SERVICING

AN INTRODUCTION TO FAULT-FINDING

PART 7 **G. J. KING**

GORDON KING CONTINUES THE SERIES DISCUSSING TUNER-AMPLIFIERS AND THEIR PROBLEMS, PICKUPS AND THEIR ASSOCIATED CORRECTION NETWORKS AND ENDS WITH A BRIEF RESUME OF HI-FI AMPLIFIER SPECIFICATIONS.

I want to begin this month with the hi-fi type of radio receiver, called the tuner-amplifier. This is an integration of a stereo (two channel) amplifier and a radio receiver always tuning the f.m. band (Band II) and sometimes a.m. bands as well, and invariably embodying a stereo decoder. This type of equipment is ousting the ordinary radiogram in certain areas of application, for, coupled to a pair of good speaker systems and a record playing unit the tuner-amplifier constitutes the 'heart' of a music system of significantly greater quality potential than the average radiogram.

Real hi-fi radio reproduction is not possible from the a.m. bands owing to the necessary restriction of the i.f. passband to avoid interference between adjacent stations. Sadly, even such passband restriction is unable to keep unwanted stations from the wanted in the medium waveband after dark, and as a consequence we get an annoying background of whistles and monkey chatter. Moreover, the passband restriction deletes the higher-order sidebands of the modulated signal and hence impairs the treble output.

With f.m. things are not like this because in Band II each channel is allotted 200 kHz of 'elbow room', thereby permitting full expansion of all the sidebands without restriction.

The f.m. system has attractive attributes over and above the a.m. system, including enhanced signal-to-noise performance, the ability to reject a.m. signals and interference and a parameter known as the 'capture ratio'.

The capture ratio stems from the nature of f.m. demodulation and from the amplitude limiting engineered into the i.f. channel of the receiver. It means that when two signals are present in the same channel (or close together in the receiver's passband) the weaker one is almost completely rejected and only the stronger of the two gives an output, free from interference.

A capture ratio of two or three decibels ensures that a co-channel signal is muted when the wanted signal is only about 10dB above it. Nothing like this degree of rejection is possible on a.m. All this boils down to the fact that the f.m. radio system is truly hi-fi, and that a.m. cannot be regarded in this light at all.

DEVELOPMENTS

Contemporary radio tuners and the tuner sections of tuner-amplifiers are fast taking in the latest devices, including field effect transistors (f.e.t's.), integrated circuits (i.c's.), crystal and ceramic i.f. filters supplementing the bandpass transformer couplings. F.e.t's. are used mostly in the front-end as the r.f. amplifier and, sometimes, the mixer (with a bipolar local oscillator). Since their transfer characteristics exhibit second-order components they yield fewer third-order intermodulation components at high signal level than bipolar counterparts, whose characteristics contain an abundance of third-order components.

This means that unwanted spurious signals are minimised, particularly at locations close to a powerful station group. They also provide other attributes, including relatively low noise working and good 'mixing' properties. Thus a tuner section (f.m.) containing an f.e.t. r.f. amplifier and an f.e.t. mixer is likely to out-perform an 'equivalent' incorporating bipolar devices in these stages under a wide range of operating conditions.

THIRD ORDER INTERMODULATION

One problem with simple f.m. front-ends is third-order intermodulation when operated in a strong, locally derived signal field. One symptom of this is a spurious signal at Radio 3 frequency (from $f_2+f_4-f_3$, where f_2, f_3 and f_4 are the frequencies of Radios 2, 3 and 4 respectively). This can result in 'burbles' and similar sort of interference on Radio 3, and possibly 'birdies' inteference when Radio 3 is stereo encoded.

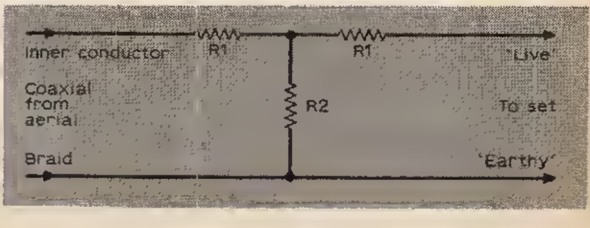


Fig. 1: Simple attenuator for reducing intermodulation problems.

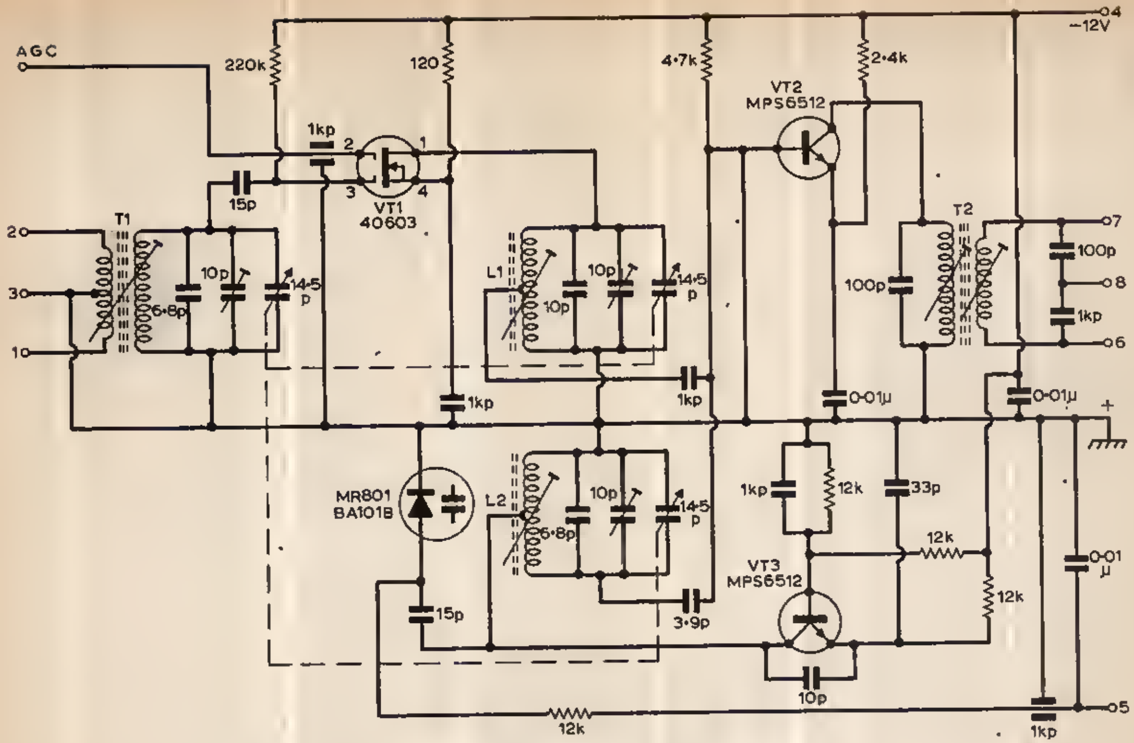


Fig. 2: Circuit of the "front-end" of a typical British tuner-amplifier.

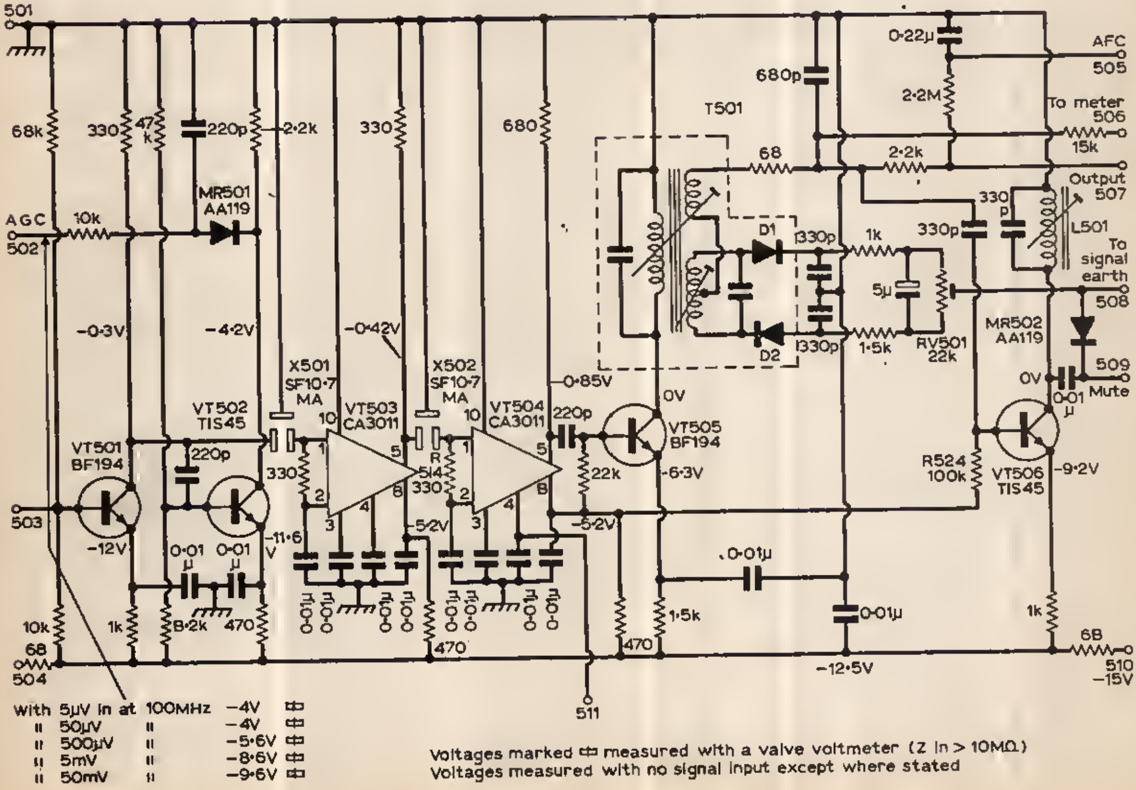


Fig. 3: The f.m. i.f. channel of the tuner-amplifier shown above.

One solution lies in attenuating the signal from the aerial to the set. Belling Lee make plug-in attenuators over a range of values; alternatively a simple resistive pad can be made up as shown in Fig. 1.

FM FRONT-END

The f.m. front-end of a typical British tuner-amplifier is shown in Fig. 2. Here VT1 is a dual-gate f.e.t. with the input signal applied to one gate and an a.g.c. potential to the other. The mixer is bipolar VT2 and the local oscillator bipolar VT3.

Aerial coupling is by T1 primary, and since this is centre-tapped 300 ohms balanced feeder can be connected across terminals 1-2 or 75 ohms coaxial (unbalanced) across 2-3. Not all input circuits permit this dual mode of feeder connection, and if the design is essentially for 300 ohms balanced (or 240 ohms European DIN) the best coupling from coaxial is obtained through a 'balun' transformer.

A.f.c. is applied to the local oscillator from a varactor diode (MR601), and this receives its control bias from the f.m. detector. The varactor is in parallel with the oscillator tuned circuit, so the frequency of this is altered by the control bias which appears in appropriate polarity from the f.m. detector when the tuned carrier is displaced from the centre of the i.f. passband.

The i.f. signal is developed across T2, and is coupled to the f.m. i.f. channel from the capacitance tap on circuit No. 8.

FM IF CHANNEL

The f.m. i.f. channel is shown in Fig. 3, and the input goes to circuit No. 503 and thence to the base of VT501.

The channel includes two ceramic filters of the kind already mentioned (X501/X502) and a couple of i.c's. (VT503/VT504). The ceramic filters take the place of the usual i.f. transformers and because they exhibit steeply rising and falling response sides extremely good i.f. selectivity is secured. The only alignment required is of the ratio detector transformer T501.

The i.f. signal at VT501 collector is fed to the first filter and from this to the first i.c. The second filter couples the two i.c's., while VT505 bipolar transistor drives the ratio detector, composed of diodes D1/D2, etc. This circuit is balanced, and preset RV501 allows this to be optimised, one mode for adjustment being for the least response to an a.m. signal.

It will be noticed that the ratio detector yields potential for the tuning meter as well as for the varactor diode on circuits 506 and 505 respectively. Demodulated audio (or multiplex signal in the case of stereo) from circuit 507 is coupled to the stereo decoder.

VT506 is concerned with the muting, etc., while VT502 amplifies i.f. signal at VT501 collector and passes it to the rectifier MR501. The resulting filtered d.c. constitutes the a.g.c. potential for the f.e.t. r.f. amplifier (Fig. 2).

FAULT FINDING

Fault finding in a circuit of this kind is best carried out by feeding a modulated 10·7MHz (or a signal at the i.f.) into the strip, starting at the final transistor (VT505 in this case), then working forward until the point of inactivity is located.

To find the actual component which is in trouble, after locating the faulty area or stage, might well require the testing of voltages, etc. at the electrodes of the various devices, and to help in this respect the voltage references in Fig. 3 have been retained.

Servicing of f.m. front-ends is not recommended—apart, possibly, from the replacement of transistors—and trouble in this area is best left to the maker or distributor to clear. This applies to professional service organisations as well as to the amateur repairer.

A word about the replacement of f.e.t's. would not be amiss. The insulated gate types in particular are vulnerable to static discharges, and when making a replacement always retain the shorting clip (fitted by the maker) until the device has been completely soldered into the circuit.

From the testing, adjusting and servicing aspects, the BBC's stereo test sequence at the close-down of Radio 3 can be of a great help in determining such parameters as stereo separation (e.g., degree of crosstalk), signal-to-noise, frequency response, etc.

SOURCE INPUTS

When a radio tuner is used with a hi-fi amplifier a 'flat' response is required since the de-emphasis is performed in the tuner. Inputs with 'flat' responses thus include radio, high-level tape replay and auxiliary. If an amplifier is equipped with an input for the signal direct from a tape head, then equalisation will be included to cater for the replay response. The only equalising then required is that pertaining to the gramophone pickup, and a good starting point is the pickup (cartridge) itself.

PICKUPS

There are two versions. One the magnetic which works rather like a generator, and the piezo, using either a natural crystal or processed ceramic, which works on the transducer principle.

When a gramophone record is made the modulation is imparted to the groove from a cutting head via a special electrical filter having a specific

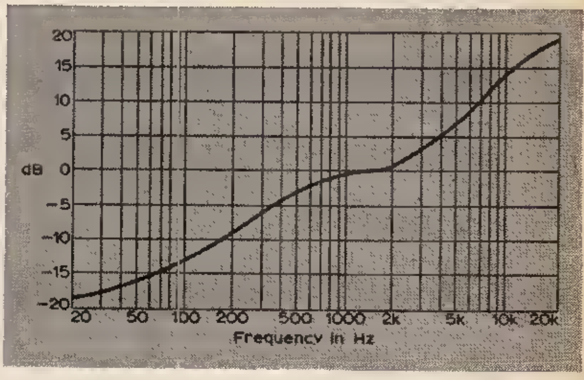


Fig. 4: Graph showing the standard RIAA recording characteristic

recording characteristic. The bass end of the spectrum is attenuated and the treble end is boosted. On replay, therefore, the bass needs to be boosted and the treble attenuated to secure a 'flat' audio output.

The standard recording characteristic is given in Fig. 4. This has an 'average' slope of about 4dB/

octave, but the RIAA equalising, as it is called, is very carefully engineered into the magnetic pickup input circuits of hi-fi amplifiers and good quality radiograms, etc., so that the response is exactly the reciprocal of that shown in Fig. 4. The net result is that a 'flat' output from the preamplifier which, of course, is the signal requirement of the control section and power amplifiers.

Now, it is the velocity of the imparted modulation which follows Fig. 4 curve, and because magnetic pickups yield an output proportional to the velocity of stylus deflection the output from the pickup applied to the equalised preamplifier is thus after the style of that in Fig. 4. Hence the reciprocal equalisation just referred to.

A piezo pickup, on the other hand, produces an output which is proportional to the amplitude of stylus deflection (not velocity). This implies that a piezo pickup playing a record cut to the standard RIAA response produces an almost 'flat' output without equalisation.

All piezo cartridges need to be loaded into a very high resistance of not less than 1MΩ and for the best results and to secure full advantage of the inbuilt equalisation and thus obtain a 'flat' output from a disc recorded to the RIAA standard.

A magnetic cartridge (whose source is inductive), however, is commonly designed to work best into a load of round 50kΩ. If it is loaded lower the treble tends to fall, while too high a loading can lift the treble end of the spectrum and incite undue 'ringing'. Conversely, a piezo cartridge (because its source is capacitive) exhibits falling bass and rising treble when loaded into a resistance significantly below 1MΩ or so.

The signal yield from a piezo cartridge, even when loaded low, is significantly in excess of that from a magnetic cartridge when playing modulation of a given velocity. This means, therefore, that the piezo signal might well have to be attenuated before being fed to the magnetic input, to avoid preamplifier overload.

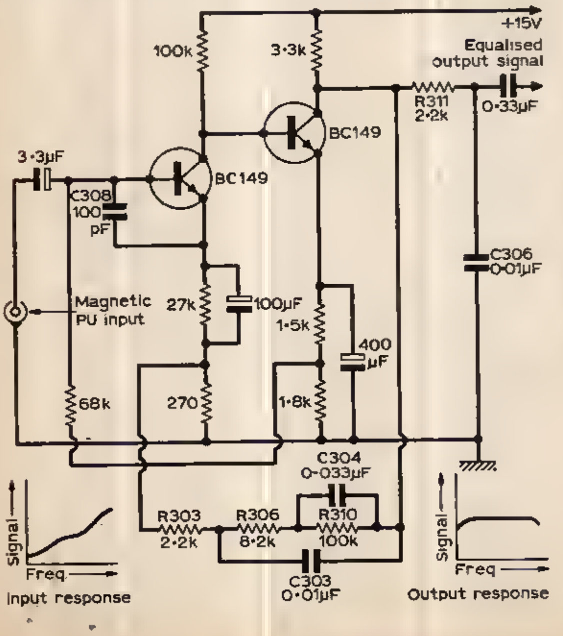


Fig. 5: Circuit of a pre-amplifier incorporating RIAA equalisation.

The peaks of signal can be clipped when the pickup signal veers towards the overload level. However, when an 'equalising' pad is included a degree of attenuation is automatic, so additional attenuation may not be necessary.

RIAA EQUALISED PREAMPLIFIER

Shown in Fig. 5 is the circuit of a fairly conventional RIAA equalised preamplifier. It is common to employ two transistors, at least, and in the circuit shown, R306/R310/C303/C304 network provides the frequency selective network, giving the necessary response characteristic inversely to correspond with the recording characteristic (Fig. 4). The overall effect is that the feedback increases with rising frequency and decreases with reducing frequency, thereby giving the required treble cut and bass boost.

R303 provides a 'flat' control of gain, and in some amplifiers the frequency selective network is switched out of circuit when the programme input signal requires a 'flat' response, a resistor such as R303 then being used to provide the appropriate input sensitivity voltage. Stereo equipment embodies two such preamplifiers, one for each channel.

The RC network C306/R311 provides a low-pass characteristic, preventing the response from extending too far above the audio spectrum. The 100pF capacitor (C308) connected directly across the base/emitter electrodes of the input transistor cuts the input response to radio frequencies and thus prevents the breakthrough of radio and television interference during low-level record replay.

RADIO/TV BREAKTHROUGH

Not all amplifiers are equipped with radio and TV filtering like this, and since the response of transistor stages can embrace the radio and TV spectrums, a symptom becoming increasingly common is, in fact, radio and TV breakthrough. This mostly happens when the equipment is switched to magnetic pickup and when it is operated relatively close to a powerful radio or TV station. It is encouraged by (i) the high sensitivity of the amplifier under this mode of operation and (ii) the relative ease at which the RIAA preamplifier can be pushed into non-linearity.

A filter which nearly always clears the trouble is given in Fig. 6. The circuit to the base should be broken and the 2·2kΩ resistor inserted in series,

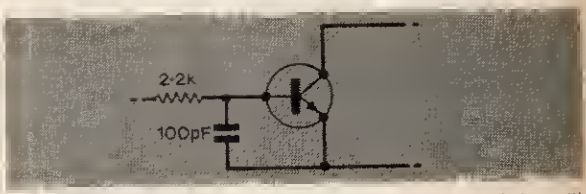


Fig. 6: A simple filter to prevent radio and TV signals interfering with audio amplifiers.

while the 100pF capacitor should be connected right across the base/emitter electrodes, as close as possible to the input transistor. Both channels should be so treated.

The RIAA preamplifier signals can get into trouble so if one channel of a stereo amplifier appears to be lacking in bass, with excessive treble output, when operating from a magnetic cartridge, then attention should be given to the preamplifier department of the affected channel. Excessive noise on the magnetic input is commonly caused by a defective preamplifier transistor or a 'noisy' collector resistor.

HI-FI SPECS

It is impossible to detail all the specifications relating to hi-fi equipment (further information on this score is given in **"Tuners and Amplifiers"** by John Earl, published by Fountain Press), but comment on a few of the more important ones would not be amiss.

Power Capacity. This is the maximum power that an audio section is capable of delivering with both channels running, the maximum being defined either to the level of sinewave clipping or to a specified value of distortion when the output is loaded by pure resistance of appropriate value in place of the speaker. The 'standard frequency' is 1kHz, but to obtain the **power bandwidth** the measurement is repeated at low and high frequencies.

Standard Output Power. This is 50mW (17dB/mW). However, in some instances values of 500mW (27dB/mW) and 5mW (7dB/mW) might be used, but the power to which any parameter (such as sensitivity) refers should be stated in the specification.

Input Sensitivity Voltage. This is the input signal at 1kHz required to yield the rated output power when the volume control is fully advanced, all filters 'out' and tone controls 'flat'.

Signal/Noise Ratio. This refers to the voltage due to components of hum and noise across the output load in terms of dB ratio to the rated output power and within the full noise bandwidth of the equipment. The volume control is generally fully advanced and the selected source input is either short-circuit or open-circuit (the former preferred since it avoids the pickup of spurious hum and noise components).

A ratio of 60dB, for example, implies that the power of the summed hum and noise in the output load is one million times below the full power of the amplifier.

Total Harmonic Distortion (THD). This is commonly measured through a distortion factor meter, in which a very sharply tuned filter 'notches out' the fundamental frequency, leaving only the harmonic components.

Intermodulation Distortion (IMD). Like THD, IMD is a function of amplifier non-linearity. This is commonly measured in terms of the amplitude of intermodulation components resulting from the introduction of two signals to the amplifier, so as to produce sum and difference frequencies.

S/N Ratio (FM). This refers to hum and noise relative to a stated modulation level (100% or 30%). Measurement is similar to that of S/N ratio of an amplifier, and the usable sensitivity of an f.m. tuner is commonly given as the input required for a S/N ratio of 45dB.

Owing to the wider passband involved and the action of decoding, a stereo receiver has a S/N performance below that on mono, particularly at the lower signal input levels, which is the reason why stereo receivers should always be operated with the best possible f.m. aerial system, consistent with the location and prevailing signal field on Radio 3.

END OF SERIES

NINE BAND RECEIVER—*continued from page 690*

AERIALS

The telescopic type aerial has a bracket, so that it can be bolted directly on the left hand side of the case, about 1in. from the back. An insulated socket is fitted on the side of the case for an external aerial. Many transmissions can be received at ample volume with the telescopic aerial alone but an external aerial will greatly improve the reception of weak signals.

DIAL SCALE

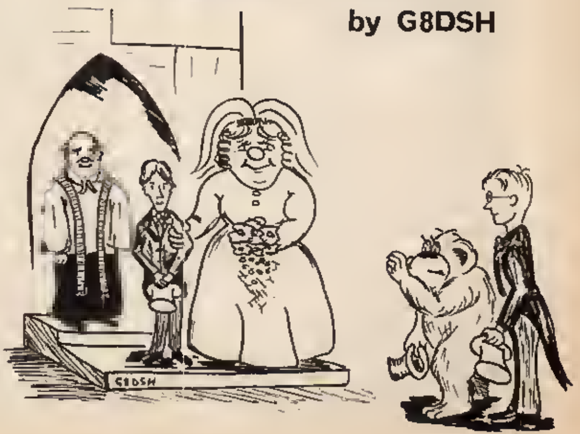
Because each of the nine bands covers a relatively small frequency range, the main tuning scale is fitted with a card marked 0 to 50.

The bandswitch has nine positions, and the card scale under it has ten frequency markings. The bandswitch pointer comes to rest between these markings, which thus show the approximate frequency coverage of that particular range. For example, if the pointer rests between 4·6 and 5·0, the range is 4·6-5·0MHz, while if it is between 5·0 and 5·6 the range is 5·0-5·6MHz, covered with the normal tuning control.

The full markings are as follows: 3·6—3·8—4·3—4·6—5·0—5·6—6·3—7·4—10—15. This scale is best put under the perspex. ■

MAXWELL

by G8DSH



"—a bit of a mismatch somewhere!"