ON0EME 1296 MHz Moon Beacon

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The idea came from the EME gathering in Örebro, Sweden. On a Sunday morning in May 2011 we, together with the group of EME interested amateurs, had a discussion how to promote the hobby. One of the points brought up was a beacon tracking the Moon. During our way back home we discussed the issue and found that many parts to build a beacon were already present. The project was born. The total project was built by Dominique HB9BBD, Luc ON3LNL, Walter ON4BCB, Marc ON5OT and Eddy ON7UN.

It was a challenge to build an automatic station, switching on when the Moon would rise above the horizon and tracking the Moon towards moonset.

The design goal was to create a standard in frequency, amplitude and timing, and for an automated station to be operational as long as the Moon was visible at the beacon's location.

Figure 1: The complete ON0EME beacon installed on top of a 10 ft shipping container

Design Criteria

Using VK3UM software we were simulating antenna diameters, power and noise figures and came to the conclusion that with the available 3.7 m diameter solid dish and a well constructed feedhorn, the beacon would be audible in the loudspeaker of a receiving station with a 2.4 m dish and a reasonable LNA. To achieve this, we would need to have a transmit power of 400 W or more.

To be a frequency standard, we would want to reference lock the LO to a GPSDO, so that frequency accuracy would be good enough to put a marker at the start of our EME section of the 23 cm band. A second use for the GPS reference is to give accurate timing references for transmissions and for its own antenna tracking system.

The beacon should have a very stable output power, so that it can be used to check EME propagation conditions. For the same reason, the antenna must track the Moon accurately, even in high winds, so mechanical stability is one of the main design points.

We would also need to have a remote monitoring and control system, so users can check if the beacon is active and transmitting. We ourselves would need to be able to check voltages, temperatures and power, so we would need to build a complete telemetry system for the housekeeping of the beacon.

The entire must be modular, and in case of problems any module must be able to be removed and repaired easily. Spare modules would need to be constructed for fast repair.

We would also need to apply to the licensing authorities in Belgium to obtain a special high power license for an unmanned station.

Location

But first of all we needed to find a location with good Moon window at both low and high declinations. The location would need to be safe for people around the antenna, but it should not be in a residential area because the air cooling will make some noise around the clock. An industrial area would have fewer zoning issues and moderate level of noise should be no problem.

We did find a suitable location in an industrial area. There are some small obstructions at lower elevation angles but most of the month the antenna can see the Moon during its complete cycle.

The Licence

Before we applied to the Belgian authorities for a licence, we made contact with IARU through our national VHF Manager. We were proposing a high power unmanned station to transmit on 1296.000 MHz. We wanted to be on this frequency because a previous EME beacon had also used 1296.000 MHz and it is the start of the EME segment of the 23 cm band. Also all our EME equipment is optimized for 1296 MHz, and not for the beacon band around 1297 MHz. At that moment the IARU conference was going on in South Africa but we were too late to put this point on the formal agenda. Finally, however, IARU did agree on this frequency and the local licensing authorities were contacted.

At this conference in Cambridge, we ask the international EME community to support 1296.000 MHz for EME beacons. With a consensus from the EME community, a formal proposal will be made on the agenda of the next IARU conference.

It took around 3 months to get the OK from the Belgian licensing authority, but with a restriction on the minimum elevation. We are only allowed to activate the beacon when the moon is above 10 degrees elevation, where even side lobes of the antenna are no problems for people surrounding the antenna.

From that moment we could really start with the hardware!

The Antenna

We had a German made antenna by RFS in Hannover with a very heavy fixed AZ-EL mount. We asked an amateur friend with very fine mechanical skills to assist us with the motorization. Marc, ON5OT agreed and the mount was transferred to his workshop. Marc built a very heavy duty azimuth gearbox on top of the mount to turn the upper part, rotating on a conical bearing. A construction with 6 wheels running around the central fixed pipe was made to guide the heavy rotating part with a minimum of back-lash (Figure 2). The azimuth encoder is placed on top of the azimuth gearbox, and limit switches are installed on the fixed section of the mount.

Figure 2: The bottom AZ bearing with the AZ limit switch and equipment box (note the air exhaust for one of the two PA bricks)

We also had a very heavy duty 50-inch stainless steel ball screw actuator for the elevation. Marc made a complete rework on the actuator, changing bearings and making a waterproof oil retaining ring on the output. A new casing for the motor and gearboxes was made, as well as a new connection point where the elevation actuator can balance.

As seen in Figure 3, the antenna is attached to the mount at two points high up on the dish hub, and the elevation actuator pushes on the bottom edge of the hub. The elevation bearings are made from brass with stainless steel. At one end of this elevation axis is the elevation encoder, and the other end is to be fitted with limit switches for the elevation actuator.

Figure 3: Back structure of the antenna with AZ and EL motors and equipment box

Feedhorn

For the feedhorn (Figure 4) we used an OM6AA designed round septum polarizer with a 'Super VE4MA' choke ring. The reflector f/D is 0.375 so this combination should do. We made some Sun noise measurements with good results compared to the expected values from the VK3UM software. Return loss of the transmit port was measured better than 28 dB with the feedhorn in the antenna. The feedhorn is connected to the output power combiner by a length of Ecoflex 15 cable.

Figure 4: OM6AA round septum feed with 'Super VE4MA' choke ring

Antenna foundation

As we needed to have the antenna up in the air a bit, to overcome obstacles and also for safety and security reasons, we decided to mount the antenna on a 10 ft shipping container. We first made a concrete slab and made a construction of H beams. The container was mounted on two H beams and on top of the container 4 more H beams made a base frame to install the antenna mount. The complete concrete foundation, container and antenna mounting is connected together with M20 stainless steel hardware to make one heavy-duty construction capable of withstanding high winds.

The final height of the antenna is about 4 m above ground level.

The Transmitter

Exciter

We wanted a ref locked LO for the exciter. We spoke to DB6NT and he came up with a very compact custom made exciter system based on his 3rd Generation transverters. He uses a 108 MHz crystal and phase locks this with his PLL circuit, referenced to a 10 MHz source. After this stabilized LO there is an x12 multiplier and after that some gain stages which are keyed. The output of this exciter is 1 W. The 10 MHz GPSDO is a commercial unit we had on hand made by Timewave.

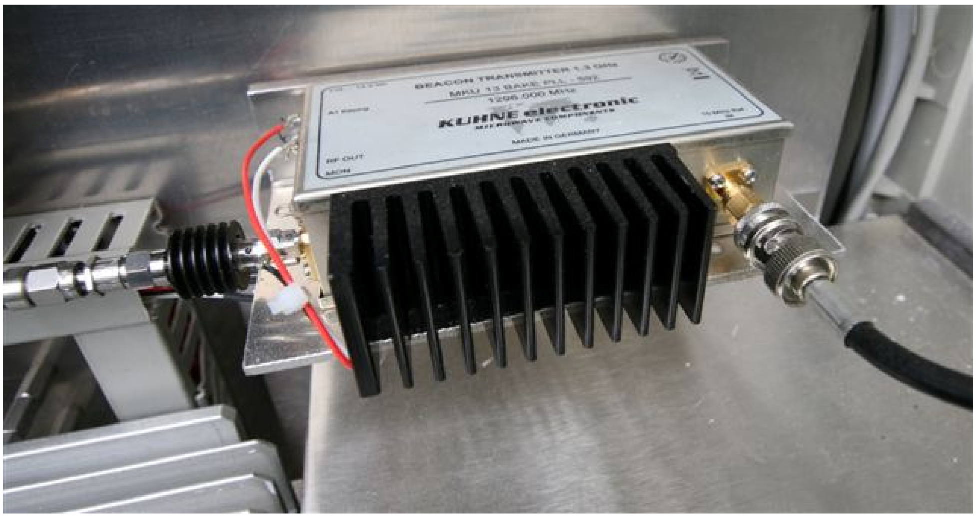


Figure 5: DB6NT custom made beacon exciter

Driver

We needed about 8 W of drive for our output SSPAs, so we used the obsolete Mitsubishi M57762 module as a driver amplifier, since we had plenty in stock. That module is mounted on an oversized heat sink. We needed to attenuate the output from the exciter to the driver by around 10 dB so we made a good match between the exciter and driver amplifier.

Power amplifier

The final amplifier needed to have much attention, since we wanted to have a good reliable system that could be powered up for years. We spoke to Bert PE1RKI and he suggested to build two power 'bricks' and phase combine them. Bert used extra copper to cool the devices and each block was mounted on a large heat sink with two 110 mm fans each. Since we wanted to make sure the output combiners of each power brick would hold this duty cycle we asked Bert to build the output boards on Rogers 5880 material and use ‘2-ounce’ copper. Bert made a new output design using this heavy-duty board material. The output combiner includes forward and reflected power sampling for our monitoring and control system. The output coupler is connected to the feedhorn using 5.6 m of Ecoflex 15 cable, and the total loss from the amplifiers to the feedhorn is about 0.7 dB.

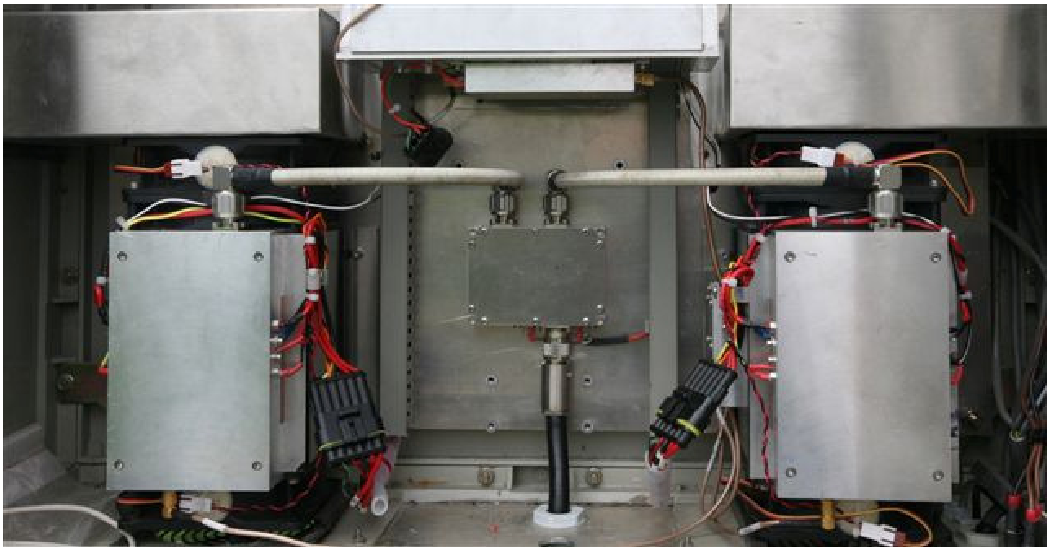


Figure 6: Two power amplifiers combined in the hybrid coupler (centre)

Power supplies

We had a good number of Astec switched power supplies delivering 2 x 28 V each at 15 A. Since we have two devices in each power brick we decided to give each device a separate power supply. In total we installed three Astec power supplies, two for the amplifier bricks and the third is used for the AZ and EL motors. For the rest of the equipment a 15 A 12 VDC power supply is used. The monitoring and control system can switch off the complete beacon so has its own separate 12 V supply which must be powered all the time.

Monitoring and Control

Monitoring and control (M&C) forms a very large part of a complex automated system like this one.

Antenna control

The antenna controller is based on the well-known and reliable ‘OE5JFL v2’ tracker, which we modified for our needs. A stripped down version of the original OE5JFL design was made which only supports the MAB25 12-bit absolute encoders. We built the controller on a single-sided PCB with DIL components.

We also made software and hardware modifications in order to know when the Moon is more than 10° above the horizon, in order to meet our license. We got a lot of help from Hannes supporting us with the source code of his project. We also needed automatic tracking of the Moon after power-up at any time, and automatic return from moonset to wait for the next moonrise. The antenna controller communicates with the separate M&C (monitor and control) controller by a serial port.

Figure 7: Beacon controller including antenna positioner, GPS receiver and beacon keyer

Motor controllers

The azimuth and elevation are both DC motors with variable speed control.

We use H-bridge drivers rated at 25 A (Devantech MD004) that are controlled with PWM by the antenna controller. A special interface was designed so the motors would move slowly while tracking. When the antenna has been stopped after the Moon has set in the west, the interface will move the antenna high speed to the new position ready for moonrise in the east. It will then go back to the slow mode for tracking the Moon during the next cycle.

Beacon keyer

The beacon keyer is a G4JNT design with software and hardware modifications. We have added an external ‘enable’ input to start the beacon message exactly on the minute at ‘00’ GPS time. If a longer CW message needed, we can change the keying cycle to start on every odd-numbered minute.

The CW beacon message can be programmed via a serial interface and is stored in a non-volatile memory (EEprom).

GPS reference

The GPS reference has three functions:

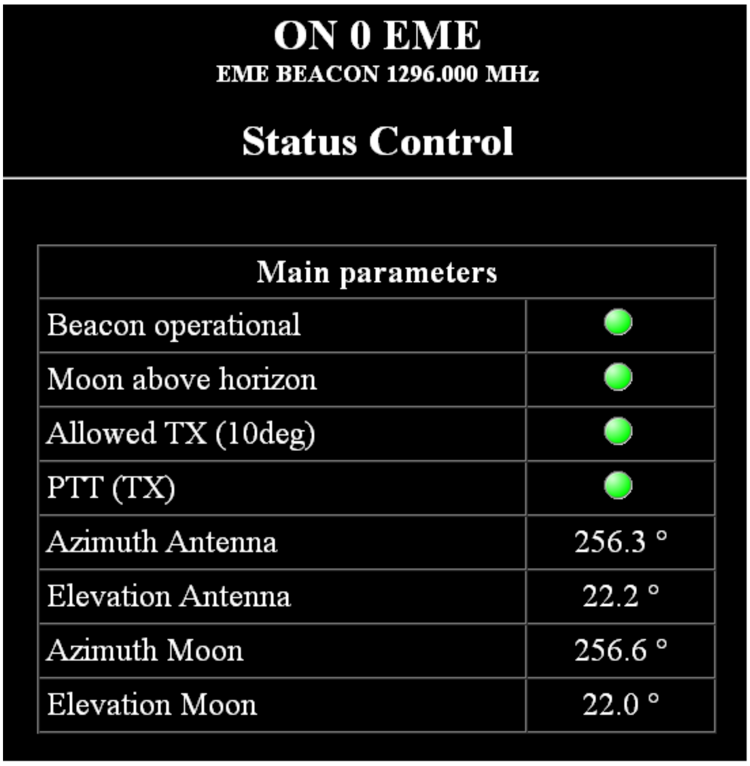
1. It is used as a GPSDO for our 10 MHz frequency standard for the beacon exciter
2. The GPS NMEA time string is used to start the CW beacon message accurately on the minute
3. The NMEA 0183 $GPMRC string is used to update the position (longitude and latitude), time and date for the OE5JFL tracker.

An active GPS patch antenna is used, installed outdoors behind the antenna in order to avoid desense of the GPS receiver module by the transmitted signal.

Remote monitoring and control

The remote Monitoring & Control (M&C) hardware is a universal project using a microchip 18F45K22 microcontroller with several digital inputs and outputs, 10-bit ADCs, two UARTs and an embedded web server.

The M&C part is not needed for full functioning of the beacon, but is intended to allow users to check the current status of the beacon, the azimuth and elevation of the antenna and the object that is being tracked. The frequently updating web page at http://www.on0eme.org is also an indication if the beacon is really transmitting.


ON 0 EME

EME BEACON 1296.000 MHz

Status Control

Main parameters	
Beacon operational	
Moon above horizon	
Allowed TX (10deg)	
PTT (TX)	
Azimuth Antenna	256.3 °
Elevation Antenna	22.2 °
Azimuth Moon	256.6 °
Elevation Moon	22.0 °

Figure 8: The web page gives frequent updates to check the beacon status

For our needs to run the system, we can remotely control the antenna to a maintenance or survival position, check telemetry, voltages of the power supplies, temperatures of the power amplifiers, cabinet temperature, forward and reflected power, GPS 3Dfix, switch on and off the outside lights and generally control all parameters of the antenna tracker.

Last but not least, we did not want to have any PC or operating system involved in the project, so the complete beacon is controlled and monitored using dedicated individual processors as described above.

IT and IP connectivity

In order to have Internet remote control we use an ADSL connection to an ISP.

A router and hardware firewall handles the Internet security, port forwarding and dynamic domain name updating. A webcam is used for remote surveillance and security.

An automatic IP power mains switch allows us to remotely cycle the mains power of the beacon, web server, router, webcam, lights etc in case of problems. This switch has a 'ping' function that is used to reset the embedded web server etc if needed during unattended operation.

Conclusion

ON0EME has been on air since March 31st 2012.

It has been in daily operation since, and is now stable after some difficulties in the start-up period.

Reception reports have been received from stations with dishes as small as 180 cm.

Acknowledgements

We would like to thank:

- Hannes OE5JFL for his support, his tracking hardware, which is still the 'stand alone reference' in tracking hardware
- Marc ON5OT, for all help in the mechanical construction, for the ideas on the drives and motors. Marc was responsible for the complete mechanics of this beacon
- Luc ON3LNL for the software development and debugging of the M&C. Luc has written the M&C software together with Walter ON4BCB
- Our sponsor (who would like to stay anonymous) for the use of his site and electrical power.