JAGADISH CHANDRA BOSE: THE PHYSICIST WHO WAS FORGOTTEN

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This paper touches upon the exposure Jagadish Chandra had with the leaders of science in Cambridge, his joining Presidency College, Calcutta ,his initiation and researches as a physicist, before he switched over to become one of the leading Plant electro-physiologists.

Contrary to popular belief, the objective of Bose was to establish experimentally Maxwell's theory of Electromagnetic wave propagation for short waves rather than explore the commercial aspects of wireless signal transmission. A cursory glance is made at the history of electromagnetism that led to Maxwell's Electromagnetic theory.

Jagadish Chandra's extraordinary intuition and skill in instrumentation carried out in the most primitive and ill equipped laboratory conditions, led to the production of equipment some of which is still used in modern communication. In this attempt, he turned out to be the first person to produce, transmit and receive millimeter waves that are used for much of today's mass communication. Unknown to most, he anticipated the first semiconductor, the seed of today's computer and electronic revolution.

Caught in the transition of classical to modern Physics he decided to change track and was forgotten as a physicist that he was, only to be remembered sixty years later to have been the first one to produce millimeter waves and anticipate semiconductors.

Jagadish Chandra Bose found himself in the right place at the right time. After his studies at St. Xavier's College under Father Lafont, he set off for England in 1880 to study medicine. Afflicted by *Kala azar* before he left India, he had difficulties in continuing the study of medicine. Instead, he joined Christ's College, Cambridge, in 1881, under the tutorship of Lord Rayleigh, who was a polymath. Rayleigh had received the Nobel Prize for discovering Argon. He took Jagadish under his wings. Jagadish also studied under Francis Darwin, son of Charles Darwin , Sir James Dewar and Sydney Vines the great physiologist. Europe was surging ahead in scientific studies and research. Cambridge was in the front line.

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Jagadish completed his *Tripos* in *Natural Sciences*, Physics, Chemistry and Botany. He also obtained a degree from London University. Equipped with excellent recommendations, he returned home after four years (1885) to seek an interview with the Viceroy Lord Ripon who was very pleased to meet Jagadish. But despite the instructions from the Viceroy, the Director of Public Instructions (D.P.I) Sir Alfred Croft, who, even after fifty years of Macaulay, believed that Indians cannot be trusted to teach exact sciences and are only given to mysticism, offered him not an IES (Indian Educational Service) but a Provincial service which Jagadish promptly declined. Later on Lord Ripon, not having seen Jagadish Chandra's name in the gazette, reprimanded the D.P.I who reluctantly offered him an officiating Professorship of Physics at Presidency College, Calcutta, at a salary one third of his British equivalent.

In 1885, Bose joined Presidency College and carried out his commitment as a Professor but refused to draw any salary. This continued for three years. Jagadish Chandra was by now married to Abala Das, (a niece of the famous barrister and patriot, Chittaranjan Das), lived with his sisters by turn. The D.P.I Sir Alfred Croft and the Principal of the college Mr. C. H. Tawney realized the worth of Jagadish Chandra and raised his salary to the same level as for a British Professor. Jagadish Chandra was paid in retrospective effect. Later on Sir Alfred turned out to be one of his best well wishers.

This example illustrates the intransigence that gave him extraordinary patience in carrying out his research single-handedly, and also his pride as an Indian fighting against the naked discriminatory policy of the British. Jagadish won the fight. He teamed up with his mentor Father Lafont to help him in science popularization. Jagadish also gave lectures at the Indian Association for Cultivation of Science (IACS) set up by Dr Mahendralal Sircar in 1876. This was the time when the Bengal renaissance had brought extraordinary people from all walks of life together, in self-assertion as Indians. Several years passed and Jagadish Chandra realized that rather than spend his life as a Science teacher he would like to become a Scientist and a teacher.

It was in 1894 that Jagadish Chandra made the resolve of getting involved in scientific research. Abala Bose fully supported his resolve. Jagadish Chandra used to visit the Asiatic Society where he came across a paper written by Professor Oliver Lodge, entitled…"Heinrich Hertz and his successors". He was fascinated by the article.

Choosing an area of research is always difficult. As a matter of fact, Jagadish Chandra changed his area of research at different stages of his life. But at every stage his research was based on accurate experiments since Jagadish Chandra knew that experimental research was his forte.

According to D.M. Bose[1], his nephew and a well known physicist, the research activities of J.C. Bose extended from 1894 to 1937, the year he died, can be divided into three periods.

1) During the first period (1894–1899), he produced the shortest of then possible electromagnetic waves (the microwaves)and extensively studied their quasi-optical properties. His researches with coherers not only led to the anticipation of semi-conductors but the effect of microwaves on the coherers led to the next important phase of research.
2) The second period (1899-1904) began with his study of the fatigue effect in metallic coherers, used for detection of electric waves, from which he went over to the study of various other inorganic systems which exhibit stress under different kinds of physical stimulation. The similarities in responses of inorganic and organic systems led to his famous and controversial generalization about the responses in the living and the non-living.
3) The third period that logically followed led to his studies on Plant Electrophysiology and led to monumental investigations, which, like most of his researches, were ahead of his time. These researches lasted till the end of his life.

After reading the book of Prof. Lodge, Jagadish Chandra decided to take up experimental study of Maxwell's electromagnetic waves and their various facets and he hit the Bull's eye. This article deals with the first period of his research career.

James Clerk Maxwell

James Clerk Maxwell (1831-1879), born in an aristocratic family in Scotland, was a shy young boy whose talent in mathematics was recognized very early in his life. He joined the University of Edinburgh and was taught by scientists like Sir William Hamilton. Maxwell turned out to be an exceptional scientist who came to be classed with Galileo, Newton and Einstein. He made major contributions to subjects like Heat and Thermodynamics but his most profound contribution was his publication of "A Dynamical theory of the Electromagnetic Field." and this discovery and the researches that followed changed the world that we live in today.

Going a few centuries back in time: Static electricity and magnetism as separate entities were known for a long time, going back to Thales (BC 624 - 546) of Miletus in Ionia (present day Turkey) and possibly further back in time by the Chinese and Indians. It was known that magnets attract or repel each other and static charges attract or repel each other. But a magnet does not attract a charged body and a charged body does not attract or repel a magnet.

Alessandro Volta (1745-1827) of Italy chemically produced current electricity in the year 1800 and thereby opened a main gate of science, leading to great discoveries. The serendipitous discovery of Hans Christian Oersted (1777-1851) that electric current switched into or turned off a wire deflected a magnetic compass needle placed nearby, showed that electricity and magnetism are interlinked . His publication was followed by several discoveries of electromagnetism by Andre M. Ampere (1775-1836) of France and the major discoveries of Michael Faraday (1791-1867)of England changed the world. That magnetic field and electric current could produce rotational motion (motors), rotation of cylindrical coil in magnetic field produce electricity (generators) were shown by Michael Faraday but the way electric and magnetic fields interacted to produce waves that travelled at the speed of light was not known until Maxwell stepped in.

Maxwell unified various theories pertaining to electricity and magnetism and came to the stupendous discovery that visible light is nothing but a small section of electromagnetic waves that travel at the speed of about 310740 km per second which was remarkably close to the measured value of speed of light. He stated,

"The agreement of the results seems to show that light and magnetism are affections of the same substance and that light is an electromagnetic disturbance propagated through the field according to electromagnetic laws."

This proposition threw up many questions. Can light be produced by electromagnetic interaction? Do electric waves have the same characteristics as light waves? Can they be reflected, refracted, diffracted and polarized? How does one produce electric waves and detect them and subject them to various tests?

Heinrich Hertz, the Maxwellians, namely Oliver Lodge, G.F. Fitzgerald, Oliver Heaviside and independently Jagadish Chandra Bose were some of those pioneers to answer these questions. Maxwell died at the age of 48 before these questions were answered by experiments. Professor G.F. Fitzgerald of Dublin University had no doubts about the correctness of Maxwell's waves. He suggested the following :

"Get hold of a Leyden jar. Charge it. Discharge it into a loop of wire. The arrangement will generate very high frequency."

That may have been the lead, way back in 1882.

Heinrich Hertz (1857-1894) is believed to have been advised by his teacher Herman von Helmholtz (1821-1894) to undertake the research suggested by Fitzgerald to carry out experiments to produce electric waves and showing that they have optical properties.

Heinrich Rudolph Hertz

The initial experiment that Hertz designed was simple. He took a circuit ending with two small metal spheres, closely placed. He took another circuit with similar metal spheres which may be called a detector ring placed about 1.5m away. The first circuit was connected to an Induction coil, connected through a switch. As soon as the switch was closed, a spark appeared between the small copper spheres of the first circuit followed almost instantaneously by a spark in the detector ring physically displaced from the first. The electric discharge in the first circuit produced an electromagnetic wave which while passing through the second ring *induced a voltage* that caused a spark. Hertz systematically carried out a number of experiments, placing Maxwell's equations on a firm footing. Hertz measured the wavelength of the wave by producing stationary waves and it turned out to be about 66 cm. Hertz tested their optical properties. Hertz's publication of his paper in 1888 created a sensation. But Hertz did not live long enough to carry out all the studies he possibly had in mind and died at the age of 38 from an infection due to catarrh leading to what was diagnosed in those days as blood poisoning.

Frequency, cycles per second, was later named after Hertz and designated as Hz.

Millimeter Waves

Bose was a few months younger than Hertz and started his research in Electromagnetic waves (or Electric waves as he called them) in 1894, the same year that Hertz had to leave them abruptly owing to his early death.

Bose came across an interesting paper. The author had discussed how ships out in the open sea were helpless without any signal from the lighthouses. Light signals shone from the light houses in the coasts would be scattered as they passed through fog and be invisible and even red light, the longest visible light would not be visible[2] (*The Electrician,1891)*. If signals with electric waves having wavelength larger than infrared could be used that would possibly not be impeded by fog and reach the ships out into the ocean. Bose made up his mind to undertake research on Maxwell's waves. In his own words, he wanted to show

"That the waves had all the properties that light was known to have , and the theory of electromagnetism said that they ought to have "

Bose was fully aware that he was an experimental scientist and not a mathematical physicist (as one of his celebrated pupils S.N.Bose later turned out to be)[3]. His strength lay in planning and designing instruments to carry out experiments that would offer legitimacy to theoretical physics.

He built his laboratory, 20 ft.square, adjacent to a bathroom in his office in Presidency College. The first thing that he noted were the limitations of the experiments that had been reported by researchers in England and Europe. The electric waves that were produced got reflected on the walls and stray waves interfered with the main electric waves whose properties were being studied. The appliances required to study the usual optical properties of electrical waves were unwieldy because the waves were long. Had Hertz been alive, he would have, in all likelihood, got over these impediments. A number of scientists such as Lodge and Righi (Marconi's teacher) were trying to produce electric waves of shorter wavelengths.

It fell on Bose to realize that the wavelengths should be larger than infrared yet small enough with sufficient energy to penetrate walls rather than get reflected and he devised ingenious gadgets to guide the waves and recapture them. In his lecture delivered at Royal Institution on 29th January 1897, Bose summarized his objective of going for electrical waves of millimeter wavelength:

"For experimental investigation, it is also necessary to have a narrow pencil of radiation, and this is very difficult to obtain, unless waves of a very short wavelength are used. With large waves diverging in all directions and cutting around corners, all attempts at accurate work is futile…All these drawbacks were ultimately removed by making suitable radiators emitting very short waves."

Figure 1 is a complete millimeter wave bench that he prepared with the clear objective of radiating millimeter waves, guiding them, receiving them and detecting them. Several parts of this bench could be patented, but Jagadish Chandra's revulsion for patenting, discussed later in the paper, prevented him from doing so. The entire apparatus could be fitted into a box measuring 60 cm × 30 cm × 30 cm[4].

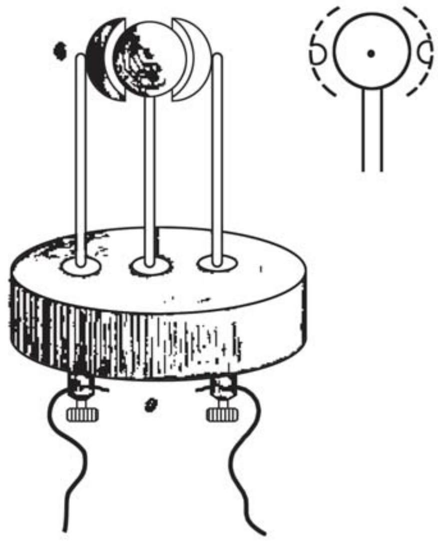


Figure 2a. Bose's radiator

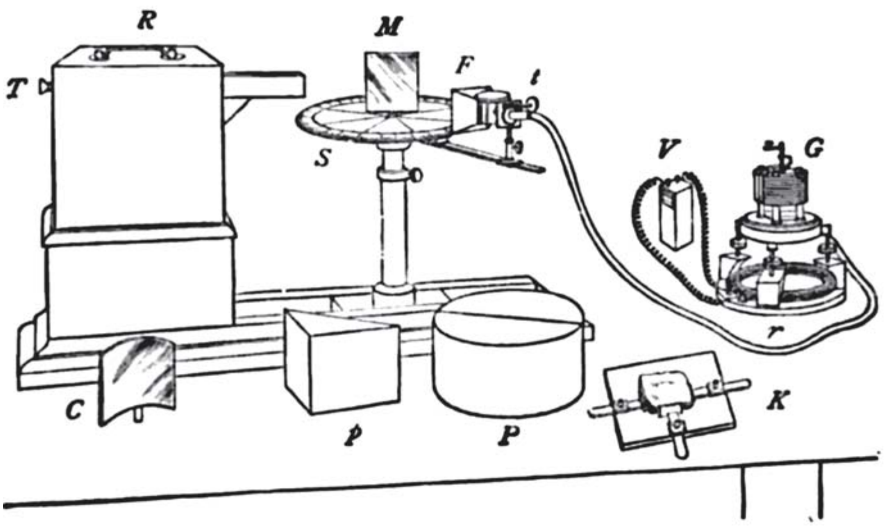


Figure 1 : The complete millimeter wave bench. L is the lens at the exit of the wave guide. F is the pyramidal collecting funnel that was the first horn antenna devised by Bose (not patented).

The Radiator

Professor Lodge had reported that he had shielded sparking points by semi-spherical covers in order to arrest spurious waves of different frequencies emanating, getting reflected all over the place. Bose made a similar radiator but smaller in size and having noticed that the sphere (shown in Figure 2) gets pitted after several sparks, covered it with platinum. The wires connected to the sparking plugs were connected to a coil specially designed by him. He placed the whole device (the radiator) inside a tin structure to avoid stray waves and used a metal tube (which formed the *waveguide* to guide the wave. The wave was then led to a truncated pyramid like structure which came to be known as the *Horn Antenna*). In order to minimize multiple reflections in the transmitter box, Bose used blotting paper soaked in some electrolyte[5,6]. Figure 2(a) shows Bose's diagram of one of his radiators for producing short (5 mm) radiation. Oscillation is produced by sparking between two hollow hemispheres and the interposed sphere. There is a bead of platinum on the inside surface of each hemisphere.

For some experiments, a lens of glass or of sulphur was used to collimate the radiation. This was the first waveguide-lens antenna. The lens was designed according to the refractive index measured by Bose at the wavelength in use. Figure 2(b) shows Bose's drawing of such a radiator; the sparks occur between the two outer spheres and the inner sphere. Bose was able to measure the wavelength of his radiation with a reflecting diffraction grating made of metal strips. That was a novelty.

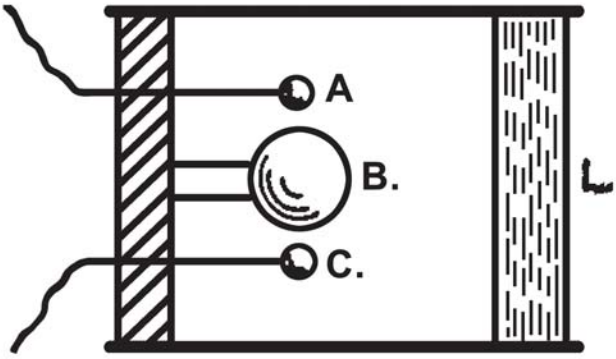


Figure 2b : (L is the Lens)

The deflection of a galvanometer helped in carrying out the experiments to verify the quasi optical properties of the electromagnetic waves. Jagadish Chandra used ingenious methods to detect polarization and other properties of light. He used devices like ringing a bell, a telephone or even firing of a cannon ball for spectacular demonstrations of remote signaling by invisible rays.

Coherer

Detection of electrical waves is as important as its production and transmission[7]. Professor Lodge modified the detection device produced by Professor Branly which Lodge called the Coherer and the name stuck. Branly's and Lodge's Coherers needed to be adjusted after every event of detection. The detector was essentially finely powdered iron filings inside a glass tube. The current caused by the electrical wave made some iron filings melt and stick together, thereby reducing the resistance and causing more current to flow. The detector needed to be reset every time by tapping. Bose made the coherer with springs in such a way that they would spring back to their original position after detecting a wave and therefore are 'self-adjusting' (Figure 3). Bose did not stay with this type of coherer. He kept working on various types of metal contacts and found that point contact on a metal or cat whiskers provided the best type of detectors[4]. He used many materials in this device. He measured and plotted the current/voltage or the I/V characteristics (Figure 4). Instead of the usual straight lines (Ohm's Law), he found two groups, one in which the current increased as the radiation was absorbed (i.e., the resistance decreased) as in iron (as in Branly's coherer), and the other where the current decreased (i.e., the resistance increased) as in potassium. The first ones he designated as positive and the second as negative. Quoting from Engineer (ref. 4), " His masterpiece, made from galena, could detect the entire EM wave spectrum lying between millimeter electric waves and violet light. He called it an "Electric eye" and patented it." and in this, one could see how close he had come to anticipating p-type and n-type semiconductors.

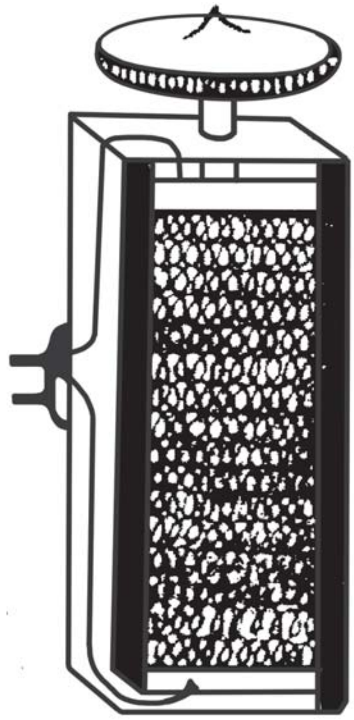


Figure 3 : Bose's spiral spring self-adjusting Coherer

Instant Recognition

Bose read his first paper before the Asiatic Society in 1895. He was invited to deliver a demonstration lecture at the Town hall of Calcutta where the Governor Sir William Mackenzie was present. Jagadish Chandra sent a signal longer than the infrared and the invisible ray penetrated blocks of wood, human body, two walls and rang a bell and fired a cannon ball 23m away. This was an amazing demonstration of remote control which held the audience spellbound. That was in 1895. So, in less than a year, Jagadish Chandra ,working alone, helped by a tinsmith, produced an instrument that generated microwaves which could travel through space and activate relays and also make a novel self- adjusting Coherer respond. *The Statesman* and *The Electrician* were full of praise for his inventions. Emphasizing particularly on the usefulness of Bose's Coherer, and taking lead from the publication by *The Electrician*, the Englishman wrote[3]:

"Should Professor Bose succeed in perfecting and patenting his "Coherer", we may in time see the system of Coast lighting throughout the navigable world revolutionized by a Bengali Scientist single-handedly in our Presidency College."

Bose's second paper, "On the index of Refraction of sulphur for the electric ray", communicated to the Royal Society for Publication by Lord Rayleigh and another paper on a unique method of measuring wavelength of electromagnetic waves, communicated by Lord Rayleigh, led to the conferment of D. Sc degree by the University of London (1896), with the rare distinction of his being exempted from further examinations. He was invited to make a presentation of his research at the Royal Society and based on strong recommendations by Sir Alfred Croft and Sir William Mackenzie. Sanction for Bose's visit to England was officially announced (on 1^{st} July 1896) as *"It has been settled that Professor Bose should proceed at once on deputation to England to be present at a meeting of the British Association."*

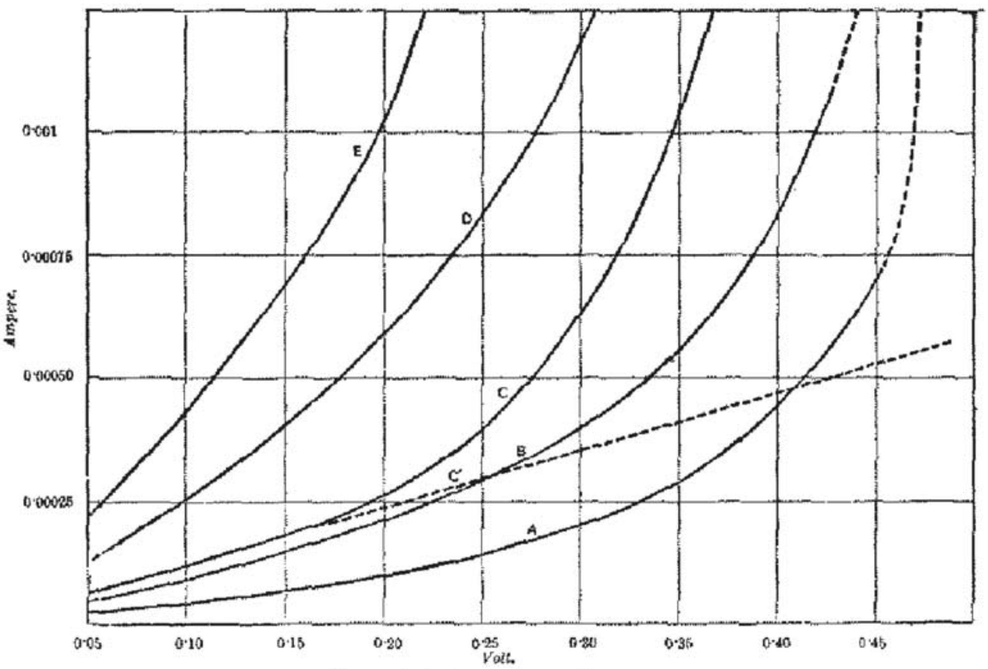
Jagadish Chandra went to England and delivered his lecture on the quasi-optical behavior of millimeter waves to an august gathering of scientists at the British Association at Liverpool on 21^{st} September, 1896. Among the eminent scientists present were Lord Kelvin, Sir Gabriel Stokes, Professors J.J. Thomson, Fitzgerald, Everett, Oliver Lodge and a few continental scientists. Bose, 38 years old, was *"a little nervous at the beginning. It has not often fallen on me to address such a critical audience. But I soon got interested in my subject and was encouraged by the kind manner with which the paper was received."*

Lord Kelvin (1824-1907), the famous Physicist, broke into a warm applause. He climbed up the gallery to meet Abala Bose and congratulated her on the brilliant performance of her husband. He did not stop there. He wrote to Lord George Hamilton, then the Secretary of State for India:

"*It would be conducive to India and the scientific education of Calcutta , if a well-equipped physical Laboratory is added to the resources of University of Calcutta in connection with the Professorship of Dr. Bose."*

The Baker Laboratory, it is believed, is the outcome of the mail from Lord Kelvin.

Nikola Tesla and Guglielmo Marconi[3]



Characteristic Curves of a Single Point Iron Receiver

A, B, C, D, E are different curves for different initial currents, C' is the curve for a constant resistance.

Figure 4 : The I/V characteristics measured by Bose for a single point Iron receiver. Note the similarity to modern semiconductor junctions with knee voltage of about 0.4 volts (Caption from reference 6).

Unknown to most in Europe , an extraordinary inventor, a Serbian American, was "playing with" remote control using electromagnetic waves around 1893. He built a boat and a handheld device which could control the speed and direction of the boat. He was Nikola Tesla (1856-1943), famous for his inventing Induction motor and introducing Alternating Current power supply. Tesla coil invented by him was widely used by scientists all over the world[5]. His work was going on in parallel to that of Bose, unknown to each other. Unlike Bose, Tesla lost no time in patenting his inventions. He had eight American patents on electrical wave transmissions, all of which preceded those of Marconi.

Guglielmo Marconi (1874-1937), a rich Italian with Aristocratic connections, had a single point agenda. It was to use electrical waves for message transmission. He had no compunction about infringing into available technology without acknowledgement. He used the Tesla coil, Tesla earthing and with the help of a friend L. Solari in the Italian Navy, had a receiver made which, it is believed, used the receiver technology of Bose which was not patented.

Marconi was a good engineer and an extraordinary marketing manager. Sending the letter 'S' (based on the Morse code) across the Atlantic brought him international fame. In response to Edison's dismissal of the claim of transmitting and receiving an electrical signal round the curved earth as "A figment of Marconi's imagination", Marconi travelled in the ship SS Philadelphia to US on February 1902 and arranged to keep receiving radio signals, noting them and getting them countersigned by the Captain. He did not waste time in throwing a huge party where he invited Graham Bell, the inventor of telephone. Marconi came to be known as the inventor of Wireless Telegraphy. Marconi's connections with the Italian Aristocracy and the British Royalty enabled him to arrange sending a message from the American president Theodore Roosevelt to King Edward VII in 1901 and make big news.

It is alleged that Marconi in his speech at the grand party with Graham Bell, did not mention Tesla or Bose or even his childhood friend L. Solari in the Italian navy. Bose never claimed that he invented the radio. His preceding Marconi by two years in wireless telegraphy is attributed to a letter that Sister Nivedita had written to Rabindranath Tagore[6].

That may have given rise to the widely held idea in India that "Marconi had cheated out on Bose in the invention of Radio". It must be admitted that it was Marconi who made "wireless telegraphy" into a viable technology which caught on.

Marconi received the Nobel Prize in the year 1909. Neither Bose nor Tesla had any share of it. Years later, in 1943, the American Supreme Court dismissed the claim of Marconi's company in US, and annulled the patent with Marconi as the inventor of Wireless Telegraphy. The long judgment was interpreted by the followers of Tesla as favouring Tesla to be the inventor of Wireless Telegraphy. There were others who disputed such an interpretation. When Bose was asked by his nephew as to who Jagadish Chandra believed was the true inventor of Radio, Jagadish Chandra replied that "*It is not the inventor but the invention that matters"*[3].

That Jagadish Chandra's role in Wireless Technology has not been duly acknowledged in the West has much to do with Bose's aversion to patenting. The following section from Dasgupta[6] is a transcript of Bose's letter to Tagore:

"A week after his lecture in the Royal Institution in May 1901, Bose wrote to Tagore that just prior to the lecture, the proprietor of a famous telegraphy company (most likely Dr. Alexander Muirhead, a D.Sc in Electricity) had sent him a cable indicating that he wanted to see Bose urgently . When they met, he pleaded with Bose not to reveal the details of his work in the lecture but rather allow him to take out a patent on Bose's behalf, so that they may share the profit."(possibly from making crystal radio)

Bose's repugnance at the overture made by the billionaire, "who to make further profit came to me like a beggar," was undisguised. "If only Tagore would witness the country's (England's) greed for money", he wrote to Tagore in disgust."What a dreadful all consuming disease it was."[3,9] It is possible that Bose believed that we Indians are superior to the Westerners at the very least in our apathy to worldly possessions.

Patric Geddes[7] described Jagadish Chandra as a *Rishi* (hermit).

Aversion to Patenting

It is also possible that Bose genuinely believed that knowledge should be available to all and should not be constrained by patenting[8,10]. Patenting, it is believed, was forbidden in the Bose Institute that Jagadish Chandra had founded. It is interesting to note in this context that Bose's recognition as a pioneer in semiconductor technology was due to his American Patent (1904), which made him first Indian to have an American Patent. Bose was almost forced by two Western ladies, Sister Nivedita and Mrs Ole Bull, to submit the patent application for his "electric eye". Mrs Bull even lent Bose the $80 necessary for this purpose. That was in 1901.

By now Jagadish Chandra had moved away from his research in microwave generation, transmission and reception. This is evident from the articles in the "History of wireless"[5] which is an exhaustive study. Out of nineteen authors only two had mentioned Bose. Out of a total of 705 references made by seventeen authors there are only two references to Jagadish Chandra except for one chapter dedicated to him written by two Bengali authors, one of them being the main compiler of this collection. Had Jagadish Chandra obtained patents or commercialized crystal radio using galena, the situation possibly would have been different.

That Bose was forgotten in the West had other reasons as well.

Long distance wireless telegraphy became the most sought after engineering achievement and it could be carried out only with long waves and not short or microwaves. The short waves penetrate the ionosphere and are not reflected, unlike long waves. That explained how Marconi's signals with long waves could negotiate the earth's curvature.

The use of and interest in millimeter waves, first invented by Jagadish Chandra, almost ended with his establishing the validity of Maxwell's equations at the millimeter wave range. The use of wireless telegraphy using long waves assumed great importance during the first world war by which time John Ambrose Fleming's Valves (diodes) had been invented and their complex versions were being widely used. Transistors were yet to come. The use of microwaves was far off.

It was around the year 1900 that Jagadish Chandra changed track. He could not continue with researches on millimeter waves or his point contact detectors that anticipated semiconductors. Quantum mechanics was unknown and possibly beyond the mathematical training of Jagadish Chandra. Fleming's discovery of electronic valves ,diodes, was a different kind of technology that could hardly be practised and developed in an ill equipped laboratory like that of Bose. The physicists of the first few decades of the twentieth century, namely Max Planck, Albert Einstein, Niels Bohr, Paul Dirac, or S.N. Bose, to name a few of the pioneers, were totally engaged in a different type of physics. Technologies that grew afterwards were very different.

Changing Track

Jagadish Chandra got engaged with a different problem altogether. The question was "Where is the boundary between the living and the non-living?" An extract from Bose's Royal Institute discourse (10th May 1901) below reflects his thoughts :

"I have shown you this evening an autographic record of the history of stress and strain in the living and the nonliving. How similar are the writings? So similar indeed that you cannot tell one apart from the other. We have seen the responsive pulse wax and wane in one as in the other. We have seen response sinking under fatigue, becoming exalted under stimulants and being killed under poison. Amongst such phenomenon, how can we draw a line of demarcation, and say here the physics ends, and there the physiological begins? Such absolute barriers do not exist. .… It was when I came upon the mute witness of these self-made records, and perceived in them one phase of a pervading unity that bears within it all things—the mote that quivers in ripples of light, the teeming life upon our earth, and the radiant Sun that shines above us –it was then that I understood for the first time a little of the message proclaimed by my ancestors on the bank of the Ganges thirty centuries ago —"They also see but one, in all the changing manifolds of the universe, unto them belongs the Eternal Truth—unto none else, unto none else!"

It was his faith in Universalism that may have made Bose to mentally bridge the gap between the living and non-living. Bose and many illustrious thinkers of his time were somewhat carried away when Bose's experimental results appeared to hold answer to the unresolved philosophical question and their faith. Bose possibly made the mistake of basing his conclusions on the fulfillment of necessary conditions of electric response only but not the sufficient conditions.[3] In the words of D.M. Bose[1],

"*Bose was not familiar with the contemporary physicochemical investigations carried out by men like Ostwald, Bredig and their school and was therefore unable to undertake a correct interpretation of these borderline investigations of his. While his Western contemporaries designated them as inorganic models of some properties of living systems, Bose with his pantheistic background saw in the similarity an evidence that the responsive process seen in life has been foreshadowed in the living."*

Bose's presentation in the Royal Society evoked mixed response. Some were ecstatic and some skeptical. Dasgupta[6] believes that this was when Bose began getting marginalized as a scientist in the Western world[8].

His researches on Plant Electrophysiology using instruments, such as the indigenously constructed Resonant Recorder, which could measure with unbelievable accuracy and amplification, revealed facts about plants that were sensational as well as controversial. These results, belatedly, are receiving attention[12,13].

There is a "resurrection" of Jagadish Chandra Bose not only in the area of plant physiology but also in Physics where he was, as just stated, virtually forgotten. Millimeter waves that had no use about one hundred years ago, have come back in a big way. Having a short wavelength (1 to 10 mm), these have high frequency and can pack a lot of information. These may be designed to have a narrow beamwidth (remember Bose's lecture at the Royal Institution on 29th January 1897, trying to get a narrow pencil of radiation). Millimeter waves interact with the atmosphere and lose energy to oxygen . These are suitable for short distance transmission (hand held mobile phones, televisions) or inter-satellite communication where oxygen is absent.

In recognition of his contributions, 'IEEE IN MILESTONE RECOGNITION' have commemorated a milestone based on the early radio experimental work by Dr.Jagadish Chandra Bose. His experiments in the early 1900's were conducted on equipment operating at 60GHz approximately at 5mm wavelength. The plaque was installed in the main building of Presidency College, Calcutta, on 15th September, 2012.

Pearson and Brattain (Brattain received the Nobel prize for inventing the transistor along with Shockley and Bardeen) in their seminal paper[11] acknowledged :

"*The demonstration of the existence of radio waves by H. Hertz in 1888 created potential demand for a suitable detector, but it was not realized until 1904 (Bose's American patent) that semiconductor rectifiers were well-suited for this purpose. J.C. Bose found that point contacts (cat whiskers) on galena, silicon carbide, tellurium, silicon etc. were good detectors of radio waves.*"

It is also on record that Sir Neville Mott, Nobel Laureate in 1977, for his contributions to solid state electronics, remarked,

"J.C. Bose was at least 60 years ahead of his time and he had anticipated the p-type and n-type semiconductors."

Bose's ability to look much ahead of his time may be explained in the words of his good friend Rabindranath Tagore :

"I found in him (Bose), a dreamer and it seemed to me, what surely was a half truth, that it was more his magical instinct than the probing of his reason which startled out secrets of nature before sudden flashes of his imagination……"

Dasgupta[6] summarizes Bose's contribution to Indian Science as

" Bose made pure science a credible occupation for Indians in the eyes of the world. In this lay his ultimate success and significance in the history of the western scientific tradition and in the social and cultural history of modern India."

The Bose Institute that Bose dedicated to the Nation (30th September 1917) one hundred years ago, has played a big role in fulfilling Bose's dream and effort to '*make pure science a credible occupation for Indians in the eyes of the world.*'

It was long before 1917 that Bose had started dreaming about the Institute. It may not be out of place to try to catch a glimpse of this long dream of his. There was an all round effort being made by some of the outstanding Indians of this period to set up academic Institutions.

To name a few, one remembers the Indian Association for the Cultivation of Science set up by Dr Mahendralal Sircar in 1876. This was set up in Bowbazar on a piece of land gifted by the Government and Rs 50,000 that Mahendralal had collected. It was here that C.V. Raman carried out his research that received the Nobel prize.

A few years later, in 1893, when J.N. Tata met Swami Vivekananda on his way to Chicago, the Indian Institute of Science was conceived which was eventually set up in the year 1909, after both these visionaries had passed away.

Sir Asutosh Mookerjee, as the Vice Chancellor of Calcutta University, dreamt of imparting post graduate education and with huge donations from Taraknath Palit and Rashbehary Ghose, he set up the Science College next to the Bose Institute, in 1916, next to which the Bose Institute came up a year later. He appointed the young S.N. Bose and Meghnad Saha as lecturers and both turned out to be world renowned scientists. C.V. Raman joined as the Palit professor .

When Bose, as a young scientist, lectured in the Royal Society, his dream began to sprout. He dreamt of having an Institute which would be a centre of learning while Tagore, around the same time, was dreaming of Visva Bharati that emerged from the Ashram that he were to set up.

What all these dreamers faced was the need to procure funds to set up and run these Institutions. Bose contributed his life's savings of Rs 4,00,000/-and prevailed on the Government to contribute towards the cost of the building and an annual grant which was sanctioned with quite a bit of reluctance on the part of some members of the administration[3].

In the "Voice of Life", Jagadish Chandra's inaugural address (on 30th Novemer 1917), he began his speech with the following statement:

I dedicate today this Institute –not merely a Laboratory, but a Temple…Out of the very imperfection *of the senses, man has built a raft of thought by which he makes daring adventures on the great seas of the unknown….The personal yet general, truth and faith whose establishment this institute commemorates is this: that when one dedicates himself wholly for a great object, the closed doors open, and the seemingly impossible will become possible for him."*

Professor D.M. Bose took over as the Director after J.C. Bose and served Bose Institute from 1938 till 1967. He made significant discoveries in Cosmic rays, artificial radioactivity and neutron physics. Others followed and have helped fulfill much of Bose's dreams in various fields of scientific research with relentless efforts of competent scientists and students of this Institution.

In its re-birth, Bose's brain child the Bose Institute, we are confident, will go from higher to higher success.

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