The Rehbock (Roebuck), a very revolutionary radar-range-calibrator

It is known that the piezo-electric phenomenon in crystals can convert a mechanical force in to an electrical energy (emf) and that an electrical energy can be converted in to a mechanical force. When we excite a piezo-electric-resonator electrically this will create a deformation of the crystal at resonance. (neglect for the moment the particular mode of excitation).

Telefunken's clever idea was to use this piezo-electrical effect to create a RF signal transponder.

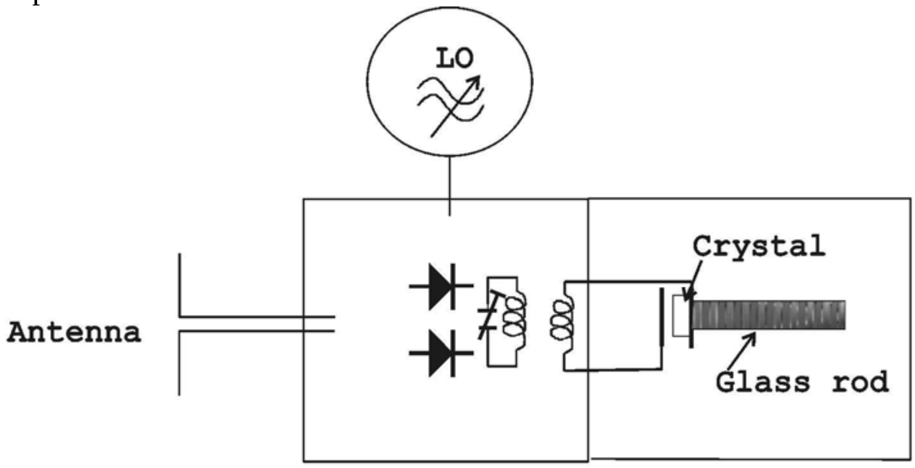

Fig. 11: Principle diagram of the Rehbock apparatus

We will follow the route of the radar signal (stimulus) after it has been received by the antenna circuit. This signal is passed onto a balanced mixer circuit. The local oscillator was tuned at 25 MHz below the receiving frequency (this was dependent upon the particular frequency of the crystal-delay-line device, which sometimes could be at about 26 MHz). Let us assume that the radar signal (RS) is transmitted on 560 MHz and that the intermediate frequency (IF) is 25 MHz then the local oscillator (LO) had to be tuned on 560 - 25 = 535 MHz. The IF output was loaded (tuned) by an inductively coupled band-filter. This band-filter was itself, on its secondary side, loaded by the (transponder) crystal device onto the axis of which was mounted a glass delay-line. The ultra sonic vibrations, due to the prf of the radar set, caused a sonic wave pattern travelling inside the glass rod towards its opposite end. These sonic waves were bounced back towards the (quartz or tourmaline) crystal. After this sonic vibration reached its face of origin it excited the crystal at its correct (mechanical) mode. This, consequently, produced the RF signal at the appropriate intermediate frequency. This signal is then being mixed up in frequency and passed on, now in reversed direction, towards the radar set (IF + LO = RS).

These sonic waves were, due to some mechanical mis-match, not entirely absorbed at the inner surface of origin. But were partially (attenuated) bounced back towards the other end of the glass delay-line again. This process was repeated several times. I have determined that its 5 th reflexion could be very well received by the radar set under test. Each time interval was slightly delayed in respect to its previous one. Due to this phenomenon an individual calibration chart had to be constructed for every Rehbock apparatus.

The American summary report “The High-Frequency War, A survey of German Electronic Development” explained, quite extensively, the principles of this interesting “Artificial target”. I have selected some of the details.

…The wave travels with a speed characteristic to the type of glass (approximately 6000 m/sec) through the rod. …The high frequency of 25 megacycles is necessary for the complete transformation of the wide pulse spectrum, and produces in the glass a wave length of only 0.2 mm. …The glass rods as used in practice cause little distortion of the reflected pulses, thereby preserving the original pulse shape. …The glass is chosen so as to have the smallest temperature coefficient relative to the delay time, which is only 3×10^{-6} *per degree* (K, AOB). *Because of this property, it is possible to consider the rods as presenting normal delay time.*

All seems to be very simple, though this wasn’t the case. First, we have to consider that quartz crystals were commonly being made for the fundamental vibration mode up to about 10 to 12 MHz. For higher frequencies commonly the, so-called, overtone mode had to be used or, multiplier stage(s) had to be employed.

In 1931, Straubel introduced the first high frequency tourmaline oscillator. (27)

On 2 April 1931 a patent application was filed in the name of Carl Zeiss Jena, which became classified under the number: DRP 612 997. Its aim was a: Piezo-electric oscillator or resonator by means of tourmaline. This patent was certainly based on Straubel’s work. Tourmaline quartz oscillators could be made for ≈ 400 MHz regions. (28) A disadvantage was that these, so-called, ultra high frequency resonators were very difficult to produce because of the thickness which was often < 0.01 mm! In my opinion, this was the main reason why the optical firm Carl Zeiss became involved in this field. The Germans produced those kinds of tourmaline crystals, generally, for frequencies up to about 40 MHz (fundamental mode) (see hereafter). The disadvantage of the increased power loss of tourmaline resonators was compensated for by the simplicity of its circuit design. No multiplying stage(s) was necessary to obtain high frequency output. Tourmaline plates, of equal thickness, resonate at about 35 % higher frequency and were in some respects easier to manufacture.

Zeiss produced tourmaline crystals with rather good results. However, it is known from allied surveys shortly after the end of WW II, that the Zeiss company also manufactured quartz crystals up to rather high frequencies. According to the interrogation, on 30 November 1945, of (the famous) Mr. Gerber who worked for Carl Zeiss in Jena and which was issued in the FIAT Final Report No. 641, (p. 9) (29): -
In response to questions regarding the Zeiss technique of thin-quartz grinding, Gerber stated that quite a large number of plates of 49° cut had been produced at 60 MHz by very careful handwork by very skilful workmen. The laboratory made a very few at 100 MHz, but the reported 200 MHz was projected research only..............Tourmaline crystals were made as high as 400 MHz by skilful handwork. These were 7 mu thick.....

The tourmaline (or eventually quartz) crystal and the glass delay-line can be seen in the right hand section of figure 11.

The first attempts to get this transponder device working satisfactorily were hampered by a considerable amount of generated (signal) noise, which was transmitted back towards the radar receiver. They finally discovered that this noise was originating from inside the glass delay-line itself. It was found that the sonic signal path wasn’t travelling in a straight line towards the reflecting (inner) surface of the glass rod, but that a dispersion of the (ultra) sonic waves took place. The solution, to counter this disadvantage, was found by frosting the surface of the glass cylinder. The stray sonic waves were thus absorbed and couldn't be reflected.

After a long search I have recently traced, in the British Library, a Telefunken (secret) patent application which claimed: - a crystal in conjunction with a delay-line device to convert electrical signals into ultra sonic waves and its re-conversion into an electrical signal". This application even claimed an echo (noise) reducing technique as well. (30)