Jagadish Chandra Bose
The Physicist who was forgotten

Dr. D. P. Sen Gupta
Retd. Professor, Indian Institute of Science, Bangalore

This paper touches upon the life of the great Polymath, Acharya Jagadish Chandra Bose, his upbringing, his academic achievements, his researches with emphasis on his wireless transmission of millimeter waves that were far ahead of his time and hence went unrecognized for decades, his invention of diode which would not have been recognized had it not been for a patent that he was forced to apply for and was granted. With radical changes in communication technology, he is recognized as the forerunner of smart phones widely used today.

Jagadish Chandra Bose, grew up on the shoulders of a dacoit. His father Bhagavan Chandra Basu was a Deputy Magistrate and he appointed a dacoit who on being released from the jail came to Bhagawan Chandra for a job. Bhagawan Chandra appointed him as a servant to take care of his four-year-old son Jagadish. Bhagavan Chandra set up a primary school for children of washer men, sweepers and other low earning people of the town and sent Jagadish to the same school. After completing high school education away from home, he went to St. Xavier's College in Calcutta where he came under the influence of Father Lafont. After 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 to continue the study of medicine and joined Christ's College, Cambridge, in 1881 under the tutorship of Lord Rayleigh, who was a polymath. Rayleigh got 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.

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 (1881-1885) 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 ned to offer a Professor's position to Jagadish Chandra but was compelled to offer him one after much hassle, described in reference (1)

Jagadish teamed up with his mentor Father Lafont and helped him in science popularization. Jagadish Chandra 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 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 the year of 1894 that Jagadish Chandra made the resolve of getting involved in research. Abala Bose, his wife, 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 extending from 1894 to 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) *During the second period, extending from 1899 to 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 from the second phase led to his studies of 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.*

Jagadish Chandra after reading the book of Prof. Lodge decided to take up experimental study of Maxwell's electromagnetic waves and their validity for different frequencies and wave lengths. He chose frequencies just beyond infrared and was the first person to produce and wirelessly transmit millimeter waves. today.

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.

Maxwell 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) was 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.

Bose came across an interesting paper. The author had discussed how the ships out into the open sea were helpless without any signals 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 sft in area, 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 the 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 to be studied. The appliances required to study the usual optical properties of electrical waves were unwieldy because the waves were long.

It fell on Bose to realize that the wavelengths should be larger than infrared yet small enough with enough energy to penetrate walls rather than get reflected and he devised ingenious gadgets to guide the waves and recapture them. The 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."

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 60cmx30cmx30cm.

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 firing a cannon ball for spectacular demonstrations of remote signalling by invisible rays.

Coherer

Detection of electrical waves is as important as producing and transmitting it (5). Professor Lodge modified the detection device produced by Professor Branly which Lodge called the Coherer and the name stuck. Bose used various types of metal contacts and came to find 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. 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 e.g. 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 (ref4) "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.

Instant recognition

Bose published his first paper in 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 the year 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 Jagadish Bose's 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 a second 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.

Jagadish Chandra was invited to make a presentation of his research at the Royal Society and based on strong recommendations of Sir Alfred Croft and Sir William Mackenzie, sanction for Bose's visit to England was officially announced, (on 1st July 1896)

"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 21st 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, 38years 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)
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. 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 transmission 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 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 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 a 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 telephones. Marconi came to be known as the inventor of Wireless Telegraphy. Marconi's connections with Italian Aristocracy and 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 has to 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 transcription 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)

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 may also be possible that Bose genuinely believed that knowledge should be available to all and should not be constrained by patenting (8). 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), the first Indian to have an American Patent. Bose was almost forced by two Western ladies,

one was Sister Nivedita and the other Mrs Ole Bull to make the Patent application, for his "electric eye". Mrs Bull lent Bose the $80 necessary for submitting the patent application. That was in the year 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 got 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 as long waves are. 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 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 practiced and developed in an ill-equipped laboratory of Bose. The physicists of the first few decades of the twentieth century, namely Max Planck, Albert Einstein, Niels Bohr, Paul Dirac, 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 observations:

"I have shown you this evening an autographic record of the history of stress and strain in the living and the non-living. 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 mentally bridge the gap between the living and non-living. Bose and many illustrious thinkers of his time who 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 fulfilment of necessary conditions of electric response only but not sufficient conditions. (3)

To quote 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 and Dasgupta (6) believes, that this was when Bose began to be marginalized as a scientist in the Western world."

His researches on Plant electrophysiology using instruments, such as the Resonant Recorder, that he got made with unbelievable accuracy and amplification revealed facts about plants that were sensational and controversial. These are, belatedly, receiving attention. (10)

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 from now, have come back in a big way. Having a short wave length (1 to 10 mm) these have high frequency and can pack a lot of information. These may be designed to have a narrow beam width. (remember Bose's lecture at the Royal Institution. 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 was 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 Transistor along with Shockley and Bardeen) in their seminal paper (ref 11) acknowledged:

"*The demonstration of the existence of radio waves by 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……."

References

1) D.M. Bose, *Introduction to the J.C. Bose Memorial Volume of the Transactions of the Bose Research Institute (1951)*
2) Bhattacharya and Engineer: *"A collection (*Bose Institute 1995)
3) D.P. Sen Gupta, "*Jagadish Chandra Bose: The man and His Time:" in "Remembering Sir J.C. Bose,* IISc Press- World Scientific, 2009
4) M.H. Engineer, *The Millimeter Wave Researches of J.C. Bose, in Remembering Sir J.C. Bose,* IISC Press –World Scientific in *Remembering Sir J.C. Bose*
5) Tapan K. Sarkar et.al (Eds) History *of Wireless.* A. John Wiley and Sons Inc. Publication, 2006
6) S. Dasgupta, Jagadish *Chandra Bose and the Indian Response to Western Science*. (Oxford University Press 1999). IISc Press-World Scientific Publication 2009.
7) P. Geddes, *The Life and Work of Sir Jagdish Chandra Bose*. Orient Longman, Green and Co. 1920
8) K. Rajesh, "*J.C. Bose: The Inventor who would not patent.* Science Reporter. NISCOM 2000
9)J.C. Bose, *Patraboli (Letters of J.C. Bose) ed.* D. Sen (Basu Vigyan Mandir, 1994.
10) Virginia A Shepherd: *Reflections on the Many-in-One: J.C. Bose and the Roots. Of Plant Neurobiology: in Remembering Sir J.C. Bose,* IISc Press-World Scientific Publication 2009
11) G.L. Pearson and W. Brattain, *Proc. IRE 43 (1955) 1794-1806*
12) D.T. Emerson, *"The Work of Jagadish Chandra Bose:100 years of Millimetre wave Research,* http://www.tuc.nrao.edu
13) Daniel T. Emerson: "*Jagadish Chandra Bose's Millimeter wave Research in the Nineteenth Century"* National Radio Astronomy Observatory.demerson@nrao.edu

Acknowledgements

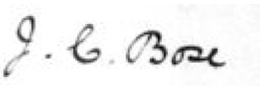
The author gratefully acknowledges help and encouragement from Professor Sibaji Raha of Bose Institute and to Professor Soumitra Sen Gupta (IACS, Kolkata), Professor Arnab Raichaudhuri (IISc, Bangalore) and Professor Kundan Sengupta (IISER, Pune) for reading through the manuscript and making useful comments.

About the author

Dr. D P Sengupta An honours graduate in Physics from Calcutta Presidency College and in Electrical Engineering from IIT Kharagpur, Dr. Sen Gupta took his Ph.D from Liverpool University. He carried out teaching and research for about three decades at the Indian Institute of Science (IISc), Bangalore. He received awards for teaching excellence at both Liverpool University and IISc where he was awarded a special chair for Energy Studies. He was an AICTE Emeritus Fellow at the IISc as well as a Visiting Professor at the National Institute of Advanced Studies, Bangalore. He has co-authored several books including "Remembering Sir J C Bose", which was published by IISc Press and World Scientific Publishing Company. Among many others, he won Prof. S.N.Bose award from Government of West Bengal.

Born	30 November 1858 Mymensingh, Bengal Presidency, British India (now in Bangladesh)
Died	23 November 1937 (aged 78) Giridih, Bengal Presidency, British India (now Giridih, Jharkhand, India)
Residence	Kolkata, Bengal Presidency, British India
Citizenship	British Indian
Alma mater	Hare school St. Xavier's College, Calcutta Christ's College, Cambridge University College, London[1]
Known for	Millimetre waves Radio Crescograph Contributions to plant biology
Spouse(s)	Abala Bose
Awards	Companion of the Order of the Indian Empire (CIE) (1903) Companion of the Order of the Star of India (CSI) (1911) Knight Bachelor (1917)
	Scientific career
Fields	Physics, biophysics, biology, botany, archaeology, Bengali literature, Bengali science fiction
Institutions	University of Calcutta University of Cambridge University of London
Academic advisors	John Strutt (Rayleigh)
Notable students	Satyendra Nath Bose Meghnad Saha Prasanta Chandra Mahalanobis Sisir Kumar Mitra Debendra Mohan Bose

Signature



Source and Courtesy: ***https://en.wikipedia.org/wiki/Jagadish_Chandra_Bose***