A new generation of medium-power TV transmitters

L. F. Howard

Summary The B7442 and B7445 UHF Television Transmitters are among the first of a new generation of transmitters designed to take advantage of recent advances in circuit integration techniques and high-efficiency thermionic amplifiers.

The extensive use of broadband circuits at i.f and r.f, coupled with a single edition u.h.f klystron amplifier, has resulted in a transmitter design in which only three submodules in the transmitter system change with operating channel.

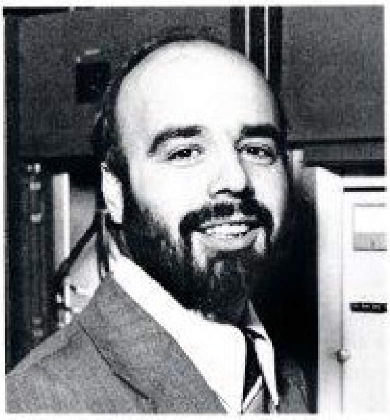
The concept of modular design has been adopted throughout both the transmitter and transmitter system. For ease of maintenance, any module within the transmitter may either be replaced by a pre-aligned spare, or be maintained/repaired *in situ*.

The transmitters have been designed to be compact and fully self-contained to minimize installation requirements. An external heat exchanger/blower module completes the transmitter installation requirements.

The Independent Broadcasting Authority (IBA) has ordered a number of the 15kW and 4·5kW versions of these transmitters for use with the United Kingdom's fourth television channel which is scheduled to open in 1982.

L. F. Howard
Len Howard joined the Marconi Broadcast Division, Television Transmitter Development Group in 1965 and was responsible for a variety of u.h.f television transmitter and systems designs until 1974 when he was appointed Section Leader in the development group responsible for the design of the B6124, 300kW H.F Broadcast Transmitter. He rejoined the TV Transmitter Group in 1976 for the development of the B7400 Television Drive equipment.

In October 1979, he was appointed to his present post of Group Leader, TV Transmitters.



Introduction

The authorization granted to the IBA to commission and install the transmitters for the fourth United Kingdom television programme came at a time when recent advances in circuit integration and thermionic r.f amplifier operating efficiency had rendered many previous television transmitter designs obsolete. A new generation of Marconi medium power u.h.f transmitters being designed to incorporate the advanced techniques available was extended to include transmitters designed specifically to meet the IBA requirements for main station (parallel operation) and passive reserve (main with passive standby) at a wide range of powers and frequencies in the u.h.f broadcast spectrum.

Design concepts

The requirements for the transmitters were first examined from the operator's viewpoint and five fundamental requirements were formulated.
(1) The equipment should be compact and designed for ease of installation;
(2) it should maintain quality of performance for long periods of unattended operation;
(3) it must be reliable;
(4) it should be easy to maintain;
(5) it should operate at the highest possible efficiency.

Within these guidelines it was possible to define some more specific design requirements which can be stated briefly under a further four headings.

(1) Maximum use to be made of state-of-the art technology within the drive and transmitter control areas.

(2) Where solid-state amplifiers were to be employed these should be of a broadband u.h.f design operating comfortably within the limits of present day solid-state amplifier technology.

(3) The final stage thermionic amplifier was to be chosen on the basis of a modern design incorporating the latest design advances and offering high orders of reliability and efficiency.

(4) In order to satisfy the ease-of-maintenance requirements, a modular design concept was to be adopted throughout the transmitter system. The electrical and mechanical boundaries of the modules were to be defined such that each module would be designed to perform a discrete function and be convenient to test and pre-align outside the transmitter. An additional requirement was that in the event of module failure, the minimum of system adjustment should be necessary when a pre-aligned replacement was installed.

The benefits for the operator which accrue from this design approach are:
i) that the transmitter down-time may be minimized,
ii) that many of the modules are common to all the transmitters, regardless of power of operating channel, thereby reducing spares holding requirements and that the spares modules may be used for operator training or familiarization, this offsetting any lack of familiarity which might otherwise result from unattended operation.

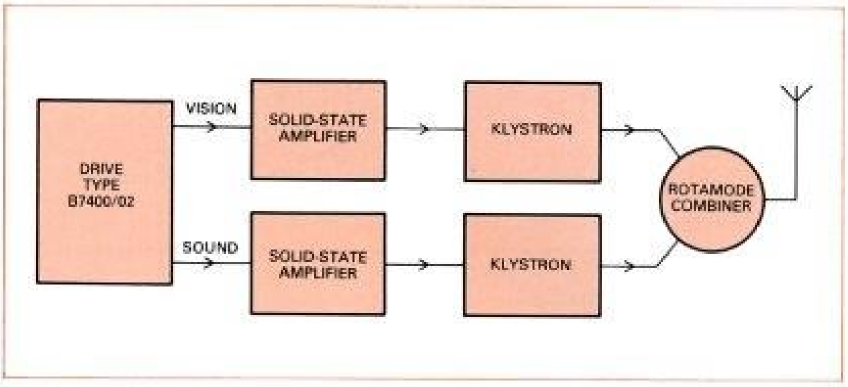


Fig. 1. Block diagram of separate vision and sound transmitter Type B7445

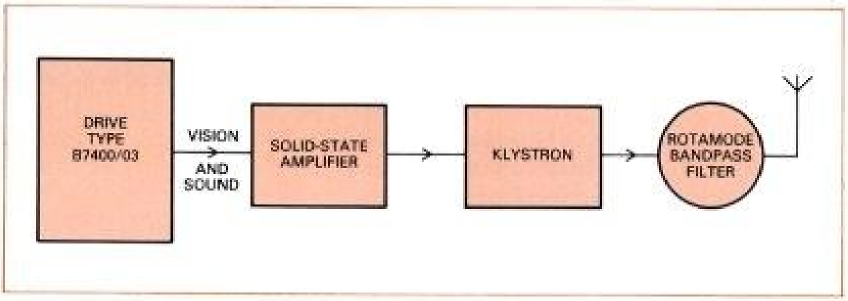


Fig. 2. Block diagram of common-amplifier (vision and sound) transmitter Type B7442

The choice of final r.f power amplifier

The success or failure of any transmitter to meet its design requirements is largely determined at the time the design concept is defined. The choice of the final amplifier to be used is a crucial decision since among other factors, safety and protection circuitry, power supply requirements, control complexity, cooling and intermediate power amplification requirements depend upon the output amplifier selected.

For the transmitter power range under consideration both the tetrode and the klystron are viable alternatives for the output amplifier. With its high efficiency of operation, the tetrode might appear at first glance to be an obvious choice, especially since recent tetrode developments have advanced the power handling capabilities of these devices into what were previously exclusively klystron operating ranges. Further the tetrode-equipped transmitter offers the advantages of higher operating efficiency coupled with the use of a low-cost air cooling system requiring minimal maintenance. The advantages of the tetrode are, however, offset by its relatively low gain, necessitating the use of multiple stages and higher power intermediate amplifiers for the higher power transmitters.

The klystron was therefore selected for the final r.f amplifier on the basis of its proven reliability in television application, as well as its high gain which permits the design of an intermediate power amplifier whose requirements are comfortably within the limits of currently available solid-state devices. The advent of the high efficiency YK1220 klystron, with its compact mechanical assembly and its cooling system flexibility, has enabled the B7442/5 design to maximize the advantages of the klystron amplifier. A fully adjustable h.t power supply enables maximum advantage to be taken of the high efficiency of the YK1220, and the pumpless, vapour-phase cooling system adopted offers a relatively simple-to-maintain alternative to the air cooling system of the tetrode with an equivalent reliability.

The block diagram of the B7445 transmitter (figure 1) reveals the major advantages of the klystron amplifier; the transmitter requires a minimum of 'building blocks', hence complexity is reduced and reliability enhanced. Figure 2 shows, for comparison, the block diagram of the common-amplifier B7442 transmitter. The basic similarities of the transmitters may be clearly seen.

The B7400 i.f modulated drive equipment

The B7442/5 transmitters employ two editions of the u.h.f variant of the B7400 drive equipment.[3] The design concept of the drive, in which system and frequency conscious circuits are separated from those circuits performing basic signal processing, allows the majority of the drive circuits to be common regardless of drive application. By this means the differences between the drive editions used for the separate vision and sound transmitter and the common-amplifier transmitter are confined to two modules of the drive.

Both editions of the drive employ i.f modulation techniques and the precorrection for differential phase, differential gain, i.f linearity, frequency response and phase/frequency response is applied at the intermediate frequency. A surface acoustic wave bandpass filter is employed at i.f to impart the vestigial sideband shaping and to prevent radiation of out-of-band signals.

The separate vision-and-sound edition of the drive employs two identical, but separate r.f circuit configurations for the vision and sound signals. Each circuit comprises a mixer, channel filter and broadband r.f amplifier. In this configuration the drive r.f output signal levels are nominally 0·5W peak sync and 0·5W f.m sound. In its common amplifier configuration the r.f circuitry devoted to the sound signal in the separate vision-and-sound drive is omitted and the remaining r.f circuitry is used for the common, vision plus sound, signal. Additional circuits operating at the sound i.f are provided to enable the radiated vision-to-sound power ratio to be adjusted to either 10:1 or 5:1. Provision is also made for the down-conversion of the detected r.f output of the transmitter for vision and sound metering. Figures 3 and 4 show the block diagrams of the separate sound-and-vision, and common amplifier variants of the B7400 drive.

The drive is designed to permit maintenance and servicing by either module or printed circuit replacement techniques, or by individual component replacement. As an aid to fault finding and servicing, each module is fitted with a coaxial output monitor socket and a selection of strategically-positioned on-circuit test points. The modules can be withdrawn from the drive assembly to permit access for

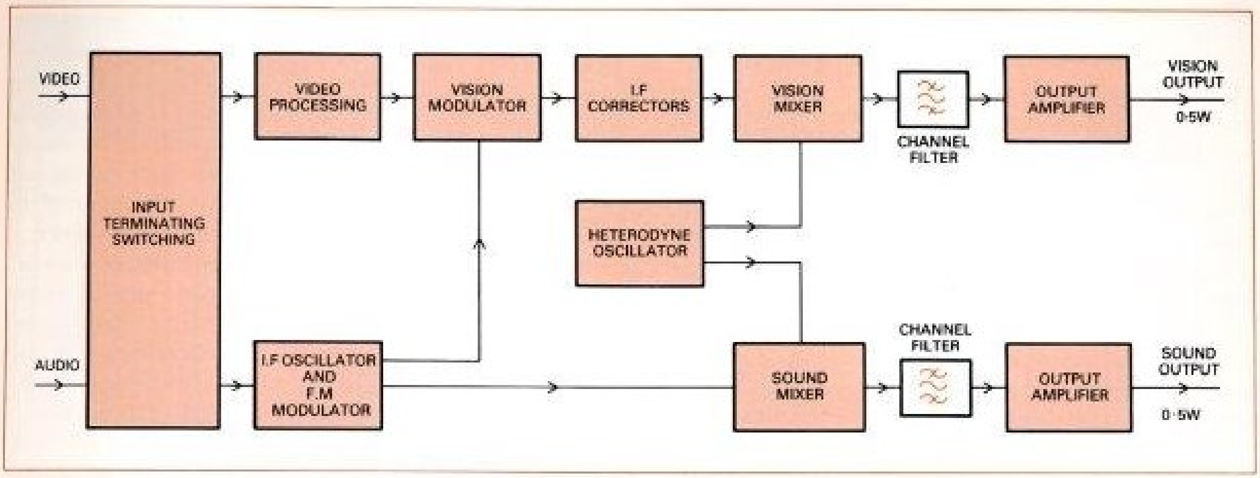


Fig. 3. Block diagram of driver for separate vision and sound

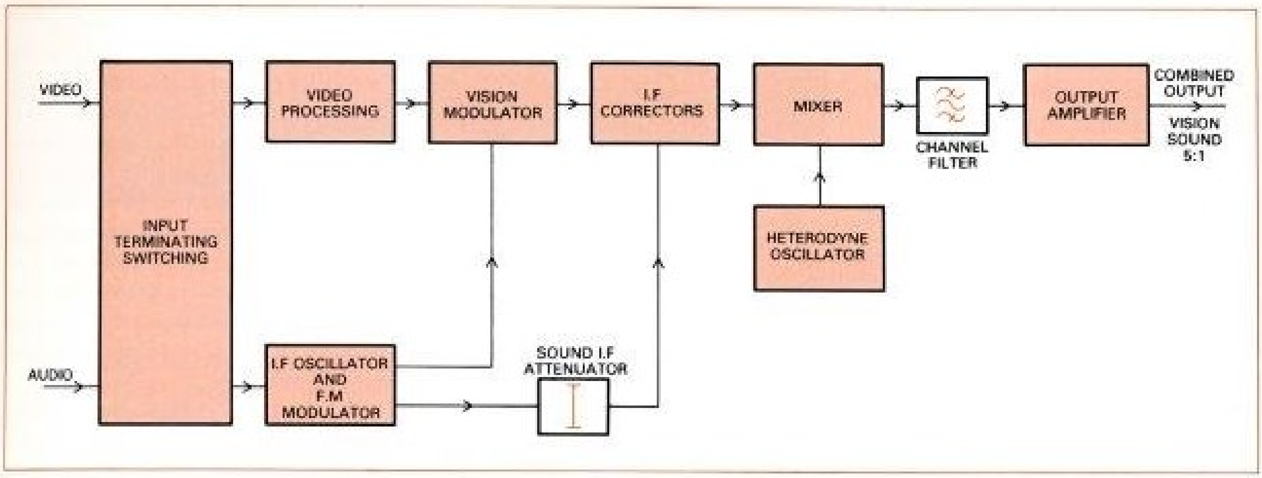


Fig. 4. Block diagram of driver for combined vision and sound

major alignment with no necessity to interrupt the drive operation. A meter with a range/function selection switch completes the service aid facilities on the drive.

Solid-state amplifiers

In the B7445 transmitter one module assembly houses both the vision and sound solid-state intermediate power amplifiers. The amplifiers themselves are of a modular construction, three are used for the vision signal and a single module amplifies the sound signal. Each amplifier module is broadband tuned (470–860MHz) and may be pre-aligned before incorporation into the assembly.

The vision amplifier employs an LA261B amplifier module in its input stage, the output of which is split by a broadband u.h.f splitter and routed to a pair of LA263A amplifier modules. A broadband u.h.f coupler combines the outputs of the LA263A modules to complete the amplifier system. The amplifier modules are operated in Class A and have a gain of approximately 9dB, each being fully protected from the effects of output mis-termination. The unintentional disconnection of the amplifier load, therefore, has no detrimental effect.

The sound amplifier employs the LA261B module working in Class A as in the input amplifier of the vision amplifier.

The B7442 common-amplifier transmitter employs the same amplifier configuration as the vision amplifier of the B7445, but the LA216B pre-amplifier is replaced by a mechanically identical LA261A amplifier.

In both transmitters the solid-state amplifier module is fitted with a switched range meter on its front panel enabling output powers, supply voltages and module current demands to be monitored. Fixed step, variable attenuators fitted within the module allow the gain of the amplifier assemblies to be adjusted to channel requirements. The amplifier assembly may be withdrawn on slide mountings when access is required to the amplifier sub-modules.

The klystron amplifier

The high efficiency YK1220 klystron incorporates established design techniques in its heater and cathode assembly with the latest developments in high efficiency operation, thereby combining proven reliability with enhanced cost effectiveness.

Particular attention has been paid to the mechanics of the klystron and its electro-magnet assembly, resulting in a compact, single-edition design which may be operated on any channel in the u.h.f broadcast band.

The klystron heater, operated from a d.c supply, normally requires a five

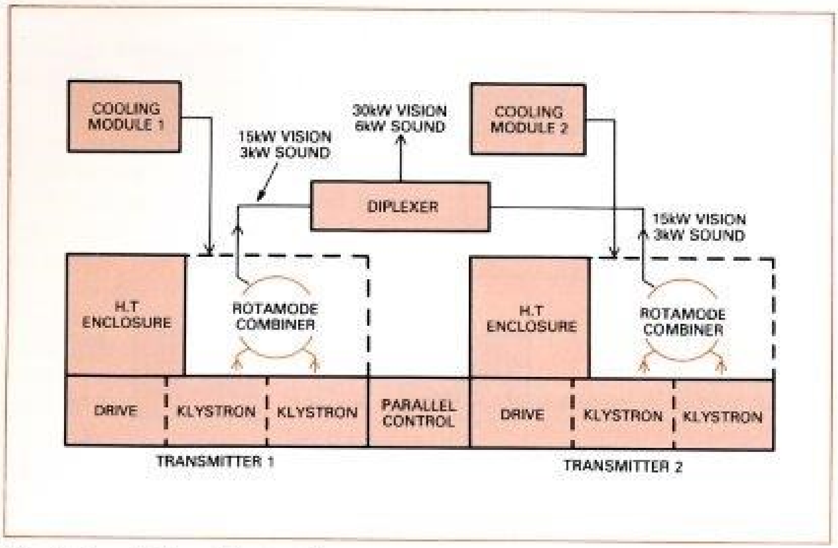


Fig. 5. Layout of parallel operation

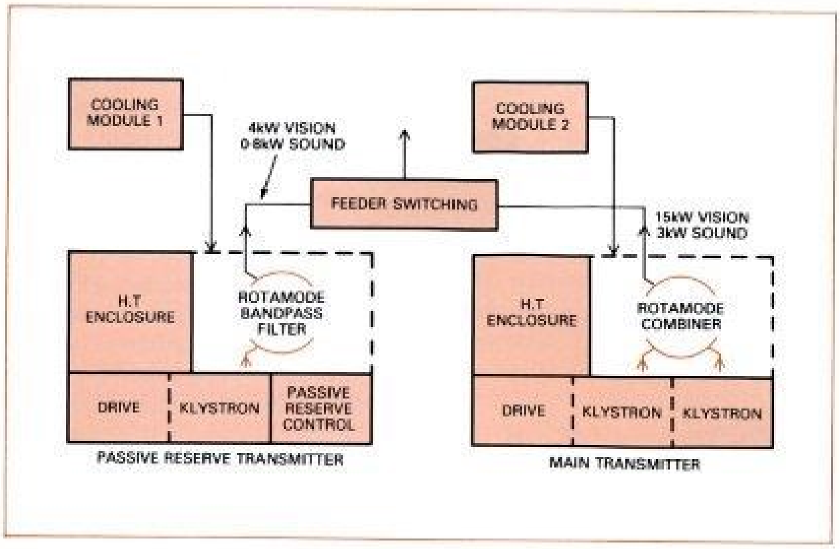


Fig. 6. Layout for passive reserve operation

minute warm-up period before the beam is energized. The heater may however be operated continually at a reduced voltage, 'black heat' condition for standby transmitter operation. The starting delay is thereby reduced to one minute. 'Black heat' operation is not counted toward the 'working' heater hours normally equated to the klystron life.

The focus supply to the electro-magnet is a current-stabilized supply and in the B7445 design, economy is effected by operating the sound klystron electro-magnet in series with the vision. In this instance the focus current is stabilized to suit the vision klystron requirements.

A klystron metering panel is fitted above each klystron in the transmitter, allowing the operating condition of the klystron to be readily ascertained. Focus and heater supply controls and the heater hour meter are grouped on this panel for operator convenience.

A full range of over-voltage and current protection devices is incorporated into the klystron power supplies, r.f circuits, and cooling system to safeguard the operation of the klystron. Personnel safety is assured by the mechanically-interlocked safety panel which prevents access to the high voltage terminals of the klystron.

Control protection and power supplies

The control and protection circuitry employs COSMOS logic in conjunction with electro-magnetic relays for compactness and reliability. The start-up/shut-down sequencing circuits, fault protection and memory circuits are accommodated in a total of six printed circuits mounted on three guide-mounted chassis. Each chassis may be withdrawn for servicing and alignment without interruption of the operating status of the transmitter.

Light emitting diode indicators are fitted at appropriate control circuit positions to aid fault location and diagnosis. The indicator circuits may be extended to a remote point for automatic operation. Open collector logic or a relay interface may be employed for remote connection of indicator and control functions.

The test points incorporated into the transmitter control circuits may be accessed by the test lead and meter facility of the drive equipment as a first aid to servicing and alignment.

The transmitter has been designed to comply with the safety requirements of the IEC. Typically, accessible potentials are limited to 70V peak, and a mechanical safety lock ensures that all potentials exceeding 300V are isolated and earthed via the visible contacts of the isolator/earth switch assembly before access may be gained to the transmitter.

The modular design concept has been extended to the power supply assemblies of the transmitter, and a common module design approach has been adopted for the low-power drive, control, and solid-state amplifier supplies. The power supplies are protected by re-settable circuit breakers.

The klystron beam supply employs a tapped transformer to enable a range of beam voltages to be established. The adjustment of the beam voltage and the voltage applied to the accelerating anode allow the klystron efficiency to be optimized at any particular operating channel.

Cooling

A forced air system is employed for the cooling of the transmitter cabinets. An externally mounted blower provides a supply of filtered air via a duct system to the inlet at the roof of the transmitter, from where the cooling air is distributed through the transmitter by a series of internal ductworks and finally is vented via the cabinet roof into the exhaust duct. The airflow to and from the transmitter may be incorporated into a re-circulating system within the transmitter building when required.

Fig. 7. Front view of a parallel installation of Type B7445 Transmitters

The cooling air for the klystron assembly is bled from the cabinet cooling system and ducted to an inlet point in the cabinet roof above the klystron bay. A small internal duct routes the air to the klystron air-inlet manifold, the exhaust air being absorbed into the cabinet exhaust.

An air pressure switch connected to the air duct inhibits the transmitter run-up sequence if the air pressure falls below a pre-determined limit. An internally mounted fan provides the cooling air to the klystron cathode assembly when the standby 'black heat' condition is in operation.

Vapour phase cooling is employed for the klystron collector. The system is pumpless and, with the exception of the externally mounted steam condenser, is totally contained within the transmitter. The accommodation of the cooling system within the transmitter allows the system to be adjusted during the transmitter assembly stage thereby reducing the installation requirement and adjustments to a minimum.

The cooling circuit components are mounted on a pre-assembled module and each can be removed for maintenance. Access to the main storage tank for routine cleaning is gained via inspection covers in the transmitter roof. Tank filling is by means of a pipe extended to the back of the transmitter where a tank-contents sight glass is situated.

The system employs a minimum of control components and these are grouped together where access can readily be gained from the front of the transmitter. A water drainage system built into the circuit enables the klystrons, tanks and pipework to be easily drained.

Protective components are fitted to ensure that malfunction does not result in damage to the klystron. A water-level alarm is incorporated to provide early warning that water replenishment is necessary

The steam condenser and cabinet blower have been designed to be integrated into a cooling assembly complete with air filter, starters and protection, and, if necessary, the control and sensing circuits of the air re-circulation system to form a self-contained module within the transmitter system.

The mechanical design

Important mechanical design aims for the B7442 and B7445 transmitters were ease of access to sub-modules, compactness and mechanical adaptability.

The transmitter circuits are contained within a free-standing cabinet whose dimensions are 2170 wide×325 deep×1900mm high. An h.t enclosure at the rear accommodates the klystron beam supply components. The Rotamode combining unit and band-pass filter assembly modules occupy the floor space at the rear of the transmitter and the complete installation occupies a rectangular floor area of 2170 wide×1960mm deep. Should it be required the Rotamode assembly may be positioned separately from the transmitter.

The bay occupied by the second klystron in the B7445 can be used in the B7442 for the 19in rack-mounted framework which can accommodate the system-control and monitoring equipment in a main and standby arrangement. Thus, the B7445 main and B7442 standby can be accommodated in the space for two mechanically identical transmitter assemblies, two external cooler modules and a feeder switching assembly.

Transmitter circuits are arranged so that units are located in the same place in both transmitters. A drive and control bay incorporating the low voltage supplies and the solid-state amplifier is positioned at the left-hand side of the cabinet, the klystron bays, including the collector cooling circuit, are at the right. A panel above the doors mounts the meters, indicators and controls necessary to give immediate indication of the working status of the transmitter when the doors are closed.

Conclusions

The design philosophy outlined for the B7442/5 transmitters allows a maximum use of a common active component, the YK1220 klystron for vision only, sound only and combined vision and sound operation. The advantages of the tetrode have been recognized and the aims of the klystron transmitter design have been to maximize the operational efficiency of the transmitter by careful attention to choice of components, cooling and power supply design.

References

1. J. F. H. Binns and L. F. Howard: 'A universal television driver transmitter', International Broadcasting Convention, 1978, I.E.E. Publication No. 166, pp.72–75.