SIR J.C. BOSE AND RADIO SCIENCE

A.K. Sen
Institute of Radio Physics and Electronics
Calcutta University
92, Acharya Prafulla Chandra Road
Calcutta 700 009, India

ABSTRACT

Sir J.C. Bose's pioneering works in quasi-optic millimeter wave research in Calcutta, India about 100 years back during 1890s are highlighted. He developed an elegant millimeterwave spark transmitter, self recovering coherer detector, wire grid polariser, cylindrical diffraction grating, dielectric lens and prism, rectangular waveguide, horn antenna and microwave absorber, for the studies of reflection, refraction, absorption and polarisation of millimeterwaves and its application to wireless remote control for firing a gun. All these pioneering activities indicate that he was well ahead of his time and prompted us to call him the father of Radio Science.

INTRODUCTION

The foundation stone of Radio Science was laid nearly one and half century back in 1858 when James Clark Maxwell predicted mathematically the existence of electromagnetic waves. Unfortunately, he did not live long to see his prediction verified experimentally by another Bristish Physicist, Oliver Lodge, who demonstrated the existence of the waves transmitted along wires, in 1887 eight years after the demise of Maxwell. In 1888 Henrich Hertz, a German Physicist successfully demonstrated the existence of electromagnetic waves at 60 cm wavelength propagating along free space. The work of Hertz and some of his successors inspired J. C. Bose, who started the experiments in a remarkable and novel manner by reducing the wavelength to millimeterwaves, down to 5 mm, while earlier as well as subsequent investigators worked with longer waves in the decimeter and centemeter regions. Bose, infact, had chosen the millimeterwaves to ensure a very sharp radio beam which he felt essential for studying the quasi-optical properties of millimeterwaves.

BOSE'S PIONEERING WORKS IN RADIO SCIENCE

The pioneering works of Sir J. C. Bose, F.R.S., includes the following developments :

1. Spark transmitters generating polarised sharp beam radiowaves at Millimeterwave length.
2. Sensitive spiral spring coherer for millimeterwaves.
3. Galena detector for millimeterwaves, infrared and optical waves.
4. Dielectric lens for millimeterwaves.
5. Wire grid polariser for millimeterwaves.
6. Cylindrical diffraction grating for millimeterwaves
7. Horn antenna.

Using these instruments Bose worked on the following :

(a) Wirless radio remote control at millimeterwaves,
(b) Measurement of refractive index of dielectric materials,
(c) Measurement of wavelength of millimeterwaves by cylindrical grating.
(d) Polarisation study by wire grid polariser.
(e) Total reflection in prism-pair with air space.
(f) Selective absorption in materials

BOSE'S MILLIMETERWAVE SPARK TRANSMITTER

Sir J. C. Bose developed his millimeterwave spark transmitter using unique hemispherical metallic cups as shields for the stray radiations from the spark, in unwanted directions, with a matallic ball in between the cups as shown in Fig. 1. If we look into Bose's spark transmitter with current knowledge in Radio

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Science, it would appear that Bose's metallic cups with the ball constituted an `open resonator ` of high Q, producing coherent radiation at the resonant frequency of the resonator. Bose, infact, found the sparks to be silent without the usual crakling sound. This, perhaps, imply that the current was not spiky but sinusoidal, producing a coherent radiation at millimeterwaves.

BOSE'S SPIRAL SPRING COHERER

Bose developed a highly sensitive spiral spring coherer with numerous point-contacts in series as shown in Fig. 2, with a voltaic cell to bias the coherer and a dead-beat galvanometer for detecting the current in the coherer, during reception of millimeterwaves. Unlike the-then prevailing metal filling coherer, in the Bose's spiral spring coherer, the loss of sensitivity due to `fatigue' of the coherer, after long continued radiation, could be restored by slightly adjusting the bias voltage. Bose's spiral spring coherer, perhaps, functioned as a Metal-Semiconductor-Metal (MSM) detector, with a fine rusting layer on the spring acting as the semiconductor. Bose worked extensively on the mechanism of `fatigue` in the coherer with a view to controlling the fatigue and found that the `fatigue` is primarily due to allotropic changes in the material of the coherer near the contact produced by the impact of incident millimeterwaves.

BOSE'S GALENA DETECTOR

Bose's search for a satisfactory self-recovering detector prompted him to develope a Galena (PbS) detector which is a highly effective self recovering detector, sensitive to millimeterwaves as a well as to infrared and visible radiation, as shown in Fig. 3. It appears that Bose's Galena detector worked as a point contact Galena detector for millimeterwaves, while at infrared and millimeterwaves it acted as a potoconducting detector.

BOSE'S DIELECTRIC LENS

Bose developed hemispherical sulphur dielectric lens-pairs with the plane surfaces face-to-face separated by a thin metallic plate, having a hole at the centre, for passing millimeterwaves through it. The lens-pair was used to measure the refractive index of sulphur at millimeterwaves with a set up as shown in Fig. 4. In recent years, dielectric lens for millimeterwaves are being developed using low loss synthetic dielectric materials for development of quasi-optic systems for millimeterwaves like horn lens and focal plane array.

BOSE'S PRISM-PAIR WITH VARIABLE AIR-SPACE

A pair of prisms with their broad surfaces kept face-to-face with variable air space was used by Bose to study how the total reflection in a prism depends on its nearness to the other prism of the pair. When the air-space is nil, the prism pair forms a cube and it then passes through the millimeterwaves and continue to do so till the air-space exceeds a critical value after which transmission is reduced and replaced by total reflection. Thus the prism pair with variable air-space may be used as very good variable attenuator of millimeterwaves.

BOSE'S WIRE GRID POLARISER

Wire grid polariser for millimeterwaves was first developed by Bose, as shown in Fig. 5, by suitably scaling down the size of the wire grids as well as their spacings used at much longer wavelengths by Hertz. If the electric field is parallel to the wires of the grid, the wave is reflected back, while for electric field perpendicular to the grid wire the wave is transmitted through the grid. Commercial wire grid polarisers, working on the principle of Bose's wire grid polarizer, are now available in the millimeterwave and submillimeterwave bands, in the frequency range 200-2200 GHz.

BOSE'S CYLINDRICAL DIFFRACTION GRATING

Bose suceeded in measuring the wavelength of millimeterwaves by using cylindrical diffraction grating developed by himself, as shown in Fig. 6 Rowland's method of using the cylinderical grating for obtaining diffraction of light spectra was, in fact, found by Bose to be applicable to the production of spectra of millimeter wave radiation. The cylindrical grating of Bose may be used as an antenna of high angular resolution in radiotelescopes at millimeterwaves and submillimeterwaves.

BOSE'S HORN ANTENNA

Bose developed the World's first horn antenna, which is now widely employed as a feed to parabolic antenna at microwaves and millimeterwaves. He, in fact, developed the horn antenna to have greater collecting area of the detector system in his polarisation appartus as shown in Fig. 7. In the apparatus a rectangular waveguide developed by Bose is also seen to be used on the receiving side on the left side of Fig. 7.

DIPLEXER FOR MILLIMETERWAVE RADIOTELESCOPE FRONT ENDS BASED ON BOSE'S DIELECTRIC LENS HORN AND WIRE GRID POLARIZER

The concept of Bose's quasi-optic components like the dielectric lens wire grid polarizer and horn antenna at millimeterwaves are now being used for the development of broadband diplexer at millimeterwaves and submillimeterwaves and used in receiver front ends for radiotelescopes to combine efficiently the signal and local oscillator signals in the mixer unit.

BOSE'S MILLIMETERWAVE LINK FOR REMOTE CONTROL

Bose developed the World's first wireless communication link at a millimeterwavelength of 5 mm, using his spark transmitter and spiral spring coherer, as shown in Fig. 8, while a photograph of his historic millimeterwave link being displayed by himself at the Royal Institute in 1897 is shown in Fig. 9. Recently, modernised versions of such millimeter wave links at 26-40 GHz ,53 GHz, 60 GHz, 80 GHz and 110-140 GHz are being widely employed, in recent years, for ISDN, Computer Communication for Local Area Networks (LAN) at 60 GHz, Covert communication at 38 GHz and 60 GHz, Intersatellite communication at 60 GHz for Global information system, Personal communication Network (PCN) for hub to cell link at 38 GHz , Multipoint Video Distribution Services (MVDS) at 40 GHz, High Definition TV (HDTV) Broadcasting by satellite links at 35 GHz and Millitary Communication Networks (MCN) at 20/44 GHz. Besides these, millimeterwave links are also being used for Communication networking in built-up cities with roof-top links at 40-100 GHz and also at 27 GHz.

BOSE'S ABSORBER FOR MICROWAVE AND MILLIMETERWAVES

Bose used his millimeterwave link instrument to study the absorption and transmission of the electromagnetic waves in various substances. He used a piece of brick or a block of pitch to be very transparent at millimeterwaves but opaque to optical waves while a thick stratum of water is quite opaque to millimeterwaves although it is transparent to optical waves. Thus the absorption in materials is selective with respect to wavelength, and, therefore, Bose referred to the materials as `coloured materials`.

CONCLUSION

From the wide variety of quasi-optic components, subsystems and systems at millimeterwaves developed by Sir J. C. Bose, F.R.S., at Calcutta, India, it appears, that `he was well ahead of his time'. Also the break through in communication by `wireless` made by Bose prompted us to call him the father of Radio Science. Infact, Sir J.C. Bose's works cover most of the Commissions of URSI like Commissions A, B, C, D, E and F. Even his subsequent works in Life Science also covered a new Commission K of URSI on the Biological effects of electromagnetic waves. Many of his instruments and experiments, however, need further research with modern instrumentation and measuring equipments to probe deeper into his work and obtain fruitful new results and techniques at millimeterwaves. For the purpose, our millimeterwave group at the Institute of Radiophysics and Electronics, University of Calcutta, in collaboration with the Bose's Museum at the Bose Institute, has planned to undertake a programme to study of Sir J. C. Bose's works at quasi-optic millimeterwaves. It is still a mystry, how Sir J.C. Bose could conceive of such a large number of pioneering experiments, which he performed successfully in an age when there was no knowledge of solid state physics, no computers to work out the difficult electromagnetic boundary value problems involved in the design of the components and systems and there was no sophisticated measuring instrument for microwaves and millimeterwaves. It appears that Sir J.C. Bose was, perhaps, driven by his strong physical concepts, deep intuitions and strong determination to succeed. He was, however, not interested in patenting his pioneering millimeterwave instruments, as he considered that the scientific developments and knowledge should be kept open for all.

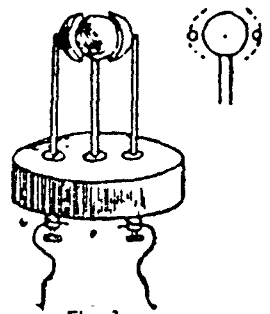


Fig.1
J. C. Bose's Spark transmitter

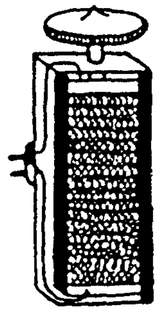


Fig.2
spiral spring detector

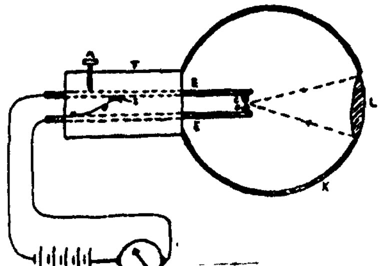
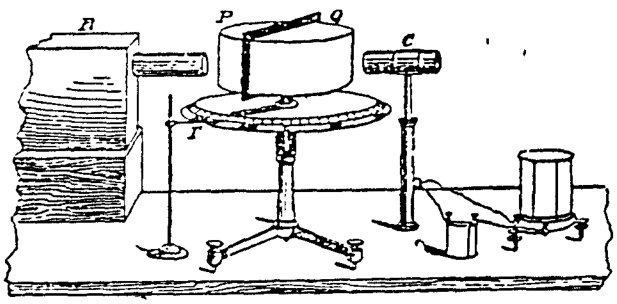


Fig.3
Bose's Galena detector used as a "Universal Radiometer" of "Tejometer"



—ELECTRIC REFRACTOMETER
R, THE RADIATOR C, THE RECEIVER.

Fig.4
Focal points of Bose's hemispherical dielectric lens pair

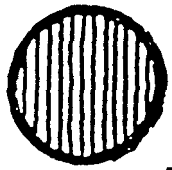


Fig.5
wire grid poloriser

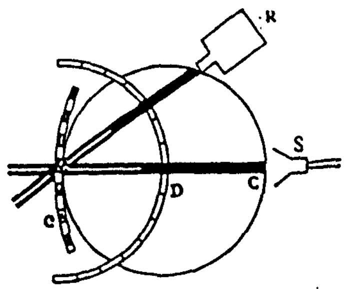


Fig.6
Bose's cylindrical grating showing transmitter and receiver positions along focal curve

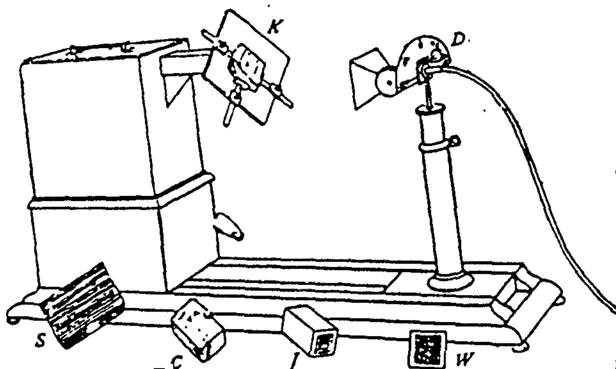


Fig.7 Bose's polarisation appratus
(K, the Crystal Holder S, a piece of Stratified Rock C, a Crystal J, the Jute Polariser W, the Wire Grating Polariser D, the Vertical Graduated Disc by which the Rotation is measured)

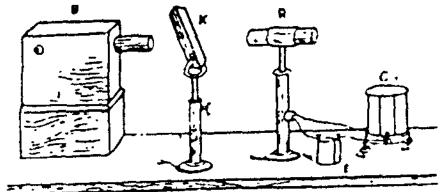


Fig.8 Bose's millimeter wave link for remote control

B, Metallic box enclosing the Ruhmkorff coil and Radiator
K, The crystal to be examined E, Voltaic Cell
G, The Galvanometer R, Tube enclosing sensitive receiver

Fig.9 Photograph of bose's millimeter wave instruments

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