A POOR MAN's ANTENNA ANALYSER

(The RSGB and RadCom were given priority over publication of this article, but after many months of "inaction", I have decided, for the benefit of fellow amateurs, to publish it myself on this web-site)

(With sincere thanks to that outstanding engineer/designer, Jim Tregellas VK5JST (1), whose original work inspired me, for his patience, advice, understanding, tolerance and good humour in answering my many e-mails instead of telling me where to go!)

PART 1

With being a "canny Scot" (not to mention an O.A.P radio amateur), perhaps comes a certain increased motivation to look for cheaper, which in turn generally means simpler, solutions to problems which confront me in this life-long, yet still stimulating hobby of ours.

I am in no doubt that, as a result of the lack of proper measuring equipment, mostly limited to a home-brew multimeter and a G.D.O. (grid-dip oscillator – blame Lee de Forrest for the "grid"!), I must have spent – sorry, *wasted* - hundreds of hours and miles of copper wire, in numerous early attempts at making the perfect antenna and any associated loading coils or traps. The G.D.O usually gave me more dips than the "big dipper" and I mostly had little idea what they *really* meant.

Many moons later, along came the now almost ubiquitous "antenna analyser", in particular the MFJ-259. It seemed too good to be true – a possible solution to most of my problems…except one, I couldn't really justify spending £200 or more on one little black box. Luck was at hand however, on a visit to my old pal Bob Hope (the late LA2UA/5Z4LW) in Stavanger. Bob had won an MFJ-259 in a raffle, could see no need for it and would I like it (for past services rendered!). I didn't have to be asked twice.

The completed "Mk1" antenna analyser

My world changed. Suddenly, guessing went out of the window, and I could accurately measure a host of previously semi-mysterious variables, and design and analyse the performance of antennas, especially portable and/or mobile. I was truly hooked and when, some years later, the opportunity arose to buy the later "259-B" version for £100 new in the U.S.A. arose, how could I resist?

I have since extolled the virtues of these analysers countless times, whilst always being aware that the cost is still beyond the pocket of many amateurs. Many times I have asked myself if such an instrument could be home-brewed and at much less cost. The simple answer is yes, but a full blown version with digital frequency display and covering say the WARC bands, would clearly not be for the beginner or the faint-hearted. Still, the seed had been sown.

At about that time, I had an e-mail from Patrick GW1SXN mentioning that Jim VK5JST had designed an MFJ 259B-type antenna analyser around a very stable, constant amplitude, wide-band "power" oscillator and a multi-function LCD display, the whole lot being controlled by a P.I.C. chip. It was (and is) available to Australian amateurs (and indeed anyone anywhere) in kit-form and at the then incredibly low price of *less than £40*! In true amateur fashion, Jim had also made the circuit and an excellent description, freely available on the internet (2).

Despite an intrinsic fear of P.I.C. chips (based wholly on my ignorance thereof), the Scot in me surfaced again, with the reasoning that if an Aussie could do it for £40, maybe (by cutting a few corners), a Scot could do it for under £20! The target was set..

Fortunately, I have a reasonably well-stocked junk-box. The first step was to design an ultra-simple but accurate 4-digit frequency counter around the now almost obsolete 74C925 counter chip I had saved from my long-gone days as a physics/basic electronics teacher. This worked to perfection. Then the problems began – the *oscillator*. Clearly this had to be stable, both in terms of frequency and amplitude, as well as sinusoidal (i.e. harmonic free), ideally from below 1.8MHz to at least 30MHz, as well as being capable of supplying some power to a low-impedance load.. This required something better than the many Hartley, Clapp, Colpitts, Tesla, Franklin etc. oscillators I had built back in the 60s, in my search for that elusive rock-steady VFO for my first all-band, home-brew CW rig. There was only one solution – I would need to "copy" that part of Jim's circuit. After much staring at the circuit and head scratching, I finally felt I understood roughly how it worked. More problems…Jim used a double sided P.C.B (one side acting as a ground-plane) and transistors which I could not find here in the U.K. After much pouring through Towers transistor data book, I plumped for what I considered to be a near-equivalent, readily available and costing a few pence each. I could have ordered the P.C.B. from Jim, but this was "cheating" going a bit far! I opted (to Jim's total amazement and, more especially, horror) for my much-practised, miniaturised Veroboard techniques. After many months of utter frustration (spread over two winters), but driven on by stubbornness and a determination to make it work against all the odds, I finally succeeded…not quite perfectly…I had to add an FET buffer stage…Jim later reckoned my chosen transistors, despite seeming to be near-identical, were in fact "marginal"…I would now agree!!
I now had the necessary low output-impedance power oscillator with which to feed a fairly traditional Wheatstone bridge circuit. A few diodes and some op-amps completed the set-up. All that was left to do was to produce a new meter scale, to show antenna resistance (at resonance) and S.W.R. (Unlike Jim's design, I had decided on the KISS approach, which meant my analyser could not compute impedance and/or reactance). A quick check of my miscellaneous antennas showed that my analyser was in indeed not only capable of producing the same basic results as the MFJ-259, but at a fraction of the cost. I had in fact reached my target of "less than £20". Admittedly, I did have most of the components in my junk box, but I believe the target figure would have been achieved (or very close to it) had I had to buy all or most of the components.

Sad to say, having reached my goal, the instrument (as with many other completed "challenges)" now adorns a shelf in the shack. But, in a way, that's not the end of the story…rather the beginning of another.

PART 2

In the course of my lengthy initial project, it had been forcibly demonstrated to me why commercial antenna analysers can provide (at a cost!) an indication of, and indeed allow you to measure, so many different variables other than simply R, X, Z, SWR, frequency etc. They are in fact designed around a sophisticated micro-processor carrying out some clever computations. All this further depends on a stable, constant amplitude, wide-band, sinusoidal, high-level oscillator, as well as an accurate digital frequency counter.

Last winter, forever seeking a challenge, I asked myself just what minimum "feed-back" the average amateur *really* needs, to ensure his/her antenna, commercial or home-brew, will work with the maximum efficiency theoretically possible for that particular design. I am also constantly aware that antennas are the one field in our hobby where it is still possible to experiment and meet the "raison d'etre" of our licence [as stated in the introduction thereto – Para.1, sub para. 1(1)(a)], and ultimately where considerable savings can indeed be made.

First of all, I observed that the majority of us work with *resonant* antennas. This means that the input impedance of the antenna, whilst perhaps not the ideal 50 ohms, *is* purely *resistive*, i.e. the reactance X is zero, hence the input impedance Z is simply R. Secondly, none of us needs a sophisticated oscillator of the type described earlier – we already have an even better one…in our rigs. Indeed, what are rigs but high quality, stable, relatively powerful oscillators?! Furthermore, we do not need a frequency counter/display as yet again, virtually all rigs have one of these too! We *do* need an SWR-meter as this, together with a knowledge of R, will allow us to properly *match* the "R" of our antenna to the output impedance of our coax and our rigs (generally 50 ohms).

Let us first of all look at how an antenna analyser such as the MFJ-259 (and its derivatives) works? The answer in some ways is "quite simply"…
Referring to Fig.1, the output of the oscillator is fed to a digital frequency counter and also provides a relatively small input voltage across one diagonal of a conventional Wheatstone bridge with 50 ohm resistors in three of its arms, the unknown resistor $\mathbf{R_x}$ (the antenna) being placed in the remaining arm. This results in voltages v' and v'' appearing at opposite ends of the other diagonal. The MFJ analyser then uses op-amps to amplify these voltages (and their difference v' ± v'') and a micro-processor to interpret them, ultimately producing readings of SWR and of R, X and Z.

In the design which follows, a somewhat higher drive voltage is used for the bridge (typically $10V_{rms}$). This obviates the need for amplification. By restricting measurements to SWR and R *at resonance*, X = O, and the ***µ***-processor is not needed either! Errors caused by the diode forward voltage drops are minimised by using *Schottky* barrier types ($V_f \approx$ 200mV or less) and a sensitive meter (50µA or 100µA) is also used. Finally, and best of all, the instrument is wholly portable, requiring no batteries or other source to power it.

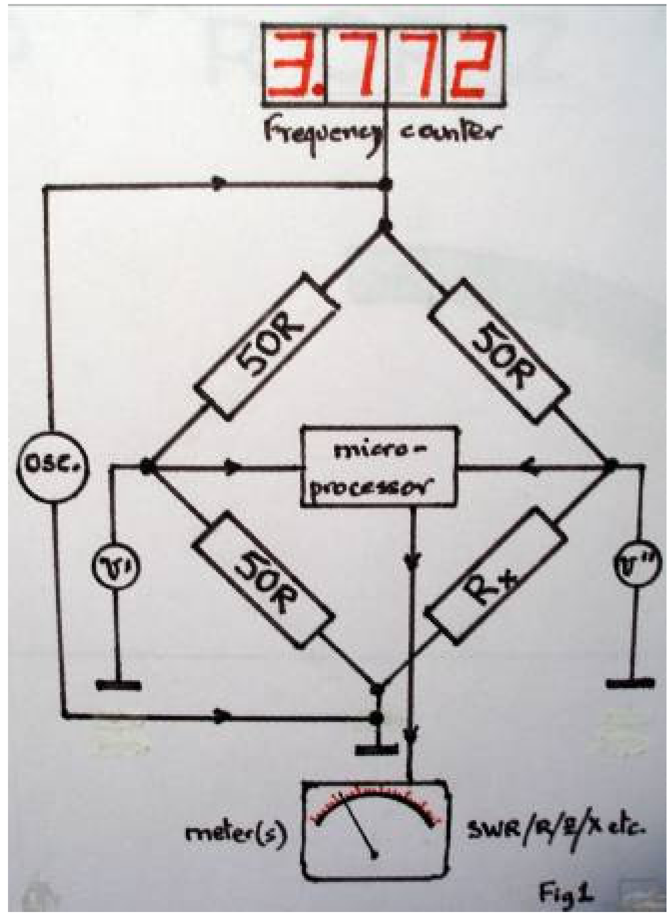
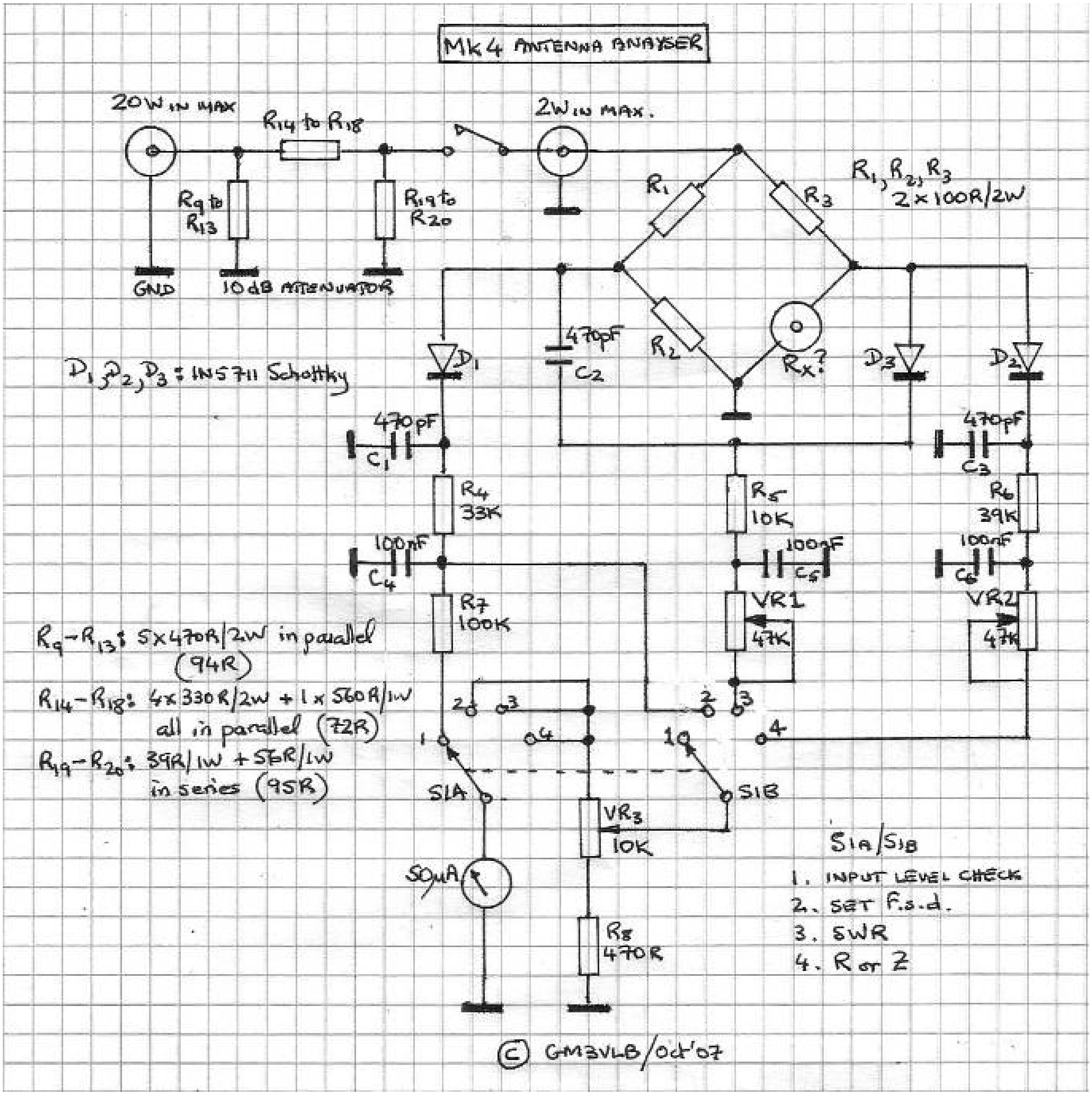


Fig.1

In the circuit diagram (**Fig 2**) below, resistors R9 to R20 form a Π-pad 10dB attenuator (**2**). Two inputs to the bridge are available. When the "HIGH" input (20W max.) is selected (transceiver input to "HIGH I/P" and switch closed), the signal passes to the bridge via the 10dB attenuator which reduces the power by a factor of 10. When the "LOW" input is used (2W max.), the signal is fed directly to the bridge.

Initial calibration is done (no antenna connected) by switching S1A/B to position 1 and applying about 1→2W directly to the bridge (or about 10→20W via the attenuator). Check the meter reading is in the "INPUT OK" range. Switch to "SET FSD" (position 2) and adjust VR3 for full-scale deflection. Then switch to "SWR" (position 3) and adjust preset VR1 to give full-scale deflection, and finally to "R or Z" (position 4) and adjust preset VR2 for full-scale deflection. (I used 10-turn trim-pots for VR1 and VR2 because they happened to be available, as well as a 10-turn pot for VR3 – not necessary). As a final check, if you have a reasonable 50R dummy-load, connect it to the antenna terminal and check the SWR is 1 : 1 and the resistance is 50 ohms!



Mk4 ANTENNA ANAYSER
20W IN MAX
R14 to R18
2W IN MAX.
R1, R2, R3 2×100R/2W
R9 to R13
R19 to R20
GND
10dB ATTENUATOR
D1, D2, D3 : IN5711 Schottky
470pF
C2
Rx?
470pF C1
470pF C3
R4 33K
R5 10K
R6 39K
100nF C4
100nF C5
100nF C6
R7 100K
VR1 47K
VR2 47K
R9–R13: 5×470R/2W in parallel (94R)
R14–R18: 4×330R/2W + 1×560R/1W all in parallel (72R)
R19–R20: 39R/1W + 56R/1W in series (95R)
S1A
S1B
VR3 10K
50uA
R8 470R
S1A/S1B
1. INPUT LEVEL CHECK
2. SET F.s.d.
3. SWR
4. R or Z
© GM3VLB/Oct'07

Fig.2

Over many years managing ‘O’Level Electronics projects in schools, I developed (as mentioned in Part 1), my own “Veroboard” assembly method which has worked well for both simple and more complex projects. The layout of the main board is shown in Fig.3 below. A slight variation of the technique, using double-sided PCB was used for the construction of the 10dB attenuator (Fig.4).

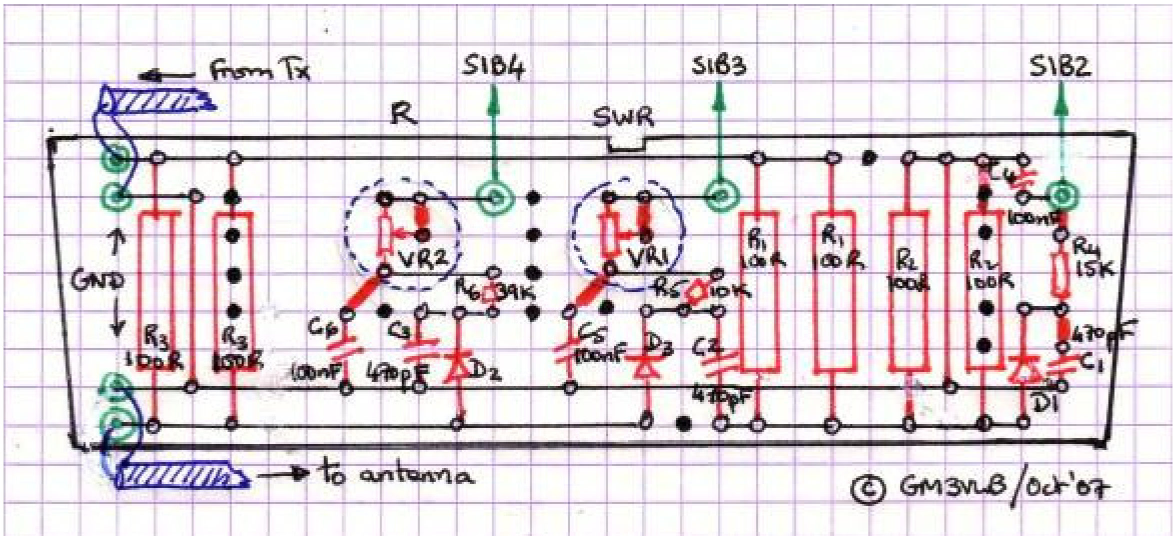


Fig.3

VR1 and VR2 are shown “dotted” as the exact placing of these components will depend on their shape, physical size and pin payout. The edges of the board are tapered as the ABS plastic boxes used are themselves tapered. This board slots into the “guides” at each side of the box.
The dimensions of this board are approximately 2.9” (tapering to 2.8”) by 0.8”

A slight variation of this “Veroboard technique”, using double-sided PCB was used for the construction of the 10dB attenuator (Fig.4 below).

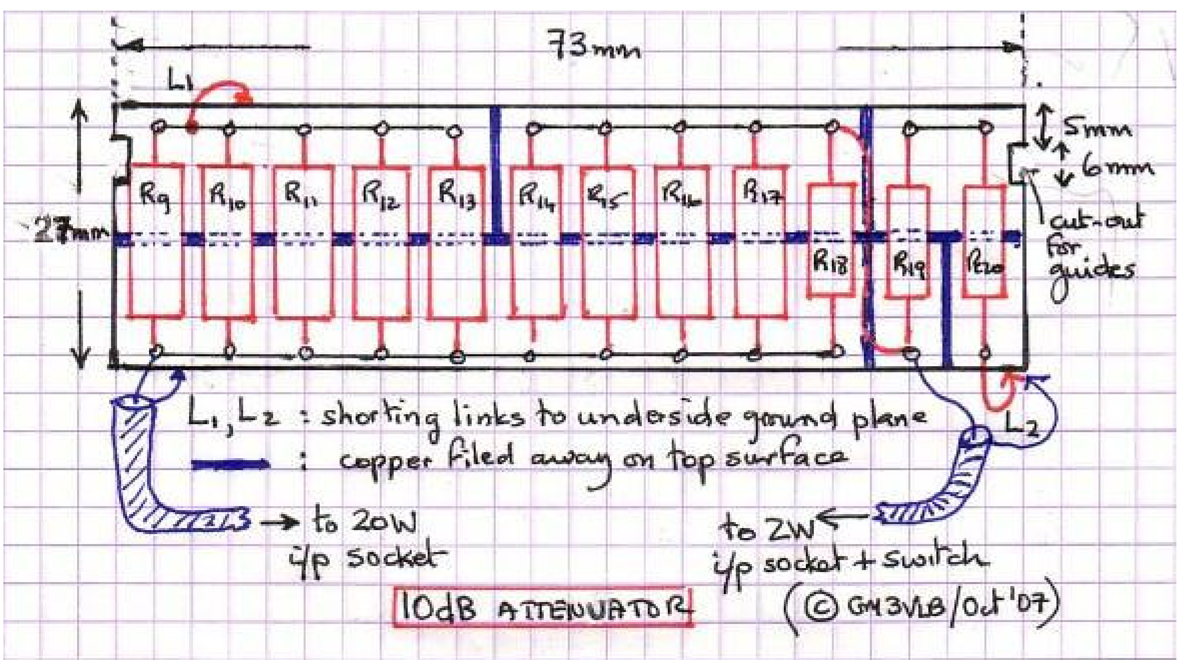


Fig.4

In use, the antenna is connected, the TX is set to the desired frequency and bridge input power and full-scale deflection are adjusted as above. The SWR and impedance (Z) are noted. The TX is now moved to a slightly ***higher*** frequency (not too much…+1% or so) and the meter re-calibrated. If "Z" now ***drops***, the antenna is ***too short*** for the desired frequency…if however "Z" rises, the antenna is too long. Adjust its length accordingly. At resonance, R will be a minimum (X = 0 and R = Z). The SWR at resonance will indicate what matching, if any, is needed.

Having selected a suitable meter, the SWR and R scales can be created, either by calculation (as described in Part 3) or by connecting various *known* resistors (e.g. in the range 0 to 500 ohms) across the antenna input. The corresponding SWR scale points (for each value of R) are found knowing that SWR = R/50 (when R is greater than 50Ω) or SWR = 50/R (when R is less than 50Ω). For example, a 100Ω resistor gives an SWR of 2 : 1…A 10Ω resistor will show an SWR of 5 : 1, and so on.

Those with basic skills such as the ability to use a soldering iron, identify different components on the relatively simple circuit diagram (Fig.2) and mount them on Veroboard (Fig.3 and Fig.4) or other preferred method, should have no problem constructing this "analyser". If you are confident doing basic, repetitive calculations using a calculator, a more accurate method for producing the "SWR" and "R" scales is described in Part 3. It is not necessary to fully understand the preceding theoretical discussion – you can simply use **equation (4) for "SWR"** and **equation (6) for "R"** Either way, it should be possible to build this most useful instrument for under £20. All parts are readily available. One word of advice…avoid cheap, "VU-meter" type meters. It is possible to use them, but their non-linear scales cause additional, unnecessary complexity. Rallies are a good source of quality alternatives. I have ***a few*** brand new, military-quality linear Russian 50μA meters, complete with re-calibrated scales, available for **£15** (inc. P&P). Finally, for those who might perhaps wish a bit more understanding of "*how the thing works*", I shall describe the theory behind this instrument in a bit more detail in Part 3.

PART 3

Fig.5 represents the basic circuit. Let us assume the oscillator applies an r.m.s. voltage **V** across the bridge. As $\mathbf{R_1 = R_2 = R_3 = 50\Omega}$, $\mathbf{V_A}$ is **V/2**. $\mathbf{V_B}$ will depend on the relative values of $\mathbf{R_3}$ and the unknown load $\mathbf{R_x}$. $\mathbf{V_A}$ and $\mathbf{V_B}$ are then rectified by $\mathbf{D_1}$ and $\mathbf{D_2}$ respectively, producing d.c. voltages.√**2** times the r.m.s. values. Diode $\mathbf{D_3}$ produces a third d.c. voltage representing the *difference* between $\mathbf{V_A}$ and $\mathbf{V_B}$. If we represent these three d.c. voltages by $\mathbf{v_1}$, $\mathbf{v_2}$ and $\mathbf{v_3}$ (and, for the time being, neglect diode forward voltage drops), we have:

$$\mathbf{v_1 = \sqrt{2}V_A}$$

$$\mathbf{v_2 = \sqrt{2}V_B}$$

and $$\mathbf{v_3 = \sqrt{2}(V_B - V_A)}$$

Let us consider the following three bridge conditions:

(i) $\mathbf{R_x = 0}$

(ii) $\mathbf{R_x}$ **= 50 ohms**

and (iii) $\mathbf{R_x = \infty}$

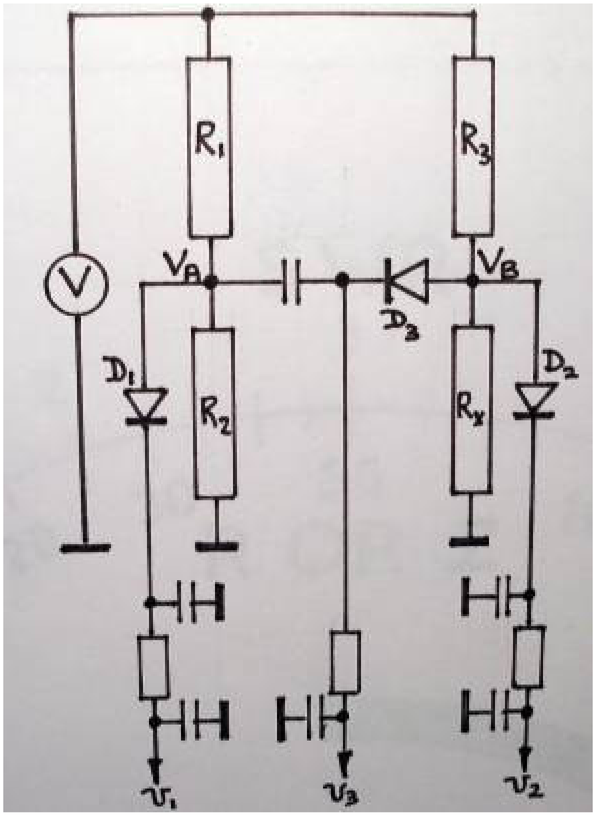


Fig.5

R_x	V_A	V_B	v_1 (= $\sqrt{2}\ V_A$)	v_2 (= $\sqrt{2}V_B$)	(the magnitude of..) $v_3 = v_2 - v_1$
0	**V/2**	**0**	**0.707V**	**0V**	**± 0.707V**
50	**V/2**	**V/2**	**0.707V**	**0.707V**	**0**
∞	**V/2**	**V**	**0.707V**	**1.414V**	**± 0.707V**

Table 1

Studying this table, we see that $\mathbf{v_1}$ does not change with changing load and can therefore be used to represent applied input power or voltage. We also see that the value of $\mathbf{v_2}$ depends on the value of $\mathbf{R_x}$, ranging from **0V** when $\mathbf{R_x = 0}$ to $\sqrt{2}$**V** when $\mathbf{R_x} = \infty$. We can therefore use $\mathbf{v_2}$ to represent $\mathbf{R_x}$. The scale is clearly *non-linear* but can be established using a selection of known resistors for $\mathbf{R_x}$, or by calculation (see later). It should be noted that the scale will be incorrect for reactive loads. However, $\mathbf{v_2}$ is always a *minimum* at resonance - a useful indicator thereof. Finally, voltage $\mathbf{v_3}$ is **0V** when $\mathbf{R_x = 50\Omega}$ (SWR = 1) rising to a maximum of **0.707V** when $\mathbf{R_x}$ tends either to zero or to infinity (SWR = ∞ in both cases).
$\mathbf{v_3}$ can thus be used to indicate SWR on a scale calibrated from 1 to infinity (∞).
Jim VK5JST demonstrates mathematically that the resulting SWR scale ***is*** in fact correct, irrespective of whether $\mathbf{R_x}$ is purely resistive or complex (i.e. **R + jX**)

Creating an *SWR* scale from readings of v_3

Consider the case where $\mathbf{P_{IN} = 2W}$ and $\mathbf{R_{IN} = 50\Omega}$, so that $\mathbf{V_{bridge} = 10V}$ (r.m.s.). (from $\mathbf{P = V^2/R}$)

In all cases $\mathbf{V_A = V/2}$ (= **5** volts) and $\mathbf{V_B = V\ [\ R_x\ /\ (R_x\ + R_3)]}$ (R_x and R_3 form a potential divider)

If $\mathbf{v_d}$ is the diode forward voltage drop, $\mathbf{v_1 = \sqrt{2}\ V_A - v_d = \sqrt{2}V/2 - v_d = 0.707V - v_d}$

$$\mathbf{v_2 = \sqrt{2}V_B - v_d = \sqrt{2}V\ [\ R_x\ /\ (R_x\ + 50)] - v_d}$$

If $\mathbf{R_x > 50\Omega, v_2 > v_1}$ hence, $\mathbf{v_3 = v_2 - v_1 = \sqrt{2}V\ [\ R_x\ /(R_x\ + 50)] - \sqrt{2}V/2}$

factorising …….. $\mathbf{v_3 = 0.707V\ [(\ 2\ R_x\ /(R_x\ + 50) - 1]}$

or, simplifying $\mathbf{v_3 = 0.707V\ [(R_x\ - 50)/(\ R_x + 50)]}$ ……………………...(1)

or, in another form $\mathbf{v_3 = 0.707V\ [\ 2(1 + 50/R_x) - 1]}$ ……...…………………(2)

If $\mathbf{R_x < 50\Omega}$, $\mathbf{v_2 < v_1}$ hence $\mathbf{v_3 = v_1 - v_2 = - 0.707V\ [(R_x\ - 50)/(\ R_x\ + 50)]}$

Hence, for $\mathbf{R_x}$ > or < **50Ω** $\mathbf{v_3 = \pm(\ v_2 - v_1\ ) = \pm\ 0.707V\ [(R_x\ - 50)/(\ R_x\ + 50)]}$ ……...(3)

Table 1 shows that $\mathbf{v_3 = 0.707V}$ when $\mathbf{R_x = 0}$ or ∞**,** i.e. the full-scale deflection voltage "$\mathbf{v_{fsd}}$" is **0.707V.**
Let $\mathbf{v_x}$ be the value of $\mathbf{v_3}$ for *any* other value of the load $\mathbf{R_x}$. We therefore have:

$\mathbf{v_x = v_{fsd}\ [(R_x\ - 50)/(\ R_x\ + 50)]}$ when $\mathbf{R_x > 50}$ and $\mathbf{v_x = v_{fsd}[(50 - R_x)/(50 + R_x)]}$ when $\mathbf{R_x < 50}$

$\mathbf{(R_x\ - 50)/(\ R_x\ + 50)}$ can be re-written as $\mathbf{[(R_x/50 - 1)/(R_x/50 + 1)]}$**.** The value $\mathbf{R_x/50}$ is in fact the **SWR** (when $\mathbf{R_x > 50\Omega}$). Similarly $\mathbf{[(50 - R_x)/(50 + R_x)]}$ can be written as $\mathbf{[(50/R_x - 1)/(50/R_x + 1)]}$ where $\mathbf{50/R_x}$ is the **SWR** (when $\mathbf{R_x < 50\Omega}$).

It follows that in both cases $\mathbf{v_x/v_{fsd} = (SWR - 1)/(SWR + 1)}$

As the meter angular deflection $\boldsymbol{\theta}$ is proportional to **v** (for meters with *linear* scales), we have

$$\theta_x/\theta_{fsd} = v_{x}/v_{fsd} \quad \text{or} \quad \theta_x = \theta_{fsd}\,(v_{x}/v_{fsd}) \quad \text{or} \quad \theta_x = \theta_{fsd}(SWR - 1)/(SWR + 1) \;\ldots\ldots\ldots\ldots(4)$$

θ_{fsd} is of course the angle for full-scale deflection for the particular meter used (in my Russian meter case 87˚). Equation (4) allows us to calculate the angle for any value of SWR, for any meter. E.g. for my meter, for an **SWR of 3** (i.e. 3 : 1), $\boldsymbol{\theta_x}$ **= ½ of 87˚,** i.e. **43.5˚.** Or, if **SWR = 1.5,** $\boldsymbol{\theta_x}$ **= 1/5th of 87˚,** i.e. **17.4˚.**

A table of angles corresponding to chosen SWR values can thus be constructed, and a new scale produced, for any chosen meter. I found Jim VK5JST's points very convenient and used these. The scale is *numbered* at SWR 1, 1.5, 2, 3, 5, 10 and ∞, with 4 intermediate graduation marks between SWRs 1 and 1.5, 1.5 and 2 and 2 and 3, as well as single marks at 4, 6, 7, 8 and 9.
N.B.: The forward voltage drop of the diode is not a variable in Equation (4), and as stated previously, the scale is also correct for *reactive* loads.

<u>Creating a *resistance* scale from readings of v_2</u>

We saw earlier that $\mathbf{v_2 = \sqrt{2}V\,[\,R_x/(R_x + 50)] - v_d}$. If we now assume (for calculation's sake) that, for the *Schottky* barrier-type diodes used, the forward voltage drop $\mathbf{v_d}$ is typically **0.2V** (or less), and that $\mathbf{[R_x/(R_x + 50)]}$ can be expressed in other more mathematically convenient ways, we have

$$v_2 = 14.14\,[R_x/(R_x + 50)] - 0.2 \;\ldots\ldots\ldots\ldots(5)$$

When $\mathbf{R_x = \infty}$, $\quad \mathbf{v_\infty = \sqrt{2}V - v_d = 14.14 - 0.2 = 13.94}$ **volts**

When $\mathbf{R_x = 0}$ $\quad \mathbf{v_0 = -\,v_d = -\,0.2}$ **volts**

When $\mathbf{R_x = 50\Omega}$ $\quad \mathbf{v_{50} = 7.07 - 0.2 = 6.87}$ **volts**

If we choose $\mathbf{v_{50}}$ (i.e. **6.87 volts)** to be "half full-scale", then **f.s.d.** (at an angle of 87˚) will be **13.74 volts.**
N.B: This means that $\mathbf{v_\infty}$ **(for** $\mathbf{R_x = \infty}$) will actually be 0.2 volts *beyond* f.s.d. (less than 1.3˚ in practice). Similarly, $\mathbf{R_x = 0}$ will occur at a point on the scale 0.2 volts below true 0 volts.
To obtain the angle $\boldsymbol{\theta_x}$ (for any $\mathbf{R_x}$), we use Equation (5) above to calculate $\mathbf{v_2}$ for each chosen value of $\mathbf{R_x}$ and apply simple proportion as follows:

$$\theta_x/\,\theta_{fsd} = v_2/v_{fsd} \quad \text{from which we get} \quad \theta_x = \theta_{fsd}(v_2/v_{fsd})$$

Hence $\quad \boldsymbol{\theta_x = v_2\,(87/13.74)} \quad$ or $\quad \boldsymbol{\theta_x = 6.33\,v_2} \;\ldots\ldots\ldots\ldots(6)$

Ex. What is the scale angle representing a resistance $\mathbf{R_x}$ of 35Ω?

Using equation **(5)** above, we find $\mathbf{v_2}$ is **5.62 volts.** Hence, from equation **(6)** $\boldsymbol{\theta_x}$ **= 6.33 x 5.62 = 35.6˚.**

N.B. The $\mathbf{R_x}$ scale will in fact only be correct for one specific level of input power which in this design is $\mathbf{P_{IN}}$ **= 2W,** giving an r.m.s. bridge voltage of **V = 10 volts**. The scale is also correct at ½ f.s.d., i.e. $\mathbf{R_x}$ = **50Ω**. If $\mathbf{P_{IN}}$ were only **0.2W** (i.e. an unlikely *10 times* less), there would be a progressively increasing error above and below 50Ω. For example, for a *real* $\mathbf{R_x}$ of 15Ω, the needle will be just over 1.5˚ too low, representing an *apparent* $\mathbf{R_x}$ of 13.5Ω – hardly discernible, and quite insignificant in the matching process.

Similarly, for a *real* $\mathbf{R_x}$ of 200Ω, the needle will be just under 2˚ too high, representing an *apparent* $\mathbf{R_x}$ of 228Ω, again hardly discernible and fairly insignificant. One could in fact make the scale accurate at any convenient level of $\mathbf{P_{IN}}$**,** e.g. 1W**.** The figure chosen of 2W (or 20W for short periods of time through the 10dB attenuator) was chosen as the best compromise. Most rigs can reduce power to between 10 and 20W and the 2W option is convenient for QRP rigs such as the FT817. I repeat, this is not a *digital ohm-meter* – nor was it intended as an accurate scientific measuring instrument. It is a cheap, simple, hand-held, supply voltage-free, *informative* instrument, which allows the user to set up his/her aerial by indicating, fairly accurately, S.W.R. and input resistance at resonance. If necessary, simple transformer matching can then be used at the aerial input, thus dispensing with the lossy, inappropriate A.T.U. (another costly gadget).

N.B. High SWR presents NO risk of damage to the rig. If the aerial I/P is open-circuit, the impedance presented to the rig is **100Ω** (an SWR of 2 : 1). Similarly, if it is short-circuit, the impedance is **33.3Ω** (an SWR of 1.5 : 1). Both values are thus well within the safety limits of all transmitters.

The above photos in fact show prototype Mk2. The Mk3 version was based on a *non-linear* 200µA VU-meter instrument. I now keep this analyser in my own car for tuning my /M aerials (no risk then of losing/damaging my MFJ259B). The final Mk4 version uses the Russian 50µA meter and forms the basis of the present article. I shall, in the next few months, have a limited number of complete instruments (less than a dozen) available on a *first come/first served* basis (cash in advance) at a cost of £60 (inc.P&P). A few D.I.Y. kits, as well as re-scaled meters may also be available (contact GM3VLB for details).

Acknowledgements:

(1) Jim Tregellas, VK5JST (http://users.send.com.au)(e-mail: endsodds@internode.on.net), who planted the seeds, and in true radio amateur spirit, was free with his help and advice. (N.B. Jim's "Q-meter" design is also well worth looking at).

(2) 10dB Π Attenuator: p151, RSGB Radio Data Reference Book, by George Jessop G6JP