Chapter 6

Accessories

Easy 3db splitter for 10GHz

by Tim Leighfield, G3KEU

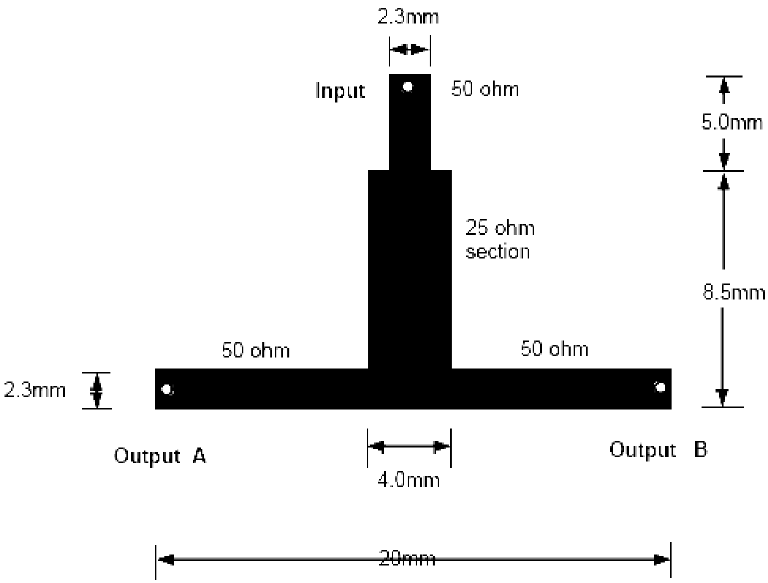
Occasionally the need arises to divide the output of an RF source to feed, for example, the 10224MHz LO inputs of separate receive and transmit mixers. Less common is the need to split the received signal for distribution to two receivers.

In both cases, a 3dB loss is obviously incurred when comparing output to input levels.

The PCB layout shown here (not to scale) can be etched on RT 5870 Duroid. If other types of microwave printed circuit board are used, the dimensions shown below would need to recalculated.

With care, the lines could be cut, rather than etched, using a sharp scalpel and a hot soldering iron to encourage the surplus copper laminate to lift. Once etched or cut, the pcb should be soldered into a small tin-plate or brass box.

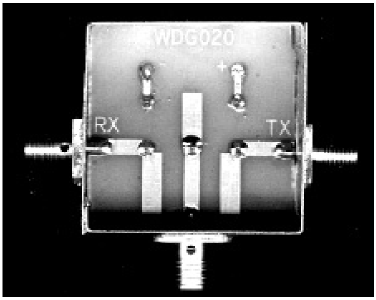
SMA connectors can then be soldered to the box and directly to the ends of each stripline forming the arms of the divider.



23cm Accessories

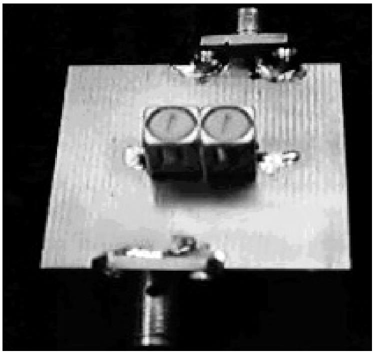
Useful 'add ons' from G3WDG

TX/RX RF switch using a "low cost" pcb mounting relay:
A tx/rx relay for 1.3GHz has been prototyped using a relatively low cost pcb relay. The performance of the relay has been enhanced by tuning out the reflected power with tuning tabs on the FR4 pcb. Insertion loss of the relay is about 0.3dB, isolation is better than 40dB and return loss in "through mode" is around 20dB. The relay is rated to 15W power handling (To be tested).



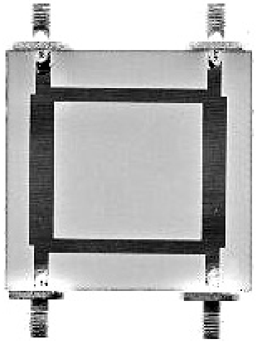
An add-on filter using a Toko helical filter for the 23cm transverter:
A simple filter using a TOKO helical filter has been developed as an "add on" to the 23cm transverter to clean up the spectrum if required by local regulations.

Insertion loss is only 1.8dB, and the filter provides about 32dB and 42dB local oscillator and image rejection respectively.



Quadrature Couplers:
Various quadrature couplers are being worked on, as splitters and combiners for balanced PAs. These use the branched arm configuration which theoretically produce two signals. -3.0dB down on the input signal, 90 deg apart in phase.

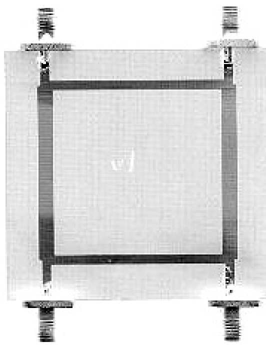
Non ideal couplers do not have an equal amplitude split and may not achieve 90 deg phase difference. For balanced amplifiers, an amplitude difference of 0.1 to 0.2dB is usually tolerated, and phase inaccuracy of up to about 5 degrees from true quadrature is generally acceptable.
To date, two microstrip couplers have been developed, shown in the photo above.
The one on the left uses 1.6mm thick FR4 as the substrate material, while the one on the right uses 0.8mm thick duroid.



Performance
FR4 coupler:
S11 -35dB at 1296
S21 -3.45dB at 1296 phase = -140
S31 -3.50dB at 1296 phase = 129
S41 -35dB at 1296
S21-S31 0.05dB phase = 91 deg, dissipative loss = 0.47dB. Estimated power handling 40-50W

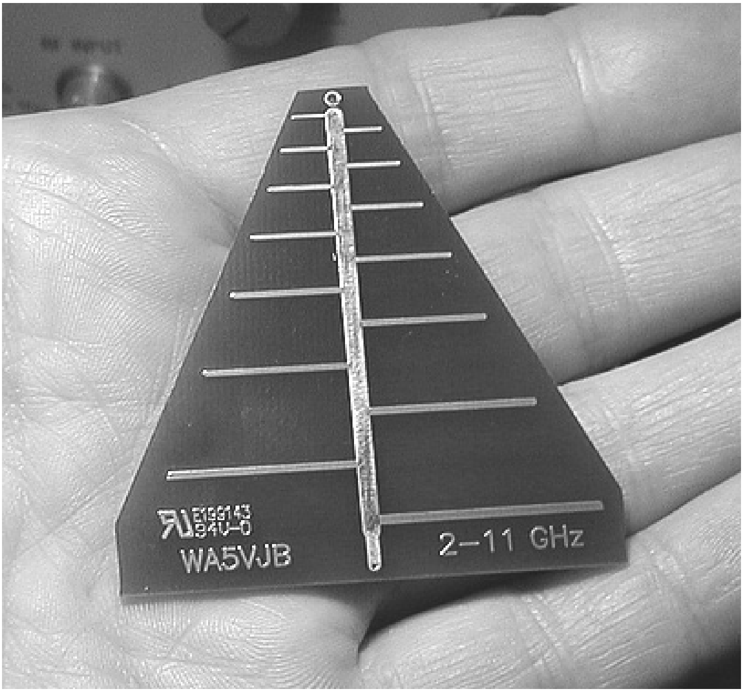
Duroid Coupler
This coupler covers the whole 1.25 to 1.35GHz band with excellent phase and amplitude balance. It should be an excellent candidate to combine the output of two 35W amplifiers.

Loss is about 0.15dB, and power handling should be in the region of 80W. Input return loss (IRL) is better than 20dB (1.2 VSWR over the whole band and reached about 38dB at 1296. Isolation at 1296 is about
40dB.



An RF Microwave Signal Sniffer

by John A. Jaminet, W3HMS



Often, I like to know immediately if my transverter or amplifier is QRV… 100% …YES or NO !

In the past, I have found that it's possible to see a signal on a voltmeter from the MON jack on my DB6NT transceivers …. without in fact having an emitted signal. The fault was my antenna relay! Thus I made a promise to myself that I would eliminate this circumstance once and for all. The means which I used is simple, effective and quite old in the history of radio.

It is a field strength meter which works in the RF field close to the antenna, e.g., a few feet, and it operates without need of batteries, a power supply, or a resonant circuit.

In use, start a few feet from the feed and come closer to the feed.

The circuit uses just 4 parts plus a radome. The most important part is the log-periodic antenna (LPD) imprinted on a piece of PCB and available in the USA and in England. The frequency range is 2-11GHz. It is pictured above.

The circuit is so very simple: the centre conductor of a piece of semi-rigid .085 coaxial line connects to a diode with output to a 25 (or so) micro-amp meter. A capacitor of about .001uF is connected between the 2 terminals of the meter and the outer conductor of the cable is connected to the other terminal of the meter. Meters of 50 or 100 microamps should be acceptable but less sensitive. A simple radome for protection against poor usage of this sniffer is an old plastic peanut can which I emptied myself.

This is hard but essential work … if it is too tough for you, you may mail the peanut cans to me for emptying , HI! There is no attenuation according to my test on my 10GHz beacon where the same radome covers the slot antenna.

The sniffer is so simple to operate: start in front of your parabola at a distance of about 15 feet if you have some power (like 40 watts) or at a few feet with QRP and meander slowly towards your antenna with the polarization like your RF source. With 40 watts, I tend to back into the dish as I can avoid looking into the feed. You will know by meter movement when your signal is strong enough or you will have a clear sign that some work is needed on your MW gear!

There are two sources for the LPD :
The UK Microwave Group and WA5VJB.
(email him at wa5vjb@flash.net)

Using 24-28VDC Coaxial Relays with 12V Supplies

Hans ON4CDU

There is always interest concerning relay power supplies.

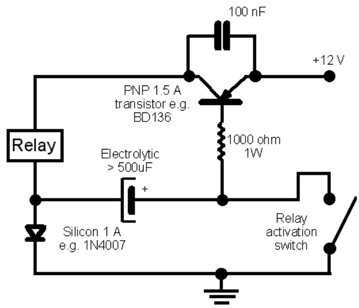
Here's a circuit based on the fact that all relays, once activated, need a much lower voltage to remain active.

The circuit originates from one by Tony, I0JX.

When the PTT switch is closed, the relay is activated by almost 24 volts, which is the sum of the PSU voltage and the charged electrolytic capacitor.

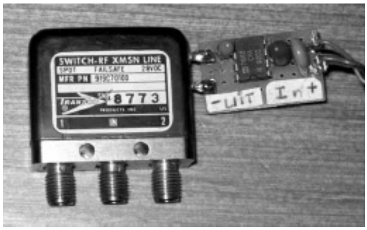
As the capacitor discharges, the voltage across the relay falls to the 12 volt level which is sufficient to hold the relay over.

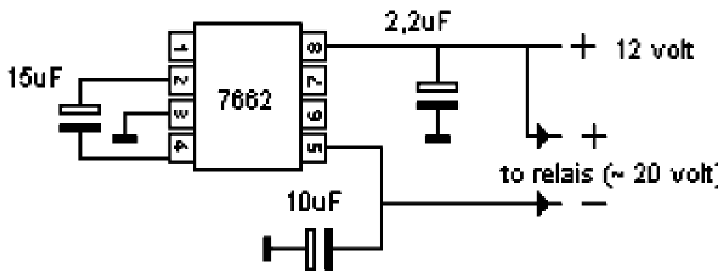
You can adjust the values of **R** and **C** to suit your relay.



Here's a simple one based upon an IC7662 chip.(see photo right:)

With just four components, it is easily assembled and can be attached directly to the relay as shown on the left in the photo. The circuit is shown below.





More Ideas for Home Made Microwave Dummy Loads

Richard T. Nadle, K2RIW

INTRODUCTION

In 1999 I submitted an article to the Microwave Reflector on the subject of the 10GHz Circular Waveguide experiments that were performed by the Ten-X Microwave Group (from Long Island, New York) using 3/4 inch copper plumbing tubing. One of the components we had constructed multiple times were Circular WG dummy loads by machining a piece of 3/4 inch wooden broomstick handle and placing it inside a piece of the 3/4" copper tubing. This made a high performance "slow absorber". If the point on the broom stick handle was sharp enough, the reflection was less than -35 dB; that's a VSWR of 1.04:1

FANCY MATERIALS REQUIRED? - Neophyte microwavers have been led to believe that very special materials are required to construct high quality WG dummy loads and attenuators. This is somewhat true only if the performance must be obtained in the smallest possible package and be maintained over all environmental conditions and the recommended frequencies for that particular WG. However, we microwavers are usually not that fussy! If a Home-Brew WG attenuator is 2" long, compared to the commercial and more expensive product that's 1" long, and if the attenuation has a slight slant with respect to frequency, I doubt the crafty Microwaver would mind. He will simply calibrate it versus frequency.

With those concepts in mind, you will soon realize that many of the inexpensive materials at your disposal can be used to construct rather high quality fixed attenuators, variable attenuators and dummy loads.

Paul Wade, W1GHZ used bicycle tyre material as a microwave absorber (see earlier pages ...editor). I believe that the small VSWR that Paul experienced would almost completely disappear if his material had been cut into a tapered (wedge-like) shape. We used wooden dowels and broomstick handles and achieved Home Brewed dummy load VSWRs as low as could be measured, once we used a proper taper.

PAD CONSTRUCTION -- Although we didn't perform the experiment, we speculated that high performance WG fixed attenuators could be constructed by placing a wooden "bullet" in the WG that had been sharpened on both ends. This technique should work equally well on Circular WG and Rectangular WG. The attenuation can be adjusted by changing the length, width and placement of the wooden "bullet", or by placing a number of bullets in the WG. If the desired attenuation is too large, when using a reasonable-sized wooden bullet, there are at least two alternate approaches:

1. **The bullet doesn't have to symmetrically fill the WG.**

A small diameter, sharp-pointed piece of wood (a dowel, or a sheet of wood) that is placed in one of the WG corners will perform admirably. The exact cross section of the attenuator doesn't matter. As long as it has a taper that is slow enough in cross sectional change per wavelength, than there will be very little reflected energy (VSWR). By moving the piece of wood from a WG corner, toward the centre of the WG, the insertion loss will increase.

This technique can be used as an attenuation Fine Tuner. Again, with proper taper, the VSWR will not change appreciably as the absorber is moved toward the WG centre.

2. **A full-sized WG low loss bullet could be constructed from Balsa wood.**

This low density material will have a much slower attenuation constant in dB per inch.

PAD CONSISTENCY

The Dissipation Factor (or Loss Tangent) that is caused by the wooden bullet is strongly affected by the moisture content of the wood. Therefore, I recommend painting the wooden bullets with a weather-proofing paint so as to maintain their moisture content (loss consistency). Depending on the Dissipation Factor of the paint that is chosen, I suspect there will be a slight loss increase after the bullet is painted. Don't judge the final insertion loss until the paint has dried. There probably are some low Dissipation Factor paints, such as lacquer, which will have very little impact on the bullet's additional loss.

MORE PAD & ATTENUATOR DATA

Concerning WG components, here's THE BOOK: George Southworth, "Principles and Applications of Waveguide Transmission", D. Van Nostrand Co., 1950; 689 pages (an oldie but goody).

Sometimes this book is available from used book web sites; it's a good buy. It contains some of the best PICTURES of how rectangular and circular WG really works with lots of performance curves (you won't need the math to understand the pictures (pages 166 & 169), it's almost an animation) -- amazing stuff for 1950.

On pages 269 to 276 you'll find pictures of linear, binomial, Gaussian, and exponential WG impedance stepping functions for broadband impedance matching, 14 designs for dummy loads (pages 368 to 371), about 25 attenuator designs.

Page 121 (A & B) has pictures are 21 of the circular WG modes (with the relative sizes of pipe shown, same frequency) made with an "RF absorbing camera".

The book shows some great transition devices, hybrids, mode killing devices & devices for launching higher modes (pages 354 to 362), round WG components (pages 269, 327 & 328), circular guide fin line (page 133), a great section explaining choke flanges (page 201), a circular pipe polarization rotating device that's "home brewable" (page 207), the shapes of circular and rectangular WG (of constant periphery) that give minimum loss (page 193 … the popular ones are not optimum), "skeleton WG" (page 175), about 15 kinds of WG irises (page 246 & 255), circular WG filters (page 307), the Qualcomm duplexing filter explained (page 309), rotary vane phase shifter (page 333), rotary vane attenuators defined (page 375), a way of designing a variable conductance dissipative film (page 377), 33 pages of horn data (only portions have appeared in other WG or antenna books), 8 kinds of "backfire" feeds including the Cutler (pages 448 to 454), eight types of WG slot antennas (pages 425 & 430), five kinds of corner reflectors, waveguide lens antennas, some TWT and magnetron info, etc. The picture on page 186 shows me how I could make S-band WG out of rain gutter down spout tubing. Let a Microwaver stand in a good hardware store with that book in hand and I think he'll get some great and crafty microwave ideas.

ARTICLE REPEAT (IN PART) -- Below I have repeated two sections of the 1999 article. The numbers refer to the section numbers of the original article; there were 14 sections.

Two sections of the 1999 K2RIW article entitled "Circular WG Frequencies, More Accuracy, More Experiment Data"

7. DUMMY LOADS

In circular WG are quite easy to construct. Simply sharpen a 3/4" broom stick handle and force it into the 3/4" copper pipe. About 3" of taper and 2" of non-taper is FB. The usual moisture in the wood makes a great "slow absorber", which makes it more forgiving of errors. The main difference between a -35 dB S11 dummy load (VSWR = 1.04, [sharp tip]) and a -20 dB S11 (VSWR = 1.22) seems to be how sharp the point was at the tip of the broom stick handle and was the taper too abrupt (too short). There may be some variations caused by knots in the wood, but we didn't seem to have that problem. The completed circular WG dummy load consists of a ~ 7" piece of 3/4" pipe with the tapered broom stick handle in it plus a copper pipe coupler at the open end. Some of the broom stick absorber can stick out the pipe far end, if you prefer. It is easy to place this load on any other piece of circular WG, while running component tests. These pipe couplers really are "sexless" connectors. For experienced rectangular WG users, it will feel strange to make connections in 2 seconds and not worry about screwing down the flanges to get a good VSWR.

9. PADS

We never did this, but it would be easy to design circular WG fixed attenuators by decreasing the length of broom stick absorber and tapering both ends to have a good impedance match from either direction. In this case I would recommend painting the absorber to keep the moisture content (absorption) constant.

If it is found that the loss is too great for a convenient length of tapered wood absorber, consider making the absorber out of six "splines" by using thin sheets of wood, or out of balsa wood. These low density materials (with tapered ends) will allow a lower insertion loss to be constructed from a longer length of wood absorber. Also, the slower loss characteristic will cause a lower VSWR for a particular taper rate.

A Voltage Standard for the Ham shack

Paul Wade W1GHZ ©2004

Recently, while tuning up a new project, it seemed like the knob on the power supply turned awfully far just to reach 12 volts — then I noticed the "low battery" indicator on the digital multimeter. The voltage was already above 16 volts. Fortunately, that project has an internal regulator so no damage was done. However, it was annoying — this digital multimeter replaced one whose flaky range switch caused similar problems.

At times, I've pulled out the old Simpson VOM - the red needle is reliable but not as precise.

A few nights later, I found a bag of parts buried on the workbench — probably purchases from a hamfest last summer. Among the gems was an IC marked AD581L. A quick search at www.analog.com showed it to be a precision voltage reference, laser-trimmed to exactly 10 volts. Just the ticket for untrustworthy digital meters. The AD581 has only three terminals:

an input of 12 volts or higher, an output of 10 volts, and ground. No external components required.

I dug up a small ABS plastic box, a couple of pin jacks, and a cord with an Anderson Powerpole connector. Two holes and three solder joints completed the assembly. The photo shows the complex assembly — I added a bypass capacitor, just because. A schematic is hardly necessary.

Time to spark it up — the output was 10.01 volts on the digital multimeter. Pretty good, but the L suffix is specified to be within 5 millivolts, so I tried a lab-grade meter, and read 10.003 volts — really good. The data sheet talks about aging for 200 hours to stabilize, so I ran it for a week and measured again: 10.0031 volts. Is this accuracy necessary? Probably not, most of the time.

I tried several digital multimeters of various age and quality, and obtained the following readings:
10.10, 10.03, 9.96, and 9.98 Volts, a range of 70 millivolts.

None is off by more than 0.4%, not bad considering that these were cheap meters rated for 1% accuracy when new, and never calibrated since. 1% accuracy is fine for most measurements, but some things, like battery testing and charging, require finer resolution. We've learned the hard way that good, fully-charged batteries are essential for successful portable operation.

Comparison to an accurate standard is a good way to get more accurate results.

This is a handy little gadget that you can build, even if your homebrewing skills aren't quite up to tiny surface-mount microwave components. The AD581 is readily available from

www.analog.com,

or an equivalent part, the LT1031 from **www.linear.com** (see application notes AN82 and AN42); both are available from Digikey.

In either case, you can pay for as much accuracy as you need. Other voltages are also available. Many are lower noise than normal voltage regulators, so they might be good voltage references for low-noise oscillators. Some of these parts may be available as surplus — mine apparently was — so let us know if you find a good source.

A Simple but Handy Diode Detector

From the F.U.N New Zealand VHF/SHF/UHF Newsletter

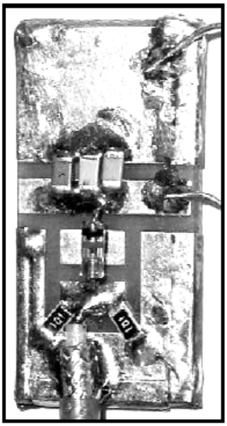
Component list for diode detector

Hot carrier Schottky diode HP5082-2835 (or similar)
100 ohm SMD 1206 resistors. (2 off)
100 pF SMD 1206
1nF SMD 1206
10nF SMD 1206
Offcut of double sided PCB 1.6mm
(Run wires through PCB near the resistors and capacitors

Parts are commonly available via the VHF Groups/ RS/ Farnell/ scrap pcbs and other sources. Contact the scribe if you have difficulty locating suitable components.

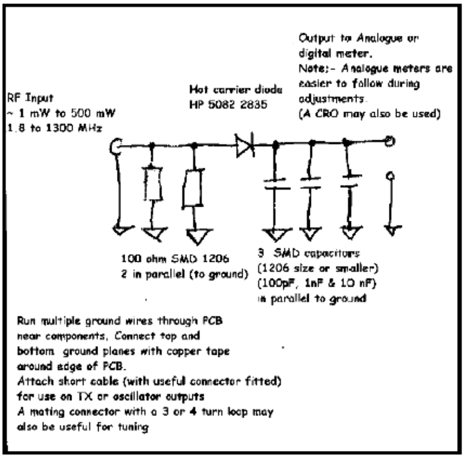
The detector can be connected to the output of an oscillator/TX via a short coax cable and connector or used with a multi-turn loop to detect oscillator/ multiplier operation. The detector works from ~1 mW to 500 mW (maximum dissipation of the 1206 resistors. The detector may be used from 1.8 MHz up to 1300 MHz. Adding a further capacitor will lower the LF limit. If required a chart can be drawn to convert the volts to power in mW, using the formula.

P (in mW) = 1000 x [(V + 0.25)^2/ 100]



Thank you those who have sent information for the column

Input for the column may be sent to Kevin ZL1UJG at rfman@xtra.co.nz



A low-cost high-performance RF power sensor

by Herbert Dingfelder, DL5NEG

What is it good for?
A lot of radio amateurs are afraid of building gear for GHz frequencies because they fear that they have no chance to measure at these frequencies. Well, the most interesting parameters of a signal are frequency and amplitude. Reasonably priced frequency counters up to 3GHz are widely available now but RF power meters are still quite expensive. This circuit transforms a RF signal into a DC voltage level which can easily be measured with a low-cost multimeter. Using the graph shown later in this article, you can then determine the RF signal level.

How does it work?
The 5 resistors at the input form a combined 3dB resistive pad and RF termination. The RF diode (BAT62-02W) rectifies the signal, the capacitors on the DC side form a broadband short circuit for RF. Having the different capacitance values in the arrangement shown (the pF very close to the diode) is very important for a flat frequency response.

The **component layout** shown on the next page is for scaling. One grid square is one millimetre.

The ground vias are very important for a constant frequency response. The more the better.

I have marked my vias in the drawing to give you an idea where the vias are most important.

I have used silver coated copper wire with 1mm diameter, the thicker the better. I have used FR4 PCB material with a thickness of only 0.8mm to keep the ground vias short. You can use 1.5mm material as well but the stripline has to be 2.5mm wide then.

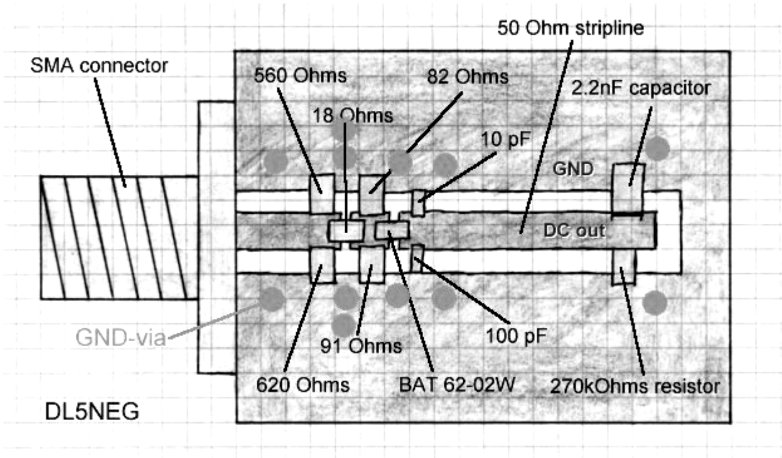
RF input is the SMA connector on the left side of the circuit board. The rectified DC voltage is present on the stripline right to the diode. Just measure the voltage across the markings shown as GND and DC out. See below for finding out how much RF input power causes a certain DC level at the output.

How can I convert the DC level to the RF power level?
I have built a number of these circuits and the variation from one sample to another is very small.

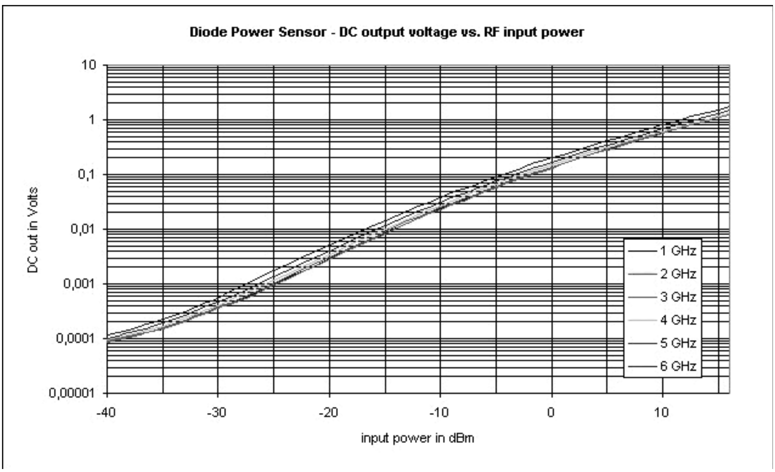
So if you built such a circuit for yourself and stick to the component mounting drawing above, you can use my measured values. You can even use BAT62 diodes in different packages for frequencies up to 2.5GHz. Above 2.5GHz it makes sense to use the very small package that I have used to keep the self-resonance frequency high.

In the graph below you can see the DC output voltage that the circuit gives at certain input power levels at certain frequencies. ***(This graph can be seen in full colour on DL5NEG's website)***

PCB layout



50 Ohm stripline
SMA connector
560 Ohms
82 Ohms
2.2nF capacitor
18 Ohms
10 pF
GND
DC out
GND-via
91 Ohms
100 pF
620 Ohms
BAT 62-02W
270kOhms resistor
DL5NEG

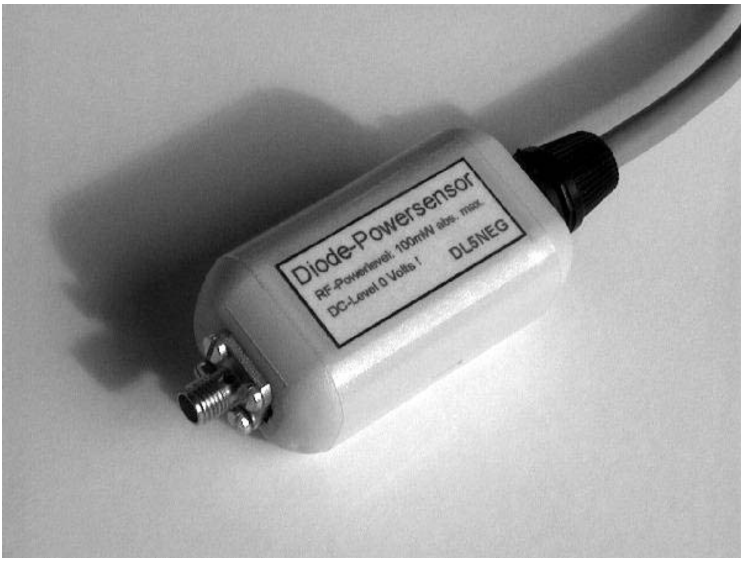


Diode Power Sensor - DC output voltage vs. RF input power
DC out in Volts
10
1
0,1
0,01
0,001
0,0001
0,00001
-40
-30
-20
-10
0
10
input power in dBm
1 GHz
2 GHz
3 GHz
4 GHz
5 GHz
6 GHz

As you can see the DC output voltage is practically independent of frequency up to 3GHz. Above 3GHz there is a slight frequency dependency but, using the graph above, you can still determine the RF power with high accuracy. If you feel that the graph does not give you precise enough information you can download the complete table from my website as text file.
Go to **www.dl5neg.de**
Any questions? Just don't hesitate to contact me by email and I will be glad to provide you with answers.

Email: homepage.feedback@dl5neg.de

This diode sensor by itself will be interesting enough to many readers but I would also like to draw your attention to the sub-page on my website that describes a full-blown handheld power meter, using the aforesaid diode sensor (amongst others). It provides the radio amateur with a fully featured power meter for very little money. Due to the fact that the measured sensor tables are put into the software (with interpolation within the measured 1dB steps), the reading is extremely precise, usually well below 0.5dB absolute error. Details can be found at:
http://www.dl5neg.de/powermeter/powermeter.html
I have another page that gives an overview on the working principles and the pros and cons of diode, thermal and log amp sensor and
you might feel it’s worth visiting at:
http://www.dl5neg.de/powermeter/theory/powersensors.html



Tuned Audio Level Meter for RF Measurements

Roger Blackwell, G4PMK

At Round Table meetings, great interest is always generated by the antenna gain measurements. Central to these measurements is the use of tuned audio level meters such as the HP415 for measuring signal levels. I published a design for a home-brew 1 kHz audio level meter some time ago [1], which does the same job and can be used both for antenna range work and many other microwave measurements.
So here is a revised and updated version. It's a tuned audio amplifier for use with 1 kHz modulated sources (both commercial signal generators and home-brewed sources) and an external diode detector. It has a dynamic range of over 50 dB. I'll cover the companion modulator and some of the uses of the meter in a future article.

The design consists of an input section, three amplifier-filter sections and a precision rectifier and meter buffer. The input section includes provision of a small amount of forward bias of either polarity, which will improve the square-law response of most common detectors. The audio driver transformer provides a suitable AC load for the detector, allows injection of this bias to the detector and provides a modest voltage step-up. The 10 dB step attenuator is split across the signal chain in the interests of best dynamic range. The circuit runs from two alkaline PP3 batteries which allows portability. An audio output is always useful was when making antenna measurements, so this design has an audio output, intended for use with one of the ubiquitous battery-powered PC/personal stereo active speakers.

This output provides about 100 mV pk-pk into a 5k load when the meter reads 100% FSD. The instrument should be constructed in a metal case using good audio construction techniques, including a single common connection for the case and circuit at the input socket, which ought to be a BNC or similar type. You can build the circuit on matrix board if you wish (as was one of the prototypes), although a PCB artwork should be available via the Internet [2] by the time you read this.

All connections to the input circuit, step attenuator and set level control should use screened leads.

Some of the components require a bit of care in selection. The 10nF capacitors in the filter stages (2 per stage, a total of 6) should be ±5% or better tolerance types. Resistors should be ± 2% or better, metal film or similar. The three presets are used to trim the filter centre frequencies and can be small cermet types. The 10 dB step attenuation switch should be a two-wafer type so as to maximise the isolation between sections. The bias switch is a single pole centre-off type. The input transformer used in the prototypes was the venerable LT44 transistor inter-stage transformer, still available from Maplin (HX82D) as are other suitable transformers (PX79L or PX80B). The PCB layout and prototypes used an LT44.

It makes sense to get the best and largest meter you can find for this project, since you will be taking measurements directly off the meter scale. The 4u7 electrolytic across the meter terminals was added to damp out jitter due to noise; depending on your meter movement and personal preference you may find it unnecessary.

The meter will need re-calibrating in

dB according to the following table:

%FSD	dB	%FSD	dB
100	0.0	25.1	-6.0
79.4	-1.0	20.0	-7.0
63.1	-2.0	15.9	-8.0
50.1	-3.0	12.6	-9.0
39.8	-4.0	10.0	-10.0
31.6	-5.0	1.0	-20.0

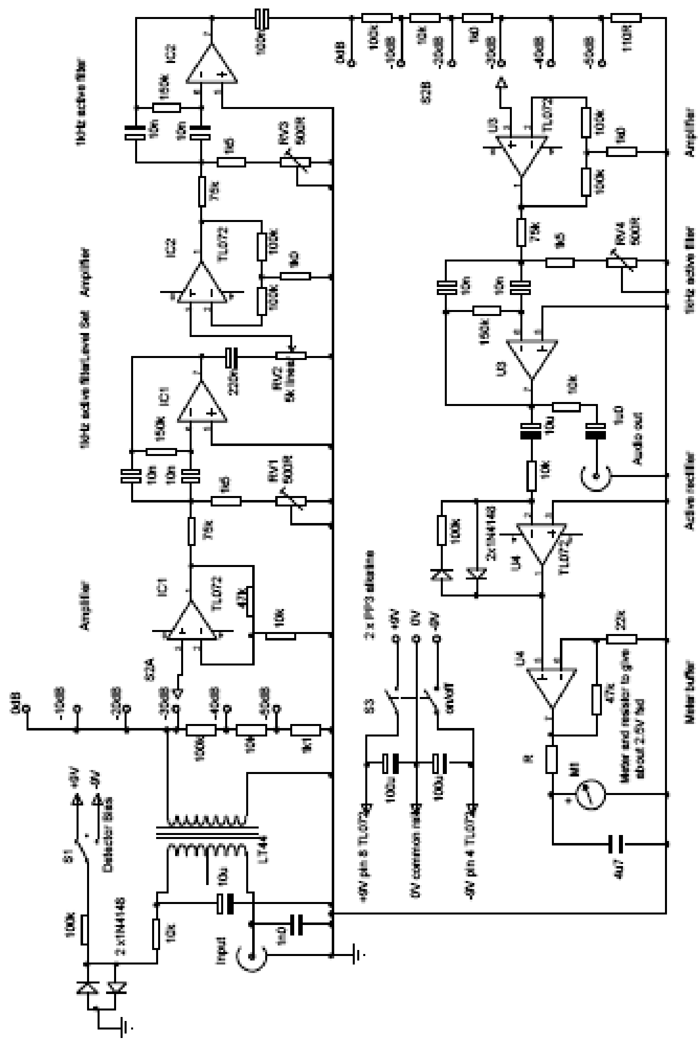
If you leave the original scale in place, then any reading can be converted to dB with the formula

$dB=10.\log_{10}(100\%FSD/100)$

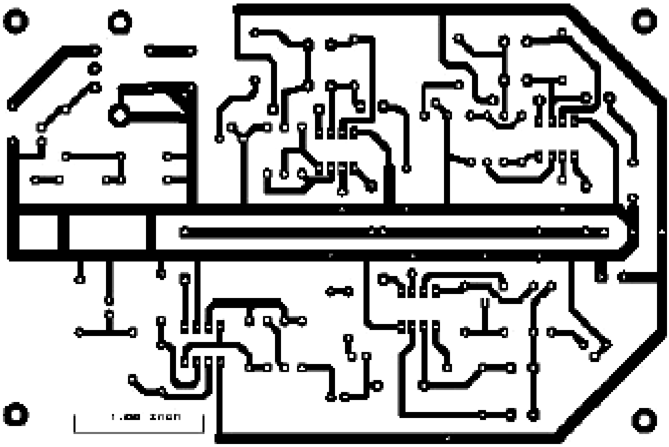
which is easy enough with a calculator. Setting up the meter is quite simple. Inject a low-level (few mV) 1 kHz tone into the input, and adjust the attenuator and level set control for an on-scale reading. Ideally do this with the 1 kHz modulating source you plan to use. Now peak each of the three filters in turn by adjusting the 500R presets. Check that with a short-circuited input residual circuit noise is about 20% FSD on the 0dB attenuator range with the level control set to about 50%.
That's all there is to it!

The prototype sensitivity was such that about 100 mV RMS gave 50% FSD on the -50 dB setting with the set level control at mid range.

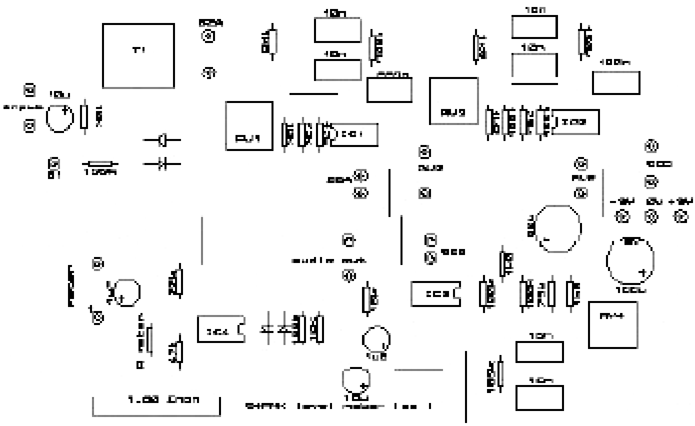
[1] Receiver Measurements, Ch 12, The VHF/UHF DX Book, edited by G3SEK,
RSGB.



Amplifier
1kHz active filter/Level Set
1kHz active filter
Active rectifier
Meter buffer
Audio out
Input
Detector Bias
2 x PP3 alkaline



Track Layout



Component Layout

Using the Tuned Audio Level Meter

Accessories

To use the level meter, you need to provide an RF source, amplitude modulated at the 1 kHz frequency to which the level meter is tuned. If you have a signal generator or QRP Tx capable of amplitude modulation, that will do nicely; if not then it's a simple job to provide an external modulator for whatever RF source you use.

Fig 1 shows a low-level (mW) modulator based on a PIN diode and a simple oscillator. By using appropriate construction techniques, SMD style components and sensible values for the RF chokes and bypass capacitors, available as surplus. Actually, I have a confession to make; I use a klystron source for 10GHz, modulated by feeding 25 V or so via a capacitor to the reflector. Sufficient AM is produced to render this source quite suitable for measurement applications. A Gunn oscillator could no doubt be modulated in a similar way.

The other item needed to complete your measurement outfit is a detector. One can often find suitable detectors on the surplus market - I'm thinking of those with an N-type plug on one end and BNC socket on t he top, or one of those SMA m/f types, both look something like a coaxial attenuator. The diode type and polarity will determine what setting of the bias switch to use.

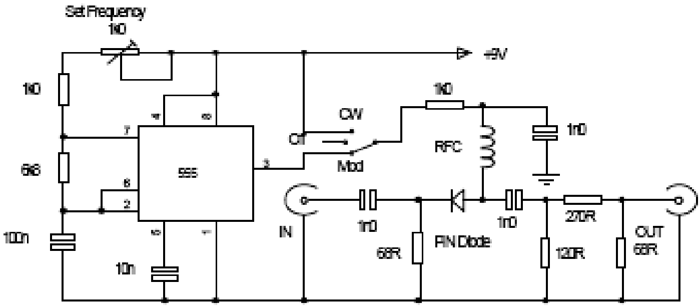


Fig 1: 1kHz amplitude modulation accessory

this can be made to work up 2 GHz or so. Make the audio frequency adjustment easily accessible so it can be trimmed for best response with the level meter. The 2-pole centre-off switch allows selection of both modulated and unmodulated signals without disconnecting the modulator from the source.

For higher frequencies, it may be possible to utilise a commercial semiconductor switch; I have used the Mini-Circuits ZFSW series to 5 GHz or so, and there are occasionally waveguide PIN modulators or switches Remember that this is a series diode, so the device you are connecting it to should provide a DC return for the bias current.

Often a -3dB or larger attenuator between detector and source is a good choice and serves as well as a normalising impedance. If you cannot come across a surplus detector, then make your own in the body of a N-plug, with the diode connected between the centre pin and a feed through capacitor fitted on a disk of brass soldered on the top of the clamping nut.

If you are lucky enough to find one

at a reasonable price, a *slotted line* should have a detector fitted on the sliding carriage, and will enable you to make vswr measurements of components very easily.

Antenna Measurements

The interest shown in making antenna measurements using tuned audio level meters was what originally prompted these articles. I'll refer you to some references [2,3,4] for a full treatment, however here are some of the basics. This incarnation of the level meter has a separate audio output, designed for use with an external battery-powered amplifier/speaker. This is useful, not only to hear what's Really Going On, but also to aid alignment of the antennas; if you are changing antennas for comparison purposes, it's particularly important that both are aligned for maximum forward gain rather than just visually.

Gain Measurement

For accurate gain measurement - or even accurate comparisons between different antennas - it is essential that the antenna under test is located entirely within a three dimensional region of uniform field strength with a flat phase front. You will need a *source antenna* to create this RF field, and if you want to measure absolute gain you will also need a *reference antenna* of known gain. If you just want to compare two antennas, the reference antenna isn't required. The reference antenna could be one that's been measured elsewhere, or a standard gain horn, which can be home-made from published data.

For the purposes of this description, the source antenna is treated as the transmitter, and the antenna under test as the receiver. This is usually the most convenient setup, but the transmitter and receiver can be interchanged.
To create the uniform field mentioned earlier, the source must be in the *far-field* of the dish under test, and vice-versa. That means a distance greater than:

$$\mathbf{2D^2 / \lambda}$$

between the two antennas, where D is the diameter of the dish, or the greatest dimension across the aperture for other antennas. If you are concerned with Yagi antennas, you can calculate the equivalent aperture (a.k.a. capture area):

$$\mathbf{D_{EQ} = G\lambda^2/4\pi}$$

where G is the gain over isotropic (in linear, not dB terms), ? is wavelength. D_{EQ} can then be substituted for D in the equation above.

For example, a 60 cm dish will have to be at least 24m away from the source at 10 GHz.

The ideal antenna range is floating in free space, and several ingenious range geometries have been devised to avoid the effects of ground reflection - if you can measure across a deep canyon or between two high buildings, then do it! However, for most amateur measurements we have to use a level range and cope with the effects of ground reflections somehow. In most range geometries, both of your antennas need to be well clear of the ground and other reflecting objects. In general try and choose a level site for measurements - free of buildings, cars trees and metal objects. Ideally the surface between the two antennas should be flat, and smooth to a quarter wavelength or so - which is no doubt why measurements are often made in large empty car-parks. If possible, use vertical polarisation of the antennas as then the angle of incidence of the transmitted signal with the ground can be set to minimise reflections - this is known as the Brewster angle and is about 15° for soil surfaces. The spacing between the source and receiving antennas needs to be 7.5 times the source antenna height to achieve this Brewster angle. However, you also need to meet the far-field criterion mentioned earlier, and this may require impractical heights for the receiving antenna. In any case, it should be possible to check that you have a suitable set-up, by investigating the signal strength across the plane of the receiving antenna, using a dipole-on-a-stick probing antenna and the level meter. The signal strength should remain constant (within a dB or so) across the whole volume into which you are going to place your test antennas.

Dish Focussing

This is pretty much the same as gain measurement, but obviously doesn't require a reference antenna. You'll still need a source and a transmitting antenna though.

Having the detector/level meter attached to the dish to be adjusted will be more convenient. The level meter is also well suited to setting up circularly polarised feedhorns.

Gains and losses in components

Because of the dynamic range possible with the level meter, it is a very useful tool for measuring gains and losses - in cables, amplifiers or just about anything else. Of course, it doesn't matter if frequency conversion takes place, as long as there is an output at some frequency that can be fed to the detector. It's important to check that you are keeping within the linear characteristics of any active devices. Filters are a particular favourite application of mine - a band-pass filter response for example can be quickly plotted with a signal generator and the level meter. Very handy if you don't have access to a sweep generator or network analyser.

Using a Slotted Line for matching and impedance measurements

A slotted line is one of the most useful accessories for the level meter. These are sometimes available on the surplus market. You're more likely to come across a waveguide version, which consists of a length of guide with a slot along the top.

Some kind of movable carriage runs along the top, with a probe whose end projects through the slot. A detector is connected to the probe. These lines are also made in coaxial airline form as well. You can use them for making SWR and impedance measurements, using just the level meter and a modulated source. Here's how:

Simple VSWR measurement

VSWR is defined as the ratio of maximum and minimum voltage on the line:

VSWR = Vmax /Vmin

The square law detector used with the level meter means what is indicated on the meter is a power ratio, so:

VSWR = v (Vmax/Vmin)

First slide the carriage along for maximum indication, then use the Level Set control on the level meter to set FSD (100) on the meter. Now adjust the carriage for a minimum reading. The VSWR is then:

√ (100/reading)

If you have actually calibrated the meter in dB, then FSD will be 0dB, and the minimum reading is a 'loss' in dB , so:

VSWR = antilog$_{10}$ (Loss dB/20)

Impedance measurement

This is a bit more involved, so I'll go through it in steps.

A) Place a reference short (for waveguide, a metal plate) across the output side of the slotted line. Find the positions of TWO peaks, and hence the distance between them.

That's the guide wavelength, λ_g.

B) Connect the device to be tested in place of the short. Move the carriage to a maximum, and set the meter for FSD. Note position of the carriage.

C) Move carriage either towards the load or towards the generator (remember which!) for minimum. Note the position of the carriage again, and read the meter scale for

VSWR as described earlier.

D) Now dig out the pad of Smith charts [5] and draw a VSWR circle on the chart.

E) Translate the distance between the two points already noted (max and min) into fractions of λ_g using the length of λ_g obtained above in step C. From the left hand side (R=0) of the chart, move the appropriate fraction of a wavelength around the circle— forward = towards load = clockwise; backwards = towards generator = anticlockwise.

The point on circle is the impedance in normalised terms.

If you are fortunate enough to have a 50 ohm coaxial slotted line, then the impedance is normalised to 50 ohms. If you are using a waveguide slotted line, then the waveguide impedance is:

$$377 * (a/b) * (\lambda_g/\lambda_o)$$

where λ_o is the free space wavelength, and a and b are the internal dimensions of the waveguide.

I've used this technique very successfully with a WG16 slotted line to make and adjust WG to coaxial transitions for 10GHz.

So that's a few applications of the Tuned Audio Level Meter - of course there are others. Why not write up your application for *Scatterpoint*?

[1] Scatterpoint Issue 4.
[2] Antenna Gain Measurements, Fred Brown W6HPH, QST Nov and Dec 1982.
[3] IEEE Standard Test Procedures for Antennas, ANSI/IEE 149-1979
[4] UHF Antenna Ratiometry, Richard Knadle K2RIW, QST Feb 1976.
[5] *In Practice*, RadCom March 2001.

A downloadable bitmap of the Smith chart is at http://www.ifwtech.com/g3sek/in-prac/smith.gif

1kHz Amplitude Modulated Gunn Oscillator for RF Measurements

David Wrigley, G6GXK

A useful accessory for the previously published "Tuned Audio Level Meter" (ref. 1) is this simple 10GHz Amplitude Modulated Gunn Diode Oscillator.

Using this equipment, tests can be carried out on antennas and other parts of your 10GHz equipment, using the significant dynamic range of the tuned audio level meter.

Basics

The obvious choice for a 10GHz source is a Gunn diode – it is very low cost, simple and easy to operate. The one problem is that it isn't so easy to amplitude modulate.

The straightforward application of a modulating voltage to the Gunn diode produces lots of FM, which may well cause problems due to unexpected off frequency responses. A separate pin diode or FET modulator was the next thought, but that would require two transitions to get to SMA and back to WG and a horn. It was then that the Solfan combined Gunn diode and detector combination was considered as a possible source of AM. Such unit have been used in wideband transverters and one of these was selected for some preliminary tests. This particular unit came from a PW "Exe" WB transceiver had a piece of 2BA screwed plastic rod (knitting needle) entering the cavity as a fine frequency adjustment.

The Gunn was fired up with 7.0V and the output adjusted with the aid of a cavity wave-meter to be approximately 10368MHz. With a power measuring device (diode detector) in front of the Gunn diode assembly, the effect of passing a 5mA current through the Solfan detector diode was checked. A quite definite change in output level was seen of about 10 to 20% in amplitude. The extent of this could be peaked by adjustment of the screws around the detector diode, which project into the waveguide. Further checks with a 1KHz modulating signal were carried out. These proved that the resulting modulated Gunn output had no problem in end-stopping the Tuned Level Meter when fed from a simple diode detector and small horn. This has surely got to be the simplest, lowest cost method of getting 10GHz AM!

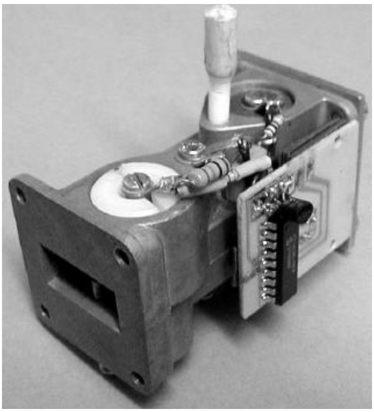
Audio Source

The next thought was to generate an accurate 1KHz signal. Past experience had shown that it is not so simple to produce a 1KHz signal with sufficient stability and accuracy to reliably pass through the narrow filters of the tuned level meter. The final solution was to use a PIC16F84 microprocessor to give precisely 1KHz . Well, within about 40ppm, and that is amply good enough.

The program is based on the fact that the instruction period of a PIC microprocessor with a 4MHz crystal is precisely 1 microsecond. Therefore the program consists of two 500us delays interspersed with toggling an output line, and then finally looping back to continuously repeat the process. The result is a precise 1KHz square wave. Since the harmonics are outside the pass-band of the tuned level meter, there is no problem. The whole PIC generator consumes about 6mA including the LM78L05 regulator. The PCB was designed to use "In Circuit Programming" so wires can be attached to the 5 pads provided and fed from the programmer socket. To program this PIC chip "in-circuit" you need to connect 5 wires to the appropriate pins of the programmer socket as detailed on the circuit in the zip file and just use the programmer as you would normally – the power is supplied from the programmer so no other supplies are necessary. Alternatively you could program the PIC before assembly or a ready programmed PIC chip can be supplied (ref. 2). A zip file of the overall circuit, the PCB layout and the hex file for programming is downloadable from our website. (ref. 3).

The PCB was stuck to the Gunn diode assembly using thick double sided adhesive tape. (as used in the automotive industry – this is so good that it will even stick on registration plates!).

The picture below shows the basic assembly.



It had been intended to supply the whole thing from a 12Volt Battery pack and the trial unit used a 7V 1.5A regulator, which was to hand. A small regulator PCB with an LM 317 will eventually be built to take over this job. The total consumption including the Gunn diode is about 100mA. And the TO220 style LM317 should have no problem handling the 0.5W dissipation without any special heat sink. Once the basic system had been built up, further trials took place. At about 25metres the level meter showed about half scale on the –10dB range using a small horn. Use with a dish would give considerably more output and therefore this was considered to be acceptable.

Some further lessons were learnt from these trials:-

1. A proper fixing was required for a camera pan and tilt tripod
2. Some mechanical protection was required for the PCB and Gunn assy.
3. A simple sight was required for the initial lining up of the transmitter. Even a small horn is quite strongly directional.
4. It is essential to make sure that the batteries in the tuned level meter are fully charged before a long measuring session.

Failure to get a sensible reading can result in all sorts of unnecessary checks and adjustments.

The first three items were dealt with by designing a sheet metal cover to support and protect the assembly. This cover was built from 0.8mm thick Zintex (zinc plated steel) sheet which was folded and MIG welded. This could equally well have been soldered with large fillets.

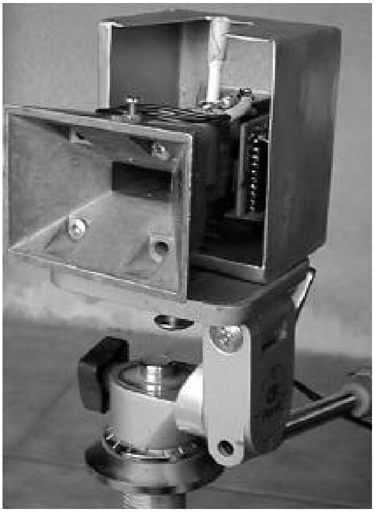
The cover had a simple sight (hole and cross-wires) built into it. It also had two 0.25inch x 20tpi nuts welded in to provide tripod attachment. A full sized drawing for the cover is downloadable from our website within the zip file previously mentioned. The picture on the following page shows the final assembly mounted on a camera tripod.

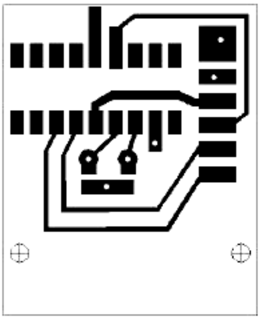
Conclusion

So having built up the 10GHz transmitter, this completes the equipment

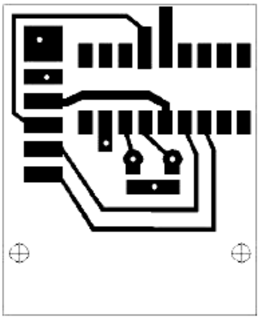
required to carry out comparative tests on 10GHz antennas.
These are:
1. Modulated Gunn diode source with small horn – as described here.
2. Battery and regulated power supply for the transmitter
3. Waveguide mounted diode detector assembly and small horn (would be normally fitted directly to the illuminating horn of the dish under test or via a transition to an SMA connector output of the horn)
4. AF tuned level meter to the Roger Blackwell design published in Scatterpoint issue 4 and 5.
10GHz is perhaps the most commonly used microwave band – it certainly one of the easiest to get onto. This equipment will help us to
get the best from our equipment
and also demonstrate when we have succeeded in improving it

References
1. Tuned Audio Level Meter for RF Measurements, Roger Blackwell G4PMK, "Scatterpoint" –issues 4 & 5.
2. Email the author: g6gxk@arrl.net
3. UK microwave group website:
www.microwavers.org

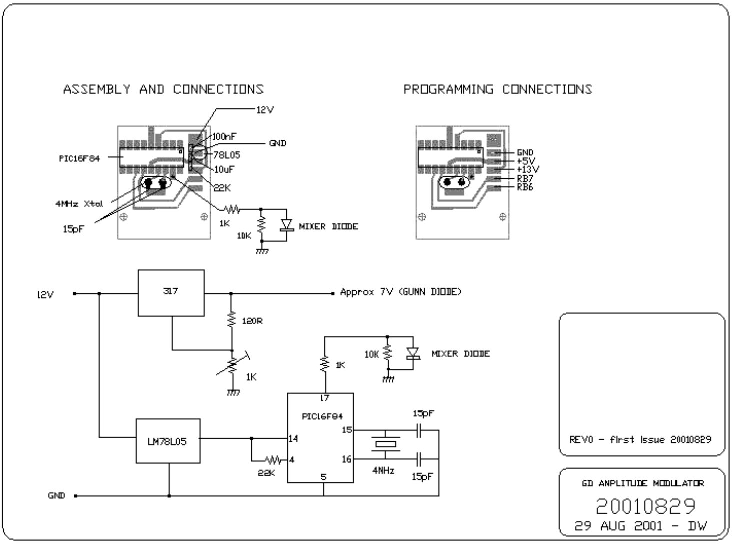




COPPER



MIRROR IMAGE
FOR IRON-ON RESIST


ASSEMBLY AND CONNECTIONS
PROGRAMMING CONNECTIONS
12V
100nF
GND
78L05
PIC16F84
10uF
22K
4MHz Xtal
15pF
1K
10K
MIXER DIODE
GND
+5V
+13V
RB7
RB6
12V
317
Approx 7V (GUNN DIODE)
120R
1K
10K
MIXER DIODE
17
PIC16F84
15pF
LM78L05
14
15
16
4
22K
5
4MHz
15pF
GND
REV0 - first issue 20010829
GD AMPLITUDE MODULATOR
20010829
29 AUG 2001 - DW

Single LED Battery Status Indicator for the 'Rover'

Paul Wade, W1GHZ © 2005

Fading batteries are an all too frequent part of rover operation. Battery voltage fades slowly and silently, usually unnoticed until something doesn't work quite right, and then the problem is still sometimes overlooked. A simple warning device that doesn't distract from normal operation would help.

Battery status is easily monitored by the battery voltage – a "12 volt" battery, like a car battery, delivers around 13 volts when fully charged, dropping to below 12 volts when nearly discharged. A rover operator could check this periodically, but there are periods of attention overload: simultaneously digging out weak signals, maintaining liaison, doing PR with onlookers, and keeping antennas from blowing over in the wind can fully occupy most of us. So, while we could easily read a DVM, or just push the right button sequence on an FT-817 to measure the voltage, it may get neglected until something doesn't seem right.

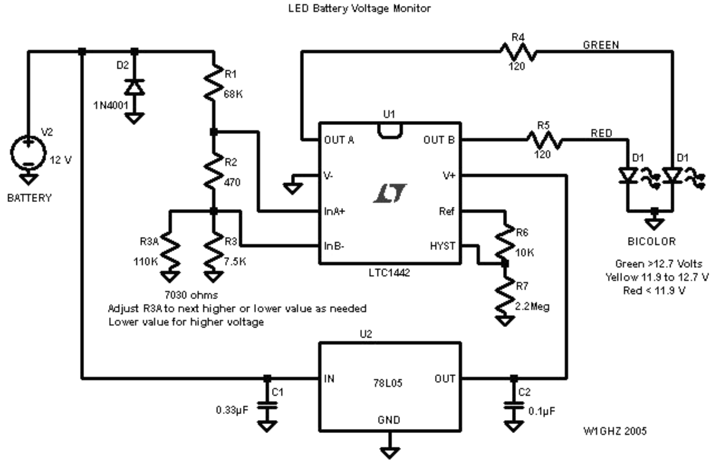
A simple indicator, like an LED, is much easier to notice without being a distraction. It occurred to me that a multi-colour LED could be used as a status indicator. The most common combination is red and green; obviously, green for good and red for bad. When both colours are lit, the output is yellow, which could be a warning state. Thus the simple display would be green if the battery is good, yellow when the battery is getting low, and red when it is dying.

Now we need a simple circuit to detect the voltage and drive the LED. Integrated circuit comparators are cheap, but the difference between a good battery and a dead one isn't large, so the voltage must be reasonably accurate. The comparison voltage, reasonably accurate over time and temperature, may be obtained from an integrated circuit voltage reference at a modest price.

A comparator has two output states: high when the "+" input is at a higher voltage than the "—" input, and low when the "+" input is at a lower voltage. To drive the bi-colour LED, one comparator should turn off the green light when battery is nearly dead and another comparator should turn off the red light when the battery is near full charge. In between, both lights are on, so the display will be yellow.

I have some LM393 comparators, the cheapest one available, in the junk box. However, all the available bi-colour LEDs have a common cathode lead and separate anodes, so the open collector outputs of the LM393 would not drive the LED without external transistors – too many parts for a simple circuit. A bit of research located a dual comparator with a built-in voltage reference, the LTC1441 (**www.linear.com**), with a price comparable to a voltage reference alone. The only drawback was that this comparator will not operate at 12 volts, so a 5-volt three terminal regulator is necessary to reduce the voltage. The complete circuit is shown in the schematic, **Figure 1** on the next page.

The voltage divider R1, R2, and R3 sets the voltage trip points for the comparators in U1, so that the red light goes out at voltages above about 12.7 volts and the green light goes on at voltages above 11.8 volts.
Since I used ordinary 5% resistors, the necessary adjustment for tolerances is



provided by R3a. If the trip points are too low, R3 is decreased by replacing the nominal value of R3a, 110K, with the next lower standard value, 100K, or 91K if necessary. If the trip points are too high, R3a is increased to 120K or 130K.

Once the adjustment is made, the resistors will probably drift and age together to maintain the desired ratio. When I bread boarded this circuit, it appeared to work fine, with the colour changing as planned.

However, when the voltage was set exactly at the trip point, thermal noise switched the comparator on and off randomly at a rate invisible to the eye but visible on an oscilloscope. The comparators are too sensitive! The solution is to add some hysteresis, so that there is a slight difference between the on and off trip points. The LTC1441 has a pin for adding hysteresis, by adding R6 and R7. The values shown provide about 0.1 volts difference between the on and off voltages.

My breadboard didn't look robust enough for rover use, and I had a bit of spare area on a PCB for another project, so I made a quick layout of Figure 1 and added it to the board, piggybacking on a $59 Miniboard with ExpressPCB **www.expresspcb.com**

Figure 2 is the PCB layout for use with the free ExpressPCB software – the plain version I built and two others with PowerPole connectors on the board, to monitor voltage as it enters a box. The file is available at **www.w1ghz.org**

A photo of the complete battery status indicator is shown in **Figure 3.** Small and simple, with one LED, two ICs, eight resistors, and two capacitors. Total parts cost, new from DigiKey (**www.digikey.com**), is about $3. I found three choices for bi-colour LEDs in the catalogue: the 160-1057-ND had the best three colour combination, the 67-1124-ND was pretty good, but the 160-1715-ND had a very greenish colour when both are lit so the yellow state is harder to discern. Any of the three LEDs run about $0.30, so choosing the best colour doesn't cost extra. I included the unit in Figure 3 inside my Battery-Sharing Switch, so I now have one box to control my batteries with just one light to keep an eye on.

Fig. 2

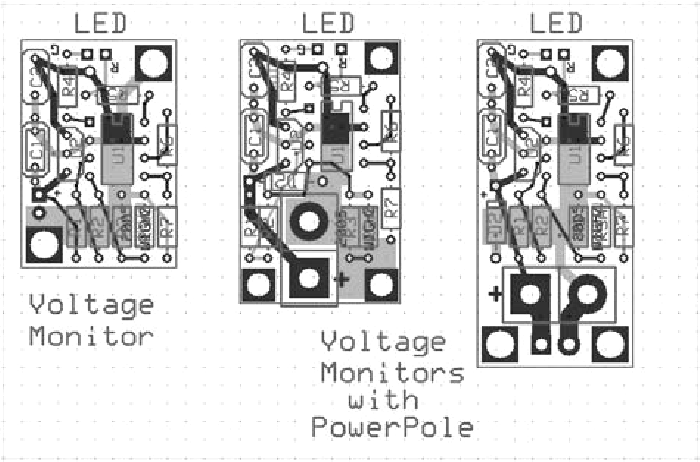
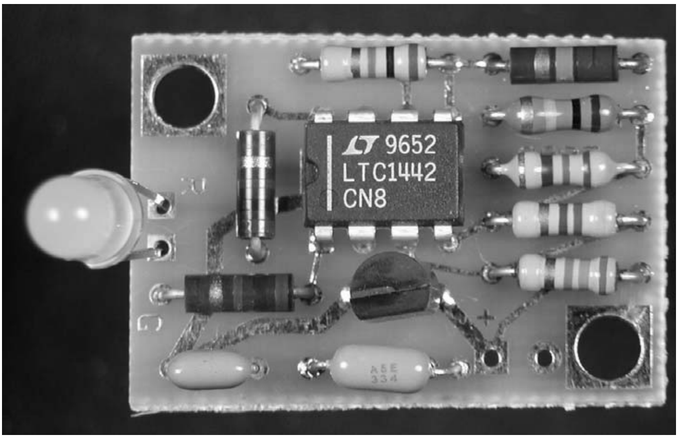

LED
LED
LED
Voltage Monitor
Voltage Monitors with PowerPole

Fig. 3


9652
LTC1442
CN8

Circular Waveguide to N type Adapter for 47GHz Power Measurements

Kerry Banke, N6IZW

As I started getting my feet wet with experiments on 47GHz and above, I was looking for a way to roughly measure power. I have an HP436A, Gigatronics 8540C, and PMI 1018B, all with heads rated to 18GHz .

The questions were would any of these heads respond at all to 47GHz, how would I couple 47GHz to the power head and how could I do a rough calibration? The calibration turned out to be fairly easy as Will Jensby, W0EOM, loaned me a multiplier module for which he had measured the power output.

The experiments that myself and Don Nelson, N0UGY, had been performing mostly used 0.188 inch ID hobby tubing as circular waveguide so I needed a transition to the type N connectors on my power meters.

The one thing I wanted to avoid was adding any more probes & transitions to increase losses and aggravate the moding situation. I came up with this approach that is very crude but effective.

The basic concept is to have the circular waveguide slip concentrically over the centre pin of the male type N connector, without touching it. I did this by cutting a Type N double Female (bullet) in half and drilling out the centre to hold the outside of the .188 ID tubing. The tube is located so that it is concentric with the centre pin and set in length to just seat against the rear of the connector on the power meter when tightened by hand.

I have no access for equipment to sweep frequency to see the effects of moding so here are my findings at 47GHz.

The Gigatronics reads 10dB low, the HP head is closer to 20dB low and the PMI doesn't respond at all (>20 dB low). The Gigatronics responds at 76GHz as well but I currently have no way to check the calibration.

Hopefully this will encourage others to try their power meters at millimetre wave frequencies.