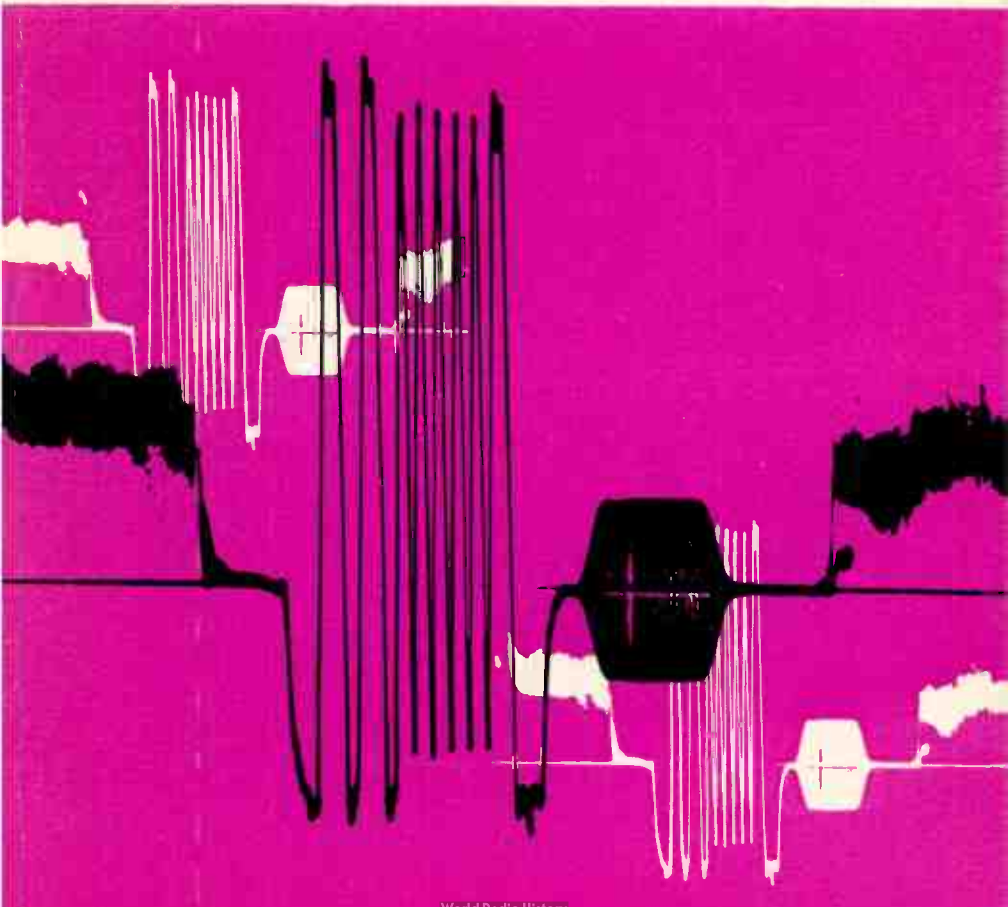
Science Museum

# Broadcasting in Britain

1922-1972

Keith Geddes



*The cover design depicts a 625-line colour waveform, showing pulses added for distributing the accompanying sound to transmitters (see p 54). The pulses represent, in coded form, the audio information that must be conveyed during each line-scanning period (sixty-four microseconds). They are situated in part of the twelve-microsecond interval between scanning lines, and are followed by the packet of 4.43-MHz oscillation that synchronizes the decoding circuits in colour receivers*

A Science Museum Booklet

# Broadcasting in Britain

## 1922–1972

A brief account of its engineering aspects

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*Frontispiece  Marconi House, London, showing the aerial of the BBC's first station, '2 LO' (1922–25): Early broadcasting transmitters were in towns and cities, to provide as many people as possible with the strong signal needed by crystal sets. (Marconi House survives as the 'Marconi Wing' of Citibank House, at the Strand's western junction with Aldwych)*

Chapter 1

# The Formative Years

Though 'wireless telegraphy' by Morse Code dates from 1896, the transmission of speech and music became practicable only during the 1914–18 War, when thermionic valves made it possible to vary the magnitude of a radio wave in proportion to the output signal from a microphone. Even then, the idea of using radio to entertain the general public seems to have occurred to very few people. However, when experimenters in 'radio telephony' began to enliven their transmissions with improvized entertainments, these were enthusiastically acclaimed by their audience of radio amateurs. Manufacturers then realized that there was, potentially, a mass market for receivers, and themselves began to radiate entertainment.

In Britain, the Marconi Company began such transmissions, from their works at Chelmsford, in February 1920; on June 15, in association with the *Daily Mail*, they radiated a recital by the famous soprano, Dame Nellie Melba, which aroused great public interest. In the autumn, however, the Post Office banned the transmissions, after complaints that they interfered with legitimate communication. It was over a year before the Post Office relented, in response to a petition from the amateur movement to allow Marconi's to include telephony within their schedule of transmissions, 'primarily to serve the scientific purpose of improving the receiving arrangements'. Fifteen minutes of telephony were to be permitted during a weekly half-hour of transmission for amateurs; the transmissions were, in fact, padded out to nearly one hour, by frequent compulsory breaks during which the station had to listen for possible instructions to give way to more important traffic.

Regular transmissions began on February 14, 1922, from '2 MT', located in a hut at the Marconi field station at Writtle, near Chelmsford.

The 250-watt transmitter, powered by a petrol engine, was built from components that were at hand, by a team of young engineers who also put on the broadcasts as an out-of-hours chore. Each Tuesday, after reinstating any parts of the transmitters cannibalized for other work during the preceding week, they would radiate improvized programmes, made memorable by the comic talent of their senior member, P P Eckersley. Later in the year, the Post Office licensed three more transmitters, including another Marconi station; this was 2 LO, situated at Marconi House, London.

The Post Office's extreme caution at this period was in part a reaction to the situation in America, where the experimental phase had led straight to a broadcasting 'boom'; in the month of May 1922, for example,

1 *Broadcasting a duet from Marconi House* (1922 *or early* 1923)*: The 'telephone' microphones then in use were designed for close speaking, so the two singers could not conveniently share the same microphone*

there were 99 additions to the list of stations. The result, of course, was a chaos of mutual interference.

The need to avoid a similar situation in Britain, by restricting the number of transmitters, was a prime consideration in the prolonged negotiations that took place during 1922 to thrash out a broadcasting system. The interested parties finally agreed that transmission should be in the hands of a monopoly – the British Broadcasting Company – whose profits were to be legally restricted to 7½%, with capital subscribed by the British radio industry. Its income was to come from annual receiving licences and from a royalty on receivers, the import of foreign receivers being banned for two years.

The new company began regular broadcasting from 2 LO in London on November 14, 1922 to be joined the next day by 5 IT (previously operated by Western Electric) in Birmingham and 2 ZY (previously operated by Metropolitan Vickers) in Manchester. It was not until December, however, that the directors of the company appointed a General Manager, Mr J C W Reith, and it was not until February, 1923 that he in turn appointed a Chief Engineer, P P Eckersley. Nevertheless, by October of that year eight 'main' stations had been opened, substantially as laid down before the BBC was formed. They gave about 50% of the population of Great Britain a signal strong enough for clear reception on a crystal set.

Five Marconi engineers* who followed Eckersley to the BBC between 1923 and 1926 subsequently reached senior positions in its Engineering Division. But in 1923, to leave Marconi's for the BBC was to abandon a career in the mainstream of radio communication, and to entrust one's future to an organization seemingly devoted merely to the popularization of a technical hobby. In fact, as Eckersley foresaw, the future of broadcasting depended upon its outgrowing this 'hobby' status, and the BBC's policy was to make reception of its programmes as easy as possible. In order to extend the service to large towns not covered by the 'main' stations, the BBC set up between November 1923 and the end of 1924 eleven 'relay' transmitters; these were of low power (100–200 watts), and their aerials were usually suspended between factory chimneys. For a modest outlay they increased to 70% the proportion of the population within 'crystal range' of a transmitter; many of the remaining 30% could receive a service if they used valve receivers.

## Simultaneous broadcasting

With the opening of the Belfast station in 1924, the chain of nine 'main' stations was completed. Each station had its own studios, and initially originated all its own programmes. There were obvious advantages, however, in linking transmitters by telephone lines so that programmes could be shared, and 'simultaneous broadcasting' was introduced on a limited scale following experiments in May 1923. In the first experiment, the telephone lines were driven by a 40-watt public-address amplifier, to ensure an adequate signal at the far end. It was reported that, though the test was successful from a radio point of view, '. . . very considerable derangement in telephone trunk line traffic resulted.'

At that period, the telephone trunk network consisted of a mixture of underground cables and overhead lines, neither really suitable for broadcasting. The underground cables suffered from high-frequency loss, and the 'loading' technique that maintained adequate response up to a frequency of 2½ to 3 kHz (appropriate to a telephone circuit) caused a steep cut-off above that frequency. The routes used for broadcasting were therefore chosen to include as little underground cable as possible. The losses on overhead lines were lower and more uniform across the frequency band, but performance changed markedly with weather conditions; during the first quarter of 1930, an overhead line normally noted for its good performance averaged one reported fault for every five hours of programme carried. In addition, overhead lines were liable to be brought down by bad weather and road accidents.

* Ashbridge, Bishop, Kirke, MacLarty and Wynn.

The situation improved only in 1931 when the Post Office began transferring the 'simultaneous broadcast' network from overhead lines to selected underground circuits whose loading coils and repeater-amplifiers had been modified to give uniform response up to 6 kHz. By 1932, cables were coming into service that had been designed from the outset to handle broadcast programmes as well as telephony, and had a response extending to 8 kHz.

One of the first major applications of simultaneous broadcasting was in 1923–4, when the 'relay' stations were opened.

These originated very few programmes, and it had initially been intended that each station should take its programmes from the nearest 'main' station; in the event, however, local public opinion obliged the BBC to supply all relay stations with the London programme, notwithstanding the loss of quality resulting from long land-lines.

The first step towards extending broadcasting to the predominantly rural areas not covered by existing stations was the opening of a 25-kW long-wave transmitter (5 XX) at Daventry in July 1925, relaying the London programme. This was the most powerful broadcasting transmitter in the world, and the first to use long waves. Though other European countries followed Britain in setting up long-wave transmitters, America did not; their receivers thus had no long-wave band and the British receiver industry was effectively protected from American competition.

Because of the good long-distance propagation of long waves, and the great power of the transmitter, Daventry itself covered 55% of the population of Great Britain and brought 80% of the population within 'crystal range' of at least one transmitter.

## Receivers

Valve receivers and loudspeakers were available from the beginning of broadcasting but the crystal set had two great advantages: it was cheap, and it was simple. It consisted basically of a tuned circuit and a crystal detector, and had no batteries, the power delivered to its headphones all coming from the transmitter. Most designs used a wire 'cat's whisker' and the performance of the set depended upon making it touch a favourable spot on the crystal with just the right pressure; the slightest vibration spoiled the adjustment. Being devoid of any form of amplification, a crystal set was insensitive, and the sound was further weakened if several pairs of headphones were connected to the same set. Selectivity was poor – that is, the set could not separate transmissions of comparable strength unless their wave-lengths differed widely.

But valve receivers were much more expensive: whereas a typical crystal set cost only one or two pounds, a two-valve set was unlikely to cost less than £7, and a model with four or more valves could easily cost


2 *A crystal set of* 1925*: An alternative coil was plugged under the set for long-wave reception*


3 *Crystal-set accessories (life size), about* 1925

4 *An early valve receiver* (1923) *with horn loudspeaker* (1924): *'Reaction' was controlled by moving the coils at the left, and gain adjusted by switching valves in and out of circuit*

over £50 (1926 prices). They also required batteries. The 'low-tension' accumulators used for heating the valve filaments were particularly inconvenient, requiring frequent re-charging at the local radio shop or garage. Even learning to operate a valve receiver could be a daunting prospect; one expensive receiver of 1923 was provided with two closely-printed pages of quite complex instructions. But the maker's catalogue promised a rewarding performance: '. . . within fifty miles or so of a high-power broadcast station, music on the loudspeaker is so loud that it can be heard five hundred yards away.'

Early valve receivers depended for their sensitivity and selectivity upon 'reaction' – that is, upon feeding part of the output of a valve back to its input. If the reaction control were turned a little too far, the feedback was enough to maintain the valve in a state of oscillation, and the receiver effectively became a transmitter at a wavelength close to that of the station it was tuned to receive; that station was then spoiled by howling noises for everyone else in the neighbourhood. Stable amplification of the radio-frequency signal became straightforward only with the advent of the 'screened-grid' valve in about 1927.

The listener's licence entitled him to use 100 feet of wire in the construction of his aerial, and for satisfactory reception he needed to do so, unless he lived in a particularly favoured district or possessed one of the small minority of receivers offering satisfactory amplification before the 'detector' stage. Ideally, some 70 feet of the wire, secured by a porcelain insulator, ran horizontally towards the house from a tree, or a specially

## YOUR FIRST WIRELESS SET.

When you have your first wireless set installed for you—

DO NOT DELAY—

TO TAKE FULL ADVANTAGE—

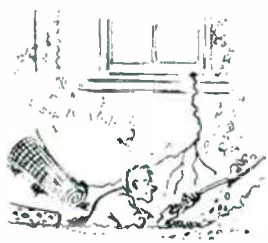
OF ITS ENTERTAINMENT—

FOR ONCE—

YOU GET—

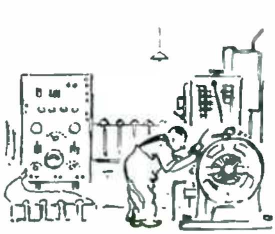
BITTEN—

WITH THE SUBJECT—

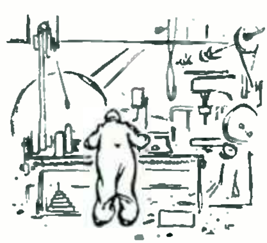


YOU WILL—

NEVER AGAIN—



HAVE—



MUCH—

LEISURE FOR LISTENING.

erected mast, in the garden. A stay-wire from the chimney stack, and another insulator, enabled the remaining 30 feet to run, steeply but not quite vertically, down to a 'lead-in' tube let into the window frame. The receiver was installed immediately inside the window, and the headphones or the separate loudspeaker connected to it by an appropriate length of wire.

An effective earth was also required; water pipes could be used, but a BBC article of 1928 recommends a metal plate 3 feet square, buried vertically in ground which, 'if not naturally damp, can be made so artificially'.

Where a lower efficiency was acceptable, a frame aerial could be used. Apart from its convenience, it offered directionality which allowed discrimination against an interfering signal. Its very inefficiency made the frame aerial essential for a superhet receiver, which utilized an oscillator capable of radiating interference.

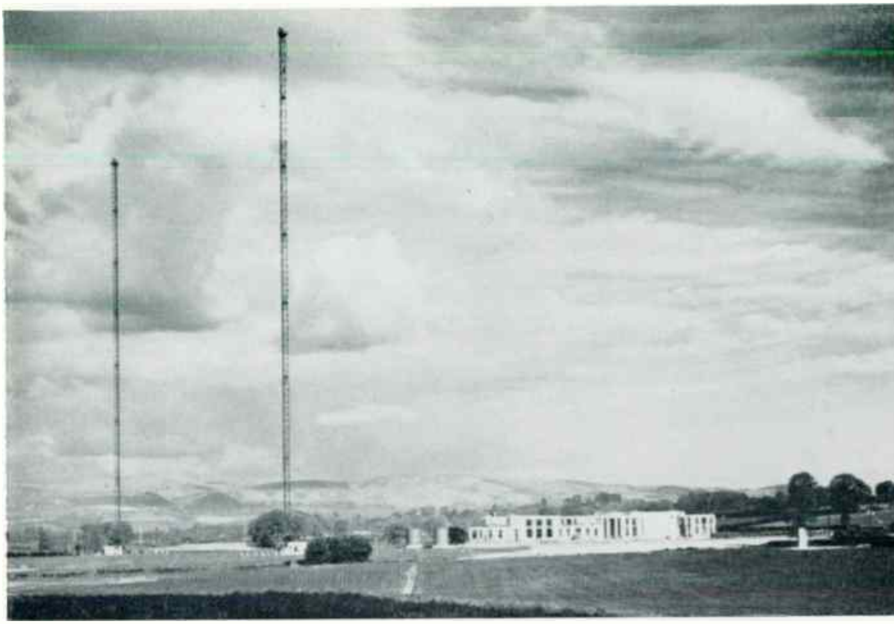
Though the 'hobby' attitude to broadcasting was eventually to diminish, it flourished throughout the 1920s. Many people without previous experience of radio built their own receivers, by obeying the explicit instructions issued with kits of parts or published in such magazines as *Wireless Constructor* (circulation 250 000). Even those patronizingly dismissed by its editor as 'ready-maders' took pride in the number and remoteness of the foreign stations they could pick up.

## The regional scheme

In 1925, when the increasing number of transmitters in Europe was causing serious interference, the BBC convened an international conference to discuss the problem, and drew up a provisional wavelength plan as a basis for discussion. The conference produced the so-called 'Geneva Plan', whereby Britain was allocated exclusive use of one long-wave and nine medium-wave channels. The BBC's need to complete the coverage of rural areas and to provide an alternative programme could be reconciled with this plan only by abandoning the existing pattern of 'main' and 'relay' transmitters, sited in cities and towns.

In their place, five 'twin-wave' stations were built, each having two high-powered transmitters. The sites were chosen to achieve maximum coverage of each region, but centres of population were avoided in order to minimise the number of people receiving excessively strong signals.

The new type of station, providing two programmes at comparable strengths, hastened the disappearance of the crystal set. Though, in its advocacy of the regional scheme, the BBC had demonstrated to the Post Office that a well designed crystal set could in fact separate the two transmissions, in practice the survival of this type of receiver had largely rested upon the strong signal, on a single wavelength, near an urban transmitter.



6 *Twin-wave station at Washford Cross, Somerset* (1933): *The BBC's 'regional scheme' provided for five high-power stations, each radiating two programmes over a wide area*

7 *'Drama' studio at Savoy Hill,* 1928*: A late example of a heavily draped studio using a 'meatsafe' microphone*

## Microphones and studios

Before broadcasting began, virtually the only microphones were those used in telephones, designed to transmit a limited range of frequencies, and to be held close to the mouth. The earliest broadcasts were, in fact, made with the aid of such microphones, sometimes with a small horn added to increase sensitivity.

The first microphone adopted for use throughout the BBC was the Marconi-Sykes 'Magnetophone'. This was a moving-coil instrument in which the sound impinged directly upon a flat coil of aluminium wire, which was mounted within the field of a strong electromagnet by being stuck on to pads of cotton wool with 'Vaseline'; a disadvantage of the design was the tendency for the coil to drop off during transmission. The microphone was slung on foam rubber within a large 'meat-safe'.

The large size of this microphone caused its coil to be shaded from high-frequency sound coming from the side or from the rear, imparting a 'boomy' quality to reverberant sound and thereby aggravating excess low-frequency reverberation, the most common acoustic fault of small studios. As an antidote, early studios were heavily draped to suppress reverberation altogether, though this made them unsympathetic to the performer and uninteresting to the listener. Artificial reverberation was

8 *'Musical control', Savoy Hill,* 1930*: The decor was intended to ensure that the sound quality was suited to domestic listening conditions*

sometimes added, by means of a loudspeaker and microphone situated in a highly reverberant room, separate from the studio.

The Marconi-Reisz carbon microphone, introduced in 1926, was much smaller, and had a more uniform frequency response; despite its slight background hiss, and a tendency to distort loud sounds, the BBC used it almost exclusively from about 1928-32, both in the studio and for outside broadcasts.

## Outside broadcasting

From the earliest days, studio programmes were supplemented by outside events; operas were relayed from Covent Garden, dance bands from the Savoy Hotel, religious services from St Martin-in-the-Fields.

In April 1924, King George V made his first broadcast, during the opening of the British Empire Exhibition at Wembley. The programme was transmitted by all BBC stations, and the *Daily Mail* made arrangements for loudspeaker relays to crowds throughout the kingdom; it was estimated that nearly ten million people heard the broadcast. On an evening in the following month, there began a memorable series of broadcasts of the 'cellist, Beatrice Harrison, playing in her garden and being answered by the song of a nightingale.

Outside broadcasting taught engineers how to cope with all types of acoustics; for example, relays from the Palm Court of the Grand Hotel, Eastbourne, successfully conveyed its distinctive 'live' quality. Land-lines back to the studio were, literally, a weak link; most were in underground cables with a restricted frequency response, and might at any moment become noisy, making it necessary to substitute a stand-by line.

So long as the BBC remained a private company, newspaper interests successfully opposed the broadcasting of sporting events, but when the *Company* became a public *Corporation* on January 1st, 1927, the restrictions were lifted, and during that year running commentaries on many events were broadcast for the first time, including the Boat Race, the Cup Final, the Derby and the Wimbledon finals.

## Empire broadcasting

Until the mid 1920s, long-distance radio communication was achieved by the use of very long wavelengths, comprising too narrow a range of frequencies to be of use for broadcasting. The situation was completely transformed, however, by the discovery that wavelengths of 100 metres and less could reach distant points by reflection from the ionosphere – the layer of ionized particles constituting the uppermost part of the earth's atmosphere. Within a very short time, the Marconi company established a network of short-wave 'beam' stations. This development opened up the prospect of the BBC's providing an English-language service to the

Empire, but the feasibility of short-wave broadcasting could not be assumed from the success of point-to-point short-wave communication. The signals would have to be picked up by simple aerials feeding domestic receivers, whilst the large areas to be covered limited the extent to which the transmissions could be 'beamed'. Moreover, reception would have to be good enough to sustain the listener's interest, often in competition with locally transmitted programmes. In 1927, therefore, the BBC initiated tests, in collaboration with the Marconi company, from a 25-kW transmitter at Chelmsford. The transmissions were restricted to a single wavelength – 24 metres – and were not beamed, but results were nevertheless good enough for the BBC to propose, in 1929, the construction of a more ambitious experimental station at Daventry. At this time of great economic depression, however, neither the British Government nor the Empire countries would finance the scheme, and it languished until November 1931, when the BBC undertook to proceed with Empire broadcasting at its own expense. The Daventry station was opened in December 1932; it was equipped with two transmitters and eleven aerials (five directional and six non-directional), and was able to use eight different wavelengths.

## The Blattnerphone

Empire broadcasting created an urgent need for sound-recording facilities, so that programmes could be transmitted to each time-zone in turn. Gramophone recording would not serve, being too expensive for everyday use, and involving a delay of at least twelve hours while the discs were processed, thus preventing the transmission of topical items.

The only machine at that time capable of providing direct playback was a magnetic recorder of German manufacture. The BBC had shown interest in the original version, an office dictating-machine invented by a Dr Stille, as early as 1925, but had found its quality inadequate for broadcasting. By 1929, however, Louis Blattner had undertaken exploitation of the machine in this country, had named it the 'Blattnerphone', and had improved it to the point where the BBC was interested in an operational trial, which began in 1930. The quality of reproduction, particularly the constancy of pitch, was not good enough for music recording, and a typical application was the repetition, in an evening news bulletin, of a speech or running commentary recorded earlier in the day.

The Blattnerphone was the forerunner of the modern tape recorder, in so far as it involved magnetic recording on a tape. The tape, however, was of steel, 0.08 mm thick, and ran at a speed of about 150 centimetres per second, so that a half-hour programme required a massive spool containing nearly three kilometres of tape. Editing was possible, but involved soldering or welding the tapes, whilst any irregularity in the tape surface could damage the recording or play-back heads. Despite these shortcomings, use of the Blattnerphone in the BBC's domestic services gradually increased and the Empire service made great use of it from the outset.

## Broadcasting House

For its first London studio, the BBC made use of a small room in Marconi House, in the Strand, but on May 1, 1923 moved to spare accommodation at the Institution of Electrical Engineers' building on the embankment. By 1927, this 'Savoy Hill' site was developed to its limit. The total of seven studios would clearly be insufficient for the two independent programmes that the 'regional scheme' was to provide, and in 1928 the Corporation completed arrangements to build new headquarters, to be known as 'Broadcasting House', on a site near Oxford Circus. The BBC initially considered that it would not need to occupy the entire building, and planned to lease the ground floor frontage as shops, though in the event this idea was dropped. Broadcasting House was opened in May 1932. It was tall by the standards of the period, having eight storeys above the ground floor and three below it. Its twenty-two studios, including a concert hall with seating for an audience of 724, were contained in a central tower within the building, to ensure adequate insulation from traffic noise; this studio tower was built of brick to avoid sound conduction from the steel-framed office accommodation surrounding it. Studios on different storeys were insulated from each other by interposing rooms such as music libraries and book stores. A sophisticated air-conditioning system controlled temperature and humidity.

Many of the studios were designed for specific purposes. The 'vaudeville' studio was provided with spotlights for the artistes and tiny 'pit' and 'gallery' seating areas for a studio audience. On the third floor was a 'religious service' studio, complete with 'altar', while one of the talks studios was made to look like a library, for the reassurance of speakers who might have been frightened by the functionalism prevailing in other studios. The sixth floor 'drama' suite included an elaborate 'effects' studio.

No studio was self-contained, the amplifiers for all microphones being situated in the building's main control room. The programme was controlled primarily from this room, or from a control panel equally remote from the studio itself; any 'mixing' of a studio's various microphones was, however, done from its adjoining listening room.

This imposing building reflected the status that broadcasting had acquired in its first ten years. The number of receiving licences passed five million during 1932, and the receiver industry estimated that fifty million pounds' worth of business would result from that year's Radio Show at Olympia.

Chapter 2

# The Coming of Television

The transmission of moving pictures was accomplished only in the 1920s, but still pictures were transmitted over wires by Alexander Bain in about 1850, and in the 1860s a system developed by the Abbé Caselli was operated commercially between Paris and Lyons. In both instances, the complexity of a two-dimensional scene was reduced to a single stream of information for transmission as an electrical signal; this 'scanning' principle is the basis of all television.

With the discovery, in 1873, that the electrical conductivity of selenium increased with exposure to light, it became possible in principle to derive a signal from an actual scene, and a number of inventors proposed systems for 'seeing by electricity'.

The proposal that is best remembered today was that of Paul Nipkow, who in 1884 patented the spirally perforated scanning disc that Baird was to use forty years later; there is no evidence that Nipkow himself ever constructed a practical apparatus. The response of selenium to light is too sluggish to allow the rapid scanning of the scene needed for portraying movement. Moreover, early workers were handicapped by the absence of any form of amplification that would enable the signal from the selenium cell to control a light source at the receiver.

Because of these fundamental limitations, interest in television waned, but was revived by the invention of the cathode-ray tube in 1897. Dieckmann in Germany (1906) and Rosing in Russia (1907), embarked on constructing experimental apparatus in which mechanical scanning at the transmitter was combined with display on a cathode-ray tube. With the technology of the period, there was no hope of their succeeding, but Rosing's experiments had an indirect result of great importance. As an academic he was able to enlist for his research work on television the spare-time assistance of a young student, Vladimir Zworykin. Their association, lasting from 1910 until he graduated in 1912, inspired Zworykin with the passionate interest in television that was to lead him to the invention of the iconoscope, as related later in this chapter.

Very simple calculations suffice to prove that television inevitably involves much higher frequencies than can conveniently be handled by mechanical systems, and in 1908 a noted consulting engineer, W Campbell Swinton, proposed, for the first time, using a deflected beam of electrons as the scanning medium at the transmitter. In 1911 he elaborated his proposals, describing a transmitting tube in which an electron beam scanned a mosaic of light-sensitive photo-emitting elements, mutually insulated. This was a remarkably close prediction of the way in which Zworykin was to achieve high-definition television by all-electronic means some 20 years later.

Swinton did not attempt to realize his scheme. In 1924, he re-presented his proposals in a lecture to the Radio Society of Great Britain, together with some suggestions for their modernization. In the ensuing discussion, a 'selenium' pioneer, Llewellyn B Atkinson, said: 'I do not believe there is sufficient call for seeing by electricity to lead anybody or any corporation to lay out the large sum of money which is necessary to complete the investigation.' Campbell Swinton ruefully agreed.*

## The low-definition era

Notwithstanding these sentiments, the prospects for television were at that time brighter than ever before, with valves to solve many of the technical problems and the popularity of 'listening-in' to suggest a lucrative application.

Experimenters were at work in Germany and America, while in England John Logie Baird was beginning to attract public attention. In March 1925 he demonstrated the reproduction of shadow images during a three-week engagement at Selfridge's store, and a few months later (using apparatus which he presented to the Science Museum in 1926) scored a notable 'first' when he reproduced a recognizable image by reflected light; much less light could be reflected from a subject than could be used in the creation of shadow images, so Baird's achievement was a significant one. A weakness of the apparatus was that at each moment it only utilized the light falling on the single point then being scanned. Baird's next step was to overcome this weakness by using a mirror-drum scanner in the light projector, which scanned the subject (otherwise in darkness) with an intense spot of light, enabling an ordinary photo-cell to serve as the pick-up device. This was the basis of the Baird 30-line system, current in the later 1920s and early 1930s, for which the 'Televisor' receiver was designed.

In 1928 the BBC came under pressure to co-operate with the Baird company, by making one of its stations available for regular transmissions. The Corporation's refusal was widely criticized and in 1929, following pressure from the Postmaster General, a transmitter was made available for short transmissions outside normal broadcasting hours. Nevertheless, the Corporation's reluctance was soundly based. The tiny 30-line pictures, flickering at only 12½ pictures per second, had little entertainment value, nor was any substantial improvement possible so long as the vision signal had to be confined to the narrow band of frequencies that could be permitted in a medium-wave transmission. To transmit a

* Another speaker was more optimistic: 'I should advise Mr Atkinson to preserve his relics of 40 years ago very carefully in case they are required for storage and exhibition in one of our national museums when the problem has been solved.' In 1930, Mr Atkinson did indeed present to the Science Museum relics of his experiments of 1882.

9 *A 30-line television picture: As displayed on the Baird 'Televisor', the picture was enlarged by a lens to the size shown here, and had the reddish orange colour of the neon lamp employed as light source*

television programme, in vision and sound, would have occupied two channels, which could only have been provided at the expense of current plans for an alternative radio programme. The BBC's chief engineer, P P Eckersley, made it clear that whenever better pictures were demonstrated, the Corporation would try to transmit them, but that this would be impossible on medium waves.

In the event, Baird did not begin development of a standard higher than 30 lines until 1933, whilst for several years even the task of realizing the full potential of the 30-line system took second place to the launching of a succession of publicity-catching variants: 'Phonovision' (signals recorded on gramophone records); 'Noctovision' (an infra-red device for seeing in the dark or through fog); transatlantic television; colour television; stereoscopic television; large-screen television (an array of 2 100 small lamps).

By 1931, the quality of Baird's 30-line pictures had improved sufficiently for the BBC to feel justified in providing a studio in Broadcasting House (opened in 1932), undertaking the production of programmes, and instituting collaboration in engineering matters. There was never any intention of instituting a service on 30 lines however, and Baird was required to issue a warning with all sets and kits of parts that the experimental transmissions might cease after March, 1934. Only a few thousand Televisor kits were ever sold and fewer than a thousand ready-made receivers, though experimenters in many parts of Western Europe are known to have received the transmissions on home-made apparatus. The BBC's highest annual expenditure on 30-line television, in 1933, was only £7129; the transmissions finally ceased in September 1935, when the establishment of a high-definition service was under way.

## High-definition television

From about 1930, several British firms besides Baird's began investigating television. One of these – the Gramophone Company Ltd – merged with other organizations in 1931 to form 'Electric and Musical Industries Ltd' (EMI) which mustered a formidable team of research engineers, under Isaac Shoenberg.

Initially, the EMI team designed receivers using cathode-ray tubes, but retained mechanical scanning for generating the picture signals. As their work proceeded, they progressively increased the number of scanning lines in their pictures, from 120 to 180 and then to 243. They also introduced 'interlaced' scanning whereby, though only 25 pictures a second are transmitted, each area of the screen is scanned 50 times a second, causing flicker to be substantially reduced. To achieve this effect, all 'odd-numbered' lines down the picture are traced out during one scan, and all 'even-numbered' lines during the next. Interlacing is now employed in all television systems.

From 1933, the Baird Company too were experimenting with standards of 120, 180 and 240 lines, though without interlacing. These figures suggest that at this stage EMI and Baird were making comparable progress, but BBC engineers attending demonstrations of the rival systems were consistently more impressed by the EMI apparatus.

In 1932 the EMI engineers began work on an electronic camera tube, as an alternative to mechanical scanning. By virtue of EMI's link with the Radio Corporation of America (RCA), they had access to work that was being carried out in the RCA laboratories on a revolutionary new camera tube, the 'iconoscope'. This was to prove the crucial factor.

## The iconoscope camera tube

The 'spotlight' technique of scanning the subject with a moving spot of light, used by Baird, could not be used for distant subjects, and was confined to studio use, since it required darkness. It was, however, the only available alternative to scanning a normally lit scene one point at a time, thereby wasting the light from all other points. This inefficiency became proportionately worse as the standard of definition was raised.

10 *Emitron camera*, 1936*: Unlike modern camera tubes, the Emitron required the electron beam to scan the illuminated side of the 'target'; this accounts for the characteristic shape of the camera, with the electron gun protruding diagonally, below and in front of the lens. An optical viewfinder was used, in a twin-lens reflex arrangement*

The other major obstacle to high-definition television was the impracticability of mechanical methods of scanning; as the scanning frequency increased, the equipment became progressively bulkier and less manageable.

Both these obstacles were surmounted by Zworykin's 'iconoscope' camera tube. It utilized light more efficiently, by a principle known as 'charge storage', and used an electron beam for scanning, thereby avoiding the need for moving parts.

Vladimir Zworykin, who had worked on television in St Petersburg with Rosing, arrived in the United States as a penniless refugee in 1919. At that period television did not exist as a subject for study in the handful of laboratories with facilities for electronic research, and Zworykin was able to work on television only intermittently over the next ten years. Nevertheless, in 1923, while working for Westinghouse, he demonstrated and patented a pick-up tube embodying charge storage, and soon after moving to RCA in 1930 produced the first iconoscope.

The heart of the tube was a mosaic of tiny photo-sensitive elements sparsely deposited on a sheet of mica, and thus insulated from each other; these elements emitted electrons when acted upon by light. On the back of the sheet was a metallic coating, from which the output signal was obtained, by capacitative coupling to the elements of the mosaic. The mosaic was scanned by an electron beam, and when an optical image was focussed on to the mosaic each element underwent a cyclic process, charging up continuously as a result of the light falling upon it, and being discharged periodically by electrons from the scanning beam.

In practice, only about 5% of the charge generated by the light was utilized, but even with this limited storage the sensitivity of the tube was adequate, though low by present-day standards.

The 'Emitron' camera tube, developed by EMI engineers in 1933–4, was based on the iconoscope, but incorporated significant differences in manufacturing technique.

## The choice of system

In 1934, EMI and the Marconi company merged their television interests in a new company, the Marconi–EMI Television Company, Ltd., which was thus able to profit from the Marconi company's expertise in the field of transmission. Since the signal generated by a high-definition television system contains a band of frequencies extending from DC to several megahertz, it could not be accommodated in the wavebands then in use, and new techniques had to be devised for transmitting it in the largely unexplored v.h.f. waveband.

The merger further strengthened the resources ranged against the Baird company which, from an early stage, had been aware of the threat from EMI, and had reacted strongly. In 1933, as soon as it became evident that the BBC was taking an interest in EMI's achievements, the Baird company made representations to the BBC, the Postmaster General and the Prime Minister, attacking the Corporation on the grounds of EMI's link with an American company.

It was against this background that the Postmaster General, in May 1934, appointed a Television Committee to advise him on 'the relative merits of the several systems . . .'; in practice, this meant the Marconi–EMI and Baird systems. The Committee, after a thorough investigation of technical progress in this country, and also in the U.S.A. and Germany, reported in January 1935.

It recommended that a service be instituted by the BBC, with Baird and EMI equipments used alternately for a trial period. It decreed that 'the definition should not be inferior to a standard of 240 lines and 25 pictures per second', and that both transmissions should be readily usable by a single receiver.

The *Wireless World* expressed itself agreeably surprised that the report had specified so high a standard, and reported that news of its publication 'fell like a bomb-shell on the ears of American radio engineers'.

It was therefore even more surprising when, only a month after the report was published, Marconi–EMI announced that they were abandoning their 243-line standard and would use 405 lines, 25 pictures per second (interlaced). By choosing more lines they were requiring transmitters and receivers to handle higher frequencies for a given sharpness of picture, and the decision was made with considerable misgivings. The Baird company, still heavily committed to mechanical scanning, elected to use the minimum standard specified.

The two companies installed their apparatus in Alexandra Palace in North London. Marconi–EMI used the Emitron camera exclusively – for studio work, for film transmission and for such outdoor programmes as could be staged within the practical range (1 000 ft) of extension cables linking the cameras to the studio equipment.

The Baird equipment had no provision for outside broadcasting. A mirror-drum 'spotlight' scanner was used for close-ups and interviews, and a mechanical flying-spot scanner for film transmission. By this time Baird had belatedly realized that only an electronic camera would be satisfactory for large-scale studio productions, and was experimenting with a camera tube invented by the American pioneer, Philo T Farnsworth. However, the tube did not incorporate the vital principle of 'charge storage' and never gave satisfactory results. As a stop-gap, Baird had to use an 'intermediate-film' process; the programme was filmed, and its sound recorded, on special film which passed directly into a processing plant and was scanned, still wet, 64 seconds after exposure. The whole structure was bolted to the floor, so that the camera was completely immobile.

The official opening of the BBC's service – the world's first regular service of high-definition television – took place on November 2, 1936; as planned, the Baird and Marconi–EMI systems were used during alternate weeks. It was soon evident that the Baird system was markedly inferior, and had less potential for improvement. The official announcement of the exclusive adoption of the Marconi–EMI system came in February 1937.

Overnight, Baird ceased to be a figure of importance on the television scene, though he continued to work on a variety of schemes until shortly before his death in 1946 at the age of 57. He was a man of undoubted vision, and a resourceful experimenter; at a time when established opinion held, quite correctly, that high-quality television was inherently impossible with contemporary resources, Baird had nevertheless demonstrated television of a sort. As a result, he was hailed by the Press and the lay public as a great inventor, and embarked on a decade of euphoric improvization, mistakenly believing that his methods could be refined to produce high-quality pictures. But the scientific facts were against him, and his unwillingness to accept them, which in the short term had operated in his favour, in the long term proved his undoing.

The success of the Marconi–EMI system was primarily due to the development of the Emitron camera, but equally significant was the shrewdness with which the engineers chose the basic constants of the system. Many features of the 405-line standard have since been universally adopted, whilst the standard itself, though obsolescent, has continued to give good service into the 1970s.

Chapter 3

# The Pre-War Years 1932-1939

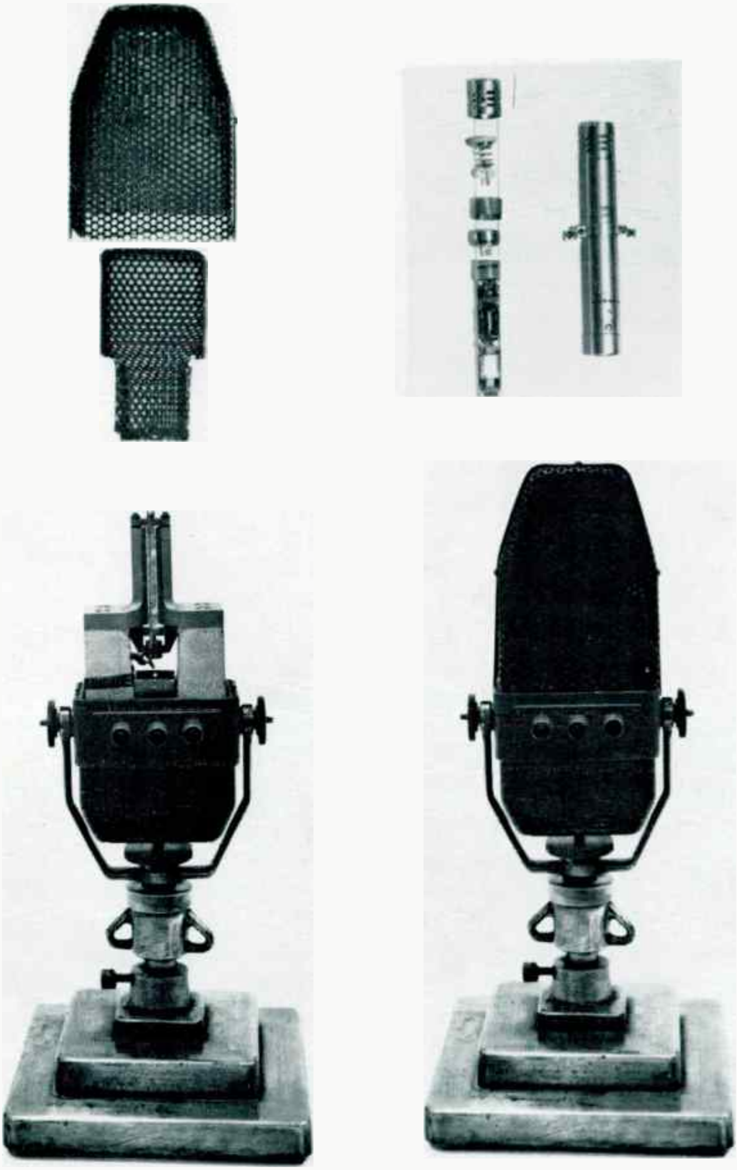
Throughout this period, building up the network of transmitters for the 'National' and 'Regional programmes was a major task; by 1939, they achieved coverage of 94% and 87% respectively. The short-wave station at Daventry was expanded from two transmitters to eight, and a modest start was made in foreign-language broadcasting.

In studios, the BBC–Marconi ribbon microphone was generally adopted. Its excellent frequency response had the further merit of being the same for sounds from all horizontal directions.

The 'Blattnerphone' recording machine was taken over by the Marconi company and re-appeared, much refined, as the 'Marconi–Stille' recorder, but by 1935 its position was challenged by the development of a method of disc recording that allowed immediate playback; conventional gramophone recording involved a delay for processing. The new method used a metal disc coated with a layer of cellulose lacquer, in which the groove was cut; it was due to Cecil Watts, a musician with a talent for engineering, who in the early 1930s established the Marguerite Sound Studios (MSS) to exploit it. The BBC borrowed an MSS experimental recorder for tests in October 1933, and over the next year or two collaborated with Watts in improving the design. In June 1935, the BBC's first disc recording 'channel' (two recorders) was installed at its music studios at Maida Vale, and by the end of 1936 two further channels had been added. Watts machines were also used for the BBC's first mobile recording unit, introduced in 1935. This was housed in a large van, and gathered material for 'feature' programmes. Its two successors, which took the road in 1936, were even bigger, each containing a small studio. Built on bus chassis, they were legally restricted to 20 mph, and were unable to negotiate the roads in the remote regions that they had originally been intended to explore.

For 'news' applications, technical facilities obviously had to give way to mobility, and by 1938 portable equipment had been designed that could be carried on the rear seat of a large car; two sets of this equipment were in service at the outbreak of war.

From 1936, the BBC also used another method of recording which achieved better reproduction than was obtainable from tape or disc. This 'Philips–Miller' system (developed by Philips, Eindhoven, from patents by an American, Dr J A Miller) ingeniously combined disc and sound-on-film techniques. The recording medium was a clear film, 7mm wide, covered on its top side with a thin, opaque skin, It ran below a cutting stylus which was vibrated vertically by the sound signal. Because its



11 *The BBC-Marconi ribbon microphone* (1934) *and an AKG capacitor microphone* (1969)*: The earlier microphone, despite its greater size, is much less complex than the later one, which includes an amplifier employing a field-effect transistor*

12 *Philips 'Superinductance' receiver*, 1933: *By good design, this 'straight' set was given a performance equalling that of contemporary 'superhets'*

cutting edge was shaped like a very shallow 'V' across the film, the vibrating stylus cut away a varying width of opaque skin. The resulting 'variable area' recording was ready for immediate playback by conventional optical means. Two channels of Philips–Miller equipment were in service from November 1938.

## Receivers

Between about 1927 and 1934, radio receivers developed rapidly. The battery-powered receiver, connected to an outdoor aerial and tuned in by manipulating two tuning controls and a reaction control, gave way to the all-mains superhet, with built-in moving-coil loudspeaker, automatic volume control and single-knob tuning. Its sensitivity enabled a few feet of wire within the room to serve as an aerial. This form of receiver was to undergo little basic change in the next twenty years.

The 'superhet'* principle has remained the basis of all subsequent receivers. It came into use because the so-called 'straight' set, in which the tuning knob had to vary all the tuned circuits simultaneously, could not readily achieve the selectivity demanded by the growing congestion of the broadcast wavebands; it was difficult to keep all the circuits 'in step' as the receiver was tuned, and their performance inevitably varied across the waveband.

In a superhet, the signal from the aerial is 'mixed' with the output of a tunable oscillator, to form a signal at their 'difference' frequency. All the circuits that follow are permanently tuned to accept only one narrow range of 'difference' frequencies centred on, say, 0.5 MHz. Thus, if the oscillator frequency is 1.8 MHz, a station at 1.3 MHz is heard. Rotating the tuning knob changes the oscillator frequency to, say, 1.9 MHz, and brings in a station at 1.4 MHz.

This technique enables the tuned circuits that give the receiver its selectivity to be designed for optimum performance at a single frequency, and to be precisely adjusted, once and for all, during manufacture.

In the years immediately before the war, a short-wave band became an essential selling point on all but the cheapest receivers, though few British listeners made much use of it; they tended to confine their listening to the BBC, except on Sundays, when many chose the lighter fare offered by Radio Luxemburg or Radio Normandy. Under these circumstances, a more useful facility was push-button tuning, which was also widely installed. Over this period, the technical sophistication, stylish appearance and keen value of mass-produced receivers undermined home construction, and only a dedicated minority continued to build their own receivers.

## Television

In February 1937 the television service adopted the 405-line standard exclusively, and in May the first television outside broadcast took place, when three cameras showed the Coronation procession as it passed Hyde Park Corner. Though the 'Emitron' camera tubes produced acceptable pictures despite the dull, rainy weather, they were not really sensitive enough for outside broadcasting, and later in the year were replaced by 'Super Emitron' tubes, about five times more sensitive. Outside broadcasts from Central London made use of a special balanced-pair cable, laid by the Post Office, to convey the vision signals to Alexandra Palace. It was found that, with suitable correction, signals could be sent through a mile or two of ordinary telephone circuit before reaching the special cable, thus extending its effective range.

For more distant outside broadcasts the signal was sent back to Alexandra Palace by radio, using a 1 kW mobile transmitter operating at 64 MHz, and an aerial mounted on a fire-escape ladder.

* Originally 'supersonic heterodyne', then 'superheterodyne.'

13 *The 'Marconi-EMI' studio at Alexandra Palace*, 1936: *The scope of early television programmes was restricted by cramped and poorly equipped studios*

By the end of the year the technical soundness of the system was established beyond doubt. The Emitron and Super-Emitron cameras produced excellent pictures, and the range of the transmitter exceeded expectations. The radio industry had risen to the challenge of incorporating a totally unfamiliar technology into receivers that the general public could handle. Nevertheless, public response was disappointing. Though 2 000 people a day had visited an ambitious television exhibition mounted at the Science Museum, fewer than 2 000 receivers had been sold.

One reason lay in the inadequate hours of transmission. Until the old 'Baird' studio was re-commissioned for 405-line operation late in 1938, there was only one studio, and it was possible to produce only two hours of material each day (from 3 to 4 and from 9 to 10), including a proportion of 'repeats'; there were no Sunday programmes until April 1938. Sales of receivers were also restricted by their price, which was out of most people's reach; the typical set of 1937 was a luxury model with a 12-inch (305 mm) screen and cost half as much as a small car. Finally, it seems likely that, with such spectacular advances so recently achieved, many people delayed buying receivers in the hope that better models would soon be available, or the fear that changes in transmission standards would make current models obsolete.

In February 1938 the Postmaster General announced that transcommon-frequency group, transmitting to Europe. Later, a new long- and medium-wave station was built at Ottringham, near Hull, which fed a total of 800 kW to its aerials, and could reach Berlin in daylight.

For more distant areas, short-wave facilities were greatly increased. Three completely new stations were built, and the BBC's total complement of short-wave transmitters was increased from 8 to 36.

There was no way of preventing the Alexandra Palace television transmitter from affording guidance to aircraft, and the service was closed throughout the war. However, in 1941 the transmitter and aerial were used for an important military assignment. This involved a very advanced German system which was designed to guide bombers accurately to a target in England by a radio beam transmitted from France, but which had the misfortune to operate in the same frequency band as the Alexandra Palace transmitter. It was arranged for one of the system's signals to trigger a powerful response from Alexandra Palace; as a result, the system's 'range' facility was completely confused, and the aircraft did not receive the instructions to release their bombs.

## Studio centres

To meet war-time conditions, a complete upheaval of studio facilities was necessary. Apart from evacuating whole departments from London to regional centres, the BBC prepared a separate network of emergency studios and control centres, and an emergency headquarters at Evesham, Worcestershire. The network of land-lines provided by the Post Office was greatly expanded, to serve the 60 low-power transmitters, to enable programmes to be routed through London for censorship, and to provide alternative routes for emergency use; telephone circuits in use for communication and programme distribution eventually totalled over 30 000 miles.

It was decided to abandon the elaborate pre-war system whereby all studios were dependent upon battery-powered microphone amplifiers in a central control room, and to make each studio self-contained. This was accomplished by installing, in all of the BBC's 150 studios, simple equipment built around a microphone amplifier of extremely high performance, which had been designed just before the war for outside broadcasting. Despite the enforced simplicity of war-time studios, standards were maintained. Radio drama, it was found, could survive without the impressive 'dramatic control panel' from which the producer had directed actors, 'effects' operators and musicians in separate studios, unable to see any of them. Rooms pressed into service as studios were often provided with unexpectedly satisfactory acoustics merely by hanging up lengths of 'Cabot's quilting' – cotton sheeting stuffed with dried eel-grass.

## Recording

The war created a growing need for recording facilities. The risk of air-raids after dark made it prudent to pre-record programmes during daylight, whilst the expansion of overseas broadcasting increased the demand for repeating programmes on different services. Pre-recording also eased the problems of censorship. Finally, effective reporting of the war demanded extensive facilities for mobile recording.

The BBC's meagre pre-war facilities were quite inadequate for the task, and new equipment was hurriedly sought.

Six channels of Philips–Miller equipment were in commission before the invasion of the Low Countries cut off further supplies of the machines, and of the special film, which was made in Belgium; continued use of the system was possible only when arrangements were made to have the film produced in America. Though the Marconi–Stille system was obsolescent, one further channel (ie two machines) was bought; erasure and re-use of the steel tapes made it possible to operate the system despite the difficulty of obtaining new tapes from Sweden.

In disc recording, there were fewer obstacles to expansion. One particular type of American equipment was available, and some 40 channels were imported. They had facilities for recording at 33⅓ rpm on 17¼-inch (438 mm) discs, giving a playing time of a quarter of an hour, but required considerable modification to bring them up to an acceptable standard of performance.

The demand for mobile recording equipment was met mainly by producing over 50 machines of a type designed by the BBC just before the war. This equipment was technically satisfactory and extremely rugged, but its bulk made it 'transportable' rather than 'portable'; moreover, the reporter had to be accompanied by a recording engineer. Accordingly, in 1943/4, the BBC developed, in association with the MSS company, a midget recorder weighing only 35 lbs (16 kg), based on a clockwork portable gramophone. It was truly portable, and simple enough to be operated by the reporter. Such historic despatches are those recorded by Stanley Maxted at Arnhem were made possible by this equipment, of which some seventy units were produced.

## The war-time civilian receiver

The priority given to the BBC's war-time needs could not be extended to those of its listeners, and by 1943 the annual production of receivers for sale to the public had dwindled to 50 000. This was obviously insufficient to offset the decay of old receivers, which the shortage of spare parts and of skilled service engineers was accelerating, and an unbranded 'War-time Civilian Receiver' was produced, in mains and battery versions. If first appeared in July 1944, and over a quarter of a million were sold. The receiver was of stark appearance, and was universally known as the 'Utility Set'.

15 *The Light Programme 'continuity' suite in Broadcasting House, London,* 1949: *In the BBC's 'continuity' system, introduced during the war, an announcer and a technical operator link all the items broadcast by a particular network into a smooth-running sequence*

Chapter 5

# The Ascendancy of Television

Immediately after the war there was little indication that within ten years there would be more people in Britain watching television than listening to the radio. In *Wireless World* for May 1946 there was a small paragraph announcing that the television service would re-open in June*; a slightly longer paragraph in the June issue reported that shortage of wood had so far prevented the production of any receivers.

Thereafter, British television made slow headway against post-war difficulties. In 1948, there were some 50 000 receivers picking up the Alexandra Palace transmissions, and the BBC was planning to extend the service to the rest of the UK. It was at this stage decided to retain the 405-line standard indefinitely. Though other countries used or proposed to use various other standards, all with more lines, there was at that time no immediate prospect of establishing a common standard, even for Europe. A higher standard would have used up more of the radio spectrum for a given quality of picture, hence aggravating overcrowding of the available wavebands, whilst existing equipment was in any case incapable of exploiting its potential advantage in definition.

Between December 1949 and August 1952 the BBC commissioned four high-powered transmitters, bringing television within reach of about 80% of the population. Over the next four years, seven medium-power stations were added, increasing coverage to 97%. These shared channels already in use by the high-power stations. Mutual interference was minimized by radiating vertically polarised waves from some stations and horizontally polarised from others, by making some of the transmitting aerials slightly directional, and by arranging that nominally identical transmitter frequencies were, in fact, very slightly different; this difference could be chosen to ensure that the interference pattern on the screen was of minimum visibility.

To link the various transmitters, the Post Office installed coaxial cables and microwave radio links, capable of carrying the necessary 3-MHz band of frequencies, equivalent to 750 telephone circuits. This 'simultaneous broadcasting' network was mostly two-way, so that outside broadcasts could be originated from all parts of the UK and programmes produced in regional studios for national distribution.

* The Hankey Committee had recommended in 1943 that, though research into an improved specification (including colour) should be pursued, post-war television should initially retain pre-war signal standards.

## Cameras and studios

The outside broadcast of the wedding of HRH Princess Elizabeth and HRH the Duke of Edinburgh, in November 1947, marked the first use of a new camera tube, the CPS* Emitron, based on the American 'orthicon'. It was more sensitive than earlier tubes, and was free from their spurious 'shading' signals, which had required continual adjustment of correcting controls.

However, the CPS Emitron had one serious failing. Any excessive highlight in the scene, such as a momentary glint off metal or glass, caused the tube to become unstable. On the viewer's screen, a white patch spread out from the offending point, obliterating the whole picture, and the camera-tube had to be briefly switched off to restore normal operation. When the 3-inch image orthicon tube became available from America in 1949, its freedom from this fault, and its greater sensitivity, caused it to be preferred to the CPS Emitron for outside broadcasting, though its picture quality was less good. In particular it produced an exaggerated accentuation of sharp edges which, while imparting a useful illusion of resolution to the picture, made it look 'embossed'. Under studio conditions, where highlights were easier to control, the merits of the two tubes were more evenly balanced, and both types were therefore used.

In 1956, a new design of CPS Emitron overcame the problem of instability, but by this time a tube had appeared that superseded all earlier types and was to maintain its supremacy for the remainder of the 'monochrome' era.

This was the 4½-inch image orthicon, developed by the English Electric Valve Company in response to the BBC's dissatisfaction with the 3-inch tube, which the company had manufactured under licence since 1950. There were sound reasons for expecting that the 50% increase in target diameter, though fraught with problems, would bring about a more than proportionate improvement in performance. This proved to be the case, and the 4½-inch tube achieved great success in both home and overseas markets. The situation was, in fact, the exact inverse of what is commonly supposed to happen; America was importing a British development of an American invention.

In 1949 when the BBC acquired a site at White City for the construction of an ambitious studio centre, the television service was still confined to its two pre-war studios at Alexandra Palace. Interim accommodation was urgently needed, and between 1950 and 1956 eight new studios were opened in the West London area; one had been a variety theatre, and the rest were converted film studios. A start was also made in providing studios at the BBC's regional centres.

Over this period, new studio facilities were introduced. Lighting installations were designed for more rapid control than had been needed

* Cathode-Potential Stabilized.

for film production. Back projection widened the range of scenic effects and electronic switching techniques made possible such 'special effects, as Lilliputian figures moving within a normal scene. A new type of scanning equipment greatly improved the fidelity with which film could be televised.

## Telerecording and standards conversion

There was no regular provision for recording television programmes ('telerecording') until 1949, and the first six years of BBC television are lost to us. There were also more immediate consequences. A programme could be repeated only by re-staging it, preferably before cast, costumes and settings were dispersed, and evening programmes could only employ performers who were not currently working in the theatre. Without editing, the pace of a production was dictated by practical considerations such as costume changes, whilst any mishaps were mercilessly exposed.

Telerecording was accomplished by filming the programme from the screen of a special high-quality monitor. This basically simple method (which is still widely used for some purposes) is complicated by the difficulty of moving the film from frame to frame without thereby losing part of the picture; the moving spot of light that forms the television image is absent for less than 2 milliseconds between the bottom of one scan and the top of the next. In one design of equipment, produced expressly for the 1953 Coronation, alternate scans from the screen were simply blacked out. Since in television all the 'odd-numbered' lines are dealt with during one scan and all the 'even-numbered' ones during the next, the film contained only, say, the odd-numbered lines, broadened electronically (by vertical 'spot wobble' on the monitor tube) so as to fill in the gaps. This loss of information was surprisingly tolerable, though critical examination of the long-shots in the recording of the Coronation service reveals that people's eyebrows were only intermittently visible.

The use of film telerecording was restricted by its cost, as well as by the noticeable loss of technical quality it entailed, and it did not affect the predominance of 'live' programmes.

One application of telerecording is the international exchange of programmes. Since the line structure of the picture is eliminated in the filming process, no problem arises when different line-standards are used in the two countries involved.

Somewhat similar arrangements were needed for the exchange of 'live' programmes involving a change of line standard. The original programme was displayed on a high-quality monitor, again with the gaps between lines eliminated electronically. A camera trained on the screen was operated on the line-standard of the 'user' country. The first use of such 'standards conversion' apparatus was in 1952, when pictures relayed from Paris were broadcast by the BBC; the systematic exchange of programmes between European countries ('Eurovision') began in 1954.

Both in film recording and in the form of standards conversion outlined here, technical quality is lost by having to display the original signal as an optical image and then re-scan that image. In later methods of recording and standards conversion, these processes are avoided.

## Receivers

Post-war television receivers benefited from war-time work on radar, but had much in common with pre-war sets. In particular, they still employed long, thin picture tubes with circular screens (reduced to a rectangle by a rubber mask), making for small pictures and large cabinets. The size and weight of a receiver was in part due to its massive mains transformer, which supplied a low voltage for heating the valves and a very high voltage for the picture tube. Around 1950, designers got rid of the transformer by connecting the valve heaters in series across the mains supply and deriving the high voltage from the line-scanning circuit.

When the first regional transmitter opened, some manufacturers produced separate 'London' and 'Birmingham' models tuned to the appropriate frequencies, but soon sets were produced which could be pre-set by the dealer, to any one of the five BBC channels. It was only in 1955, when an alternative programme became available in the London area, that it became necessary to provide means for the viewer to change channels.

## 'Independent' television

The BBC's monopoly of television broadcasting was ended by the Television Act, 1954, which provided for an additional service, to be financed entirely by the sale of advertising time. Programmes were to be produced by a number of companies, each with a regional franchise, and radiated by a central body – the Independent Television Authority.

The new service, which became known as ITV, was allocated channels in Band III (174-216 MHz). These frequencies were three or four times higher than those hitherto used in this country for television, and required new designs of transmitters, aerials and receivers. The shorter wavelength of the Band III signals made them less able to bend round obstacles, so that pockets of poor reception within the service area of a transmitter were more troublesome than they had been for the Band I channels used by the BBC. By way of compensation, the smaller wavelength meant that more elaborate aerials could be designed for a given overall size, whilst the more nearly 'optical' range of Band III signals reduced interference between transmitters using the same frequency.

In September 1955, just over a year after the Television Act became law, the ITA's London transmitter was operational, serving over 12

16 *Projection tube, about* 1950*: It was possible to obtain pictures larger than the screens of contemporary picture tubes, by optically projecting onto a translucent screen an enlarged image of a small but extremely bright picture formed on the screen of a special cathode-ray tube*

million people. Before the end of 1956, three more transmitters had been commissioned, bringing about 60% of the population within reach of the ITA's programmes, though as yet only about half of the households with television had sets able to receive them.

## Radio

The years just after the war were primarily a period of restoration rather than expansion, though the opening of a 'Third Programme', for material appealing only to minority audiences, was a major innovation. The BBC installed high-fidelity disc recorders of its own design, but the future of recording was soon seen to lie in the magnetic tape recorder, which had undergone remarkable development in Germany before and during the war. As early as 1935, a recorder using ¼-inch (6.5 mm) acetate tape with a ferric oxide coating had been marketed in Germany. Its performance, however, had not been up to broadcast standards. It had been improved considerably by the beginning of the war, but it was in 1940/41 that the major breakthrough occurred. Workers at the research establishment of the German broadcasting organization rediscovered the fact (previously known in America and Japan) that both the distortion and the noise level were dramatically reduced if the audio-frequency current magnetizing the tape were augmented by a current at an ultrasonic

17 *A BBC correspondent, equipped for the Commonwealth Transantarctic Expedition of* 1956*: The portable tape-recorder increased the range of events that radio could cover*

frequency, rather than by the direct current customarily used. Thereafter, 'Magnetophon' tape recorders found increasing application in German broadcasting, as well as for military purposes.

At the end of the war, a limited number of Magnetophon machines were brought to this country; the BBC put a pair into service in the autumn of 1946, for replaying music recordings obtained from the continent. Other machines were handed over to manufacturers so that British versions could be developed, and in July 1948 EMI lent specimens of their first recorder to the BBC for appraisal and for service trials. Though the verdicts were quite favourable there was a further period of trial and deliberation before the BBC first entrusted the 'repeat' of a live programme to tape, in April 1950.

18 *V.h.f. aerial at Wrotham, Kent: The cylindrical structure at the top of the mast radiates the BBC's three radio programmes*

By 1955, the BBC had 200 static and mobile tape recorders in service, handling 60% of its recordings.

## Frequency modulation

Before the war Edwin Armstrong (an American engineer with several major radio inventions to his credit) had demonstrated that interference-free reception could be achieved by using the v.h.f. frequency band and frequency modulation (f.m.). (In f.m. the sound signal varies the frequency of the radio wave, whereas in amplitude modulation (a.m.) it varies the magnitude.) Commercial stations using frequency modulation were licenced from the beginning of 1941, and when America entered the war in December of that year, production of f.m. receivers was running at an estimated 1 500 a day.

Before the war ended, the BBC was contemplating the use of v.h.f. transmissions to augment the medium-wave service, but did not regard the case for using f.m. rather than a.m. as having been established. Field trials with low-power transmitters, using both methods of modulation, were started in June 1945. The results were encouraging, but did not yield a conclusive answer to the question 'f.m. or a.m.?'. An experimental high-power station was therefore built, at Wrotham, Kent, and further tests began in 1950 with the object of resolving this uncertainty, and of providing detailed information on the service area achieved. The results clearly showed frequency modulation to be preferable, and plans for a v.h.f./f.m. service went ahead.

In May 1955 Wrotham began radiating the BBC's domestic programmes, and was rapidly followed by other stations. By installing a new receiver, a listener within the service area of a v.h.f. transmitter could, for the first time, hear evening programmes without interference; moreover, the fidelity of reproduction was greatly improved.

By the end of 1956, about three quarters of a million f.m. receivers had been sold, but factors that were to inhibit public interest in the new service were already at work. The BBC's audience-research figures for 1955 showed that most of the evening audience was watching television, whilst in 1956 transistor sets (for medium and long waves only) appeared on the British market, and soon became the most popular form of receiver for the predominantly day-time audience left to radio.

Chapter 6

# New Dimensions in Broadcasting – Colour and Stereophony

Whilst many features of present-day broadcasting were actually or potentially established by 1956, there were some notable restrictions. Colour television existed in America, and had been successfully demonstrated by the BBC using the American techniques, but there was no prospect of a colour service in Britain. There was no entirely satisfactory means of recording television programmes; pictures could be relayed only from Europe, and then only with noticeable loss of quality. Radio was exclusively monophonic, and 'local' radio non-existent.

## Colour television

In principle, colour television can be achieved quite simply, by sending three signals, similar in form to 'monochrome' signals but respectively conveying the 'red', 'green' and 'blue' content of the scene. At the receiver, each signal is made to create a picture in the appropriate colour, and the three pictures are superimposed.

Systems in which the three signals are conveyed simultaneously over three separate circuits have been used in 'closed circuit' applications, but early attempts to broadcast colour used the 'sequential' technique, in which only a single signal is transmitted. Discs made from segments of red, green and blue filter-material are synchronously rotated in front of a 'monochrome' camera and a 'monochrome' receiver, persistence of vision merging the rapid succession of red, green and blue pictures presented to the eye.

Unfortunately, for satisfactory results, such a 'sequential' system requires three times as many pictures per second as monochrome television, so (like a 'simultaneous' system) must either occupy three times as wide a band of radio frequencies, or employ a degraded standard of definition. An equally serious objection to both types of colour system is that they are not 'compatible' – that is, they cannot provide a satisfactory black and white picture on existing monochrome receivers.

Nevertheless, a very advanced sequential system was developed during the 1940s by America's Columbia Broadcasting System (CBS) and in 1950 was actually adopted by the Federal Communications Commission as the official American colour standard.

During the late 1940s, however, American research scientists were examining the characteristics of human colour vision in search of tolerances that could be exploited for colour television, and in 1951 the National Television System Committee (NTSC) proposed an elegant new system which exploited the eye's tolerance of blurred colouring in an otherwise sharp picture. The transmitted signal occupied no more of the waveband than a monochrome signal, and was also compatible; by means of advanced techniques of modulation, a normal monochrome television signal was augmented by an additional low-definition colouring signal, sharing the same band of frequencies yet contrived to produce very little interference on monochrome receivers. In colour receivers, decoding circuits reconstituted separate 'red', 'green' and 'blue' signals.

At the same time, the Radio Corporation of America (RCA) introduced a radically new design of cathode-ray tube which enabled three coloured images to be simultaneously displayed on a single screen. The screen was covered with tiny dots of red-emitting, green-emitting and blue-emitting phosphors, in an orderly array. Three electron guns, side by side in the neck of the tube, supplied electron beams bearing the appropriate colour signals, and a perforated sheet of metal ('shadow-mask') just behind the screen ensured that each beam could only reach its own colour of phosphor-dots.

With these two inventions, colour television at once became technically feasible. In 1953 the FCC gave its approval to the NTSC system (reversing its previous ruling on the CBS system).

Unfortunately, America's dedication to commercial broadcasting hampered the establishment of a colour service. With few colour receivers in use, sponsors were unwilling to bear the extra expense of originating programmes in colour; with few of the programmes in colour, the public were unwilling to buy colour receivers. As late as 1961, seven years after the first commercial transmission in colour, only one of the three major networks was transmitting colour at all.

In Britain, the prospect of colour television made it necessary to reconsider the future of the 405-line standard. By simply using the NTSC system in a 405-line version (which had been shown to give excellent results) the two established networks could readily have been converted to colour. To have done this, however, would have committed the country for many more years to a standard which larger screens were already making obsolescent in the late 1950s.

The alternative was to change to the 625-line standard, which had been generally accepted in continental Europe since 1953. The transition, however, would be complicated by the need to keep faith with the owners of 405-line receivers. The existing 405-line services would have to be left in occupation of the valuable v.h.f. bands for perhaps ten years, and the new 625-line transmissions established exclusively on u.h.f. bands (between 470 MHz and 960 MHz) which had been allocated to television but not yet used. It was known that at the very short wavelengths of the u.h.f. bands, hills cast marked shadows, necessitating many more transmitters than are needed at v.h.f., and there was some doubt whether the needs of all European countries could be met without unacceptable interference between the numerous stations that would have to share each channel.

Before informed decisions could be reached, it was necessary first to carry out field trials to find how u.h.f. television signals propagated, and also laboratory tests to find what level of interference between stations could be tolerated. Armed with this data, engineers could then attempt to work out an internationally acceptable allocation of frequencies.

The results proved favourable, and at Stockholm in 1961 a plan was agreed for the European Broadcasting Area, involving thirty-six countries and over 4 000 u.h.f. stations. The plan (which was exclusively for the 625-line standard) provided for Britain to operate sixty-four main stations, each radiating four programmes; to extend the coverage, about 1 000 small 'relay' stations were envisaged. Subsequently, the BBC has devised computer programmes, allowing more detailed planning than would otherwise have been practicable for an operation of this magnitude, and as a result the required coverage will in fact be achieved with about fifty main stations and 450 relay stations.

A relay station is sited so that it can receive good signals from a main station, or from another relay station. The signals thus received are passed to 'transposers', one for each programme, which shift their frequencies to different channels, for amplification and re-transmission.

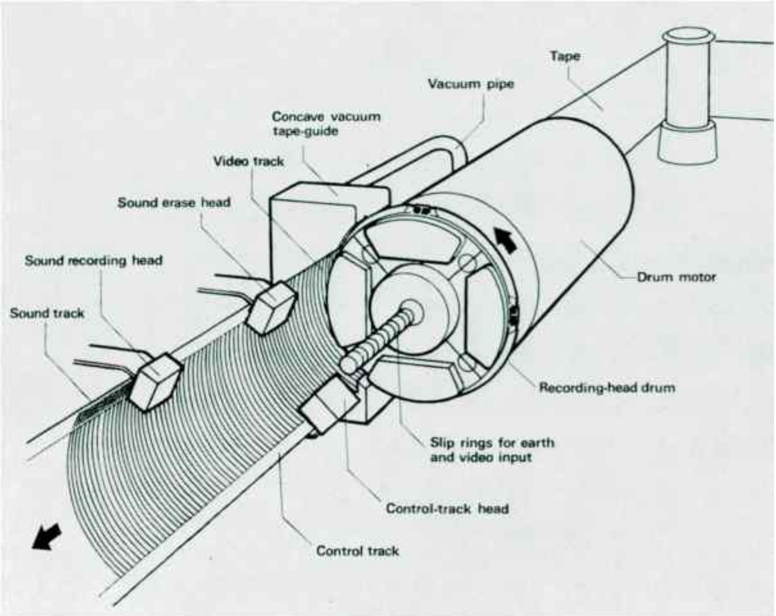
Britain's first implementation of the Stockholm plan came in 1964, with the opening of a second BBC network (BBC 2), transmitted exclusively on 625 lines, u.h.f.

The large number of u.h.f. transmitters has made it essential to provide for unattended operation of both main and relay stations. The station's performance is automatically monitored and, when a fault is detected, remaining resources are automatically redeployed to maintain the best service possible; usually this merely involves a slight fall in effective radiated power. At the same time, the occurrence of a fault is reported to a manned centre, so that an engineer can be sent to repair it.

## The choice of a colour system

The Stockholm plan largely resolved the 'standards' dilemma. Meanwhile, however, a new complication had arisen. In America, practical experience of the NTSC colour system had shown that the form of coding employed made the 'colouring' information unduly susceptible to some of the distortions it encountered along its path. Accordingly, France and Germany had each developed a variant of the NTSC system, using methods of coding designed to be more tolerant of distortion.

Once again, extensive field trials and laboratory tests were necessary; to make the task even more formidable, the French system, 'Secam', itself underwent periodic modification in attempts to improve its performance, whilst the German system, PAL, provided for either 'standard' or




21 *The principle of the four-head videotape recorder*

f.m. sound signals). From 1967 to 1969, with 625 lines and colour on only one network, colour receivers too had to be dual-standard, and were largely used for viewing 405-line monochrome pictures.

Subsequently, as the 625-line service has spread, the advantages of the new regime have taken effect. All three networks are on u.h.f and come from the same transmitting mast, so a single, compact aerial suffices; the receiver needs only a u.h.f. tuner, and need operate only on 625 lines.

## Videotape recording

Recording the signal from a television camera on magnetic tape is a great deal more difficult than recording a sound signal; an impracticably high tape speed is required if a convential form of recorder is to accommodate the rapid oscillations that occur in a television signal, and this speed must be held to an impracticable constancy if the reproduced picture is not to wobble.

Both difficulties were overcome by the 'Ampex' company in a recorder of revolutionary design that was introduced on to the American market in 1957, and was first used in Britain by an ITV company, Rediffusion, in the following year. This uses a tape 2 inches (51 mm) wide, running at only 15 inches (38 cm) per second. The recording is laid down as a succession of narrow tracks *across* the width of the tape by four heads

22 *Videotape machine: A high proportion of programmes are pre-recorded on tape and edited before transmission*

spaced around the rim of a wheel, which spins rapidly in a plane perpendicular to the tape's length; a guide curls the tape around the rim so that recording is continuous. By this means, a recording speed about a hundred times faster than the tape speed is achieved, and is stabilized by the inertia of the wheel.

The Ampex machine produced negligible loss of picture quality, and eclipsed a recorder of more conventional design that the BBC had developed to the stage of service trials. The specification of the original Ampex recorder has remained the basis of subsequent generations of videotape recorders for broadcast use, though simpler types, in which the recorded tracks lie almost longitudinally, have been evolved for less exacting applications.

Within a few years, videotape recording was used for all studio or outside broadcasts other than the minority whose nature demanded 'live' transmission.

## Satellite communication

The possibility of using artificial earth satellites for long-distance radio communication was discussed in some detail in a *Wireless World* article of October 1945, twelve years before Sputnik I was launched; the author was Arthur C Clarke, now famous as a writer of science fiction.

Television must be transmitted on very short wavelengths, which cannot reach far beyond the horizon, and a satellite overcomes this limitation by providing straight paths between distant points. However, the great distances involved and the small size of the satellite cause the transmission loss to be very great, so that the satellite must amplify the weak signal it receives before returning it to earth.

The first satellite capable of relaying television was '*Telstar I*', launched on July 10, 1962, operating in conjunction with earth stations in America, England and France, whose huge 'dish' aerials followed it across the sky. The satellite orbited the earth every two and a half hours and even during the most favourable orbits was visible from both sides of the Atlantic for only a few minutes.

Because of the historical significance of '*Telstar*', and the publicity that the project had received, it was decided to broadcast the first television pictures transmitted by the satellite rather than confine them to an audience of engineers. Thus when the British Post Office's earth station at Goonhilly, Cornwall, received only very weak signals, the engineers' sense of dismay was shared by millions of viewers; the French station, however, received good pictures.

Frenzied checking at Goonhilly revealed that the fault lay in an internationally agreed definition, which contained an ambiguity, and had been differently interpreted by the American and British engineers. A component in the Goonhilly aerial was reversed, and highly successful results were obtained the following day.

Satellite communication entered a new phase a year later with the first successful launching of a 'synchronous' satellite – that is, one whose orbit was such that it always stayed above the same point on the earth's surface. This advance (prophesied in Clarke's 1945 article) made relays continuously available over a wide area. In April 1965 the first commercial satellite was launched by the international body ('Intelsat') set up to operate satellite communication for civil use.

Subsequently, the television audience has grown used to seeing events televised 'live' from all parts of the world. Such transmissions are very expensive, because each television circuit uses satellite capacity that would otherwise be available for carrying about a thousand telephone circuits; telephony is, of course, the mainstay of satellite communication.

## Standards conversion

With the opening of BBC 2 on 625 lines, conversion between the 625-line and 405-line standards became necessary on a greater scale than hitherto. Subsequently, there has been a further large increase, with all BBC 1 and ITV programmes originated and distributed on 625 lines, but transmitted on both standards.

Equipment existing in the early 1960s, in which a camera operating at one standard was focussed on a picture displayed at the other, inevitably produced significant loss of quality, which would have become unacceptable when 405-line viewers received only converted pictures. The equipment also required the attendance of a skilled operator, which would be unacceptable when, to avoid the expense of separate 405-line and 625-line distribution networks, large numbers of converters were operated at transmitter sites.

To overcome these difficulties, the BBC undertook the development of a new form of standards conversion equipment in which the signal was not displayed as a picture, but was retained as a waveform throughout. As well as 'prolonging' the lines of the 625-line picture to occupy the longer line period of the 405-line standard, a converter has to average between neighbouring lines of the 625-line picture. These processes require storage of the picture information, but by arranging for the two standards to scan down the picture together it is sufficient to provide for the storage of only one or two lines of signal.

Such was the urgency of the project that the BBC simultaneously developed two quite independent designs of 'line-store' converter. The two designs differed radically in the techniques they employed for averaging, but both employed high-speed electronic switching to route into separate circuits the six hundred or so 'picture elements' into which each line was dissected.

Prototype models of both designs were successfully developed and put into service at Television Centre. Subsequently, the design that was cheaper to make was produced commercially, a total of sixty-nine converters eventually being installed within the BBC and ITA distribution networks.

The exchange of programmes with the United States is complicated by the fact that the picture is scanned sixty times a second on the American 525-line standard, as against fifty on European standards. It is thus no longer possible for the two standards to scan down the picture together, and very much more storage must be provided in the converter. Again, the BBC concurrently developed two forms of converter, but this time one was an 'interim' version, which was relatively simple but which produced a picture of diminished size framed by a black border. It entered service in 1967, and in the following year was succeeded by a more advanced version, free from this limitation, which enabled British viewers to see live colour pictures relayed by satellite from the Olympic Games in Mexico.

The heart of this 'field-store' converter is a bank of fused-silica delay devices – polygonal slabs into which the signal is launched as an ultrasonic wave; after numerous reflections from the faces of the polygon, the wave is converted back to an electrical signal. Each of the various slabs imposes some precisely known delay (up to 3.5 milliseconds in value), and the converter's logic circuits deduce, for each line of the incoming signal, which slabs should be switched into circuit to make the information emerge just when it will be required to contribute to the output signal. For colour pictures, the conversion process must also include translation of the colour information between the NTSC and PAL systems.

## Digital techniques in broadcasting

In 1972 the BBC began to put into service a new system, of its own design, for distributing the sound signal of a 625-line television picture within the picture signal.* This is done by fitting a sequence of pulses into the brief gaps that occur between successive scanning lines. By this means, the cost and complication of a separate sound-distribution network is avoided. Moreover, since the pulses are simply a succession of twenty-one 'Noughts' or 'Ones' within each gap, the sound signal does not lose quality as the distribution path is lengthened; it is merely necessary for the pulses to remain identifiable, which they do over even the longest links. At the transmitter the pulses are removed and reconverted to a sound signal before being broadcast.

This system is significant as the first operational application to broadcasting of the so-called 'digital' techniques that are increasingly being used in many branches of communication. By 1972 the BBC was on the point of extending digital-sound techniques to the distribution of stereo radio programmes, whilst both the BBC and the ITA had demonstrated experimental 625-line/405-line standards converters performing the much more formidable task of handling television signals in digital form.

## Cameras and studios

Britain entered colour television at a very timely stage in the evolution of camera tubes. Early colour cameras had employed three image-orthicon tubes; the characteristics of this type of tube were not well suited to colour work, whilst their large size made for a clumsy camera whose sensitivity was impaired by the long, and consequently inefficient, light paths between the lens and the tubes.

In 1950 RCA introduced the 'vidicon', a tube whose target responded to light not, as in other tubes, by emitting electrons, but by becoming more conductive. Because of its small size, cheapness and simplicity of operation, the vidicon has been widely used in closed-circuit and industrial television, but its use for broadcasting has been restricted by limitations of performance, particularly its tendency to smear moving objects.

By replacing the vidicon's antimony-trisulphide target with one of lead oxide, the Philips company was able to develop the 'Plumbicon', which retained the vidicon's merits while greatly improving its perfor-

* See cover picture.

23 *Colour television studio equipment: Lights and monitors suspended from the roof leave the floor free of obstruction*

24 *The compactness of a modern colour camera makes for freedom of movement, here illustrated by the use of a 'crane' (Wendy Hiller in rehearsal for* Peer Gynt, 1972)

mance. The first Plumbicon tubes appeared in 1957, and in 1964, when the BBC had to make its forward plans for colour cameras, small-scale production had begun, though only experimental Plumbicon cameras existed, and none were in operational service. Moreover, important technical deficiencies of the tube were yet to be overcome, and its future depended entirely upon one manufacturer. Such was the tube's promise, however, that the BBC made the bold decision to base its plans for colour exclusively on the Plumbicon, and tacitly confirmed this by taking no steps to ensure the development of an image-orthicon camera capable of meeting its requirements. Subsequent events have shown the wisdom of this course, Plumbicons (or similar tubes produced by other manufacturers) having become universal in new designs of colour camera.

The first generation of colour cameras to be installed in Britain included both three-tube and four-tube types. In a three-tube camera, the monochrome ('luminance') signal is formed by adding together, in appropriate proportions, the signals from the 'red', 'green' and 'blue' tubes. If the three images are slightly misregistered, the sharpness of the picture suffers, though the colouring may still be acceptable. Registration becomes less critical if a fourth tube is included solely to provide the 'luminance' signal.

Colour studios are planned for high productivity, and are in use twenty-four hours a day, scenery and lighting being rigged during the night in readiness for camera rehearsals and recording during the day and evening. The BBC quotes a daily output of thirty minutes' programme from each studio, with only half a day a week for maintenance.

An essential factor in this achievement is the studio lighting equipment. Rigging time is minimized by providing a very large number of lights, suspended from remotely-controlled hoists closely spread over the ceiling. By this means, light is immediately available at any point in the studio, and the floor is kept clear of obstruction. Each lighting plot is 'filed' in computer-type stores, and can be instantly recalled. It has been found that a useful degree of dimming can be used without upsetting the colour of the illumination.

Correct exposure of the colour cameras, which should be accurate to an eighth of a stop, is primarily achieved by control of the incident lighting level (1600 lux), and iris controls are used only for fine adjustments. A scene must be restricted in contrast to a range of only thirty to one, and to enable this condition to be met without requiring completely uniform illumination of the scene, costumes and scenery are restricted to an even narrower range (twenty to one).

Thus, artistic and engineering staff have co-operated to overcome technical limitations by maintaining strict quantitative control over each individual aspect of the operation.

## Local radio

With the advent of v.h.f./f.m. broadcasting, local radio became technically feasible. V.h.f. waves grow rapidly weaker beyond the service area, whilst f.m. is more tolerant than a.m. of signals picked up from other stations on the same frequency. It is therefore possible to plan local broadcasting with a considerable degree of frequency-sharing between stations in different parts of the kingdom.

In 1967 the BBC received government approval for an experimental trial of local broadcasting, and eight stations were opened between November 1967 and January 1968. In 1969, approval was given for twelve further stations, and the BBC made plans to increase the total number to about forty, which would have given 90% population coverage. Following the change of government in 1970, however, the BBC's network was halted at the twenty stations (75% coverage) already authorized, and a Bill was introduced providing for up to sixty commercial stations to be established under the control of an Independent Broadcasting Authority (IBA), which would succeed the Independent Television Authority.

The Bill (which is expected to have become law by the time this booklet is published) provides for each station to have both a v.h.f. and a medium-wave transmitter. A low-power medium-wave transmitter on a shared channel gives satisfactory service during daylight, but after dark there is considerable interference between stations.

The BBC's local-radio studios are designed to be operated by non-technical staff. A new form of limiter amplifier brings variations in sound level, occurring during a programme, within the range required by the transmitter. The signal is delayed on its way to the gain-controlling circuit, which can thus be brought into action by the time the signal reaches it. In this way, even a sudden loud sound is accommodated without distortion.

## Stereophony

In 1958, stereophonic gramophone records came on the market (using a technique patented in 1933 by one of the designers of the Marconi–EMI television system). At the same time, the BBC began to investigate the 'studio' end of stereophonic broadcasting, and to radiate experimental transmissions in which 'Third Programme' and 'Television Sound' transmitters respectively carried the left-hand and right-hand signals; it was appreciated, however, that a practical service would have to await the development of a 'multiplex' system for broadcasting both signals from a single transmitter. Several such systems were then under development, and in 1961 the Federal Communications Commission approved one of them for use in the United States; this was the 'Zenith-GE Pilot-Tone System', named after the firms that had jointly developed it.

To be successful, a stereo multiplex system must operate within existing channel allocations, and must also be 'compatible' (ie must provide an acceptable service for those with monophonic receivers); the problem is, in fact, rather like that of colour television transmission. Moreover, the pilot-tone system has points in common with colour coding methods, a monophonic signal being augmented by a coded signal conveying the stereophonic information. Unfortunately, however, the ear is in some respects less easily deceived than the eye, and bandwidth-saving tricks of the type devised for colour television cannot be used. The stereo signal applied to the transmitter has, in fact, over three times the bandwidth of the monophonic signal, and thus cannot be transmitted on medium waves. On v.h.f., where the use of frequency modulation in any case necessitates wider spacing between channels, the additional bandwidth of the signal can be accommodated. The addition of stereo to a transmission makes very little difference to monophonic reception; stereophonic reception, however, cannot tolerate nearly as weak a signal as monophonic reception without becoming noisy.

The multiplex signal in the pilot-tone system may be thought of as coming from a rapidly operating change-over switch, alternately giving connection to the left-hand and right-hand signals. A monophonic receiver does not follow these rapid alternations, but simply reproduces

25 *Stereo control cubicle in Broadcasting House, London: The studio manager faces away from the observation window, and is thus spared conflict between the visual scene and the stereo illusion he is creating*

the average value of the left-hand and right-hand signals; this is the required 'compatible' signal. A stereophonic receiver is equipped with a 'decoder', which contains a change-over switch operating synchronously with the coding process; thus, one output circuit is always connected at moments when the input is conveying the 'left-hand' signal, and the other at moments when it is conveying the 'right-hand' signal. The switch is synchronized by the 'pilot-tone' after which the system is named.

The BBC began field-trials of the pilot-tone system in 1962, and in 1966 regular broadcasts commenced. These were confined to the 'serious music' network, and radiated only from the London area's v.h.f. transmitter at Wrotham. Spreading stereophony to the rest of the country was delayed by the need to use carefully matched circuits for distributing the 'left-hand' and 'right-hand' signals or, alternatively to use wide-band circuits for distributing the multiplex signal. The latter method was adopted, using radio links, and the service was extended to parts of the Midlands and the North of England in 1968; this gave a population coverage of about 60%, but little further progress has been made by 1972.

Extension of stereophony to the 'light music' network (scheduled for Autumn 1972) has been delayed by the need to provide stereo facilities in the numerous studios contributing to this network.

## The prospect from 1972

In its engineering aspects, British broadcasting has reached a point of relative stability, with many former uncertainties resolved. When existing plans have been implemented, people living almost anywhere in the UK will have a choice of three colour television programmes and three stereophonic radio programmes, and many will in addition have a local radio programme; moreover, all technical provision has been made for a fourth television network. Both the 625-line PAL colour standard and the pilot-tone stereo system are highly satisfactory, and likely to remain in use for many years.

## Radio broadcasting

In the 1950s, many engineers thought that as soon as a v.h.f. radio service was established, medium-wave broadcasting would rapidly lose importance. In fact, the imminence of commercial radio, which depends upon a mass audience that v.h.f. cannot yet command, has created an urgent new demand for medium-wave channels.

It is too early to say whether the additional realism made possible by 'quadraphonic' sound (four-channel stereo), with two speakers in front of the listener and two more behind him, will eventually cause it to supersede two-channel stereo as the norm for high-fidelity reproduction. Nor can it be said which of numerous competing schemes for achieving quadraphony would be used. Any four-channel system adopted for broadcasting, however, would have to be compatible with the existing pilot-tone stereo system.

Another recent development in sound reproduction, stimulated by stereophony, has been a revived interest in headphones. For the solitary listener, headphones can provide high fidelity more cheaply than loudspeakers, avoid disturbance to other people, and reproduce stereo signals with a striking illusion of immersion in the performance, though they cannot, of course, provide quadraphonic reproduction. Headphones incorporating a v.h.f. stereo receiver have been marketed, offering stereophony to listeners 'on the move'.

## Television broadcasting

The possibility of broadcasting from satellites to small communities or even to individual viewers is receiving much study, but its initial application is likely to be in those developing countries where scattered communities cannot economically be served by existing methods of distribution.

Considerable uncertainty exists over the extent to which broadcasting will be affected by two recent innovations which offer alternative sources of television.

The first of these is the extension of the 'wired' system by which many people, especially those living in 'difficult' areas, receive their programmes. Though traditionally such systems have simply been an alternative means of distributing the normal broadcast programmes, in America there has been an increasing tendency for the operators to originate programmes as well, and since April 1971 the Federal Communications Commission has actually required the operators of all systems with more than 3 500 subscribers to originate programmes on at least one channel. In Britain, on July 1 1972, Greenwich Cablevision Ltd began to distribute locally originated television programmes, free of advertising, in addition to those of the BBC and the ITA. (The viewer pays an inclusive rental for the service, which thus differs radically from 'subscription television' systems, in which he pays for individual programmes of 'premium' calibre, such as new feature-films. A service of this type was operated by Pay-TV Ltd for a trial period in areas of London and Sheffield from 1966-8, but the company was disbanded after the Postmaster General imposed restrictions on continuation of the service.) The significance of this development lies in the fact that it is feasible, technically if not economically, for a wired system to provide many more channels than can be provided in any one area by broadcasting.

The other innovation is the development of various 'video cassette' systems which enable the viewer to reproduce recorded television programmes on a normal receiver. In some systems, the programme material must be bought or hired ready recorded, but others are essentially domestic videotape recorders, permitting the viewer to record programmes 'off the air' or even to produce his own material from a television camera. It remains to be seen whether any of these systems will become cheap enough for widespread use.

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