CW Beacon Exciter for 50 MHz

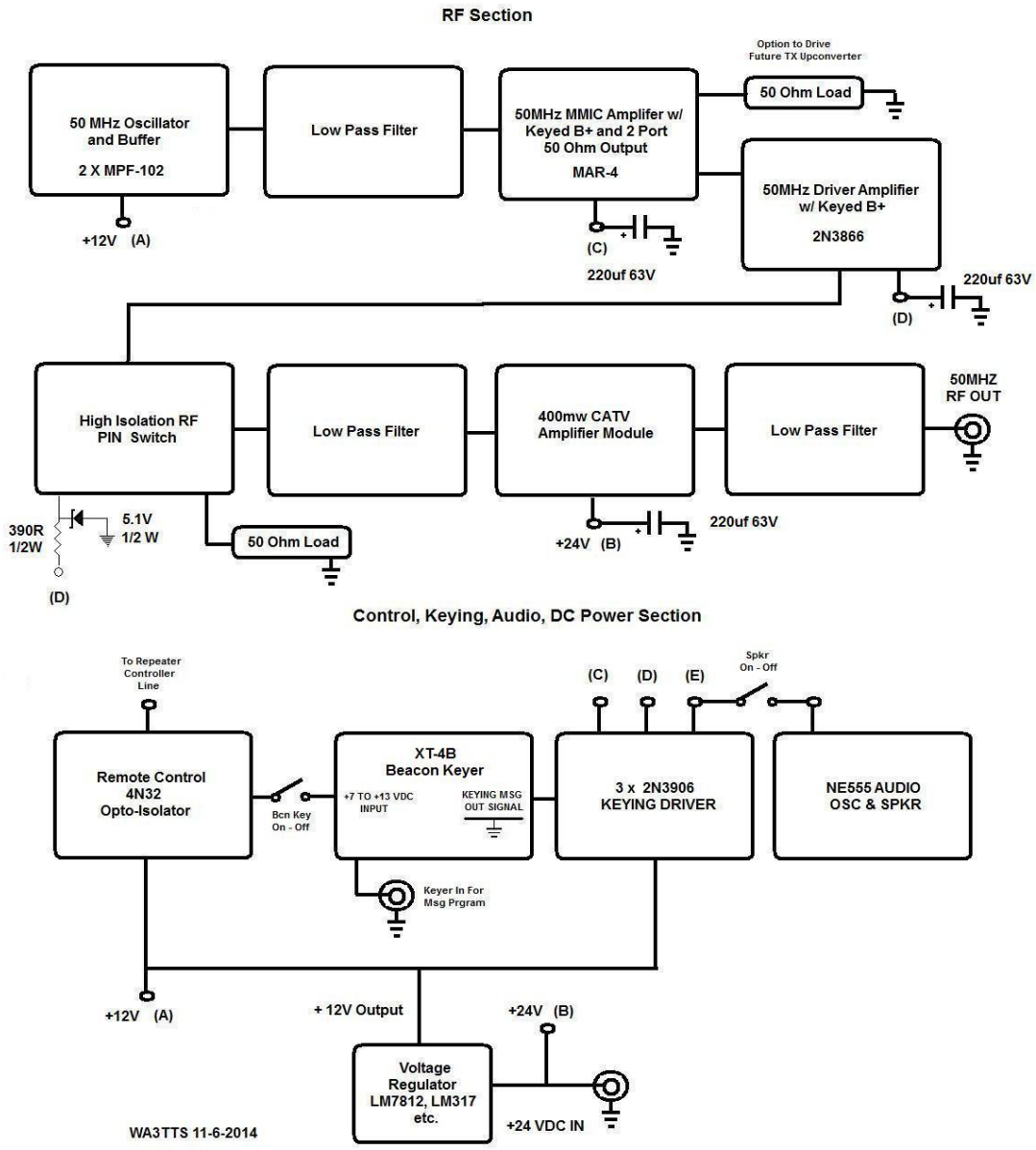
By Michael Sapp, WA3TTS

A basic CW beacon exciter for the 50MHz amateur band is presented with an RF power output in the 400 milliwatt range. This project originated as a replacement for a local 50MHz beacon (W3HH/B) that had expired after many years of service in the EN90 grid square. For this new beacon, an emphasis was placed on using common components where possible and using a modular design which could be easy to maintain, repair, or upgrade. Careful attention was also made to meet and exceed FCC spurious emission requirements[1] with respect to minimizing higher-order harmonics and fundamental back wave suppression during key-up intervals. A remote control feature is also included for operating the beacon exciter in an unattended manner as required by FCC regulations[2].

Although this 50MHz CW beacon exciter can be used to drive a suitable power amplifier for higher power levels, the nature of the 6M amateur band is such that signal reports from rather remarkable distances can be received from other amateur and SWL stations using only this exciter by feeding the RF output into an omnidirectional antenna with a low loss coaxial transmission line. Of course, an optimal antenna location and height will yield improved results. Yet, a strong E-layer ionospheric band opening can yield surprising results even with a modest antenna. (More on this subject later in this article).

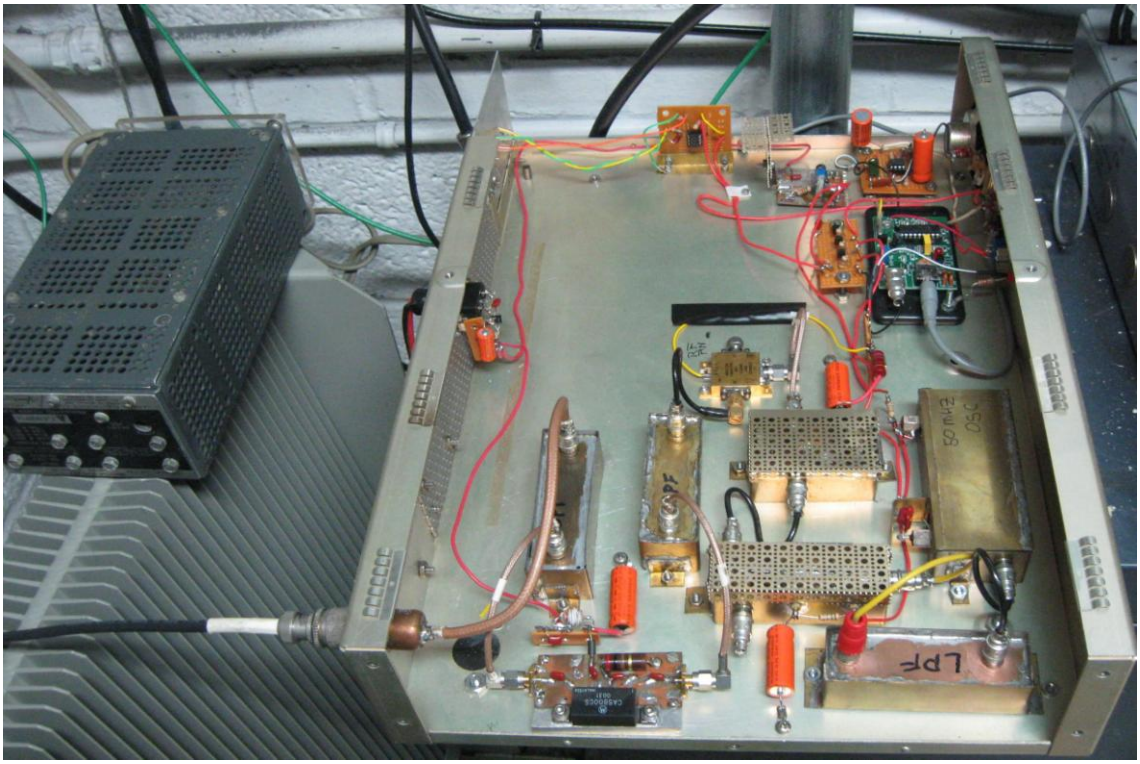
Below is a block level diagram of the basic 50MHz CW Beacon Exciter which is laid out with a separate "RF Section" and "Control, Keying, Audio & DC Power Section."

[1] FCC § 97.307 Emission Standards, (c), (e)
[2] FCC § 97.203 Beacon Station, (d)

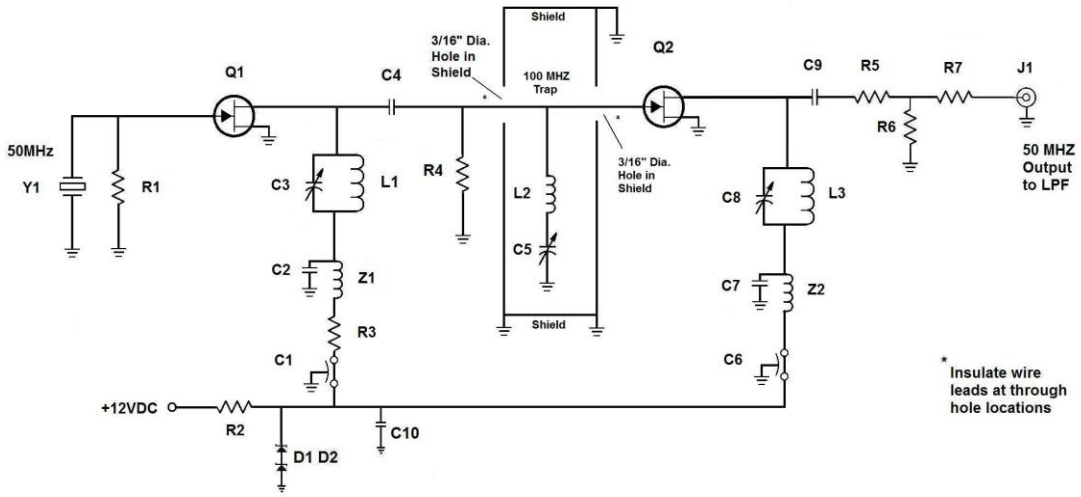


This 50MHz CW Beacon Exciter was built in a surplus telecommunication equipment cabinet that was located on e-bay at an affordable cost. The cabinet is large enough to allow for upgrades or changes should any module require replacement or future additions considered. For example, the dual 50 ohm output from the MAR-4 amplifier module could be used to drive another transmitting upconverter from the second MAR-4 output port for multi-band beacon operation. A 9th order Chebychev low pass filter (LPF) before the MAR-4

amplifier stage provides excellent harmonic filtering to allow a clean 50MHz output from the MAR-4 amplifier stage to drive a future transmitting upconverter for a band of one's choice. Since this port is not currently in use, it is terminated into a 50 ohm non-inductive resistor that is soldered into the 2nd MAR-4 output connector. Phono plugs were used to lower connector costs for this project. (See 50MHz beacon photo below.)



50 MHz Oscillator & Buffer, Detail & Parts List.



Parts List

Y1	50.06 to 50.08 MHz 3rd-overtone crystal	R1, R4	100K 1/4W.
Q1, Q2	MPF-102.	R2, R6	150 ohms 1/4W.
D1, D2	5.1V Zener diode, 1/2W.	R3	100 ohms 1/4W.
C1, C6	0.001uF feedthrough (1000pF).	R5, R7	10 ohms 1/4W.
C2, C7	0.001uF, 50V polyester film capacitor.	C4	5 pF, 50V silver mica.
C3, C8	10 - 60 pF ceramic trimmer capacitor.	C9	22pF, 50V silver mica.
C5	1 - 20 pF ceramic trimmer capacitor.	C10	0.1uF, 50V poly film.
Z1, Z2	100uH (or more) 1/2W molded inductor.	J1	50 ohm BNC Female.

L1, L3 220nH (0.22uH) 5T #24 enamel wire, close wound on .25" drill bit shaft, with 1/2" leads. Scrape enamel from 1/2" of the wire leads nearest to coil on drill bit shaft. Bend leads at right angle to coil. Remove coil from drill bit shaft and cut leads to 1/2" length. Lightly pull on the coil's 1/2 inch long leads until the 5 coil turns are slightly separated and 0.25" long. Check and adjust coil value on antenna analyzer at 50MHz in Inductance measuring mode. Trim coil leads as required after soldering into circuit. Check and readjust coil length.

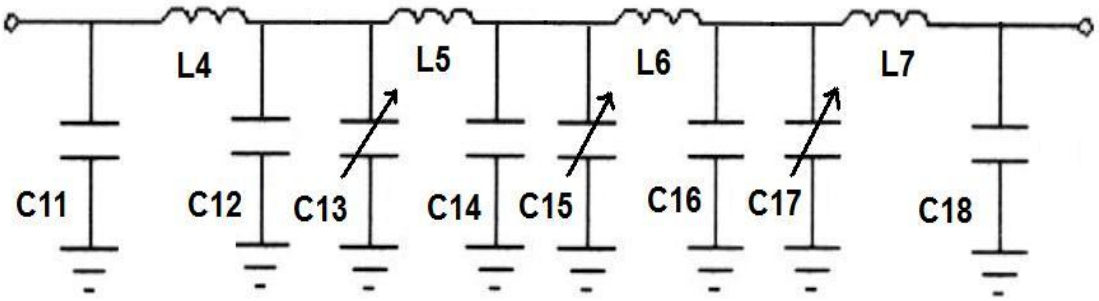
L2 260nH (.260uH) 5T #24 Enamel Wire Close Wound, 1/2" leads. Scrape enamel from 1/2" of the wire leads nearest to coil on drill bit shaft. Bend leads at right angle to coil. Remove coil from drill bit shaft and cut leads to 1/2" length. Check and adjust coil value on antenna analyzer at 50MHz in Inductance measuring mode. Check and readjust close-wound coil turns.

Shield: 015" or .025" T x 3/4" W K&S Metals Brass Strip #8233 or #8238.

Data Sheets & References

www.daycounter.com/Calculators/LC-Resonance-Calculator.phtml
www.pronine.ca/coilcal.htm
www.fairchildsemi.com/datasheets/MP/MPF102.pdf
www.icmfg.com/order_crystals.html

50 MHz Low Pass Filter & Parts List.



Note: Preset and ink "dot" mark position of C13 and C15 at 4pF. Preset and ink "dot" mark C15 at 34pF. C15 tuning will have the greatest effect on return loss (SWR).
Parts List x 3 (Build 3 of these filters)

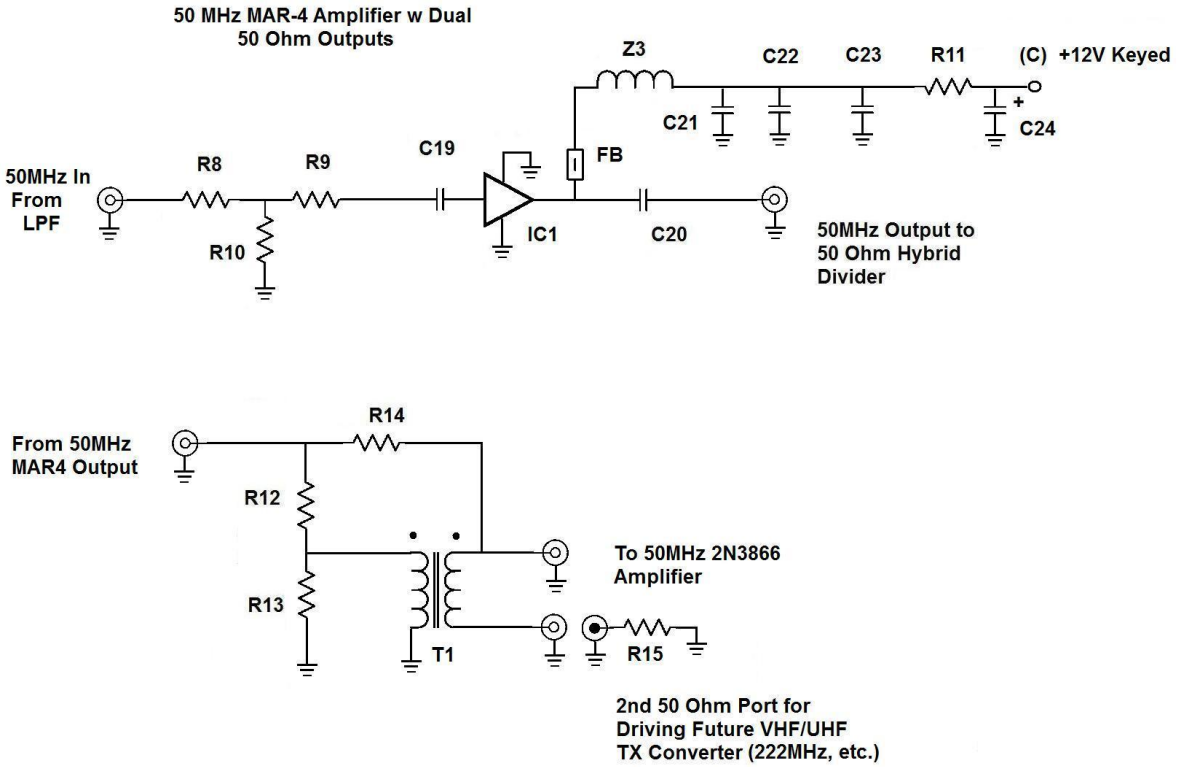
C11, C18	100pF 100V silver mica
C13, C17	1-10pF ceramic trimmer
C12, C14, C16	150pF 100V silver mica
C15	10-60pF ceramic trimmer.

L4 , L7 184nH (.184uH) 4T #24 enamel wire wound on 0.25" drill bit shaft, close wound with 1/2" long leads. Scrape enamel from 1/2" of the wire leads nearest to coil on the drill bit shaft. Bend coil leads at right angles to coil and cut leads to 1/2" length. Then remove coil from drill bit. Then lightly pull or compress the coil's leads until the 4 coil turns are separated and the coil is .310" long. Check and adjust coil value on antenna analyzer at 50 MHz. Trim coil leads as required after soldering into circuit. Check and readjust coil length.

L5, L6 198nH (.198uH) 5T #24 enamel wire wound on 0.25" drill bit shaft, close wound with 1/2" long leads. Scrape enamel from 1/2" of the wire leads nearest to coil on the drill bit shaft. Bend coil leads at right angles to coil and cut leads to 1/2" length. Then remove coil from drill bit. Then lightly pull or compress the coil's leads until the 4 coil turns are separated and the coil is .475" long. Check and adjust coil value on antenna analyzer at 50MHz in Inductance measuring mode. Trim coil leads as required when soldering into circuit. Check and readjust coil length.

Data Sheets & References

www.pronine.ca/cheblf1.htm
www.aade.com/filter.htm



Parts List

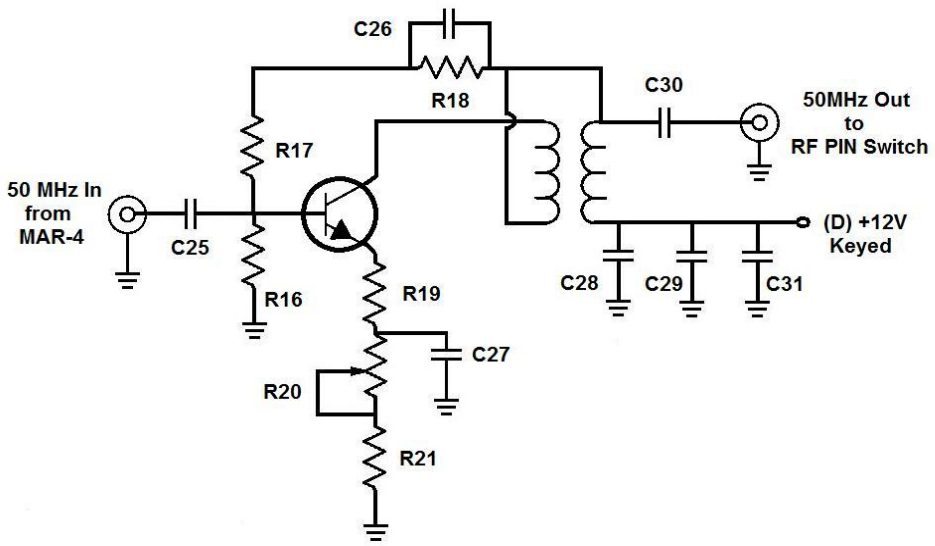
R8, R9	10 Ohms 1/4W.	C19, C20, C21	0.001µF, 50V poly film.
R10, R11	150 Ohms 1/4W.	C22	0.01µF, 50V poly film.
R12, R13, R14, R15 (R12-R15 can be pairs of 100 Ohm 1/4W resistors in parallel).	50 Ohms 1/4W	C23	0.1uF, 50V poly film.
		C24	220µF, 35V electrolytic.
IC1	MAR 4 MMIC or equiv.	FB	T61 Ferrite bead.
T1 10T Bifilar #30 Wire on FT61-50 toroid.		Z3	100uH 1/2W molded inductor.

Data Sheet & Reference

www.minicircuits.com/pdfs/MAR-4+.pdf

"A Hybrid Combiner for Signal Generators," 1989 ARRL Handbook, Test Equipment & Measurements, 25-36.

50MHz 2N3866 Driver Amplifier and Parts List



Parts List

C25, C30	0.001µF, 50V silver mica.	C29	1µF 35V tantalum.
C26, C27, C28	0.01µF 50V polyester film.	C31	220uF 35V electrolytic.
R16	1K ohms 1/4W.	R17	560 ohms 1/4W.
R18	3.3K ohms 1/4W.		
R19, R21	4.7 ohms 1/2W (or two 10 ohm 1/4W resistors in parallel).		
R20	100 ohm 15T 3/4W Cermet potentiometer (Bourns 3006P-101LF or equiv.)		

T2 10T Bifilar #30 wire on a FT61-50 toroid core.

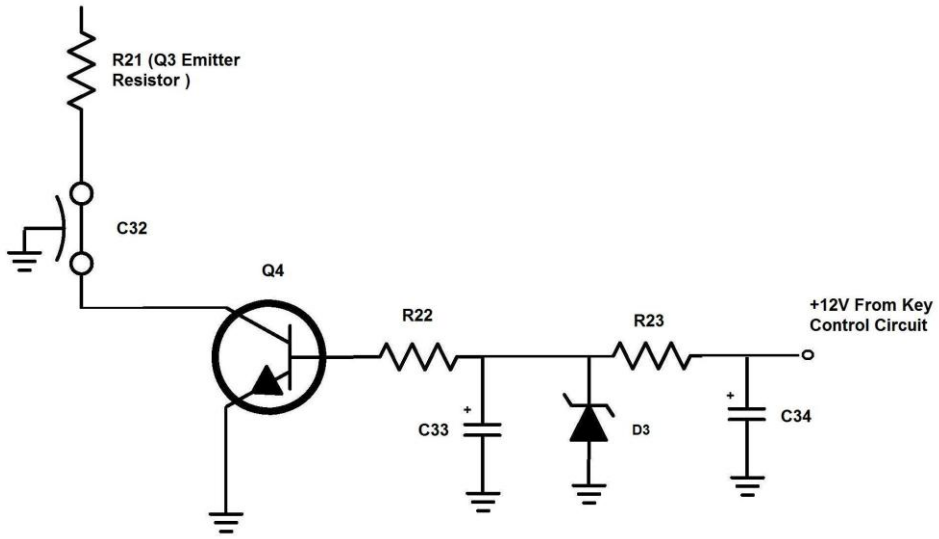
Q3 2N3866.
Q3 TO-5 heat sink (not shown).

Data Sheet & Reference

pdf1.alldatasheet.com/datasheet-pdf/view/15076/PHILIPS/2N3866.html
www.dxzone.com/dx21535/w7iuv-hf-preamplifier.html

"Three Watt Transmitting Converter for 6 Meters," 1989 ARRL Handbook, VHF Radio Equipment, 31-13.

50MHz 2N3866 Emitter Keying Option, Detail and Parts List



Parts List

C32 1000pF (0.001µF) 50V (or more) feed-through capacitor.
C33 100µF. 10V electrolytic.
C34 100µF. 35V electrolytic.

R22 1K 1/4W resistor.
R23 2.2K 1/4W resistor.

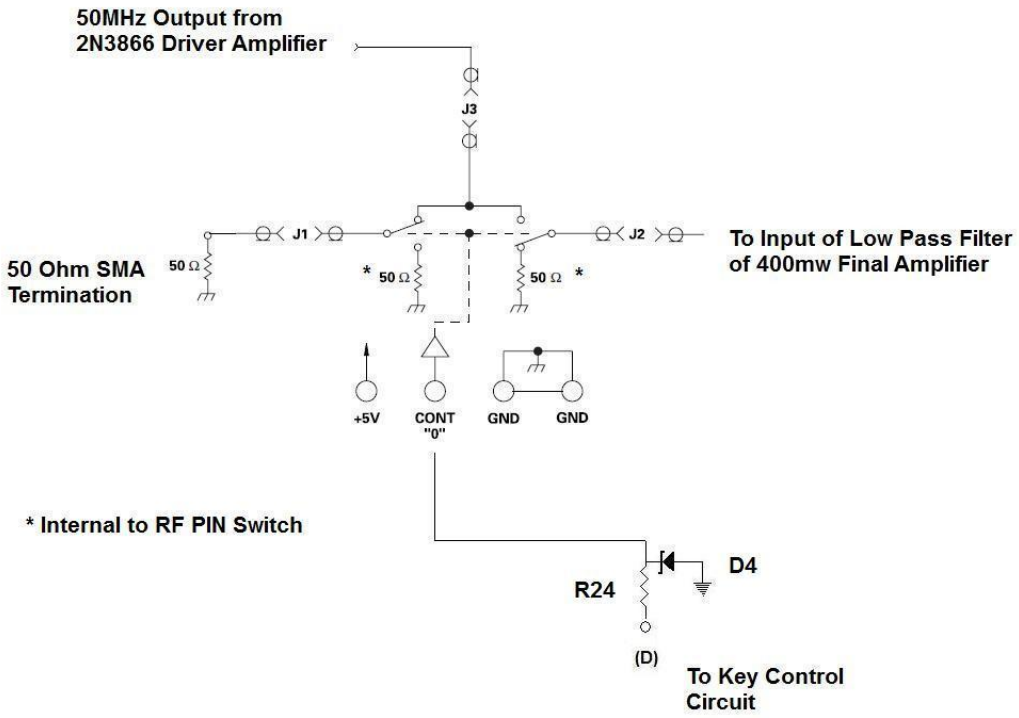
Q4 2N2222 NPN transistor.

D3 5.1V 1/2w Zener diode.

Data Sheet & Reference

www.sm5bsz.com/txmod/rt0282eng.htm

RF PIN Switch Detail & Parts List.



Parts List

RF PIN Switch Daico 0622 or Mini-Circuits ZSDR-230, SPDT and TTL control type.

50 ohm SMA termination.

R24 390 ohm 1/2W resistor.

D4 5.1V 1/2W Zener diode.

SMA Jumper cables (2) for RF connections.

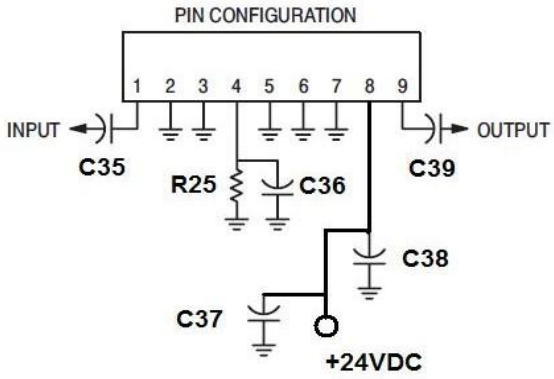
Data Sheet & Reference

pdf1.alldatasheet.com/datasheet-pdf/view/140517/DAICO/CDS0622.html

Final Amplifier Module Detail & Parts List

IC 2

(CA5800C)



Parts List

C35, C39	0.001µF (1000pF) 50V silver mica.
C36, C38	0.1µF, 50V polyester film.
C37	220µF, 63V electrolytic.
R25	200 ohm 1W (or 90 ohms 3W). See text.

RF Connectors (2) SMA or BNC female chassis mount.

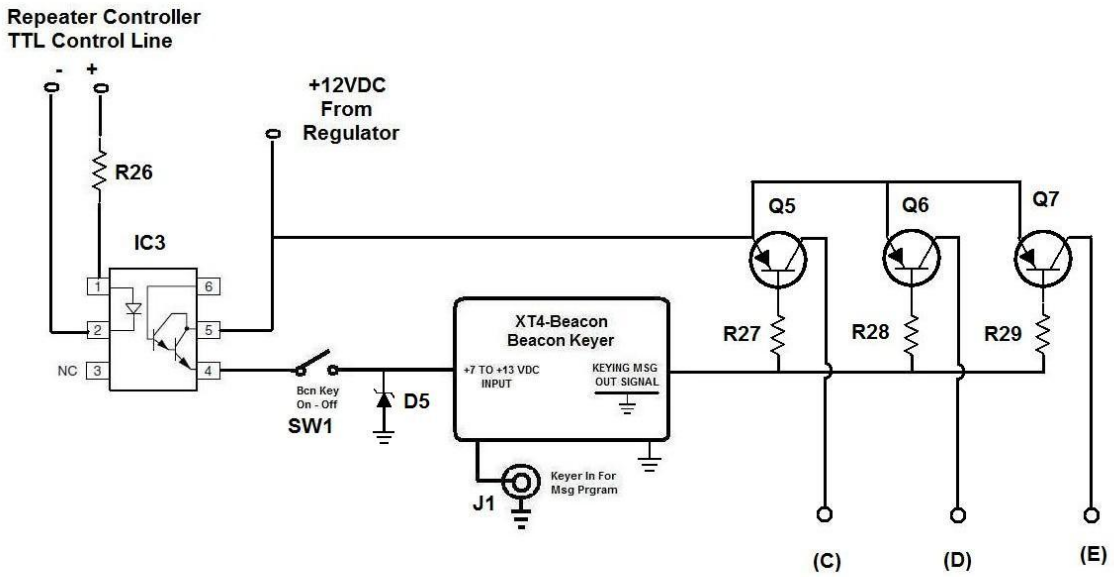
IC2 Motorola CA5800C 1W wide band linear amplifier module.

Data Sheet & Reference

www.freescale.com/files/rf_if/doc/inactive/CA5800C.pdf

Motorola RF Device Data Volume II, Fifth Edition, 1988.

50MHz Beacon Keying Control



Parts List

R26	1K 1/2W.	SW1	SPST low volt & current switch.
R27, R28, R29	4.7K 1/2W.	J1	1/8" stereo jack.
IC 3	4N32 or 4N33 optoisolator.	D5	12V 1/2W Zener diode.

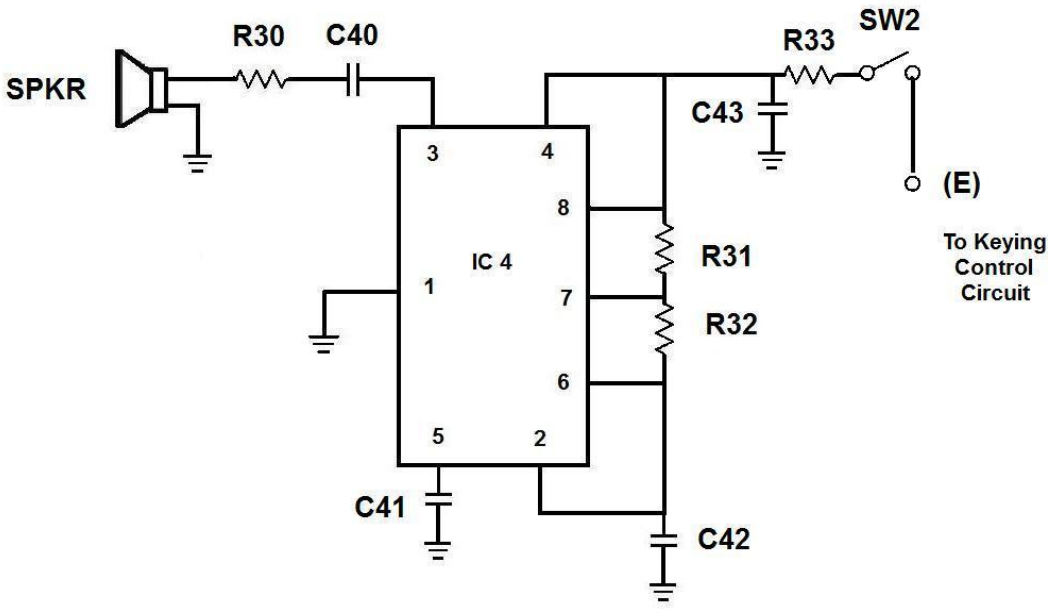
Q5, Q6, Q7 2N3906 PNP transistor.

XT-4B Beacon Keyer Module (www.unifiedmicro.com)

Data Sheet & Reference

www.vishay.com/docs/81865/4n32.pdf

555 Message Audio, Detail & Parts List.



Parts List

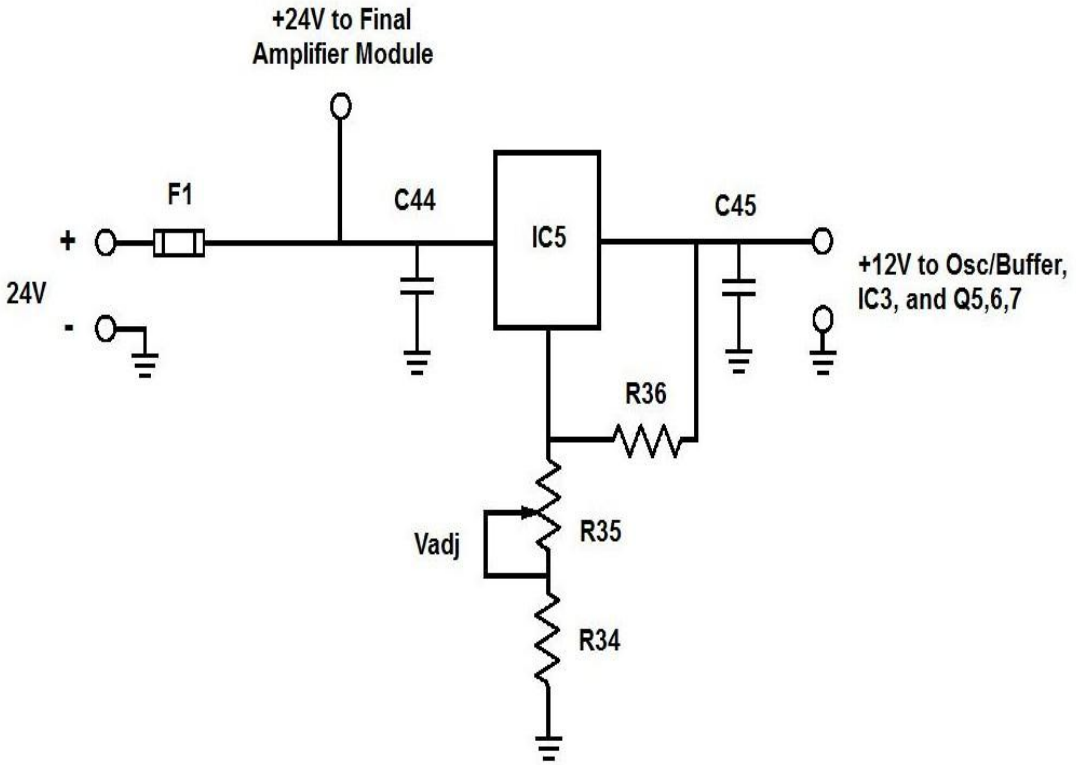
C40	220µF, 35V electrolytic.	C41, C42	0.01µF. 50V poly film.
C43	22µF, 35V electrolytic.		
R30	47 ohms 1/4W.	R33	10 ohms 1/2W.
R31, R32	15K ohm 1/4W .		
IC4	LM555.	SPKR	Small 8 Ohm speaker.
SW2	SPST low current & voltage switch.		

Data Sheet & Reference

www.fairchildsemi.com/datasheets/LM/LM555.pdf
www.ti.com/lit/ds/symlink/ne555.pdf

"A High Performance Audio Communication System," UHF and Microwave Equipment, p32-60, 1988 ARRL Handbook.

Voltage Regulator, Detail & Parts List.



Parts List

F1	2A fuse.	IC5	LM317, adjustable voltage regulator.
C44	0.1µF, 50V poly film.	C45	1µF, 35V tantalum capacitor.
R34	1200 ohms 1/2W.	R35	1K ohm 3/4W 15T Cermet pot, 3/4W (Bourns 3009P-1-102LF, etc.)
R36	220 ohms 1/2W.		

IC5 Heat sink or mount kit (Not Shown)

Data Sheet & Reference

www.fairchildsemi.com/datasheets/LM/LM317.pdf

Construction Notes

Oscillator and Buffer Amplifier

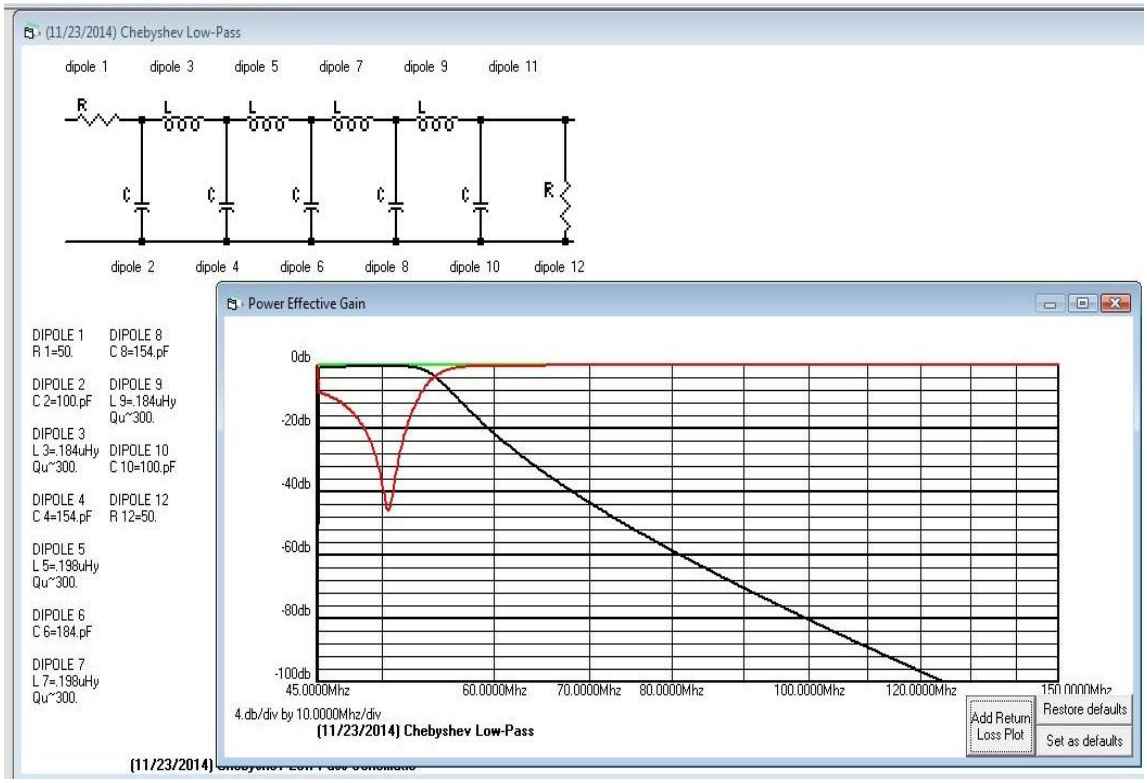
A simple MPF-102 overtone oscillator was used from the 1971 *ARRL Handbook* receiver project[3]. A 5pF output coupling capacitor was used to minimize oscillator loading interaction with the MPF-102 buffer amplifier stage. A 100Mhz shunt LC circuit is used to reduce the second harmonic of the 50MHz oscillator. The buffer amplifier simply voltage-drives the 3dB T-attenuator pad with no attempt at RF impedance matching at the amplifier output, similar to the design philosophy found in active "Gilbert Cell" mixers (MC1496, NE602, etc.) A brass sheet shielded-section isolates the 100 MHz shunt filter and further isolates the oscillator from the buffer amplifier. Construction is dead-bug style on an FR4 ground plane and 3/4" wide by .025" brass strips form the enclosure side walls (K&S Metals #8233, etc.)

Low Pass Filter

A 50 ohm, in-out, 9th-order, Chebychev low pass filter is used after the oscillator and buffer stage as well as for the input and output of the final amplifier module. C15 will have the greatest effect on the filter's return loss (SWR). The filter can be tuned with an antenna analyzer feeding the filter input port and the output port terminated in 50 ohms. Another approach with an antenna analyzer is to use a 10 or 20 dB pad on the filter output with the attenuator feeding a frequency counter equipped with a relative level indicator. With this method, tune for the best return loss (SWR) that is consistent with

[3] "A Receiving Package For 1.8 to 144 MHz," 1971 ARRL Handbook, p142 - 148.

maximum signal throughput to the frequency counter (or other power level monitoring instrument). Mark each filter input and output after tuning, as this simple approach to filter tuning is not likely to result in bi-directional filter performance. A plot of the LPF using the AADE filter software is shown below:



MAR-4 With Dual 50 Ohm Output.

This stage was originally used with the intention of using the 50 MHz signal to also drive a 50 to 222 MHz transmit converter for a multi-band beacon project. If one is only building the 50MHz beacon, the power divider can be omitted and some additional attenuation used on the input-output of the prior LPF stage to make up the 6dB power reduction of the power divider. One could also substitute a 2N3866 gain stage for the MAR4 amplifier and adjust the gain

accordingly. Also note that the MAR-4 data sheet includes a B+ resistor (R11) value guide for device operation at various B+ levels.

50 MHz 2N3866 Driver Amplifier

The 2N3866 Driver Amplifier was salvaged from the prior EN90 beacon. To save time, it was not converted to emitter keying and the B+ was keyed along with a 220uf capacitor to limit key clicks from the B+ switching. A better approach to this stage would be the well-known W7IUV HF Receiver Preamplifier[4] operated at 40 to 50 milliwatts of output power at 50MHz. The usual FT-43 core for HF operation of the W7IUV preamplifier would have to be replaced with a Type 61 core for the higher 50MHz frequency range and the emitter resistor adjusted for the desired output level. A RF milliwatt termination meter, such as a Bird 6250, is very useful for this purpose.

It is interesting to note that the "Three Watt Transmitting Converter for 6 Meters" in the 1988 ARRL Handbook uses an essentially identical set of W7IUV type amplifier stages as RF drivers for it's final amplifier along with a Type 61 ferrite transformer core[5]. One can also emitter-key the 50MHz 2N3866 driver amplifier with an NPN transistor (2N2222, etc.) to take advantage of the key-up bias cutoff condition as an alternative to using an RF PIN switch.

RF PIN Switch

With the 400mW amplifier stage and filters constructed, I still had some back wave that was noticeable during beacon keying. This condition was from

[4] W7IUV Preamp, http://www.w7iuv.com/
[5] "Three Watt Transmitting Converter for 6 Meters," VHF Radio Equipment 31-15, Figure 37, 1988 ARRL Handbook.

using the existing 2N3866 amplifier stage from the old W3HH beacon that had no emitter keying provision. Rather than add emitter keying to the existing amplifier stage, a "quick fix" was to use an RF PIN switch between the driver and the final amplifier stage. I had a few commercial RF PIN switches on hand, so they provided a quick way to obtain the desired CW back wave suppression without the use of emitter keying. For this project, there was a desire to get the beacon on the air as soon as possible, so the RF PIN switch provided a convenient solution versus modifying or building a new emitter-keyed 50MHz driver amplifier stage.

The SPDT RF PIN switch used was a Daico CDS0622 TTL driver type with internal 50 ohm terminations. These devices can be found on e-bay in the $30~$40 range. Cost wise, they are similar to that of a surplus SMA relay and can offer up to 60dB of port isolation. Check the data sheet carefully for isolation versus frequency performance. Another alternative SPDT RF PIN TTL switch commonly available is the Mini-Circuits ZSDR-230 which can also be found in a similar "used-surplus" price range. (Note: Emitter keying of the 2N3866 driver stage could eliminate the need for the RF PIN switch. The RF PIN Switch can be a useful option if an amplifier gain stage is already available, but not practical to modify for emitter keying.)

50MHz Final Amplifier

The final amplifier is a Motorola CA5800C designed for wide band operation from 10MHz to 1GHz with B+ voltages to 28V. Output power is 400mw typical (800mw PEP) at the 1dB compression point. These devices are still available "new-old-stock" on the surplus market in the $10 range, making it an economical choice. An "old" data sheet I had on had specified a 200 ohm 1W resistor from Pin 4 of the CA5800C to ground, However, newer data sheets specify a 90 ohm 3 watt resistor from Pin 4 to ground. It is important not to overdrive the final amplifier, so increase the 2N3866 stage gain slowly until the CA5800C amplifier output saturates, then reduce the drive level by a dB or more. Use adequate heat sinking. For example, I mounted the final amplifier board and CA5800C to a 0.25" thick aluminum plate, which was then bolted to the enclosure chassis. The amplifier module should run warm to the touch, but not hot to the touch.

Keying Control

An XT-4B Beacon Keyer module from Unified Microsystems is used for generating the CW beacon message. This CW message module requires +7 to +13 volts DC operating power at 5ma. The low current and voltage requirements allow a the use of a 4N32 or 4N33 opto-isolator IC as a simple remote control means for interfacing with a repeater controller for unattended beacon operation. Zener diode D5 was included as a reminder of the XT-4B's voltage requirements. If one decides to operate the 2N3866 50MHz driver stage at

higher voltage by turning up the LM317 regulator output, keep in mind the XT-4B's DC voltage limits.

555 Timer Message Audio

A simple code practice oscillator can be used with the keying control circuit for occasions when one desires to reprogram the CW message. It is more convenient to have this feature than to remove and replace the XT-4B Beacon Keyer for each message change.

LM317 Voltage Regulator

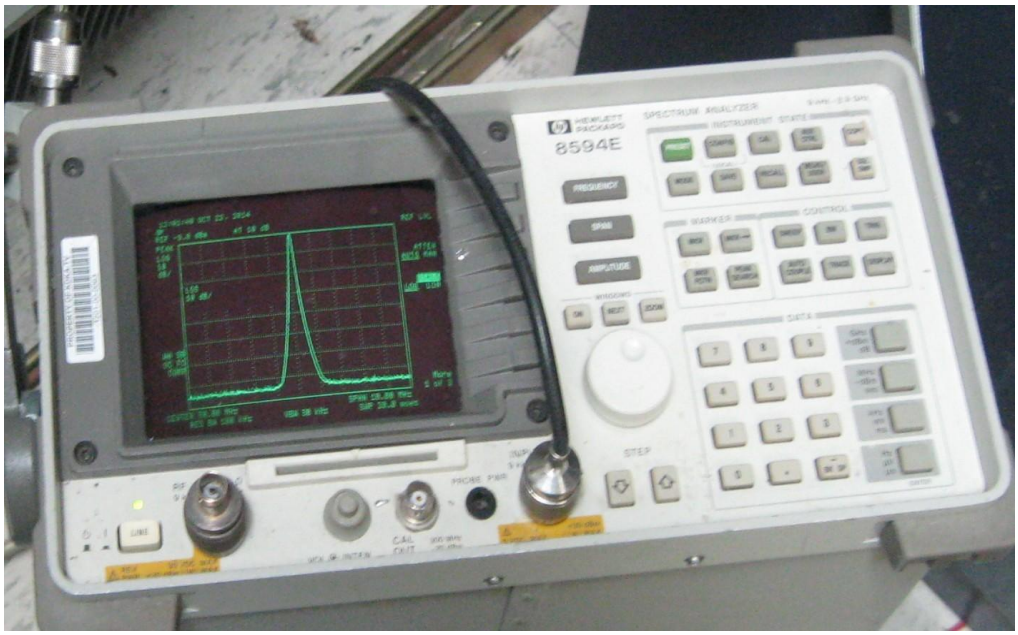
The LM317 provides an adjustable voltage level for the various beacon stages, which are individually Zener regulated to lower voltages where needed.

50MHz CW Beacon Performance Measurements

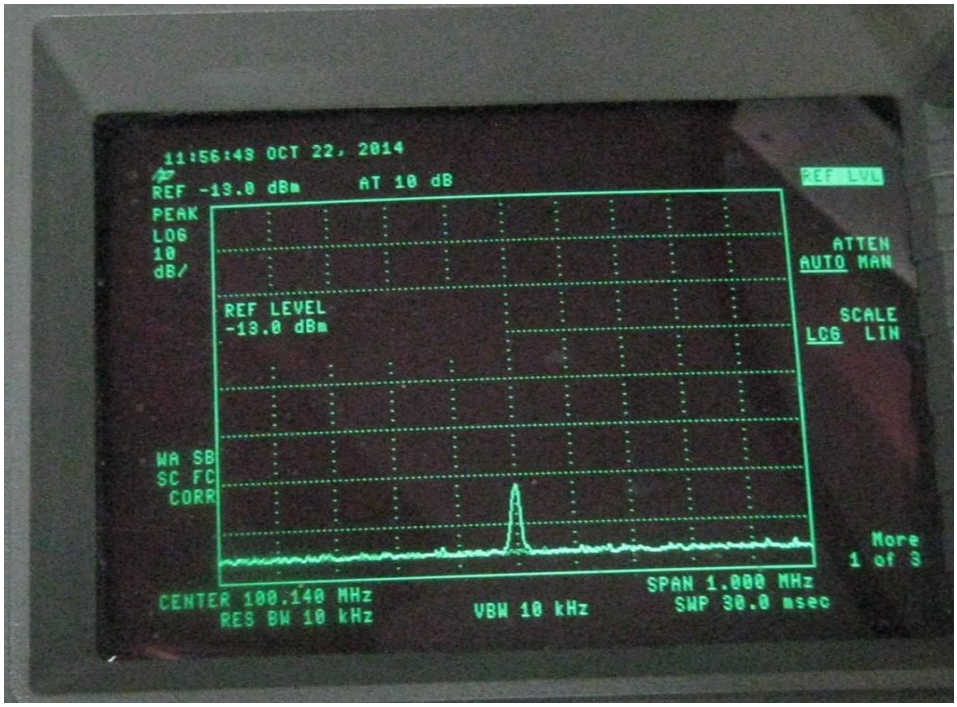
FCC Part §97.307 Emission Standards, (e) states: "The mean power of any spurious emission from a station transmitter or external RF power amplifier transmitting on a frequency between 30-225 MHz must be at least 60 dB below the mean power of the fundamental. For a transmitter having a mean power of 25 W or less, the mean power of any spurious emission supplied to the antenna transmission line must not exceed 25 µW and must be at least 40 dB below the mean power of the fundamental emission, but need not be reduced below the power of 10 µW. A transmitter built before April 15, 1977, or first marketed before January 1, 1978, is exempt from this requirement."

Applying these FCC requirements to this 400mW 50MHz beacon exciter, spurious emissions cannot exceed 25 microwatts (-16 dBm), and must be 40dB below the mean power of the fundamental emission (400mw in this case is +26dBm - 40dB = -14 dBm), but need not be reduced beyond 10uW (-20 dBm).

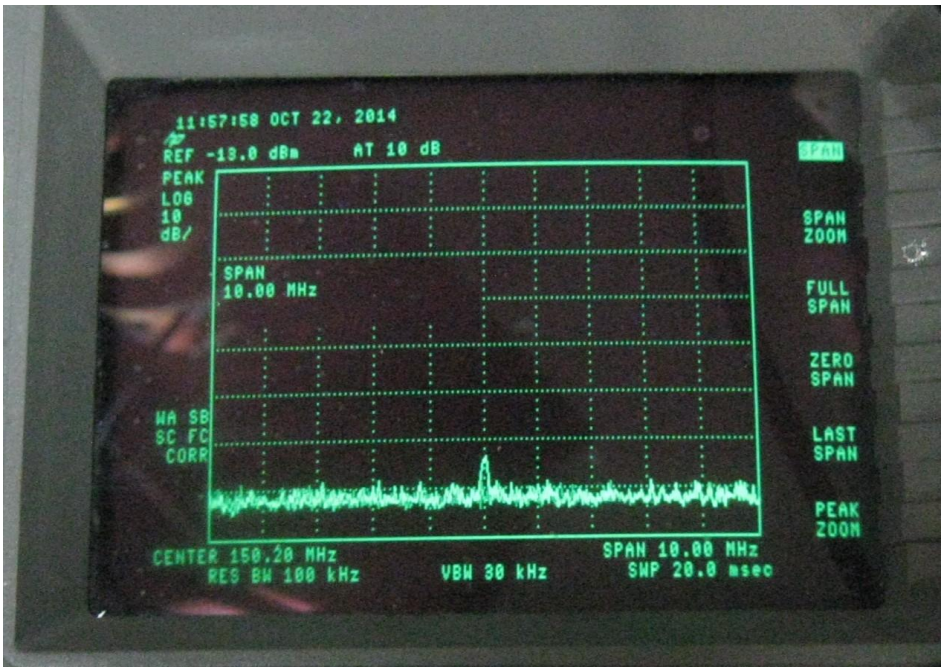
In addition, FCC Part §97.307 Emission Standards,(c) states: "All spurious emissions from a station transmitter must be reduced to the greatest extent practicable."



50MHz Beacon 400mW Fundamental Output



50MHz Beacon 2nd Harmonic -74 dB Down (+26dBm -74dB = -48dBm)



50MHz Beacon 3rd Harmonic -75 dB Down (+26dBm -75dB = -49 dBm)

While the average radio amateur may not have access to a spectrum analyzer, the current availability of low-cost DVB receiver "dongles" in the $20

range, and SDR receiver software, does provide an affordable alternative as an effective RF visual frequency and power measuring aid for projects such as this one. A switched 50-ohm attenuator and directional coupler, such as those offered in the Elecraft Mini-Module Kits, could complete a basic---but very useful---visual RF evaluation package for the radio hobbyist.

One Special Phone Call

This 50MHz beacon was completed and on the air around the time of the transition to digital television in the spring of 2009. Having the local CH2 TV station vacate 57MHz was a blessing, as the 50KW transmitter generated about 4 to 5 S-units of broadband noise at 50Mhz when pointing one's 6M beam in that direction from 4~5 miles away.

It was about this time, when one morning, I received a rather special phone call. The conversation went something like this. "Hello. I'm the engineer at the local CH2 TV station. I was tuning around the 6 meter band and heard your beacon, and thought I would give you a call. It sounds pretty good. Why don't you stop up at the transmitter site in the next few days as I would like to show you the new 50KW digital new digital transmitter."

Rather amazed by the invitation, I visited the transmitter site a few days later. One thing lead to another and the WA3TTS 50MHz beacon soon became the "pilot light " for the legacy CH2-TV broadcast antenna-- with the understanding that this special privilege could change at any time. At the writing of this article, it is coming up on 5 years since the DTV transition. During this time period, this modest 50MHz CW beacon has been in continuous operation at the local Pittsburgh CH2-TV transmitter site.

Rigid Feed Lines to the Dielectric Communications TF Series CH2 Superturnstile Antenna

Note the "Motorola VHF Low" LPF which keeps several watts of UHF TV energy from getting to the 50MHz beacon. A pair of Polyphasers in series also provide some extra surge protection. An electrical 1/4 wave delay line made from RG59 cable provides the 90 degree phasing for the second element of the turnstile antenna.

Local CH2-TV Legacy Antenna System

Local CH2-TV Legacy TF Series Dielectric Communications CH2 Superturnstile[6] Antenna @ 1000' HAAT[7].

A special thank you to the local Pittsburgh CH2-TV engineer for hosting this modest 50MHz CW beacon and for teaching us, through example, the true nature of the Free Space Path Loss equations[8].

[6] http://www.dielectric.com/inc/catalogs/TV_Planner-press_ready.pdf
[7] Height Above Average Terrain.
[8] http://www.rohde-schwarz-usa.com/rs/rohdeschwarz/images/8GE01_Antenna_Basics.pdf