

Testing Compact Antennas for LF Dynamic Range

John Reed, KA5QEP
ka5qep@sbcglobal.net

(Here is the first in a series of three articles on compact receiving antennas. This time, John looks at dynamic range. Next time, he evaluates sensitivity at LF. In the third installment, he performs a real-world test of sensitivity down at VLF.)

Introduction

With many of us restricted in the size of antennas we can use, this article will give information which should be useful for selecting a small antenna. Bill Bowers and I have gathered a variety of these antennas, some of which are currently available for purchase at retail outlets, while others are no longer available but may occasionally be found for sale as used equipment. One is homebrew, and was written up in *The LOWDOWN* earlier.

Information on dynamic range is important for active antennas, since the higher the dynamic range, the better the antenna will be in minimizing intermodulation products. These mixing products can easily be produced in the longwave band.

For example, the second order difference frequency of two strong AM broadcast stations near my location is 70 kHz; and while not in the beacon or LowFER bands, it is not hard to see how broadcast stations at other locations could cause mixing products in these bands. These mixing products are produced by the antenna itself, so a low pass filter inserted in the lead-in will have no effect.

It is difficult to find accurate measurements of dynamic range. Manufacturers sometimes give these measurements in their literature, but the methods used in getting these data normally aren't described, and their accuracy is sometimes suspect. In this report, all the antennas will be tested under the same conditions, using the same equipment, so comparisons can be made more objectively. The following antennas will be reviewed:

MFJ-1024 This antenna is currently in production and may be purchased at a reasonable price. At this writing, it lists for \$159.

Dressler ARA-60 This antenna has been discontinued.

Wellbrook LFL-1010 This antenna is also in production, but can only be purchased from the maker in Wales. It's an untuned loop design and will benefit by being oriented in the direction to the transmitter. The current price is \$317.

Clifton Labs Z1501D This is a new antenna that just came on the market. It covers 20 kHz to 30 MHz, and is available in kit form or pre-assembled. In kit form you will pay \$169. Fully assembled, with power coupler, it will cost \$289.

RF Systems DX-10 Pro This antenna is part of the RF Systems antenna selection. The literature claims that this antenna uses a helical element, but the element is sealed so no more information is available. The current price is \$449.

RF Systems DX-500 This is a wide band (30 kHz to 500 MHz) antenna which covers the LF spectrum. The current price is \$349. Tests of the intercepts were not done on this antenna since it overloaded badly on the strongest station near my location. In this nonlinear region, the tests would be meaningless.

LF Engineering H-800 This antenna is currently available and priced at \$149.

LF Engineering H-900 This is a deluxe version of the H-800, above, also available. The current price is \$189. There was very little difference between the H-800 (above) and this antenna in the tests, however.

Lankford Ultralinear Whip This is a homebrew design by Dallas Lankford, in a version constructed by the author. See *The LOWDOWN*, October 2005 issue.

Ratzlaff LF Antenna This antenna is made by Steve Ratzlaff. It comes with a 24 volt power supply, which should make it able to withstand strong signals better. Steve will build this antenna for those interested in it. It comes completely assembled with power supply for \$190. You can reach Steve at: steveratz@wildblue.net or by postal mail:

Steve Ratzlaff
72187 Darr Road
Elgin, OR 97827-8201

Palomar Engineers Loop This antenna is no longer in production. It is the only indoor design that will be examined. It is a tunable, rotatable small ferrite loop. However, you won't find measurements in this review for the Palomar antenna. I tried to find second and third order mixing products for this antenna, but none were there. The tuned loop eliminates any chance for intermodulation at these signal strengths.

The Tests

Notes on Tests

All measurements were made under the following conditions:

- At the same time each day, early afternoon. This minimizes propagation effects and helps ensure consistent measurements.
- Calm weather, dry ground.
- All tests are done with regulated power supplies, 12 volt in most cases.
- All computer equipment is turned off during the tests. This includes printers and modems, since the new plug in power supplies for these units are very noisy.

Intermodulation Distortion (IMD)

Intermodulation distortion refers to the generation of spurious signals by the active elements in an antenna. A good introduction to the theory and measurement of second and third order IMD intercept points is given in a PDF document on the Clifton Laboratories web site. It can be downloaded by going to the Clifton Lab site at <http://www.cliftonlaboratories.com> then looking at Current Products, and picking the Z1501 Active Antenna page. There you will find a PDF document entitled, *Observations on 2nd and 3rd Order Intercepts of the Clifton Laboratories Z1501D Active Antenna.*

The method of measuring intercepts given in the above document (called whip simulation) will work if the antenna can be disassembled so that test leads from signal generators can be connected directly to the active elements. However, most of the antennas being tested for these

reviews are enclosed, sealed units and this isn't possible. Instead, I will use two broadcast band AM station carriers as signal generators. These stations are:

KGFF, 1450 kHz, located about ½ mile from my location and broadcasting with a power of 1000 watts. This signal pegs the S-Meter on most receivers.

KOKC, 1520 kHz, located about 40 miles from my location. The signal from this station gives an S-Meter reading of +50 dB over S9 during the day.

The second order intercept is computed using:

$$OIP_2 = S_{KGFF} + S_{KOKC} - S_{IMD2}$$

and the third order intercept using:

$$OIP_3 = (2 * S_{KGFF} + S_{KOKC} - S_{IMD3}) / 2$$

where S_{KGFF} is the strength of the carrier of KGFF, S_{KOKC} is the strength of the carrier of KOKC and S_{IMD2} and S_{IMD3} are the strengths of the IMD signals, all in dBm. The intercept points computed will be in dBm.

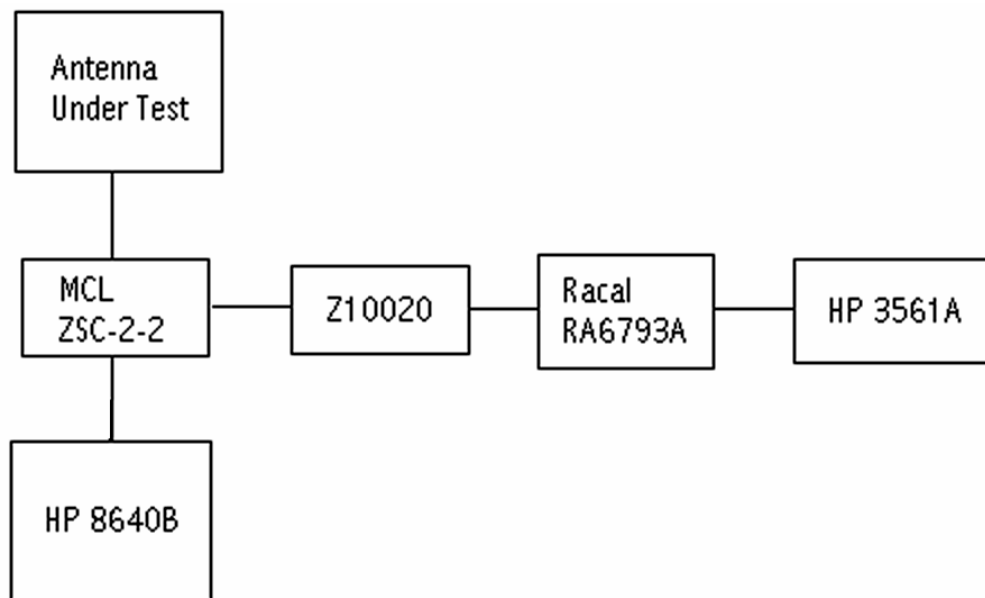
Comparison of intercepts using these broadcast band signals compares favorably with intercepts I obtained using the whip simulation method discussed in the Clifton Lab document above for both the MFJ and Clifton Lab active antennas using two HP signal generators and a Mini-Circuits combiner.

Test Equipment Setup

The equipment consisted of:

HP 8640B Signal generator
MCL ZSC-2-2 Signal combiner
HP3561A Signal Analyzer
Z10020 Clifton Labs broadcast band reject filter
Racal RA6793A Communications Receiver

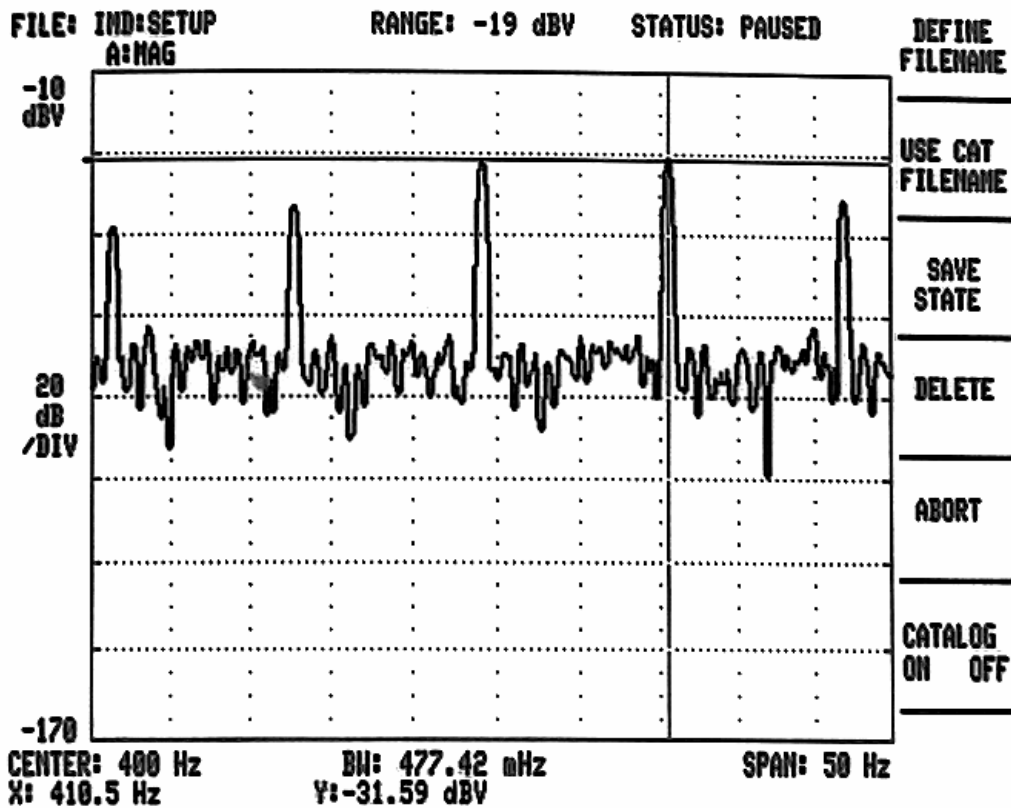
After several attempts, the best setup for testing dynamic range turned out to be:



The method of making measurements was:

- 1) Tune in the carriers of the two broadcast band signals, KGFF at 1450 kHz and KOKC at 1520 kHz on the RA6793A.
- 2) Adjust the frequency of the signal generator to that of the station's carrier plus 10 Hz, and adjust the generator's amplitude to match that of the carrier. The level of the signal generator is then that of the carrier. Record these levels.
- 3) Tune the intermodulation products at 2970 kHz for the second order and 4420 kHz for the third order with the RA6793A and HP8640B.
- 4) Match the level of the HP8640B to that of the intermodulation products, and record these levels.

This is one of the displays from the HP 3561A signal analyzer:



The signal at the center of the display is the carrier or intermodulation product. In this display the frequency divisions are at 5 Hz intervals, therefore the signal 10 Hz higher is from the signal generator. The advantage of this method is that it allows weak intermodulation products to be measured that would ordinarily be lost in noise. The signal analyzer's bandwidth is $\frac{1}{2}$ Hz when using a range of 50 Hz as shown in the above display, reducing noise greatly. It is possible to use smaller bandwidths by reducing the range of the analyzer.

All necessary data are now available to calculate the intercepts IOP_2 and IOP_3 .

Test Results

The following table gives the manufacturer's published data for the second and third order intercepts (labelled Mfg. IOP_2 and Mfg. IOP_3), and what I found in the tests for these values.

The antennas are listed in the table in terms of the second order intercept, lowest to highest. All values are in dBm.

Antenna	Mfg. IOP ₂	Tested IOP ₂	Mfg. IOP ₃	Tested IOP ₃
MFJ-1024	---	30	---	19
H-800	---	36	23	19
H-900	>55	36	>35	21
AR-60	---	44	50	27
DX-10	70	45	40	26
Ultralinear	---	48	---	29
Z1501D (12V)	---	55	---	33
Ratzlaff	---	74	---	*
Z1501D (13.8V)	67-88	74	40	*
LFL-1010	70	75	40	*

* For these high dynamic range antennas, 3rd order IMD was below what my test setup could reliably measure, limiting these values to something greater than 38 dBm.

If you compare the prices given in the descriptions of these antennas, you'll see you don't always get what you pay for. The two RF Systems antennas don't have good ratings. In fact, the DX-500 couldn't even handle my local broadcast station and is therefore not measured or included in the table, while the DX-10 is at best average; yet they are both quite expensive.

In addition, there tends to be a lot of inflation in manufacturers' specifications. The most accurate ones are the Wellbrook and Clifton Labs IOP₂ and IOP₃ values. To obtain the best values from the Clifton Labs antenna, you will need to make sure your voltage supply is close to 13.8 volts.

Dynamic range isn't the whole story, however. In articles that will follow, I plan to explore the question of sensitivity, first in the LF spectrum, and then at VLF (30 kHz and below). I think you will find these future articles very interesting.

*From **The LOWDOWN**, December 2010, a publication of the Longwave Club of America.*

www.lwca.org