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TELEVISION TRANSMITTER DEVELOPMENT 1931-1936

ON the 2nd November 1936, from the Alexandra Palace, London, the world's first high-definition television service was inaugurated.

Comment at the time is very revealing: "The average member of the Public regarded as incredible the possibility of seeing clear reproductions on a screen of events which were taking place simultaneously at a distant place. Something of this doubt may still persist, for television has made its debut in an advanced state of perfection, before a Public almost completely unprepared for the more usual process of steady development over a period of many years."

The system and methods used were so well chosen and carried out that they remain basically unaltered to the present day. In the ever expanding field of electronics this is a remarkable fact, and as we approach the 25th Anniversary of the initial Television Broadcasting Service, worthy of comment and consideration. What were the major technical developments in the transmission field which led to this great achievement? They may be briefly listed as follows:

(a) 1925/7 brought a major breakthrough in international radio communication by the Marconi Company's development of the short wave beam system operating down to a wavelength of 15 metres and attaining signalling speeds of up to 200 words per minute for long periods.

(b) For the excitation in correct phase of the extensive aerial arrays the concentric feeder was invented and widely applied.

(c) The attempt in 1928 by Marconi Research to replace Morse telegraphy by high-speed facsimile transmission on the London–New York service, which used Marconi Short Wave Beam Stations at both terminals. These experiments were unsuccessful in their real object but were instrumental in revealing the mechanism of long-distance short-wave communication and finally led to a very full understanding of radio propagation. It was discovered that information transmitted by very short pulses could be accurately reformed only by confining the signals to a direct ray, and that this condition would be realized only on wavelengths below 10 metres.

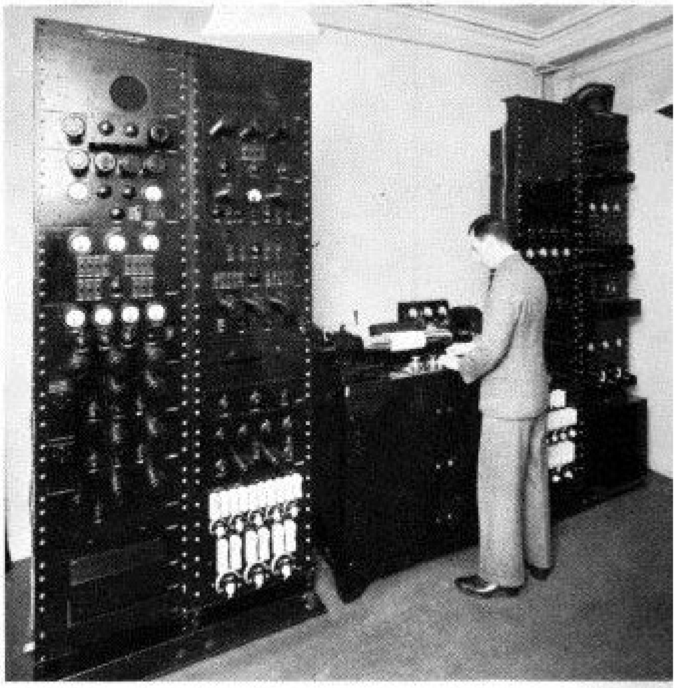

Fig. 1. The Marconi Facsimile Apparatus. Work on this equipment provided many of the answers to the problems arising in the development of the television transmitters at Alexandra Palace.

These were tremendous events in the history of radio telegraphy and opened the way to further advances in ultra short-wave communication, to the final development of relatively high-power transmitters suitable for high-definition television.

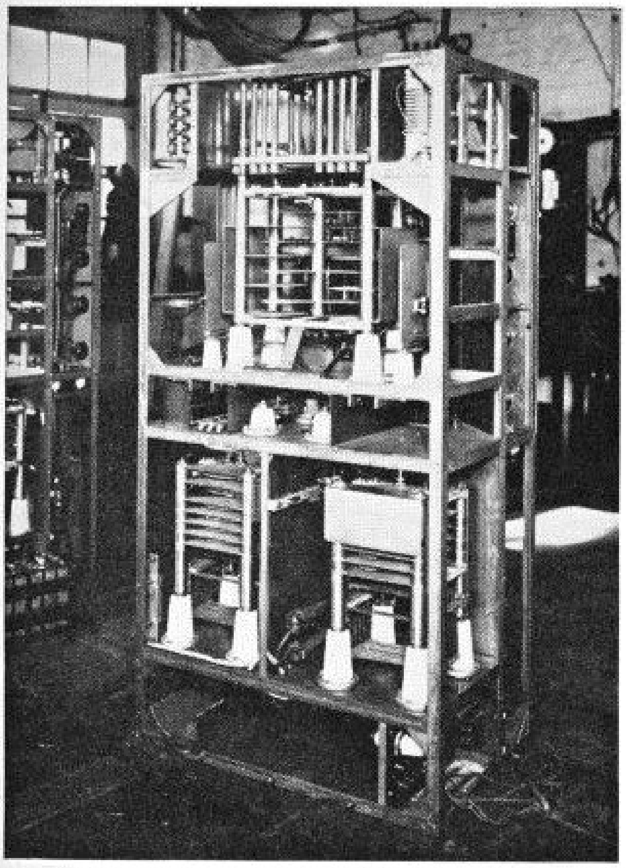

Fig. 2. A SWB4b Transmitter which provided the basis for the experimental transmitter from which the Alexandra Palace transmitter was developed.

The Alexandra Palace Transmitters were a focus of international interest in 1936. The grey-finished panels housed equipment, the technique for which had been gradually built up over the previous five years from the triple viewpoint of signal generation, transmission and reception and was confidently expected to meet future requirements of expansion and improvement. It all started from very small beginnings:

In 1930/1 Electrical and Musical Industries had a small research group developing a mirror drum film scanner for 120 lines 24 frames per second. Late in 1931 they requested the Marconi Company to supply a low-power USW Transmitter with a suitable modulator for use with this scanner. For this requirement a low-power "SWB" type transmitter (used for experimental transmissions between Rome and Sardinia on 10 metre wavelength) was modified and made to deliver 360/400 watts output at 44 mc/s. The fundamental modulation bandwidth was 180 kc/s. This was considerably higher than anything hitherto required, as although an all-electronic keying system was used during the SW high-speed facsimile tests, the fundamental pulse periods were 6 to 10 kc/s.

Consideration of the problem led to the logical conclusion that the best point to apply modulation was at the grids of the final amplifier as this presented the lowest capacity and required only a moderate voltage swing for full control of output. Suitable low impedance valves were available, and for this transmitter an anode impedance of 700 ohms was possible and a bandwidth of 500 kc/s between −3dB points was achieved. The signal generator used for the tests was a low-power marine transmitter plus an improvised slide back voltmeter, and during this initial work the measurement of results obtained was perhaps the greatest difficulty. Cathode ray tubes were gas-filled and difficult to use and with a low frequency response. For the high modulation frequencies more faith was placed in the S.W. "Scope" with low capacity diodes used at that period for the determination of aerial radiation patterns. For general monitoring a $\frac{1}{2}\lambda$ dipole with a centre thermal ammeter which could be viewed

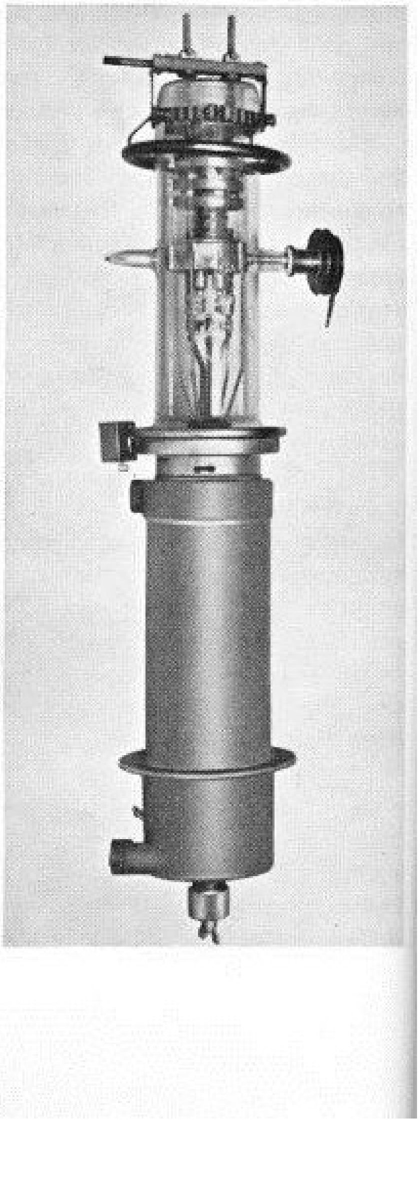

Fig. 3. A CAT9 Valve.

with binoculars was useful. No major difficulty was experienced with anode circuit loads of sufficient resistance and correct impedance to match the 70/80 ohm concentric copper feeder, or of accurately measuring the output.

In January 1932 the transmitter was installed in the E.M.I Research Laboratories at Hayes and worked in conjunction with a $\frac{1}{2}\lambda$ dipole erected on the roof. Thus began the liaison between the Marconi Company and E.M.I which was to lead to the formation in April 1934 of the Marconi–E.M.I Co Ltd to exploit the television system which their co-operation had produced and which in 1936 was elected to be the British standard.

Our next step was the development of a water-cooled class B Amplifier to increase the radiated power. This was designed around the CAT4 valves, similar to those used in the SW Beam Transmitters in which they were oil cooled. They were "double-ended", the anode being central to two glass envelopes from which emerged at opposite ends the grid and cathode connections. This amplifier was added to the low-power transmitter in June 1933 and represented a real advance. Modulation was passed to the grids of the CAT4 Amplifier and the original transmitter became the driving source. A peak output of 4 kW with a bandwidth adequate for the 150 line Film Scanner was obtained. The set-up gave a better understanding of the fundamental limitations of power output and modulation bandwidth. The requirements were becoming clear. The necessary loading of the anode circuit to attain a condition for wide bandwidth was under control, but the overall performance was seriously affected by the constants of the grid arms of the balanced bridge circuit. The high inductance of the grid-filament assembly in the "double-ended" valves set a definite limit.

As linearity of output was a function of grid loading, this was a particularly difficult problem, as a reasonably constant impedance during the full grid voltage swing had to be attained without introducing too much capacity to space. The use of soft iron for the grid circuit inductance of the final stage was partially effective.

The B.B.C were now showing interest in the progress being made and demonstrations to Sir John Reith gave increased impetus to the development.

At this time liaison by Marconi Research with G.E.C Valve Research stimulated experimental production of two compact water-cooled valves with constants suitable for high performance in the USW band. They were ultimately typed as CAT15 and CAT9 and proved a major contribution to the final success.

In the Autumn of 1933 an intermediate amplifier was constructed around the first of these valves embodying all previous experience. The result was an output of 3 to 4 kW with 2·5 megacycle total bandwidth. This gave ample driving power for the final stage and linearity was improved by iron loss loading the anode circuit. Modulation was passed back to this intermediate amplifier and the overall performance gave 10 kW to the aerial at 1·4 megacycles video bandwidth for use with a 180 line Mirror drum 24 frame Film Scanner.

The transmitted waveform was now established and was similar to that used in the trans-Atlantic facsimile tests except that a margin of power had to be retained for line and frame synchronizing pulses. This fixed a definite output level for picture black, from which the transmitter was controlled to full output by picture white and to zero output by the synchronizing pulses.

The receiving engineers preferred complete cut-off so that no high voltage could override the synchronizing intelligence. The problem presented at the transmitter was how to establish a constant black level throughout all conditions of the television signal, as this was dependent upon the HT anode supply to the final amplifier remaining constant from

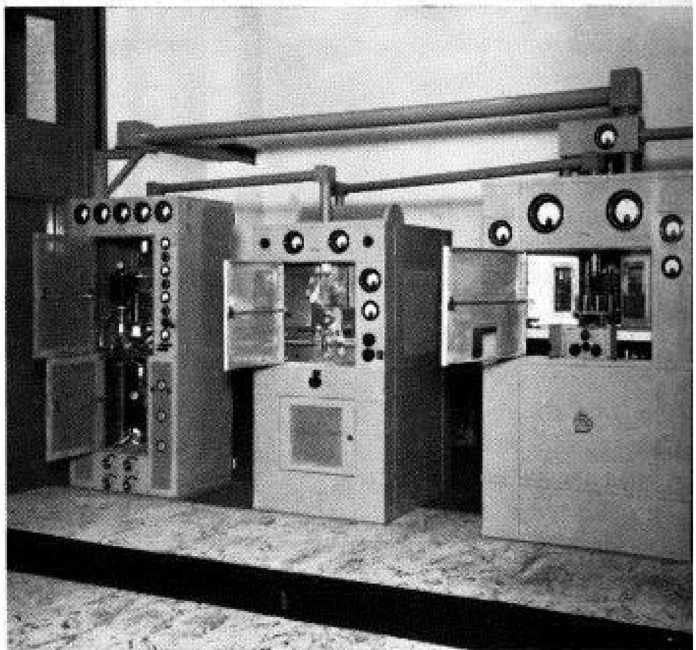

Fig. 4. The Vision Transmitter at Alexandra Palace.

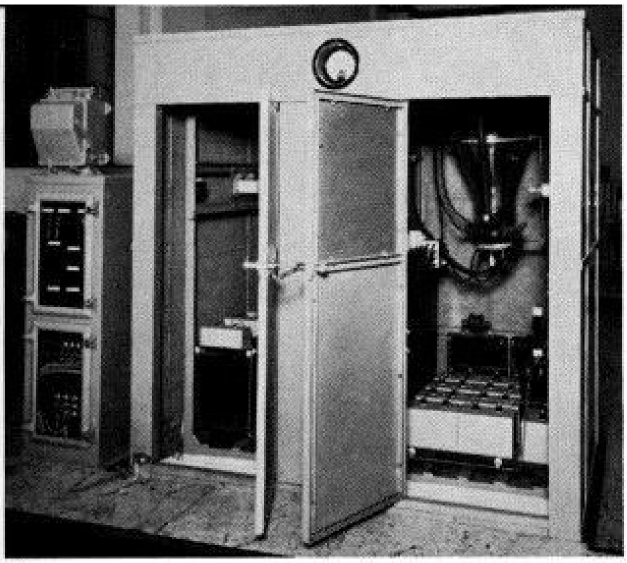

Fig. 5. Rectifiers for the supply of high-tension DC current to modulator anode circuits of the vision transmitter.

no load to full load and from zero frequency to the limit of the video bandwidth. Fortunately low impedance mercury-filled rectifiers existed and it was ultimately possible to achieve the necessary conditions and to avoid the side-effect of supply lead resonance. This work was a major contribution to the success of the system.

On 23rd February 1934 a low-power Sound transmitter was added to the Experimental Station with new masts and aerials and the first complete USW high-definition Radio Television System was established for trials and demonstrations of 180/250 line 24 frame transmission.

A decisive phase in the development had now been reached. It anticipated the appointment by the Government in May 1934 of the Television Committee and there was a pause while evidence was prepared, presented and plans laid for future work.

New developments were taking place in the vacuum laboratories. The I.E.E had received in July 1933 Dr Zworykin's famous paper, "Television with Cathode Ray Tubes" describing the "Iconoscope" which paralleled work at Hayes on the Emitron. These were dramatic developments opening the way to an entirely electrical television system with no moving parts.

A new power amplifier for 30 to 40 kW output on 44 megacycles was quietly being developed around four of the new special single-ended CAT9 valves. Then in January 1935 the report of the "Television Committee" was issued and recommended:

"A start should be made by the establishment of a service in London with two television systems operating alternately from one transmitting station."

The disclosure that the establishment of the London Television Service was to be decided by competition with the Baird Company had immediate reactions.

On 12th February 1935 a demonstration was given to the Television Committee Technical Sub-Committee of 202·5 lines per frame and 50 frames per second giving 405 interlaced lines and 25 complete pictures per second, the system definitely to be specified by the Marconi–E.M.I Co, for the London Station. It was a bold and far-reaching decision but necessitated a very careful review of the Radio Transmitter development programme, as the video bandwidth was to be doubled.

Instead of proceeding with the high-power amplifier utilizing four CAT9 valves it was decided to go for medium power with two valves in order to replace the CAT4 amplifier which was unsuitable for the extended video bandwidth.

Every effort was made to achieve a compact assembly for operation at high voltage by the use of smooth and liberal contours, capable of integrating water and air supplies, and so removing any risk of resonant absorption or interaction by isolated structures. The new amplifier was completed on 15th March 1935 and installed at Hayes to be ready for a full-scale demonstration to the Technical Sub-Committee of 405 line television and the prototype Radio Transmitter put forward in the specification for the London Station was now complete. Modulation was passed to the grids of the CAT9 Final Amplifier and on 1st April 1935 a successful full-scale demonstration was given to the Technical Sub-Committee to assist them to finalize requirements.

The modulator used at this time was not capable of fully exploiting the new final amplifier and this was a further development which had to be undertaken.

The major development was now complete, it remained now to turn to details of installation, safety precautions, monitoring and control circuits for Alexandra Palace, Muswell Hill, the site chosen for the London Station. It had been a place of amusement since 1875, so the B.B.C followed tradition in introducing the latest form of diversion 60 years after—one which has now expanded to such unpredictable proportions.

It is interesting to note that Television Development is a unique illustration of a peace-time effort which gave us the tools for war—Pulse technique, CRT's, Cathode followers and USW valves. These paved the way for radar and new navigational systems which were undreamed of before 1936.