Construction project:

Improved VHF-UHF masthead amp

Here's a design for an improved masthead amplifier, to boost signal strength and improve reception of TV and other signals in the VHF and UHF bands. It will cost you considerably less than commercially available units.

by ANDREW PALMER

For good TV and FM reception, you need to present the RF input of your receiver with signals that are as strong as possible compared with atmospheric noise and the noise that is inevitably generated inside the receiver's own 'front end'. Otherwise, in striving to amplify the weak signals, the receiver will have to amplify the front-end noise to the point where it will become evident on your TV picture as 'snow', or audible as 'hash' in your FM stereo program.

There are various kinds of situation where achieving a satisfactory signal-to-noise ratio can be a problem, but three of the most typical are as follows:

1. You are in the 'fringe area' with respect to the reception of the signals concerned, making it difficult to achieve sufficient signal strength – even with a large and elaborate antenna system.
2. You are in a reasonable signal area, but it is not feasible to use an antenna system capable of producing the strongest possible signals, and your TV or FM receiver is a little elderly. Although too good to throw away, its RF front end has a fairly high noise level – enough to cause an obvious deterioration in reception.
3. You are in a reasonable signal area and your antenna is producing fairly strong signals, but you need to feed a number of sets in various rooms of the house. After passing through the necessary splitter units and cable runs, with their inevitable losses, the signal levels reaching the receiver(s) are not strong enough.

The complete project consists of two parts: the amplifier itself, in the PVC tube in the foreground, and the power feed unit.

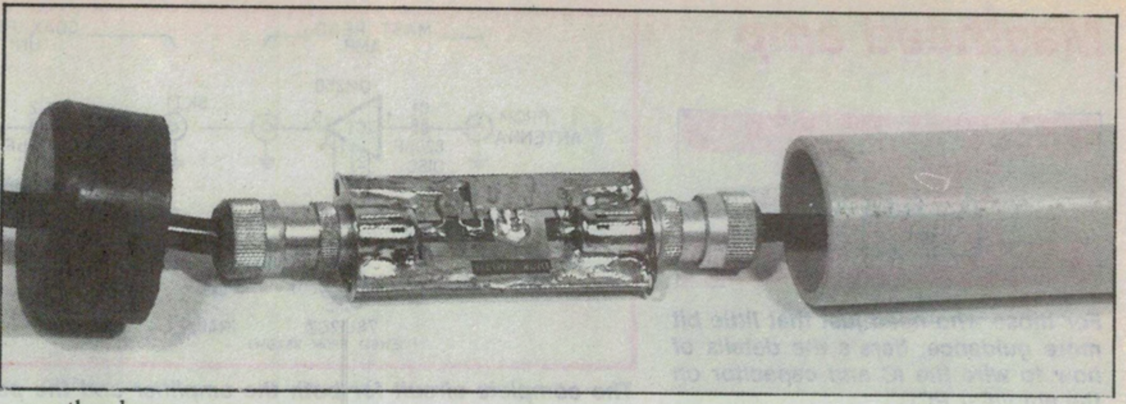
In all of these common situations, reception can generally be improved quite noticeably by fitting a wideband RF preamplifier, preferably at the top of the antenna mast. In other words, a 'masthead amplifier'.

Why should it be at the top of the mast? Basically, because this allows it to amplify the signals picked up by the antenna before they suffer from any attenuation or other deterioration due to the cable and things like splitters.

Fairly obviously, the masthead preamp can't improve the basic ratio between signals and noise as picked up by your antenna. In fact it will inevitably make things slightly worse, by contributing some extra noise of its own. But by placing it as near to the antenna as possible, we maximise the ratio between received signal strength and amplifier noise, and at the same time boost the strength of the signals to be pumped down the cable. Any attenuation introduced by the cable system will therefore affect both the amplified signal and amplifier noise equally, without affecting the ratio between them.

With the alternative approach of fitting an amplifier down at the receiver end of the cable, the signals will already have suffered some attenuation by the time they reach it. This will immediately provide a poorer ratio between the signal at the input to the amplifier, and its own inherent noise – preventing it from giving as much improvement.

A look inside the PVC tube, showing the small amplifier PCB and the way that the cables connect to it via co-ax plugs and sockets.



By the way, although a masthead amplifier inevitably contributes some noise of its own, this is quite small and typically rather less than that added by the tuner section of a TV receiver – particularly if the receiver is not one of the latest models. And of course fitting it to the top of the mast allows it to operate on the signals at the most favourable point.

So if you're in a fringe area, or have a less-than-ideal antenna system with a slightly older receiver, or need to feed the signals through quite a few splitters and cables, a masthead amplifier could well give you noticeably better reception.

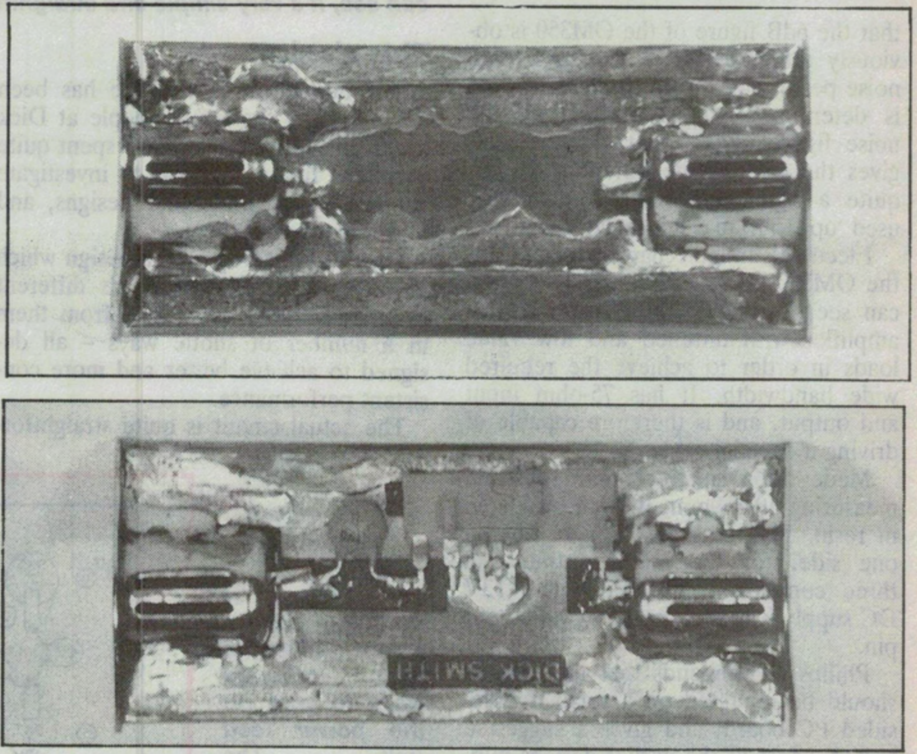
How about the flip side – does a masthead amp have any drawbacks? Certainly. Because they are a wideband amplifier, handling all the channels together, a really strong signal on one channel can cause amplifier overload and produce interference with the other channels.

It's *not* likely to be of much benefit if you're in a strong signal area, or where you have one really strong local signal and you're trying to improve the reception of much weaker signals. Unless you take special steps to prevent the strong signal from overloading the amplifier, it could well make things worse rather than better.

The same tends to apply where you have a strong local VHF signal from a primary transmitter, and some weaker UHF signals from translators.

Of course a masthead amplifier can't in itself do much with other kinds of reception problems either – like 'ghosting', which is caused by multiple versions of the same signal coming by different paths. With this kind of problem, all the amplifier might let you do is swing the antenna around to a position which minimises the ghosting, making up for the reduction in wanted signal strength with its additional gain.

A masthead amplifier isn't a universal cure-all, then, although it can improve reception in a lot of situations.



Two close-up views of the amplifier PCB, showing the component side (above) and the ground-plane side (top). Only four actual components are needed: the hybrid IC, a capacitor and two co-ax sockets.

About masthead amps

There have been quite a few designs published for VHF-UHF masthead amplifiers, in various magazines. The last one published in *Electronics Australia* was in the August 1979 issue, although a similar Booster/Distribution amplifier designed to be mounted inside the roof (rather than at the masthead) was described in the March 1987 issue.

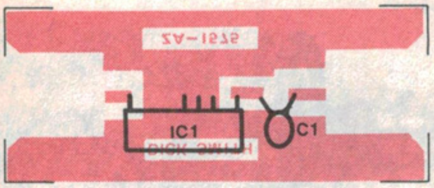
Most of the designs published in Australia in the last 10 or so years have been based on one or another of a family of hybrid VHF/UHF wideband amplifier IC modules manufactured by Philips Components – the OM300 series. These devices are expressly designed for this kind of use, offering good amplification and low noise performance up to about 860MHz.

The current design is no exception, using the device that has probably been most often used: the OM350. This provides typically 18dB of gain over the band from 40MHz to 860MHz, with a noise figure of 6dB.

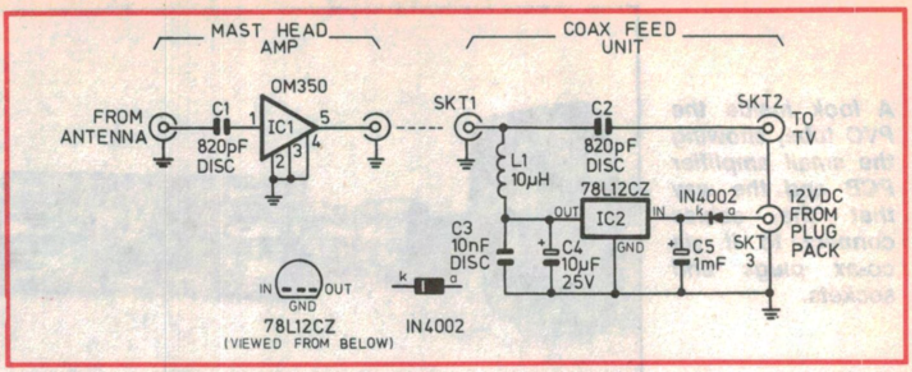
Incidentally, *noise figure* is a measure of the noise introduced by the amplifier itself. It is actually the ratio of *input* signal-to-noise ratio to *output* signal-to-noise ratio, so that the lower the noise figure the better. An ideal amplifier would inject no additional noise of its own, so that the ratio between input and output signal-to-noise ratio would be unity or 0dB.

The UHF tuners in many older TV receivers typically have a noise figure of somewhere between 11 and 14dB, so

Masthead amp



For those who need just that little bit more guidance, here's the details of how to wire the IC and capacitor on the amplifier PCB.



The complete circuit for both the amplifier and the power feed unit. As you can see, it's very simple and straightforward.

that the 6dB figure of the OM350 is obviously rather better. Since the overall noise performance of a receiving system is determined almost entirely by the noise figure of its input circuitry, this gives the OM350 the potential to give quite a significant improvement when used 'up front' in a masthead amplifier.

Electrical and mechanical details for the OM350 are shown in Fig.1. As you can see, it is basically a two-transistor amplifier with untuned and low value loads in order to achieve the required wide bandwidth. It has 75-ohm input and output, and is therefore capable of driving a co-axial cable.

Made on a small ceramic substrate measuring 19 x 9mm, it is encapsulated in resin. Five pins are brought out on one side, for the input, output and three common connections. The 12V DC supply is fed in via the signal output pin.

Philips recommends that the OM350 should be mounted on a small double-sided PC board, and gives a suggested layout. Most of the earlier designs published have used this layout or something very close to it, and have generally given reasonable results – at least for some constructors. However others have found the results disappointing, and there have been suggestions that minor layout and construction variations could have caused troublesome peaks and notches in the response.

Although on the surface there's not much involved in using the OM350 in this kind of application, it's actually a good deal more critical than you'd think. At UHF, an extra millimetre of lead length or PCB pattern can resonate with stray capacitance, to produce quite significant changes in gain at certain frequencies. Similarly even short lengths of signal path which do not maintain the correct characteristic impedance level can produce mismatch reflections, setting up standing waves and again producing undesirable peaks and notches.

This design

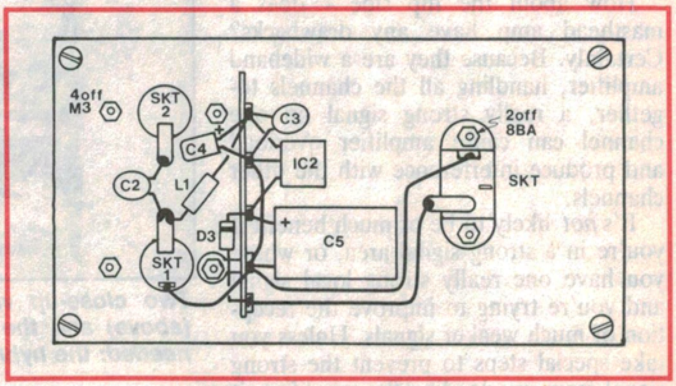
The design described here has been developed by the R&D people at Dick Smith Electronics, who have spent quite a deal of time and effort to investigate the problems with earlier designs, and find ways around them.

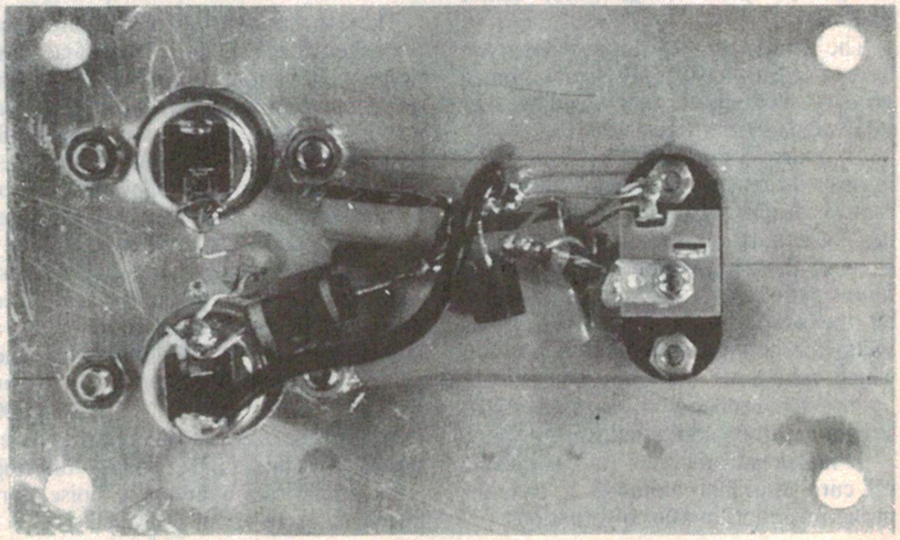
They've ended up with a design which may not look all that much different from the others, but differs from them in a number of subtle ways – all designed to achieve better and more consistent performance.

The actual circuit is quite straightforward. The OM350 itself forms the heart of the masthead amplifier proper, with an input coupling capacitor C1 to prevent its bias from being disturbed by the antenna or its balun. Power to the OM350 is sent up the co-ax cable from a small matching feed unit, via shunt inductor L1. Output coupling capacitor C2 again prevents the DC supply from being disturbed by the input circuitry of the receiver.

The DC power is derived from a standard 12V DC plug pack supply, with a small three-terminal regulator

The diagram at right and picture below illustrate two different ways to wire up the power feed unit. The approach at right gives a neater result, however.





chip IC2 used to provide smoothing and regulation. Diode D1 is used to prevent damage to the regulator if the plug-pack polarity is accidentally reversed.

So there's nothing terribly different about the new design in terms of its circuit. It's in the area of physical layout that it differs, particularly for the masthead unit itself. Great care has been taken to minimise excess lead lengths, and reduce any discontinuities in terms of characteristic impedance.

As with the original Philips recommendations, a double-sided PCB is used. However in this case the OM350 and its input capacitor are not mounted on the opposite side of the board from the copper tracks. Here they are mounted directly on the track side, to allow even shorter lead lengths.

This approach has a number of other advantages as well. One is that there is less disturbance to the 'ground plane' action of the copper on the other side of the board. Another is that the signal tracks can be more easily designed to function as striplines of the correct impedance, to provide fewer discontinuities in the signal path.

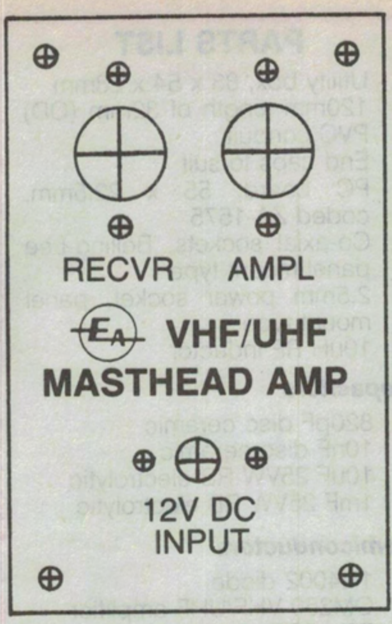
To improve the performance still further, the DSE people have designed the PCB so that the co-ax connectors mount directly to it in axial fashion, again with minimum disturbance to the characteristic impedance in the signal path. The outer earthed sleeves of the sockets can also be bonded directly to the 'ground plane' copper on each side of the board, for minimum inductance.

And finally, to make sure that the 'ground' copper on both sides of the PCB does indeed provide a true unipotential ground, the two are bonded firmly along both sides by lengths of copper shim soldered full length.

All of these steps have produced a design that is straightforward and quite easy to reproduce, yet provides a consistent high order of performance. The measured response of all units produced to date is within 1dB from 10MHz to typically 1GHz. There is only one small dip, of less than 1dB, at around 630MHz – which does not appear to be amenable to easy removal. This has no noticeable effect, however.

This performance appears to be significantly better than has been achieved by most previous designs. In fact it is achieving very close to the maximum performance possible from the OM350 – but of course this will depend on you wiring it up in the correct fashion. More about this shortly.

By the way, the PCB design for this project is the property of Dick Smith Electronics, and cannot be reproduced commercially by other firms.



Above: Here is the front-panel art for the power feed unit, actual size. A photocopy makes a handy template when drilling the front panel. At right is a view of the final panel after assembly.

The board is designed to be housed in a short length of PVC electrical conduit, with matching tightly fitted end caps to keep it waterproof. The idea is that the input and output co-ax cables pass through the end caps, and then terminate in plugs which mate with the sockets on the PCB. The complete assembly can then be put together inside the PVC tube, with 'Silastic' or similar sealant around the cable entry holes and the end cap edges. A strap clip can then be used to mount the amplifier on the mast, near the antenna terminals.

The power feed unit is housed in a small 'UB5' size utility box, measuring 83 x 54 x 28mm. As there are very few components involved in this unit, they are simply wired point-to-point.

Construction

The most critical part of the project is the actual masthead amplifier assembly, of course. But this needn't present any problems, provided that you tackle it in a logical fashion.

First cut the copper shim into two strips 55mm long by 15mm wide. Crease these down the centre, and bend them around the edges of the PCB so that they lie flat on the copper of both sides. Then solder both of them carefully along the full length of both sides, so that they each bond the two copper laminates together.

Next take the two Belling-Lee panel-mount sockets, and solder them carefully into the appropriate cutouts at the ends of the PCB. Take care to position them with the centre spigot just resting on the central stripline track, so that it won't be moved out of position during the soldering. Note that the outer sleeves of the sockets should be soldered to the adjacent 'ground-plane' copper along both sides of the sockets themselves, and on both sides of the PCB as well.

With all of this 'heavy' soldering done, you can now solder in the OM350 and its input coupling capacitor C1. For both of these, the idea is to trim their leads as short as possible, while still providing *just enough* exposed metal for soldering to the PCB tracks (say 1.5 to 2mm at most). Then you do the actual soldering as quickly as possible, so that the components are not damaged by overheating.

Note that the five pins of the OM350 are not arranged symmetrically. The input pin and the three earthing pins are close together near one end, while the output pin is further away at the other end. Make sure you wire it the correct way around, with pin 1 nearest capacitor C1.

Assembly of the power feed unit involves little more than drilling and reaming out the holes for the three sockets, using a photocopy or tracing of the front panel artwork as a template.

Then you can carefully stick on the Dynamark dress panel, mount the sockets and wire things up.

Wiring of the small components is a little tricky here because of the point-to-point wiring, but shouldn't present any problems if you use the wiring diagram and internal photograph as a guide. Two lugs cut from a small 7-lead tagstrip are used to support the components as shown.

The main point to watch from a performance point of view is that the leads of coupling capacitor C2 are again kept as short as possible, to minimise series inductance. To make this possible, the centre spigots of the sockets should be bent over towards each other. Then the capacitor leads should be cut to the shortest possible length which still allow C2 to span between the two. The other things to watch are that regulator IC2 is connected into circuit correctly, and that diode D1 and electrolytic capacitors C4 and C5 are also connected in the right way round.

PARTS LIST

1	Utility box, 83 x 54 x 28mm
1	120mm length of 32mm (OD) PVC conduit
2	End caps to suit
1	PC board, 55 x 22.5mm, coded ZA-1575
4	Co-axial sockets, Belling-Lee panel mount type
1	2.5mm power socket, panel mount type
1	10uH RF inductor

Capacitors

2	820pF disc ceramic
1	10nF disc ceramic
1	10uF 25VW RB electrolytic
1	1mF 25VW RB electrolytic

Semiconductors

1	1N4002 diode
1	OM350 VHF/UHF amplifier
1	78L12CZ regulator

Miscellaneous

Length of copper shim, 110mm x 20mm; small 7-way tagstrip; dress panel for utility box; machine screws and nuts, etc.

Testing & installation

When both units are finished in the electrical sense, it would be a good idea to connect them temporarily together via a short length of co-ax, and try them out to make sure everything is working correctly. It is better to do this *before* you fit the amplifier unit into its protective tube, and mount it up on the mast!

The easiest plan is to connect the amplifier and power feed unit into the antenna lead right at the receiver, and then use the receiver to check that they're working. With power supplied to the feed unit from a 12V DC plug pack, the signals fed to the receiver should be noticeably stronger via the amplifier setup than with direct input from the antenna.

If all seems well, you're now ready to fit the amplifier unit into its housing and instal it up on the masthead.

The procedure here is to first drill a hole in the centre of each of the PVC end caps, just large enough to take the co-ax cable snugly. Then you'll need to cut the antenna downlead, say 30cm or so from the antenna end, and poke each of the two cable ends through a cap (from outside to inside).

This done, you then fit a Belling-Lee type co-ax plug to each one, soldering the connections carefully. The PVC tube is then slipped over the amplifier board, and the plugs fitted into the appropriate socket at each end of the board to complete the connections. After this the end caps can be slid along the cables and over the ends of the PVC tube, to complete the housing and hold everything together. The length of the tube is carefully set so that when the caps are fully on, they will hold the co-ax plugs firmly in the amplifier sockets.

The final step is to add fillets of 'Silastic' or similar sealant around the cable entry points and the edges of the caps, to seal the complete unit and keep out moisture. It would be a good idea to add a dollop of the same sealant to the antenna end of the short input cable, to prevent moisture from seeping down inside the co-ax.

Needless to say the amplifier unit is mounted up on the mast near the antenna terminals, using a strap clip around the outside. The power feed unit is located at the receiver end of the cable for a single-cable system, or just before the splitter unit if you are using one. If you're using more than one splitter, the feed unit will need to be fitted just before the *first* splitter encountered by the signals as they pass down the cable.

That's about it. There's nothing to adjust – just hook it all up, apply the 12V power to the feed unit and away it goes.