The Crudley-Bathbrush 26?1?---a homebrew MW DX receiver

by NHP

A couple of years ago, Randy Tomer suggested that a fairly decent MW DX receiver could be had for about $200 by upgrading the sensitivity and selectivity of a TRF (#12-655) and adding a digital readout. Well, I agreed with him at the time, and still agree. To start with, hearing MW DX is about 70% listening on the the right frequency at the right time and 30% (or less) owning a fantastic receiver---location is important also to say the least. As well, MW DX is limited by local noise and sideband splatter, so there are limits to the amounts of selectivity and sensitivity that can be used to advantage on MW. Stability of local oscillator tuning is easily achieved at the relatively low MW frequencies. The major problem with any MW DX receiver is achieving a reasonable degree of strong signal handling, so that your local doesn't pop up all over the dial. The TRF portables don't do too badly even in this field, considering the simplicity of their circuitry.

Rather than modify an existing receiver, I decided to build one from scratch, using textbook circuitry and available components (no surplus or custom-built components). The idea was not to build the best possible receiver, that will come later I hope, but to build one which was inexpensive, but that would rival the FRG-7 or similar receivers in its ability to hear MW DX. Portability and simplicity of operation were also requirements as I wanted to use it on beverage DX'peditions. In fact, simplicity of circuitry was a requirement, as I had (and continue to have) enough difficulty troubleshooting simple circuits.

Well, I didn't quite make it with exact textbook circuitry. The mixer and local oscillator ended up being tinkered with a fair bit. Because the supplier I got the coils from had longwave coils available, I decided to use some bandswitching, and get a longwave band as well. That introduced problems in tracking in the two sections of the variable capacitor that I won't go into here, especially as this was supposed to be a MW receiver. The RF transformers throughout this receiver came from an English supplier, Ambit International (200 North Service Road, Brentwood, Essex CM14 4SG, England). These are the inexpensive shielded, slug-tuned variety found in solid state radios the world over. I got them from Ambit because I was unable to find an American mail-order distributor. J.W. Miller has some similar ones, but for 3-4 times the cost.

I chose not to use an RF amplifier in this receiver because the mixer would have gain, and too much gain before the IF filter is not a good idea. An RF amplifier would have introduced another stage of tuning in front of the mixer which would have been useful, but I couldn't find any inexpensive, small 3-gang tuning capacitors, and wished to avoid a preselector tuning capacitor. An attenuator control (a 5k-ohm linear potentiometer) was placed between the antenna input and the mixer, as I was sure there would be signal handling problems (see Figure 1). The mixer circuit is a conventional one using a 40673 MOSFET, which is reputed to have the best signal handling ability of the various single-ended mixer designs, and has some gain too. Often the 40673 circuit has a 10k resistor placed across the output transformer in order to avoid excessive voltage swings and the resulting spurious responses. I tried this but found little attenuation in the spurs I did find--just a decrease in gain, so I left the resistor out.

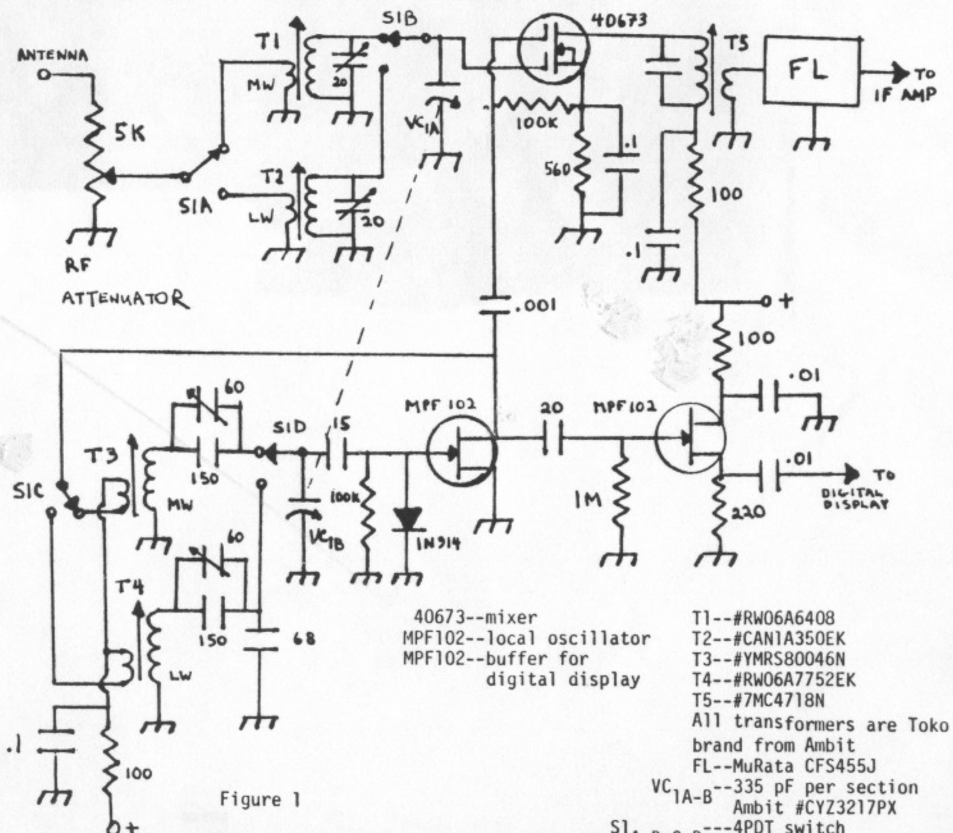
The local oscillator (LO) circuit is a little unconventional in that it uses a "tickler coil" for its feedback. Most FET oscillators use a tap on the tuning coil for feedback. The 40673 mixer requires about 5 volts peak to peak signal from the LO for best operation and gain, and I found that the tapped-coil FET circuit didn't provide enough voltage, particularly with the peculiar bandswitching arrangement I had to use to make the LO "track" with the mixer tuning. The circuit I used provided a greater voltage output, yet did not seem to generate an undue amount of harmonics. Incidentally, the tuning capacitor was a 2-section 335 pF per section "Polyvaricon" from Ambit. A 6:1 vernier drive is used with it, and I can tune to the nearest kHz without backlash.

I used a digital display with this receiver, because I already had one with the necessary 455 kHz offset, a Radio West DD-2. It would have been time consuming and reasonably expensive to put together a tuning dial with even 10 kHz accuracy, so I opted for the digital display. Torrestronics and Mattis Electronics also sell digital display kits suitable for 455 kHz (addresses in A DXer's Technical Guide; yes, that's a plug for the book). I use my digital readout for three different receivers now, so it was a good investment. To avoid any loading of the LO by the digital display, a buffer amplifier is placed between it and the display input, again see Figure 1.

The IF filter used in the finished product was a MuRata CFS-455J with 3 kHz bandwidth at -6dB and 9 kHz at -70dB. This filter can be obtained direct from MuRata (unfortunately they have a $100 minimum order), from Gilfer Associates (their 3kHz MOD-1 kit at $45; you might check as to whether they will sell the filter separately) or from Ambit (£12.25, about $29 US; more if customs duty must be paid). Gilfer might give better value if the US government wants their cut. I tried out two other filters before settling on the CFS-455J. The MuRata CFG-455I is rated at 4 kHz at -6dB and 10 kHz at -70dB, has more spurious responses, but is a bit cheaper at £7.25 from Ambit (about $17 US). I also had a Collins 455FD-29 which I believe costs in excess of $70 when purchased from Collins nowadays.

How did they work out, and why did I settle for the CFS455J? I first tried the CFG-455I filter and was fairly impressed with it. The tuned transformers (T5 and T6) at the input and output seemed to eliminate any filter spurious responses even next to locals. Tuning across CKDA-1220 would yield readable audio at about 1216.6 kHz and readability cease as one tuned beyond about 1223.4 kHz. Lots of splatter on either side though, but in another test, there was no problem hearing Belize 834 between 830 and 840 with both channels at about double strength to 834. The transition point from splatter to readable audio and back was somewhat indistinct, as it was also with the CFS-455J. The CFS filter yielded readable audio between, say 1217.4 and 1222.6 kHz with lots of splatter on either side, and has allowed a goodly number of split channels through--weak audio on Tahiti-738 when in Seattle for example. The Collins filter was very impressive; readable audio would appear at 1218.5 and cease at 1221.5 (this has a 2.9 kHz -6 dB bandwidth) and the transition from readable audio to splatter was very sharp. Of course, with none of these filters would it have been possible to log a station on 1215 kHz (or even 1200 kHz much of the time) because there was just too much splatter. Tuning around semi-locals yielded some interesting results. Using a station at 600 kHz, each filter had about the same readable audio bandwidth as before, and with about the same quality of transistion from splatter to readable audio and back. But once you had tuned past readability using the Collins filter, you were treated to large amounts of splatter, which was much more obnoxious sounding than the splatter noted with the ceramic filters. So although readable audio would cover a DX signal within 3 kHz either side of the 600 kHz semi-local when using the CFS filter, heavy splatter would obliterate any signal within that range anyway when using the Collins filter. Where the Collins filter made a difference was on 660 kHz where a TVI het is at 660.8 kHz. The TVI could be positioned outside the steep skirts of the Collins filter and XERPM or WNBC would be free from the TVI het. This is not really possible with the more gradual skirts of the CFS filter. These experiments were all performed with a shield between the filter inputs and outputs with little change in the results.

I chose the CFS filter for this design due to its relative inexpensiveness; I felt it to be more suitable for this cheap and simple circuit than the steeper skirted Collins filter. However, if I build a receiver with a really good quality mixer, IF amplifier, detector etc., then I would choose the Collins for its ability to "shave off" interfering carriers a few hundred Hertz away. So far, I've not really missed the Collins filter in this radio, except for DX'ing channels like 660. The CFG filter (similar to the CFR series but smaller) would be more useful for anyone who DXes few split channels and wants to save a few dollars.

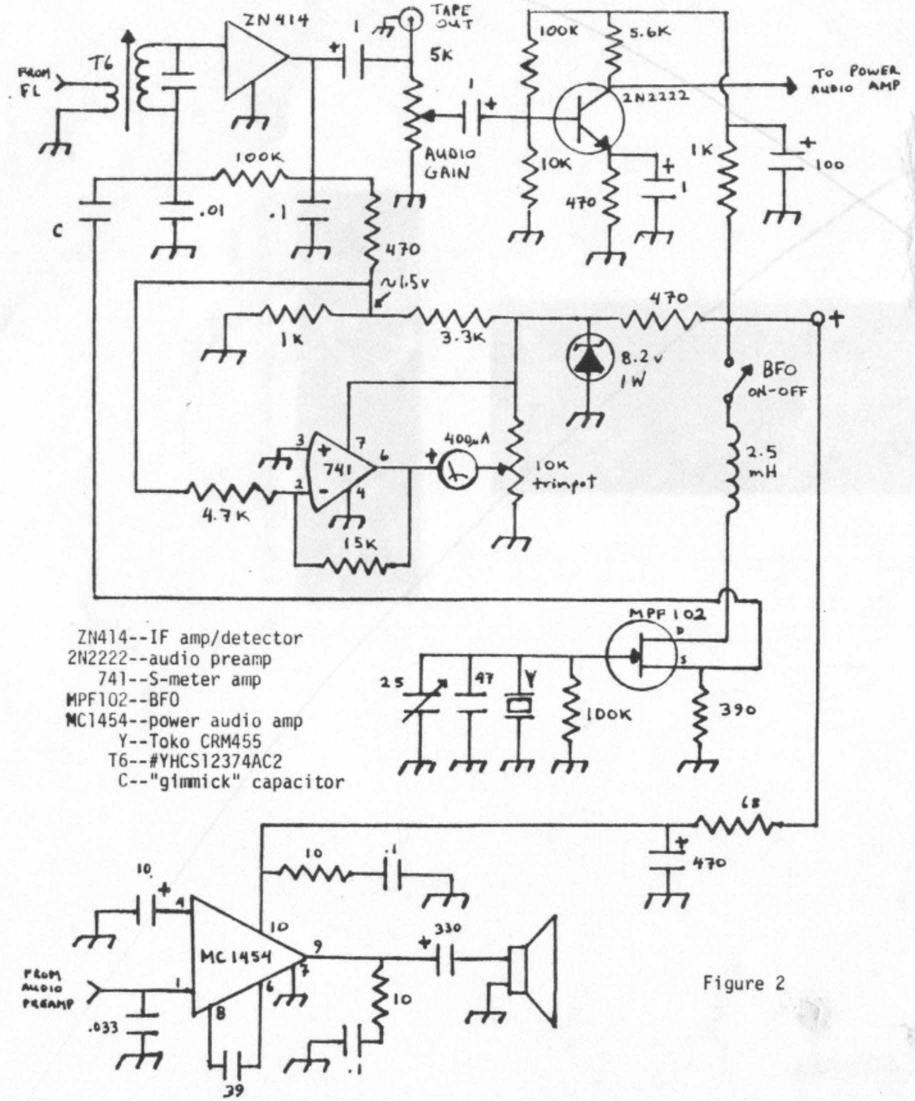


40673--mixer
MPF102--local oscillator
MPF102--buffer for digital display

T1--#RW06A6408
T2--#CAN1A350EK
T3--#YMRS80046N
T4--#RW06A7752EK
T5--#7MC4718N
All transformers are Toko brand from Ambit
FL--MuRata CFS455J
VC_{1A-B}--335 pF per section Ambit #CYZ3217PX
$S1_{A-B-C-D}$---4PDT switch

Figure 1

There is only one IF stage in this radio and it is included in an integrated circuit with the detector. This IC, the ZN414 is available from Circuit Specialists, Box 3047, Scottsdale, AZ 85257, and was originally intended for use as a small TRF (rather than superheterodyne) style AM radio using a high-Q ferrite RF coil. It features RF gain on the order of 70 dB, has sone automatic gain control in the circuit as it is portrayed here and needs between 1.2 and 1.6 volts for its power supply. This voltage is provided by the divider made up of the 3.3k and 1k resistor in Figure 2. The IF filter and matching transformers provide the 455 kHz signal to the exclusion of others, and T6 matches the 2k impedance of the filter to the high impedance input of the IC. Incidentally, T5 matches the high impedance of the 40673 output to the 2k input of the filter. The gain of the ZN414 is not fully controlled by its available AGC voltage, so on semi-locals and locals the RF attenuator in this radio must be backed off to allow distortion-free audio. As the radio was meant for DX'ing rather than listening to locals, I didn't consider the overloading a problem, and the ZN414 certainly simplified the building of the IF stage.



ZN414--IF amp/detector
2N2222--audio preamp
741--S-meter amp
MPF102--BFO
MC1454--power audio amp
Y--Toko CRM455
T6--#YHCS12374AC2
C--"gimmick" capacitor

Figure 2

A basic S-meter can be obtained by putting a 1 mA meter between the 1.5V supply and the 470 ohm resistor in the ZN414's circuit. It will indicate about .35 mA when no signal and about .6 mA for the strongest signal before the device overloads. I wanted an S-meter which gave greater meter range and indicated "0" when no signal was coming in. I had to abandon the textbooks almost entirely at this point, but what I came up with seems to work fairly well. A stronger signal at the ZN414 input will draw more current from the voltage divider. As this happens the voltage available at this point decreases. So the stronger a signal is, the lower the voltage will be at this point. This voltage is fed to the inverting input of a 741 operational amplifier. The output voltage of this configuration of the amplifier increases as the input voltage decreases, so a stronger signal at the ZN414 input means a greater voltage at the output of the 741. The output voltage is compared with the voltage available across a trimpot used as a voltage divider, hence the zener diode; the voltage must be steady at this point. The trimpot is set so that the voltage at its wiper terminal is equal to the voltage output of the 741 when there is no signal at the ZN414 input. The meter will read "0" at this point. If you use a different value meter (say 1 mA) it will still read "0", but maximum signal strength at the ZN414 input will only indicate 400 uA on the meter. The value of the trimpot could be reduced to allow for a greater current flow, or the value of the 15k resistor from pin 2 to 6 of the 741 could be increased for greater gain in the 741. You'd have to tinker a bit for a different value meter. I eventually replaced the 10k trimpot with a 1k trimpot between a 5.6k resistor, and a 3.3k resistor to ground. Easier adjustment of meter zero was the result.

A beat-frequency oscillator (BFO) is useful for spotting carriers of weak MW signals, but for this purpose you don't need a variable frequency BFO. One set to 455 kHz will do for carrier spotting. The MPF102 circuit in this radio works fine with a minimum of components. The frequency determining element is a ceramic resonator ("Y" in figure 2) worth about 75 cents (again from Ambit). You need a resonator which is parallel resonant at 455 kHz. "Transfilters" usually used as emitter bypass filters are series resonant at 455 kHz and will oscillate up at about 480 kHz. The only "problem" with this circuit is that it has a good output voltage. "C" in Figure 2 is simply a length of insulated wire running from the BFO output, which is draped in the neighborhood of the ZN414 input. The BFO does a good job with that small amount of coupling.

Fortunately, we return to the realm of the textbook with the audio amplifier. A 2N2222 provides preamplification, and an MC1454 IC is the power amplifier. A switched headphone jack can be placed in the speaker line. The 68 ohm and 470 uF capacitor are for greater filtering of the DC supply. If your supply is very clean, you could omit these components. I used a cheap 12 volt DC adapter to power this and it works fairly well. This radio can use a 9 to 14 volt DC supply, although the 470 ohm resistor between the power supply and the zener diode may have to be changed with one extreme or another of voltages. At 12 volts, the current used by the entire radio ranges from about 20 to 70 mA, depending on the audio gain setting. The current drawn by the digital display is another matter however...

I constructed the mixer, local oscillator/buffer, IF amp/detector, S-meter/BFO, and audio amplifier on different PC boards, for ease of troubleshooting and modifying. In a way, the hardest part of the whole project was to set up the boards for easy access, and to place the whole works in a box with jacks, controls etc. in useable positions. I used a 6"x8"x3½" "mini-box" to contain this lot, and if one were an expert designer, the circuit could be fitted into a lot smaller space I'm sure.

Alignment is fairly straightforward if you use a digital display and have the S-meter circuit set up right. Assuming that everything is working (you should be able to hear your locals at any rate), let the radio warm up for ¼ hour at least, with the S-meter disconnected. Set up the S-meter circuit for meter zero, by setting the RF attenuator to full attenuation or grounding the antenna input, and adjusting the trimpot for a zero reading on (preferably) a milliameter with a larger range than the one you will actually use. Now tune to a local, and get as much signal as possible, overloading the IF and keeping the AF gain down. Observe the meter reading at this point, and see if your meter will take it. If there's too much current, reduce the 15k resistor between pins 2 and 6 of the 741, or increase the trimpot value. If there's too little current to go full-scale on your meter, do the opposite. Keep cutting and trying until you get a meter range between zero and full scale of your intended S-meter scale, then replace the test meter with the S-meter. Now adjust the local oscillator for the desired tuning range. I found that mine covered 515-1650 kHz (read this from the digital display). The lower edge of the band is set with the trimmer capacitor, the upper edge with T3's adjustable slug. You may have to go back and forth until you get the desired range. The longwave band covered 148-420 kHz, using T4 and its trimmer.

Now, tune in a weak, steady signal (check that it's not a spur) anywhere in the band. Adjust the slug of T6, then of T5 for maximum signal as indicated by the S-meter. Tune to a weak, steady signal between 1400 and 1500 kHz; make it weak with the RF attenuator if necessary. Peak the mixer trimmer capacitor on that channel. Tune to a weak steady signal around 600 kHz and peak the signal by adjusting the slug of T1. Go back to around 1400 kHz, repeak the trimmer, return to around 600 kHz, repeak T1 until you get to a point where further adjustment is unnecessary. Finally, tune the receiver to any signal and make sure that the digital display reads exactly that station's frequency. Then turn on the BFO and adjust the 25 pF BFO trimmer capacitor for zero-beat with the desired signal. The ceramic resonator can drift around 40 to 50 Hz from this setting, but that will not be noticed when spotting MW carriers, and it's a lot cheaper than using a crystal in the BFO.

So, has the radio worked according to my original requirements? More or less... Conditions have been generally poor in the last couple of months, but I've heard virtually anything on this radio that the HRO could pull in--CBW-990 at 2PM PST, HIJB-830, HLAZ-1566, 1YA-756...I've also compared it with a FRG-7 in Seattle, and the general opinion is that it is comparable to that. The FRG-7 has somewhat better audio and AGC action, but the homebrew has 1 kHz readout and no birdie on 910 kHz. Sensitivity seems pretty good using an unamplified 3' box loop, but then sensitivity is not that important when conditions are right; I've heard W. Germany-756 with the Realistic TRF held up to that same box loop!

Signal handling ability is OK as long as the RF attenuator is kept set fairly high when using the loop. A birdie from CKDA-1220 is noted on 1530 ((2x1220)-(2x455)) and a birdie from CKNW-980, CJVI-900 and CFAX-1070 ((3x980)-(900+1070)=970) is found on 970. Both can be knocked down with the attenuator, but at the expense of sensitivity. Using a longwire with the radio in this high signal area is a dead loss. CKDA alone puts out .4 V rms into a 5k-ohm load from my unamplified loop. However, the two-pole antenna tuner described in the Technical Column of the January 27,1979 DX Monitor makes longwire listening possible, and clears up the 1530 and 970 birdies to boot. I think that I would wire in a two-pole preselector if I were to build this again, but there's no room in the present box. I did try replacing T1 with a higher Q custom wound pot core (tnx EHG) which attenuated the