

ECE 50 YEARS

1946-1996

COMMEMORATION OF A GREAT HERITAGE

Editors

B S Sonde, A Selvarajan

December 1996

DEPARTMENT OF ELECTRICAL COMMUNICATION ENGINEERING
Indian Institute of Science, Bangalore

Front cover: Founder's statue
J N Tata (1839-1904)

Published by
Department of
Electrical Communication Engineering
Indian Institute of Science, Bangalore 560 012
(for private circulation only)

Printed by Omkar Offset Printers, Bangalore
Tel: 609026/608186

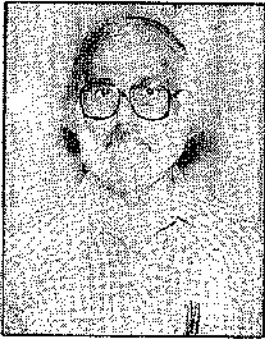
CREDITS

Concept, Design & Execution	:	Gururaj N Kadloor, CEDT-IISc.
Sketches/Cartoons	:	V C Janardhana Swamy
Graphics/Plots	:	S V Gopaliah
Assistance	:	R Srinivasa Murthy Susheela Nagaraj A V Leelavathi V Saraswathi S R Ramakrishna R Muniraju Rupendra Raju

Director's Foreword	G Padmanaban	5
Golden Jubilee Publications		6
Editors' Preface	B S Sonde / A Selvarajan	7
Industrial Associate Programme		8
1. A Historical Perspective	B S Sonde	9
2. ECE - In Retrospect	G V Anand	23
3. ECE - Today	A Selvarajan	37
4. ECE - Vision 2000	D K Anvekar, K V S Hari	55
5. ECE - Strength	T S Vedavathy, D K Anvekar	58

CONTENTS

DIRECTOR'S FOREWORD



The Founder of this Institute had a great vision in creating this Institution with emphasis on Chemistry and Electrical Technology. Although, the Department of Electrical Communication Engineering became an independent entity in 1946, it was part of Electrical Technology and identified as a separate section in 1923. The Department can be proud of its illustrious past and has contributed significantly to the development of this branch of engineering in the country. It has kept abreast of development in technology and has worked closely with government, public and private sector industries in the area. The alumni of the Department have brought laurels to the alma mater. The Department has major R&D interests in the broad areas of communication, microelectronics and signal processing. It has taken steps to modernize its curriculum and augment its interaction with industry. The Department can look forward to a glorious future. I am confident that the Department will be a key player in the country's effort to benefit from the communication revolution sweeping the globe. I have great pleasure in wishing the faculty, students and staff of the Department of the very best.

November 1996

G Padmanaban
Director

INDIAN INSTITUTE OF SCIENCE, BANGALORE
ECE 50 YEARS : 1946 - 1996
Golden Jubilee Publications

- Proceedings of International Conference on :
Emerging Microelectronics and Internconnection Technologies (EMIT'96)
(organized jointly with ISHM - The Microelectronics Society)
February 12-16, 1996 496 pp
Published by New Age International (P) Limited; Publishers, New Delhi

- Proceedings of Workshop on :
ECE Education and Research in India - Future Directions
July 12-13, 1996
Volume 1: Papers 130 pp
Volume 2: Report & Recommendations 38 pp
Published by Indian Institute of Science, Bangalore

- Proceedings of Conference on :
Communication Technologies (CT 96)
December 13-16, 1996 246pp
Published by Indian Institute of Science, Bangalore

- **ECE 50 YEARS - Golden Jubilee Commemoration Volume**
Published by Indian Institute of Science, Bangalore
December 1996 92pp

GOLDEN JUBILEE ORGANIZING COMMITTEE

B S Sonde
G V Anand
T V Srinivas

A Selvarajan
T S Vedavathy
Kumar N Sivarajan
N Sai Shankar

M Satyam
Anurag Kumar
D K Anvekar

EDITORS' PREFACE

Learned persons and eminent educationists have often said: "In a University what matters most is not imposing structures and laboratory facilities, it is not the strength of the student body, not even the distinctions won by the faculty members. What matters most is the quality of education that is imparted" This has been the motto of the Department of Electrical Communication Engineering (ECE) ever since its inception, now celebrating its Golden jubilee in the year 1996. Although ECE got its present status as a Department, the first of its kind in India, at the Indian Institute of Science in 1946, ECE teaching and research had commenced at the Institute many decades earlier as a part of erstwhile Department of Electrical Technology (ET). Several leading scientists and academics have led the ET Department and later its ECE Section which became a full fledged Department with high distinction and provided a sense of direction to the programmes: Research, Teaching, Scientific & Technical Advice and consultancy which has been of great strength to the Department. Also, merited students have come from far and near in the Country and also from abroad for higher education, training and research in advanced & emerging areas. Today, many of the alumni of the Department occupy key positions in education, science, industry, government administration and the like all over the world. In celebrating the Golden Jubilee of the Department, the faculty, staff and students of the Department are now paying a rich tribute to this great heritage. This commemorative publication "ECE 50 YEARS" is a major effort in this connection.

This book is divided into several chapters. Beginning with a historical perspective, tracing the origins of the Department and linking it with

the historical developments of the Indian Institute of Science in pursuit of excellence, the next chapter covers ECE - in retrospect based on the contributions and inputs from the faculty-past and present and alumni, down the memory lane of their association with the Department. The next chapter deals with ECE - today giving the present status of the Department, including its programmes and activities. The faculty/staff/students of the Department are listed here and the faculty profile is also included here. The next chapter covers a future vision of the Department focusing on the year 2000 sharpened by discussion and review at various levels in the Department. The concluding chapter covers the ECE strength, which gives a listing of all the Degree, Diploma awardees from the very beginning. This includes a listing of Ph D / M Sc (Engg) theses which were awarded degrees from the Department. Besides this text material, the book contains a veritable collection of photographs, interesting sketches, graphics and a few cartoons in a lighter vein.

It is hoped that the book will be a useful collector's item and a memento for everyone associated with the Department in its long record of service to education, science and industry in the Country. The encouragement and support received from colleagues, retired faculty, alumni and the Institute's administrations in organising this material is gratefully acknowledged.

Bangalore
November 1996

B S Sonde
A Selvarajan

DEPARTMENT OF ELECTRICAL COMMUNICATION ENGINEERING

INDUSTRIAL ASSOCIATE PROGRAMME

The industrial associate programme has been launched since April 1996 with the objective of facilitating interaction between the Industry and the Department for mutual benefit with a view to stimulate development in the areas related to electronics, communication, signal processing, and computers. This programme provides a forum for the exchange of ideas and information on a regular basis. It also enables the participating industries—Industrial Associates—and the Department to make use of each other's strengths and facilities towards developing a vibrant R&D culture.

The benefits to the Industrial Associates include opportunity to:

- Interact with the Department faculty to launch new activities, courses and programmes;
- Attend technical presentations on the current activities of the Department twice a year;
- Avail technical publications and brochures;
- Discuss technical problems and to solve them through consultancy projects at concessional fees;
- Have access to laboratories in the Department through faculty approval and concessional fees, where applicable;
- Have access to the Department library;
- Be informed about the seminars, short courses, tutorials and conferences in the Department, and be eligible for concessional fees if any;
- Approach funding agencies jointly with the Department;
- Add and update the expertise of their technical personnel;
- Pursue Masters and Doctoral programmes by their personnel;
- Benefit first from the ideas and products developed in the Department, and transfer technology from the Department at concessional fees;
- Strengthen R&D and improve the product or process at low cost.

Any industry or company in the areas related to electronics, communications, signal processing and computers can become an Industrial Associate by paying an admission fee of Rs. 10,000 and an annual (April to March 31) membership fee of Rs. 10,000 (for small-scale industries) or Rs. 20,000 (for medium-scale and large-scale industries). The Industrial Associates will be eligible for tax benefits on the fee paid for this programme.

The application form as well as any further information may be obtained from
Dr. Kumar N. Sivarajan /
Dr. Anamitra Makur
ECE Department
IISc, Bangalore 560 012
Phone: 309-2658 / 309-2745
Fax: 334-0563
Email: kumar / amakur @ece.iisc.ernet.in

1. A HISTORICAL PERSPECTIVE

A. EARLY PERIOD

1909

Establishment of Indian Institute of Science.

1911

Department of Electro Technics established, later renamed Electrical Technology (1913).

1923

Wireless Laboratory, later renamed Electrical Communication Engineering Section (1928) set up in the E T Department.

1.1 By the beginning of the 20th century, electrical science and engineering had already advanced to a great extent to become an important part of everyday life. At the same time, telegraph and telephone networks had progressed considerably on the world scene and Guglielmo Marconi had demonstrated wireless telegraphy across the Atlantic (1901). Besides, in the first decade of this century, electronics was taking its first steps through thermionic valves. It was in this period, India had just begun its electrical power generation schemes, viz., Cauvery hydroelectric power station near Mysore, thermal power stations in metropolitan cities and Tata hydroelectric power system near Mumbai, but, the electrical industry was yet non-existent in the country. In such a situation, the decision of the planners of the Indian Institute of Science to establish the Department of Electrical Technology (ET) as one of the first Departments of the Institute was indeed bold and far-reaching. This has enabled the Institute to lay a strong foundation for electrical science and technology in the country and provide an excellent base for education, R&D, industry and utilities in this area. Also, the Department could nurture electronics, communications and related areas, when they were introduced in its academic and R&D work in later years (Box A). As a result, the history of electrical/electronics/communications education and R&D in India is indeed synonymous with the growth of these activities at the Institute.

2. THE EARLY YEARS

2.1 The ET Department was planned, equipped and set up by Prof. Alfred Hay, the first Head of the Department, who joined the Institute in 1908. Being in the front rank of electrical engineering teachers in England and well known as the author of standard works on the subject, viz., Continuous Current Engineering, Alternating Currents, and Transmission & Distribution, he brought great prestige to the Department. It was a matter of great good fortune for the Department, that it had a person of Prof. Hay's stature to guide its destinies and foster its development in the early years. Through his many contributions and hard work, Prof. Hay laid a strong foundation for higher education and research in electrical engineering in India. Some of Prof. Hay's major achievements were:

- Planning and constructing building for the Department/ (the present Physics building housed ET until 1948);
- Setting up of laboratories/lecture halls/workshops in the new building;
- Launching the first post-B.Sc. (Physics + Maths), 3-year ET course in India, leading to Certificate of Proficiency (COP) Award;
- Highly selective (5-6/year) Student admissions based on merit only and on an all India basis;
- Training of laboratory / supporting staff in electrical skills;
- Thorough training of students through well focused, advanced level courses and research

B. EXTRACTS FROM W J POPE COMMITTEE REPORT (1921)

ET is the only Department at the Institute having regular courses, systematic lectures and practicals;

A range of valuable equipment/facilities have been established here;

42 students have graduated in ET in the first decade;

Vigorous training programme for new entrants should be emphasized; Advanced instruction should be encouraged in addition to original investigations.

C. PROF. K SREENIVASAN ON PROF. HAY'S TEACHING

... He was a marvellous teacher in his insight into and mastery of the subject and in lucidity of exposition. I have not met the like of him in all my long life. With remarkable economy of words and direct approach, he would illuminate even difficult ideas and concepts with great clarity ...

work - particularly in the areas of DC/AC machines and electronic / magnetic materials;

- Earning great respect and affection of the students.

Prof. Hay retired from the Institute in 1922 and returned to England. In recognition of his meritorious service, Prof. Hay was conferred the first Honorary Fellowship of the Institute in 1922. The Special Committee appointed by the Government of India to review the work of the Institute under the Chairmanship of Sir, William J Pope (1921) commended highly of the ET Department in its first decade (Box B).

Prof. K Sreenivasan, one of Prof. Hay's students (~ 1920) had this to say on his teaching excellence. (Box C).

2.2. Prof. J K Catterson - Smith succeeded Prof. Hay as the Head of ET Department in 1923. The Department saw a period of rapid growth and expansion under Prof. Catterson - Smith's stewardship. Major achievements in this period were:

- Revision and updating of the post - B.Sc. 3-year ET course; e.g., "thermionic valves" (both vacuum and gas-filled) and "Wireless" introduced as new subjects;
- Wireless laboratory set up (1923) and equipped, for the first time in India;
- Electrical Engineering laboratory upgraded by adding new machines and measuring instruments;

- First high voltage laboratory in the Country established, assisting the growth of electrical industries in the Bangalore area in later years; e.g., Government Porcelain Factory;

- Founding of the Electrical Engineering Society (1923) and launching of its publication, "Electro Technics" (1926). [The society and its publication continued through 1964-65];

- Wireless Laboratory renamed as Electrical Communication Engineering Section (1928); post of Assistant Professor in ECE created; S.R.Kantabet, an early student of the Department appointed as Assistant Professor in ECE (1928);

- Supplementary Course (1 year) in ECE for ET/BE graduates launched (1929-30);

- Research work encouraged - covering areas like short wave beam antenna arrays, short wave transmission and antenna testing;

- Many alumni becoming leaders and outstanding scientists / engineers in India and abroad.

Prof. Catterson - Smith was a man of vision and imagination with an artistic outlook. By what he did and achieved in a short time at the Institute, he became the founder of higher education and research in Electronics and ECE in India. Prof. Catterson - Smith returned to England in August 1930. At this time, the Department had a Faculty/Staff of 8 members: 1 Professor, 3 Assistant Professors and 4 Assistants. In recognition of his monumental contributions to the academic and research work at the Institute, he was also conferred the Honorary Fellowship of the Institute

**D. PROF K. SREENIVASAN
ON
PROF CATTERSON SMITH**

... He was an admirable teacher; and he earned the esteem and affection of his students not only as a teacher and research guide, but also by his sympathetic understanding of them and his courtesy and helpfulness. He always endeavoured to bring out the best of them ...

**E. EXTRACTS FROM
RBS SEWELL
COMMITTEE REPORT (1931)**

Justification for a separate ECE Section in the ET Dept. Growing importance of ECE on the world scene.

1928: First Assistant Professor of ECE appointed; Two students also admitted; 1-year supplementary ECE Course started; 1931: Students number at 11, indicating growing interest in ECE.

Main activity: Teaching programme at level equivalent to B.Sc. (Engg) at British Univ.; Recognized by IEE (London) and IE (India); Sufficient evidence of high standard.

Facilities: Well equipped modern Wireless laboratory for teaching and research; A combined direction finding and wireless reception room set up; Linked to the main laboratory by telephone; Topics of interest: Telegraphy, Telephony and Radio.

Future: Studies in thermionics and radio measurements to be taken up; Additional equipment recommended.

(1930). Prof. K.Sreenivasan (An Assistant of Prof. Catterson - Smith in the 1920s) has this to say on Prof. Catterson-Smith. (Box D).

2.3. Prof. F N Mowdawalla, an early student of Prof. Hay in the post - B.Sc. 3-year ET course (1912-15) succeeded Prof. Catterson-Smith as the first Indian Head of the ET Department in June 1931. He brought with him his field experience of several years in the hydro-electric department in different states, superposed on his earlier experience as Assistant to Prof. Hay (until about 1920) and later as Assistant Professor (1924-26). Being deeply attached to the Institute, Prof. Mowdawalla developed the Department in every possible way. Besides being a strict disciplinarian, he was an excellent teacher and he earned the respect and admiration of his students. One of his major achievements was the commencement of the first 3-year course in ECE at the post - B.Sc. level in 1932 to replace the earlier 1-year supplementary ECE course. He also strengthened other sections in the Department and expanded the research programmes. But, in early 1932, Asst. Prof. Kantabel left the Institute to take up an assignment with the Govt. of India. At that time, Mr. K.Sreenivasan was appointed as the Asst. Professor of ECE, and Mr. S.P.Chakravarti as Lecturer. While, Asst. Prof. Sreenivasan concerned himself with Electronics and Radio, Mr. Chakravarti specialized in Telegraph and Telephone Communications on wires and cables. In this same period, the Govt. of India appointed a Review Committee under the Chairmanship of Lt.Col. R.B.S.Sewell. The Committee made many interesting comments on the ECE activities in the Department. (Box E).

The laboratory facilities were improved

considerably by acquiring new apparatus, instruments and components. Cathode-Ray Oscilloscopes were also added to the Department for both instruction and research. The year 1932 was declared as the second International Polar year. Students and faculty conducted many interesting experiments by recording echoes from the ionosphere using locally developed apparatus, the results of which were later published in international journals. Prof. Mowdawalla, unfortunately left the Institute in July 1934, after only 3 years service as the Head of the Department.

2.4. The void created by the departure of Prof. Mowdawalla was filled by the arrival of Prof. Kenneth Aston (1935), who had long teaching experience at the University College, Cardiff in England. Prof. Aston had extensive knowledge and experience in electrical machine design. During Prof. Aston's term, the ECE activities grew further and also the syllabus for the course was revised in step with the prevailing trends. He also strengthened the Electrical Engineering Society, which became a major mouthpiece for dissemination of new knowledge in the subject by both the students and the faculty. Stalwarts like Prof. C.V.Raman also addressed the Society in this period, as can be seen from the technical programme of the Society for a typical year, 1942-43. (Box F).

The Government of India appointed another Review Committee in this period under the Chairmanship of Sir J.C.Irvine (1936), which commended highly of the ECE research and academic programmes in the department (Box G). In this period, national leaders like Mahatma Gandhi paid a visit to the Department (1936), which was a great inspiration to the faculty and

F. ELECTRICAL ENGINEERING SOCIETY

Programme for the year 1942-43

August 1942

- 2 Business Meeting, Elections
- 12 Wartime Recovery and Production of Nonferrous Metals in India: Dr. J.C.Ghosh
- 19 The Broadcasting Studio Building in Mysore; Dr. G.H.Koenigberger

September 1942

- 2 Specific Heat of Solids: Sir C.V.Raman
- 9 Location and Layout of Small Industrial Plants: Mr. H.S.Sidhu
- 16 Maintenance Problems in Engineering: Mr. A.Perry
- 23 Electrical Insulating Materials: Dr. S.K.K.Jatkar
- 30 Economics of Radio Industry: Mr. T.R.Jayaraman

November 1942

- 11 The Hydrogen Bond: Mr. G.R.Sivarama Rao
- 18 Colour photography: Dr. S. Dutta

December 1942

- 2 Locomotive and its Accessories: Mr.P.D. Madhekar
- 9 Recent Cosmic Ray Experiments: Mr. V.Sarabhai

January 1943

- 13 Some Aspects of Power Generation by IC Engines: Mr.K.B.Krishna Rao
- 20 Electric Kilns: Mr. Ramchander Rao
- 27 Gaseous Fuels for Automobiles: Mr. S.N.Choudhry

February 1943

- 3 Protective Devices for Transmitters: Mr. M.Madan Mohan
- 10 Measurement of Radio Field strengths; Mr. A.Abraham
- 17 Cathode Ray Oscillograph: Mr. M.Rahman
- 24 Electric Traction: Mr. S.N.Roy

March 1943

- 3 Business Meeting

students. Prof. Aston returned to England in 1944 at the conclusion of his assignment. At the same time, Asst. Prof. Sreenivasan went on deputation to Madras for another assignment. This period was also marked by major world events, like world war II and new discoveries in science and technology, particularly in ECE. This was perceived by the planners of the Institute, who decided to upgrade the section of ECE into a full fledged Department.

3. ECE SECTION TO ECE DEPARTMENT

3.1. The transformation of the ECE Section into a full fledged ECE Department was announced by Prof. J.C.Ghosh, Director of the Institute in 1946, almost anticipating the crucial role that ECE could play in independent India in the coming years. At this time Dr. N.B.Bhatt who was section i/c of ECE in the ET Department was assigned to officiate as the Head of the ECE Department. Prof. S.P.Chakravarti who had succeeded Prof. Aston as the Head of the ET Department was assigned to continue with the truncated ET Department. Dr.Bhatt brought in his knowledge, training and experience in electro-acoustics in USA to strengthen research in this subject in the new Department. Also, the 3-year post-B.Sc. ECE course was revised to be in step with the post - world war II advances in ECE. Very soon Asst. Prof. Sreenivasan returned to the Institute and he was made the first Professor and Head of the ECE Department. Being a person having long association with the Institute, first as a student, then as an Assistant and later as an Assistant professor, Prof. Sreenivasan devoted his full time and energy in planning and building up of the new Department. Major

G. EXTRACTS FROM JC IRVINE COMMITTEE REPORT (1936)

Popularity level of ECE/ET: Very high; out of 182 students admitted to IISc (1934-36), 50% at ECE/ET.

Recommended emphasis: Advanced instruction and research, in line with IISc policy; Progressively abolish junior classes to fulfill this.

Current research: Wave filters, Telegraph repeaters, Telephone transmission, Ionosphere.

Future: Education and research in Communication engineering and Sound recording to be taken up.

activities successfully, completed by Prof. Sreenivasan were:

- Planning and constructing a new building for the ECE Dept.; a modern E shaped building, of about 3000 sq.m floor area having wide corridors, functional laboratory/class/office rooms, workshop, stores and an auditorium. Besides, there was also an impressive foyer at the entrance. A well laid out garden in the front enhanced the beauty of the building. Although it was planned to have five floors for the building, only two floors were completed for want of funds. Laying of the foundation stone and opening of the building were both performed by Pandit Jawaharlal Nehru - India's first Prime Minister, (a rare occasion!)
- Many laboratories were set up and new equipment added.
- New faculty joined the Department and many visiting professors came from different parts of the world for short and long assignments; viz. Professors Norbert Weiner, P.H. Craig, Vincent C Rideout, L.I. Baida and A.I. Vishnevsky.
- The first analog computer in the country (PREDA) was established in the Department and new lines of research and training were launched using this facility.
- The post B.Sc. three year ECE course (D IISc) was fully revised and made up to date. Also, a PG course(DIISc-PG) was launched at the post B.E./DIISc. level, for the first time in India, to specialize in Electronics Engineering and Ultra-Shortwave and Microwave Engineering.

- Research work in different areas was encouraged and research Degrees leaving to AIISc were also conferred for the first time. Publication of research papers was also encouraged.
- Close association was established with the newly set-up public sector companies like Indian Telephone Industries Ltd. (1948) and Bharat Electronics Ltd. (1955). In addition, links were forged with national laboratories under CSIC, DRDO and other agencies.
- The Department also participated in a commendable way in the establishment of the Institution of Electronics and Telecommunication Engineers (1953) and Prof. Sreenivasan was elected as its III President during 1956-57.

3.2 By the time Prof. Sreenivasan retired from the Institute in 1959, the Department had attained an eminent position, not only in India but also abroad for the quality of its training and technical personnel it produced at different levels. The ECE alumni were occupying key positions in Education, Science, Industry, Utilities, Defence services as well as in the Government. This brought great prestige to the Department which brought world-wide attention. However, Government of India Review Committees appointed in this period viz., Alfred Egerton Committee (1948) & J.C. Ghosh Committee (1955) had divergent views. (Boxes H & I)

Prof. Sreenivasan was succeeded by Prof. S.V.C. Aiyar (1959) who brought to the Institute his long experience in teaching and research in ECE as well as in administration at many institutions in the Bombay Presidency, in particular, College of

H. EXTRACTS FROM ALFRED EGERTON COMMITTEE REPORT (1948)

Recommendations: ECE 3-years course to be closed down soon; Such courses now available at many other locations in India. Concentrate on PG teaching and research.

Equipment/Facilities: Very meagre and mostly out of date; Reason for low research intensity.

Current research : Ionosphere; Non-synchronous vibrators for radio sets; MW radio transmission; UHF studies; Calibration of wavemeters; Reverberation recorder.

Work done for Govt. Depts.: 100 Hz standard signal transmission for P&T; Testing of UHF transmitters/receivers.

Future: Advanced training and research in the emerging areas of radio and radar.

Engineering at Pune. Prof. Aiya was also President of the IETE in 1958-59. Prof. Aiya advanced the teaching and research activities, strengthened the laboratories and associated facilities and enhanced the Department still further. Prof. Aiya's contributions were;

Launching of new research programmes, particularly in atmospheric radio noise and its interference to communication, as well as in transistor electronics and instrumentation.

Increasing Ph.D. and M.Sc. engineering registration of students, spotting out talent among them and providing scholarships.

Increasing interaction with national laboratories and industries to undertake new lines of research and advanced instruction.

Publication of research papers by faculty members and students and also preparation of research monographs (e.g. Relative efficiencies of Indian languages by Prof. B.S. Ramakrishna et al) and text books (Prof. B.S. Sonde, Prof M. Satyam, et al).

Setting up of two new buildings for the Department to house Acoustics laboratory and Electron Devices laboratory.

Admission of foreign students and sponsored defence service officers for ME course;

Revising and upgrading both B.E. & M.E. ECE programmes and making them more relevant to the needs of the Country.

Encouraging faculty members to develop new lines of research, new instruments and facilities

(e.g. Digital Computer Demonstrator by Prof. N.S. Nagaraja) and bringing in new interactions with other leading institutions in India and abroad. e.g. University College London (Prof. Harold Barlow and Prof. John Brown) Tohoku University Sendai, Japan (Prof. Kunio Mano); Research Institute of Atmospherics, Nagoya University, Japan (Prof. A. Kimpara).

3.3 By the early sixties, the Department had already become a bright spot in the ECE Education and Research Scene in India and was attracting the most talented students from all over the country. This was a time when new IITs were being set up in the country. A USA delegation headed by Prof. John D. Ryder, Dean of Engineering, Michigan State University which was visiting India in connection with the establishment of IIT/Kanpur, also visited the Department in the spring of 1961. Their impressions on the ECE Department and its programmes which were published in the Proceedings of the IRE (Box J) were highly laudatory. Another important event in this period was the gift of a bust of Heinrich Hertz from the Govt. of West Germany, which was formally installed in the foyer of the Department. Prof. Aiya not only brought cohesion among the various laboratories and teaching/research programmes in the Department, but also, he contributed a great deal to build up comradeship among the students, the faculty and the supporting staff. The setting up of an ECE club, organising a number of cultural programmes, picnics, festival cricket match, etc. were indeed well appreciated by one and all. Another major programme in the period was the international Antenna Symposium arranged for the first time at the Institute, which attracted wide attention.

I EXTRACTS FROM J C GHOSH COMMITTEE REPORT (1955)

Main activity: 3-year DIISc (ECE) Course; 110 students trained during 1948-55.

Recommendations: DIISc (ECE) not to be closed, but to be strengthened; Reputed Course; Excellent training; Strong foundation for PG students; Admissions to be increased by 100% to meet the growing demands in the II plan period.

Launch PG Courses: Specialization in Electronics Engg, US&MW Engg. Line Comm. Engg, Acoustical Engg. based on AICTE grants received & new building available (since 1951).

Current research: US&MW Engg, Radio Wave propagation, Directional antennas, Pulse Techniques, Line communication, Acoustics; 40 papers published (1948-55)

4. NEW DEVELOPMENTS

4.1 On Prof. Aiya's departure from the Institute (1969) to take up a new assignments in the Govt. of India, Prof. B.S. Ramakrishna became the Head/Chairman of the Department. This was a period of major changes nationally and internationally and the Department responded to these in an admirable way.

New activities were launched in the Department in this period, viz., the Centre for Information Processing by DRDO under the ADGES programme of the Govt. of India (1971) and the Centre for Electronics Design Technology (CEDT) an Indo-Swiss project (1974). Many new faculty members joined the Department and new research and academic programmes were introduced. Of particular importance were research in Digital and Optical Signal Processing, SAW Devices, and post-graduate Diploma courses, both under CIP and CEDT. Besides, both the B.E. and M.E programmes were considerably updated and the unit system of instruction was introduced. Also, Ph.D. and M.Sc. (Engg) research was greatly enhanced. Sponsored students under QIP & External Registration Programme were also admitted for research conferments. These activities brought further prestige to the Department, as can be seen from the extracts of yet another Govt. of India Review Committee headed by Prof. T.R. Seshadri.

While the CIP was closed down in 1979, the CEDT was expanded and strengthened in the following years to become a leading Centre in Electronics Design and Technology, and a model for establishing similar centres in India and Abroad.

4.2 After Prof. B.S. Ramakrishna's term was over the mantle of leading the Department fell on Prof. N. S. Nagaraja who provided a mature and enlightened guidance and support to the various programmes. This was followed by Prof. N.N. Biswas, Prof. (Mrs.) R. Chatterjee, Prof. B.S. Sonde, Prof. M. Satyam, Prof. A. Kumar, Prof. V.U. Reddy in the succeeding years and now Prof. A. Selvarajan. During each of these periods, the Department has moved ahead on the strong foundation laid by its preceding Heads/Chairmen and has always strived to keep its flag flying high.

The great heritage of the Department has been its major strength. With the many sided achievements and academic/research contributions in ECE for over 7 decades, the Department is now looking forward to the next millennium with dedication and promise to enhance its contributions and reach in the service of the nation.

(See Table 1 and Figs 1-6 for growth of the Department)

Compiled and prepared by Prof. B.S. Sonde, based on personal discussions with and writings of (late) Prof. K. Sreenivasan and (late) Prof. S.V.C. Aiya. In pursuit of Excellence - A History of Indian Institute of Science by B.V. Subbarayappa (Tata McGraw Hill, 1993) and Platinum Jubilee Souvenir of EE Dept. (Dec. 1986) also were useful here. All the Contributions are gratefully acknowledged. (ECE Golden Jubilee Organising Committee).

J. IMPRESSIONS OF USA DELEGATION

TRAVEL STILL BROADENS. We return to report once more on travel - this time primarily to India to visit educational institutions.

Our first impression was of people, people everywhere - hands that must be kept busy, and mouths which must be fed. In talking with Indian engineers, and long-time British and American residents, we were told that India is indeed making progress on its population and economic problems. Our second impression was of the excellence of people in government and in colleges sure of their direction and that of India. In engineering education there was realization of the need for change, but some doubt as to the methods to be employed in bringing it about.

This doubt was not so apparent at a bright spot in the educational field - the Indian Institute of Science at Bangalore. We were taken in hand by Dr. S.V.C. Aiya, Head of Electronics and Communications, and also immediate past president of the Institute of Telecommunications Engineers of India. A fast tour revealed excellent research

facilities and plans for more. Areas of activity included atmospheric noise, artificial dielectrics, surface-wave transmission, information content of languages (for which India provides ample material), and some very pure acoustic- research on the Indian drum. We say pure, since the results are not likely to be applied to drum design, especially when the research shows the design produced by 2000 years of empirical effort to be correct!

Being a professor-part time we willingly accepted Dr. Aiya's invitation to address a meeting of students, faculty, and Bangalore communications engineers, and we can at least report that the event was enjoyed by the speaker.

Bombay, Madras, Calcutta, Delhi all were points of educational interest and the Taj Mahal surpassed all words or pictures. We returned ready to go again.

John D. Ryder

(Reproduced from Proc. IRE, 49, 11, p.1613, November 1961)

K. EXTRACTS FROM T R SESHADRI COMMITTEE REPORT (1971)

Recommendations: BE Course to be broad based; Newer areas to be considered. ME Course to be of 2 years duration. BE/ME teaching to be reoriented to include a large basic science component. 1 year Course in peripheral fields to be introduced for research students.

Current research: Acoustic standards, Architectural acoustics, Atmospheric radio noise studies, Random vibrations, Statistical theory of communication, Transistor circuits, Wave propagation antennas and microwave techniques.

Future: Research and advanced instruction to be emphasized.

Table 1. Progress of ECE Teaching Programmes at the Institute

Year	Programme	Year	Programme	Year	Programme
1911	Electrical Technology (ET) Dept. set up; Systematic lectures and training in ET started; Post-B.Sc. 3-years Course launched; Certificate of Proficiency Award to successful students.	1958	Award of Degrees in place of DIISc at IISc; BE (ECE) = DIISc; ME (ECE) = DIISc (PG)	1975	A new 1-year DIISc (PG) Course launched for sponsored BE(ECE)/MSc (Phy) Degree holders; Specialization; Electronics Design and Technology; This Course upgraded to M Tech (ED) since 1987.
1923-25	Planning and setting up "Wireless Laboratory" in ET Dept. for training and research in electronics and radio; Courses in electronics and radio introduced for ET students in final year; First time in India.	1963	Restructuring ME (ECE) based on the Thacker Committee Recommendations; Emphasis on Mathematics, Materials Science and Technology and Instrumentation as core subjects; Rigorous theoretical/experimental analysis and research/design oriented project work as part of curriculum; Course duration : 2 years.	1981	Introduction of 7 point Grading System in lieu of earlier 5 point Grading System, for better resolution in grading.
1928-29	Wireless Laboratory renamed as Electrical Communication Engineering (ECE); Section Supplementary course (1-year) in ECE launched for ET/BE graduates.	1970	Restructuring BE/ME programmes at IISc under the unit system; Credits fixed for theory/practicals/project work; Average term load: 16 credits; Flexible Curriculum: Core, Electives, Project work; 5-points Grading System in place of marks system; First time in India.	1983	Restructuring ME (ECE) based on the Nayudamma Committee Recommendations; 3 Semester (1 1/2 year) programme - emphasis on advanced level courses and project work; Qualifying thorough GATE essential for admission; A new 4-year Post-B.Sc. ME (Int) (ECE) course launched; First time in India; Post-B.Sc. 3-year BE(ECE) continued for the time-being.
1932	Post-B.Sc. 3-years ECE course launched in ET Dept.; First full-time ECE course in India.	1971	Centre for Information Processing (CIP) set up in ECE Dept. sponsored by Min. of Defence. (CIP continued until 1979).	1986	Post-B.Sc. 3-year BE (ECE) course of long standing phased out.
1946	ECE Section/upgraded to ECE Dept.	1974	A new 1-year DIISc (PG) Course launched for sponsored BE (ECE)/MSc (Phy) Degree holders; Specialization: Digital Communication & Data Processing.	1991	Electrical Sciences (ES) Divisional Review of ME (Int) Course; Strengthening and Restructuring Course work by introducing Divisional core subjects, specifying new Departmental Core subjects, addition of new electives and providing 1 full year for project work.
1947	Course work evaluation based on examinations and award of marks commenced at IISc; Diploma of IISc (DIISc) award in place of earlier Cert. of Prof.	1974	A new 1-year DIISc (PG) Course launched for sponsored BE (ECE)/MSc (Phy) Degree holders; Specialization: Digital Communication & Data Processing.	1996	Divisional Review of ME and ME (Int) courses in ES Division; Decision to phase out ME (Int) (ECE) course, strengthening of ME (ECE) course and launching new ME Courses in emerging areas jointly with other Depts/Centres.
1956	DIISc (PG) in Electronics Engg/Ultra Short and Microwave Engg/Line Comm. Engg of 12 months duration for DIISc (ECE)/BE(ECE) Degree holders; Advanced level Courses, Project Work, Industry/R&D Lab training emphasized; First ECE PG Course in India. Deemed University status for IISc.	1974	Centre for Electronics Design & Technology (CEDT) set up in ECE Dept. supported by DOE, UGC, SDC (Indo-Swiss Agreement), to train design engineers and technologists needed in electronics industry. First time in India; CEDT now a full-fledged Centre in IISc since 1983.		

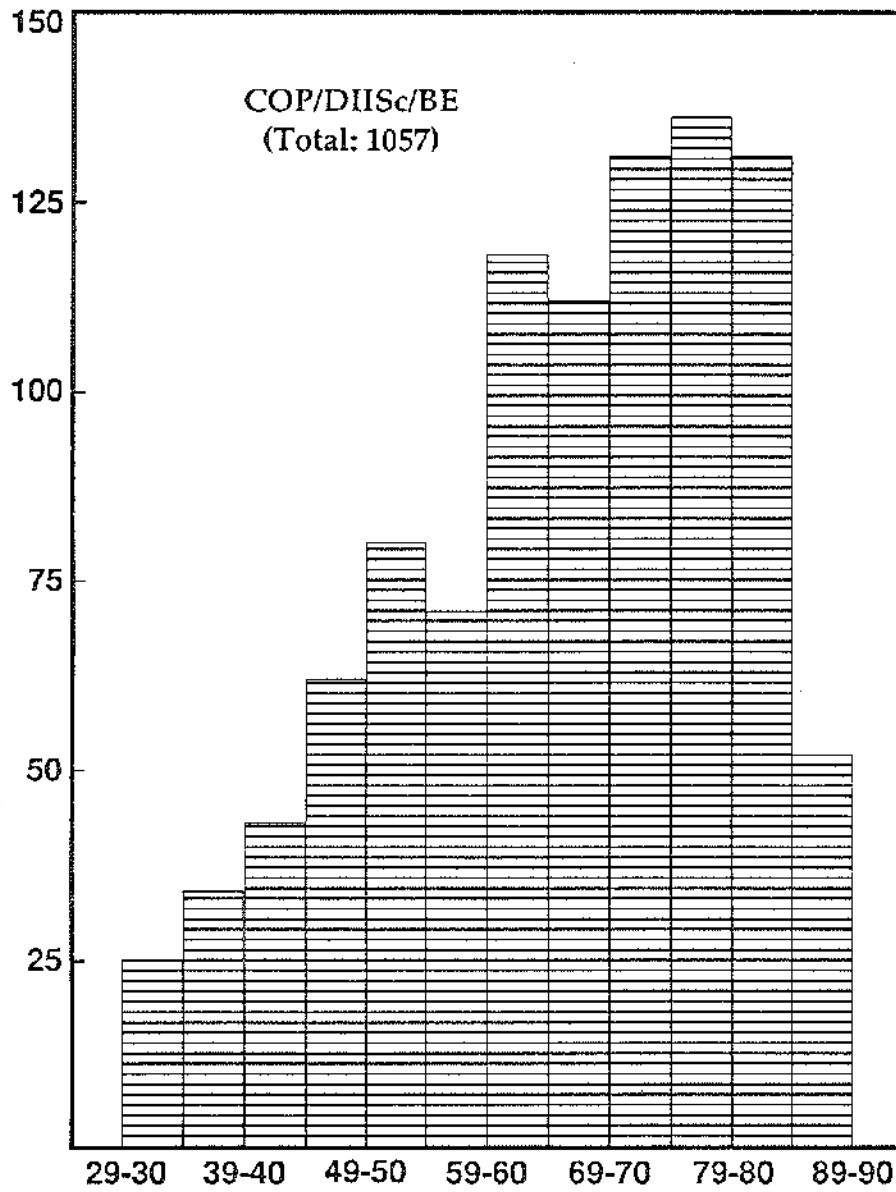


Fig. 1. Progress of BE(ECE) conferments

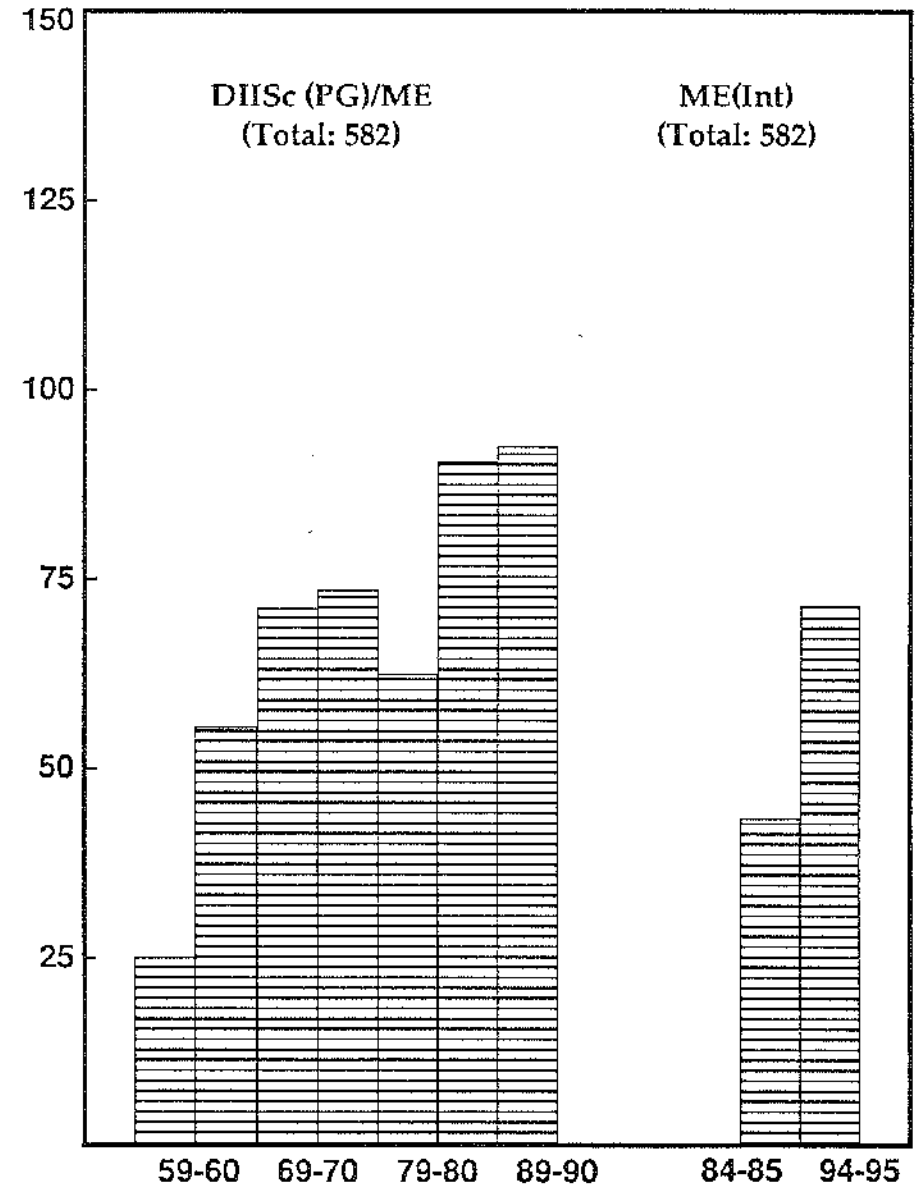


Fig. 2. Progress of ME(ECE) conferments

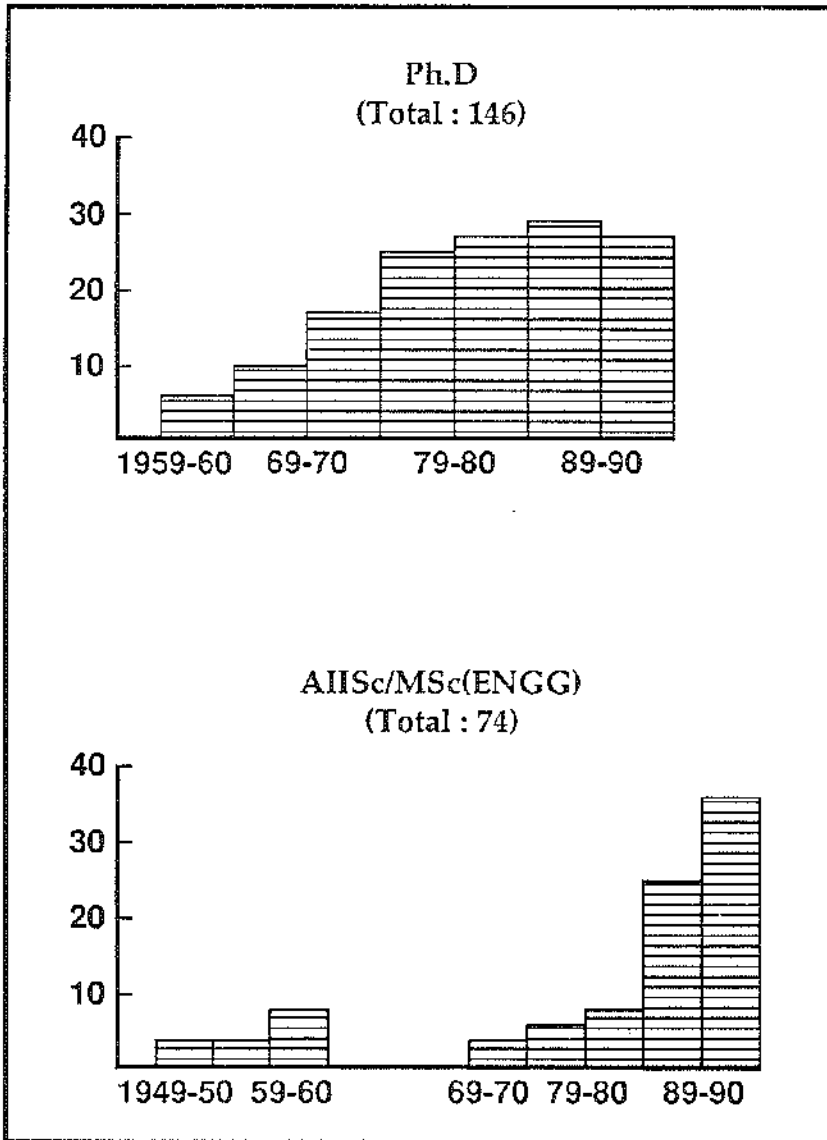


Fig. 3. Progress of ECE Research conferments

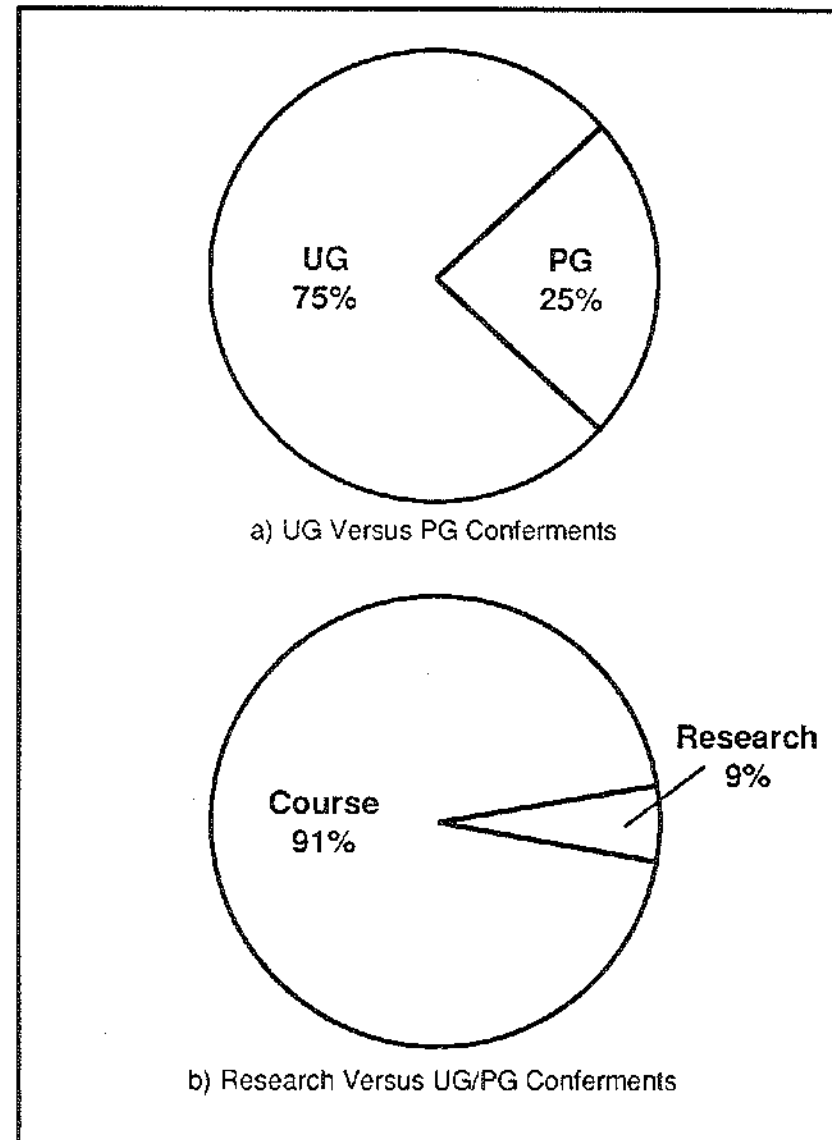
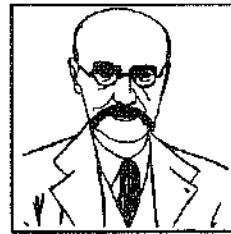


Fig. 4. Breakdown of Course/Research Degrees Conferred

Fig. 5 ECE / ET AT THE INSTITUTE : A CHRONOLOGY

ET

1908-22 Alfred Hay
Prof. & Head



1911 Establishment of ET Dept



1923-30 J K Catterson-Smith
Prof. & Head

1931-34 F N Mowdawalla
Prof. & Head



1936-42 K Aston
Prof. & Head



1944-47 S P Chakravarti
Prof. & Head



ECE

1923-25 Wireless Laboratory setup

1928 Redesignated as ECE Section

1928-32 S R Kantabet
Asst. Prof. & Section i/c

1932-44 K Sreenivasan
Asst. Prof. & Section i/c

1946 Establishment of ECE Dept

1946-47 N B BHatt
Asst. Prof. & Dept. i/c

1947-59 K Sreenivasan
Prof. & Head

1959-69 S V C Aiya
Prof. & Head



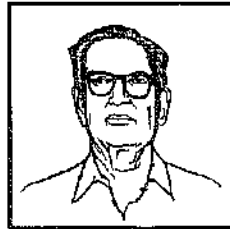
Fig. 5 (contd.)

ECE

1969-74 B S Ramakrishna
Prof. & Head/Chairman



1971 Establishment of Centre for
Information Processing (CIP)*
(B S Ramakrishna Prof. i/c
1971-79)



1974-77 N S Nagaraja
Prof. & Chairman

1974 Establishment of Centre for
Electronics Design and
Technology (CEDT)
+ (B S Sonde
Prof. i/c 1974-81)

1977-78 N N Biswas
Prof. & Chairman



1978-79 B S Ramakrishna
Prof. & Chairman



1979-81 R Chatterjee
Prof. & Chairman

ECE

1981-85 B S Sonde
Prof. & Chairman



1985-88 M Satyam
Prof. & Chairman



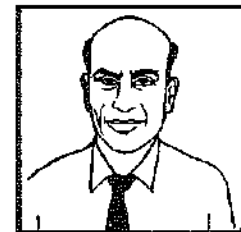
1988-92 A Kumar
Prof. & Chairman



1992-95 V U Reddy
Prof. & Chairman



1995- A Selvarajan
Prof. & Chairman



* CIP closed down in 1979 + CEDT now an independent centre.

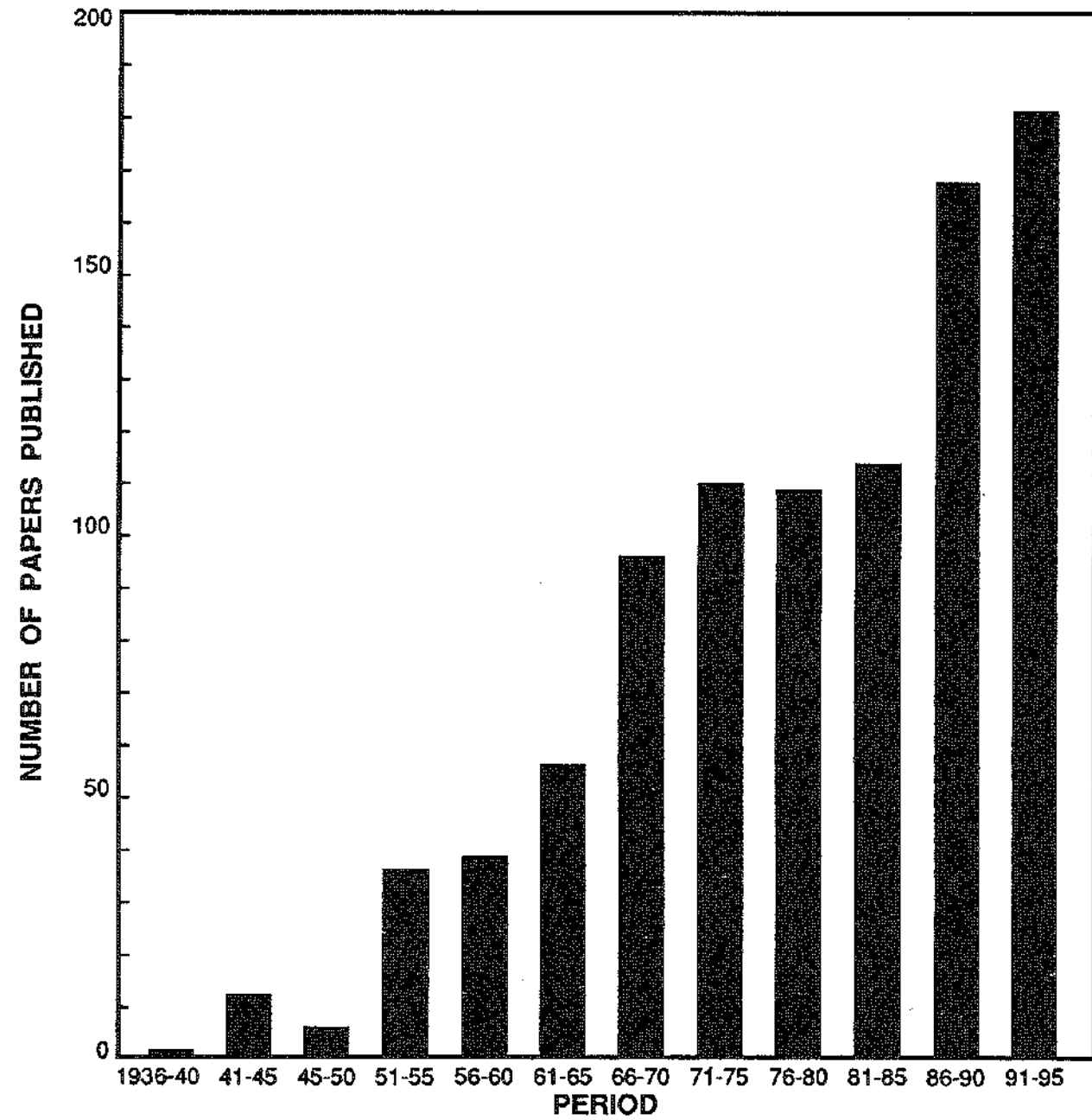


Fig. 6. Growth of ECE Publications

2. ECE - IN RETROSPECT

1. INTRODUCTION

1.1 Universities are places which make exacting demands on the intellectual resources of the students and the teachers alike. They are also the places which create bonds of friendship, mutual regard and affection which last a lifetime. On both these counts, we, the alumni of the ECE Department of IISc are singularly fortunate. While the high standards of achievement set by the founding fathers of the Institute and assiduously nurtured by succeeding generations have stood us all in good stead in our professional careers, the bonds of friendship have been a great source of joy. I am yet to meet an ECE student who does not have happy memories of the good days spent at the Institute or does not recall with genuine pleasure not only the scholarship of the teachers, but also their fads and foibles. The teachers cherish with equal warmth the contributions of students who passed under their guidance. The article, the material for which was called from various sources including several alumni, is a trip down the memory lane (See Box A) as well as a tribute to the ECE Department and the great traditions established by it.

2. SOME REFLECTIONS

2.1 Prior to the birth of the ECE Department, training and research in the areas of electronics and communication were carried out in the Department of Electrical Technology (ET). Students with a Bachelor's degree in physics and mathematics were admitted to the ET Department for a 3-year course leading to the award of the Certificate of Proficiency in Electrical Technology. About 10-12 of these students branched off for specialisation in communication in the 3rd year. A separate Department of ECE

was carved out of the ET Department in 1946 for reasons that are some what obscure and apparently not entirely academic. Professor S. Sampath, a distinguished alumnus, who was then a 2nd year student in ET, recalls a traumatic incident associated with the birth of the ECE Department. Professor S.P.Chakravarti tendered his resignation from the post of the Head of the Department of Electrical Technology as a mark of protest against the decision made by the Institute to split the ET Department and 'relegate' him to the post of the head of the newly created ECE Department. In his farewell speech, delivered in the presence of the then Director of the Institute, Sir J.C.Gosh, Professor Chakravarti stated his view that the unilateral decision of the Institute authorities to separate ET and ECE was a grievously wrong one that would prove detrimental to both the disciplines! What would have happened if the bifurcation had not taken place would never be known; but fortunately, the two Departments with separate identities have continued to flourish in a spirit of cooperation.

2.2 Dr. N.B.Bhatt, who later became the Founder Director of the Solid State Physics Laboratory at Delhi, took charge of the new ECE Department pending the appointment of the permanent head. Dr.Bhatt had come to the Institute from the M.I.T., USA, with a reputation for his work in electro-acoustics, and taught applied electronics besides the subject of his specialization. He advised the young Sampath, who had initially opted for the ET stream to change his option to ECE. The young man took the advice, fascinated as he was by the style of Dr.Bhatt's teaching and the quality of his mind, and has never regretted it. This is just one example of the qualities of head and heart of the great teachers of the Department that enabled them to win the trust and respect of

the students.

2.3 Another experience, again involving Dr. Bhatt, has been narrated by another old student Dr.D.L.Subrahmanyam, a leading consultant in electronics and electroacoustics. After getting his Master's degree in applied physics, Subrahmanyam joined the ECE Department as a research scholar and worked in 1946 on the project in electronic instrumentation under the guidance of Dr.Bhatt. The project was to design and build a logarithmic amplifier for displaying the exponential decay of sound in enclosures as a straight line on the CRT screen. The unit was built and named as Reverberograph. After completion of the project, Dr.Bhatt requested Sir C.V.Raman, then Head of the Department of Physics, to visit ECE Department for a demonstration. Much impressed by the demonstration, Sir C.V.Raman, in his characteristic enthusiasm, persuaded Dr.Bhatt and his student to write a paper for the Journal of the Indian Academy of Sciences within 48 hours to beat the deadline for publication. The paper was communicated to the journal by Sir C.V.Raman himself, and was published. This demonstration of mentorship and encouragement made a tremendous impact on the young Subrahmanyam and spurred him on to scale still higher peaks in his scientific career.

2.4 Soon after the formation of the ECE Department, the Certificate of Proficiency Course was converted to a Diploma (DIISc) course, and with this change, a system of evaluation of students' performance based on examinations and award of marks commenced at the Institute. The curriculum for the ECE course still had much in common with ET. In its early years, the ECE Department also shared many facilities like the

workshop, laboratories, and lecture halls with the ET Department which was then located in the building now occupied by the Department of Physics. By today's standards, the ECE Department then was miniscule in every sense—about 15 students in each year, 4 or 5 faculty members, and about half a dozen rooms which served both as laboratories and office rooms for the staff. In the words of Professor B.S.Ramakrishna, who served on the faculty of the Department with distinction for over 30 years, the annual budget of the ECE Department in those days would not fetch today a lunch for an international seminar it hosts. Yet, this small corner in Bangalore attracted some of the choicest students from all over the country. The process for selecting the students was quite simple. At that time there were some 20-25 universities in India, and there was some kind of a fuzzy grouping of them into north, south, east and west zones. The top-ranking B.Sc.(Hons) or B.Sc. students of each zone were selected and offered admission. Much of the teaching was in general engineering subjects, and communication engineering subjects figured only in the final year. The utmost importance was attached to the conduct of laboratory experiments. Students had plenty of homework to do; but there were few examinations, possibly one in each subject at the end of the year. A great deal of importance was also attached to the practical training programme which occupied a substantial part of the summer vacation every year. The most common training centres, which were also the places where most students eventually found employment, were All India Radio, Overseas Communication Service, Army workshops, and later government factories like BEL, ITI, and HMT, and R&D establishments such as LRDE, CIL, and NAL. After the completion of the 3rd

phase of practical training, the students got the Diploma DIISc(ECE). Being an offshoot of the already well-established DIISc in ET, there was no difficulty with regard to its recognition. Mr. M J Viswanathan, who belongs to the 1954 batch, vividly remembers the interviews conducted on 8th April 1954 in the library tower for the post of Technical Assistant in AIR. He and most of his classmates were selected and given postings. After a distinguished career in AIR/DD, one example of a few thousand success stories of the ECE Department. Mr.Viswanathan retired as Chief Engineer in October 1989.

2.5 The outstanding feature of the DIISc course, and perhaps of all courses offered by the Institute at that time, was the relaxed atmosphere. The students must have found the absence of tension that goes with the system of frequent examinations, and the presence of an excellent library, good residential and recreational facilities, delicious food, and a salubrious climate, far more invigorating intellectually than the competitive atmosphere of today. No wonder that many students considered life at the Institute was like living in Paradise. The scholarship, enthusiasm and dedication of teachers like D.J.Badkas, H.N.Ramachandra Rao, N.B.Bhatt, K.Sreenivasan, S.K.Chatterjee, and later S.V.C.Aiya, B.S.Ramakrishna, S.Sampath, N.S.Nagaraja and N.N.Biswas made a tremendous impact on their minds. They were also enthused by the fact that the alumni of yester-years were in good positions and known to be doing creative work in several prestigious organisations. Admittedly, the students then worked less hard than their present-day counterparts, but they went out of the Institute exuding confidence that they could handle any job that might be assigned to them.

2.6 The general staffing pattern of the Institute until about the mid-sixties was one Professor one or two assistant professors, and a few lecturers in each department. The professor was, naturally, the head of the department and had complete sway over its management. Professor K.Sreenivasan, who had been in charge of the ECE section of the ET Department for 12 years, took charge as the first Head of the ECE Department in 1947, after the brief stint of Dr.N.B.Bhatt. Professor Sreenivasan was a multifaceted personality who defies categorisation in conventional terms. He was fond of saying, 'Research is an integral part of the life and work of the Department', and then he would say almost in the same breath, 'Research is your own business, but teaching is our moral responsibility'. He also never lost an opportunity to declare that he had not done any research for ages. Notwithstanding these contradictions, his phenomenal dedication to work and loyalty to the Institute are undisputed. It is known that, when his father died one morning, he performed the cremation ceremony and came to the Department to resume his work. None of his students can ever erase from their minds the image of Professor Sreenivasan, clad in a spotless white khadi suit, standing at the entrance to the ECE Department at 6.28 every morning, for he used to conduct his classes between 6.30 and 8.00 in the morning, six days a week. He was very keen on his students having a firm grasp of the fundamentals. Series and parallel resonance was one of his favourite topics, and he would insist on the students drawing the graphs with different LCR values.

2.7 Professor Sreenivasan was greatly interested in new technical developments. He had many friends among the officers of the Royal

Air Force (RAF), mostly Cambridge graduates, working in radar and communication. They would meet him in the Department frequently during the II world war, prior to the formation of the ECE Department. He was very keen that Indians should learn about radar, called 'radio location' in those days, the technology of which was still top secret in India. So he advised his students to join the Air force. Many students of the 1943 batch including N S Nagaraja, who later became a professor in the ECE Department, took his advise and joined the Radio Location branch of the RIAF. Professor Nagaraja received training in radar both in India and in Britain during the war and later served in the Civil Aviation Department of the Government before joining the faculty of the ECE Department in 1954 and working there until his retirement in 1979.

2.8 Professor Sreenivasan had an enormous interest in laboratory buildings, gardens, lawns and roads. During a short period when he was the acting Director of the Institute, he got all the Institute roads metalled and tarred. He would ride on a steam-roller to ensure that the roads were made to his satisfaction. He is said to have remarked once that the Institute, like the earth in Hindu mythology was carried on the shoulders of eight persons. The list of eight did not include any teachers or senior administrators; but, contained mainly names of service staff. One of the names on this list was that of Mr. V Ramachar, a retired engineer who was employed to look after the maintenance of roads and buildings of the Institute, and who executed the roads project to the professor's expectations. Another person on this list was Mr. R Vijayendra, a draughtsman in ECE Department who retired recently after nearly 40 years of service. Professor Ramakrishna recalls the skill with which Mr.

Vijayendra converted sketches of any type-graphs, circuit diagrams, building or machine drawings-into masterpieces of drawings fit for the most demanding printers in the world. Numerous drawings of Ph.D thesis, technical papers and design documents in the Institute archives bear testimony to his superb draughtsmanship.

2.9 A Review Committee headed by Professor Alfred Egerton visited the Institute in 1948, two years after the formation of the ECE Department. This committee recommended the closure of the 3-year DIISc (ECE) course citing the availability of such a course at other locations in India! It recommended concentration of effort in postgraduate teaching and research in the emerging areas of radio and radar. It also noted the very meagre and mostly outdated equipment and facilities as the reasons for low research intensity in the Department. Obviously, the Institute authorities decided not to act on the recommendation to close the DIISc (ECE) course, and with good reason. The next Review Committee in 1955, which was headed by Prof J C Ghosh, came out strongly in favour of continuation of the course by recommending a doubling of the intake of students to meet the growing demand in the II Plan period. This Committee noted the high reputation of the course and commended the excellent quality of training as a strong foundation for postgraduate studies. It also noted an upswing in research activity in ultrashortwave and microwave engineering, radio wave propagation, directional antennas, pulse techniques, line communication and acoustics.

2.10 The ECE Department moved into its present building in 1951. The site for the Department building was chosen with the

intention of locating it far away from the High Voltage Engineering laboratories. A Second and probably unintended benefit of this location has been the extremely quiet and unpolluted ambiance. Professor Sampath recalls an amusing incident that occurred during the ceremonial inauguration of the new building by Prime Minister Pandit Jawaharlal Nehru. The Department had set up two demonstrations for the Prime Minister's viewing during the visit: Vibration patterns of Indian musical drums, resulting from a classical piece of research by Professor B.S.Ramakrishna, and an early warning radar set, reclaimed from military equipment used during the war, that could display echoes from the Nandi Hills, located about 50 km away from Bangalore. As the Prime Minister was watching with interest the chalk patterns on the musical drum, Smt. Indira Gandhi, who had accompanied her father, picked up an attenuator pad lying on the table and asked the Director, Prof M.S.Thacker, who was standing nearby, what it was. The latter, without batting an eyelid, said 'part of a radar set'! He did not have to explain how a radar component had found its way into the Acoustics laboratory.

2.11 A significant event in the mid-1950's was the visit of Professor V.C. Rideout from the University of Wisconsin, USA, as a Visiting Professor to the ECE Department under a programme called Technical Cooperation Mission. He taught courses on servo-mechanisms and analog computers during his stay. More importantly, he introduced analog computers as a new line of work. With the help of two faculty members N.S. Nagaraja and S Sampath, he designed and built India's first analog computer PREDA (Philbrick-Rideout Electronic Differential Analyser). V. Rajaraman,

who was a research scholar at that time, obtained his M.Sc degree by research for his work on PREDA under the guidance of Professor Nagaraja.

2.12 Another distinguished visitor to the Department during this period was Professor Norbert Wiener. He paid a week long visit in December 1955 and delivered a series of six lectures on information theory. Mr. S K Lakshmana Rao, a faculty member in the Department, was assigned the task of taking full notes of the lectures. This series of lectures was the forerunner to the course on Information Theory introduced in the curriculum of the Department and also to the information theoretic study of six Indian languages carried out by Dr B S Ramakrishna and his colleagues.

2.13 A postgraduate course DIISc(PG) in Electronics Engineering/Ultrashort and Microwave Engineering/Line Communication Engineering for DIISc/B.E. degree holders in ECE was started in the Department in 1956. It was the first postgraduate course in ECE in India, and comprised advanced level courses, project work, and industry/R&D laboratory training. Soon thereafter the Institute attained the status of a deemed University and DIISc and DIISc(PG) were rechristened respectively as B.E and M.E. The introduction of the postgraduate courses brought capital grants for the purchase of equipment and additional faculty positions. By the end of the decade, the ECE Department had about 10 faculty members. From time to time, there were also visiting professors from abroad. A full-fledged Department of Mathematics also started functioning in the Institute in the mid fifties, and mathematical instruction became a regular feature of all courses in engineering.

2.14 By the close of the decade of fifties, research had taken roots in the ECE Department in the areas of electronics, acoustics, microwaves and analog computers; but it was still largely confined to the faculty. Most of the students who joined for research left as soon as they got a job or a fellowship abroad. There was no agency to sponsor academic research or even applied research, the sole exception being a grant of Rs.1 lakh (a very tidy sum in those days) by Mr. J.R.D.Tata for research promotions through publications at that time, since research and publications were not the hallmarks of distinction in engineering. The main motivation for research was curiosity and the thrill of discovery, and perhaps a conscious or subconscious desire to achieve fame and recognition. With some people, research was a passion or a way of life, providing immense internal satisfaction. How else can one explain a phenomenon like Professor S.K.Chatterjee sitting at the same table in the library for 50 years and poring over journals past the age of eighty?

2.15 Professor Sreenivasan retired in 1959 after more than 30 years of service at the Institute. After a short gap of about 1 year, he became the Director of the Madras Institute of Technology where he served for another 13 years. Physically and mentally he remained much the same until his death in 1993 at the age of 94. There is no doubt that he loved the Institute like nobody else before or after him. He bequeathed all he had to the Institute.

2.16 Professor S.V.C Aiya took over as the Head of the Department on the retirement of Professor Sreenivasan while Professor Sreenivasan made his mark during his tenure at the Institute, the reputation of Professor Aiya as

an experimental physicist in electronics and radio science, and as an inspiring teacher and educationist preceded his arrival at the ECE Department. Before coming to the Institute, Professor Aiya had planned and set up the Department of Electrical Communications at the College of Engineering in Poona, started the immensely popular B.E course in Telecommunication Engineering, and initiated research in atmospheric radio noise and its interference to radio communication. In many ways he was a strong contrast to Professor Sreenivasan. He was a colourful person, witty and controversial, who never hesitated to call a spade 'a bloody spade'. He had a zest for life, and for cigars. According to Dr N S Jayant, one of several illustrious students of Professor Aiya, the cigars left a long log-normal trail behind him, with an attenuation of a mere 1dB/km/hour. The lectures of Professor Aiya were a lively affair, interspersed with "physical explanation" and proverbs in four different languages. He was known among his students as O.M or 'Old Man', and the old man certainly taught the youngsters a trick or two. Perhaps the most celebrated of these are two rather conflicting games, viz., 'kite flying', and 'Hitting the nail on the head', as he called them. Dr Jayant has confessed that playing them has proved crucial for his survival and sanity.

2.17 One of the first concerns of Professor Aiya was that research should not remain confined to the faculty only and that training in research must form a part of the work of the Department. He had an instinct to discover talent among students long before it would flower, and he knew how to nurture it. Proof of this is the glittering array of 18 Ph.D. students whom he guided at a time when Ph.D in engineering was a rare phenomenon.

The list of his Ph.D students, comprising such well-known names as N.Seshagiri, N S Jayant, A Prabhakar, M Satyam, and BS Sonde, reads like a veritable who's who in electronics and communication and covers an amazingly wide spectrum of expertise from electronic devices and circuits to communication and information technology. Professor Aiya also encouraged other members of the faculty to take research students. There was a significant growth in the number of research students who stayed long enough to complete their Ph.D., and soon research activity began to flourish in the areas of electron devices, circuits, instrumentation, microwaves, antennas, and acoustics, in addition to atmospheric radio noise. New laboratory buildings for research in acoustics and electron devices came up, and the Department expanded from its original single building to the present complex of three buildings. When the duration of the M.E. course was increased to 2 years in 1963, a research/design oriented project became a part of the curriculum, and the research interests of the faculty began to get reflected in the project work of the M.E. students also. Professor John Brown of the Imperial College of Science and Technology, London, and President of IEE, London during 1979-80, who visited the ECE Department several times during Professor Aiya's tenure in his capacity as the first Head of EE Dept at IIT/Delhi has the following to say, 'It would have been very easy for Professor Aiya to have concentrated entirely on his own personal research, but he chose the more difficult, and ultimately the more rewarding, route of using his energies to encourage others to establish new lines of research. A measure of the success of a laboratory director is not the quality of his own work, but rather the extent to which he has motivated his staff to operate at a level to which

they would not themselves have aspired. Professor Aiya's rating on this measure must indeed be a high one'.

2.18 During the sixties there was a great demand in the country for trained Ph.D students as well as experienced faculty members from several newly established research laboratories and IIT's. The Institute was naturally the hunting ground for scientific talent. Many faculty members, particularly at the middle level, who were uncertain about the prospects of their advancement locally, began to leave the Institute. The initial reaction of the Institute management was that supplying trained teachers to the country was as much a function of the Institute as supplying trained Ph.D students. But, it was soon found that by the time the Institute decided to recruit a candidate at a certain level, he got a post at the next higher level at other institutions. The Institute authorities realized that the Institute faculty must be provided opportunities to advance their career at the Institute itself. Thus began the scheme of merit promotions which brought with it the entire paraphernalia of periodic assessment, peer review, etc. Tenure appointments gave way to 5-year contract appointments renewable upon satisfactory performance. The atmosphere in which the good and the mediocre coexisted had disappointed once and for all.

2.19 An important fact of life during Professor Aiya's time was the ECE Club. Professor Aiya encouraged the students to organise get-together and picnics and participated enthusiastically in these activities. The club continued to function for a few years after Professor Aiya's departure and then gradually folded up.

2.20 The year 1969 marked the end of an

important period for ECE Department. In this year, Professor Aiya left the Department to take up the Directorship of NCERT at Delhi, and Professor S K Chatterjee retired leaving his wife Rajeswari Chatterjee and student Dr. Anand Kumar to carry on the legacy of teaching and research in electromagnetics and microwaves. Professor S K Chatterjee continued his labour of love at the library of the Institute for more than two decades thereafter, almost until his last days. His profound knowledge of and passion for his subject were reflected in the animated discussions that he often had with his students and colleagues. The intensity of his devotion to Science was marked by the warmth of his affection for students. He must have been aware of the difficulties of most students in unraveling the mysteries of an arguably difficult subject like electromagnetic theory, for he was rather generous in his evaluation of answer scripts. But this generosity led to the circulation of some amusing stories in the student community. Gullible students were often advised by some of their seniors that the number of marks awarded by Professor Chatterjee were directly proportional to the number of filled pages in the answer script. One story, which must be taken with more than a pinch of salt, was that in one examination conducted by him the highest marks were scored by a student who submitted a fat bunch of papers stapled at both ends and covered with writing only on the first and the last pages. Such are the joys of academic life!

3. A NEW ERA

3.1 Professor B S Ramakrishna succeeded Professor Aiya as the Head of the ECE Department. But soon thereafter, the position of the Head of the Department was replaced by the

Chairman of the Department. A Committee of Professors headed by the Chairman started looking after the various functions which were earlier managed more or less singly by the Head of the Department. While Professors Sreenivasan and Aiya were the architects of the ECE Department during its formative years, Professor Ramakrishna, who had been a part of the Department almost throughout this period, sustained and consolidated its growth. Professor Thomas Kailath, Visiting Professor from Stanford University and a long-standing friend of ECE Department, and Professor Ramakrishna were instrumental in procuring for the Department a large long-term research grant from the Ministry of Defence for starting a research centre called Centre for Information Processing (CIP) in 1971. The CIP, headed by Professor Ramakrishna, had a mandate to undertake research projects in the areas of acoustical and speech signal processing, optical signal processing, and surface acoustic wave devices. Another project on microwave tunable devices based on YIG single crystals was also taken up at a later stage, in collaboration with some faculty members in the Department of Inorganic and Physical Chemistry. Although the CIP ceased to exist in 1979 due to the stoppage of grants, research in the areas of signal processing and photonics had taken firm roots by then, and continued to flourish in the Department. In the meanwhile, another grant for a research project in underwater acoustics had been received from the DOE (Department of Electronics). These projects heralded the era of sponsored research. Since then, sponsored research has grown considerably in strength and has now become a major source of funding for the Department (See Table 1).

3.2 The early seventies witnessed a massive

influx of faculty members into several departments of the Institute, including ECE. Among those who came to the ECE Department on this wave were N N Biswas, T A Raju, S V Pappu, P S Naidu, D N Bose, S G Joshi, V K Bhargava, A Selvarajan, and P S Moharir. Several of them came from outside India following the visit of a search committee consisting of the Director, Professor S Dhawan and a few senior Professors of the Institute to several universities in the U.S.A, UK, and Canada. Some of the new entrants joined the regular faculty of the Department, while the others got appointed in the CIP and acted as adjunct faculty. They were a mix of engineers and physicists, in keeping with the tradition of the Department. The Department was enriched by their wide spectrum of expertise, new ideas, and varied personalities. Dr Joshi, in the traditional Indian dress of kurta and pyjama, with his ever-ready smile and his zest for Hindi, attracted the attention of one and all. He spoke chaste Sanskritised Hindi (à la the characters of the popular television serial Mahabharat), and took great pains to converse with everyone in that language. Several technical reports on SAW devices written by him in both English and Hindi are lodged in the departmental library. Ironically, after a stint of about 5 years in the ECE Department, he went back to U.S.A. Dr Bhargava regaled everyone with his witty remarks, irrelevant jokes and hearty laughter. Dr Moharir, a fresh Ph.D. from IIT Kanpur with a wide range of interests and a measure of diction, would always have the last word in any discussion. For Professor Biswas, it was a homecoming. He had already made his mark in the world of computers, and has continued to work in the same intense but quiet way after his return to Bangalore and even after his retirement. Professors Pappu and Raju, stalwarts in their

respective fields of optics and microelectronics, had contrasting personalities. While Professor Pappu could not tolerate incompetence and bureaucratic red tape, Professor Raju took everything in his stride with a shrug and a smile. Dr. Bose, who is now a Professor at the Materials Science Centre at IIT Kharagpur, recalls with pleasure his association with Professors Raju and Satyam in their joint efforts to build up the electron devices laboratory, and with Dr T S Vedavathy of ECE and Professor A R Vasudeva Murthy and Dr N Kutty of the IPC Department in the YIG project. Dr Bose had the privilege of 'looking after' Professor John Bardeen, Nobel Laureate and co-inventor of the transistor, when the latter paid a 3-week visit to the Institute. One of the pleasant memories of Dr Bose is about his 'brave deed' of participating in a tour of Kodaikanal with two bus-loads of students, organised by the ECE Club. The only members of the 'early seventies' group still with the ECE Department are Professors Naidu and Selvarajan, the others have either retired or left after staying here for varying periods of time. Professor Naidu, a geophysicist, and Professor Selvarajan, a specialist in optics, came in as custodians of the two extremes of the frequency spectrum. They also came from opposite ends of the globe. While Dr Naidu flew in all the way from Canada, Dr Selvarajan, just walked across from the Department of Physics, barely half a kilometer away.

3.3 A Centre for Electronics Design Technology (CEDT) was started in the Department in 1974 under an Indo-Swiss Agreement, with the support from DOE and UGC to train engineers and technologists for the electronics industry. The CEDT offered a postgraduate Diploma Course in Electronics Design and Technology primarily for

industry-sponsored candidates, and also undertook product design for the electronics industry. Nurtured by Professor B.S.Sonde in its early years, the CEDT became a model for other similar centres started elsewhere in the country and abroad. The CEDT moved out of the ECE Department after attaining the status of an independent centre in 1985, and the postgraduate diploma course was upgraded into an M.Tech Course in 1987.

3.4 Professor Ramakrishna was the architect of a major change in curriculum organisation that occurred in the Institute in 1970. The entire teaching work of the Institute was organised on the basis of the so-called unit system according to which each course carried a certain number of Credits (usually 3, but in some cases 2 or 4) proportional to the total number of effective contact hours. Every course was open, in principle, to every student of the Institute to take and count towards his/her credit. The average course load of a student was fixed at 16 credits per semester. Each department prescribed a set of courses as core or compulsory courses for students working towards a degree in that department. The students could make up the balance of Credits required for the degree by choosing courses of their liking. This system has proved so successful that it is still being followed with only minor variations. That it offers great flexibility to the students to design the curriculum according to their interest is obvious. It also offers the teachers the freedom to float new courses in tune with their research interests or to update existing courses to keep abreast of new developments. Thus, the students get exposed to new ideas, imbibe the research atmosphere of the Department, and are equipped to take up research/design projects in areas of current

interest.

3.5 Professor Ramakrishna relinquished the Chairmanship of ECE Department in 1974. He remained in charge of the CIP till the end, and in charge of the acoustics laboratory until he left the Department in 1980 to take up the Vice-Chancellorship of the University of Hyderabad. During his tenure of more than three decades in the Department, he successfully built up a school of research in acoustics. He made pioneering contributions to architectural acoustics. One of his proudest achievements is the acoustical design of the huge Centenary auditorium of Madras University, a masterpiece which made architects and builders in India aware of the importance of acoustical design.

3.6 Following professor Ramakrishna, the position of chairperson of the Department has been held successively by Professors N S Nagaraja, N N Biswas, R Chatterjee, B S Sonde, M Satyam, A Kumar and V U Reddy roughly for a period 2-4 years each and by Professor A Selvarajan who is the current Chairman.

3.7 The post-seventies period saw the march of the Department towards democratisation. Several factors contributed to this process. The abolition of the position of the Head of the Department meant that all important decisions affecting the Department were taken by a Committee of Professors instead of by a single individual. The introduction of the unit system gave faculty members freedom, within certain broad guidelines, to introduce new courses matching their research interests. The easier availability of grants from sponsored research projects (Table 1) meant that individuals had greater freedom in planning their research

programmes and goals. These changes gave better opportunities for individual talents to flourish, though at the cost of a certain degree of cohesiveness that marked the older dispensation. Democratisation also shifted the responsibility for the growth of the Department more to the individual faculty members from the Head of the Department.

3.8 The 3-year DIISc/B.E Course of the ECE Department has been one of its biggest success stories, as evidenced by the high proportion of top positions in the ECE field in academic institutions, R&D establishments, and industry held by the ECE alumni of the Institute. Admissions to this course were highly sought after. This state of affairs began to change when the University Grants Commission reduced the duration of the B.E course in other universities from 5 years to 4, while the duration of the B.Sc course continued to be 3 years. This meant that the number of extra years that a student had to put into get a B.E degree via the B.Sc.-B.E route as compared to the direct route increased from 1 to 2. The rapid increase in the number of institutions and universities offering courses leading to a Bachelor's Degree in ECE meant that fewer good students were willing to spend 2 extra years to get a B.E degree from IISc in spite of the high reputation of its ECE Department. The Institute responded to this situation in 1983 by replacing the post B.Sc. 3-year B.E course by a unique post B.Sc. 4-year M.E course, called the integrated M.E, thus reducing the disparity in duration at the M.E level from 2 years to 1 1/2 years. But this was still not enough to attract many bright students in a rapidly changing employment scenario, in contrast to the regular 1 1/2-year M.E Course (for graduates in engineering) which continued to attract the best

students. In order to optimally utilise the talent and resources of the Department, and to meet the growing demand from the industry for specialists in the areas of tele communication, signal processing and microelectronics, it was decided this year to close down the 4 year integrated M.E programme, and from 1997-98 start 3 new 1 1/2 year M.E Programmes in telecommunication, signal processing and microelectronic systems. The first of these courses will be run exclusively by the ECE Department, while the other two will be run jointly with the EE Department and the CEDT respectively.

3.9 In research, the areas of electron devices, circuits, communication, microwaves, antennas and acoustics have been cultivated by the Department for a long time. New areas such as signal processing, switching theory, communication networks, and photonics have been added to the list in recent years. The expansion of research activity has been helped to a great extent by several sponsored projects including major ones in hybrid microelectronics, telematics, microwaves, networking, photonics and ocean acoustics, funded by various agencies of the Government.

3.10 As one looks back at the years that have passed, one recalls vividly not only many old students and faculty members but also other members of the staff who served the Department with great devotion and loyalty. Messrs. G Selvappullai, Rangaswamy Iyengar and N Srinivasa Rao in the Office, Messrs L Abel, Namdev Rao, and U Sadananda Rao in the Workshop, the draughtsman Mr. R Vijayendra, Mr. Gopalan Nair and Mr. M Jani who operated the duplicating machine and also ran the popular

coffee club, and Mr. Hussain who was always busy with the ammonia printing machine, are known to many. They and many others like them were always ready with a smile to do that little bit of extra work whenever the need arose. For this, the Department must thank the founding fathers of the Institute who established the fine traditions that allowed all sections of the employees to thrive and give their best. The main ingredients of these traditions are academic freedom for the faculty and the students, concern for the welfare of the employees and an enlightened interpretation of rules and regulations.

3.11 While the Department has achieved a fair degree of success in its mission of training students and carrying out basic research, applied research is an area where its efforts have been sporadic and not so successful. In this context, it would not be out of place to recount an incident that occurred nearly 25 years ago. When the Indo-Pakistan war broke out in 1971, sanctions imposed by the western countries shut off the sources of supply of several vital components. A major electronics company looking for indigenisation of component manufacture approached the ECE Department for the development of quick heating cathodes required for RF pentodes used in military equipment. Professor M Satyam and his associates in the electron devices laboratory, known as the tube laboratory at that time, were asked to apply their minds to the problems and come up with a quick solution. They worked hard to understand the basic parameters controlling the heating time etc., and succeeded in designing and fabricating quick heating filaments. In the meantime the war was over and imports were freely available again. The giant electronic company quietly changed its requirement from a quick heating filament to

a quick heating pentode, which the Department was not in a position to supply. The effort of the preceding months culminated in half a dozen scientific publications (in reputed journals) on the transient characteristics of filamentary electron emitters, but the original objective of indigenous technology development remained unfulfilled due to the lack of support from the industry. Changing the attitude of indifference exemplified by this episode is a major challenge facing the Department and the scientific community in the country at large.

4. FUTURE CHALLENGES

4.1 As the Department crosses the landmark of 50 years and marches towards a new millennium, it is gearing itself up to meet a future full of new opportunities and challenges. The nation is currently in the throes of major and rather swift socio-economic changes, and the Institute cannot be immune to these. There is a greater need than ever before to make scientific research more relevant to the needs of the society. There is also a great pressure on institutions of higher education and research to generate more resources and to reduce their dependence on public funding. In other words, education and research must become more need-based and application-oriented. These demands appear at first sight, to conflict with our cherished ideal of academic freedom. But it is well to remember that every freedom is circumscribed by social responsibilities, and also that applied research does not curb the creativity of a scientist but only channelises it in a purposeful manner.

4.2 The challenge before the Department today is not only to find the directions in which its talents should be so channelised, but also find industrial

partners who are willing to enter into a mutually beneficial symbiotic relationship with it. The Department has recently taken several initiatives in the pursuit of this objective. One such initiative is the decision to start the new M.E programmes. An Industrial Associateship programme has been launched to increase interaction between the Department and industries in the area of electronics, communication, and information technology. Discussions held with some industries and other potential sponsors for taking up applied research projects have started bearing fruit. Many of these projects will call upon several individuals to pool their talents in pursuit of a common goal, and everyone concerned will have to learn the art of participation in and management of such cooperative group activities-But making pioneering contributions to education and research is not a new experience to the Department. There is every reason to believe that the latest efforts will succeed in establishing new paradigms of cooperation between academic institutions, research organisations and industry.

Compiled and prepared by Prof G V Anand
Contributions received for this chapter from
faculty members-
past and present as well as from alumni are
gratefully acknowledged
ECE Golden Jubilee Organizing Committee.

A. DOWN THE MEMORYLANE : REFLECTIONS BY PAST FACULTY & ALUMNI

1. Prof B S Ramakrishna (Chairman of Dept - 1969-74)

- I consider myself fortunate in knowing the ECE Dept for 47 out of the 50 years it has completed;
- By today's standards, the ECE Dept in the 40's and 50's was miniscule in every sense - about 15 students in each year and some 4-5 rooms which served both as labs and staff offices. Yet, this small corner in Bangalore attracted some of the choicest students from all over India - for some mysterious reason;
- When I joined the ECE Dept in 1948, Prof K Sreenivasan was the Head and Mr S K Chatterjee, Mr H C Basak and I constituted his team. Prof Sreenivasan was a multifaceted personality and defies categorization in conventional terms;
- Prof S V C Aiyar who succeeded Prof Sreenivasan as Head of the Dept, was in many ways a strong contrast to Prof Sreenivasan. He had an instinct to discover talent in students long before it would flower and he knew how to nurture them;
- As IISc moved into the 1970's major changes also took place in curriculum organization, research direction, administration, funding etc. While these changes gave better opportunities for individual talents to flourish, there is no doubt that the cohesiveness of the Dept suffered; However, the Institute remains the best employer in the Country;

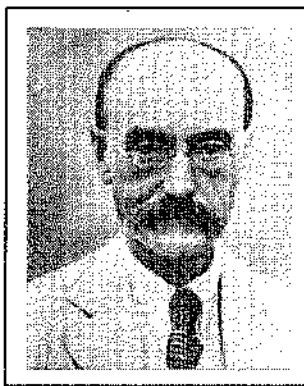
2. Prof N S Nagaraja (Chairman of Dept . 1974 - 77)

- I was a student in the ET Dept specializing in ECE during 1940-43. In those days, the Dept was located in the present physics building;
- Prof K Sreenivasan handled the main communication subjects; Dr Saroj Datta taught us measurements;
- Those were the years of World war II and there was a lot of dislocation owing to many disturbances. But, Prof Sreenivasan had many friends among the RAF officers, who used to visit the Dept. Prof Sreenivasan was greatly interested in technical developments, particularly radar, the technology of which was still secret at that time. He was therefore keen that the faculty and students should learn and master this new subject;
- When I rejoined the Dept as Lecturer in 1954, there were many changes. New lines of work were started - particularly Analog Computer under Prof V C Rideout, which group I joined. I was involved in the development of PREDA and V Rajaraman was associated with me as a research student in this project;

3. Prof S Sampath (Faculty Member 1953-61)

- I was a student of the Dept during 1945-48, the transition period from ECE Section to ECE Dept. Even in the formative years, ECE Dept had begun to be looked upon as a model and glowed with the brilliance of a lamp destined to light other lamps in the Country;
- I spent 8 happy years in the Dept as a faculty member, teaching several courses, assisting in the setting up of new laboratories and guiding students in their project work ;
- I recall with pleasure the opportunity that I had to associate with Prof V C Rideout;
- I have fond memories of the glittering array of students like M M Sodhi, B S Atal, O P Gandhi, S C Gupta, V Rajaraman, T K Ramaswamy, K S P Kumar, R P Wadhwa and N S Jayant, to name a few;

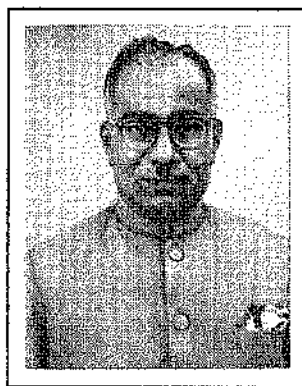
HEADS OF ET DEPT & ECE SECTION / DEPT



Alfred Hay



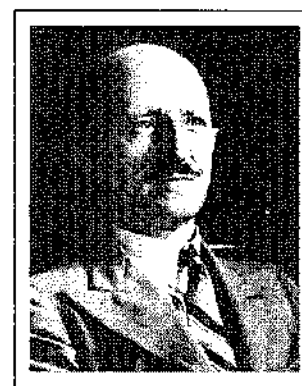
J K Catterson-Smith



S R Kantabet



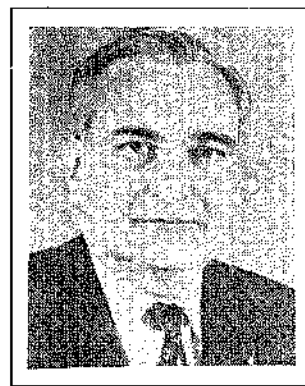
F N Mowdawalla



K Aston



S P Chakravarti



N B Bhatt

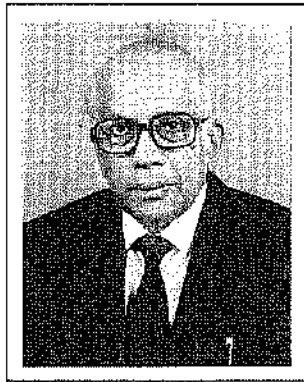


K Sreenivasan



S V C Aiya

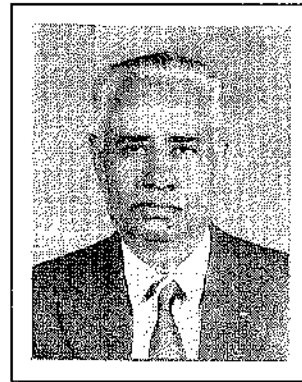
CHAIRMEN OF ECE DEPARTMENT



B S Ramakrishna



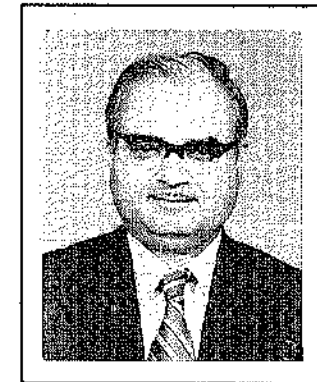
N S Nagaraja



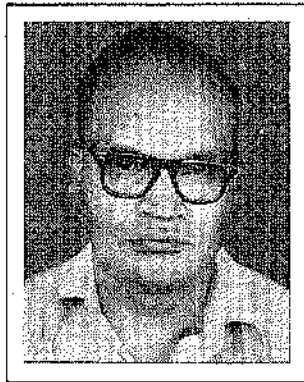
N N Biswas



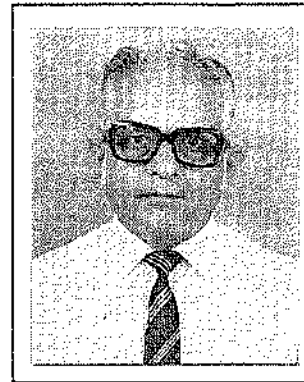
R Chatterjee



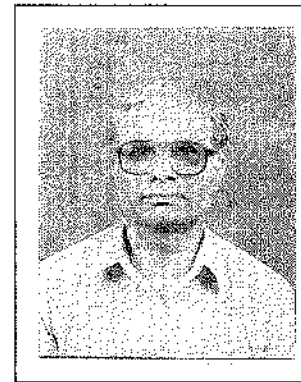
B S Sonde



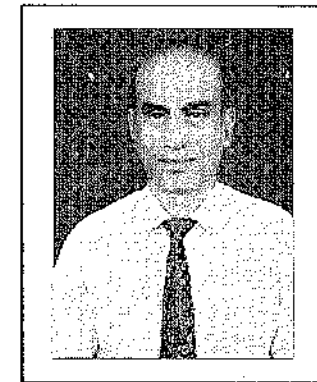
M Satyam



A Kumar

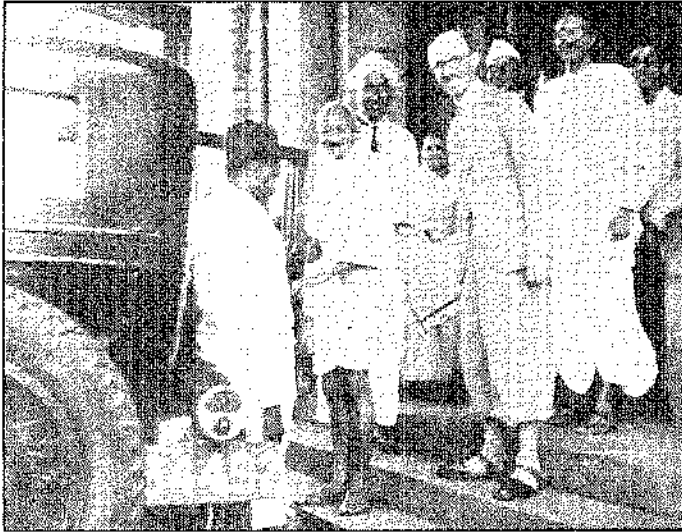


V U Reddy

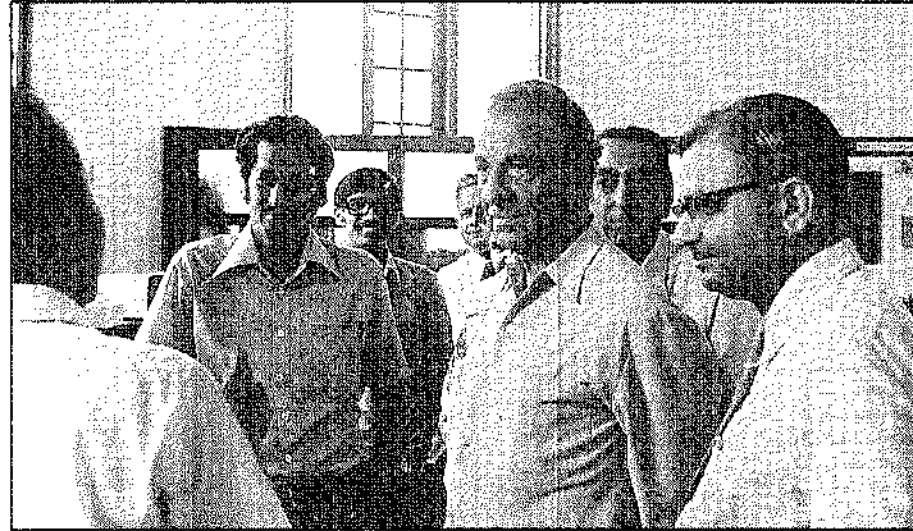


A Selvarajan

DISTINGUISHED VISITORS



Mahatma Gandhi's visit to the Department of Electrical Technology (1936) Prof. Kenneth Aston and Sir C V Raman are also seen in the picture.

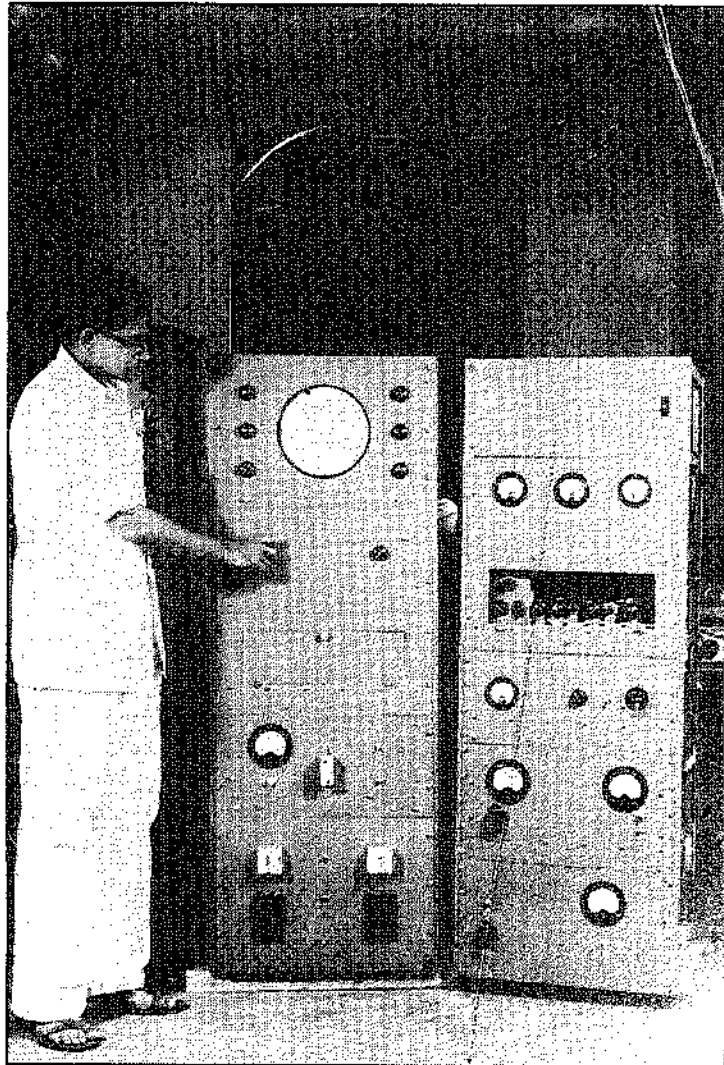


Mr J R D Tata's (President of the Court) visit to the ECE Department (1978); also seen in the picture is Mr J J Bhabha (second from right).

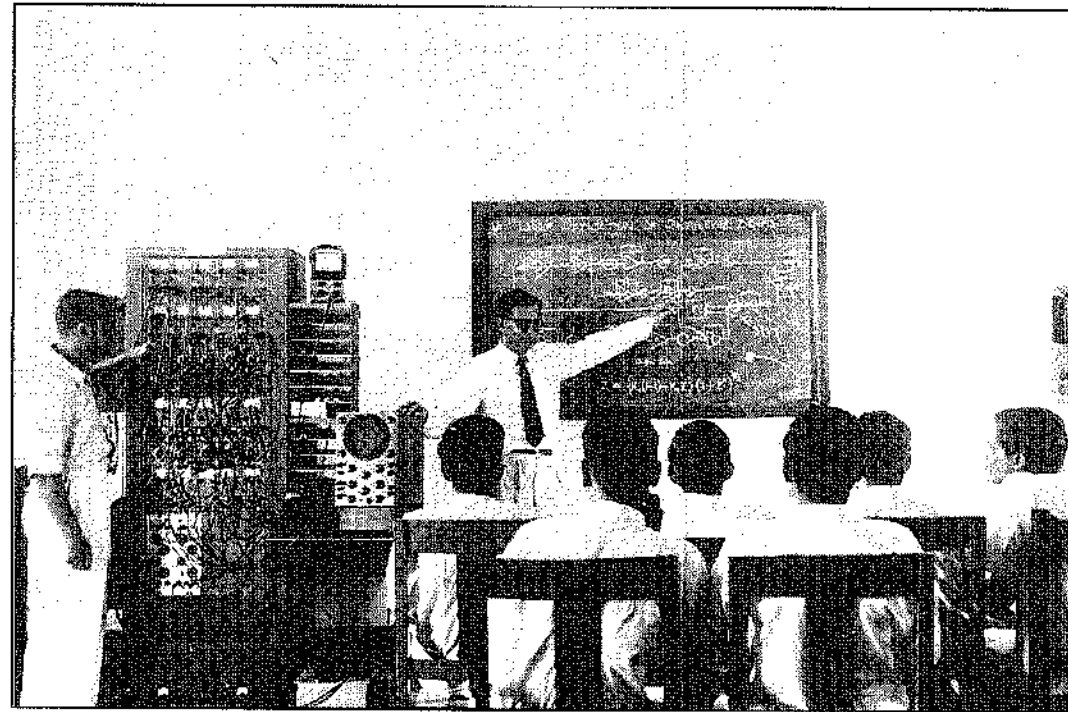


Jawaharlal Nehru's visit to the Institute (1948) for laying the foundation stone of the Department of Electrical Communication Engineering. Sir A Lakshmanaswamy Mudaliar (extreme left) and Sir V N Chandavarkar (second from left) are also seen in the picture.

ECE IN THE 1950s



Automatic Ionospheric Recorder



Electronic Differential Analyzer (PREDA)