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Homebrew

Boxing up the power and SWR meter

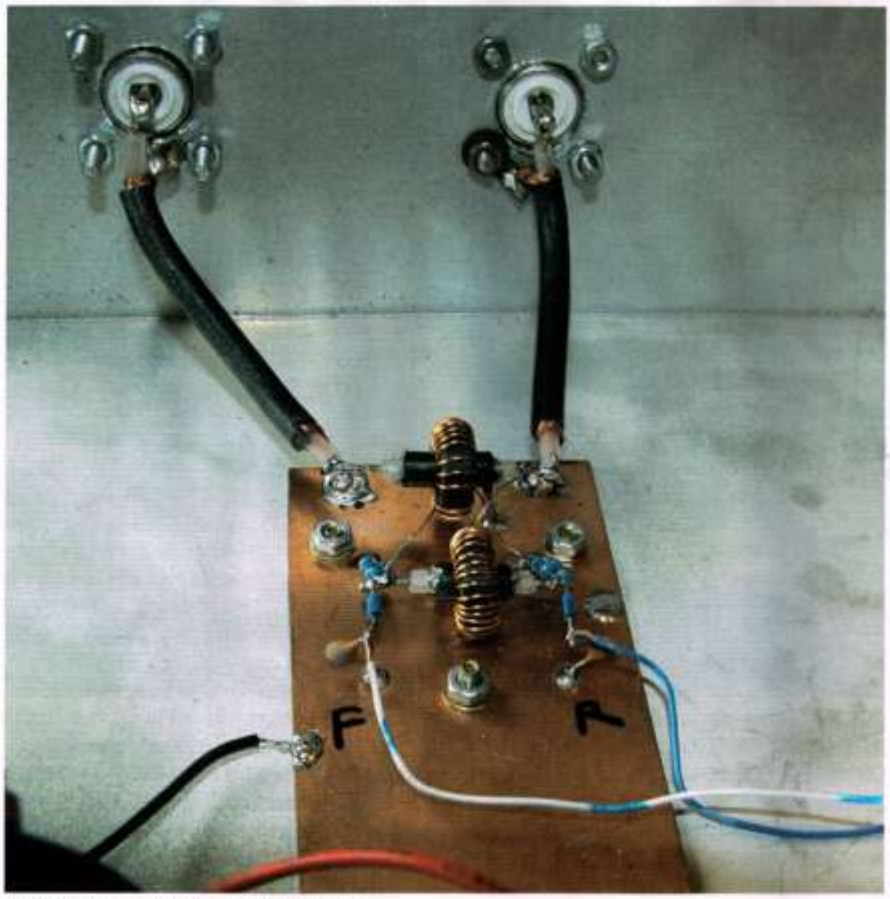

PHOTO 1: Assembled directional coupler.

RECAP. Over the last couple of months, we have looked at power measurement, RF couplers and various types of directional coupler. Our experiments have shown that couplers based on resistive attenuators are inherently broad-banded. Couplers based on transformers or capacitors will have limited bandwidth. It may be possible to achieve good performance over several octaves or perhaps even several decades of bandwidth, provided that great care is taken in the design and construction of the coupler circuit.

RF couplers are generally quite simple devices, often consisting of nothing more than a few turns of wire on a ferrite core. It is possible to optimise the design for a particular application. Transformers wound on low-to-medium permeability cores tend to have good performance at HF/VHF. The length of the wires used for transformer windings should be kept as short as possible. In practice, this means that VHF transformers often use a single turn for one winding and a relatively small turns ratio. This results in a relatively low coupling factor when the transformer is used as an RF coupler. At LF/MF, the requirements are completely different. The high inductances required for LF transformers call for high permeability core material and a relatively large number of turns. To cover all frequencies from LF to VHF, some compromises must be made.

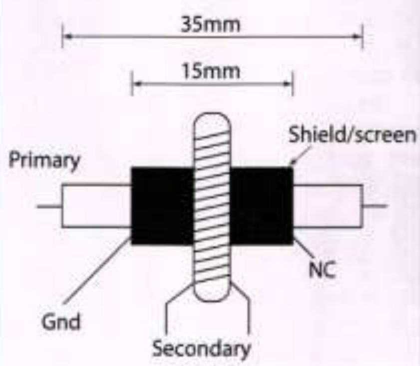

FIGURE 1: Transformer construction details.

The choice of core material can be critically important. The readily available toroid cores are FT** ferrite and T** powdered iron. **Table 1** shows permeability values for the most commonly available types. Further details for each individual core size and type is available from the Toroids Info website **[1]**. For most constructors, the best core for LF/HF transformers comes down to a choice between Type 43 or Type 61 ferrite toroids. Other, more exotic, ferrite mixes may well be more suitable, but they are not so readily available.

PROJECT. This month's construction project is a HF directional wattmeter and SWR meter. The directional coupler at the heart of this project is a 'Tandem Match' type as discussed in last month's Homebrew. The two identical transformers are wound on FT50-43 ferrite toroids. The current transformer T1 primary is a single turn consisting of a 35mm length of RG58 or similar 50Ω coax cable. The secondary is 26 turns of 0.375mm (diameter not critical) enamelled copper wire (Maplin YN86T or similar), equally spaced around the toroid core. The transformer construction details are shown in **Figure 1**. The voltage transformer T2 is identical, except that the single turn is the secondary winding in this case.

To be compatible with my existing transmitting equipment and licence conditions, the meter should be able to measure power up to 400W. This is 200V peak or 141.42V RMS in a matched 50Ω line. The transformer turns ratio of 26 gives a coupling factor of just over -28dB. It is quite easy to modify the design for a different coupling factor. For various practical reasons, most RF couplers used in HF power meters use a coupling factor somewhere between -20dB (10:1 turns ratio) and -30dB (32:1). Lower attenuation values could result in excessive power levels at the detector, while higher attenuation calls for unreasonably large turns ratios (100:1 in the case of a -40dB coupler).

Figure 2 shows the schematic of the power/SWR meter. The circuit is very easy to build and produces consistent results provided that good HF/VHF practice is followed. Keep ground connections short, straight and direct. The coupled ports are terminated by parallel pairs of 100Ω, 0.6W metal film resistors (Maplin M100R or similar). The RF detector diodes are 1N5711 or BAT43 Schottky types. A well matched pair

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PHOTO 2: Cutting the round hole for the meter movement.

PHOTO 3: Rear panel, with one socket installed.

of point-contact germanium diodes like OA91 or 1N34 should also work well in this circuit. Transmitter and load connections are via chassis-mounting SO-239 'UHF' type coax sockets. The assembled directional coupler is shown in **Photo 1**.

Details of the Forward/Reflected and Power/SWR switching are also shown in Figure 2. The microammeter is a 200μA moving coil type. A different meter can be used if the Adjust resistances (2k2 & 100k) are scaled accordingly. Separate pots are provided for calibrating the power and SWR ranges. The SWR set/calibrate pot is mounted on the front panel. The pair of forward-biased diodes across the meter terminals provide some protection against extreme overload. The switches are simple SPDT or DPDT types.

My meter has a single power range from 0-400W. It would be relatively easy to add one or more ranges using a multi-pole switch (one pole for each range) and separate calibration resistances for each range. Beware of trying to cover a very large power range unless you use some form of compensation for detector diode non-linearity (see September/October Homebrew). The meter is quite accurate at power levels above 10W.

The voltage drop across the detector diode junction is around 100-200mV at low current levels. 0.2*26= 5.2V peak on the main through-line = 270mW. At this level, there will be zero watts indicated on the meter.

METAL BASHING. For our previous projects, I have used both home- and commercially-made metal enclosures. For this project, I have chosen to use a rather fancy off-the-shelf project box. As the new power meter will be an important part of my shack equipment, the extra cost and the effort required to label the controls properly can probably be justified. The box is a Maplin LH40T. The base and front panel are aluminium; the top cover is vinyl-covered steel.

Cutting large holes in sheet metal is one of the more difficult jobs for the amateur constructor. Small round holes with a maximum diameter of 10-12mm or less are easily made using a drill. Larger holes or rectangular apertures are much more difficult to make unless you have access to specialised metalworking tools. I use a sheet metal nibbling tool for cutting out large or odd-shaped apertures. This approach is quite slow, but it leaves a reasonably smooth edge to the cut aperture. Any slight rough edges can be cleaned up with a file. I have not had much success with alternative methods like a jigsaw or hole cutting attachments for a power drill; these have been ineffective and in some cases quite dangerous. High quality hole punches are probably the best solution, although this calls for a separate and possibly expensive tool for each size and shape of aperture. Regardless of which method you use, always wear eye protection when using metalworking tools.

Photo 2 shows how I cut the round hole for the meter movement using a sheet metal nibbling tool. You can see the 8mm starting hole at the centre. The holes in the back panel for the SO-239 sockets were drilled out to 8mm using a power drill and then opened out to 14mm using a tapered reaming tool. This is a hand tool and not a drill attachment. Square sockets with four holes for the mounting bolts are always preferable to the cheaper single-hole mounting sockets. This is particularly true with PL259/SO239 connectors. Cheap and nasty plugs have a tendency to jam

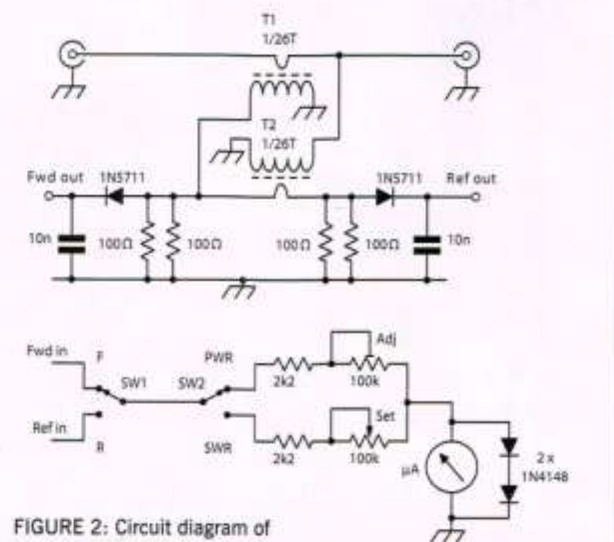

FIGURE 2: Circuit diagram of the power/SWR meter.

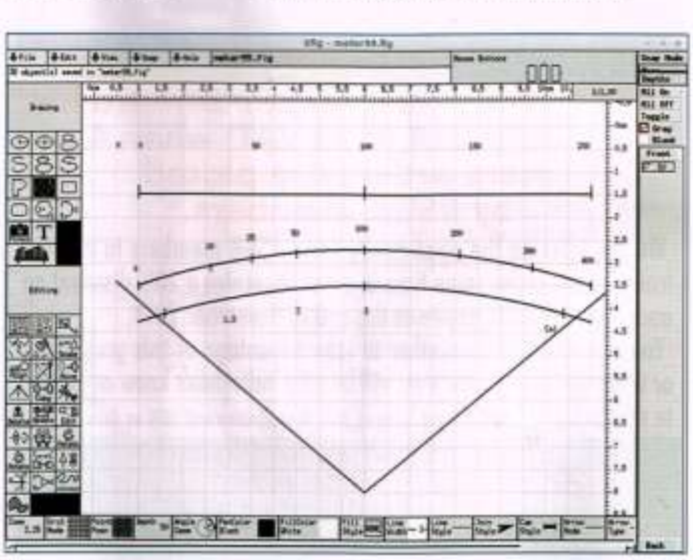

FIGURE 3: Producing a meter scale in *Xfig*.

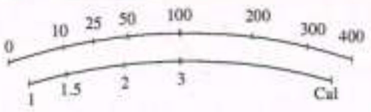

FIGURE 4: Finished meter scale.

$$\rho=\sqrt{\frac{P_{ref}}{P_{fwd}}}$$

$$VSWR=\frac{1+\rho}{1-\rho}$$

$$\rho=\frac{VSWR-1}{VSWR+1}$$

FIGURE 5: Useful formulae for calibrating the meter.

in the socket. The extra force required to remove a stuck plug will often unscrew the socket from the panel. At best, this can be an inconvenience, in the worst case, a twisted socket could damage components inside the enclosure. **Photo 3** shows the back panel with one socket installed.

PAINTING. As the case was supplied with a protective film over the aluminium parts, the metal was clean and free from scratches. To prepare for a coat of primer, the surface was rubbed smooth using fine 800-1200 grade wet or dry paper. Spray painting is another tricky area for the typical home constructor. Unless you have an air compressor and a spray painting gun, you will probably be using a 'rattle-can'. I used car primer from a spray can. Aerosol paints are mixed very thin so that they don't block the small spray nozzle. This makes them very prone to paint 'runs'. Apply several thin coats and leave a few minutes between each coat. The paint is less likely to run if the surface is flat rather than vertical. If possible, do your painting on a warm dry day (some chance!).

Wear a mask and make sure you have adequate ventilation. Let the primer dry fully before giving a rub of fine wet paper (800-1200). Make sure the panel is clean and dry before painting. I usually use car paint for my projects. The local auto factors sells off the unfashionable colours at a very low price. In this case, I gave the front panel a couple of coats of Rustoleum gloss paint. The colour is Winter Grey, which matches the colour of my HF transceiver (February 2012 and **[2]**). The Rustoleum paint takes a long time to dry. It is best to wait at least 24 hours before doing any further work on the panel.

There are several ways of applying labels to a painted panel. Label tape systems like Dymotape or Brother offer a convenient solution. I'm not too keen on this approach unless the colour of the tape is a very close match to the panel colour. I have used iron-on toner-transfer film for PCB etching and for 'silk screen' layer labelling of home-made PCBs. I would hesitate to use a hot clothes iron on a recently painted panel. Of all the labelling methods I have used, I still find Letraset or similar types of rub-on transfers tend to provide the best results. The panel of the meter was labelled using Letraset 5mm Helvetica Bold transfers. Once the paint was fully dry, the letters were rubbed on carefully using a ball point pen. There are symbols and punctuation characters at the bottom of the Letraset sheet such as £, $, ; etc. As you are unlikely to need these later, you can use them for practice before tackling the final job.

Once the panel has been labelled, you can give it a few coats of clear lacquer to protect the lettering and paint. Be very careful at this stage. The thinner in most spray lacquers will melt the plastic lettering if you start with a heavy coat.

Give the panel a very light 'dust coat'. Let this dry for a few minutes before applying several light coats with drying time between each coat.

TABLE 1: Permeability values for the most commonly available core types.

Ferrite	
Type 43	$\mu_i = 800$
Type 61	$\mu_i = 125$
Powdered iron	
Type 2	$\mu_i = 10$
Type 6	$\mu_i = 8.5$

PHOTO 4: The finished power/SWR meter.

THE METER SCALE. If you are clever enough to do the maths in your head, you could probably get by with using the standard microamps scale in the meter. For those who are not so gifted, a properly calibrated meter scale gives a nice 'professional' touch to your project. The internet search engines will find a nice selection of ready-made meter scales for power and SWR. If you are lucky, you might even find one to suit your project. Software for creating meter scales is also available from several sources. I have found that a standard vector drawing programme like *Xfig* (running on Linux) has everything I need to produce meter scales. I also use it to produce schematics and other line drawings. **Figure 3** shows a simple way to produce meter scales using *Xfig*. Accurate measurement of the original meter scale is the key to success. The Arc drawing tool in *Xfig* provides a very easy way of producing curved lines based on three points. Once you have the measurements of the original scale, it is quite easy to make a replica with your own custom values. **Figure 4** shows the finished scale when all the guide markings have been removed. This can be glued into your meter in place of the original scale. Tip: use a glue stick instead of a stronger adhesive. It may take more than one attempt to achieve accurate calibration.

If your meter has a metal back-plate for the original scale, these can usually be reversed so that you can stick your new scale on the back of the plate. This avoids damaging the original scale. The assembled project is shown in **Photo 4**.

SCALE CALIBRATION. Assuming you have a good quality meter that shows linear needle deflection with increasing current, the power scale will follow a square law. In my case, for a maximum of 400W at the top of the scale, 100W will be mid scale and 25W at 25% deflection. Cheap meters can be quite non-linear. They are still useful, but they must be calibrated individually for accurate results. In any case, it is a good idea to check your meter at several power levels and several different frequency bands to ensure it is behaving as expected.

I used a 50Ω dummy load and a peak reading voltmeter (September 2014) to calibrate my meter. The SWR scale was calibrated using the formulae in **Figure 5** as a guide. As a starting point, for a meter that is adjusted for set/calibrate at full scale, the SWR=3:1 point will be at the mid point of the scale.

WEBSEARCH

[1] www.toroids.info
[2] http://homepage.eircom.net/~ei9gq/installed.jpg