# SERVICING

## AN INTRODUCTION TO FAULT-FINDING

**PART 4**

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**NOW THAT GORDON KING HAS COVERED THE BASICS OF FAULT-FINDING CO-AUTHOR 'MAC' HELLYER DISCUSSES THE PROBLEMS OF RECEIVER ALIGNMENT WITH PARTICULAR REFERENCE TO THE TEST EQUIPMENT NEEDED FOR THIS TASK.**

ENOUGH has been said by Gordon King in the earlier parts of this series to absolve me from a tedious description of the make-up of superhet circuitry. In this section, we shall now be able to concentrate wholly upon alignment of the a.m. and the f.m. receiver.

A little theory must creep in since the most practical of readers should still be blessed with some natural curiosity. We need to know why we are twiddling that screw, that slug, that bit of wire, and not just be content to follow a mechanical sequence of instructions.

Servicing consists very largely of using one's native wit to interpret or augment the information given by manufacturers. In many cases, handling a piece of equipment that may be obsolete or, even if new, backed by the most meagre data, one has to fall back on one's knowledge of basic principles and experience of designers' whims to solve some very tricky problems.

Our intention here is to provide a few short-cuts toward those neat solutions. So general principles have to be the order of the day. There will always be exceptions in design, so long as there are exceptions in men. Bravo! say I—there is no more hideous prospect than the "People's Set", which can be serviced by numbers, or, more likely if the double-entry cost-watchers have their way, thrown away when it goes wrong! We all saw what could happen, on page 1030 of the April issue of PW. ("The Committee Supet-FET".)

## AM ALIGNMENT

Gordon King has said, already, that a.m. receivers are still stuck with capacitive tuning, although the f.m. receiver, and, particularly, the combination a.m./f.m. set, may have tuning gangs plus variable inductors plus potentiometer plus fixed tuning all wrapped up in one package.

If alignment has to be carried out, begin by sorting out the a.m. section, identifying the stages (see Part 2) and then making up your mind what kind of circuit you are about to tackle. This is assuming that you are not able to get the manufacturer's detailed information, always supposing he has got around to preparing it for publication!

The tuning I have spoken about is the 'front-end' tuning, where the frequency of an oscillator beats with that of the incoming signal to provide a steady intermediate frequency, the i.f. So, before we can tackle the front end, we must make sure the several

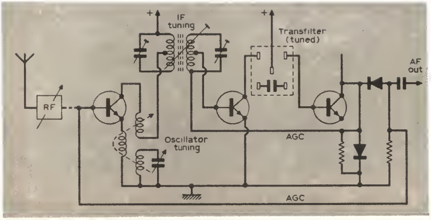



*Fig. 1: The skeleton circuit of the tuned section of a typical a.m. receiver. The fixed tuned Transfilter, now becoming quite common, helps to reduce the amount of re-alignment required.*

parts of the i.f. circuitry are doing their job. But before we can do this, it is necessary to check the audio section and the detector.

Let me refresh your memory with Fig. 1. Here we have a skeleton circuit of an a.m. receiver, showing the tuned circuits with which we are concerned here, the detector and a hint of the audio section that will follow. It is obvious that a signal injected at a post-detector stage must be at audio frequencies. In the old days, it was easy enough. A finger tapped on the appropriate valve grid, or on the 'hot' end of the volume control would produce a healthy 'buzz'. Mains pickup and the high impedance of the input circuits made this possible. With a battery-operated piece of equipment or the low-impedance circuitry of semiconductor devices, the 'disturbance test' type of operation is not so effective. It can, in fact, be positively dangerous.

## SIGNAL INJECTION

The answer is to inject a signal of known characteristic (even if unknown precise amplitude), simply to verify that the following stages are working. We are not interested so much, at this point, in their exact efficiency, their lack of distortion, their overall output. For the following tests we need some method of indicating variations of output, either at the final part of the receiver—the feed to the loudspeakers—or at some earlier audio stage, where the readings may be more convenient.

It must be stressed again that when signal injection methods are employed, we are not expected to measure the output accurately. As Gordon King has explained, the quality of one piece of test equipment is determined by (a) the standards to which one must test the circuit, (b) the quality of associated gear and (c) the standard of testing we wish to apply.

Signal injectors are the easiest of all test instruments to make and apply, and there have been numerous suggested circuits in PW. We shall skip lightly past the subject, pausing only to remark that if you are thinking of alignment, it can be argued that you will be using a signal generator. There are very few of these that do not incorporate an audio output facility. There is your post-detector tester, ready made.

The 400Hz or 1kHz note we hear from the loudspeaker is suitable for rough tests and basic alignment in an emergency. It is certainly no more than a guide for precise circuit adjustment of the modern set. Visual alignment checking is needed so a meter, or some other visual indicating device, will have to be used. So this is where the ordinary multimeter can be pressed into service.

With valved equipment, nothing is easier than a low a.c. voltage-reading meter (say from 0-5V a.c.) across the loudspeaker or a dummy load. The dummy load, it should be said, has not been outdated by transformerless output transistorised receivers. For test and measurement purposes, the output circuit should always be correctly loaded.

Figs. 2(a) and (b) show alternative ways of indicating audio output, for both valved and transistorised equipment. We include these notes on valved equipment simply because the accent here is on servicing and it is in the nature of things that servicing will be required more often on older equipment. Measurement of anode current in an output

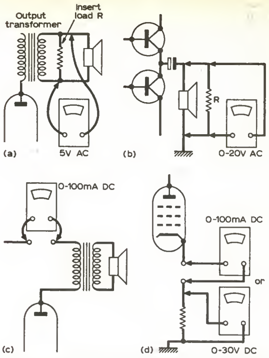



*Fig. 2: Measuring output, (a) across dummy load or shunting speaker, (b) across speaker of transformerless stage, (c) current indication in series with anode load, (d) in series with cathode or voltage across bias resistor.*

stage of valved equipment, either in the anode or cathode lead, is an alternative, where a low voltage d.c. meter, or a 0-100mA d.c. meter is available, Fig. 2(c) (d).

## MEASURING OUTPUT

Breaking into the output stages of a transistorised amplifier for such alternative readings is neither easy nor desirable. Because of the low impedances of emitter circuits, voltage variations are too small to be of any great value, and should, in any case, be stabilised.

But let's do things properly. Let us consider the output power that we should get, and make arrangements to measure that. There are two things to consider here: audio power measurement and indication of standard audio output. They are not the same. As Gordon King will be showing later in greater detail, measurement of audio power is not a simple process, and interpretation of results must be made with great care.

Briefly, the expected outputs from general apparatus would be: (a) small transistorised radios, 500mW to 1 watt (b) larger radios, 1 watt to 3 watts (c) tape recorders and record players, 2-6 watts (d) small amplifiers, up to 10W (e) larger amplifiers, 10 watts upwards.

Standard outputs are related to the sensitivity of the apparatus. For example, a radio may be quoted as having a sensitivity of 25$\mu$V for m.w. reception, 40$\mu$V for l.w. reception and 1$\mu$V for both s.w. and v.h.f. reception. Alone, these figures mean nothing. They must be related to the standard audio output and to other factors such as signal-to-noise ratio. In the case of these quoted figures, the audio output would be 50mW for a s/n ratio of 6dB, relative to the 0dB figure of 1$\mu$V.

This gives us a clue to the statement 'decibels below 1 volt' which may sometimes be used. 'Decibels below 1 milliwatt' is another alternative and 'field strength' yet another. The last term is employed to assess sensitivity when loop or ferrite rod aerials are used.

For now, we do not need to worry too much about all this. Practical service work very often consists of bringing up to scratch the circuits that may be only a little out of alignment. If components in tuned circuits have been replaced or if maladjustment has occurred, then the procedure is to check the alignment throughout and to make the small alterations found to be needed.

## VISUAL DISPLAY

The oscilloscope is invaluable here, saving hours of careful tabulation and giving both the facility of viewing the result of the input signal and of measuring it. A secondary facility, often overlooked, but quite important, is the ability we have, when viewing a trace, of determining how much output is signal and how much noise and distortion—common causes of faulty results when only a meter is used.

We shall later look more closely at this matter of noise and distortion assessment. For now, a brief note on the practical alignment of a typical receiver, using a standard signal generator and a measuring device, augmented by an oscilloscope. Response curves are the usual method of measurement and, very often, a manufacturer will give no more than the expected curves in his service manual, referenced to some level and bandwidth. It is as well to be clear at this point, therefore, what we mean by response curves, reference levels and bandwidth.

Fig. 3 shows a selection of the graphs one would produce by plotting the output from the receiver (vertical axis) against the frequency at which the signal was applied (horizontal axis). It is possible to produce these curves from careful and detailed measurements but it is much simpler to feed to the receiver a signal which varies regularly across the bandwidth, locking this to the timebase of the oscilloscope and displaying the output from the detector of the receiver. Such an input signal is obtained from a sweep generator, or 'wobbulator' (see page 1038 PW April 1971).

The response characteristic of a superhet receiver is mainly that of its i.f. circuits, for the r.f. circuits are not so sharply tuned. Quite often, response testing and alignment concentrates on the i.f. circuits, leaving the r.f. section of the receiver to be aligned on one or two spot frequencies and checking the padding and trimming of the oscillator.

The acceptance band of a receiver has to take in the sidebands of the transmission for full handling of the higher frequency components of the modulation, but if it extends too far beyond this, the signal-to-noise ratio will suffer. A perfect response characteristic—an impossible one—is shown in Fig. 3 (a). All the frequencies within the passband are received with the same sensitivity; those outside the passband having no effect. In practice, the response curve may be more as (b), where the 'usable' bandwidth is that between the −3dB points. This is where output power falls by 3dB or half its maximum value.

Note, however, that the response curve may be neither as flat as (a), nor as gently peaked as (b). In fact, it may be double-humped, as in (d). One important point here is that the reference point, relative to the −3dB level, is the centre frequency of the passband, and not the peak of the humps.

Merely to state the frequency limits at which a curve is 3dB down is not enough. This tells us what the gain of the receiver is, but not the extent of the rejection of unwanted frequencies. Always plot beyond the −3dB points, as shown in the accompanying curves.

Making response measurements of the a.m. receiver with a low audio frequency modulating signal (example: 30% modulation at 400Hz), we feed the signal generator to the mixer input, as shown in Fig. 4. It is essential that the impedance from which the signal is derived is as low as possible. In the mixer input, the tuned circuits will not be at the intermediate frequency, so the low impedance is needed. Hence the two resistors, Ra and Rb, where

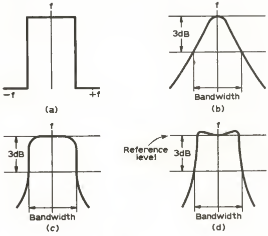



*Fig. 3: (above) Response curves, carrier frequency f with +f and −f representing bandwidth limits. (a) ideal curve, (b) peaked response, with bandwidth indicated at −3dB (c) flat tuning to give desired response, same peak level and bandwidth as (b) but quite different response. (d) double-hump tuning as approach to flat top response of (a)*

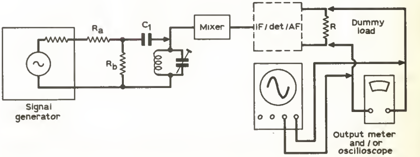



*Fig. 4. (right) Instrument set-up for measuring i.f. response. Note attenuator resistors Ra and Rb, and isolating capacitor C1.*

a reduction of the generator output impedance from the usual 50 or 75 ohms to as little as 10 ohms can be effected. The values are easily worked out: for a generator of 50 ohms output, to present a 10 ohm (very nearly) load to the mixer input, we need to make Ra around 40 ohms (nearest preferred value 39 ohms) and Rb 10 ohms. The choice of values gives a 10:1 voltage ratio also, just in case you want to work out sensitivity figures.

The value of C1 should be such as to make its reactance at the test frequencies no greater than 50 ohms. At an i.f. of 470kHz, C1 would thus be around $0 \cdot 01\mu$F. Its inclusion is to prevent the d.c. bias conditions being upset.

Disabling the a.g.c. is the next consideration although the method of disconnecting the a.g.c. line and putting a fixed bias in its place may not be so simple with modern sets. Sometimes the manufacturer will indicate a method of killing the a.g.c. action. The need to do so is evident from an understanding of a.g.c. action, which has already been described.

If we feed to a receiver aerial input a signal varying between say a microvolt and a volt, we may find that at around 5-10 $\mu$V input, a 2:1 increase in input produces very nearly a 2:1 increase in output. But after about 100 $\mu$V input, the curve relating output to input flattens drastically, and it needs a good deal more 'in' to produce just a little more 'out'. The a.g.c. curve, in other words has a definite 'threshold value' with two fairly linear slopes, above and below that threshold. In fact, a.g.c. "quality" is often defined in terms of the mean slope of the curve above the threshold.

Assuming first that the a.g.c. is prevented from working, our tests would comprise first setting the generator to the reference frequency, with its output adjusted so that at full receiver gain the rated full output is obtained. The generator output is then attenuated to produce the 'standard' output, 50mW. The receiver's gain control can be used to set the output indicator to a convenient value and then left strictly alone.

The generator is swung over the required frequency band and output plotted relative to the reference. The bandwidth is the frequency difference between the 3dB 'down' points.

If the a.g.c. cannot be 'killed', there are alternative ways of going about the checking. We can tackle the problem 'backwards', measuring for a constant output for a 3dB increase of input, with the attenuator of the signal generator set to increase the test input by 3dB, then the two limiting frequencies where the monitor reading is returned to the reference level define the bandwidth.

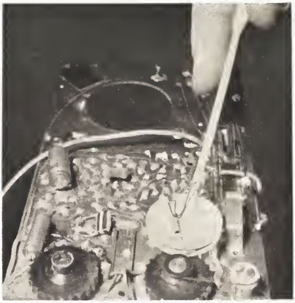
*Close-up of am./f.m. tuner showing part of a.m. ferrite rod aerial at left and drive cord and pointer.*

Another way of testing bandwidth without having to 'kill' the a.g.c. is to keep the carrier frequency of the generator constant and to vary the bandwidth. This cannot be done with the normal signal generator, as modulation frequency and depth are often fixed. But where a c.w. only output is obtainable and a separate audio generator is available to apply a varying input, then the r.f. generator can be set up to the central frequency and the modulation varied in frequency, without any change in depth, and a note made of the points at which the output reading (across the detector load, for utmost accuracy) is $0 \cdot 707$ of the reference level. These limits are the bandwidth, i.e., bandwidth is twice modulation frequency.

## CW TESTS

It is not so easy to align higher quality receivers. The sides of the response curve can appear deceptively steep, because of the relative phase shift of the sidebands. The way to overcome this possibility of error is to use a c.w. (unmodulated) input and to read off the d.c. voltage at the detector.

One snag: there may be some standing d.c. voltage. It can be allowed for and carefully taken into account by subtracting it from final readings. The use of a d.c. valve voltmeter or similar instrument allows us to back off the settings to obtain a new zero.



*Before attempting alignment it is essential that drums, cords, springs and attachments are in order. Always check traverse of pointer before making adjustments.*

Working on s.s.b. receivers can be a good deal easier. Better-class communications receivers work also in the single-sideband mode and these can be aligned by using the beat between the input signal and the internally generated carrier, with a.g.c. switched off—which is usually possible with these sets.

## PRACTICAL POINTS

Procedures must differ between makes and models. Some general rules follow:—

(1) Allow sufficient warming up time before making tests. On valved equipment, fifteen minutes for both receiver and test gear should be regarded as the minimum. Despite all the advertising, transistorised equipment does not 'warm up' to operating conditions 'in the twinkling of an eye'. One very famous hi-fi amplifier I recently tested took seven-and-a-half minutes for the current in the output stages to settle to a steady reading, and that is not exceptional.

(2) Check mechanical points. Dials and cursors, pointers and drums should be run from end to end of their travel and limits noted. Where datum points are provided by makers, these should also be checked before alignment commences. In general, maximum frequency (minimum wavelength) should be indicated when the capacitor plates of the usual ganged capacitor are fully unmeshed.

(3) Make any necessary adjustments to counteract backlash, so that a setting of the cursor or pointer accurately reflects the setting of the tuned circuits.

(4) Check before operations that the required trimming tools that are available. It is simply asking for trouble to use worn grub-screw drivers where hexagon-holed slugs are used, or when core slots are only suitable for miniature plastic tools. Some time ago *PW* presented a set of plastic trimming tools to readers. Mine are still in use, augmented from time to time by filed plastic knitting needles and crochet hooks.

(5) Cores of inductors, despite all our efforts and care, may jam. The only recourse then is to drill or chip them out, taking great care not to damage the former wall or the inductor. Resetting of new cores may need either a rubber band inserted in the core or the use of a non-hardening adhesive. There are core-locking compounds that provide an adequate fixing but still allow some adjustment.

(6) Finally—before starting, make sure that test gear is isolated and that there are no false return loops. Connect the neutral side of a.c./d.c. equipment to chassis if you have no isolating transformer and provide capacitive isolation, as previously described.

## GENERAL PROCEDURES

Consider a combination a.m./f.m. receiver, as shown in skeleton form in Fig. 5. Crystal filters are used widely and we can expect to find this trend growing. No alignment is normally required except for the last stage, which will be peaked up to the intermediate frequency. A little care is needed here and some 'swing' about the nominal frequency may be necessary. A good idea is to peak the last i.f. to the input from a weak signal after the rest of the alignment has been done, bringing it into tune only temporarily at first.

Where tuned circuits are used throughout, inject a signal at the frequency changer that will produce a 50mW output across the appropriate load. As power in watts is the voltage squared divided by the resistance, we can work out the required reading. (For 3 ohms this will be 0·387V, for 8 ohms, 0·633 volts and so on.)

A meter that has a full-scale deflection of around 2·5V a.c. is required. Exact readings are not important at this stage as our aim is to maintain the output at the same level while bringing the circuits into tune, turning down the input as the gain increases. For this, the volume control will be turned to maximum, and if there are tone controls fitted, the treble control will be adjusted for the least top-cut.

Tuned circuits should be adjusted for peak output, starting at the rearmost and working toward the mixer. After initial peaking, go back over these adjustments. With some sets, there may be a tendency for one tuned circuit to 'pull' another, and readjustment should be made until no further improvement can be gained.

Where the response curve is humped, two peaks will be found as the signal generator is swung over the passband. In this case, the middle position should be used. Tune for the slight dip between the peaks.

## IF REJECTION

Before readjusting the signal generator, remove it from the mixer input and apply the signal, still at intermediate frequency, to the **aerial** input, then tune any i.f. rejection circuit to give the **minimum** output. It is always wise to make this test early on, then rechecking after mixer alignment. For this test, increase the i.f. output from the generator and switch the receiver to the medium-wave band (where breakthrough could be bothersome), turning the tuning gang till the vanes are fully meshed, i.e. the low frequency end of the band.

Another rejection circuit that will be found nowadays is the 19kHz pilot tone filter. This is also tuned for minimum output with a strong 19kHz tone injected.

Alignment of the broadcast band is conveniently done at this point. Set the generator to around 600kHz (500m) and the pointer of the set to the same

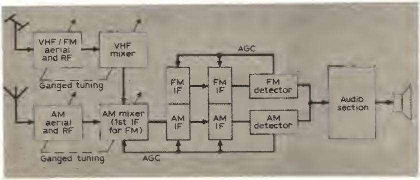



*Fig. 5. Block diagram of combined a.m./f.m. receiver, with switching omitted, as a guide to following the alignment procedures described in the text.*

frequency, after checking that it traverses the scale correctly, and reaches any datum points marked by the manufacturer with the correct scale indication.

Adjust the padder and/or the oscillator coil (if this is adjustable) and obtain maximum output. Then readjust to the other end of the band, setting the trimmer. Best procedure is to carry out these operations for the mixer first, then peak up the aerial circuits and return to the mixer for readjustment, then again to the aerial to make sure the circuits remain in tune. Adjustments of this nature take time and demand patience. Maybe this is why realignment of receivers can be a costly job! It is never good enough to make a perfunctory gesture of 'twiddling the cores'. The long wave adjustments can then be done.

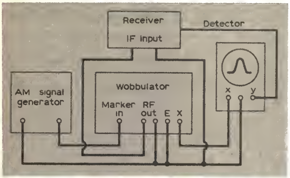



*Fig. 6 Instrument set-up for checking i.f. response of f.m. receiver.*

Do not attempt them in reverse order, as settings of the medium wave tuning can affect the long wave band. Similarly, where there are several short wave bands, first adjust the highest frequency band.

Long wave adjustment often consists of adjustment of one trimmer in the mixer circuits and one in the aerial circuits. There is rarely any need to check tracking over the band as carefully as one would with medium wave tuning, there being few stations available.

Short wave adjustment often requires slight movement of coil turns and care has to be taken with the dressing of leads. Tuning is considerably simplified by the omission of padders in the short-wave section of most receivers. Instead, we find coil adjustments, or core settings being made at the low frequency end of each band and trimming used at the high frequency end.

## FM ALIGNMENT

Most adjustments to f.m. tuned circuits are carried out nowadays with the aid of a wobbulator and oscilloscope. Here, we find the output displayed, the signal swept over the response band and variable capacitors and coil cores adjusted to obtain the correct response curve. Addition of an a.m. marker generator aids the set-up, and the inter-connection of these instruments is shown in Fig. 6.

Because the average serviceman is unlikely to possess a wobbulator, we shall concentrate here on the adjustment of f.m. circuits using only an ordinary signal generator and a high-resistance meter. A more tedious job, but practically as efficient.

First requirement is a d.c. voltmeter, capable of reading around 10 volts, with a 20,000 ohms/volt sensitivity at least. This is connected across the d.c. load of the ratio detector, the aim here being to keep the reading to a set level, determined by circuit characteristics, by turning down the generator input as the circuits are brought into line.

With the generator tuned to the f.m. intermediate frequency (10·7MHz), and with the modulation switched off, the signal is injected at the mixer and

*◀ Oscilloscope trace of response curve using wobbulator, with marker pip at top of curve (centre frequency f).*

*A similar response curve but this time the marker pip is placed at the —3dB level on one side of the curve. ▶*

the i.f. circuits aligned for maximum output. The correct procedure, again, is to start at the rearmost and work forward, but even more care is needed and constant rechecking is necessary.

If a ratio detector is used, the next step is to note the output reading from this 'peaked-up' process, transfer the meter to the a.f. output capacitor and note that the reading is now exactly one-half of what it was before. The ratio detector winding is adjusted to achieve this.

After this, repeat the steps until no further improvement can be gained. It is important to ensure that later steps do not impair earlier results; hence this need for repeated operations.

The ratio detector is finally balanced. The coil that gave its 'half-volts' reading earlier is now readjusted for a minimum reading. The mean of these two is calculated: i.e., halfway between the maximum and minimum voltages that can be obtained by adjusting the coil of the ratio detector. This is the setting for correct alignment.

**END OF PART FOUR**

**NEXT MONTH 'MAC' HELLYER WILL DISCUSS HOW FM STEREO SIGNALS ARE GENERATED AND TRANSMITTED. THEN FOLLOWS DETAILS OF TYPICAL STEREO DECODERS AND THEIR ALIGNMENT.**