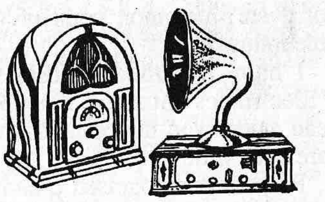
Vintage Radio



by PETER LANKSHEAR

The saga of the Crystal Set

Recently I was taken to task because, in its six years, this 'Vintage Radio' column has not yet featured crystal sets. The point has been taken, and this month we cover some aspects of this classic and in its time, most important receiver.

The basic crystal receiver comprises only three components: an inductor, a diode and a headphone — although to be completely accurate, there are also two virtual capacitors formed by stray capacitance of the aerial and the headphone leads. It would be impossible to create a simpler receiver than the elementary crystal set, yet entire books have been written about it. What other type of receiver has remained basically unchanged for 80 years?

In the period from the advent of broadcasting to the arrival of the cheap transistor receiver, making crystal sets was one of the traditional childhood activities. There were several reasons for its popularity. Crystal sets were inexpensive, simple to make, cost nothing to run and what is more, they *worked.*

There is no receiver simpler than the basic crystal set, yet an endless series of circuit variations appeared in radio and hobby publications and were eagerly assimilated — previous models torn apart and the new variations tried. Many young experimenters got 'bitten with the radio virus' as a result, and went on to make radio their careers.

Like much electronics technology, the origins of research in the electrical characteristics of crystals go back to the 19th century. The earliest work of which I can find any record was by Ferdinand Braun in Germany during 1874, in what could be regarded as the first research into semiconductors. Braun reported that various combinations of metals with oxides or sulphides, with small contact areas, displayed unilateral electrical conduction characteristics.

As with many early discoveries, here was a solution waiting for a problem. Braun went on to other work, including cathode rays, and it was a further 25 years, in 1901, before he conducted experiments into the use of crystals for radio detection. He worked with galena (lead sulphide) and iron pyrites, but it was psilomelane, a mineral containing manganese, with a sensitivity equal to that of the electrolytic detector, that he considered showed the greatest promise. Braun reported his findings to Telefunken, but there seems to be no record

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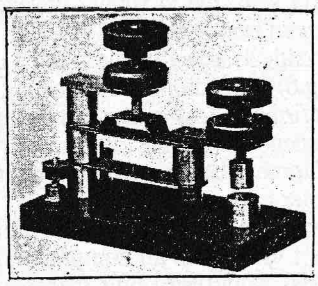

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Fig.1: A crystal detector advertised in the Marconi 'Yearbook of Wireless Telegraphy & Telephony' for 1914.

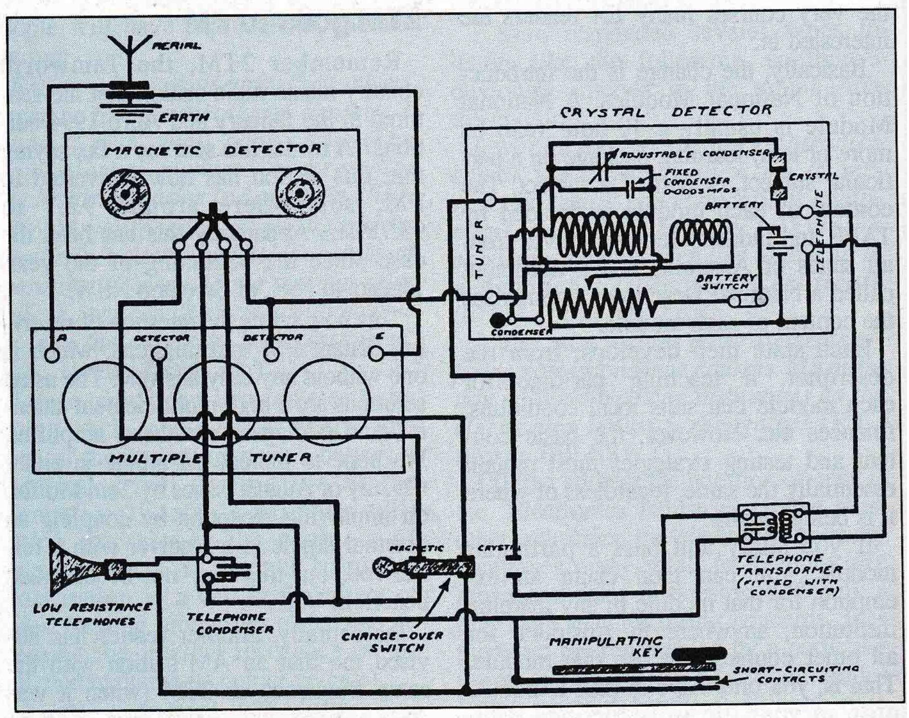

Fig.2(a): The circuit of a 1915 shipboard Marconi receiver installation, providing the choice of a magnetic detector ('maggie') or a type 20 crystal set. Note the battery and rheostat for biasing the crystal.

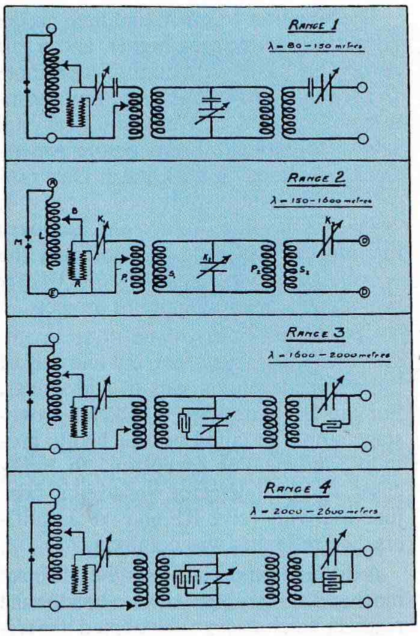

Fig.2(b): The various configurations of the versatile Marconi multiple tuner — much more complex than the domestic crystal sets of a decade later.

Fig.3: The British GEC variometer tuned Gecophone crystal set No1 of 1922, in a dovetailed mahogany case. Many sets of this era were similar in appearance to scientific instruments.

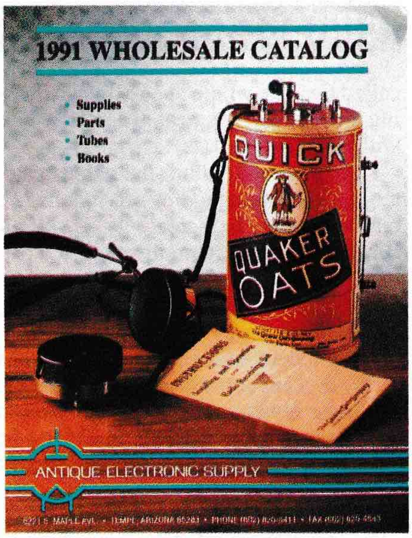

Fig.4: In 1919, US firm Quaker Oats offered this novel crystal radio, based on one of its cardboard oats cartons, for $1 plus two carton labels. By 1921, they had issued 250,000 sets. It was featured on the cover of Antique Electronic Supply's 1991 catalog, reproduced here.

of that company or anyone else making practical application of his work.

The noted Indian scientist Sir Jagadis Chunder Bose, also in 1901, patented a detector of electromagnetic radiations, including Hertzian waves, which used a pair of galena crystals in contact. Bose considered that his detector worked as a variable resistance self-resetting coherer, but no further development seems to have followed.

Various detectors

Meanwhile, radio communication had developed into a commercial enterprise depending for reception on magnetic and electrolytic detectors, and coherers. Fleming's diodes, an adaptation of the 1884 patented Edison Effect lamp, were used by the Marconi Company as detectors from 1905.

The first practical application of a crystal as a detector has been credited to one of Lee De Forest's employees, a retired army general, H.H. Dunwoody. This was in 1906, the same year that De Forest himself first experimented with the triode valve.

Dunwoody had been experimenting with silicon carbide, or carborundum, which is made by heating a mixture of carbon and silica with an electric arc, and whose crystals approach diamond in hardness. He developed his detector to the point where the crystal could be clamped between steel electrodes, creating an extremely rugged and stable device; he found too that a polarising battery increased sensitivity considerably. By applying a bias voltage, the forward conduction point of the crystal was brought nearer to zero voltage. We see this same characteristic today in the forward voltage drop of silicon diodes.

Fig.5: This 1924 novelty model, known as 'Uncle Tom', was made of Staffordshire china with the coil wound around the top hat.

Carborundum's success seems to have encouraged widespread research into crystal rectification, and in the period up to World War I a large variety of examples appeared. The more popular detectors incorporated molybdenite, galena, bornite, zincite, iron sulphide and tellurium. Some of these depended on metallic contact, whereas others used two different crystals in contact.

Some combinations were sold under trade names. These included the Perikon (chalcopyrites and zincite), Pyron (iron pyrites and silicon) and Bronc Cell (tellurium and graphite). Fig.1 illustrates a detector assembly using a zincite/bornite combination.

Often, these crystal detector assemblies were switchable. One gets the impression that there was a suspicion of reliability about crystals. It was common to mount two or more crystals in a turret, so that rapid changes could be made. In other cases, the tuner could be switched to either a magnetic detector or a crystal. A complete 1915 shipboard receiver circuit with this feature is shown in Fig.2.

Rather than rectifying more or less evenly over their entire surface, a few crystals were found to have sensitive spots that worked best when touched lightly with a piece of fine wire. This piece of wire came, of course, to be called a 'catswhisker' and one of the most sensitive crystals was a piece of galena, a common lead ore. One source of high grade crystals was the American town in Northwestern Illinois actually called Galena, where at one time, a thriving mail order business was carried on with radio enthusiasts.

Unlike carborundum, the galena crystal had the advantage of not requiring a biasing voltage to increase its sensitivity. Biasing added the complication of a battery and rheostat, and the operator having to remember to switch the current off after use.

The modern semiconductor diode is a direct descendent of these detectors, and the point contact germanium diode can be seen through a magnifying glass to be fundamentally a catswhisker in contact with a tiny piece of crystal.

Unsuitable at sea

Despite its good performance with weak signals, the galena crystal was not popular in marine service. As anyone who has 'tickled' a crystal will know, a slight bump is sufficient to dislodge the catswhisker; obviously, on a ship in a storm or with gunfire, this fragility would be hopeless.

Another weakness of the galena crystal is that it can be paralysed by strong nearby transmissions and atmospherics.

However, its simplicity and relative sensitivity made the galena crystal popular with amateurs, who were quite prepared to fiddle with catswhiskers, forever looking for more sensitive spots. When broadcasting commenced in the early 1920's, the galena crystal receiver played a significant part, especially in areas within a few miles of a transmitter.

The galena crystal did not have the monopoly in home receivers, though. Some proprietary crystal assemblies, such as the popular Red Diamond, used other crystal combinations and were somewhat more stable.

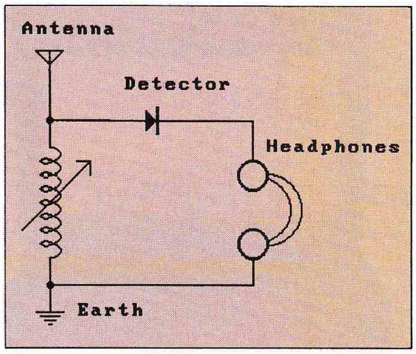

Fig.6: The fundamental circuit used in the five crystal sets illustrated. Although as simple as you could get, its weakness is lack of selectivity due to heavy damping of the tuned circuit.

A crystal set's performance is vitally dependent on its tuning system. The complex Marconi tuner in Fig.2 is capable of superior results, but would have been quite out of the question for a domestic receiver. It required considerable operational skill and the cost would have been quite prohibitive. In fact, in the heyday of the crystal set, the listener who could have afforded a Marconi tuner or similar would have been able to buy a valve receiver anyway.

Affordable radios

Manufacture of crystal sets for radio listeners boomed in the early and mid 1920's, especially in England. The book *Vintage Crystal Sets 1922-1927* by Gordon Bussey lists more than 200 different models and their makers.

The remarkable popularity of the crystal set in England was due to two factors. One was the proximity of a large number of listeners to a transmitter; the other was economic. Wages in Britain were low, and a crystal set was all that many could afford. Furthermore, anyone with a small degree of skill could make one.

The situation was different here and in America. Income was higher, and a fair percentage of the community was remote from transmitters. Even so, both commercially made and homebuilt crystal sets were popular, a remarkable American example being the Quaker Oats promotional model featured in Fig.4. Locally, firms like Emmco and Radiokes manufactured components to meet the needs of enthusiasts, and *Wireless Weekly* provided them with plenty of projects.

Only so much could be done to improve a simple crystal set, but one way of improving reception was to add valves. For the Brownie user, a matching two-stage amplifier could be attached to provide loudspeaker reception. In many cases, a crystal detector was used in conjunction with valve RF and AF amplifiers, and reflexing was common.

A different approach was the 'electromechanical relay', in which a headphone receiver mechanism was coupled to a microphone. Energised by dry cells, there was sufficient power for a horn speaker. One well known model came from the English firm of S.G. Brown, who adapted their telephone repeater relay developed about 10 years earlier.

American practice generally was not to bother with crystals in valved receivers. To increase performance of simple receivers, regeneration and reflexing were used extensively, but by 1925, the classic TRF with two RF stages, a grid-leak detector and two audio stages had become practically universal. In our part of the world, there was the whole range of receivers from the superheterodynes right down to the home built crystal set.

Contrasting with the Marconi installation in Fig.2, amateur and broadcast crystal sets were not very complex. Indeed, although they were made at very different times and places, the receivers in Figs.3 - 8 have the same simple unse-

Fig.7: The Brownie Wireless Co. produced several crystal sets, their No.2 having an ebonite case. The coil is inside, tuned by a slider between the earphone terminals. For long wave coverage, an additional coil plugged in at the top.

Fig.9: Variometers were frequently used as variable inductors for tuning in the better grade sets, such as the GEC model in Fig.3. They could also be used to provide variable coupling in double-tuned sets.

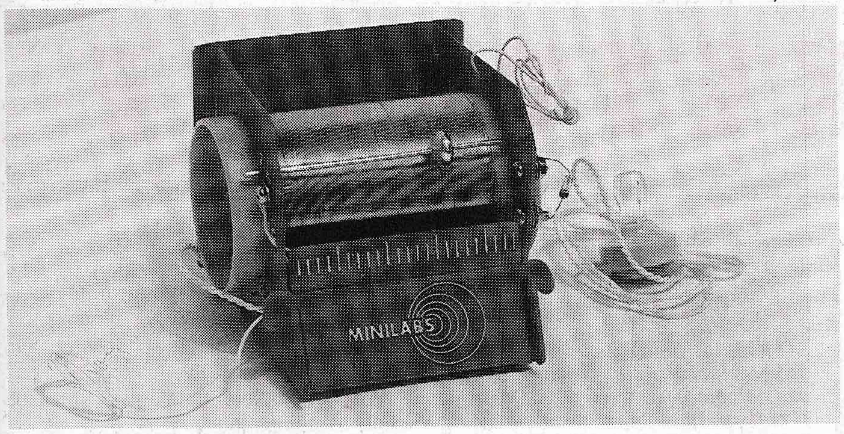

Fig.8: Plastic may have been substituted for ebonite and wood, and the crystal diode is non-adjustable, but today's basic crystal set has not otherwise changed in 70 years. This one comes as a kit from Dick Smith Electronics.

lective circuit, and this was to be their downfall. While there was only one transmission in the area, there was no problem; but if more stations opened, the inherent lack of selectivity became all too apparent.

I confirmed this by tests with the Brownie and the Dick Smith Electronics receivers. With five local transmissions of similar strength spaced fairly evenly over the broadcast band, it was not possible to separate the stations completely, the best compromise being an annoying background from at least one interfering transmission.

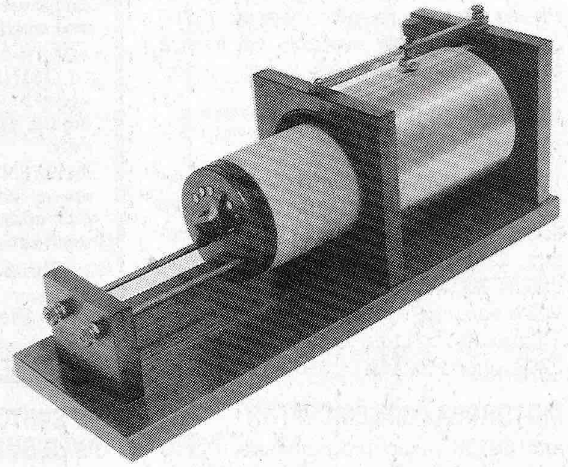

Fig.10: The expert's crystal set was often built around a loose coupler, which could be up to a metre in length. Both coils were of variable inductance, via switched taps or a slider. The position of the inner coil allowed adjustment of the coupling — not a thing of beauty, but very effective.

Huge variety

The solution was of course, improved selectivity; but the problem was to achieve it without sacrificing precious signal strength. Tapping the aerial and crystal down the coil would certainly reduce loading, but at the cost of volume.

For the experimenter, an endless variety of clever circuits now followed, each one claiming to be the answer. It is amazing the remarkable number of variations that were created around the simple crystal set. Virtually every issue of the numerous radio magazines that came on the scene had some new design or circuit configuration. Few, however, approached the Marconi Multiple Tuner in complexity and versatility.

In fact, there *is* a way of combining selectivity and sensitivity, and is the principle of operation of the Marconi tuner. This is to have two tuned circuits, critically coupled with one tuning the aerial system and the other feeding the detector.

Given large, high Q coils each tuned to the operating frequency, and accurately coupled to each other electrically or physically, it is possible to have an efficient transfer of one narrow frequency band. Too close a coupling passes a broad range of frequencies, whereas minimal coupling causes excessive attenuation.

We are familiar with this characteristic in superheterodyne IF transformers. As these operate at one frequency, the spacing of the coils can be fixed, but for a crystal set which has to tune a range of frequencies, the coupling has to be adjustable.

Two popular methods of controlling coupling were the *variometer* and adjustable coils mounted on swinging arms. Very impressive crystal sets were also built around the *loose coupler*. With skilled operation, the loose coupler can produce quite remarkable results, but these are rather large technical looking devices, some approaching a metre in length — although the one illustrated in Fig.10 is only half this.

Modern germanium or diodes are very efficient, but theoretically they could benefit from a small bias voltage. Recently R.G. Newlands of the NZVRS carried out some quantitative research into biasing germanium diodes and found that there was about a 3dB improvement, which is just discernable, in rectified voltage by applying about 0.75 volts of forward bias. For extracting the last fraction of performance this is probably worthwhile. For someone who wants a bit of variety, and a challenge, there is still scope for experimentation with the humble crystal set.

As I indicated at the beginning, although the crystal set is a deceptively simple device, there is a lot that can be written about it. But I suspect that if I carry on much longer at this stage, the Editor may reach for the delete key!

(Editor's Note: For those who do want to experiment with a crystal set, I described a very flexible model back in June 1988 — the 1988 Deluxe Crystal Set. This includes two tuned circuits with 'preset' adjustable coupling, and also adjustable DC bias for the diode. Photocopies of the article are available from our Reader Information Service.) ❖