Sound and Vision Winter 1965/1966

C. A. LEWIS, B.Sc, Grad. I.E.E.

MICROWAVE BROADCAST LINK SYSTEM IN GHANA

SYSTEM REQUIREMENT

THE EXPANSION of the services of the Ghana Broadcasting System called for a reliable means of linking the studios at Accra with the National Service broadcast transmitters at Korforidua and Kumasi (Eastern and Ashanti Regional Headquarters) and new International Service transmitters at Ejura, in northern Ashanti.

The requirement was for six 15 kc/s programme channels originating at the Accra studio and terminating at Ejura, about 180 miles away, with facilities at the intermediate stations Ajankote, Kumasi and Jamasi, for extracting any of the through channels. In the return direction, Accra was to receive four channels, two from Kumasi and two from Korforidua (Fig. 1).

TOPOGRAPHY

The country through which the route passes is varied. The low flat coastal plain round Accra is grassland with clumps of trees and shrubs interspersed with patches of bush. Inland lies a 1,500-ft range of folded volcanic rock, rising in places to 3,000 ft. Crossing these hills, it turns north-west along the scarp of the 1,500-ft Kwahu plateau, composed largely of sandstone. This is the region of the high rain forest with trees reaching 150 to 200 ft and forming a thick canopy over dense moist undergrowth. Most of the route is in this region. To the north of the plateau lies Ejura, where the rain forest begins to give way to savannah, characterized by shorter and more widely spaced trees on a continuous carpet of grass and shrubs. Here the country is more open and gently undulating.

CLIMATE

The climate also varies. Inland in open country it is hot and dry with intermittent rainfall. The forest lands of the Ashanti are hot and humid with heavy rains. The flat coastal plain is warm and fairly dry.

MICROWAVE SOLUTION

Comparative cost studies usually indicate that, where no cable already exists, the frequency-modulated microwave link system is the most economical means of providing communications circuits capable of handling several hundred telephone channels or carrying a television programme over long distances. Where terrain and weather conditions are severe, this cost advantage increases many times.

The replacement of valves by semi-conductors and conventional wiring by printed boards has brought about a reduction in equipment size and power consumption. At the same time reliability has been increased and maintainability improved.

Once the problems relating to planning and engineering a microwave system are resolved, installation, commissioning and maintenance become relatively straightforward tasks which can be accomplished with the minimum of specialized personnel.

SYSTEM DESCRIPTION

Radio Equipment

The microwave radio relay equipment type MH141 was selected as the main bearer, operating on a frequency plan using r.f carriers in the neighbourhood of 6,500 Mc/s. It is satisfactory for the transmission of

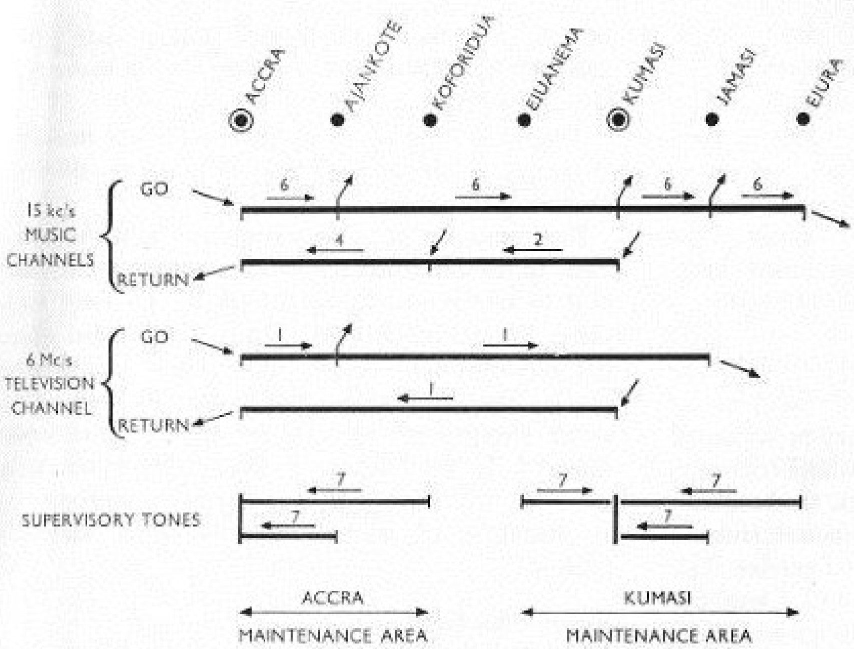

Fig. 1. Channel access and supervisory diagram.

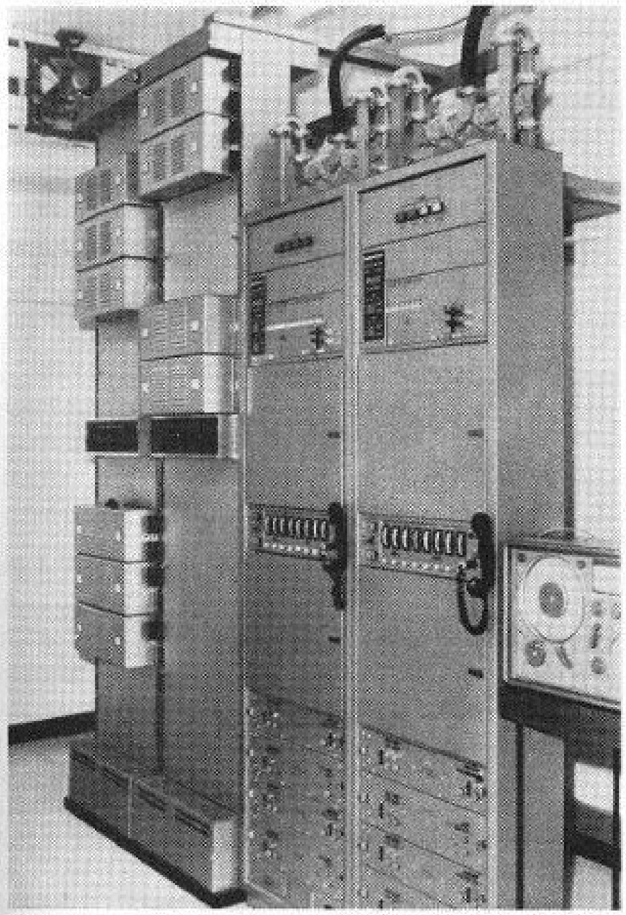

Fig. 2. The broadcast link equipment, MH141, in the foreground with the multiplexing equipment, MH105, behind. The aerial branching equipment is shown on top of the link equipment.

up to 300 telephone channels or a television programme over medium haul routes (Fig. 2).

To achieve the required reliability of performance of 99·9%, duplicate equipment is provided at all stations. Both equipments operate continuously but at different frequencies. Normally the traffic, in this case six music channels, is fed to both transmitters in parallel, an automatic traffic switch selecting traffic from the operational or standby receiver as determined by a logic unit. This unit operates from fault information provided by the equipment monitors.

The standby equipment is arranged so that it may be remotely set to accept a television programme. In this event the operational equipment carries the six programme channels, while simultaneously the standby equipment carries a television picture. By providing television-insertion equipment at Accra and extraction at Ajankote and Jamasi, the microwave bearer can thus be employed as an emergency television link between studios and transmitters (Fig. 3).

A separate single channel u.h.f radio link, running in parallel with the microwave link, acts as bearer for the command tone which operates the multichannel/television traffic selectors simultaneously at all stations in the system. The control of this tone is invested in the TV terminal stations at Accra and Jamasi.

The u.h.f link is equipped with an engineer's order wire having omnibus speech and calling and capable of supplementing the order wire on the main bearer in an emergency.

Multiplexing Equipment

When a number of sound channels are to be transmitted on the same carrier, it becomes necessary to transpose the audio frequencies to lie within a band of frequencies acceptable to the microwave equipment. One method of achieving this is for each audio channel to frequency modulate a separate sub-carrier. This arrangement is not economical of equipment bandwidth since typically six channels would require a 7 Mc/s wide baseband.

The multiplex equipment type MH105 employed on this system uses frequency division multiplex by which up to twelve music channels may be arranged side by side in the baseband. Each channel transmits audio frequencies from 50 to 15,000 c/s, the baseband signal being in the form of amplitude-modulated single sideband signals with suppressed carrier. The channels are grouped in pairs separated by 5 kc/s, the group separation being 13 kc/s. The frequency limits for twelve channels are 20 to 295 kc/s (Fig. 4).

Aerials and Feeders

The requirements for aerials for a microwave system are: high gain to reduce the transmitter power required for a given performance; good directivity to minimize interference to and from other systems and to reject reflections from objects along the path; a good impedance match to avoid cross-modulation due to reflections within the feeder.

The use of parabolic reflectors with a waveguide horn feed at the focus has proved satisfactory and 10-ft diameter reflectors are used at all sites with the exception of the short Accra–Ajankote path where sufficient signal level can be obtained with lower gain, 6-ft diameter aerials.

The bandwidth of the aerials is 7% of mid-band frequency, which is more than adequate for the four-frequency plan used.

Rectangular copper waveguide connects the equipment to the aerial. At 6,500 Mc/s the feeder attenuation is approximately 2·0 dB/100 ft. To keep these losses to a minimum plane reflectors are used where the aerial height exceeds 100 ft. This arrangement enables the aerial to be mounted at the foot of the tower, thereby greatly reducing the length of feeder required. In this position it is necessary to cover the parabolic reflector with a radome to prevent the accumulation of water- or wind-borne materials (Fig. 5).

Aerial Branching

The transmit and receive r.f channels of both operational and standby equipments are combined for application to a common aerial. The three-port ferrite circulators and associated waveguide filters for this purpose are mounted on top of the radio cabinets. The non-reciprocal properties of the ferrite-loaded components help to minimize any effects of impedance mismatch in the aerial and feeder as well as giving added protection to the transmitting klystrons.

Aerial Towers

Self-supporting galvanized lattice steel towers carry the aerials at all sites. Since the beamwidth of the transmitted ray is small (1°), the rigidity of the

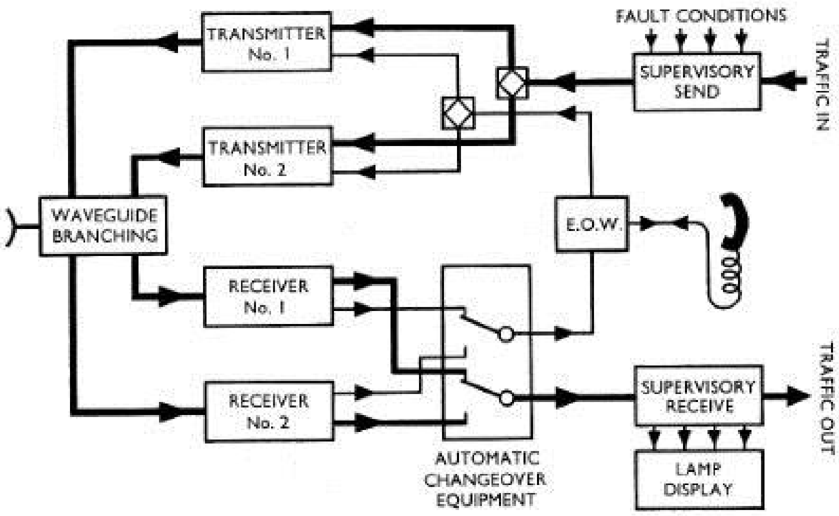

Fig. 3. MH141 block diagram.

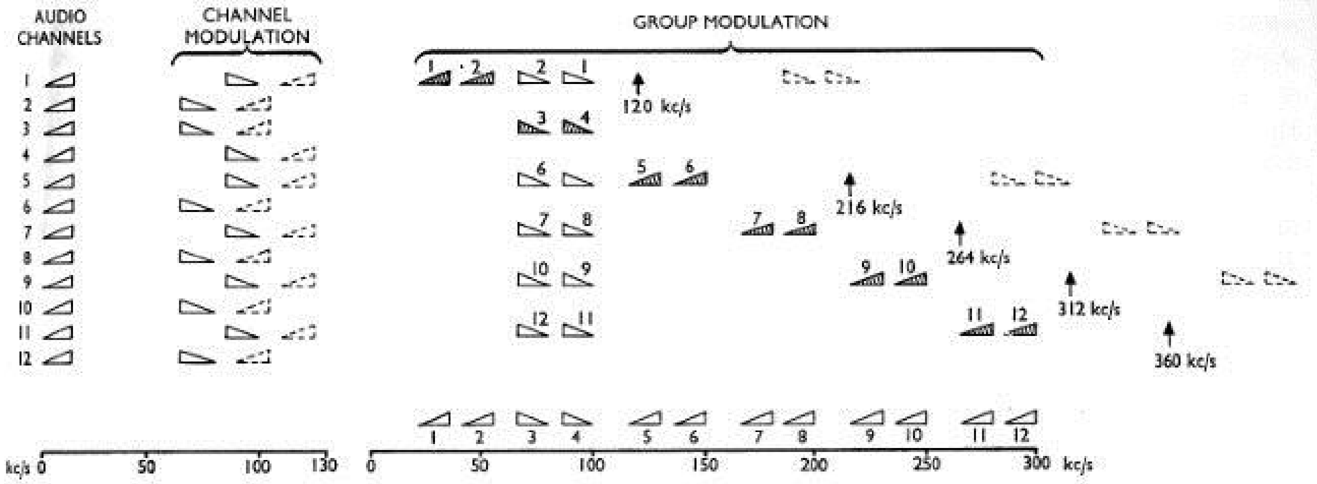

Fig. 4. Channel-frequency allocation in baseband.

aerial system is of prime importance. The towers are designed so that the twist and sway of the aerials does not exceed $\pm\frac{1}{2}°$, $\pm\frac{1}{4}°$ respectively, apart from a very small percentage of the time (0·01%) when the wind velocity is greater than 40 m.p.h.

Power supplies

The radio and carrier equipments operate from 230-V single-phase a.c supply. Where the equipment shares a common site with broadcast equipment, power is taken from the station supply through a voltage regulator.

At Ejuanema and Korforidua, where no supply is available, a dual diesel alternator set provides a reliable source of power. The supply for Kumasi comes from the nearby town via an automatic voltage regulator, and a standby-to-mains diesel alternator starts up automatically to maintain the supply in the event of a failure of the incoming mains.

PLANNING CONSIDERATIONS

Propagation effects

Reliable microwave communications require an unobstructed line-of-sight path between terminals, together with first Fresnel zone clearance over all obstructions on the intervening ground. The standard atmosphere has a refractive index (k) imparting a curvature to the ray and giving an increased clearance. Occasionally k changes, effectively reducing this clearance and thereby attenuating the received signal. The influence of diurnal and seasonal variations of atmospheric conditions on microwave propagation is considerable. Where the air is disturbed signals are steady, but during calm periods fading is often severe, particularly at night.

Strong ground reflections, or reflections from objects along the path, reaching the aerial via a longer path can give rise to interference with the direct ray causing partial cancellation or enhancement. An effect of random atmospheric irregularities is to scatter the rays whereby the received signal, being the resultant of unequal, varying sectors, fluctuates rapidly. In a well-designed system, since by careful siting of the aerials, k-fading and interference fading can be largely overcome, these random atmospheric effects are likely to be most prevalent.

Route Planning

The problem of route planning often resolves itself into satisfying a number of conditions, the chief being that of keeping the number of repeaters to a minimum and ensuring maximum accessibility to the sites. In general, the solution is dependent upon the topography and propagation conditions and usually can only be solved by ground, supplemented by radio surveys, together with close co-operation with the administration concerned.

In Ghana the position of nearly all sites has been dictated by the requirements of the broadcast transmitters, leaving only the selection of repeaters between Korforidua and Kumasi, a distance of 100 miles as the crow flies.

The ideal path length in the tropics is 25 miles. The topography suggested a repeater on the edge of the escarpment at Ejuanema, creating two hops of approximately 60 miles and 50 miles. A radio survey

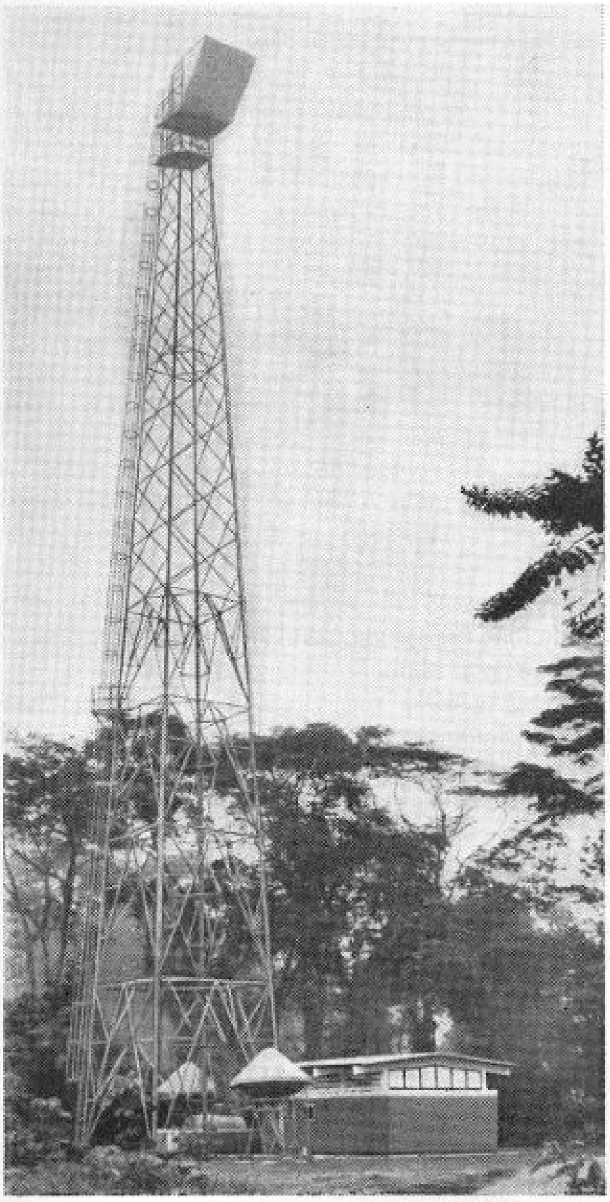

Fig. 5. Repeater station at Ejuanema. The aerials at the base of the tower fire at reflectors at the top. The station is unattended and has its own power supplies.

carried out over the longer path indicated that although deep fading would occur, particularly during heavy rainstorms, the equipment fading margins were sufficient to ensure that the required performance reliability would be met.

Much of the region containing the route has been reasonably well mapped so that profiles of all paths could be drawn and aerial heights established. The profile for the long Kumasi–Ejuanema hop was also able to be verified by reference to the results of an aero-survey carried out previously for Messrs Philips of Eindhoven.

MAINTENANCE

Equipment Design

The radio link type MH141 is the third generation of microwave equipment designed by Marconi Italiana. By using transistors, not only has a very high degree of reliability been obtained, but better performance than would have been achieved using valved circuits.

Each unit comprising the equipment possesses an intrinsic linearity (phase and amplitude) together with wide operating margins, such that when finally assembled, optimum performance is achieved without the need of further adjustment or realignment. This characteristic of the equipment has two important advantages:

(a) that performance is not critical and is stable with time, and

(b) interchange of units and modules can be carried out without need for realignment.

The general layout of the equipment is shown in the photograph. A single cabinet contains two complete transmitters and receivers, all the necessary supervisory equipment for duplicate operation including automatic changeover, and an engineer's order wire. The r.f waveguide components of each terminal are mounted inside the cabinet and accessible through a hinged panel, on the inside of which are mounted the units comprising the receiver (Fig. 6).

The remote alarm equipment is accommodated in the top part of the cabinet and the four power supplies, two for the receivers and two for the transmitters, are mounted at the bottom of the rack. All units are easily accessible from the front.

The MH105 carrier is a well-proven valved equipment. As is usual practice for transmission equipment, the units are mounted on both sides of the rack and protected by easily removable covers. The sub-assemblies are accessible once the covers are removed. A feature of the design is in the arrangement of the various units, so that the extraction of one may be effected without interfering with the operation of the rest of the equipment. The carrier generators, being common to the channels, are duplicated, and a failure of one causes no degradation in performance of the equipment.

Routine Maintenance

Maintenance itself falls into two categories—preventive and corrective. Preventive maintenance in the form of routine inspection and checking of selected parameters enables the end-of-life condition to be anticipated. In addition, these inspections help to maintain a continued interest in the equipment and improve the ability to test and fault-find rapidly.

The equipments are designed to have highly stable characteristics, so that maintenance is reduced to a minimum. On the MH141, monitoring meters, situated in the central part of the cabinet, allow a rapid check of the correct operation of each terminal equipment. These checks include:

Receive carrier level
Receive pilot level
Transmitter r.f power
A.f.c operation.

A meter fitted to each receiver is employed in conjunction with a wander lead to check levels and normal operation of the circuits.

A portable test meter, provided with each MH105 carrier equipment, can be used to check the cathode currents of all valves. Test points are placed in accessible positions so that level checks and voltage measurements may be carried out without disturbing the operation of the equipment.

Corrective action will depend on effective reporting and locating, which is a function of system design. Fault-reporting equipment is provided at each microwave station in the form of simple on/off tones. Up to seven indications can be sent from each unattended station and these are received at the associated Maintenance Centres, Accra and Jamasi. A lamp display panel installed at each Maintenance Centre gives the following fault conditions for every station in the maintenance area:

Main radio GO
Standby radio GO

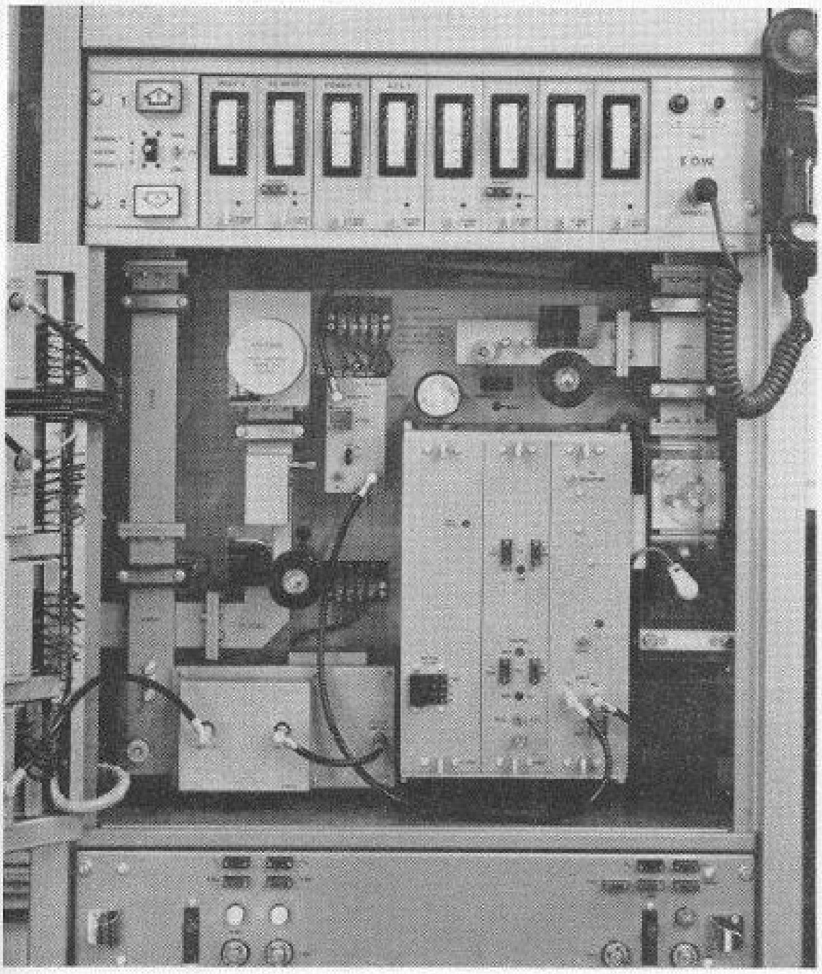

Fig. 6. General layout of the MH141 equipment.

Main radio RETURN
Standby radio RETURN
Carrier equipment
U.h.f bearer
Power equipment.

Reception of a fault indication is accompanied by an audible alarm which may be muted.

SUMMARY OF PERFORMANCE

These results are typical of those taken at the time of acceptance.

Music channels

Overall performance from Accra to Ejura (i.e. six links in tandem over a distance of 196 miles).

Channel bandwidth 50 to 15,000 c/s
Amplitude distortion, ref. 1 kc/s ± 2 dB
Distortion, for +6 dBmO output 1%
Noise level, ref. +6 dBmO output −59 dB unweighted.

Television channel

Overall performance from Accra to Jamasi (i.e. five links in tandem over a distance of 170 miles).

Bandwidth 5 Mc/s
Amplitude distortion referred to 1 Mc/s −3 dB (at 5 Mc/s)
Random noise −60 dB
Periodic noise −46 dB
50 c/s square-wave response 3%
T-pulse response 4%
2T-pulse response 2%
Picture linearity 5%.

Frequency Plan

		Set A	Set B
Operational	GO	6,467	6,719
	RETURN	6,689	6,497
Standby	GO	6,526	6,778
	RETURN	6,749	6,555

Frequencies are approximate and in Mc/s. Set A and Set B frequencies are used at alternate stations giving three-hop overshoot protection.