P. W. JINKINGS, B.Sc (Eng.), A.M.I.E.E

NEW 5kW AND 1kW F.M BROADCAST TRANSMITTERS

DURING RECENT YEARS there has been a trend for national broadcasting networks to transfer their services to v.h.f channels because of the constantly increasing level of interference on the traditional medium wavebands.

This move, allied to the change from an amplitude modulated system (a.m) to one using frequency modulation (f.m) has led to a number of advantages beyond the original one of obtaining interference-free transmissions. Probably the most important of these is the ability to achieve the high-quality standards set by discerning listeners, the number of whom has increased with the availability of really high-fidelity receiving equipment all over the world at reasonable prices. Lower-power transmitters can be used as a result of the high effective power gains available from aerials at the frequencies used, and although the service areas are limited by the propagation characteristics at v.h.f, the stations can be located at centres of population without the dispersion of radiation over lightly or unpopulated areas which occurs with long-range medium-frequency stations. The simplification which results from the use of low-power transmitters, without the need for complicated cooling and power distribution systems, means that the number of maintenance periods can be drastically reduced to such an extent that unattended operation is a real possibility. Operating costs are thus reduced and stations can be sited in the most favourable positions in the service area, since access becomes of only secondary importance.[1]

In order to exploit the above advantages to the full, it is necessary to consider every aspect of the transmitter design, both electrical and mechanical, with these points in mind.

To summarize, the requirements for equipment operating this class of service are:

1. Power output tailored to the requirements of the majority of stations without a multiplicity of separate designs.
2. High standard of performance with regard to audio fidelity and frequency stability.
3. The utmost reliability in service over long periods.
4. Simple mechanical construction to facilitate maintenance and servicing, together with ease of installation.
5. Low cost.

POWER OUTPUT REQUIREMENTS

In 1952 a C.C.I.R Conference in Stockholm produced a plan allocating the effective radiated powers and frequencies for all European frequency-modulated broadcasting stations for frequencies between 87·5 Mc/s and 108 Mc/s (Band II). A further conference in Stockholm in 1961 reviewed and extended this plan. As these plans are based on fundamental principles they are applicable throughout the world.

An examination of these plans, together with the knowledge of the practical power gains which could be achieved from aerials, suggested that the majority of requirements could be achieved with only two transmitter powers, without recourse to unrealistic demands on the aerial designer. These powers were 5 kW and 1 kW, but in some cases double these powers would be needed. It was felt that to meet these latter requirements a parallel arrangement of transmitters would be the most economical solution, rather than separate transmitter designs.

Subsequent development of v.h.f broadcasting, not only in Europe, but in all parts of the world, has shown the wisdom of this policy, reflected in the sale of a large number of transmitters of the two powers decided upon. In view of this success it was decided to design new transmitters to replace the well-proven BD321 and BD322 transmitters, but incorporating the latest advances in design philosophy which had evolved since the appearance of the earlier equipments in 1955 and 1956. The new 5-kW transmitter is the type BD330 and the 1-kW the type BD329.

TRANSMITTER PERFORMANCE

In a frequency-modulated transmitter the performance in regard to audio frequency fidelity and carrier stability is determined solely by the drive and the means used to modulate the carrier frequency. The Frequency Modulated Quartz (F.M.Q) system developed by the Marconi Company in 1947 has proved to be ideal for this application, and advantage was taken during the design of new transmitters to produce a drive based on this principle, which has proven itself so well in service under all operating environments.

This new drive[2] was required to give an extended modulation frequency range with reduced distortion, and emphasis on the long-term constancy of performance and stability of the final radiated frequency. In addition the setting-up procedure was to be simplified and the mechanical design modified to be compatible with that of the projected transmitters.

In the F.M.Q system, a quartz crystal is maintained in oscillation in its highly stable series resonant mode at about 4 Mc/s. The low impedance presented by this mode is transformed to a high value by means of a quarter-wave network. A variable susceptance, connected in parallel with this high impedance, gives a linear variation of frequency of oscillation of the crystal with susceptance. Special crystals are used which are free of spurious resonance on either side of the resonant frequency, and which have the low temperature co-efficient necessary for high stability over a wide range of ambient temperatures.

The variable susceptance is obtained by means of a balanced modulator (Fig. 2) to the parallel input of which the output of the crystal oscillator is fed, while the modulating a.f signal feeds the push–pull input. With no audio input the output of the modulator is zero. Application of the modulating signal results in a double-sideband zero carrier output which is first retarded by 90° and then applied to the grid

Fig. 1. The 1kW f.m Transmitter, BD329. The right-hand picture shows the F.M.Q drive removed.

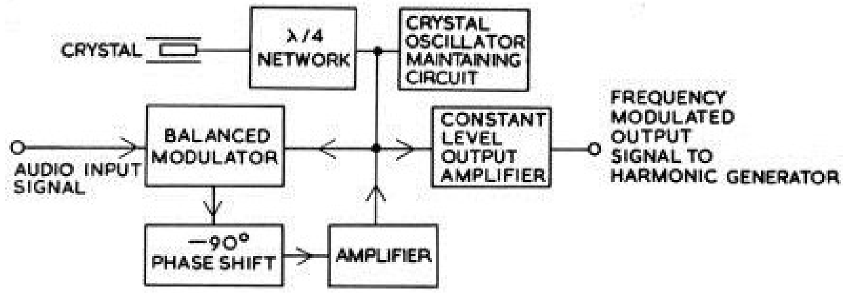

Fig. 2. Simplified block schematic diagram of FMQ modulator.

of a current amplifying stage. The amplified current is drawn from the frequency-determining circuits of the oscillator and, being 90° out of phase with the voltage existing at this point, constitutes a reactive load, thereby causing the frequency of oscillation to vary in sympathy with the modulating signal.

The linearity of modulation is determined mainly by the balanced modulator linearity and by maintaining a sufficiently large constant amplitude of the r.f signal relative to the modulating signal. Centre frequency stability is determined by the balance of the modulator and by its being maintained under all conditions of environment. It is in the design of this modulator that the improved performance of the new version of the F.M.Q drive is principally achieved.

The 4 Mc/s output from the F.M.Q modulator is passed to a harmonic generator unit to produce the final radiated frequency at a level of 10 W.

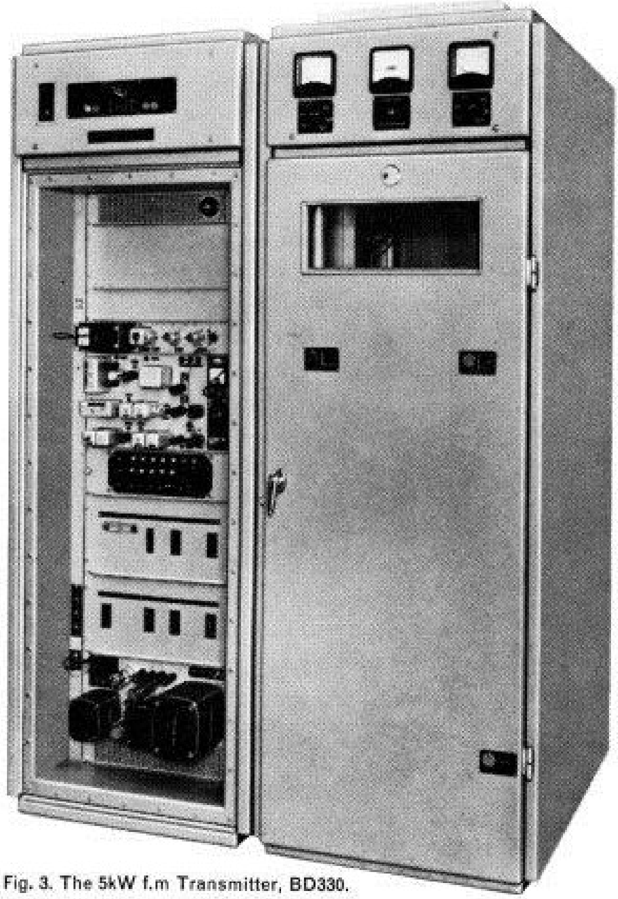

Fig. 3. The 5kW f.m Transmitter, BD330.

RELIABILITY

Experience has shown that one of the most common causes of breakdown in transmitters is the failure of rectifier valves, both high-vacuum and gas-filled. With the advent of semi-conductor diodes, with their high inherent reliability, it was decided to consider their application to transmitters generally.[3] The main difficulty was their susceptibility to breakdown when subjected to high transient voltages of even short duration of the order of microseconds. These transients can occur in several ways, such as surges on the mains supply due to switching of other equipment or system switching. Similar transients may also be set up in the equipment concerned due to commutation of the rectifiers or load switching. These transients have, in the past, led to reports of short lives of semi-conductor devices, and it was felt that if they could be eliminated completely the long potential lives of semi-conductors would be obtained. An intensive investigation to this end was instigated, involving many hours of life testing, together with injected transients, and short-circuit testing. This resulted in the design of surge suppression circuits tailored to the transformer and circuits used in any particular application.

For high tension supplies, the voltage required is in excess of that of the individual diode rating and hence a series chain is necessary. To provide an even distribution of voltage across the diodes under all working conditions, a.c, d.c and transient, a capacitor and resistance are required to be fitted across individual diodes. The value of the capacitance will depend upon the number of diodes in series, the capacitance to earth of any diode and the phenomenon of hole storage. The value of the resistor depends upon the worst leakage current any production diode can possess. An advantage of the series string of diodes is that it provides a measure of redundancy that enables the assembly to continue to function satisfactorily even in the event of a number of diodes developing a short-circuit condition.

The results of these investigations have been applied to the new f.m transmitters, and the success of this may be judged from the field results obtained with the thirty 1-kW transmitters in service with one large administration. Each transmitter has 100 diodes and operates for an average of 5,000 hours per year. During the 2½ years these equipments have been in service only two diode failures have been reported.

Reliability in unattended operation is further increased by ensuring that in the event of a mains failure not exceeding 3 seconds, the transmitter will restart immediately without waiting for the delays involved during the sequence starting procedure. For longer mains interruptions the transmitters will restart automatically in about 30 seconds. Short-term interruption of supply may be quite common on the more remote sites fed by long overhead feeders, due to circuit-breaker reclosing after lightning strikes or during system switching.

While full overload protection is provided, transient faults, due to possible flashovers, etc., trip the transmitters, but circuitry is provided to restore the power automatically. Only if the fault persists, and after three restorations is the transmitter shut down.

It is a known fact that fuses have a finite life even when not subjected to overloads, and also their fault clearing time is neither consistent nor repeatable. In view of this it was decided to replace them in all a.c distribution circuits with miniature circuit breakers, which give accurate discrimination and graded inverse time characteristics to suit the circuits being protected.

TRANSLATOR OPERATION

In the case of the 1-kW equipment, it is possible to replace the F.M.Q drive with a 10-W translator to enable it to operate as a high power translator. This facility was considered desirable to meet those 'gap-filling' cases where a rather higher power than usual for this class of service was needed. An example is the service to a mountainous district where a relatively large area is screened from the radiation of a master station, or where local programme sources are not available.

PARALLEL OPERATION[4]

Reference has already been made to the need for powers of 2 and 10 kW in certain cases under the Stockholm Plan, but a considerable increase in reliability may be achieved, particularly at unattended sites, by fitting transmitters as parallel pairs, even when the extra power is not essential. In these cases the extra initial cost can be offset by reducing the aerial gain. Thus it was considered to be a requirement, when the designs were being formulated, that the standard transmitters should be readily converted to parallel operation when required.

The improvement in reliability can only be achieved if, in the event of failure of either one transmitter or

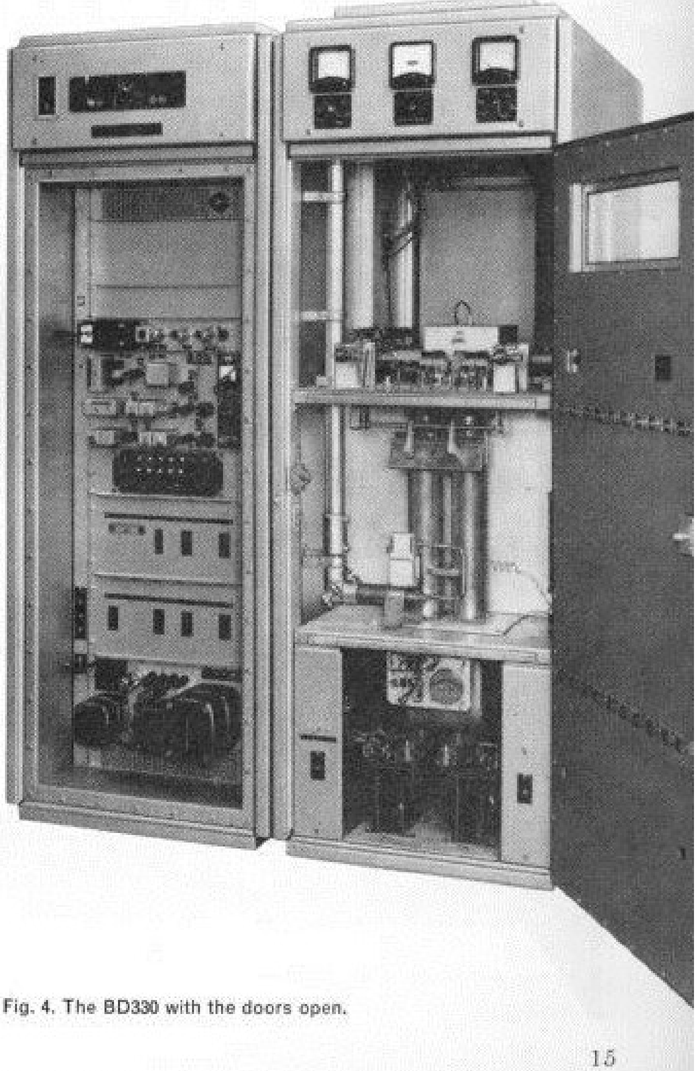

Fig. 4. The BD330 with the doors open.

drive, the remaining unit can operate singly, and the changeover can take place automatically without loss of programme.

Each transmitter is fitted with a drive unit, but only one of these is selected to be the working drive. The output of this is split, by a hybrid unit, to feed each transmitter. In the event of the failure of this drive, detected as a loss of level, automatic circuits switch the other drive to the hybrid and disconnect the faulty input.

The output of the transmitters may either be passed to an aerial array via a combining unit, or, for better reliability, fed by individual feeders to separate halves of the array. In either case, the failure of one transmitter results in a loss of 6 dB at the receiver. This can be reduced to 3 dB by switching the working transmitter directly to the whole aerial, but this is not normally considered to be worth while, especially in view of the complication involved if this is to be automatic.

To maintain the outputs of the transmitters in phase, the co-axial cables connecting the input hybrid to each transmitter are cut to exactly equal lengths, and fine adjustment is obtained by means of the tuning control of the transmitter penultimate stage. Phase indication is given by means of a phase comparator, which compares the phases of the voltages on the output feeders of the transmitters, and indicates a null on a meter when these are exactly in phase. The high differential phase stability of the transmitter ensures that once the phasing operation has been carried out, it will be maintained over long periods of unattended use.

All the additional equipment required for paralleling is mounted in the cabinet of one transmitter. All transmitters are drilled to take this equipment and the wiring is fitted in such a way that any single transmitter installation can be simply converted to parallel operation on site.

HARMONIC SUPPRESSION

Since f.m transmitters operate in a band which is harmonically related to the Band III television channels, and can be sited in a service area shared with one of these channels, it is important that the

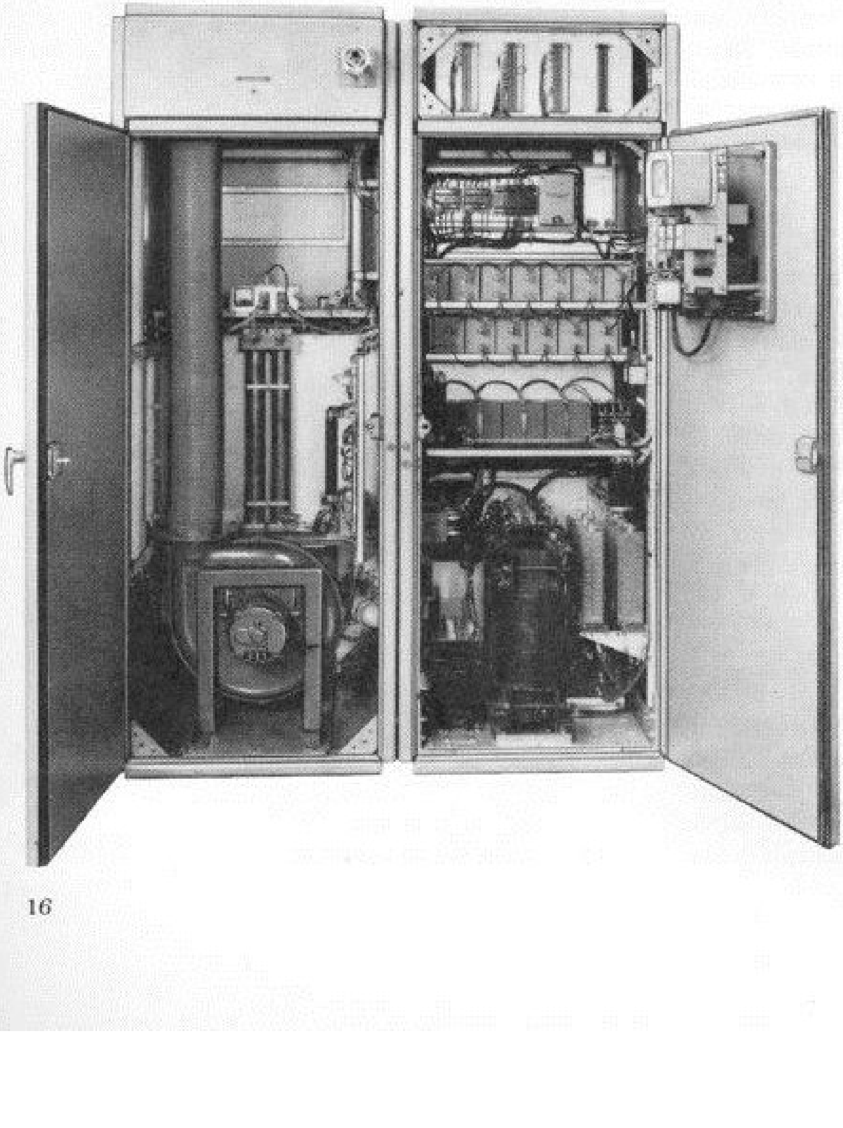

Fig. 5.
The BD330 from the rear with the doors open.

harmonic radiation be reduced to a minimum. This can be radiated either directly from the transmitter circuits or via the feeder from the aerial. The first case is minimized by mounting in carefully bonded metal cabinets to give good screening, and the latter by means of a co-axial harmonic filter mounted as an integral part of the transmitter.

The harmonic filter has a constant diameter outer conductor of the same size as the associated 2-in. feeder and a stiff inner conductor consisting of a silver-plated assembly of cylinders joined by solid rods. This arrangement functions as a low pass filter in which the lengths of rod in the inner assembly act as series inductive sections of high impedance and the cylinders act as shunt capacitive sections. The positioning of the cylinders is so arranged that the reflections caused by the discontinuities cancel out at the pass-band frequencies. At harmonic frequencies, however, the reflections do not cancel out and therefore the harmonics are subjected to an attenuation of between 30 and 40 dB. This attenuation, together with the inherent attenuation in the transmitter, results in a harmonic output of the order of 70 dB below the fundamental level.

Having discussed the technical aspects relevant to the electrical design of both the 1-kW and 5-kW equipment, the practical interpretation is best considered by reference to the individual transmitters. The accompanying photographs illustrate the salient points of these in conjunction with the following text.

5-kW F.M TRANSMITTER TYPE BD330

The transmitter is housed in two cabinets, one containing the F.M.Q drive, power supplies and control circuit while the other houses the r.f circuit and cooling blower.

The r.f circuits consist of a two-stage amplifier, each stage employing tetrodes in push–pull. The frequency-determining circuit, with the exception of the first-stage grid, consists of low Z_0 quarter-wave lines, the lengths of which can be adjusted by movable short-circuiting straps at the low-potential ends. These give pre-set coarse adjustment of frequency, while fine adjustment is made by capacitance tuning.

This arrangement gives rise to the minimum of moving parts, all other assembly being only of sheet-metal thus keeping the cost of these equipments at a very economic level .

When operated in parallel, the drive changeover unit and input hybrid mount above the harmonic generator unit of the F.M.Q drive in one of the pair of transmitters.

Operation as a Television Sound Transmitter

The previous description has been of an f.m sound broadcasting transmitter operating in Band II, but the factors which have influenced its design are also appropriate to television sound transmitters. The same basic transmitter can be made suitable for operation in either Band I or Band III by changing the appropriate frequency-determining elements. The mechanical arrangement of the basic equipment is such that these elements can be fitted in the cabinet on the same fixings.

When working on Band III, the F.M.Q harmonic generator has an output in Band I and an additional frequency tripler unit succeeds it. The Band I transmitter is type BD332 while the Band III version is type BD333.

1-kW F.M TRANSMITTER TYPE BD329

In this case the transmitter is mounted in one cabinet with all the r.f circuits in a withdrawable unit at the top. Below this is mounted either the F.M.Q drive or the 10-W translator unit, type BD328. The remainder of the cabinet contains the power supplies and control circuits.

The r.f unit contains a two-stage amplifier consisting of a double tetrode driving two radiation-cooled tetrodes in push–pull. Again the frequency-determining circuits consist of quarter-wave lines.

Adequate cooling is provided by a small blower, the air from which scavenges the r.f unit.

CONCLUSION

It will be seen that both the 5-kW and 1-kW transmitters have been designed to exploit the necessary features outlined in the introduction to this article.

Both are simple to install in the sometimes inhospitable and inaccessible sites made necessary by the requirements of obtaining the optimum service area. For transport, the component parts can be broken down into readily handled loads, and no special underfloor ducts or external services of any kind are needed apart from a mains supply and aerial system.

REFERENCES

1 B. Bjerkmann: The Development of Broadcasting in Norway; *Sound & Vision broadcasting*, Vol. 1, No. 2, Summer 1960.

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

3 B. E. Fox: High Tension Rectifiers for High Power Transmitters; *Point to Point Telecommunications*, Vol. 7, No. 2, February 1963.

4 W. J. Morcom: The Operation of Transmitters in Parallel; *Sound & Vision broadcasting*, Vol. 2, No. 1, Spring 1961.