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A SURVEY OF RESEARCH AND DEVELOPMENT IN ELECTRONICS AND TELECOMMUNICATION IN INDIA OVER A CENTURY (1850-1950)*

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The article summarises the research and developmental work in the area of electronics and telecommunication carried out in India during the period 1850-1950. Starting with the early development of telegraph communication around 1850, the progress in telegraph and telephone communication, broadcasting and wireless communication is recorded. In education and research, the facilities created through various institutions and laboratories are discussed. Research papers in specific fields are listed in Appendices I and II. It is observed that major research centres have been at the universities of Allahabad, Calcutta, Dacca, Banaras and the Indian Institute of Science, Bangalore. Some general comments on the status of research are also included.

INTRODUCTION

The era of telecommunication started with the invention of telegraphy by Henry Joseph in 1831 and of magneto-telephone by Graham Bell in 1875. Electronics, as related to telecommunication, was born with the invention of audion, a three-electrode valve, by De Forest in 1906. During the latter half of the nineteenth century, most of the basic principles of communication and electronic devices were known. The first half of the twentieth century saw the development of these theories into useful devices, instruments and systems, leading to global communication through wireless and cables, broadcast radio and television, automatic exchanges, radar and solid state devices. Control theory and information theory then led to a better understanding and optimization of large-scale systems. A detailed account of the global developments in wireless communication and electronics during the 19th and the first half of the 20th century has been recorded.[1,2].

In the Indian context, the Indian Telegraphs Department was established in as early as 1853, and this was later expanded to form the Post and Telegraph (P & T) Department of the Government of India. Both cable and wireless communication were handled by the P & T Deptt. The telegraph circuits to Persia and Near East

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were operated by the Indo-European Telegraph Department, and the Cable Companies operated the submarine telegraph cables in the Indian waters. During 1925-45, the telecommunication in India grew further and the total responsibilities were shared by (i) Indian P & T Dept. (ii) All India Radio (AIR), and (iii) the Indian Radio & Cable Communication Co. (formerly I. R. T. Co.) for communication with foreign countries. The Ministry of Defence had their own telecommunication branches and some private firms started assembling radio sets. During the post-war period (after 1945), new departments, *e.g.* Civil Aviation Department (Communication Branch), Overseas Communication Services, and a few public sector factories were established. Many new educational and research facilities also helped in the process of expanding telecommunication activities in the country.

As part of the INSA programme on "History of Science and Technology in India", the author has collected information on the research work done in India during the period 1850-1950 and the present article is a brief report based on this information. The early work during 1839-1923 relates mostly to the telegraph communication established in the country[3] and the relevant references have been listed in Appendix I. During the period 1924-1950, a number of original research in the major areas of (a) Telecommunication and Broadcasting, (b) Ionosphere and Propagation, (c) Electronic Circuits and Systems, and (d) Materials and Components, were conducted in the country. The related published research papers have been listed in Appendices II-A, II-B, II-C and II-D, respectively. Many of these papers have also been referred to in the excellent article on "Research in Electrical Communication in India since 1865" by S. P. Chakravarti.[4] Other sources from which the references of the papers have been collected are (a) *Science and Engineering Abstracts* published by IEE (London) ; (b) *Abstracts and Refrences in the Proc. I.R.E. (USA)*, (c) *Transactions of the A.I.E.E. (USA)*, and (d) *Indian Journal of Physics.*

EARLY WORK (1839-1923)

Within a few years of the invention of telegraphy in 1831,East India Telegraph Co. laid the 20-mile long telegraph line in India in 1838, and this was the first long line ever constructed in the world[3]. The telegraph line was extended to 10,000 miles by 1858, as reported in the 'General Report of the Electric Telegraph in India' by Sir W. O' Shaughnessy, FRS, the founder of the Telegraph Dept. of the East India Co. He also laid a submarine cable of 7000 ft. across the river Hoogly in Calcutta, as reported in the *Journal of the Asiatic Society*, (Bengal) in 1839 [I – 11]. Calcutta-Diamond Harbour line commenced operation on Oct. 4, 1851, and the following trunk lines were completed by 1856 :

(a) Calcutta-Agra-Delhi-Peshawar,
(b) Agra-Bombay-Madras,
(c) Calcutta-Dacca,
(d) Calcutta-Berhampore (Orissa).

For transoceanic telegraph circuits, Aden-Bombay (1856 miles) and Madras-Penang (1510 miles) undersea telegraph cables were laid in 1870 by Eastern Telegraph Co.

For telephone communication, the first manual telephone exchange was installed in Calcutta in 1880. The Indian Railways introduced telephone connections between railway stations by 1886. Automatic telephone exchanges were introduced at Shimla, Lahore, Amritsar, Ootacamund and Conoor by 1922. Radio communication was under the control of the Army initially and later on, this was transferred to the P & T Dept. However, no radio broadcast was introduced till 1927.

During the period under review, great discoveries and inventions were made in England, continental Europe and USA, which led to the development of telegraphy, telephony, telephotography, radio communication and broadcasting. In India, there were hardly any research facilities at that time. Even then, a number of outstanding research work was carried out mainly in the areas of telegraphy, microwaves and wave propagation. Since telegraphy was the main mode of electrical communication till 1900, most of the investigations related to the problems in telegraph transmission were conducted by the engineers of the P & T Dept. and the Railways. Notable among them were G K Winter, W E Ayrton, E O Walker, Williams, and L Schwendler. The papers published by them have been listed in Appendix I. After the World War I, Edmunds undertook an investigation of the field strength of several longwave telegraph transmitters in India and reported the results in *Electrician* [I - 8]. His results were very valuable since such measurements were made for the first time in the country and they dealt with the variation of field strength at daylight and darkness hours.

Pioneering work in the area of microwaves and on the properties of EM radiation was carried out by J C Bose in the Presidency College, Calcutta, during 1895-1900 [I-4]. With the help of indigenously fabricated instruments, he generated E M waves at wavelengths of 6 mm, 1.2 cm and 2.5 cm and performed the following experiments :

(a) selective absorption, (b) laws of refraction using sulphur and ebonite, (c) total reflection and critical angle using glass prism, (d) double refraction and polarization. He delivered a lecture with demonstration on this topic at the Royal Institution, London on 29th Jan 1897. The first observation of the effect of visible light (and infrared also) on galena, tellurium and other materials was made in Calcutta by J C Bose. He also constructed a light detector and called it *Tejometer*. However, his work did not get sufficient publicity at that time and the long-wave communication held the field for many years to come. The above pioneering research work by both Indian and British Scientists resulted in a few publications as listed in Appendix I.

TELECOMMUNICATION SERVICES (1922-1950)

Automatic telephone exchanges were introduced in India as early as 1922 (Strowger automatic switch was invented in 1889). A 5-digit Auto telephone

exchange was installed in Bombay by A T M Co. of U K in 1924. In 1927, Overseas wireless telegraphy with U K, South Africa and some other countries was established with the installation of radio transmitters and receivers in 16 m and 34 m bands. Bombay-Kirkee-Dhond carrier system for multichannel telephony was installed in 1934 by Ericsson Co. for Indian Radio and Cable Communication Co. Ltd. Single channel and 3-channel carrier systems with repeater stations connecting important cities such as New Delhi-Bombay, New Delhi-Calcutta, etc., were installed by 1935. Telecommunication facilities were extensively expanded during 1943-46 (World War II) jointly by the Defence Services Communication Board and P & T Dept. to meet the requirements of the Eastern (War) Front.

In 1927, sound broadcasting was started simultaneously in Calcutta and Bombay by a private company, the Indian Broadcasting Co. The Government of India took over radio broadcasting in 1930 and All India Radio (AIR) was established in 1936. The call sign of AIR, *Ākāśvāṇī,* was coined by the poet Rabindra Nath Tagore at Madras. At the time of independence in 1947, there were only six medium-wave radio stations at Bombay, Madras, Calcutta, Delhi, Lucknow and Tiruchi, covering only 25% of area and 21% of population of the country, and also four short wave stations at Bombay, Delhi, Calcutta, and Madras. Few small transmitters were also in operation in some princely states.

In the pre-war period, the use of wireless communication in aviation and for guidance of aircrafts was only nominal. During the war, however, major airports in the country, particularly Dum Dum airport in Calcutta, were equipped with sophisticated electronic equipment, such as Instrument Landing System (ILS), Radar, VHF Direction Finder, *etc.* to meet the operational requirements of the Eastern Front (of the Defence Department). After 1945, the Civil Aviation Deptt. of the Government of India had a full-fledged communication branch and a Development Unit was entrusted with further imporvements in aviation electronics in the country. In addition to private radio manufacturing firms, a few telecommunication factories, *e.g.*,Indian Telephone Industries, Bangalore, Hindustan Cables Factory, Burdwan, and Bharat Electronics Ltd. Bangalore, were planned in the public sector to manufacture sophisticated equipments indigenously.

EDUCATION AND RESEARCH (1924-1950)

Teaching of Electrical Communication Engineering at the degree level started first in the Department of Electrical Technology, Indian Institute of Science (I I Sc), Bangalore, sometime in early 1920s. Wireless communication was included as a special paper in M Sc Pure Physics course of the University of Calcutta in 1926. Later the University College of Science and Technology, Calcutta started an Electrical Communication Engineering section in the Dept. of Applied Physics. The two sections of Wireless and Electrical Communication were subsequently merged and the Institute of Radio Physics and Electronics, University of Calcutta was established in 1949 under the leadership of Prof S K Mitra. During the late 1940s,

the three engineering colleges at Jabalpur, Madras, and Poona, and the Madras Institute of Technology, Madras started offering degree level courses in Telecommunication Engineering. The Jabalpur Engg. College also started offering postgraduate courses in Advanced Electronics, Radio and UHF Engineering and VHF and Carrier Telephone Engineering. Other colleges started offering P G courses in early 50s. In the meantime, the Indian Institutes of Technologies (IIT) at Kharagpur and Madras were being planned and IIT Kharagpur started functioning in 1951. Both the Institutes have full-fledged departments of Electronics and Electrical Communication Engineering. An excellent account of the status and facilities of these institutions has been given by S P Chakravorti[5].

Research facilities in electronics and telecommunication were created first at the II Sc Bangalore and at the University College of Science, (Physics Deptt.) Calcutta, during mid-1920s. Prof K Srinivason of I I Sc published his first paper on field strength measurements in 1926 (II-A-60). Prof S K Mitra and his group started work on ionosphere and propagation in 1925 and published their first paper in 1928 (II-B-72). Subsequently, investigations on ionosphere and propagation were started in the Physics Deptts. of the universities at Allahabad, Dacca, Banaras and Delhi. The research departments of AIR and P & T also contributed in these areas. The list of the laboratories of universities, colleges and other organisations where useful research was carried out is given in Table 1 in chronological order.

TABLE 1

Universities, Colleges and other Organizations where Research works were carried out

Sl no.	Year of commencement of Research	Institution/Organisation
1.	1839	East India Co., Telegraph Department.
2.	1895	Presidency College, Calcutta.
3.	1923	Post and Telegraph Dept., Govt. of India.
4.	1926	Indian Institute of Science, Bangalore.
5.	1929	University College of Science & Technology, Calcutta.
		(a) Wireless Laboratory, Physics Dept.
		(b) Palit Laboratory, Physics Dept.
	1941	(c) Kanodia Electrical Comm. Engg. Lab., Dept. of Applied Physics.
6.	1933	Dacca University, Physics Dept.
7.	1934	Meteorological Department, Govt. of India.
8.	1935	Central College, Bangalore, Dept. of Physics.
9.	1938	Allahabad University.
10.	1939	Baroda College, Physics Laboratory.
11.	1940	Indian Association for the Cultivation of Science, Calcutta.
12.	1940	Banaras Hindu University, Physics Laboratory.

13.	1942	University College of Rangoon, Dept. of Physics.
14.	1942	Science College, Patna, Physics Dept.
15.	1942	Government of Madras.
16.	1942	All India Radio, Research Dept.
17.	1942	Rajshahi College (now in Bangaladesh), Physics Dept.
18.	1943	Annamalai University, Physics Dept.
19.	1945	National Physical Laboratory, New Delhi.
20.	1948	Government Engineering College, Jabalpur.
21.	1948	Bengal Engineering College, Shibpur, W. B.
22.	1949	Department of Radio Physics & Electronics, Calcutta University.

In view of the importance of research in radio and allied topics, a proposal for the establishment of a Radio Research Board was made in 1936 by Prof. M N Saha and S K Mitra and was supported by distinguished scientists of the commonwealth countries. But the Govt. of India rejected the proposal at that time. However, the Board of Scientific and Industrial Research (BSIR) [also Council of Scientific and Industrial Research] was established in 1942 and the following committees relating to radio research were founded :

(a) Radio Research Committee,
(b) Atmospheric Research Subcommittee, and
(c) Ultra Shortwave Research Panel.

BSIR allocated responsibilities and funds to various universities and institutions to conduct research and developmental activities in the above areas including the development of radio parts, components and materials. The communications sub-committee of National Planning Committee, Bombay, worked during 1939-41 and submitted a comprehensive report which clearly stressed the urgent necessity for research work under Indian conditions and recommended establishment of a Central Research Station for research in Communication engineering in all its branches. (CentralElectronics Engineering Research Institute, Pilani was later established in 1956). After the cessation of World War II, there was free flow of information regarding the research and development activities all over the world and this added to the urgency of the need for similar activities in this country. This improved the research climate and availability of funds in various laboratories. Furthermore, many institutions and colleges started teaching and research programmes in Electronics and Communication, specially during 1950s.

Although World War II restricted research activities in this country, there were a considerable number of publications during the period under review (1924-50). For appropriate appreciation, the papers have been grouped into four categories, *viz.*

(a) Telecommunication and Broadcasting (Appendix II-A)
(b) Ionosphere and Propagation (Appendix II-B).

(c) Electronic Circuits and Systems (Appendix II-C)
(d) Materials and Components (Appendix II-D).

The papers in each of the four appendices have been listed in the alphabetic order of the authors and not chronologically. Number of papers in these groups are 68, 142, 103 and 33, respectively (a total of 346). A distribution of the publications among various fields has been shown in Table 2. It is also seen from the table that the major research centres have been in the universities of Allahabad, Calcutta, Dacca and Banaras and II Sc., Bangalore. The major interest was in the areas of Ionosphere, Propagation, Atomospherics and Measurements. The research groups at the Calcutta University, Dacca University and II Sc., Bangalore were the major contributors of the research papers. The works of the Calcutta group have been published in the internationally acclaimed reference books, *The Upper Atmosphere*[6] and *Collected Research Papers*[7] by S K Mitra. The other two books published during the period are by V V L Rao[8] and S P Chakraborti[9].

TABLE 2

Fields of research and names of Universities/ Organisations where the work was done

Sl No	Topic	No. of papers in the area.	Names of Universities/ Organisations
	Group A		
1.	Antenna	9	BHU, DU, IISc
2.	Broadcasting	19	IISc, CU, AIR, OCS
3.	Telegraphy and Telephony	20	IISc, P & T, OCS
4.	Lines and Filters	18	CU, BHU, IISc, P & T.
5.	Avionics	2	CU
	Group B		
1.	Noise and Interference	20	IMD, IISc, DU
2.	Ionosphere	64	ALU, BHU, CU, DU, IISc AIR
3.	Propagation	58	ALU, BHU, IISc, CU, DU, DELU
	Group C		
1.	Amplifiers	6	CU, IISc
2.	Circuits	15	ALGU, CU, IISc
3.	Electron tubes	11	ALU, CU, DU
4.	Measurements	30	ALU, IISc, CU, DU
5.	Oscillation & Modulation	14	IISc, ALU, BHU, CU
6.	Rectifier & Voltage Stabilizer	18	CU, DU, DELU, IISc
7.	Sound & Ultrasonics	2	—
8.	VHF, UHF, & MW	7	CU, DU, DELU, IISc, NPL, JEC

	Group D		
1.	Capacitor	3	IISc, NPL
2.	Dielectric & Insulating Materials	15	CU, DU, ALU, IISc
3.	Resistances	3	CU
4.	Magnets	3	IISc
5.	Accoustic materials	9	CU, IISc

* AIR—All Indian Radio.
ALU—Allahabad Univ.
ALGU—Aligarh Univ.
BHU—Banaras Hindu Univ.
CU—Calcutta Univ.
DU—Dacca Univ.
DELU—Delhi Univ.
IISc—Indian Institute of Science, Bangalore.
IMD—Indian Metereological Dept.
JEC—Jabalpur Engg. College,
NPL—National Physical Lab. New Delhi.
P & T—Post & Telegraph Dept.
OCS—Overseas Comm. Services.

From Appendices I and II, it is seen that during 1839-1950, 372 (26 + 346) papers were published in 38 overseas and 18 Indian journals. Out of the 346 papers published during 1924-50, 168 contributions were from nine authors only and the rest 178 were contributed by 187 authors. Before 1924, only one paper was published in India and the rest were published abroad. Out of the 346 papers during 1924-50, 128 were published in overseas and 218 in Indian journals. Out of the 128 papers published abroad, fifteen or a little more were in French and German journals while the rest were in English ones. Among the overseas ones, three journals published the majority of the papers and they are (showing the number of papers in brackets) :

(a) *Nature* (31)
(b) *Philosphical Magazine* (23)
(c) *Proc. Inst. Radio Engrs. USA* (14)

Among the Indian journals, the *Journal of I I Sc*, Bangalore was started in 1918 and the *Indian Journal of Physics* in 1927. By 1930, more and more Indian journals were published and papers were contributed in them. Out of the 218 papers, as many as 177 were published in six important journals and they are (showing the number of papers in brackets) :

(a) *Indian Journal of Physics* (11)
(b) *Science & Culture* (21)
(c) *Proc. Indian Acad. Sc.* (15)
(d) *Journal of I I Sc* (7)
(e) *Electrotechnics* (Bangalore) (12)
(f) *Current Science* (Bangalore) (9)

Number of publications in each 5 year period during 1924-50 are shown in Table 3 (last two columns). The data indicate that the average number of papers progressively increased as the research activities grew through the period.

TABLE 3

Growth of Research Activities During 1924-1950

Period	Number of Publications	Number of topics	Number of new topics	Number of new authors (Indians)	Publication in Journals	
					Overseas	Indian
1924-1929	25	12	10	10	18	7
1930-1934	51	17	5	25	34	17
1935-1939	88	20	8	40	39	49
1940-1944	84	26	4	54	10	74
1945-1950	98	27	6	67	27	71

DISCUSSIONS

To assess the growth of research activities in Electronics and Communications, the number of papers published in 5 year periods have been indicated in Table 3. The number of topics of research (further subdivision of fields of research shown in Table 2), the number of new topics and the number of new authors in successive periods are also indicated in the table (based on Appendix II). It is evident that the research activities developed over the years and more workers of new laboratories got involved in wider fields of research. During the intervening war period (1939-45), the growth rate had been slow, but in the postwar period the activities grew again at a faster rate (this study is not included here).

It would be an interesting study if one attempted an evaluation of the status of Indian research in Electronics and Communication *vis-a-vis* the global scene. In Appendix III, a short list of important research findings in India has been given. Along with the topics and authors (from Appendix II), the original/contemporary researches in other countries are also indicated. As for example, O' Shaughnessy's work on telegraph communication was pioneering and dates earlier than similar work elsewhere. Similarly, the researches of J C Bose on 'millimeter wave generation and the effect of microwaves on crystals and dielectrics' were pioneering. Other such pioneering/contemporary researches were carried out by : (a) S K Mitra *et al.* on Ionosphere (discovery of D & C layers of Ionosphere) (b) S. P. Chakraborti on filters and telecommunication, (c) Khastagir *et al.* on atmospherics and propagation, (d) Ramamurti on ceramic capacitors, *etc.* A general conclusion, however, may be drawn that the standard of research deteriorated during the war years, because of the complete blackout of communication with the outside world and lack of proper facilities. After the war, the Indian scientists woke up to the fact

that the world has moved far ahead in Electronics and Communication, specially due to the defence efforts in USA and UK. It took considerable time and effort to regain the lost ground and to bring up the indigenous research to the world standard during 1945-55.

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APPENDIX I

Early work on Telecommunication in India (1839-1923)

1. Ayrton W. E., 'Discussion on W. H. Preece's Paper on Lightning and Lightning Conductors with Reference to India', *Jour. Soc. Telegraph Engineers*, 1872.
2. Ayrton W. E., 'On Some Points in Connection with Indian Telegraphs', *Jour. Soc. Telegraph Engineers*, 1873.
3. Ayrton W. E., 'Indian and American Telegraphs, *Jour. Soc. Telegraph Engineers*, 1875.
4. Bose, J. C., Properties (Polarisation and Refraction) of the Electric Wave', *London Electrician* **36**, 289, 290, 291, 1895 ; *Proc. Royal Soc*, **59A**, 160-167, 1895 ; *Proc. Royal Soc.*, **62A**, 301-310, 1897.
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6. Director General of Telegraphs, India, 'A Descriptive Note about a Tree Struck by Lightning', *Jour. I. E. E.*, 1891.
7. Draper, George, 'Earth Currents and Aurora Borealis of 4th Feb. 1872', (Observations at Bombay by STACEY and British Indian Submarine Cable Company), *Jour. Soc. Telegraph Engineers*, 1872.
8. Edmunds, P. J., Long Distance Radio Reception in India', *Electrician*, 1923.
9. Mallock, "Indian Telegraph Iron Wire Gauge', *Jour. Soc. Telegraph Engineers*, 1874.
10. Melhuish, W. F., 'On Signalling Across Rivers in India with Cardew Vibrating Sounders', *Jour. I. E. E.*, 1891.
11. O'Shaughnessy, W., 'A Report about the Construction of 20 Miles Long Telegraph Line in India near Calcutta', *Jour. Asiatic Society (Bengal)*, 1839.
12. Schwendler, Louis, 'On General Theory of Duplex Telegraphy', (Read before the Asiatic Society of Bengal), *Jour. Soc. Telegraph Engineers*, 1877.
13. Walker, E. O., 'On a Magnetic Storm in India', *Jour. Soc. Telegraph Engineers*, 1883.
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22. Winter, G. K., 'Induction Between Suspended Wires', *Jour, Soc. Telegraph Engineers*, 1875.
23. Winter, G. K. and Culley, 'Induction on Telegraph Wires on Same Poles', *Jour. I. E. E.*, **14**, 427, 1875.

APPENDIX II-A

Papers in the area of Telecommunication and Broadcasting (1924-1950)

1. Ahmed, W., 'ON Effect of Resistance Component in Wave-filter Elements and Performance of Non-ideal Filter Sections, *Indian Jour. Phys.*, **16**, 229, 1942.
2. Banerjee, S. S. And Singh, B. N., High Frequency Modulation of Ultra Short Waves', *Indian Jour. Phys.*, **11**, 91, 1937.
3. Banerjee, S. S., 'Critical Dimensions of Tuned Transmitting Circular Loop Aerials', *Phil. Mag.*, **27**, 174, 1939.
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APPENDIX II-B

Papers in the area of Ionosphere and Propagation (1924-1950)

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APPENDIX II-C

Papers in the area of Electronic Circuits and Systems (1924-1950)

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APPENDIX II-D

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APPENDIX III

A Short List of Important Research Findings in India and Contemporary Researches in Other Countries

Sl. No.	Year of publication/development in India.	Description of the research in India and that in other countries.	Ref. From Appendix I & II
1.	1839	O' Shaughnessy constructed near Calcutta 20 mile long line including 7000 ft. river crossing by submarine cable for telegraphy using electromagnet. First use of submarine cable in the world indigenously made by him.	I-(11)

		Joseph Henry invented telegraph in 1831 ; he signalled over one mile using horseshoe magnet. Dover-Calais telegraph line using submarine cable was opened in 1851.	
2.	1873	G. K. Winter observed in India induction on telegraph wires on same poles ; he published his observations in 1875. Prof. Hughes started investigation on similar line in 1868 and published his observations in 1879.	I-(22, 23)
3.	1890	W. F. Melhuish succeeded in signalling across river Hooghly using water as conductor and Cardew vibrating sounder and published the findings in 1891. Experiment on subaqueous telegraphy (use of water as conductor for telegraph) was first started in India also by O' Shaughnessy (probably in world also) in 1849 to overcome the difficulties of crossing the rivers in India.	I-(10)
4.	1895	J. C. Bose published four papers about the effect of electric ray on crystals and dielectrics. Experimental verification of Maxwells theory (electric ray) by Hertz was announced towards the end of 1887 and was published in 1888.	I-(4)
5.	1921	Leafield's (England) signals (Wireless telegraph) for Egypt are good at 8 P.M. and midnight using ordinary receiving apparatus. Official report from Indian P&T Dept. to British P&T Department.	

		Edmunds (probably) carried out the observations and published in 1923. Federal Wireless Co. successfully tested wireless telegraphy between Sanfrancisco and Honolulu (2100 miles) in 1912.	I-(8)
6.	1926	Sreenivasan measured field intensity of Madras (Fort) radio station at Bangalore. The earliest work in the measurement of field-intensity was of Duddel and Taylor in 1905.	IIA IIA-(60-63).
7.	1926	In the early days of radio broadcasting in India, S. K. Mitra and his group used to broadcast from the University College of Science, Calcutta, during 1926-28. Broadcasting station at Calcutta was inaugurated in August 1927.	
		Regular broadcasting started in U.K. in early 1920 with musical programme and news.	Ref. :(1, 2)
8.	1926	Catterson-Smith measured characteristics of beam transmitting aerials at I I Sc., Bangalore.	IIA-(11)
		S. G. Brown proposed in 1899 directional (beam) transmission and reception.	
9.	1928	Sreenivasan published on long wave radio reception and atmospheric oxygen.	IIA-(63)
		Fessenden suggested atmospheric absorption of wireless signal in 1907.	
10.	1929	L. C. Verman and Richard described a Vacuum Tube voltage regulator that can be used with any D.C. machine.	IIC-(99)
		Stoller constructed in 1917 probably the	

		first voltage regulator for D.C. generator used in aircraft.	
11.	1929	Sreenivasan published relation between longwave reception and certain terrestrial and solar phenomena.	IIB-(125)
		Fessendin in 1908 correlated radio transmission with magnetic disturbances.	
12.	1931	Rakshit measured height of the Heaviside layer at Calcutta.	IIB-(96)
		Briet and Tune measured the height using pulse technique in 1925.	
13.	1931	Rakshit surveyed and made a contour map of field strength of broadcasting station of Calcutta.	IIB-(95)
		Similar field strength survey was first made of New York in 1924. Pickard mapped wave front around a transmitting station in 1907.	
14.	1931	K. Singh published on principle of copper oxide rectifier which was first disclosed by Grondhal in 1926.	IIC-(91)
15.	1931	Mitra and Sil studied the variation in resistance of thermonic valves at high frequencies.	IIC-(55)
		Benham published similar observations in Feb. 1931.	
16.	1932	S. P. Chakravarti published on 'telephony by carrier and one side hand.'	IIA-(12)
		Squier demonstrated carrier telephony in 1910. A.T. & T. Co. of U.S.A. started using S.S.B. for commercial purpose in 1918.	

17.	1933	Mitra and others studied the effect of solar eclipse on ionosphere. Turpain in 1912 studied the influence of the eclipse of sun on the propagation of electric wave.	IIB-(76)
18.	1934	Mitra, Ghosh and Syam proved by observed results that meteors affect condition of ionosphere. Marries in 1927 suggested that meteors may effect ionosphere.	IIB-(77)
19.	1935	Mitra and Syam experimentally proved existence of 'D' layer first suggested by Appleton and Radcliffe in 1930.	IIB-(79)
20.	1936	Mitra received echoes from middle atmosphere and suggested the layer as 'C' layer (first observation).	IIB-(81)
21.	1936	Khastagir and Sengupta measured electrical properties of soils.	IIB-(47)
22.	1939	Khastagir and co-workers studied parabolic wire reflector on a wave length of 3 metres. Gresky in 1928 studied parabolic reflectors at $\lambda = 2{\cdot}98$ cm.	IIA-(50)
23.	1944	Rakshit and Bhattacharyya published on three-phase R-C oscillator using three R-C coupled amplifiers with feedback from output to input. J. Van der Mark and Bath Vanderpol in 1934 first used the circuit for producing oscillation.	IIC-(66)
24.	1945	Ramamurti published development of high	IID-(27)

		dielectric constant ceramic capacitor. Manufacturing of cermaic capacitor started in 1944 in U.S.A.	
25.	1945	Amarjit Singh developed 10 cm magnetron.	IIC-(90)
		Randle and Boot developed 100 kw, 10 cm magnetron for radar in 1939.	
26.	1948	Dasgupta and co-workers constructed horizontal Electron microscope.	IIC-(32)
		Bruche and Johanson demonstrated first Electron microscope in 1931.	
27.	1949	Venkiteshwaran and co-workers made ground equipment for radiosonde.	IIB-(142)
28.	1949	A.N. Bhattacharya published on Instrumental Landing System (ILS) for aircrafts.	IIA-(10)
		Pickles published in 1945 on portable ILS used in airforce during World War II.	
29.	1949	Chakravarti published a new secrecy device for communication system.	IIA-(33)
		Tigerstedt suggested a method of secrecy in speech transmission in 1918.	
30.	1949	Chatterjee and Srikantan studied electron transit time in negative grid oscillator.	IIC-(28)
		Transit time effect on input conductance of a triode was published by Ferris and North in 1936.	
31.	1949	Chatterjee and Srikantan studied absorption of U.H.F. waves by sea water.	IIB-(32)
		Branly in France and Righi in Italy measured in 1899 signalling power (absorption) of electric wave through tap water, sea water and mineral oil.	