VINTAGE **RADIO**

BY ROGER JOHNSON

Restoring a crystal set, & their **place in history**

This month's story concerns one of the simplest of all radios -- a crystal set, and its a crystal set with one of the simplest circuits possible at that. But the simplicity starts and finishes with the circuit.

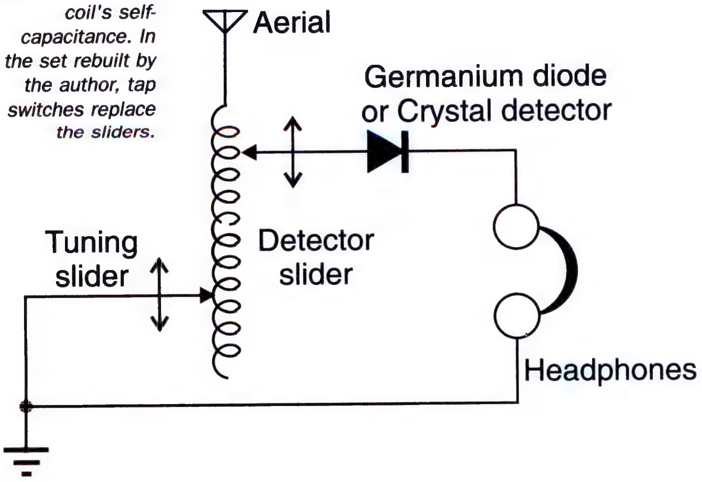
CRYSTAL SETS are almost a sub-culture amongst radio and vintage radio enthusiasts, and some very elaborate designs have been proffered by members of various crystal set societies. But these sets are far more than just a curio and a challenging pastime, despite what many people may think. In fact crystal sets have had three important roles in the long history of radio.

Firstly, crystal set radio pre-dates just about any valve radio. ('Crystal set' in this context refers to radio without valves.) Detection may not have necessarily been by a lump of galena and a length of spring steel wire. Some very VERY early types may have used a Marconi magnetic detector or a carborundum detector.

For example the 'Mark III' tuner of World War I was actually a very elaborate crystal set with provision for a variety of detectors, including a diode valve, and could drive a sensitive loudspeaker.

Secondly, a crystal set was the answer for those who couldn't, or wouldn't, purchase a valve radio in the 1920s. A crystal set was seen as a serious answer for budget priced radio. The fact that usually only one person could listen to it at any time seemed of no great importance then.

The deceptively *simple circuit for a 'slider tuned' crystal set, which makes use of the coil's self-capacitance. In the set rebuilt by the author, tap switches replace the sliders.*



Thirdly, a crystal set was almost universal as a 'first step' in fostering a budding interest in radio, for a young lad or girl. When valve radios were still out of reach for a youngster's budget, a crystal set was often the only answer. Just about every lad with a mechanical or curious bent built a crystal set, whether they went on to develop a career in electronics or not.

Crystal sets were probably built right up to about 1960 or perhaps beyond. Some were sold commercially as a complete unit, particularly by the 'Aegis' brand, and from the 1950s a germanium diode tended to supersede the old lump of galena and cat's whisker wire.

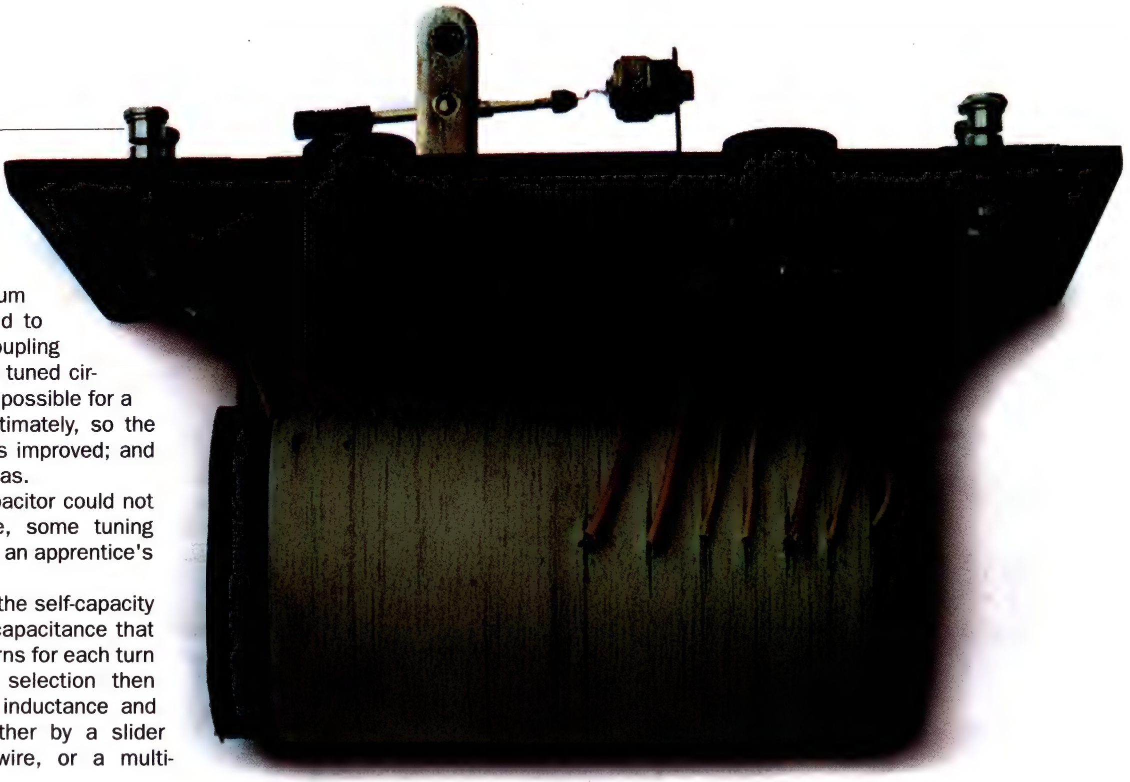
Limitations

Some elaborate and sensitive crystal set designs have been developed over the years, and some of them will actually separate the local stations! (Refer *EA* for June 1988: the 'Deluxe Crystal Radio'). Sets like this often rely upon today's vastly increased signal strengths, which allow bandpass tuning to greatly enhance selectivity.

But in the early 1920s and the mid 1920s in particular, crystal set design was not so eloquent. Firstly, the 'B' class, or commercial radio stations were limited to only 500 watts power. The 'A' class stations, i.e., those which derived their revenue from licence fees and which ultimately went on to become the ABC, had transmitter power from 3kW to 5kW. As there were only two stations in all cities except Sydney, selectivity was not a problem unless one resided close to the B class transmitter. As a result, very simple crystal sets were practical and the order of the day.

Basic tuning

Many, many crystal sets comprised little more than a coil and variable capacitor forming a tuned circuit. The coil often had taps at every 10 or so turns on a total of 60, such that the aerial and the detector could independently be selectively coupled to the tuned circuit.



The author's *coil for his switch-tuned set.*

This was to facilitate optimum antenna coupling as an aid to selectivity, and optimum coupling of the detector so that the tuned circuit was loaded as little as possible for a given reception locality. Ultimately, so the theory goes, selectivity was improved; and in many circumstances it was.

But what if a tuning capacitor could not be afforded? At the time, some tuning capacitors cost as much as an apprentice's weekly wage!

The answer was to use the self-capacity of the coil, i.e. the small capacitance that exists between adjacent turns for each turn of the coil. The station selection then depended on varying the inductance and capacitance combined, either by a slider contact over enamelled wire, or a multi-tapped selection switch.

The circuit of such a device is abidingly simple, and is shown in Fig.1. One slider selects the coupling for the crystal detector, and the other varies the length of the coil, and hence the inductance and capacitance (combined).

Such a scheme also has another advantage. The 'Q' of such a coil is quite high, and it is a high-L/low-C circuit. This will increase the voltage developed across the coil at resonance, such that the detector can be tapped lower 'down' the coil and reduce the loading – which will enhance selectivity.

A lost cause?

The little radio shown in Fig.3 was the topic of much discussion between its intended owner and the author. It originally purported to be a valve radio, but an ungainly three-coil tuner, the small cabinet as well as the series of vacant holes behind the control knobs suggested otherwise.

Further investigation showed that the three-coil tuner had been fitted where a crystal detector had once been, and the little labels were actually crystal set labels. There were two binding posts, no doubt for the filament battery, which were of a different style to those at the top of the panel.

Inside was an enormous 23-plate tuning capacitor, a dud Philips type A110 (1925) valve, and a grid leak and grid capacitor strung together in a fairly untidy manner.

My guess was that this radio started life as a crystal set and perhaps together with an old valve and some bits and pieces was given to a novice, perhaps 10 years later, for him to build a valve radio. The new owner presumably thought that it would be nice to go that one step further and 'upgrade' the crystal set.

Originally, there were only two controls, and behind each control was an arrangement of holes around the circumference of a circle. So the only possibility was for a switch-tuned receiver in which the taps replaced a continuously variable slider.

Another factor which affected slider-tuned sets was that they had to rely on a coil of enamelled wire, and not cotton-covered wire. The enamelled wire tended to be of a fairly hefty gauge, as thick as 20 SWG. The thicker wire was chosen to prevent short circuiting of one or many adjacent turns by the slider contact.

As a result of the thicker wire, the number of turns to the inch was reduced to about 30 turns. This meant a large diameter former – often 5" (125mm) and containing up to 300 turns, with a length of about 10" (250mm). That is why those very early slider-tuned crystal sets had such enormous coils.

On the evidence available, this particular crystal set had only two controls and these were both stud switches. (The Americans prefer to call them 'tap switches'.) Therefore, there was no tuning capacitor. However the cabinet simply did not allow for a 5" diameter, 10" long coil former. So in this case the coil was most likely a 3" former, and allowing for end space, no more than 6" in length. It was also enclosed in the small cabinet, making access to sliders somewhat difficult. Everything points to a switch-tuned coil wound with medium to fine gauge wire, and in keeping with the day, the wire would have most likely been cotton covered.

The holes for the studs were all over the place, but they seemed to be in arcs of 1-1/2" (38mm) radius. One switch was obviously for the 'earth' end, which altered the tuning parameters. The other switch was by implication for positioning the tap for the crystal detector.

A big, long coil

At this stage I decided that speculation must give way to design and construction – or reconstruction, if you prefer.

To contemplate winding a coil for this receiver, the constraints of space had to enter the equation as already mentioned. Fortunately, a very enterprising person has devised a coil winding chart, which is a sort of ready reckoner for coils: a series of parallel and graduated line-graphs. The first is for capacitance, the second for frequency, the third for inductance. Then there are a series of four other graphs

The completed *switch-tuned crystal receiver. As acquired it had been converted into a one-valve set, so restoration required some sleuthing and 'unconversion' – as well as coil design and winding.*

giving coil diameter, turns-per-inch (i.e., wire gauge), number of turns and overall coil length. Unfortunately, multiplying the turns per inch by the length of the coil does not give the total turns! (There may have been a printer's error in which one of the line-graphs was misplaced a fraction of an inch).

First of all we need to select the capacitance. Now with a variable capacitor, you would select its maximum capacitance. However, for this purpose, the self-capacitance of the coil was assumed to have a value of 30pF to tune a frequency of 550kHz.

With a fine pencil and ruler, you join the capacitance graph to the frequency graph and read the inductance – in this case, 2500uH (or 2.5mH).

Next you extend the inductance graph to the coil diameter (3") and this line intersects a 'base line'. You then select the turns-per-inch. You connect this selection back through the base line point referred to before, and then read off the total turns and coil length.

In this case, some 30 SWG DCC (double cotton covered) wire was to hand, which meant 55 turns per inch for the sake of calculation. The result was 300 turns, or thereabouts, close wound, resulting in a coil almost 5" in length.

The same exercise was repeated to determine the top end. It was assumed that for 1.5MHz, the capacity would be about half, so the tap for the top of the coil would be at about 150 or so turns. In fact, it was chosen to be about 120 turns.

As the original front panel had split and a new one would need to be cut, there would be the opportunity to change the number of switch and tapping positions. As a result the number of tuning taps was changed to 17, because it is easier to arrange an odd number of taps in a symmetrical manner. There were a total of seven detector taps, again an odd number.

Calculating the taps was guesswork relying upon experience. For the tuning taps, there are four intervals of 5 turns, four intervals of 7 to 8 turns, four intervals of 10 turns and four intervals of 20 turns, approximately. All of those figures do not add up to exactly 300 turns, but no matter.

The coil former was marked out and drilled at the required distances from the start of the winding. The detector taps were placed at about 20 turn intervals from the top of the coil, marked out in a similar manner.

When completed, the coil's total inductance was measured on a digital meter and came out at 2200uH. Something went right! The small difference in a coil of this size is negligible.

As well as being split, the original front panel also had too many holes in it that were not original. It had been made of thin but solid timber, and painted black. A new piece of similar thin solid timber was selected, and duly marked out for the switch studs.

Then it was into the spares department to see how many brass switch studs could be unearthed. By salvaging another old and derelict panel, 24 studs and their stoppers were unearthed, and they all cleaned up a treat. I also turned up a genuine crystal detector, with a lump of galena and the swivel arm. These items were all duly cleaned up and polished.

Assembly & results

In the first instance, the coil was lashed together on the workbench using test leads dangling in all directions. The outside antenna was connected (if you can call 10 to 12 feet of hookup wire thrown over a bush an antenna), together with a germanium diode and a pair of headphones.

It worked! Not only that, but two stations could be separated out from a quite powerful local transmitter. The assumptions made for the coil were obviously not too far out...

Better still, when the cat's whisker detector was hooked up that worked as well – although the germanium diode does give a slightly louder signal.

By inserting a small capacitor in series with the antenna, slightly better results again were obtained, and a further small improvement was obtained by connecting a 1nF capacitor across the phone terminals. These components were not in the original design, but can be added externally to improve results.

The end result is most gratifying. Scrounging around for parts, particularly the tap switch assemblies was no mean task.

So too was calculating the coil, winding it, and marking out the switch holes with a template after first using a protractor and a piece of paper. The design is so simple, yet restoring it required skills significantly different from valve radio.

All in all, it was a very satisfying project. If you get a chance to tackle a crystal set restoration yourself, I can recommend it! ■