

CRYSTAL RADIO RECEIVER

Definition

A **Crystal radio receiver** is a very simple radio receiver, popular in the early days of radio. It needs no battery or power source and runs on the power received from radio waves by a long wire antenna. It gets its name from its most important component, known as a crystal detector, originally made with a piece of crystalline mineral such as galena. This component is now called a diode.

Basics

The **crystal radio receiver** (also known as a **crystal set**) is a very simple kind of radio receiver. It needs no battery or power source except the power received from radio waves by a long outdoor wire antenna.

Introduction

Simple crystal radios are often made with a few hand made parts, like an antenna wire, tuning coil of copper wire, crystal detector and earphones.

Because crystal radios are passive radio receivers, they are technically distinct from ordinary radios containing active powered amplifiers in many respects. This is because they must receive and preserve as much electrical power as possible from the antenna and convert it to sound power whereas ordinary radios amplify the weak electrical energy "signal" from the radio wave. Today making and operating crystal radios is a popular hobby for many reasons, including:

- Historical and nostalgic significance
- The astonishing results one can get from its utter simplicity
- The challenge of receiving weak distant signals without amplification

Crystal radios can be designed to receive almost any radio frequency since there is no fundamental limit on the frequencies they will receive. The most common crystal radios are designed for the AM Broadcast Band and the *49-meter* international short wave band, partly because the radio waves are stronger in those bands. Early radios commonly received spark signals as low as 20 kHz and below. Although crystal radios are designed to detect AM, they also frequently detect FM fairly well which is in the 100 MHz range.

Groups of enthusiasts and a number of web sites are devoted to their construction. Regular contests are held comparing the performance of various designs with each other. Reportedly, modern diodes, ultra-thin litz wire inductors, and low loss capacitors yield performance far beyond that of the original receivers.

How it works (simple version)

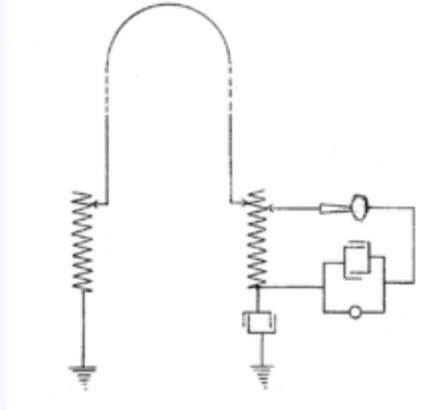
A crystal radio receives programs broadcast from radio stations. Radio stations convert sound into radio waves and send out the waves everywhere. Radio waves travel across the crystal radio antenna all the time. Radio waves make radio wave electricity flow between the antenna wire and the ground wire. This electricity is connected to the crystal radio by the antenna and ground wire. The crystal radio uses a tuner to tune the electricity to receive just one station. The tuner can be as simple as an adjustable one-slider tuning coil that resonates with the antenna because the antenna also acts like a capacitor. Then it uses a crystal detector to convert this radio wave electricity back to sound electricity. The detector can be made from a special rock of galena in a holder. It uses earphones to convert the sound electricity to sound you can hear in the earphones.

History

Crystal radio was invented by a long, partly obscure chain of discoveries in the late 1800s that gradually evolved into more and more practical radio receivers in the early 1900s; and constitutes the origin of the field of electronics. The earliest practical use of crystal radio was to receive dot and dash coded radio signals transmitted by early amateur radio experimenters using very powerful spark-gap transmitters. As electronics evolved, the ability to send voice signals by radio caused a technological explosion in the years around 1920 that evolved into today's radio broadcasting industry.

Early years

Early radio telegraphy used spark gap and arc transmitters as well as high-frequency alternators running at radio frequencies. At first a primitive detector called a Branley Coherer was used to indicate the presence (or absence) of a radio signal. However, these lacked the sensitivity to convert weak signals.



Greenleaf Whittier Pickard's U.S. Patent 836,531 "Means for receiving intelligence communicated by electric waves" diagram.

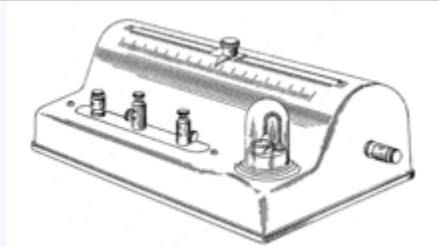
Around 1906, researchers discovered that certain metallic minerals, such as galena, could be used to detect signals. These devices were called 'crystal detectors'.

Greenleaf Whittier Pickard on August 30, 1906 filed a patent for a silicon crystal detector, which was granted on November 20, 1906. Pickard's detector was revolutionary in that he found that a fine pointed wire known as a "cat's whisker", in delicate contact with a mineral produced the best semiconductor effect. A crystal detector includes a crystal, a special thin wire that contacts the crystal and the stand that holds the components in place. The most common crystal used is a small piece of galena. Several other minerals also performed well as detectors. Another benefit of crystals was that they could demodulate amplitude modulated signals. This mode was used in radiotelephones and to broadcast voice and music for a public audience.

Crystal sets represented an inexpensive and technologically simple method of receiving these signals at a time when the embryonic radio broadcasting industry was beginning to grow.

In 1922 the (then named) U.S. Bureau of Standards released a publication entitled, *Construction and Operation of a Simple Homemade Radio Receiving Outfit*. This article showed how almost any family having a member handy with simple tools could make a radio and tune in to weather, crop prices, time, news and the opera. More than any other system, the design contain therein, was responsible for bringing radio to the general public. NBS followed that with more selective two circuit version *Construction and Operation of a Two-Circuit Radio Receiving Equipment With Crystal Detector* that was published the same year and is still frequently built by enthusiasts today.

1920s and 1930s



U.S. Patent 1,748,435 , "Crystal radio apparatus", 1930. H. Adam

While there were a number of earlier experiments with radio broadcasts to the general public, some historians consider the Autumn of 1920 to be the beginning of radio broadcasting for entertainment purposes. Pittsburgh, PA, station KDKA, owned by Westinghouse, received its license from the U.S. Department of Commerce just in time to broadcast the Harding-Cox presidential election returns. In addition to reporting on special events, broadcasts to farmers of crop price reports were an important public service, in the early days of radio.

In 1921, factory-made radios were very expensive. Many of them cost more than \$2,000 USD (in year 2005 equivalent dollars), and less affluent families could not afford to have one. Newspapers and magazines in many countries urged readers interested in radio to acquire one of the inexpensive crystal sets or build their own. To minimize the cost, many of the plans suggested winding the tuning coil on an empty cylindrical oatmeal box. For years afterwards, home experimenters used oatmeal boxes as coil forms for homemade radios. Even the crystal itself could be made by mixing powdered sulfur into molten lead to form the lead sulfide "crystal".

The crystal radio did not require batteries, but it did require the user to purchase a commercially made set of headphones (or telephone receivers as they were called in those days), since that accessory was not suitable for home construction.

Non-electric amplification

- As gas lighting and kerosene lamps were widely used before the adoption of electric power, their flame was used for sound amplification. A ceramic cone with a pinhole on its tip was inserted in the middle of the flame, and an earphone unit was attached to the cone's open bottom and sealed air-tight. This acted like a little pump, modulating the fire by periodically sucking away the combustible mixture at negative half-wave, and injecting it back on positive.
- Air pump amplification was first used in pathophones, where a pump was driven by the same spring motor as a turntable. A needle-sized air pipe was placed near a sound membrane, which acted as an air valve and modulated the air flow, amplifying the sound. This method was easily converted for crystal radio, either in a dedicated device or just by putting a "pumped" pathophone's needle on an earpiece's membrane instead of a gramophone record.

Valveless amplifier

"Carbon amplifier" consisting of a carbon microphone and an electromagnetic earpiece sharing a common membrane and case. This was used in the telephone industry and in hearing aids nearly since the invention of both components and long before vacuum tubes. This could be readily bought or handcrafted from surplus telephone parts for use with a crystal radio. Unlike vacuum tubes, it could run with only a flashlight or car battery and had an almost infinite lifetime.

Cristadyne

In the early 1920s Russia, devastated by civil war, young scientist Oleg Losev was experimenting with applying voltage biases to various kinds of crystals, with purpose to refine the reception. The result was astonishing - with a zincite (zinc oxide) crystal he gained amplification. This was negative resistance phenomenon, decades before the tunnel diode. After the first experiments, he built regenerative and superheterodyne receivers, and even transmitters. However, this discovery was not supported by authorities and soon forgotten and no device was produced in mass quantity beyond a few examples for research. This was partly due to the low education and overall ignorance of leadership, and partly due to the totalitarian nature of the USSR regime.

The USSR opposed freedom of information, and registered all radio receivers until 1962, typewriters and copy machines until its demise, and the rule is not formally denounced yet. Crystadine was produced in primitive conditions; it can be made in a rural forge - unlike vacuum tubes and modern semiconductor devices. It is an unwanted discovery to the authorities, and was consigned to obscurity. Oleg Losev died 1943 in besieged Leningrad, abandoned and nearly forgotten.

1940s

When Allied troops were halted near Anzio, Italy during the spring of 1944, personal portable radios were strictly prohibited, as the Germans had radio detecting equipment that could detect the local oscillator signal of superheterodyne receivers. Some resourceful GIs found that a crude crystal set could be made from a coil made of salvaged wire, a rusty razor blade and a pencil lead for a diode. By lightly touching the pencil lead to spots of blue on the blade, or to spots of rust, they formed what is called a point contact diode and the rectified signal could be heard on headphones or crystal ear pieces. The idea spread across the beachhead, to other parts of the war, and to popular civilian culture. The sets were dubbed "**foxhole receivers**" by the popular press, and they became part of the folklore of World War II.

In some Nazi occupied countries there were widespread confiscations of radio sets from the civilian population. This led to particularly determined listeners building their own "clandestine receivers" which frequently amounted to little more than a basic crystal set. However anyone doing so risked imprisonment or even death if caught and in most parts of Europe the signals from the BBC (or other allied stations) were not strong enough to be received on such a set. However there were places such as the Channel Islands where it was possible.

Later years

While it never regained the popularity and general use that it enjoyed at its beginnings, the circuit is still used. The Boy Scouts (who emerged as the unofficial custodians of crystal radio lore) kept construction of a set in their program since the 1920s. A large number of prefabricated novelty items and simple kits could be found through the '50s and '60s, and many children with an interest in electronics built one.

Building crystal radios was a craze in the 1920s, and again in the 1950s. Recently, hobbyists have started designing and building sophisticated examples of the instruments. As much effort goes into the visual appearance of these sets as well as their performance, and some outstanding examples can be found.

Annual crystal radio DX contests and building contests allow these sets to compete with each other and help form a community of interest in the subject.

Attempts at recovering RF carrier power

Crystal radio tuned to strong local station can be used just as a power source for another amplified power-efficient (more often regenerative) receiver for distant stations that can never be heard with plain crystal radio.

There is long history of less successful attempts and unverified claims to recover the power in the carrier of the received signal itself. Traditional crystal sets use half-wave rectifiers. As AM signals have a modulation factor of only 30% by voltage at peaks, no more than 9% of received signal power ($P = U^2 / R$) is actual audio information, and 91% is just rectified DC voltage. Given that the audio signal is unlikely to be at peak all the time, the ratio of energy is, in practice, even greater. Considerable effort was made to convert this DC voltage into sound energy. Some earlier attempts include a one-transistor amplifier in 1966.

Sometimes efforts to recover this power are confused with other efforts to produce a more efficient detection.. This history continues now with designs as elaborate as "inverted two-wave switching power unit" and bridge amplifiers.

Construction and operation

Importance of grounding

The long wire type antennas often used with crystal radios are Monopole antennas. To receive signals from this type of antenna, a ground reference is needed to provide a place for the antenna signal electricity to flow into and out of. Because crystal radios have no other source of power than the electrical power they receive from the antenna, the grounds for crystal radios must be much better than those used by amplified radios. The importance of this is easy to overlook by those familiar with amplified radios. Amplified radios use energy (voltage) detectors and as such do not need to take much raw power from the antenna and need little or no physical ground. Crystal radios rely on power detection and need to encourage as much antenna current as possible to flow. This requires effective grounding.

The Naive Circuit

An impractical crystal radio circuit illustrated here is often naively proposed to tune the medium wave AM broadcast band with a tuner made of a fixed parallel coil and variable capacitor *tank circuit* with the antenna and ground connected across it.

There are many practical crystal radio circuits, but connecting both the antenna and a variable capacitor across a fixed coil like this makes tuning the whole two octave AM Broadcast Band impractical.

The reason for this is technical. Most crystal radio antennas are about 60 feet long and 20 feet high to be effective, and act something like a 250 to 300 pF capacitor (actually antennas have capacitance, resistance and inductance, but these are mostly capacitive.) If we connect a typical 250 pF antenna to the top of a tank that uses a coil of more than about 75 μH we cannot tune above about 1400 kHz at all. We must drop the size of the fixed coil below 75 μH to have *any* chance of tuning the top of the band (around 1600 kHz or 1710 kHz.) Even with a 70 μH coil, we need a 1000 pF variable capacitor to tune near the bottom of the band around 540 kHz. But now we need that same variable capacitor to vary down to about 4 pF to reach the top of the band at 1710 kHz. That is a variation from 100 % to down to about 0.4%. It is impractical to implement an air variable capacitor that can achieve a variation range that even approaches that. In practice, stray capacitance of air variable capacitors limits the range from 100 % to about 5%. Other kinds of variable capacitors are seldom used for crystal radios because of their excessive losses. Consequently, knowledgeable designers do not suggest this circuit.

Source: http://www.juliantrubin.com/encyclopedia/electronics/crystal_radio.html