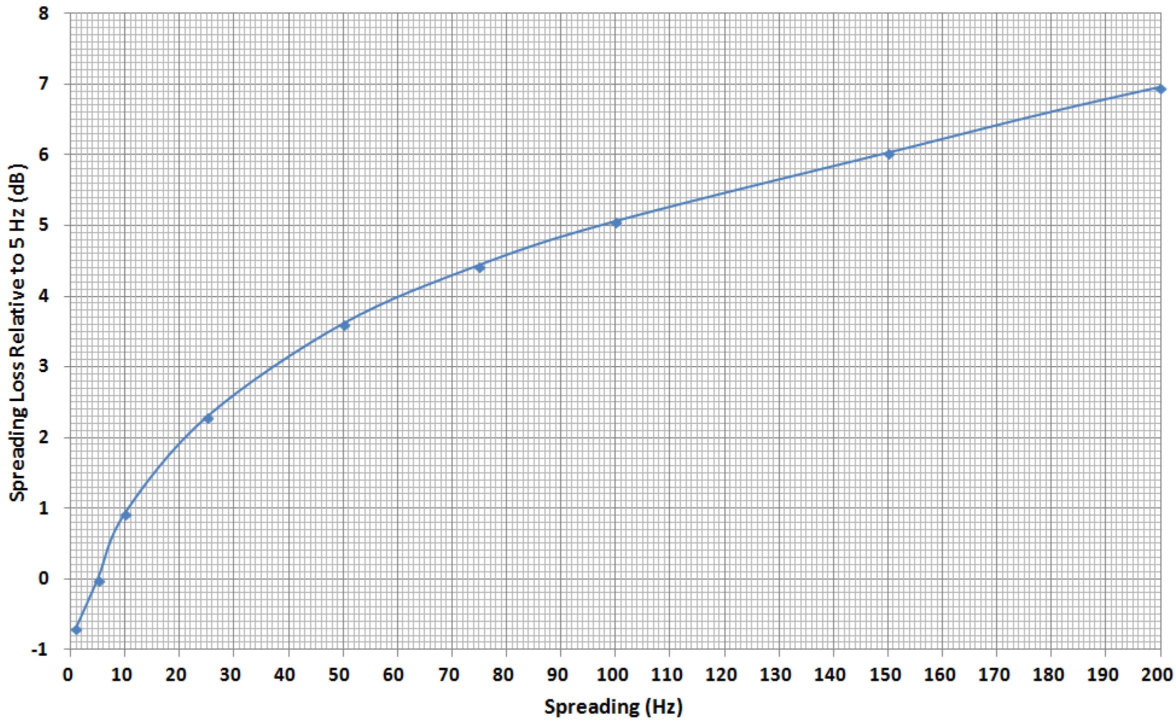

Fig 1: Libration Spreading Loss derives from DUBUS Paper by VK7MO and G3WDG[1]

The good news is that there are times when the libration spreading drops to very low levels and full advantage can be taken of narrow bin-width sub-modes such that QRA64A. Such times only occur once per Lunar month but are the times one should choose for QRP EME (for example 5 watts with a 2' 6" dish). The Moonsked program by the late GM4JJJ shows both the spreading and lunar degradation so one can select the best time for QRP EME.

Libration spreading gets to its lowest values when stations are in close to antipodean positions. Thus a good option for QRP EME is from the East Coast of the USA to the South-West of Australia.

The following shows an example of the spreading over a month between VK7MO and G3WDG. In this case the libration spreading got down to 3 Hz on 11 April 2016 and thus there was essentially no libration loss.

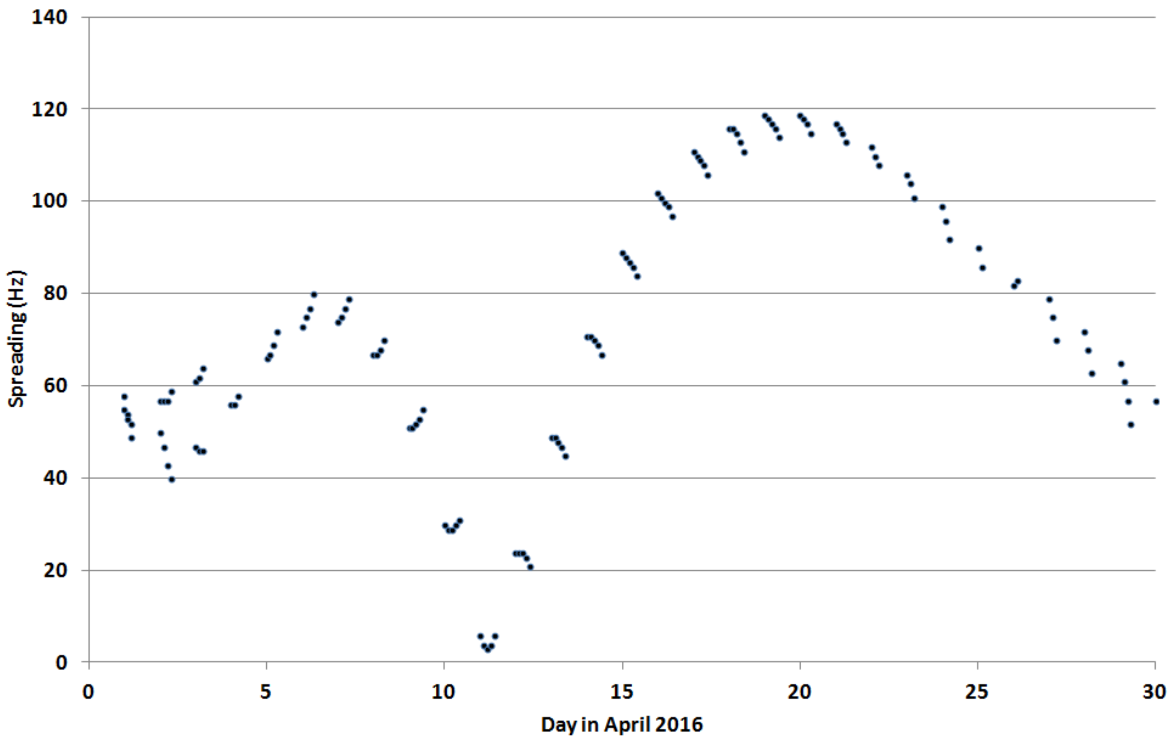

Fig 2: Example of Low Libration spreading.

ABSORPTION

Atmospheric absorption starts to become an issue at 10 GHz but is only significant when the Lunar elevation is below 5 degrees. Fig 3 shows that absorption can typically cost about 1 dB at 5 degrees and 5 dB at the horizon in temperate regions. In tropical regions it can increase by a factor of 3 or 4 times. At 24 GHz atmospheric absorption is about 10 times worse which rules it out for operations near the horizon and in particular in the tropics.

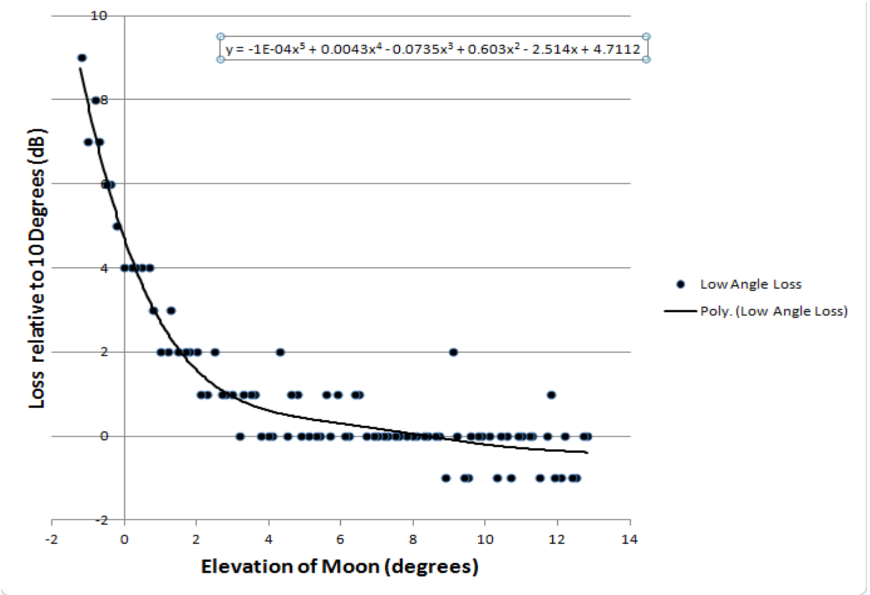

Fig 5: Loss due to absorption at 10 GHz measured by VK7MO from G3WDG[2]. (Precipitable water at the receiving end was 20 mm).

URLs to find forecasts of Precipitable Water are as follows:

North America: http://wxmaps.org/pix/nam.pw

Australia: http://wxmaps.org/pix/aus.pw

Europe: http://wxmaps.org/pix/euro.pw

As a rough guide the absorption loss (includes both attenuation and increased noise due to attenuation) at the horizon in dB is around one quarter of the Precipitable Water (PW) in mm. PW is typically around 40 to 60 mm in the tropics and 10 to 30 mm in temperate regions. This means that small dish operations over long distances where the elevation angles are close to the horizon are much more difficult in tropical areas.

GROUND NOISE

Ground noise can be an issue at 10 GHz when beaming close to the horizon as is necessary to achieve very long distances. As shown in Fig 5 below when beaming over the sea the ground noise continues to increase on Vertical polarization but does not on horizontal polarization. It is postulated that this is because Horizontal Polarization reflects rather than emits radiation from the water, where-as Vertical Polarization does not reflect and thus receives the emitted noise from the water. This feature can be taken advantage of to improve system performance of long distance EME such as breaking World Records [2].

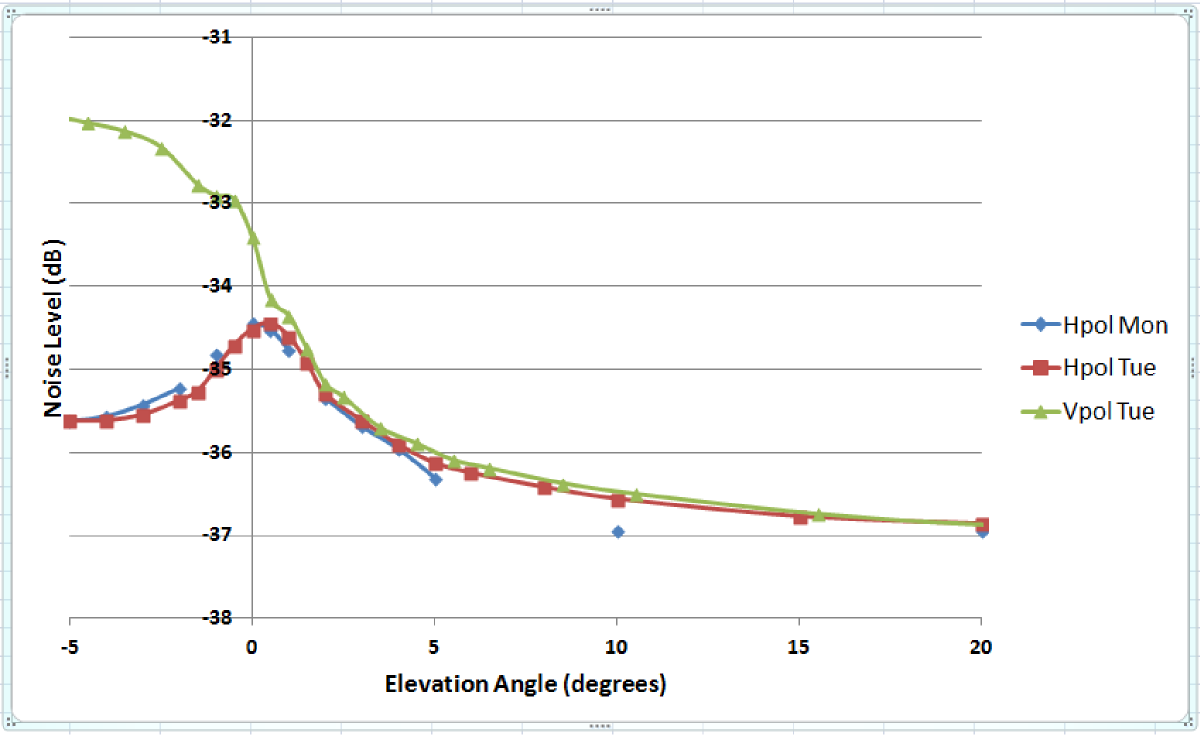

Fig 5: Ground and Absorption Noise measured over the sea by VK7MO with the assistance of VK7WLH.

MODE

The QRA64D sub-mode in WSJT-X, developed by Nico Palermo, IV3NWV[3], and Joe Taylor, K1JT [4] is generally used at 10 GHz and gains 10 to 16 dB on CW. It is more sensitive than JT4f up to 130 Hz spreading[1].

VARIATION OF CONDITIONS

As seen above libration spreading can produce variations of up to 7 dB, Luna degradation up to 2.3 dB, and Moon noise up to 2 dB. So overall one can have variations between "good" and "poor" conditions of up to around 10 dB. Below 5 degrees elevation absorption can add significant additional loss as indicated above.

REMOVING VARIABLES

Frequency and Doppler: At 10 GHz Doppler shift varies by over 40 KHz and can change at up to 1 Hz/second. Accordingly, it is necessary to use automatic Doppler correction such as provided by WSJT-X. In addition the absolute frequency needs to be not only stable to within a few Hz over a transmit cycle but to gain maximum sensitivity it is desirable to have the absolute frequency accurate to within 10 Hz so that one can use a narrow tolerance (10 or 20 Hz) on WSJT-X to reduce false syncs to a minimum. To meet these requirements it is necessary to GPSDO lock the transverter and preferably the IF radio.

Tracking the Moon: Small dishes do not pick up enough Moon noise for tracking and one must have a system of tracking to better than 0.5 degrees in both Azimuth and Elevation. An inclinometer is adequate for elevation but Azimuth requires some known reference. The key is to use a rifle-scope which has been previously calibrated to the dish on Sun noise. If the Moon is visible one can track the dish optically or at least set the Azimuth calibration when the Moon appears through clouds. The Sun can also be used for calibration if it is above the horizon and visible (but you must provide protection from eye damage such as by covering the rifle-scope with a No 13 welding slide). If it is cloudy one can use some feature such as a tower or house that is visible and identifiable on Google Earth. But there are some situations where nothing is available for an Azimuth reference in which case VK3HZ has developed a differential GPS system that can give accurate Azimuth bearings to better than 0.1 degrees on a 5 metre baseline(5).

Polarization: At 10 GHz, circular polarization is rare and most stations use linear polarization. Linear to linear polarization has been shown experimentally by G3WDG (6) to have an advantage of about 1.5 dB over circular to circular due to the characteristics of lunar reflection, it is easier to set up and small portable stations are also used for terrestrial where linear polarization is the norm. Horizontal linear polarization also has advantages in lower ground noise over the sea(2). The general rule for DXpeditions is that the portable station decides on the polarization and other stations who wish to work them adjust their polarization to suit. While I generally use Horizontal Polarization I can adjust polarization by the use of brackets to mount the dish for Vertical Polarization and +/- 45 degrees.

Timing: WSJT-X requires timing to be accurate to better than 1 second to reliably decode. Internet time will often not be available in the field. GPS timing is the solution for portable operations and can be implemented in-expensively with a USB GPS receiver and a program called NMEATime to give results to better than 0.1 second (7).

POWER AMPLIFIERS

The cost of Power Amplifiers is the biggest negative in going to 10 GHz EME. TWTs are available on the surplus market but require very high voltages, which raises questions of arcing over due to humidity and rain. Safety when operating in the field at night is another concern. 60 watt Solid State Amplifiers are available from Khune, DB6NT at about US$ 3700 and 30 watt PAs for about half that price. The majority of home stations run at least 50 watts and given that they generally have large dishes and must cope with around 2 dB more moon noise it is preferable that the portable station run at least 50 watts. Never-the-less if one is prepared to wait for "good" conditions one can make many contacts with the larger stations with 10 to 20 watts and a 2 foot 6 inch dish.

PRIME FOCUS OR OFFSET DISH

An offset dish should have improved performance due to less waveguide loss, less blocking and lower noise as it's feed points to the sky. The problem with offset dishes is that they are not normally designed to beam at or near the horizon and the feed, pre-amp, waveguide switch and heavy PA are all well out in front making it difficult to maintain mechanical balance on a tripod. While you can mount a small offset dish such that the bottom is fully above the tripod this becomes problematic for anything larger than a 2 foot dish. The big advantage of a prime focus dish is that you can use a Shepherd's crook waveguide feed and mount all the heavy gear behind the dish to give mechanical balance on a tripod - thus a prime focus dish is much preferred for small dish portable EME.

AUTOMATIC TRACKING

I have never used automatic tracking for portable operations. Primarily because this is one more thing to carry, set up and go wrong, but also because manual tracking is easy to operate during the transmit and receive periods on WSJT.

PHYSICAL ISSUES

A 2 foot 6 inch dish fully assembled and ready to go can be carried in the back of an SUV - this has the advantage that it can be set up very quickly and I have for example worked 3 or 4 stations at each of 4 separate grid locators on a single Moon Pass. A four foot dish gives a very useful 4 dB more gain but needs to be carried on the roof of a vehicle and assembled on site. Above four foot becomes very difficult to assemble by one person and is more suitable for fixed location dxpeditions rather than collecting multiple grid locators.

DL0SHF BEACON

The DL0SHF Beacon runs the QRA64D sub-mode on 10368.025 MHz with 40 watts to a 24 foot dish and Vertical Polarization. It is an excellent way of testing small dish systems or small horns. Tune to 10368.024 MHz and run "full Doppler" on WSJT-X.

WORLD DISTANCE RECORDS

Portable to Portable operations can be used to find locations with close to zero elevation take-offs to achieve World Record distances as below:

VK7MO (4 foot dish and 60 watts) to the late WA3LBI (8 foot dish and 150 watts), 18725 km [(8)]

ZL/VK7MO (4 foot dish and 60 watts) to G3WDG (4 foot dish and 75 watts), 19105 km [(2)]

4 foot dishes and 60 watts combined with "good" conditions are required to overcome absorption losses at the low elevations required for World record distance contacts.

SYSTEM RELIABILITY

On a typical portable DXpedition I might travel over 10,000 miles - much of it on rough dusty roads. At each new grid locator it is necessary to find a suitable location - preferably with a take-off to both moon-rise for North America and moon- set to Europe. The equipment must be unpacked, set-up and many cables need to be connected (there is a right place for everything and it must all be re-packed exactly as it was packed). An accurate azimuth reference must be determined. The equipment must then be set up and tested well in advance so there is time to resolve any issues. I carry as much redundancy as possible - two IF radios, two GPSDO's and two computers and for long trips a back-up 10 GHz system with a smaller dish. An independent GPSDO locked weak signal source is very useful for system testing as is the simple test of cold sky to ground - PA current is a good means to check that power is coming out. Operations will often have to be conducted at night without upsetting other travelers who are sleeping. If you are to maintain the interest of hams around the World you must come on each time you say you will. This means not only that the equipment is reliable but being in position when you say you will be - so things like sleep and meals are secondary. Internet connectivity will often not be available.

OPTIONS

Fig 4: compares the power required for "good" and "poor" conditions with various antenna sizes following:

Dish Size	Best Case (watts)	Worst Case (watts)
2' 6" to 4 foot	15	Too much
2' 6" to 10 foot	3	30
4 foot to 4 foot	5	50
4 foot to 10 foot	1	10

PRACTICAL RESULTS

- 4 x 5 inch aperture horn (equivalent to a 5 inch dish) worked G3WDG (10 foot dish and 75 watts) under "very good" conditions.
- 2 foot back-up dish and 60 watts, worked several grid locators to stations with 8 foot dishes and above.
- 2 foot six inch dish and 50 watts, activated over 100 grid locators around Australia.
- 4 foot cut-up petal dish and 60 watts, worked G3WDG 4 foot dish and 75 watts for the current World 10 GHz EME record of 19105 km.

ACKNOWLEDGEMENTS

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CONCLUSIONS

A 4 foot dish is physically viable for portable operations and with 50 watts can work a similar station under even the worst conditions. A 2 foot 6 inch dish can be carried set-up inside an SUV or operated from a small balcony and will allow you to work most home stations under average conditions.

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