

Longwave Receivers

Past & PRESENT

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Introduction

Over the past 7 years or so, there have been many reviews of receivers that can receive longwave signals, or can be modified to do so, and which have appeared in the *Lowdown*, the journal of the Longwave Club of America. This is a compilation of all these reviews, including the original tests and comments. This collection was suggested by Bill Bowers, who supplied several of these receivers for testing and suggested the title, which is a play on the title of the well-known publication "*Shortwave Receivers, Past and Present*" by Fred Osterman of Universal Radio Research.

The results are organized by the date of manufacture of the receiver, the oldest being presented first. This follows the title *Past & Present*.

Testing Philosophy

The objective of the tests was to measure those receiver parameters which are important for longwave reception. Since the signals which are being received are usually weak, and there are few strong signals to interfere with reception, the main objectives are sensitivity, selectivity, stability, frequency resolution and accuracy in display and tuning, an accurate, stable and adjustable BFO, freedom from internal spurious responses (spurs), and freedom from radiated noise, especially if an indoor tuned loop is used. If the receiver has a good noise blanker, this will be a plus. The author has found that a good tuned and rotatable ferrite loop antenna easily beats an outdoor active whip or wire antenna if quiet

electronics can be used for the receiving equipment. If the receiver generates radiated noise, this interferes with using an indoor loop antenna.

Receiver parameters such as second and third order dynamic range, blocking and cross modulation are not very important for LF and are not considered in these tests. If strong broadcast band signals interfere through second or third order effects, a low-pass filter can always be inserted in the antenna lead in to eliminate this problem. You can either build your own low-pass filter (see articles in the Lowdown), or find one for sale by entering “broadcast band low pass filter” into Google.

Equipment Used for These Tests



This photo shows the test equipment used for these tests. From top to bottom this equipment is:

- HP3561A Dynamic Signal Analyzer
- HP3335A Synthesizer/Level Generator
- HP3585A Baseband Spectrum Analyzer
- HP8443A Tracking Generator
- HP141T Spectrum Analyzer, consisting of:
 - HP8553B RF Section
 - HP8552B IF Section

Also used, but not shown is an old HP 651B Test Oscillator and a Marconi TF2091B Noise Generator.

I like HP equipment. It's well designed with quality construction and is accurate. It used to be said that HP stood for "High Priced", but that's not always true. Older HP equipment in good condition can be found at very reasonable prices.

Description of the Tests

Results are presented in graphical format whenever possible. The most important graphic shows the receiver's sensitivity in the range zero to 500 kHz along with any spurious responses in that range. This display represents sensitivity values obtained by connecting one of the signal generators to the receiver input, and watching the audio output on the HP3561A.

The narrowest filter available in the receiver's CW mode is always selected, although this does not affect the test values. The sensitivity values are dependent on the bandwidth used by the HP3561A, which is very small, not the receiver's filter. Using the 3561A to measure the signal makes this test independent of the receiver's filter. This means all the tests can be compared directly, without regard to the filter used in the receiver. The BFO is tuned to 400 Hz and the receiver audio response is viewed on the HP3561A. The sensitivity curve is generated by setting the generator to a frequency in the 0-500 kHz range and tuning the receiver to the same frequency. The amplitude of the input signal is

reduced until this response is 6 dB over the noise level as seen on the 3561A. At this level the signal can be just heard over noise. The signal generator amplitude is recorded, and another frequency is selected. This is repeated until a full sensitivity curve is obtained. The results are plotted with a Mathematica graph program written for this purpose by the author. Spurious responses (spurs) are obtained by placing a 50-ohm shielded shunt on the receiver input and tuning through the 0-500 kHz range and noting spurs when they occur. Spur strengths as displayed on the 3561A are also plotted along with the sensitivity curve.

The second graphic is the receiver's filter curve. This is obtained by inputting random RF noise from the Marconi noise generator into the receiver's input connection and observing the output audio on the HP3561A. The display is photographed and added to the report. This graphic shows the quality of the filter and indicates filter leakage and noise outside the passband.

The remainder of the report consists of a summary of the important features (The bottom line) and Performance notes, which are my impressions of the receiver. These are self-explanatory except for the display noise value. To obtain this a battery powered portable tuned to 200 kHz was moved away from the receiver until the S meter showed S-9. This distance was measured and used as a rating for receiver generated noise.

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Chapter 1

CEI Type 357 LF-VLF Communications Receiver



This is a picture of the front panel of my Communication Electronics Inc. (CEI) Type 357 LF-VLF receiver. This receiver was made for the NSA and production was started in 1966. At that time its cost was \$4,200, which would be about \$28,000 in today's dollars. CEI put a lot of effort into the design and construction of this receiver. This receiver has the military designation R-1401A/G.

Description

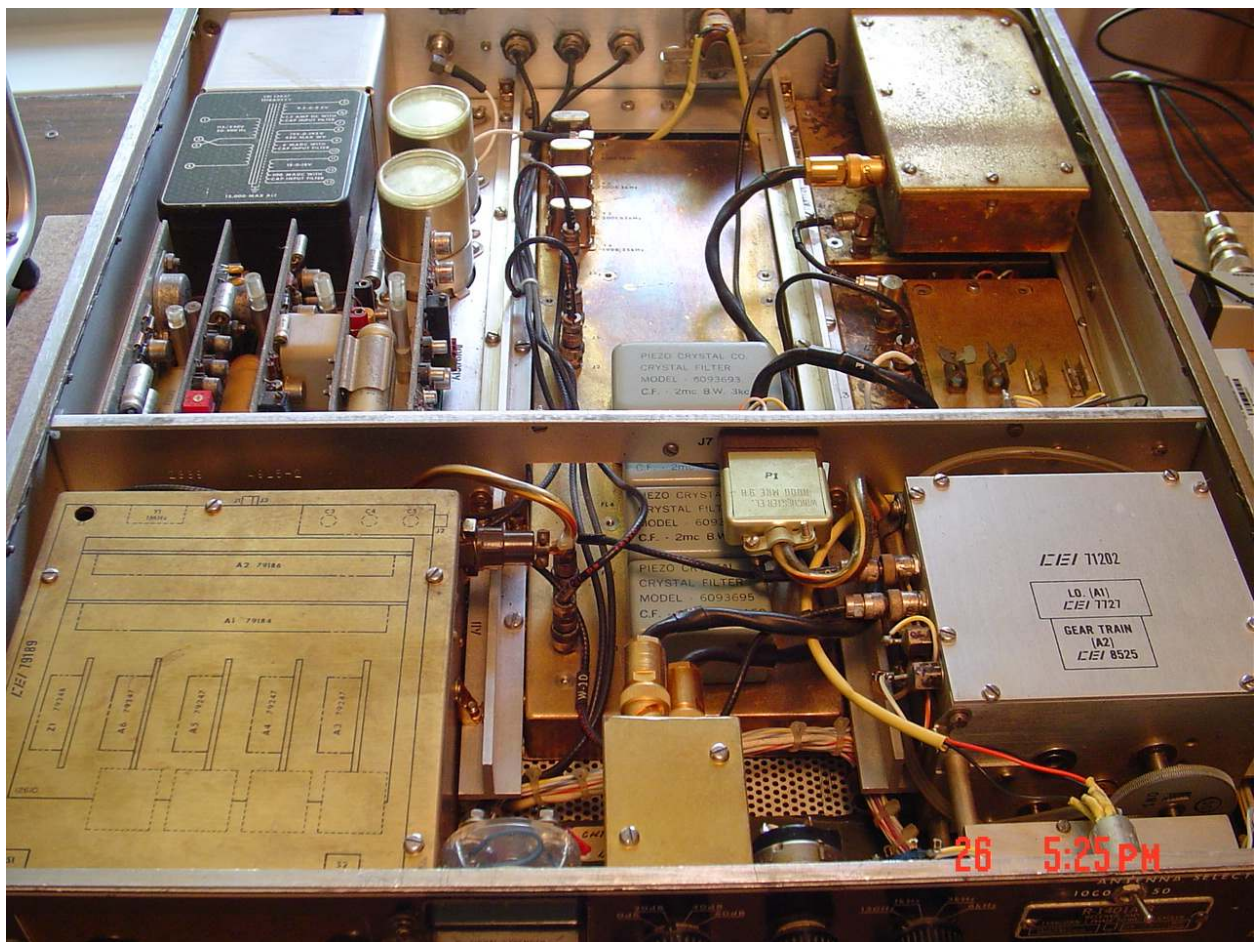
The Type 357 is an all solid state, except for nixie tubes, receiver covering zero to 600 kHz in one band. It has provisions for CW, AM and sideband reception.

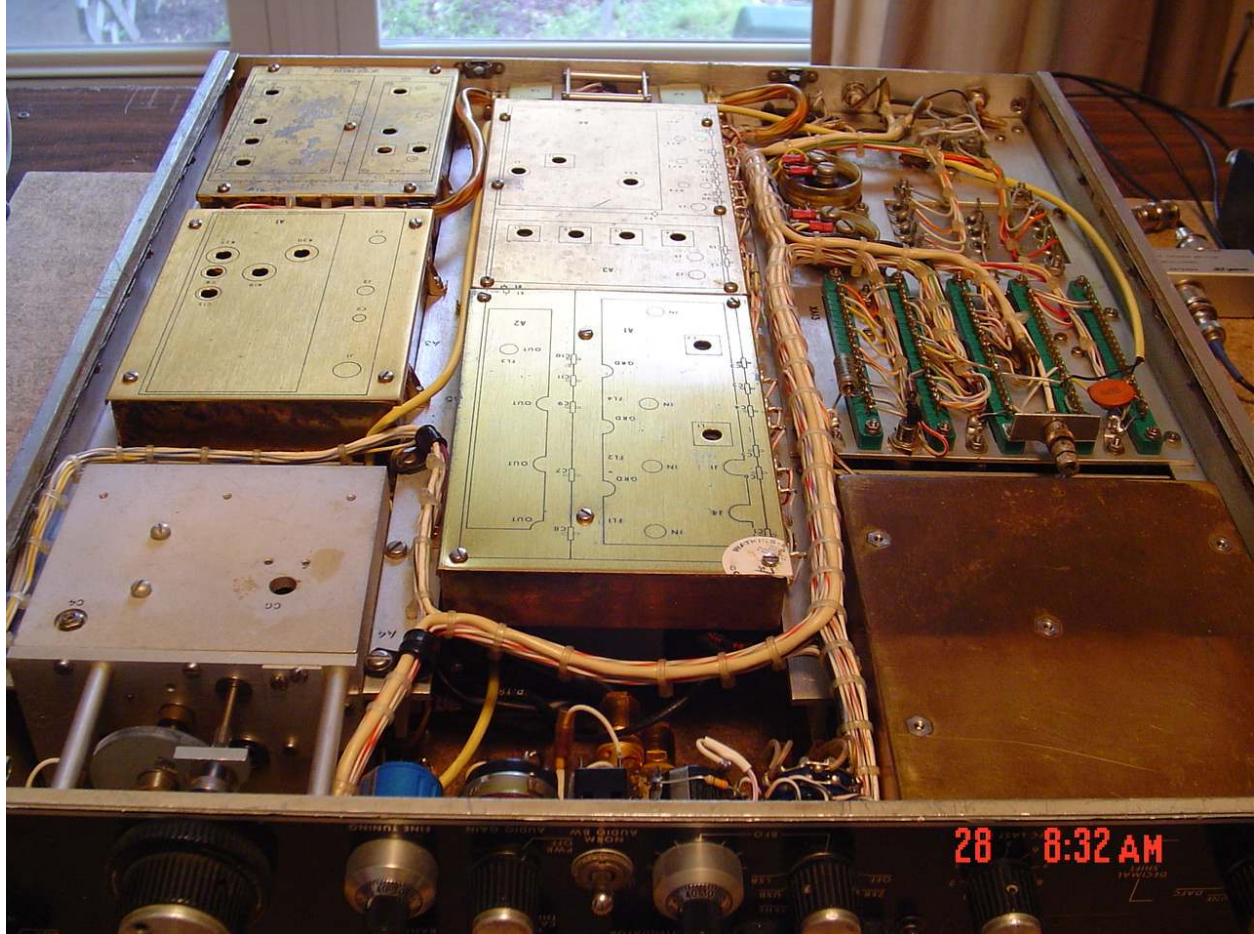
You can find a complete description of this receiver and its many variations at:

<http://watkins-johnson.terryo.org/CEI-Receivers/357.htm>

There you will find the statement: “The 357 is one of the greatest VLF-LF receivers ever made.” That’s quite a recommendation. In the following tests, we’ll see how it stacks up against some of the other receivers in my reviews.

Construction Quality

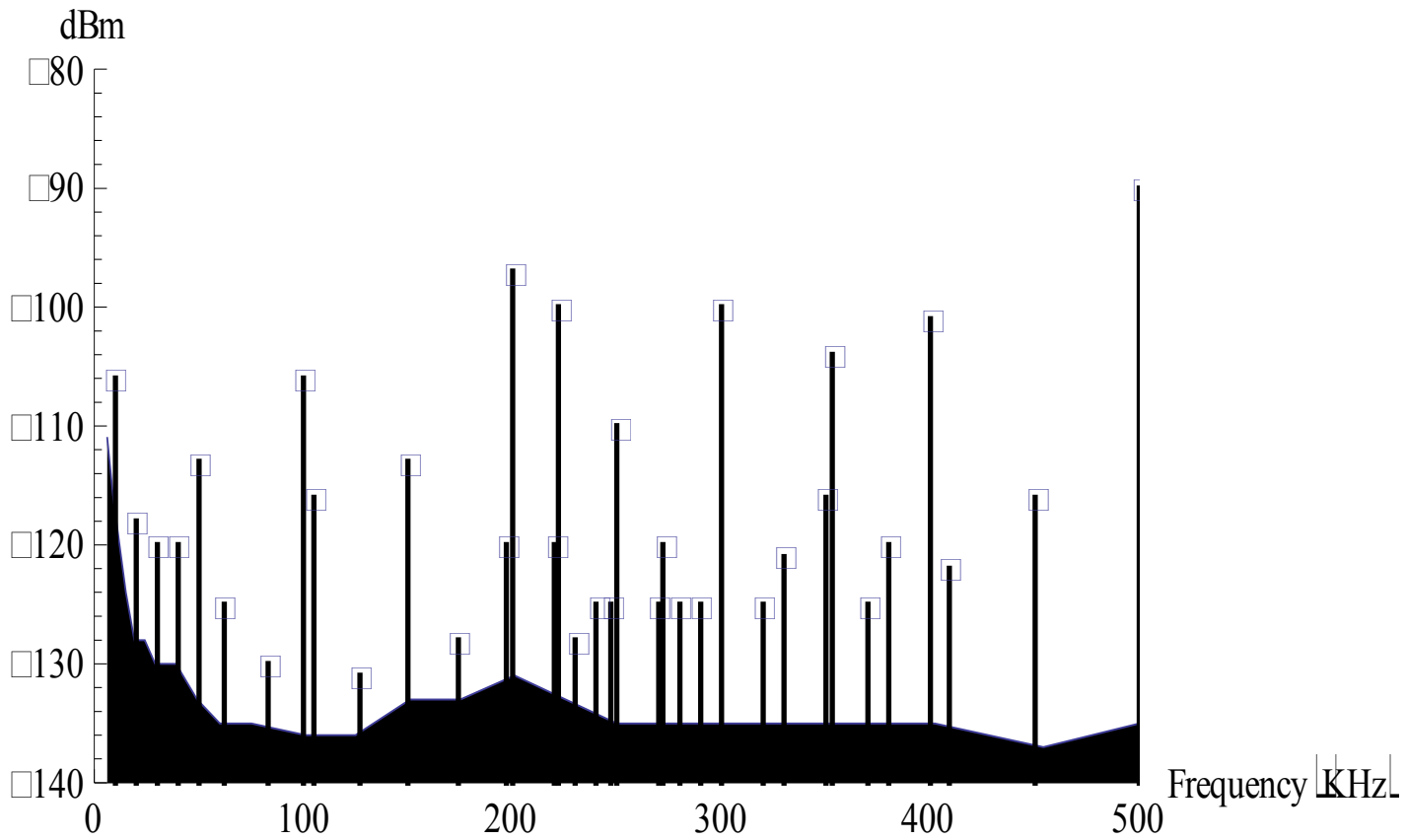




These are photos of the inside top and bottom of the receiver. This is an example of 1960's mil-spec design. The receiver is made up of modular printed circuit board units, each of which has coax cables that plug into it and is very well shielded. In fact, according to the manual these shields are made of brass, silver plated and flash plated with gold. We referred to an effort of this kind as "Gold Plating" when I was working. The tuning is done with anti-backlash ball bearing gearing. No expense was spared to obtain top quality construction and performance.

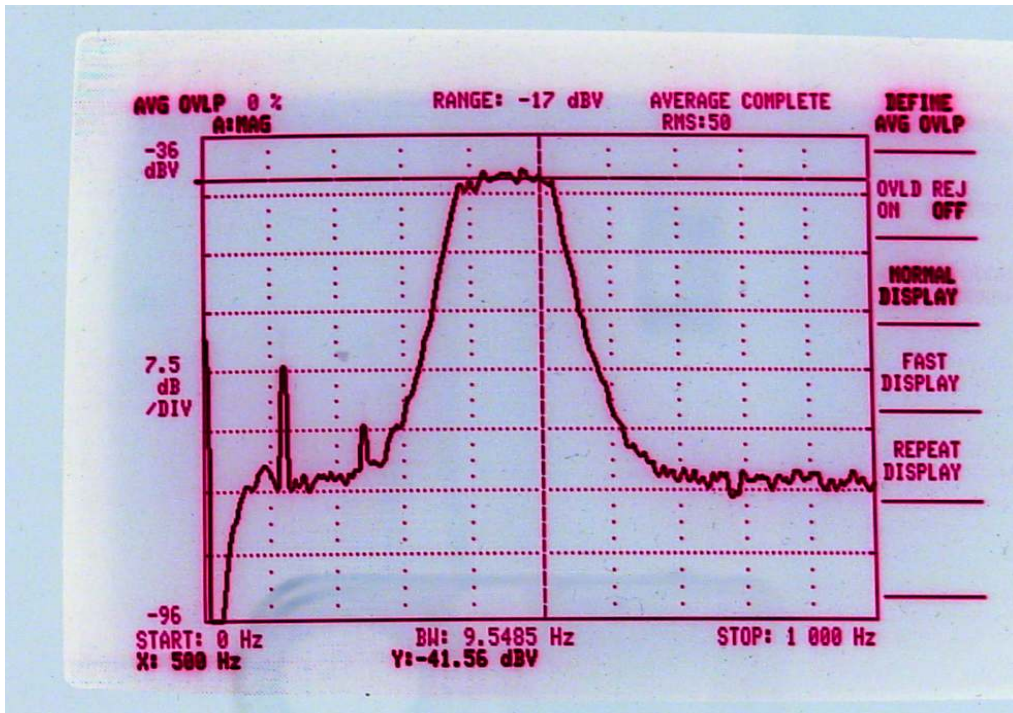
Sensitivity

CEI Type 357 with spurs

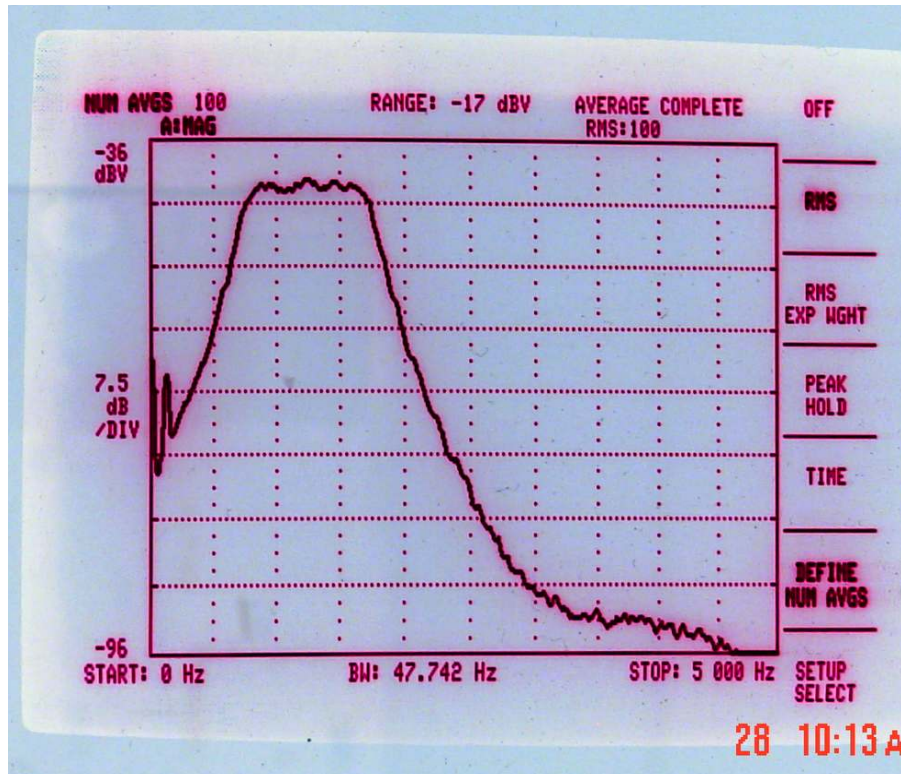


Sensitivity is excellent as can be seen from the graphic, about -135 dBm. There is very little phase noise and it is gone above 50 kHz.

For the CEI Type 357 thirty-five spurs were found which is a poor result. This nullifies much of the benefit of the excellent sensitivity.



This is a photo of the signal analyzer output of the receiver when tuned to a random noise source. Vertical divisions are 7.5 dB and horizontal divisions are 100 Hz. This quartz crystal filter has a bandwidth of 150 Hz and is a narrow band CW filter. This plot indicates that there is little filter leakage and adjacent signals outside the passband will seldom be heard. This filter also has a good shape factor and is an excellent filter.



This is a plot of the spectrum of the receiver's 1000 Hz filter. Horizontal divisions are 500 Hz. This is another well designed filter.

The bottom line:

- Construction quality – First class mil-spec construction, excellent
- LF Sensitivity – Excellent
- LO Noise – Analog oscillator, excellent
- Internally generated spurs – Poor. Many spurs exist in the tuning range.
- Filter selection – Excellent filters.
- Tuning resolution – Analog with fine tuning. The receiver can be locked to the 10 Hz digit with DFC. A front panel control can be used to select this digit from 0 - 9 (Digital Frequency Control)
- Frequency display – 10 Hz nixie display – Good
- LO stability – Analog, good. DFC at 10 Hz resolution - Good

- BFO – Analog, voltage control diode. No frequency display. Drifts badly – Poor.
- Noise blanker – Excellent, performs very well.
- Display noise – Very low, excellent

Performance

The excellent sensitivity is marred by the presence of numerous spurs. Many times, I have thought I had a weak beacon only to discover when I tested this assumption by disconnecting the antenna, the signal was still there. I don't DX with it very much for that reason.

Availability

At one time these receivers were plentiful. I paid \$200 for this one. Lately however prices are at a premium. Recently one sold on eBay for \$1500. They are not easy to find today.

Chapter 2

Eddystone EC958/3 Communications Receiver



Here's a photo on my EC958/3 on the workbench. The loop that I use is sitting on top of it showing that it has no detectable radiated noise. Also shown is a small counter that I can use to find the frequency it's tuned to giving 10 Hz accuracy. This is difficult without a counter since the receiver is analog tuned with mechanical dial readout. To get accurate frequencies when using the dial it is necessary to calibrate the dial to the closest calibration reference point. It's also difficult to read the dial closer than about 500 Hz.

Description

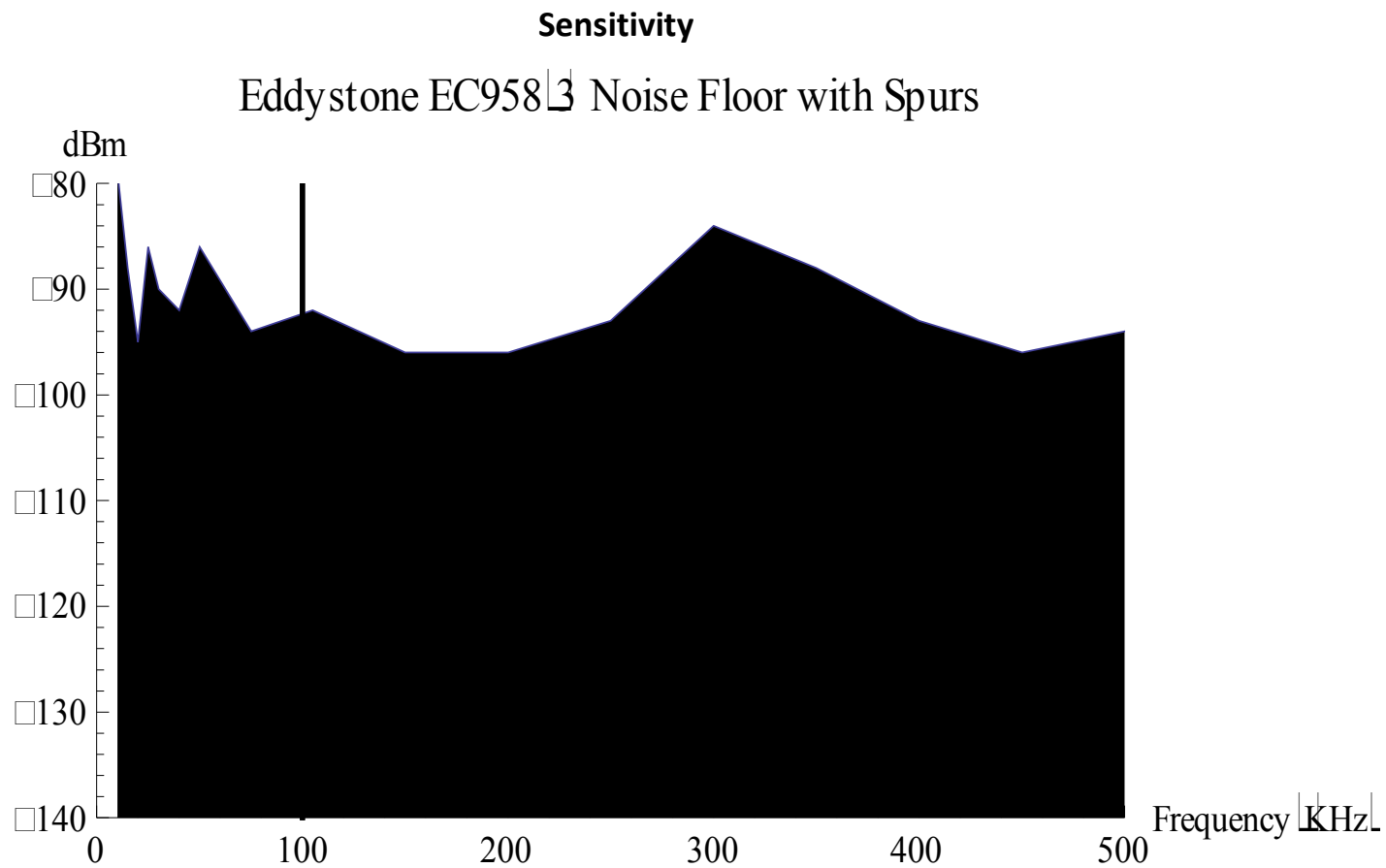
The EC958/3 is a high-quality communications receiver built by the British firm Eddystone. Eddystone is no longer in business, having been bought by Marconi. In its time this was considered quite a good LF receiver. A description can be found in "Shortwave Receivers, Past and Present" fourth edition, page 187. There you will find the quotes: "One of the best receivers ever made by Eddystone" and "Outstanding on longwave and VLF".

These receivers were made for use by the Canadian military. They were manufactured in Britain and exported to Canada. Date of manufacture started in 1969.

Construction Quality



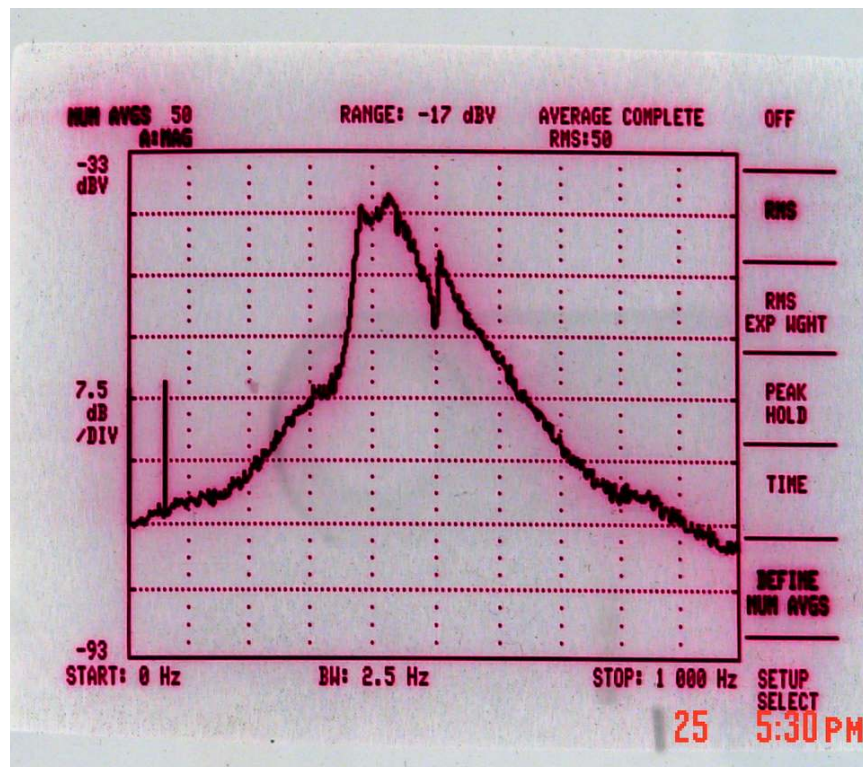
This is a photo of the inside of the receiver. Construction is British equivalent to USA mil-spec. The construction is unique. The large die cast box in the upper left hand side of this picture contains the coil turret. This is a large rotary turret that is rotated by the band switch. Mounted on this turret are all the coils and trimmer capacitors for the 10 bands on six disks. There are wipers in the box that contact switching points on each turret disk. This avoids the normal band switch with all its wiring and chances for signal crosstalk and noise pickup. Six of these bands tune the VLF, LF and MF frequencies: 10 kHz to 1600 kHz. From 1.6 MHz to 30 MHz the receiver uses a Barlow-Wadley loop scheme that gives a tuned 100 kHz sub-band every 100 kHz. These frequencies are outside the scope of this review, and in the LF and VLF frequency bands, the configuration is the standard double tuned RF amplifier, tuned mixer and analog tuned LO which all track with a single four section air variable capacitor.



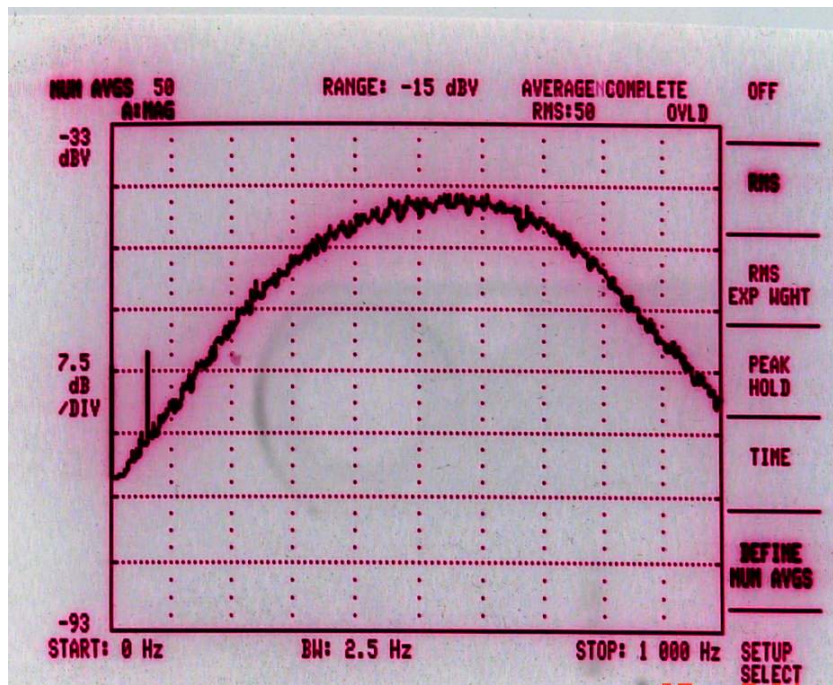
This receiver has relatively low sensitivity. The reason for this is there are two tuned circuits before the RF amplifier from 54 kHz to 500 kHz and one tuned circuit from 10 kHz to 54 kHz. You can get a hint of band changes at about 24 kHz, 54 kHz, 126 kHz and 280 kHz. The tracking of the tuned circuits is harder to maintain close to the band edges.

The EC958/3 has only *one spur* at 100 kHz which is an excellent result reflecting the care that went into shielding and band switching.

Filters



This is a photo of the signal analyzer output of the receiver when tuned to a random noise source. Vertical divisions are 7.5 dB and horizontal divisions are 100 Hz. This stated bandwidth for this crystal filter is 150 Hz. This filter consists of two crystals and is not the high quality that you will find on modern communication receivers. Nevertheless, it is quite effective.



This is a spectrum analyzer plot of the receiver's 400 Hz filter. This is a tuned LC filter working at 100 kHz IF frequency and has a very broad response. Other filters are 1.3 kHz, 3 kHz and 8 kHz. These are all LC filters.

The bottom line:

- Construction quality - Excellent
- LF Sensitivity – Poor, about -95 dBm
- LO Noise – Analog LO, no phase noise is apparent. Excellent
- Internally generated spurs – 1, Excellent
- Filter selection - Good
- Tuning resolution – Analog dial, poor
- Frequency display – approximately 500 Hz minimum resolution, poor
- LO stability – Analog oscillator, Fair
- BFO – Analog, good stability, no readout except on the knob - Fair
- Noise blanker – None fitted
- Display noise - Superb. None was found.

Performance

This is a fun receiver to play with on LF. These receivers were manufactured from 1969 to 1973, before synthesizers were perfected, and now they are like antiques. It can receive most weak beacons that my Harris can receive. The only problem is when a beacon is really weak and I have to use my 5 Hz audio filter with it, tuning the frequency and BFO close enough to use the audio filter is difficult. There is some backlash in the analog gearing and that, along with uncertainty in the frequency and BFO readouts make this a challenging task.

Availability

This will be a difficult receiver to find. Very seldom one shows up on eBay, but sometimes some of the Canadian surplus outlets have one for sale. Eddystone receivers are still popular in Britain and there is a dedicated group of fans, the Eddystone User Group.

Chapter 3

Mason A-3B Suitcase Receiver

Here's the suitcase:



Here's what is inside that old worn out looking suitcase:



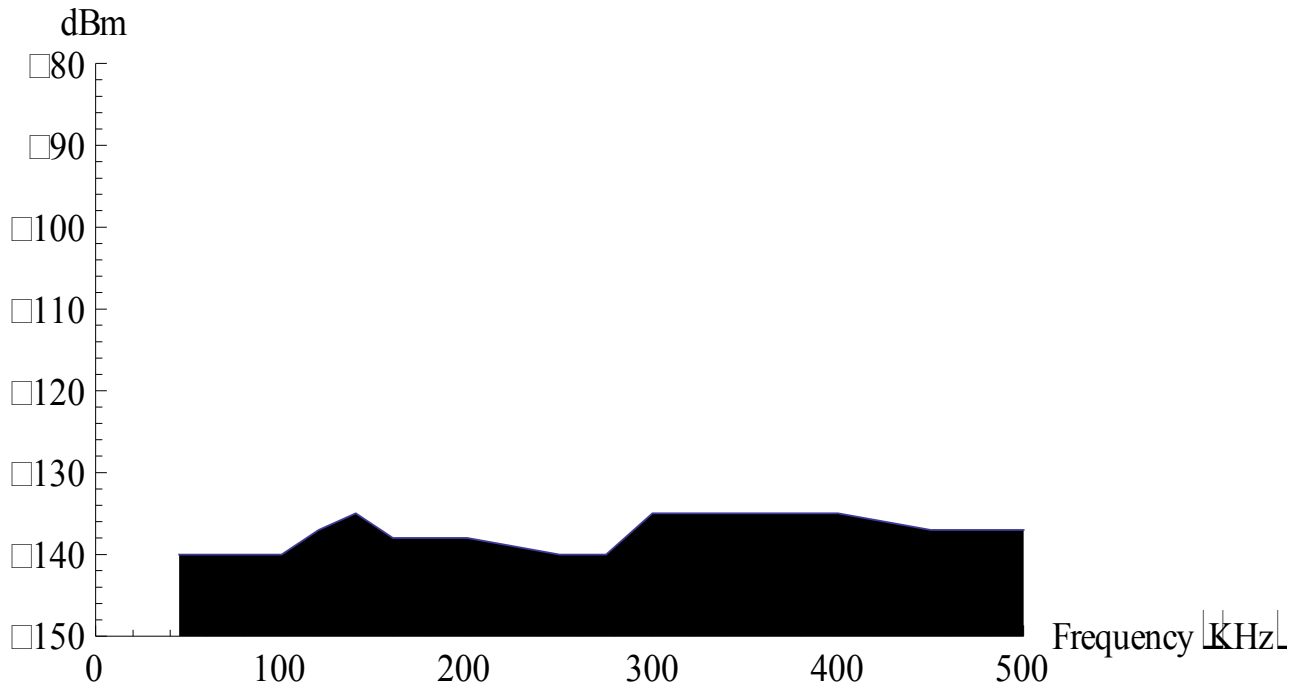
Description

This is a receiver that you won't see often. It came from a government surplus equipment sale at Langley, VA, headquarters of the CIA. It's a portable that is self-contained, complete with panadapter scope and runs on 15 AA batteries. The panadapter is on the left side of the suitcase. When in use it is mounted on the raised suitcase lid. The screen is viewed by looking into a small folding mirror in its top.

This equipment is obviously designed for bug sniffing in remote locations and has frequency coverage from 20 kHz to 1600 MHz using 9 tuners. The LF spectrum is covered by two of these: The VLF-LF section which covers from 20 kHz to 300 kHz, and the MF section that covers 300 to 1 MHz. You can see the band change at 300 kHz in the sensitivity plot below. Below 300 kHz there is a lowpass RF amplifier that is used in the circuit. Above 300 kHz the circuit uses a tuned RF amplifier.

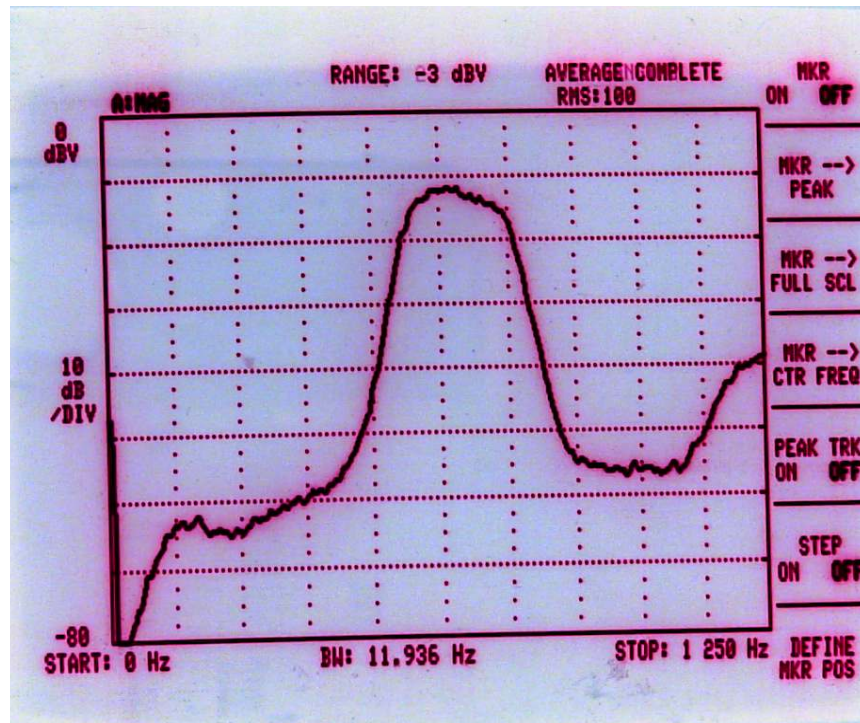
Sensitivity

Mason A-3B Noise Floor with spurs



The A-3B is a very sensitive receiver. You won't see any spurious responses with this receiver. None were found. Also notice that there is no phase noise. This superb sensitivity and low noise performance come at a price, however. Its local oscillator is analog tuned and the frequency readout is from metallic tape that is wound from one spool to a second spool when the tuning knob is rotated.

Filters



This is a photo of the spectrum analyzer output of the receiver when tuned to a random noise source. Vertical divisions are 10 dB and horizontal divisions are 125 Hz. This filter has a stated bandwidth of 200 Hz and is the narrowest filter available. On the analyzer the bandwidth appears to be close to 200 Hz. Ultimate rejection is fair at 50 to 60 dB. The filter appears to have some leakage on the high frequency side. It is a quartz crystal filter.

The bottom line:

- Construction quality – Excellent
- LF Sensitivity – Superb at close to -140 dBm
- LO Noise – Superb, none can be seen
- Internally generated spurs – Superb; there are none.
- Filter selection – Good with the 200 Hz crystal filter.
- Tuning resolution – Poor, analog
- Frequency display – Poor, analog metal tape readout
- LO stability – Poor. Drift is noticeable
- BFO – Fair, analog varactor tuning with some drift
- Noise blanker – Not an option.
- Display noise – Superb, none was detected.

Performance

This isn't a receiver that will be too useful for LF DXing. The difficulty in reading the frequency, along with drift and backlash in the tuning make it hard to use. Also it overloads easily on most antennas. It was designed to use small antennas that are packed into the suitcase. For LF it can be connected to an AC wall outlet to look for bugs which apparently use power circuits as communication lines. The power line can also be used as a low frequency antenna.

Availability

These are seldom seen for sale and usually go at a premium price because of interest in the receiver by collectors. They are no longer being manufactured. The F. G. Mason Engineering Company was dissolved after its owner, Frank Mason was indicted for conspiracy with an official of the West German government involving the sale of Mason Engineering equipment to West Germany.

Chapter 4

Racal RA6217A/RA6337A

The Racal RA6217A receives from 980 kHz to 30 MHz. It wouldn't be of much interest to an LF listener, but it has an accessory LF upconverter, the Racal RA6337A that covers 3 to 980 kHz. The receiver I am reviewing has this option.



Racal RA6217A Receiver with RA6337A sitting on top.

Description

The interesting thing about this receiver is that it incorporates the Wadley loop as a frequency synthesizer. At one time this circuit arrangement was popular and was first used by Racal in their RA17 receiver. Other receivers which have used this circuit are the Eddystone EC958, Barlow Wadley XCR-30 portable and the Yaesu FRG-7 plus several more. This circuit differs from the usual phase lock loop since it uses mixing instead of phase locking to correct the output frequencies. Here's what the manual says about this:

The output of the first V.F.O. is also fed to the 'Harmonic Mixer' M4, where it is mixed with harmonics (up to the 32nd) of the 1.0 mc crystal oscillator. The output circuit of the Harmonic Mixer restricts the useful settings of the 1st V.F.O. to intervals of 1.0 mc; that is when the 1st V.F.O. frequency minus a 1.0 mc harmonic produces a difference of 37.5 mc. This signal is amplified, filtered and mixed with the 40 mc 1st IF spectrum in the 2nd mixer to produce a wideband 2nd IF output between 2 and 3 mc.

Thus, if the 1st V.F.O. drifts, an equal change occurs in both 40 and 37.5 mc channels and the drift is cancelled in the 2nd Mixer. The stability of this frequency selection system is therefore that of the 1.0 mc crystal. The 1st V.F.O. is set by the Megacycles dial of the receiver and acts as an electronic bandswitch.

This system gives an accurate synthesized frequency without phase noise.

Between the one MHz loop output frequencies, analog tuning is used. This is done with ball bearing, anti-backlash gearing tuning a capacitor which works very well. Even though this receiver was built 45 years ago, the tuning is still smooth and works perfectly. I did re-grease the gearing, which was needed.

Eventually phase locked loops were improved so the phase noise problem wasn't as bad, and their simpler circuitry made the Wadley loop unnecessary. My desire to test a receiver that had no phase noise makes this an interesting comparison to most of the other receivers that were tested. You can find this receiver in *Shortwave Receivers, Past and Present*, page 556.

Tuning

A receiver that tunes over 1 MHz bands will be prone to overload since the mixers will be subjected to a wide band of signals. For this reason the RA6217A has a built in preselector with two tuned circuits, and adjustable front end attenuators. The LF converter has its own preselector. There is a lot of dial turning when using this receiver. First the MHz knob is set to an integer, for LF this is 0, then the kHz knob is turned to set the desired frequency, finally the preselector is tuned. This is a photo of the frequency tuning section:



The MHz selector is the large knob on the left, and the kHz is the large knob on the right. Frequency readout is displayed on the odometer type mechanical readout. The readout gives accuracy of about 200 Hz, but only if the tuning has been calibrated at the nearest 100 kHz calibration frequency. There are no digital displays or circuits in this receiver, making it a quiet performer. Finally, the preselector must be adjusted. The LF converter is not only an upconverter, but most of the circuitry is for preselection. It is tunable down to 3 kHz! Tuning is done by listening for maximum noise or signal. On LF the preselector tuning is quite sharp. This is a photo of the RA6337A LF upconverter:



The first knob on the left is an attenuator, allowing attenuation of up to 40 dB in increments of 10 dB. The center knob is the preselector band, and the rightmost knob is for preselector tuning. The preselector tuning frequency is read off the rotating drum next to the tuning knob.

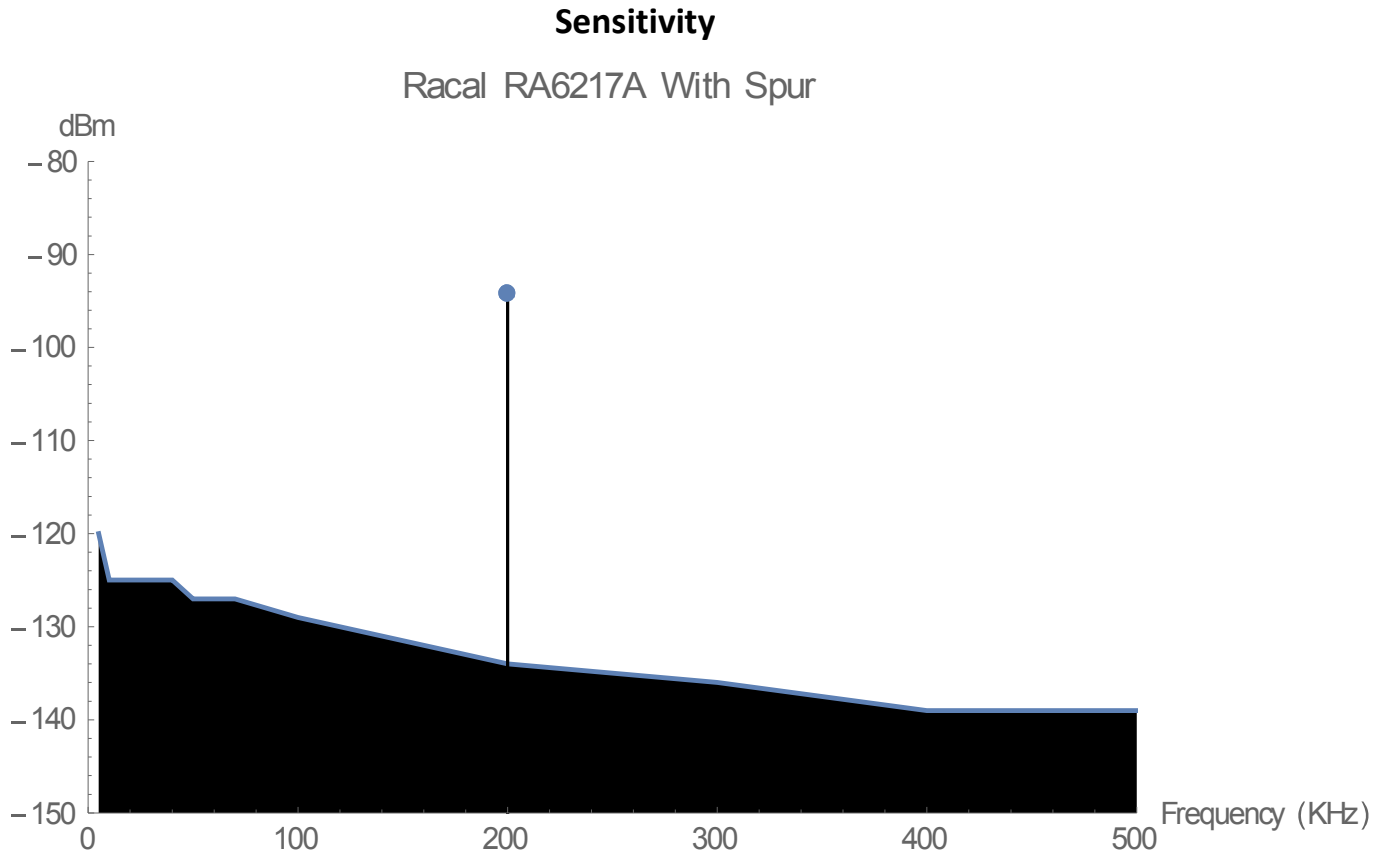
Construction

This is a photo of the inside of the receiver with the top panel removed:



This photo shows the high quality of construction. Shielding is extensive, and consists of welded aluminum enclosures. The main components are mounted on a die cast aluminum chassis. Wiring is done with Cannon combination coax and wire connectors and coax SMC connectors with Teflon cables. Even though this receiver was built during the years 1965 to 1975, this one works fine, without any

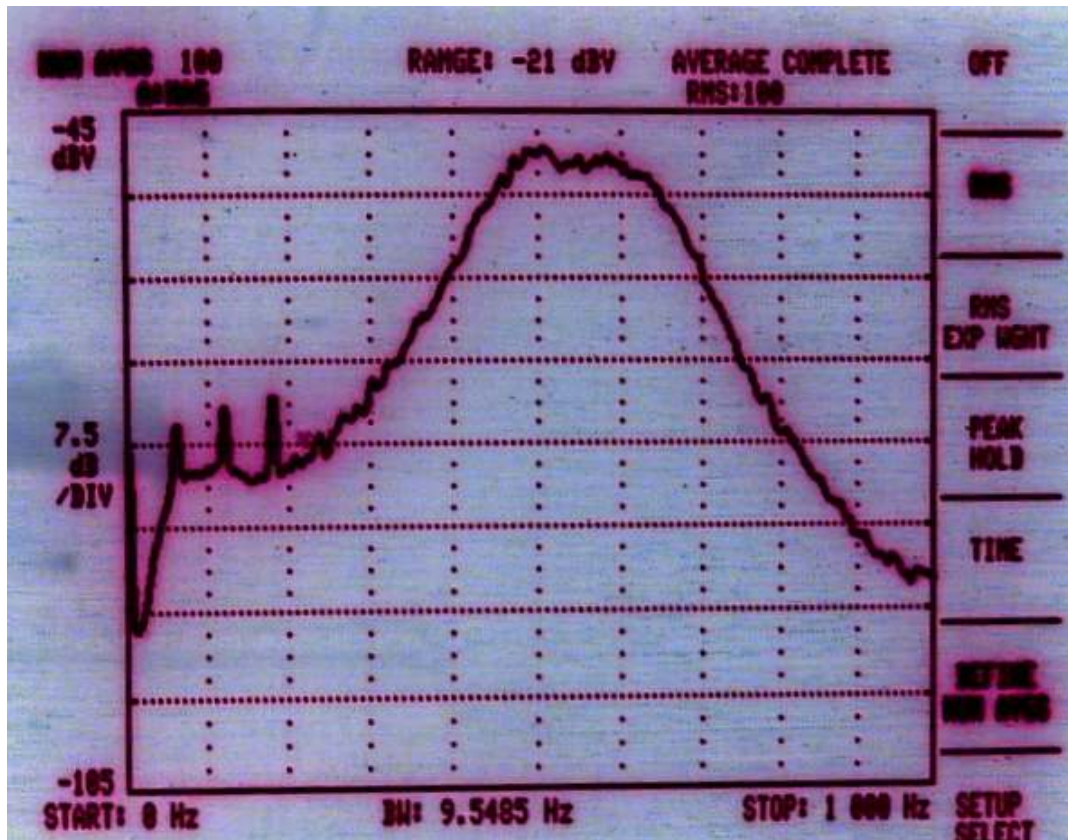
problems. It is all transistor, both silicon and germanium. I have read that germanium transistors lose performance with age, however there doesn't seem to be any indication of that.



In this receiver only one spur was found which is an excellent result. You will see that the sensitivity of the receiver changes only about 10 dB over this range, reflecting the absence of any phase noise in the local oscillators. Also, the sensitivity is quite good, better than most of the other receivers tested, especially at VLF. Phase noise is almost non-existent due to the Wadley loop synthesizer.

Filters

The filters in the receiver are 0.2, 1, 3, 6 and 13 kHz. These are all crystal filters. Only the 0.2 kHz filter will be shown:



The shape factor is fair, and ultimate rejection is also just fair.

The bottom line:

- Construction Quality – Excellent
- LF Sensitivity – Excellent
- LO Noise – Superb
- Internally generated spurs – 1 Excellent
- Filter Selection – 200 Hz, good
- Tuning resolution – Analog fine tuning with infinite resolution, but some warm up drift - Fair
- Frequency display – 200 Hz after calibration to nearest marker – Fair
- LO Stability – Analog temperature compensated crystal oscillator Wadley loop first IF and analog tuned second IF. Drift is small after warm up – Fair
- BFO – Analog tuned with some drift during warm up. Also, the BFO lost its calibration and ended up way off. I reset it, but this happened a second time. Poor.
- Noise Blanker – Not available
- Display noise – None detectable – Superb

Performance

I was hoping that this old receiver would be good with its low noise Wadley loop first oscillator and no radiated noise. However the lack of precise tuning is a limiting factor. In order to catch a weak signal you have to know exactly where to tune. It may be possible to hook a counter to one of the outputs (second VFO) on the back panel to get a more accurate indication of tuned frequency. I'll be trying to do this in the future. One problem with this is that the second VFO tunes backwards; increasing the tuning frequency decreases the VFO frequency. The first oscillator is always accurate.

Availability

These are occasionally seen on eBay, along with its foreign relative from Britain, the RA1217. The British version is electrically nearly identical, but finding British hardware, if needed, can be difficult.

Chapter 5

Raytheon Model 1230

Along with Its Short History

This chapter reviews an unusual receiver with an interesting history. Because there isn't much available literature about this receiver I will go into more detail than in previous reports about its design and performance.



RAYTHEON MODEL - 1230
RECEIVER

**THE NEW STANDARD OF
RECEIVER EXCELLENCE**

- SYNTHESIZER STABILITY
(Better than 1 Hz/day at any freq.)
- CONTINUOUS TUNING (2-30 MHz)
- TRACKED PRE-SELECTION ON ALL BANDS
- DIRECT DIGITAL READOUT TO NEAREST Hz
- PHASE LOCKED DETECTORS FOR AM, FM, FSK
- INDEPENDENT SIDEBAND AVAILABLE
- ALL SOLID STATE including DISPLAYS

S4475

FOR MORE INFORMATION WRITE TO: **1973**

RAYTHEON COMPANY

MARKETING DEPT. (5P1)
P.O. BOX 1949
GOLETA, CALIFORNIA 93017
AREA CODE 805 967-5511

In the early 1970s, Raytheon decided to produce a communications receiver that would be revolutionary. It would have one Hertz resolution of the tuning, unheard of at that time, which would be displayed on LEDs. This would require not only implementation of lots of digital logic but also the ability to control stability closely. Since there weren't any microprocessors at that time many logic chips would be needed in the counting and display circuits. And since frequency synthesis was only in its infancy, frequency locking of an analog tuned oscillator to harmonics of a stable oven controlled oscillator was chosen, an early form of synthesis. The expected buyers of this receiver were probably not hams or SWLs, because the cost (\$4475) would buy a nice new car at the time. For example, a Pontiac Trans-Am sold for \$4700 in 1972 and you could buy two Ford Pintos for less than the price of this radio.

The story I was given by the seller was that Raytheon finished the design work and 10 prototype units were built, aligned and tested. Then a small number of production units were started, probably less than a hundred. The technicians were in the process of building, alignment and quality control on these production units, when this work was terminated because Raytheon picked up a large government contract. All work on the production Model 1230 units was abruptly discontinued, and the prototypes and unfinished production units were disposed of. Some of these ended up in the hands of the technicians and engineers who had worked on them. The person I bought this one from got it from one of those technicians. When I got the receiver, it was a long way from working. It was dead, no display and no audio and it had not yet been aligned. It did come with some handwritten tech notes dealing with the alignment of the front ends of the prototype units and several of the early production models. Also, I got a manual, but it's not complete or up to date. After many months of troubleshooting I was able to get it working up to specs. It seems to be a pretty good HF receiver; the tuning goes from 2 to 30 MHz. Raytheon had an LF upconverter in the design stage for it, but I suspect none were ever produced. To do the LF tests I used Todd Roberts' upconverter. The seller told me that if I could get this Model 1230 going, it would probably be the only working one in existence.

Description

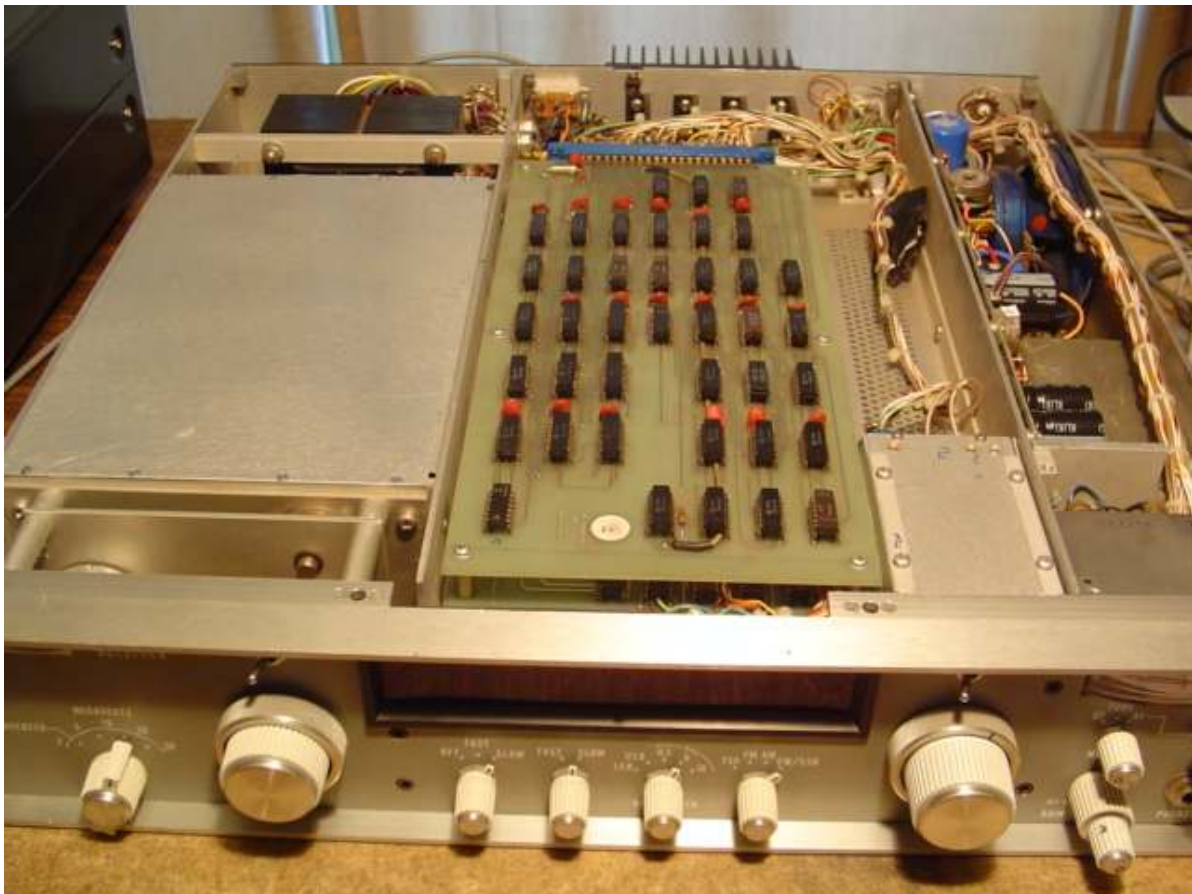


This is a photo of the front panel of my Model 1230. From left to right the controls are:

- Bandswitch. The bands are 2-5, 5-10, 10-20 and 20-30 MHz.
- Main tuning. This knob drives a four-section variable capacitor using steel dial cord and gears. The small toggle switch above this knob locks the coarse tuning to 1 kHz harmonics of an oven controlled oscillator.
- AGC control, OFF, FAST and SLOW times.
- Counter timing, FAST (0.1 sec) and SLOW (1 sec). With the fast setting the display reads to the nearest 10 Hz frequency. With the slow setting the display reads to the nearest Hz.
- Bandwidth. This selects an IF filter for reception. The selections are: LSB, USB, 0.5 kHz, and 6 kHz which are Collins mechanical filters and 16 kHz, an LC filter.
- MODE. The selections are FSK, FM, AM and CW/SSB

- Fine tune. Fine tuning tunes the second IF oscillator and has a range of about 40 kHz. The toggle switch above the knob allows the tuning to be locked at 1 Hz increments.
- Gain control, a concentric knob with RF and AF gains.
- The two small knobs near the meter control the meter function (RF, AF or tuning) and audio outputs 1 or 2.

Construction



This is the top view of the receiver. The large shielded box on the left is the tuner. The small box on the right is the second oscillator. The printed circuit board in the center is one of two logic boards. There is a second logic board below this one. These boards control the frequency counting, display and frequency lock functions. In all there are 101 TTL chips in plug in sockets on these two boards. I

checked each of these chips and found many that were installed with bent under pins which I had to remove, straighten and reinstall.



This is the bottom view of the receiver. It contains the analog board. You can see the four mechanical filters towards the back of this board.

Circuit Description

Front end (Raytheon calls this the Tuner).

The signal from the antenna connects to the tuner which is in the shielded enclosure. It consists of three tracked, tuned circuits, one before the RF amplifier and two after. The RF amplifier is unusual in that the band switch not only selects the tuning coils, but also switches in one of four different RF amplifiers, one for

each band. These must have been designed to have optimal sensitivity in each of the four bands. RF tuner gain can be adjusted on the front panel. From there, the signal goes to the first mixer, a double balanced diode unit. The first oscillator is controlled by the coarse tuning control and is tuned by the fourth section of the main capacitor.

First IF

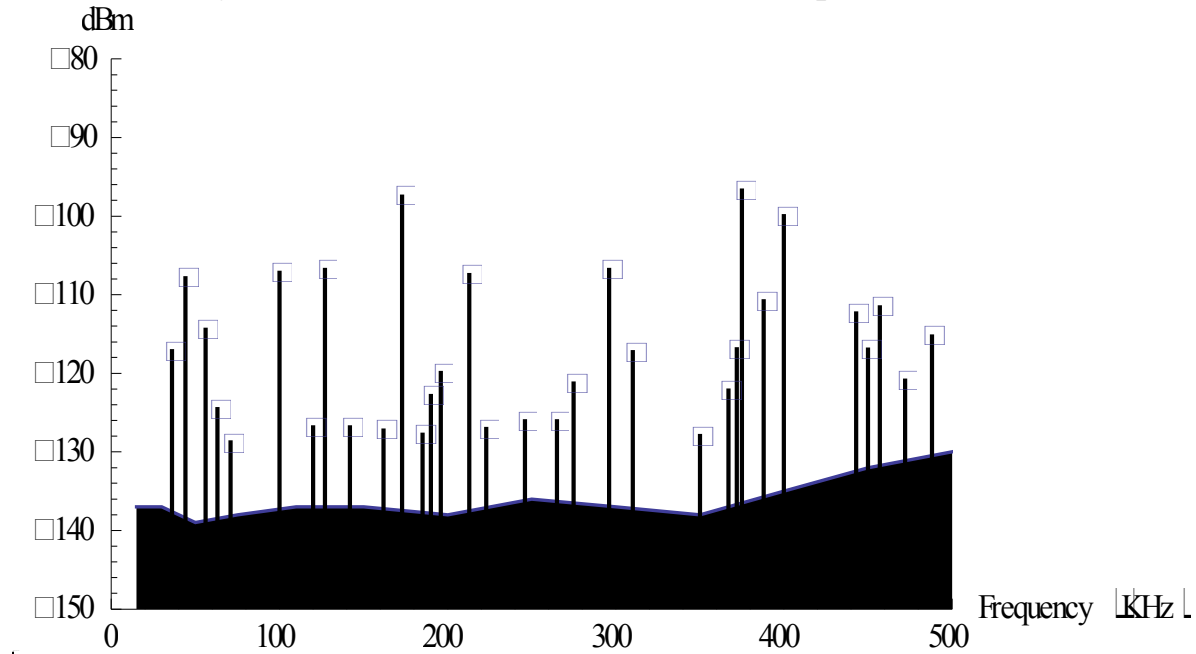
The first IF operates at 1750 kHz and has a bandwidth of 40 kHz. The second local oscillator is tuned by the fine tuning knob and has a range that allows the signal to be tuned in the first IF bandwidth. There are three first IF amplifiers, but they have a 40 kHz wide bandwidth so the narrow dynamic range will probably not be too good.

Second IF

The second IF is 500 kHz. Four Collins filters and an LC filter are used for final bandwidth selection. The Collins filters are the same as were used in the Collins 51S1 receiver. The bandwidths are 16 kHz (LC filter), 6 kHz, LSB, USB and 500 Hz, mechanical filters. The 500 Hz filter has its response offset by 1000 Hz to give a beat note of that frequency.

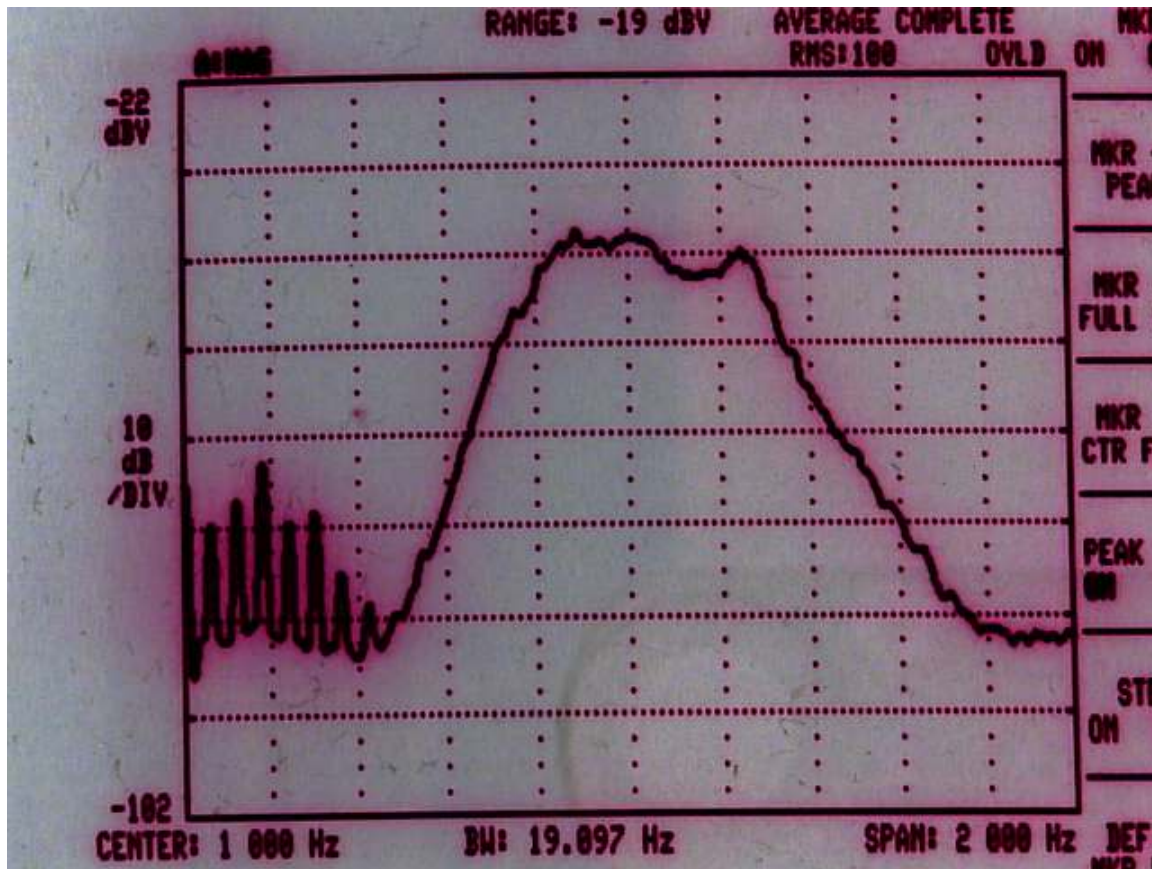
Sensitivity

Raytheon Model 1230 Noise Floor with spurs



Sensitivity is excellent at an average of about -136 dBm. For a tuned front end, this is an impressive sensitivity. For example, the Eddystone and SAIT receivers tested had tuned front ends and average sensitivities of only -95 and -100 dBm. The downside in this receiver are spurs. I found 32 in the range tested. This is probably due to the large number of TTL chips working on the two digital boards.

Filters



This is a photo of the spectrum analyzer output of the receiver when tuned to a random noise source. Vertical divisions are 10 dB and horizontal divisions are 200 Hz. This is the 500 Hz CW filter in the receiver. You can see some digital noise and hum in the LF part of the spectrum. There is more work to be done with bad capacitors I suspect.

The bottom line:

- Construction quality – Good
- LF Sensitivity – Excellent at about -136 dBm
- LO Noise – None because of upconversion
- Internally generated spurs – Poor
- Filter selection – Good
- Tuning resolution – Analog, excellent
- Frequency display – 1 Hz – Excellent
- LO stability – Superb when both controls are locked to the built in oven controlled crystal oscillator
- BFO – Fixed at 1 kHz, fair. The receiver must be detuned so that the signal is about 1 kHz away to get the correct BFO frequency. There is no actual BFO.
- Noise blanker – Not an option.
- Display noise - I had to keep my portable receiver at least 12 inches away for reception of a weak beacon. – Good.

Performance

When tuning in the shortwave bands, this is a very sensitive receiver. Better than the ICOM IC-R9000, Racal RA6793A, Harris RF-590 and about equal to the NRD-545 or my modified NRD-525. When listening using side band detection there is more work in tuning. I had to first get the coarse tuning on the station, then lock the coarse tuning and finally adjust the fine tuning. The audio however is excellent in both side band and AM modes.

ARRL Frequency Measuring Test (FMT)

Several times a year, the ARRL runs a frequency measuring test. Hams try to measure accurately transmitted signals using whatever means they can come up with. I have participated in these tests using the Harris RF-590 along with the HP3561A and generally can measure the transmissions to better than one Hz

accuracy. On one of these tests I used the Raytheon model 1230 with no added equipment. Prior to the test, I set the oven oscillator accurately since it had drifted some over the 40 plus years since it was built. During the test I just zero beat the transmitted signals using the audio output and listened with headphones. I was accurate to one or two Hz. Pretty impressive for a 40 plus year old receiver. Most hams use GPS or rubidium frequency standards and SDR receivers and don't do much better than this. Doppler shifts due to changing ionospheric conditions limit the accuracy no matter how accurate your equipment might be.

Availability

It's doubtful that you will ever see a working Model 1230 for sale. If you want one and see one for sale that isn't working, be prepared for a lot of work to get it going. If you like electronic puzzles as I do it will be a fun project.

Chapter 6

Watkins-Johnson DMS-105R

Tunable Demodulator



Here is a receiver that isn't called a receiver. It's called a "Tunable Demodulator". The tuning range covers the LF spectrum and it makes a good receiver in that range.

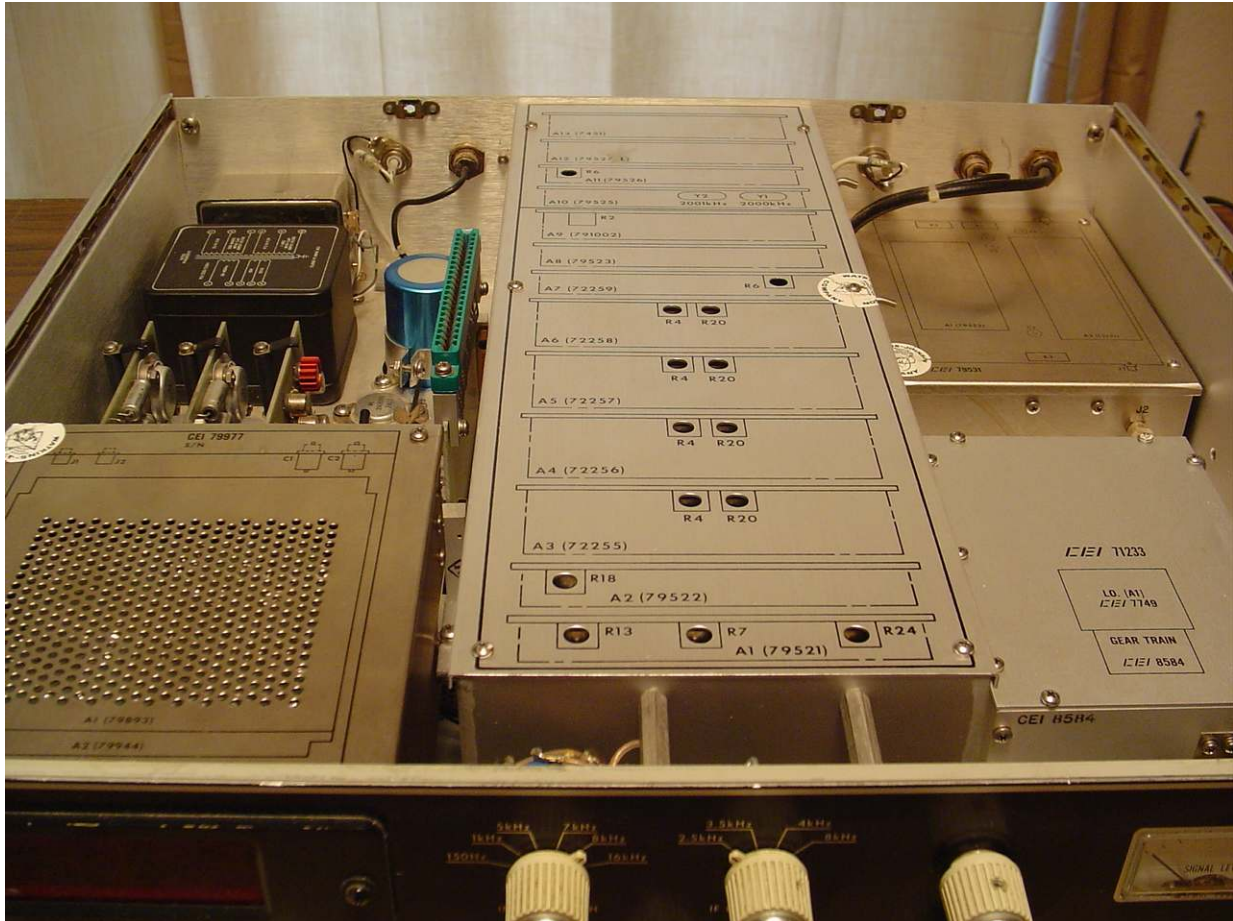
Description

These units are rare. I've never seen another one for sale since I purchased this one. I bought it from a Canadian surplus outfit. I will give a more complete description in this review since there are no other reviews for it available.

This piece of equipment was designed to follow another receiver and tune to that receiver's IF frequency to provide filtering and demodulation. It has a good selection of filters and several choices of demodulation methods. It tunes from 1 kHz to 1600 kHz in two bands: 1-600 and 540-1600 kHz. This reception frequency is converted to an IF frequency of 2.0 MHz by an analog local oscillator. There is only this single IF frequency. There are six IF crystal filters of bandwidth 150 Hz, 1 kHz, 5 kHz, 7 kHz, 8 kHz and 16 kHz. In addition, single sideband filters are available with bandwidths 2.5 kHz, 3.5 kHz, 4 kHz and 8 kHz which are four of the above crystal filters sliced in half. The BFO offset frequency can be selected from three options: variable, 1 kHz or zero. The tuned frequency is displayed on a five digit LED display. The user has a choice of two displays: XXX.XX or XXXX.X. A form of frequency control called DFC is included that locks the last tuning digit to a selected number from 1 through 10.

This unit is Tempest Qualified which means that it emits no external radiation that could be intercepted by a nearby Tempest receiver to let someone eavesdrop on that external radiation to learn the tuned frequency or the content of the received signal of this receiver.

Construction Quality

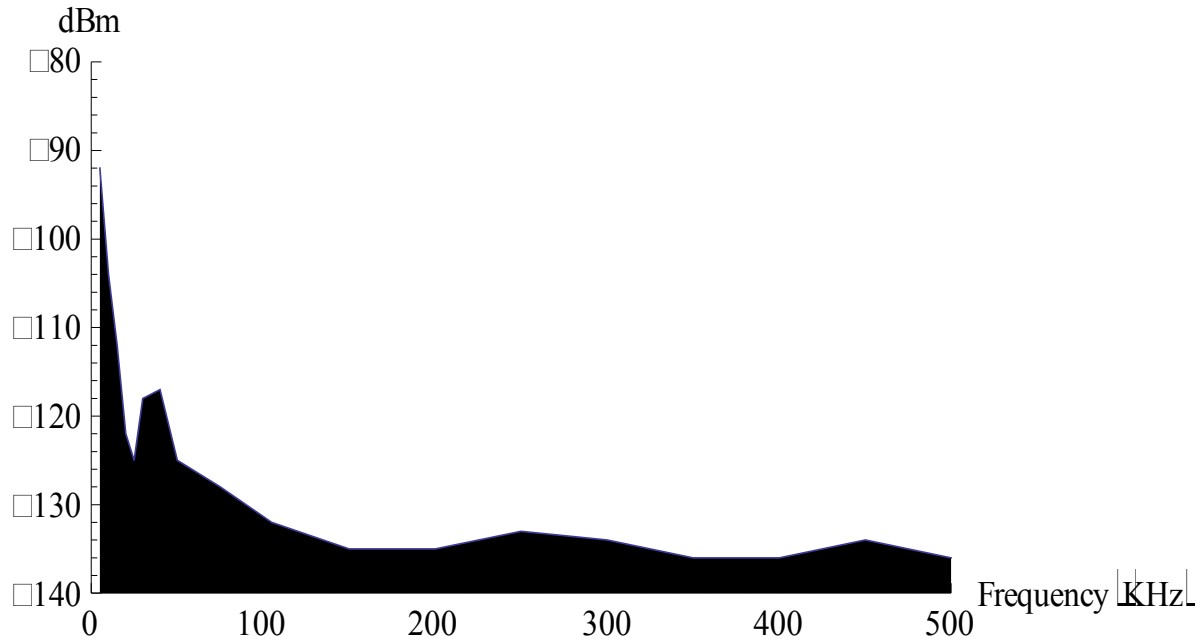


Construction

This is a piece of equipment that was built with mil-spec requirements in mind. All signal circuit boards are well shielded and connected with MB (miniature bayonet) connectors. Tuning is done with ball bearing anti-backlash gearing of a variable capacitor and is very smooth. A fine-tuning control is included that uses a varicap diode. The receiver consists of many units that can be easily swapped with spare units to do repairs in the field quickly and easily.

Sensitivity

WJ DMS105R Noise Floor

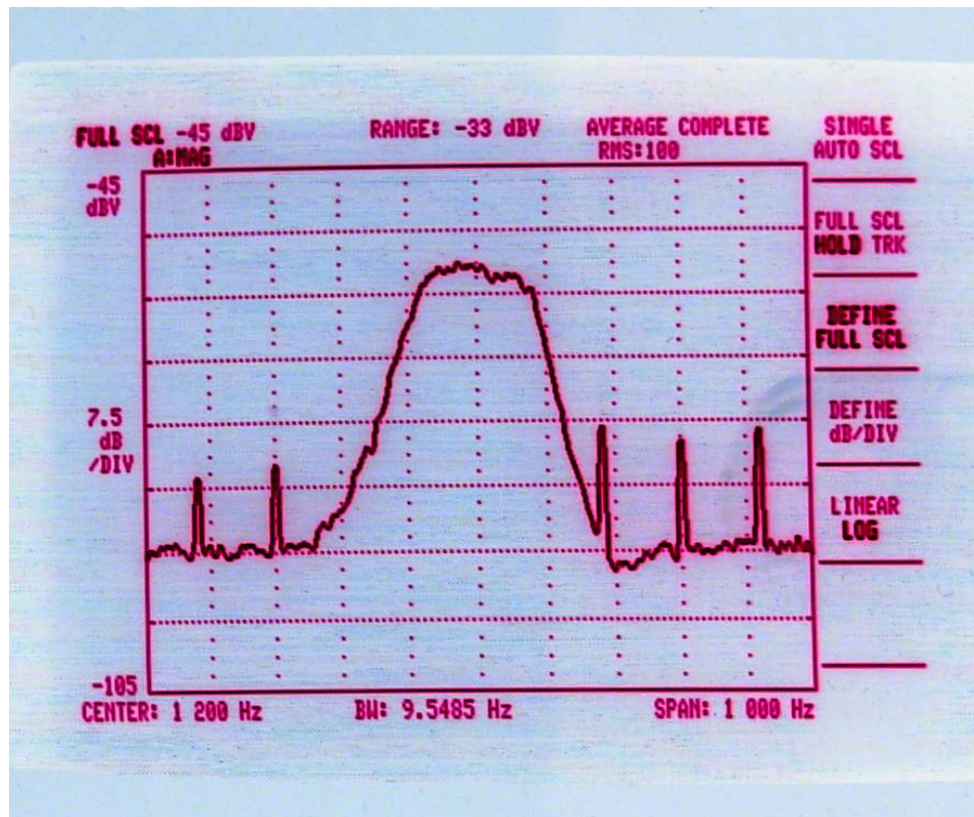


I tuned from 1 kHz to 500 kHz looking for spurs. However, you won't see any spurs on this graph, because none were found.

Filters

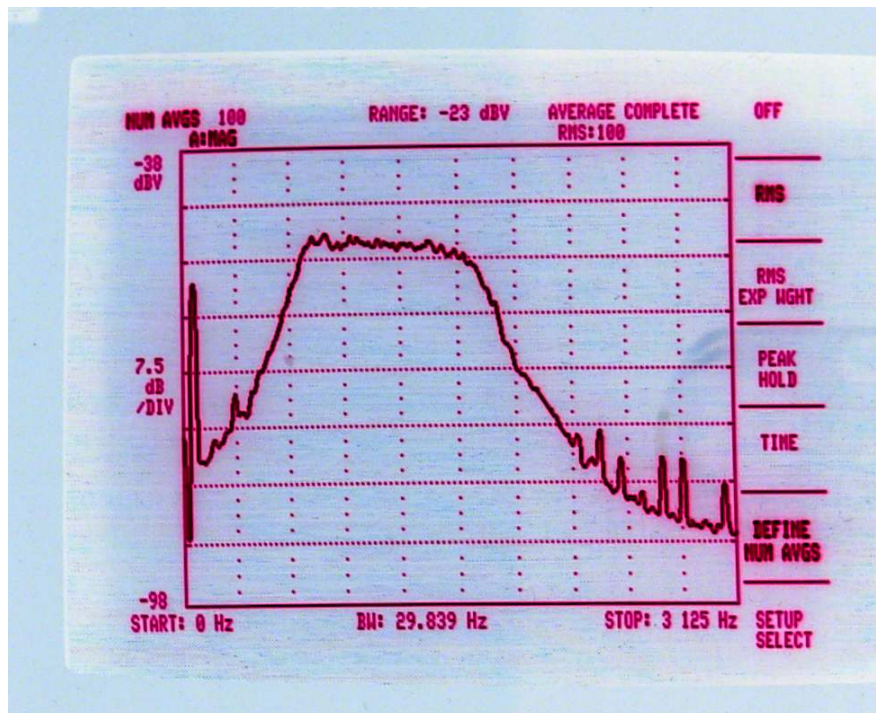
There are six filters that can be selected that could be used for CW reception. However only the first two, 150 Hz and 1 kHz are likely to be useful to LF DXers.

Here is the spectrum obtained from the 150 Hz filter:



In this display, vertical divisions are 7.5 dB, and horizontal divisions are 100 Hz. You can see spikes at 120 Hz intervals. This is 60 Hz harmonic noise from the power supply. It isn't obvious in the audio output. Out of band noise is high and is down only about 40 dB from the filter peak.

Here is the spectrum of the 1 kHz filter:



In this display, vertical divisions are 7.5 dB, and horizontal divisions are 310 Hz.

The bottom line:

- Construction quality – Excellent. First class mil-spec.
- LF Sensitivity – Excellent. This is a sensitive receiver. Average sensitivity is about -135 dBm.
- LO Noise – Excellent. Typical of analog tuned oscillators.
- Internally generated spurs – Superb. There are none.
- Filter selection – Good. Some out of band noise is present.
- Tuning resolution – Poor. The analog tuning is too fast. Even the fine tuning control which uses a varicap is too fast. I changed the varicap voltage control to a 10 turn pot which helps.
- Frequency display – Good at 10 Hz. Fair at 100 Hz.
- LO stability – Good for an analog tuner.

- BFO – Poor. The variable option drifts and is unstable. The crystal controlled 1 kHz position would be useful if was changed to a lower frequency.
- Noise blanker – Not available.
- Display noise – Superb. None detected. Tempest qualified rating insures this.

Performance

The lack of a noise blanker, 10 Hz display and drifty BFO limits this receiver's use for beacons.

Availability

These are very rare. I don't know how many were made. This one is serial number 1 so I suspect not many were ever produced.

Chapter 7

SAIT MR 1411 Communications Receiver



SAIT MR 1411 Receiver

Description

This receiver is a maritime unit designed to function as the main receiver on a large vessel. It covers VLF to 30 MHz with modes AM, CW, USB and LSB. It was manufactured in Britain and the original design was by Hatfield, a British company. These receivers were manufactured by Mentor, also a British company

and sold by SAIT, a Belgium company. For a description see "Shortwave Receivers Past and Present", fourth edition, page 632.

VLF up to 4 MHz reception is best described as contorted. A signal in this range is passed through an RF amplifier and mixer with three tuned filters and then upconverted to the signal frequency plus 10 MHz. This signal is then passed through the normal RF circuits for shortwave frequencies in the range 10 to 14 MHz. All the RF amplifiers and mixer circuits are gang tuned with gears and padding capacitors to tune the LF to 4 MHz frequency range and function as a variable IF. At this point the signal has gone through a total of six ganged tuned circuits. Now there is a second IF which is variable from 2.55 MHz to 2.56 MHz and is used for fine tuning and has its own ganged and tuned filters. There is a third mixer in this circuit which converts the variable 2.55 to 2.56 MHz IF to 455 kHz where final filtering and detection takes place.

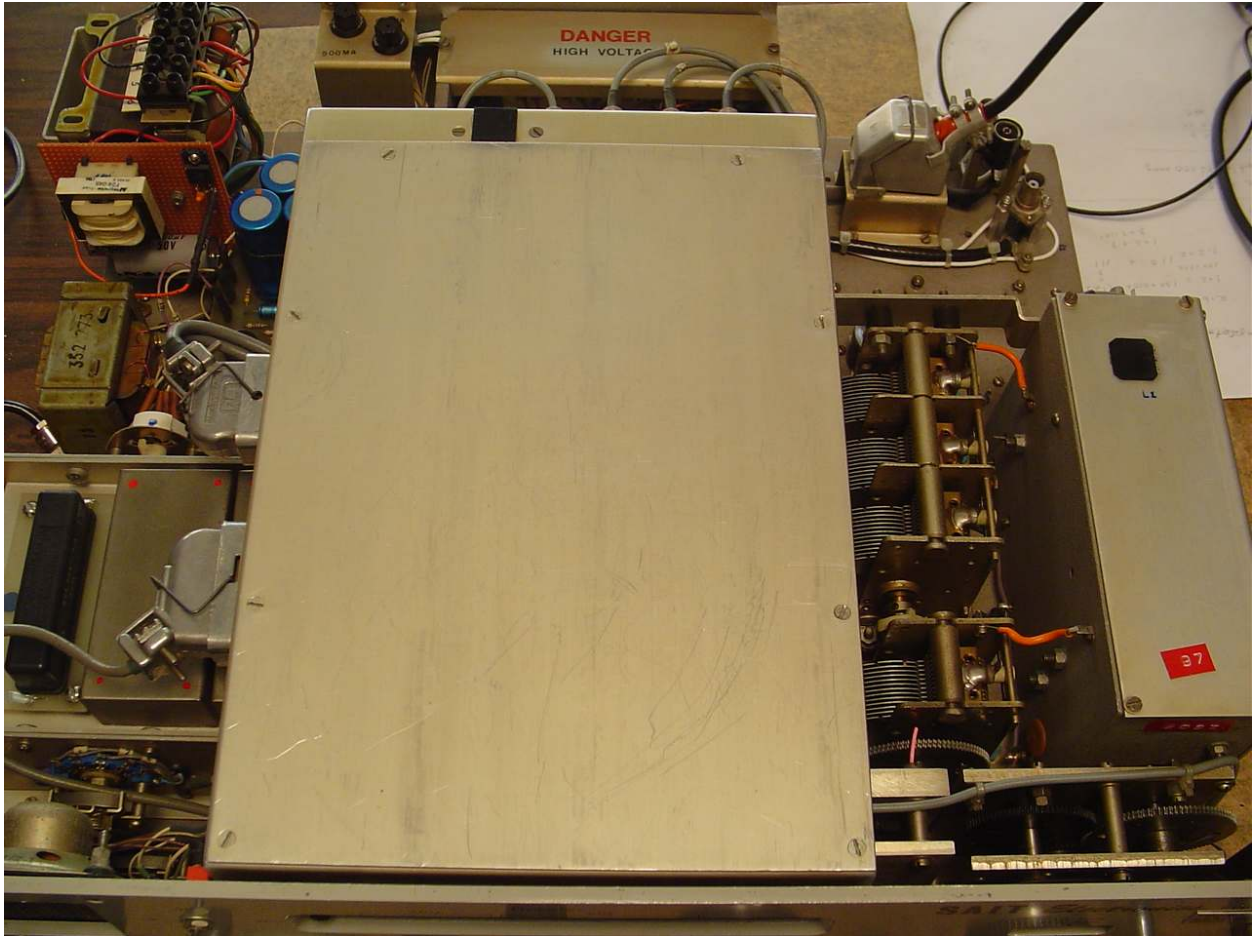
It's possible to lock the frequency of the receiver at 10 kHz points and tune across a 10 kHz range with the fine tuning control. This gives good stability at any frequency and represents an early form of frequency synthesis.

This receiver doesn't have a noise blanker, but does have an IF noise limiter. A noise limiter works by clipping the IF signal above a level set by the operator. It isn't as effective as a blanker but does give some help with high noise levels.

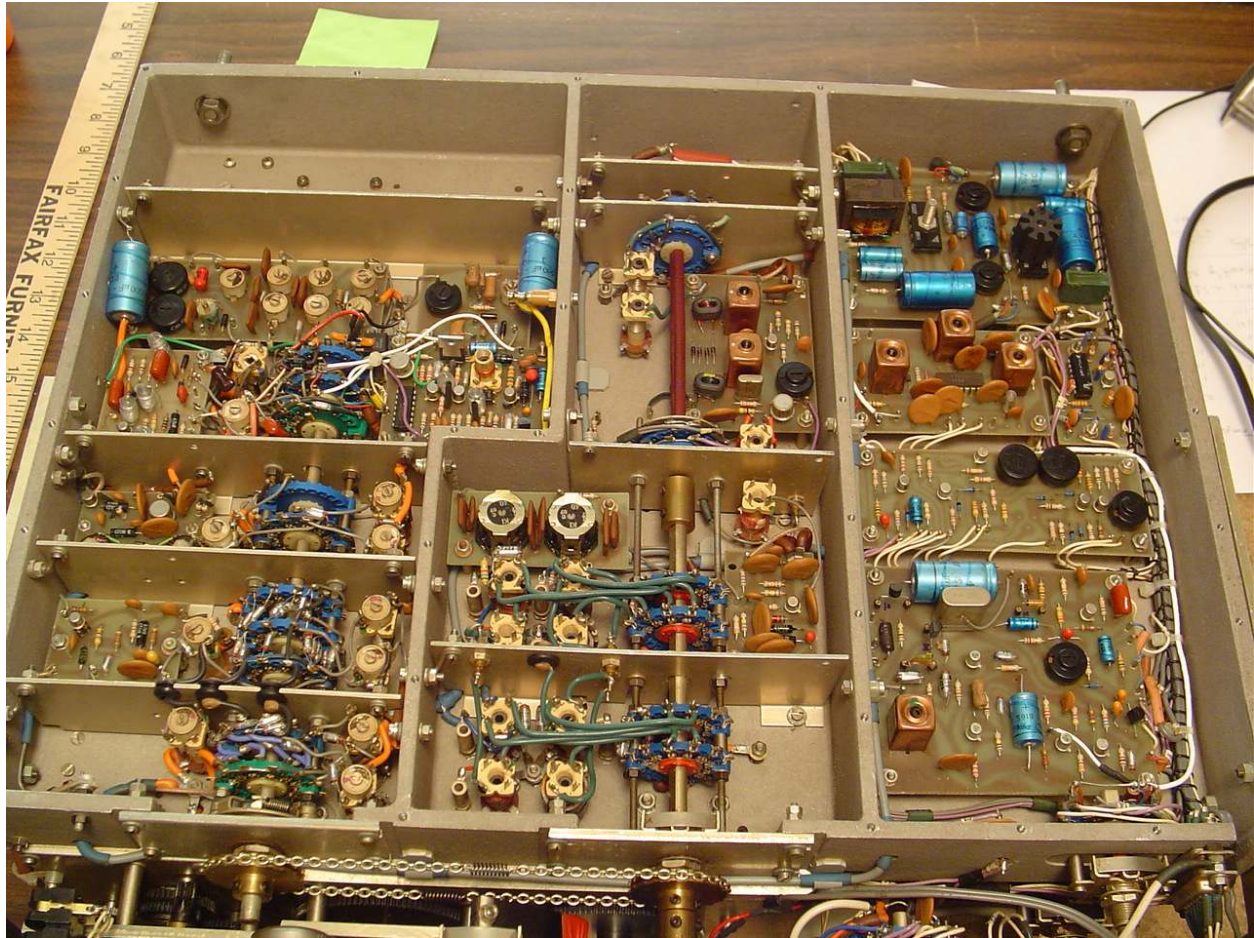
You can imagine what a job it would be to align this receiver. I have tried to do this and have been somewhat successful. However, after alignment there is a tendency for the circuits to change their frequencies once everything has been completed and reassembled leading to less than perfect operation.

Construction Quality

Here are pictures of the top and bottom of the MR 1411 with covers removed.



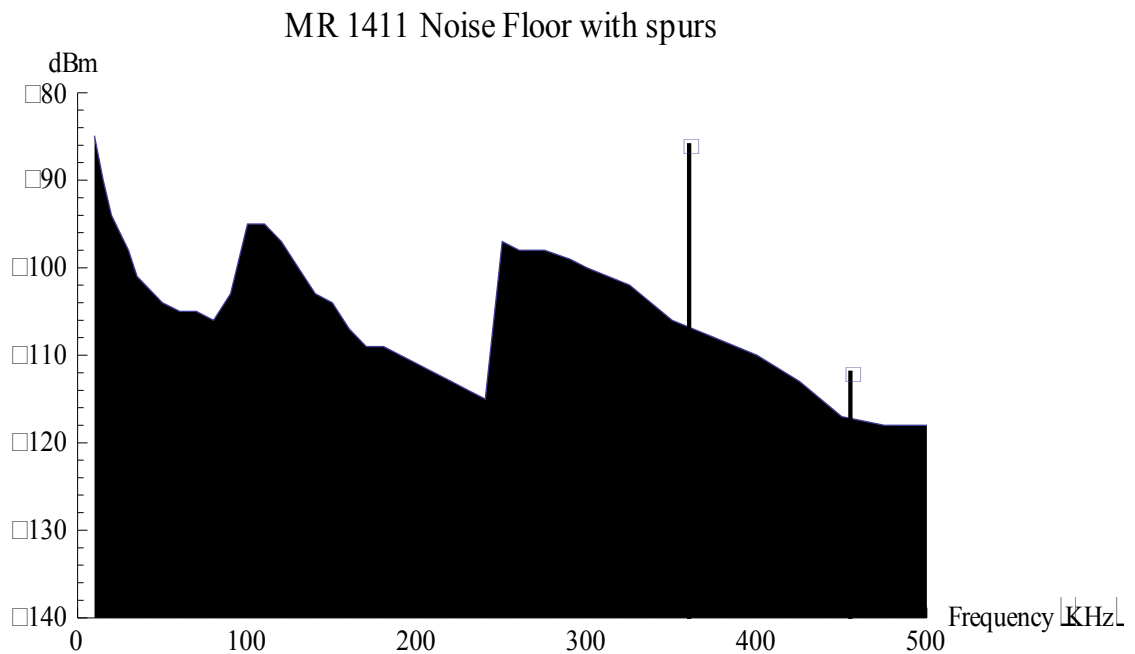
This is the top view of the chassis. The large shield box in the center contains the counter and frequency display circuits. The small box on the right side is the variable IF shield box. You can see one of the four section capacitors between these two boxes. There is a second variable capacitor under the counter shield box which is ganged with gears to adjust it.



This is a view of the bottom of the chassis. You will be able to see many of the RF coils in this view.

Construction quality is excellent. The chassis is die cast aluminum with all sensitive circuits contained in separate shielded compartments. It's a heavy receiver with lots of aluminum and weighs 50 pounds. Solid and well built.

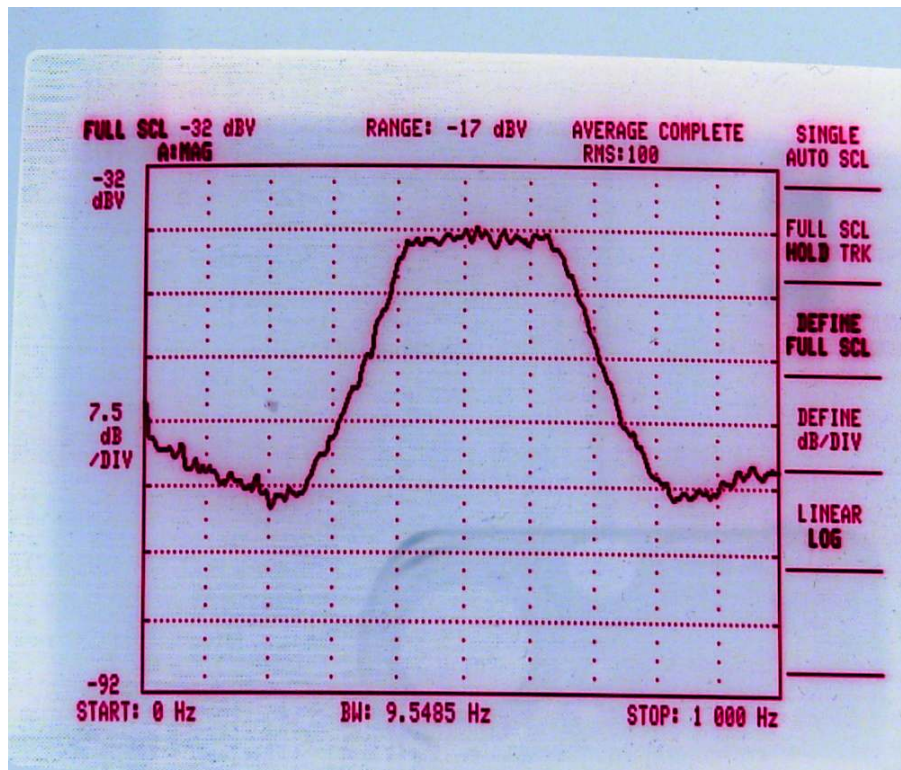
Sensitivity



You can see where the bands start and end by looking at the sensitivity. The VLF band ends at 100 kHz; the next band ends at 250 kHz and the next band goes up to 600 kHz. Tracking is difficult to maintain at the start of each band so the sensitivity is less there.

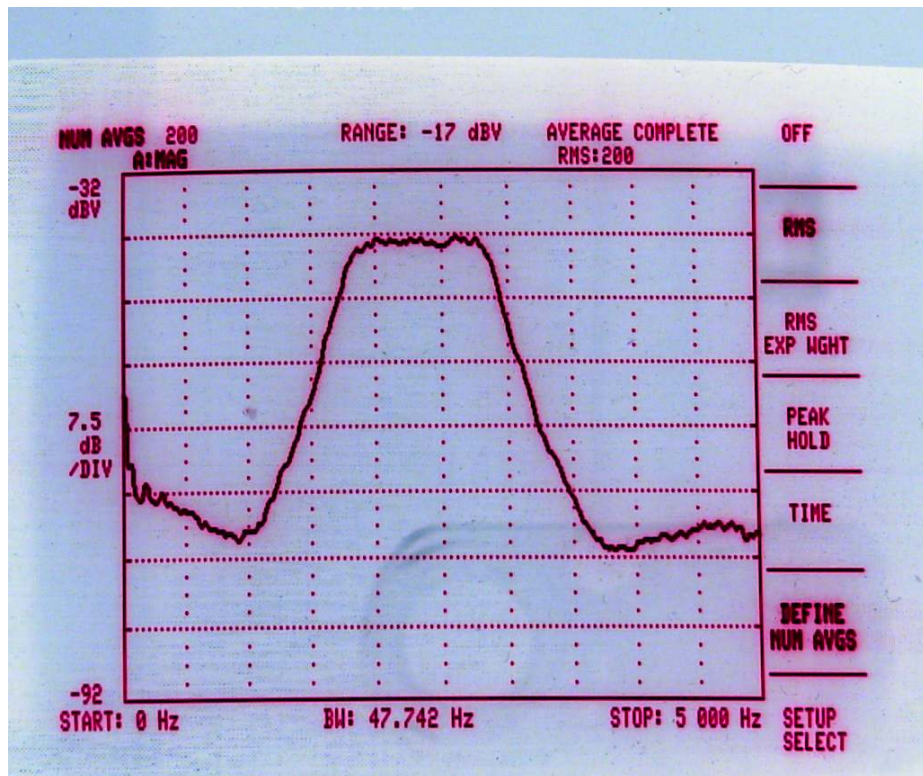
For the MR1411 only two spurs were found which is an excellent result reflecting the care that went into shielding. One spur is at 360 kHz and one is at 455 kHz which is leakage of the BFO back into the signal path.

Filters



This stated bandwidth for this crystal filter is 400 Hz.

All filters are mounted right on the switch that controls the bandwidth leading to a clean filter response. There is no need for switching diodes, relays or wiring in this arrangement.



This is a spectrum analyzer plot of the receiver's 1 kHz crystal filter. Again, the spectrum is very clean with very little out of band noise.

The bottom line:

- Construction quality - Excellent
- LF Sensitivity – Fair to poor. If the beacon you are DXing is just above one of the band change frequencies, sensitivity will be poor.
- LO Noise – Analog LO, no phase noise is apparent. Excellent
- Internally generated spurs – Only two. Excellent
- Filter selection - Good
- Tuning resolution – Analog fine tuning of 10 kHz bands. Fair. There is sometimes a problem getting the frequency to lock correctly. Also, the main tuning knob requires many turns to go from one end to the other. This makes changing bands a chore.
- Frequency display – 10 Hz resolution on nixie like displays - Good
- LO stability – When locked to 10 kHz points – Good.

- BFO – Analog, good stability, no readout except on the knob – Fair
- Noise blanker – This receiver has an IF noise limiter – Fair
- Display noise – I had to keep my portable 6 inches away from the front panel display to hear my test beacon. This is a good rating.

Performance

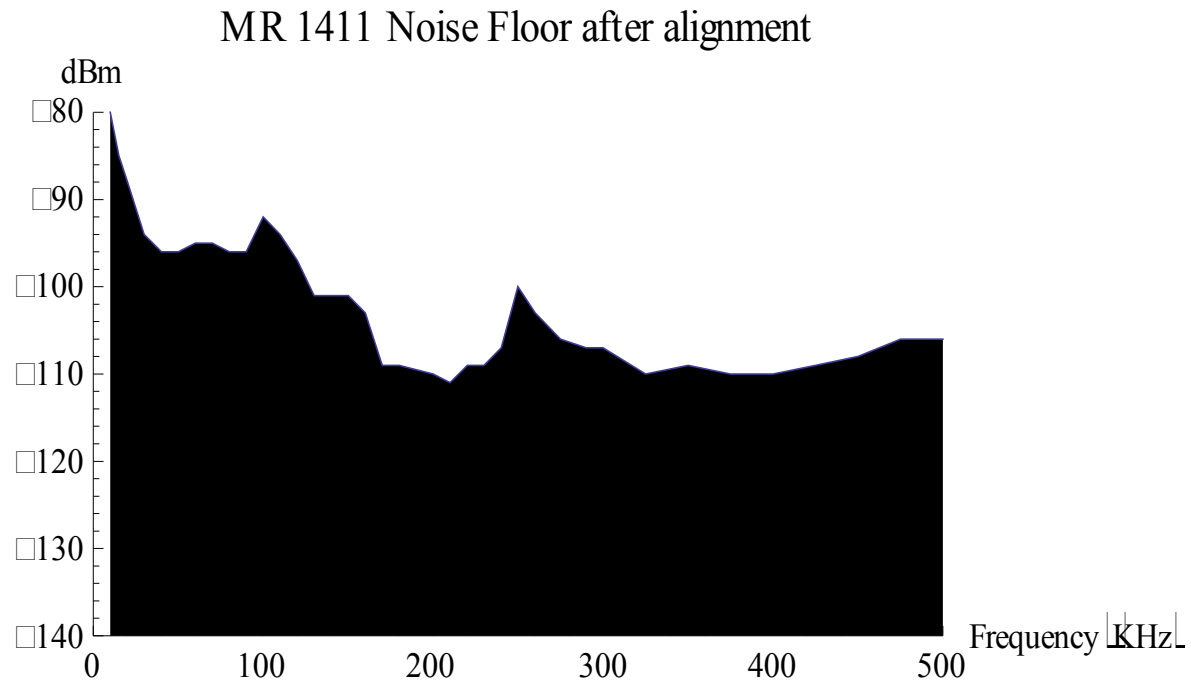
I can't recommend this receiver as a LF DX receiver. The difference in sensitivity when bands need to be changed is too great. In attempting to DX a beacon in Houston that I use for testing I found that the sensitivity was so poor that it was not possible to hear it. On many other receivers it was easily received. This beacon's frequency is just above the 250 kHz band change point where the sensitivity is poor.

Availability

Very rare and seldom seen for sale.

Post Test Alignment

I spent about a week working on re-aligning this receiver. After this effort, here is a revised plot of the sensitivity. Compare with the first sensitivity plot to see the improvement:



This has changed two ratings, LO noise and LF sensitivity. These ratings are now changed to:

- LO noise: Good. There is now what appears to be some LO noise, ending about 200 kHz. This is surprising for an analog oscillator; however, the phase locking frequency control may be adding some phase noise.
- LF sensitivity: Fair at an average of about -110 dBm.

This exercise points out how important tracking alignment is in these older receivers. They need a lot of TLC.

Chapter 8

Harris RF-550 Communications Receiver



Harris RF-550 Receiver

Description

This receiver must have been designed to function as a communications unit for embassy use since a prominent feature of the set is a phase lock detector for reduced carrier transmissions. This phase lock detector is excellent and can produce high quality audio on shortwave broadcasts. Also, independent side band capability is built in. A lot of effort went into making the receiver sensitive and spur free. The manual states: ***“The RF-550 provides nearly spurious free***

performance. A double conversion design employs a first intermediate frequency (IF) of 158.25 MHz, with crystal filtering near the input of the RF-550.”

We’ll see in the tests that follow that things didn’t turn out as well as the designers had hoped at least in the LF spectrum.

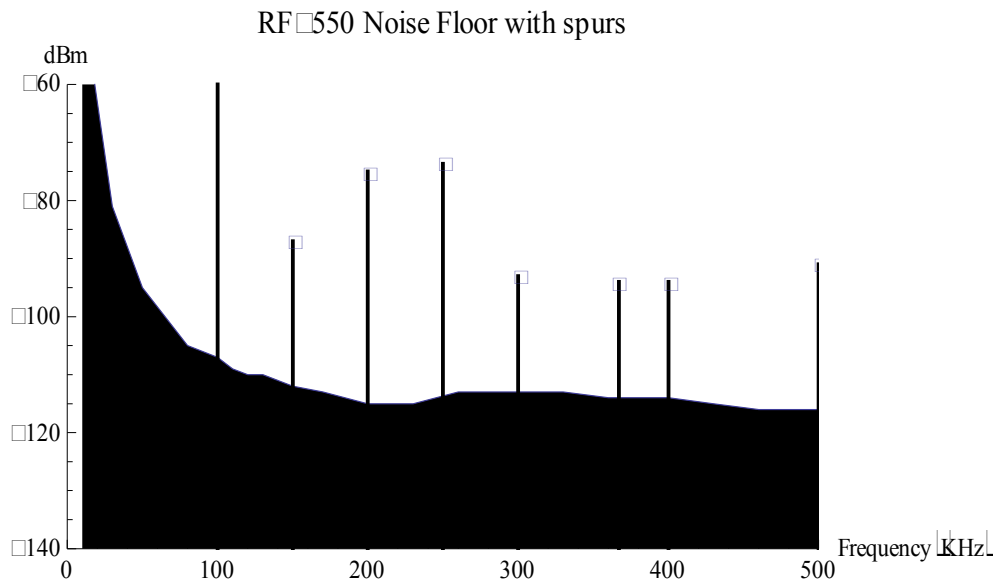
Other items about this receiver:

Tuning is with switches that control each digit in the display. There is no tuning knob except for a fine-tuning control that covers ± 100 Hz. This method of tuning takes some getting used to. This design is used on fixed frequency “set and forget” receivers. Specified coverage is from 100 kHz to 30 MHz. You can find more information in “Shortwave Receivers Past and Present” fourth edition, page 614.

Construction Quality

Construction quality is excellent. Construction is Mil-spec with lots of shielding. All internal components are on circuit board plug in cards or plug in shielded boxes that can be easily and quickly replaced. This set’s weight is 45 pounds.

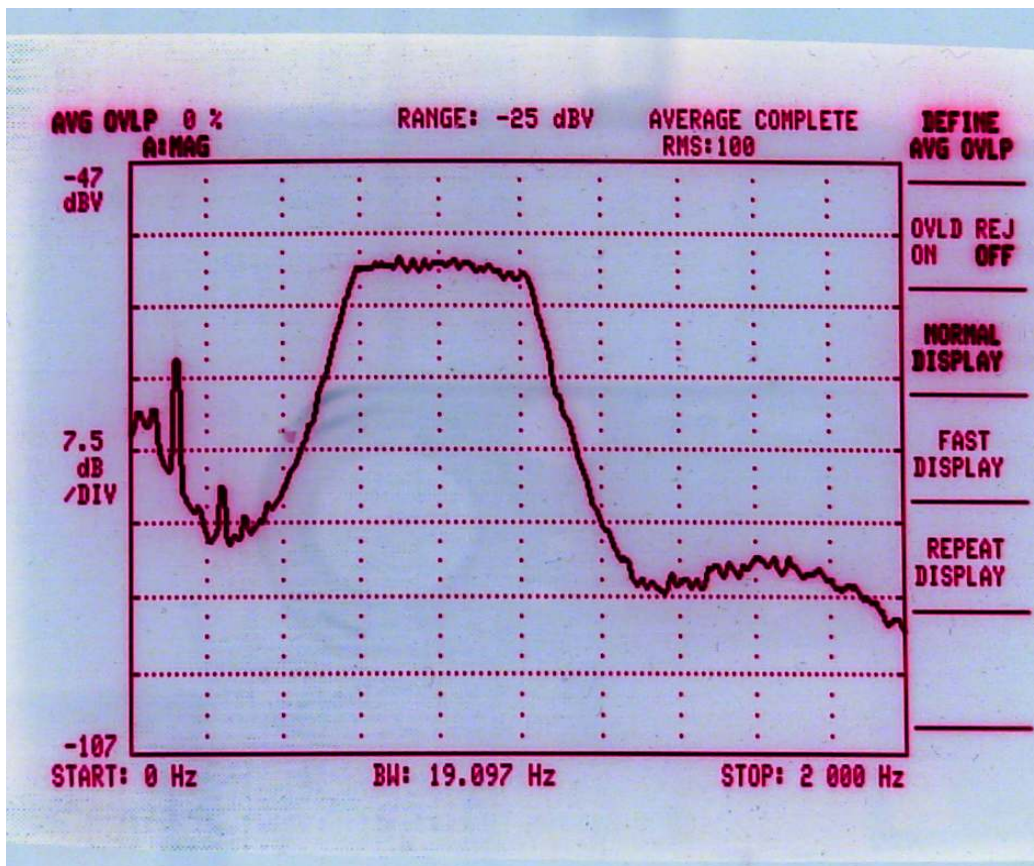
Sensitivity



I did not display the spurs below 100 kHz. There was one at each kHz and the plot would be too confusing. These became smaller in amplitude when 100 kHz was reached. The receiver's low frequency specification is given in the manual as 100 kHz and these spurs are probably the reason for that spec. There are eight spurs between 100 and 500 kHz. This is a good rating for this receiver, but far from what the manual stated.

Filters

This is a photo of the spectrum analyzer output of the receiver when tuned to a random noise source. Vertical divisions are 7.5 dB and horizontal divisions are 200 Hz. This stated bandwidth for this crystal filter is 500 Hz.



Other filters are for voice reception and aren't suitable for CW use.

The bottom line:

- Construction quality - Excellent
- LF Sensitivity – Good. Sensitivity averages about -113 dBm from 100 to 500 kHz.
- LO Noise –Fair. Phase noise is high close to zero, but drops rapidly, and is gone at 200 Hz.
- Internally generated spurs – 8 from 100 to 500 kHz, a good rating; 90 from 10 to 100 kHz, a poor rating.
- Filter selection – Fair. The only useable filter for CW is 500 Hz.
- Tuning resolution – Fair at 100 Hz. There is also a geared analog knob for fine tuning that works well, however calibration may not be too accurate.
- Frequency display – 100 Hz resolution on LED displays – Fair. The fine-tuning knob has marking at 10 Hz increments.
- LO stability – Crystal controlled. Good
- BFO – Analog, good stability, but no readout except on the knob – Fair. The BFO also has a geared tuning knob with 10 Hz markings.
- Noise blanker – Not available.
- Display noise – I had to keep my portable 1 inch away from the front panel display to hear my test beacon. This is an excellent rating.

Performance

This receiver wasn't designed to be a CW receiver and isn't a good choice to DX beacons. If you're into broadcast band or shortwave listening however, this is a receiver to consider. The phase lock system gives superb synchronous detection. The phase lock synchronous system locks and holds on to a carrier better than the Sherwood Engineering SE-3 synchronous detector I have. The carrier for phase locking passes through the 500 Hz narrow CW filter before it is used by the phase detector. There is also an option to base the AGC on this carrier called "Coherent AGC". Audio performance is good using synchronous detection.

Availability

Rare and seldom seen for sale.

Chapter 9

Harris RF-590 Communications Receiver



This is one of my favorite beacon receivers. I have owned it for many years, and it has always been a solid, reliable performer. I have done several modifications to improve it for LF:

Post IF filtering Lowdown, January 2003, page 23

Noise blanker Lowdown, June 2001, page 19

 Lowdown, September 2002, page 15

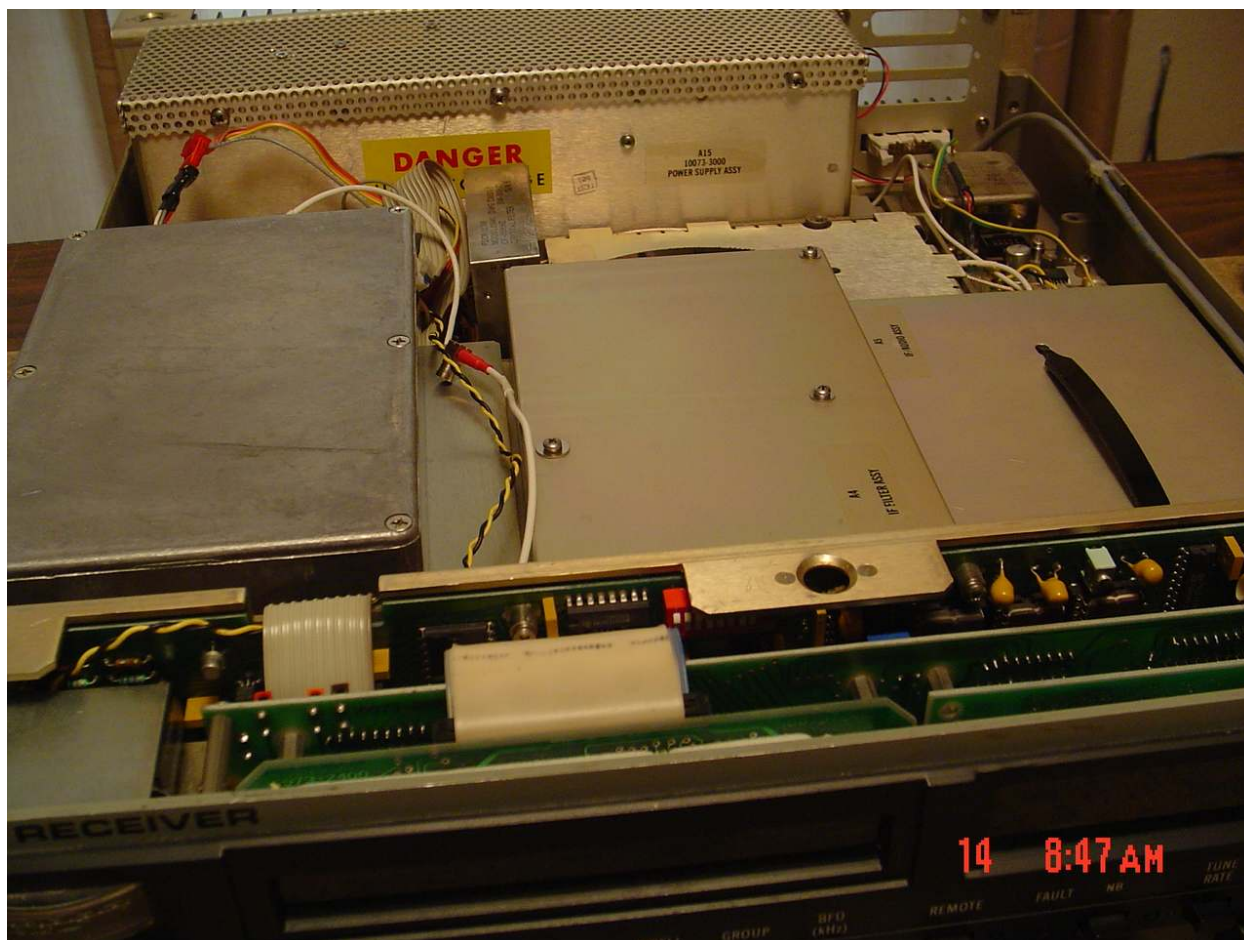
VLF improvement Lowdown, August 2006, page 18

Description

The RF-590 is a high quality general purpose communications receiver mainly designed for government and military uses. A description of it can be found in *Shortwave Receivers, Past & Present*, fourth edition, page 614.

Construction Quality

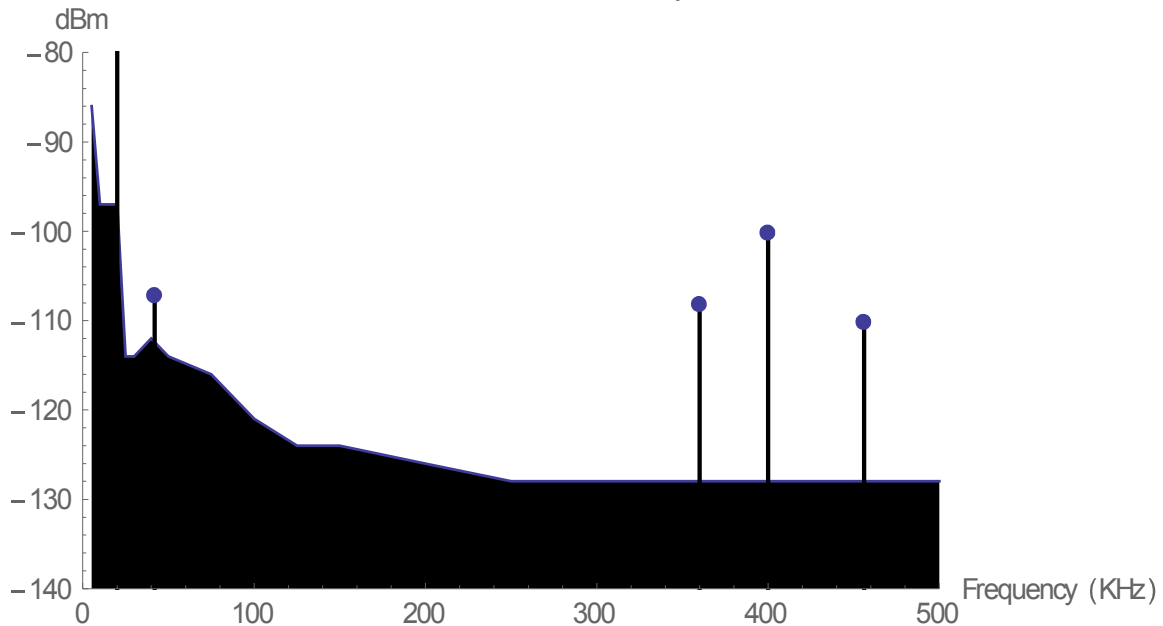
Below is a photo of the RF-590 inside view with the top cover removed. Construction is mil-spec, indicating best commercial practice. Notice that most circuit boards have shields around them. The large box on the left isn't standard. It's my homebrew noise blanker. The other boxes contain circuit boards.



This is a quiet receiver, having only five spurs as you will see in the sensitivity graphic below.

Sensitivity

RF-590 Noise Floor with Spurs

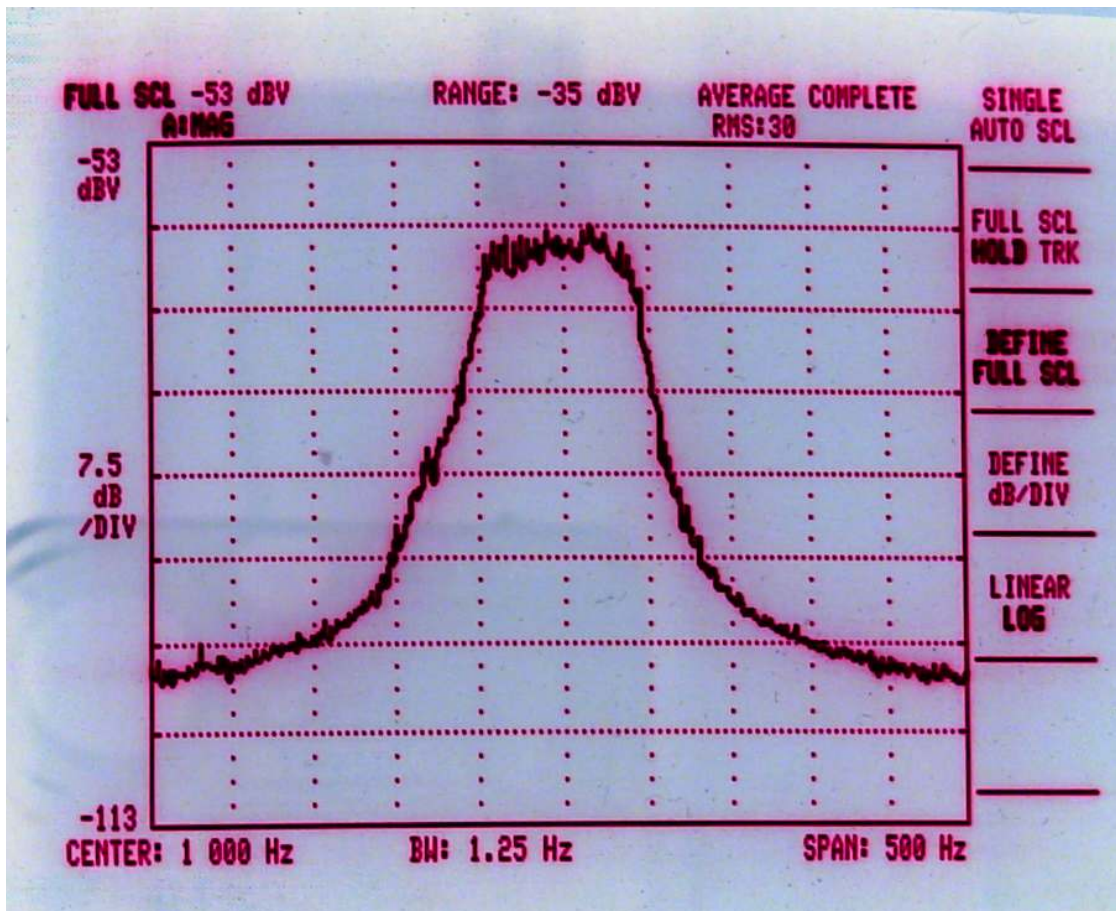


There is some phase noise, which is not large and gone by about 200 kHz.

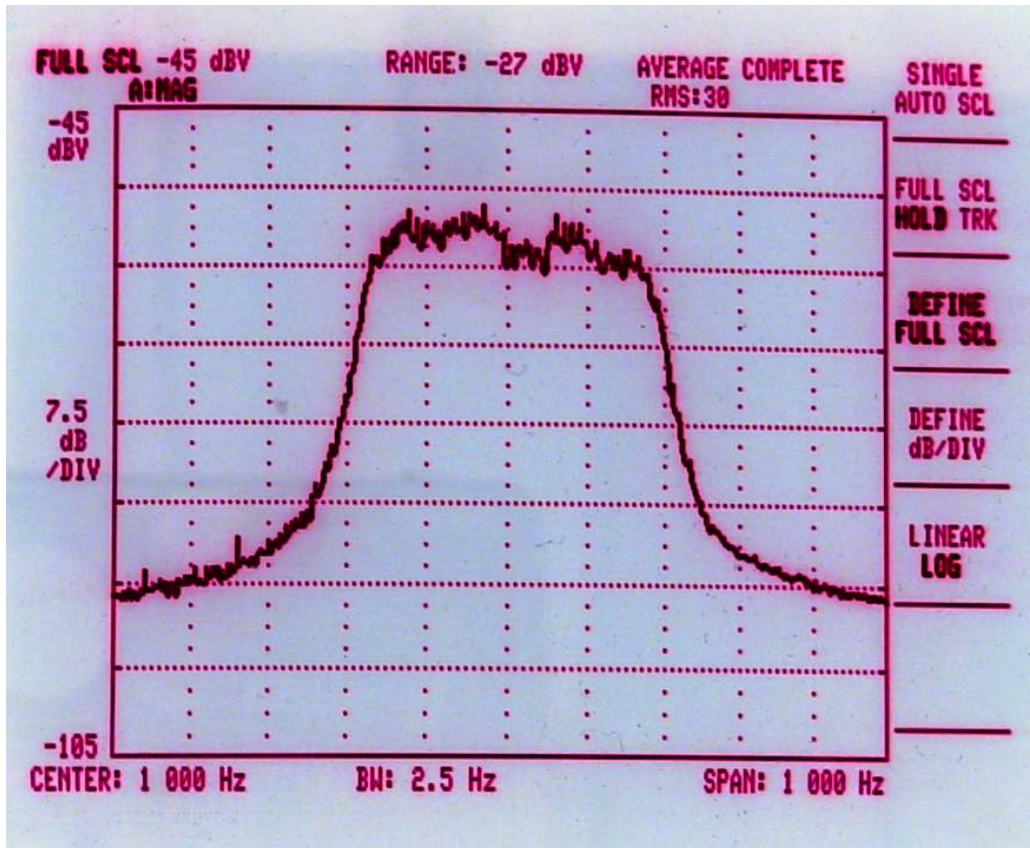
Average sensitivity above 200 kHz is -130 dBm which is a good rating.

Keep in mind that this receiver has had the first mixer replaced with one having better LF characteristics, so an unmodified receiver would not have this good sensitivity.

Filters



This display is of a 100 Hz crystal filter that was added to the receiver. The horizontal divisions are 50 Hz, and the vertical divisions 7.5 dB. This shape factor of this filter is excellent. There is very little filter leakage and ultimate rejection is also excellent. Signals outside the passband will seldom be heard.



This is a plot of the frequency response of the 300 Hz Collins mechanical filter. This is a standard filter in this receiver.

The bottom line:

- Construction quality – Excellent
- LF Sensitivity – Good
- Synthesizer phase noise – Good
- Internally generated spurs – Good
- Filter selection (modified receiver) – excellent
- Tuning resolution – 1 Hz, Excellent
- Frequency display – 1 Hz Excellent
The receiver is tuned by selecting one of the digits on the display
The selected digit will be changed by rotating the tuning knob
- Stability – LO and BFO are controlled by a TCXO, excellent
- Noise blanker – Can be purchased from Harris for about \$3000. I homebrewed my own.
- Display noise – 16 inches. Noisy in this category. Fair rating. If you are using an indoor loop antenna you will find some unwanted interference.

Availability

RF-590s and RF-590As show up for sale occasionally. With a full complement of filters expect to pay \$1000 to \$1500 for the RF-590 model. The 590A model is very close in specs to the 590 but will cost more since it is a later version. The main difference in the two models is in the design of the synthesizer.

Chapter 10

HP 3586C Selective Level Meter

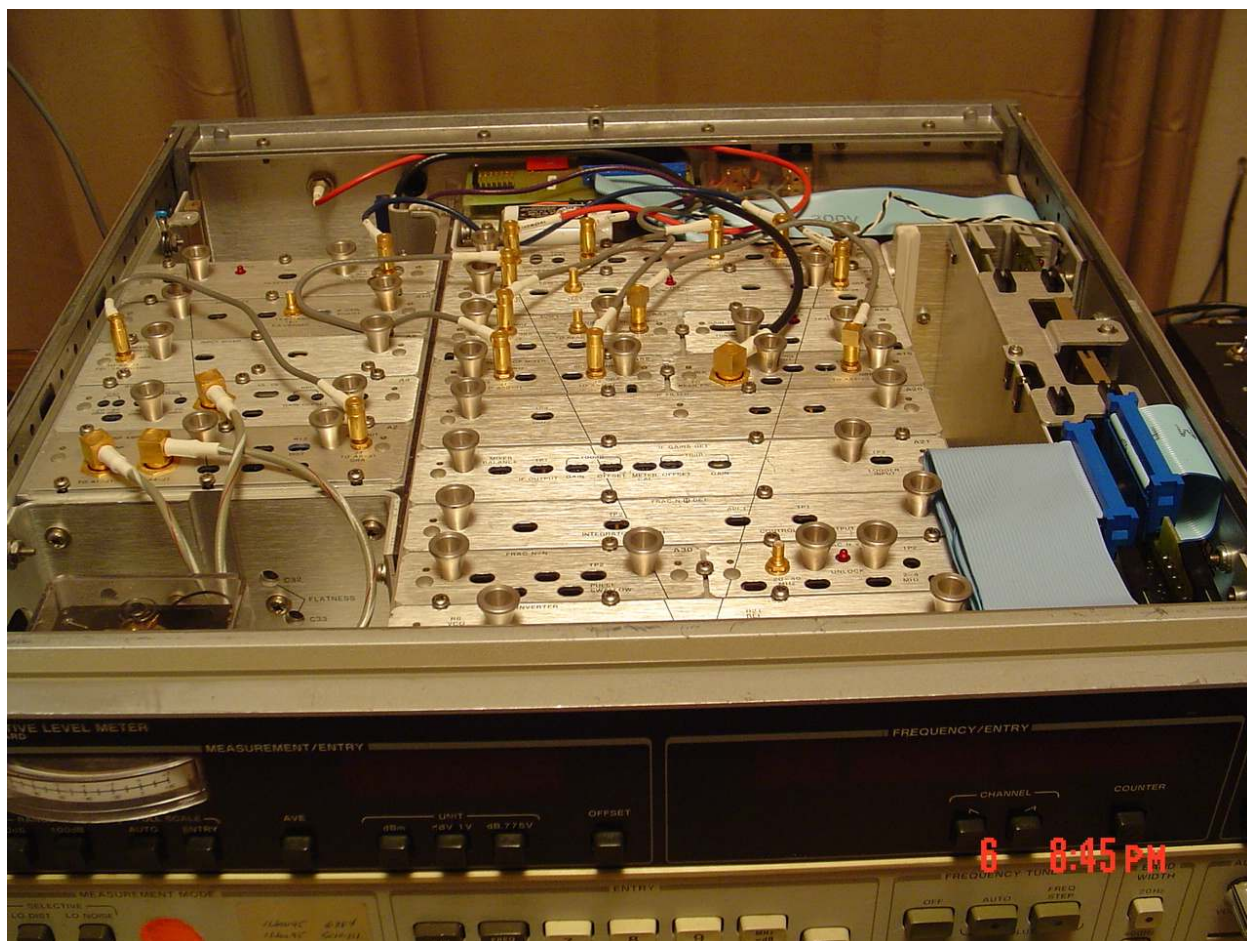


Front panel of HP 3586C Selective Level Meter

Description

This is a piece of test equipment made by Hewlett-Packard for testing of frequency demultiplex systems. It's called a Selective Level Meter and its function is to measure voltages of signals at different frequencies. This piece of equipment was not designed to be a normal receiver. There is no AGC system and the gain varies with the input signal strength. It will take some practice to use it as a receiver.

Construction Quality

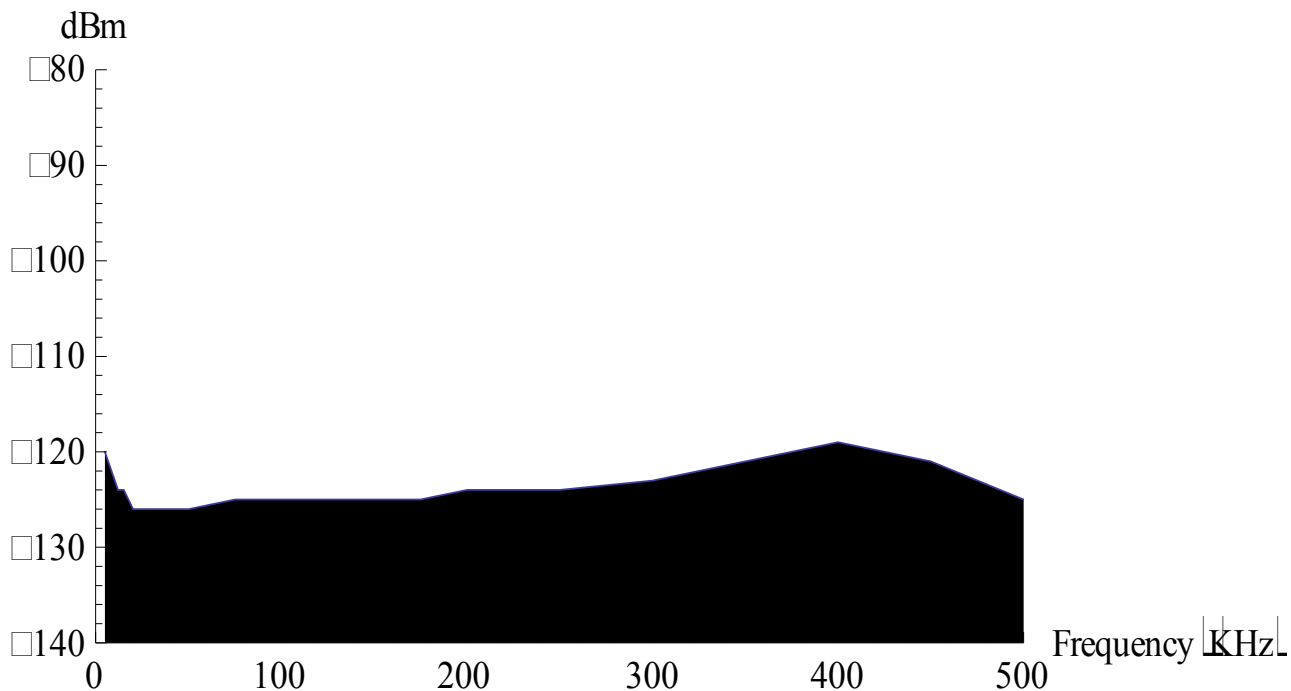


Under the hood of the HP3586C

This is a piece of equipment that is really well designed. It consists of three independent sub-chassis which are isolated from each other with floating grounds. These are the signal processing chassis (left side), the synthesizer (center) and the power supply and display boards on the right. The circuit boards in each of these chassis plugs into its own shielded container. The circuit boards have gold wire traces, and are hooked up with military grade connectors and cables. You will see the results of this careful design in the sensitivity test below.

Sensitivity

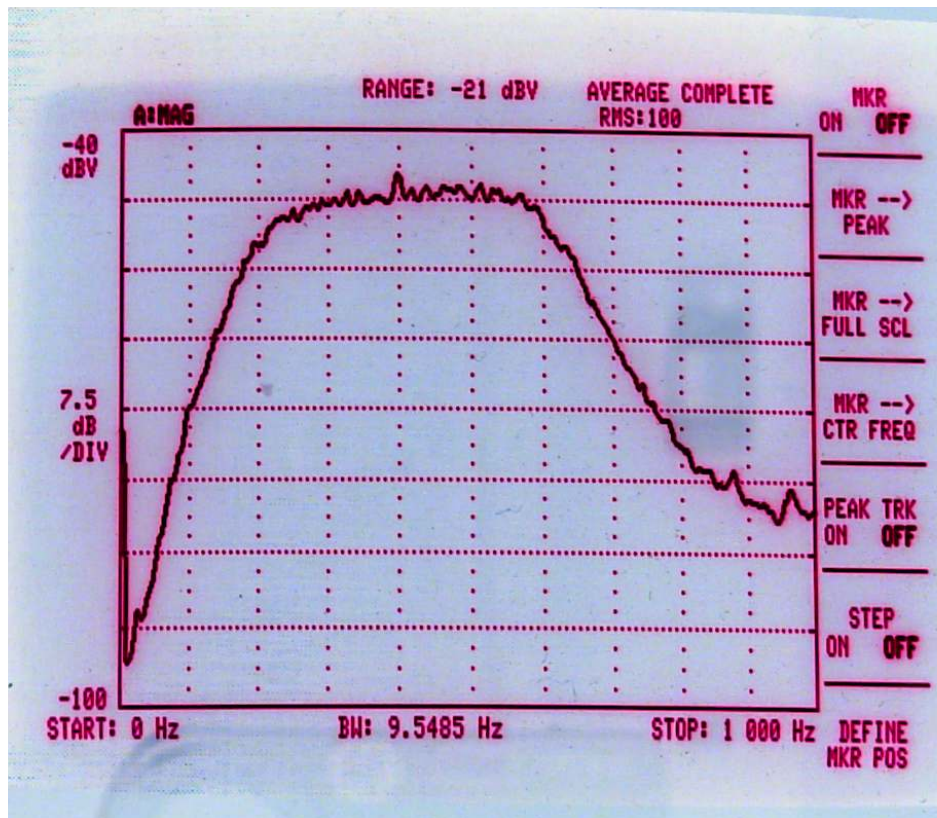
HP3586C Noise Floor



I tuned from 5 kHz to 500 kHz looking for spurs. However, you won't see any spurs on this graph, because none were found. Sensitivity is good at about -125 dBm average.

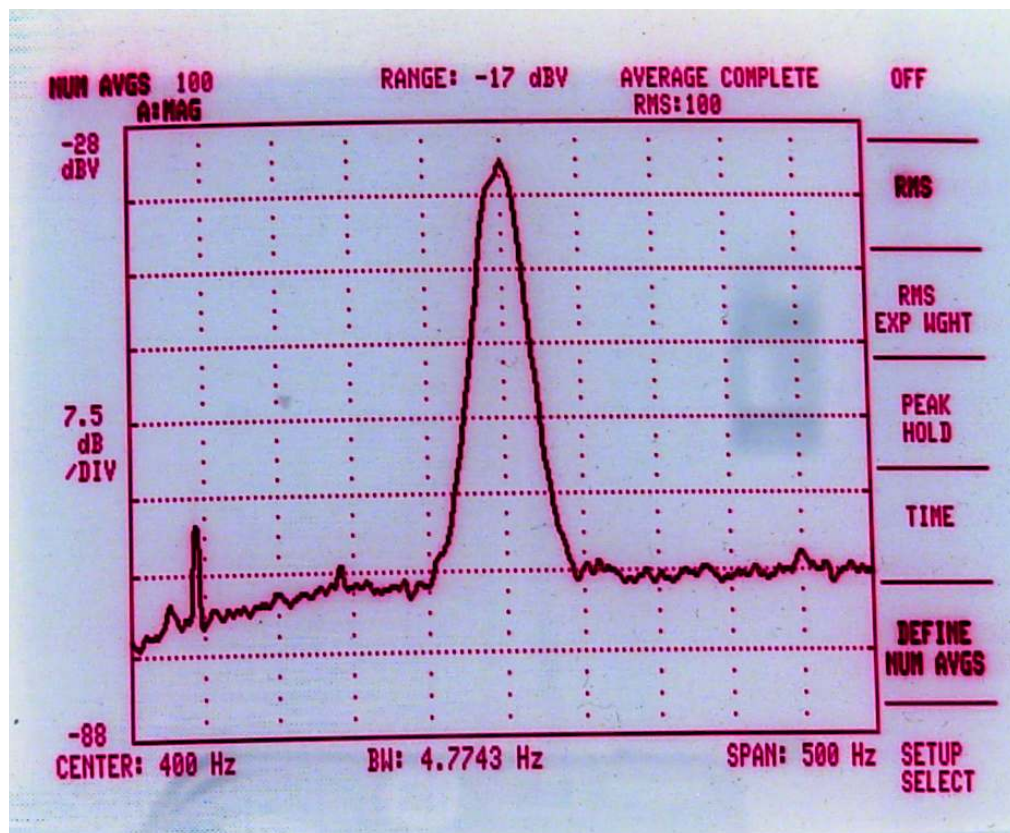
Filters

There are two filters that can be selected that are useful for CW reception, 400 Hz and 20 Hz. Here is the spectrum of the 400 Hz filter:



In this display, vertical divisions are 7.5 dB, and horizontal divisions are 100 Hz.

Here is the spectrum of the 20 Hz filter:



In this display, vertical divisions are 7.5 dB, and horizontal divisions are 50 Hz. This is a very sharp filter with excellent ultimate rejection.

The bottom line:

- Construction quality – Superb. Best of any receiver I'm familiar with.
- LF Sensitivity – Good. Average about -125 dBm. Flat down to near zero.
- LO Noise – Superb
I don't know how the HP engineers eliminated phase noise from their synthesizer design, but they did it.
- Internally generated spurs – Superb. There are none.
- Filter selection – Superb. You will seldom find a sharper IF filter than the 20 Hz filter. It is perfect for beacon DXing with little ringing because of the Gaussian spectrum shape. You probably won't need to add an audio filter.
- Tuning resolution – Superb. Any tuning resolution can be selected down to 1/10th Hz. For example, if you want the tuning to change by 3.7 Hz, you can select that interval.
- Frequency display – Superb at 1/10th Hz.
- LO stability – Excellent. Temp compensated XTAL oscillator. With HP option 400, oven XTAL oscillator, superb.
- BFO – Fair. XTAL controlled BFO. By changing two crystals in the unit, the BFO can be set to any frequency you want.
- Noise blanker – Not available.
- Display noise - I had to keep my portable receiver at least 18 inches away from the display to get good LF reception on the portable. This is a poor rating and the only downside to this unit.

DXing with the HP3586C

The antenna used with the HP3586C should be either tuned or have a low pass filter of 500 kHz in the antenna line. The unit looks at the whole spectrum up to 30 MHz and sets its gain from that voltage. Without front end protection this gain setting is used to avoid overload. If there are strong broadcast stations present, the initial gain will be set too low. If the gain is raised to recover weak signals, the unit will overload.

You will need to do some homework to get the best results from reception.

I found some good advice on using this piece of equipment as a receiver in an article on the internet with the title: **“A Practical Guide for Using the HP3586A/B/C Selective Level Meter”**.

Availability

The good news is that the 3586A/B/C is abundant in the surplus test equipment market. Used prices range from \$100 over \$1000. If you get one, make sure it is operational. Parts may be hard to find, and many parts are factory selected for each unit. The A and B units are similar to the C but are modified to perform additional functions used in telephone communications. However, they will perform equally well as the C unit as a receiver.

There are selective level meters made by other manufacturers, but I'm not too familiar with them. Look for the names Cushman, Wandel & Goltermann and Rycom.

Chapter 11

Sony ICF-2001D Portable



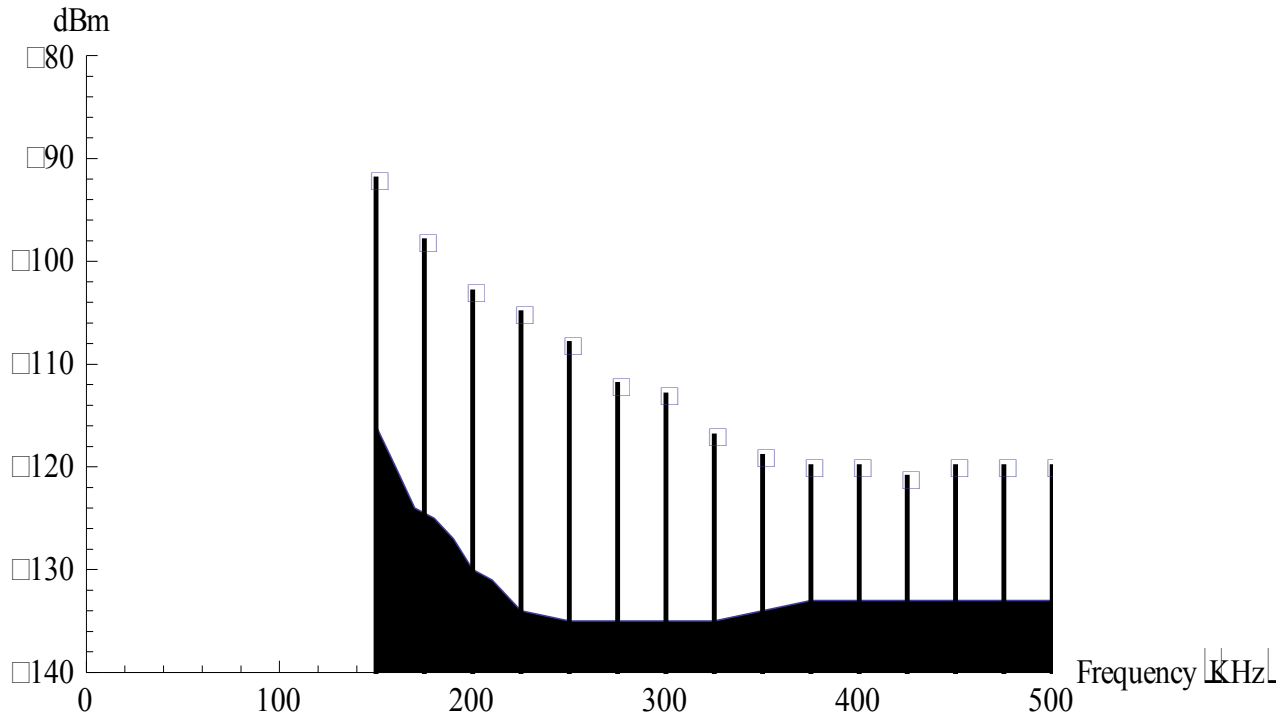
Description

Here's a test of a portable. This was one of the best but is no longer in production. It's identical to the Sony ICF-2010 which was sold in America. The ICF-1001D was sold overseas.

It features tuning and display to 100 Hz or 1 kHz, user selectable. Also, external antennas can be connected. There is a built-in loop antenna which is used on LF if no external antenna is available.

Sensitivity

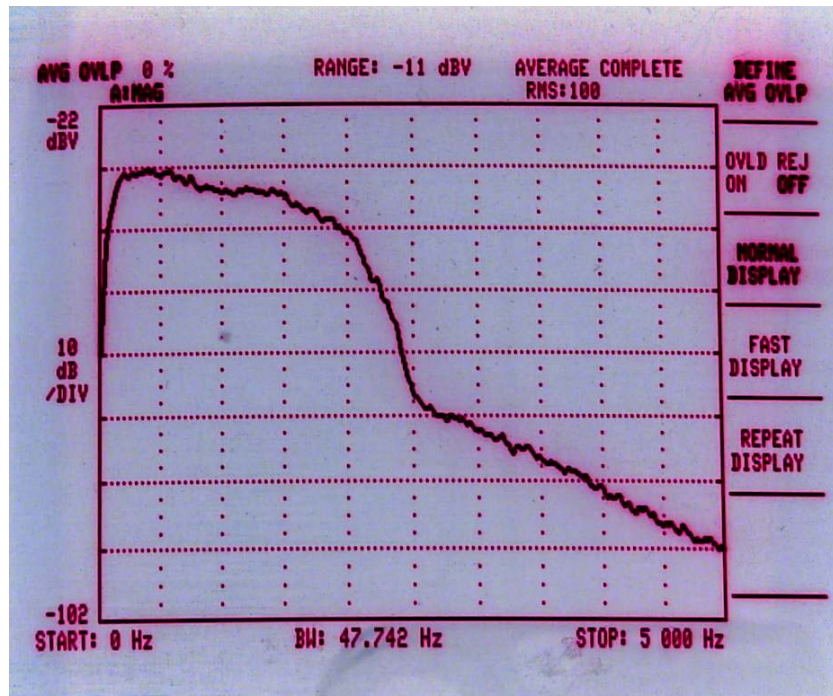
Sony ICF-1001D Noise Floor with spurs



This receiver can be tuned no lower than 150 kHz. Sensitivity is excellent at an average of about -135. There is some phase noise that is noticeable below 200 Hz. This test was done with the receiver's sensitivity control in the DX position.

The spurs are very predictable, falling exactly on every multiple of 25 kHz. Also, the amplitudes appear to be decreasing in a predictable manner. This is a fair rating for this measurement.

Filters



This is a photo of the spectrum analyzer output of the receiver when tuned to a random noise source. Vertical divisions are 10 dB and horizontal divisions are 500 Hz. This is the CW filter in this receiver. It appears to have a bandwidth of about 2 kHz and the skirts indicate it is a ceramic filter. This receiver has a selectivity modification that was done by Radio West. It decreases the stock selectivity which is about 3 kHz in the sideband or narrow AM position to about 2 kHz. The ultimate rejection is only fair and the filter top is not square.

The bottom line:

- Construction quality – Commercial practice, fair.
- LF Sensitivity – Excellent at about -135 dBm
- LO Noise – Ends at 200 kHz. Fair
- Internally generated spurs – Fair
- Filter selection – Poor for CW reception
- Tuning resolution – 100 Hz – Fair
- Frequency display – 100 Hz – Fair
- LO stability – Excellent. Temperature compensated crystal oscillator
- BFO – None. Beacon reception has to be done in LSB or AM mode.
- Noise blanker – Not an option.
- Display noise - I had to keep my portable receiver at least 2 inches away for reception of a weak beacon. – Excellent.

Availability

Sony produced many of these and they can be found on eBay and the shortwave dealers that sell used receivers.

Chapter 12

Racal RA-6793A Communications Receiver

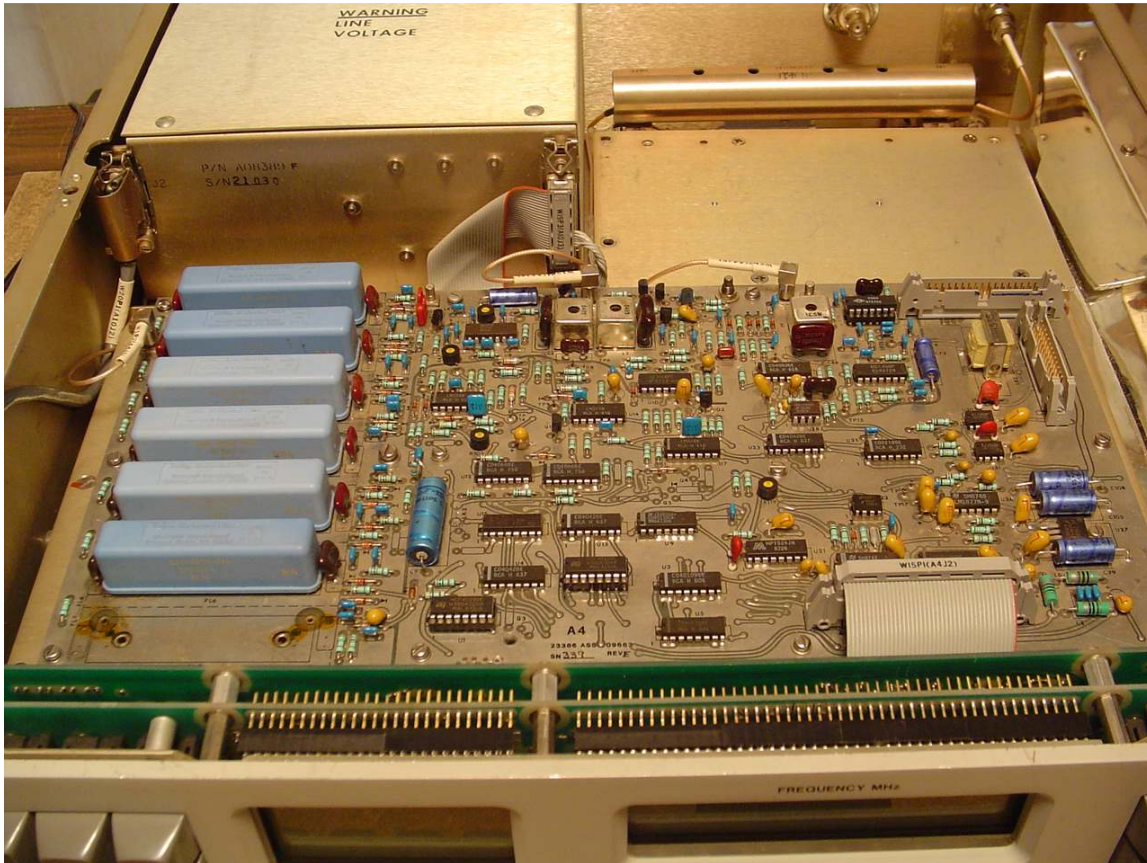


Front Panel of Racal RA6793A Communications Receiver

Description

The Racal RA6793A is a high-quality communications receiver intended for government and military users. A description may be found in “Shortwave Receivers Past & Present”, fourth edition, page 561. Normally this receiver covers 500 kHz to 30 MHz, however this receiver has been fitted with the factory installed LF Extension which lowers the low frequency limit to 10 kHz. The price of this receiver was \$7737 and the LF extension option was \$2764 in 1988.

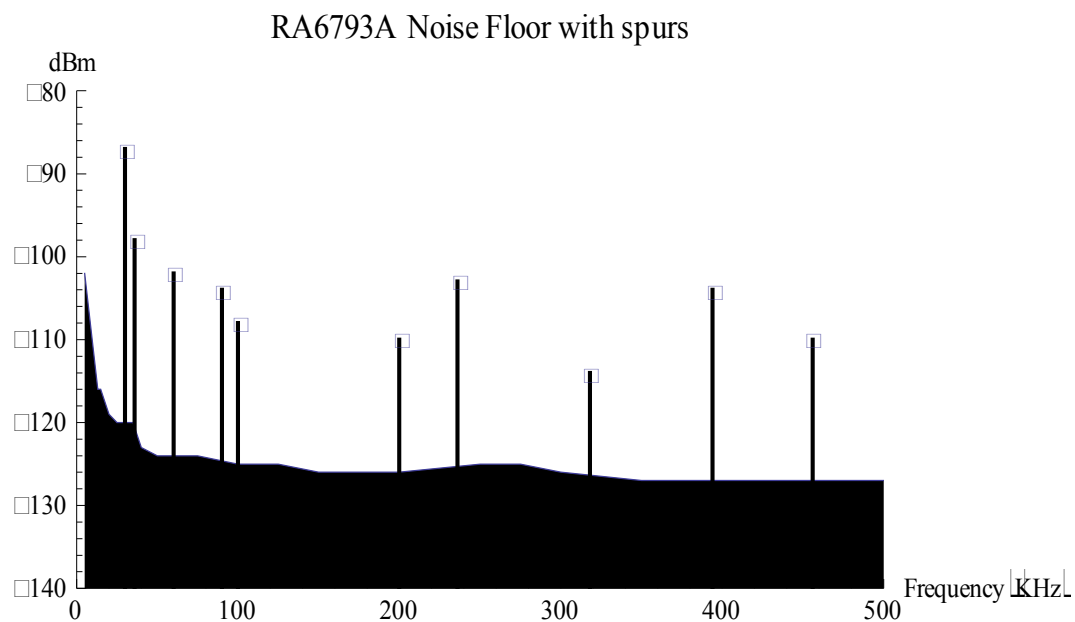
Construction Quality



Under the hood of the RA6793A

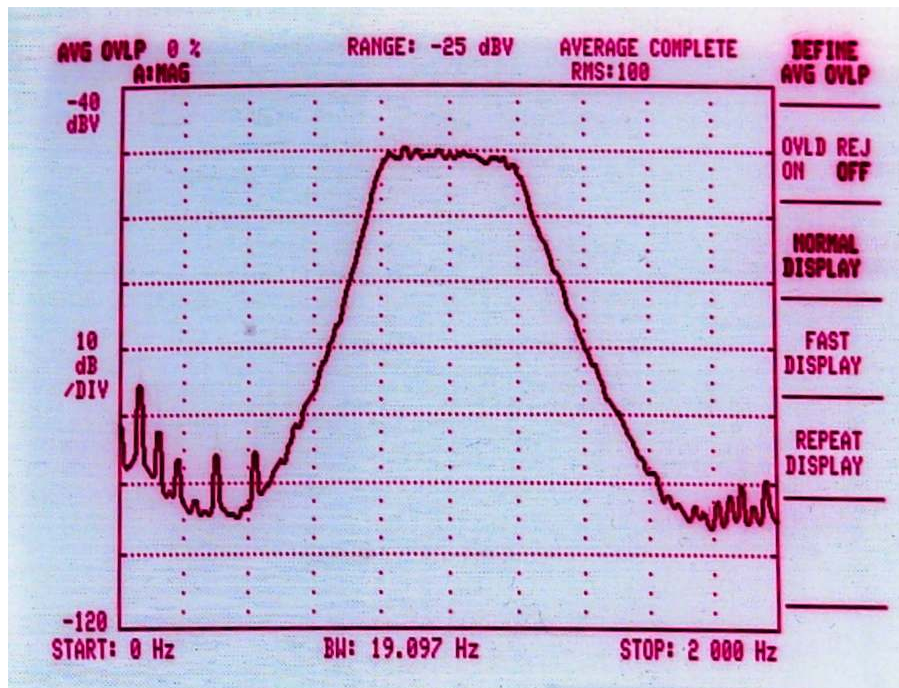
This is a photo of the inside top of the receiver. Construction is mil-spec which indicates best commercial practice. You can see six Collins mechanical filters installed on the left-hand side of the board. The construction could use more shielding since at high frequencies some digital noise from the front panel and CPU board is apparent in the audio. The first mixer, second mixer and synthesizer boards are shielded and are on the bottom side of the receiver.

Sensitivity



The RA6793A has good sensitivity at LF and excellent phase noise characteristics. Phase noise disappears at around 50 kHz. For the RA6793A ten spurs were found which is a good result.

Filters



This is a photo of the spectrum analyzer output of the receiver when tuned to a random noise source. Vertical divisions are 10 dB and horizontal divisions are 200 Hz. This filter has a stated bandwidth of 300 Hz and is a standard filter in the 6793A. This plot shows the flat top spectrum and good shape obtained with the high quality Collins mechanical filters. Ultimate rejection is about -55 dB. In all there are six filters in a standard receiver: 300 Hz, 1 kHz, 3.2 kHz, 6 kHz and the USB and LSB filters. Space is available for one more filter.

The bottom line:

- Construction quality – Good. More shielding would be helpful.
- LF Sensitivity – Good
- LO Noise – Excellent.
- Internally generated spurs – 10, Good
- Filter selection (standard filter complement) – Excellent
- Tuning resolution – 1 Hz – Excellent

- Frequency display – 1 Hz – Excellent
(Why did Racal decide to make the medium tuning rate 30 Hz? 10 Hz would have been much better.)
- LO stability – Oven XTAL oscillator option – Superb
- BFO – Adjustable in 10 Hz steps with the same stability as the LO – Excellent.
- Noise blanker – Not an option.
- Display noise - I had to keep my portable receiver at least 12 inches away for reception of a weak beacon. – Fair.

Performance

The strong suit of the Racal R6700 line is the front end. It has a quad DFET double balanced mixer that is resistant to intermodulation effects. This isn't too important on the LF band. On the broadcast band and shortwave this receiver is an excellent performer. On LF it is also a good performer, however the lack of a noise blanker limits its use at my location.

Availability

The 6793A is a newer model of the 6790 receiver. The 6793A has 100 memories and the 6790 had none. Also the 6793A has a Hall effect keypad that has a good feel, but the 6790 has a membrane keypad.

RA6793s are rarely seen for sale, however RA6790s show up quite often on eBay and some of the surplus dealer websites. 6793A or 6790 receivers without the LF option tune down to 500 kHz. Receivers with the LF option however are much more difficult to find. Some 6790s are sold with an LF capability that is obtained by replacing the firmware chip with one that lets the receiver tune down to 10 kHz. This is not the factory installed option and will have LF performance that is inferior compared to a receiver with the factory installed option.

Chapter 13

JRC NRD-525 Communications Receiver



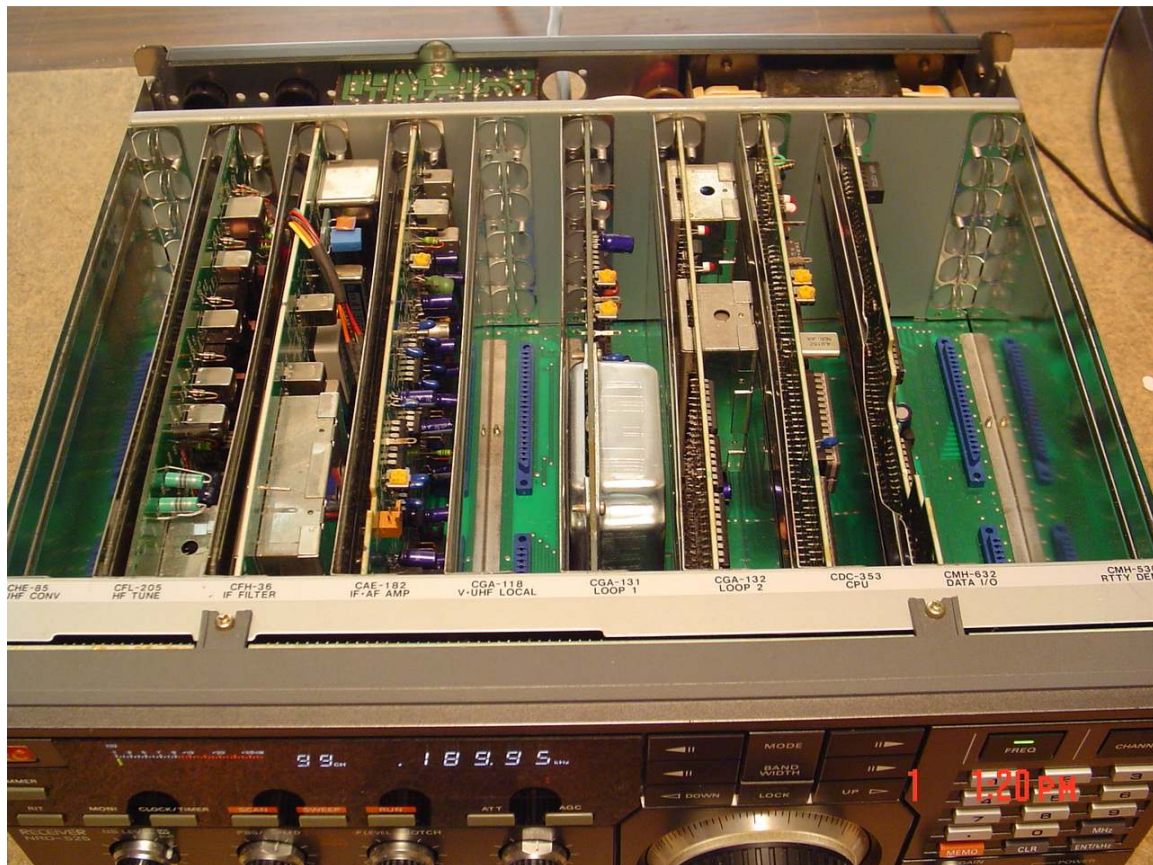
Front Panel JRC NRD-525 Receiver

Description

The NRD-525 is a consumer grade communications receiver. Japan Radio Co., (JRC) is no longer in the consumer communications receiver market. The NRD-5x5 series ended with the NRD-545. The 525 was a popular receiver, manufactured in large numbers. It had many features that made it a good shortwave performer.

You can find a description of this receiver in *Shortwave Receivers, Past and Present*, fourth edition, page 349. Also, there are many descriptions and reviews of it on the internet. At one time, there were some add-ons that could be purchased. A Swedish firm named ESKA made a phase locked AM detector board that was excellent. And many filters could be purchased to improve the performance. These have since disappeared. I purchased the ESKA accessories and modified a second NRD-525 with these. A review of that receiver will be in a later article. However, those add-ons were primarily for shortwave use and don't help with longwave performance much.

Construction Quality

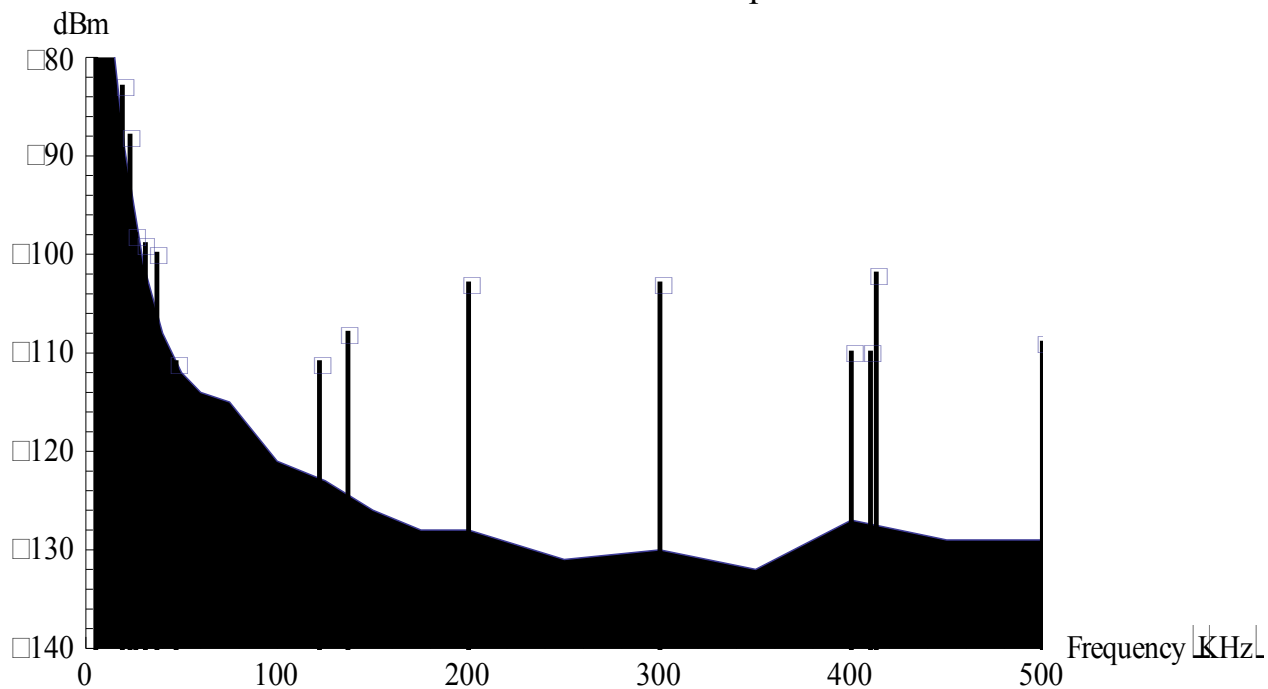


This photo shows the interior of the 525. The receiver is built up from plug in circuit boards. Each plug-in board position has built in sheet metal shields to separate it from its neighbors. This method of construction is better than most

other ham and commercial shortwave receivers which use computer type assemblies. This shielding is somewhat effective at shortwave frequencies, but at LF and VLF is not as helpful. Many of the components are surface mount. These are the large size surface mount components that can be replaced with discrete components without too much trouble.

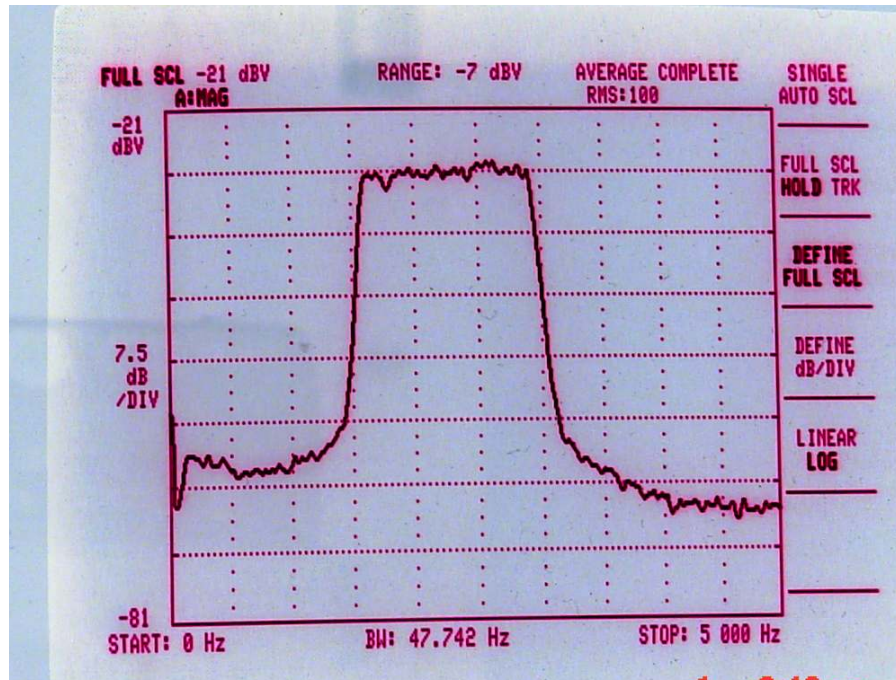
Sensitivity

NRD □525 Noise Floor with spurs



Phase noise is high and is a problem up to about 200 Hz. LF sensitivity past that is about -130 dBm, a good rating. Twenty spurs were found which is a fair rating. Nearly half of these are below 50 kHz.

Filters



This is a photo of the audio spectrum of the output of the receiver when it's hooked to a random noise source. Vertical divisions are 7.5 dB and horizontal divisions are 500 Hz. This filter has a bandwidth of 1500 Hz and is the optional narrow band AM filter. I don't have a narrow CW filter installed. Notice the moderate level of noise below the filter peak. This is known as filter ultimate rejection. It is only between -35 and -40 dB. This has been a complaint about this receiver, and the ESKA add on board corrects the problem.

The bottom line:

- Construction quality – Better than typical consumer grade electronics
 - LF Sensitivity – Good
 - LO Noise – Fair
- Phase noise continues until about 200 kHz

- Internally generated spurs – Fair
- Filter selection – Fair, not optimum for CW DX or beacons
- Tuning resolution – 10 Hz – Good
- Frequency display – 10 Hz – Good
- LO stability – Temp compensated XTAL oscillator – Excellent
- BFO – Adjustable in steps with the same stability as the LO.
However, there is no way of finding the accurate BFO frequency and this frequency sometimes jumps from the original setting. Poor
- Noise blanker – The noise blanker is not too effective. Fair
- Display noise - I had to keep my portable receiver at least 17 inches away from the display to get good LF reception on the portable. This is a poor rating.

Performance

I don't use this receiver for LF DXing. The difficulty with using the BFO and lack of good CW filters make it unsuitable. JRC apparently didn't have CW reception at the top of their design goal list when it was built. On shortwave, it is a good performer.

Availability

The NRD-525 was produced in large numbers and there are many of them for sale. Used ones typically go for \$500 to \$700.

Chapter 14

NRD-525 Modified



Inside View

Description

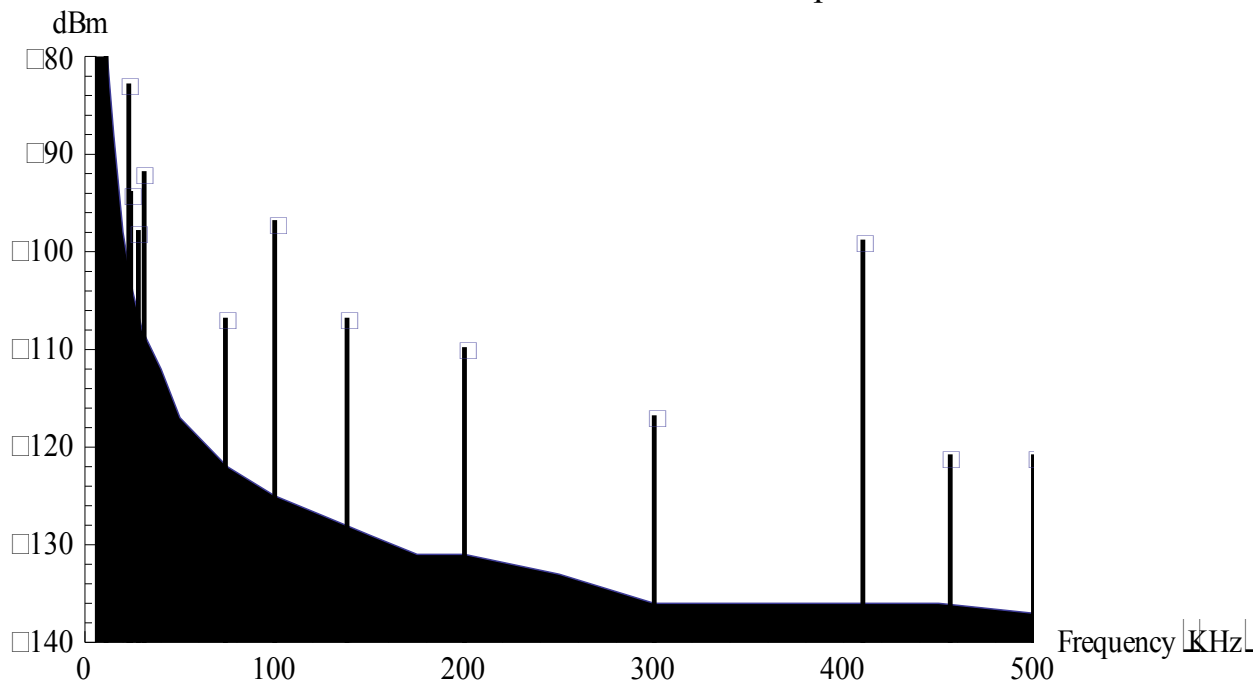
This receiver is basically the same as the unmodified receiver in part I. It has been modified as follows:

Modifications

- It has the ESKA PLAM (Phase Lock AM) board which contains phase locking circuits for synchronous detection of AM signals as well as a second set of post IF amplifier filters. This is the fourth board from the left in the above photo. Synchronous detection is not useful for longwave DXing, but the second set of filters eliminates noise outside of the first filter's passband which is notorious on an unmodified NRD-525.
- ESKA AGC modification circuit. This slows down the AGC action which is too fast on the unmodified receiver.
- Pühler Electronics roofing filter. This is a filter sold by Peter Pühler in Germany. It's a high quality monolithic crystal filter at the first IF frequency of 70.455 MHz and bandwidth 5.5 kHz. It replaces the original JRC roofing filter of bandwidth 20 kHz. This helps in recovery of weak signals near strong ones.
- Quiet display power supply. My own design, see *Lowdown*, June 1999, page 21. This power supply replaces a DC-DC converter in the unmodified receiver which is noisy. You can see part of this board in the above photo. It's the last board on your right.
- Internal shields. The CPU and synthesizer boards were shielded by brass plates. These shields are on both sides of the PC board and top and are sealed with copper conductive tape. I also made shields for the RF board. This didn't help with spurious responses and in some cases made them worse. This shield was removed.

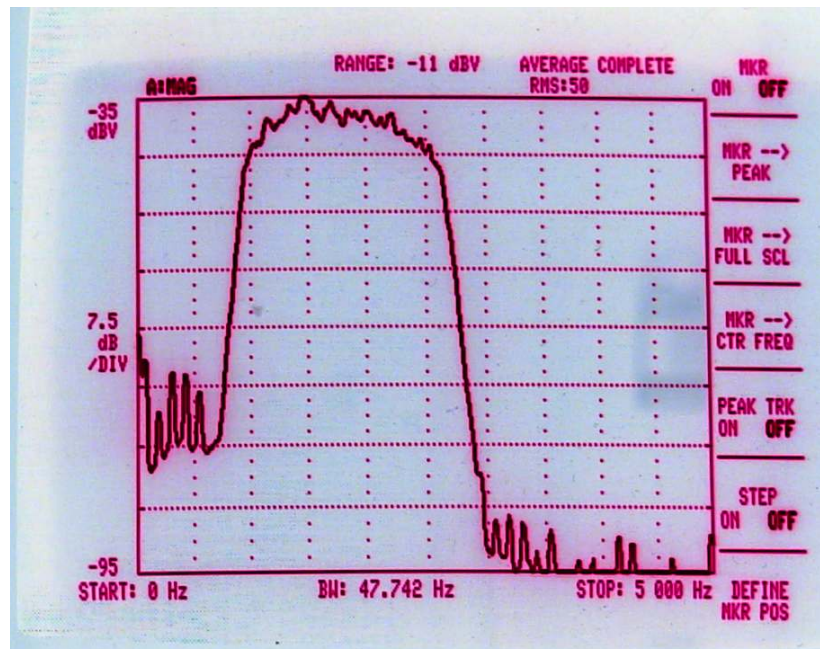
Sensitivity

Modified NRD □525 Noise Floor with spurs



Fifteen spurs were found which is a fair rating. The unmodified receiver has twenty spurs, still only a fair rating. The shielding didn't accomplish much improvement, and was a lot of work. This shows how difficult it is to remove spurs. However some receivers have only one spur or none at all due to the care that went into their overall design. Sensitivity has been improved once the phase noise dies away at around 300 kHz. This averages about -135 dBm, an excellent rating.

Filters



This is a photo of the audio spectrum analyzer output of the receiver when tuned to a random noise source. Vertical divisions are 7.5 dB and horizontal divisions are 500 Hz. This filter has a bandwidth of 1500 Hz and is the optional narrow band AM filter. I don't have a narrow CW filter installed in this receiver. The plot indicates that adding a second filter after the IF amplifier has improved the ultimate rejection over the standard NRD-525 shown in the test of the unmodified receiver in Part I. You won't find better ultimate rejection for any other receiver in the report with better ultimate rejection. The addition of post IF filters (sometimes called "Tail Filters") is a good modification for many receivers.

The bottom line:

- LF Sensitivity – Excellent. Some of the noise in the unmodified receiver must be coming from the synthesizer. The shields have improved this.
- LO noise – Still only fair. Shielding can't improve synthesizer noise.
- Internally generated spurs (15) – Still only a fair rating

- Display noise - I had to keep my portable receiver at least five inches away from the display to get good LF reception on the portable. This is a good rating and a nice improvement over the unmodified receiver which required a seventeen-inch separation to achieve the same result.

Other test results were unchanged.

Overall, these modifications didn't help LF reception to any great extent. They were mainly for the improvement of shortwave reception, which is now excellent due to improvements in the roofing filter and ESKA board.

Availability

The ESKA phase lock AM board and AGC modification kit are no longer available. The Pühler Electronics roofing filter is still available. Consult Peter's web site at:

<http://www.puehler-electronic.de/aktiv.htm>

The power supply and shielding modifications were homebrew.

Chapter 15

ICOM IC-R9000 Communications Receiver



Description

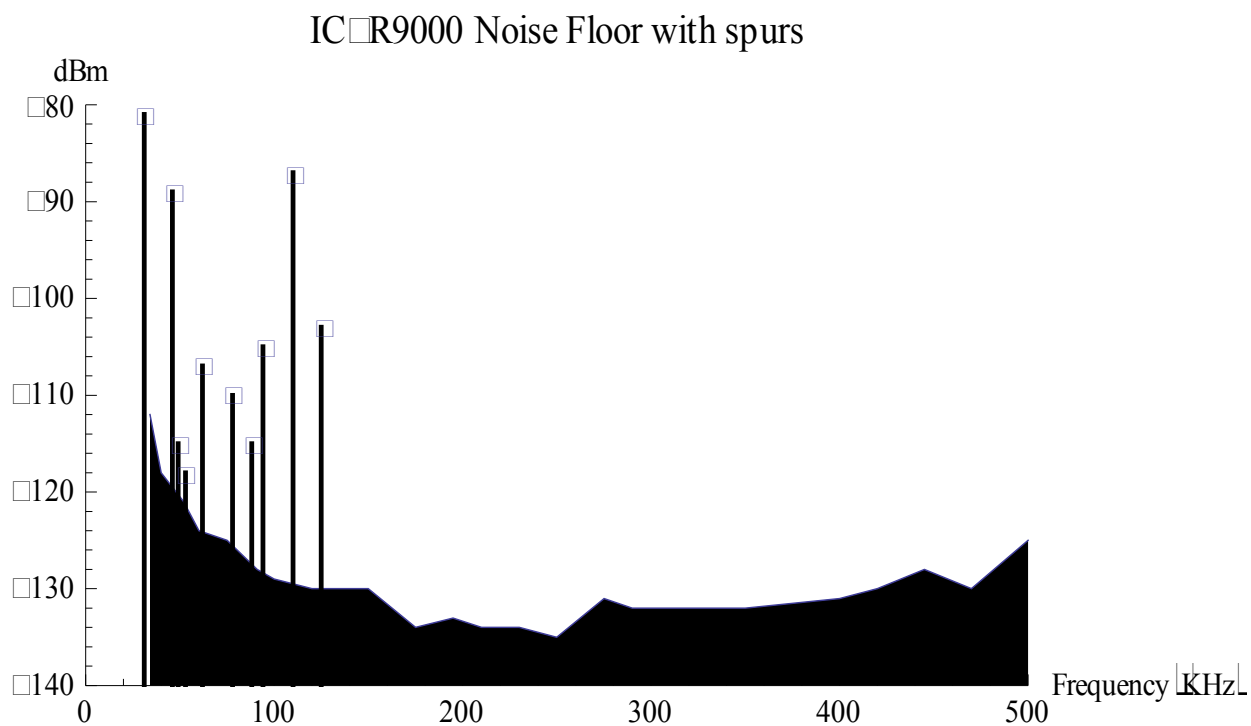
The ICOM IC-R9000 is a premium grade communications receiver. It was designed for use mainly by government agencies and others for surveillance countermeasures (bug chasing). As such it has nearly “DC to Daylight” frequency coverage, 100 kHz to 2 GHz with no skips, along with a built in CRT spectrum display. This receiver was the first in ICOM’s line of full coverage supersets and is the predecessor to the IC-R9500. The IC-R9500 inherited many of its features from the IC-R9000 and was designed with more extremely useful additions. The R9000 is a heavyweight receiver at 44 pounds.

Construction Quality



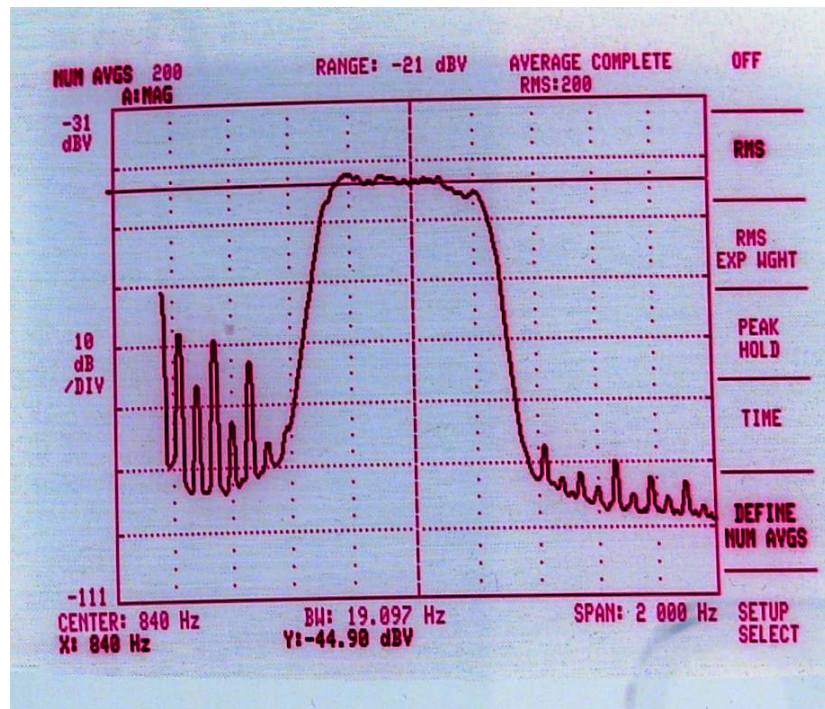
This is a view of the insides of the receiver with the top cover off. The shielding is extensive and the receiver is very well made. You will see the results of this attention to shielding in the sensitivity test below.

Sensitivity



The sensitivity is good at around -130 dBm average. For the IC-R9000 ten spurs were found which is an excellent result. Eight of these are below the stated low frequency limit of 100 kHz and only two are above that frequency.

Filters



This is a photo of the spectrum analyzer output of the receiver when tuned to a random noise source. Vertical divisions are 10 dB and horizontal divisions are 200 Hz. This filter has a measured bandwidth of 460 Hz and a spec bandwidth of 500 Hz. It is the narrowest filter that can be implemented and only marginal for beacon use.

The bottom line:

- Construction quality – Excellent
- LF Sensitivity – Good
- LO Noise – Excellent. Only a trace of phase noise could be found in the receiver's specified tuning range.
- Internally generated spurs – Excellent. Only two spurs were found in the specified tuning range. This is a quiet synthesizer.
- Filter selection – Fair.

- Tuning resolution – 10 Hz – Good
- Frequency display – 10 Hz – Good
- LO stability – Oven controlled XTAL oscillator – Superb
- BFO – Poor. The BFO frequency is fixed at 1000 Hz and cannot be changed.
- Noise blankers – Excellent. There are two blankers with adjustable thresholds. They are very effective.
- Display noise - I had to keep my portable receiver at least 28 inches away from the display to get good LF reception on the portable. This is a poor rating. This is understandable because of the CRT display.

Performance

This receiver was not designed to be a first rate CW receiver. The filters, tuning increment and BFO are not totally suitable for receiving beacons. However, on shortwave, it is an excellent performer, equal to or better than any other receivers I own. All these deficiencies with CW reception were corrected in the next set in this series, the IC-R9500.

Availability

These receivers are seldom seen for sale and when they do show up command a premium price, typically \$2000 to \$3000.

Chapter 16

USSR Brigantina Radio Receiver

In reviews of receivers in this book, you will see examples from:

USA: Racal, Harris, Raytheon, HP

Britain: Eddystone, AOR

Belgium: SAIT

Japan: ICOM, JRC, Sony

India: ETÓN

Now, here's one from another country, Russia.

It's a radio you probably have never seen before, and aren't likely to see in the future. It's a result of cold war technology, produced by the Omsk Research Institute (ONIIP) in Siberia. There's some information about it in "*Shortwave Receivers, Past & Present*" fourth edition, page 243 where it's identified as the M-3142 Brigantina. I found it on the website for American MilSpec. The owner of this company said he had never seen anything like it, so I had to learn more about it. Since he offers a money back guarantee if the purchaser isn't satisfied, I decided to purchase it to satisfy my curiosity. I was hoping it would turn out to something special. Here's what it looks like:



After researching it, I was able to translate some specifications from a Russian website:

TECHNICAL SPECIFICATIONS

Frequency range 0.01 - 30 MHz

Reception modes: A1A (CW) / A2A / H2A / H3E / R3E / A3E (AM) / J3E (SSB) / J2B / J7B / F2C / F1B / G1B

Default manual tuning step - 100 Hz; optional keyboard settings - 10/100/1000 Hz

Number of programmable channels 100

Frequency stability after 2.5 minutes: $1 * 10^{-7}$

Daily (4 hours after switching on) $5 * 10^{-9}$, and in the operating temperature range $5 * 10^{-8}$

Antenna input impedance 75 ohms

Maximum antenna input voltage 100 V (in the range of 0.1-30 MHz)

Noise figure in the frequency range (up to 0.1 MHz / ≥ 0.1 MHz) no more than 30/16 db

Intermodulation dynamic range of at least 85 dBm (with interfering signal \geq 50 kHz offset)

Blocking dynamic range with interfering signal \geq 50 kHz offset, at least 120 dBm

In frequency ranges 0.41-0.535 and 1.5-30 MHz at least 130 dBm attenuation of interfering signals (with frequency offset \geq 5%)

In frequency ranges 0.41-0.535 and 1.5-30 MHz at least 150 dBm attenuation of interfering signals (with frequency offset \geq 10%)

Attenuation of the opposite side band is 86 dBm in SSB mode. (Filter ultimate rejection)

AGC control range 120 dBm

Time frequency adjustment is not more than 200 ms

Operating conditions: Operating temperature range -10 ... 50 ° C

Storage temperature -50 ... 70 ° C

Relative humidity at $t = 40$ ° C, maximum 98%

Power Consumption 50 W

MTBF 5000 hours

These specifications are not spectacular; the dynamic range specs are “good” according to the Sherwood Engineering ratings, not excellent or superb. The sensitivity is good, but not excellent.

I discovered that after powering it up with a 24 volt DC supply it would operate for 5 or 10 minutes, then quit with the Russian language messages “Not ready”, and “Fault 10” displayed on the read-out. With no manual, I didn’t know what to make of that. There were connections on the back panel that used BNC connectors, which was a big help. One was labelled “External Standard Out” in Russian. I hooked a spectrum analyzer up to this one, and found that the internal standard was 10 MHz at +5 dBm and it failed after 5 or 10 minutes. There was also a switch labelled “Internal Standard” or “External Standard”. Moving this switch to External and hooking a signal generator to the “External Standard Input”

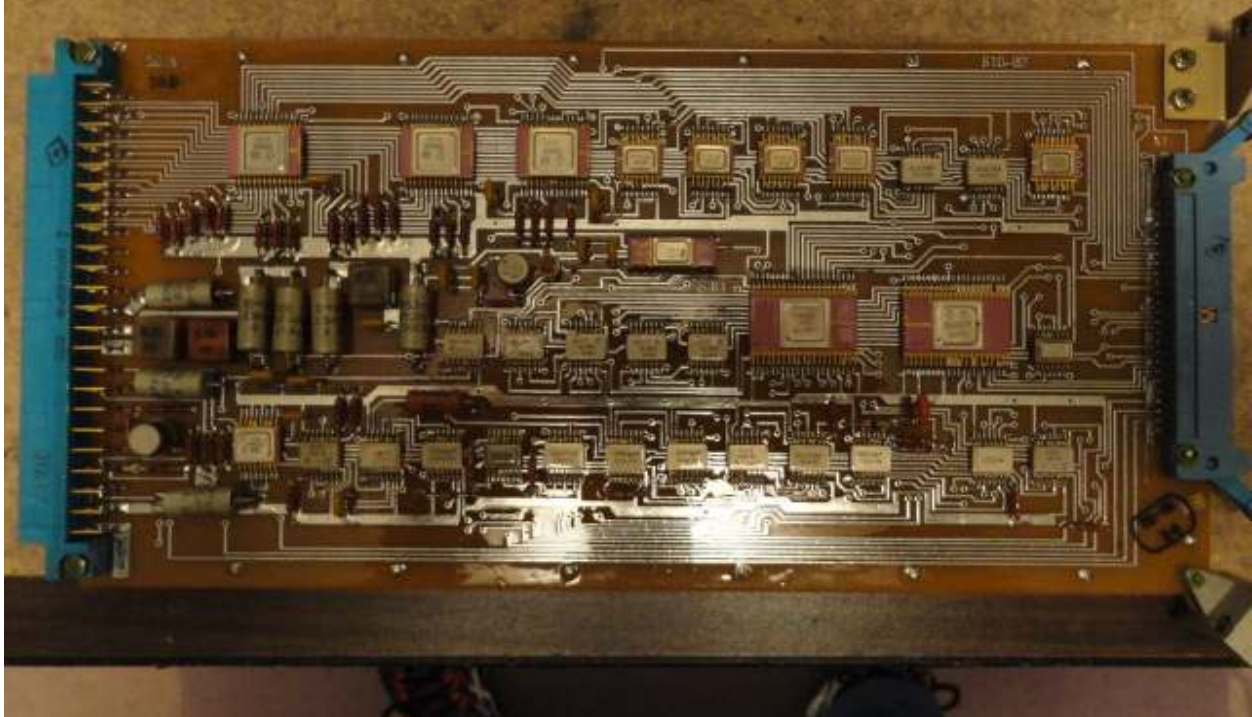
BNC connector got it working. It no longer failed after a few minutes. The next problem was more serious. There was no audio output from the speaker or headphones when hooked to those connections below the speaker. I never got it working completely. I spent a lot of time and effort seeing if I could, but had no luck. With no manual or schematics, and parts with Russian designations with no way to cross reference them, troubleshooting was impossible. I had to assume that it had been in service longer than 5000 hours.

Here's a photo of the interior after the front panel is pulled off:



There are eleven plug in modules, each of which plugs into a 72 pin connector at the rear of the chassis, and cables with miniature coax connectors on the front which are visible in the photo. The circuits are arranged so that the digital signals, carried by the 72 pin connectors are removed as far as possible from the RF signals carried by the cables in the above photo. Surprisingly, these connectors are SMB, used in many of our own mil-spec receivers. The build quality is excellent and reminds me of the HP Selective Level Meter I reviewed earlier.

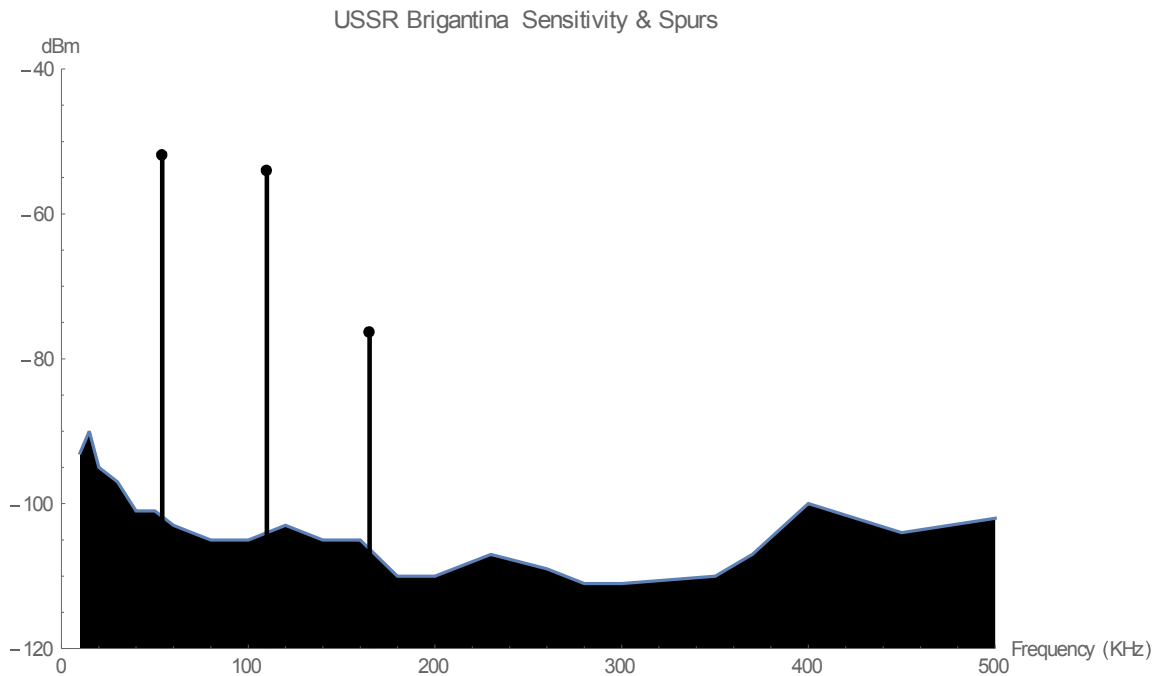
This is a sample of one of the cards. This one isn't shielded. Most of the others are, with soldered on metal shields on the front and back of the board.



All the ICs are Russian made surface mounted integrated circuits. There is no way to cross reference them, or to know what their function is. There are no matching 72 pin connectors available so an extender cable can't be made up. In addition, the cards are all sprayed with a protective coating that makes signal tracing difficult.

After I got it running with an external frequency standard, I hooked the spectrum analyzer to a BNC connector labelled "IF Output". The IF is 128 kHz, and it had a good IF signal. With random noise input into the antenna it was clear that the Brigantina has a roofing filter with bandwidth of about 30 kHz and a broad response. This is not very good for close in IMD.

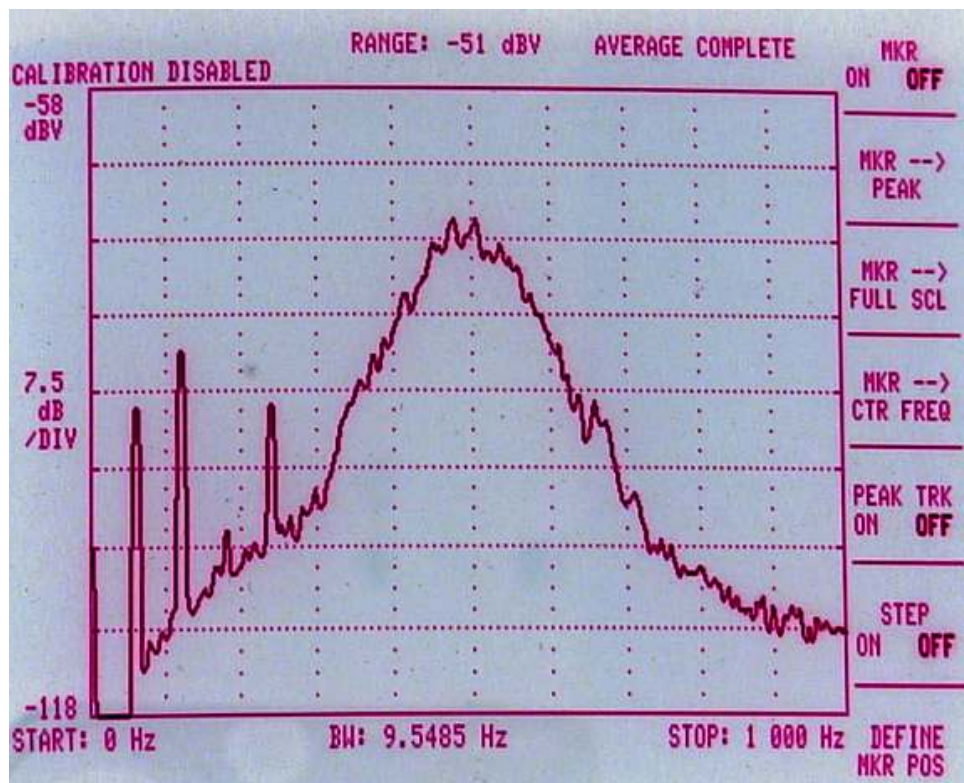
I hooked the IF Output connection up to an AOR AR7030 tuned to 128 kHz to make some measurements. The AR7030 is sensitive, has excellent dynamic range and gave a good audio output. Here is a plot of the Brigantina sensitivity and spurs using this setup:



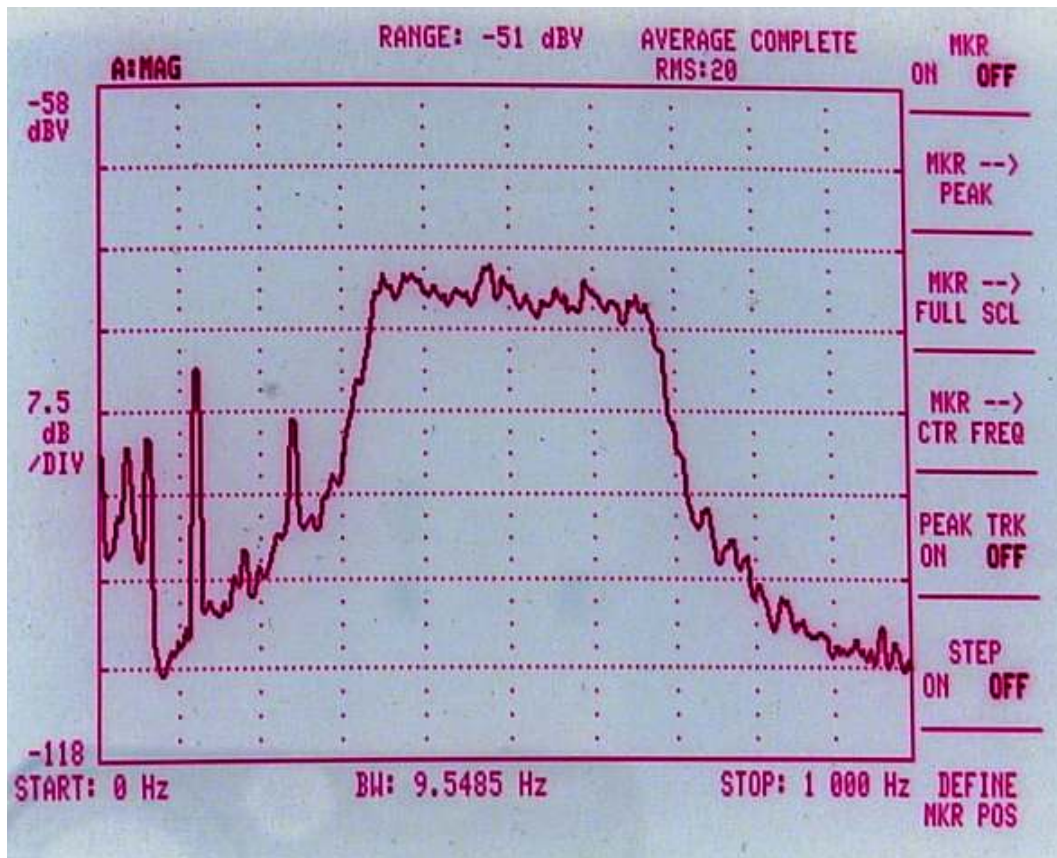
The sensitivity averages about -105 dBm. That's fairly insensitive since some of the better receivers reviewed have sensitivities less than -130 dBm. There are only three spurs, well done comrade. In addition there is very little radiated noise from the display and membrane keypad.

Filters

There are two filters that would be of interest for DXing. First is a crystal filter with bandwidth of about 200 Hz:



And a mechanical filter of bandwidth 350 Hz:



Note the spikes on the LF side of each of these filters. This may be from the DC-DC converters (see Power Supply discussion later).

Brigantina isn't user friendly, or a very good ergonomic design. For example, to adjust the volume, it's necessary to push a membrane keypad button to select volume, turn the tuning knob for the desired volume, then push another keypad button to get back to tuning. I didn't like the membrane keypad. Some keys were very sensitive, but others required a heavier push. Many of the keys have no feedback to tell the user if the desired key had been activated.

I sent it back to American MilSpec. Scott Sidener, owner of American MilSpec is a great person to work with. If you find anything on his web site you like, I recommend buying from him. He will gladly give you a refund if you aren't pleased.

Brigantina - Part 2



Brigantina with IF receiver AR7030

After returning Brigantina to Scott, he relisted it at a “fixer upper” price, so I decided to get it back to see what I could do with it. At this lower price, I wasn’t worried about digging into it and maybe messing something up. In addition, I had found a user’s and maintenance manual in Russian on the web and was able to download it. This gave me some confidence that I could work on it. It took several months to translate the manual but I finally have it in a form which is usable.

There were several things that were not working well on Brigantina:

- The frequency standard would only work for a short time
- There was no audio output
- Dynamic range seemed to be poor

In addition, the antenna input needed a Russian connector which I couldn't find and there was no LSB filter built in. If LSB reception is needed, it would be necessary to change the main tuning frequency and adjust the BFO. This would take a lot of button pushing and knob turning. There was probably no chance that I would ever find a LSB mechanical filter for it.

Frequency Standard

First was the problem with the frequency standard. It suddenly started working, and has been operational ever since. That was several months after I got it back, and I don't have a clue why this happened. I no longer have to hook up an external 10 MHz standard which I had put together. The built-in standard is very accurate.

No Audio Output or LSB Reception

The AR7030 is hooked up to the second IF output and tuned to 128 kHz. This provides good audio and in addition solves the problem of LSB reception. I changed some cables in Brigantina to output a filtered version of the second IF signal so that I could use the many high quality 128 kHz mechanical filters in Brigantina. I was lucky to find another Russian made 128 kHz AM mechanical filter with a 6 kHz bandwidth for Brigantina that allows the 7030 to tune either USB or LSB.

Dynamic Range

My earlier review of this receiver noted the poor dynamic range with my "1460 test". This turned out to be incorrect. With the change made in the IF output and adjustment of signal strength sent to AR7030, Brigantina + AR7030 is now a top notch performer in this test. It is as good as or better than the RACAL RA-6793A which was my strongest performer. The first mixer uses a quad DMOS FET like the RACAL and with automatic sensitivity control (discussed later) this receiver has a strong front end. The designers of Brigantina looked at many receivers, including RACAL to get ideas for their new receiver, and this mixer may have been one of those.

Antenna Input

Here is a photo of the Russian RF connector on the left, compared to a standard UHF connector on the right:



The UHF connector was a perfect fit with no modifications needed to the connector or receiver.

In what follows I'll outline several unusual features of Brigantina.

Automatic Sensitivity Control

This receiver has one unique feature which I haven't seen on any other receiver, automatic sensitivity control. The receiver *automatically* adjusts the attenuators in the front end depending on signal strength detected. This can be turned off if desired, but in using the set, I discovered that this is very effective at overcoming dynamic range problems. It's interesting to check the attenuation values when tuning weak and strong signals. On weak signals it will be zero, and near strong signals can go to over 20 dB of attenuation.

This is a photo of what the attenuator display shows for weak or no signal:



This left display shows the frequency, 2.182 MHz, the international distress frequency and on the right the attenuation being used, in this case 0 dB. The Russian characters ДБ indicate dB. Here's a second photo of the receiver tuned to 1460 kHz, my weak test signal which is near the strong local broadcaster at 1450 kHz:



This display indicates the frequency, 1.460 MHz, and the attenuation used for this signal, -24 dB. This attenuation makes a big difference in hearing this weak signal.

Power Supply

When I first saw this receiver, I was curious about the assembly on the rear panel. It's shown in this photo of the rear of the receiver:



This assembly is made of heavy cast metal. In reading the manual I learned that the large center part contains the +24V DC supply and consists of an AC transformer (for 220-240VAC, 40-65 Hz input voltage), rectifiers and capacitors. The smaller six cast boxes contain switching DC-DC converters operating at 100 kHz for changing 24VDC to 5V, 12V, 27V, -24V and $\pm 15V$. I had always assumed that switching power supplies were too noisy for use on sensitive receivers, but the shielding and filtering used here must be well designed. I have not heard any noise from these DC-DC converters, but it may be seen in the filter spectra. The power for the receiver can be from AC (220-240V, 40-65 Hz) or 24V DC at 1.5 amp. I use a 24VDC linear plug-in supply.

Preselector

The built in preselector was reviewed in a Russian article that I translated. In that publication, the preselector was stated to have the same selectivity as large, mechanical tuned preselectors, but is able to switch fast and is much smaller. It is built into the receiver as a large sealed module. It operates by switching capacitors with relays, depending on frequency. The frequency ranges covered are:

- 0 to 399 kHz: Lowpass filter 0 to 445 kHz

- 400 to 599 kHz: Tracking filter, Q = 24
- 600 to 1499 kHz: Bandpass filter, 500 to 1600 kHz
- 1500 kHz to 30 MHz: Tracking filter, Q = 24 to 20 MHz, decreasing to Q = 15 at 30 MHz

This is good performance for this component. Note that the tracking filter functions from 400 to 599 kHz in the beacon band.

The bottom line:

- Construction quality – Superb
- LF Sensitivity – Good at -105 dBm
- Synthesizer phase noise – Excellent
- Filter selection – Excellent with the AR7030 hooked up, using the built in mechanical filters.
- Tuning resolution – Good at 10 Hz
- Frequency display – Good at 10 Hz
- BFO – Not operational, but Excellent with the AR7030
- Display noise – Fair at 12 inches on LF, better on MW.
- Noise blanker – Not an option.

To summarize, I like this receiver and use it regularly for MW DX. I have gotten used to its quirks. It's only fair on LF, lacking sensitivity, but on medium wave where strong signals are always a problem, it performs well and is one of my best receivers.

Availability

You probably won't find this receiver for sale in the USA. However I think you can buy a new one from ONIIP (Omsk Research Institute) in Siberia for one million Rubles. That works out to about \$17,000 at the present exchange rate.

Chapter 17

Cubic CDR-3250 VLF-HF Receiver

This receiver is made in America by Cubic Communications Inc., and is usually found in government installations. There are only two knobs and the many options in the software are controlled by a menu system that's fairly easy to use. However it requires some button pushing and knob turning to get things done.

This receiver is probably meant to be controlled remotely, since there is a lot in the manual dealing with remote control. When in local control mode the menu system is manipulated by pushing buttons or with the tuning knob. The other knob on the front panel is only used for audio gain.

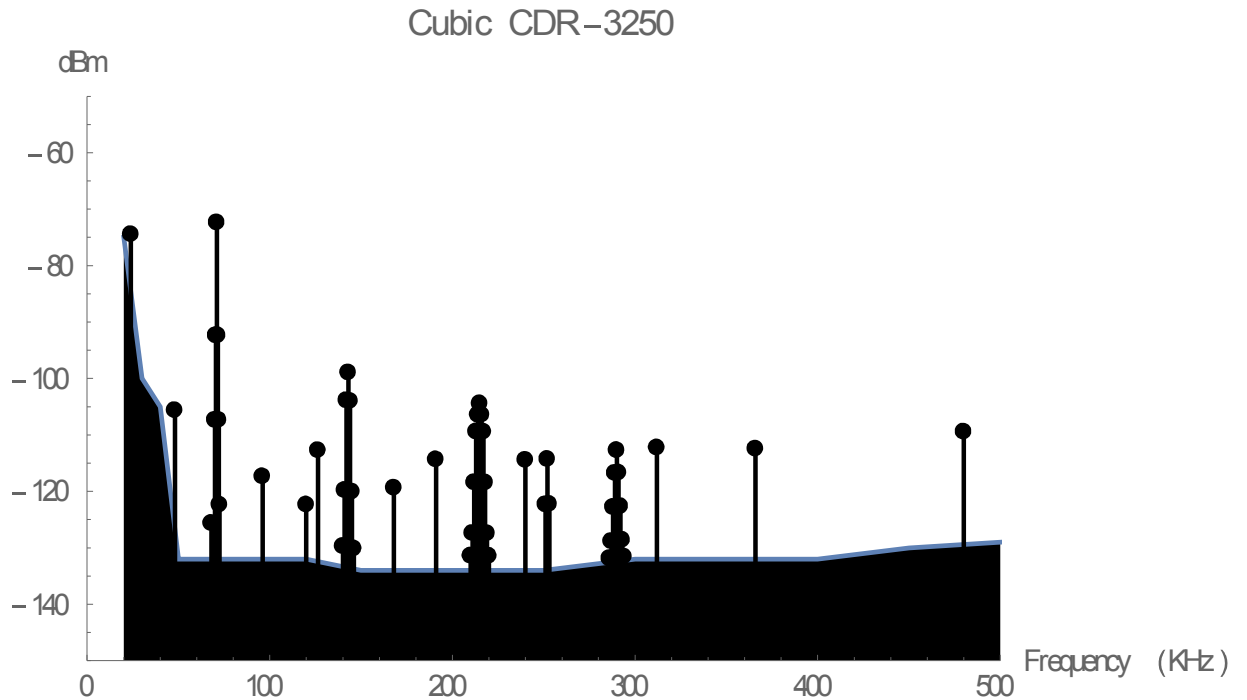
The receiver itself is half rack size, but the mounting is a full rack, so there's a lot of empty space in the chassis. You can find a description of the various options and some specs in *Shortwave Receivers, Past & Present*, fourth edition, page 121.

The following photo is of half the front panel showing the fluorescent display with parameters which have been selected, softkeys, buttons and the tuning and audio gain knobs at the right.



Cubic CDR-3250 front panel

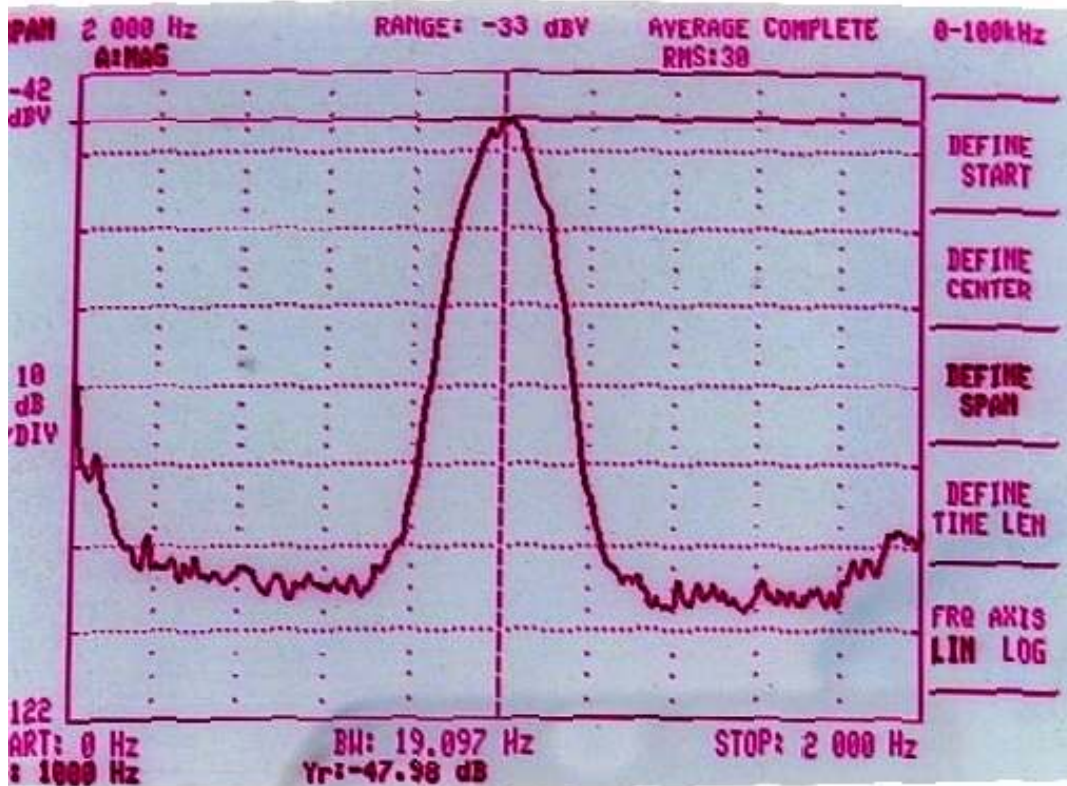
Sensitivity



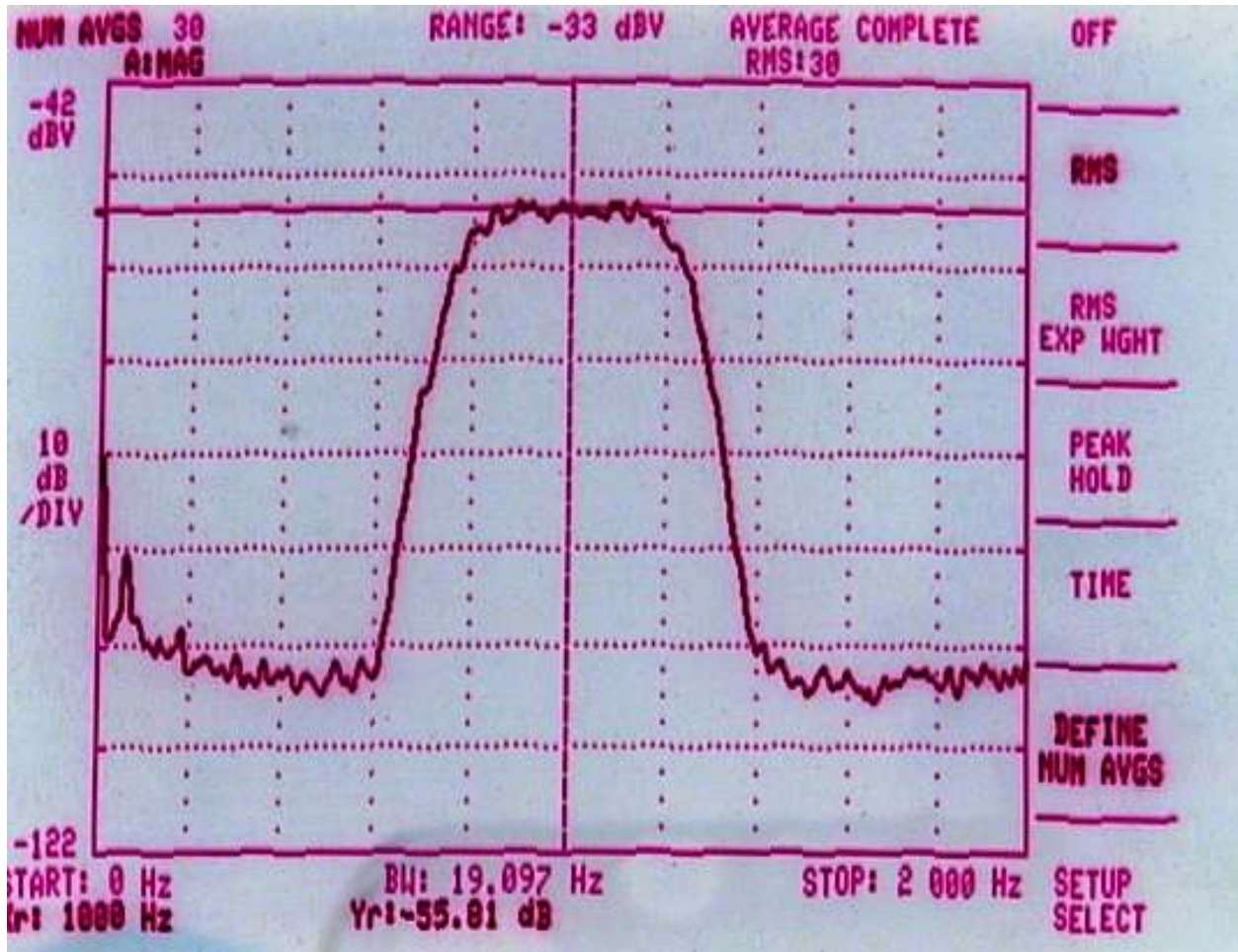
This receiver has many spurs in the LF band, making it almost unusable there. Although it's very sensitive, chances are that your DXing there will be troubled with spurs.

Filters

Filters are implemented in software and are of finite impulse response design, which means they can be configured to be linear phase, unlike the infinite impulse filters used in the NRD-545. A finite impulse response filter is an optimum filter since it has minimum ringing and is symmetric. There is a choice of 51 filters, of which any four can be picked for quick selection, those remaining can be selected through a menu table. Here are two examples:



100 Hz Filter Spectrum. Divisions are 200 Hz



500 Hz Filter Spectrum. Divisions are 200 Hz.

The shape factor is excellent, the filter top has only very small ripples and the ultimate rejection is also excellent. A filter this good would be difficult to fabricate with analog components.

The bottom line:

- Construction Quality – Excellent mil-spec construction.
- LF Sensitivity – Excellent
- LO Noise – Superb above 30 kHz.

- Internally generated spurs – There are many, especially below 500 kHz, poor
- Filter Selection – 51 filters, superb
- Tuning resolution – 1 Hz tuning, superb
- Frequency display – 1 Hz display, superb
- LO Stability – Temperature compensated master oscillator, superb
- BFO – Digital with 10 Hz tuning locked to master oscillator, excellent
- Noise Blanker – Not available
- Display noise – This receiver holds the record for display noise, over six *feet*. This is not a record to strive for. Poor.

Performance

While the specs for this receiver look impressive, performance does not seem to match the specs. The noise from the display not only radiates from the front of the unit, but also gets into the signal path at LF. This noise looks like it may be generated by a switching power supply for the fluorescent display.

Although the filter curves are impressive looking, I didn't like the sound on AM. I DX AM with SSB and normally use a 2 to 3 kHz filter. I tried several of the built in digital filters, but they all sounded too high frequency and were unpleasant to listen to. This was not helpful for weak station IDs. The filters on my NRD-545, which are also digital, have a similar sound. There is a control called **High Frequency Roll Off** in the menu. I tried changing this, but it did not make much difference. This receiver would not be my choice for DXing, either in the LF or MW bands. I like lots of knobs, analog IF filters and low radiated noise.

Availability

Shortwave Receivers, Past & Present says these receivers are typically unavailable.

Chapter 18

AOR AR7030 Communications Receiver



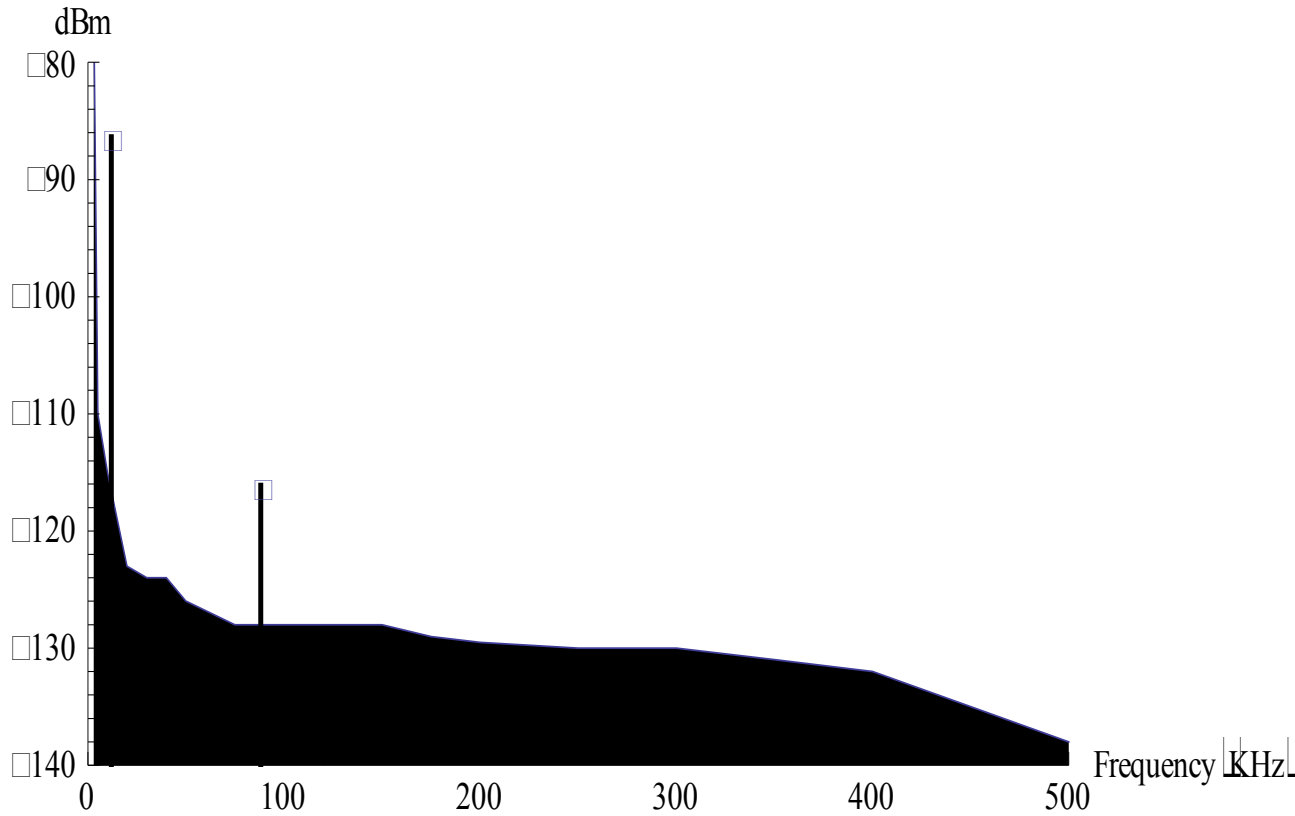
Steve Ratzlaff loaned his AR7030 to me to make the low frequency tests on it. Thanks to Steve for his generous offer.

Description

The AR7030 is a high-quality communications receiver made by AOR. In their review, *Passport to World Band Radio* states that “In terms of overall performance for program listening, as good a receiver as we’ve ever tested.” The audio is exceptional and the receiver is very quiet and sensitive. The tests will bear this out. I also must agree with Passport that the ergonomics are ‘convoluted’. I could work with it well enough to make the tests with no problems however.

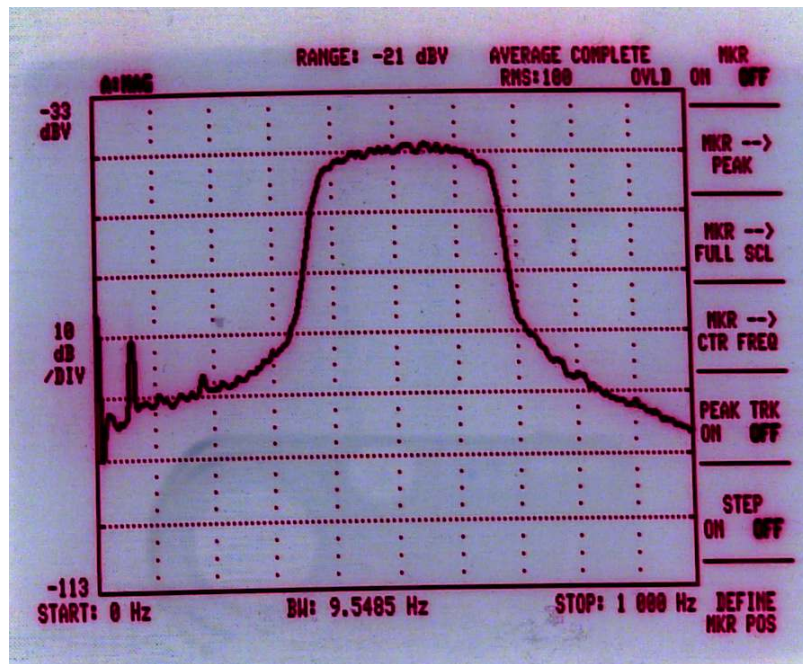
Sensitivity

AR 7030



The sensitivity is close to -130 dB or better over the range 100 to 500 kHz. There are only two weak spurs, an excellent result. Phase noise is well controlled, and is gone at 100 kHz. Obviously, a lot of work went into designing a quiet and sensitive receiver.

Filters



This is a photo of the spectrum analyzer output of the receiver when tuned to a random noise source. Vertical divisions are 10 dB and horizontal divisions are 100 Hz. This optional filter has a bandwidth of 250 Hz.

The bottom line:

- Construction quality – Excellent for consumer grade equipment.
- LF Sensitivity – -130 dBm or better in most of the LF band – Excellent
- LO Noise – Gone at less than 100 kHz - Excellent.
- Internally generated spurs – 2 – Excellent
- Filter selection (with optional filters) – Excellent
- Tuning resolution – 2.655 Hz – Good
- Frequency display – 10 Hz – Good
- LO stability – Temperature compensated XTAL oscillator – Excellent
- BFO – Adjustable in 33.33 Hz steps with the same stability as the LO – Good.

- Noise blanker – Optional, but was not on this receiver.
- Display noise - I had to keep my portable receiver at least 6 inches away for reception of a weak beacon. – Good.

Performance

Since I haven't had the chance to use this receiver much, I asked Steve if he would comment on his experiences with it:

"I find it has superb weak AM voice recovery. Several years ago I had several other decent radios and had them all in a stack where I could feed the same antenna to each and select each audio to headphones, and compared them all for winter weak TP and some TA LWBC reception. The 7030 consistently came in on top for being first to get weak audio. For CW reception its decent VLF sensitivity and tuning all the way down means I don't have to use an LF converter, especially for listening to the Russian Alpha signals. Its strong-signal performance is near-legendary but that is of little concern in this rural area with no strong stations within about 80 miles.

Anyway, that's all I can think of at the moment, for any comments on the radio. It's not my primary NDB DXing radio due to its not having 1 Hz tuning, which works so well with the external narrow audio filter. But otherwise it's probably my overall best radio. I have a Harris RF-590 which sees little use; it's not nearly as easy to use as the R75 or AR7030, plus it has the well-known filter blowby issue. It's not a radio for quick tuning around either, with all the button pushes you have to do to change tuning rates and get back to a 1Hz tuning."

Since this review, I purchased my own AR7030. I must disagree with Steve about comparing the RF-590 and AR7030. I don't find the RF-590 difficult to use, in fact comparing it to the AR7030 I have come to the opposite conclusion. I feel the RF-590 is much easier to use than the AR7030. I find the best use for the AR7030 is to back up my Brigantina, where only a few of its options need to be changed. I don't care for the AR7030 menu system. As was stated in one of the reviews of the AR7030, you will either love it or hate it.

Availability

The AR7030 is no longer being manufactured. It was only manufactured from 1996 to 1998. Since it has such good specifications there is a high demand for it and used ones bring good prices. They are occasionally seen on eBay or at some of the better known short wave radio sellers.

Chapter 19

JRC NRD-545 Communications Receiver



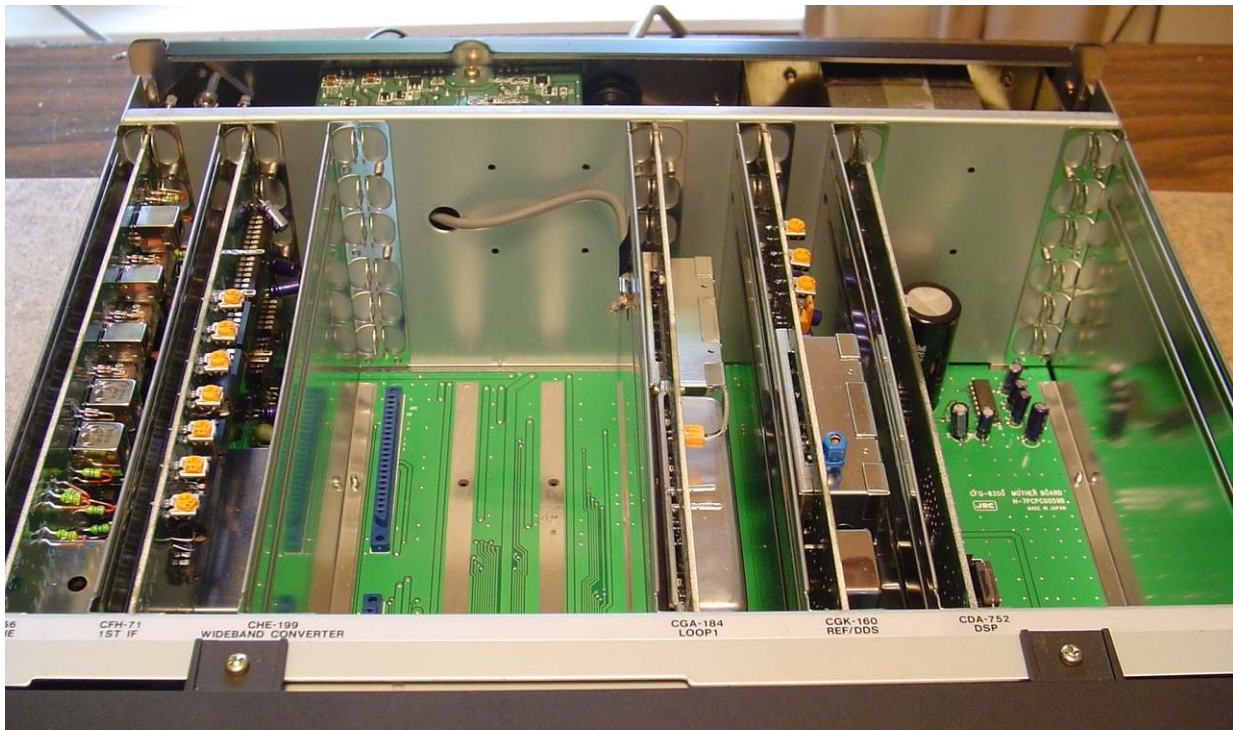
Front Panel of JRC NRD-545 Receiver

Description

The NRD-545 is a consumer grade communications receiver. Japan Radio Co., (JRC) is no longer in the consumer communications receiver market. The NRD-5x5 series ended with the NRD-545 which occurred around the end of 2008. The 545 was Japan's first and last digital signal processing consumer grade receiver.

You can find a description of this receiver in "Shortwave Receivers, Past and Present" fourth edition, page 350.

Construction Quality

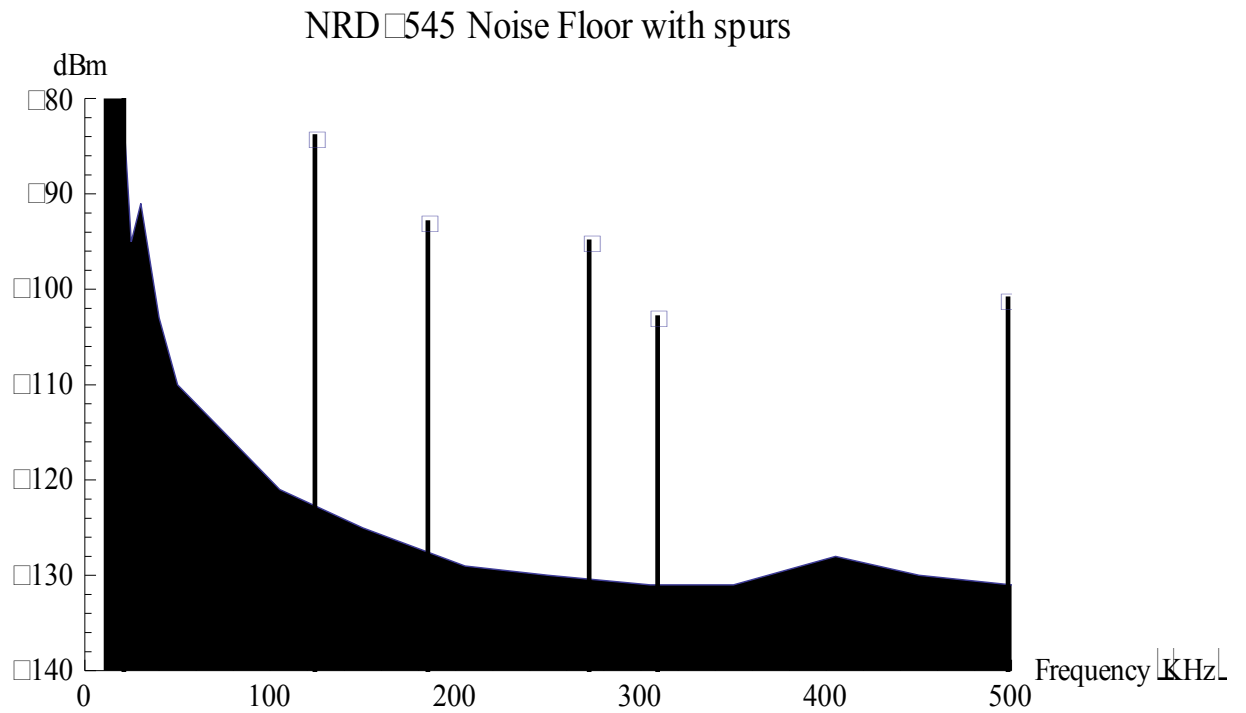


NRD-545 Under the Hood

This photo shows the interior of the 525. The receiver is built up from plug-in circuit boards. Each plug-in board connector has built in sheet metal shields to separate it from its neighbors. This method of construction is better than most other ham and commercial shortwave receivers which use computer type assemblies. This shielding is somewhat effective at shortwave frequencies, but at LF and VLF may not be as helpful. Many of the components are surface mount. These are the large size surface mount components that can be replaced with discrete components without too much trouble.

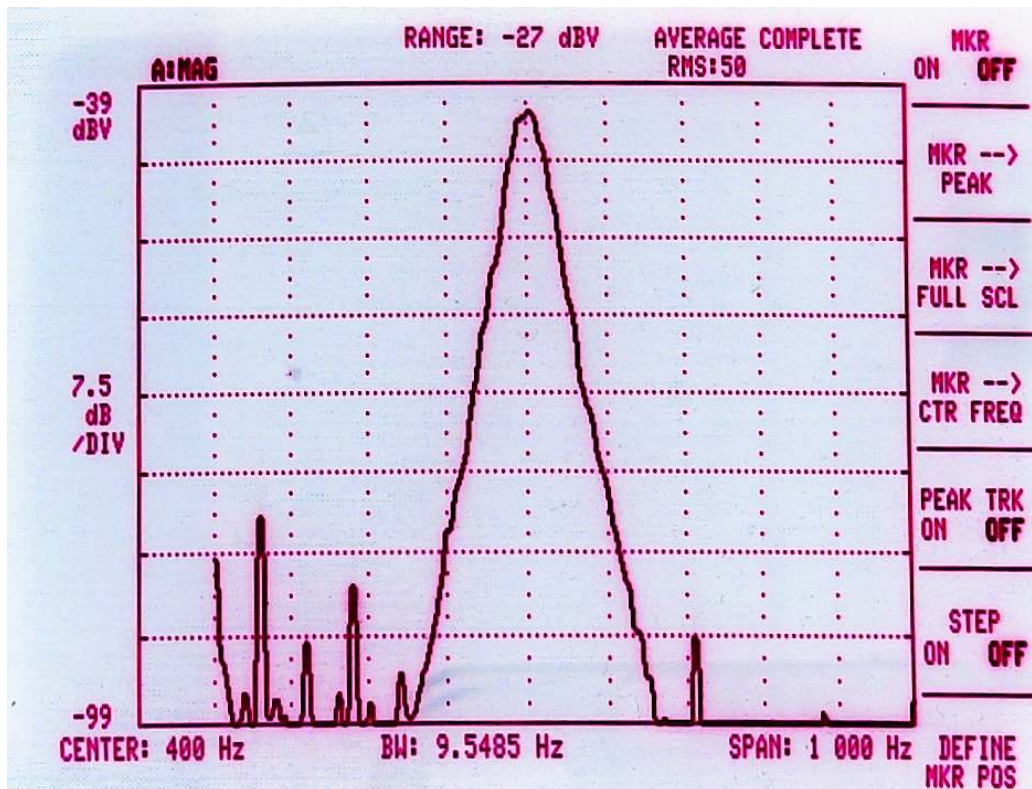
You can see a lot of empty space in this receiver. Many of the circuit boards that were present on earlier NRD models are no longer needed since their function is now done by the digital signal processing chip. Some of this empty space could be utilized by the VHF-UHF accessory board which isn't in this receiver.

Sensitivity



Sensitivity levels out at about -130 dBm, an excellent rating. See part 2 of this section for a sensitivity improvement. Nine spurs were found which is a good rating.

Filters



This is the spectrum of the 10 Hz filter, the most selective filter. The horizontal divisions in this plot are 100 Hz, you can see that the -6 dB bandwidth isn't really 10 Hz, it's actually about 50 Hz. An accurate measurement confirms this. This is still an impressive filter, better than any crystal filter I've seen except for the HP3586C 20 Hz filter.

For the technically inclined, these filters aren't finite impulse response (FIR) filters, but instead they are infinite impulse response (IIR) filters. The main difference between these two filter designs is that the FIR filters usually are designed to have linear phase but with IIR filters this isn't possible. This means that IIR filters may have longer impulse responses (more ringing). I haven't noticed this being a problem with the 50 Hz filter shown above.

The bottom line:

- Construction quality – Better than typical consumer grade electronics
- LF Sensitivity – Excellent
- LO Noise – Fair
Notice that the phase noise continues until about 250 kHz, like the NRD-525.
- Internally generated spurs – Nine, good.
- Filter selection – Superb
- Tuning resolution – 1 Hz – Excellent
- Frequency display – 10 Hz – Good
(JRC should have added the one Hz digit to their display.)
- LO stability – Temp compensated XTAL oscillator (Optional) Excellent
- BFO – Adjustable in 10 Hz steps with the same stability as the master oscillator. Excellent
- Noise blanker – The noise blanker implemented in the DSP is not too effective – Fair.
- Display noise - I had to keep my portable receiver at least 12 inches away from the display to get good LF reception on the portable. This is a fair rating.

Performance

I like this receiver for shortwave listening. With 1000 memories, pass band shift and more filters than I could ever use it's a great performer. On longwave it's a good performer. If JRC had added the 1 Hz digit on their display that would have helped to tune accurately. I have to use the or frequency buttons and count the number of times I push the button to get one Hz tuning. The performance of the noise blanker is marginal; it removes some minor noise but not bad noise. I haven't found the digital noise reduction feature to be very useful.

The ergonomics of this receiver are great. There are no dual knobs, and frequently used features are all at the user's fingertips.

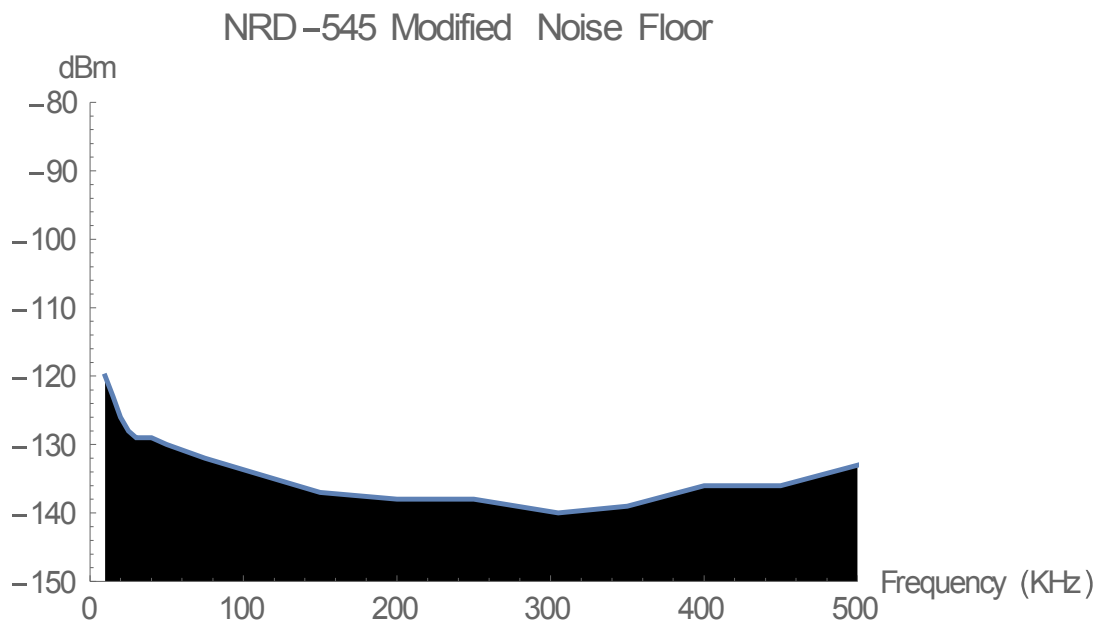
Availability

Since production stopped about a year ago, this receiver is now in high demand. There are a few for sale, and expect to pay a new price for a good used one.

NRD-545 Part 2

VLF Sensitivity Improvement

Several years ago, I found a modification which was claimed to improve the sensitivity at VLF. It was designed by Dallas Lankford and can be found in the files of the NRD-545 yahoo group. It's called the NRD-545 LF & VLF sensitivity mod. It involves replacing three capacitors in the front end with larger values and rewinding the mixer coil with more turns. This would normally be a simple operation, but replacing the stock SMD capacitors with leaded types requires drilling very small holes in the HF Tune circuit board. If you have the equipment and are willing to give it a try, I suggest doing this mod. Here is a plot of the sensitivity after doing this modification (spurs are unchanged and aren't shown):



This graph tells the story. The VLF sensitivity is now outstanding. It is my best VLF receiver. With its selection of filters, noise blanker and now excellent sensitivity it beats everything else I have here. That includes the Harris RF-590, which was modified for VLF and has my homebrew noise blanker, the Racal RA6793A, which includes the factory VLF mod, the CEI Type 357, and several others. It is the only receiver I have that I can hear the Russian Alpha radio navigation transmissions on 11.9, 12.64 and 14.88 kHz when conditions are good. If I can hear them clearly with the 545, I can get a hint of them on some of the other receivers if I use narrowband audio filtering.

Chapter 20

ICOM IC-R75 Communications Receiver



Front panel of the IC-R75

Description

The ICOM IC-R75 is a consumer grade communications receiver. The owner gets a lot of receiver at a reasonable price. This is one of the very few consumer grade receivers still being manufactured. This one is a loaner from Bill Bowers. It has the optional narrow crystal filter installed, the FL-53A (250 Hz at the third IF of 455 kHz) and an FL-100 (500 Hz at the second IF of 9 MHz). It also has the optional CR-282 high stability ovenized crystal installed. You can find a review of this receiver in *Passport to World Band Radio*. There are many reviews of it on the internet as well as a description in *Shortwave Receivers* fourth edition, page 324.

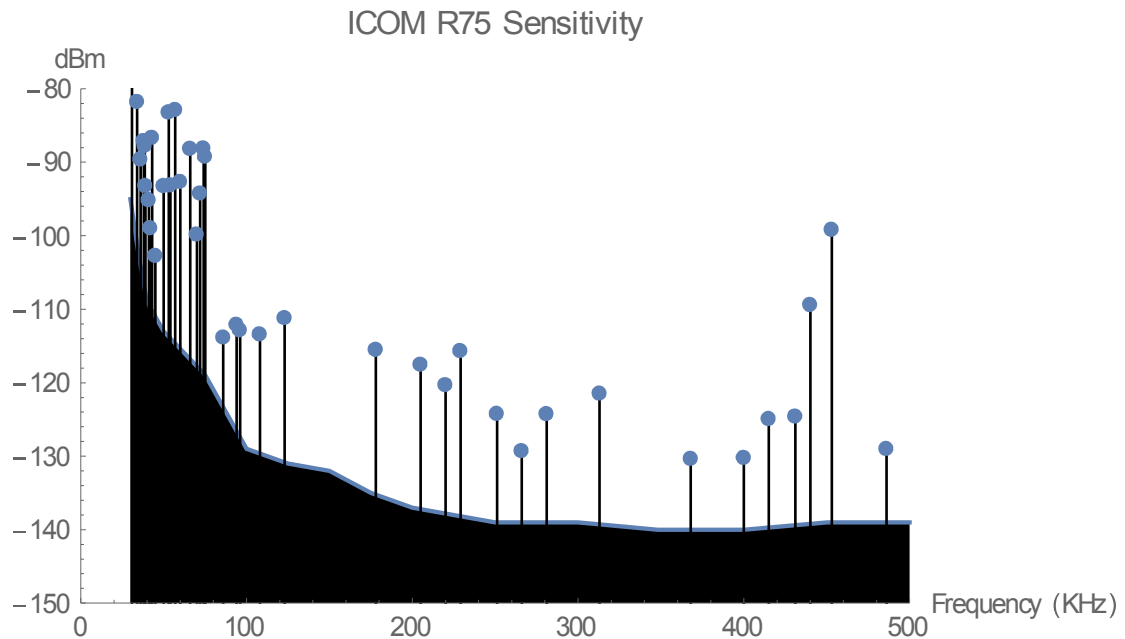
Construction Quality



Under the hood of the IC-R75

This is an example of modern automated electronic construction as used by many computer manufacturers. If you look inside a computer, you will see similar construction. The small SMD components are placed on the circuit board by robots and flow soldered. Shielding is minimal with this construction with only small slip on metal shields around sensitive components. The SMD components used in this assembly are small, and not easily removed or replaced by using standard tools. The lack of shielding shows up in the sensitivity graphic.

Sensitivity



This is a plot of the measured sensitivity for the IC-R75. There are two preamplifiers that can be switched in. Preamp 1 helped marginally from 100 to 300 kHz. Preamp 2 was not helpful and was not used. There are numerous spurs, 34, and is a poor result. This is probably a result of poor shielding. See part 2 of this chapter for big improvement in spurs.

Filters

The following filters are available as optional equipment for the IC-R75. There are two IF frequencies, 9 MHz and 455 kHz. There is a good selection for each of these IFs:

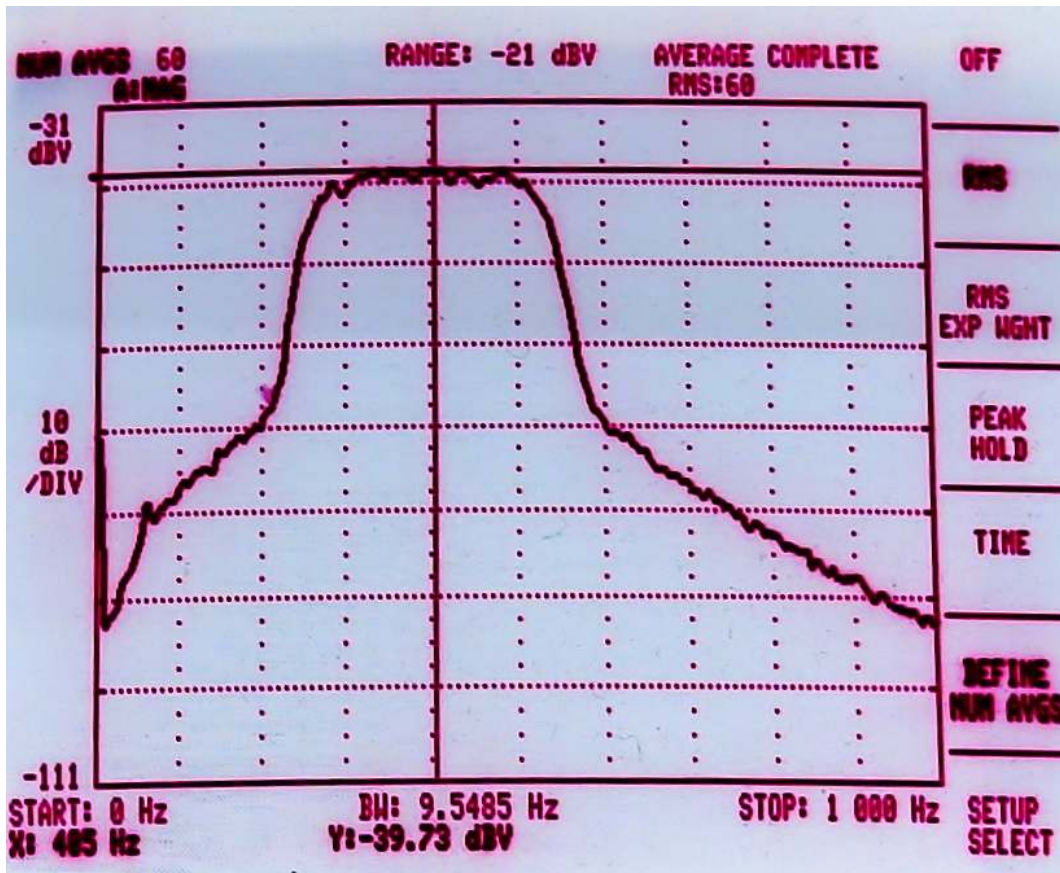
9 MHz Filters

- FL-101: CW Narrow Filter 250 Hz
- FL-232: CW/RTTY Filter 350 Hz
- FL-100: CW/RTTY Wide Filter 500 Hz
- FL-232: SSB Narrow Filter 1.9 kHz
- FL-103: SSB Wide Filter 2.8 kHz

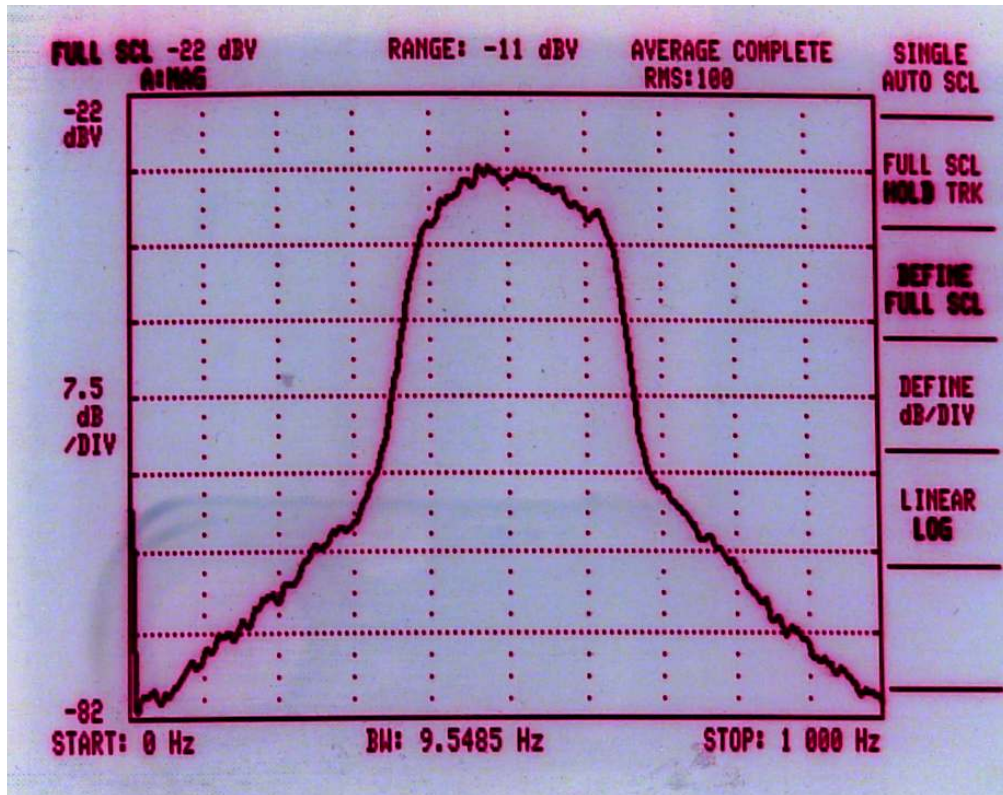
455 kHz Filters

- FL-53A: CW Narrow Filter 250 Hz
- FL-52A: CW/RTTY Filter 500 Hz
- FL-222: SSB Narrow Filter 1.8 kHz
- FL-257: SSB Wide Filter 3.3 kHz

The following two spectra show the difference between using the 500 Hz and 250 Hz filters in the 9 MHz position. The 455 kHz filter was 250 Hz in both these spectra.



Spectrum of the IC-R75 audio with filters FL-101 (500 Hz) and FL-53A (250 Hz).



Spectrum of IC-R75 audio with filters FL-100 (250 Hz) and FL-53A (250 Hz).

The added selectivity at 9 MHz has improved the skirt selectivity. Overall the receiver has slight leakage outside the passband and adjacent signals won't normally be heard outside the passband.

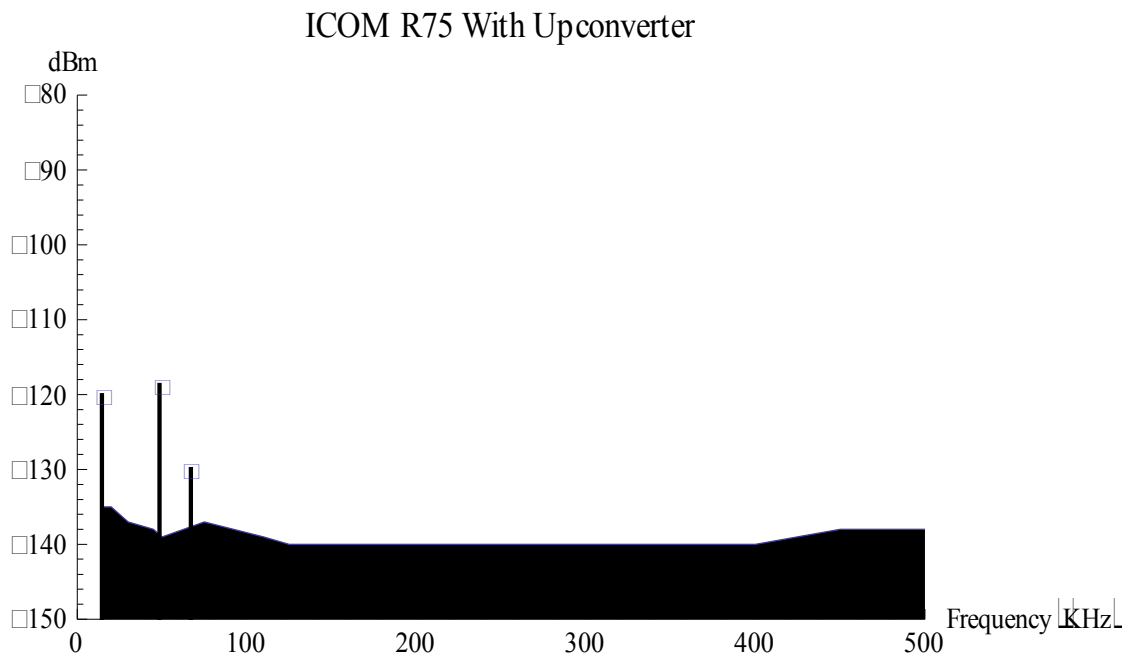
The bottom line:

- Construction quality – typical consumer grade electronic construction.
- LF Sensitivity – Good at -125 dBm
- LO Noise – Good, disappears at about 150 kHz
- Spurs – Poor below 200 kHz, fair above this.
- Filter selection with optional filters – Excellent
- Tuning resolution – 1 Hz, excellent
- Frequency display – 1 Hz, excellent
- LO Stability – Temperature compensated XO, excellent
- BFO – Adjustable in 10 Hz steps with stability regulated by the TCXO, excellent

- Noise blanker – Very effective with 2 adjustable blankers, superb.
- Display noise – I had to keep my portable 10” away from the front panel, fair

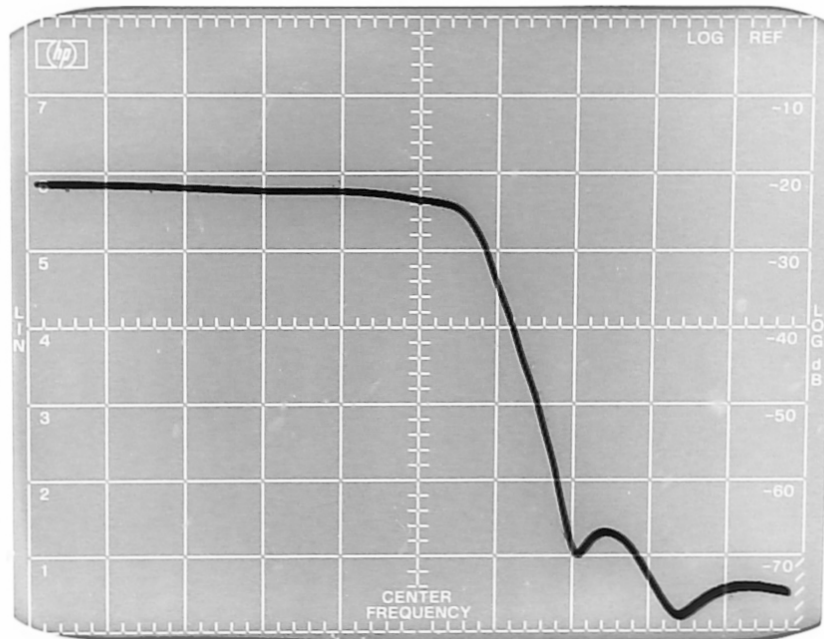
Part 2 IC-R75 With Upconversion

Todd Roberts sent me an email with an interesting idea. He suggested testing an R75 with a low pass filter with 500 kHz cutoff followed by an upconverter that heterodynes the 0-500 kHz spectrum to 3 to 3.5 MHz. It seemed that this could possibly eliminate many of the spurious responses that showed up in the previous test of the R75. He shipped me his R75 along with his filter and upconverter for testing. This is the sensitivity plot with the upconverter:



This is a huge improvement in both the sensitivity and especially the spurious response content of the receiving system. The spurs now only number three and these are all generated by the upconverter. The sensitivity is superb, right down to 10 kHz. Below 10 kHz upconverter oscillator phase noise increases quickly. Synthesizer phase noise is now completely gone. The upconverter system consists of a 500 Hz lowpass filter oscillator and mixer.

500 kHz Lowpass Filter



This is a spectrum analyzer display of the low pass filter. 500 kHz is at the center of the display. The frequency axis on this plot covers 200 kHz so the filter is effective at 520 kHz. The attenuation of broadcast band signals is about 60 dB. In the pass zone, attenuation is only one or two dB.

A low pass filter is a necessary part of the system since, without it, you will be hearing signals heterodyned from the 2.5 to 3.5 MHz band as well as those from the 0 to 500 kHz band.

Upconverter Mixer

The conversion loss in the upconverter mixer is less than a dB. For this reason, as well as the small loss in the low pass filter, the sensitivity of the whole system with filter and upconverter is very close to that of the receiver itself in the 3 to 3.5 MHz band. Sensitivity now averages -139 dB and LO phase noise is non-existent.

I measured a second order IMD intercept at a 20 kHz spacing of +22 dBm, and a third order IMD intercept of +6 dBm. The IMD dynamic range at this spacing was 81 dB for the second order and 83 dB for the third order. These are good ratings and since there aren't many strong signals on the LF band I don't expect any problems with intermodulation distortion.

The bottom line:

With the lowpass filter and mixer these bottom line parameters have changed:

The bottom line:

- LF Sensitivity – Superb, close to -140 dBm
- LO Noise – Superb, none above 10 kHz
- Spurs – Excellent at only 3.

Other parameters remain unchanged.

Chapter 21

ETÓN E1 Portable Receiver



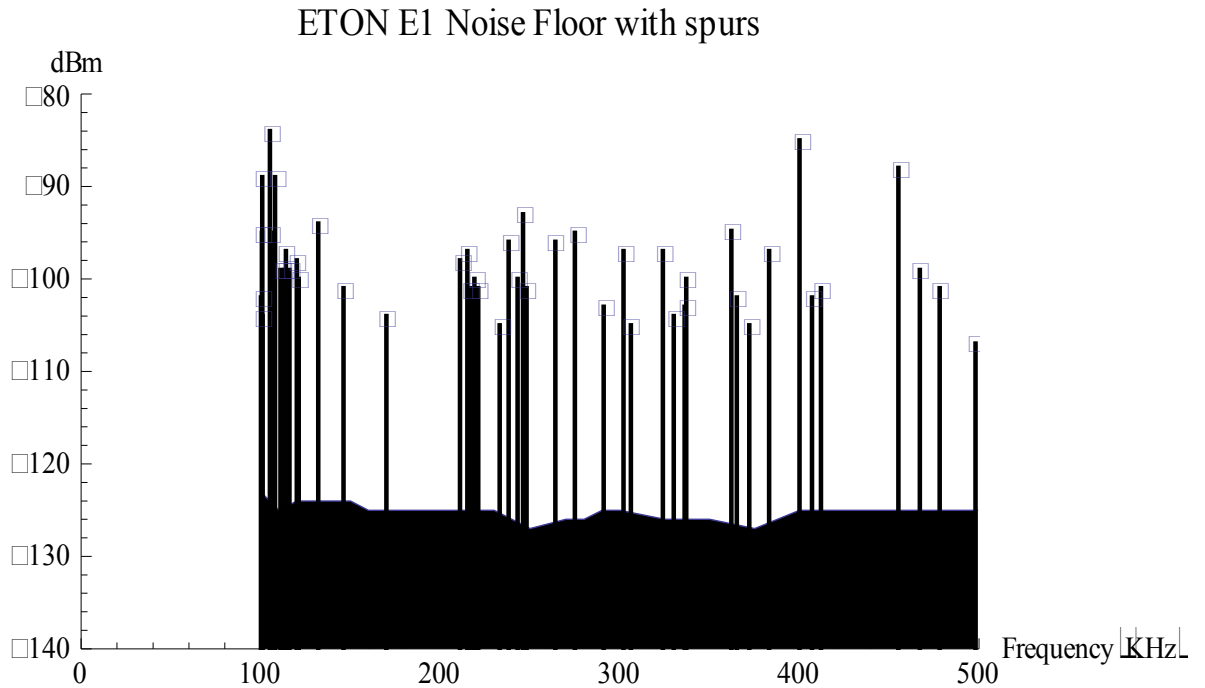
Description

You may find a portable useful when you want to DX beacons from a remote location. Based on a review in *Passport to World Band Radio* this one should be a good choice. *Passport* gave it a $4\frac{3}{8}$ out of a possible 5-star rating. All the other portables they tested only received a 3 star or less rating with most coming in with a 2-star rating. In their review, they stated “The Etón E1 is the top portable performer of all time”.

It features tuning and display to 10 Hz or 1 kHz, user selectable. Also, there is a passband tuning knob that works well and inside there are front end filters before

the RF amplifier and mixer, unique to this portable. The RF amplifier can be turned off if large signals are causing overload.

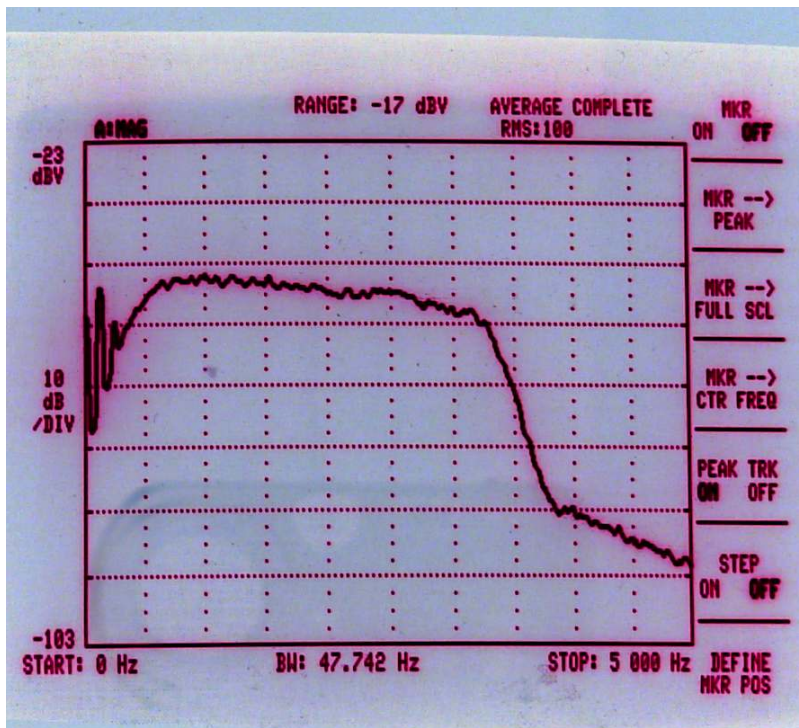
Sensitivity



This is a plot of the sensitivity along with spurs in the ETON E1 portable. The receiver can be tuned no lower than 100 kHz. Sensitivity is good at an average of about -125 dBm and no phase noise is apparent over this tuning range. The sensitivity testing was done with the RF amplifier selected. Without the RF amplifier, the sensitivity would be about 6 dB lower.

This receiver holds the record for the number of spurs of any receiver tested, 46. These are just the larger spurs that could be heard. There are actually many more small spurs. To plot them all would have made the sensitivity plot difficult to see. Apparently, it is more difficult to eliminate spurs in a portable because of the difficulty in shielding in the limited space available.

Filters



On this spectrum plot, vertical divisions are 10 dB and horizontal divisions are 500 Hz. This filter has a stated bandwidth of 2300 Hz and is the narrowest filter available. On the analyzer, the bandwidth appears to be closer to 3 kHz. Ultimate rejection is only fair at about 50 dB. This is typical of ceramic filters.

The bottom line:

- Construction quality – More shielding would be helpful but may not be possible.
- LF Sensitivity – Good at about -125 dBm
- LO Noise – Excellent over the range that can be tuned.
- Internally generated spurs – Poor
- Filter selection – Poor for CW reception
- Tuning resolution – 10 Hz – Good

- Frequency display – 10 Hz – Good
- LO stability – Fair
- BFO – None. Beacon reception can be done in SSB or AM mode.
- Noise blanker – Not an option.
- Display noise - I had to keep my portable receiver at least 8 inches away for reception of a weak beacon. – Good.

Performance

This is a choice for portable beacon DXing. It has more than adequate sensitivity and the front end filters should help to attenuate strong broadcast band interference. To use it with an external antenna you will need to get an adaptor for a PAL connector, available at Radio Shack. As far as the spurs, these will have to be lived with. What's missing from this set is some way to carry it. There is no strap or handle.

Reliability

This receiver was given to me by Bill Bowers after the display developed vertical black lines on the LCD. This is a common problem with this portable and makes the display nearly illegible. The only fix is to put in another LCD. Soon after that it started turning itself on, which ran the battery supply down. I tried rebooting the firmware, but this had no effect. As a solution, I removed the batteries when not using it. After that, it became difficult to turn on. I finally gave up, removed the useful components (several Murata ceramic filters) and scrapped the rest. I wouldn't give it high marks on reliability.

Availability

I searched the internet for ETÓN E1s for sale but it appears that this model has been discontinued. Also, the Grundig G1 which is nearly identical has also been discontinued.

Chapter 22

ICOM IC-R9500 Communications Receiver



Description

The ICOM IC-R9500 is a premium grade communications receiver. It is designed for use mainly by government agencies and others for surveillance countermeasures (bug chasing). As such it has “DC to Daylight” frequency coverage (except for cell phone frequencies) along with a built in spectrum display. This receiver is the second in ICOM’s superset series, the first being the IC-R9000. It comes at a premium price, \$13,500. It’s a heavyweight receiver, weighing in at 44 pounds.

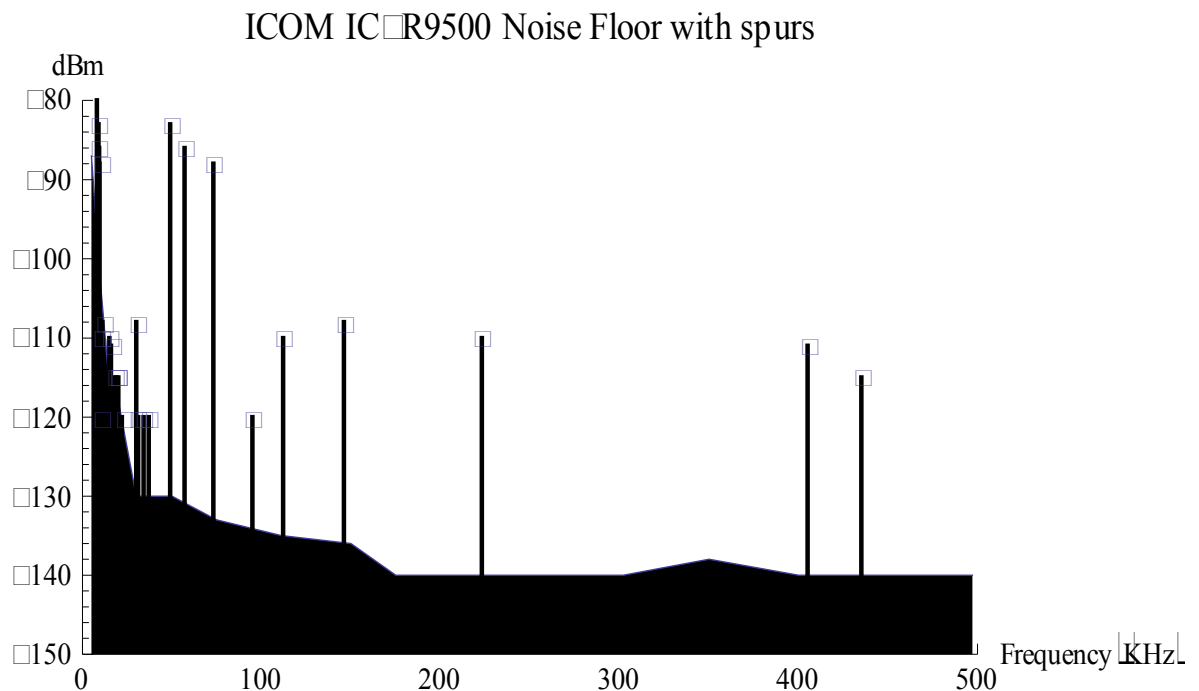
You can find a write-up of this receiver in *Passport to World Band Radio*. Many of its features, too numerous to mention in this review, are reviewed there. It was given a 5-star rating by *Passport* along with high praise.

You can also find information about it in *Shortwave Receivers, Past & Present*, fourth edition, page 327.

Construction Quality

The unit is well sealed and would require some work to get at the insides, so I didn't take any photos of the interior. You can assume that construction quality is first rate.

Sensitivity

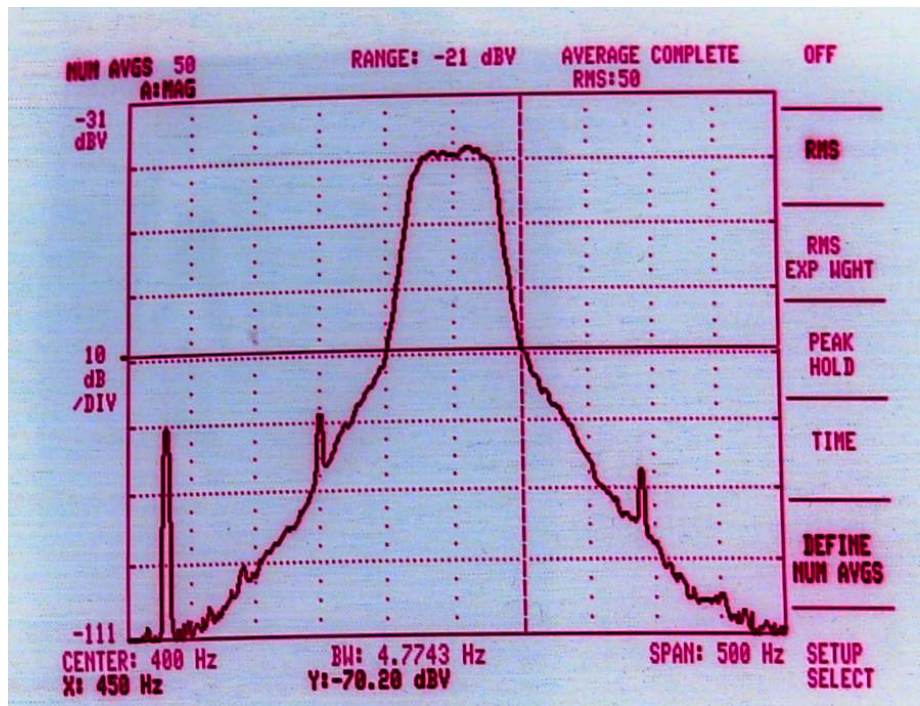


For this test, the preamplifiers were used when possible. Preamp1 helped from 100 kHz to 500 kHz. Preamp2 was only a marginal improvement from 100 to 300 kHz. It was not used for this test.

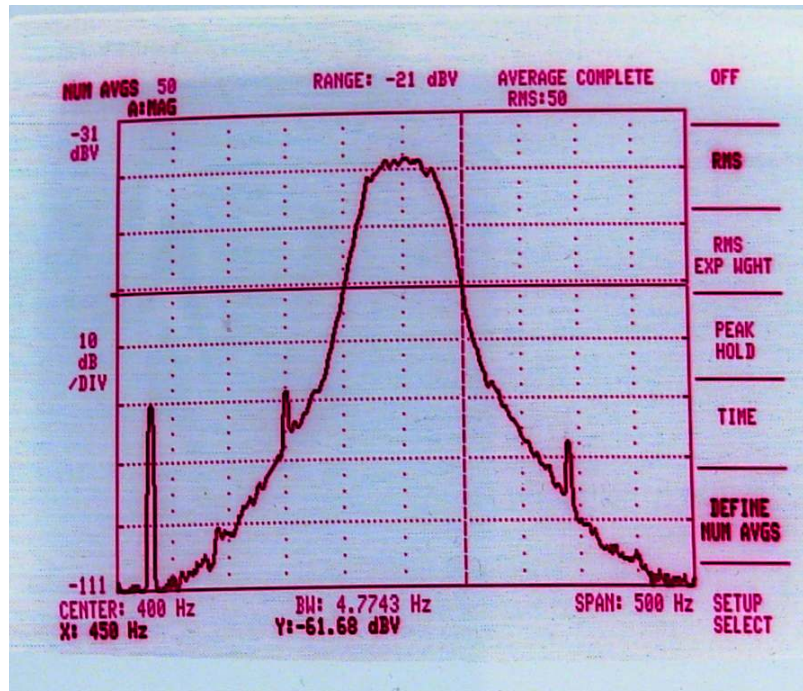
Note that the origin for the vertical axis for this plot has been reset to -150 dB. The noise floor was so low for this receiver that I had to change the plot from what I had been using (-140 dB) to -150 dB. This is an exceptionally quiet receiver.

For the IC-R9500 28 spurs were found which would normally be a poor result. However, most of these spurs fall below 150 kHz and won't affect beacon DXing. In the event you will want to DX VLF beacons, this receiver may not perform well.

Filters



This is a photo of the spectrum analyzer output of the receiver when tuned to a random noise source. Vertical divisions are 10 dB and horizontal divisions are 50 Hz. This filter has a bandwidth of 50 Hz and is the narrowest filter that can be implemented. This is a high quality digital filter with no noticeable leakage and an ultimate rejection of at least 70 dB. There are two choices of filters at each bandwidth, sharp and soft. The above filter is the sharp filter with a flat bandpass and steep filter sides. There is also a soft setting:



The soft setting gives a rounded passband and less steep sides. With this soft setting, I expect that the filter will not ring as much.

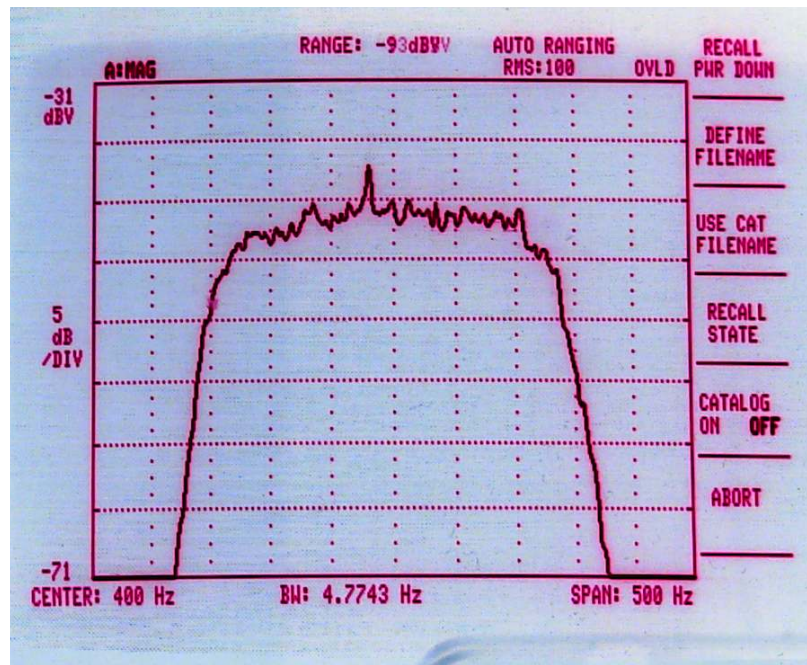
The bottom line:

- Construction quality – Excellent
- LF Sensitivity – Superb
- LO Noise – Good. The LO noise drops to negligible values around 170 kHz.
- Internally generated spurs – Poor below 150 kHz.
Excellent above 150 kHz.
- Filter selection – Superb. The filter choice is now excellent for CW reception. The filters in the R9500 are DSP. **This is a big improvement over the R9000 which only had a 500 Hz narrow CW filter.**
- Tuning resolution – 1 Hz – Excellent. **This deficiency in the R9000 was corrected.**
- Frequency display – 1 Hz – Excellent. **This deficiency in the R9000 was corrected.**
- LO stability – Temp compensated XTAL oscillator – Excellent

- BFO – Superb. Adjustable in 5 Hz steps with the same stability as the LO. The BFO is now excellent for beacon reception. **This was another deficiency in the R9000 which has been corrected in the R9500.**
- Noise blankers – Fair. There are two blankers with adjustable thresholds. See **Performance**, below. **This is the only component in the R9500 that is not as good as the R9000.**
- Display noise - I had to keep my portable receiver at least 15 inches away from the display to get good LF reception on the portable. This is a fair rating, however better than the R9000 with its CRT display.

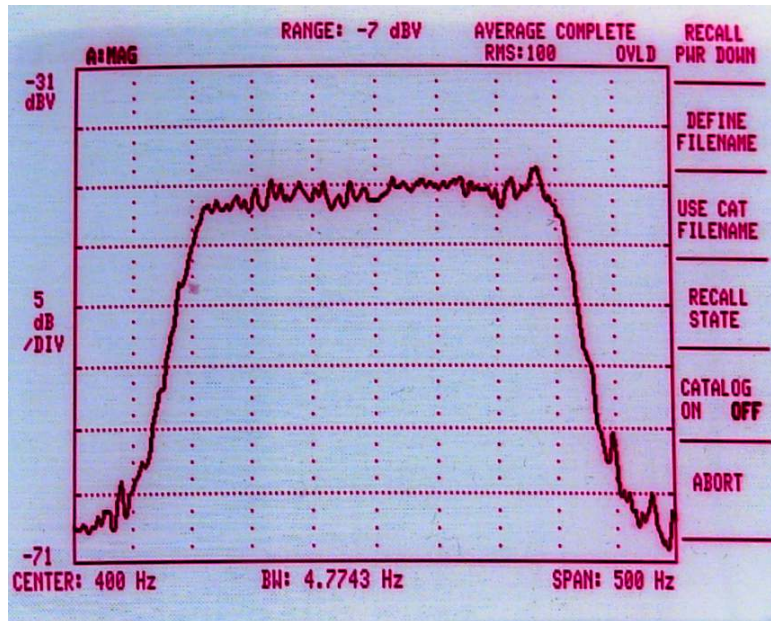
Performance

I did a comparison in beacon reception to my favorite receiver, the Harris RF-590. For testing I found a beacon, LNC near Dallas, TX on 239 kHz. The ID is heard on 240 kHz during the daytime weakly at my location in central Oklahoma with my outdoor Wellbrook loop. Noise is usually a problem and requires the use of a good noise blanker to hear the signal. Here's a spectrum plot from the Harris showing the signal as a small spike near the center of the bandpass:



The beacon was also readable on an ICOM IC-R75 using its noise blanker.

I tried for this beacon with the IC-R9500. There are two blankers, both with adjustable depths and widths. I tried both of these and many settings of the widths and depths. I could never recover the signal with any setting. Here is the spectrum from the R9500:



Later in the afternoon the noise let up, and I was able to receive the signal on the R9500. From this I must conclude that the blanker is not very effective. The blanker is implemented in the DSP software. I have another receiver with a software noise blanker, the NRD-545. The blanker on this receiver is only marginal also. Noise blankers work better if they are built into the analog part of the receiver, before the A/D conversion. If blanking is left until the DSP processing and the noise is strong, the signal may be lost due to the finite range of the A/D converter.

All other features that I tried using this fine receiver are first rate. The changes made in the R9500 from the R9000 have made the R9500 a great CW receiver.

Availability

This receiver is no longer in production. Used ones will be hard to find.

Thanks go to Bill Bowers for allowing me to test his new IC-R9500.

Chapter 23

WinRadio Excalibur Pro SDR



WinRadio Excalibur Pro SDR Receiver

Thanks to Doug Williams, KB4OER, we have a test of an SDR receiver. He loaned me his Excalibur Pro for this test. This was an interesting test for me since I had not used an SDR previous to this. I hooked it up to my Lenovo ThinkCentre computer which has additional RAM and a solid-state disk. With its 3.5 GHz CPU the computer has plenty of processing power to run this unit.

Description

All the controls of the receiver are done with software running on the computer by using the mouse and keyboard. To be honest, I like real knobs, lots of them, but the software knob (which can use a mouse wheel) works well and the other

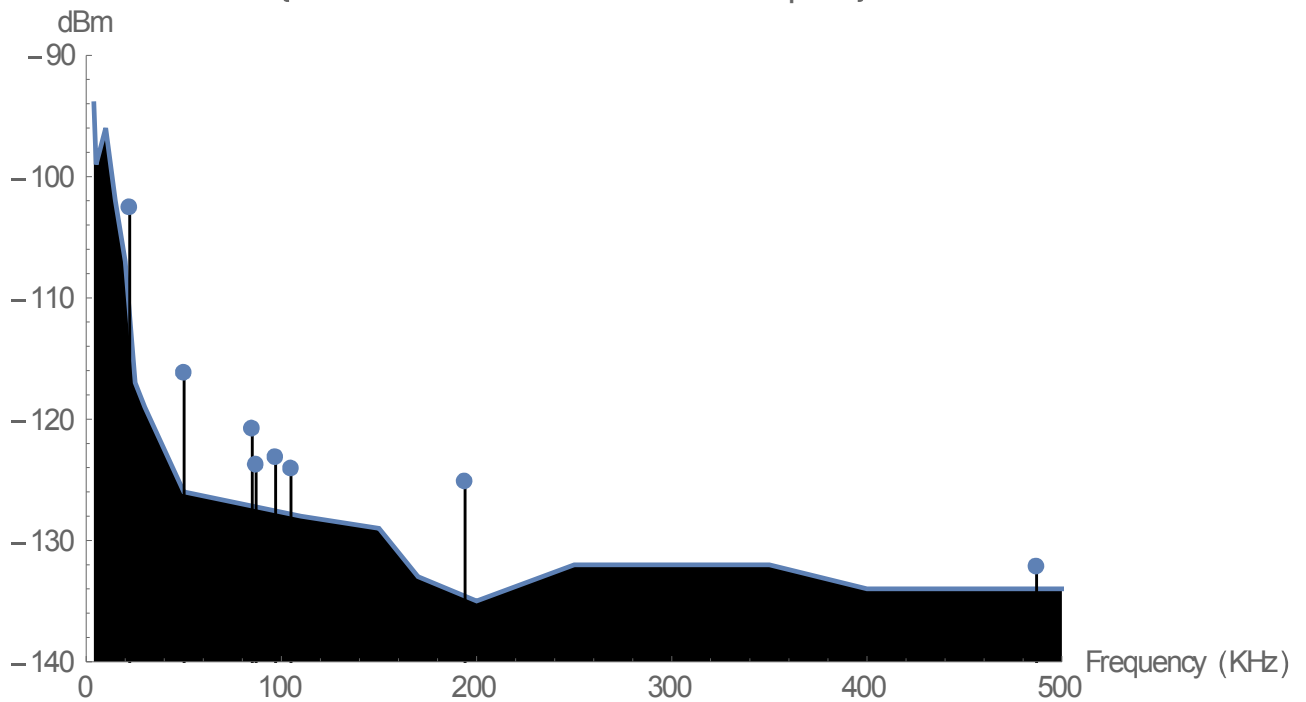
controls are available by clicking on various software buttons using a menu system. There is a multitude of options and it took me a while to find the best ones for LF listening.

Construction Quality

The unit is well sealed and is housed in a cast aluminum container. The connections are antenna input, USB hookup and power, supplied by a plug-in wall wart. It was easy to hook up, the software was easy to install, and it worked the first time I turned it on.

Sensitivity

{Excalibur Pro Noise Floor with spurs}

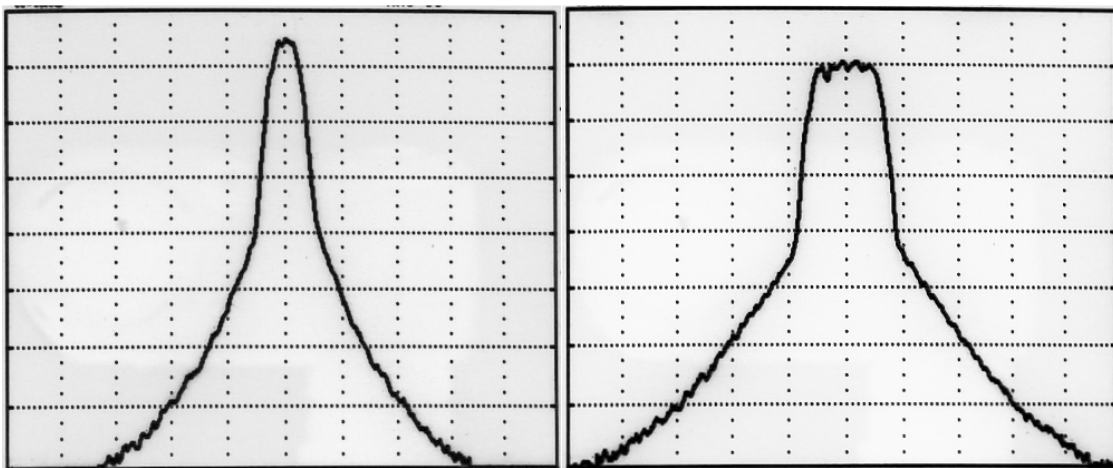


Note that the origin for the vertical axis for this plot has been reset to -140 dB. The noise floor was so low for this receiver that I had to change the plot from what I normally use (-130 dB) to -140 dB. This is an exceptionally quiet receiver, quieter than most receivers previously tested. The preamplifier was not used in this test.

For the Excalibur Pro 8 spurs were found which is a good result. These spurs were not strong, the maximum being about 10 dB over the noise level. Several of them were not CW spurs but were clicking noises. During actual on the air reception the spurs would be so weak that they would probably not be noticeable above the noise levels on LF.

Filters

There are many filters available which are implemented in software using the FIR (Finite Impulse Response) algorithm. The ones I used for listening were the 20 Hz and 50 Hz, which have the following frequency responses:



20 Hz filter spectrum

50 Hz filter spectrum

These filters are just about theoretically perfect. They are brick wall; the -6 dB bandwidths are exactly as specified and the ultimate rejection is excellent. In addition, they are linear phase which means ringing is minimized.

The bottom line:

- Construction quality – Excellent
- LF Sensitivity – Excellent at an average of -135 dBm
- Internally generated spurs – Good below 100 kHz.
Excellent above 100 kHz.
- Filter selection – Superb.
- Tuning resolution – 1 Hz – Excellent.
- Frequency display – 1 Hz – Excellent.
- LO stability – Temp compensated XTAL oscillator – Excellent
- BFO – Adjustable in 1 Hz steps with the same stability as the LO. Superb.
- Noise blankers – There are two blankers with adjustable thresholds.
Excellent
- Display noise - Computers are very noisy. I had to keep my noise detector (portable tuned to LF) at least six feet away from the receiver and computer to keep the noise at half scale on the S meter. Poor

Performance

AM Broadcast Band

With these specifications in mind, I was expecting great results from real on the air DXing. Performance on the AM broadcast band is truly excellent with good reception of a weak station right next to a strong one. The audio is great. It easily matches or beats any of the receivers I have here. The only problem I have is that since I use a tuned rotatable ferrite loop, which is close to the receiver for most of my AM DXing, the noise from the computer makes that impossible.

LF and VLF DXing

Turning now to the main topic of this review, how does this receiver do for DXing LF and VLF signals? I compared it with my best VLF and LF receiver, the JRC NRD-545 with VLF mod, discussed in the LOWDOWN, October 2015.

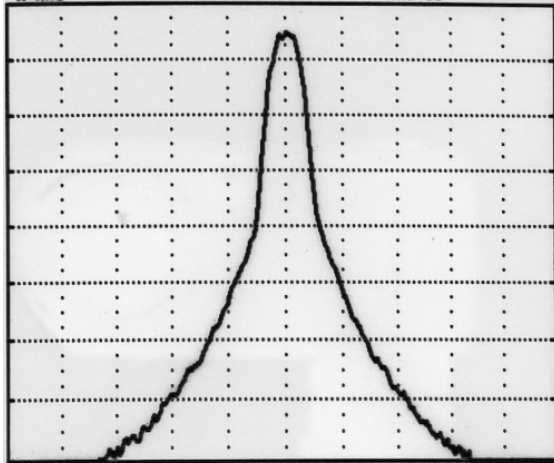
The results were surprising. I was expecting, based on my bench tests, that the NRD-545 would be beaten badly by this receiver. That assumption was incorrect. The NRD-545 easily beat the Excalibur Pro every time during testing. It could receive signals perfectly that were not even detectable on the Excalibur Pro. During early morning and evening listening sessions I tried many times to bring the Excalibur performance up to that of the NRD, but no amount of adjustment of controls could do that.

After a week of listening I was seeing if I could receive the Russian alpha radiolocation VLF beacons on 11.9 (α -1), 12.65 (α -2) and 14.88 (α -3). α -2 and α -3 were covered by electronic noise, probably microprocessor QRM, but on the NRD-545, α -1 was clear and very good. I could just catch a hint of it on the Excalibur. To do this I modified the Excalibur 20 Hz filter so that it was no longer a perfect brick wall. This can be done by changing the operator length of the filter. To get the ideal filters shown on the above spectra an operator length of 5000 samples was used. The filter shape can be changed by using a shorter length. I found the best reception of α -1 was with a length of 1500 samples.

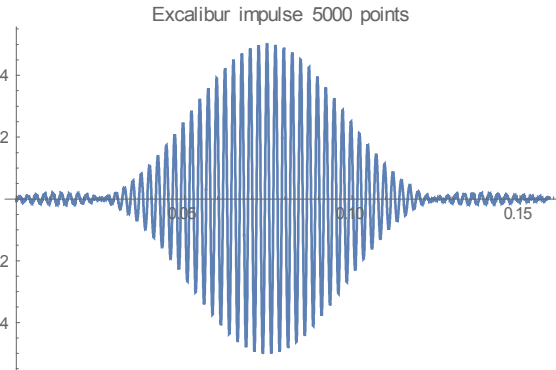
Filtering Compared in Frequency and Time Domains

Normally filters are specified in the frequency domain. The values of the passband at -6 dB and -60 dB are considered important for how well the filter performs. This is obviously what is needed in a CW pileup, when one wants a single signal to be selected among many others, as well as in USB or LSB voice traffic if QRM is present. The other domain, time, is normally not given much thought. However, in the case of weak signals with high amplitude noise consisting of impulses it should be.

Here is the spectrum and impulse response of the Excalibur Pro 20 Hz filter with a 5000 sample operator:

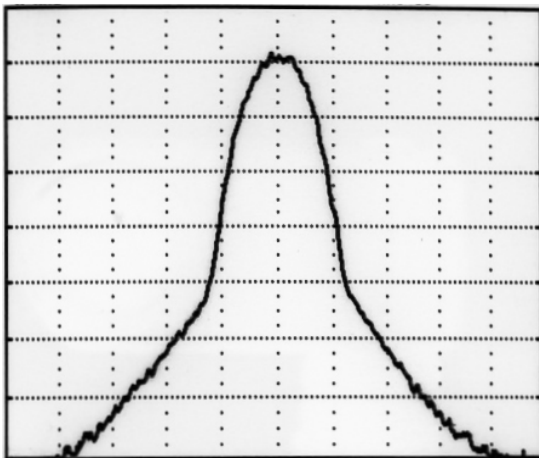


5000 point filter Frequency spectrum

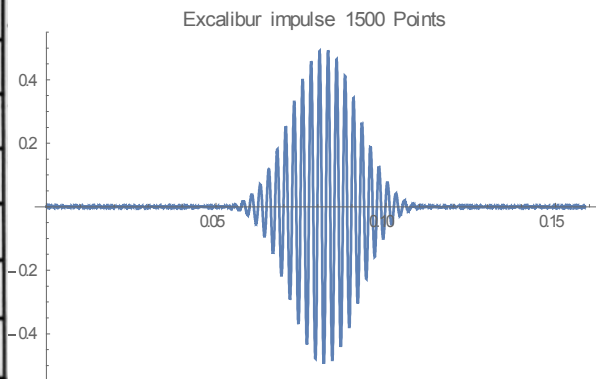


Impulse Response

Using this same filter with an operator length of 1500 samples gives the spectrum and impulse response:



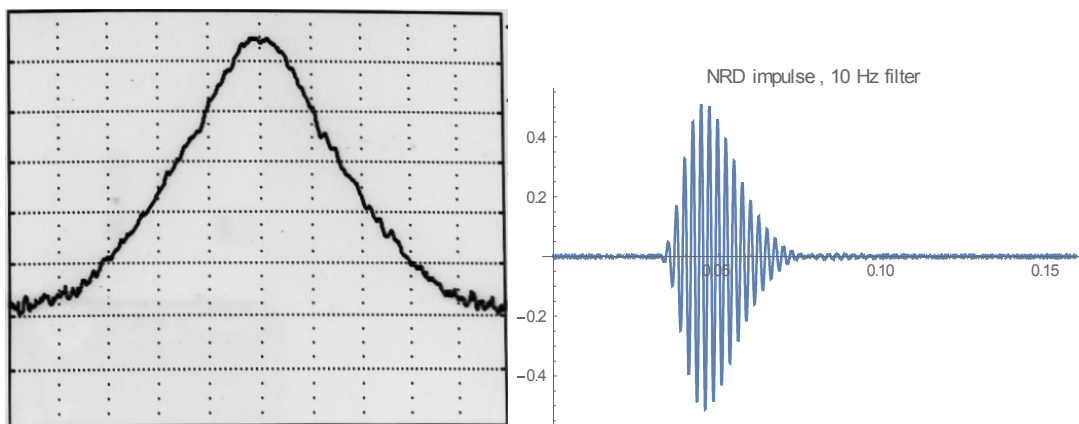
1500 point filter Frequency spectrum



Impulse Response

This is an example of complementary domains. When the bandwidth is increased in the frequency domain, the length of the impulse response in the time domain is reduced. For strong impulsive spike noise, the time domain becomes important since in filtering each noise impulse will be convolved with the filter impulse response. If the impulse response is long, as in the 5000 point filter, these filtered noise impulse responses will have more overlap with the desired signal, burying this weak signal in noise.

Compare this to these same displays for the NRD-545, 10 Hz filter:



NRD-545 10 Hz Filter Spectrum

Impulse Response

This impulse is much shorter than the 5000 point Excalibur filter, and shorter than the 1500 point Excalibur filter. The measured time lengths for these three filters are:

NRD-545 Filter = 40 msec

Excalibur 1500 filter = 50 msec

Excalibur 5000 filter = 95 msec

This explains why the Excalibur 5000 point filter performs so poorly in noisy conditions, but the 1500 point filter and NRD-545 filter should not be much

different. I don't have an explanation for why the Excalibur did not perform better with this filter.

In summary, this has been a very interesting testing sequence for me and brought back memories of several articles in the Lowdown that I wrote in the June, July and September, 1997 editions. Wow, how time flies! That was almost 20 years ago. Those articles were prompted by how poorly my new Watkins-Johnson HF-1000 performed for longwave DXing. The conclusion was similar. The HF-1000 had FIR digital brick wall filters and it's problem was similar to the Excalibur's. The recommendation that I gave then was to add an analog audio filter to the HF-1000's output. The best analog filters use Gaussian spectrum bandpass curves.

Availability

The Excalibur Pro is still in production. You can purchase a new one for about \$1000 from WinRadio dealers, however I have seen them for sale for \$800.

Appendix

LF-VLF Upconverters

For listening to VLF and LF beacons, one way to do this with a receiver that doesn't cover these frequencies or performs poorly there is to use an upconverter to upconvert the VLF and LF bands to a higher band in the shortwave spectrum. This was illustrated by the ICOM IC-R75 pair of tests. An upconverter consists of a low pass filter, passing frequencies below 500 kHz which prevents signals above 500 kHz from mixing with the upconverter's oscillator signal, usually 3, 3.5, 4 or 10 MHz. After the filter, the LF signals are input into a mixer with one of the above oscillator signals. The VLF-LF spectrum can then be received in the 3-3.5, 3.5-4, 4-4.5 or 10-10.5 MHz bands.

I have three upconverters that I will test. These are:

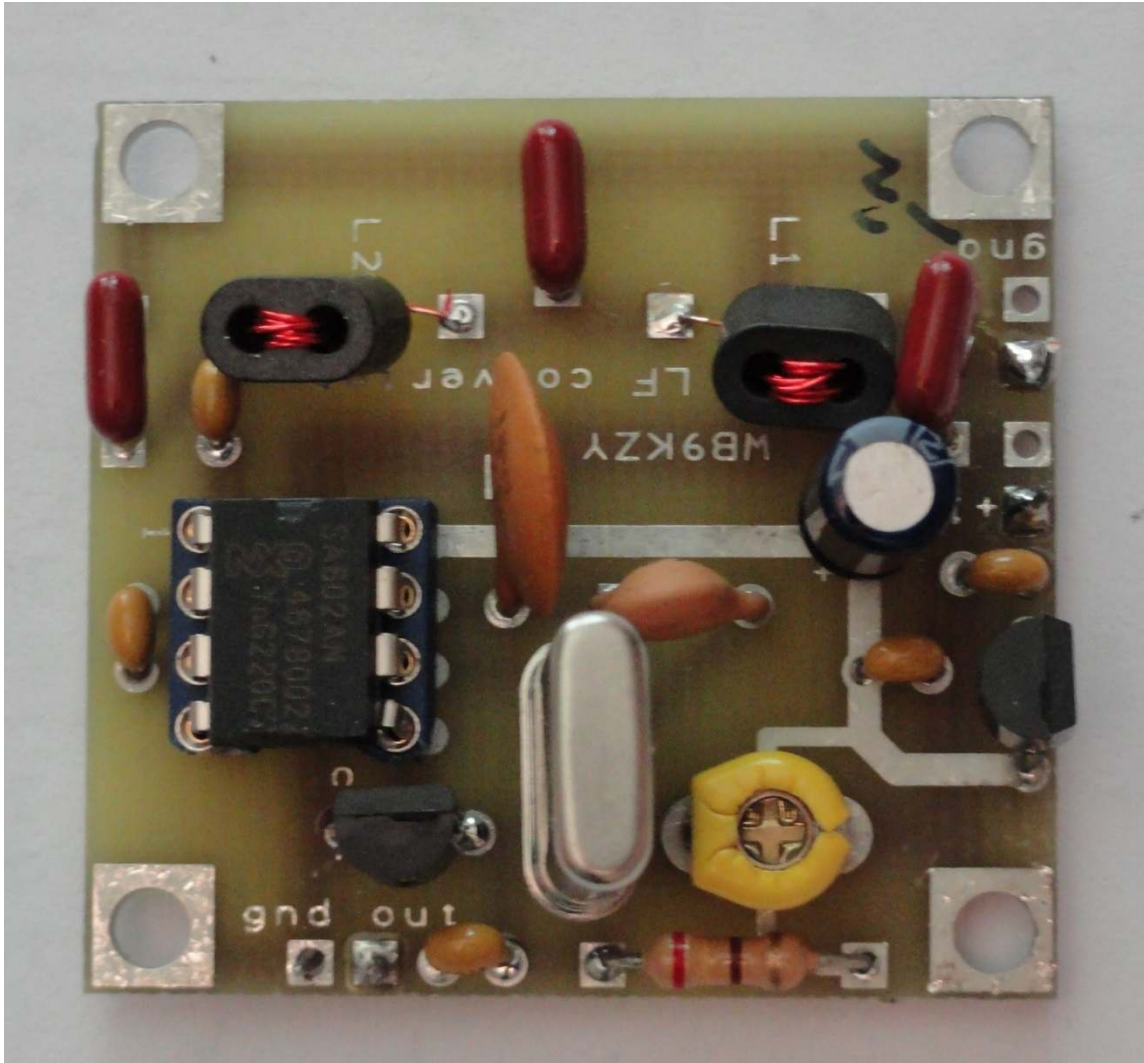
- A kit, made by Jackson Harbor Press, see <http://wb9kzy.com>
- AMRAD VLF Converter; you will have to build this yourself. You can find plans on the web. Todd Roberts used to sell built units, but I'm not sure he still does. The conversion frequency is 3 MHz.
- Heros Technology Ltd upconverter, sold by a British company. You can find them on the web at:

<https://www.herostechnology.co.uk/pages/products.html>

There are two models with conversion frequencies of 3.5 or 4 MHz.

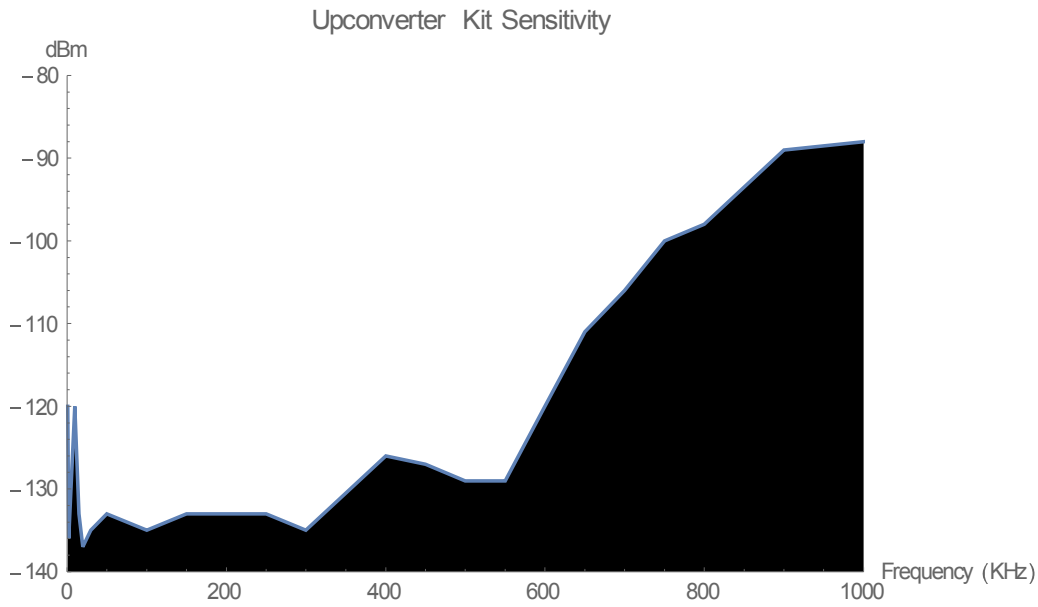
Jackson Harbor Press Kit

Here's a way to get on VLF-LF for very little money. It comes in kit form with all components plus two crystals, 4.0 MHz and 10 MHz. This allows a choice of the conversion frequency. It is easy to put together with no surface mounted components. You will have to wind the two coils on the included binocular forms for the low pass filter. The kit sells for \$14 plus shipping. This is a photo of the unit after I assembled it:



Sensitivity

The following graphic is a plot of the sensitivity of the assembled kit, obtained by inputting a signal in the 0 to 1000 kHz range from a signal generator into the unit (with the 4 MHz crystal plugged in) and measuring the output of the converter in the 4 to 4.5 MHz range with an HP3586C selective level meter. The signal was recorded when it exceeded the noise level by 10 dB.



The effect of the low pass filter can be seen starting at about 600 kHz. Sensitivity is good in the VLF-LF band at between -135 and -130 dBm.

Low Pass Filter Leakage

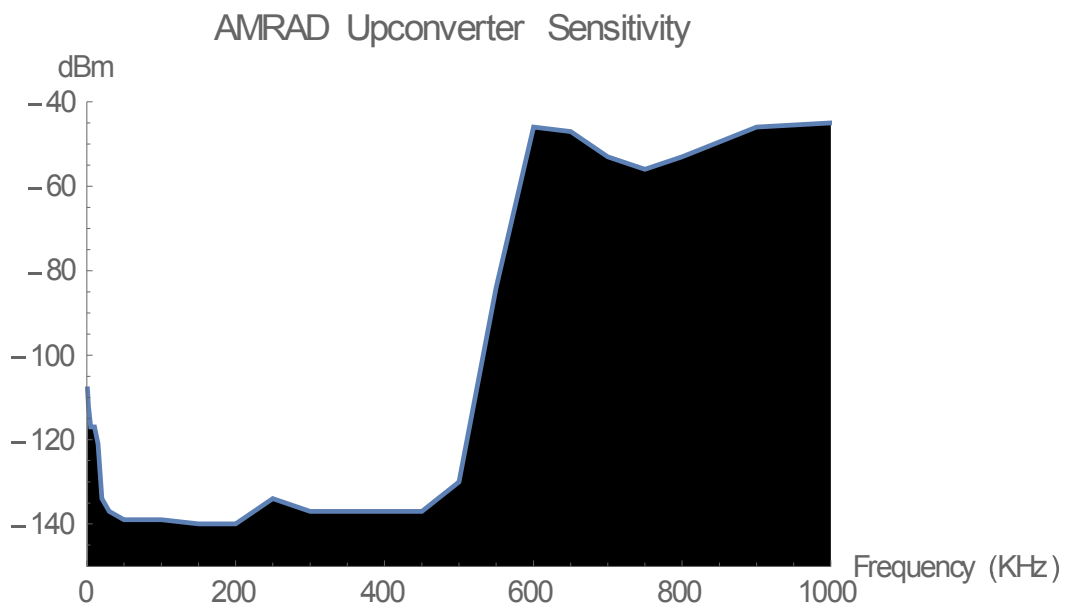
To measure the effectiveness of the low pass filter, the upconverter output was hooked to a spectrum analyzer tuned to the 0 to 500 kHz range, and the signal generator was set to an output of 0 dBm and tuned through the range from 1 MHz to 10 MHz. Any responses seen on the spectrum analyzer would indicate that signals in the MF to HF range would leak through the unit and be heard as incorrect LF signals. From 3.5 to 4.5 MHz input the spectrum analyzer showed output in the 0 to 500 kHz of a nearly constant -34 dBm signal. In other words, the low pass filter attenuates signals by about 34 dB in the HF band from 3.5 to 4.5 MHz. Also in the 7.5 to 8.5 MHz band there were responses in the 0 to 500 kHz band of -53 dBm. This is due to the second harmonic of the 4 MHz oscillator signal mixing with the input signals. Since the oscillator and mixer are all on a single chip there isn't anything that can be done about harmonics of the oscillator. To improve the relatively poor performance of the low pass filter, an additional low pass filter could be added between the antenna and this unit. These can be found on the web. This small unit is still a bargain at only \$14.

AMRAD Upconverter

This is a photo of the upconverter as assembled by Todd Roberts:



The lowpass filter on the right is must be connected to the converter on the left. The sensitivity graphic looks like:



Sensitivity is excellent at almost -140 dBm over nearly all the VLF and LF bands. The effect of the low pass filter is clearly seen, starting at 500 kHz and is almost a brick wall. For this sensitivity plot the maximum signal has been reset to -40 dBm. On the other two displays it is -80 dBm. The low pass filter in the AMRAD unit is very effective.

Low Pass Filter Leakage

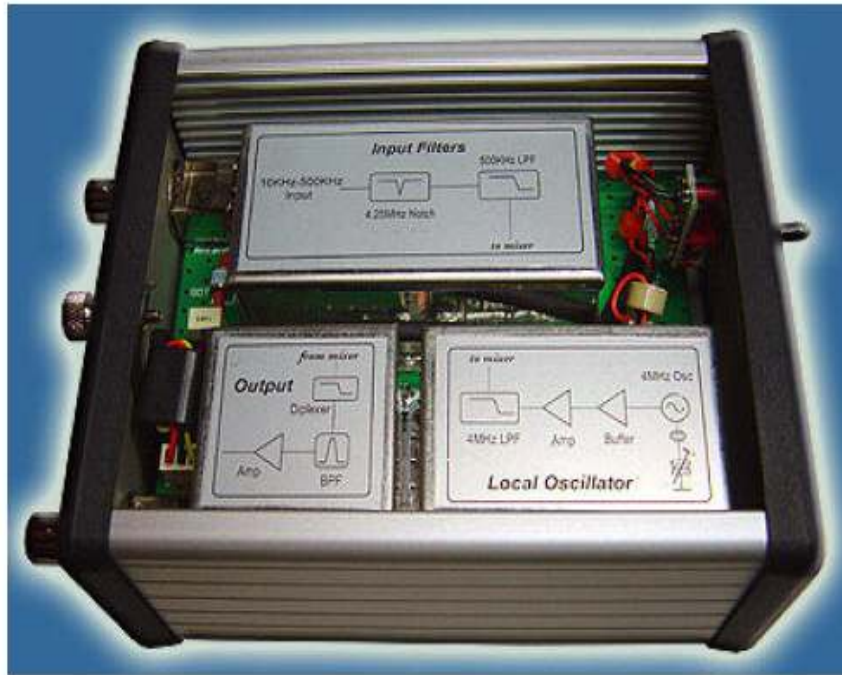
0 dBm signals in the band 2.5 to 3.5 MHz were nearly constant at -82 dBm in the 0 to 500 kHz spectrum analyzer display. With 82 dB of attenuation, more low pass filtering should not be needed. This is a well-constructed and designed unit.

Heros Technology Ltd. Upconverter

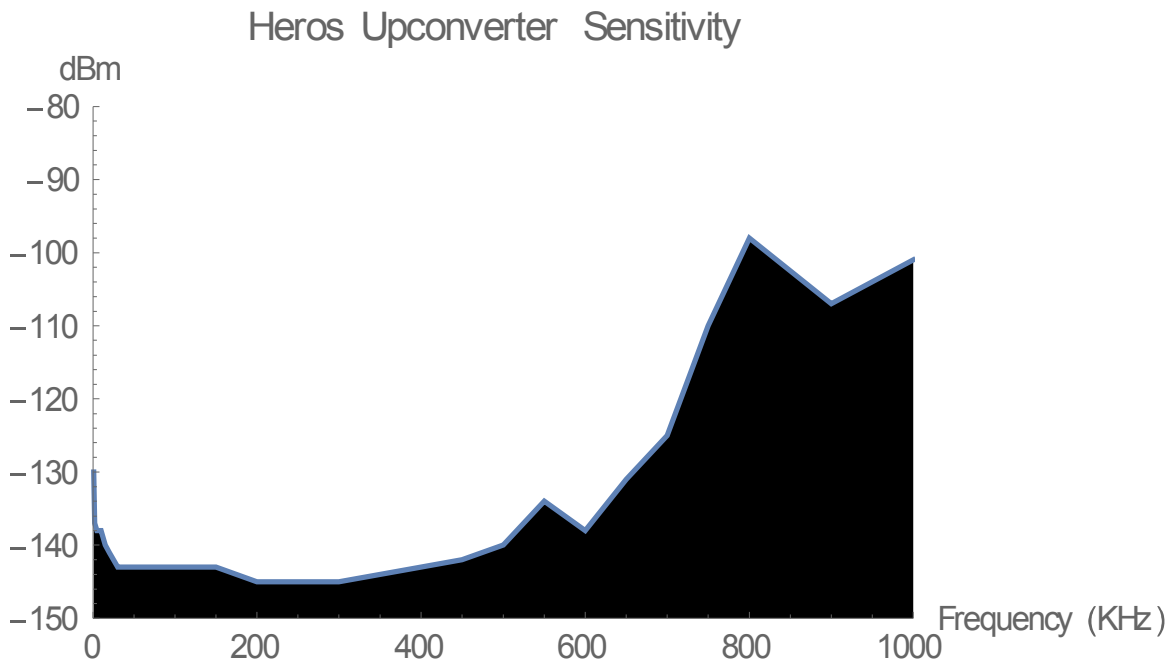
This is a photo of the Heros Technology unit:



This is a carefully designed and constructed unit. Here's a photo of the inside with the top cover off:



There is extensive shielding and attention was given to filtering both the input and oscillator signals. The sensitivity graphic looks like:



This unit is the most sensitive of the three, with nearly -145 dBm over almost all the VLF-LF range. At 2 kHz, the sensitivity is -137 dBm while the AMRAD unit has a rating of -112 there.

Low Pass Filter Leakage

The sensitivity graphic shows that the low pass filter is not of the same quality as the AMRAD unit. This shows up in the leakage test. The conversion frequency is 3.5 MHz for this unit, and from a signal generator input of 0 dBm tuned over the 3 to 3.5 MHz band the response in the 0 to 500 kHz band is constant at -78 dBm. This is a good in this band. In the 3.5 to 4 MHz band, the response in the 0 to 500 kHz band is -78 dBm at 3.5 MHz increasing to -41 dBm at 4 MHz. Additional low pass filtering may be required depending on the antenna used and strength of HF signals in the 3.5 to 4 MHz band.

Conclusions

Any of these upconverters will do a good job of making any receiver that covers HF frequencies into a good VLF-LF receiver. The AMRAD and Jackson Harbor Press kit will require some construction while the Heros unit is ready to use. It is more expensive however. There were some older models once made by Heathkit and Palomar Engineers that can be found for sale occasionally. These were not available for testing. At one time, I had a Heathkit unit, but as I remember it was way down in sensitivity and I didn't use it much.