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Evolution of Microwave Research in India

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Microwave research in India, first started by Bose in 1895 and revived by Chatterjee in 1946, has continued to progress with emphasis on 'antenna and propagation' due to the efforts made by a large number of scientific workers in the country. This paper records the systematic growth of different aspects of microwave research in India in a very condensed form, leaving the details of the work available in original papers classified under 'References' for the reader desiring further background.

1 Introduction

The pioneering work of Sir J C Bose[1] between 1895 and 1897 at about 5 mm wavelength using spark gap generator and semiconducting coherer ushered microwave research in India. The work of Bose has been illustrated by Ramsey[2] in a review paper. The interest in microwaves waned due to the lack of proper coherent microwave generator and success of long-distance long wave communication.

Investigations by Chatterjee[3] and Chatterjee *et al.*[4-6] on the dielectric properties of materials, artificial sea water and electron transit-time effects in tubes at UHF between 1946 and 1949 leading to researches at X, K and Q bands can be said to be the first to revive interest in microwaves after a gap of nearly fifty years.

This paper summarizes in a very condensed form microwave research in India, restarted by Chatterjee in 1951 at the Indian Institute of Science, followed by scientific workers in other institutions in India.

2 Microwave Resonator

Perturbation effects, interaction of modes, operation under coupled modes, etc., were investigated extensively by Chatterjee[7]. Study of open resonators with a central wire by Chatterjee and Chatterjee[8] formed an important part of the investigations on surface waves. Surface wave resonator was studied by Zacharia and Chatterjee[9]. Investigations on the resonant frequencies of lossy dielectric spheres excited in symmetric TE and TM modes by appropriate delta function sources by Chatterjee *et al.*[10] were utilized to verify the frequencies of maximum absorption of biological spheres[11] obtained experimentally. Bhatt *et al.*[12] have studied recently double-dielectric fin-line resonators, coupled rectangular slot resonators, cylindrical dielectric resonators and elliptic microstrip disc resonator.

3 Guided Waves

Extensive investigations on guided waves supported by dielectric and dielectric-coated structures such as uniform and tapered circular and rectangular dielectric rods, overmoded dielectric rods, uniformly corrugated dielectric rods, parallel-plate dielectric waveguides, dielectric loaded guides, dielectric-coated wire, duo-dielectric-coated wire, wire coaxially coated with three dielectric, dielectric-disc backed by a metallic disc and uniformly grooved metal rod, carried out by Chatterjee *et al.*[13], anisotropic dielectric rod by Paul[14], beam waveguide by John[15], metal rod with thick dielectric coating by Chatterjee *et al.*[16], have contributed significantly to our basic understanding of electromagnetic surface wave phenomenon.

4 Excitation of Surface Waves

Excitation of surface waveguides and dielectric structures has been studied by Rajeshwari and Chatterjee[17], John and Chatterjee[18], Dilli[19], Sen and Chatterjee[20], Chatterjee[21], Girija and Chatterjee[22] and John[23].

5 Radiated Waves

Radiation characteristics of uniform and tapered circular and rectangular dielectric rods, dielectric spheres, truncated dielectric spheres, dielectric hemispheres, dielectric coated structures of different geometery, corrugated dielectric and metal rods, overmoded dielectric rods, have been studied exhaustively by John Glory *et al*[24], Shankara and Chatterjee[25], and Chatterjee[26]. The study has led to a proper understanding of the physical mechanism of radiation

from dielectric and dielectric-loaded antennas, and thus has opened up a new line of further investigations. The work on radiated waves from dielectric bodies of different shapes by Chatterjee and her associates spread over a period of thirty years has been very ably dealt with by Chatterjee[27] in a recent book. Some of the work on radiation characteristics of antenna done by Chatterjee forms the content of a book by Chatterjee[28].

Microstrip antenna is a newly emerging field in the microwave and millimetre waveband. Chatterjee and Ganeshan[29] have investigated the radiation characteristics of microstrip antenna and have tried to explain the mechanism of radiation. Bhatt *et al.*[30] have contributed significantly to the field of microstrips.

6 Artificial Dielectrics: Simulated Plasma

Analysis of artificial dielectrics composed of parallel metal strips, three-dimensional array of disc delay dielectrics and experimental investigation with the help of an X-band interferometer, study of wire grid structure to simulate plasma at X and K bands and experimental work with the aid of a spectrometer and investigations on the interaction of microwaves with the laboratory model of simulated plasma, have been carried out by Chatterjee *et al*[31].

7 Microwave Absorber

Reflection and absorption characteristics of a structure consisting of a two-dimensional array of magnetic dipoles distributed over a plane of metallic sheet have been studied, using a microwave spectrometer by Chatterjee *et al*[32]. The structure behaves as an efficient absorber or reflector depending on the proper orientation and distribution of the elements of the array.

8 Diffraction and Scattering

Investigations on diffraction and backscattering of microwaves by circular dielectric discs with the help of an image plane, and measurement of backscattering cross-sections of metallic bodies of revolution such as circular ogives, cone spheres, double-backed cones, partially capped spheres, spherical segments and models of some types of aircrafts using a laboratory-made monostatic radar and statistical analysis of echo pattern of complex targets, have been carried out by Chatterjee *et al*[33].

9 Instruments and Components

Development of microwave interferometer, image plane apparatus, spectrometer, surface wave resonator, antenna range and various types of X, K and Q bands equipment for near-field measurement by Chatterjee *et al.*[33,34], has helped the growth of microwave research. Bhatt[35] has developed fin-line components. Chatterjee[36,37] has discussed several aspects of microwave engineering.

The above report is based only on available published literature. In addition to the work mentioned above, important useful contributions have been made in the evolution of microwave research in India by B R Nag of the Institute of Radio Physics and Electronics, Calcutta University; J S Chatterjee of the Jadavpur University; G Sanyal and B N Das of the IIT, Kharagpur; Kailash Chandra of the NPL, New Delhi; Amarjit Singh of the CEERI, Pilani; G P Srivastava of the Delhi University; Krishnaji of the Allahabad University; and R P Shenoy of the DRDO. Details about their contributions could not be collected and reported due to lack of time.

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