The National HRO Receiver: A Historical Reconstruction

Brian R. Page, N4TRB

You know you're an engineer when you fall in love (at first sight none-the-less) with a piece of machinery. My case of what I expected to be forever unfulfilled love occurred during a visit to the museum of the Radio Society of Great Britain. John Crabbe, G3WFM, curator of the collection, powered up a brilliantly restored National HRO receiver and allowed me to take it for a spin.

All it took was a couple of turns of the precision worm drive tuning dial and I was smitten. After that, I found myself lingering by HROs on sale tables at hamfests and browsing Internet auction sites whenever an HRO was offered for sale. Still, I imagined this was just an interest, a flirtation; I knew I could handle it.

Then one day the inevitable happened: an HRO followed me home. I became the proud owner of a World War II vintage, 1942, National HRO receiver that was in great condition considering its age. Fortunately, there is plenty of information on the World Wide Web to help with the physical restoration of most any historically significant piece of ham radio equipment. The HRO is no exception and I quickly learned about replacing time-worn electrolytic capacitors, cleaning the air variables, and lubricating the moving parts.

Aside from returning the hardware to functional specs, I also wanted to reconstruct the historical context of this renowned receiver. While the HRO is a vacuum tube device, it didn’t simply arise out of a vacuum. Instead, it was the culmination of technical evolution spanning decades. However, before we dive into the HRO’s (r)evolutionary technology, let’s look at ham receiver state-of-the-art on the eve of the HRO’s debut in 1934.

The decade of the 1930s was both tremendously exciting for amateurs and equally challenging. Spark transmission had been outlawed only in 1927 and as the decade began most amateurs had even stopped using it. The now famous “1929 Hartley” transmitter design predominated over crystal-controlled transmitters even into the mid-1930s, although crystal control steadily gained ground. Without the rock solid stability of crystals, a reply to your “CQ CQ” might appear literally anywhere in the band.

On the receiving end of the equation, battery-powered regenerative receivers ruled the day. Receiver selectivity, that ability to discriminate between two adjacent signals, has always been problematic with regens. A *QST* writer observed in a 1935 article that regenerative “receivers wouldn’t stay put in *characteristics* long enough to make a selectivity [test] run – and even if they did, the information wouldn’t mean much to the user.” Or, as another writer described the same phenomena “…the slightest movement of the vernier knob of the tuning control caused the signal to disappear and it was possible to hold the signal for any appreciable length of time only when the operator used a vise-like grip on the tuning knob and held his breath."[1]

Superheterodyne receivers existed, of course, having been invented by Captain Edwin H. Armstrong of the U. S. Signal Corp during World War I; however, many hams considered superhets suitable only for AM phone reception. Nevertheless all receivers of that day, whether regenerative or superheterodyne in myriad forms, suffered from the same problem when working with CW signals. In heterodyning a local oscillator with the fundamental or intermediate frequency, two audio tones were ultimately produced, one on each side of zero beat. From the operator's point of view, each CW signal appeared at two places on the dial.

Incredibly, some hams actually considered this an advantage! If QRM interfered with reception, they could tune to the "image" signal on the other side of zero beat and perhaps escape the QRM. But the net effect was that the bands appeared twice as crowded! And crowded they were. While in 1930 there were fewer than 20,000 amateur stations in the U. S., by 1932, that number had grown to 30,000 and by 1934 it was well over 45,000.

This is the world into which the National HRO receiver suddenly appeared early in 1935. Yet, as a receiver practically legendary for its stability, selectivity, and bandspread, it suffered from none of these maladies. Was it simply a product of genius? The result of a secret government research effort? A gift from extraterrestrial aliens? It turns out that the truth *was* out there; and my research quickly led to a series of remarkable papers, mainly from 1932, by James J. Lamb (1900 – 1986), Technical Editor of *QST* (Figure 1).

Improving receiver performance was a major theme in the early 1930s and Lamb published no fewer than seven major articles in *QST* addressing the existing deficiencies. Lamb was not alone in this endeavor. His efforts were joined by the likes of Don Mix, QST Assistant Technical Editor, together with George Grammer; Howard Chinn; James Millen (much more about him later); J. B. Dow of the Navy Bureau of Engineering; Robert S. Kruse, and Ross Hull, *QST* Associate Editor. Perhaps only old timers will recognize these names today; but together they represent a veritable Who's Who in 1930s radio engineering. This line-up also illustrates how the ARRL and *QST* magazine were once at the forefront of electronic engineering. The designs of these engineers had global impact in both the amateur and commercial worlds.

Now, to get back to my National HRO receiver: its technical excellence grew out of a set of three Lamb articles appearing in 1932.[2] Lamb didn't mince words in attacking the

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[1] Lamb, James J., "Receiver Selectivity Characteristics," *QST*, Vol. 19, No. 5 (May 1935), p. 39. Hoffman, W. H. and Mix, D. H., "Revolutionizing High-Frequency Tuner Design," *QST*, Vol. 14, No. 2 (Feb. 1930), p. 9.

[2] Lamb, James J., "What's Wrong With Our C. W. Receivers?" *QST*, Vol. 16, No. 6 (June 1932);
Lamb, James J., "Short-Wave Receiver Selectivity to Match Present Conditions," *QST*, Vol. 16, No. 8 (Aug. 1932);
Lamb, James J., "An Intermediate-Frequency and Audio Unit for the Single-Signal Superhet," *QST*, Vol. 16, No. 9 (Sept. 1932).

problem. His first article was entitled "What's Wrong with Our C. W. Receivers?" Therein, he explains the problems and details his suggested new approach utilizing three major innovations:

1. a high order of RF selectivity
2. exceptional stability
3. audio modulation that doesn't degrade selectivity and stability.

According to secondary sources, Lamb's first article didn't create much of a stir. It may have been the lead article and have occupied eight full pages in *QST*, but it was heavily theoretical. And even though he sketched out a plan for a receiver capable of separating signals a mere 500 Hz apart and rigorously defined "single signal" reception, this opening salvo didn't detail the hardware to back up his theory. That all changed two months later with the second installment of Lamb's single signal trilogy.

The second and third articles, appearing in the August and September issues, eliminated all doubt that the future had arrived. And it arrived with a bit of good news for the average ham. As Lamb explained, the foregoing theory might lead one to anticipate "a fearfully monstrous machine to put those abstractions to work." However, the ham could "Chuck that illusion right at the start. The rig that does the business is nowhere near as entangling as the principles on which it is based."

In a nutshell, and hardly doing justice to the magnitude of his innovations, Lamb detailed seven stages of signal processing between antenna and headphones. These included a tuned pre-selector stage to filter interference while also preventing the HF oscillator in the succeeding detector stage from radiating back through the antenna. This first detector and oscillator heterodyned the input signal to the intermediate frequent stage where extraordinary selectivity was made possible via the crucial contribution of crystal filtration. The IF filter was followed by an IF amplifier and then a second detector that heterodyned a beat frequency oscillator (BFO) for CW reception. The single signal that remained was then fed to an audio amplifier.

Lamb made no claim to have invented these technologies. Indeed, he expresses some surprise that his scheme had not been previously explored and adds, "a pretty thorough search and inquiry of people who ought to know have uncovered no previous disclosure of the combination of features that, coordinated, go to make up what we believe to constitute a new order of c.w. receiver performance."

Nevertheless, Lamb's 1932 *tour de force*, comprising theory, schematics, photographs, and the testimony of experienced operators was an obvious revolution in receiver engineering. An editorial note with the third article declared "Extended experiment with this most recent of Jim Lamb's creations has left us with the firm conviction that it is really the set about which we have dreamed all these years." Now with the perspective of time, I will go so far as to say that this is the most influential receiver design ever published in *QST*. One measure of its influence is that all of the innovations introduced by Lamb in this 1932 marvel were quickly adopted by manufacturers of high-performance receivers and quite simply taken for granted as the right, proper, and obvious way to construct a receiver. It was, quite simply, the first modern receiver.

Since Lamb's prototype was extraordinary and its importance was fully appreciated at the time, I wondered what had become of it. To explore that mystery, I contacted Perry Williams, W1UED, ARRL Archivist. A bit of exploration turned up the original Lamb prototype tucked away in a cabinet at ARRL headquarters in Newington (Figure 2). I was almost as excited by the news of this rediscovery as I had been at acquiring an HRO receiver! At this point in my research, finding the original single signal receiver was like finding a long-lost friend. What else could I do but fly off to Hartford and see it for myself!

Those familiar with the National HRO probably recognize its indebtedness to the Lamb design sketched above. This is no mere coincidence. The HRO was the product of the extraordinary design team lead by James Millen, W1HRX, with Herbert Hoover, Jr., W6ZH, Dana Bacon, W1BZR, and others. Millen, at the time, had a close association with several of the leading lights at the ARRL, including Lamb. More than a few ARRL lab projects arose from discussions that took place at Millen's rural bungalow in Middleton, Massachusetts.

The HRO, which is splendidly documented elsewhere, achieves perfection through the use of crystal filtered IF selectivity, a spectacular precision worm drive tuning arrangement and micrometer indicator dial designed by National engineer William Graydon Smith, and an innovative coil tray system that permits the use of precisely calibrated coil sets for each band. The HRO was immediately successful and was produced in staggering numbers for service in World War II. Some of its fame today results from its widespread use by the British to intercept German coded transmissions that were deciphered by the code-breakers of Bletchly Park. Versions of the HRO remained in production for 40 years!

By emphasizing the contribution of James J. Lamb, I'm not in any sense disparaging the efforts of Millen, Hoover, and the HRO design team. The HRO is no mere copy of Lamb's single signal superhet; indeed, the circuitry of the HRO departs from Lamb's design in a couple of areas. However, overall the HRO embodies the ground-breaking, truly revolutionary design principles so coherently articulated by Lamb. Moreover, the actual implementation of the HRO has a sublime elegance in its own right. If Lamb was the choreographer, James Millen, Herbert Hoover, Jr., and the National design team were the dancers who gave us a brilliant performance.