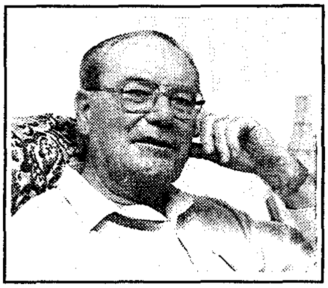


When I Think Back...

by Neville Williams

Readers have their say: Superregen receivers, trans-Atlantic radio, etc.

Thanks to a reader from Balwyn, Victoria, we have the opportunity to understand, perhaps for the first time, how an old-time super-regenerative receiver really worked. Again, a retired Queensland radio operator shares with other readers a visit to the deserted wind-blown foreshore where Marconi planned to receive the first ever trans-Atlantic wireless signals.

In the August 1990 issue, in the second of two articles about Major Edwin Howard Armstrong, I referred to his invention of the superregenerative receiver and mentioned, *inter alia,* that there had always been a great deal of uncertainty as to how it actually worked.

Regenerative receivers, TRFs and superhets have all lent themselves to a fairly straightforward 'mental image' kind of explanation, but not so the 'superregen' receiver — or, more specifically, the superregenerative detector.

For hobbyists and professionals alike, it has always been something of an enigma.

I referred in the article to an 'accepted if rather superficial', explanation of how the circuit worked but, since then, have come across a rather better one in Morgan E, McMahon's book A *Flick of the Switch* (Vintage Radio, 1975). Whether it's sufficiently explicit, in isolation, I leave you to judge:

The superregenerative circuit is by far the most sensitive of all one-tube receiver circuits. The circuit breaks into and out of self-oscillation at random times, making a hiss in the headphones. When a signal (even a very weak one) is present, the circuit breaks into self-oscillation in coordination with the signal, hence the signal is heard in the headset. It has disadvantages because it is not very selective and it bothers nearby receivers by radiating its own signal.

Fortunately, I also mentioned an engineering-level paper on the subject by Hikosaburo Ataka (of the Meidi College of Technology, Tobata, Japan) published in the *Proceedings of the IRE* (USA) for August 1935 — an issue to which I had no ready access. But Mr Alan M. Fowler of Balwyn, Victoria did and he kindly made a copy available to me, which I was most happy to peruse.

It is a thoroughly professional document containing some 44 pages of text, and providing a detailed mathematical, graphical and practical analysis of superregenerative detectors. At first reading, however, I despaired of being able to communicate its contents in a concise form or, much less, isolate the vital clue needed to unravel the logic of the circuit.

But gradually, the picture cleared and, like Rex Harrison in *My Fair Lady,* I found myself exclaiming 'I think you've got it ... I think you've got it!' So, read on:

Superregen detector

As with their ordinary regenerative counterpart, superregenerative detectors rely on the fact that the inherent RF losses of the associated tuning circuits can be offset by the provision of positive RF feedback from the output to the input of the stage; in other words by the use of so-called 'regeneration' or 'reaction'.

In ordinary regenerative detectors, the amount of feedback needs to be critically adjusted by the operator to bring them to the threshold of self-oscillation, with the residual RF circuit resistance either near-zero for best reception of amplitude modulated signals, or slightly negative to produce active oscillation and thereby a heterodyne beat for the reception of CW transmissions.

In a superregenerative detector, there is no user-operated reaction control, the RF feedback (or regeneration) circuitry being configured to promote RF oscillation whenever the voltages applied internally to the detector so permit. That statement calls for further explanation.

In addition to its normal signal and supply voltages, a superregenerative detector is subject to an additional input — a cyclic supersonic wave generated by a separate 'quenching' oscillator or a self-generated 'blocking' voltage resulting from the use in the 'grid-leak' circuit of R/C components exhibiting an unusually long time constant.

As the terminology rather implies, the purpose of this extra input is periodically to 'quench' or 'block' the self-oscillation of the detector so that, instead of being continuous, the oscillation occurs in distinct pulses or 'packets' at the intended supersonic repetition rate — i.e., at a selected frequency above the audio range.

The arrangement was patented by Armstrong, circa 1923 and greeted with considerable interest by professionals and amateurs alike, who were attracted by the term 'super' and the prospect of reduced dependence on the unpleasantly critical reaction (regeneration) control.

As it turned out, superregen receivers proved to be even less predictable or acceptable in their behaviour than their regenerative counterparts — in large degree because very few seemed to understand why or how they were supposed to work!

As we indicated in the earlier article, do-it-yourself articles about superregen receivers published in *The Australasian Wireless Review* during 1923 provided a classic example of the (technically) blind leading the blind!

What really happens

For those able to cope with his graphs and mathematics, Ataka offers a lengthy and detailed analysis of quenching action and so on, with due acknowledgment to earlier papers by E.O. Hulbert *(Proc. IRE* USA, August 1923) and H.O. Roosenstein *(Hochfrequenz and Electroakustic*, Bd42, s85, 1933).

Priorities aside, the essential clue to the basic operation lies in Ataka's Fig.38, reproduced herewith. It crams quite a few concepts into one drastically simplified diagram but, more to the point, it conveys what he is trying to communicate.

Plotted on a time scale (left to right) it indicates the behaviour of a superregenerative detector, during one cycle of supersonic quenching voltage — which is assumed arbitrarily to be sinusoidal in form, as distinct from a more angular shape.

At the extreme left, the quenching voltage is at reference zero and the tuned circuits are passive, maintained so by their inherent RF losses.

When the quench voltage approaches a level shown arbitrarily as Em, the gain of the detector rises, the positive output/input feedback becomes effective, the apparent tuned circuit resistance reverts to negative and the stage begins to oscillate, as indicated by the 'oscillatory voltage' envelope.

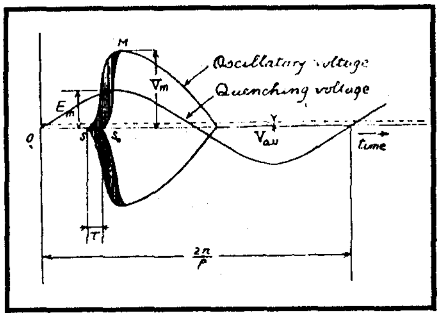
(To be more explicit, Ataka's draftsman should perhaps have filled the envelope with a closely spaced RF waveform).

The oscillation passes through a maximum amplitude Vm, as shown, then tapers off to nothing as the quench voltage cycles through reference zero into the negative region, progressively reducing the gain of the detector and therefore its ability to counteract the losses in the associated tuned circuits.

It follows that the instantaneous output current of a superregenerative detector will cycle in response to the supersonic quench frequency, with a superimposed 'packet' or 'envelope' of oscillations at the resonant frequency of the associated tuned circuits — one burst for each quench or blocking cycle.

(One might further suggest that, if the end result is visualised as an RF carrier grossly over-modulated at a supersonic rate, an array of other by-product frequencies would also be present).

As it happens, the low-pass RF choke and capacitor normally found in the output circuit of any detector could be expected to prevent the supersonic, the oscillatory and any other RF by-



Ataka's Fig.38 provides the essential clue to the operation of a superregen detector. The quench signal initiates and quenches packets of RF oscillation. Extraneous noise and/or signal advances the trigger point (shaded) affecting the duration of the oscillatory burst and superimposing a resultant audio component on the anode current and voltage (dotted line, Vav).

products from reaching the audio system, reducing the detector output voltage and current to an average mean value, able to be read on a meter and free from significant audio components.

What's the purpose?

To many readers, what I have said thus far will simply have re-stated the obvious. But what's the purpose of it all? How does such a configuration detect incoming signals, to apparent advantage over a normal detector and why the loud rushing noise experienced between signals? This is where Ataka's article comes into its own.

His research indicated that, having achieved peak amplitude, shown as Vm in his Fig.38, the packets of oscillation are thereafter substantially uniform in their amplitude, shape and rate of decay.

He postulates further that, in the absence of extraneous phenomena, the oscillatory packets would always commence at the same relative point on the time scale, shown as So and equivalent (arbitrarily) to quench voltage Em. On this assumption, the mean anode current after low-pass filtering would be constant.

However, Ataka says, practical circuits behave quite differently. As the quench or blocking voltage approaches the level which enables the oscillatory burst, the detector becomes extraordinarily sensitive to any extraneous energy effectively reinforcing the quenching voltage. This includes any noise source as, for example, particle noise within the detector itself — 'shot effect' in the case of a thermionic valve.

Effectively adding to the quench voltage, the noise voltage tends to trigger the oscillatory burst earlier than would otherwise be the case — by time interval 'T' in Fig.38, at point 'S' instead of 'So'. As a result, the oscillatory burst is supplemented by the shaded area, resulting in a variation in the mean anode current and voltage, as suggested by the dotted line 'Vav'.

Because 'shot' and other wide-band noise contains audio components, these will inevitably modulate the 'advance' interval 'T', the duration of individual oscillatory packets and therefore the mean value of the anode current and voltage. In other words, the anode current and voltage will tend to vary with the signal and/or noise envelope.

This is the source of the noise, in the absence of any other signal, and its prominence is indicative of the huge energy gain between the tiny disturbances capable of triggering the oscillation in the turn-on region and the end effect on the detector anode current.

In the presence of a weak amplitude modulated input signal, the oscillatory packets are triggered partly by the signal and partly by the noise, so that the recovered audio is a mix of the two. With stronger signals, the triggering effect of the noise diminishes and the signal/noise ratio of the recovered audio progressively improves, as with any other detector.

Optimising performance

Over the years, articles on superregenerative detectors have emphasised the need to experiment with various aspects of the circuit, backed up by empirically determined guidelines for the amplitude and frequency of the quench signal, etc. The emphasis has traditionally been on 'what', rather then 'why'.

Throughout the paper, Ataka sheds a fair amount of light on the 'why' factor and, for the occasional engineer who still needs to know, it would be well worthwhile getting hold of a copy of the original paper.

One other vital clue to the basic operation is supplied by a diagram, reproduced herewith, namely Ataka's Fig.39. It follows from the broad statement that the sensitivity of a superregenerative detector depends on maximising the shift in anode current (Vav in Fig.38) for a given level of input signal.

While it obviously involves the configuration of the oscillatory circuit itself, Fig.39 concentrates on the relative amplitude and frequency of the quenching voltage.

Diagram (a) suggests a situation where the 'advance' region is prominent but the quench frequency is much too low, resulting in a relatively small shift in the mean anode current and voltage.

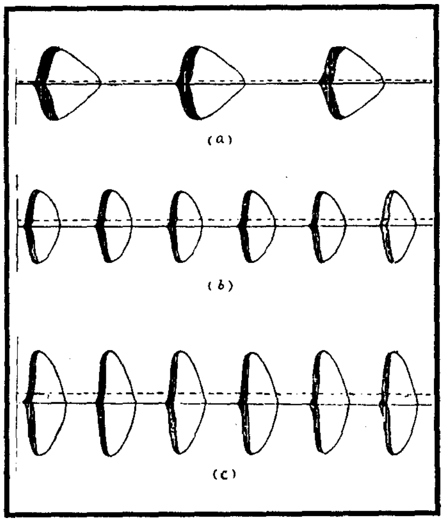
Diagram (b) suggests a significantly higher quench frequency, producing a somewhat greater variation in the anode current.

Diagram (c) shows the same quench frequency but, as well, a greater quench amplitude, yielding much improved sensitivity.

Yet another diagram (not reproduced) shows the sensitivity peaking with a quench frequency (typically) around 200kHz, with much less prominent sensitivity peaks at about twice and three times this figure.

As I said earlier, there is much more in the paper for those who need to know, including an explanation of the circuit's chronic lack of selectivity, which he attributes to the by-product frequencies resulting from the quenching action. But what has been said will hopefully provide a coherent answer to the question about how it really works. That it was foremost in Ataka's mind is suggested by his 'Conclusion'. I quote:

The amplification by super-regeneration is performed by the building-up of free oscillation which is initiated by the impulse of the signal. When the effective resistance of the oscillatory circuit in the receiver is brought to be sufficiently negative to start the oscillation, the *receiver* **becomes very sensitive for the impressed electromotive forces. The slightest impulse is sufficient to start the oscillation.**



The sensitivity of a superregen detector depends on the magnitude of the anode current/voltage change. In (a) the quench frequency is too low; (b) suffers because the quench signal is still of Insufficient amplitude; (c) is closer to optimum, as Indicated by the greater displacement of the dotted line.

Without pursuing the matter, I would expect that, given the need to do so, Ataka's analysis could be adapted to solid-state devices.

Queensland reader

So much for an interesting but now substantially outdated piece of technology. From W.A. ('Blue') Easterling, VK4BBL of Burleigh Waters, Qld, comes a letter thanking me for past articles and in particular for one in the October 1990 issue entitled: 'From Sparks and Arcs to Solid State'.

`Blue' says that he, too, has seen it all — from sparks to satellite — remarking that there were still a few spark-equipped ships running as late as 1954. That he has been around personally is attested by a string of amateur callsigns dating back to 1947 or thereabouts: VK4BBL, -2ABL, -9WE, -4BL, -2BJ.

Blue also says that, around 1928, his father — with assistance — assembled a 4-valve TRF receiver, complete with outdoor aerial, horn loudspeaker, trickle charger and B-battery eliminator. It proved a boon to the family during the depression years that followed, silenced only once when the power was cut off because of an unpaid account. They were even able to sample broadcast band DX, with regular reception from Montreal, Canada.

Around 1936 he acquired a pair of headphones for one shilling (10c), which led to the construction of his own crystal set, followed by a 2-valve regenerative Reinartz receiver with plug-in coils, which rewarded him with short-wave signals from Schenectady, NY, on about 9MHz.

Then came war service, a part-time course with the Marconi School, a first-class COCP (Commercial Operator's Certificate of Proficiency) in 1950, followed by 32 years with OTC in the coastal radio service. Looking back over the latter period, he says:

In La Perouse in 1950, most of the staff were old-timers who graduated in spark and then had the grind of learning CW after the 1927 Convention so that they could validate their tickets. From them I heard much of the early radio history, first-hand.

Peter Gillon had been at sea the night that the Titanic went down; too far away to help, but he heard the whole horrendous episode. Even then, nearly 40 years on, the old chaps were still shaken by the tragedy. They are all silent keys now, but OTC Archives managed to record much of their reminiscences.

The above observation is a perfect example of how old timers carry — perchance to the grave — rich fragments of electronics history. How neatly their recollections would have slotted into Stephen Rapley's 'Bright Sparks' sessions, broadcast over ABC National radio in mid 1989.

Prompted by past articles in this present 'Think Back' series, Blue Easterling goes on to mention that he also has to hand 'a mine of information' from a former Marconi engineer closely associated with Marconi's pioneering efforts — in the form of a much treasured book entitled *Wireless Over 30 Years* by RN. Vyvyan.

In fact, I have yet to deal specifically with Marconi, but his name has been mentioned on several occasions; it could scarcely be otherwise in a series concerned with the history of wireless communication. Vyvyan's 'warts and all' account of events certainly follows naturally on the biography of another of Marconi's engineering associates, Professor J.A. Fleming, in the April 1990 issue. I quote from Blue's letter, with minor abbreviations:

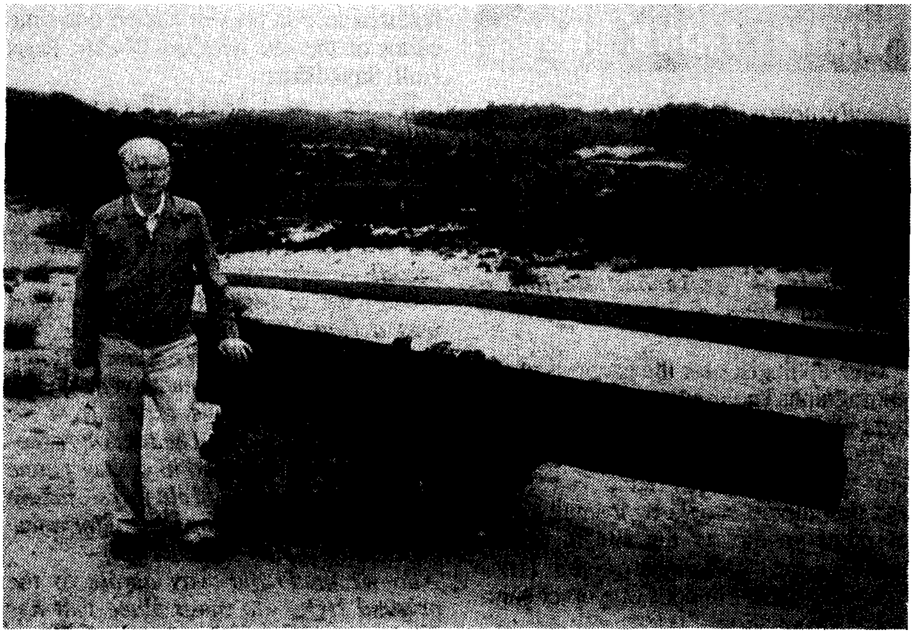
Last year I visited two ham friends of my VK9 days. Ned W1RAN took me all over New England, USA, and we visited the old Marconi site at South Walfleet on Cape Cod. This was the first Marconi station in the Americas, and was intended to receive the first transatlantic signals. The purpose was kept secret at the time; had the tests failed, the company would have suffered some derision and also, I think, some drop in share values.

The station planned for South Walfleet was identical with that erected at Poldhu, where Vyvyan had assisted Dr Fleming for a time with the procurement and commissioning of the various plant *items.*

In February 1901 Vyvyan was selected as the construction engineer for the Cape Cod station, and shown the plans for the aerial systems to be installed at each station. They were formidable looking arrays calling for a ring of 20 masts, each 200ft (60m) high in a 200ft diameter circle.

Made from wooden beams, bolted together, the purpose of the masts was to support an inverted cone of some 400 wires, insulated at the top but joined together at the base, right over the transmitter building.

Vyvyan considered the structures to be fundamentally unstable, with each mast guyed to the next but only to ground in a



After the best part of a century, bits and pieces of Marconi's pioneering wireless station remain on the sandy foreshore of Cape Cod. Pictured with this hunk of timer, steel and concrete is WA (call me 'Blue') Easterling, himself an old-timer from the 'sparks to satellite' era and now retired after 32 years with OTC in the Australian Coastal Radio Service.

radial direction, away from the centre of the system. It would be a case of 'one down, all down', he said, but his objections were overruled. He sailed with Marconi for site selection and construction and, by late June, 1901, the buildings and masts at South **Walfleet**, *Cape Cod were up.*

In August, with no more than a stiff breeze blowing, the tops of the masts on the windward side at Cape Cod were bending to such a degree that **Vivyan** *cabled London for permission to dismantle the top sections. Pity the poor riggers who actually did the job!*

At **Poldhu**, *as the masts were nearing completion, a gale on September 17, blew them down. Three weeks later, the masts at Cape Cod met the same fate, with one mast penetrating the roof of the transmitter room and another missing* **Vyvyan** *by just* **3ft** *(1m).*

Marconi was in a proper bind. Rapid improvisation saw the so-called **triatic** *fan array erected at* **Poldhu** *at* **150ft** *(45m), involving 54 wires at 1-metre spacing and joined at the bottom. Tests were run with* **Crookhaven**, *Ireland, with good results.*

Marconi then headed for Newfoundland, a separate British colony at the time, arriving at St Johns on December 5. The local authorities were most helpful, making a room available at Signal Hill.

On December 9, Marconi cabled **Poldhu** *to commence tests from* **3pm** *to* **6pm** *each day and these started on December 11.*

At Signal Hill, a balloon carrying the antenna broke away on the first ascent. Next day a kite aerial was sent aloft to **400ft** *(121m) but its climbing and diving altered the capacitance so much that the associated tuned circuits were all out of kilter.*

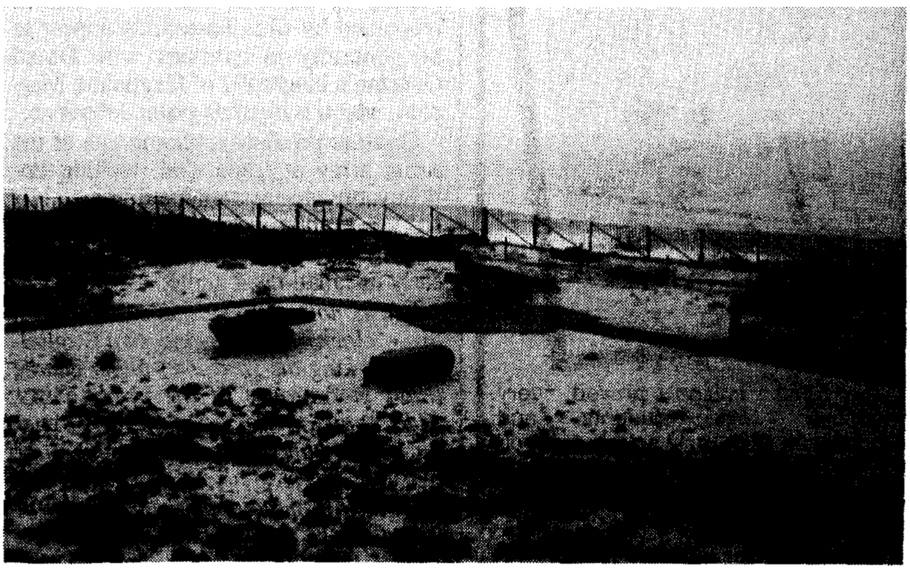
Marconi took them out of circuit and the first **'SSS'** *signals were heard on Thursday 12th with just the aerial, a sensitive self-restoring* **coherer** *of Italian navy design, a headphone and ground. It caused a worldwide sensation, although not without a few sceptics. But the experiments at Signal Hill came to an abrupt halt when the Anglo-American Telegraph Company served notice that it had a monopoly in Newfoundland of all telegraphic communications. Marconi was duly shown the door!*

The Canadian government thereupon invited him to that country, with a promise of assistance by way of funding and real estate. The new station was built at Glace Bay on Cape Breton Island and it was there that the main experimental work was done that led to a regular commercial service.

The South **Walfleet** *station on Cape Cod had meanwhile been rebuilt with four towers, each* **210ft** *(64m) high, similar to Glace Bay and* **Poldhu**, *and the first signals were exchanged with Glace Bay. The first official message, sent from the USA for relay to* **Poldhu** *on January 18, 1903, was from President Teddy Roosevelt to King Edward VII.*

Four years of experimental work followed, with a full commercial **USA/UK** *service beginning in early February, 1908. But South* **Walfleet** *has long since been abandoned, with the site now under the control of the National Parks and Wildlife Service.*

Cape Cod is, in fact, a huge sandpit and geologically unstable. The Atlantic has been eating away at *it since the events at the turn of the century and half the original transmitting site has gone. The safety fence in my photographs runs*



In 1901, Guglielmo Marconi and engineer R.N. Vyvyan gazed from this point out over the 3000km-odd of ocean that separated them from Poldhu, in Cornwall, WC Half the original transmitting site — beyond the barrier fence — has been eroded by wave action.

directly across the centre of where the transmitting building once stood.

There is still a fair amount of debris from the two stations: rusting steel, chunks of timber, concrete anchorings, etc. A large shelter shed houses a display of models of the second station, a memorial cairn and various bits of memorabilia.

Blue apologises for the haziness of the photographs enclosed, by reason of poor light and an approaching cyclone.

He is most appreciative, however, of the kindness of his American hosts and the interest shown by a small group of other visitors to the site in details which he had memorised from Vyvyan's book. He adds one other snippet of information:

The transmitter used at Sth. Walfleet was 20kW, designed by Fleming and comprised of two spark transmitters in series, inductively coupled. Keying the monster was a problem.

Initially he tried breaking the primary of the 20001200V transformer with a big key and a water resistance, but finally put an iron-cored inductor in series with the primary and used a key (or relay contacts) to short it. Key up and the voltage drop reduced the 2000V to a value that would not actuate the spark gap; key down and the full voltage was restored. Not conducive to high speed keying... I wonder what they used when they went into full commercial service?

As **seen through the eyes of an engineer, Vyvyan's account of events, as recounted by Blue Easterling, appear to be generally in harmony with David Gunstan's biography of Guglielmo Marconi, which is my own prime reference.**

Gunstan provides a photograph of the aerial array at Cape Cod, looking unbelievably unsubstantial and vulnerable. No less graphic is his description of the keying arrangements of one of those early installations. I quote:

It was not until December 16 (1902), at 7 o' clock in the morning, that Guglielmo, working the yard-long pump handle (read metre-long) of the sending key, tried again to raise Cornwall. "Better put your hands over your ears", he warned his staff, and started to call Poldhu with three dots — the Morse for `5'. Crash! crash! crash! went the sparks, again and again."

Blue says that he rounded off his trip to the USA, wearing his proverbial VK-amateur hat, with a visit to the former stamping grounds of one of the first men featured in this present series: one-time editor of the old *Wireless Weekly,* Ross Hull. Says Blue:

We went to a hamfest/fleamarket at Willimantic Ct, where I was quite at home. It was the same junk that I' ve seen at hamfests here, and one would almost suspect that someone charters a 707 to carry it from place to place around the world!

Our visit to ARRL HQ at Newington was a flop. Arriving in the rain, we sloshed our way into the main building and inspected the museum (very good). People came and went and took no notice of us whatever. The lass on reception was more involved in a long phone conversation with the 'ole folks', taking time off only to accept payment for a few publications (plus 8% state tax).

So we made our way across to the original HQ — to me a place that has always been the Holy of Holies. It was barred and bolted; NO VISITORS! It was being refurbished, I discovered, with entirely commercial gear of an unknown brand—not even as supplied by regular QST advertisers; nothing homebrew, despite the workshop facilities and staff. It was a great let-down after having come so far.

Last but not least was Blue's closing par, which should grab readers who combine an interest in technical history with amateur radio:

I came back by train to Los Angeles where I was the guest of Jerry, N6AV; went out into the Yucca Desert and stayed overnight with W6BA, who has an antenna farm that would rival OTC's Doonside.

On the day before I left, I was shown the gear of the late Don Wallace, now in the possession of Jan N6AW, who was his technician. It was like Aladdin's cave: stuff going back to before WW1; receivers that we used to drool over in 1930's magazines; much homebrew as well.

I met Don in Port Morseby around 1965 and found him a most affable man. He, too, had a huge antenna set-up at Rolling Hills near Long Beach; none of this end-fed 67ft of wire in the ceiling, like me!

Thanks, Blue, for an interesting letter and the chance to share your trip down memory lane. Thanks also for your kind remarks about the historical articles. As your contribution has demonstrated, no one contributor has a monopoly of information about a particular subject. Snippets of information about the past are tucked away in bookshelves and drawers all over the nation, just waiting to be re-discovered. ■