A SIMPLE BEACON SYSTEM

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INTRODUCTION. Beacon transmitters provide several primary benefits. They expose enhanced propagation, indicating conditions we might otherwise not observe. They produce a constant signal source, helping assure that receiving systems are functioning properly. On some bands, beacons mark the narrow band/weak signal portion of the band, discouraging encroachment of wide band activities. Band plans and a beacon list are published in the American Radio Relay League *Repeater Directory*. The beacon system described in this paper is proving beneficial on all counts.

Perceiving operational and technical obstacles, few are willing to equip stations for relatively unoccupied bands. Many amateurs are unfamiliar with weak signal VHF/UHF/microwave propagation characteristics, believing the "line-of-sight" myth. Demonstrations of beacon reception to potential VHF/UHF/microwave enthusiasts can help dispel the myth.

This paper documents progress on the N4MW/B beacon system (see Figure 1). Since the system design depends on availability of surplus, a general description emphasizing integration of diverse equipment is presented rather than a particular construction plan. I hope that the information provided in this paper assists and encourages others to implement needed beacons on multiple bands and in diverse areas.

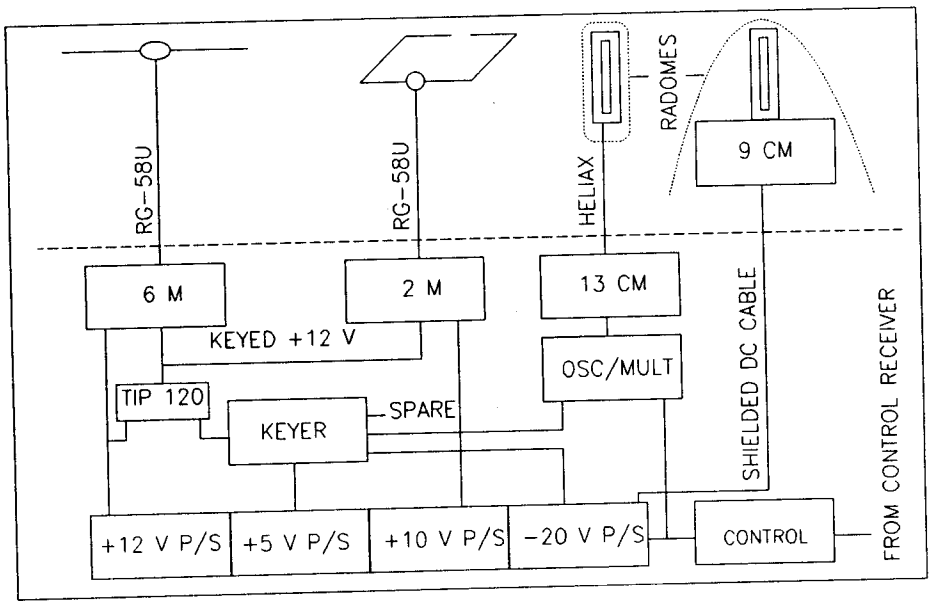

Figure 1. N4MW Beacon System

BACKGROUND. Federal Communications Commission rules permitting beacon operation are found in Part 97 sections 97.84 and 97.87. Beacons are defined as one-way transmissions conducted in order to facilitate measurement of radio equipment characteristics, observation of propagation or transmission phenomena, or other related experimental activities. Rules for unattended beacons are stricter than for attended beacons. The rules pertaining to unattended (automatically controlled) beacons are summarized below.

1. Operation is limited to one concurrently operating transmitter per band.
2. Appropriate control provisions/procedures are required.
3. If the FCC orders, operation must cease until problems are resolved.
4. Operation is permitted on the following frequencies (in megahertz):
   28.2-28.3, 50.06-50.08, 144.275-144.3, 220.05-220.06, 222.05-222.06, 432.3-432.4.
   Operation is permitted on any authorized (non-specific) frequency above 450 MHz.
5. Below 450 MHz, permitted emissions are NON, A1A, F1B or J2A.
   Above 450 MHz, any authorized emission type is permitted.
   For F1B and J2A emissions, maximum radio or audio frequency shift is 1000 Hz.
6. Technician or higher class license is required.
7. Power is limited to minimum necessary not to exceed 100 watts.
8. For Morse identification, the /BCN or /B callsign suffix is applied.
9. The maximum interval between identifications is one minute.

In addition to FCC Rules, the ARRL has adopted beacon subband recommendations where not specified in the FCC rules. These subbands are as follows (in megahertz): 902.2-902.4, 1296.3-1296.4, 2304.3-2304.4, 3456.3-3456.4, 5760.3-5760.4 and 10368.3-10368.4. Note that the N4MW/B 13 and 9 cm beacons have not yet been changed to fall within the recommended beacon subbands, but will eventually be moved. Any subsequent beacons will comply with the recommended allocations.

HISTORICAL SUMMARY. Paul Wilson W4HHK, the pioneer Memphis area beacon operator, operates beacon transmitters on 70 cm and 23 cm (see Table 1). He utilizes available commercial surplus supplemented with homebrew. The W4HHK/B beacon transmitters are operated continuously as unattended beacons. Paul also built a unique solar assisted battery powered 2 m intermittent beacon in EM65 licensed to D. B. Wilson W4UDQ.

Band (MHz)	28	50	144	220	432	902	1296	2304	3456	5760	10368
Callsign	N4MW/B	N4MW/B	N4MW/B	N4MW/B	W4HHK/B	N4MW/B	W4HHK/B	N4MW/B	N4MW/B	N4MW/B	N4MW/B
Latitude (degrees)	35.1 N	35.1 N	35.1 N	35.1 N	35.1 N	35.1 N	35.1 N	35.1 N	35.1 N	35.1 N	35.1 N
Longitude (degrees)	90.0 W	90.0 W	90.0 W	90.0 W	89.5 W	90.0 W	89.5 W	90.0 W	90.0 W	90.0 W	90.0 W
Status	Planned	Active	Active	Planned	Active	Planned	Active	Active	Active	Planned	Planned
Mode	CW	CW	CW	CW	CW	CW	CW	CW	FSK	FSK	FSK
Frequency (MHz)		50.07	144.28		432.4		1296.3	2304.07	3456.04		
Power (watts)		1	4		1		10	4	0.04		
EIRP (dBW)		2	2		4		4	4	-10		
Polorization		H	H		H		H	H	H		
Pattern		E/W	Omni		Omni		E/W	Omni	Omni		
Antenna		Dipole	Squalo		Dual Halo		Horn	Alford Slot	Alford Slot		
Height (meters)		60	60		20		20	60	60		

Table 1. Memphis Area (EM55) Beacons

In 1990 Memphis area amateurs installed a 23 cm FM repeater atop a defunct feed mill, 60 meters above ground. The radio equipment room is located directly beneath the roof, allowing short feedlines. A repeater's success made apparent the potential of the site for beacons. I acknowledge and thank Ray Escue K4RDK, for securing the site for amateur radio use, Ken Schildt N4VSD for locating the site, James Butler KB4LJV for programming the keyer EPROM, and Bill Dearing N4HKS for the logistics ($), Cissy N4ZRW, my XYL, for her understanding and support and W4HHK for inspiration and assistance.

DESIGN. All transmitters are commercial or military surplus, keyed simultaneously using a single keyer. Optoisolators are used instead of mechanical keying relays, providing a flexible and reliable means of keying different types of transmitters with different keying requirements using a common keyer. Common power supplies provide power to multiple transmitters where needed. Equipment is located inside a controlled access room, mounted in a locked EIA cabinet rack. On/off control of primary power source to all beacon transmitters is provided by a 23 cm FM link and a Dual Tone Multi Frequency control code sequence.

KEYER. The beacon code keyer is the standard W4RFR EPROM design with the relay eliminated (see Figure 2). Four 4N30 darlington output optoisolators provide outputs to key the various transmitters. Ideally, the transmitters would all be keyed by switching a logic level input to ground. More often, current must be switched at the power supply input to the transmitter amplifier stages. The 4N30 will not handle enough current, so a TIP 120 darlington transistor is added as a current amplifier.

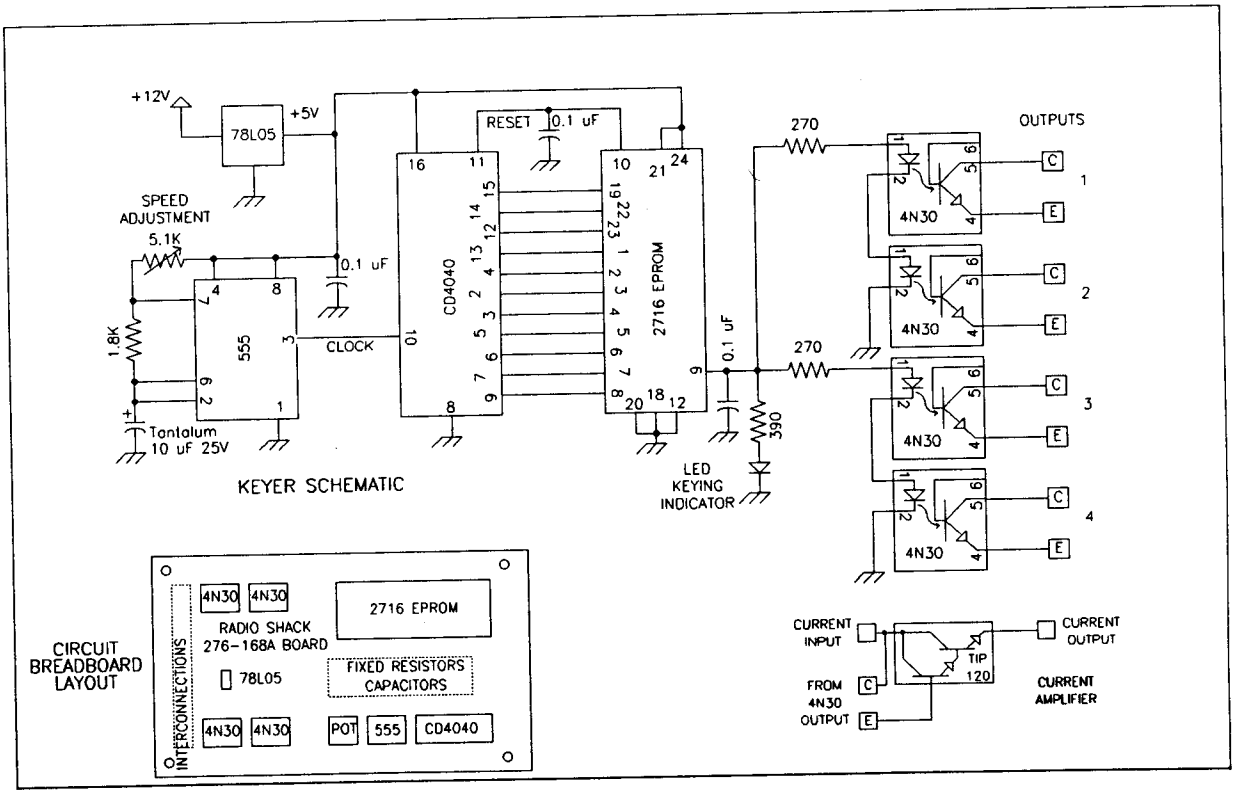

Figure 2. Modified W4RFR Code Beacon Keyer

The keyer is constructed on a Radio Shack project board. The four optoisolators are mounted on the keyer board. The board is mounted inside an aluminum box. A barrier terminal strip allows for connection to a +5 volt supply and to the various keyed devices. An externally visible LED indicates the keyer function by flashing in synchronization with the message transmission.

Programming of the EPROM is simple but requires an EPROM "burner". The 2716 EPROM is a 2K by 8 bit device. The beacon keyer uses only two of the eight bits, one for the code sequence and the other for resetting at the end of the message. Each bit represents one element of a Morse character. Dots are one bit. Dashes are three bits. One bit separates dots/dashes within characters. Character spaces are three bits. Word spaces are 7 or 9 bits. Long dashes are 50 or more bits long. The EPROM is programmed to contain byte values of 1 or 0 to represent Morse elements and element spaces. A string of 2s forces reset to the beginning of the message. The rest of the EPROM contents do not matter. The EPROM program can be seen from the following example using 215 of 2048 possible bytes or about 11% of the potential message capacity:

For the code sequence:

DE(WORD SPACE)N4MW/B(WORD SPACE)EM55(LONG DASH)(SHORT PAUSE)(RESET)

Program the EPROM as follows:

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11101010001000000011101000101010101110001110111000101110111000111010101110100011101010001000000011101000101010101110001110111000101110111000111010101110100011101010001000000011101000101010101110001110111000101110111000111010101110100011
10101000000010001110111000101010101000101010101000111111111111111111111111111111111010100000000100011101110001010101010001010101010001111111111111111111111111111111111
11111111111111111111111100000000000000000000000022222
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The message content must be arranged so as to provide at least one identification each minute. This can be done by keeping the message short or by interspersing two or more identification sequences within the message string. Keying speeds between 10 and 15 words per minute are reasonable. A long dash is desireable for equipment adjustment and strength measurement purposes.

EQUIPMENT. With 70 cm and 23 cm beacons already operating locally, two meters seemed both the easiest and most immediately useful band to implement. A re-crystaled exciter board from an RF Communications RF-403 FM transmitter was mounted in an aluminum box. A BNC connector and two feedthrough/bypass capacitors provide all necessary connections. A constant +10 volts supplies the oscillator and low level transmitter stages. A keyed +12 volt to the high level stages produces a chirp-free 4 watt signal on 144.280 MHz. A simple gamma matched "squalo" built from copper pipe produces reasonably omnidirectional horizontally polarized radiation.

The next band added was 13 cm. A Motorola transmitter strip was re-crystaled to provide 72 MHz output. A homebrew multiplier produces 288 MHz drive and is keyed by one of the keyer optoisolators. An AN/GRC-144 military surplus telemetry transmitter provided a multiplier/amplifier assembly and diode doubler capable of accepting 288 MHz low level input and producing 4 watts at 2304 MHz. An Alford slot was constructed from copper pipe and fed through 10 meters of half inch Heliax. A weatherproof radome was made from a length of PVC pipe capped at the top. The cable end and antenna slips inside the PVC radome, which is clamped to the top of a mast pipe so that the antenna clears the mast.

The six meter transmitter, a General Electric exciter board relocated from W4HHK, requires a constant +12 volts and keyed +12 volts. To minimize current switched by the primary keyed +12 volts source, another optoisolator and darlington transistor were installed inside the transmitter box to switch the supplied constant +12 volt. The antenna is a dipole oriented east/west.

The 9 cm beacon uses a Frequency West PLO "brick" source producing 50 milliwatts to an Alford slot. Source and antenna are mounted on a mast pipe under a weatherproof cover made from a TVRO feed cover. DC voltage is supplied through a shielded cable. Power supply current must be continuous to maintain frequency lock. An expedient keying method is to FSK the source by varying the -20 volt supply slightly. One of the keyer optoisolators is used to modulate the DC supply by about 0.1 volt, producing a distinctive frequency shift. The supply voltage is modulated using one of the keyer optoisolators to switch a resistor in and out of the power supply feedback circuit. Typically, the resistor can be connected in parallel with the voltage adjustment potentiometer.

The 13 and 9 cm Alford slot antennas (see Table 2 and Figure 3) are constructed based upon the G3JVL 2304 Alford slot (G3WDG, RADIO COMMUNICATION, June 1983). Tube wall thickness and length beyond the slot should not be critical. Coaxial 4:1 balun length is for PTFE dielectric line (.141 semirigid typical). Where feasible, make the balun from the feedline, eliminating connectors.

METRIC UNITS	FREQUENCY								
(millimeters)	144.3	220.3	432.3	902.3	1296.3	2304	3456	5760	10368
TUBE DIAMETER	295.38	193.48	98.6	47.24	32.88	18.5	12.33	7.4	4.11
TUBE LENGTH	3847.98	2520.49	1284.44	615.39	428.35	241	160.67	96.4	53.56
SLOT WIDTH	41.51	27.19	13.86	6.64	4.62	2.6	1.73	1.04	0.58
SLOT LENGTH	3656.38	2394.99	1220.49	584.75	407.02	229	152.67	91.6	50.89
BALUN LENGTH	415.14	271.92	138.57	66.39	46.21	26	17.33	10.4	5.78

ENGLISH UNITS	FREQUENCY								
(inches)	144.3	220.3	432.3	902.3	1296.3	2304	3456	5760	10368
TUBE DIAMETER	11.63	7.62	3.88	1.86	1.29	0.73	0.49	0.29	0.16
TUBE LENGTH	151.5	99.23	50.57	24.23	16.86	9.49	6.33	3.8	2.11
SLOT WIDTH	1.63	1.07	0.55	0.26	0.18	0.1	0.07	0.04	0.02
SLOT LENGTH	143.95	94.29	48.05	23.02	16.02	9.02	6.01	3.61	2
BALUN LENGTH	16.34	10.71	5.46	2.61	1.82	1.02	0.68	0.41	0.23

Table 2. Alford Slot Antenna Scaling Dimensions

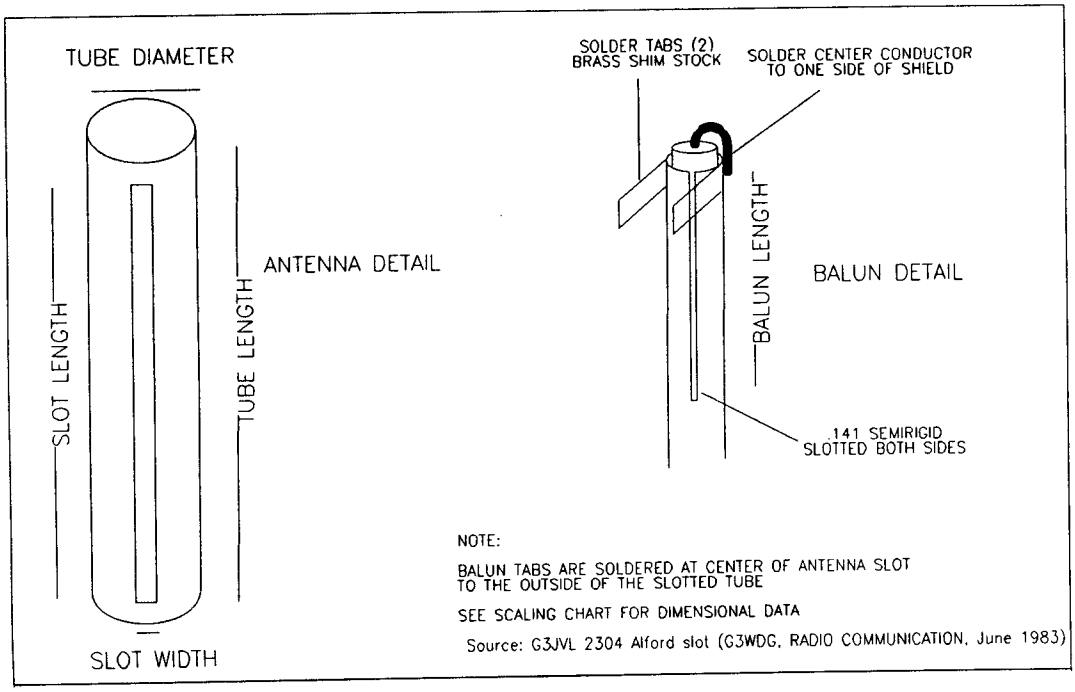

Figure 3. Alford Slot Antenna Construction

RESULTS. Reception reports have been received from several distant stations. W4HHK has used the 13 cm beacon to help diagnose a failed preamp. Rex Turner W5RCI, receives the 13 cm and lower frequency beacons consistently over a 100 km path. Al Ward WB5LUA has received the 13 cm beacon 20 dB over the noise over a 672 km path. At my location (14 km) the 13 cm beacon is received with no antenna connected to the converter! It is interesting to monitor the 13 cm and 9 cm beacons while mobile in motion – the Doppler and multipath resulting from vehicle motion are extremely pronounced, sometimes sounding like aurora. The 9 cm beacon is received using a TVRO LNA as both antenna and preamplifier inside my shack (14 km) and at ground level at the W4HHK QTH (a 28 km obstructed path) .

PLANS. Future plans are to add transmitters for 10 m, 1.25 m, 33 cm, 6 cm and 3 cm as equipment becomes available. A 10 m beacon will allow for propagatation observations during the approaching solar cycle minimum.

Suitable transmitters for 1.25 m and 33 cm are being sought. N4VSD has constructed a loop style antenna for 1.25 m to produce a horizontally polarized omnidirectional pattern. Alford slot antennas can be constructed for higher frequency bands.

The 6 cm and 3 cm beacons will be similar to the 9 cm configuration, if suitable Frequency West style sources can be obtained. Each source must operate from a separate power supply so that the frequency shift can be set individually. An alternative is to use a single regulated higher voltage supply (–24 volts) and multiple adjustable pass regulators to provide the modulated –20 volt outputs.

CONCLUSION. I hope that this paper encourages additional beneficial beacon operation. Beacon operators everywhere appreciate beacon reception reports, which help to establish normal performance expectations as well as to record unusual propagation trends. Please send beacon reports for W4HHK to P. O. Box 73, Collierville, TN 38017 and for N4MW to 3205 Covington Pike, Memphis, TN 38128. My band opening alert telephone number is 901–382–4919 and I currently operate all bands through 3456 MHz.