Measuring SWR at 1296 MHz - My Way..

14 October 2010

Have you gone looking for an easy way to measure SWR (or RF power) at 1296 ??? One thing is for sure, it isn't easy - simply because the "normal" range of SWR meters most of us own do not go up to 1300 MHz.

Of course, it is different if you own a Bird RF power meter (eg a model 43) with a plug-in element that covers that part of the spectrum - but many of us don't have that type of equipment available - at least at a hobbyist level. Diamond Antennas do make such a meter - their SX1100 - which covers as follows : Frequency range: S1 (1.8 to 160MHz) S2 (430-450MHz, 800-930MHz, 1240-1300MHz) - where S1 and S2 are two different sensor ports. By the way, this particular meter is available here in Australia from Ross at **Strictly Ham** (http://www.strictlyham.com.au/diamond/meters/vswr-power-meters). Ross also handles the Daiwa CN-801G meter made specifically for the 1300 MHz band. Telling you where to buy such a meter makes this process simple - except I didn't attack it that way.

Last year I spotted a KDI CA-523 Directional Coupler on eBay AU (seller rf-buy2008 (http://stores.ebay.com/rf-buy2008) from China - still listed now at around $US26 posted free - a year later, though The-Test-Equipment-Store (http://stores.ebay.com/The-Test-Equipment-Store) (USA) lists them too - at a hugely-inflated price), specifications nominally 30dB covering 500 MHz to 2 GHz, with SMA connectors. My original thoughts were to simply use this device as a standard piece of test equipment coupled into the output cable of 23cm transmitting gear to sample frequency, look at spectrum purity etc.. I duly won the bidding at about $US16 and received the coupler about 2 weeks later.

Frequency Maximum Insertion

Frequency Coupling Flatness Minimum Maximum Loss Above Maximum Maximum

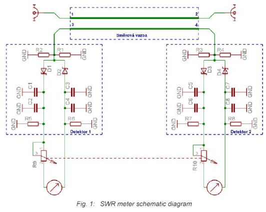
Model Range (Note 4) (Note 4) Directivity Input/Output Coupling Loss Peak Power Avg. Power

No. GHz dB dB dB VSWR dB kW Watts Outline

CA-523 .5-2.0 30 ± 1.2 ±0.75 18 1.20 0.2 3 50 2

It worked at 1300 MHz into the frequency counter but my 'experimeter-type' thoughts turned to the creation of an SWR meter slash power meter utilising it.

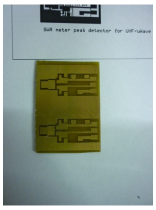
A bit of web searching allowed me to locate an article titled "SWR Meter for 144-1296 MHz Bands" by Jack, OK1TIC. Original article PDF is **here (http://ok1tic.nagano.cz/?download=uWave%20PSV%20metr.pdf)** (Local server copy **here** (/~vk4adc/web/images/UserFiles/File/23cminfo/uWave PSV metr_EN.pdf)). Jack uses a home-made directional coupler where I have a commercial one but the ideas behind the detector impressed me. In particular, the method he used to detect both positive and negative half-cycles and thus improve detector efficiency - and output voltage - is a vast improvement on many "conventional" approaches. He refers to G7EYT's contribution on the FRARS web site, as per G4RFR, article here (http://www.frars.org.uk/cgi-bin/render.pl?pageid=1085).



Jack's schematic

I set about testing that style of detector circuit using a few different diode types with RF from the sig gen at +10dBm and very quickly found out that most garden-variety/readily-available diodes mostly fail to operate well above 400 to 500 MHz. I suspect that it is the junction capacitance, even though quite low (typically below 1-2pF) - that kills the efficiency.

One other thing I realised is that if I wished to use both coupler output ports then I would have to make up two identical "detectors". These days that is relatively easy because of the advent of surface mount parts and easy-to-create PCBs. I proceeded to make up a layout to suit a few different diode styles and then printed two detectors side-by-side on one piece of PCB material. I also placed a trimpot in series on each detector so that I could adjust their sensitivity to be the same - something I hoped would make the process easier since I was going to use just one 50uA FSD meter movement and switch it across each detector, using a single "FSD calibration" pot.



Developed & etched PCB

Then came the crunch - what diode type was I going to use ??? It is hard to find **good** microwave SMD diodes available at short notice these days but **RS Components (http://australia.rs-online.com/web/)** currently have an offer to send web orders free so I did some searching on their web site and came up with 3 possibilities :

RS Stock No.	Description
610-9197	Diode,RF,Schottky,detector,microwave,dual,CC,SOT323,HSMS-286F
544-4865	Diode,RF,barrier,Schottky,dual,SOT143,BAT15-099
621-8831	Diode,barrier,Schottky,dual,series,SOT23,HSMS-2822

These were all marked available as local stock to Australia so I ordered 5 of each - their minimum quantities - with a next-day delivery assured.

The first one was a Common Cathode style so wasn't really going to help in this case but would be good for other projects where low power RF switching was required. Of course I could always mount two of these diode arrays - one each way - using only half of each package. The latter two seemed promising - the BAT15-099 and the HSMS-2822.

The PCB construction was very easy, very quick. I used only one 0805 SMD 560pF capacitor as the integrator on each leg where Jack had used a 100pF plus second cap, a 560pF. I used parts that were from the same component bags for each side with the hope that they would turn out to be virtually identical in sensitivity. I decided that the best (and easiest) diode to use was the HSMS-2822 as these had two diodes in the package, in series - so the common pin was the cathode of one diode and the anode of the second.

The next step was to measure both detectors independent of the directional coupler. That meant checking each with a range of RF inputs from the signal generator. Happily, both detectors actually outputted the same meter reading with the trimpots at minimum resistance with 0dBm input. The main thing I had to remember to do afterward was to set the trimpots so both detectors read the same on the meter at the same RF input level.

Let's do some maths at this point. One (1) watt = +30dBm less the coupler loss of 30dB = 0dBm output to the detectors. Ten (10) watts = +40dBm so +10 dBm to the detectors. Twenty (20) watts = +43 dBm so +13 dBm to the detectors. My sig gen will output +13dBm up to 1040 MHz so I might be able to calibrate for actual power along the way. Of course, this assumes that the 30dB coupling loss is (1) correct and (2) stable with frequency. The manufacturer's specs above say a coupling of +/- 1.2dB of 30dB with a flatness of +/- 0.75dB so it is *possible* to calibrate it for RF power accurately if you go to extra effort.

With the directional coupler in circuit, the meter did not read at all on +13dBm (20mW) when fed into the main RF input port - as expected. The transverter was fired up with FM selected on the driver transceiver with a 50 ohm dummy load on the through-output of the coupler, and the meter went over-scale.... Even with full series potentiometer resistance in circuit, the meter was still being supplied with too high an input.

The series FSD-set potentiometer that I used initially was obviously too low a value and I ended up revising that to a 1 megohm linear style so that it could handle the output power level of the 23cm transverter. That solved the over-scale issue.

Next, would it actually indicate relative SWR ?? Yep, it did. Setting the switch to the Forward position, meter to FSD then across to Reverse and the meter read just under "8" on the 0 - 50 scale. That "8" (or 16%) can be interpreted on the scale below. { These values have been calculated in Excel using the standard formula for SWR. }

SWR AS A PERCENTAGE OF FULL SCALE DEFLECTION

Meter Scale %	SWR Value
0	1.00
1	1.02
2	1.04
3	1.06
4	1.08
5	1.11
6	1.13
7	1.15
8	1.17
9	1.20
10	1.22
13	1.30
15	1.35
17	1.41
20	1.50
25	1.67
30	1.86
33	1.99
35	2.08
40	2.33
45	2.64
50	3.00
55	3.44
60	4.00
65	4.71
67	5.06
70	5.67
75	7.00
80	9.00
82	10.11
85	12.33
90	19.00
95	39.00
100	Infinity

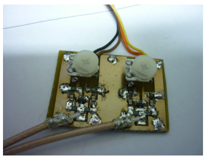
Ok, that meant it was about 1.4:1 at 1300 MHz... Given the connecting cable and the load were an unknown factor at the frequency, it was probably approximately correct.

Next step was to connect my "normal" shack dummy load to the output, calibrate to FSD - and the Reverse reading was now around "5" (or 10%) corresponding to a SWR around 1.2:1. Again, that seemed reasonable. I do have a 2 GHz RF load packed away in my WIA Prac Assessment case but it didn't seem to be worth the hassle of finding that particular load.

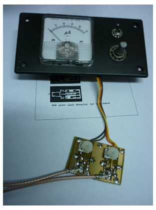
There is one further set of tests that should be made at this stage - the infinity tests. This is testing the meter with (1) an open circuit load and (2) a short circuit load - if you can call these two conditions a "load". The precursor to these is that the meter needs to be fed via an in-line power attenuator (3, 5 or 10dB) so that the source device (transmitter / transverter) is not damaged. The short and open circuit tests should both have a 100% (or full scale) Reflected reading after calibrating for FSD on Forward. This corresponds to an infinity / infinitely high SWR value. Unfortunately I don't have one of these available so these tests aren't possible at this time.

I then used a piece of double-sided tape to hold the PCB on the 'bottom' of the jiffy box, formed the wires and screwed the lid on because, at least for now, I was finished.

The photos below show how I built mine.... { Mouse over images to see larger }



This is the completed dual detectors PCB, the LHS one is the Forward detectors, RHS is Reverse.
The two 50 ohm teflon coaxes to the SMA male plugs are identical lengths.



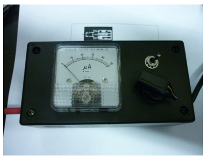
This shows how the PCB is wired across to the meter with a piece of 4-wire ribbon cable.

The inside of the plastic "jiffy" box. I know it should be metal but... The extra holes in the middle of each side were drilled before I realised I needed to allow space for the long-ish 2 x SMA coupler connections...

Connection note : The SMA closest to the RF input connection goes to the "Forward" detector.

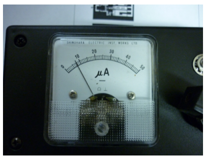
This shows the little PCB after mounting to the "bottom" of the jiffy box.

This view is probably the most important of all on this page as it shows which coax goes where....



The "completed" box with an old "pointer-style" knob on the potentiometer shaft. The toggle switch is in the Reverse position.

The input and output coax leads are basically permanent connections with the input terminating on an N-series male, the output on an N-series female.



With RF power applied and after "cal-ing' to FSD, this was the reverse reading on the first RF load.

Hey, I know it's not fancy. The meter scale is uncalibrated - and will most likely remain that way.

The main thing with SWR is that the reflected power indication desired is a minimum - plus I do have a "cal" scale (as listed above) to refer to if I really want to know what the actual SWR value really is !!

Eventually I will calibrate the variable control with an approximate RF power scale to be accurate at, for example, 50% deflection on Forward. For now, that isn't necessary to evaluate the SWR of antennas at 23cm.

All of the above tells you how it was made - but **how did it actually work with antennas** ???

Pleasantly surprising.... I took a DC power supply plus the 23cm gear (still on FM mode) out to the back yard, connected a recently-built 20 element 23cm yagi, pointed it at nothing-ness (sky), set Forward deflection to FSD, switched across to Reverse and read the scale - ' 5 ' - so 10% FSD or 1.22 : 1 - and I was pretty happy with that for a built-to-dimensions antenna, no fine tuning.

I then connected an older 23cm yagi in it's place and it read just under ' 20 ' - or 40% FSD - so around 2.3:1 - not so good. Running my fingers along the back of the boom and even onto the 'cold' side of the driven element (with the yagi pointing away from me of course - being aware of ERP and microwave cooking effects....) caused the SWR to change and it even dropped down to nearly 1:1 (no reflected reading) at one point.

This latter yagi will get some feedpoint investigation shortly - maybe a new folded dipole ???? Since I can now easily evaluate SWR at 1296 MHz, it isn't a problem any more.

Now for a PS : { a Post Script, not a power supply - that's a P/S}

The dedicated microwave enthusiasts will tell you to watch out what type of cable you use at 1296 and above. I grabbed a short coax patch cable that I thought was Cellfoil / 9006 - which turned out to be RG58C/U - and the attenuation over about 350mm was such that the above meter would not actually get to the FSD point on Forward !!!! As soon as I realised what I had picked up / done, I rushed off and grabbed the correct cable and the obvious difference in cable loss was absolutely amazing. The old warning about cable types was refreshed in my mind, proof positive.