Experiments with a Replica of the Bose Detector

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***Abstract* – A particular detector was used in Marconi's transatlantic experiment. A replica of this detector was made in order to investigate its efficiency when used in a "crystal" receiver. It was found that the use of a bias voltage improved the performance significantly but a faint random noise was heard in headphones. Experiments with a simple spark transmitter gave an idea of the type of sound that Marconi's transmitter might have produced in earphones.**

I. INTRODUCTION

On December 12, 1901 Marconi received the first radio transmission across the Atlantic. The distance was 3500 km and the message was the 3 dots of the letter S. Scientists at that time claimed that the radio waves went like rays of light and thus had to pass a wall of salt water 160 km's in height. Such a connection was not possible and it was said that: "anyone who believed this did so as an act of faith based on the integrity of one man" [1].

Scepticism also appeared in the press in connection with the centenary of Marconi's birth in 1974. Such a pessimistic view was not easy to accept by one who in early youth had read about exciting achievements made by Marconi and had come to regard him as a hero.

But at the same time studies in UK could support Marconi's claim [2]. Reception might result from radiation at high frequencies (HF) instead of 800 kHz. His transmitter produced a strong impulse field with a wide spectral response. This signal was repeated many times each second. In his receiver a rectified signal of short duration would occur at this frequency. This signal might, with proper harmonics, produce an audible and characteristic sound in earphones to which Marconi was acquainted.

II. RECEPTION WITH WORLD'S FIRST CRYSTAL RECEIVER

Up to about 1902 Marconi used a "coherer" as a detector, which had been invented earlier. A radio signal impressed upon this device reduced an inherent resistance of several Mohms down to about several kohms. An impressed current from a 1.5 V battery could then activate a sensitive relay, which in turn activated a Morse printer and a hammer ("tapper") by means of another larger battery. The hammer was knocking at the coherer which made it return to the insulating condition. When used in the transatlantic experiment however, Marconi should have told [3] that the device operated on the background noise from distant lightning. It was impossible to record the signal from the Poldhue transmitter. It was the so-called "Italian navy coherer" or the "Self restoring coherer" which made reception possible [3]. Recently it was documented that this detector had been invented by Dr. J. C. Bose [4].

Measurements [2] have shown that it acted as a rectifying crystal. A radio signal of 50 mV with 50% modulation could be heard. The level of bias used during these measurements was not given. Since the antenna at Signal Hill had a height in the order of 130 m, a field strength of about 1 mV/m might suffice to provide reception. Such a signal might reach Newfoundland at frequencies in the range 5 – 15 MHz during favourable conditions [2].

The rectifying properties of the detector have also been verified by V. J. Phillips [5]. He also provided a circuit diagram of the original detector. It shows that a single cell battery (i.e. 1.5 V) was used, as in Marconi's coherer.

Specifications for Marconi's earphone have not been found. In [6] the resistance of a "sensitive and previously very much employed" single earphone is given as 800 ohm. The sensitivity is not specified properly, it might be about the same as my earphone (1930'ies), which gives audible sound for a signal of about 2 mV (rms, at 400 Hz).

The driving voltage for the transmitter at Poldhue was an impulse with a short rise time. Wiring and stray inductances would resonate at HF when subjected to such an impulse and produce a ringing tail. The mean power of such a complex pulse have been estimated to 40 MW [2], the same order of magnitude as the pulsed and troublesome Soviet "Woodpeckers" of 1976.

A hot-wire ammeter was probably used to monitor the output current to the antenna and adjustments made to maximise this current. A high spark rate would then be as important as a large spark-over voltage. An increase in gap length would reduce the rate, so that trade-offs had to be made.

Information provided [7] indicate however that Fleming had written that a spark rate of only 21 Hz was used. It would then take several half cycles to produce a spark, resulting in a reduction in efficiency.

A simple spark transmitter was made many years ago by means of an ignition coil from a scrapped car. The coil was connected to a car battery through a fast low voltage relay with its armature fed from a mains transformer in series with a rheostat. A copper lead few meters in length was connected to the HT-outlet to make a simple antenna and an air gap made to the casing of the coil. By adjustment of the rheostat it was possible to have the relay operating at about 50 – 100 Hz with sparks in the gap about 10 mm in length. A characteristic humming sound was heard in the earphones of a crystal receiver separated at a distance from the transmitter. A motor vehicle without proper ignition noise suppression might produce similar sounds.

III. Replica of the Detector

A simple replica of the detector was made in June 1979 [8]. It consisted of a carbon plug (from a 4.5 V battery) mounted in a hole in block of plexiglass with a 6 mm iron bolt in a threaded section at the other end. Ends of the bolt and the plug were slightly grinded. By turning the bolt it was possible to adjust the pressure on a drop of mercury placed in between. The detector was mounted in my crystal receiver tuned to a local AM radio station. The power of this transmitter, located at a distance of 12 km, was 200 kW at a frequency of 216 kHz. The field strength was estimated from nearby measurements to be about 10 mV/m. The receiving antenna was about 10 m long and 7 m above earth. This transmitter was closed down in 1995 and other local stations do not give sufficient signal strength for reception.

By turning the detector gently a position was found where the station could be faintly heard. A faint disturbance in motion would terminate the reception and the detector had to be handled again to restore reception. This operation could be time consuming. Since it was reason to assume that Marconi had used a bias voltage for the detector, a 100 ohm potentiometer was inserted between the detector and the headphones. The potentiometer was connected to a battery resistance both ends, so that the bias could be varied from 0 to 4.5 V. At a bias of 0.5 V reception using double earphones (4 kohm, from the 1930'ies) was acceptable. Reception was then comparable to the use of a point contact germanium diode (Philips OA81) without bias. This diode is similar to 1N34. The detector was measured in a Tektronix 575 Curve Tracer and the response is shown in Fig. 1 [9]. This V-I characteristic was copied by hand from the oscilloscope display using transparent paper. Due to slight fluctuations (noise) in the display a broad curve had to be drawn. Rectification was not perfect. The current was measured at 0.5 V bias by an ammeter to be about 40 microamp in the forward direction and 20 in the reverse.

At zero voltage the dynamic resistance (dv/di) can be found from Fig. 1 to be about 60 kohm, which would call for an earphone of very high resistance. At 0.5 V the dynamic resistance was reduced to be about 5 kohm, a good match for my 4 kohm earphone. An earphone with a smaller resistance would require a higher level of bias voltage. With the use of bias it was easy to know when the detector was active since a faint random noise was heard. A colleague of mine suggested that it might be due to tunnelling effects through an extremely thin insulating layer.

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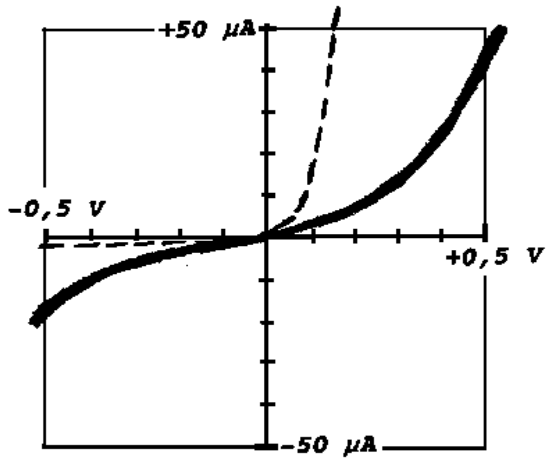

Fig. 1. Characteristic curve for the replica detector. The curve for a typical point contact germanium diode (OA81, 1N34) is shown by dotted line.

The response of an OA81 is shown in Fig. 1 for comparison Several other germanium diodes gave the same result. The characteristic curve for these diodes (i.e. 1.2 mA for 0.5 V, at room temperature) resembled closely a curve for a "good crystal" (possibly galena) found in a radio data book from 1932, but the reverse current was much smaller. At zero bias the dynamic resistance of the germanium diodes was found to be in the order of 10 - 20 kohm. For this reason, two or more diodes in parallel improved reception. A genuine galena detector, which was invented by Dr. Bose in 1899 [4], was not available. According to the literature it is assumed to have the same order of sensitivity as germanium. At about 1906 the carborundum detector appeared. It had a high resistance and a bias voltage in the order of 5 V was required to make it useful.

IV. Conclusions

Use of a bias voltage for the detector did improve the sensitivity for reception when a 4 kohm earphone was used. The sensitivity was then roughly equivalent to the use of a point contact germanium diode. A faint random noise was heard when the detector was in operating condition. A slight movement of it would turn it into a non-rectifying state and readjustments to make it operate again could be time consuming. Prior to 1901 a more stable and sensitive galena crystal detector had been invented by Dr. Bose. Had Marconi been willing to cooperate with him the transatlantic experiment might had been more convincing and perhaps better documented.

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