Selected landmarks in

The History of TELECOMMUNICATIONS

A contribution to the Institution's 150th anniversary celebrations in 2021 from the IET History of Technology Network

This is one of a series of timelines which focus on a selection of engineering and technology landmarks which have occurred during the lifetime of the Institution since its foundation in 1871.

Comments regarding any errors in, or significant additions to, this timeline should be sent to the History of Technology Network Manager Anne Locker by Email to alocker@theiet.org

The establishment of the Society of Telegraph Engineers in 1871 resulted from the growth and usage of the electric telegraph during the preceding 30 years or so and the resultant demand for specialist engineering expertise.

See footnote for more information about the pre-1871 telegraph era

Date	Event
	1870 TO 1879
1871	**IET established as the Society of Telegraph Engineers**
1873	James Clerk Maxwell publishes his seminal paper *Treatise on Electricity and Magnetism* in which he converts the concepts proposed by Michael Faraday into mathematical form. Maxwells Equations are the fundamental mathematical basis of electromagnetic wave communications
1874	Frenchman Jean-Maurice Emile Baudot develops the 5 unit telegraph code, a digital code in which each letter of the alphabet is represented by 5 bits i.e. 0 or1. Telegraph operators used a 5 key piano like keyboard to send the codes. The signal length of every letter is the same unlike the Morse code. The SI (systeme internationale) unit for symbol rate, the 'Baud', is named after him
1875	Alexander Graham Bell in Boston, USA constructed his first experimental telephone using a primitive design of transmitter and receiver
1876	Bell transmits the first words by telephone to his assistant Thomas Watson who was located about 100ft away behind closed doors in another room, "Mr Watson, come here, I want to see you".

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Date	Event
1876	Sir William Thompson (later Lord Kelvin) exhibits Bell's telephone to the British Association for the Advancement of Science
	Bell files for a patent *'for apparatus for transmitting vocal sounds'*. But soon after Elisha Gray of Western Union based in Chicago who had also been developing a telephone device, filed a similar patent application However Bell, and not Gray, was granted the patent. Telephony is analogue unlike Morse Code telegraphy
1877	The Bell Telephone Company is formed in the USA
	In the USA Thomas Edison designs a carbon transmitter for use in telephones
1878	In order to market his newly patented telephone in the UK market Bell forms The Telephone Company Ltd.
	In the UK David Hughes a professor of music with an interest in electricity, also designs a carbon microphone. Francis Blake, an officer in the US Coast Survey, further developed Hughes design and offered it to Bell who accepted it as superior to Edison's design and his own. The Bell Companies throughout the world used the Blake-Hughes transmitter in telephones for some 20 years.
1879	In the UK The Telephone Company Ltd opened Britain's first public manual telephone exchange at 36 Coleman St, in the City of London. Later that year two further exchanges opened one at 101 Leadenhall Street, EC2 another at 3 Palace Chambers, Westminster. Calls between customers, then known as subscribers, were established manually by female operators. As manual exchanges grew in number and size it presented new employment opportunities for women
	Prof David Hughes (see 1878) accidentally discovered that with no physical connection he could receive energy in a telephone in the form of clicks from a spark generated by an inductance coil up to a considerable distance. He demonstrated the effect to the Royal Society (RS) who failed to realise that these findings confirmed Maxwell's theory (see 1873). If the RS had realised the significance of David Hughes' demonstration we may speculate that today the 'Hughes' rather than the 'Hertz' could be the SI unit of frequency?
	1880 to 1889
1880	In the UK a High Court judgement decided that a telephone was a telegraph, and that a telephone conversation was a telegram, within the meaning of Section 4 of the Telegraph Act, 1869. This meant that to continue operation the multiple private telephone companies which had emerged had to obtain a licence from the PMG (Postmaster General)

Date	Event
1881	In the UK the Government authorised the Post Office to offer a public telephone, in addition to, a public telegraph service. The Post Office proceeded to convert some telegraph service exchanges to (manual) telephone exchanges.
	The National Telephone Company was formed in March in the UK to exploit the market in Scotland, the Midlands and Ireland.
1882	Patents for Central Battery (CB) systems are filed by G.L. Anders in London. Feeding power to telephones from an exchange, CB working avoids the need for local batteries at the subscribers premises. CB prevails until the modern era when electronic terminal equipment, locally powered, is required for instance for broadband connections to the Internet.
1885	UK long-distance telephone trials take place between London and Liverpool. Copper wire had been found more suited for voice transmission but long distances required thick, and hence heavy, conductors to minimise attenuation Long routes required wires weighing up to 800 lb/mile(225kg/km). A 2 wire circuit from London to Glasgow equated to some 320 tons of copper.
	Oliver Heaviside a member of the STE (soon to be renamed the IEE) proposes that the attenuating effect of cable capacitance could be offset by adding inductance. Known as ‘loading’ adding inductance extends the distance telephone signals could travel without significant attenuation thus improving long-distance communication. (see 1899)
1888	German physicist Heinrich Hertz experimenting under controlled laboratory conditions transmits and detects electromagnetic (EM) waves generated by sparks thereby confirming the mathematical theories of James Clerk Maxwell (see 1873). As a result, EM waves became known as ‘Hertzien waves’ initially
	The Ericisson Company of Sweden combine telephone transmitter and receiver into one instrument - the first telephone handset
1889	Almon Strowger a funeral director in Kansas City, USA, filed for a US patent for an electro-mechanical step-by-step automatic telephone system. His patent was issued in 1891. He had suspected that his local manual board telephone operator who was married to Strowger’s competitor was diverting his business to her husband. . The Strowger system of switching was widely used by many countries for the next 100 years or more
	1890 to 1899

Date	Event
1891	In this pre-electronics era various techniques were devised to detect reception of EM signals generated by sparks. Eduard Branly created one device – the coherer - consisting of iron filings, carrying a current, in a small glass tube. When subjected to EM fields the filings would stick together and the resistance reduced. Marconi later developed an improved device, the magnetic detector.
	The first international telephone service is inaugurated between London and Paris following the laying of a submarine cable across the English Channel.
1892	A public automatic telephone exchange based on Strowger's design is opened in Indiana USA
1894	During a memorial lecture for Hertz following his untimely death, Prof Oliver Lodge transmitted and received 'Hertzien' waves over a distance of 60m. Although no meaningful intelligence was transmitted the demonstration indicated the potential of using 'Hertzian' waves for wireless telegraphy
1895	In Russia Aleksandr Popov demonstrates wireless communication using lightning conductors as transmitting and receiving aerials
	The UK Post Office Trunk telephone service opens
1896	Guglielmo Marconi, in Italy developed a keen interest in the potential of 'Hertzien' waves following tuition from Prof Augusto Righi in Bologna. Using a Righi spark gap as a transmitter and a coherer for reception, he found that improved reception was achieved by earthing and using high aerials. He also devised a method of 'unsticking' i.e., decohering, the iron filings in coherers by tapping them with a bell mechanism, after each signal reception.
	Marconi moved to the UK the largest potential market for wireless telegraphy and submitted a patent for …'Improvement in telegraphy and in apparatus therefore'. His original wireless telegraphy patent
	Marconi successfully demonstrates his equipment to Sir William Preece E-in-C of the Post Office by transmitting between two buildings in the City of London
	A rotary dial is developed in the USA – forerunner of the standard telephone dial used before the advent of push button telephones
1897	Marconi demonstrates wireless telegraphy 14 miles between Lavernock Point near Cardiff and Flat Holme, an Island in the Bristol Channel.
	Marconi establishes the '*Wireless Telegraph and Signal Company'* to manufacture his spark gap transmitters and the coherer/de-coherer receivers. The company name is later changed to the *'Marconi Wireless Telegraph Company'*

Date	Event
	Eduard Branly is attributed by some sources as the person who first used the term ‘Radio’ instead of ‘Hertzian’ waves
	Marconi visiting Italy successfully communicates with ships 12 miles offshore using spark transmitters. Ship-to-shore radio is proven practical
1898	Karl Braun inserts inductive coupling in a transmitter separating the aerial from the spark generator resulting in improved signal transmission distances. He also develops a crystal detector device.
1899	Michael Pupin adds induction coils (Pupin Coils) to cables at regular intervals to reduce attenuation in accordance with Heaviside’s theory (see 1885)
	Municipalities in the UK are authorised to establish their own telephone systems. In 2021 only Kingston-Upon-Hull remains of the original companies so created
	1900 to 1909
1900	Prof Reginald Fessenden in the USA recognised the need to generate continuous waves and an alternative to the coherer detector, if speech was to be transmitted by ‘Hertzian’ waves. He successfully transmits telephony a short distance using very high frequency spark generation (10,000/sec) to simulate a continuous signal which is then modulated by a microphone in the aerial lead. An electrolytic detector, in place of a coherer, is used for conversion back to voice
	The first CB (see 1882) manual telephone exchange is established in Bristol
1901	Marconi successfully transmits the letter ‘S’ by Morse code using a spark transmitter, between Poldhu in Cornwall and Signal Hill Newfoundland – the first transatlantic wireless transmission. Later that year an Atlantic telegraph service was established in Crookhaven in Cork in 1901 by Marconi and later moved to Valentia, in Ireland in 1914.
	In the USA Prof Reginald Fessenden patents wireless telephony.
1902	To explain how Marconi was able to transmit EM waves from UK to USA beyond the optical horizon, UK IEE member Oliver Heaviside and Arthur Kennelly in USA propose the existence of an ionised layer above earth’s surface reflecting the signals. Known today as the Kennelly-Heaviside (or E) layer. In 1926 Edward Appleton identified another layer in the ionosphere, the Appleton or (F layer), which reflects short wave radio signals.
1903	In Berlin an *International Preliminary Conference on Wireless Technology* is held to discuss the use of the new technology for communicating with ships at sea

Date	Event
1903	Fessenden transmits telephony over a distance of 20km by using a modulated arc as a CW (continuous wave) signal source and electrolytic detector
	Marconi establishes a regular wireless telegraph service, mainly for news media, between Poldhu Cornwall and Cape Cod
1904	John Ambrose Fleming at UCL in the UK, working as consultant for Marconi, creates the two element thermionic diode valve –so named as it acted like a water valve with current flow only in one direction making it a better detector of electromagnetic signals. Fleming's diode was based on his understanding of the Edison effect. In USA the term 'tube' was used instead of valve. Some regard this as the birth of the electronics era?
1906	In Berlin a follow-up conference to the 1903 event is held but using the new name *International Radiotelegraphic Conference*. The expression 'Radio' in place of 'Wireless'. Radio probably derived from 'radiation'
1906	Lee de Forest in the USA adds a third element to Fleming's valve (see 1904) creating the triode. Triodes and diodes enable designs of electronic amplifiers and oscillators to be created.
	On Christmas Eve (24 December) 1906, Reginald Fessenden transmitted the first human voice over the radio from Brant Rock, Massachusetts to ships in the Atlantic owned by the United Fruit Company, for whom he worked.
1907	Marconi establishes a public wireless telegraph service between Ireland Canada and the USA. For transatlantic voice wireless service see 1919
1909	Braun and Marconi awarded Nobel Prize in Physics for their development of wireless telegraphy
	1910 to 1919
1910	US Signal Corps Major George Squier develops the Carrier multiplexing technique when successfully transmitting 2 simultaneous voice signals over a single private telephone circuit. US operator AT&T developed a commercial carrier system between 1914-1918
1912	First UK Strowger electro-mechanical step-by-step automatic exchange opens in Epsom, Surrey. Eventually a UK network of automatic telephone exchanges will be established forming a circuit switched PSTN (Public Switched Telephone Network)
	The UK Post Office takes over all private telephone networks except those of the municipalities creating a monopoly. The monopoly will survive until the early 1980s when competition is re-introduced. Private telegraph networks had been taken over by the Post Office in 1870

Date	Event
1913-14	Marconi Company engineer and wireless pioneer H.J. Round patented a number of ideas for radio valve improvements including that of an indirectly heated cathode.
1914	Submarine telephone cable laid between Dover and Dunkirk in France
	Multiple different designs of electro-mechanical switching systems developed and manufactured in the USA, Europe and elsewhere. The *Lorimer* design built by the Canadian *Machine Telephone Co* is installed in Hereford and the Western Electric *Rotary* design in Darlington. Other designs are also installed and evaluated by the Post Office (see 1922)
1915	Submarine telegraph cable laid between UK and Russia
	During the summer of 1915, former Marconi engineers led by C.E. Prince successfully demonstrated the first air-to-ground voice communication using an aircraft radio telephony transmitter.
1916	Amplifiers (see 1906) are developed and used experimentally for the first time at Liverpool on cables between London and Belfast and London and Dublin
1917	An ex-army hut is erected at Writtle, near Chelmsford Essex and used by the Marconi company to develop voice radio for aircraft (see 1922).
1919	On 19 March Marconi makes an East-West voice wireless call between Ireland and Canada.
	1920 to 1929
1920	Following WW1 thermionic valve technology had advanced to the stage where spark transmitters were obsolescent.
	Experimental entertainment broadcasting from the ex-Army at Writtle, (see 1917) by Marconi engineer Peter Eckersley commencing in February proved popular with those who could receive the signals using crystal sets. The transmitter operating at 700m wavelength with an approx. power of 200watts, had a call sign 2MT. The circuitry was similar to that designed by Eckersley in 1920 for use at Croydon aerodrome. However the PMG (Postmaster General) bans further broadcasting later that year due to interference concerns
	In the USA commercial stations commenced broadcasting
1922	The UK Post Office standardises on the Strowger step-by-step system. Extremely durable Strowger systems lasted until the mid-1990s
	By 1922 amplifiers for cable systems were routinely installed in buildings known as repeater stations to improve transmission performance..

Date	Event
	After petitions from the Wireless Society of London the PMG rescinded the ban on broadcasting (see 1920) and in May a transmitter,2LO transmitting on 350m at 100watts began broadcasting from Marconi House in the Strand, London This transmitter is on view at the London Science Museum. Clearly demand existed for a broadcasting service
	The BBC (British Broadcasting Company, renamed a Corporation in 1927, was established in October at a meeting at the IEE Savoy Place between Marconi company, General Electric, British Thompson-Houston, Radio Corporation Ltd, Metropolitan Vickers and Western Electric. BBC broadcasts commence in November using 2LO. Peter Eckersley becomes BBC Chief Engineer
1923	BBC moves it's studios to the IEE buildings in Savoy Hill
	Vladimir Zworykin at Westinghouse Electric USA develops an electronic camera tube for TV usage, but images lack definition and are low contrast see 1933
1925	John Logiie Baird gives what is widely regarded as the first public demonstration of a part mechanical television system at Selfridges, London. He uses spinning discs containing a spiral of holes for both scanning and display to create an image of an illuminated ventriloquist's dummy.
1926	Rugby Radio Station is established providing a 16kHz high power transmitter using water cooled valves generating a worldwide signal. The huge induction coil from this equipment is on display at the London Science Museum. A second 60kHz transmitter is also established for a radio telephony service to the USA
	Edward Appleton at Cambridge identifies the existence of another ionised layer (see 1902) which also reflects radio signals but of shorter wavelength. Named the Appleton (or F) layer Appleton was awarded the 1947 Nobel Prize in Physics
	In Japan Kenjiro Takaanagi gives a PRIVATE demonstration, at a school, of an electronic TV system using a cathode ray tube. However he does not patent it
	The first 'true' demonstration of television by John Logie Baird took place at Baird's laboratories at 22 Frith Street, Soho, on 26 January 1926.
1927	In larger cities customer (subscriber) growth necessitates a requirement to introduce a translation technique to allow direct dialling. Known as Director working, electro-mechanical relays convert dialled numbers into routeing codes.
	A public radio telephone service commences between London and New York

Date	Event
	A time signal generated by the Royal Observatory Greenwich for mariners is transmitted worldwide by Rugby radio Station
1928	In San Francisco, USA Philo Farnsworth gives what is regarded as the first PUBLIC demonstration, to the press, of a fully electronic TV system (see 1925/1926)
	In the UK John Logie Baird demonstrates colour TV using his system (see 1925)
	Creeds No 3 teleprinter is adopted as standard UK telegraph machine
	1930 to 1939
1931	Microwave radio point to point relay system trials are conducted between Dover and Calais. Their success shows that the frequency band 1000-10000MHz has potential for providing communication facilities.- see 1949 and 1952.
	Voice frequency telegraph systems allow direct dialling between telegraph zone centres. This service will be replaced by the Telex service – see 1958.
	Vladimir Zworykin, a Russian immigrant to the United States, working at Westinghouse Laboratories in Pittsburgh, developed a prototype iconoscope, the first electronic television camera.
1932	Anti-sidetone induction coils are introduce in telephone circuits
	In the UK EMI (Electrical and Music Industries) develop the Emitron which will be at the heart of early BBC TV cameras (see 1936)
	UHF (ultra high frequency) radio systems operating in the 300 -3000MHz frequency band are introduced. An early system Is used across the Bristol Channel. Later e.g. in 1937 UHF systems are used for links across the Irish sea
1933	Polyethelene (Polythene) was discovered which had a low dielectric constant making it a suitable cable insulation material, particularly for submarine cables. Gutta Percha, the solidified sap from a tree, had been used previously.
	In USA RCA (Radio Corporation of America) acquire Zworykin's patent and produce the iconoscope. It has much greater light sensitivity (see 1923)
1934	Negative feedback technique is discovered by H. S. Black in the USA. It will greatly improve performance of telephone repeaters

Date	Event
1935	12 channel carrier system trials, in the range 12-60kHz, were conducted in the UK between Bristol and Plymouth. On de-loaded multi-conductor cable. Later developments allowed for 24 channel operation which became the norm for the long distance telephony network prior to co-axial cable system usage (see 1938)
1936	BBC commence broadcasting TV using, on alternative weeks, the Baird system and the EMI electronic design. The EMI system clearly gave superior pictures and became the initial standard adopted in the UK (see 1925 & 1932)
	EMI design a method for transmitting 405 line TV over screened pairs. The technique will be used to broadcast the coronation of George VI in 1937.
1937	Alex Reeves at STC (Standard Telephones and Cables) invents Pulse Code Modulation (PCM) . PCM will become the fundamental building block of digital transmission but cannot be realised physically or economically until solid state electronic technology becomes available
1938	Co-axial cable systems were introduced. In the UK and many other countries. A coaxial cable system was established between London and Birmingham, and in 1940 extended to Manchester, with 4 co-axial tubes of 0.45in (1.14cm) diameter. One pair used FDM (see below) in the range 50-2100kHz to provide telephony. The other pair provided a 1.6MHz bandwidth TV channel. Coaxial cables became the standard for long distance circuits alongside microwave radio relay links
1938	FDM (frequency division multiplexing) standards which enable increased numbers of voice circuits to be transmitted per cable are published by the ITU (International telecommunications Union)
	1940 to 1949
1945	Arthur C Clarke publishes an article in Wireless World magazine proposing a network of man-made satellites be placed in geostationary orbit which could act as extra terrestrial radio relay stations providing worldwide coverage - see 1965
1946	Erlangs, named after Agner Erlang who established the definition, are introduced as the international unit of telephone traffic measurement.
	Cabinets and pillars are introduced for local network distribution in the UK
1947	John Bardeen and Walter Bratten, members of team led by William Shockley at Bell labs USA, create the first transistor- birth of solid state electronics

Date	Event
	Cellular radio concepts for telephones in vehicles are developed in the USA by Douglas Ring and Rae Young at Bell Labs. They define the structure which achieves economies by reuse of frequencies and handover techniques as the vehicle moved geographically. between cells It will become the basis of all worldwide mobile telephone networks
1948	Claude Shannon, at Bell Labs USA, is regarded as the founder of information theory. Shannon publishes a paper, 'A Mathematical Theory of Communication' building on the work of Harry Nyquist.. Shannon's theories establish the required conditions for a discrete sequence of samples to capture all the available information in a continuous time signal of finite bandwidth.
1949	A microwave radio relay link operating at 900MHz is established between London and the BBC TV transmitter at Sutton Coldfield.
	1950 to 1959
1951	4MHz coaxial cable systems are standardised in the UK. Using FDM in the range 60 -4092kHz these systems have capacity for 16 supergroups (960 voice channels) or one 405 line TV channel with 6 mile repeater spacing .
	Charles Hard Townes publishes concept of the MASER (microwave amplification by stimulated emission of radiation) see 1956
1952	An analogue microwave radio relay link is established between Manchester and Kirk O' Shotts near Edinburgh. Operating in the 4GHz band it provides TV service
1953	In the UK cable pressurisation is introduced in the trunk and junction network to improve waterproofing
1956	TAT 1, the first transatlantic telephone cable, is completed. Linking Oban Scotland to Clarenville Newfoundland, then onwards to Sidney Mines Nova Scotia. The Atlantic coaxial cable section used 2 cables with highly reliable thermionic valves in submarine repeaters. Providing 36 FDM high quality voice channels between Europe, USA and Canada telephone traffic surges
	A MASER is built by Nicolaas Bloember at Harvard University. MASERS when suitably cooled, provided low noise signal amplification at Satellite Earth stations
1957	USSR launch the world's first artificial satellite Sputnik. It highlights the opportunities of this technology for satellite telecommunications
1958	UK introduces STD (Subscriber Trunk Dialling) whereby customers could dial their own long distance calls directly without operator intervention.

Date	Event
	SCORE (Signal Communication by Orbiting Relay Equipment) satellite, the first to relay voice signals, is launched by the USA. SCORE broadcast a taped message from the US President Eisenhower saying "peace on earth and goodwill toward men everywhere"
	A dedicated automatic switched network for teleprinters called TELEX is introduced in the UK. Previously teleprinters signals were routed over the PSTN by modulating a 1.5kHz tone
1959	Radiophone manual services launch in the UK in South Lancashire. The service will launch in London in 1965
	To meet increased traffic demand on TAT 1 (see 1956) audio channel spacing is reduced to increase the number of circuits available to the public
	TAT 2, of similar design to TAT 1, is established between France and Newfoundland
	1960 to 1969
1960	US launch ECHO – a passive reflecting satellite for communications
	TASI (Time Assignment Speech Interpolation) is introduced to further increase capacity on TAT 1 (see 1956 and 1959). TASI enables idle circuit time during pauses in conversations to be allocated to other users
	The LASER (Light Amplification by Stimulated Emission of Radiation) providing coherent light is developed. This stimulates research into its use for optical telecommunications – see 1966
1960	Radio paging systems launched in the UK
1961	12 MHz co-axial cable systems are introduced in the UK with 3 mile (4.8km) repeater spacing on long distance routes. Operating in FDM in the range 312 – 12388kHz these systems provide 2700 voice channels
1962	TELSTAR an active low orbit satellite enables live TV between Europe and USA
	A trial electronic digital telephone exchange system is opened at Highgate Wood, North London. Using TDM (Time Division Multiplexing) and PAM (Pulse Amplitude Modulation). PAM proves problematic so PCM (see 1937) used for later trials
1964	Successful development of the technology paves the way for a geostationary satellite network. With 11 countries support, the Intelsat Agreement was signed on 20 August 20, 1964. Arthur Clarke's idea is a step nearer (see 1945)

Date	Event
1965	The first Intelsat satellite, Early Bird (later re-named Intelsat 1) is launched. Early Bird was the first operational commercial satellite to provide regular telecommunications and broadcasting services between USA and Europe
	In the UK microwave radio relay systems form a national long distance network complementing trunk cables. Used to transport both analogue TV and telephony they operate in the SHF (super high frequency) 4GHz and 6GHz bands and have repeaters typically spaced 30 miles apart. In London and Birmingham special radio towers are built. The BT Tower, an iconic landmark in London (originally the Post Office Tower), for a short period is the tallest building in the UK.
	In the USA the 1ESS (Number One Electronic Switching System) a stored programme controlled (SPC) circuit switch manufactured by Western Electric first enters service in Succasunna, New Jersey.
1966	Charles Kao and George Hockham of STL (Standard Telephones Laboratories) publish a paper in IEE Proceedings proposing glass fibres as waveguides for optical communications providing glass losses can be reduced to 20dB/km or less
	Semi-electronic telephone exchange systems are developed allowing computer control and storage. Two such types introduced in the UK are the Plessey 5005 Crossbar (TXK) and the Reed Relay type (TXE) . TXE2 is used for small exchanges and TXE4 for large. These systems reduced further Strowger exchange growth
	PCM digital line systems (see 1937) are trialled in the UK. based on the USA 24 channel capacity model. They provide short haul systems for use on junction routes with de-loaded cables. However the European 30 channel PCM standard will be adopted eventually for the UK (see 1976)
1967	Plans for a network interconnecting ARPA (Advanced Research Projects Agency) Network sites in the USA (an ARPANET) are published. A wide area network using mini-computers equipped with IMPs (Interface Message Processors) to interface with the physical transmission network. IMPs are forerunners of routers.
1968	Donald Davies at the UK NPL (National Physical Labs) proposed Packet Switching for more efficient transmission of data. In the USA Paul Baran proposed a similar idea at about the same time. Packet Switching became key for the Internet.
	Due to problems found during the trial of TDM-PAM (see 1962) a new trial electronic stored programme control switching system using TDM-PCM commences at Empress exchange near Earls Court London. A second TDM-PCM trial is conducted at Moorgate exchange in the City of London

Date	Event
1969	ARPANET a packet switched network (see 1967 and 1968) is established which will lead eventually to the foundation of the Internet ARPANET uses a Network Control Program (NCP) which is replaced by TCP in 1983
	Decade 1970 to 1979
1970	Corning Glassworks in the USA announce they had developed glass with losses below the target 20dB/km level required for practical Optical Fibre systems (see 1966)
	A millimetric circular terrestrial waveguide system, which can provide large capacities for trunk networks, is demonstrated in the UK. By the mid-1970s plans are in place for deployment of such systems in the UK trunk network. (see 1978)
	ISTD (International subscriber trunk dialling) allows UK subscribers to dial USA numbers direct. The service is progressively extended to most other countries.
1971	Plans for a UK Packet Switched network for data transmission are proposed
1973	Motorola becomes the first company to develop a handheld, as opposed to within vehicle, mobile telephone for use in the cellular network (see 1947)
1974	The architecture of Transmission Control Protocol (TCP) which will allow different computer networks to interoperate is published in the USA by Vint Cerf and Robert Kahn. TCP will later be split into two parts in 1988 –a slimmed down TCP part and a routing part IP (Internet Protocol) see 1978. TCP/IP will become the key enabler of the public Internet.
1976	The International Telecommunications Union (ITU) publishes a recommended standard for Packet Switched Networks called X25 aimed primarily at wide area networks. X75 for the interconnecting links-is also published
	30 channel PCM trials are conducted in the UK. 30 channel PCM with a transmission rate of 2048Mbit/s was favoured by Europe whereas 24 channel was North American The UK decided to standardise on the European 30 channel rate of 2048Mbit/s which will become the base for the digital transmission network based on PDH (Plesiochronous Digital Hierarchy) of 2, 8, 34, 140 and 565Mbit/s. This marked a move away from telephony analogue technology to a system more suited for a variety of services including data, voice or video.
	UK's last manual telephone exchange Portree Isle of Sky is closed
	In the USA the 1AESS SPC circuit switched telephone exchange system, an upgrade of the 1ESS with a faster 1A processor (see 1965), enters service

Date	Event
1977	Field trials of prototype Optical Fibre systems are carried out in the UK, USA and other countries Their success will mean major changes to the future planning and provision policy for cable networks worldwide. (see 1978)
	An EPSS (Experimental Packet Switching System) is established in the UK between London – Manchester- Glasgow (see 1971)
	ITT (International Telephone and Telegraph) in USA develop computer controlled digital telephone switching equipment, System 12. Manufacture is carried out by ITT subsidiaries mainly in Europe where it sells well (see 1982).
1978	In the UK following the successful 1977 trials digital Optical Fibre systems are set to become the basis of future trunk and, to a lesser extent, junction networks in preference rather than co-axial cable, microwave radio links or any planned millimetric trunk waveguide. For the local network however, until Internet usage dominates domestic demand for broadband data and video services in the 21st century, there is no economic case for fibre to the premises (FTTP)
	TCP is split into two protocols. A slimmed down TCP would manage data flow control and error correction while a separate Internet Protocol (IP) would deal with the routing of packets across the networks
1979	Japan becomes the first country to introduce a cellular mobile telephone service. An analogue system based on AMPS (advanced mobile phone system)
	INMARSAT – an organisation for maritime satellite communications is formed
	1980 to 1989
1980	First commercially manufactured UK Optical Fibre (OF) link goes into full time service between Brownhills and Walsall in the West Midlands. The first phase of OF systems use the 850nm band and graded index fibre. Later systems use the lower loss 1300nm or 1500nm bands and singlemode (monomode) fibre as designs and components become available.
	Trials of submarine optical fibre cable in Loch Fyne Scotland
	Pilot version of UK's standard digital computer stored programme controlled automatic electronic telephone exchange, System X (code TXD) opens as a tandem at Baynard House London
	USA launches a cellular mobile telephone service using AMPS see 1979

Date	Event
	UK's largest co-axial cable system completed – a 60MHz route between London and Birmingham the cable has 18 tubes each pair capable of carrying 10800 voice channels in FDM in the range 4404 – 59580kHz. No further systems of this type are deployed due to the shift to optical fibre provision.
1981	System X Local Exchange goes into service at Woodbridge Suffolk
	In the UK Post Office telecommunications monopoly is ended and competition re-introduced (see 1912). Most countries follow similar paths
1982	First ITT System 12 digital computer controlled switching system is installed in Brecht, Belgium. Although reasonably successful in the Europe and Mexico when adapted for the US market System 12 is ultimately unsuccessful. .
1983	ARPANET changes from using its original Network Control Program (see 1969) to TCP working. It also splits into 2 parts one for military and one for civilian use. The civilian part will go on to form the public Internet.
	Trials of an Integrated Digital Services Network (ISDN) commence in the UK. ISDN provides facilities, particularly for business customer, for the transmission of voice, data or video
1984	Motorola launched the DynaTAC, the first hand-held phone that could connect over Bell's AMPS. It weighed over a kilogram and was affectionately known as The Brick, but it quickly became a must-have accessory for wealthy financiers and entrepreneurs.
1985	Cellular mobile telephone services launches in the UK by Racal Vodafone and Cellnet (a joint venture between BT and Securicor). This first generation system (1G) was analogue and used a modified AMPS version called TACS (Total Access Communication System). The forecast of user numbers expected within the first 10 years was exceeded within 7 months of launch
	WDM (wavelength division multiplexing), an optical form of FDM (see 1938) increases per optical fibre capacity by simultaneously transmitting light of more than one wavelength and is widely used. Variants include DWDM (Dense WDM) and CWDM (Coarse WDM)
1986	AXE10 a Swedish design computer controlled telephone exchange equipment is introduced into the UK network to complement System X
	EDFA (Erbium-doped fibre amplification) is developed by Southampton University. Other forms of fibre amplification include Raman amplifiers based on Raman scattering and Semiconductor Optical Amplifiers Optical amplification is simpler and more reliable than digital regeneration and allows for greater repeater spacing this reducing costs.

Date	Event
1987	GSM (in French 'Groupe Speciale Mobile' in English Global Systems for Mobiles) is a technical committee established by CEPT (Council for European Posts and Telecommunications). to standardise next generation mobile phone services (2G) to allow roaming. GSM standards are Intended for use across Europe but they are eventually adopted internationally. Unlike analogue 1G, GSM is a digital TDMA (Time Division Multiple Access) system using the Integrated Services Digital Network. (ISDN). GSM provides both voice and text SMS (short message system)
1988	A specification for ADSL (Asymmetric Digital Subscriber Line) is published in the USA. ADSL adds a wideband channel above the voice band for data download and a narrower bandwidth channel for data upload. It becomes a means of enabling operators to provide broadband computing capacity to customers over existing copper telephone lines
	TAT 8 the first transatlantic optical fibre submarine cable is complete. Running between Tuckerton New Jersey USA and via Penmarch, France to Widemouth Cornwall UK.
1989	Tim Berners-Lee at CERN (in French – Conseil European pour la Recherche Nuclear) writes a paper titled 'Information Management: a proposal' for information exchanges between CERN sites. It will eventually form the basis of the public World Wide Web. (WWW)
	ATM (Asynchronous Transmission Mode) is specified by the ITU (International Telecommunications Union) using a combination of circuit and packet switching for the transmission of voice, data and/or video in Wide Area Networks and the ISDN (see 1983). Although adopted in Europe in the USA Frame Relay is developed. (see 1990). ATM is now largely superseded by IP (see 1978)
	Decade 1990 to 1999
1990	BT Long Distance network becomes 100% digital
	The USA commences digital in place of analogue TV broadcasting. Other countries follow. This will eventually lead to innovations like Smart TVs
	Frame Relay, a slimmed down version of X25 (see 1976) is adopted in the USA in preference to ATM (see 1989) for WANs. Like ATM, Frame Relay is now largely superseded by IP (see1978)
1992	Civilian part of ARPANET becomes free from US Government control – this is the birth of the public Internet
	2G cellular mobile services based on GSM launch in the UK (see 1987). Later evolution of 2G incorporates a packet switched standard GPRS (general packet radio services).Users are able to browse the web from their mobile.

Date	Event
	SDH (Synchronous Digital Hierarchy) is progressively introduced into transmission networks in place of PDH (Plesiochronous Digital Hierarchy). SDH creates a synchronous multiplexed signal transmitted on optical fibre, radio relay links, satellite links, and at electrical interfaces between equipment. The advantage over PDH is that SDH greatly simplifies the network. SDH was originally defined by ETSI (European Telecommunications Standards Institute) and later adopted by the ITU as a world standard. However in the USA and Canada a similar system called SONET (Synchronous Optical Network) is used
1996	TAT12 and TAT13 enter service and are the first transatlantic submarine optical fibre cables to use optical amplifiers rather than digital regenerators (see 1985)
	2000 to 2009
2000	3G (third generation) mobile radio services arrive using UMTS (Universal Mobile Telecommunication System) standards. Mobile devices become less for making voice calls and more about using UMTS high speed data capability for viewing video, sharing files, playing games or surfing the web
2003	Luxemburg company Skype launches software enabling VoIP (Voice over Internet Protocol) calls over the Internet. VoIP will impact the PSTN (see 2018)
2007	The iPhone is launched in the USA by Steve Jobs of Apple. Revolutionary in design it eliminated the physical keyboard and replaced it with a touchscreen alternative. This enabled larger screen displays. The Smartphone was born and the original mobile telephone had now evolved into a hand held on-line computing device.
2009	Charles Kao is awarded the Nobel Prize in Physics for his work on optical fibres.
	2010 to 1019
2012	4G (Fourth Generation) mobile radio technology is launched in the UK ushering in the era of the Smartphone.
2013	Zoom, a company founded in 2011 in California USA launches software enabling videoconferencing facilities. During the 2020 pandemic Zoom usage explodes
2017	In the USA 1AESS SPC exchanges (see 1965 and 1974) are progressively taken out of service as telephony moves from the PSTN to the Internet VoIP (Voice over Internet Protocol) facility.
2018	New Zealand, Germany, France, Netherlands and Switzerland are well advanced in programmes to close their PSTN and move customers onto VoIP telephony.

Date	Event
2019	UK Regulator Ofcom issues a policy statement that UK PSTN (circuit switched) networks will be closing and customers moved to VoIP for delivery of telephone services. Openreach (part of BT) announces a target date for UK PSTN closure of end 2025. Once PSTN shut down is fully implemented Openreach aims to de-commission equipment then close and vacate 80% of PSTN exchange buildings from 2030 onwards.
	2020 to 2021
2020	Research into improving optical fibre performance includes consideration of Hollow Core Fibre (HCF). Solid glass fibre cores reduce light speed compared with a vacuum due to interaction with the core material. The delay this causes is minute but with ever increasing demands for high speed data and lower losses, fibre improvements are continually sought. Replacing the solid core with a vacuum is currently impractical, but an air core offers similar benefits. However HCF presents significant challenges yet to be overcome. .
	Roll out of 5G (Fifth Generation) mobile technology commences. Based on ITU specifications 5G is a step-change up from 4G. It addresses the increasing demands of new applications such as supporting IoT (Internet of Things). 5G will run 100 times faster than 4G with minimal latency. With smaller cells geographic connection densities will be greater than any previous mobile generations.

FOOTNOTE

The coming of the electric telegraph revolutionised human communications. This footnote can only provide a very brief summary of those events. For those seeking more detailed information Ken Beauchamp's book The History of Telegraphy (see Bibliography) is recommended.

Proposals made as far back as 1753 suggested electrostatic telegraphs. In an issue of the Scot's Magazine that year an anonymous writer, using initials C.M., suggested 26 insulated wires connecting terminals, one wire for each letter of the alphabet, selectively conducting static electricity from Leyden Jars under control of a sender. At the receive end these could be arranged to move one of 26 pieces of paper, each having a different letter of the alphabet. The CM. system was never built but in 1816 Francis Ronalds demonstrated a working model of an alternative electrostatic telegraph at Hammersmith, UK. This used just one wire. Static generated from a friction disc at the sending end could move pith balls at the receiving end. Movement of the pith balls indicated to the receiver that a signal had been sent. Each appropriate letter would be identified by a complicated synchronised clock arrangement at each end. But range was limited and did not represent a commercially viable system. Parts of Ronalds' Hammersmith equipment are on display at the London Science Museum

The first successful system was designed by Cooke and Wheatstone in 1937 in the UK and demonstrated along the railway between Euston and Camden Town. An analogue device it used 5 needles at the receiving end which deflected when current was received on combinations along 5 wires connecting to the sending end. Although limited to just 20 of the

26 letters of the alphabet it was nevertheless used by the railways, initially between Paddington and West Drayton.

In the USA Samuel Morse developed a digital electric telegraph using his famous code system whereby combinations of short and long electric pulses represented letters of the alphabet. Morse's system was first demonstrated in 1846 using a pair of wires mounted on 'telegraph' poles, 40 miles linking Washington and Baltimore. The simpler digital system using Morse Code was gradually adopted worldwide and is still in places in use today.

Initially deployed to support the growing railway networks telegraph systems were increasingly made available to the public. Telegraphs, or telegrams as they became known, provided the primary means of urgent communications for many people even until the 1940s before home telephones became more widely available in most countries.

As networks grew nationally attention moved to usage for international telegraphy. In 1850, a 25 mile cable, with gutta percha as insulation, was laid between England and France but unfortunately soon damaged by trawlers. A second attempt in 1851 was more successful and many relatively short submarine routes were established in Europe. But the big challenges were intercontinental telegraph cables, in particular between the Europe and America - an oceanic distance of some 2000 miles between Ireland and Newfoundland.

To make the attempt a company, the New York, Newfoundland and London Telegraph was formed by Cyrus Field, an American businessman. After overcoming huge challenges with the terrain the land section New York to Newfoundland was completed but laying the transoceanic section to Ireland resulted in several initial failures. Eventually in 1858 a cable link was completed and Queen Victoria exchanged messages with US President Buchanan. Unfortunately, the cable failed after a few weeks and, delayed due to the American Civil war, it was not until 1866 that a second more successful cable was laid and brought into service. The impact of the telegraph on international communications was enormous. Conveying messages which had previously taken weeks was now almost instantaneous and international telegraph cables eventually circled the world.

Initially telegraph messages required skilled operators to send and receive them. Automation and system improvements naturally followed. In 1874 Jean-Maurice Baudot introduced his 5 unit code (see timeline). New Zealander Donald Murray developed the Baudot system in 1901 by using a typewriter with a QWERTY keyboard to produce a perforated paper tape, which was then fed into a tape transmitter. At the receiving end a printer mechanism could print onto another paper tape – the 'Ticker Tape' so popular with stock markets. Many others contributed developments with a variety of printing telegraphs. Teleprinters, using standard QWERTY keyboards, simplified the sending and receiving of messages.Telex networks exploited the advantages of teleprinters as .

The electric telegraph provided, for the first time in history, near instant national and international communication with the authority of the written word. Sometimes regarded as obsolete it is interesting that today telegraphy, in the form of text messaging on mobile phones or Emails, remains so popular. .

FURTHER INFORMATION

WEBSITES

Visit the Science Museum website

https://www.sciencemuseum.org.uk/communication

For the detailed history of UK telecommunications see BT website

https://www.bt.com/about/bt/our-history/history-of-telecommunications

JOURNALS

The Story of Transatlantic Communications : Proceedings of IET Seminar to celebrate 150th anniversary of the first telegraph cable, Museum of Science and Industry, ,Manchester, 28th October 2008

175 Years of UK Telecommunications Journal of the Institute of Telecommunications Professionals, Vol 6, Part 4, 2012. Papers presented at an IET/ITP seminar

1906-1981 75th Anniversary Edition, The Post Office Electrical Engineers Journal, Vol 74 Part 3 October 1981. A wide ranging review of 75 years of UK telecommunications

A Mathematical Theory of Communications by Claude Shannon, Bell Systems Technical Journal 27, (July/August) 1948

BIBLIOGRAPHY

(Copies of most of the following are available from the IET Library)

Beauchamp, K., *History* of *Telegraphy- its technology and Applications*, IET History of Technology Series No 26, London, 2001

Bray., W.J. *The Communications Revolution: The Telecommunications Pioneers from Morse to the Information Superhighway* Springer Science + Business Media LLC 1995

Burns, R.W. *Television – an International History of the Formative Years* IET History of Technology Series No 22, London, 1997

Burns, R *John Logie Baird, Television Pioneer*, IET History of Technology Series No 28, London 2000

Burns, R., *Communications : an International History of the Formative Years*, IET History of Technology Series No 32, London, 2004

Bussey, G *Wireless: The Crucial Decade 1924-1934* , IET History of Technology Series No13, London, 1990

Garrat, G.R.M *The Early History of Radio*, IET History of Technology Series No 20, London, 1994

Gordon, J.S., *A Thread Across the Ocean – the story of the first transatlantic telegraph cables*, Walker and Company, New York, 2002

Huurdman, A.A., *The Worldwide History of Telecommunications*, Wiley and Sons, New Jersey, 2003

Phillips, V.J., *Radio Wave Detectors,* IET History of Technology Series No 2 London

Povey and Earl *Vintage Telephones* IET History of Technology Series No 9, London

Wheen, A., *DOT-DASH to DOTCOM : How Modern Telecommunications Evolved from the Telegraph to the Internet*, Springer-Praxis, Chichester UK,, 2011

Wood, J *The History of International Broadcasting Vol* 1, IET History of Technology Series No 19, London 1994

Wood, J *The History of International Broadcasting Vol* 2, IET History of Technology Series No 23, London,2000