Working the big satellite – by Andrew Barron ZL3DW

The biggest and arguably most challenging satellite for amateur radio operators to use for ham QSOs is the largest by a wide margin and it also has the highest orbit. Yes of course, I am talking about the moon and the mode is called 'moon bounce' or more commonly 'EME' (Earth – Moon – Earth). I am definitely no expert on the subject having, to date a single confirmed 2m band EME QSO with RX1AS a 'big gun' EME station in St Petersburg, Russia. But since there has not been a Break-in article dedicated to EME for a while, I thought I would write a general interest article on the topic. If I get something wrong, don't complain... write something better.

In January 1944, German technicians were surprised to see echoes with around a 2.5 second delay while testing an experimental 120kW Radar station operating on 564 MHz. The station, code named 'Würzmann', was located on Rügen island (Göhren) on the shore of Baltic sea, (locator JO64UI). They had inadvertently beamed the collinear antenna array at the rising moon. When the moon passed out of the antenna lobe, the signal disappeared. The technicians repeated the experience the following evening. They were seeing the first known radio echoes from the moon. The "moon bounce" technique was developed for military and commercial use by the United States Military in the years after World War II, with the first successful reception of echoes off the Moon being carried out at Fort Monmouth, New Jersey on January 10, 1946 by John H. DeWitt as part of Project Diana. The Communication Moon Relay project that followed led to more practical uses, including a teletype link between the naval base at Pearl Harbour, Hawaii and United States Navy headquarters in Washington, DC. The first amateur radio echoes from the moon were sent and received on the 2m band by Ross Bateman, W4AO, and Bill Smith, W3GKP in July 15, 1950. But it was not until July 17th 1960 that the first trans-USA EME ham QSO was made, from California to Massachusetts via the moon on 1296 MHz, using a 1kW transmitter and 18 foot dishes. Four days later signal reports were exchanged both ways marking the first two way EME ham QSO.

The moon is a very long way away and is not a particularly good radio reflector because the moon is spherical and the surface is rocky and irregular. As a radio reflector, the moon is only about 7% as good as a flat reflector the same radius would be. This means that the signals received back from the moon over the 770,000km average return path distance, are very weak indeed. The received signals are fluttery and distorted by effects including; multiple reflections from the moon's curved surface, path loss, heat noise, ducting and fading in the Earth's atmosphere, and Faraday rotation which alters the polarisation of the radio signal. The next best extraterrestrial object for echo purposes is Venus - five minutes round-trip time and roughly a million times more difficult to detect reflected signals from than the moon. However, this has already been done by hams using the 20m dish at Bochum in Germany with a transmit signal of 5kW on the 2.4GHz band. Not your average ham station!

The typical path loss on an EME path is around 250 to 310 dB depending on the VHF-UHF band used. To overcome the path loss, you need high gain antennas (preferably 15dB plus) and reasonable power levels (100W to 1kW). You also need to radiate a signal that is not going to be bent back to Earth by the Ionosphere. For these reasons EME is restricted to the VHF, UHF and microwave bands. Most activity is on 2m with significant activity on 6m and 70cm, and some activity on the ham bands up to 10GHz.

Because of the signal distortion and weak signals received, almost all EME QSOs are conducted using CW or now more commonly the JT65 weak signal mode developed by Joe Taylor, K1JT. JT65 is one of the digital modes included in the WSJT software package that Joe makes available for free, at; http://physics.princeton.edu/pulsar/K1JT. SSB is not commonly used for EME QSOs because of the extremely weak signals, and flutter, noise and distortion on

the received signals and is often only possible between 'big gun' stations running very large antenna arrays or dishes and high power. However, sometimes short SSB or CW contacts are made after the JT65 QSO has been conducted, especially if very strong signals were noted in both directions. The WSJT software is extremely effective in very weak signal conditions and has opened up EME and modes like meteor scatter to hundreds of hams with modest stations and aerial systems. It is possible, but not easy, to work EME using a single 12 element 2m Yagi and 100W especially if the station at the other end has a 4 or 6 antenna array.

To quote the WSJT operating manual, "WSJT is a computer program for amateur VHF/UHF communication using state of the art digital techniques. It can help you to make contacts using fraction-of-a-second signals reflected from meteor trails, as well as steady signals more than 10 dB weaker than those needed for conventional CW. The software includes several operating modes; **FSK441,** designed for high speed meteor scatter, **JT6M,** optimized for meteor and ionospheric scatter on 6 meters, **JT65A, B and C** for Earth-Moon-Earth (EME) and weak troposcatter and **CW** for EME using timed, computer-generated transmissions". "JT65A is generally used on 50 MHz and for HF band non EME contacts, JT65B is used on 144 and 432 MHz, and JT65C on the 1296 MHz band and above. The B and C JT65 modes are slightly less sensitive than mode A, but progressively more tolerant of frequency drifts and rapid libration fading".

When you use JT65 your station transmits continuously for 60 seconds and then receives for the following 60 seconds (times depend on the JT65 mode). During each period a maximum of around 20 characters of text information can be sent, so the information you send in an EME QSO is kept to an absolute minimum. A typical initial transmission might contain 'CQ', your callsign and Maidenhead grid. The response would be your callsign, the answering station's callsign and their grid. In the following over you would send the signal report which is always 'O' (normally sent three times as OOO), the other station will respond by sending 'RO' which means I have seen your O report and respond with an O report for you. You normally go back with 'RRR' meaning I have received your report thanks, and they finish the QSO by sending '73'. So in an EME QSO the signal report on your QSL card is always 'O', rather than the 59 / 599 type of report used for other types of ham contacts.

Unlike satellite operation, you don't really need elevation control on your Yagi antennas for 2m EME. This is because for the longest distance between points on the Earth's surface the moon needs to be at low elevation. Most EME activity takes place at local moon rise and moon set. Another important factor is 'ground gain'. This is the effect when a signal reflected from the ground adds to the direct signal. The signal improvement can reach a theoretical maximum of 6dB and because of the phase relationship on the reflected and direct path will occur at a measurable elevation, or at several elevations with deep nulls between. If the station Yagi is placed at a height at which the main antenna lobe coincides with a ground gain enhancement the signal as the moon passes through the right elevation will be improved. Using an antenna elevated to point at the moon when it is higher in the sky extends the time that EME operation can occur, but you don't get the added ground gain. Ground gain gives a much needed boost to the receive signal on the 6m and 2m bands, but because the earth is a relatively hot body the additional noise received impairs the signal improvement on 70cm and above.

You can try EME with a medium size satellite or VHF DX station say 10 -12 elements on 2m. Load up WSJT point your antenna at the Moon and see if you can decode any signals! But to avoid hours of frustration I recommend that you seek help from a local EME expert before trying to transmit. 2m activity is at the low end of the band, just above 144.1 You can find out who is transmitting, their frequency and period (1^{st} or 2^{nd}), and an idea of their setup, by looking at the

N0UK logger http://www.chris.org/cgi-bin/jt65emeA . For example (K6MYC/4XP32/KW) means K6MYC is using four cross polarised 32 element Yagis and 1kW of power.

I hope this article gives you a taste of the EME world, it is not for the faint hearted and you do need a great deal of skill and patience. Some days the signals are weak or there is too much distortion, or fading and it just does not work, other days it is really exciting.