Jagadish Chandra Bose: The Real Inventor of Marconi's Wireless Detector

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1. Introduction

The invention of radio, one of the most important inventions of the 20th century is attributed to Guglielmo Marconi of Italy. Though it is disputed whether Nikola Tesla's patent on radio precedes that of Marconi, it is well-known that the first demonstration of radio transmission over several thousand miles was done by Marconi in the year 1901. There have been other claims of radio transmission which precede that of Marconi, but Marconi's experiment is the only one which was not conducted in a hidden laboratory and was open for scientific scrutiny and commercialization (which he himself did).\

Figure 1: Sir J. C. Bose

There were other eminent scientists who helped Marconi and they were duly acknowledged. Prof. Fleming was a technical advisor to Marconi's company and helped him setup his transmission station for the 1901 experiment. He had agreed to Marconi's precondition that the complete credit for the 1901 transatlantic experiment will be that of Marconi [6]. With regard to the receiving device, Marconi claimed that it was gifted to him by his friend, Solari.

The present article puts forth the fact that the receiving device used by Marconi, a mercury autocoherer was invented by Sir Jagadish Chandra Bose. Bose was the first to report this invention in his paper [9] presented at the Royal Society. Bose's invention has clear precedence to all other claims. There is further circumstantial evidence to support this. The classic paper by Dr. P. K. Bondyopadhyay [1] published in 1998 investigates this in detail.

This article is organised as follows. In Section 2, the setup of Marconi's first Transatlantic Experiment is discussed. Section 3 discusses technical details of the autocoherer, the receiving device. Section 4 details the controversy surrounding the coherer thus justifying its importance and provides substantial evidence that it was invented by Bose. Section 5 concludes the article.

2. Experimental Setup for Marconi's 1901 Experiment

2.1 Transmission by means of modulation

Heinrich Hertz's historic experiments dealt with generation and reception of electromagnetic waves of wavelength 30 centimeters to 8 meters. However he didn't conceive the idea of modulation. In 1889, he stated that continent size dishes will be necessary to send audio frequency range wireless waves for voice communications [6]. It was Marconi who conceived the idea to 'modulate' electromagnetic (EM) waves using a Morse code to send information. This implied generating a short duration wave for a dot, a longer wave for the dash and no wave for a space.

2.2 Marconi's experimental setup for transmission of signal

The transmitter used by Marconi is now referred as a spark transmitter. It was designed by Prof. Fleming [21]. It contains a two-stage spark circuit which causes multiplication of voltage to produce a high alternating current. The first stage capacitor is charged by a low voltage, while the second stage capacitor discharges at a much higher voltage giving rise to a high alternating current. This current was coupled to the transmitting antenna. Several periods of the supply generator were required to charge the first capacitor, and it is estimated that the second loop had a spark rate of just two to three sparks per second [22].

The antenna used by Marconi is believed to be a cone antenna designed by Fleming [2]. Marconi had modified Hertz's dipole to a monopole. It is believed that Marconi used an end-loaded antenna at the top of the monopole to improve performance. A study about the different possible atenna structures Marconi may have used is given in [7].

2.3 The 1901 experiment

Marconi alone had the strange idea that he will be able to send information riding on electromagnetic waves over the horizon. Other scientists disputed this, since they believed that EM waves travel in a straight-line and they shall diverge off the surface of the earth which is spherical. To test his hypothesis, Marconi established a huge transmitting antenna at Poldhu, Cornwall, UK (Section 2.2) to send a signal to be received at Newfoundland, St. Johns, which was at a distance of around 2000 miles. [3]

On December 12, 1901, Marconi received the letter 'S' (three dots) at Newfoundland which was transmitted from Poldhu. The receiving antenna (150m long wire [22]) was put on a kite, from which a wire came to a pole and finally to the receiver. The receiver consisted of some kind of a 'coherer' and a telephone receiver to hear the signal using an earphone. Marconi claimed to hear the three dots representing the signal 'S'. This is the famous transatlantic experiment of Marconi, which surprised the world.

2.4 **The receiving equipment**

Marconi used an autocoherer to detect the electromagnetic waves. The antenna received the RF signal and provided a current at the same frequency. This current had to be detected on a galvanometer or a paper tape recorder. A reasonable way to do this is to convert the current into a direct current which could then be measured. This suggests that rectification of current was required, which is done using diodes these days. However, no diodes were available at that time and instead a 'coherer' was used.

The device, coherer forms the focus of this article and shall be discussed in detail in the next section. The autocoherer used by Marconi to receive the first transatlantic signal was invented by Sir J. C. Bose [1].

3. Autocoherer: The Receiving Device

The device used to detect RF signal received by the antenna during the late 1800's is called a coherer. The antenna was followed by a tuning circuit which picked up the desired frequency and fed the signal to the coherer. The coherer converted the AC (RF signal) to a DC signal (or a low frequency signal), which could then drive a Morse printer or an earphone. An improved version of the coherer called the autocoherer was used by Marconi in his 1901 experiment. Both the devices are explained now.

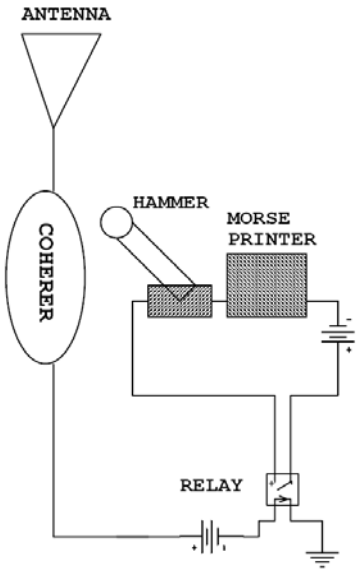

Figure 2: Receiving apparatus using a coherer

Coherer: The name coherer was coined by Prof. Oliver Lodge [3]. Coherer is a two terminal device whose resistance drops sharply on application of a direct or alternating voltage more than a given threshold. Coherers were built by enclosing metal filings (generally silver and nickel) in a tube with electrodes dipped in it.[1] When the RF or direct signal was applied across the coherer, the filings *cohered* and the resistance decreased sharply [3,7] (from the order of tens of thousands to tens of Ohms). Several explanations of how a coherer worked are given in [15].

[1] Interestingly, Bose invented a more accurate coherer called the Spiral Spring Receiver. [15]

The coherer was connected in series to a battery and the antenna which received the RF signal. When the RF signal was received, it lowered the resistance of the coherer and the battery passed a small DC. This switched on a relay connected in series with the coherer. The relay drove a secondary circuit consisting of a Morse printer which recorded the signal [17].[2] This is shown in Figure 2.

The coherer had a disadvantage that it had to be tapped mechanically to *uncoher* it, i.e. get it back to the initial state of high resistance. Therefore, for continuous reception of the signal, the coherer had to be tapped after each detection. For this purpose, the secondary circuit driven by the relay also triggered a mechanical arrangement which hammered the coherer tube to decoher the particles. Coherers were not accurate and the mechanical tapping system made them unreliable. Coherers were followed by autocoherers which decohered automatically and were more accurate.

Autocoherer: Autocoherers retained their initial state ('restored') automatically after once being subject to RF signals. Sir J. C. Bose invented the Mercury Autocoherer coupled with a telephone detector in the year 1899[3] [9].

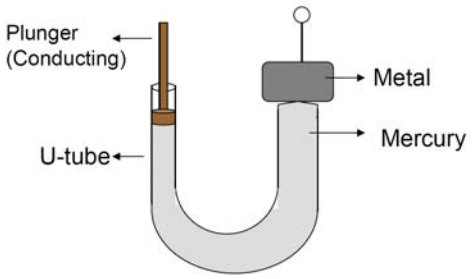

Fig. 3: A drawing of the coherer designed by Bose

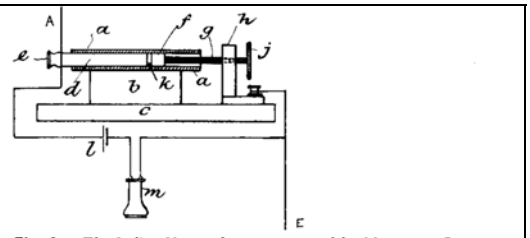

Fig. 1 *The Italian Navy coherer as patented by Marconi in September 1901* (Brit. Pat. 18 105)

d = carbon plug
f = adjustable iron plug
k = drop of mercury
A = antenna
E = earth

Fig. 4: Coherer patented by Marconi (Brit. Patent 18105)

Bose's arrangement had a U-tube filled with mercury. There was a plunger in one limb and a metal piece in the other (depicted in Figure 3). The pressure was varied by the plunger, which formed a metal-mercury contact in the second limb. Bose found out that the applied voltage and the pressure greatly influenced the cohering properties of the arrangement. He used different metals in his study to understand their cohering properties. The behavior of the device as an autocoherer was disclosed in his paper presented at Royal Society [9] and is quoted herein:

> "Another coherer was found apparently irresponsive to radiation, there being the merest throb (sometimes even this was wanting) in the galvanometer spot, when a flash of radiation fell on the receiver. Thinking that this apparent immobility of the galvanometer spot may be due to response, followed by instantaneous recovery, the galvanometer needle being subjected to opposite impulses in

[2] Some of the references,don't clearly show the biasing battery for the coherer. It is unclear that the dc energy came from the RF signal or the biasing battery.
[3] The author doesn't have information about other forms of autocoherer which existed before this.

rapid succession, I interposed a telephone in the circuit; each time a flash of radiation fell on the receiver the telephone sounded, no tapping being necessary to restore the sensitiveness. The recovery was here automatic and rapid."

Bose's autocoherer design used a mercury-metal interface and a telephone to detect the signal from the Autocoherer.

The action of the autocoherer is to generate a DC signal on being subject to a RF signal, such that it could be recorded. After generating the DC for a small interval (period of RF signal detection), the coherer restores to its original state automatically. It may be observed that this action is close to that of a diode-detector and diode was invented some 40 years later! In [3] and [19], the Mercury autocoherer was rebuilt and tested. The authors therein confirm the rectifying action of the autocoherer and the similarity of its transfer characteristics to that of a diode.

4. Bose invented Marconi's Wireless Detector

The claim that Bose invented the autocoherer is supported by two pieces of evidence. The primary evidence is the precedence of Bose's invention to all recorded/claimed inventions of the device. To show this clearly, a timeline of claims of coherer invention is discussed herein. The events following Marconi's 1901 experiment are also summarized. The persistent debate on Marconi's receiving device and Marconi's elusive comments on it shows its importance in context of the 1901 experiment. The second set of evidence is circumstantial, for instance, record of letters written by Bose talk about patent offers for his receiving device.

The timeline of the events is given below in Table 1.

Time	Invention/Claim
1878-1880	David Edward Hughes uses some kind of a coherer. No use of mercury.
1891	E. B. Branly (Paris) uses a coherer. Doesn't use mercury.
Apr. 27, 1899	J. C. Bose reads his paper, "On a Self Recovering Coherer and study of cohering action of different materials" [9] at the Royal Society, UK. His coherer uses conductors separated by mercury and telephone to detect signal.
May 1, 1899	Tommasina states the following in his paper presented at Comptes Rendus (Paris): "In my researches into contact coherers, after having obtained some very sensitive ones by means of a drop of mercury placed between cylindrical brass electrodes…" there is no mention of mercury in the paper except this one line. Use of a telephone is also not stated. [1]
1900	Tommasina states in one of his paper, "a drop of mercury decoheres automatically…" at the Geneva Society's Proceedings.
Sept. 1900 – Feb. 1901	P. Castelli (Italy) invents coherer using Mercury. Claimed in an article in Italian publication L'Elettricista. (Prof. Banti, editor), 1902.
Jan. 1901 – Late 1901	L. Solari (Italy) invented the mercury coherer. Claimed by Marconi.
Sept 1901	Marconi patents a Steel-Mercury-Carbon Coherer on his name.
Dec. 1901	Marconi conducts the famous transatlantic experiment. He claims that the coherer was gifted to him by Solari, his childhood friend and calls it the 'Italian Navy Coherer'.
1902	Prof. Banti, editor, L'Elettricista [10] (Italian publication) sparks a controversy in regard to the inventor of the coherer used by Marconi. He concludes that both Castelli and Solari share credit for invention of coherer.

April 1902	S. P. Thompson sparks a controversy in regard to the inventor of the coherer by writing letters to Saturday Review [Ref. 13-26 of 3] (England). He claims that Lodge, Castelli and Solari are possible inventors of the coherer.
June 1902	Marconi delivers lecture at Royal Institution of Great Britain on his transatlantic wireless signal reception. He talks about the Italian Navy Coherer, but doesn't give a definitive source from where he acquired it.
July 1902	Solari categorically denies that Castelli had invented the Coherer [11]. He claims that, "the idea of the employment of mercury had been suggested to me by something which I had read in some English publication which I found myself unable to trace…"
Dec. 1902	An article challenging the patent application filed by Marconi for the coherer is published in the Electrical Review. Marconi's patent on the coherer is modified and the Steel-Mercury-Coherer is considered a gift from the Italian Navy.
June 1903	An article by Guarani [12] claims T. Tommasina as the inventor of the coherer used by Marconi. L. Solari finally gives up claim of inventing the coherer, but denies that Tommasina had invented it.
1997, More than 90 years later	Ms. Mita Mukherjee publishes in The Telegraph, Calcutta, "Bose invented Marconi's Wireless". [13]
Jan. 1998	P. K. Bondyopadhyay uncovers that Bose invented the coherer used by Marconi. The paper is published by IEEE. IEEE publishes several other papers on J.C. Bose in the same year. [1,5,9,14,15]

Table 1: Timeline of events with context of Marconi's receiving device.

The roaring debate over the receiving device shows its great significance in context of Marconi's experiment. The timeline clearly show that Bose was the first to publish a autocoherer which used, a. A mercury-metal interface, b. Telephone to hear signal. This was indeed the arrangement used by Marconi. The autocoherer patented by Marconi [8] is shown in Figure 4. The patent read, "coherers made according to this invention consist of a drop of conducting liquid lying between two conductors… the liquid is mercury…" He reported in context of the 1901 experiment [23] "…I had substituted a telephone receiver believing that I could then detect much fainter signals.."

The only claim in the same year as Bose is by Tommasina, whose paper has a reference to mercury, however no mention of its self-cohering property or use of telephone. Solari and Castelli reportedly invented their coherers more than a year later than Bose's publication. There is no formal publication of their work and the evidence in their favour is acknowledgment of their invention by *honorable* individuals. Bose has clear precedence to all these inventors. It cannot be concluded whether these inventors independently re-invented the device or if these were inspired/ made fraudulent claims.

Some appealing circumstantial evidence complementing the primary evidence is as follows:

- J C Bose's letter to Rabindranath Tagore, Nobel Laureate [16]: (In context of his 1901 lecture at the Royal Society, 17th May 1901, reproduced)

A short time before my lecture, a multi-millionaire proprietor of a very famous telegraph company telegraphed me with an urgent request to meet me. I replied that I had no time. In response he said that he is coming to meet me in person and within a short time he himself arrived with patent forms in hand. He

made an earnest request to me not to divulge all valuable research results in today's lecture : "There is money in it -- let me take out patent for you. You donot know what money you are throwing away" etc. Of course, " I will only take half share in the profit -- I will finance it" etc. … See, the research that I have been dedicated to doing, is above commercial profits. I am getting older - I am not getting enough time to do what I had set out to do -- I refused him.

Here, the proprietor is believed to be Major Stephen Flood Page, the Managing Director of the Marconi's Wireless and Telegraph Company [5].

- **Solari's might be mentioning Bose**: Solari's statements in regard to coherer were not consistent with that of Marconi. He completely refuted that Tommasina, Castelli, Hughes or Marconi had invented the coherer. He might be mentioning Bose, when he says, "the idea of the employment of mercury had been suggested to me by something which I had read in some English publication which I found myself unable to trace…".

- **Marconi acknowledged Bose**: Marconi kept changing his stance with regard to the origin of the coherer throughout his life deepening the mystery surrounding it. This can be studied in Section VIII of [1]. Later the book by Dunlap [4, ch. VIII, p. 95], which Marconi personally edited, devoted one and a half page in a tribute to Bose for providing crucial support to Marconi at the critical juncture when Marconi needed it most.

The precedence of Bose over all other inventors leaves no doubt that he invented the Metal-Mercury coherer. It is interesting to note that other events complement this prima-facie evidence.

5. Conclusion

The article covers details of concepts and equipment used in Marconi's 1901 transatlantic experiment to proivde a context to understand the wireless detecting device. The article then discusses the construction and working of coherers and autocoherers. Through a systematic analysis of the timeline, it is concluded that there is prima-facie evidence to show that Bose invented the detecting device used by Marconi. Further circumstantial evidence supports this. Bose's credibility needs no introduction, given his well-known work in plant physiology, field of microwave engineering [14,15,18], claim to the first patent on a solid-state device [20] and twenty-seven papers in the journal Nature.

Marconi is considered and celebrated as the inventor of radio for his 1901 transatlantic experiment.[4] In effect, the author holds the view that the invention of radio should not be attributed to Guglielmo Marconi alone, but Guglielmo Marconi and Jagadish Chandra Bose. It may be argued that other individuals also helped Marconi in his experiments (for instance, Prof. Fleming). In regard to this, it may be noted that not only the contribution of these individuals is well known to the world, but they willingly left claim to the invention. For putting the history of science in the right perspective, this hole should be now filled and reflected in the educational material used at all levels around the world.

[4] There are claims that Marconi's foremost achievement was public demonstration of sending wireless signal remotely over a mile in 1896. It is worth noting, that Bose had given a public demonstration of wireless transmission over a mile in 1895 and over 3 miles in 1896 in presence of the governer of Calcutta!

Many aspects of the history of telecommunication are still shrouded in mystery and there are numerous puzzles to solve, as recorded in [24]. Efforts are needed to investiagtes and disseminate conclusions to mainstream education.

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