The History, Development, and Future of Telecommunications in Europe

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From the French Revolution to EURONET —and beyond

IN TRYING to delimit my subject for the reader and for myself, I chose three major divisions for this discussion of European telecommunications. *History* is what happened before I was born; *developments* happened during my lifetime up to the present; and the present laboratory or experimental stages are logical continuations of the former two, leading us into the *future*.

We will look historically at telecommunications between the French Revolution and World War I. This era saw the beginnings of visual telegraphy, the electric telegraph, the telephone, wireless telegraphy, and amplifier tubes in cable and radio telephony.

In a lecture at the Second World Telecommunication Forum, M. Leprince-Ringuet drew attention to the fact that the fall of Troy was communicated to Argos by the kindling of fires on the mountains of the Greek Isles. So, although telecommunications may be much older than my starting point, I prefer to start where "the code is known."

In developments since the 1920's, we will look at four main areas: Multiplex (phantom, carrier wave on cable, coaxial cable, and microwave link), Automatic Telephony (electromechanical and electronic switching), Telex (HF radiotelephony, submarine cables, and satellites), and Mobile and Data Communications.

Then, looking to the future, we will cover System X, System 12, fiber optics, and new services coming to fruition.

History of Telecommunications—French Revolution to WWI

Visual Telegraphy

In 1791, Chappe (1762–1805) demonstrated a simple visual telegraph in the municipalities of Parcé and Brulon in the Department of Sarthe, France [1]. The transmitting station was on a high site, and an observer seeing it from a distance reproduced the sign for the next traject. In the beginning, signs were put in one of 26 dial positions. Later, the alphabet consisted of three straight lines that could be put in different directions. Sixty-six possibilities were used, covering capital and small letters and figures. On March 22, 1792 Chappe proposed to the Legislative Assembly, of which he was a member, that his system of "instantaneous communication" be given a trial. He received funds for a demonstration covering a distance of 35 km. After this, Carnot ordered a line from Paris to Lille which, after great difficulties, came into use on August 17, 1794. Napoleon saw the strategic importance of these connections: in 1795—Paris-Metz-Strasbourg, and in 1798 on towards Landau. Connections were made in: 1805—Paris-Lyon-Turin-Milan, and later to Mantua and Venice; 1809–1810—Paris-Lille-Antwerp-Flushing and Amsterdam; 1813—Metz-Mainz; 1823—Paris-Bordeaux-Bayonne; 1830—Paris-Le Havre; 1832–1834—Avignon-Montpellier-Bordeaux; and in 1842—Dyon-Strasbourg. From 1844 to 1854, the French army constructed visual telegraph lines in Algiers, because they were less vulnerable to sabotage than the electric telegraph that was also already available.

In England from about 1795 onwards, Lord Murray constructed a visual telegraph system connecting London to other harbors: Portsmouth, Plymouth, and Liverpool [2]. In his system, six windows could be opened or closed by shutters, yielding 64 possibilities. A signal took only three minutes from London to Plymouth and back (500 miles). In 1832, King Frederic William of Prussia agreed to the building of a visual telegraph between Berlin and Koblenz (completed

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in 1835). In Russia, Czar Nicholas I opened visual telegraph lines between Warsaw and Moscow/Petrograd in 1838.

Errors arose due to bad sighting conditions, and on the Paris-Bordeaux line corrections were made at Tours. The telegrapher did not need to know the code. In Alexandre Dumas' novel *The Count of Monte Christo*, the main character bribes a telegrapher to let him send a false telegram that ruins his enemy, the banker Danglars.

The Electric Telegraph

In 1809, Samuel Thomas Soemmering constructed an electrochemical telegraph, in which gas production at one of the 35 electrodes indicated the reception of a certain sign. He demonstrated transmission over 150 meters to the Bavarian Academy, also over a wax-insulated line across the Isar [3].

For this experiment he had the cooperation of the Russian Attaché Paul Schilling von Canstatt, who invented a magneto-electric needle telegraph in 1832 and demonstrated it in Bonn in 1835. In 1837, the Czar asked him to build a telegraph line from Petrograd to Zarskoje Selo (30 km), but he died before it was ready. In Göttingen, Professors Carl Friedrich Gauss and Wilhelm Weber had a telegraph line constructed from the Physics Institute to the Astronomical Observatory (1 km) in 1833. It used a mirror galvanometer and an induction coil, and was in operation until 1838.

In 1836, a young officer, William Cooke, returned from India and heard about Schilling's experiments. He asked Charles Wheatstone for help and they obtained a patent in 1837. After a demonstration near London, they were able to sell their five-needle telegraph to the Great Eastern Railway. Other companies followed and Cooke and Wheatstone founded the Electric Telegraph Company. By 1852, England had 6500 km of telegraph line.

In 1838, Samuel Morse tried to sell his telegraph (successfully tested on Sept. 4, 1837) to France, but it was considered too vulnerable. In 1842, Arago found a simple way to protect the telegraph line by putting it alongside a railway, then constantly guarded. In 1845, telegraph connections were available between Paris and Rouen in France and between London and Portsmouth in England. The Netherlands obtained the electric telegraph in that same year, and in 1846 Austria-Hungary and Belgium followed. In 1849, Berlin-Cologne, and in 1852 Paris-Lille were electrified.

In 1845, a young artillery officer, Werner Siemens (1816–1892), had difficulties working with the Wheatstone needle telegraph [4]. He made some improvements and asked the mechanics, Bottcher and Halske, to build a new one according to his design. This was successful and led to the foundation of the telegraph construction firm Siemens and Halske in 1847. In 1848, Siemens and Halske received the order for a telegraph line from Berlin to Frankfurt. In 1849, Siemens was released from the military service. The Berlin-Frankfurt line was ready just in time for the announcement of the election of Frederic William of Prussia to Emperor of Germany by the National Convention at Frankfurt—March 28, 1849. In the same year, the Berlin-Cologne-Verviers line was constructed by Siemens. Further orders in Prussia followed, and in 1851, 75 printing telegraphs were delivered for the Petrograd-Moscow line.

In 1852 Werner Siemens visited Russia twice, and he came back with large orders for the construction and maintenance of the state telegraph system on the following lines: Myslowitz (Germany)-Warsaw-Petrograd-Helsingfors-Abo, and Reval-Petrograd-Kiev-Odessa/Sebastopol. Werner asked his brother Carl to head the office in Petrograd. In 1850, the Prussian-Austrian Telegraph Union was founded in Dresden. Also in 1850, a sea cable was laid between Dover and Calais, but it was soon defective. A year later an improved cable was laid with better results. In 1851, Wurttemberg, France, Belgium, and Prussia signed an agreement on telegraph traffic. More countries wished to join and in 1865 the International Telegraph Union was founded in Paris. By 1855 there already was a telegraph network in India. William Siemens, another brother, who headed the Siemens Office in England, took the initiative for the Indo-European London-Calcutta telegraph line in 1867. The technical system used, developed by Werner Siemens in Berlin, was based on sensitive relays, punched tape feeding of the transmitter, and a printing telegraph. It was ready in 1870, laid through the Persian Gulf from Bushir to Karachi, and was 11 000 km long. It worked satisfactorily until 1931. In the beginning, iron wires were used for telegraph lines, and later copper. (Carl Siemens bought a copper mine in the Caucasus in 1864.)

As to apparatus, one had the choice between the Morse type, the Hughes type (1858, based on an ingenious mechanical synchronization mechanism between transmitter and receiver, in which the timing of a pulse controlled the symbol to be transmitted and received), the Foy-Bréguet type (using the symbols of the visual telegraph), or the Baudot type (1874, a code with five impulses for each letter, easily used in multiplex arrangements). In 1903, the I.T.U. preferred the Hughes and Baudot types.

The first transatlantic cable was laid in 1866. In 1874, on the initiative of the Siemens Brothers, a special cable-laying ship, the *Faraday*, was constructed. It laid six transatlantic cables of very good quality in the next ten years.

The Telephone

In 1861, a German physics teacher, Philipp Reis, demonstrated an electric telephone for a physics society in Frankfurt, and later in the autumn for Emperor Franz Joseph of Austria and King Max II of Bavaria. In 1863, William Thomson developed a condenser microphone. However, only after the Bell telephone came to Europe was there a general interest.

Alexander Graham Bell gave a lecture in Plymouth for the British Association, and demonstrated his telephone for Queen Victoria at the Isle of Wight in 1878, with connections to Southampton, Cowes, and London. His patent was dated in 1876, and in 1878 Bell made his honeymoon visit to

England. A high English civil servant gave Werner Siemens a present of two Bell telephones in 1877. The latter was very impressed, and wrote to his brother Carl: "We will take out a telephone patent soon; there are several ways of improving the Bell concept" (Nov. 6, 1877). Werner improved the magnetic circuit by using a horseshoe magnet, and in 1877 he had already reached production of 700 telephone apparatus per day. On May 9, 1878, David Edward Hughes (of the printing telegraph) demonstrated a contact microphone for the Royal Society in London. Hughes (1831–1900) lived in the United States from 1838 to 1857, where he became a professor of music [5]. The keyboard of his telegraph looked like that of a piano. He gave an early demonstration of wireless telegraphy in London, across 500 yards, but he gave up when members of the Royal Society were not impressed (1880).

In 1881, the first telephone exchange was opened in Berlin, and at the end of the year had 458 subscribers. In 1882, Stuttgart followed with 75 participants. In December 1877, the first Swedish telephone circuits were laid in Stockholm between the Stockholm gasworks and the gasometer and between Cedergren's shop and his home. In early 1878, a large number of fixed telephone circuits followed, along with telephone trials over long distances (Malmo-Lund). In Stockholm, Bell Telephone opened a telephone exchange with 121 subscribers on Sept. 1, 1880, followed precisely a year later by a State telephone exchange with 32 participants. Another private network, Allmanna Bolaget, of which Cedergren was the head, became the strongest in this category, even stronger than the State network. In 1923, all private networks were transferred to the telephone administration [6].

In December 1877, the Swiss telegraph operation got two telephones from Siemens and Halske in Berlin. Experiments were carried out between Bern, Thun, and Interlaken [7]. In December 1877, Bellinzona was connected with Luzerne and in January 1878 with Milan. In Vienna (1877) and Bellinzona (1878), there were early telephone connections for music and opera. In 1881, a stereophonic connection with the Opera was demonstrated at the Paris International Exhibition. A telephone exchange with 200 lines was opened in Zurich in 1880, and a second exchange with 500 lines soon followed. Bern and Basel got their exchanges in 1881, and Geneva in 1882. On February 1, 1883, the interurban Zurich-Winterthur net was opened. Before 1889, interurban connections existed between Geneva, Lausanne, Bern, La Chaux-de-Fonds, Basel, Zurich, St. Gallen, and many other cities. In 1900, a telephone cable through the Gothard tunnel brought Tessin into the national net.

The telegraph was nationalized in England in 1871, and in 1880 the High Court decided that the telephone fell under that monopoly. Concessions were given to several companies, and in 1881 London had three exchanges with 1100 subscribers.

In France, M. Antoine Bréguet demonstrated a Bell apparatus at the Académie of Sciences, October 29, 1877. Several societies were formed to exploit American patents, but a fusion in 1880 led to the Société Générale du Téléphone. Many large French cities installed their telephone exchanges between 1883 and 1886: Reims, Roubaix, Tourcoing, Caen, and Bordeaux. Between 1885 and 1887, interurban connections followed: Paris-Rouen-Le Havre, and Paris-Brussels. In 1888 and 1889, Paris-Marseilles and Paris-Bordeaux followed. The French administration took over all existing telephone nets in 1889 (until then in the hands of S.G.T.). The combination of microphone and telephone for professionals came from Ader (S.G.T.) in 1879. For the general public, such a model became available in 1893 (Berthon-Ader). In Sweden, L.M. Ericsson developed a handset for switchboard operators in 1884, and one for the public in 1892. A German firm, Mix and Genest, brought the telemicrophone to the market in 1887.

Ericsson [8] designed the helical microphone in 1880; this consisted of two series-connected contacts and a device for simple and accurate regulation of the contact pressure. In 1881 the Gavle Telephone Association made comparative tests between Bell and Ericsson telephones, and found the latter to be superior. This led to increasing demand. In 1882, Western Electric established the Bell Telephone Manufacturing Co. in Antwerp, Belgium. Ericsson patented a carbon granule microphone, in which the carbon granule chamber was divided into six sectors (to prevent the granules from becoming too closely packed together), in 1888. About 1895, the idea of supplying the microphones of the subscribers' telephones from a central battery (CB) in the telephone exchange was put forth in the United States (advantage: no batteries on the subscribers' premises). In 1903, Ericsson described such a CB system in a Swedish patent, and delivered a CB exchange to the Hague.

Heaviside outlined the merits of adding inductance to cables in 1887, and in 1893 mentioned the possible use of series coils. In 1899, Pupin filed a patent on coil loading of cables at regular distances. Ebeling and Dolezalek, of Siemens and Halske, worked on the practical application of "pupinized" cables, and used them on lines near Berlin, and in 1906 on the first telephony cable through the Bodensee between Friedrichshafen and Romanshorn. There were good contacts with Pupin, who wrote in his autobiography, *From Shepherd to Inventor*, "I understood my invention now much better than ever before, and I am convinced that the scientific experts of Siemens also understood it very well. Their commonsense descriptions were better than my own." The experimental results justified a large trial and this was made on the Berlin-Cologne cable which started in 1912 but, due to the war, was not completed until 1921. The results were completely satisfying and led to the construction of a large European cable network.

Automatic switching came to Europe in 1901 when the Strowger Company built an experimental exchange in Berlin. The Strowger patent covered the step-by-step driven decadic switch with vertical and rotary movements. Siemens and Halske concluded a license agreement with Autelco, the firm exploiting Strowger's inventions. Siemens also obtained a patent on a fundamental step-switch preselector technique (1901). Automation in Europe started with a central battery self-selection system in Munich in 1909 (2500 participants), followed by Amsterdam in 1911, and Dresden in 1912. In 1912, van Kesteren (Netherlands P.T.T.) drew attention to the advantages of a four-wire system on which he received a patent [9]. Another improvement for this case was balancing at the ends (Ohnesorge, German P.T.T.).

Whether one can make a desired telephone call at a certain moment is a matter of chance. During the first two decades of this century, the probability problems involved were studied by Erlang (Denmark), whose work became better known after publication in an English journal [10]. Starting from hypotheses, the relation between the number of lines, the traffic offered, and the blocking probability were derived. In honor of his work, the CCITT introduced the unit erlang. The traffic in erlangs is equal to the average number of lines found engaged during the observation, or it can be calculated from the equation $y=c\ t_m/60\ T$, where c is the number of engagements during the observation, t_m is the mean holding time (minutes), and T is the duration of the observation (hours) [11]. Erlang started from a Poisson distribution for the probability of just x lines being busy. Engset, a Norwegian mathematician, used a Bernoulli polynomial distribution instead. Other active researchers in this field were Pollaczek (Poland) and Vaulot (France). A critical examination of the validity of the Erlang and Engset formulae was made in the theses of Kosten (Delft 1942) and Palme (Stockholm 1943).

Wireless Telegraphy

Guglielmo Marconi was born on April 25, 1874 in Bologna. He studied physics in Livorno under Professor Roza and read papers by Righi, Branly, and Hertz. Early in 1895, he commenced experiments to determine whether it would be possible to transmit telegraphic signs over a distance by means of Hertzian waves. He used an improved Branly coherer with nickel and silver filings between two silver plugs in a tube. In August 1895, he discovered that connecting the spark-gap to a wire or capacitance above ground, and the other end to earth, increased the distance over which he could communicate. With cubes of 100-cm side at a height of 8 m, he could transmit over 2400 m all around [12]. In 1906, a demonstration was given for William Preece, then chief-engineer of the British Post Office (BPO). The conventional spark-gap produced heavily damped oscillations that covered a wide frequency spectrum. Marconi's rotating disc discharger greatly improved this, and after the middle disc was provided with copper studs at regular intervals, a musical tone was heard.

In 1900, Marconi made the capacitance and the inductance adjustable, so that syntony between transmitter and receiver could be arranged. This led to Marconi's patent 7777. Sir Oliver Lodge already had a patent on syntonized telegraphy (1897), but this was not backed by experiments. Nevertheless, this patent presented difficulties in acquiring Marconi's patent in the United States, and Marconi bought the Lodge patent.

Several Marconi demonstrations were attended by foreign guests, among them Professor Slaby of the Technical High School in Berlin, who was working with Count von Arco and later with Professor Braun on wireless telegraphy in Germany. In 1897 and 1899, Marconi did experiments with the Italian Navy, which decided in 1898 to adopt the Marconi system. On March 27, 1899, Marconi's wireless messages crossed the English Channel between Wimereux and South Foreland. In 1900, the English Navy gave its first big contract to Marconi. In January 1901, wireless communication was established between St. Catherine Point on the Isle of Wight and the Lizard in Cornwall, over a distance of 300 km; this proved to Marconi that electric waves were able to make their way around the curvature of the earth. Only 150 watts were needed [13].

This encouraged Marconi to try transatlantic reception. There were setbacks: the large antenna systems erected on both sides of the ocean were destroyed by heavy winds, and Marconi tried reception in Newfoundland with an antenna suspended from a kite. The receiver was very crude—a few coils and condensers, and a coherer. On December 12, at 12:30 p.m., Marconi handed the earpiece to his assistant, Kemp, and asked him whether he heard anything. Indeed, he too heard the three dots of the letter "s"; another assistant, Paget, did not hear anything, but Marconi said he was a little deaf. Marconi gave the wavelength in a 1908 lecture as 366 m, but Fiore, in an article 50 years after the event, put it at 1800 m [14]. The circumstances were abominable, and a wavelength of 366 m was quite unsuitable for daylight reception.

In 1902, experiments followed on board the liner *Philadelphia*; in daylight, signals were received at a distance of 700 miles, and at night up to 2100 miles. This time the messages were recorded on tape and signed by Captain Miles. Marconi suggested that the difference between day and night reception was due to solar influences. At that time the existence of the ionosphere was already assumed (Kennely-Heaviside), but it was not proved until twenty years later.

By the end of 1902, seventy ships were equipped with wireless telegraphy, and 25 land stations had been erected. Among the ships were the large German ships *Kaiser Wilhelm der Grosse* and *Kronprinz Wilhelm*, and the Dutch cruiser *Evertsen*. Among the ground stations were Borkum and Scheveningen. Italy ordered a high-power station for Coltano on January 27, 1903. In 1904, Professor J.A. Fleming, a consultant to Marconi's company since 1899, invented the diode. In 1905, Marconi found and patented directional aerials. In 1906, Franklin (of the Marconi Co.) invented the variable disc-capacitor, also in its three-fold construction, ganged for simplicity of operation. In 1901, Marconi set up a school for wireless operators, who remained in the service of his company when placed on ships.

At that time, Marconi was close to a monopoly position with his large number of stations, ships, and operators. At times his stations would not answer calls from ships with different installations. An international conference in Madrid, in 1906, ratified a proposal made in Berlin in 1903 that all coastal stations should receive and transmit to all ships, regardless of the type of apparatus installed. To Marconi's disappointment, this treaty was ratified by Great Britain in 1908.

". . . this proved to Marconi that electric waves were able to make their way around the curvature of the earth."

On October 15, 1907, transatlantic Clifden-Glace Bay service was realized. In 1902, Marconi patented a "magnetic detector," an important improvement compared to the coherers [15]. It was a cyclic hysteresis detector, in which a band of soft iron wires moved slowly past the poles of stationary permanent magnets. An oscillatory current passing through a coil has the effect of moving the domains, so that a loud click is heard in a telephone earpiece connected to a search coil. It was used until 1918.

In July 1902, King Victor Emanuel III invited Marconi to join him on a visit to Czar Alexander III of Russia, and to make experiments on board the cruiser *Carlo Alberto* while traveling. In Kronstadt, the signals from Poldhu, 1600 miles away, were well received. Among the guests coming on board was Popov, who greeted Marconi as "the father of radio." After the trip, Marconi was offered the use of the cruiser with its full complement of 600 ratings, for long-range testing over the transatlantic route. In 1909, Marconi and Braun shared the Nobel Prize. In 1911, the Coltano station, 500 kW, was brought into service. The contract for an Imperial chain of wireless stations was signed in March 1912, but there were rumors of corruption; a new contract, July 30, 1913, had to be canceled in 1914 because of the war. For shipping, a good directional finder was important and, when one was patented by Bellini and Tosi, it was taken over by the Marconi Co., to which Bellini became a consultant.

Danish engineer Valdemar Poulsen patented a successful arc transmitter in 1903. He used a fixed carbon electrode opposite a slowly rotating carbon cylinder, which always gave the arc a fresh spot on the carbon. Later, Poulsen used a copper and carbon electrode in a hydrogen or hydrocarbon gas [16]. Another improvement was Wien's quenched spark transmitter [17].

Amplifier Tubes in Cable and Radio Telephony

In 1903, Robert von Lieben applied for a patent on a heated cathode tube with amplifier characteristics. His first invention was a cathode ray tube controlled by a magnetic field. In 1906, he invented a triode with Reisz, and in 1912 a consortium of German industries bought the patent. In 1903, a Berlin professor, Arthur Wehnelt, found the oxide cathode, which, with indirect heating, was to be important in the future. Lee de Forest patented his audion in 1907. The use of the high-vacuum triode by Langmuir (1912) was a step forward. In Europe, the first triode oscillator patents were taken by Meissner (April 1913). After a visit to Telefunken, Franklin claimed a patent in June 1913. Armstrong had a similar idea in October 1913, and Round in 1914 [12]. In 1916, Schottky developed the tetrode with an extra screen.

A great storm severed all overhead lines between London and the North of England on March 27, 1916. Afterwards, only the new London-Birmingham-Liverpool cable [18] remained. Two repeaters were installed in Liverpool for connections to Dublin and Belfast. Four repeaters were installed in Birmingham in May 1916. During the war, Colonel (later General) Ferrié managed to produce valves in series which produced uniform characteristics (later known as "the French valve"). On the other side, repeater connections between Berlin-Constantinople and Charleroi-Bucharest were top efforts.

In the Netherlands, a factory for telegraph apparatus (N.S.F.) was set up in 1917, as the warring countries did not deliver the telegraph apparatus necessary for Dutch shipping. Philips produced simple receiving triodes in 1917, and transmitting triodes in 1919. In 1922, Philips charged Balth van der Pol with radio research. (He had worked with Fleming, J.J. Thomson, and Appleton in England; also on triode theory.) Within a year he demonstrated an eight-valve 200-kW transmitter for the English authorities in Carnaervon, and a 50-kW one-valve transmitter for General Ferrie. He used the chrome-iron anodes that could easily be water-cooled, as the extension coefficient of glass and chrome-iron were equal. Tellegen introduced a third grid to hold back secondary electrons, and his pentode (1926) was considered an important improvement. In 1928, Black and Posthumus independently invented the negative feedback principle; the application of Black's patent to telephony is more widely recognized. Van der Pol's work on relaxation oscillations is well known, as are his contributions to nonlinear circuit theory, radio propagation (with Bremmer), and frequency modulation.

Marconi had noted that the effect of daylight was less at long waves and he tried wavelengths from 3000–20 000 m for long distances. However, during the war he began to think that he was heading up a blind alley in limiting his research to long waves. This led to a series of investigations, largely carried out on board his yacht *Ellettra* between 1921 and 1924. Directional antennas for wavelengths between 20 and 92 m were used. With 12 kW he could reach distances of 10 000 km by night and 2500 km by day. In 1926, a system of 20-kW transmitters was set up to connect London with many places in the Empire and the world, beginning with wireless telegraphy, and occasionally, experimentally, radio telephony. There was competition between cable and wireless interests, and the governments recommended a fusion. Cable and Wireless Ltd. was founded with 43.75% of voting power for the Marconi Co. An offer of the new company to provide telephone communications with the Empire was rejected, however, as the Post Office wanted its own independent network. In November 1929, an earthquake broke 10 of the 21 cables in the Atlantic, but the traffic was taken over by the shortwave beams without problems.

Numans and van der Pol set up a radiotelephone service from the Netherlands to the Dutch East and West Indies in March 1927. From 1919 to 1923, a Netherlands Indies-Netherlands two-way radio telegraph service had operated. In 1933, the telephone connection with the East Indies was single sideband (probably a first on short waves over such distances). In connection with the use of ever higher frequencies, the magnetron was developed as a transmitting tube. Posthumus treated the functioning of the magnetron with split anode in basic expositions (later of importance for radar) [19].

Development since the 1920's

Multiplex—Phantom, Carrier Wave on Cable, Coaxial Cable, Microwave Link, FDM, PCM, TDM

The earliest method of getting extra circuits on a multipair telephone, telegraph cable, or open-wire pole route, was by using both wires of an ordinary two-wire circuit effectively parallel, as one conductor of a phantom circuit. Invented in 1882, phantom working became practical around 1900 and was employed extensively in the United States on open lines and in Europe on cables [20]. F. Jacob (England) and F. van Rysselberghe (Belgium) suggested balancing by using twisted wires or other methods of adjustment (patents in 1882, 1883).

Phantom circuits were used in England from 1898 onwards—Leeds-Hull, London-Bristol. By 1911, the BPO had 236 phantom circuits—London-Liverpool and London-Glasgow (600 km). Phantom working on loaded cable was also used on the Leeds-Hull line and on submarine cable (across the

English Channel and England-Holland). In Germany, the phantom principle was widely used (Berlin-Vienna, Berlin-Budapest); in 1898, it already had 19 phantom circuits, 3552 km long.

In 1909, Ernst Ruhmer showed how to send four telephone conversations over one pair of wires. From 1923–27, Fritz Loschen sent 6 to 20 telegrams on audio frequencies over one pair of wires. In 1930, the 160-km sea cable between Stralsund and Malmö was doubled in capacity by carrier frequency use. From 1935–36, 200 telephone calls were sent over one coaxial cable between Berlin and Leipzig, followed soon by connections all over the country. In England the first carrier systems were installed from 1932–1933. They provided a single carrier above the audio band on overhead routes. From 1936 onwards, 12-channel equipment was available. It was easy to arrange for extra frequencies by using a pair of transformers and four copper-oxide or selenium rectifiers (Ring-modulator). As the circuit was balanced with respect to the carrier, the carrier could be used for signaling. International agreement on bandwidth and spacing was reached in 1938. Carrier system No. 7, introduced in the United Kingdom, 1940–41, was designed to these parameters: a 12-channel group in the 60–108 kHz frequency band that could be translated into the 12–60 kHz line frequency band via a 120-kHz carrier. By 1950 most routes had 24 channels in this manner [21]. The first experimental coaxial cable system was in service in 1938, followed by a truly standardized system in 1950. A line frequency range of 60–2540 kHz was used, 10 super-groups (600 circuits) being accommodated within the line spectrum. Repeaters were spaced at 9.6-km intervals on 2.6/9.5-mm coaxial cable pairs. In 1951, the 4-MHz coaxial cable system was introduced (960 circuits), and in 1960 the 12-MHz coaxial line system with 2700 circuits (which still had valve repeaters). By the late 1950's however, reliable high-frequency transistors had become available, and in 1960 the first transistorized coaxial system was installed between Hastings and Eastbourne. It had 300 circuits in the 60–1300-kHz range. 4-MHz transistor systems were produced in 1967, 12-MHz systems in 1971, and 60-MHz systems with 10 800 telephone circuits were available in 1973.

In the Netherlands, three speech channels were used experimentally on an open wire connection between the Hague and Groningen in 1923. In 1931, extra carrier wave channels were available on the Netherlands-England sea cable. In 1936, the Dutch P.T.T. introduced the PTT 12-channel system with a repeater distance of 60 km. From 1948 onwards, a 48-channel system was used which was built in cooperation with Philips and Standard Electric. In 1962, two 120-channel systems were installed, with repeater distances of 6 km. In 1954 a coaxial cable was used on Amsterdam-Haarlem lines (960 channels), and in 1973 on Amsterdam-The Hague (3 coaxial pairs, ultimately 32 400 channels).

The first microwave connection was Calais-Dover in 1931. The microwave net for Eurovision and the FM broadcast net led, in several European countries, to the building of a large number of towers that could also be used for microwave connections. In the Netherlands, this started in 1950 with a link over the Scheldt between Goes and Terneuzen. In 1978 a microwave net connecting all districts was realized.

PCM was invented in 1937 by the Englishman Reeves, then a member of the staff of the Paris Laboratory of ITT. Reeves returned to England in June 1940, but there was more urgent work for him to do. In December 1940, Deloraine, his boss at L.C.T., went to the United States where the military showed an interest. An experimental order was placed with Bell Labs. A full-scale, 24-channel system was used in the field by the United States military at the end of WW II. After the war, the Bell system was the first to benefit from this new technique [22]. Usage did not become general until the advent of reliable transistors and integrated circuits. Mr. Deloraine returned to France and in 1945 invented time division multiplex (TDM). The first applications, here too, were in integrated military tactical telephone networks. A TDM exchange was proposed in 1962, but it was 1969 before field trials were made (system RITA, France).

In London, an experimental TDM exchange exposed the fact, in 1963, that technical and design problems had to still be solved. In Italy in 1965, the first European 24-channel PCM systems were tried. In the United Kingdom, the first digital line system (in 1968) was also 24-channel PCM (1.536 Mb/s). It is claimed that London (Empress) had the first PCM switching exchange in the world in that year. The Centre Nationale d'Etudes des Telecommunications, founded in 1944, started its studies of electronic switching in 1965, and in 1970 an experimental system, "Platon," served all 50 000 subscribers in the Lannion area. On the basis of this experiment, the system E10 was introduced into the French network in 1972. In 1983, France had an expanding modern network with 4.3 million E10 lines. CIT-Alcatel has delivered this electronic TDM switching system to 34 countries.

Marconi used a microwave link to connect the Vatican with Castel Gandolfo in 1932. Professor Vecchiacchi experimented in 1937 in Italy with a wavelength of 1.50 m for the Milan-Rome connection. A first version was completed in 1941. In 1947, a broadband relay on 30 cm followed (Milan-Turin). A nationwide network was ready in 1957 (960 channels per carrier) and it was extended in 1961 to 2700 telephone channels per carrier. Both France (Thomson C.S.F.) and England (GEC Telecommunications) are organizing a new nationwide radio relay system at 140 Mb/s in the 11-GHz band.

Automatic Telephony—Electromechanical and Electron Switching

Strowger had invented the step-by-step driven decadic switch with vertical and rotary movements in 1895. The dial was invented in 1896. McBerthy of Western Electric developed the rotary system (1908), in which the machine-driven switches performed solely rotary movements, but the further development was left to ITT's Belgian subsidiary, Bell Antwerp. Rotary automatic exchanges were installed at Dudley and Hull about 1920. In 1922, an improved Strowger system, with call storing and translating schemes, the "director" system, was adopted for London. In 1923, Siemens set up a fully automatic interurban exchange in Weilheim, Bavaria. In 1910, the Swedish administration had its own factories, named Televerket, and it was looking for, preferably, a Swedish system for automatization of the Stockholm network.

Betulander and Palmgren had developed a register-controlled relay system for small exchanges. This system was adapted to the capacity required for a large exchange. It used small non-numerical switches in the form of relay groups, interconnected through link circuits. The switching system was called a *link* system. The connections were set up by common control equipment, the *markers*. A link system, made up of two switching stages, A and B, can have k groups of n switches with a capacity of m lines in the A stage, and m groups of k switches with a capacity of h lines in the B stage. The markers hunt for a free path through the partial stages and set up the connection. Link systems have made it possible to use crossbar switches on a large scale. In October 1919 the world's first crossbar system was demonstrated.

Hultman of Televerket invented the two-dimensional bare wire multiple (1915). Instead of multipled individual contact banks, the multiple consisted of bare wires which passed a large number of switch positions at right angles. During the movement of the switches, direct contact was made with the multiple wires. The contact points were so inexpensive that large register-controlled and machine-driven switches could be constructed. An agreement was made with LME, and Kaell found that the optimal size was about 600 lines, and that the switch would be simpler and more stable if it made a rotary movement, followed by a radial movement into the multiple, instead of the two perpendicular movements in Hultman's original switch. This led to the machine-driven, register-controlled 500-switch system that was selected in 1920 by Televerket for large exchanges in Stockholm and Gothenburg. An early order for this system came from the Rotterdam West exchange in the Netherlands (installed May 1923).

Televerket also decided to further develop crossbar systems. When Mathies of Bell Telephone Labs came to Sweden in 1930, he saw a crossbar switch, built as a unit, with relay-type precious metal contacts. This switch contained only 100 crosspoints in a 10 × 10 array. Five selecting bars were rotated by separate magnets in two directions to access ten sets of crosspoints. It should be noted that the basic idea for a crossbar switch came to Reynolds (Western Electric) in 1913, and that only after seeing the Swedish improvements was a renewed study made at Bell Labs, leading to commercial application in 1935. Around 1940, Televerket suggested to LME that crossbar registers should be introduced in the 500-switch system. Televerket took an active part in this work and indicated many of the technical solutions.

The manufacture of crossbar switches at LME started on a small scale in 1945. It increased continuously, and in 1975 the annual production of the Ericsson group exceeded 500 000 switches. It was not easy to find the traffic capacity of link connections. Conny Palm had some success in calculating it and the profound studies of Christian Jacobaeus led to a standard method, widely used also by other manufacturers. In 1950, Helsinki ordered crossbar equipment in connection with the 1952 Olympic games. Rotterdam introduced multistage crossbar equipment in its 500-switch exchanges in 1952. Large orders were received from Denmark, too. The breakthrough of the crossbar system was of decisive importance for the renewed development of the Ericsson group after its troubles in connection with the Ivar Kreuger crash in 1932. In 1956 it became clear that Televerket and L.M. Ericsson both had an interest in electronic switching. It was agreed that a joint Electronics Council should supervise this work. This led in 1971 to the foundation of a new company, ELLEMTEL, the first assignments of which were a semi-electronic private branch exchange for 200–800 extensions, and a stored-program-controlled (SPC) local exchange system. (In SPC exchanges, the mode of operation is determined by common computers in accordance with programs read into memories).

In 1959, LME's subsidiary, North Electric Company, received an inquiry for an all-electronic exchange to form part of a tactical communications system for the United States Air Force. The 412-L project represented a momentous advance, and ten years later NEC received an additional order (17-million dollars). In 1968, LME delivered a zone center with code switches for Tumba, south of Stockholm, and similar exchanges for the Swedish Air Force. These were the first SPC exchanges outside the United States. The code switch (Alexanderson, 1955) is smaller than the crossbar switch and has a larger multiple capacity.

The first SPC exchange of multiprocessors was installed in Rotterdam in 1971 (two processors). In 1974 Copenhagen had six processors with 17 incoming and 17 outgoing 600-line units.

Beginning about 1970, there was a strong trend in Europe to go from electromechanical to increasingly electronic forms of switching. In 1972, Switzerland outlined plans for an integrated PCM switching system with stored program control. This will be introduced gradually, starting in 1985.

We have already mentioned C.N.E.T. in France. Its purposes were to build up research, come to the highest possible technological level, and bring a national industry to life. In 1950, France had mostly rotary exchanges, but they were too slow. In 1955, the French administration requested bids for new systems. The French ITT subsidiaries C.G.C.T. and L.M.T. proposed a new system, named Pentaconta because its basic unit had fifty entries, which is a link-connected crossbar system. Ericsson, in France, developed a crossbar system of its own. The result was the French system CP400. Pentaconta was tested in Melun, and CP400 in Beauvais.

In 1956, CP400 was adopted as a standard for provincial towns, with the condition that the French companies CIT-Alcatel and AOIP could also manufacture it.

Pentaconta was adopted for Paris and other large cities. The Paris rotary system (1928) was replaced in 1966. However, a subscriber in Paris who wished to reach his correspondent in the provinces had only a 50% chance to reach him the same day. In 1975, the administration asked for offers for a space-switching system. Two systems were finally accepted—the Swedish system AXE, and the Metaconta of the ITT subsidiaries. The latter has two processors built by the ITT laboratory in Paris. In 1978, Thomson bought L.M.T. (one of the ITT subsidiaries) and the French Ericsson. This would seem to have made a clear division: space division for Thomson CSF and time division for C.I.T. The first AXE came into use in June 1979 in Orleans, and the Metaconta 11F in Clamart, Sept. 1979. Thomson CSF found

"Beginning about 1970, there was a strong trend in Europe to go from electromechanical to increasingly electronic forms of switching."

that the researchers of L.M.T. had also prepared a time-division exchange, the MT20. From this, Thomson-CSF developed three types of time-division exchange: MT20, MT35, and MT50, to be used in analog and digital networks.

CIT Alcatel added SPC to its E10 exchanges. These connect subscriber lines into the central switch through remote concentrators reached from the center on PCM links. This method is used in the Acropole project in Paris.

About 1965, England introduced reed electronic systems, such as the TXE2 small-capacity system, of which 1200 were in service in 1981. The TXE4 large-capacity system followed, originally an initiative of STC, which lacked official backing by the BPO but was adopted by it in 1972. A further development was TXE4A, which was able to interwork with the fully electronic exchanges that were only a few years away. Plessey was better known for its work in the component and material field, in data processing and automation, and in avionics and hydraulics, than for its work in telecommunications. This started in 1962 with the takeover of Automatic Telephone and Electric Company and of Ericsson, England. In 1966, it was decided to bridge the gap before the expected digital exchanges would come by ordering crossbar equipment. The Plessey 5005 was selected for this purpose. It had a mechanical control unit that was replaced by a GEC MK1C processor in the London sector switching centers, and by the more powerful MK1P processor in group switching centers.

In the Netherlands, in the 1960's, an all-electronic exchange was tried, the ETS III system of Philips. At the time, the conclusion was that reed-relays were more promising for the near future. Philips made a processor-controlled PRX system, of which the latest version PRXD is based on decentralized control by fast and powerful microprocessors. The collaboration between AT&T International and Philips Telecommunication Industry has led to the introduction of ESS5 PRX as a joint venture.

In Italy, the Face-Standard Labs studied the improvement of a Pentaconta exchange by the introduction of microprocessor control. Face also developed a system to connect digital and analog exchanges over digital transmission lines, to be used in Bologna. Telettra did studies on space-division electromechanical terminals, on space-division terminals with electronic crosspoints, and on PCM exchanges. Italtel developed the Proteo system, a digital switching system, installed in over 50 public exchange plants and accounting for more than 130000 subscriber lines in 1981. For high-capacity exchanges, a self-routing connecting network has been described [23].

In the Federal Republic of Germany, Siemens constructed the precious-metal motor rotary selector EMD in 1953, and the precious-metal reed relay ESK in 1957. Siemens crosspoint techniques were used in over 90 countries. In 1974, the computer-controlled electronic exchange EWS came on the market, followed in 1979 by the electronic microprocessor-controlled-and-stored-program Siemens system EMS.

In the German Democratic Republic, the electronic telephone switching system ENSAD was developed in cooperation with the U.S.S.R. A freely programmable control computer offers a great number of new performance features. The exchanges of the ENSAD, with their space-divided two-core switching network, can also switch PCM signals [24].

Telex—HF Radio-Telephony, Submarine Cables, Satellites

Telex (Teleprinter Exchange)—Before telex was introduced in the telephone net, there were analogous possibilities in telegraphy. In 1919, Siemens had a net of fast telegraphy all over Europe. In 1927, Lorenz produced a telex machine (on American licenses). At about that time Siemens started experiments with a telex net between its German subsidiaries. The Bundespost had its first telex line between Berlin and Hamburg in 1933, and a national telex net in 1935. After the war, in 1950, there were 4000 telex subscribers in Germany, 8000 in 1972, and 130000 in 1980. Siemens had built 100000 teletypewriters by 1958, 250000 by 1967, and 400000 by 1980. The estimated number of teletypewriters worldwide was 1200000 in 1980. The fully electronic Siemens teletypewriter has been delivered since 1976.

In 1934, ten countries agreed on an international telexnet at a conference in Prague. A national Swedish telexnet arrived in 1946. In 1951, Televerket had telex exchanges on a crossbar system. LME's development of automatic telex systems started in 1958, and these were installed in several cities. Sweden had 4000 telex subscribers in 1965, 12000 in 1977, and expects 30000 in 1990. In the United Kingdom, there was a manual telex network during the 1950's; an electromechanical automatic network was completed in 1960 (90000 subscribers in 1980). International automatic SPC gateway exchanges came from Plessey in 1977 and 1980. Eleven SPC exchanges for the inland network were contracted from GEC, to be manufactured by its Canadian subsidiary (Canadian Marconi) and delivered between 1982 and 1984. (GEC took over Marconi in 1972.)

In the Netherlands, telex was introduced in the telephone net in 1932. A separate telex net appeared in 1954 (about 40 telex channels for one telephone channel). Analogous developments took place in other European countries.

In the beginning, radio-telephony service was used for telex over long distances, but there could be many mistakes due to fading. Van Duuren's automatic repetition on request (ARQ) was of major importance in improving the telex over radio service. He had an alphabet of 35 letters; all combinations of four marks and three spaces were legal, and all other combinations led to a repeat request. Transpositions led to undetectable errors. Dr. Van Duuren invented the system during WW II and published it in 1946. It was used in many international connections and standardized by CCIR in 1956. By 1970 some 700 telegraph and telex channels from the United Kingdom were protected by ARQ.

HF Radio-Telephony, Troposcatter, Radio Science—From 1930 onwards, there was a strong tendency to use single sideband for radio-telephony (also a CCIR Recommendation). In 1939 there was a single sideband connection between the United States and the United Kingdom, and a multichannel connection began in 1952. Many ships had radio-telephony service. The Post-Office station at Rugby had 28 transmitters in 1956. A receiving station was installed in Bearly, near Stratford on Avon. The HF aerial station consisted of 30 rhombic aerials. The whole system gave complete azimuthal coverage up to 27 MHz, with dual diversity. HF radio was at an all-time peak in England in 1969, with 350 telegraph circuits and 87 telephone circuits. The Lincomplex system (Linked compressor and expander), described by Watt-Carter and Wheeler of the BPO in 1966, improved the quality of HF radio-telephony.

Troposcatter was discovered by Marconi around 1934. In fact he found strong signals at 57 cm at a distance of 168 miles, whereas the optical range was 72 miles. The scientific explanation came much later. Troposcatter was used for military purposes in Europe by SHAPE, the NATO research organization. In England experiments were carried out at 876.5 MHz, 950 MHz, and 1370 MHz, and applications were made for telephony and data services between the United Kingdom and the North Sea oil platforms. Some form of diversity is necessary for transmission and reception [25].

Radio wave propagation was one of the main subjects of study for the International Union of Radio Science (U.R.S.I.), constituted in Brussels in 1919, where it had a predecessor in the international commission of scientific wireless telegraphy (1913). In the early years, it had a rather strong European accent, as can be seen from its first presidents: General Ferrie, Sir Edward Appleton, and pére LeJay. (Appleton received the Nobel Prize for his ionospheric work.)

Submarine Cables for Telephony—For transatlantic radiotelephony, the use of repeaters was a major difficulty, as, obviously, long-life reliable tubes had to be used. In 1956, the first transatlantic telephone cable, TAT 1, was laid and put into use. A long-life pentode valve had been developed at Dollis Hill by BPO. This type-6P12 valve had a passive cathode core of platinum, stringent outgassing of all piece parts, and electrode spacing suitable for low-supply voltages. TAT 1 contained 16 repeaters in the Newfoundland-Nova Scotia section. Later, a new valve (type 10P) with a nickel tungsten alloy as core material was put into production at Dollis Hill and at the STC factory in Paignton. Three long-distance cable systems used this valve between 1961 and 1966: CANTAT 1, United Kingdon-Canada; COMPAC, Vancouver-Sydney; Cairns, Queensland-Singapore. The total length was 32000 km and in 782 repeaters it used 4692 valves. Next came the Lisbon-South Africa route, 109000 km long, using over 600 repeaters, and incorporating 3700 valves of new design and higher performance. Another source of long-life tubes was SER, a subsidiary of LME, which used passive cathode alloys, and recorded lifetimes of 100000 hours in continuous operation. After the Lisbon-South Africa cable, transistors took the place of valves in 1968. In 1974 came a British 14-MHz system: CANTAT 2. Then followed an American-British-French development of 30 MHz in TAT 6 (United States-France) giving 4000 circuits. A British system with a top line frequency of 45 MHz can provide 5520 circuits; it was tried on United Kingdom-Belgium No. 4 cable in 1977 [26]. TAT 8, probably fiber optic, is expected in 1988.

Communications Satellites—Arthur C. Clarke envisaged the use of geostationary satellites for communications in 1946. After the first Sputnik was launched in 1957, several countries decided to cooperate in the new field of communications satellites. After the Telstar and Relay satellites had been launched in low elliptical orbits, the Syncom, Early Bird, and Intelsat satellites used geostationary orbits. France built an earth station in Pleumeur Boudou and claims to have made the first connection with the United States, but Goonhilly Downs in England and Raisting in Germany were not far behind. There were 9 Intelsat V satellites, each with 27 transponders, 12000 telephone circuits, and 2 television channels. Though some satellites were launched from the Ariadne site in French Guinea, the big majority were launched in the United States. (The U.S.S.R. always had its own facilities.) Several scientific and communications satellites were built in Europe (such as Symphony, Sirio, Ans, and Irias), and several European firms built terrestrial stations.

- The Italian Society STS (part of the STET group) and GTE have installed earth stations in Italy, Argentina, and Sweden.
- Siemens constructed five terrestrial receiving stations in Raisting.
- Plessey developed a range of ground terminal stations, such as the type 45.
- Thomson CSF got the order for the domestic satellite Peratelsat for Zäire, and its 13 stations (Thomson CSF has installed 92 earth stations in 5 continents.)
- Thomson CSF is also a major participant in the French Telecom 1 satellite for data transmission, fast telecopy service, teleconference, and teletext. The Telecom 1 satellites are due to be launched by Ariadne in 1984.
- In 1985 the French-German satellites TDF1 and TV SAT will follow.

Mobile and Data Communications

For the growing service of mobile communications, efficient spectrum use is necessary. A cellular radio system service area is divided into hexagonal cells. The mobile stations talk to one another via local base stations, interconnected by land lines. An "intelligent" switch ensures proper links are established. No adjacent cell uses the same frequencies, and cell size depends on population density. Therefore the Nordic mobile system has rather large cells. A requirement was that the frequency band used be available in all four countries (Denmark, Finland, Norway, and Sweden). This limited the choice to the 453–457.5 MHz and 463–467.5 MHz bands. Setting up calls to and from mobile receivers, as well as calls between mobile stations and any fixed subscriber, should be automatic. As the telephone networks are quite different, the need for identical mobile stations necessitated a special interface unit, an SPC exchange.

"After the first Sputnik was launched in 1957, several countries decided to cooperate in the new field of communications satellites."

The Federal Republic of Germany is now on its third system. System B had 20000 subscribers, and System C can have 100000. There are 200 radio zones with base stations for mobile telephone.

The auto-paging system in Switzerland started in 1952, and was extended in 1968. Between 1978 and 1980, an automatic mobile telephone system, NATEL, was installed covering the whole country. Although frequencies are being used very economically, the first district, Zurich, is already saturated. The subscriber apparatus, mounted in a car or in a small box, can be used just like an ordinary telephone apparatus [27].

In the Netherlands, it was shown that digitized speech can be introduced via existing mobile sets. Good intelligibility is obtained at 9600 b/s with digitally controlled delta modulation. In order to use the spectrum more efficiently, other digital modulation methods, Timed Frequency Modulation (TFM) and Correlative PSK (CORPSK), were studied. It was also proposed to introduce personal automatic telephones using digital transmission via a cellular system, but it was thought that numerous problems still had to be solved before a viable international system could come into existence. The "cordless" telephone, which is connected by radio (encrypted) to its own telephone set, is much simpler. In England, FM is used, although with a bandwidth of only 12.5 kHz because of the large number of customers. Bath University studied a single sideband system for mobile radio, because of reduced spectrum pollution and channel bandwidth, in cooperation with Philips and the Home Office. They favored pilot tone above band. Five-kHz pilot carrier SSB compared favorably with 25-kHz FM, and was even better when companding and dual diversity (up to 942 MHz) were used. The Italian electricity board has its own digital mobile cellular system, with FFSK at 1200 b/s nominal rate.

In France there was fundamental criticism on FDMA and TDMA operation of cellular networks, and a slow synchronous frequency hopping system was chosen. Further experiments in part of the 900-MHz band are planned. In the U.S.S.R. too, a cellular mobile communications system with pseudonoise signals (spread-spectrum) was selected for digital information exchange between mobile objects and subscribers to the city data-transmission network [28].

For mobile maritime communications, in 1975 there was still a basic reliance on the 500-kHz and shortwave bands (4, 6, 8, 12, 16, and 22 MHz.) Many ships had FM equipment operating in the 156–162-MHz band. At that time, MAROTS—a European satellite for maritime communications—was discussed (based partly on the design of the Orbital Test Satellite (OTS) of the European Space Agency). It was thought that the Marisat program of COMSAT would be mainly used by the United States Navy. However, in 1982 the International Maritime Satellite Organization (INMARSAT) began operations for the 38 member countries from East and West, industrialized and developing countries.

Public data networks with packet switching are now available over most of Europe. EURONET serves the European Economic Community with principal nodes at Frankfurt, London, Paris, and Rome, and remote access points at Amsterdam, Brussels, Copenhagen, Dublin, and Luxembourg. Germany has had the Datex network since 1967. This is a switched network for data transmission. A synchronous circuit-switching data network was expected for 1983 along with a packet-switching service based on the Siemens EDS for 1985. The BPO has had an experimental packet-switched service since 1977, and the normal public packet-switched service has been in operation since 1980. France has the Transpac packet-switching network, introduced in 1979, and the digital leased-line data network TRANSMIC, which will be available all over France in 1985. Italy expects to implement a packet-switching data network, based on three nodes—Rome, Milan, and Naples. The Nordic Public Data Network is circuit-switched and fully synchronized, based upon TDM with integrated switching and transmission (in operation since 1977).

Looking Into the Future

System X

From 1976 on, the BPO has progressively created and implemented a total systems strategy for developments in telecommunications. The strategy is intended to provide a coordinated framework within which individual plans and projects can go forward to the best overall advantage. System X is a family of computer-controlled digital switching systems that fully conform with all existing relevant CCIR Recommendations. System X has to take into account not only the Administration objectives for new services and the extension of those currently available, but also the transition period during which the new system will have to coexist with present equipment. G.E.C., Plessey, S.T.C., and the BPO collaborated in the creation of Britain's digital-switching system which made its debut at Telecom '79 in Geneva. The first System X exchange was inaugurated in London a year later. In 1979–80, the government decided to split the BPO and make telecommunications the responsibility of British Telecom. In October 1982, STC withdrew from the System X program. One reason was that the product, highly engineered for the well-developed British network and, therefore comparatively expensive, had failed to open up any significant overseas market. STC was asked to fulfill its contract to deliver the large local exchange for System X by the autumn of 1983.

On the other hand, Plessey and GEC phased out production of the TXE 4-4A exchanges so that STC would get progressively larger orders on those exchanges. British Telecom hopes to have digital-switching capability in the 60 trunk unit sites by 1986, with full interconnection between units by digital transmission systems, and by 1988 to have adequate capacity to permit the off-loading of all trunk-traffic from the analog network. By 1988, they hope to have provided digital principal local exchanges and concentrate trunk traffic from residual analog exchanges still served by analog transmission systems. By 1990 they expect to close down the analog trunk network. Competition and privatization may also have their effects:

- The supply of approved equipment for connection to British Telecom's network;
- the licensing of value-added network services;
- the licensing of an alternative network to concentrate on offering private circuit business links;
- 51% of British Telecom's shares will be offered for public sale; and
- a business-oriented digital service will offer leased point-to-point 64-kb/s bearers at first and switched services later. This is called the Mercury network. Plessey is now the industrial leader of the System X effort.

System 12

To provide a framework for all future developments, ITT conceived Network 2000 as a broad concept base from which to draw the parameters for developing the wide range of products demanded by market change. In this future communications net, speech and data will be digital from source to receiver. With this perspective in mind, SEL and other societies in ITT are developing System 12 exchanges that are sure to be used in the future. These have decentralized processor control and a modular hardware and software structure. System 12 gives solutions that fulfill both the requirements of today and of the future network. One of the first System 12 exchanges is being built by S.E.L. for Denmark. System 12 is conceived so that, stepwise, the long term goal of Network 2000 will be reached.

Standard Electrica, Madrid, is working on the introduction of new services (Integrated Speech Data Network) in System 12. It is also constructing a local exchange for the thinly-populated area around Salamanca Concejo (System 1240), and is trying to develop Galileo, a graphical language for the conception and implementation of real-time systems. It is also in charge of Teleplan, the leading ITT group for planning and traffic calculation for telephony and data nets.

France, too, is looking at the future, and expects to have an all-digital dialing network with a 64-kb/s transmission rate, and a nationwide fiber-optic videocommunications network which will pave the way for the implementation of a wideband integrated services digital network. Recently, the French government has approved a plan to merge the telecommunications activities of Thomson and GEC. A single holding company, Thomson Telecommunications, will be formed, to be managed by GEC's subsidiary CIT-Alcatel. It is thought that in this way French industry will be more competitive. (Both industries had already been nationalized.)

Fiber Optics

In 1966, Kao and Hockam of S.T.L. pointed out that the attenuation in glasses employed for optical fibers was due to impurities, and that intrinsic losses, determined by Rayleigh scattering, are very low. In 1970, Corning glassworks fabricated single-mode fibers with losses under 20 dB/km. This led to strong research efforts in the United Kingdom, France, Italy, the Netherlands, Australia, and the United States. Based on the research efforts of the Technical Staff of CSELT (Turin), a survey in "Optical Fibre Communication," a 900-page book, was published. British Telecom has already put into service systems manufactured by GEC, Plessey, and STC, operating at 8, 34, or 140 Mb/s, respectively, between 840 and 900 nm. In 1981, already 10000 km of fiber had been ordered. Meanwhile, a new generation of fibers operates at 1300 or 1550 nm. Link attenuation over 31.6 km is 17.5–21.3 dB at 1300 nm, and 16.2 dB at 1550 nm. Over 62.4 km, the attenuation was 31.4 dB at 1300 nm, and 21.0 dB at 1550 nm. Bit rates of 140 and 560 Mb/s were used successfully on installed cables of British Telecom. A submarine optical cable was laid in a Scottish loch. The next transatlantic cable, TAT 8, will probably be a fiber-optic cable.

In France, optical cables have been developed by C.N.E.T. and by Les Cables de Lyon; in Germany, by SIECOR (a joint venture of Siemens and Corning Glass), and by Felten and Güillaume. In Italy, Pirelli develops optical cables and in the Netherlands, Philips. In the Netherlands, Philips and the PTT are experimenting on a line between Eindhoven and Helmond. In May 1981, the German Post Office announced the BIGFON field trial. By spring 1984 wideband integrated local networks based on optical fibers will be installed in 6 major cities in the Federal Republic of Germany and West Berlin. Six German telecom companies or groups received contracts to develop and install 10 local networks on the basis of their technical proposals. At the 4th World Telecommunication Forum, Geneva 1983, AEG Nachrichten Technik and Siemens described the technical features of their systems. 350 selected subscribers will get all telecommunications services currently available, the new video telephone service with the customary TV quality, and an unlimited number of television and high-quality stereo sound programs, all via only one or two glass fibers. The television set plays an important part as a multifunctional terminal for moving video communications. The tests started in 1983, and in 1985/86 decisions on the final network will be made.

The Heinrich Hertz Institute in Berlin has already reached bandwidths of 1.21 GHz on optical cable.

New services

Teletext—In 1969, BBC engineers had the idea of using the frame flyback periods of TV transmission for distribution of a magazine. This service was called Ceefax. A little later, the Independent Television Authority had its own service, Oracle. Around 1974, agreement was reached on a mutually acceptable standard for "Teletext." Since there is another service called Teletex, this may not be the definite name; broadcast videotex has also been suggested.

In the United Kingdom, two lines per field are used for this service. Thus the average transmission rate is 100 data lines per s. With 24 data lines per page, the transmission rate is 0.24 s per page, or 24 s for a complete 100-page magazine. Hence the average waiting time is 12 s (a complete magazine passes by in 24 s, thus the average waiting time for a selected page is 12 s).

Viewdata was invented in 1970 by S. Fedida (BBC). After many experiments, its feasibility was demonstrated in 1974. Viewdata has a large data bank, 70000 pages, for instance. Any page can be reached in 2 s. The data bank is reached by telephone at 75 b/s, and it transmits information back at 1200 b/s. The transmission time of a full page, using the current 10-bit asynchronous start-stop mode is about 8 s. In practice, transmission time will be between 4 and 8 s, since not all character positions are used. Integrated teletext and viewdata receivers are available. Since viewdata was taken to be the generic name, the United Kingdom called its own system Prestel. It has over 1000 information providers, responsible for 250000 pages of information. The German videotex service, "Bildschirmtext," started in Berlin and Dusseldorf in 1980. Austria started in 1981 with 400 users and 50000 pages of information. Holland is due to have 100000 users for its "Viditel" by 1985, and currently has data supplied by over 400 companies. Interactive videotex has been suggested as a name.

The first preparations for **teletex** started in the Fed. Rep. of Germany in 1976. There were no CCITT rules available at that time. In March 1981, Teletex started in Germany under nationally agreed upon rules. In November 1981 it went to international rules. Teletex will provide medium-speed error-protected transfer of text documents between the stores of user terminals with end-to-end confirmation of successful delivery. Layout and content of pages are preserved at a throughput of 2400 b/s (an A4 page in 10 s). Simultaneous transmission in both directions is possible. International connections require compatibility of the remote terminals. Teletex is faster and cheaper than telex.

The **Telefax** service was introduced in the Fed. Rep. of Germany on January 1, 1979. At that time, transmission via the telephone network made transmission of a DIN A4 page in one minute a likely target. However, recent advances and

"The 'Smart card,' available from French and Swiss producers, is used for telepayment or teleshopping by inserting it into a minitel terminal."

digital transmission at rates up to 64 kb/s mean that remote photocopying at a rate of around 5 s per copy is becoming a possibility [29].

Other Services

Other services are electronic funds transfer, teleconferencing, telemarketing, telemetry, telecontrol, alarms, videoconferencing, slow-scan tv (such as for surveillance), and electronic directory. Instead of videoconferencing, audiographic conferencing (possibly using an electronic blackboard) has certain advantages [30]. The use of a password or some form of encryption may be necessary. The "smart card," available from French and Swiss producers, is used for telepayment or teleshopping by inserting it into a minitel terminal. The home user places the card—with a microprocessor and memory embedded in it—into an add-on card reader processor. After typing in a personal identification number, the memory written into the card by the issuing authority identifies the user, indicates the money value, and automatically dates and records information within the integrated circuit [31].

Integrated services digital networks like "Bigfon" will make a wide variety of new services available to their customers.

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