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BROADCAST TRANSMITTER DESIGN

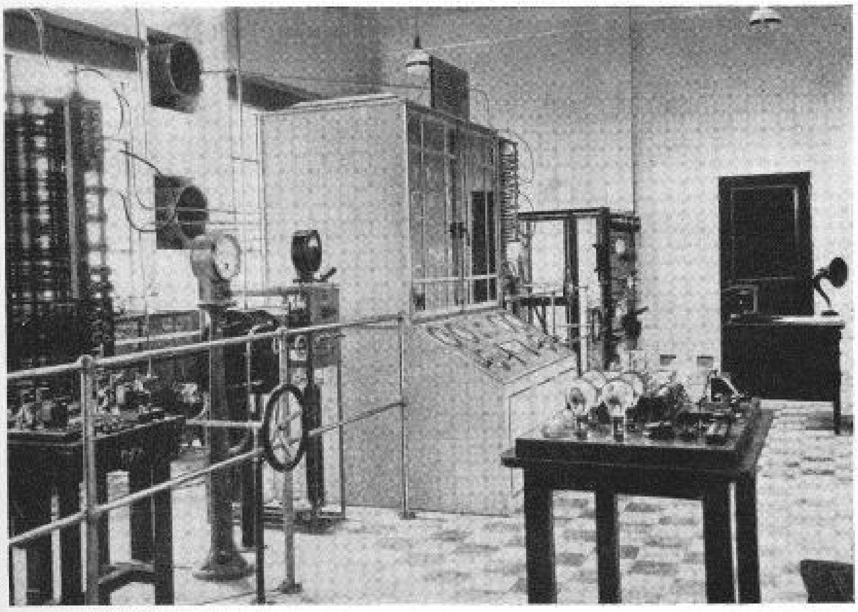
A brief review

IT IS OVER 35 YEARS since the design of medium and short-wave broadcast transmitters was undertaken on a sound engineering basis and in spite of the fact that in that time broadcasting on VHF and Television have been introduced, nevertheless transmitters of this type are still in extensive use all over the world and considerable thought continues to be given to the improvement of design.

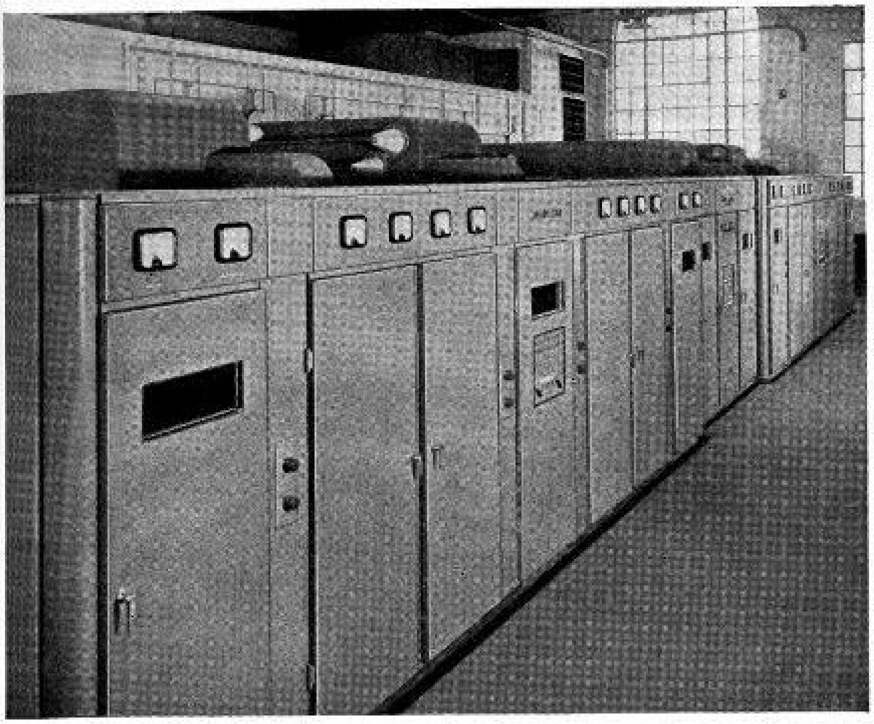
In earlier years the attention of designers was concentrated on performance and reliability. It was not easy, in those early days, to obtain the low distortion figures necessary for high quality broadcasting, except at the expense of heavy power consumption, and while the transmitters were remarkably reliable, the power taken from the mains for a given output to the aerial was very high indeed. The earliest transmitters were anode modulated, using the Heising or choke modulator principle, the modulator valves being operated in Class A. Such an arrangement is inherently inefficient. The linear amplifier transmitter was introduced a few years later but the power consumption was still excessive, the overall efficiency being 18 to 20%. The harmonic content of the modulated waveform at frequencies between 30 and 10,000 c/s was of the order of 4%.

CLASS B MODULATION

The development of the Class B modulator enabled a considerable improvement in overall efficiency to be obtained. It is interesting to recall that the Class B system of modulation was known in the early 20's and was advocated by Captain Round of the Marconi Company for use in broadcast transmitters, but the designers held back because the valves available were



Radio Nacional del Peru. View of part of the station showing the old Marconi 10 kW long-wave broadcast transmitter which is still serviceable after more than 30 years' operation.



By comparison we show here a view of a modern broadcasting transmitter employing two 100-kW MW air-cooled equipments in parallel at the Daventry Station of the B.B.C.

not satisfactory for use as Class B modulators and it was difficult to design a modulation transformer to work with them which would produce quality comparable with that of a good linear amplifier.

However, improvement in valves, greater knowledge of how to obtain the characteristics required of the transformer and the introduction of the Black system of feed-back eventually produced a Class B modulator which was entirely satisfactory. The majority of high power broadcast transmitters produced during the past twenty years has utilised this principle. Other systems such as the Chireix Dephasage, the Marconi Ampliphase system and the Doherty system have been used in various forms, but the Class B system with its relatively simple adjustment and robust components still holds the field. This is largely because the radio frequency circuits are simple and easy to adjust, an important factor, especially in the case of high power short-wave transmitters the wavelength of which must be changed frequently and quickly.

A short-wave transmitter incorporating all modern technique may have an overall power conversion efficiency exceeding 50% and medium-wave transmitters of equivalent power are operating with efficiencies of nearly 60%. In the period under review, the harmonic content in the modulated waveform has been reduced from 4 to between 1 and $1\frac{1}{2}$% over the audio frequency range. This performance has been achieved by the use of valves of improved characteristics as main modulators and the use of cathode followers to excite the grids of the modulators, but this is not the end of the development story.

HIGH EFFICIENCY AMPLIFIER

The Marconi Company has recently developed an improved radio frequency output circuit which has increased the conversion efficiency of the radio frequency output valves to 91% and sometimes higher, the exact efficiency depending on the suitability of the characteristics of the valves. The increase in the conversion efficiency of the modulated amplifier means a reduced power output from the Class B modulator and the overall power efficiency of medium-wave transmitters in the 50 to 100 kW range will, in the future, be of the order of 68 to 70%.

It is not possible within the scope of this article to describe the new circuit in detail. Those who are interested will find a full technical description in an article entitled "A New High Efficiency High-Power Amplifier" by V. J. Tyler.[1]

The new circuit is easy to adjust, consistent in performance and employs the principle of producing an approximately square waveform at both the grid and anode of the main output valves. The advantage of a square waveform at the electrodes of a valve designed for power conversion was pointed out by those who made a theoretical study of the subject in the earliest days of the valve; in fact Captain Round applied for a patent in 1919 for a circuit designed to produce this mode of operation and other workers have, from time to time, patented circuits with the same end in view, but the subject was never investigated fully and the subtleties of this method of using the valve were not appreciated.

Not only has the conversion efficiency of the main output valve been raised to a very high figure but the harmonics generated to produce a square wave at the anode are automatically filtered from the tank circuit in such a manner that the voltage and current waveforms in the output circuits are almost sinusoidal. This is an important point and it is interesting to recall that many workers, including the present writer, refrained from attempting to use square waveforms to improve efficiency because they thought that a high proportion of the power produced would be expended in the production of useless harmonics which would have to be eliminated by filter circuits.

The improved conversion efficiency of the main output valves means that the anode dissipation is greatly reduced, in fact the total loss in a valve of 100 kW output is of the order of 11 kW. This figure includes losses in the filament, grid and anode of the valve. The cooling of the valve, therefore, presents no difficulty and is effected by a relatively small amount of air. The use of steam or water cooling in such a transmitter is unnecessary.

STEAM COOLED TRANSMITTERS

During the past few years, many engineers have advocated the use of steam cooling for high power transmitters; the claim for this system being that power expenditure in pumps is obviated and that the heat extracted from the transmitter by the production of steam can easily be utilised for space heating.

This system of steam cooling was the subject of a patent application by the Marconi Company in 1934, but it is the opinion of the writer that the designer should not concentrate on means of removing waste heat but on improving the efficiency of the transmitters to such an extent that the quantity generated in the valves is so small as not to be worth recovering. This argument applies to transmitters up to a power output of about 200 kW. Having regard to the large number of high power transmitters now in operation and the relatively high cost of power, this is an important matter for broadcasting organisations who are operating them.

The floor space occupied by transmitters has been progressively reduced and the floor area required to accommodate a modern 100 kW transmitter is about half that of a transmitter of equivalent power designed before the war. This again is an important factor to broadcasting authorities because building costs are now very high.

UNATTENDED TRANSMITTERS

During the past ten years interesting developments have taken place in the design of unattended remotely controlled transmitters. The B.B.C was probably the first to put into operation high power unattended transmitters. In 1951 two 100 kW unattended transmitters were installed at the Daventry Station of the B.B.C. They were designed for parallel operation, the monitoring circuits being so arranged that should one transmitter fail, the second would carry the programme. This installation has been completely successful and the breakdown record has been remarkably good.

The B.B.C has also installed a complete network of 2 kW unattended MF transmitters. These each consist of three 660 watt units operating in parallel with complete automatic monitoring both of the transmitter circuits and comparators which compare the quality of the transmitter input and output signals. A minor fault, causing degradation of quality of one unit, will cause that unit to be switched out by a comparator amplifier.

This development, which is of great importance from the point of view of operating costs, has been completely successful and has now been extended to 1 kW, 5 kW and 10 kW FM transmitters, a number of which are now in operation. A typical B.B.C VHF FM station using this principle is described by E. W. Hayes in the present issue.

Further interesting examples of unattended installations are the systems in use both in Norway and Sweden.

The frequency modulation in these transmitters is produced by a direct frequency-modulated quartz crystal oscillator, which was designed by Mortley of the Marconi Company. This system is simple and reliable compared with other methods which use either amplitude-corrected phase modulation or direct frequency modulation.

In the amplitude-corrected phase modulation system the carrier frequency can be stabilised but at the expense of considerable complication. The systems which employ frequency modulated LC oscillators are usually stabilised by a reference quartz controlled oscillator. The directly modulated quartz crystal oscillator has many advantages in that it is easy to set up and consistent in performance.

Attention is drawn to Mortley's paper on this system, which was read before the Institution of Electrical Engineers.[2]

TELEVISION TRANSMITTERS

The development of television transmitters, which started seriously in 1936 when the first transmitter for continuous public service was installed at Alexandra Palace, has followed in a curious manner the development phases of sound transmitters some twenty years earlier. In the design of the earliest television transmitters, small attention could be paid to power consumption, all efforts being concentrated on the production of high definition pictures and high reliability.

This aim was achieved, but in latter years efforts have been made to improve efficiency and to simplify circuit design with a view to assisting fault finding and maintenance. In the earlier transmitters, the modulators were rather inefficient devices from the point of view of power consumption and an important step was the development by Cooper of the Marconi shunt-regulated amplifier,[3] which is a great improvement on the basic cathode follower principle and which has resulted in a significant reduction of power consumption and in the size and number of valves required for a given video signal output. The parallel operation of television transmitters, to ensure uninterrupted working, has been found to be successful and a number of such transmitter arrangements has been installed in stations in the U.K and overseas.

Work continues in the Marconi Laboratories on the development of new television circuits, both on the RF and video side. This work is aimed at simplifying the adjustment of these circuits, the reduction of the number of components used and improvement in power consumption.

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3 V. J. Cooper: Shunt Regulated Amplifiers. *Wireless Eng.* (May 1957).