EME on a Budget:
Moonbounce for the Rest of Us

By
Paul Bock, K4MSG

PART I - INTRODUCTION, OPERATIONAL BASICS AND PROPAGATION

The purpose of this article is to provide radio amateurs with enough background information to understand the technical challenges involved in "small-station" digital EME on the 144 and 432 MHz bands. Suggested configurations, approximate costs and operational potential will be included, all with the goal of encouraging amateurs to consider EME by showing that it is neither excessively complex from a technical perspective nor prohibitively costly when compared to other amateur activities. The article also includes a brief overview of the author's operational success to date.

A BIT OF HISTORY

Since the first successful amateur radio two-way EME (Earth-Moon-Earth or "moonbounce") communications in the early 1960s, EME has been regarded as the pinnacle of technological challenge as well as an activity requiring substantial financial resources. The latter is due to the necessity of overcoming the huge path loss (~250 dB) involved in sending a radio signal to the Moon and back. Initially this meant a massive antenna array, full legal transmit power, and state-of-the-art technology to attain the lowest possible receiver noise figure. Achieving all of these goals still meant that only CW contacts were possible because of the faint return signals, sometimes buried in noise, which required excellent hearing to detect.

Beginning in the 1970s, however, several things happened to begin to make EME possible for those with somewhat lesser capabilities (and with less expenditure):

1. The gradual development around the world of EME "super-stations" having huge arrays and the best state-of-the-art equipment that money could buy, allowing them to complete EME CW contacts with many less-well-equipped stations.

2. The development of the gallium-arsenide field-effect transistor (GAsFet) and other devices that made significantly lower noise figure VHF/UHF preamplifiers practical.

3. The development of high-quality affordable coaxial cable with lower loss at VHF & UHF.

4. The publication of practical designs for VHF and UHF kilowatt amplifiers that a reasonably technically-astute ham could build.

While the above technological improvements made EME more affordable and "do-able" by more hams willing to take on the challenges, it wasn't really until the development in the late 1990s of the WSJT series of digital transmission protocols by Joe Taylor, K1JT, that "everyman" use of the more esoteric weak-signal VHF/UHF communications modes - meteor scatter and EME - started to become more practical and affordable. These digital protocols allow the reception and accurate decoding of signals far below the noise level, as low as -24 dB and sometimes beyond.

While VHF meteor scatter was always possible during the major meteor showers - especially on CW - for anyone with a good Yagi antenna and 100 watts of power, the WSJT JT6M and FSK441a protocols fulfilled the dream of 50 and 144 MHz QSO completions using random daily meteors; i.e., the thousands of "grain of sand" micrometeoroids that enter the atmosphere every day and create usable ionized trails of 100 milliseconds or less. The near-simultaneous development of the WSJT JT44 and JT65 (a, b and c) protocols did much the same for EME that JT6M and FSK441a did for meteor scatter. It is now possible for an amateur with 100 watts and a single Yagi with at least 12 dB gain to work any of the really large EME stations and, when conditions are favorable, some of the more modest stations as well. For a single-Yagi EME station to successfully contact a 4-Yagi station still requires excellent conditions, skillful operating and a bit of luck, but it is being be done on 144 MHz.

Because of the increasing popularity of EME any ham with a modest station somewhat larger than the "minimum" to be described can, through perseverance, achieve EME DXCC and some operators have completed EME WAS. Even a station such as the one described should be able to accumulate enough "grid squares" by means of meteor scatter and EME to augment terrestrial operation and qualify for 144 MHz VUCC (and using EME, even 432 MHz!) without raising a tower or running full legal power.

EME OPERATIONAL CHARACTERISTICS & LUNAR AVAILABILITY

It is important that anyone interested in EME understand the "operational characteristics" of using the Moon as a reflector for two-way communications. Below is a short list of the major concerns.

1. **BOTH STATIONS MUST "SEE" THE MOON.** This may seem like a superfluous statement but it bears repeating that the Moon ***MUST*** be above the horizon at both ends of an EME QSO.
2. The Moon's position changes daily and the rising & setting times advance day by day by about a half-hour to an hour depending on the time of the month. This will impact potential operating times and depending on personal schedule may limit one's "on-air" availability.

3. Due to the Moon's rotational schedule relative to sources of celestial noise and the Sun the Moon is only available and useful for EME operation for about 20 days per month.

The two illustrations that follow should give a pretty good idea of how the Moon's usefulness for making two-way EME contacts varies over a one-month period. The first illustration is a table of Moon rise and set times and the corresponding azimuth of the Moon for each. You can access the table for May, 2013, at the link below and just enter the desired month and year in the appropriate boxes.

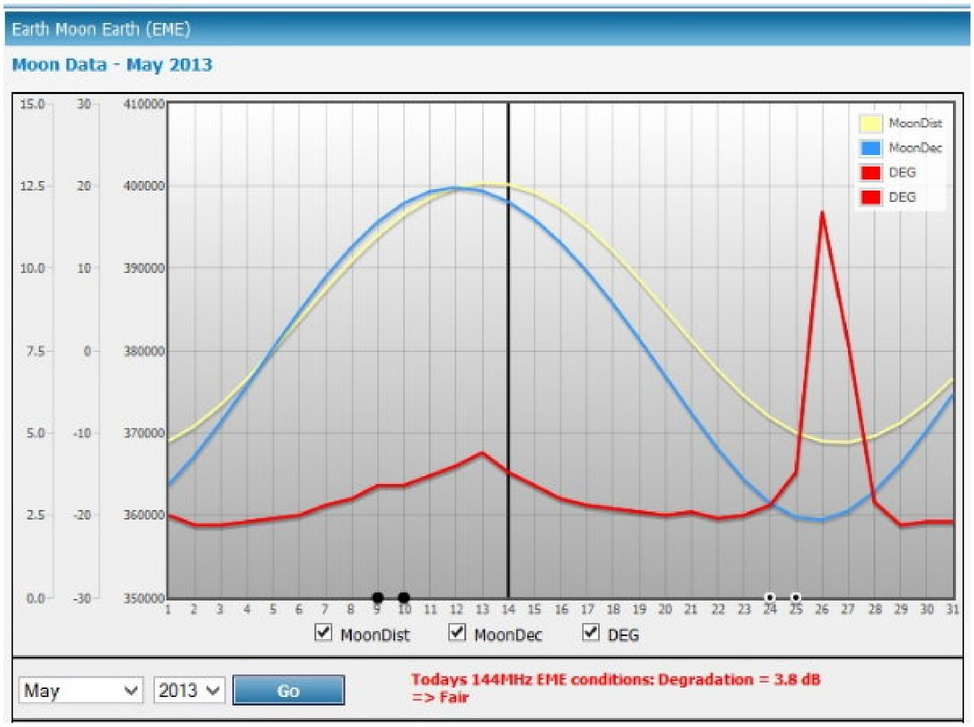
http://www.timeanddate.com/worldclock/astronomy.html?n=263&month=5&year=2013&obj=moon&afl=-12&day=1

The second illustration is a screen shot of the EME display window at the "Make More Miles on VHF" web page at http://www.mmmonvhf.de/eme.php. This particular shot is also for the month of May, 2013, but can be changed by entering a different month & year.

Date	Moonrise	Moonset	Moonrise	Moonset	Phase
May 1, 2013	1:09 AM	11:46 AM	111° ↘	250° ↙	
May 2, 2013	1:51 AM	12:53 PM	107° ↘	256° ↙	Third Quarter at 7:15 AM
May 3, 2013	2:28 AM	1:59 PM	101° ↘	261° ←	
May 4, 2013	3:01 AM	3:02 PM	96° →	267° ←	
May 5, 2013	3:33 AM	4:04 PM	90° →	273° ←	
May 6, 2013	4:04 AM	5:05 PM	84° →	279° ←	
May 7, 2013	4:35 AM	6:05 PM	78° ↗	284° ↖	
May 8, 2013	5:08 AM	7:04 PM	74° ↗	289° ↖	
May 9, 2013	5:44 AM	8:02 PM	70° ↗	292° ↖	New Moon at 8:29 PM
May 10, 2013	6:23 AM	8:57 PM	66° ↗	295° ↖	
May 11, 2013	7:05 AM	9:49 PM	64° ↗	296° ↖	
May 12, 2013	7:52 AM	10:37 PM	64° ↗	296° ↖	
May 13, 2013	8:41 AM	11:20 PM	64° ↗	295° ↖	
May 14, 2013	9:34 AM	-	66° ↗	-	
May 15, 2013	- 10:29 AM	12:00 Midnight -	- 69° ↗	292° ↖ -	
May 16, 2013	- 11:25 AM	12:36 AM -	- 73° ↗	289° ↖ -	
May 17, 2013	- 12:23 PM	1:09 AM -	- 78° ↗	284° ↖ -	
May 18, 2013	- 1:22 PM	1:40 AM -	- 83° →	279° ← -	First Quarter at 12:35 AM
May 19, 2013	- 2:23 PM	2:11 AM -	- 89° →	274° ← -	
May 20, 2013	- 3:26 PM	2:42 AM -	- 95° →	268° ← -	
May 21, 2013	- 4:32 PM	3:15 AM -	- 101° ↘	262° ← -	
May 22, 2013	- 5:41 PM	3:51 AM -	- 107° ↘	256° ↙ -	
May 23, 2013	- 6:51 PM	4:31 AM -	- 112° ↘	251° ↙ -	
May 24, 2013	- 8:01 PM	5:18 AM -	- 115° ↘	247° ↙ -	
May 25, 2013	- 9:08 PM	6:12 AM -	- 116° ↘	244° ↙ -	Full Moon at 12:25 AM Super Full Moon
May 26, 2013	- 10:09 PM	7:14 AM -	- 116° ↘	244° ↙ -	
May 27, 2013	- 11:02 PM	8:21 AM -	- 113° ↘	245° ↙ -	
May 28, 2013	- 11:48 PM	9:31 AM -	- 109° ↘	249° ↙ -	

Date	Moonrise	Moonset	Moonrise	Moonset	Phase
May 29, 2013		10:41 AM		254° ↙	
May 30, 2013	12:28 AM	11:49 AM	103° ↘	259° ←	
May 31, 2013	1:03 AM	12:55 PM	98° →	265° ←	Third Quarter at 2:59 PM

The first thing you should note from the table is that the Moon rises later and later each day. This means that if you cannot adjust your antenna in elevation and/or wish to take advantage of any "ground gain" (described later) by operating at Moonrise or Moonset you will be doing it anywhere from approximately 30 to 60 minutes later each successive day depending on the day of the month.



The screen shot shows the Moon's Distance (yellow line), Declination (blue line) and Degradation (red line) and is useful for determining what days are best for attempting operation. The smaller degradation peak occurs when the Moon is roughly coincident with the Sun, while the very large peak occurs when the Moon is passing in front of the Milky Way, a *HUGE* source of galactic noise! The best days for small stations occur when the Degradation is 2.5 dB or less. It is possible to have some success with the larger stations at degradations of 3 dB or so but when the degradation is above 4 dB it is going to be very, very tough to make QSOs - not because you cannot copy stronger stations, but because your "small station" signal is normally right at the decoding limit and any small amount of additional noise will push your signal into oblivion. Using this description of limitations you can see that for the month of May, 2013, the Moon is potentially usable for a small station from May 1 - 8 (8 days), May 16 - 24 (9 days), and May 28-31 (4 days) for a total of 21 days, although actual "useful days" will likely be fewer.

While the above are useful tools for helping you to decide when to plan your EME operation, there are still propagation issues that can nullify your attempts even on the best of days. When you are running a single Yagi at low power there will be times when you will get absolutely nowhere, but don't be too discouraged; just be patient and keep trying, and you *WILL* make QSOs!

PROPAGATION ISSUES WITH EME

There is little debate among those who have "taken the plunge" in EME that the propagation challenges can be both formidable and unpredictable. Over the decades many hams have labored tirelessly to try and quantify, to the extent that such is possible, the vagaries of propagation associated with bouncing radio signals off of our nearest neighbor in space. What follows are some short descriptions of what these phenomena are and how they can affect the EME equation.

Orbit (Perigee - Apogee)

The Moon orbits the Earth approximately once every 28 Days in a slightly elliptical orbit. At Perigee (the closest the Moon approaches the Earth) the 144 MHz path loss approaches 251.5 DB; at Apogee the value reaches 253.5 DB. Believe it or not, this 2 dB variation can mean the difference between completing a QSO or not when other factors drive signal levels down.

Faraday Rotation

As the signal passes through the Ionosphere it rotates in polarity both on the way up and on the return bounce. The amount and speed of the rotation are always shifting and are unpredictable. When using arrays of fixed polarity (such as horizontal, which is most common) it is necessary to wait for the polarity to rotate into phase for reception. At times this never happens and you are effectively locked out, regardless of how large your station antenna array may be. This is due to up to 20 dB difference between vertical and horizontal polarization. Attempting to contact another station complicates the situation even more as now the signal must pass through two different ionospheric areas before arriving at either antenna.

Spatial Polarity

First proposed by KL7WE and K9XY in 1984, this phenomenon is the reason why stations are audible at one location and not another. Imagine you are on the Moon looking at North America; a station there using horizontal polarization is pointed at you and his wavefront arrives horizontal. Now look at the station in Europe using horizontal polarization and compare his wavefront to that of the North American station and you will see that they appear to be out of phase. At times the two polarities are 90 Degrees out of phase and thus 20 DB down from one another. That is far too much for the average EME station to overcome so no QSO takes place - EXCEPT for Faraday rotation, which can rotate the wavefront into the proper polarity and allow contact to be made. The fact is that due to the Spatial Polarity effect, without Faraday rotation most EME contacts would never happen.

Libration Fading

There is a random fading effect on signals received off of the Moon caused by the rocking motion of the Moon and the signal wavefront bouncing off of the Moon's jumbled surface and taking on an irregular shape itself. The distorted wavefront is now full of peaks and nulls which sometimes add up in phase although on the average they give a 7% Pi-R-Squared reflectivity. However, when the phase additions occur the overall path loss can be **REDUCED** by as much as 6 to 10 DB.

Sky Noise

As the Moon travels in its orbit the surrounding sky is filled with the random radio frequency noise emitted by all of the stars and galaxies. Some celestial bodies are noisier than others and any additional noise adds up as so many DB of degradation to your system. Measured in degrees Kelvin it can vary from 170 or so to as much as 3000+ degrees. The Milky Way is by far the biggest contributor and when the Moon is in its vicinity communications is impossible even for the largest stations. When the Moon is near the Sun there is also more noise so those days may be unusable as well. It should be noted that on 432 Mhz and above celestial noise poses less of a problem as the sky temperature in degrees K goes down in proportion to an increase in frequency.

Scintillation

When a radio wave from a distant source such as the Moon reaches the ionosphere the phase surface of the wave is distorted by irregular patches of varying refractive index. Since these patches are constantly moving the result is an interference effect resulting in fading known as Amplitude Scintillation. This is analogous to the visual "twinkling" of the light arriving from stars. It is possible for the effect to be additive and when this occurs it can result in up to 10 dB of non-reciprocal enhancement of an EME signal.

Doppler Effect

At Moonrise the Doppler effect between the Earth and Moon at 144 MHz will cause the echos to appear 300 Hertz or so higher in frequency. As the Moon traverses the sky to a point due south the Doppler approaches zero, and as the Moon continues westward the echos shift up to 300 Hertz lower in frequency at Moonset. This can pose a problem for the operator who answers a CQ where he/she is hearing the station but is not allowing for Doppler and is calling a station using very narrow filter bandwidth. The solution is to always shift the receiver RIT to correspond to the Doppler (which is indicated by the JT65b operating window on the computer).

Moonrise / Moonset - 6 dB Ground Gain

In North America the best time to operate is at or near Moonrise, not only to take advantage of the extra 6 dB of ground gain (which will make a single Yagi perform like four) but also because that is the optimum time to work European stations. Europe has by far the largest number of EME capable stations in the world, many having eight Yagis or more, so from Moonrise to about +15 degrees elevation a single Yagi station in the eastern U.S. can hear and work many European stations with only 100 Watts and at least 12 dBd antenna gain, other propagation conditions permitting.

In Part II we'll take a look at how a "beginner"144 MHz EME station might be configured, what it will cost, and how the K4MSG EME station was initially configured.

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PART II - A BASIC 144 MHz EME STATION

STATION REQUIREMENTS

This section begins with an outline of station requirements because for many readers the bottom line is going to be - well, the "bottom line." Later on I'll discuss the details of how my station is assembled and outline the basic set-up requirements, but if the projected costs discussed in the following paragraphs are too much of a "turn-off" for any reader to consider then there is no point in him or her going beyond this part.

Based on a lot of study and my own practical experience a reasonable "minimum station" for achieving successful 144 MHz EME digital communications with larger stations would look something like the following. It can be done with less, but for repeatable success this list is probably a reasonable yardstick to use.

1. A VHF multimode transceiver capable of 144 MHz SSB operation, with output sufficient to drive an outboard amplifier. **IF A HIGH STABILITY REFERENCE OSCILLATOR OPTION IS AVAILABLE IT WOULD BE PRUDENT TO PAY THE EXTRA MONEY FOR THIS CAPABILITY**. In Digital EME as in so many other things in life, "timing is everything."
2. A combination power amplifier & low-noise preamplifier (aka a "brick") having a power output of 100 watts or more and a preamplifier noise figure of less than 1 dB (and the lower, the better). **THE UNIT SHOULD BE INSTALLED AT THE ANTENNA.** (NOTE: Don't panic, this is much easier than it sounds.)
3. A DC power supply to be situated outside to power the amp/preamp.
4. A Yagi antenna with a forward gain of at least 12 dBd. **THE ANTENNA ONLY NEEDS TO BE MOUNTED 7 TO 10 FEET ABOVE THE GROUND.**
5. A small rotor for azimuth adjustment of the antenna (a TV rotor will suffice) is recommended although manual azimuth adjustment can be used if not too much of an annoyance. Some form of elevation adjustment is recommended, even if only manual, but EME contacts can be made during the first hour after Moonrise or the last hour prior to Moonset without it.
6. The shortest possible (50 feet or less is a good rule of thumb) low-loss coax between the transceiver and the amp/preamp. "Low loss" means, AT A MINIMUM, Belden 9913. LMR-400, EcoFlex 10 Plus and AirCom Plus are better still.
7. A radio/PC interface controller such as a Rigblaster by West Mountain Radio.
8. A desktop or laptop PC installed at the operating position. Windows XP or later are recommended operating systems, and WSJT Version 9 (which is FREE from the WSJT website) should be installed.
9. An accurate time-stabilization program (such as Dimension 4, which is also free) should be installed on the PC.

Here is how the basic costs break down:

1. TRANSCEIVER: Whatever you choose to spend.
2. AMP/PREAMP: Up to **$450** new depending on brand; less if purchased used.
3. POWER SUPPLY: Up to **$200** for a new linear-type. I paid $105 shipped for a new MFJ switcher (compact, reliable, and there are *NO* noise problems with it!).
4. ANTENNA: $225-**$250** including shipping and/or local sales tax (if bought from HRO).
5. TV ROTOR: ~**$100**.
6. LOW-LOSS COAX: ~$60-**$120** depending on type and length.

7. INTERFACE UNIT: **$160** for a Rigblaster Plus II.
8. PC/LAPTOP: Whatever you choose to spend.
9. WSJT and Dimension 4 software: FREE

The bottom line of the above list is that, discounting the transceiver, power supply in the shack and the PC, the remainder of the equipment for 144 MHz digital EME can be purchased for around **$1,300** (**BOLD-FACED** maximum prices above). By judicious shopping and using eBay, eHam classifieds, etc., this can be cut considerably and if you already have some of the equipment the cost will be even less.

THE K4MSG 144 MHZ DIGITAL EME STATION

1. Icom IC-706MkIIG transceiver with a Dell laptop running Windows XP Professional, loaded with WSJT Version 9 and Dimension 4 time synchronization programs. A Rigblaster Plus interfaces the radio with the laptop. The laptop also utilizes a wireless connection to a home router for Internet connectivity for the Dimension 4 software and for monitoring the **N0UK EME Chat Page**; this last is useful for setting up QSO attempts in real time if prior scheduling hasn't been done.

2. A M2 2M9SSB 9-element Yagi (14.5' boom) mounted on a home-made wood tripod with a TV rotor for azimuth control and a homebrew manual elevation adjustment.

3. A TE Systems 1412G 200-watt, 144 MHz amplifier/preamp (0.5 dB preamp noise figure) located at the antenna. Approximately 13 feet of AirCom Plus which was in the junk box connects the amplifier to the antenna, but EcoFlex 10 Plus has almost the same characteristics. An MFJ-4230MV 13.6 VDC metered, variable 30-amp power supply is co-located with the amplifier. The metered supply provides a visual check on whether the amplifier is keying during transmit cycles (by walking outside and noting the current draw on the supply meter) and the variable output allows adjustment of the DC output voltage to compensate for AC voltage drop through the extension cord from the house to the antenna. Note that this power supply is no longer manufactured but I found a source of brand-new in-the-box units on eBay for **$105** shipped.

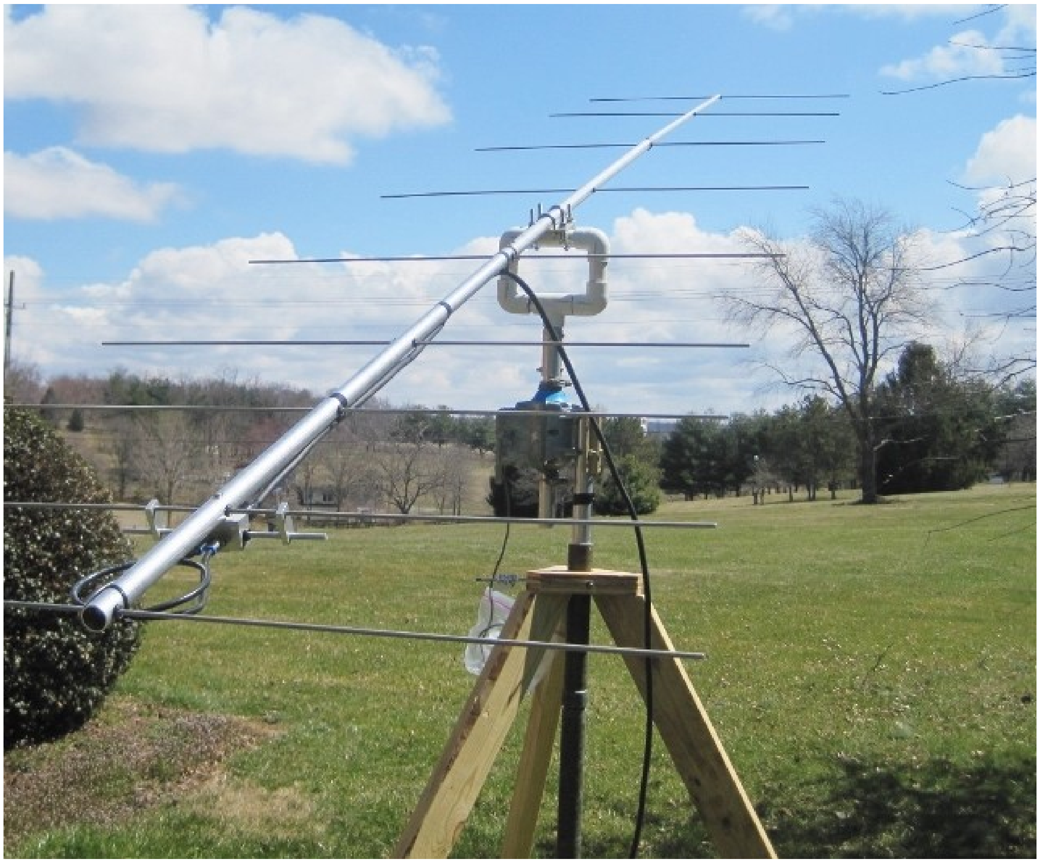
4. Initially, 50 feet of Belden 8214 low-loss RG-8/U coax was installed between the transceiver and amplifier. This was used for the first couple of weeks because the cable was in the junk box but the loss is a little worse than Belden 9913 so it was subsequently replaced with EcoFlex 10 Plus. If you're buying new, just buy the EcoFlex ($1.19/foot from Universal Radio). A similar length of 4-wire rotator cable connects the rotor control box in the shack to the rotor.

A few words on connectivity: The IC-706MkIIG uses a UHF output connector and the TE Systems amplifier uses UHF input and output connectors, while the antenna uses a Type N connector. As you will note from the photographs I use a short UHF to N coax "stub" on the transceiver output and also on the amplifier input and output to make connecting and disconnecting the equipment easier (in the transceiver case for switchover to my terrestrial 144 antenna, and in the amplifier case to speed up the connect/disconnect time of the portable "amplifier box"). Because of this the transmission lines from the shack to the amplifier and from amplifier to antenna use Type N connectors. These cost approximately $10 each for Type N connectors to fit the EcoFlex 10 Plus cable. Type N connectors are also waterproof, a big plus when it's raining while I'm operating EME with the amplifier box outside.

Thanks to already having a suitable amplifier/preamp, a Rigblaster and low-loss coax, I spent **~$500** to get on 144 MHz digital EME. Almost half of that amount was in the antenna and the balance was in the second power supply (for powering the amplifier outside), the rotor, and a few miscellaneous items.

PHOTO SECTION

The photos that follow illustrate how my initial 144 MHz EME station is configured. Captions on each photo explain the set-up and suggest what is necessary to duplicate the configurations shown.



M2 2M9SSB Yagi on wood tripod with TV rotor and homebrew manual adjustable-elevation mounting.

The main station layout at K4MSG showing the HF and VHF/UHF equipment and laptop computer, *minus* the 144 MHz amplifier (which usually sits on the top shelf next to the 432 MHz amplifier).

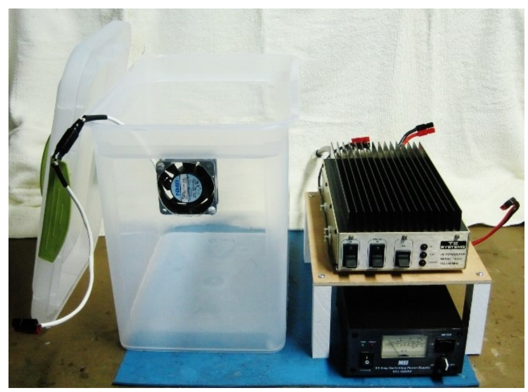
Close-up of the IC-706MkIIG transceiver and MFJ 25-amp switching power supply.

Rotor control units. The left-most unit (facing right) is the azimuth

control for the single EME Yagi; the rear control (facing front) is for the roof-mounted 144 and 432 MHz terrestrial Yagi antennas.

The Type N interface to the IC-706. The left (short) cable comes from the transceiver and the right cable goes to the external EME antenna location. This arrangement allows the EME cable to be disconnected and the cable to the terrestrial antenna(s) connected while avoiding the use of a switch or relay.

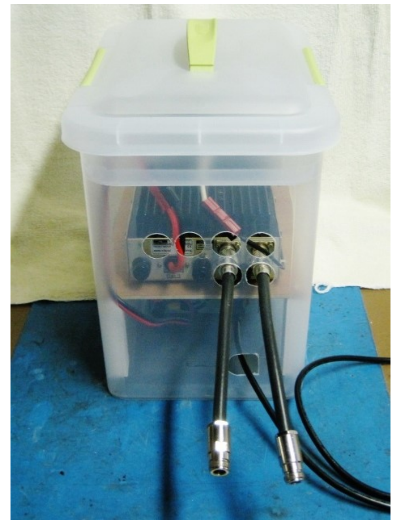
The outdoor amplifier housing showing the MFJ 30-amp switching power supply (lower), 144 MHz amplifier/preamp and homemade shelf next to the housing. Note the amplifier cooling fan mounted on the front of the housing.



The amplifier housing with power supply and amplifier/preamp installed and running. The housing is a plastic storage box available at Walmart for around $6 with suitable holes drilled for fan mounting and cable access. It has a convenient carrying handle on the removable top cover.

Rear view of the amplifier housing; note the access holes for RF and power cables. The row of four holes allows airflow across the amplifier cooling fins (the fan draws air in through these holes and blows outward).

Also note the two coax stubs on the amplifier input & output connectors; these simplify connection of the coax lines from the transceiver & EME antenna. Since the amplifier input & output connectors are UHF and not waterproof while the Type N connectors on the outer ends are waterproof if properly installed, this arrangement ensures dry RF connections despite being quick to connect/disconnect.



A plastic basin inverted over the amplifier housing protects it from both rain and direct sunlight and keeps the AC power connection to the extension cord dry (it's laying on top of the housing under the basin). The basin also overhangs the rear of the housing and protects the access holes for cables and airflow ingress.

There are countless possibilities for configuring a single-Yagi EME set-up and the descriptions and photos above merely indicate one approach. While I would recommend a minimum of 12 dBd antenna gain, 150 watts at the antenna and a preamplifier noise figure less than 1 dB, if you have better capabilities available (or more cash to spend on equipment) by all means do so. The better the initial set-up the better will be your results.

In Part III we'll take a look at actual EME operation using JT65b.

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PART III - FIRST STEPS IN 144 MHz EME OPERATION

SETTING UP THE SOFTWARE

If you've never used WSJT software you will need to download it from the Internet and then **READ THE MANUAL** to familiarize yourself with the screens. You'll also need to enter your own station parameters into the WSJT program and make sure that the necessary interfaces (serial connection, audio in, audio out, etc.) between the laptop/PC, Rigblaster, and transceiver are correct and functioning as they should. Verify that the Dimension 4 or other "time sync" software is keeping the PC clock corrected to less than a second of error. There are instructions on setting the level of the audio tones that comprise the digital signal fed to the transceiver; follow these instructions carefully, especially the procedures for balancing the tone levels ***AND*** ensuring that no ALC action takes place as this can distort the transmitted signal and make decoding difficult or impossible at the receiving station.

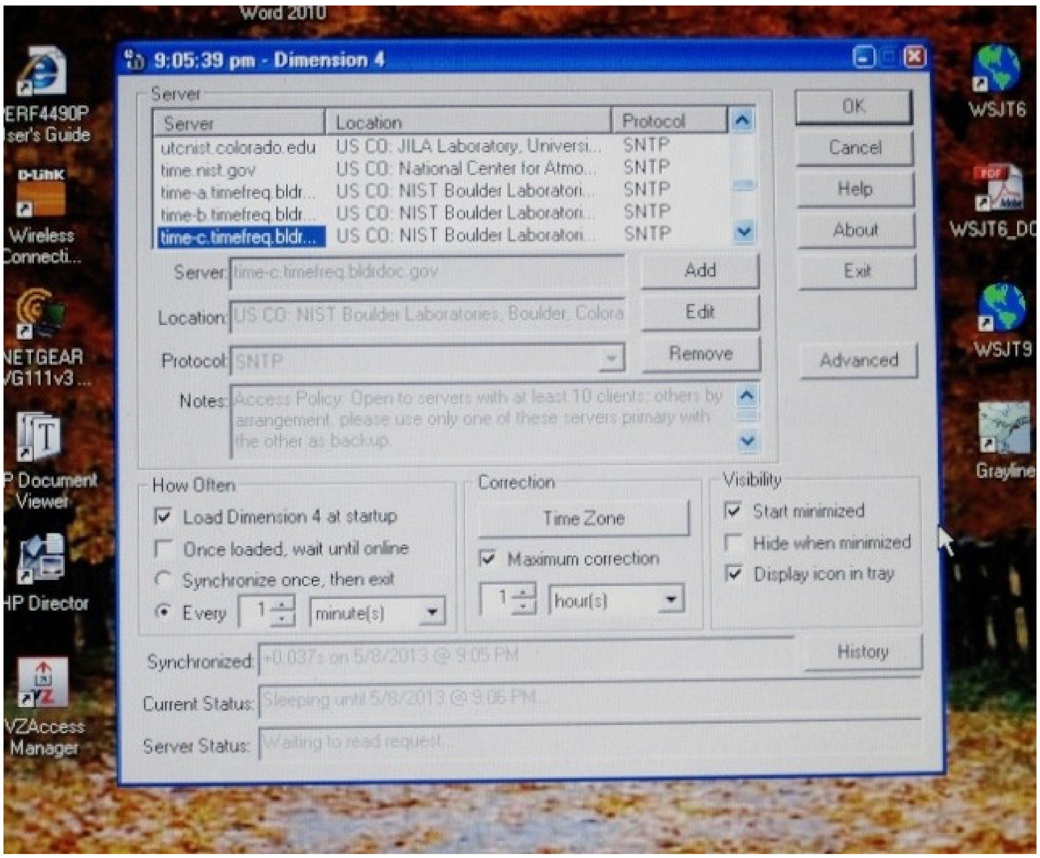
Since the WSJT manual is rather long and - not to put too fine a point on it - a bit ponderous, I highly recommend that you also download "**W7JG's Additional Tips for Using JT65 in WSJT**" which you can find at http://www.bigskyspaces.com/w7gj/JT65.pdf. Here you will find clear and concise instructions for how to set the parameters in the JT65 screen for most efficient EME operation.

Initially, you should plan to operate only at Moonrise, especially if you have no elevation control on the antenna. You can go to the "timeanddate.com" website at
http://www.timeanddate.com/worldclock/astronomy.html?n=263&month=5&year=2013&obj=moon&afl=-12&day=1

to print a list of the Moonrise times and azimuths for our area (Washington, DC) for the current month. Make sure you choose the "rise/set time/azimuth" display option. The times shown in the table are local time corrected for DST.

OPERATING AND COMPLETING CONTACTS

Begin your first EME operation by pointing the antenna at the necessary azimuth point specified for Moonrise. WSJT should be set up for 144 MHz and JT65b mode. I usually turn on the transceiver and laptop about an hour before scheduled Moonrise, bring up the WSJT screens, and check that Dimension 4 is controlling time correctly.



Dimension 4 Screen

Dimension 4 requires that the PC be connected to the Internet continuously to keep the system time accurate.

At this point I carry the amp/preamp and small power supply outside (in the special container shown in the photos of the previous section), make the connections from the shack and to the antenna, and power up the equipment. Then I return to the shack and run a couple of test sequences to check levels on the transceiver, etc. I also walk outside during the "send" portions to make sure that the red transmit LED is glowing on the front of the amplifier and that the power supply meter indicates correct current draw (about 23 amps in my particular case).

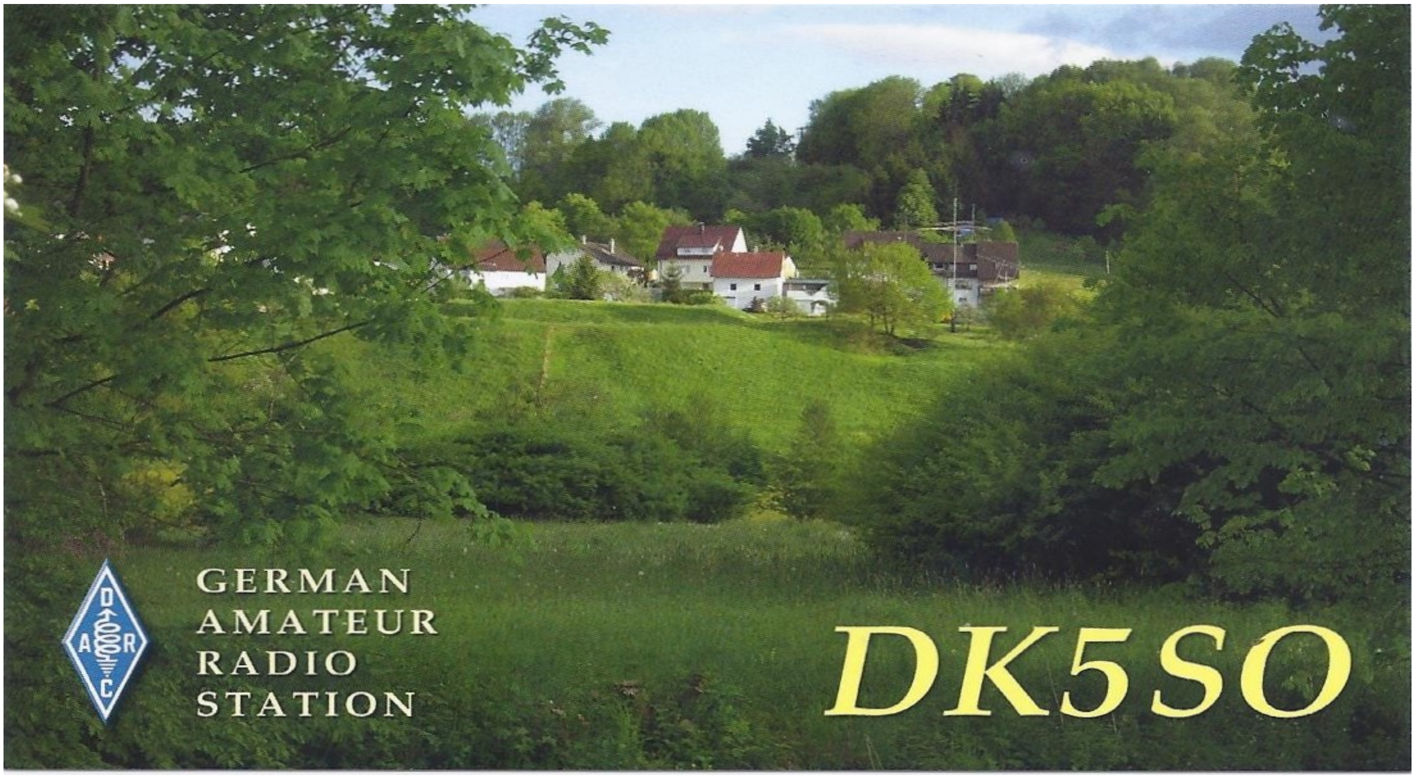
Just before the Moon is scheduled to break the horizon I bring up the N0UK JT65 EME-1 chat page (It doesn't hurt to also check the JT65 EME-2 page just to see which is being currently used) and look to see who may be active, who is calling CQ, etc. Once the Moon rises above the horizon, tune the transceiver to where stations are calling CQ and see if you get any decodes by clicking the MONITOR button on WSJT. Make sure to set your RIT to the "Doppler" offset indicated on the WSJT screen.

If you decode a CQ click the "AUTO ON" button on WSJT but first **MAKE SURE** that you are transmitting the **OPPOSITE** time period from the CQing station, i.e., if he's sending "1st" you should be sending "2nd" and vice-versa. If you decide to try a CQ yourself make sure you alert the users on the chat page by posting something **like "*CQ 144.120 2nd K4MSG Paul FM19*".**

Here is how the correct sequences look for a VALID QSO for two scenarios: Answering a CQ, and someone else answering your CQ.

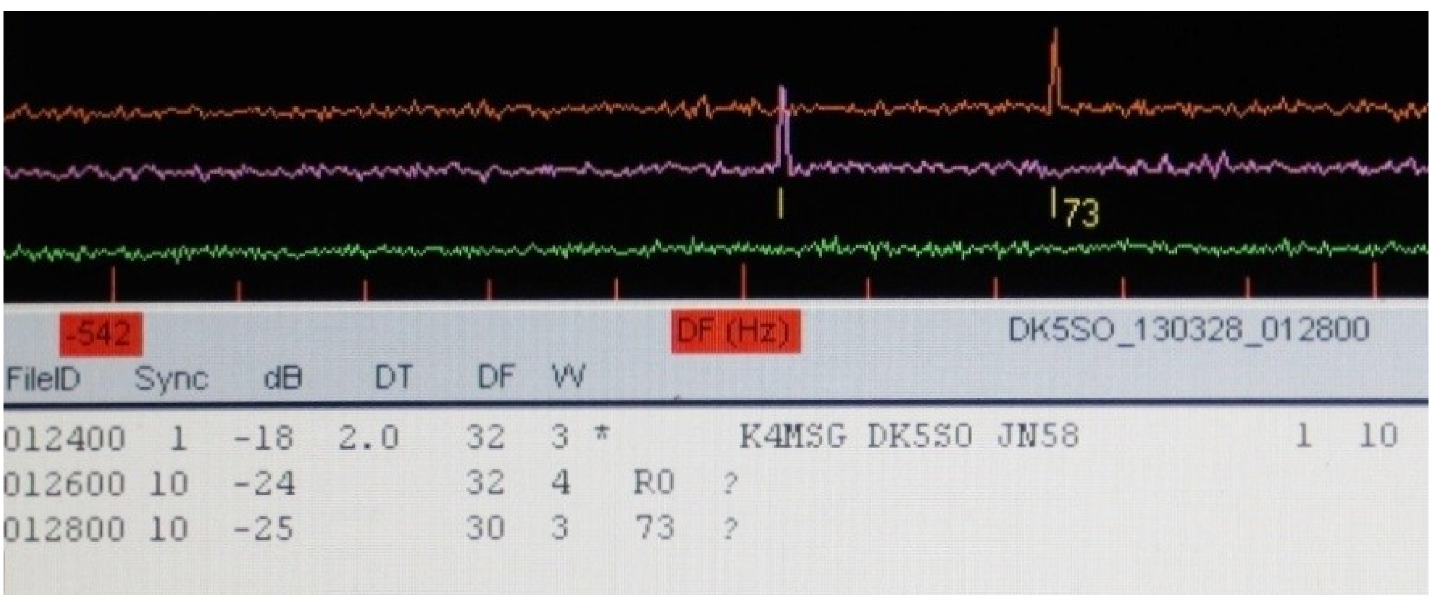
Answering a CQ

I decode: CQ G4SWX JO02
I send: G4SWX K4MSG FM19
I decode: K4MSG G4SWX KO03 OOO
I send: RO
I decode: RRR
I send: 73
I decode: 73

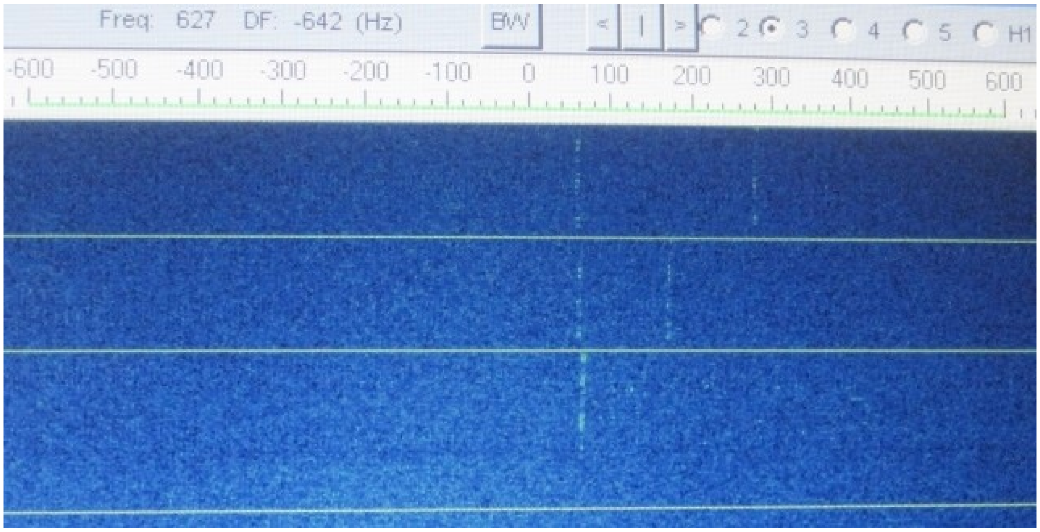


CALLING CQ

I send:	CQ K4MSG FM19
I decode:	K4MSG DK5SO JN58
I send:	DK5SO K4MSG FM19 OOO
I decode:	RO
I send:	RRR
I decode:	73
I send:	73



WSJT decode box showing three DK5SO transmissions. My CQ prefaced his first transmission and my "OOO" followed it, my "RRR" was sent after his "RO", and my "73" was sent after his "73". My transmissions were during the ODD minutes (0123, 0125, etc.)



WSJT spectrum display (waterfall) showing the DK5SO contact. The lower segment shows the transmission when he called me, the center shows his transmission of "RO", and the upper shows his transmission of "73". The last two transmissions are "two-tone" only and easy to identify on the spectrum display.

HOW SUCCESSFUL CAN A SMALL STATION BE?

Although I am a green "newbie" at EME I have been gratified with some success. Despite only operating sporadically during the first month I was able to complete eight EME QSOs in six countries (**DK5SO, G4SWX, I2FAK, RU1AA, RX1AS, S52LM, SP4K, and UA3PTW**). These contacts were made on different days and under different conditions and indicate that my set-up provides repeatable results **WHEN CONDITIONS ARE FAVORABLE**. This last caveat is very important because when you are running a single-Yagi, low-power station for EME you cannot expect to successfully achieve two-way communications via the Moon except under the best of conditions.

However, despite the limitations of using a "minimalist" set-up and coping with the vagaries of Lunar propagation I must confess that EME operation can become addictive. Success requires large amounts of patience and a willingness to devote many hours to attempting to make QSOs with no guarantee of success on any given day, but with practice and a commensurate increase in experience, coupled with increased understanding of limitations, will come increased success - and probably a degree of motivation to seek ways to incrementally improve one's EME operational capability. You will be operating on the fringes of the ultimate weak-signal challenge for an amateur station and success in making QSOs will place you in a select group of hams.

A future Part IV will describe a similar set-up and results for small-station EME on 432 MHz. Stay tuned!

Paul Bock, K4MSG, has been licensed since 1957 and holds an Extra Class license. He is currently active on CW traffic nets on HF as well as small-station EME and other weak-signal modes on VHF/UHF. Paul is a LM of ARRL and also a member of the A-1 Operator Club, QCWA, CW Operator's Club and several other ham radio organizations. He has earned DXCC, WAC, and WAS on HF and VUCC on 50 and 144 MHz.

A retired EE who worked in the Defense and Telecommunications fields, Paul is a Life Senior Member of IEEE and co-inventor of a patented telecommunications device. He is also a retired U.S. Navy Master Chief Petty Officer (E-9). He holds commercial radio operator licenses as 2nd Class Radiotelegraph Operator, GMDSS Maintainer, and General Radiotelephone Operator, all with Ship Radar endorsement.

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