Replica of
Sir J C Bose mm Wave Experiment

Challenges and outcome of the project

Muffakham Jah College of Engineering and Technology

Working replica of
Sir J C Bose mm Wave Experiment

SULTAN-UL-ULOOM EDUCATION SOCIETY
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23 JAN 2019

Muffakham Jah College of Engineering and Technology

Project Implementation committee of
Sir J.C. Bose millimeter wave experiment replica

22 January 2019

With reference to the consultancy project offered by IEEE Bangalore office for an amount of Rs. 3.01 lakhs for fabrication of J.C. Bose millimeter wave experiment replica, the following working committee has been formed for implementation and deployment of the project. The committee is advised to conduct a preliminary analysis and report back on the expected time required to execute the project.

Project Leader

1. Prof. Mohammed Arifuddin Sohel
   Professor and Head, ECE department

Project Members

1. Dr. Shaik Kareem Ahmed
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   Asst. Professor, ECE department

Noted

Advisor-cum-Director

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1. INTRODUCTION

Sir Jagadish Chandra Bose one of the fathers of Radio Physics, demonstrated in Calcutta, India, the generation, transmission and reception of electromagnetic waves. In 1895, Jagadish Chandra Bose first demonstrated in Presidency College, Calcutta, India, transmission and reception of electromagnetic waves at 60 GHz, over 23 meters distance, through two intervening walls by remotely ringing a bell and detonating some gunpowder. For his communication system, Bose pioneered in development of entire millimeter-wave components like a spark transmitter, coherer, dielectric lens, polarizer, horn antenna, and cylindrical diffraction grating. This is the first millimeter-wave communication system in the world, developed more than 100 years ago. This is the oldest Milestone achievement from the Asian continent.

For his communication system, Bose pioneered development of a host of millimeter-wave components that included a spark transmitter, coherer, dielectric lens, polarizer, horn antenna, and cylindrical diffraction grating. Bose chose quasi-optical, millimeter-wave frequency range.The wavelengths he used ranged from 2.5 cm to 5 mm. The reason for the choice of millimeter wave by Sir J.C. Bose was primarily due to the advantage of studies of quasi-optical properties of the radio waves within his laboratory of limited size that was available to him at the Presidency College . However, the components and systems developed by Sir J.C. Bose, initially at millimeter wave and subsequently at microwave, were outstanding discoveries made more than 100 years ago, in Calcutta, India, most of which are now being used, in a modernized form for Earth/space links and remote sensing and 5G communication

Sir J. C. Bose invented the Mercury Coherer (together with the telephone receiver) used by Marconi to receive the radio signal in his first transatlantic radio communication over a distance of 2000 miles from Poldhu, UK to New found land, St. Johns in December 1901.In 1895, Sir J. C. Bose gave his first public demonstration of electromagnetic waves, using them to ring a bell remotely and to explode some gunpowder. He sent an electromagnetic wave across 75 feet passing through walls and body of the Chairman, Lieutenant Governor of Bengal.Sir J. C. Bose holds the first patent worldwide to invent a solid-state diode detector to detect EM waves. The detector was built using a galena crystal. Have a look at Bose's patent and wait for an interesting article on the same soon.Sir J. C. Bose was a pioneer in the field of microwave devices. His contribution remains distinguished in the field and was acknowledged by the likes of Lord Kelvin, Lord Rayleigh, etc..

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: “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.' IEEE India Info. Vol. 14 No. 2 Apr - Jun 2019 Page 50 The Baker Laboratory, it is believed, is the outcome of the mail from Lord Kelvin.

Nikola Tesla and Guglielmo Marconi

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. .

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” 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 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.” 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 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, IEEE India Info. Vol. 14 No. 2 Apr - Jun 2019 Page 51 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.

The institute of Electrical and electronics Engineering (IEEE) a professional body with members from 160 countries, wants to pay the homage and establish the fact of invention of Sir J.C. Bose. In 1986 IEEE forum has recognized Sir J.C Bose mm wave experiment as a millstone experiment. In November 2012 IEEE approached Muffakham Jah College of engineering and technology (MJCET) for making the first working model of Sir J.C Bose mm wave experiment. In this paper we present the detail construction, design and working of Sir J.C Bose mm wave experiment working Replica designed by Muffakham Jah College of engineering and technology.

2. DESIGN AND CONSTRUCTION OF WORKING REPLICA

Bose's experiments were carried out at Presidency College, although for demonstrations he developed a compact portable version of the equipment, including transmitter, receiver, and various microwave components. Some of his original equipment still exists, currently at the Bose Institute. In 1985, the author was permitted by the Bose Institute to examine and photograph some of this original apparatus . Figure 1. Shows the sir J.C Bose original mm wave setup and MJCET designed working replica. The working replica was planned, designed and executed in the physic lab, MJCET. The detail construction and working of replica as follows.

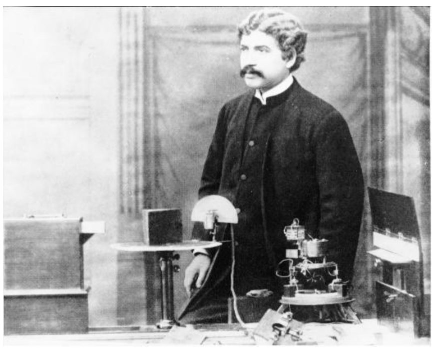


Figure 1. Original J.C Bose apparatus and MJCET designed working Replica

2.1 The Radiator

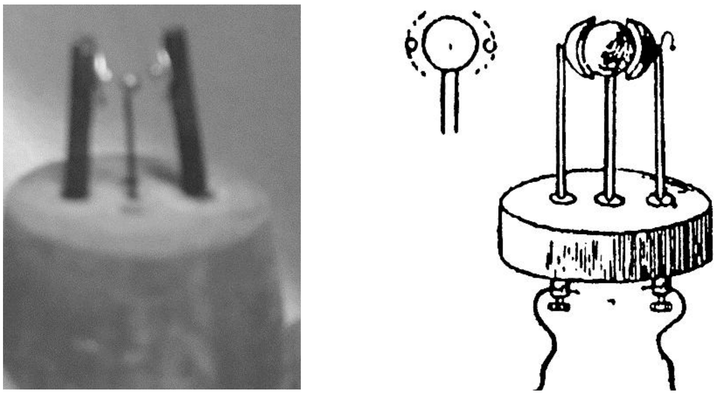


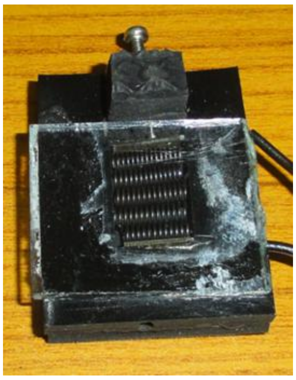
Figure 2. Sparking element of the Replica andOriginal Sparking element

In the working Replica the radiator consist of sparking element consist of DC power supply of 12V, 6Amps is connected across the primary of the coil, magnetic disturbances aerated by applying the key which results in emission of flash of radiations form the secondary coil. The sparking elements consist of two spherical beads of 0.5mm diameter and one interposed sphere situated at the center of the tow beads pf 1.5mm diameter. Figure 2 shows the sir. J. C Bose sparking element and MJCET designed sparking element. The working of the sparking element as follows.

- The wires of the primary coil are in connection with a small storage cell through a tapping key.The coil, a small storage cell and the key are enclosed in a tinned iron box which screens the space outside from magnetic disturbance.
- Each time the key is pressed, the primary circuit of induction coil is made or broken and magnetic disturbance is produced. Therefore pressing and releasing of key ensures flash of radiations.In front of the box the radiator tube (square or cylindrical). The radiating apparatus has a square tube of 1 sq. inch. cross section.

2.2 Spiral Spring receiver

Single layer of steel springs 2 mm diameter and 1 cm length placed in square piece of Ebonite with a shallow rectangular depression (Sensitive surface = 1x2 cm).Glass slide is used to prevent springs falling out. Springs can be compressed by brass piece which slides in and out using screw therefore the resistance can be varied. When radiation absorbed by sensitive contacts, there was sudden decrease in resistance and galvanometer was deflected. It responds (sensitive) to different types of radiations by varying the electromotive force which give rise to current that reaches receiver. Figure 3 shows the design of spiral spring receiver of Sir J.C Bose and working replica.



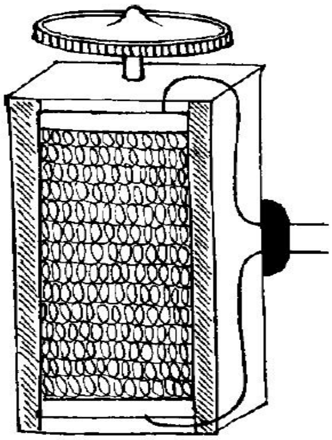


Figure 3 Spiral spring receiver of working replica and Original Sir J.C Bose receiver

2.3 Determination of Wavelength of and Cylindrical Grating

The grating made of equi- distant metallic strips, which are vertical and parallel. The diameter of the cylindrical grating is 100 cm A piece of thin sheet ebonite is bent in the shape of a portion of a cylinder and kept in that shape by screwing against upper and lower circular guide pieces of wood. Against the concave side of the ebonite are stuck strips of rather thick tinfoil at equal intervals. Figure 4 shows the design of cylindrical grating of working Replica. The diffracted waves follow the equation.

$$(a+b) \sin \theta = n \lambda$$

Where, (a+b) is sum of breadths of strip and space in the grating. (6mm)

θ is angle of diffraction

n is order of diffraction

λ is wavelength

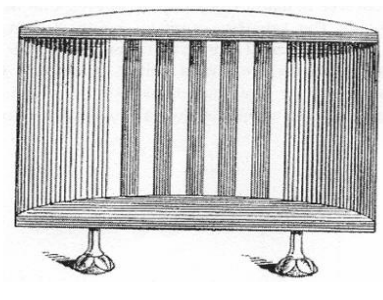


Figure 4 Design of Original cylindrical grating and working Replica

The measurement of the frequency of mm waves produced by our experimental setup has been recorded with spectrum analyzer at Research Center Imarat DRDO. Hyderabad and frequency of the Replica was around 60 GHz. This frequency is similar to what Sir J.C Bose had generated in his experiment. This is an achievement for the developers of the replica to attain same frequency as the original. Figure 5 shows the recording frequency spectra of working replica

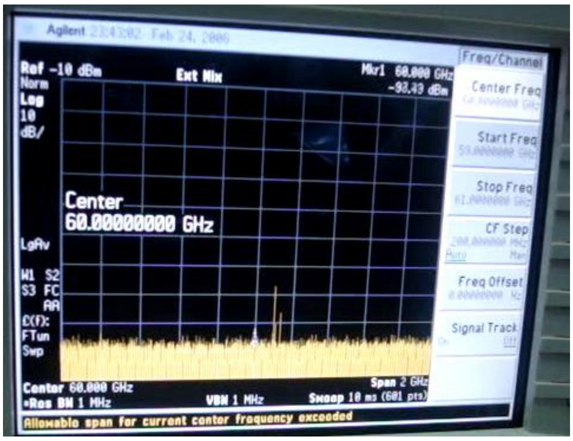


Figure 5 Photograph of 60GHz frequency generated by working replica

3. QUALITY TEST

The quality test of receiver was conducted at physics laboratory MJCET for 50 times of pressing radiator key. For each time key pressing we recorded galvanometer reading. The report of quality test is given in figure 6 and it was found that Replica receiver absorb maximum times of radiation.

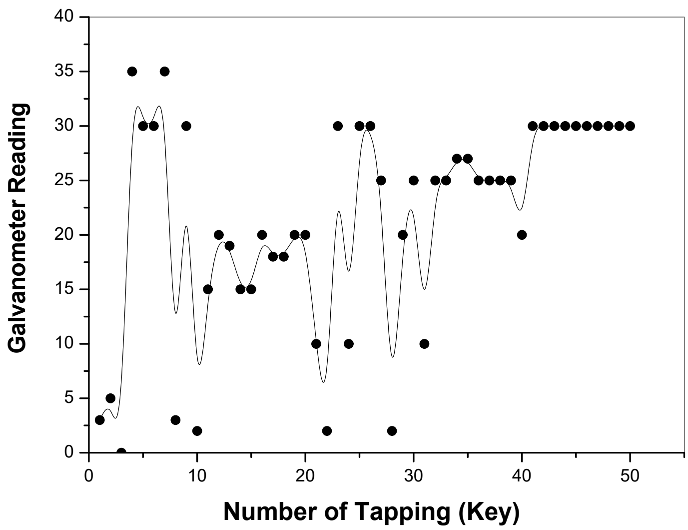


Figure 5 Variation of Galvanometer deflections with number of tapping

4. OUTCOMES

The following OUTCOMES were drawn from the present experiment

- MJCET successfully designed and demonstrated working replica of Sir J.C Bose 60 GHz experiment
- The sparking elements consists of two spherical beads of 0.5mm diameter and one interposed sphere situated at the center of the tow beads pf 1.5mm diameter
- The spiral spring receiver designed with Single layer of steel springs 2 mm diameter and 1 cm length placed in square piece of Ebonite with a shallow rectangular depression (Sensitive surface = 1x2 cm). The quality test confirms the accurate signal detection of spiral spring receiver.
- The frequency of the Replica was measured and it is around 60 GHz. This frequency is similar to what Sir J.C Bose had generated in his experiment. This is an achievement for the developers of the replica to attain same frequency as the original

5. ACKNOWLEDGEMENT

MJCET would like to thank IEEE, India for providing funding of this project. MJCET also thank *Dr. Gopala Krishna Kuppa*, Chair, India Work Group IEEE for valuable inputs which were incorporated to make it better and give accurate signal detection. We wish to thank *Dr. Janhagirdar*, RCI, Hyderabad for providing spectrum analyzer. The authors also like to thank *Dr. Basheer Ahmed*, Advisor cum Director MJCET for encouragement and support.

Special Section on
Sir J.C. Bose 160th Anniversary Celebration Presentations

1858-1937

Sir J.C. Bose 160th Anniversary Celebration on 17th Feb 2019 at Bangalore