N4MW/B Beacon Update 2010

Dave Meier N4MW
New Kent, VA (FM17kn)
www.n4mw.com - n4mw@n4mw.com

Introduction. The N4MW/B beacon system is currently in operation on all bands from 144 to 2304 MHz as well as 10 GHz. All active beacons are frequency locked to GPS. This paper will describe the beacons, with both historical background and technical information. The following table shows current beacon status.

28.250	Inactive	Deferred to WA4FC/B operation.
50.070	Inactive	Deferred to WA4FC/B operation. See also W4HHK/B in EM55db
144.280	Active	5 watts CW to Sqloop at 90 feet. Frequently heard in the northeastern states, heard in EM00 (TX) on Es.
222.060	Active	5 watts CW to Sqloop at 90 feet. Heard by K1RZ and WB3IGR. Frequency confirmed +/- 0.01 Hz by KE2N.
432.300	Active	10 watts CW to Sqloop at 90 feet. Heard by K3CB and WB3IGR.
903.280	Active	50 watts CW to WA5VJB wheel. Heard by K3CB and WB3IGR.
1296.280	Active	6 watts CW to WA5VJB wheel. Heard by K3CB and WB3IGR.
2304.280	Active	4 watts CW to Alford slot.
3456.280	Inactive	To be deployed in future.
5760.280	Inactive	To be deployed in future.
10368.280	Active	2 watts CW to waveguide slot at 95 feet. Heard by K3CB. Note: Actual frequency 10368.2799974 (about -3 Hz).
24192.280	Inactive	To be deployed in future.

Historical Background, EM55. My experience with beacon operation grew out of my long friendship with the late Paul Wilson W4HHK. In the early 1980's Paul operated beacons on 50, 144, 432 and eventually 1296 MHz from his home in Collierville, Tennessee. Later in the decade I became involved as the trustee of the only 1.2 GHz FM repeater in the Memphis area, which provided access to a building top site for beacons. This allowed the relocation of Paul's beacon equipment and more bands for coverage of all 11 bands from 10 meters through 10 GHz. In 1994 access to the beacon site was lost and the Memphis beacons ceased. A few months later, I moved to Virginia, where I remain. The Memphis beacons were first described in the 1991 *Proceedings of the Microwave Update Conference*, which were later included in the ARRL *Microwave Projects Handbook.* A copy of the original article is posted on my web site as shown in the references at the end of this paper.

FM17 Operation. In 1995, once settled in a new home in central Virginia (FM17kn), I put up the first of several towers and soon reactivated the 2 meter beacon. This beacon has remained in substantially continuous operation. I later added a 10 GHz beacon, also still in operation. The 2 meter beacon was the same unit as originally used in Memphis, a crystal controlled exciter board from an RF Communications military surplus FM transmitter. The original 10 GHz beacon used a California Microwave oscillator into a Hughes AML power amplifier. It used narrow FSK and was a bit high in frequency at 10368.585 MHz +/- drift. I heard it at distance from my airplane, but no one else ever reported reception.

A New Beginning. In 2006, after retiring from my DoD job after 34 years, I put up a new, taller tower and reworked my antenna systems. Although there is more work needed to be active on the bands above 1296, at least my rotating antennas are above the trees now. The beacon antennas are now higher, above 90 feet. Looking for other ways to improve things, I noted that others continue to enhance the frequency accuracy of their systems. A small amount of research revealed that surplus frequency synthesizers are available which provide a simple means to transfer a 10 MHz standard source to any particular frequency desired. I already had a good 10 MHz source.

Overview of beacon equipment. The left rack of Figure 1 contains most of the beacon equipment. At the top is a 48 volt UPS which powers the GPS receiver. The GPS receiver is an HP Z3801A with output on 10 MHz. This reference signal is connected in a "daisy chain" to each reference input for all synthesizers, one per band. The synthesizers are all PTS units, either PTS-160, PTS-310, or PTS-500. See below the description for each band for the particular unit used and the details of the implementation.

The 10 GHz transmitter is the black front panel chassis near the top of the right rack. In the left rack, just below the GPS receiver, is the 1296 transmitter, rack panel mounted. Below that is the 2304 transmitter, also rack panel mounted. The 1U rack chassis just above the two Bird power meters contains the identifier as well as both the 144 and 222 transmitters. Just below the two power meters is the 432 transmitter. The rack also contains a 12 volt 10 amp power supply for powering units which do not have their own AC power supply. A small control box not shown contains a solid state AC relay which is used to remotely deactivate the 12 volt supply, which effectively deactivates all beacons by powering of the identifier.

Output power monitoring is provided for all transmitters using various meters shown. The HP 432C meter in the right rack reads 2304 power. The two bird meters are for 144 and 222. Bendix meters are used on 1296 and 432. The 10 GHz transmitter is built into a Hughes AML chassis, which has internal power monitoring. 903 (not shown) is in another rack at the other end of the operating console.

10 MHz Standard. In my station, the ubiquitous Hewlett Packard Z3801A cell site GPS receiver provides an accurate 10 MHz source. I use it as the reference source for various pieces of test equipment. My Z3801A runs from a 48 volt UPS. The antenna is the HP cell site cone, pictured. The 10 MHz output connects to the first of several synthesizers, which connect in turn to each other in daisy chain fashion. To break the 10 MHz out further to test equipment, I use a simple 4 port video distribution amplifier purchased cheaply on eBay.

Synthesizers. My research revealed that there are many good solutions to providing accurate signals locked to a 10 MHz reference, such as the WA6CGR, N5AC, CT1DMK and JWM designs. Other amateurs have used synthesizers from Programmed Test Sources, Inc (PTS). The PTS units are comparatively large, rack mounted boxes, but they are very flexible, reliable and are low powered enough to not need fan cooling. A typical unit, the PTS-160 (pictured), can cover from 0.1 to 160 MHz, with front panel knobs to select frequency in 1 Hz steps. Although many PTS units have the optional internal reference oscillators, all models accept an external 10 MHz reference. Output level is variable up to +13 dBm. The output level can also be remotely set using an applied analog voltage, which can be used as a method to impart CW keying to a beacon. The output is a directly synthesized clean sine wave with the same accuracy as the reference source. I am employing several models for the current beacons, including PTS-160/310/500 units. Obviously, the synthesizer output frequency must be multiplied many times to be used for a microwave band. For example, the 10 GHz beacon multiplies 103 MHz by a factor of 102, but still produces a clean sounding CW note.

The PTS units come in a variety of models, each with many possible options. The PTS catalog, with information describing the models and options, can be downloaded from the manufacturer's web site. This information can be useful to "decode" the model number to reveal the configuration and options for any particular unit. Be aware that some models are sold with different resolutions from 1 MHz to 0.1 Hz. Units with front panel controls should have blank knobs indicating resolutions less than the maximum available. A look inside will reveal if there are empty internal slots for additional divider modules. Be sure that the appropriate modules are inside to support the resolution needed. If you have them, it is very easy to add or remove modules in the field.

Many surplus PTS boxes were originally used in automated test setups. These may contain no front panel controls. All units contain either a BCD or GPIB interface. The BCD interface is simple to program for fixed frequencies. There may be a potentiometer accessible through a small hole in the interface plate to set the output level. I have not found the GPIB interface to be useful just to set a fixed frequency for beacon service. Even so, a unit with GPIB can be modified using pull up/down resistors to be manually set on a particular frequency. I would not pass up a bargain unit regardless of the type of interface.

Two PTS-500 boxes I bought recently on eBay were missing the remote interface boards altogether. A study of the schematic revealed that the front panel controls could be activated by supplying +5.4 volts to one of the many dangling connections. Forty 2.2K pull-down resistors, one for each bit of the ten BCD panel switches, were needed to enable local programming. See the picture for my "fix". Also note the RCA connector installed to the right, which is allows access to the remote level setting input if needed later. Applying an analog voltage up to 2 volts will vary the output level up to 20 milliwatts. An internal level potentiometer can also be added easily if needed.

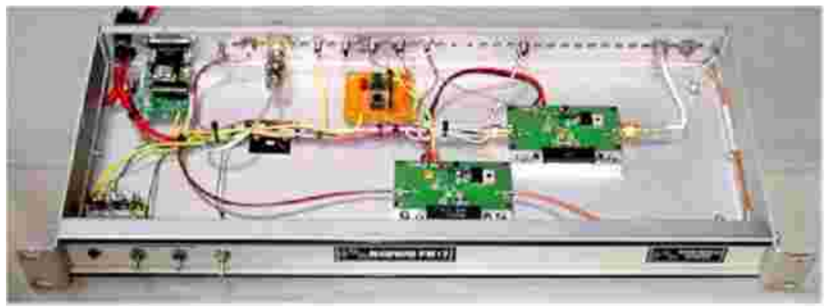
Programmable Keyer. The venerable W4RFR EPROM keyers that W4HHK and I used have been reliable. I estimate that my old unit has keyed out around 20 million identifications. the EPROM changed only once, when I relocated to FM17. I have tried out a number of keyers with reprogrammable features. I decided to use the inexpensive ID-O-Matic from N0XAS. It is inexpensive, only $20 or so. Programming is done via RS-232 connection and any simple terminal program. The many repeater oriented features are not used. I contend that beacon ID strings are better if kept simple answering the pertinent questions: who is there, where are you? In my case: N4MW/B FM17KN (10 second dash) at 15 words per minute. The long dash provides a constant signal for antennas alignment or other adjustments and measurements.

Control and Power. Several transmitters are operated from the AC line. Some of the beacon transmitters operate from a 12 volt power supply. I use a solid state relay with separate DC source to enable the AC power to the main 12 volt supply. This supply powers the keyer, such that all beacons are unkeyed if the main supply is turned off. Most beacon transmitters are set up to accept a positive going 12 volt keying signal. An optoisolator and Darlington power transistor are used as a current switch, converting the active low keyer output to the positive voltage needed to key transmitters.

Two Meter Upgrade. After purchasing my first PTS-160 unit from eBay, I begin thinking of ways to integrate it into my beacons. The 2 meter transmitter used a nominal 12 MHz crystal oscillator on a separate board, which fed into a multiplier chain and amplifier to provide several watts. An easy thing to have done would have been to substitute the PTS unit in place of the crystal oscillator. To produce the desired 144.280 MHz transmitter output, the crystal would need to operate at 12.023333 MHz, to the nearest Hertz. If I set the synthesizer to exactly that frequency, the resulting transmitter output would be 144.279996, which is 4 Hz shy of the desired frequency. Even if I used a synthesizer with the 0.1 Hz selection option, the resultant multiplied frequency would still be 0.4 Hz high of the desired frequency. I could just have picked another frequency scheme, say 12.024 X 12 = 144.288, but I really wanted to stay on the historical frequency for N4MW/B. The solution to this dilemma was to abandon the original multiplier transmitter and simply dial the 144.280000 frequency directly on the synthesizer and amplify the synthesizer output to a reasonable beacon power level. I found a solution for that on eBay, an amplifier board using a Mitsubishi M57723 module (pictured) , which produces 5 watts when driven by the synthesizer output. Keying is applied to the bias pin on the module.

Return to EM55. About the same time that the 2 meter beacon was being upgraded, the weak signal group in the Memphis area requested assistance on reestablishing a 6 meter beacon there. There is already a 6 meter beacon in the FM17 area, WA4FC/B, so there is no plan to activate another one here. I built up another ID-O-Matic keyer using the Collierville Millimeter Wave Society club call W4HHK/B. The keyer, the original W4HHK 6 meter transmitter and my old 2 meter transmitter were mounted in a weatherproof box and installed in EM55db, Collierville, Tennessee in June of 2009. Details are at QRZ.com – search for W4HHK. The picture shows the 6 and 2 meter M-Squared Sqloop beacon antennas installed on one corner of the W4HHK dish platform.

222 beacon added. I purchased a PTS-310 synthesizer at the Shelby, North Carolina hamfest. This model works up to 310 MHz, making it well suited to construct a 222 beacon similar to the 2 meter one. I chose 222.060 MHz as the desired frequency. This PTS unit happened to have no front panel controls, so the BCD programming interface had to be configured. This turns out to be trivial, just ground one pin on the interface connector to enable remote programming, plus one for each BCD bit to select the frequency, for a total of five grounded pins in my case. There is a small potentiometer adjustment accessible through the back panel to set the level, although this can also be remotely set using an applied analog voltage. I ran the beacon for a while with only 0.25 Watts out of a small amplifier module. I later obtained another small transmitter board identical to that used on 2 meters, which I modified by using a Mitsubishi M67732 module to provide 5 Watts output, keyed the same way as 2 meters.



Putting it together. The picture shows the integrated beacon controller, 144 and 222 transmitters, all mounted in a 1U rack cabinet. The N0XAS ID-O-Matic programmable keyer is located on the rear panel. A DB-9 connector is used to connect to a computer RS-232 port for programming. The active low identifier output is used to switch two Darlington output optoisolators, each driving a TIP-120 Darlington transistor current switch. The current switches provide two positive 12 volt keyed outputs. One drives the internal transmitters and the other is brought out on several RCA jacks for external transmitter keying. Other facilities are provided as follows: a red LED to monitor keying, two potentiometers for setting the keying voltage level provided to the remote level inputs of synthesizers which need to be keyed (no longer used). The antennas are the original style M-Squared Sqloops at 90 feet.

The 10368.280 beacon is generated by mixing a 10.5 GHz signal with a sample of the 144 MHz beacon, then filtering the lower sideband product on 10368.280 and amplifying to provide 2 watts output. A Frequency West source driven by a PTS-160 at 103.0643137 MHz produces a 102 times frequency of 10512.560 MHz within a few Hertz. This is combined in a mixer with 144.280 MHz sampled from the two meter beacon, then filtered to produce a 10368.280 MHz output which automatically follows the beacon keying. The 10 GHz transmitter is built into a Hughes AML chassis, which has internal monitoring of power supply, source locking, PA current and power output. The antenna is a 24 slot WR-90 fed with 90 feet of EW-90 waveguide.

The 1296.280 beacon is generated by multiplying the output of a PTS-160 operating on 81.0175 MHz by a factor of 16. A modified 6 GHz Frequency West source is used with the SRD section removed to produce the desired frequency. This drives a packaged amplifier from Down East Microwave to produce 6 watts output. Keying is produced by applying a positive voltage to the first stages of the packaged amplifier. This transmitter is built on a 2U rack panel, with -20 and +12 volt output AC power supplies on the back. The antenna is a WA5VJB wheel.

The 2304.280 beacon is generated by multiplying the output of a PTS-160 operating on 144.0175 MHz by a factor of 16. A multiplier/amplifier string from an AN/GRC-144 tactical microwave relay transmitter produces an output of 4 watts. Keying is produced by applying a positive voltage to a small buffer amplifier. This transmitter is built on a 3U rack panel, with +24 VDC output from an AC power supply mounted on the back. A small meter monitors the amplifier detector output, while an HP 432C wattmeter is used to monitor output via a 30 dB coupler. The antenna is an Alford slot.

The 432.300 beacon is generated directly by a PTS-500, which drives two amplifier assemblies. The first stage is keyed by a positive voltage. The final power amplifier stage is a M57714 device and a small circuit board containing the necessary decoupling parts (built and originally used for W4HHK/B), producing 10 watts output. +12 volt power is provided from the common system supply. A Bendix wattmeter is used to monitor output. The antenna is the original style M-Squared Sqloop at 90 feet.

The 903.280 beacon is generated by multiplying the output of a PTS-500 synthesizer operating on 451.640 MHz by a factor of 2. An amplifier stage is keyed by a positive voltage and also serves as the multiplier. The power amplifier is a Quintron paging transmitter, producing 50 watts output. The transmitter has self contained power supplies, status monitoring and metering. The antenna is a WA5VJB wheel.

More to Follow. Beacon transmitters and antennas for 3456, 5760 and 24192 have already been constructed. As more synthesizers become available, I plan to modify the transmitters to lock them to GPS. They all will be installed with amplifiers up the tower, to eliminate feedline loss.

References.

Memphis area beacons (historical): http://www.n4mw.com/mup91-1.pdf
W4HHK/B: http://www.qrz.com/db/w4hhk
N4MW beacons: http://www.n4mw.com/beacons.htm
WA6CGR Universal Microwave PLL System: http://www.ham-radio.com/wa6cgr/mwpll.html
N5AC apolLO: http://www.n5ac.com/blog/
CT1DMK Reflock: http://w3ref.cfn.ist.utl.pt/cupido/reflock.html
JWM Engineering: http://www.jwmeng.com/lnmplo.html
Programmed Test Sources, Inc.: http://www.programmedtest.com
ID-O-Matic keyer: http://www.hamgadgets.com
Hybrid RF modules: http://www.rfparts.com/module.html

Acknowledgements. I would like to thank Cissy Meier N4ZRW for putting up with buying the many synthesizers for this project. Also Fred Towers WB4KXS, who listens to my project ravings and provides ground support for my tower work. A special thanks to Owen Wormser K3CB for monitoring, reporting and confirming frequency against a Cesium standard.