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A COMPACT V.H.F TELEVISION TRANSMITTER

TELEVISION STARTED in areas of large population, the metropolitan areas of Europe and the United States, and the transmitters used were of comparatively high power as, besides the immediate area of the transmitter, the suburban areas around the cities had to be covered. In areas of very high general population such as occur in Great Britain, a system of high-power transmitters will serve a very large portion of the population. As television spreads to other parts of the world, the areas to to be covered in the immediate vicinity of the transmitter become smaller. This is because the cities are smaller or because the population is more concentrated in areas close, for example, to a river, and the distances between centres of population are greater.

The coverage of a television transmitter, as is well known, is limited by the horizon, however great the power, and even fairly close to a transmitter a range of hills will cast a sharp shadow. Intermediate size areas can be covered by transmitters giving an e.r.p of between 10 and 50 kW, but for smaller areas small size transmitters of between 1½ and 5 kW e.r.p give a completely satisfactory service. In flat terrain, with an aerial height of 300 ft (100 metres) above the surrounding country, a transmitter of 3 kW e.r.p will give a range of 10 miles to a Grade A service and 20 or 25 miles to a Grade B service. The Grade A service will deal satisfactorily with an urban area where noise level is high, and the Grade B is quite satisfactory in rural areas where the noise level is low.

We have, therefore, two basic requirements for low-power transmitters. The first, in time, came in the highly developed countries where relatively small areas of poor signal strength between high-power transmitters had to be filled in, and the second comes in countries where the population is less dense and where, perhaps, there are large gaps of open country between the population centres.

The 500-W television transmitter described here is a transmitter which is suitable for providing a service to these two types of area. The figures given for the transmission range will, of course, vary with effective aerial height and can be increased in certain directions where the terrain is suitable by use of directional aerials.

TRANSMITTER OR TRANSLATOR

Where a local area is to be served with local programmes, a conventional transmitter requiring input sound and vision signals can be used, and if a network is available, network signals can be used in addition to local signals. Where a network is not available, but the transmitter, or a site not very far from it, is within range of another major transmitter, a high-quality v.h.f receiver can be used and its output fed by line or by microwave link to the transmitter.

In certain cases, however, where local signals are not required to be transmitted, a more satisfactory arrangement can be obtained by picking up the signals from another television transmitter and "translating" them to another transmission channel. This method avoids the great complexity of the high-quality receiver which is necessary if the quality of the transmitted signal is not to deteriorate. In this case the satellite transmitter must be within range of the main transmitter it is reproducing.

The translator-type station receives the incoming r.f signal and applies it to a mixer in which an intermediate frequency signal is generated. This intermediate frequency signal is then amplified and

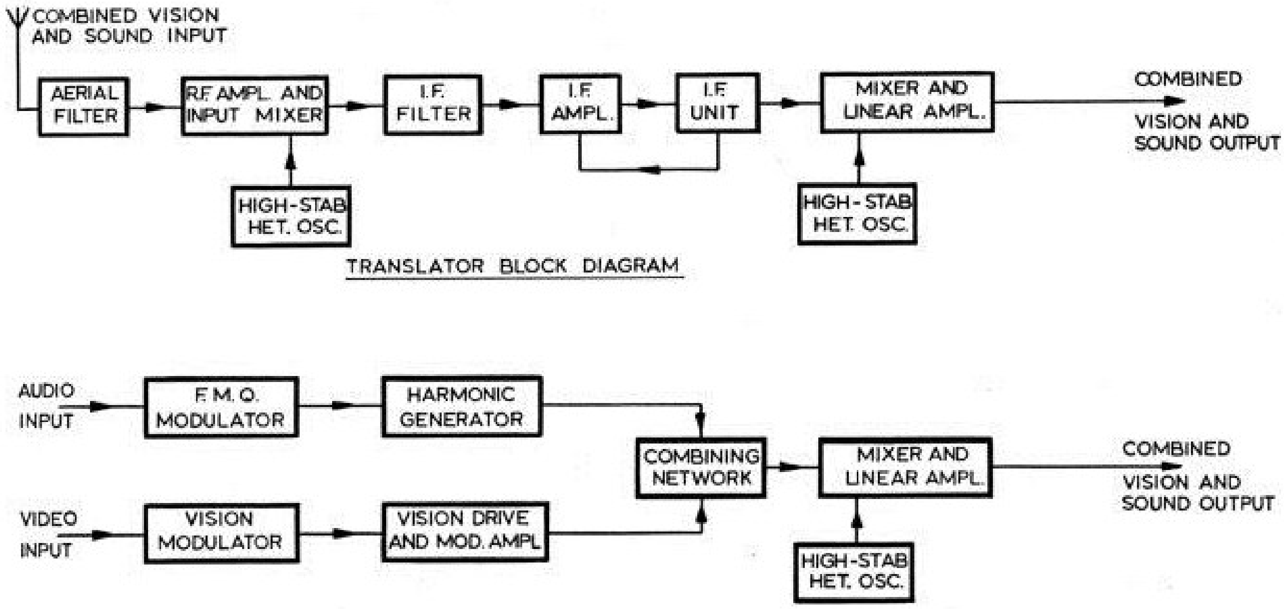

Fig. 1. Transmitter block diagrams.

followed by a further mixer stage which changes the frequency again to that required for transmission, and all that is then required are one or more stages of r.f amplification to bring the signal to the required output level. As has been stated, these translator equipments avoid a number of difficulties associated with systems where the signal is completely demodulated. In designing such a translator, considerable attention has to be given to the design of the two heterodyne oscillators to ensure an acceptable output stability.

CHOICE OF EQUIPMENT

The Marconi Company has developed a range of units from which an equipment to meet individual requirements can be built up to form either a translator or a more conventional transmitter. Block diagrams of the two types are shown in Fig. 1. The translator, by a suitable choice of heterodyne oscillator frequencies, can convert input vision and sound signals from any channel in Band I or Band III to a different channel in either band. Certain frequency conversions have to be avoided; for example, adjacent channels may not be used for reception and transmission due to the difficulty of rejecting the output signal at the input. From the receiving point of view this adjacent channel conversion has to be avoided also, since the receivers themselves may suffer from interference from the main station.

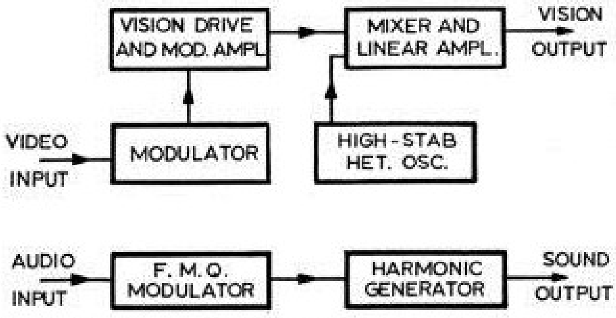

Fig. 2. Simple low-power transmitter with separate vision and sound.

In the transmitter-type equipment, low-power sound and vision transmitters are combined in a simple resistance network to replace the first heterodyne and i.f units of the translator, the vision and sound carrier frequencies being the same as the corresponding intermediate frequencies of the translator. From this point on the signal is processed similarly in both equipments, the combined intermediate frequency output being mixed with a signal of a suitable frequency from the output heterodyne oscillator to give the required radiated frequencies. These vision and sound signals are then amplified linearly to a peak vision level of 3 W. The output sound level is one-half to one-fifth of the peak vision

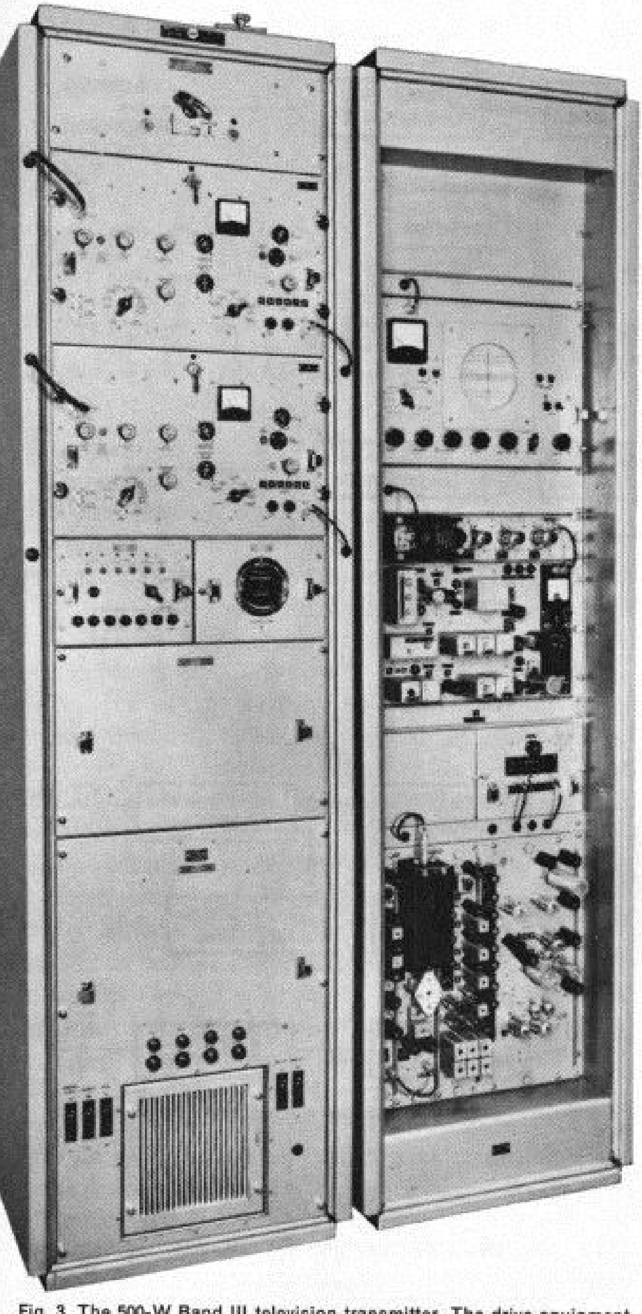

Fig. 3. The 500-W Band III television transmitter. The drive equipment and envelope monitor are in the right-hand cabinet, the amplifier cabinet is on the left.

power, depending on the transmitter standards in use. The peak envelope power varies from about twice to three times the vision peak power as the vision/sound power ratio is decreased from 5:1 to 2:1, i.e. from about 6 W to 9 W, and in order to handle this peak envelope power without excessive non-linearity, it is necessary to have a fairly large output valve. In practice, a QQVO6-40A is used. There is no great disadvantage in this as at these power levels special cooling is not required. In most cases, however, a 3-W vision power level is insufficient and amplification is required. An amplifier with a peak envelope power of up to 150 W has been designed and this is suitable for peak vision power of 50 W, but above this level the advantages of a common vision and sound amplifier are outweighed by the power loss due to the low efficiency.

Separate vision and sound amplifiers allow the economical use of higher radiated powers, but they also require separate vision and sound drives which leads to the arrangement shown in Fig. 2. This is the basis of the Marconi B6400 series of transmitters. In this equipment the vision power at the output of the linear amplifier is not limited to 3 W as the sound signal is separate and a vision peak output equal to the peak envelope power of the previous combined signal, i.e. about 10 W, can be obtained. At the same time the independent sound output can be adjusted to the appropriate level between 2 and 5 W. These signals can be fed directly to an aerial but also are suitable for driving amplifiers. The Marconi Band I amplifier B7100 and the Band III equivalent B7200 have two similar r.f units with common power supplies and control circuits built into a single cabinet. One amplifier is used as a vision amplifier of 500-W output and the other has a sound amplifier set to the appropriate level. These output levels make it possible to introduce feedback control of the radiated blanking level and an r.f envolope monitor to assist in setting up the vision levels. Fig. 3 illustrates a 500-W transmitting equipment combining a B6400 driver and a B7200 amplifier complete with these facilities. The two cubicles are each 7 ft high and $23\frac{1}{4}$ in. wide by 2 ft $4\frac{3}{8}$ in. deep.

A block diagram of the Band III transmitter is shown in Fig. 4. The output from the driving transmitter is more than adequate to drive one amplifier and in fact is sufficient to drive two in parallel. In this parallel version the two 500-W amplifiers are combined with two driving transmitters. The two amplifiers provide a 1-kW vision power and up to 500 W of sound. The two vision drive outputs are connected to the amplifier inputs by a hybrid network, and by means of detectors a drive changeover unit is used to monitor the drive level. Should the level of the drive used fail, the changeover unit selects the other and mutes the one originally in use. A similar arrangement is used in sound. In both cases phase comparators are provided so that the amplifier outputs can be adjusted to be in phase.

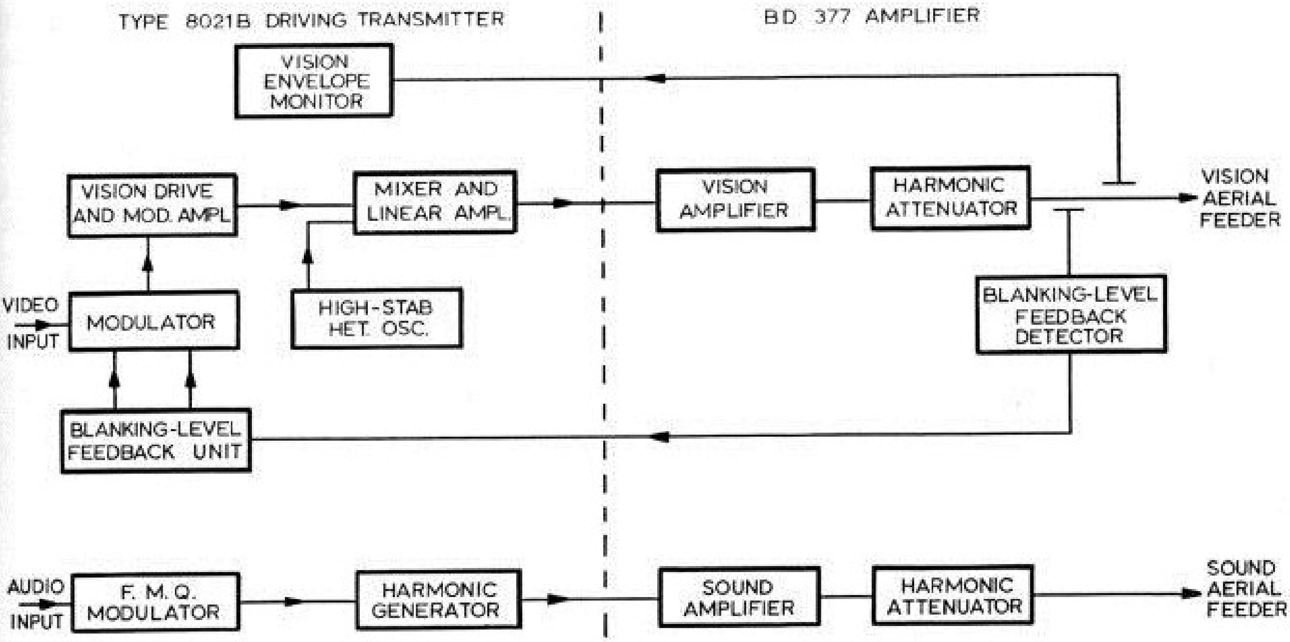

Fig. 4. Type B6400 driving transmitter with BD377 amplifier.

DRIVING TRANSMITTER

The vision and sound sections of the driving transmitter are completely separate and each has its own power supply with separate switching for the heater transformer and h.t. The switching facilities can be either local or from a control desk.

The vision units are illustrated in Fig. 5. At the bottom from right to left are the modulator, the vision drive and modulated amplifier, the mixer and linear amplifier and finally the high-stability heterodyne oscillator. Above these are the blanking-level feedback unit and a blank panel which can be replaced by a drive changeover unit when parallel operation is required. In Fig. 3, we can see the units above which comprise the 'FMQ' modulator, the harmonic generator and the r.f envelope monitor.

The first stage of the vision drive and modulated amplifier is a crystal-controlled oscillator operating at approximately 6 Mc/s: this is one-sixth of the drive output frequency and is independent of the radiated frequency. The radiated frequency is determined by the heterodyne oscillator frequency with which the drive output is mixed. In view of the low frequency of this first oscillator, the frequency stability becomes of secondary importance and temperature control of the crystal is unnecessary. The crystal frequency is multiplied by a tripler and a doubler and then applied to the final drive amplifier. The output of this stage is applied to a grid-modulated amplifier and stabilized by a simple feedback circuit. The anode circuit of this stage is the first section of a 6-stage Darlington filter which provides the required vestigial sideband frequency characteristic. Since the frequency at this point is independent of the radiated frequency, the design of this filter is much simpler than it would be if it had to be made tunable.

The input level to the vision modulator is 1 V peak to peak, and it is used also to generate clamp pulses for the blanking-level feedback unit and for the modulator itself. The modulator incorporates pre-distortion and limiting circuits to compensate for the non-linearity in the r.f amplifiers carrying the modulated signal and to prevent over-modulation due to an excessive input signal. This latter is, of course, particularly important in systems employing inter-carrier sound reception. The unit also incorporates a stage which can be connected either as a cathode follower or as a low-gain phase inverter to permit the use of the same unit for either negative or positive modulation. The output valve of the cathode follower has a clamp acting on its grid, whose potential may be either pre-set or dependent on the amplitude of correction pulses produced by the blanking-level feedback unit. The input of the blanking-level feedback unit is a demodulated sample of the output of the associated 500-W amplifier. Its feedback corrects the reference potential of the clamp to maintain the radiated blanking level constant, and compensates for changes due to variation of mains supply voltage and variation of gain. It also reduces the radiated hum

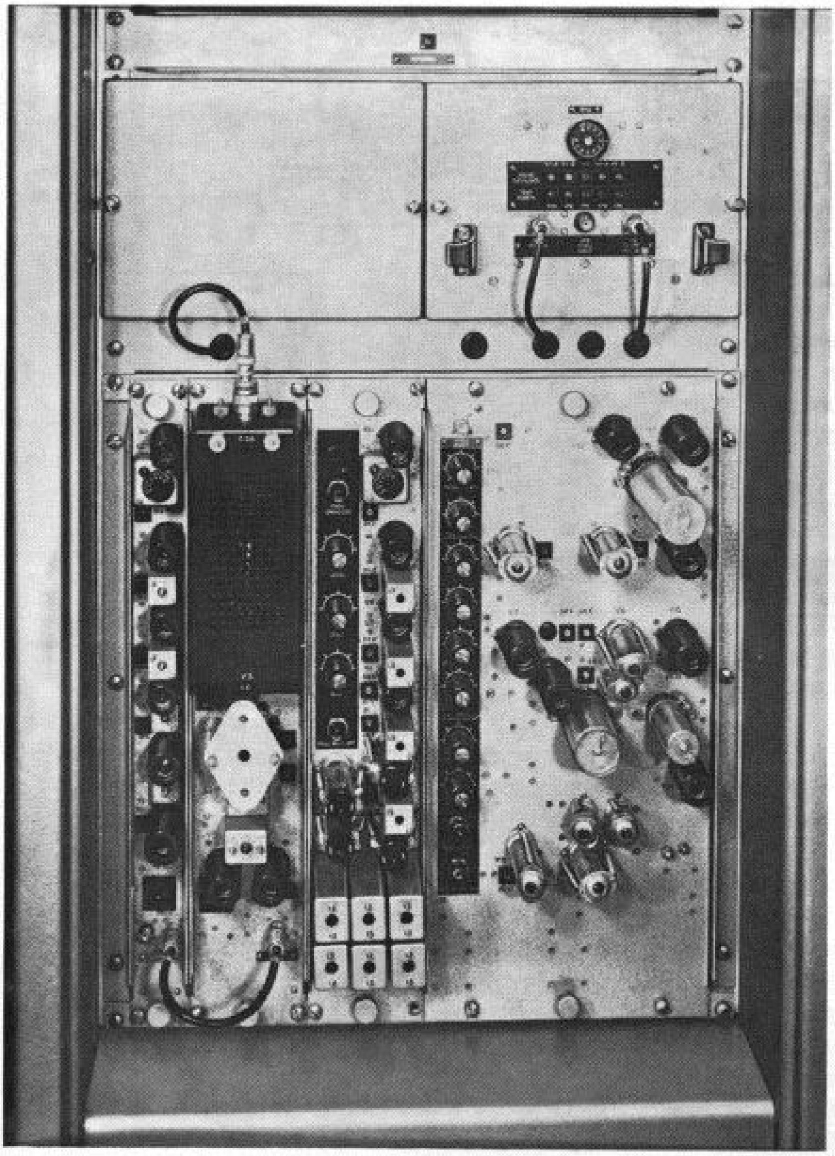

Fig. 5. Vision drive units of the 500-W transmitter.

level, although the performance in this respect is adequate without feedback.

The heterodyne oscillator is that part of the circuit which chiefly determines the radiated frequency and its crystal is housed in a temperature-controlled oven. This provides parallel feeds to the two halves of a balanced mixer in the mixer and linear amplifier, which is also fed from the output of the vision-modulated amplifier in push–pull. The output from the mixer, at radiated frequency, is taken from the anodes in push–pull. This arrangement reduces the level of the heterodyne signal in the anode circuit as well as reducing certain spurious products. Three push–pull broad-band tuned amplifiers follow, operating at radiated frequency, the final output being suitable for terminating in a 50-ohm load.

The 'FMQ' modulator is a standard type such as has been described in *Sound and Vision broadcasting*.[1] The output frequency is in the range of 3·2 to 5 Mc/s and at a level of $\frac{1}{4}$ W. Gain and frequency multiplication are provided by the associated harmonic generator to give an output of 5 W at the radiated frequency.

The 250-V stabilized power supplies for both vision and sound units employ high-efficiency regulating systems which have been described in *The Marconi*

Review.[2] The efficiency is achieved by using a saturable reactor system for the low-frequency components and a Class B amplifier for the higher-frequency elements.

The r.f envelope monitor is self-contained and the feed to the 'Y' plates is from a probe in the output of the 500-W amplifier via a passive tuned circuit, thus ensuring a performance which is independent of the aging of any amplifiers.

THE 500-W AMPLIFIERS

There are two versions of these, one for Band I and one for Band III, which differ only in the type of r.f unit used. The same basic cabinet assembly is used for both and includes power supplies, control unit, blower, air filter and isolator earthing switch. The cabinet will accommodate two similar r.f amplifiers, one for vision and one for sound. These are the second and third units from the top in Fig. 3.

After considering various possible amplifier valves, the 4CX250B, which is very compact and has all-ceramic insulation, was chosen. A pair of them are used in Class AB to give the 500-W sync. output into the aerial feeder without drawing grid current. This ensures a very good linearity as the grid-circuit damping is independent of level. It is possible to drive this pair of valves without intermediate amplification; however, as the equipment may be used with two 500-W amplifiers driven in parallel when considerably less drive is available, a QQVO6-40A pre-amplifier is employed, operating linearly. This again is operated in Class AB without grid current. The r.f input is a double-tuned circuit tuned for a good input match over the channel; the inter-valve circuit is a double, with fixed resistive secondary damping. The output circuit is a maximally flat triple-tuned circuit. The sound r.f circuits are set to a narrower bandwidth than those for the vision amplifier and the amplifiers operated at a higher bias, so as to obtain more efficient working. Input and output r.f connectors are provided on the front panel. The Band I equipment has the output harmonic attenuators mounted on the back panel of the cabinets; in the Band III equipment they are set in the main feeder run and supported from the cabinet roof. In both equipments output monitor points follow the attenuator, the types of probes used being selected according to the requirements of the station.

Each r.f unit mounts it own heater transformer but, apart from this, the vision and sound power supplies are common. All rectifiers use silicon diodes which are fully protected against surge voltages originating in the equipment and against mains-borne high-frequency surges up to 2000 V peak. In each h.t supply, the first smoothing section is common, but separate second sections are used for vision and sound to minimize crosstalk.

The control circuits are more comprehensive than for the driving transmitter because of the nature of the equipment protected, and include an air-pressure switch, a bias-proving relay, a total h.t d.c overload and cathode current overloads for the four main valves. These last are connected to a recycling system which, after a trip, will restore the h.t twice before finally removing the supply. A momentary fault will thus not cause a permanent interruption of service, but is recorded by causing an associated indicating neon to extinguish. Primary protection of all circuits is by miniature circuit breakers of the magnetic-hydraulic type.

Cooling air enters the cabinet through a washable filter on the front and cools the main body of the cabinet before being drawn into the blower. From the blower the air is ducted to the r.f units and is discharged through an aperture in the roof.

PARALLEL OPERATION

Besides the obvious advantage of doubled output power, reliability can be greatly increased by parallel operation. Failure of one amplifier need not close down the service, and one driving transmitter can be in use with the other standing by. There are two distinct problems here: amplifier phasing and automatic drive changeover.

Phasing is easier but probably the more important, as on this depends the effective power increase. Great precision is not required; a phase difference of about 23 degrees corresponds to a loss of output of 0·2 dB, while 50 degrees corresponds approximately to a 1 dB loss. Each amplifier output feeder (see Fig. 6) has a capacitive probe. These are set at equal distances from the aerials and are connected by cables of equal electrical length, thus preserving the relative phases at the probe points, to two phase comparators, one each for vision and sound. The comparators consist of rectifiers arranged to give an output dependent on the vector difference between the two inputs. No difference and zero indication therefore correspond; this is indicated on a meter adjacent to trombone-type phase adjusters, which can be adjusted in length to obtain an in-phase condition at the comparator probes, thus compensating for any difference in phase delay

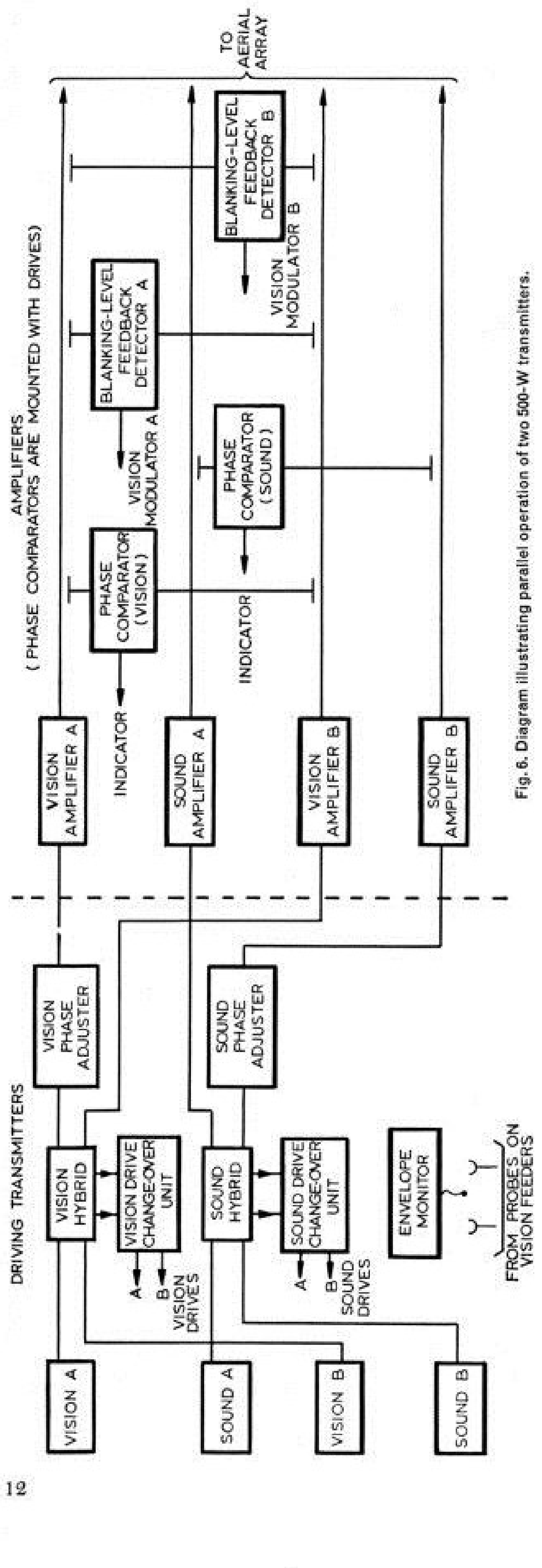

Fig. 6. Diagram illustrating parallel operation of two 500-W transmitters.

between the amplifiers. Once the phasing has been corrected manually it is rarely necessary to adjust it unless the r.f tuning is disturbed. After a brief warm-up period, a pair of transmitters switched on from cold will normally settle to within 5 degrees of their relative phase prior to switching off.

Automatic drive changeover is necessary because of the difficulties which would be associated with synchronizing and phase-locking the oscillators in the two driving transmitters. With the automatic changeover system, one drive is chosen to be preferred, by setting a selector switch. The preferred equipment drives both amplifiers in parallel through the hybrid unit. The changeover unit mutes the drive not preferred by removing the h.t from the vision linear amplifier or the sound harmonic generator. Its output circuit, however, remains connected to the second input port of the hybrid. Each input of the hybrid has an associated monitoring detector, and if the output from the preferred drive falls below a predetermined level, a switching sequence is initiated in which the drives are changed over. As each drive is adequate to drive two amplifiers there is no fall of total output when one drive replaces the other. To provide a check on the performance of each drive, both are operated for a short period at "switch-on". The fact that both have given r.f output at that time is indicated by lamps.

The two drive changeover units are identical relay units into which are plugged the appropriate sound or vision printed-board transistor amplifiers. The sound is the simpler unit; a fall in drive level of a pre-selected amount—generally 2 or 3 dB—initiating the relay-switching action. The vision unit is more complicated in that the picture component of the signal is first removed so that the action is not dependent on picture content. The point of changeover can again be pre-set and depends on the degree below normal to which the sync. level at the hybrid unit falls.

In a parallel system a drive changeover unit is fitted in each drive transmitter cabinet, one for vision and one for sound. The hybrid units, phase comparators and phase adjusters are housed in the second cabinet where the envelope monitor is fitted in the first. The envelope monitor may be connected to either vision amplifier output by coaxial links. All the low-frequency wiring associated with these units is built into every cabinet so that no changes are needed whether one cabinet is used alone or as either of a paralleled pair. This facilitates the addition of any cabinet to another, in parallel. Inter-cabinet low-frequency connections are by simple multi-way plugs and sockets on the cabinet roofs as are the external control and mains connections. A dummy plug permits isolation of two paralleled drive transmitters and allows maintenance to be carried out on one unit while the other continues in operation.

Since the blanking-level feedback unit acts on the final clamp of the vision modulator, it is necessary, when two equipments are paralleled, for whichever modulator is in use to have its clamp controlled by the combined output of the two amplifiers. This is achieved by combining r.f signals from probes on the two vision feeders before detection, the detected output being fed to the blanking-level feedback unit. Because of the complexity of switching a single blanking-level feedback unit from one modulator to the other, two detectors and sets of probes are provided, each permanently connected to its associated modulator and blanking-level feedback unit. The range of action of the blanking-level feedback is deliberately restricted so that failure of one amplifier does not result in excessive over-driving of the other.

INSTALLATION

In the preceding section, the simplicity of the plug-and-socket connections for supply, control and paralleling has been mentioned. The video input cables and the r.f connections between the cabinets also enter overhead through thick flexible pads which permit them, complete with terminating plugs, to be connected direct to their corresponding units without the need for a break at the skin of the cabinet. The r.f output from the amplifiers is taken from the feeder-monitoring sections again at high level. No air ducting is needed for the amplifiers, and this, together with the overhead wiring, means that the installation of this equipment is simple and rapid.

REFERENCES

1 J. A. Brisbane: High Stability F.M.Q Drive; *Sound and Vision broadcasting*, Vol. 3, No. 1, Spring 1962.

2 A. N. Heightman: New Methods of Regulation for Stabilised Power Supplies; *The Marconi Review*, Vol. xxi, No. 130, 3rd quarter 1959.