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WFLD—THE SELECTION OF PARALLELED U.H.F TRANSMITTERS

THIS is a description of the transmitting plant, just one of the many facets involved in the planning and construction of WFLD. Very seldom does an engineering department have the enviable opportunity to plan and construct a television station from its inception without being influenced by existing or past practices. Our engineering department has the proud reputation, in the broadcasting industry, of being hardware buyers, i.e they are not bound to any single manufacturer but range worldwide to purchase equipment to meet a specific need and specification.

In January 1966 the Field Communications Corporation decided to begin television broadcasting from Chicago and was granted, by the Federal Communications Commission, channel 32 (578–584 MHz) in the u.h.f spectrum. Due to the fact that this was a first venture into television broadcasting, Field Communication Corporation was not bound to existing or past practices by virtue of owning or operating existing transmitting plants.

The Engineering Department was in the enviable position of being able to review and evaluate existing installations in the U.S, and with the information thus obtained to project what is considered to be a modern up-to-date installation. From 1966 commercial television transmitting plants, both u.h.f or v.h.f, followed a set pattern, with practically all stations starting operations with a single transmitter. In the U.S, the trend in transmitter plant installations dates back to the major inrush of new station construction which started about 1948.

It is interesting to review up to the present time the evolution of a typical installation. At the outset one transmitter was installed representing a minimum capital investment, but if a transmitter failure occurred the station was off the air until the necessary repairs were made. In a commercial operation continuity of service is vital, for off-the-air time means loss of revenue. With the advent of high-power amplifiers the then existing transmitter was used as a driver. One minor advantage was gained in that if the amplifier failed it was possible to bypass it and feed the driver directly to the antenna. This was accomplished through the installation of by-pass switches, commonly referred to as a power cutback system. Since the primary source of major breakdowns, namely the driver transmitter, still was the main problem, virtually no improvement was achieved.

INTERCARRIER SOUND

In the meantime, practically all of the television receiver manufacturers changed over to using intercarrier sound which created a new problem for the broadcaster. Loss of sound carrier would cause an annoying hiss, but announcements still could be made visually on the picture channel while repairs were being made. Loss of picture carrier was much more serious since the sound, as well as the picture, would be lost even though there was no fault in the sound transmitter. The viewer, when faced with a blank screen and no sound, promptly switches to another station.

The first significant improvement was achieved with the installation of a complete stand-by transmitter. In

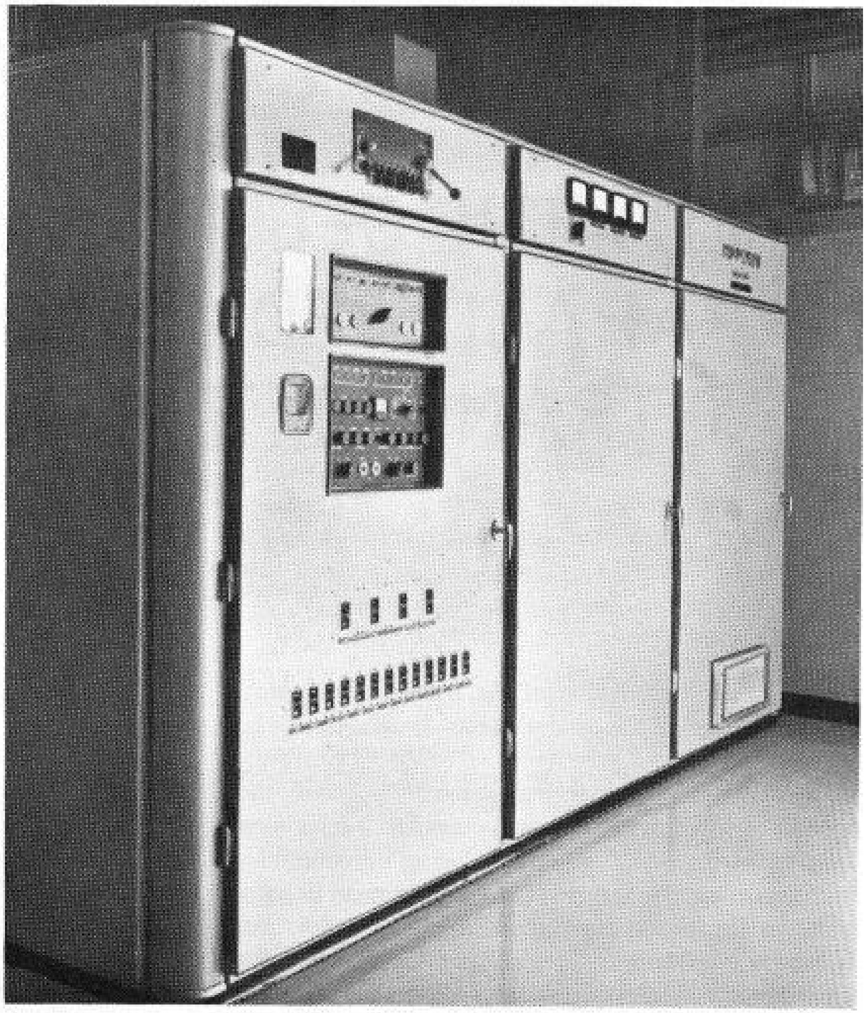

Fig. 1. The final 'A' amplifier. Control and high-voltage circuits are available from this side.

most instances, in older installations, it was the result of updating the plant with a new transmitter and the old original transmitter relegated to a stand-by operation. In others and generally the more recent installations, a stand-by transmitter was installed at the outset, usually at lower power for reasons of economy. In practically all cases the average plant operates one r.f power amplifier. The main and stand-by transmitters are so installed to feed either the power amplifier or the antenna directly, depending on the nature of the emergency. In some installations an emergency antenna is used with a separate feed system that can be switched to all units. This represents the average installation of a transmitting plant in the United States, although there are still many operating with a single transmitter without any stand-by protection.

The main objections that Field Communications had to this type of installation was the stand-by transmitter concept. The stand-by transmitter would only be used for a few minutes each year, but for all practical intents and purposes the filaments must be left on at all times during stand-by periods if it in fact was to serve its purpose. The idea of turning a television transmitter on from a cold start in a matter of minutes is just wishful thinking. Therefore it can be assumed that the operating cost of the stand-by transmitter would be practically the same as if it was actually on the air.

In the opinion of Field Communications engineers the capital investment of the stand-by transmitter, plus its operating and maintenance cost, did not represent a practical solution to the problem, especially when the equipment is to be used for only a few minutes each year.

The objective was to have all the benefits of a stand-by transmitter and at the same time fully to utilize all the equipment. The obvious solution was in the use of paralleled transmitters, a system which had been used for years overseas and had proved a practical solution.

In a paralleled operation the words 'main' and 'stand-by' are now obsolete. Each of the transmitters are half the power of an original 'main' transmitter and both transmitters are in operation at all times. The power output of each transmitter is fed to a power combiner with the power output equal to the sum of the two transmitters. The utilization of the system components is obviously at its maximum.

When comparing the capital investment of a 'main' and 'stand-by' installation with that of a 'parallel' installation, it must be remembered that each of the parallel transmitters is rated at only half the power of the main transmitter. Hence the total cost is not appreciably more.

In a parallel installation complete loss of one transmitter is scarcely noticeable on the average receiver. No loss of aural signal is experienced in the inter-carrier sets, and the decrease in signal strength is, in most cases, compensated by the receiver a.g.c circuits.

RELIABILITY AND REMOTE CONTROL

One of the requirements in the new installation was unattended operation, for the transmitter control point would be located at the main studio, with no one in attendance at the transmitter site. With this in mind it was most important to achieve a high degree of reliability, especially in the case of a u.h.f transmitter. It is rather doubtful that a main and stand-by transmitter plant installation could meet those reliability requirements. It is in fact quite an achievement to be able to switch between transmitters without transmission interruption on the air, using the more conventional installation.

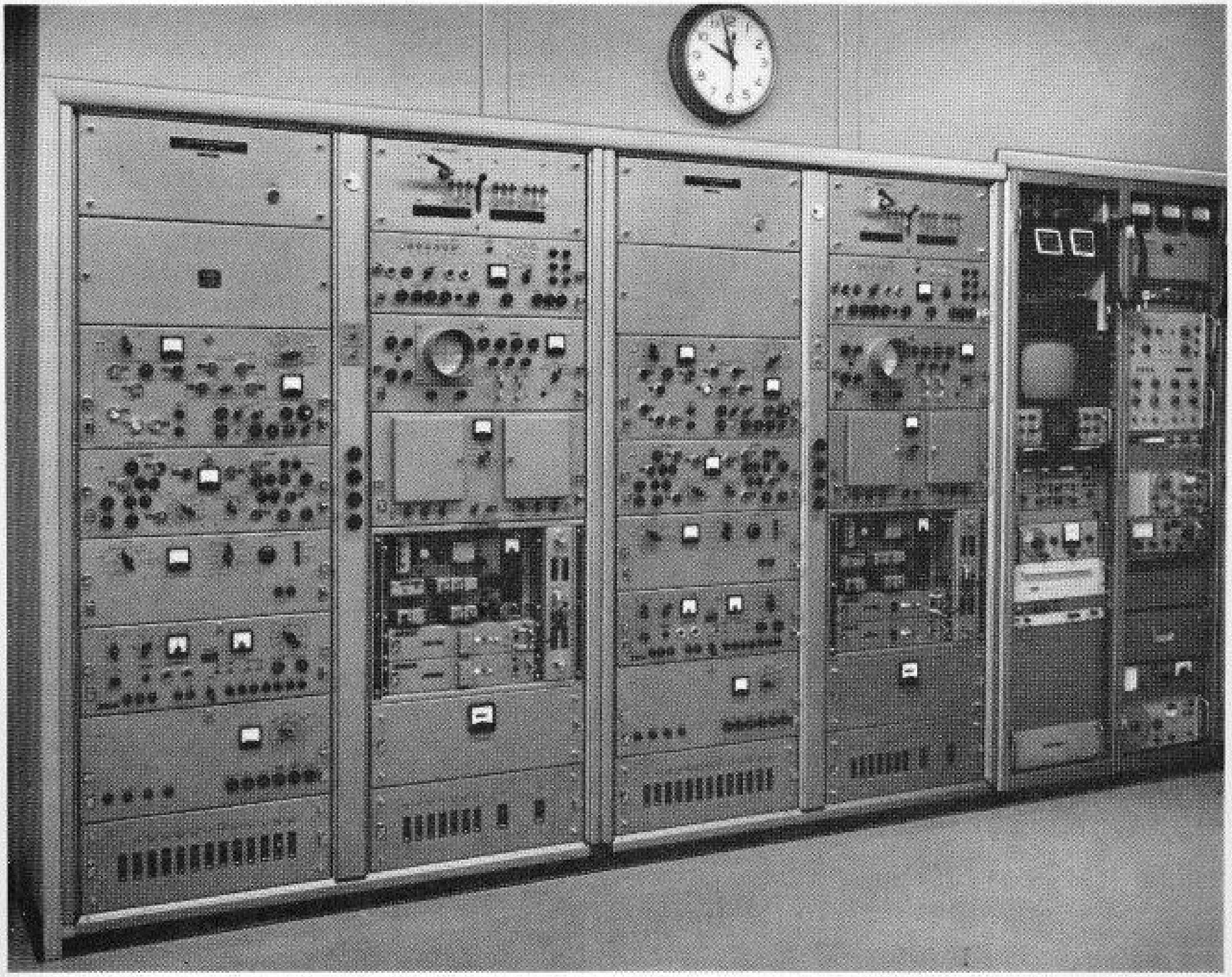

Fig. 2. Drivers and exciters. Monitoring and test equipment is contained in the two racks at the extreme right.

From a practical standpoint the engineers visualized a set of conditions that would occur in the case of a transmitter failure. For example, in the case of unattended operation of a main and stand-by transmitter installation, the engineer on duty at the studio plant would receive an indication that the transmitter is off the air. He would of course recycle the on–off switch. If after a number of attempts he was unable to restore the main transmitter to service, he would activate his remote control switching equipment and use the stand-by transmitter.

In the case of a parallel installation if one of the drivers or final amplifiers fails, the power output of the transmitter would drop 6 dB with no interruption to the transmitted picture. The operator would recycle the on–off switch and if unsuccessful in restoring full power service, would continue operating at reduced power. With the exception of the television audience in a weak signal area no one would have been aware that any transmission difficulty had been encountered. The final step that the operator would take would be to notify the transmitter supervisor that maintenance was required, which can be undertaken, and the down amplifier restored to service, without picture interruption on the air.

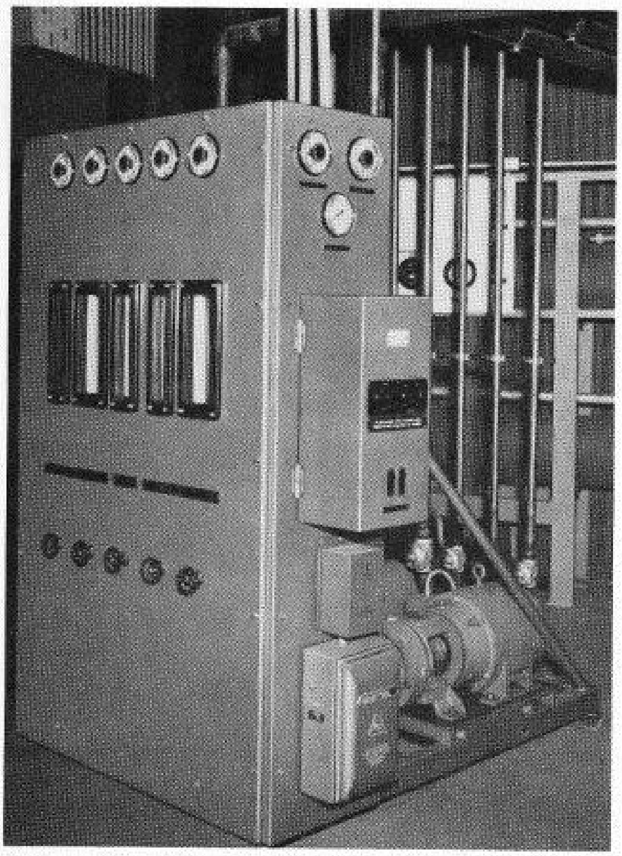

Fig. 3. The 'A' pump unit used to circulate coolant through klystrons and heat exchanger.

The cost of maintaining a television station is dependent on staff requirements and spare parts inventory. Since with parallel transmitters more time is available for emergency repairs, it is not necessary that the operators be both fast and highly proficient technically. With the broadcast day becoming longer each year, a 20-hour day being quite normal, less and less time is becoming available for routine maintenance. It is possible in a parallel transmitter arrangement to shut down one amplifier, on a prearranged basis, for routine maintenance.

EXTERNAL CAVITY KLYSTRON

It was decided at the outset of the planning stage that the practical route to follow, as far as the power amplifiers were concerned, was to choose the klystron tube over the vacuum tetrode. Considerable field experience in the application of the klystron, as a television transmitter power amplifier, was already available and the feasibility and reliability of the device had been established without question. The choice remained between two concepts of klystron design. One was the integral cavity, and the other the external cavity design. In the integral cavity design all tuning cavities are part of the tube structure itself. The advantage of this is that the klystron can be pretuned at the factory for a specific television band, thus eliminating the time required to install the tube in an external cavity and to pretune. The disadvantage in the use of the integral cavity is that a spare tube must come from the manufacturer in case of an emergency, since the tube must be tuned to a specific band. The integral cavity klystron also is designed for a specific use and does not have wide application outside of the u.h.f television service, thus eliminating the possibility of future cost reduction through mass production for other services. The external cavity klystron has the advantage in not being frequency sensitive. It is also used in applications other than television broadcasting and should be readily available from the manufacturer. A spare klystron can be stored, complete in circuit assembly, adjusted for use in the vision transmitter. This would also be suitable for insertion in the sound amplifier if necessary. Based on the above it was decided to go the route of the Eimac Type AKM 100LA/LF/LH. These klystrons are available in three editions in order to cover the range of the u.h.f television channels. The klystron is a four external cavity variety with a high perveance, low-noise gun. It uses electromagnetic focusing and requires both water and forced-air cooling.

Major decisions, arrived at early in the planning process, were that two transmitters would be operated in parallel; second, that the installation would be suitable for unattended operation by remote control; and third, that external cavity klystrons would be employed. These established the basic criteria for transmitter selection.

All available transmitters then being manufactured, both in the U.S and abroad, meeting these requirements were investigated. After careful evaluation it was decided that the transmitter which more than met all of our specifications was the Marconi 25-kW u.h.f transmitter. Two of these operating in parallel would provide a vision output of 50 kW.

One main reason for our choice of the Marconi design was that The Marconi Company had pioneered the technique of paralleling television transmitters, and since 1955 had installed units operating in this manner all over the world. Their vast experience in this field was most impressive.

The 25-kW u.h.f television transmitter has been designed in such a way as to make it entirely suitable for use under parallel conditions. This provides the engineer with the flexibility of beginning with one transmitter and at some future date paralleling a second unit, should the economy dictate this route at the outset. The auxiliary equipment required performs the functions of automatic exciter changeover and also of providing the correct phase relationship at the output of the two power amplifiers. The entire paralleling equipment is installed in the driver unit, apart from the feeder probes and phase comparator units which are used to sense the phase relationship at the output of the controlled amplifiers.

The changeover system employed operates on the output of the vision and sound exciters and avoids the use of moving r.f contacts. Contacts are provided to enable external indicators to be connected to show the state of equipment at any given moment for remote control.

The u.h.f vestigial sideband filter, consisting of two cavities and a ferrite circulator, is connected at the output of the u.h.f drive units. The cavities are tuned, one on vision carrier minus 1·25 MHz and the other at vision carrier minus 1·5 MHz at which frequency they represent a short circuit across the feeder. The reflected power is shunted by the circulator into a terminating load connected to the third port. Sideband filtering at low level has a decided advantage over the conventional method of doing this at the output of the power amplifier in that the equipment involved is significantly smaller in size and lower in power-handling requirements.

Since the shaping of the vestigial sideband is effected at low level, a simple combining unit is required to combine vision and sound at the output of the klystron amplifier.

The basic combining unit consists of two slot-type diplexers connected in a rigid coaxial ring circuit. In each arm of the ring are two cavities, one providing sound rejection, the other rejecting the colour subcarrier in the lower sideband. A load resistor is used to absorb the rejected power of the lower sideband.

The visual driver output power is 10 W peak and each driver transmitter feeds a 25-kW final amplifier to provide a combined visual output of 50 kW. One of the unique features incorporated in this transmitter that has impressed many visiting engineers is the pre-correction control of differential phase and gain. Pre-correction is applied to the video signal in the drive

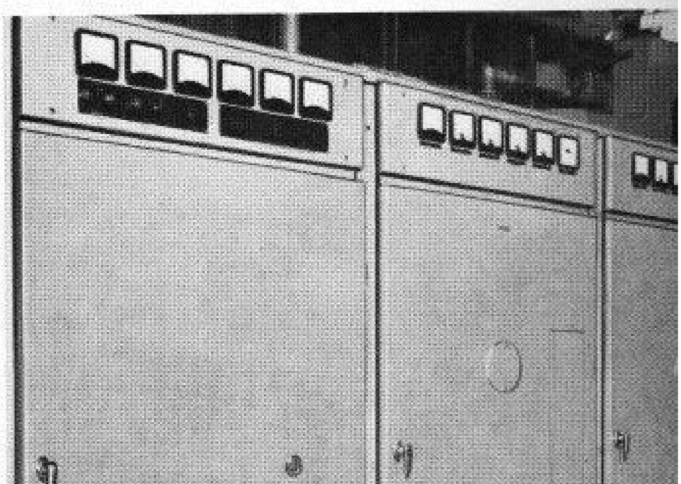

Fig. 4. Klystron tubes are installed in this side of the final 'B' amplifier.

transmitter to correct for distortion of several types inherent in the transmission system. The most important corrections applied are for distortion of group delay, differential phase and differential gain characteristics.

It is essential in any television system that the angular phase delay of the system should increase linearly with increasing video frequency. It is the slope of this relationship which is a measure of group delay. Due to the vestigial sideband transmission characteristics, this linear relationship is inherently distorted. Group delay correction is applied by means of switched all-pass networks, enabling six separate values of group delay to be used to precorrect for transmission distortion. In addition, three more group delays are available that could be used to compensate for typical receiver distortion.

Differential phase distortion is inherent in most klystron amplifiers and occurs when the relative phase of any frequency component varies according to the mean amplitude of the modulating video waveform. The method of applying differential phase correction, which is very easy to adjust, is a Marconi patented circuit. The extreme virtue of the circuit is the independence of each control. As the controls are adjusted in sequence, correction is applied successively to separate parts of the grey scale, until the differential phase over the whole range of amplitude has been corrected, without the necessity of readjusting previous control settings. The frequency response change is less than 0·5 dB at 5·5 MHz and a total correction of about 16° is available.

Differential gain is a measure of h.f linearity of the system. H.F linearity is more essential in colour transmission than in monochrome work, since it must be maintained over a greater amplitude range.

Linearity correction is effected in controlled steps and correction, due to each step, does not exceed 0·5 dB. The method used by Marconi features a three-stage feedback amplifier, with the feedback and gain being progressively modified by switching. Here again the over-riding quality of the correction circuit is operational independence of each control. The adjustment of differential gain throughout the amplitude range of video is achieved by twenty independent controls.

Other notable features include frequency response equalization to correct for high-frequency response of the system and three independent adjustable circuits are provided.

A clamp pulse generator is used to provide continuous clamped pulses of correct amplitude, duration and time, in the presence of 1·5 μsec noise spikes of

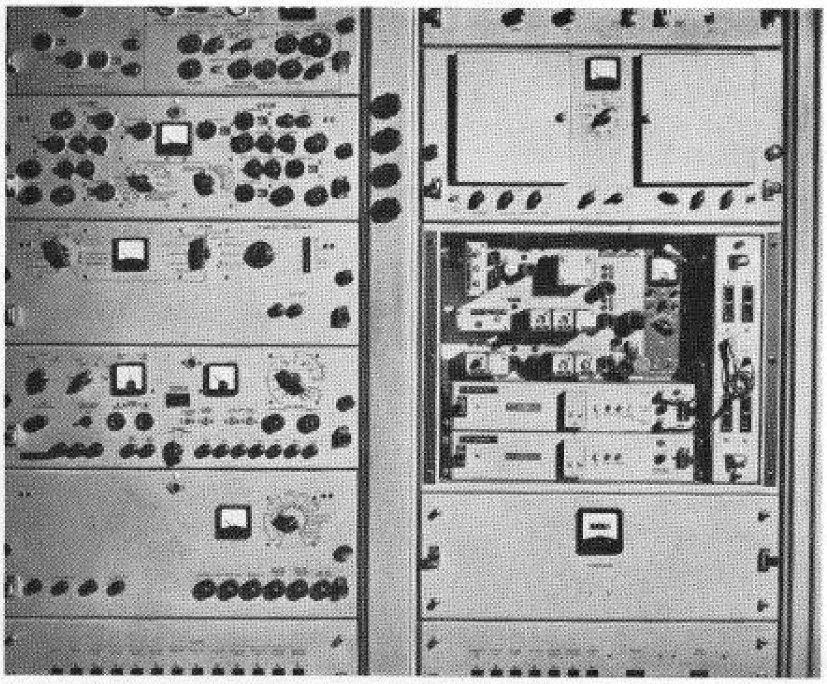

Fig. 5. Sections of the 'B' transmitter containing sound-phasing equipment. Vision phasing is contained in the 'A' transmitter.

either polarity, and equal in amplitude to the sync pulses. Misclamping cannot occur when negative noise spikes appear during the clamping period.

The diode modulator is a Marconi patent. Its basic operation is on the absorption principle, having the following advantages over grid and cathode modulation:

1. Adjustment for the correct operating conditions much simpler than for grid modulation.
2. A high degree of linearity is obtained without critical balancing of r.f voltage in amplitude and phase.
3. The load on the driving stage is constant over the modulation cycle, so that there is no drive regulation problem.

One could continue to describe any number of additional outstanding features incorporated into this transmitter; however, a detailed technical description has been covered in another article.[1] The highlights mentioned here were in fact the important features which influenced our decision.

From a practical viewpoint the power amplifiers, using the Eimac klystrons, are not too different in design from those which can be purchased in the United States. We did, however, purchase the know-how and experience of Marconi in the implementation of parallel operation of transmitters. The most important item, above all else, was the advanced design of the driver units, which stood head and shoulders above any other transmitter we had the opportunity to study.

Last, but not least, our proof of performance measurements have shown that all specifications were met in every aspect with more than ample room to spare.

INSTALLATION

Before final negotiations had been made for the purchase of Marconi transmitting equipment, it was necessary to make some preliminary layout drawings. The layout at WFLD was probably unique in that installation had to be made in a circular building, the space available consisting of an area contained between two concentric circles. One hundred and eighty degrees being allocated for this purpose. The first major problem posed was the length of the equipment. Available photographs showed eight units side by side comprising the transmitter and final amplifier units. The geometry of the available space would not accept such a configuration, especially since it would have to be doubled for a parallel arrangement. Fortunately, rear access was not required to any of the final amplifier cubicles, in fact available literature indicated that the

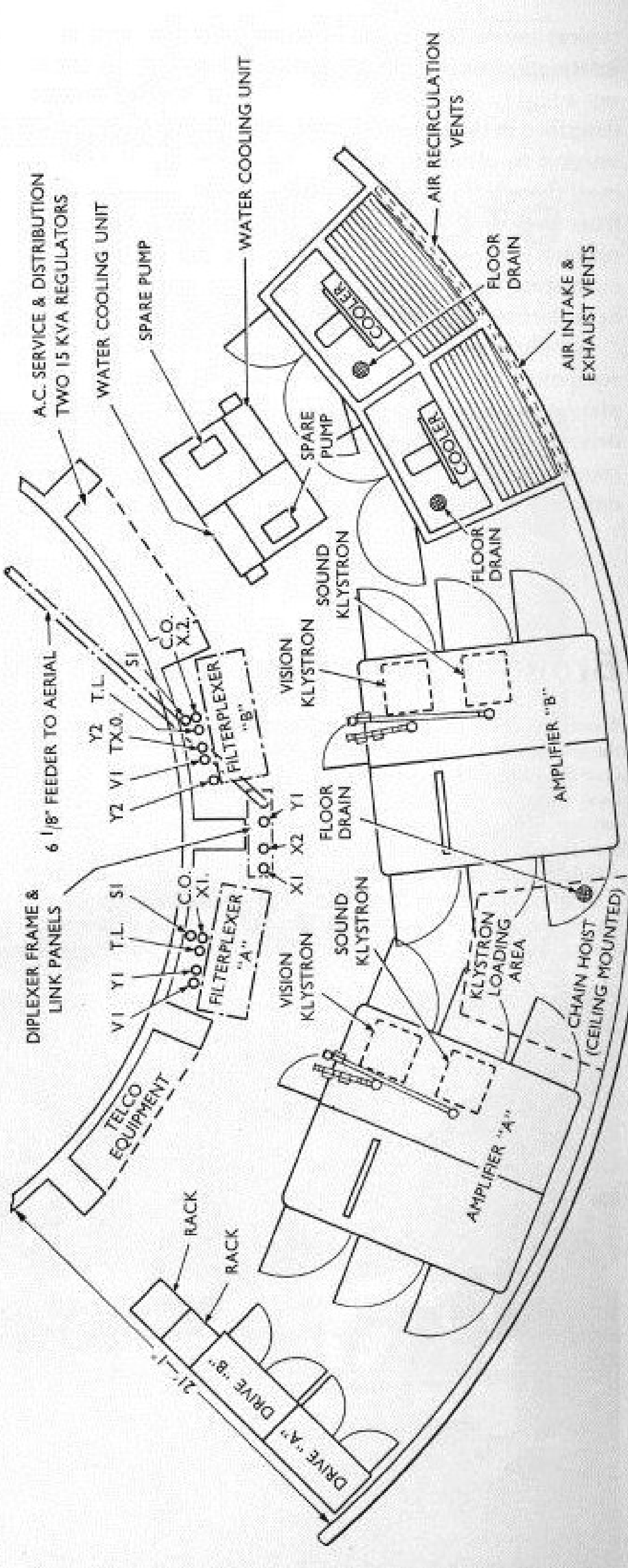

Fig. 6. The station as originally planned. As no rear access is required to the transmitters they were mounted back to back allowing the equipment to be accommodated in a curved building.

typical installation would be against a wall. Using this information to our advantage, we were able to work out a highly satisfactory arrangement which is briefly described in the following paragraph. It may well be of interest to others faced with dimensional restrictions even though those restrictions may vary considerably from our own. The Marconi Company was most co-operative in supplying dimensional information, in evaluating the practicality of our proposed layout, and in proferring additional suggestions.

As illustrated in an accompanying drawing, the equipment arrangement which evolved, features complete separation of the driver and amplifier units. The driver units form the major part of a wall between two rooms. Auxiliary monitoring and test equipment is mounted in two racks adjacent to the driver units. An added benefit derived from this arrangement was the fact that a large part of the transmitter operator's duties can be performed in an area in which the acoustical noise is extremely low as compared with that surrounding the final amplifiers. The amplifiers themselves were 'folded' over, that is to say, the backs of three cubicles were placed directly against the backs of three others, making a single, almost square enclosure for each amplifier. The centre lines of these enclosures coincide with radii of the building structure, so that the coaxial runs to the filterplexers were extremely symmetrical.

REFERENCE

1 J. Sutton: U.H.F Television Transmitters; *Sound and Vision broadcasting*, Vol. 5, No. 1, Spring 1964.