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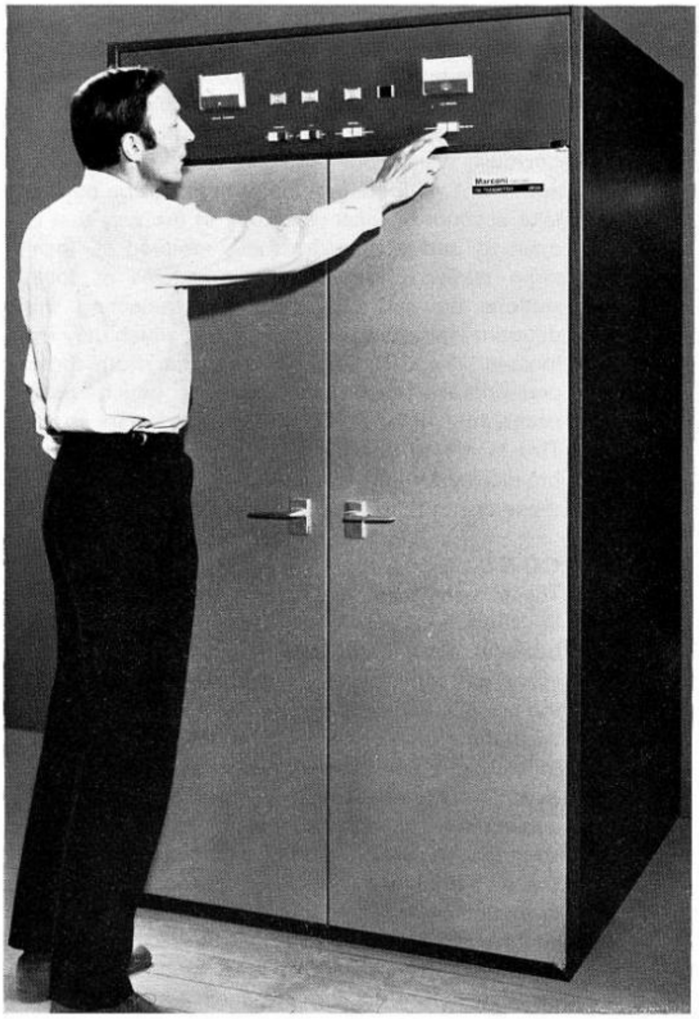
J. W. THOMPSON, C.ENG, M.I.E.E

SINGLE VALVE 10kW BAND 11 F.M TRANSMITTER

INTRODUCTION

For the first time an f.m (f3) broadcast transmitter has been designed to provide a carrier power of up to 10kW employing only a single valve. Solid-state devices are used in all the r.f drive and signal processing stages, and control and protection circuits.

By the conservative rating of all the solid-state devices, and the use of a new design of tetrode valve with an exceptionally long life, a very high order of reliability has been achieved which is of particular importance when unattended remotely controlled operation is required.



The modern streamlined appearance of the 10kW f.m. transmitter.

A unique design of frequency modulated drive, which will be described in a later issue of this journal, caters for high-quality stereo and S.C.A (subsidiary communication authorization) modes of transmission.

A version is also available providing a carrier power of 5kW. Both versions operate from either 380/440V, three-phase, four-wire or 210/240V, three-phase, three-wire supplies, each $\pm 5\%$, and 50Hz or 60Hz ± 2Hz. Power consumption is 19kW for 10kW output and 10kW for 5kW output, with a power factor of 0.9 in each case.

CONSTRUCTION

The transmitter is completely self-contained and has built-in facilities for either overhead or under floor air ducting and cabling.

The single cabinet is divided vertically, each half accommodating standard 19in rack mounting units. The left-hand section houses the drive and control equipment with the output tetrode largely taking up the right-hand section. Controls and indicators for normal operation are mounted at a convenient height at the top of the cabinet. All the heavy power supply components and the blower are mounted at floor level.

The overall height is 6ft 9in, width and depth both 3ft 6in and the approximate all up weight 712kg (1700lb).

TECHNICAL DESCRIPTION

Programme and Radio-Frequency Circuits

A block diagram showing the radio-frequency and modulation stages is shown in figure 1. The f.m drive gives an output of 1W, a level which is sufficient to drive two transmitters operating in parallel, including all cable and phasing system losses.

Low-power Amplifiers

The solid-state amplifier unit preceding the valve amplifier stage is in two sections. First is a two-

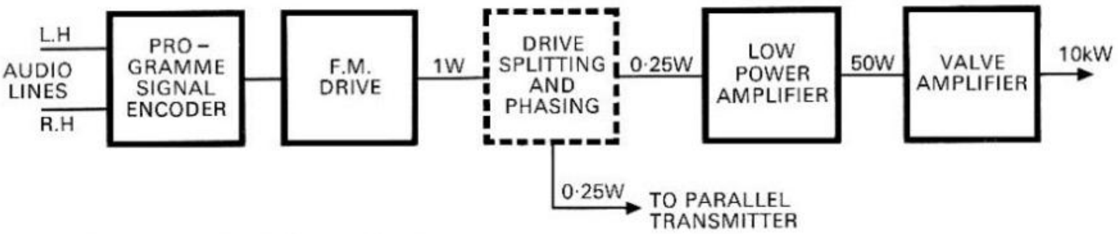


Fig. 1. Block diagram of modulation and radio-frequency stages.

stage tuned unit providing an output level of 10W to drive a second section containing four 25W amplifiers operating in parallel to give a total output of 100W (Fig. 2).

The r.f inputs are split and the outputs combined by 3dB stripline couplers which provide many advantages:

(a) An accurate and low-loss four-way division of the drive power to the individual modules.

(b) The outputs of the four modules, provided they are working at the same amplitude and phase, can be combined with minimum loss.

(c) Isolation between the inputs to the module, and the outputs from the module, prevent interaction between them which can be caused by different transistor parameters or changes in drive or load impedances.

(d) Failure of one module causes a reduction to only 56% of the fully tuned output level and, due to the partial saturation of the class-B valve amplifier, the feeder power falls by less than 2dB.

Each of the four class-C amplifiers uses a 2N5643 transistor having a collector rating of 60W with tuned input and output circuits. This conservative rating, in conjunction with individual supply lines to each module, has enabled an exceptionally high degree of reliability to be achieved. Additionally each transistor unit is mounted on a plug-in printed circuit board.

Although the amplifier is designed to operate into a 50-ohm resistive load, when tuning the grid circuit of the valve it is inevitable that mismatch conditions will occur. With this in mind the circuit has been designed so that even a mismatch of open or short-circuited feeder will not cause damage to the amplifier components.

High-power Valve Amplifier

The YL1470 tetrode provides high stage gain, and to minimize drive power it is operated in class-B reaching an efficiency of 70%. The actual drive power used is approximately half the capability of the drive unit which avoids critical tuning and allows an adequate margin for the spread of valve characteristics.

The tetrode valve has special characteristics which enable overall stability to be maintained with the high gain of a grounded cathode circuit. The electrode arrangement and coaxial connections are shown in figure 3a, and for a comparison a conventional arrangement is shown in figure 3b. Central disposition of the grid connexion enables adequate screening of the grid circuit to be easily arranged.

The long conductor to the control grid is part of the inductance of a simple tuned grid circuit, with r.f drive tapped into the circuit at a point where a match for the 50-ohm coaxial drive cable is obtained.

The anode circuit consists of an open-ended $\lambda/2$ line so that an h.t blocking capacitor is not required. Capacity tuning and capacity coupling to the feeder from the anode avoids sliding spring contacts, the arrangement lending itself to extremely clean and robust construction. A simplified circuit diagram of the tetrode stage is shown in figure 4. The drive power dissipated in the form of grid losses in the valve is a small proportion of the total, the figure is estimated to be in the range of 15 to 20W. Circuit losses and damping are deliberately introduced to increase the stability factor and account for losses of 25 to 45W over the frequency range.

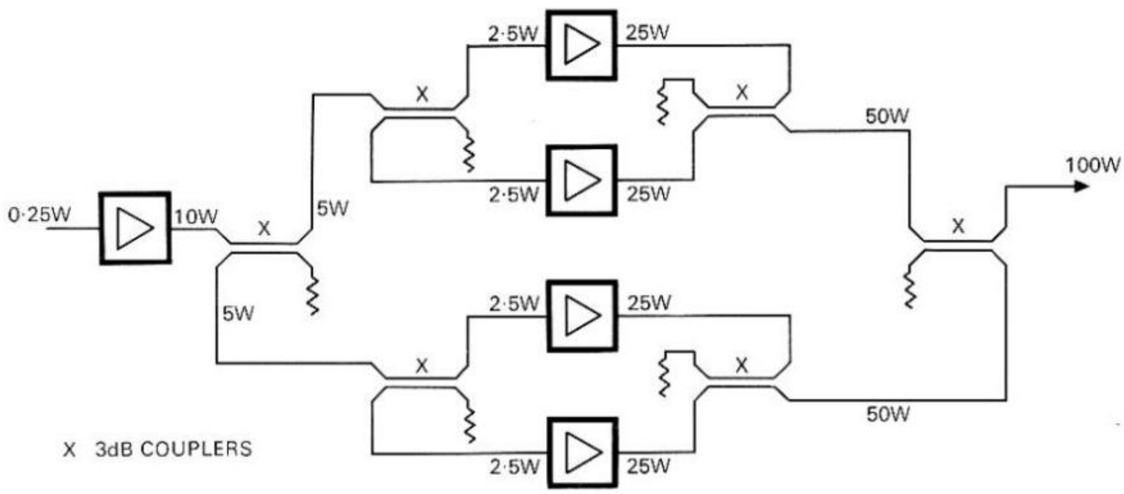


Fig. 2. Solid-state r.f. amplifier.

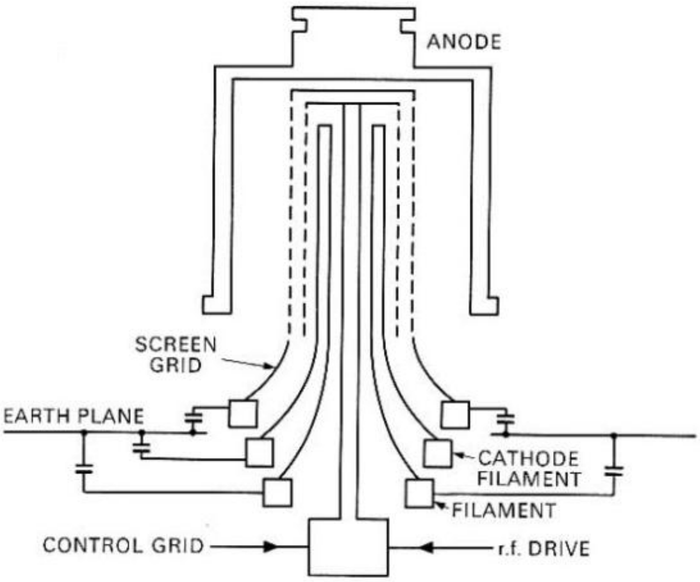


Fig. 3a. Construction of the YL1470.

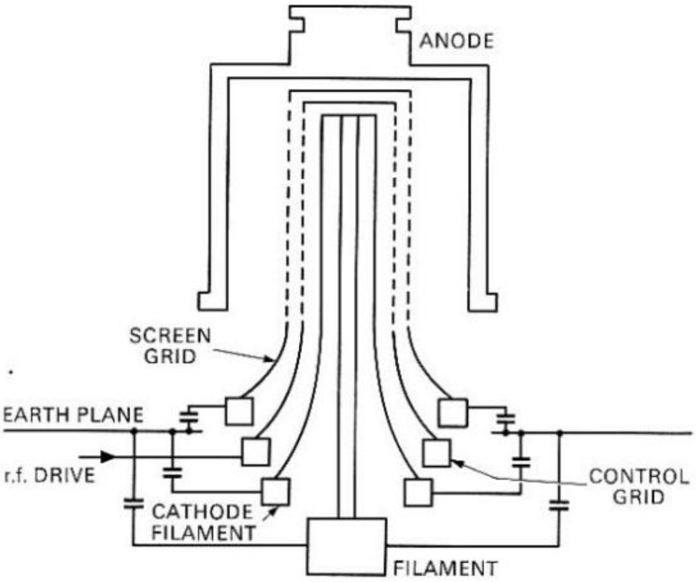


Fig. 3b. Construction of a conventional tetrode valve.

With a gain of the order of 26dB, at frequencies near 100MHz, even the small capacitance coupling from the anode to grid requires the valve to be neutralized. The well-known system of creating a bridged T filter, by introducing the right degree of inductance into the screen earthing path, is used to eliminate this feedback through the valve capacitance.

The method of adjusting the inductance between the screen contact ring and the hold-down capacitance is shown in figure 5.

To meet the stringent regulations concerning harmonic radiation a harmonic filter is built-in as an integral part of the transmitter. This filter precedes the feeder output monitoring probes which are used to indicate both the forward and reflected power and to provide an r.f sample for monitoring purposes.

POWER SUPPLIES

The f.m drive and stereo coder have individual built-in power units, and additional power supplies provide 24V d.c for the control circuits and 100V d.c for the valve control grid bias – all are solid state.

The drive amplifier uses a specially developed 24V d.c supply which is mounted separately to the amplifier. It uses a duty cycle controlled d.c regulator with low power loss. Switching frequency is 25kHz and the duty cycle is automatically varied to give the required regulation. Also incorporated is a control circuit limiting the supply to a maximum of 28V d.c for protection of the r.f transistors.

The 7000V d.c high-tension supply for the 10kW transmitter, or 5000V d.c for the 5kW version, and the 550V d.c screen supply are both derived from a single transformer, so eliminating the need for sequence switching. Both rectifying circuits use a three-phase full-wave bridge arrangement of silicon avalanche diodes generously rated to withstand short-circuit currents during the time required to open the supply when a fault is detected by the overload circuits.

These supplies are protected by miniature circuit breakers in the primary connexion to the transformers. Since the circuit breaker in the primary of the h.t transformer cannot provide adequate protection against faults occurring in the screen supply, fuse links are connected between the secondary winding and the screen supply rectifier.

The 6.8V 120A filament supply to the YL1470 tetrode is obtained from the a.c mains by a transformer connected across two supply lines in order to arrive at a near balance of line currents.

Control Circuits

Solid-state devices are used in the control logic system to energize the power contactors. A two-step switching system incorporates the required filament delay of three seconds when in the 'Standby' position, followed by 'H.T ON'. When the 'H.T ON' button is depressed the anode and screen voltages are applied simultaneously and the low-power amplifier unit is energized.

By linking across the h.t switch the transmitter can be made fully operational by the closure of a single contact, a most valuable facility when the transmitter is to be remotely controlled.

Indicator lights show the switching state at a glance and operate in the following way;

When the 'Standby ON' button is used.

(1) Upper half of the indicator lights showing the 'ON' switch has been closed.

(2) The lower half of the indicator flashes on and off during the three-second delay period.

(3) At the end of three seconds the lower half of the indicator remains illuminated to indicate that h.t can be applied to the transmitter.

When the h.t 'ON' button is used;

(1) The upper half of the indicator is illuminated to show the switch has closed.

(2) The lower half of the indicator is also

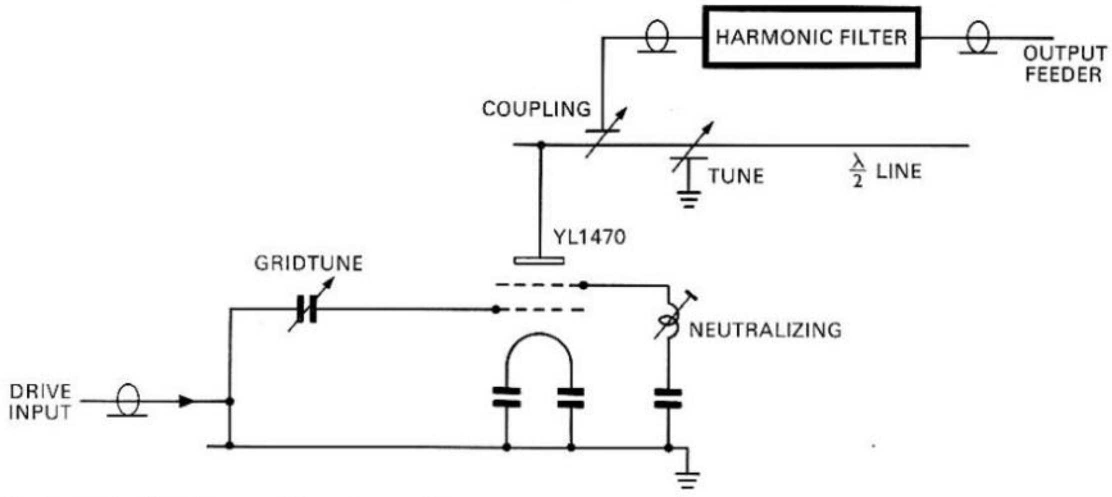


Fig. 4. A simplified diagram of the valve amplifier.

illuminated showing that the logic sequence has been completed and that the h.t contactor is energized.

The equipment is closed down by the use of both 'H.T' and Standby 'OFF' switches. Trip circuits monitor anode, screen and bias currents and reflected power, and excessive level in any of these circuits simultaneously removes the a.c supply from the h.t transformer and drive amplifier. The a.c supply is restored after approximately one second but if the fault persists the third detection of excessive level results in a lockout of the h.t and drive. Warning of this condition is given by a red lamp indicator on the meter panel.

By means of a 24V d.c logic signal, having a source impedance of 220 ohms, facilities are provided to give a remote indication of the state of the transmitter, i.e. 'Standby Condition', 'H.T ON', or 'Lockout' on a fault.

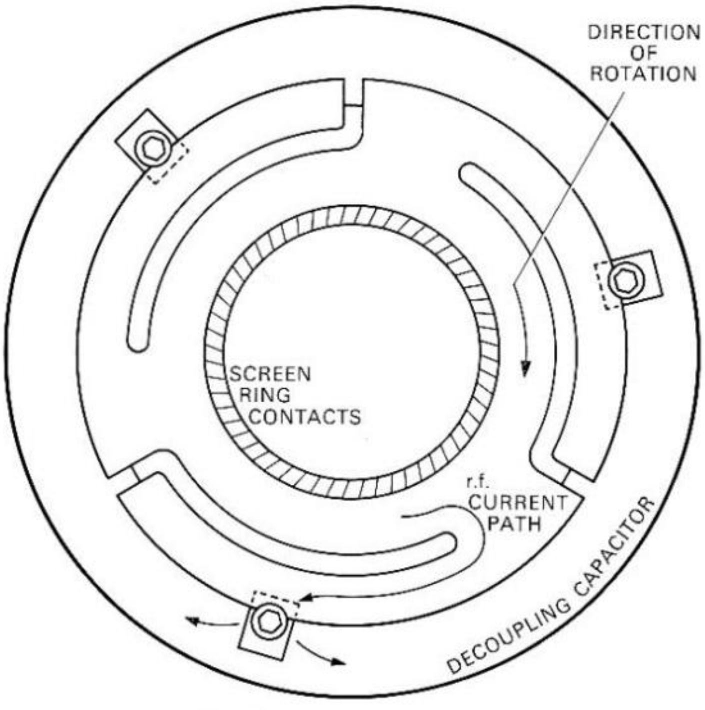


Fig. 5. Screen connecting ring of the YL1470 tetrode showing neutralizing adjustment.

Metering

Full metering facilities are provided with anode current and feeder power, both forward and reflected, being read from two meters on the top panel. Additionally a switched meter, mounted internally, monitors the supply voltages, grid and screen currents of the YL1470.

Stereo encoder, r.f drive and low-power amplifiers are all individually metered.

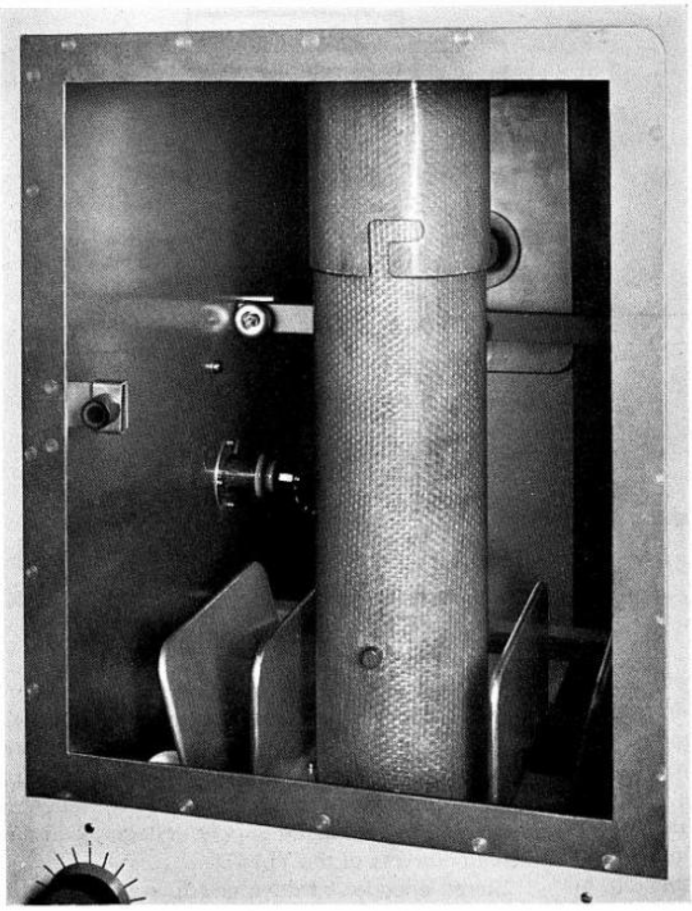
Safety Precautions

The input supply lines up to the isolator switch, which is protected by a safety cover, are completely enclosed in ducting. The isolator switch is also interlocked by means of two keys with a switch earthing all dangerous potentials. The panels giving access to the final r.f amplifier unit are operated by keys but most other units require a special tool. Exceptions to this are the control unit and drive amplifier, access to which is required during initial tuning adjustments. As the maximum potential in these units is only 24V d.c they are completely safe and no special precautions are required.

COOLING

The YL1470 tetrode is air cooled by a blower mounted immediately below the r.f stage with a ducting system so arranged that filtered air can be supplied and exhausted from the roof area, or via floor ducts, or a combination of both. Complete flexibility makes the transmitter suitable for use with any installation plan.

Air to the YL1470 is blown into the valve anode compartment and also cools the r.f lines. Most of the air passes through the anode fins and on through a fibre-glass tube to the outlet ducts. The remaining air passes through the valve holder to cool the screen and filament ring connexions before reaching the main compartment. As the air flow is always in an outward direction from the cabinet the entry of dust is prevented.



The YL1470 tetrode output stage showing the fibre-glass air ducting tube.

The blower is designed to give sufficient air for cooling at an ambient temperature of up to 45°C, and for the reduced air density prevailing up to an altitude of 7500ft.

SETTING UP AND TUNING

The f.m drive unit is normally supplied set up on the required frequency so that subsequent adjustment in the transmitter will not be required. The low-power amplifier is tuned by preset capacitors which are set up when the final r.f amplifier grid circuit is tuned for peak grid current.

Conventional circuits with simple logical adjustments are used in the valve circuit, the half-wave anode line being preset, with variable capacitors for fine tuning and loading.

CONCLUSION

Using only a single tetrode valve as the final r.f amplifier, which has a guaranteed long life, valve replacement and running costs have been dramatically reduced. All the preceding stages and ancillary units are solid state, enabling an exceptionally high degree of reliability to be achieved, making the transmitter particularly suitable for unattended operation.

By using the optional overhead ducting the transmitter will fit into almost any existing or future installation plan where space may be at a premium.

Specifically designed with remote operation in mind controls have been reduced to two switches with facilities for the use of remote indicators.

SPECIFICATION SUMMARY

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Output Feeder Impedance: 50 ohms with maximum VSWR 1.4:1.

Frequency stability: Less than ±1kHz per month with temperature variations of ±15°C.

Frequency deviation: ±75kHz for 100% modulation.

Deviation stability: Less than ±3%.

Centre frequency departure with ±75kHz deviation: Less than 1kHz up to 15kHz mod freq. Less than 2kHz up to 53kHz mod freq.

Modulation input level: Less than 250mV for 100% modulation.

A.F range: 30Hz to 75kHz.

Pre-emphasis: Zero or 50μs ± 5μs.

Linear distortion: amplitude, referred to 1kHz: Less than ±0.1dB between 40Hz and 43kHz. Less than 0.3dB between 30Hz and 53kHz. Less than ±1.0dB between 30Hz and 75kHz.

Phase-frequency distortion: Less than ±1° between 40Hz and 43kHz. Less than ±3° between 30Hz and 53kHz.

Non-linear distortion;

Distortion Factor 40Hz-100Hz: Less than 0.6% with 75kHz peak deviation. Less than 0.8% with 100kHz peak deviation.

100Hz-15kHz: Less than 0.4% with 75kHz peak deviation. Less than 0.6% with 100kHz peak deviation.

Intermodulation between 15kHz and 53kHz:

d^2: Less than 0.2% with 75kHz peak deviation.

d^3: Less than 0.3% with 75kHz peak deviation.

F.M Signal to noise ratio

Unweighted: Less than —60dB
Weighted: Less than —70dB
} Referred to ±75kHz deviation and 1kHz.

A.M signal to noise ratio: Less than —50dB relative to carrier level.

Amplitude modulation: Less than —40dB relative to carrier level.