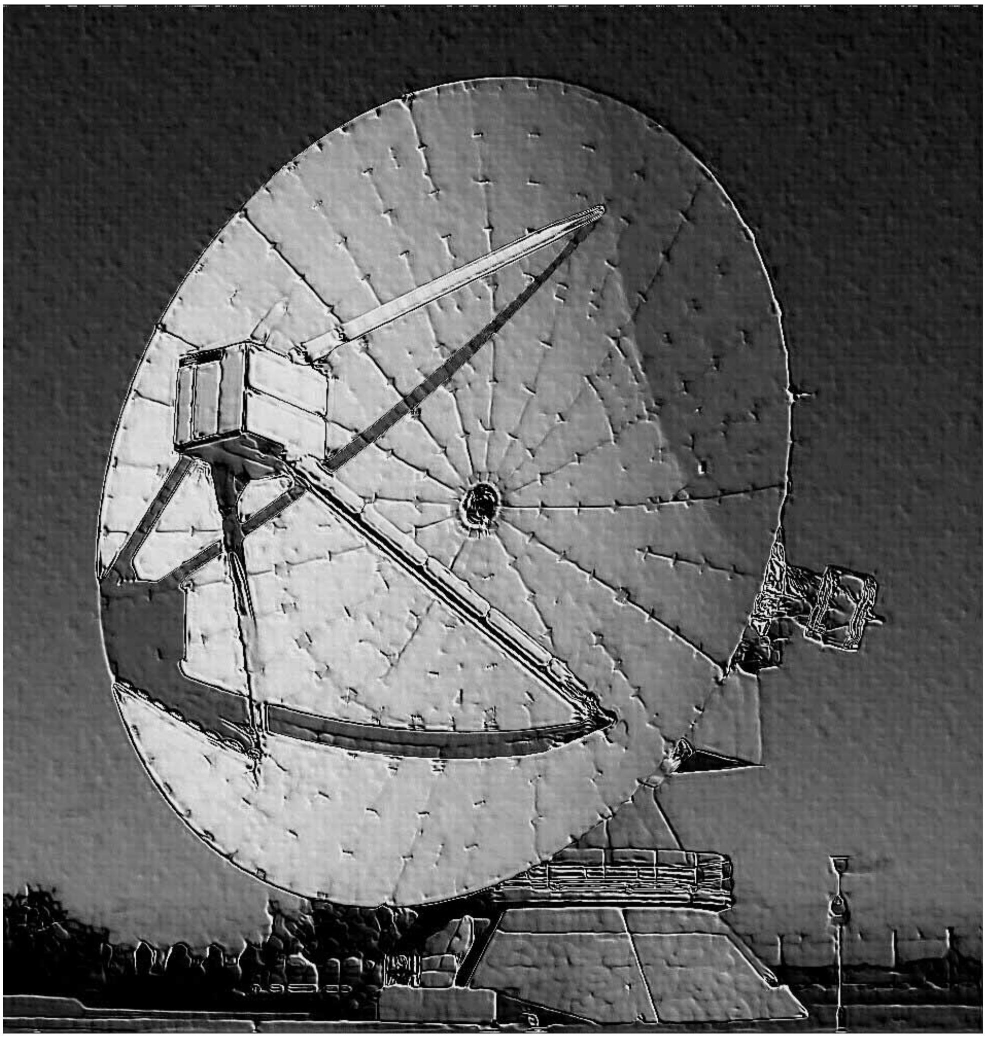
UK Microwave Group



Proceedings

2004-5

UKuG Proceedings 2004-5

Contents

Foreword

As Chairman of the UK Microwave Group (UKuG) I have the honour of introducing our first "Proceedings" to you. Over the past eighteen months, the Group has gone from strength to strength and can now rightly claim to be the principal representative organisation for amateur microwave radio enthusiasts in the United Kingdom. The UKuG Committee is determined to offer all the support it can for its Group members. This Proceedings is just one of the projects presently being undertaken by the committee. For further details of the UK Microwave Group, including its monthly newsletter Scatterpoint, you should take a look at our website, **www.microwavers.org**.

This book is a collection of presentations given "live" over the past two years at UK microwave meetings (known as "roundtables"), together with some other papers kindly submitted by several well-known UK amateurs. It is the first publication of its kind to be published by the Group and hopefully the first of many. We cannot, as yet, hope to compete with the excellent Proceedings of Microwave Update, published by the ARRL each year, but nevertheless we sincerely hope that you enjoy our modest publication.

Each year the UK Microwave Group supports two major microwave meetings, the Martlesham Microwave Roundtable, held in November, and the Rutherford Appleton Laboratory Roundtable, held in April at the R.A.L establishment at Didcot, Oxfordshire. The meetings are attended by some 60 to 120 microwave enthusiasts, several coming from both the Continent of Europe and North America. If you are reading this in some far off corner of the world I invite you to come over and meet us all at a forthcoming roundtable!

This book would not exist had it not been for the hard work of the Group's treasurer, Steve Davies, G4KNZ. In a very short space of time he has assembled and formatted this collection of material into what you can see in the following pages. In order to make the proceedings good value for money, we have published it in black and white format.

To G4KNZ, to all the contributors of material to this Proceeedings and to Mensa Printers of Sheffield, I extend my thanks for a job very well done.

Until next year,
73 and good microwaving!

Peter Day, G3PHO
Chairman UK Microwave Group
March 2005

UK Microwave Activity in 2004

Based on a presentation given at Martlesham 2004

Peter Day – G3PHO

About the author

Peter was first licenced as G3PHO in May 1961. In the early 1970s he met Barry, G8AGN, who gave him the microwave bug in the form of a baked bean can, a 9cm klystron and a 1N23 mixer diode! Operation is almost entirely from portable sites and he gets a lot of satisfaction in activating "rare" squares.

He was a member of the RSGB Microwave Committee, from 1985 until it was dissolved in 2003 and has edited the Microwave newsletter (now Scatterpoint) since 1985. Peter is also Chairman of the UK Microwave Group and has a mission to get inactive microwavers back on the air, particularly those who have unused equipment gathering cobwebs on the shack shelves!

Another interesting year

- Several “rare” squares activated
- Contest programme now accepted by most although there’s a need for a look at low bands and mm bands
- Increased participation in UK contests by F, PA and ON operators
- Use of Internet (ON4KST) still increasing and has virtually replaced RF talkback outside of contests.
- Generally poor conditions during contest weekends but good tropo in early September (for some!)
- Very poor response to annual Microwave League Table (only a handful of entries!)
- Millimetre bands still neglected in spite of high power (2 to3W) now available

Low Band Contests

These were held in March and November in 2004.

March contest:

23cm: Around 30 stations heard active	Best DX:	23cm: 569km (G4BRK – PA5AO)
13cm: at least 20 stations heard active		13cm: 428km (G4BRK – PA0WWM)
9cm: Approx. 12 UK stations active		9cm: 277km (G3PHO – G3PYB/P)

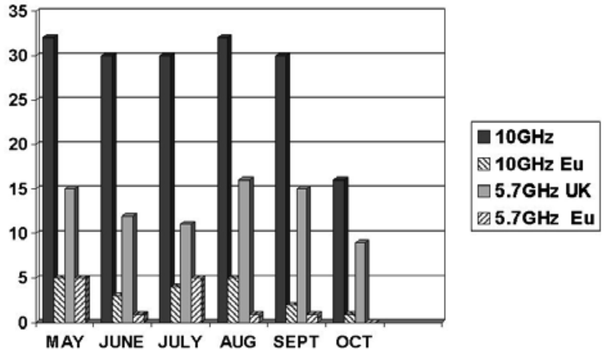
10 stations sent in logs – 6 fixed and 4 portables

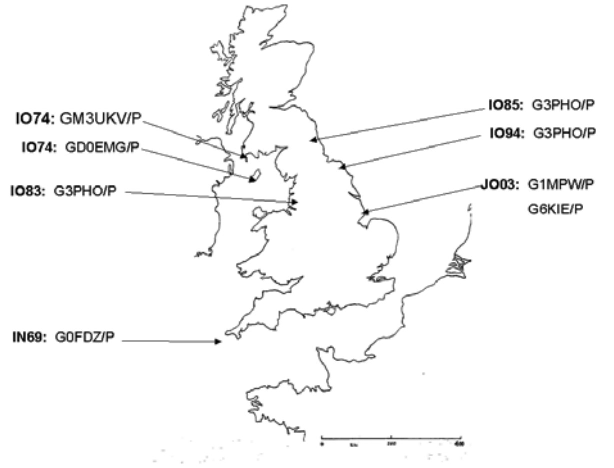
5.7GHz and 10GHz Contests

- Activity levels about same as last year … good …30+ each month except October
- 15 UK ops on 5.7GHz each contest
- 35-40 UK ops on during 10GHz contests
- Several new callsigns heard on both bands

New stations heard this year: G4RQI/P (IO93 10GHz), G0EWN/P (IO93 10GHz + 5.7GHz), M0DTS (IO94 10GHz). At least one op (M0EYT) used Internet ‘Talkback’ from his portable site.

10GHz & 5.7GHz Cumulative Contest Activity

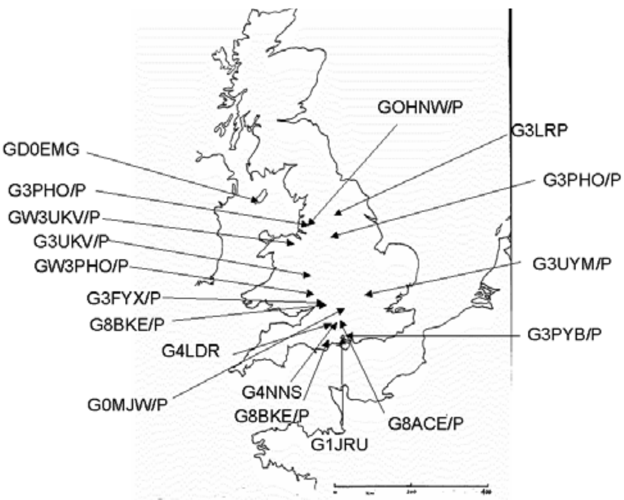




“Rare” Squares activated by UK portable stations in 2004 (3.4- 10GHz)

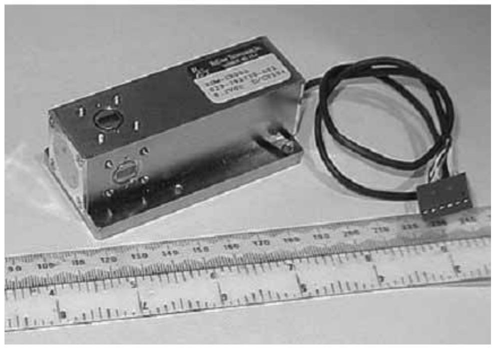
G3PHO/P ~ 5.7 & 10GHz 2004

24GHz Activity in 2004



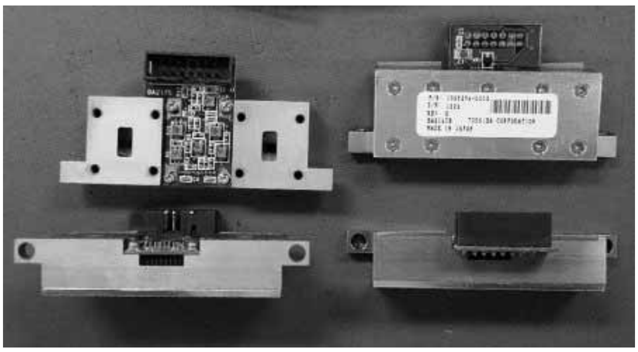
24GHz now ready to show what it can do

- High power now available
- Rainscatter and reflected paths work well
- New Zealand waveguide switches make for ease of PTT operation and low feed losses.

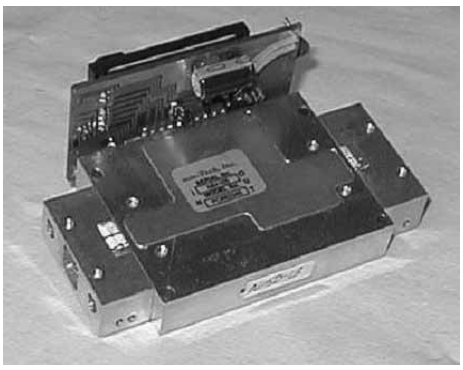


- “Flood” of half watt PAs from the USA …now estimated to over 50 in the UK!
- Now 6 working 2 watt stations in UK
- THREE 3 watt amps recently imported and MORE available from Paul Drexler W2PED
- 24GHz contests now cumulative but has not encouraged more activity… why?
- New stations in 2004: G4ZXO/P, G4EAT, G0MJW/P

24GHz GOES ‘QRO’



(a) Toshiba half watt amps from Endwave (USA)



(b) 2 and 3 watt amplifiers from Paul Drexler (USA)

G3PHO/P ~ 24 & 47GHz 2004

The 24GHz QSY

- By 01 January 2004 all IARU Region 1 narrowband operations should have moved to the 24.048 to 24.050GHz section of the band
- How many of you have moved?
- GB3SCK has!
- Don't delay … move today!
- Please be active on 24GHz in 2005

47GHz and 76GHz

Four contests for 47GHz this year … better support than last year but still room for more! 76GHz no longer a contest band due to limited activity on the band.

Small groups experiment outside contests:
Southern Group - G3PYB, G8ACE, G8BKE
Northern Group – been largely inactive this year

Known UK Ops with working 47GHz narrowband equipment:

G3FYX	G4LDR
G3PHO	G7MRF
G3PYB	G8ACE
G3UYM	G8BKE
G4BRK	G8IFT
G4DDK	G8VZT
G4KNZ	G0HNW

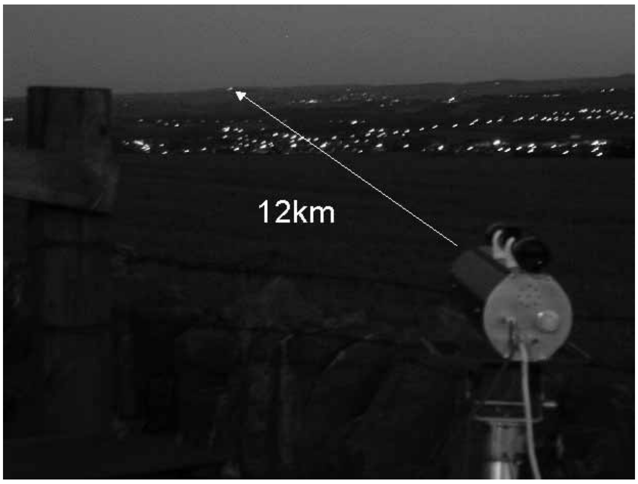
DX Openings in 2004

- Tropo openings in September
- Increasing use of ON4KST microwave internet chat room leading to more awareness of openings and therefore more DX contacts

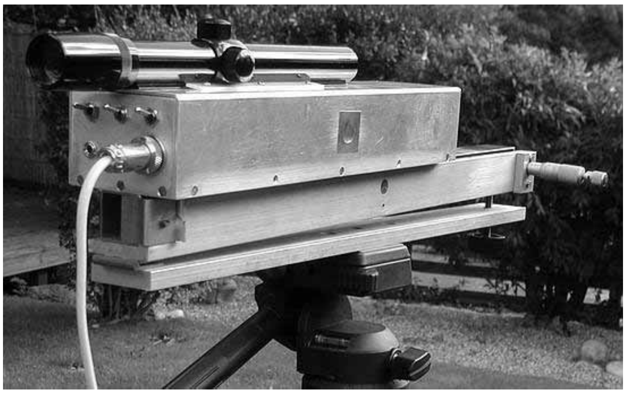
LIGHTWAVES

(a) Southern Laser Group

(b) Lightwaves Up-North – G8AGN & G3PHO



Tests over 12km path



G8AGN Laser TX

The Bands - use or lose them!

23cm	1240 - 1325MHz	NB 1296 - 1298MHz
13cm	2310MHz - 2450MHz	NB 2320 - 2322MHz
9cm	3400 - 3475MHz	NB 3400 - 3402
6cm	5650 - 5850MHz	NB 5760 - 5762MHz
3cm	10.0 - 10.125GHz	ATV and other wb modes
3cm	10.225 - 10.500GHz	NB 10.368GHz
12mm	24.0GHz - 24.250GHz	NB 24.048GHz
6mm	47.000 - 47.200GHz	NB 47.088GHz
4mm	75.5GHz - 81.0GHz	
2mm	144 - 144GHz	
1.2mm	248 - 250GHz	

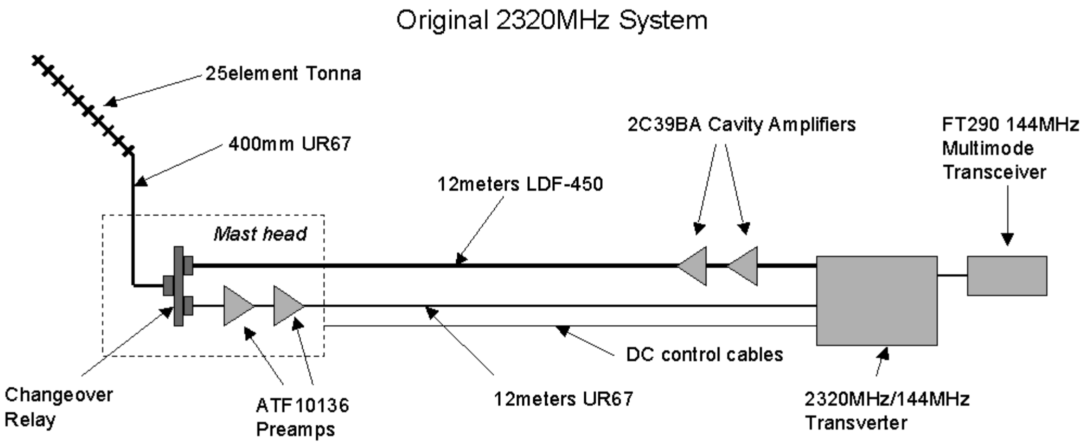
We also have the following bands:
122.25 - 123GHz, 134 - 141GHz, 142 - 144GHz (until end 2006)
241-248GHz

An Integrated Transverter System for 2.3GHz

By David Cox – G0RRJ
December 2003

Introduction
I have been operational on 2320MHz for approximately 15 years, my best DX being just over 1100km with OE5VRL/5 back in 1992. However, over the last few years I have been very inactive mainly because my 2320MHz system has been unreliable and needed replacing.

The system comprised of a 25 element Tonna for the antenna, two cascaded pre-amplifiers mounted at the masthead with a changeover relay. These pre-amplifiers were proving unreliable probably due to poor relay isolation and I had made several trips on to the roof to carry out repairs. This system required two coaxial cable runs from the shack up to the masthead, one to the mast head antenna changeover relay which consisted of a run of LDF-450 for transmit and run of UR58 for receive. In the shack I had two beautifully built brass cavities providing about 45 Watts. The old transverter of many years' service also had a fault.



After a while I found the PA blower noise very irritating and this coupled with the fact that the preamp had failed again drove me to the conclusion it was time to build a new 2320MHz system. This article describes my thought processes for the new system, it's design, the construction and the results achieved in the first ten months of operating from the home QTH.

Design Objectives
The design objectives had to meet the following criteria: -
a) Use modern solid state technology.
b) Provide good system performance on both TX and RX.
c) Reliable and easy to maintain if & when required.

Evaluating Existing System Performance
Over the years I have had several 2320MHz system configurations.

The best ever configuration was when I worked OE5VRL/5, which consisted of: -
TX - 45 Watts into 10 meters LDF-450 @1.15dB loss, a 25 element Tonna 18.3dBi, providing an eirp 2.208KW
RX - Two ATF13036 preamps located at the masthead approx. 0.25dB of coax loss between antenna and the input to the preamp.

The current system configuration consists of: -
TX - 45 Watts into 15 Meters of LDF450 @1.78dB loss, a 25 element Tonna 18.3dBi, providing an eirp 1.902KW.
RX – Single ATF13036 preamp in the shack - 1.75dB dB of coax loss between the antenna and the input to the preamp.

System Design

The systems needed to meet a minimum requirement of 1KW eirp and have a very good receive performance. As the new system was to deploy solid state technology it allows the entire system to be easily re-sited. The following location options were considered.

a) From a technical perspective the ideal position would be to site the entire system on the mast near the antenna.
b) Locate the entire system in the shack and install a mast head preamplifier.
c) Locate the entire system in the roof space.
Each of the system location had its advantages and disadvantages from my perspective and is detailed below.

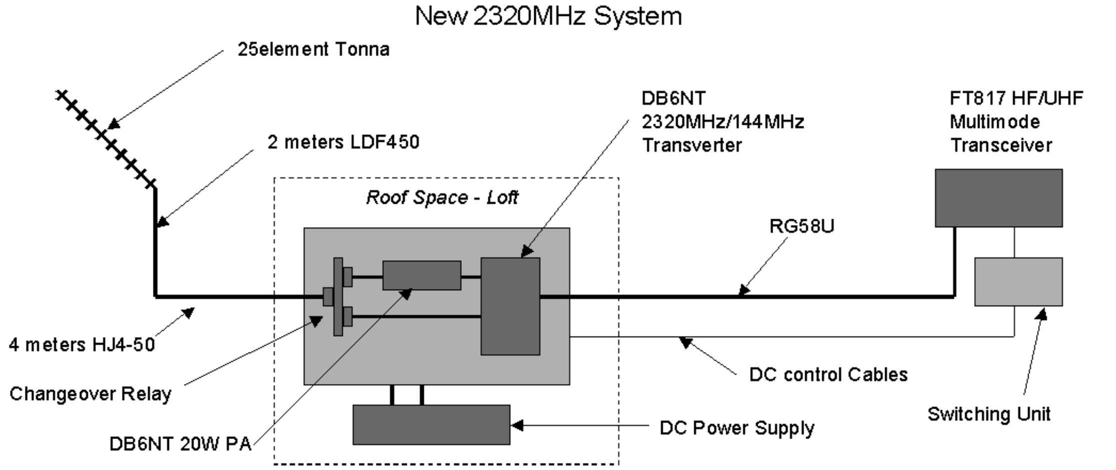
Location 1	Advantages	Disadvantages
Mast head mounted system	a) Ultimate receive performance.	a) Risk on ingesting rain water or moisture
	b) Maximum power transfer into the antenna.	b) Careful attention to DC cable requirements avoiding voltage drop on the conductors.
	c) Coaxial Cable loss approx. 0.1dB	c) Maintenance requires climbing on the roof.
	Approx. eirp (19W PA) = 1.196KW	d) Extra weight on the mast.

Location 2	Advantages	Disadvantages
Shack mounted system	a) System not exposed to the weather.	a) Significant cable loss resulting in (expensive) power being lost in the cable.
	b) Ultimate receive performance with masthead preamp.	b) Two cable runs one for TX & one for RX.
		c) mast head preamp maintenance would require climbing on the roof.
		d) Coax loss on TX (12M) = 1.38dB
		e) Coax loss on RX = 0.1dB
	Approx. eirp (19W PA) = 896W	

Location 3	Advantages	Disadvantages
Roof space (loft) mounted system	a) System not exposed to the weather.	a) a small compromise on overall system performance
	b) Good receive performance based on a single 6 meter length of Heliax coax cable.	b) Coax loss on TX (6M) = 0.69dB
	c) Good power transfer into antenna based on short Heliax cable run.	c) Coax loss on RX (6M) = 0.69dB
	d) DC supply located in the roof space simplifying the power requirements	
	e) Easy to maintain (no excursions on to the roof).	
	f) Mechanical construction easier as mast head fixing is not required, plus less weight on the mast	
	e) if ever needed to operate from a portable location the system could easily be re-deployed.	

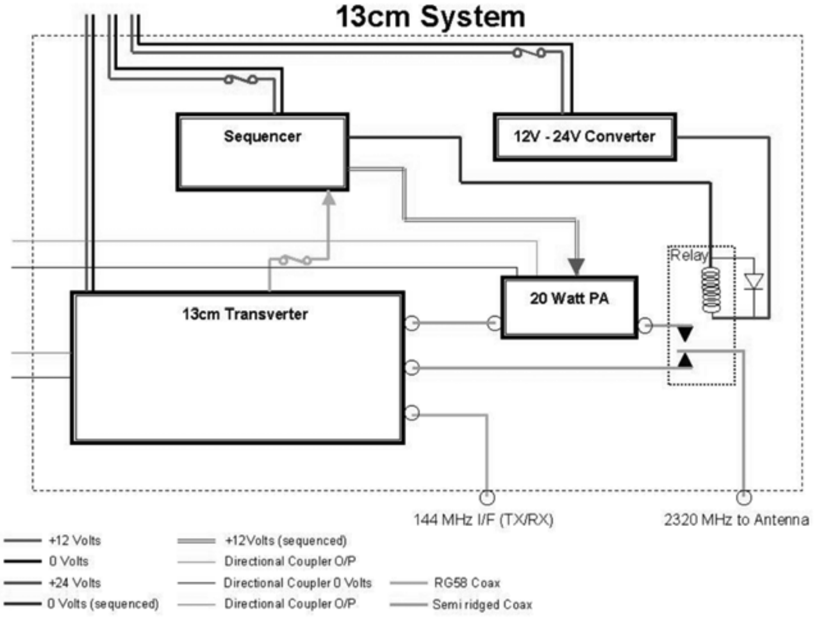
	f) No mast head preamp, although it could always be added later	
	Approx. eirp (19W PA) = 1.036W	Approx. 0.59dB more coax loss in RX path compared to other two options, which represents approx. 1.77dB down in system noise S/N

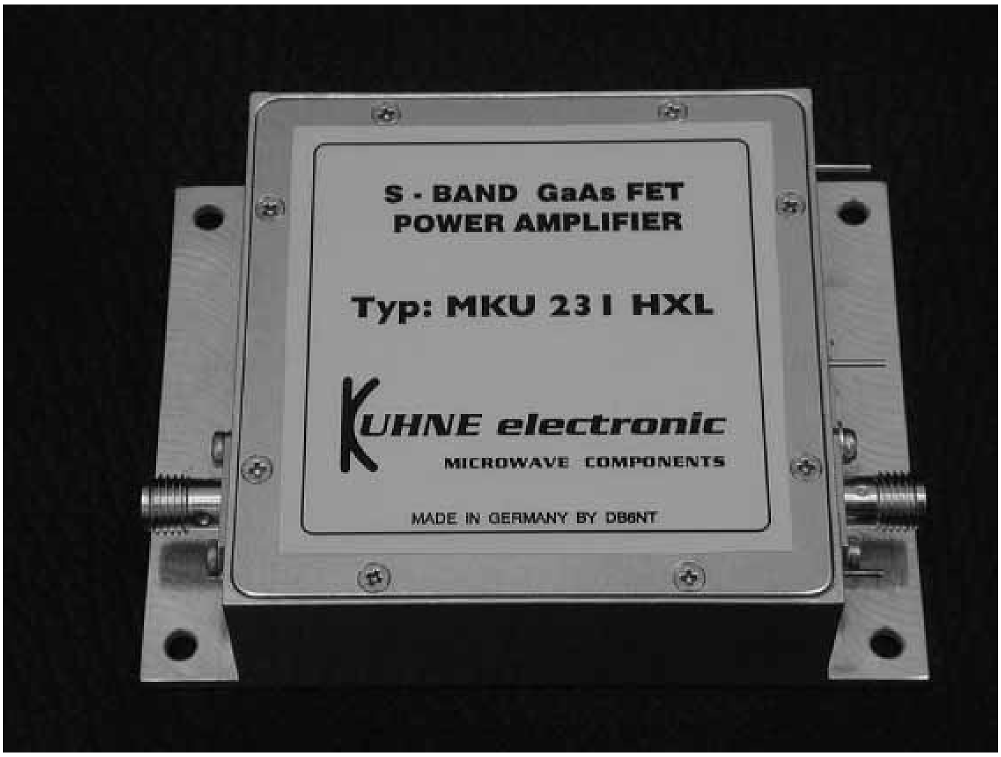
After some consideration I chose to locate the system in the roof space (Location 3) as it provided most of the advantages I was looking for. The only disadvantage was the longer cable run between the antenna and the receiver, but if this turned out to be a significant degradation in system receive performance then a mast head preamp could be installed later.



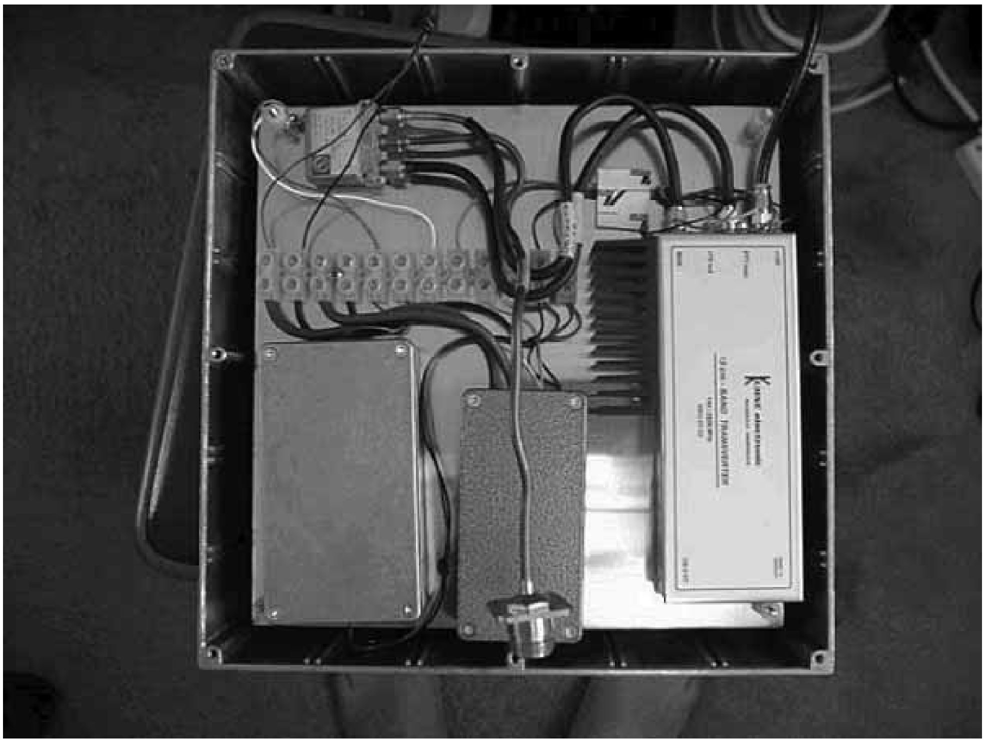
Hardware Design
I already had a DB6NT 13cm transverter, which I had purchased 18 months ago. The next step was to decide on a PA. As I already had a DB6NT transverter and experienced excellent after sales support from Kuhne Electronics their KU 231 HXL 20W 2320MHz PA was the obvious choice. I obtained a 24V SMA relay form G1MFG and built a 12V to 24V converter. I purchased a DB6NT sequencer and integrated all the components into a large diecast box.

System Block Diagram





2320MHz 19W Power Amplifier



Inside of transverter system

Top left is SMA coaxial change over relay
Bottom left is 12v – 24v converter
Right handside 144-2320MHz transverter

Bottom is the 12v – 24v converter
Above is Relay & PA sequncers and system fuses

A control cable is attached between the diecast box and the shack operating position. This provides monitoring of the directional couplers located in the DB6NT transverter and the DB6NT PA. A front panel switch to provides manual PTT. The system is connected to a 12V DC supply located in the roof space and is switched on & off with the main shack power switch.

Initial Results

This system was put into service at the beginning of January 2003. The coax connection between the transverter and the antenna comprised of 400mm of UR67 and 6 meters of Heliax type cable. During this time I worked the following stations G3XDY JO02OB, G4BRK IO91DP, PA6NL JO21BX and PA0WWM JO21BX

Microwave and VHF masts at G0RRJ in January 2003

Latest Results - after minor modifications to the antenna system

On the 12th of May 2003 I made two minor modifications I increased the antenna height by approximately 600mm. The antenna on the top of the mast is a 55 element Tonna for 1296MHz the smaller antenna below it is the 25 element Tonna for 2320MHz now at least 15 years old. I connected 2 meters of LDF-450 to the antenna and a further 4 meters of HJ4-50 to the transverter this represents 0.8dB loss in the coax. Since the 14th May 2003 I have worked PA0WWM on 2.3GHz on forty six different occasions at a distance of 428Km we have succeeded on every attempt. This exceeded my expectations. I also worked GD0TEP in far from lift conditions using meteor scatter operating techniques. I also worked DG1KJG in JO31NT at a distance of 607Km and F5HRY JN18 395Km in an early morning skeds, this would appear good time to operate. During NFD I also worked four Dutch stations PA6NL JO21BX 401Km in SSB, PA5DD JO22IC 443Km, PI4ZLD JO11WM 378Km and PA0WWM JO22FE 428Km in cw. In enhanced propagation I have also worked PA0EZ JO22OF 479Km, F6CBH JN19BH 339Km, PA3AWJ JO21GW 428Km, PA3AOH J031GN 562Km, F6APE IN97QI 407Km and GM4LBV IO86RQ 614Km who was running a couple of watts into a 67ele yagi. During the first ten months of 2003 using this system I have had one hundred and fifty eight qsos with thirty different stations in seventeen locator squares all from my home QTH.

Room for improvement?

There is always room for improvement. On receive a masthead preamp would no doubt improve things, but how much? Is it worth the time, effort, money and excursions on to the roof? Only time will tell, but I doubt it. On transmit I could increase the power by 3 to 6 dB but at considerable cost, solid state devices at this frequency don't come cheap, would I work more stations as a result? Who knows, for me it would be better to allocate the funds and effort to get going on another microwave band. However, an easier and cheaper solution available would be to improve the antenna by least a 3dB. This could be in the form of a long yagi or a dish. If I decide to improve the system this is the area I would focus my efforts at as it simultaneously improves both the TX & RX signals.

The antennas I would consider evaluating (assuming I have space on the mast available) are listed below. A 90cm dish would be an attractive solution, this has a very similar effect of increasing the power to 80 Watts but is much cheaper than a PA of this type, furthermore it improves the receive side considerably.

Antenna Type	Estimated Gain	Improvement on existing antenna
25element Tonna	18.3dBi	0dB
590mm mesh dish	20.1dBi	+1.8dB
Wimo 67ele	22.1dBi	+3.8dB
900mm mesh dish	23.8dBi	+5.5dB
1 meter mesh dish	24.7dBi	+6.4dB

Conclusions

Located at approximately 60 meters above sea level and with my share of high ground to point through I am very satisfied with the results of this system. I have still left myself with some scope to improve the system should I chose to do. However, my constructional effort will now be focussed on building a system for 5.7GHz . Hopefully this information may give you ideas and perhaps a little inspiration to join the 2.3GHz community. Thanks to Brian G4NNS who helped me with the metal work and testing the system prior to putting into service. In December 2003 I worked OE5VRL/5 again at 1178Km.

Footnote

After many rotations of the mast, the LDF-450 cable went open circuit. I am now using about 6 meters of W103 which has more loss than the LDF-450. I am also using a 45 element loop yagi. I am still making qsos and in December 2004 I worked OE5VRL/5 again. However, I am looking for a better flexible coax, perhaps Ecoflex 15 but still investigating.

Making and tuning an SMA to WG16 / WR90 transition

Brian Coleman G4NNS

Recently Ronny SM7/M0FWZ and I spent a Saturday morning making a couple of SMA to WG16 transitions and thought it might encourage others if we recorded our experiences. The initial measurements were based on a couple of professional units which seemed to work quite well, with a return loss of about 20dB when coupled to a good waveguide load.

The design we chose had the SMA socket fitted to a brass mounting plate and uses a brass plug to "blank off" the waveguide. This has several advantages. Tapping into the soft copper wall of the waveguide is undesirable as the fixing screws have to be very short indeed, if they are not to penetrate into the waveguide and upset the tuning. This makes it all too easy to strip the thread. The thicker brass plate provides more "meat" to tap into for the screws and it's hardness means the thread is much less likely to strip. Secondly, the brass plate and plug can be bolted together through the waveguide wall to hold them in place during soldering.

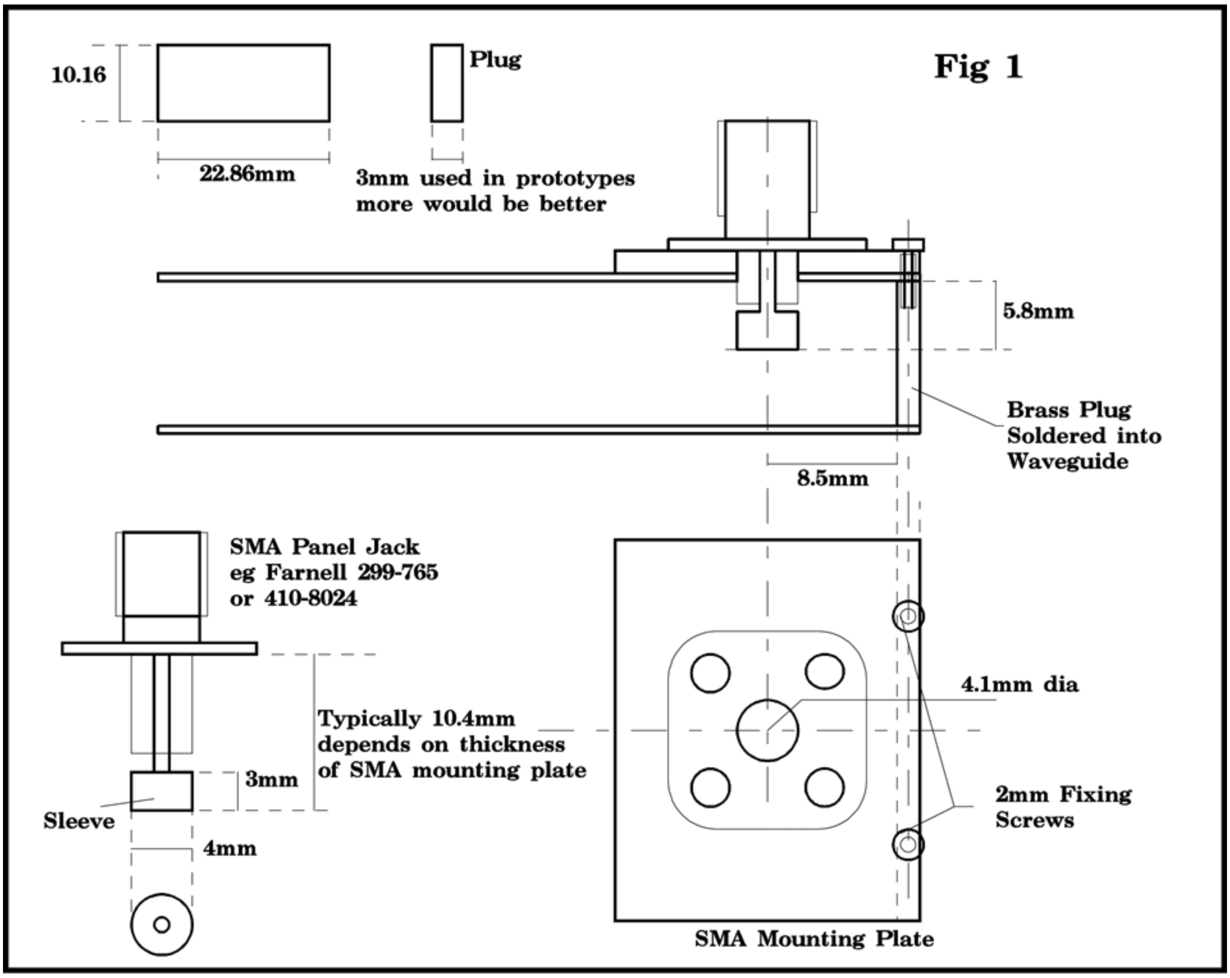


Fig 1 gives the essential dimensions but as it is easiest to convert the dimensions so that all the various holes are measured with reference to the rear and top surfaces, you will need to calculate some of your own measurements based on the (thickness) of the materials available to you.

First make the SMA mounting plate and drill the 2mm holes that fix it to the waveguide and plug. Next, use the SMA plate as a template to drill the 2mm holes in the waveguide. Next put the plug in place, in the waveguide temporarily and mark the 2mm holes through the SMA plate and waveguide to the plug. You can either drill the holes through the blanking plug 1.5mm and tap them for M2 or go all the way through the plug and waveguide with 2mm and bolt right through to the other side of the waveguide although this will be easier if the length of your plug is more than the 3mm shown in the sketch. Note that you could use larger screws such as M3 if your plug is long / thick enough. We only had 3mm available.

Next disassemble the plate and plug from the waveguide, and put them directly together so you can mark out the SMA centre hole 8.5mm from the “front” surface of the waveguide plug. Next drill the SMA centre hole to 2mm, de-burr the holes and re-assemble the plate and plug to the waveguide using 2mm fixing screws (again temporarily). Next drill the 2mm SMA centre hole through the plate and waveguide and open out to 4.1mm.

Remove the SMA plate and use your SMA socket (which should be a near perfect fit in the 4.1mm hole) as a template to mark out the four fixing holes. Drill these holes to 1.9 or 2mm and tap for 2.5mm. The plate and plug are now ready for final assembly and soldering to the waveguide.

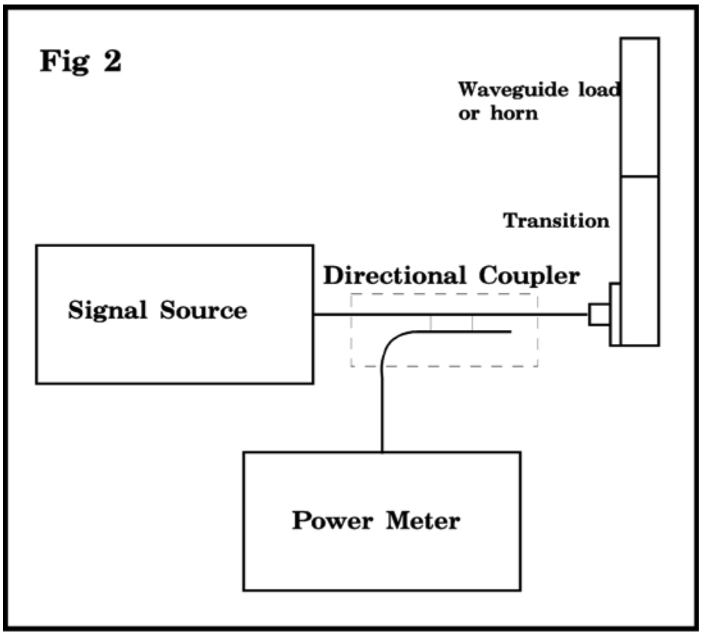
The best way to solder these is to use solder paste (as used for Surface mount) construction. Normal solder is ok but be sure to use it sparingly and make sure it flows well. A thin film of paste spread over the back of the SMA mounting plate and inside the waveguide before assembling the blanking plug is all that is needed. When the plug is inserted in the waveguide a “wave” of solder paste may form in front of it. So long as it was applied sparingly this will disappear by capillary action when the assembly is heated to flow the solder.

During final assembly before soldering use the SMA plug to align the mounting plate before tightening down the 2mm fixing screws. Remove the SMA socket and the assembly and heat to flow the solder. I use a hot air paint stripper gun rather than a blow torch as this does a better job and causes little or no oxidization to the copper or brass.

The sleeve on the probe is made from 4mm brass rod. A 3mm length of an M4 brass screw would probably do if you do not have brass rod available. It has a 1.3mm hole drilled through it to give an interference fit onto the SMA pin. If the nearest available drill is 1.5mm don’t worry, just lightly tin the SMA pin to achieve the necessary fit. But don’t solder in place just yet. The sleeve has the effect of broadening the bandwidth of the probe and allows it to be tuned by sliding the it up or down as necessary to achieve best return loss. Remove any surplus pin (length) so that before tuning no more than 5.5mm is protruding into the waveguide. You may need to shorten it later if during the tuning process.

Tuning

The tuning procedure requires a signal source, a directional coupler with good directivity, a power meter, an SMA load and a waveguide load or horn.



Your transverter can be used as the signal source. If you do not posses the other items find someone who does and ask for their help ! I have found “Microwavers” to be amongst the most helpful folk on the planet so don’t give up at this point !

Start with the sleeve fitted to the probe so that the length of the probe and sleeve as measured from the back of the SMA socket is 5.8mm + The thickness of the SMA mounting plate + (the thickness of the waveguide wall measured as 1.2mm on the H surface).

Using the signal source and directional coupler first measure the forward power into a good SMA load (a couple of 10dB attenuators will do nicely if you don’t have a load). See Fig 2 and Note 1.

Then set the directional coupler to measure the reflected power from the SMA load. With any luck this will be more than 20dB down on the forward power and will give you an idea of the directivity of the coupler which will limit the maximum return loss you can measure (and therefore be sure what you have achieved). Next replace the SMA load with the fully assembled SMA to Waveguide transition and observe the reflected power. Ronny and I noted that open waveguide seems to exhibit a return loss of about 13 -15dB when the probe is tuned so if your observed return power is 10dB or more DOWN on the forward power you are doing well at this stage.

Fit a good waveguide load or horn onto the waveguide output of the transition, to improve the waveguide output match, and the reflected power should drop further. If it drops to 20dB below the forward power I would stop right there, disassemble the probe, solder the sleeve in place and reassemble the probe in the waveguide. If tuning is necessary it is done by removing the SMA and probe and adjusting it’s length by sliding the sleeve 0.5mm either way, re-assembling and seeing whether this makes matters better or worse, always using a waveguide load or horn to ensure the match at the output of the waveguide is reasonable. It is well worth recording the results as you go so you know whether to shorten or extend the probe.

After a few “iterations” you should be able to get the return loss to 20dB or so (this is equivalent to a VSWR of 1.2:1). Perfectionists may try for more but remember that the directivity of the coupler will be a limiting factor regarding this measurement. If you need to reduce the probe length to the point where the SMA pin protrudes from the end of the sleeve, shorten the pin a little. Also remember that any other cables or connectors between the directional coupler and the transition may effect results. If possible change them and see if the results change much. A small change is almost inevitable but if you observe a large change, suspect a faulty connector or cable and if necessary repeat the tuning procedure. Once you are satisfied with the match solder the sleeve in place.

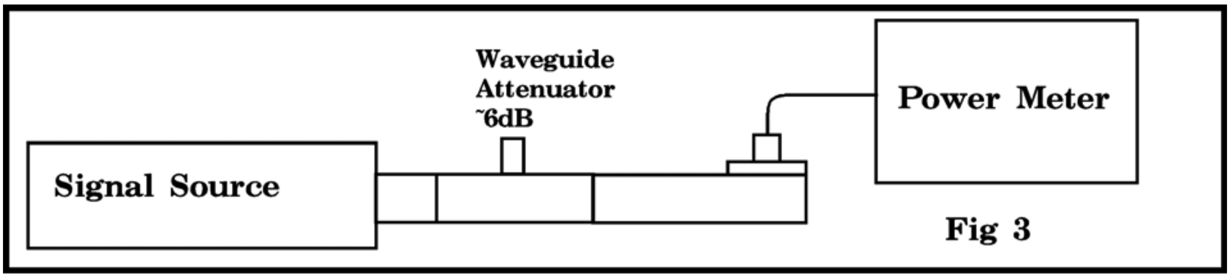
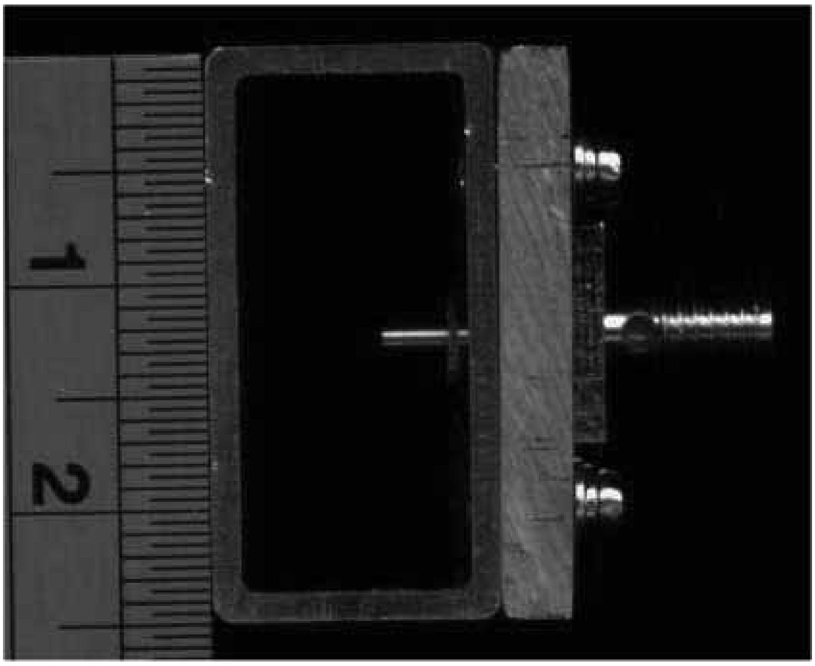


Fig 3

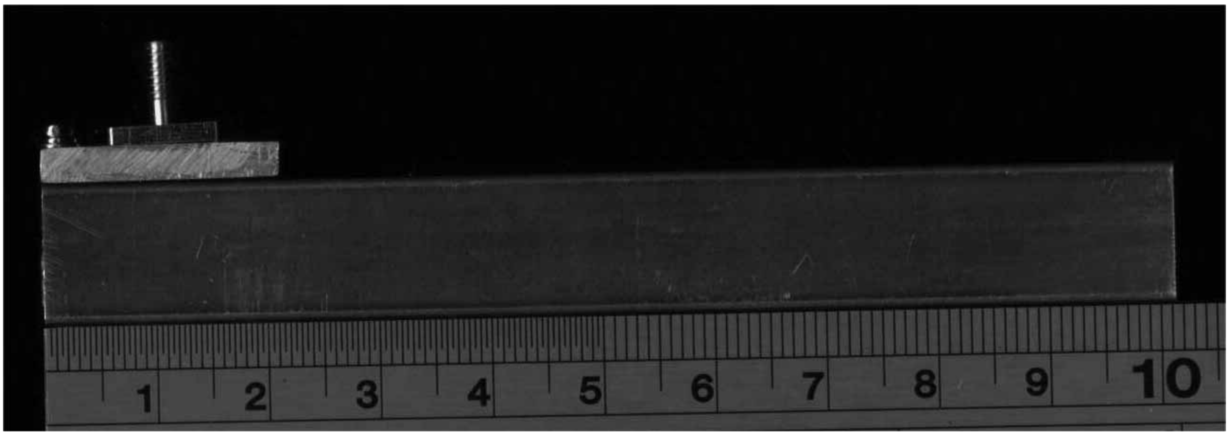
I was curious to get some idea of the loss through the transition . First I measure loss with reference to the two professional transitions in my collection. I used the set up in Fig 3 to do this. Before I inserted the waveguide attenuator in circuit, results were rather variable presumably due to the effect of reflected power on my signal source (a 20mW beacon) Note: It might be best to use an SMA attenuator of about 6dB before the coupler in Fig 2.

Once the attenuator was in place though I got consistent results. Our two home made transitions produced an output of +2dBm whilst the two professional units produced 1.6dBm. Next I tried to measure the “absolute” loss through the transition. To do this I placed two transitions back to back and measured the power through them. This turned out to be 0.6dB down on the direct SMA connection indicating a loss of about 0.3dB each.

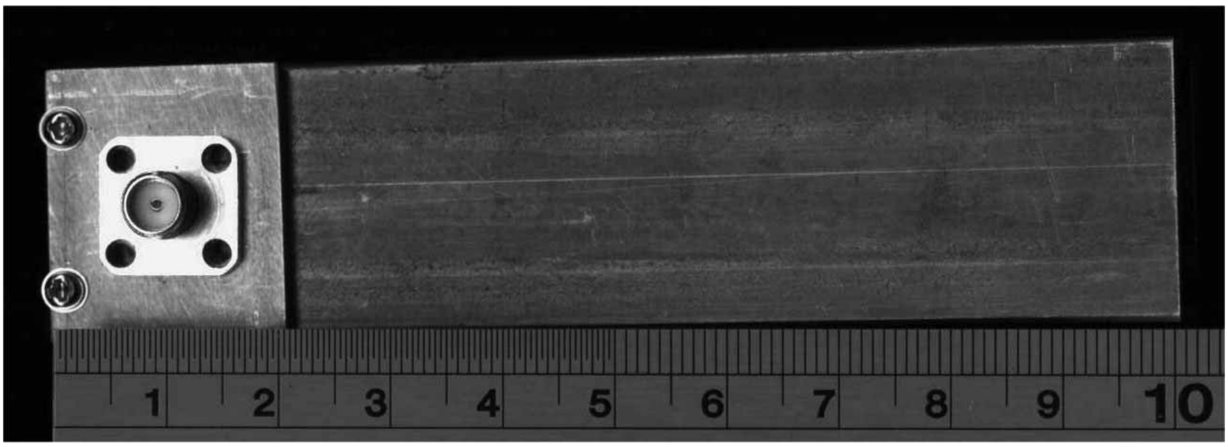
Transition (before final assembly)



End View



Side view



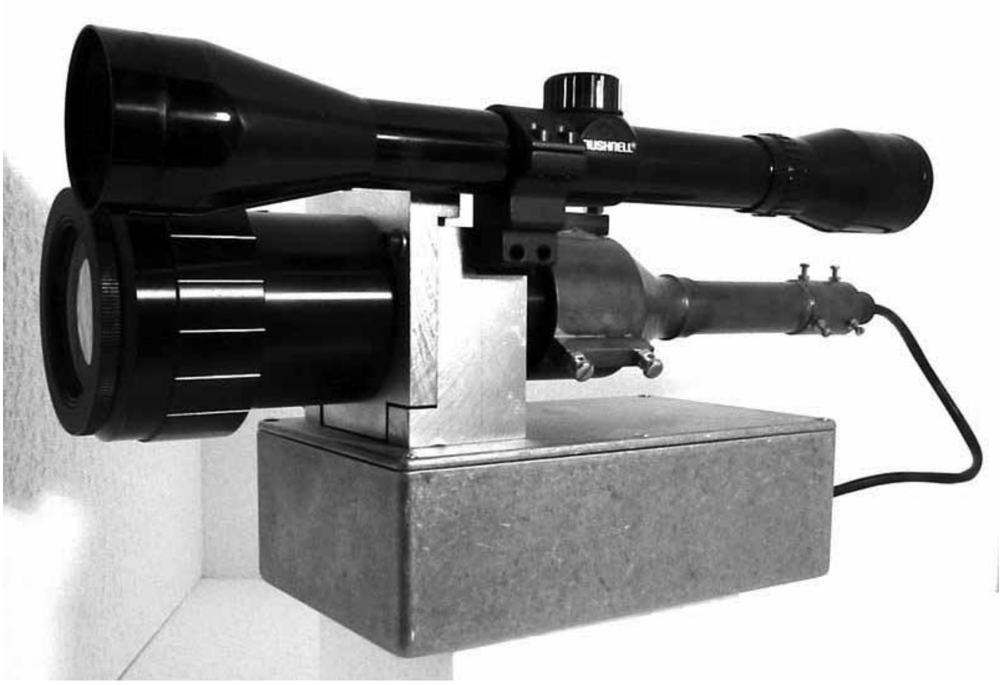
Top View

Laser Communications

Allan Wyatt – G8LSD

Introduction

This article describes the MkII version developed 1997-2001. The design aim was primarily for DX communication by keying an 800 Hz tone, but provision of PWM audio enables a wider range of experiments to be conducted.



Mk II Transceiver

NB In all of this article it should be remembered that class IIIa lasers are used. The beam must never be looked into with the naked eye or a telescope. It is strongly advocated that beam expanders are used on all laser sources to reduce the power density to safe values. Even in these cases a telescope can recombine the beam to damaging intensity. For local testing, use a diffuse reflecting plate to focus the telescope onto and/or a neutral density filter.

The original design used a 10mW HeNe gas laser. The optical bed was over 1M in length and prone to slight sag, even though well braced. The laser beam passed through a Bragg modulator and onto a 50 times beam expander with a 50 mm aperture. The laser took 6.5 mA at 2.25 kV and the encapsulated power supply was driven from 240 Volts, but in the field, driven from an inverter, it lasted only a few minutes before failing. The modulator needed several watts of 80 MHz to operate and ran from a 28 V supply. Operating from home the performance had been good with signals heard returning from a diffuse reflector at some 200 M from the laser.

The MkII is based on commercial laser module from RS. The module is rated at 3 mW at 670 nm and operates from a -12 V supply. The modulation can be TTL for data or just 0.5 V pk-pk for analogue modulation. The maximum modulation depth with a digital signal is 90%. The essential fact about semiconductor lasers is that they are always on the edge of self destruction. The operating conditions have to be exact and spikes will destroy them. Modulation should be applied to a parallel or shunt modulator. The basic diode housings normally have a reference diode as well as a laser diode. This is to facilitate a feedback loop to control the laser output. The laser cavity is only a few microns across and whilst the few milliwatts dissipated is small, the power density is vast. Good heatsinking is essential, especially with diodes operating with output powers of 5 mW or greater.

Experiments had originally been based around the Scandinavian suggestions of 25 kHz SSB. Further thought, when the experiments were not as expected, tended to suggest that as the laser frequency was not being modulated, but could be treated as a straight amplitude modulation of the beam intensity a base band approach would be better. Additionally, the detection has to take place directly with no possibility of amplification of the incoming light frequency.

The detectors (Burr-Brown OPT series) are most sensitive near to DC and the wider the bandwidth the greater the noise to be dealt with as always. The cheap OPT101P was tried with success, and after using the OPT210 (high bandwidth) it was decided to use the OPT211 as it had the lowest noise. At base band, with greater sensitivity, the overall equipment could be a sensitive audio amplifier for receive.

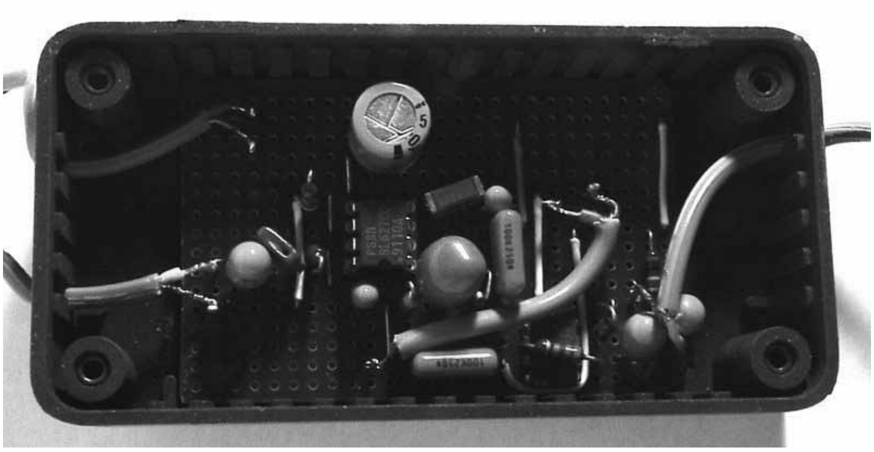
The high impedance front end mandated a sealed box and good electrical isolation. A die cast box provided most of the screening, and only a small hole in the lid just large enough for the 2.25 mm square sensor to be visible has been made. The aluminium tube has an outside diameter of 1 1/4 inches to suit standard telescope eyepiece sizes. Internally it is painted matt black to absorb off axis light.

To further secure good performance the OPT211 sensor and transconductance amplifier is coupled to an SSM2017 ultra low noise audio pre-amplifier. This device was designed for professional audio applications and has a quoted noise figure of 1.5 dB. In this present application the 13.8 V source voltage is converted in the head to + - 12 V by an isolating DC-DC converter. The signal output is AC coupled. To prevent massive overload to the SSM2017 a pair of back to back germanium diodes are placed interstage. It should be noted that the OPT211 will deliver an 18 Volt pk-pk squarewave with even moderate illumination levels. In use, with sensitive audio amplifier following the head, the background noise with the head tube covered by a black plastic cap is almost inaudible. In starlight the head generates noticable background noise, suggesting that the head itself is adequately quiet. The leads to the receiver proper are all co-axial.

Front end

The output noise from extraneous light input will fall into the passband from all colours of input light. To exclude this source of noise requires a narrow optical filter. For the HeNe line at 632.8 nm a 2 nm filter is practical at a cost of £70.00 or so. But for the systems using semiconductor lasers the frequency spread around 670 nm can be considerable. The 50 nm wide filters are available but at present the choice has been made to operate at dusk as a means of reducing extraneous light pollution.

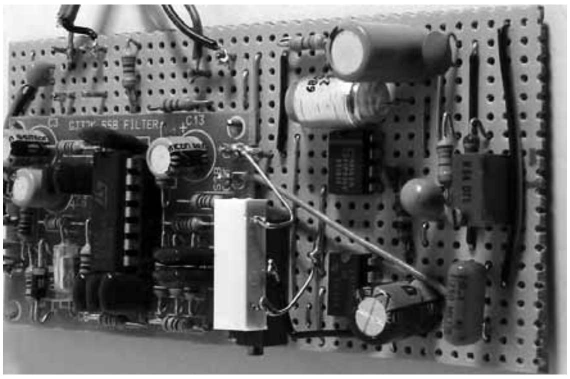
To capitalise on the low noise of the OPT211 the feedback loop had a 10 MOhm resistor in it. This lowered the bandwidth and up to 40 MOhm could have been used. I was aiming for a bandwidth of approximately 12 KHz.



Microphone Amplifier

From the original HeNe experiments I was certain that PWM audio would give the greatest punch. For the MkII a moving coil microphone is fed to a pre-amplifier consisting of a 741 op-amp and an SL6270 VOGAD amplifier. This gives a sensibly constant volume for the input to the modulator. PWM is sensitive to over modulation.

The Pulse Width Modulation is derived from a 566 waveform generator and LM393 op amp chip. The ramp voltage is set via a preset pot and the frequency also adjusted when setting up. The basic carrier frequency is approximately 8 kHz. The audio from the pre-amplifier is shaped in a Maplin SSB filter kit. The specification of 270 - 2700 Hz at the 6 dB points is achieved. In this way the carrier is safely above twice the highest frequency components contained in the audio stream. The output from the PWM source is fed into the driver circuit.

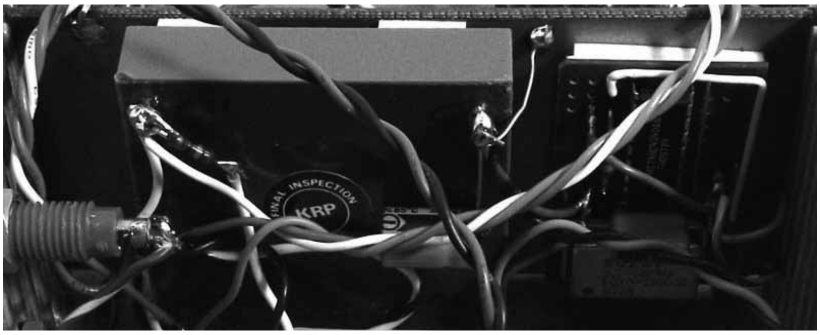


Pulse Width Modulator & Filter

To provide the TTL signals for the laser a driver stage has been incorporated. This uses a 741 op-amp and a BD135 driver stage. All modulation inputs are passed trough this driver before being applied to the laser module.

Driver Stage

The laser module requires a -12 Volt supply. The equipment is run from standard 13.8 Volt supplies, and the transmitter has to derive all the required supplies. A DC-DC converter is used to produce dual rail supplies. The laser runs from the -12 Volt rail and the main circuits run from the + 12 Volt rail. As the DC-DC converter was available (ex equipment or junk box) I needed to generate 5 Volts from the raw input to power the converter. Over kill but the transmitter does not pick up mains hum.

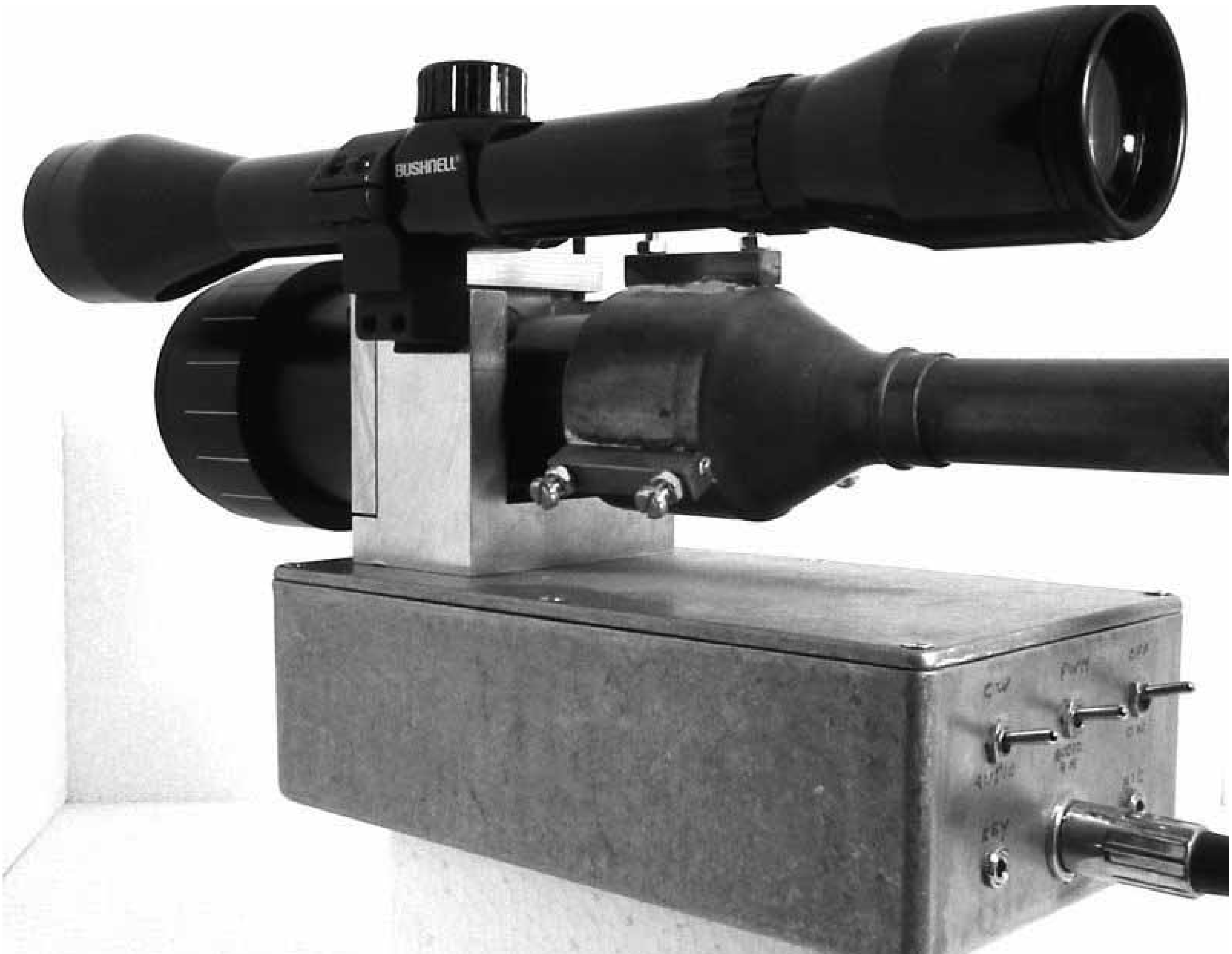


DC-DC converter & 800Hz Tone Generator

The picture shows the DC-DC converter for the split rails on the left, and the 800 Hz tone generator on the right. The tone generator is based on an encapsulated TTL oscillator running at 3.2768 MHz. This was salvaged from a Baud rate generator and when divided down by 4096 times produces a stable 800 Hz squarewave. Provision is made to be able to key the output. By passing through the driver stage no spikes are sent to the laser, and this is important for maximum life. The tone is crystal controlled to facilitate DSP filtering at the receiver. A TimeWave 955 is used with good results but for bandwidths reduced below 10 Hz a waterfall display on a computer would be better.

Finally the complete transmitter can be seen, with all modules installed within a sturdy die-cast case. The bottom contains a fixing to allow a standard photographic tripod adapter to be used. This fixing is for testing and demonstration purposes. In operation a stable platform with micro adjustments is required. The receiver head mounts into a Russian 4 1/2 reflector telescope with equatorial mount. The base is a steel tube of some 3 inches diameter fitted with heavy tripod base supports. Substantial. For the transmitter, the ex military tripod, used for the 10 GHz equipment is used. This can be held firmly to the ground, and on the top goes a heavy duty worm gear rotator. This rotator is driven by 5 phase stepper motor and is both robust and accurate.

Assembled Unit



The final unit showing the controls.

G8AGN multi-mode laser transmitter

This transmitter draws heavily on the work of G0MRF, G7JTT and David Johnson. All I have done is to bring the various circuits together to produce a complete transmitter design.

I used an inexpensive (£2.50 or $4) key-chain laser module in my transmitter. These often produce far more optical output power than their labelling suggests, so observe proper safety precautions and do not stare into the beam at close quarters.

The choice of op amps and transistors is not critical and most of the common ones should work OK.

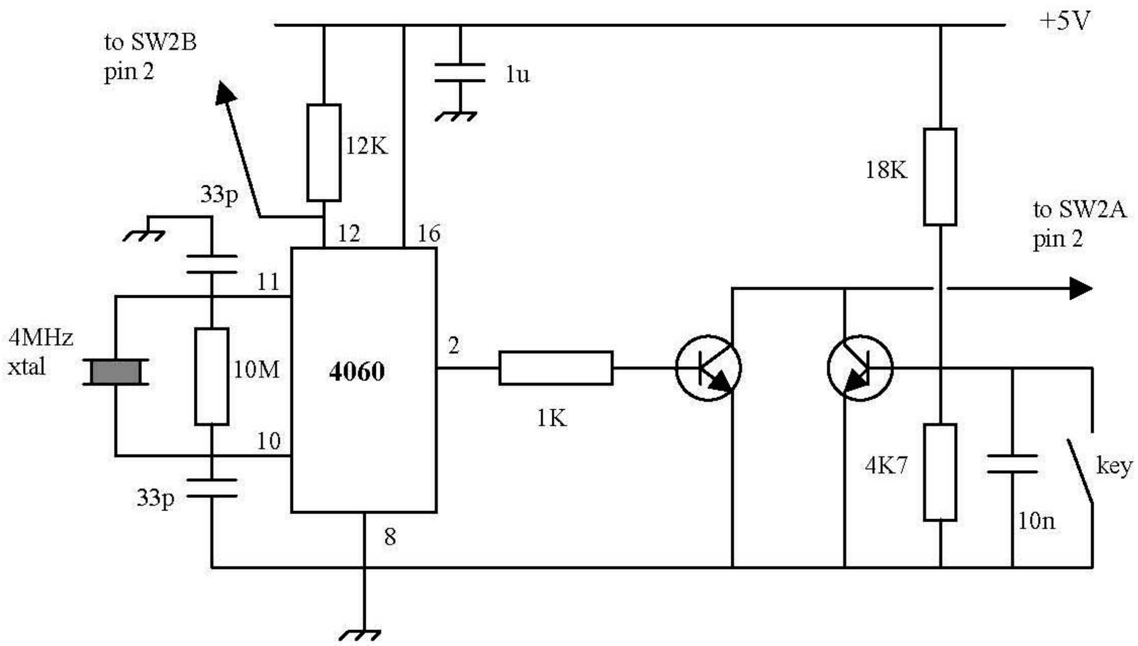
The mode switch SW2 is 3 pole, 4 way but only 2 poles are used – one to select the modulation input to the laser driver and one to enable the 4060 divider chips.
The wiper of SW2B is connected to earth.

Although not shown in detail, the power supply is conventional and based on a 7809 followed by a 7805. The nominal supply voltage is 12V. Don't forget the "idiot" diode in the positive supply lead!

Since the layout is not critical, the transmitter was built on Vero board.

Barry Chambers G8AGN, November 2004

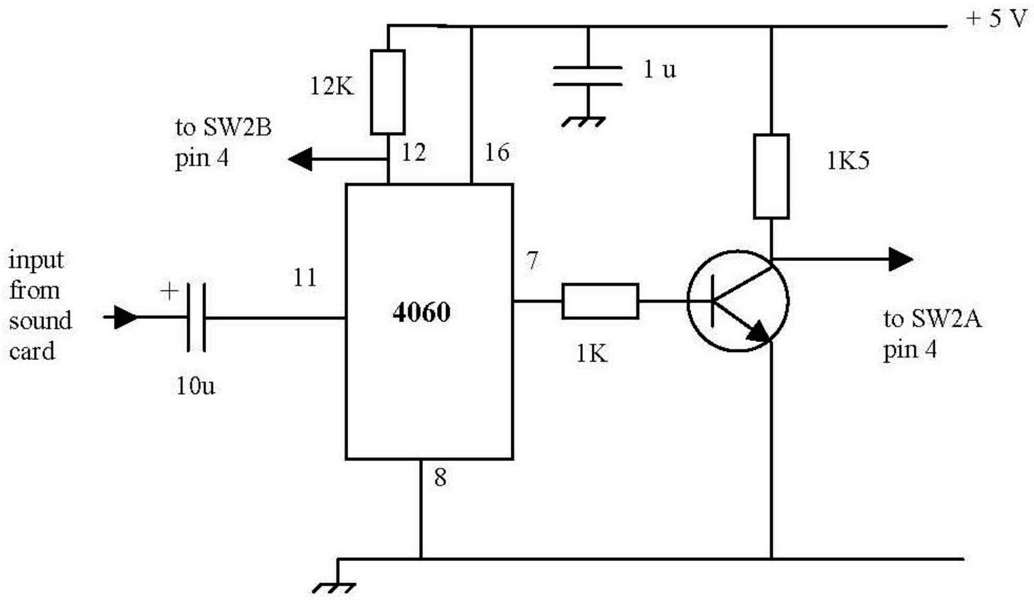
488 Hz tone generator



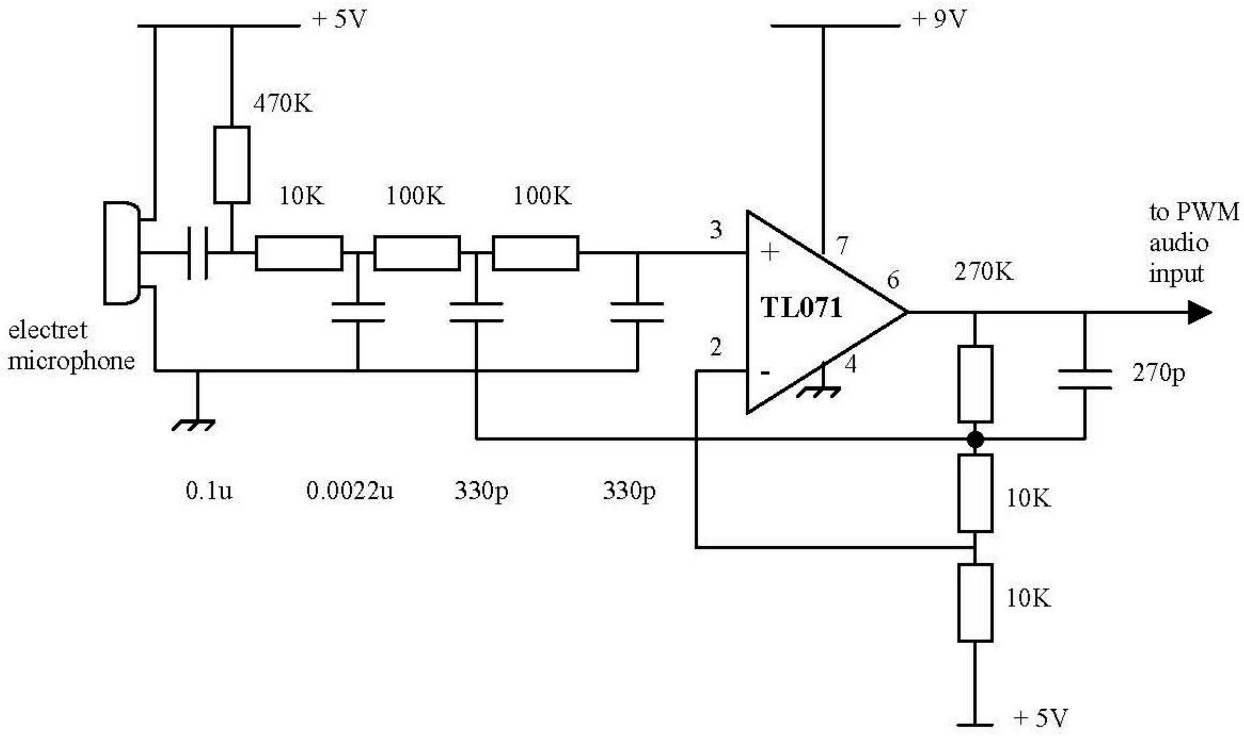
Adapted from original circuit by G0MRF. The choice of NPN transistors is not critical

Computer sound card interface for K0SM's LaserScatter software

The choice of NPN transistor is not critical. Increase the input voltage to the interface using the Windows volume control panel until the output signal from pin 7 of the 4060 is a square wave.



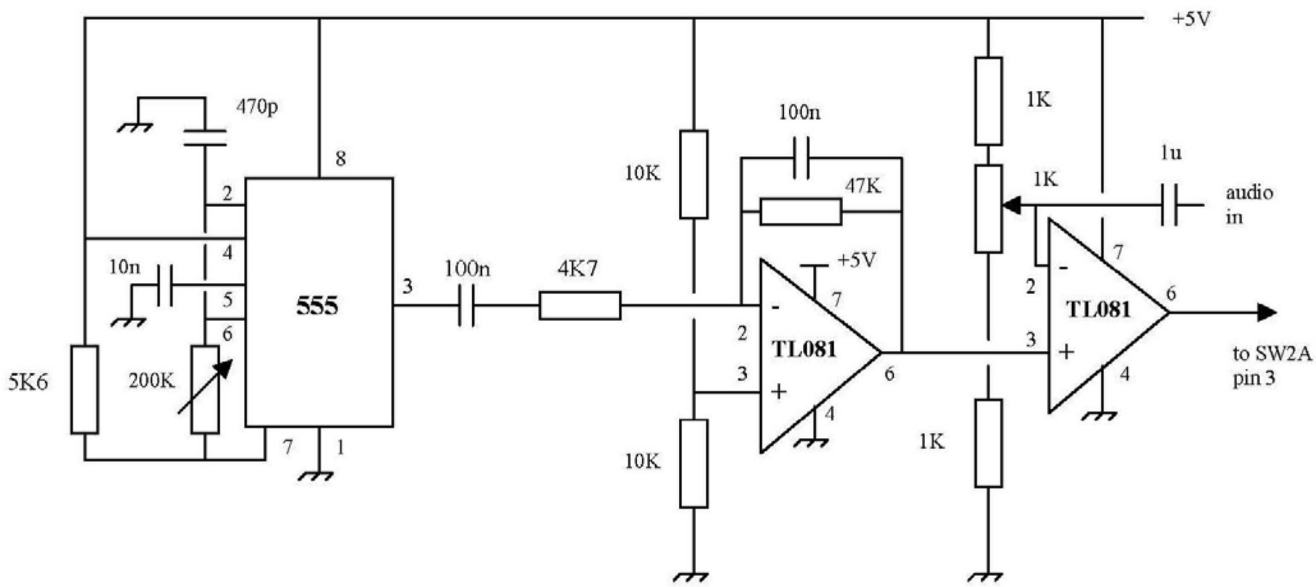
Audio amplifier and 3 kHz low-pass filter



Adapted from David A. Johnson's "Optical through-the-air communications handbook"

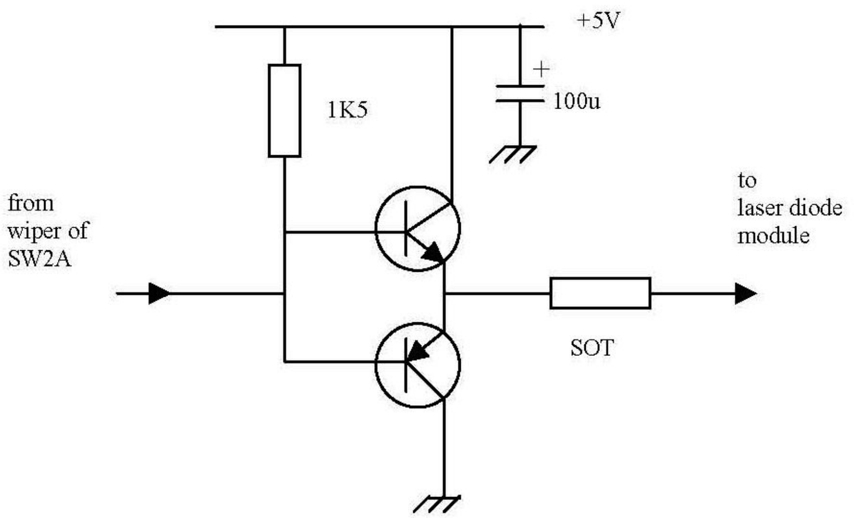
Pulse Width Modulator

Adapted from original circuit by G7JTT. Adjust the 200K pot to give a clock frequency of 10 – 12 kHz (not audible in receiver). Adjust the 1K pot for best speech quality. Other op amps may be used with no change of component values.

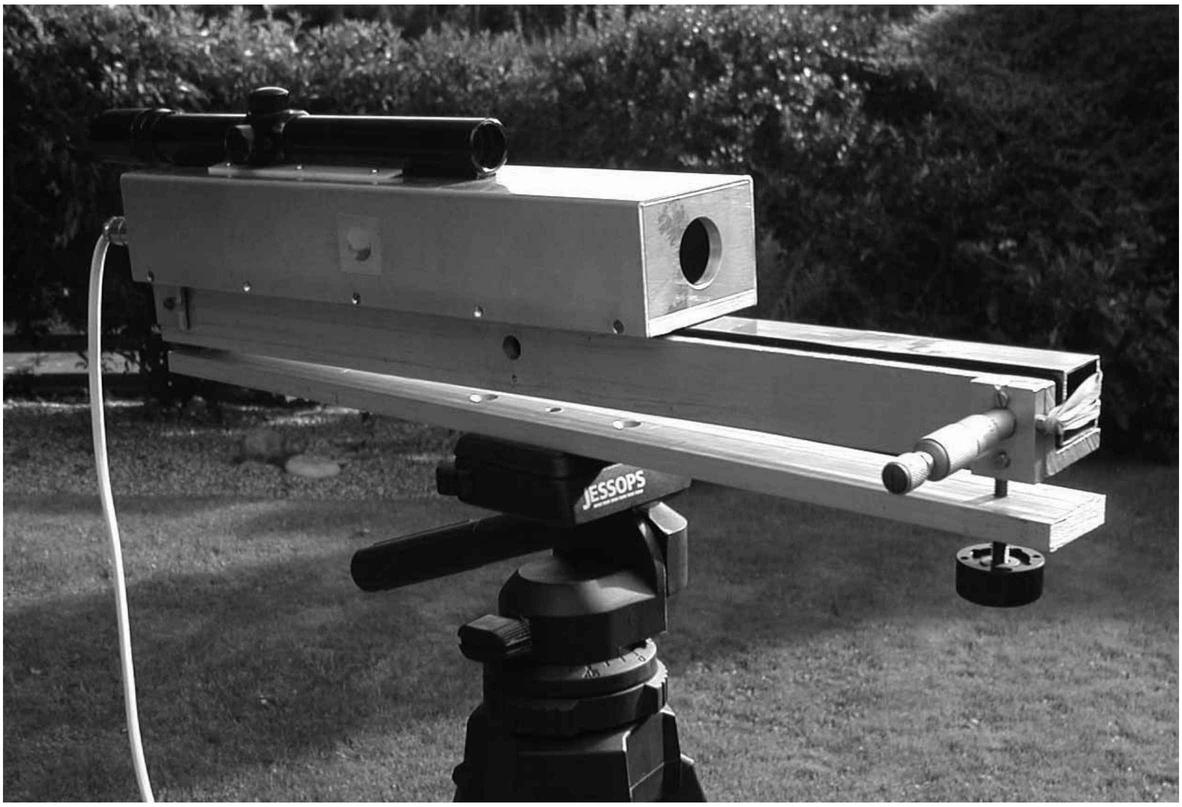


Laser driver circuit

Adapted from original circuit by G0MRF



SOT: select on test to suit laser module
The choice of the NPN-PNP transistor pair is not critical.



G8AGN Laser TX

G8AGN Laser RX

More pictures can be seen at G8AGN's web site, http://www.shef.ac.uk/~el1bc/laser_files/

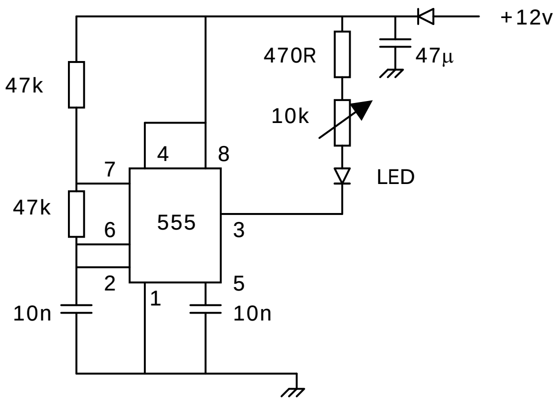
Modulated optical signal source with variable output

Barry Chambers G8AGN December 2004

The values of the 10K pot and the 470Ω resistor may need to be changed to suit the characteristics of the LED. With the pot set at 0Ω, the LED should be at the maximum desired brightness. With the pot set at maximum resistance, the LED current should be low enough that no light is emitted. Ideally the pot should have a calibrated dial.

Test the receiver in a darkened room as ambient light will affect the results (it certainly should do or else your receiver is very insensitive!) Set the pot until no output is seen from the optical receiver under test (an oscilloscope is better than the ear). Note the dial reading. Make adjustments to the receiver and repeat the reading - if the dial reading is lower, the receiver is now more sensitive, etc. Obviously, this is only a qualitative test but should still prove useful for receiver optimisation in the shack.

The LED output is modulated with a 1 kHz square wave. The frequency can be changed by altering the two 47K resistors and / or the 10nF capacitor.



ESTIMATING THE RANGE OF A FREE-SPACE LASER COMMUNICATION LINK

version 1.0, 5 Dec 2004, B Chambers G8AGN

DISCLAIMER

The information on which this discussion is based was drawn from the relevant European standard EN 60825-1-1994. The equivalent US standard is ANSI Z136. Although I have taken reasonable care to ensure that the theory and calculations given below are valid, I accept no responsibility whatsoever for any mishap which may arise from the use of this information.

The received power flux from a distant laser is given by

$$F = \frac{4Pe^{-\mu r}}{\pi(a + r\phi)^2} \text{ watts/m}^2 \qquad (1)$$

where
P = laser output power in watts
a = diameter of beam emerging from the laser in metres
ϕ = beam divergence in radians

μ = atmospheric attenuation coefficient per metre
r = distance between the laser and the receiver in metres
π = 3.14159 (pi)
e = 2.71828 (the base of natural logarithms)

If the laser is fitted with a beam expander of magnification N, then a and ϕ in (1) should be replaced by

$$a' = Na \qquad \text{and}$$
$$\phi' = \frac{\phi}{N} \tag{2}$$

The atmospheric attenuation factor μ can be estimated from

$$\mu = \frac{3.91\text{x}10^{-3}}{V}\left(\frac{0.55}{\lambda}\right)^{A} \qquad \text{per metre} \tag{3}$$

where
V = visual range in km
λ = wavelength in μm (= 0.65 for a typical solid state red laser)
$A = 0.585V^{0.333}$

The actual received power depends on the collecting aperture of the receiving optics, hence received power is

$$P_R = F\,\frac{\pi D^2 \eta}{4}\ \text{watts} \tag{4}$$

where
D = diameter of receiving optics in metres
η = transmissivity of receiving optical system (smaller than 1, due the reflections at the air-glass interfaces)

As in any other communication system, if the received power is less than the noise floor of the detector then no signal can be received. Hence if detector sensitivity is P_{min}, then for successful reception, $P_R \rangle P_{\min}$.

Combining all this information gives us the equation which must be solved to estimate the maximum range, r, of our laser link.

$$P_{\min} = \frac{Pe^{-\mu r} D^2 \eta}{(a + r\phi)^2} \tag{5}$$

In practice, this cannot be solved directly for r because it appears in both the numerator and the denominator. Hence a process of successive approximation must be used. To save the reader effort, I have provided an Excel worksheet to solve (5), at www.shef.ac.uk/~el1bc/laser_files/range.xls
A MathCAD worksheet is also available on request.

LASER SAFETY

version 1.01, 6 Dec 2004, B Chambers G8AGN

DISCLAIMER
The information on which this discussion is based was drawn from the relevant European standard EN 60825-1-1994. The equivalent US standard is ANSI Z136. Although I have taken reasonable care to ensure that the theory and calculations given below are valid, I accept no responsibility whatsoever for any mishap which may arise from the use of this information.

Many of the inexpensive red laser pointers on sale at present, especially the cheap imports, emit much higher powers than their labelling implies. It is imperative, therefore, to get an estimate of the safe viewing distance so as to avoid accidental eye damage. This is especially important if you are looking for a laser beam through binoculars or a sighting scope.

In the discussion which follows, only low powered lasers (< 10 mw) emitting red light will be considered. It is not recommended that you experiment with the higher power IR lasers which are readily available since the risk of inadvertent over-exposure and possible eye damage is much greater than would be the case when using visible sources.

The starting point for our discussion is the Maximum Permitted Exposure. This is the maximum power flux (watts per square metre) which is considered safe for our eyes. For exposures of a few seconds with red light, this can be calculated from the equation

$$E = 18t^{-0.25} \text{ watts/m}^2 \qquad (1)$$

As an example, for an exposure time t = 1 second, E = 18 watts/m^2. This may sound a lot, but on a very sunny day the Sun can produce a power flux of up to 1000 watts/m^2 at the Earth's surface – this is why it's inadvisable to stare at the Sun, as early astronomers found to their cost (especially as the effect is magnified by viewing through a telescope, as will be seen later).

The actual exposure due to viewing a given laser at a distance is given by

$$E = \frac{4PG^2}{\pi(a + r\phi)^2} \text{ watts/m}^2 \qquad (2)$$

where
P = laser output power in watts
G = optical gain of the viewing system (more on this later)
a = diameter of beam emerging from the laser in metres
ϕ = beam divergence in radians
r = distance between the laser and the eye in metres
π = 3.14159

Hence by combining (1) and (2), we can obtain an estimate of the minimum safe viewing distance, r_{min}.

$$r_{min} = \frac{\sqrt{\dfrac{4PG^2t^{0.25}}{18\pi}} - a}{\phi} \text{ metres} \qquad (3)$$

This formula neglects any attenuation due to the atmosphere since this will have only a very small effect with the laser powers under consideration here since the minimum safe viewing distance will be small (typically less than 1 km).

Let us now return to the discussion of G. If no viewing aid such as a scope or binoculars are being used, then G may be set equal to 1.

The most dangerous viewing conditions for the eye will occur at night when the pupil diameter is at its maximum, typically 7 mm, and a laser is being viewed through a telescope or binoculars since they will collect more light than the naked eye. Let's assume a pair of 10 x 50 binoculars are being used and the laser beam diameter is larger than the objective lens diameter. Then the binocular exit pupil diameter will be 50/10 = 5 mm, which is less than the eye's pupil diameter. Hence we can assume that all the light collected by the binoculars will enter the eye and G can be set to 50/7 = 7.1. If the binocular exit pupil diameter is larger than 7 mm then not all the collected light will enter the eye and G will be smaller, but it's probably better to stick to the worst case (i.e. higher value) for G. In practice there will be less than 100% transmission of light through the collecting optics which will give an extra margin of safety. Nevertheless, I've assumed 100% transmission so as to produce a conservative estimate of the minimum safe viewing distance.

Let's now get a feel for numbers. Consider a red laser with

Output beam diameter = 2 mm
Beam divergence = 1.5 mrad
Viewing time = 1 sec

The table shows the estimated minimum safe viewing distance, in metres, for three laser output powers (1, 5, 10 mW) and two values of viewing optical gain (1, 7)

Laser output power (mW)	G = 1 (naked eye)	G = 7 (binoculars)
1	5	38
5	12	87
10	17	123

In the table, the calculated values have been rounded up to the next whole metre. In practice, the eye will be protected to some extent by the normal reflex action of turning the head away from a bright light, but it is inadvisable to rely on this, especially at the higher power levels.

If the laser is fitted with a beam expander with a magnification ratio of N, then in the calculation the beam diameter, a, should be multiplied by N, i.e. $a' = Na$ and the beam divergence, ϕ, should be divided by N, i.e. $\phi' = \phi/N$.

Hence, with the same lasers as before but now fitted with a X10 beam expander we get

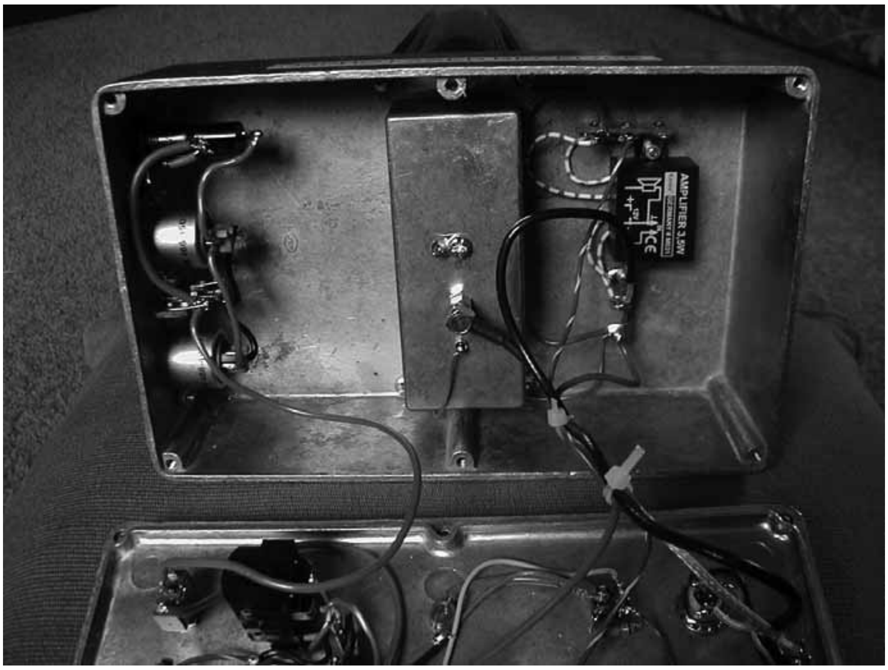
Laser output power (mW)	G = 1 (naked eye)	G = 7 (binoculars)
1	Safe	260
5	Safe	745
10	44	1109

With the lower power lasers, naked eye viewing is now safe because the beam diameter has been increased and hence the flux density impinging on the eye is below the Maximum Permitted Exposure level. When viewing through binoculars, however, the lasers are now more hazardous because the beam expander has decreased the beam divergence and hence increased the power flux collected by the eye.

G3PHO Laser Receiver

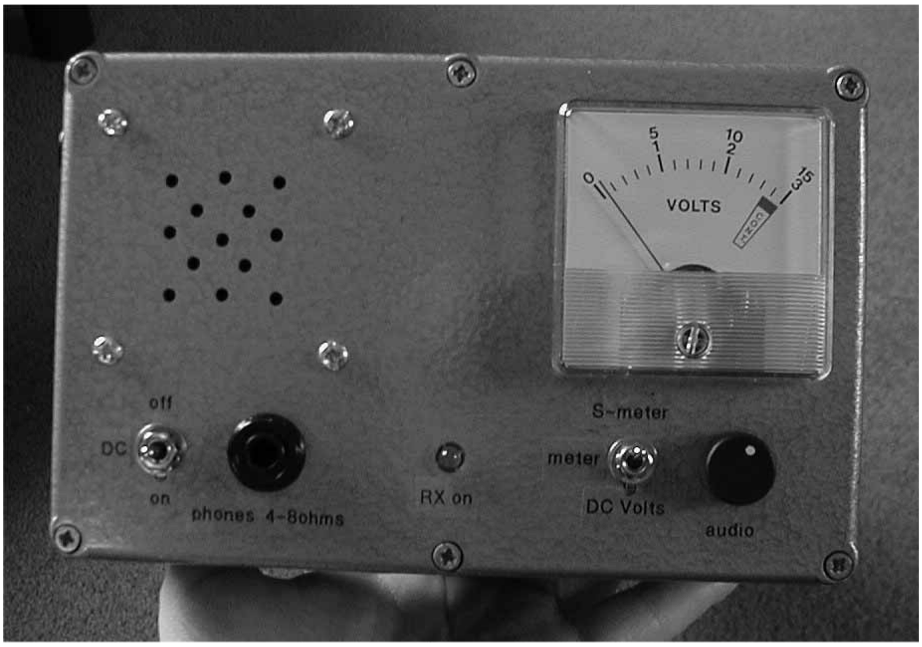
The G3PHO RX is built entirely according to Barry's article.

The plastic tube that houses the lens is a Marley 100mm diameter item from B&Q. It comes with four self tapping screws and is ideal for mounting a diecast box at one end. A 100m diameter convex lens (ex hand magnifier) is glued to one end of a Lyons coffee can which has had its base cut off and the lid discarded. The can was then painted inside with matt black paint of the type used to renovate blackboards to stop internal reflections. The 100mm lens was glued with impact adhesive and the can was wrapped with thin plastic sheet so that it became a tight but sliding fit into the Marley pipe. The lens end was inserted first. Thus you have an adjustable lens barrel capable of being focused on the photodiode at the back of the tube. The focal length of the lens was determined by means of focusing the sun on a sheet of paper. Attempts use a light source within the house gave inaccurate results.



The photo of the inside of the G3PHO RX shows a smaller diecast box mounted inside the main enclosure. This contains the photodiode and its associated op amp preamplifiers. A 1cm square hole is cut in the centre of the back of both the main RX enclosure and the photodiode module diecast box. All this is fixed so that the diode can look through the hole towards the lens and is dead centre when the whole assembly is mounted on the back of the Marley tube. Careful measurements pay dividends here. The output of the photodiode module is via an smb connector. A short, shielded cable then feeds a 3.5W audio amplifier module, purchased for only £4.99 at Maplin. An LM386 or LM380 IC would also do here.

The front panel of the main enclosure has a meter that is switched to read either DC input volts or act as a crude S meter. The latter function is enabled by reading the audio output with a simple diode (IN4148) voltage doubler soldered across the loudspeaker leads. A refinement would be to have a potentiometer to set the maximum reading as the present arrangement causes very strong signals to hit full scale unless the volume control is backed off.



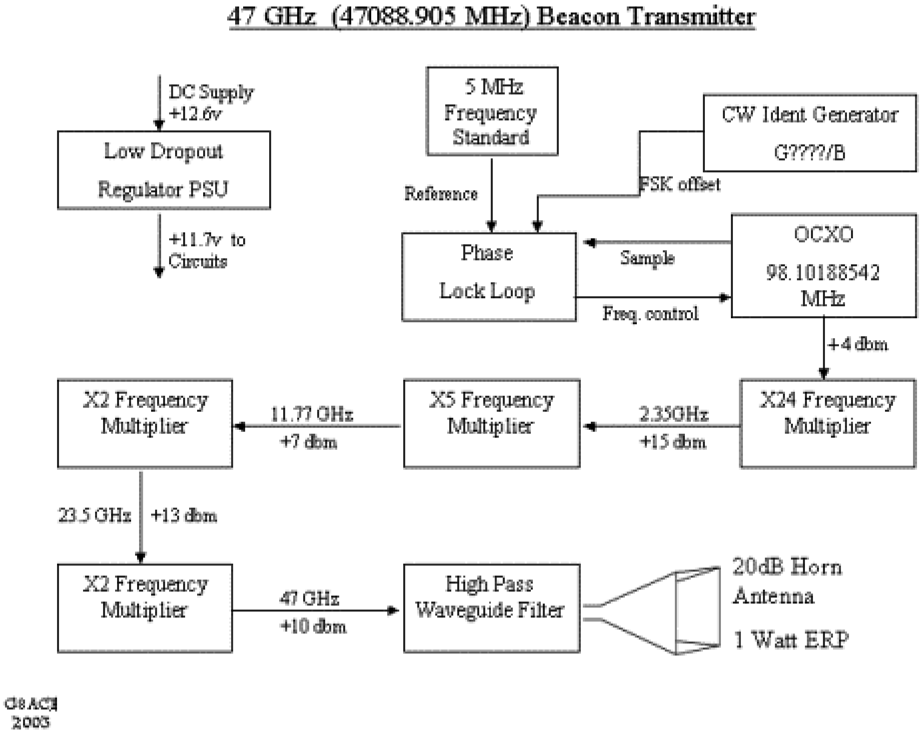
A telescope sight (6 x 40) was purchased as a new ("Buy it now") item for less than £20 on eBay but similar items can be found in gun and hunting shops around the country.

Once completed, the RX can be tested using the simple LED "marker" described elsewhere in G8AGN's notes. It can also be used to receive all manner of lights at night time. G3PHO pointed his RX through a bedroom window one night and could pick out individual street lamps at several miles distant! Sodium lighting makes a distinctive buzz-like noise in the receiver. The azimuth and elevation settings of the telescopic cross hair sight were carefully adjusted using these street lamps, so much so that when the first test with a real laser was undertaken, at some 4 miles, the sight was found to be "spot on" (if you will excuse the pun!).

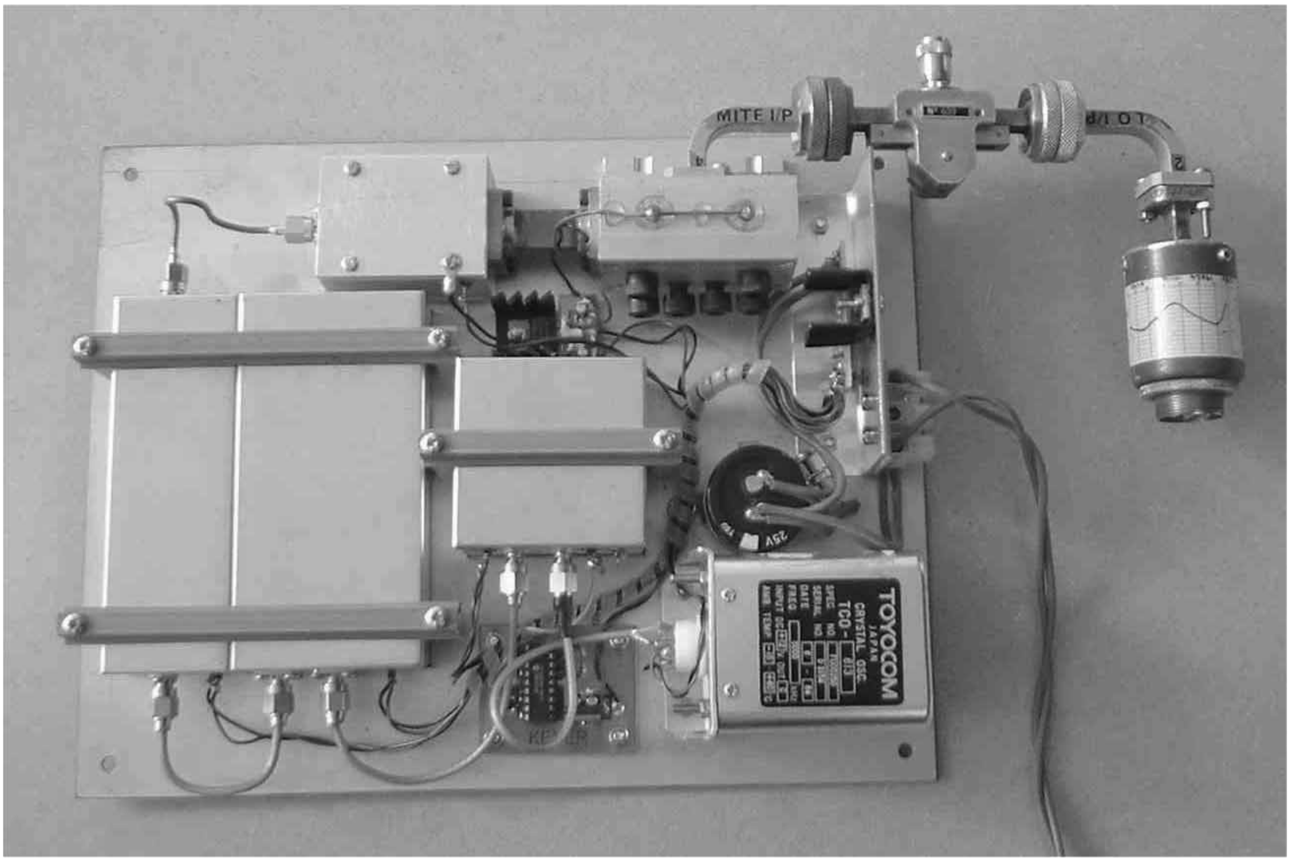
The receiver (and subsequently the laser TX, was mounted on a very substantial ex-TV Outside Broadcast tripod, made by EMI. This is the same tripod used by G3PHO to carry his 1.2m dish and portable microwave equipment. It is very stable indeed. However even this excellent tripod does not have the fine AZ/EL adjustment needed for laser communications so a micrometer adjusted system is being developed to allow the laser TX, in particular, to be very accurately positioned. The RX is less critical but still at least as sharp as a 60cm dish on 47GHz !!

47GHz Schiphol Beacon

John Hazell 8ACE



The picture below shows the Schiphol 47G beacon less horn but with waveguide and power meter head instead.



The parts are as follow:

- 5MHz OCXO bottom right.
- OCXO somewhere in the middle.
- x24 multiplier and x5 multiplier boxes together bottom left.
- Top left is the x2 to 23.5 multiplier with waveguide output
- Top right is the final x2 doubler with the WG22 attached.
- The PIC keyer and a PSU are also visible bottom centre.

The x2 final doubler uses a pair of NE325 GaAs FETs and produces 9mW at 47088.888 in the Schiphol instance, locked to the 5 MHz standard.

Boxed beacon with horn attached

The beacon is operational from 15-7-2004 on 47088.888 MHz with approx 10dBm output in a 16dB horn antenna giving approx 400 mW ERP.

The antenna is pointing to the location of PA3AWJ who almost instantly heard the beacon with 56 to 57, over a distance of 45km.

For further 47GHz beacon information from G8ACE, see http://www.microwaves.mcmail.com/beacon/beacon.htm

For further information on the Schiphol beacons, see http://home.planet.nl/~alphe078/beacons.htm

First steps of Amsat-DL towards Interplanetary microwave missions

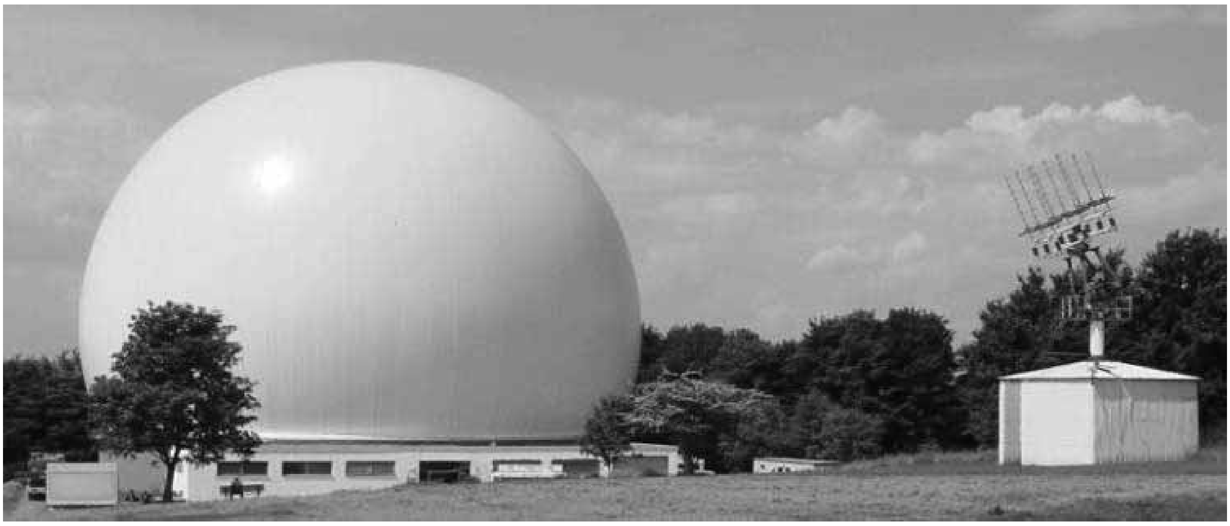
Freddy de Guchteneire ON6UG

P5 satellite = Interplanetary Satellite (Mars)

Since 1996, Amsat-DL and the University of Marburg, under project leader Professor Dr. Karl Meinzer, DJ4ZC, have been working towards a P5A mission to Mars. This would be the first attempt at communication over very long distances by radio amateurs.

Along with radio communication experiments, several institutes offered experiments that are compatible with the mission. A first meeting took place in the Phillips University, Marburg, in 1996 followed by the first designer's meeting in 2001.

A ground station for controlling such a mission was to be set-up in Bochum at the IUZ-Bochum (Sternwarte) under Director Thilo Elsner DJ5YM.



The 20m diameter antenna, installed by Prof Kaminski in 1966, needed to be verified on microwave frequencies as the antenna was damaged after exposing it to the environment during winter storms.

After initial qualification of the antenna at 11GHz the steering system was prepared with a new computer system and servo motors/controllers. The station needed to be prepared for 10.4 GHz and 2.4 GHz communications for the P5A mission control station as these frequencies are the primary command frequencies.

Recent activities around Mars by ESA , NASA and others have renewed a general interest in the P5A mission. In November 2003, a feed/receiver was installed for 8.4GHz. The current high activity around Mars was an opportunity to gather experience with the station in Bochum and to introduce the P5A mission to radio amateurs and the public. The station was first used on the 8.4GHz X-band frequency on 16 November 2003 to receive Mars Express/ESA. Later also the Odyssey/NASA and Cassini /ESA where received.

The 20m Bochum Antenna

Gain @ 10.45 GHz	min 65 dB	beamwidth 0.1 deg
Gain @ 2.4 GHz	min 52 dB	beamwidth 0.4 deg
Gain @ 435 MHz	min 35 dB	beamwidth 2.5 deg

The reception of these satellite signals marks a first for Germany and Europe and, in particular, a first for long distance amateur radio. It also marks the first steps of Amsat in Interplanetary activities.

With the reception of these satellites, the ground station was found to be able to provide the vital command communications for the P5A mission.

Work still needs to be done to further improve the station and have full remote control capability of the dish and radio hardware over the Internet by Amsat control stations. The antenna may need to be prepared for other frequencies in the microwave region for assistance and operations with any other interplanetary mission.

To qualify the dish antenna and receivers for X-band microwaves, no special equipment was used and the procedures can be used by radio amateurs to prepare their station for Interplanetary radio communications.

It is also of use to radio amateurs that want to do EME (Earth-Moon-Earth) or those who like to have their stations improved to the best possible performance.

Mars Express	8420.432MHz	(18)
Oddysey	8406.851MHz	
MER1 (B)	8435.370MHz	(29)
MER2 (A)	8439.444MHz	
Cassini	8427.222MHz	(23)
	8429.938MHz	(25)
Mars Global Surveyor	8417.716MHz	(16)
	8423.148MHz	(20)
Ulysses	8408.245MHz	
	8408.209MHz	(9)

Moon about 200K noise temp difference about 0.5 deg

Cassiopeia A	41K	abt 0.08 deg
Cygnus A	19K	abt 0.027 deg
Virgo A	3,1K	abt 1”

Weak Signal Communications and Amsat P5A

Recently, Amsat-DL is considering participating in a mission to Mars. The question is not if this is within the amateur satellite service, which it definitely is, but how many radio amateurs will be able to directly participate in the mission?

During the last 10 years computers became much cheaper then amateur radio transceivers.
DSP analyzer techniques used with powerful processing power are becoming available in almost all amateur radio shacks. Computer memory and speed are no longer a restriction. FFT Analyzer programs are available from many sources and provide a means to detect signals well below the noise floor of a receiver.

Weak signal communications improved due to modern semiconductor advances and these devices become cheap due to mass production of cellular radio and satellite equipment**.**

Tracking satellites with motor controlled antennas have become common in today’s amateur satellite stations. The amateur satellites increasingly make use of higher frequencies. Many have S-band and X-band capabilities.

The use of the Internet is now widely accepted by radio amateurs for information flow and remote control of parts of amateur stations via the Internet.

Interplanetary missions pose special difficulties for radio communications and solving these difficulties can improve the knowledge and experience of radio amateurs in general.

Besides pure electronic RF knowledge and skills, a sense of the mechanics of the movements of planets is also learned from tracking these missions. There is no doubt that these skills are part of the satellite amateur radio hobby.

The vast distances involved and weak signals discourage many amateurs to start in this field but, in actual fact, one does not need 20m dish antennas to communicate over very long distances.

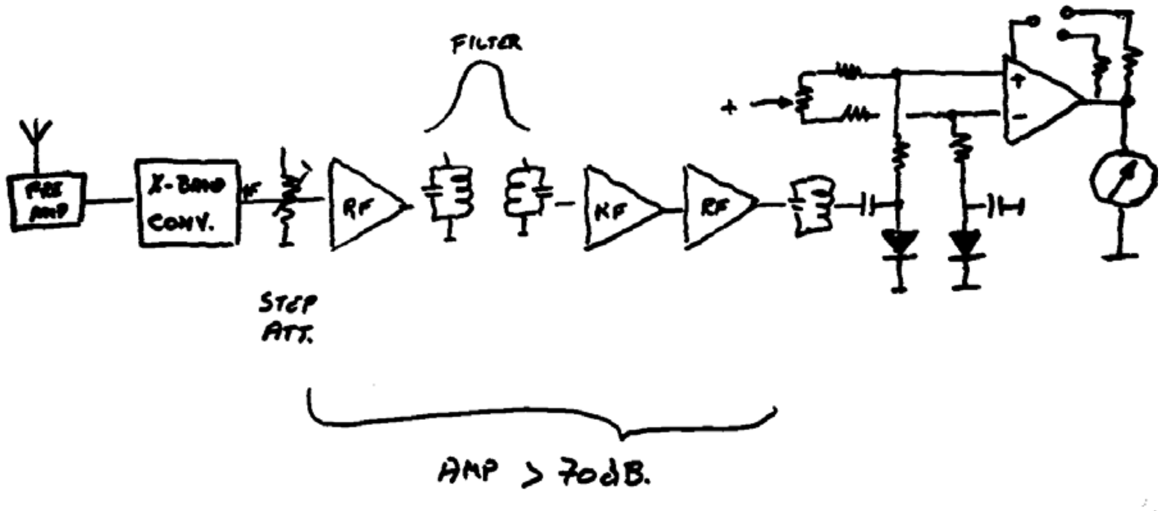
Immediately after the reception of Mars Express in Bochum, several other radio amateurs attempted and succeeded in receiving Mars Express with small antenna systems. This clearly illustrates that interplanetary radio communications are not beyond the capabilities of radio amateurs.

In the long term, after careful improvements in all fields, it can be expected that some communications are possible even with moderate antenna systems and equipment found in today's amateur radio shacks.

It is perfectly possible that by the time the P5A satellite is launched many have the capabilities to take part in the Radio Amateur Interplanetary Experiments of the future.
Before we get there, some work needs to be done and a clear understanding of the antenna and equipment performance is an absolute must.

Measuring noise is the basic first step towards calculating system performance.

A suitable noise power indicator contains a wide band amplifier with a filter that covers the X-band converter IF frequency and a diode detector.



NOISE POWER INDICATOR

Improving a system - Measuring Noise Power
James Miller G3RUH made an excellent article how to calculate your own receive capabilities for Mars missions. It is available on the Amsat-DL server and reproduced below.

Reception of Mars Spacecrafts by Radio Amateurs

by James Miller G3RUH, 2003 Nov 24

On 2003 Nov 16 and 22, radio amateurs using the 20m diameter antenna at Bochum, Germany (JO31OK) received signals from the Mars Express and Mars Odyssey spacecraft. So does this mean that such feats are beyond the ordinary amateur? Absolutely not! Here are some notes to confirm this. You too can receive Mars Express, even on a small dish.

How strong?
At the time, these spacecraft were received at an accurately measured carrier power to noise power of ~40-43 dB in a 1 Hz bandwidth.

So if YOU have (say) a 1m dish, and the capability to receive on 8.4 GHz, you can expect a mere 26 dB less. But that's still a CNR of 14 to 17 dB Hz. You can /just/ hear this in headphones, and it is "large" in a spectrum displays of the kind in popular use on PCs.

Many amateurs have antennas much larger than this, and reception of the Mars spacecraft, which make excellent point source beacons, should not be difficult.

And remember, the Bochum system was only on day #2 of its RF optimization tests! The feed horn was linearly polarized instead of RHCP, the side lobes had not yet been fully checked, and the RX noise temperature was not accurately determined. We expect another 4-6 dB in due course. So an amateur using best practice should be able to achieve results with even the smallest dish, particularly now, when Mars is quite close to the Earth.

Mars Express Details
Mars Express is, at the time of writing, en-route to Mars, carrying the Beagle lender. Its frequency is 8420.4321 MHz, and e.i.r.p. is specified as ~550 kW. The carrier supports a variety of modulation schemes. In particular, at any particular time it may be OFF, or more likely phase modulated with data. The modulation index is controllable according to mission needs. It was +/-1.25 radian during our tests, which leaves a residual carrier of 20*log(cos(1.25)) dB or -10 dB. The spacecraft's speed is of order 16 km/s, which gives a nominal Doppler shift of -450 kHz. Superimposed upon that is additional diurnal shift due to the Earth's rotation of order +/-10 kHz. The changes are very slow, and do not hinder tuning and spectrum analysis.

Mars Odyssey Details
Mars Odyssey is in polar orbit around Mars at an altitude of 400 km. At this height, a Martian orbital period is ~118 minutes, speed 3.36 km/s, and the spacecraft is occulted behind Mars a maximum 35% of the time. The frequency is 8406.8519 MHz. E.i.r.p. is (according to the docs) ~91 kW. Doppler shift has three components; gross motion of Mars (fairly static, -375 kHz at present), diurnal shift due to Earth's motion (slow at +/-10 kHz), and very fast due to its motion about the Planet (+/-100 kHz). It needs chasing!

I (jrm) do not know the modulation index used, but do know that, allowing for the range difference, we received Mars Odyssey, on the day, only 3.8 dB weaker than Mars Express. Yet Odyssey has 7.8 dB less e.i.r.p. So perhaps its residual carrier (on the day) was only -6 dB rather than -10 dB.

Calculator ON!
You don't get very far in this game without resorting to the calculator. Let us compute the expected Mars Express signal in a 1m dish with a RX noise temperature of 100K. Both these figures are chosen as nice round numbers. We also assume the object's range to be 158 million km, as it will be at the end of 2003.

Mars Express Carrier NOMINAL Calculations

```
TX power            44.4   dBm  (according to docs)
S/C Antenna gain    43     dB   (   ..     ..  .. )
------------------------------
TX e.i.r.p       Pt 87.4   dBm  (550 kW)
Residual carrier   -10.0   dB   (modulation index 1.25 radians, assumed)
------------------------------
Carrier e.i.r.p. Pc 77.4   dBm  = 54.95  kW
------------------------------

At range        R = 1.580*10^11 m:  (Mars, 2003 Dec 25)

Received flux   F = Pc/(4 pi R^2)
                  = 1.75E-19  W/m^2

Received power Pr = F A       W     For A = 0.432 m^2 (1m dish, 55% efficient)
                  = 7.57E-20  W

RX noise power Pn = k Tr B    W     For Tr=100K and B=1 Hz
                  = 1.38E-21  W

CNR           CNR = Pr/Pn
                  = 54.8
```

= 17.4 dB (B=1 Hz)

Your Station Performance

This gives you a baseline performance. Now suppose you have a 5m dish, 50K receiver, linearly polarised feed, and on Dec 01 the range is 123 million km:

Standard	17.4 as above
5m dish	+14.0 relative to 1m dish
50 K rx	+3.0 relative to 100K
Polarisation loss	-3.0 linear vs RHCP
reduced range	+2.2 123M km vs 158M km
	33.6 dB Hz

This is quite strong in headphones.

Finding the spacecraft

The easiest way to do this is to uses the JPL Ephemeris Generator to obtain the Azimuth and Elevation of Mars-Express and Mars for your location and plug these numbers into your antenna control program. The URL is:

http://ssd.jpl.nasa.gov/horizons.html

Read the instructions with GREAT care, and you'll soon master them. You can also obtain declination and right ascension if you prefer. Mars Express is object -41.

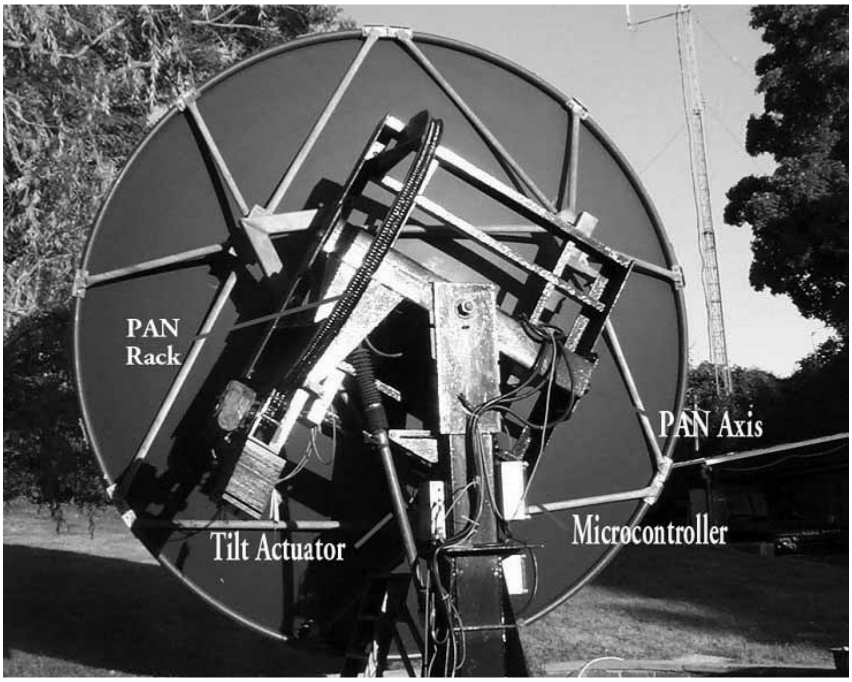
73 de James G3RUH

Azimuth & Elevation Mount

Brian Coleman G4NNS

The original "Tilt and Pan" mount

The original mount was designed to "scan" the Clark belt for use only with Geo-stationary satellites. It could not "look" directly up, to the North or below about 24 degrees to the south. So there were times when it could not "see" the moon. And even the mid-day sun was below its range for the winter months. Taken together, these factors created limitations both for EME and particularly for Radio Astronomy.



Original Tilt & Pan mount

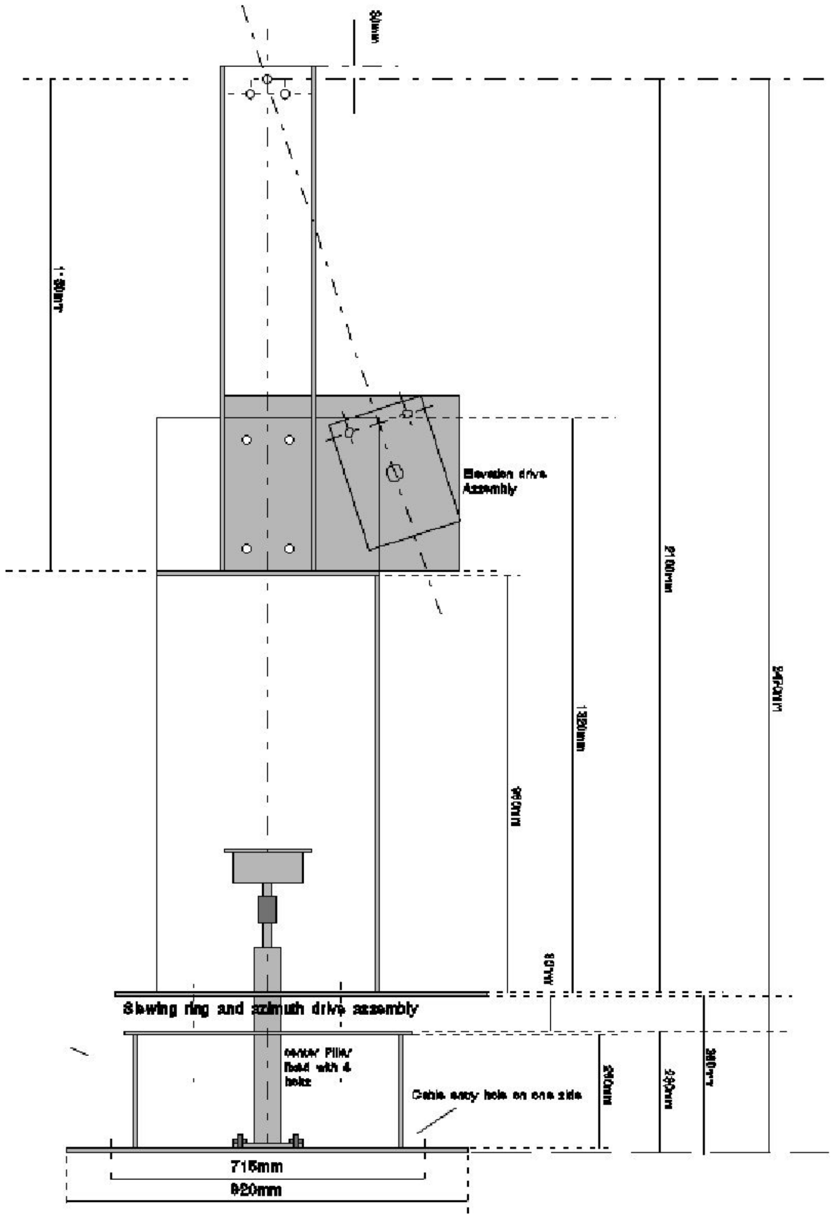
The slewing ring and gears

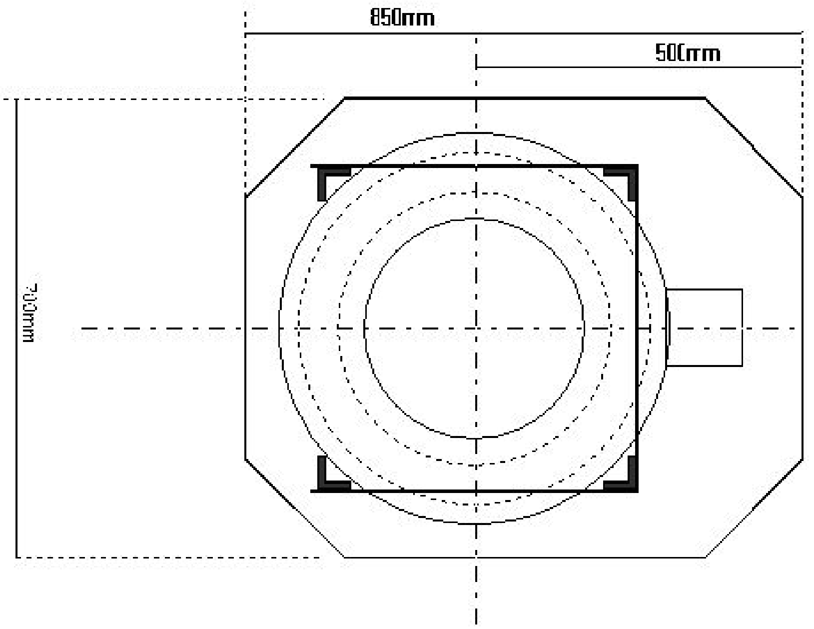
Before embarking on this project it was essential to be sure I could obtain the key components at a reasonable price. The slewing ring from a crane or digger was the most important of these. After searching around scrap yards without success, a friend who had been a crane specialist put me in touch with a company in Amesbury who re-condition slewing rings.

Slewing Ring

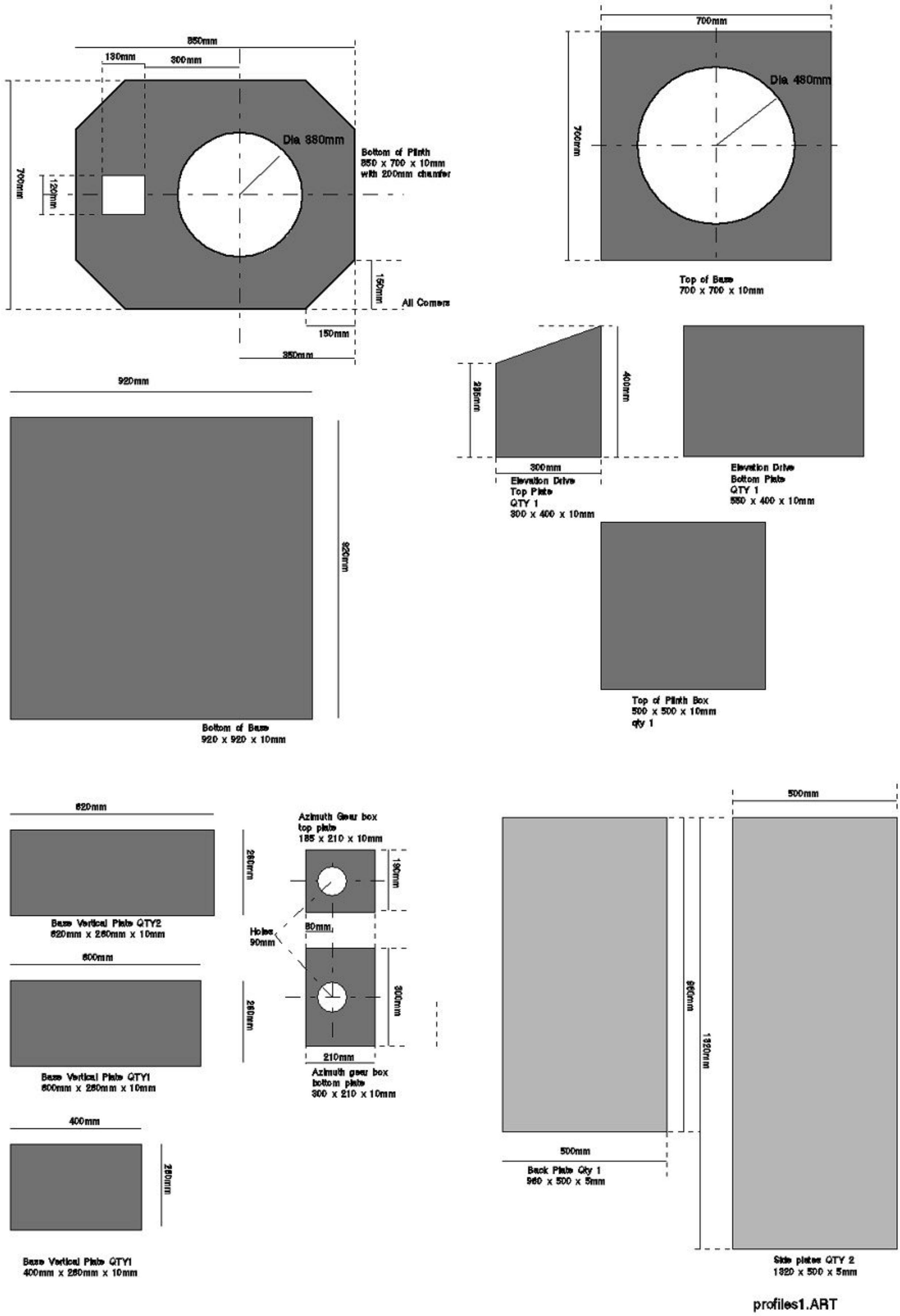
This one (about 600mm in diameter) was a reasonable price, I believe, because it was an old imperial one and probably would not fit any new machines. It appears to be brand new.

Having got they key components I sketched out the design:

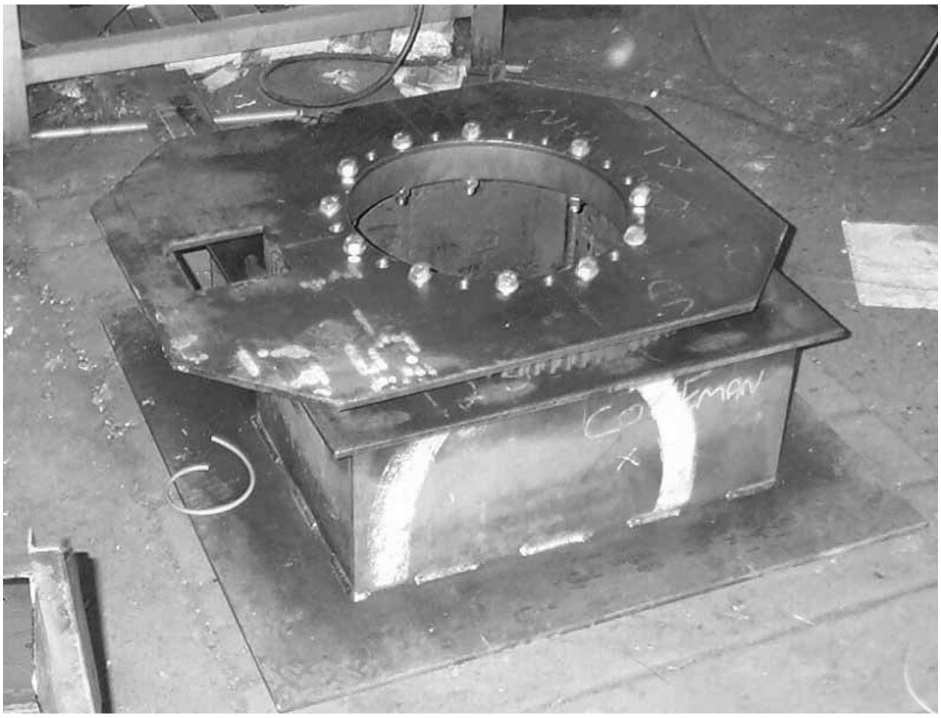




A local company cut all the necessary profiles from 5mm and 10mm steel sheet using NC machines



Another local firm undertook the fabrication



Test assembly at the fabricators

The various components were united at the fabricators to check they would all fit together.

Ian G8CPJ who has been responsible for all the precision engineering and has acted as design consultant is pictured in the foreground.

I had a great deal of help from others, especially Ian, who shares my interest in Radio Astronomy and EME.

Taking the dish off the old mount

Having got the building of the new mount under way the dish was lifted from the old mount from which certain components were to be recovered. The heavy steel pillar was sold for scrap which was, fortunately, fetching a good price at the time due to demand for steel from China.

The main parts arrive at G4NNS

Friends and friends of friends were pressed into service to assist with this project. Derek who works with my nephew is keen on banger racing and in pursuit of this hobby has a couple of trucks suitable for the odd transport job.

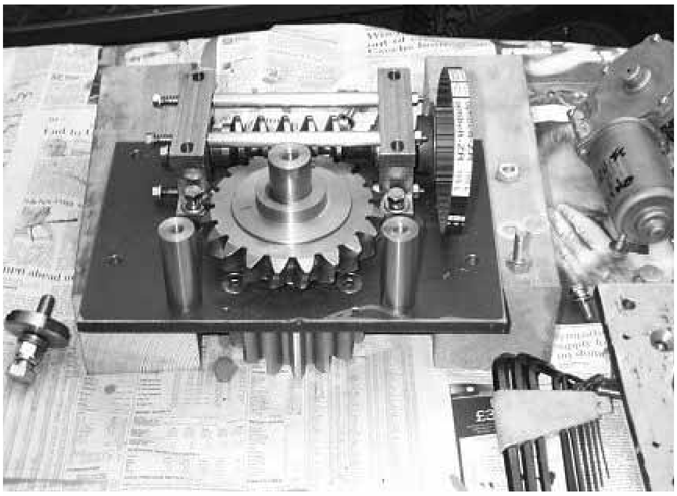
Off loading

Various farming friends and neighbours with access to the appropriate machinery were persuaded to help. Luckily for me the great British Public are reasonably tolerant of eccentrics who want to bounce signals off the moon and build radio telescopes in their back yard.

Final assembly

Positioning, final assembly and painting progressed throughout the summer as the weather permitted.

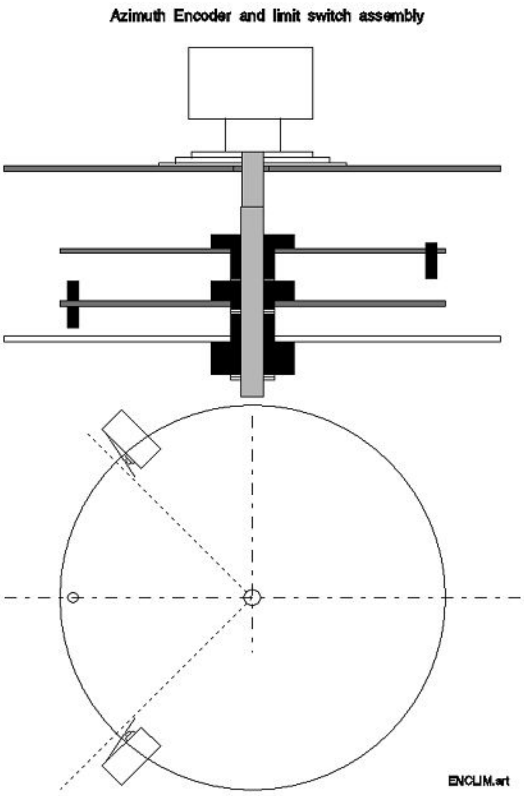
Azimuth Drive and gear box



The most taxing part of the project was the design and manufacture of the azimuth drive for which Ian G8CPJ was largely responsible. The pinion that drives the slew ring was specially made by company in Newbury who specialise in gear cutting.

The “Worm and Wheel” were found by Ian at a model engineering show for just £28. The 24V windscreen wiper motor came from my junk box. The toothed belt and pulleys came from a local engineering supply company. Everything else has been made by Ian.

Azimuth encoder and limit switch assembly



The azimuth encoder produces 4096 pulses per revolution and a calibration tick.

Two pulse trains 90 degrees out of phase enable direction to be determined.

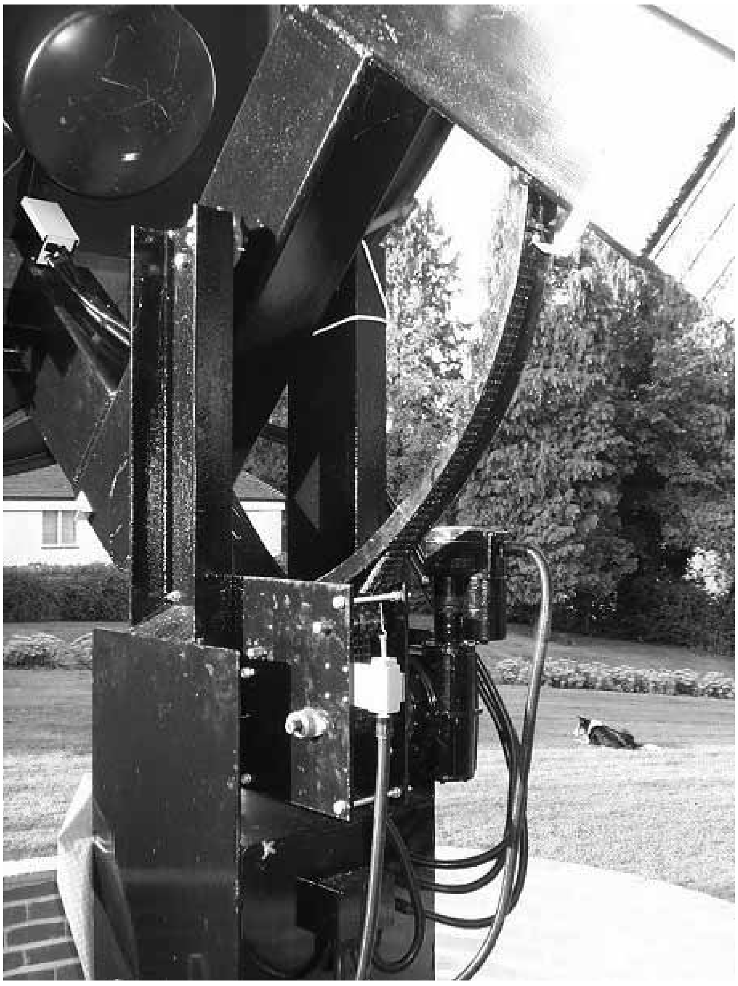
The tick was positioned roughly south and causes the counter to be loaded with a number chosen arbitrarily (2460) so that the counter can run for more than 4096 pulses to correspond to the more than 360 degrees of rotation permitted by the limit switches. The azimuth corresponding to the tick is determined during azimuth calibration using the sun.

The lower disc is free to rotate on the shaft. The upper disk is fixed to the shaft and a peg on it’s periphery strikes one on the lower disc and drives that around to operate the limit switches allowing something like 400 degrees of rotation before “hitting” the stops.

The dish is lifted back onto the new mount

With the new mount back in place a different (long suffering) farming friend was persuaded to put the dish back.

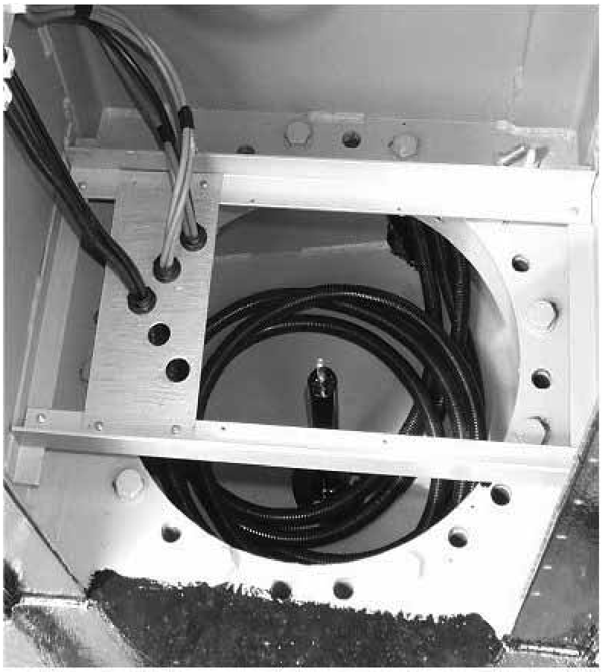
Elevation drive & inclinometer used to calibrate it



The “Pan” system on the original system used chains in a semi circular arc. This was turned through 90 degrees and reduced from 180 degrees to about 110 degrees to provide the elevation drive. The encoder is a simple reed relay operated by a magnet on a shaft which provides about 22 pulses per degree of elevation. This was calibrated using the Hilger and Watts precision inclinometer, lower right, which was capable of reading down to one minute of arc. Ian had obtained this for about £25 from an Antique shop!

Cable Well and Encoder

The cables to the RF system and Az / El control system rotate. To accommodate this the cables which are contained in flexible conduit and lie like clock springs, in the cable “well”. The Azimuth encoder is coupled directly between the rotating part of the system and ground so that it is independent of the drive mechanism; to reduce backlash. The encoder assembly includes limit switches which permit about 400 degrees of rotation but stop before the cables start to bind.

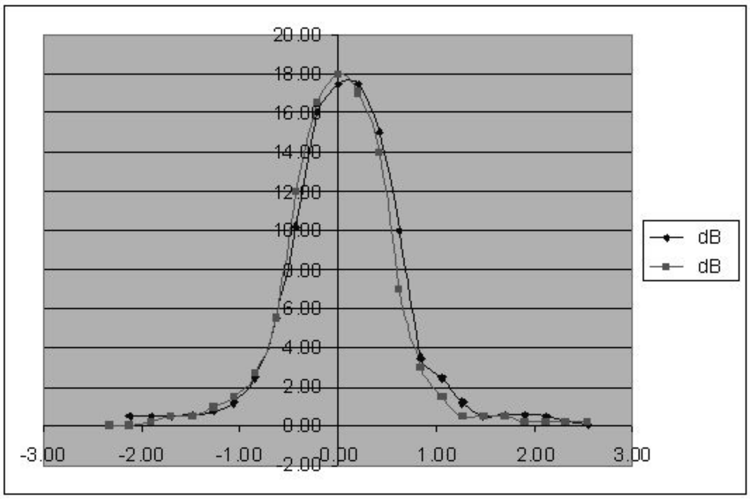


The control gear takes shape

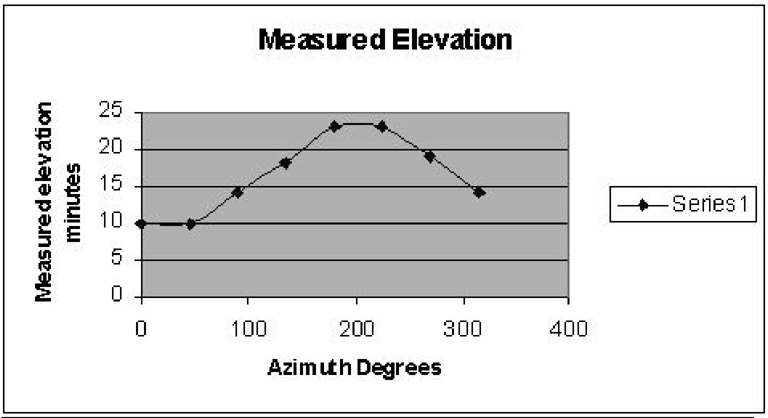
The micro controller, top, “speaks” in terms of Azimuth and elevation counts. It reads the Azimuth and elevation encoders, receives instructions from the PC running the tracking software and controls acceleration and deceleration of the Azimuth and elevation motors via 3 bit D-A converters to the speed controllers which are of the PWM type.

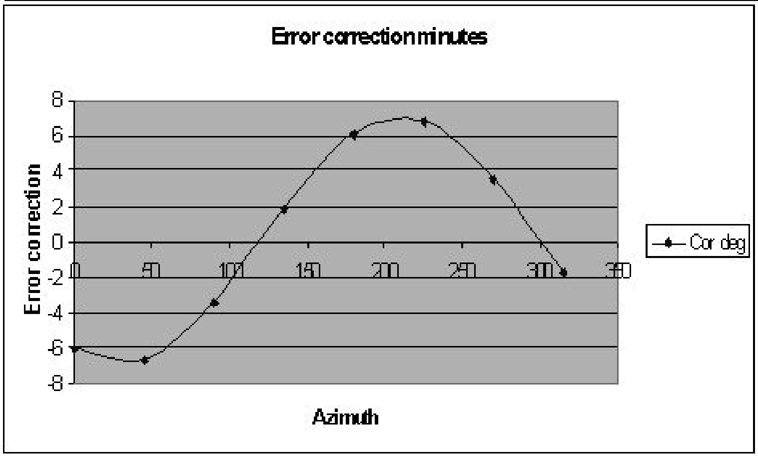
Calibration

Azimuth calibration was accomplished using the antennas sharp response on the sun. The plot below shows sun noise.



Correction of elevation



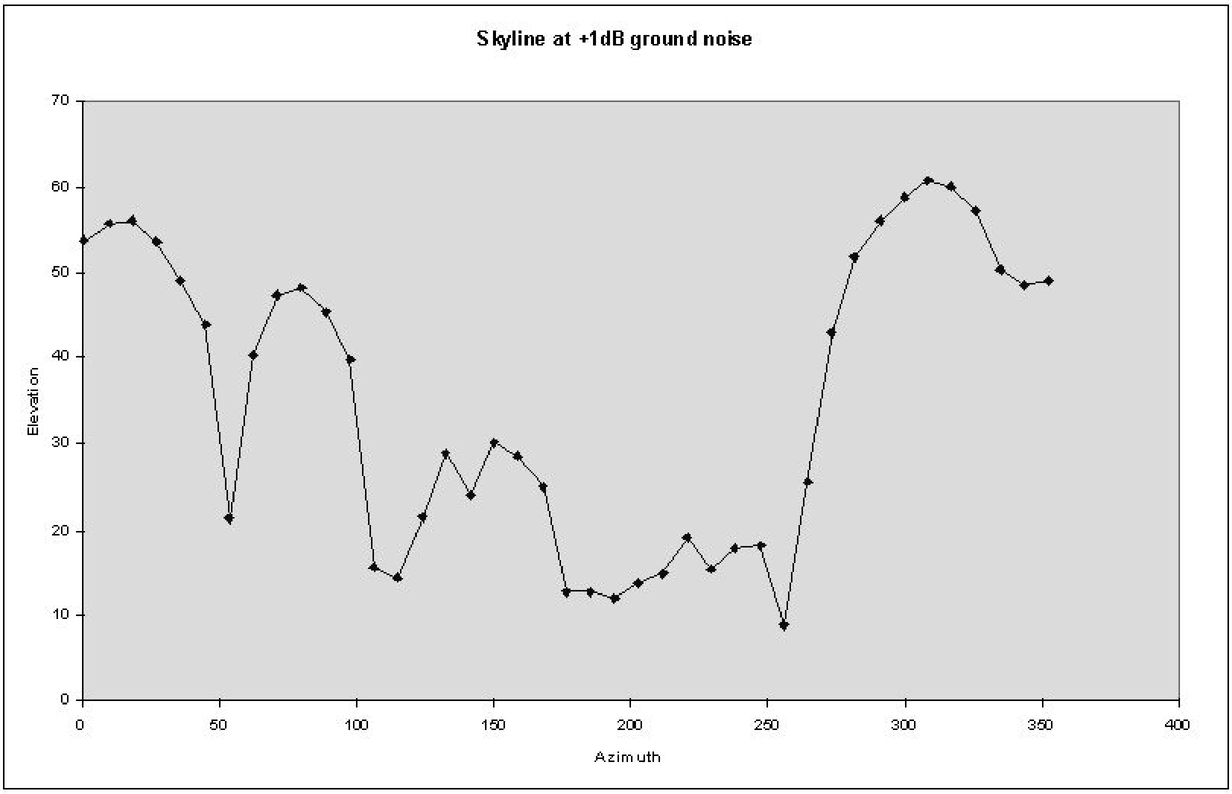


Placing a 2 ton structure so that it is precisely vertical in two planes is not easy.

On the other hand, correcting the errors mathematically is. The inclinometer was used to measure the change in elevation with Azimuth and a simple equation derived to correct for this.

Ec= Sin(Az-Ze) x Ea x Pr
Ec = Elevation Correction
Az = Azimuth
Ze = Azimuth at zero error
Ea = Error Amplitude
Pr = Encoder Pulses per Rad

Ground noise at 10GHz is used to plot the "Horizon"
With the system "up and running" it was an simple matter to plot the radio horizon using ground noise at 10GHz.



Martlesham 2004 Receiver NF Results

John Quarmby G3XDY

Band	Callsign	System	Gain (dB)	NF (dB)	
70	G4ZTR	Spectrum Transverter	8.5	4.80	
144	G3LTF	ATF54143 high dynamic	26.2	0.29	
	G3LQR	ATF54143 high dynamic	23.3	0.38	
	G3IRQ	SSB Electronics ultra low noise preamp	23.0	0.48	
	G4DZU	H/B W6PO design	19.5	0.80	
432	G4KBC	ATF54143 boxed ATC input cap	21.2	0.38	
	G3LQR	ATF54143	20.2	0.40	
	G3LTF	ATF54143	21.3	0.40	
	G4KBC	ATF54143 unboxed	22.7	0.60	
	G4KBC	CF300	15.1	1.03	
	G4KBC	ATF5413 boxed with ATC input cap	21.3	0.41	MRS 5dB ENR Source
	G4KBC	ATF5413 boxed with ATC input cap	21.2	0.43	G3SEK 9dB ENR source
1296	G3LTF	NE334 ATF10136 2 stage	28.4	0.45	
	G4DZU	WD5AGO preamp	32.9	0.48	
	G3LQR	ATF13484	23.0	0.50	
	G4DZU	WD5AGO Mk2	30.6	0.52	
	DL3IAS	DJ9BV	15.2	0.58	
	G4DZU	DJ9BV	15.3	0.65	
	G3LQR	WD5AGO NE325	24.5	0.66	
	G3LQR	2 stage WD5AGO FHX05	22.7	0.80	
	G4DZU	Angle Linear preamp	13.8	0.93	
2320	G3LTF	ATF36077	16.1	0.40	
	G4NNS	DB6NT Transverter MKU23G2	31.4	0.66	
	G3LQR	NE325	13.1	0.85	
	G3LQR	DJ9BV No2	11.6	1.84	
	G3LQR	DJ9BV	9.7	1.86	
	G3LTF	MGA86576 + Interdigital Filter	23.5	4.10	
	G3XDY	G8LMW transverter + Interdigital filter	7.9	8.60	
3400	G3LTF	ATF36077 DJ9BV Preamp	16.9	0.90	
	G3LQR	DJ9BV Preamp	15.0	1.15	
	G4BRK	Transverter & relays	18.5	1.25	
	G3XDY	Transverter & Relays	19.6	1.58	
	G3LQR	2 stage ATF36077/FHX05	17.5	2.10	
	G3LQR	DJ9BV Preamp FHX05	7.4	3.00	
5760	SM7FWZ	Homemade DB6NT transverter	24.0	0.90	
	G4BRK	DJ9BV & tvtr, no relay	18.7	1.18	
	G4HUP	DJ9BV NE325	10.6	1.29	
	G3XDY	Homemade DB6NT transverter & relay	20.5	1.48	
	M0EYT	DB6NT transverter & relay	19.0	1.75	
	G4BRK	HEMT DJ9BV & DB6NT tvtr	18.0	1.92	
	G4BRK	DB6NT tvtr only	6.5	6.50	
10368	G3LQR	Single stage preamp	9.4	0.98	
	G4ZXO	DB6NT tvtr only	26.9	1.20	
	G4ZXO	DB6NT Transverter & preamp	40.7	1.45	
	G3LQR	Two stage preamp	21.5	1.60	
	G3LQR	ATF36077	12.9	1.66	
	G4WYJ	DB6NT transverter without relay	14.6	1.67	
	G3XDY	DB6NT transverter	20.5	1.68	
	M0EYT	DB6NT tvtr and wg transitions	20.6	2.17	
	G4WYJ	DB6NT transverter	14.5	2.26	

Martlesham 2004 Antenna Measurements

Sam Jewell G4DDK

10GHz

Callsign	Antenna	Measured gain	Description	Comments
G3PHO	Horn	16.5dBi	Ridged waveguide circular horn	
M0EYT	Dish	33.1dBi	1m dish with ridged W/G horn feed	Grundig
G8BEH	Horn	22.1dBi	Secondary radar type	Long thin type with diagonal slots
G4PBP	Horn	13.6dBi	W2IMU feedhorn and radome	No dish
G4PBP	Horn	21.1dBi	Rectangular horn	
G0MJW	Dish	30.8dBi	60cm dish with horn feed	Prime focus
G4PBP	Dish	25.8dBi	35cm BSB dish with WIGHZ feed	D-MAC type

- For 10GHz the source was a Marconi Gunn source type 6058B tuning 8 to 12.4GHz.
- The source antenna was a 20dBi rectangular horn.
- The detector was a Marconi 6162/2 with Huber and Suhner 3dB pad.
- The reference antenna was a Sivers Lab PM7320X wideband reference gain horn with HP W/G - coax adaptor type X281 A

24GHz

Callsign	Antenna	Measured gain	Description	Comments
G3LQR	Dish	35.2dBi	30cm offset dish with Shepherd crook feed	Ex-18GHz link type
G8PSF	Dish	34.7dBi	35cm BSB dish with horn (?)	D-MAC type
G4DDK	Dish	32.7dBi	25cm Procomm dish with Procomm reflector feed	Prime focus
G4PBP	Dish	33.0dBi	35cm BSB dish with WIGHZ dual band feed	D-MAC type
G4ZXO	Dish	35.7dBi	45cm prime focus dish with Penny feed	Focal plane
G0UPU	Dish	36.1dBi	30cm dish with Cassegrain feed	
G4BAH	Dish	39.5dBi	48cm Procomm with Procomm reflector feed	Prime focus
G4DDK	Dish	32.5dBi	35cm BSB dish with W1GHZ dual band feed	Feed not at focus
G4DDK	Dish	36.2dBi	35cm BSB dish with 'DL' feed	IMU type feed with one choke ring. Bought Weinheim
G3PHO	Horn	22.7dBi	Rectangular horn	Copper
G3PHO	Horn	20.1dBi	Rectangular horn	'Grey'!
G8IFT	Horn	22.4dBi	Circular horn	Ex BT 18GHz link horn
G8IFT	Dish	31.3dBi	30cm 'Precision' dish	Ex BT 18GHz link dish

- For 24GHz the source was a home brew 250mW narrowband source modulated with 1kHz from a HP PIN switch.
- The source antenna was a Flann Microwave 20dB horn.
- The same detector as for 10GHz but with HP 8493C 6dB ATTENUATOR.
- The reference antenna was a 20dB reference horn loaned by WA5VJB and as used in many of the NA gain measuring contests. Thanks Kent.

A Hotplate for Microwave PCB Assembly

Dave Powis DL4MUP/G4HUP

Abstract

This presentation will describe a simple hotplate for use when assembling circuits with SMD components. The hotplate is used to raise the base temperature of the entire assembly, enabling a low wattage soldering tool to be used. A method of bonding microwave PTFE substrates to copper sheet will also be described – this method is due to Luis, CT1DMK. Improved grounding of the circuits is obtained, in addition to giving mechanical stability to the PCB.

Introduction - Why a Hotplate?

Initially my need arose as a result of using a construction technique recommended by Luis, CT1DMK, for building microwave PCB assemblies – in this case a 2 stage 3cm preamp. The PCB was 10 thou PTFE, and the intended housing was a milled aluminium box, with an integral waveguide input. An immediately obvious problem was how to mount the thin PTFE board flush to the bottom of the box once I had made the through ground connections using rivets or wires? After the exchange of a few e-mails with Luis, he outlined a construction technique which solved this problem completely – he briefly makes reference to this method in his originals article on the 24GHz modules [1], but does not give any detail in that publication.

Following this technique, I discovered another problem, for which the hotplate was the solution. Since building the hotplate, some other potential applications for it in the shack have also been recognised.

CT1DMK method for PCB fabrication

Microwave PCBs are still mainly on PTFE substrate materials for amateur applications, although a few companies who serve the amateur microwave market are moving to more 'exotic' ceramic loaded substrates for a variety of reasons – one of them being the mechanical stability of the substrate, probably one of the major disadvantages of PTFE. But for most of us, particularly those who produce their own PCB's, PTFE is likely to be around for some time to come – at least it is available as surplus on occasions!

However, the poor mechanical stability does mean that care must be taken in the handling and mounting of assembled circuits, especially when using SMD components, as hairline cracks can be caused, which will not be visible, but will prevent the circuit from operating correctly. Another problem that is difficult to overcome is good quality grounding – of course we use 'through' rivets or wires to provide the ground, as it is not practical to have 'kitchen table' through hole plating lines for the average microwave amateur! Such connections give acceptable grounding at lower microwave frequencies, but at 3cm and above they are becoming increasingly inefficient. A side effect of these grounding methods is that the ground plane side of the PCB is not perfectly flat – which creates difficulties if the board is to be mounted into a milled aluminium box, such as those available from MicroMechanik [2]

By bonding the PTFE PCB to a thin sheet of copper, both of these disadvantages can be overcome.

Preparing the PCB

Before bonding the board, all ground and through holes (eg for mounting to the box) must be made. Don't drill PTFE – punch it! PTFE based boards do not drill cleanly, with strands of material left, and trying to clean these up can result in further damage to the PCB – punching leaves a clean hole, with no such problems.

First make your punch…

Typically 1.5 or 2mm is a good size – and where do you get this from? If you can get a leather-workers punch in a 1.5 or 2mm dia size, this will work excellently on PTFE board. Otherwise, the next time you have a damaged telescopic antenna, don't throw it away! From the top section (or the next one down) you will find the material for the punch – sometimes you will find that the top section is not hollow.

Take a short length of the tube, say 7 or 8 cm, and with a tapered round needle file shape one end to a knife edge all round – to do this you will need to work at the inside and outside of the tube – work as much as possible on the inside – see Fig 1, which shows a cross sectional view of the finished punching tool.

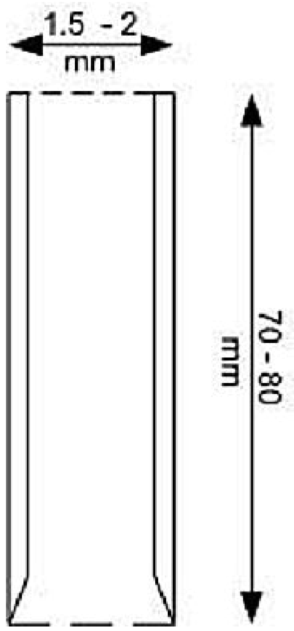


Fig 1 Cross sectional diagram of the punching tool

..then find a support..

To get a good clean punched hole, the support under the board is as important as the punch itself. Do not use soft wood, such as pine, as the work support – it's fine to place under sheet metal when drilling, but the PTFE board is too soft, and you will get a deformation of the board on the underside, as in Fig 2.

You need a firm support, either a piece of good quality hardwood, with a very fine grain, or even better a piece of smooth plastic faced board, such as an offcut from a kitchen worktop.

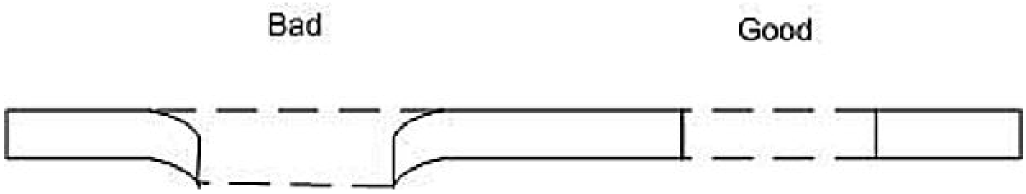


Fig 2 – Correctly and incorrectly punched holes sections

..and hit it hard!

Place the PFTE PCB on the support and place the punch in position – one good sharp hit with a hammer should cut cleanly through – if not a second hit will clear the hole. Because of the firm support you will probably find that you will need to re-shape the knife edge on the punch after every few holes. You will probably also find that the punch itself will gradually bend with use, and will need to be replaced every so often!

At the end of the punching process you should have opened up every grounding hole (for each of the decoupling capacitors, source leads of FETs and any resistors that go to ground) and the mounting holes. Refer to Fig 3. Make sure that they are all done, as punching will not work once the PCB is bonded to the copper sheet!

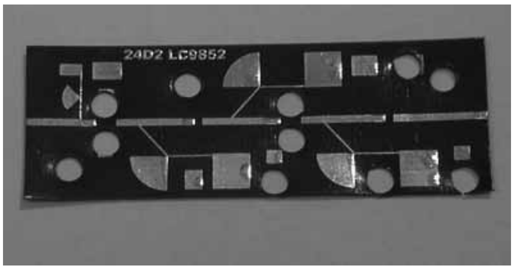


Fig 3 – Picture of punched PCB

Preparing the copper sheet

Use a thin sheet – typically 0.5 to 0.7 mm is fine for most 10G and 24G LNAs, mixers etc.   Cut the sheet slightly oversize for the PCB and ensure that it is perfectly flat, with no burrs. Clean the side to be bonded thoroughly, finishing with very fine plumbers wire wool (Stahlwolle) in 00 grade or finer to ensure a clean, grease free surface right to the edges of the sheet – do not touch the surface with you fingers once cleaned.

Bonding the sheet and PCB

Coat the cleaned and polished surface of the sheet with soldering flux (Loetfett) and place it on a flat surface that is heat resistant – a smooth faced brick or a piece of wood will do. Using a hot air gun, bring the whole plate up in temperature –as the flux melts it will evaporate and you can apply solder – build up a pool of molten solder on the sheet. Use too much solder, rather than too little – any excess will be squeezed out of the assembly anyway. As you get to this stage you can also place the prepared PCB, ground side upwards, in the hot air stream to bring it closer to the temperature of the molten solder.

Using tongs or pliers, place the PCB onto the molten solder aligning it as well as you can – the surface tension of the molten solder will tend to pull the PCB into place provided it is placed closely to start with. Remove the air stream and place a piece of smooth wood carefully on top and apply pressure until the assembly temperature has fallen enough for the solder to solidify. This pressure will force the molten solder up through the holes and out of the edges of the assembly.   Fig 4 shows a bonded PCB/sheet before the clean up- operation.

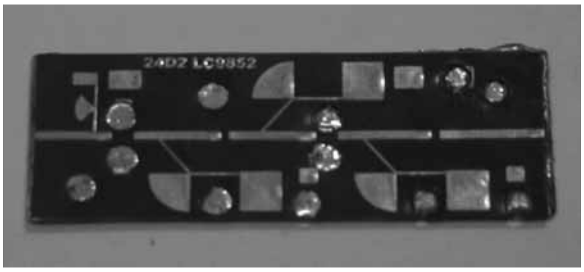


Fig 4 – Bonded PCB prior to cleaning up

Use a fine file to clean up the edges of the assembly and to trim it back to the final size – this is most easily done by holding the file in the vice and moving the work piece by hand. Placing the PTFE board in a vice may cause damage to the PTFE unless great care is taken.   Surplus flux can be removed by washing the assembly in spirit alcohol.

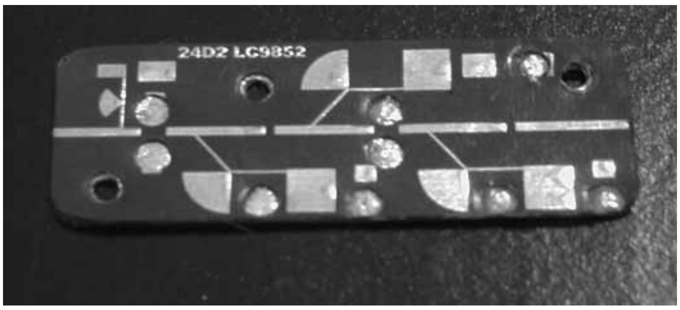


Fig 5 – Completed PCB assembly, ready for components

Finally open up any holes required through the copper sheet, eg for fixing the assembly to the box – Fig 5 shows the completed PCB assembly, ready for the mounting of components. Once all filing, cutting and drilling has been completed, wash the board again with spirit alcohol to remove any final small fragments of swarf and metal dust.

The process has converted the relatively fragile PTFE substrate into a much more resilient structure which will not easily get damaged in the following processes – but it has now one disadvantage: the thermal sinking capability of the copper sheet, although it is only thin, is sufficient that an ordinary soldering iron is not powerful enough to make good ground connections.

So – I discovered the need for the hotplate!

Hotplate Design Concept

Having built a number of DF9LN OCXOs [3] I firstly examined the heater circuit used, since it is apparent from the design that it will work well in excess of the temperatures required for the OCXO application. It is a simple circuit – basically a power transistor as the heating element, with a solid state temperature sensor and an op-amp comparator to act as a controller – see Fig 6. I ran some experiments using a 100 x 75 x 6 mm aluminium plate as the heated surface and found that with a BDX 53 darlington transistor mounted in the middle of the plate, and an LM335 sensor near one corner I could achieve nearly 100°C with a collector current of approx 3A. This was the temperature at which the plate stabilised – ie when the dissipation into free air matched the heat input. At this temperature, given the thermal gradient from the transistor junction, through the packaging and into the plate, I decided it was as close to the maximum operating temperature as I wanted to go for reliable operation. Fig 7 shows the set-up I used for these tests.

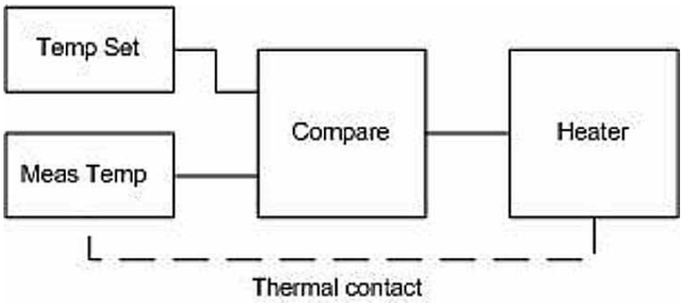


Fig 6 – Functional Diagram of DF9LN OCXO – Heater part

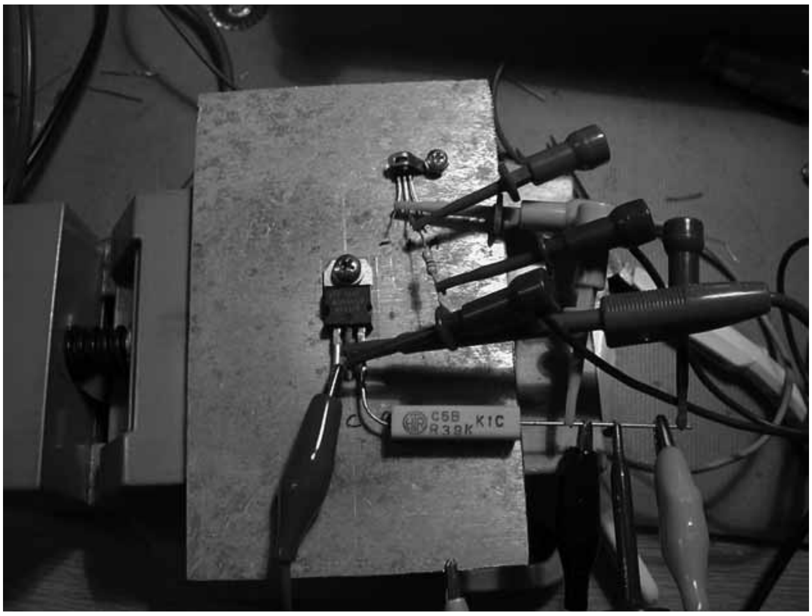


Fig 7 – Test Set-up for initial investigations

The BDX53 is capable of passing considerably more current, and could therefore take the temperature of the plate higher, but in the interests of reliability, I would recommend using resistors as heating element for temperatures higher than 100°C.

The LM335 was used, rather than the original KTY10-6 device, because it gives a linear output of 10mV/°K – as such it required minimal circuitry and processing to interface to a read out – a significant difference between this and the original application – when I built the DF9LN OCXO used for the GB3MHS 13 cm beacon, I added an LM335 so that the oven temperature could be read remotely [4]. (This was not a replacement for the KTY10-6 in the feedback loop, though)

For a prototype hotplate I decided that a simple potentiometer control of the temperature was adequate especially as there is no great demand for accuracy - ±5°C is quite good enough in this application – and the LM335 is far better than that. A moving coil analogue meter was to be used for the read-out – the resulting block diagram is shown in Fig 8

Hotplate Design Summary

In the block diagram you can see that the reference temperature is determined by the potentiometer, and is displayed by the meter when switch S1 is in the 'SET' position. When S1 is in the 'READ' position, the output of the LM335 is used to display the hotplate temperature – note that there will be a small temperature gradient across the plate, with hottest part in the centre, immediately over the heater element.

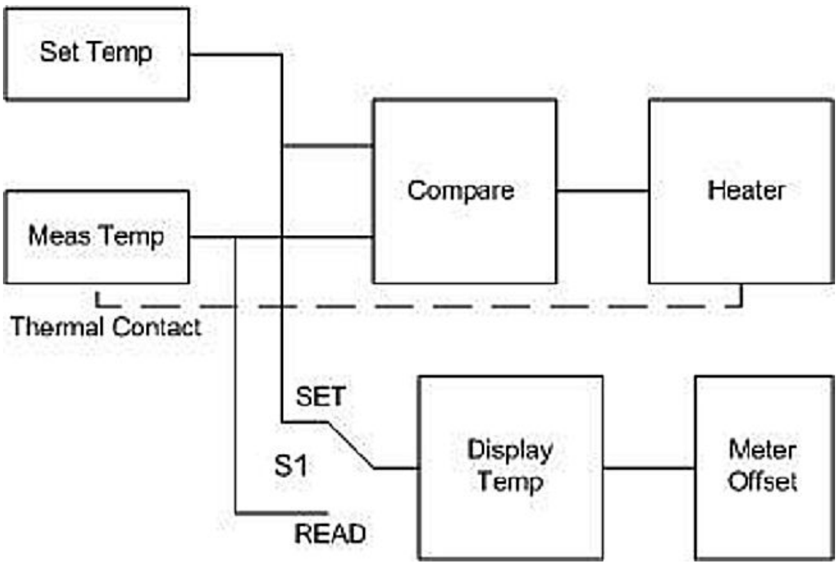


Fig 8 – Functional Diagram of Hotplate

The meter reference is 0°C – this is achieved by setting the –ve terminal of the meter at 2.73V dc, via trimmer P1 – since the LM335 gives 10mV/°K, then at 0°C it will give a 2.73V dc output – thus a 0 - 100μA meter can be calibrated (with an added multiplier resistor, in this case P2) to indicate 0 - 100°C over a 1V range

Control of the heater itself is by a comparator reading the LM335 output voltage and comparing it against the SET voltage from RV1 – the current through the transistor is limited by the emitter resistor to approx 3A.

Hotplate Circuit

Fig 9 shows the full circuit diagram. A single TL084 quad op-amp provides the comparator and the three non-inverting buffers used for voltage isolation. The amplifiers are run from a +5V dc supply via IC2 (78L05), which is also used to derive the SET and READ voltage inputs. This also limits the maximum base input voltage available to just under +5v, which limits the maximum drive that can be applied to the BDX53. The collector supply is directly from the +12V source, as is the supply for the LM335.

IC1a buffers the LM335 output voltage (READ), and this can be trimmed for accuracy with P3. IC1b buffers the potentiometer , RV1 (SET), and IC1d is the comparator. IC1c buffers the meter voltage as selected by S1. P1, 2, and 3 allow trimming of the reference 2.73V dc, the meter measurement range, and the LM335 output respectively. All connections to components off the PCB are made via 3 or 5 way jumper headers.

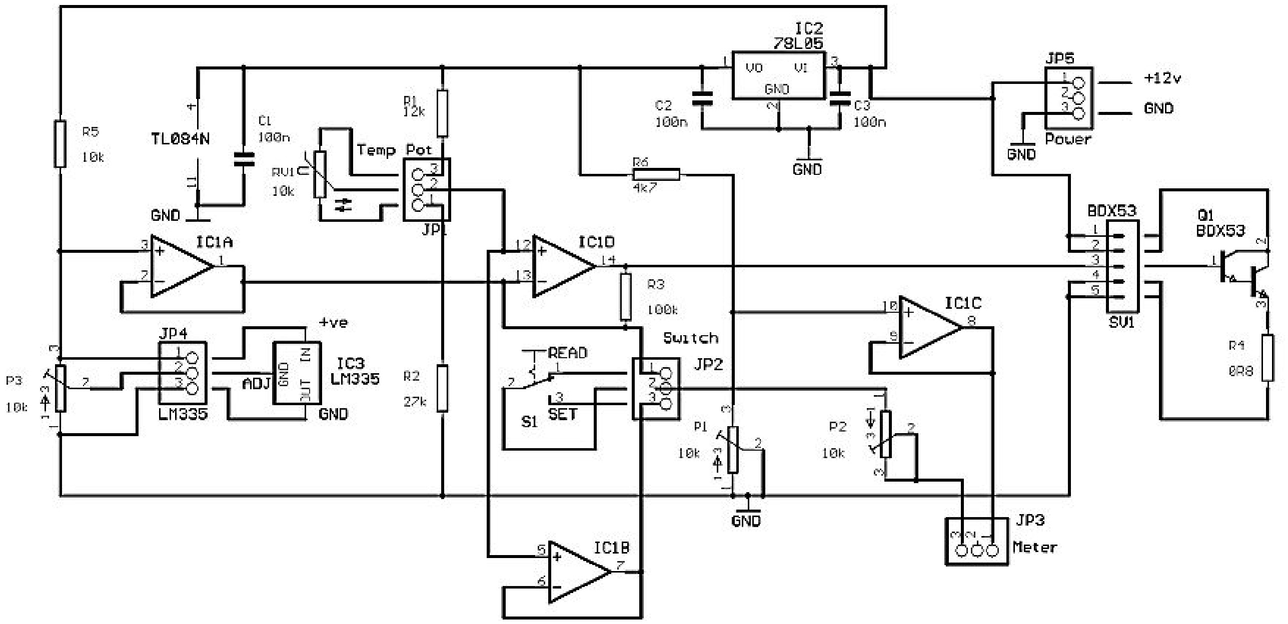


Fig 9 – Full circuit diagram of hotplate

Construction

The heater transistor and the LM335 must be mounted directly to the underside of the hotplate, using M3 tapped blind holes. Obviously, the plate must be thermally isolated from its mounting – I achieved this by using a wood surround fabricated from 10 x 5 mm and 5 x 5 mm strips glued together to form an ‘L’ shape, giving a step to support the plate – see Fig 10.

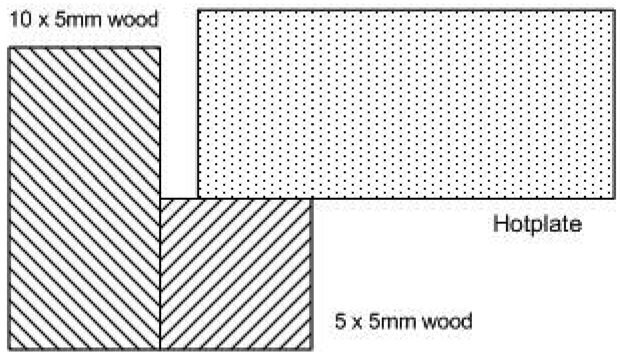


Fig 10 – Detail of support for hotplate

A PCB to hold the rest of the components (except the panel items) is shown in Fig 11, although for the prototype I used perforated board. The PCB is designed for double sided board – simply because it simplifies the tracking to have all the ground connections on one side. The component overlay is given in Fig 12. Use sturdy wires, capable of carrying the current, for the collector and emitter/ground connections of the heater - this ground can be commoned with the return side of the LM335. I have also grounded the hotplate itself, for ESP safety when working with GaAs and HEMT devices.

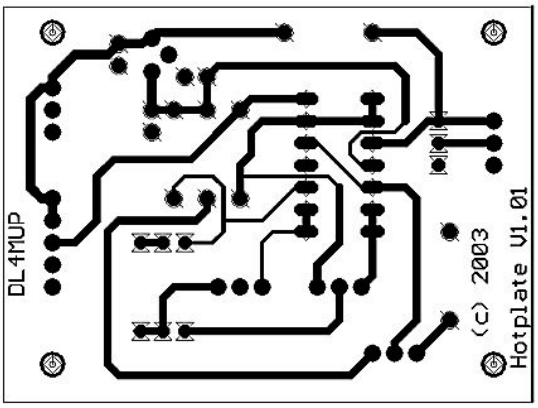


Fig 11 – PCB artwork for hotplate electronics

NOTE – due to the processes involved in reproducing this artwork, accurate dimensions of the final copy cannot be guaranteed by the author. Accurate copies of the artwork, and also the PCB component overlay and circuit diagram are available from the author at dl4mup@qsl.net

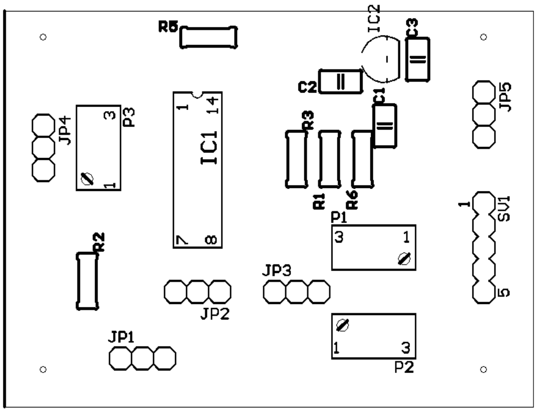


Fig 12 – PCB component overlay

The housing can be whatever you want to use – my own solution is shown in Fig 13. Another method could be to have separate enclosure for the hotplate and the electronics.

Fig 13 – Completed Hotplate

Adjustment

Once the circuit is completed and you have checked for any obvious short circuits and whiskers or solder bridges, check the output from the 78L05 before inserting the TL084 or connecting the LM335 and BDX 53.

Temporarily connect the –ve side of the meter to ground, and apply a measured 1v DC from an adjustable PSU to terminal 2 of JP2. Adjust P2 to give a reading of 100 on the meter. Remove the voltage source, and reconnect the meter –ve to terminal 1 of JP3.

Connect a nominal +12V dc supply to the hotplate – leave the BDX53 unconnected at this stage. Using a digital multimeter, adjust P1 so that the voltage at the –ve terminal of the meter is 2.73 V. Now apply an external voltage of 3.73V dc to the +ve terminal of the meter via P2, and adjust P2 for an indicated display of 100 on the meter scale. The meter is now set up to read 0 - 100°C. To set a different scale range, use an appropriate external voltage – ie for 150°C, the external voltage should be (2.73 + 150 x 10mV) = 4.23V.

Connect the multimeter to the slider of the potentiometer, RV1, and check the range of voltages available – the minimum voltage should be around 2.93V dc, and the maximum around 3.75V dc. These limits can be modified by adjusting the values of the R1 and R2 – you may need to use series/parallel combinations of resistors if you want to set precise limits – or replace them with trimmer potentiometers.

Now the TL084 can be inserted, and the LM335 connected. With S1 in the READ position, you should now see an indication of approx 20 on the meter – corresponding to the ambient temperature of the hotplate. Place S1 in the SET position and check the range of temperatures that can be set – return the setting to minimum afterwards.

Complete the circuit by adding the connections for the BDX53, and connect a DC Ammeter in the supply line, if your voltage source does not have a built in current meter. SET the meter to indicate 50°C, switch back to READ and you will see the meter indication slowly rising – it should also stop rising when it gets to 50 on the meter! While the heater is working you should see approx 3A being drawn from the supply, and as the temperature approaches 50°C this current will decrease gradually until is cuts out completely. If you continue to watch the current you will see the switching action of the circuit as it maintains the temperature of the plate.

If you have an accurate digital temperature measuring capability, you can measure the temperature of the hotplate after it has been allowed to stabilise for some time, and trim the output of the LM335 via P3 – but this degree of accuracy is only for purists – it is not necessary in this type of application!

Check that the hotplate operates correctly at higher and lower temperatures – it is now complete.

Using the Hotplate

Place the circuit board the hotplate and set the required temperature – allow the hotplate and board to thoroughly heat up for between 20 and 30 minutes. I have found that a temperature of around 90°C is needed for good soldering of the ground connections with a 'normal' temperature controlled iron (Weller 45W).

There is no method shown in this design for holding the PCB in position whilst it is being worked on – this is because I have not yet devised a solution that is mechanically simple, and can be easily fabricated with just hand tools. Some form of clip that is easy to make and use would be very useful, both for holding the assembly in place, and also to ensure a good thermal contact between it and the hotplate.

Variations

Having used the plate for building these PCBs, I would recommend that a wider temperature range is designed for – as you will see from above, around 90°C is in the right range of temperatures for this work, but that is at the top end of the range that this particular unit covers. A better top end limit would be perhaps 120°C or 150°C. To work at these temperatures, some changes to the concept would need to be made:

- Resistors should be used as the heaters, rather than transistors – with a max junction temperature of 200°C for silicon, the risk of damage to the device is too high.

- Connections to the heaters should use nuts and bolts, as solder will be unreliable at these temperatures – I did have some problems even at 100°C with wires becoming detached due to conducted heat out of the device softening the solder!

Using resistors, it would be easy to arrange, say, 4 power resistors around the hotplate, to give a better distribution of heat, with a series / parallel connection, so that they are switched by a single power transistor (which should be mounted on a separate heatsink!) The temperature sensor could be mounted centrally in the hotplate – see the concept diagram in Fig 14.

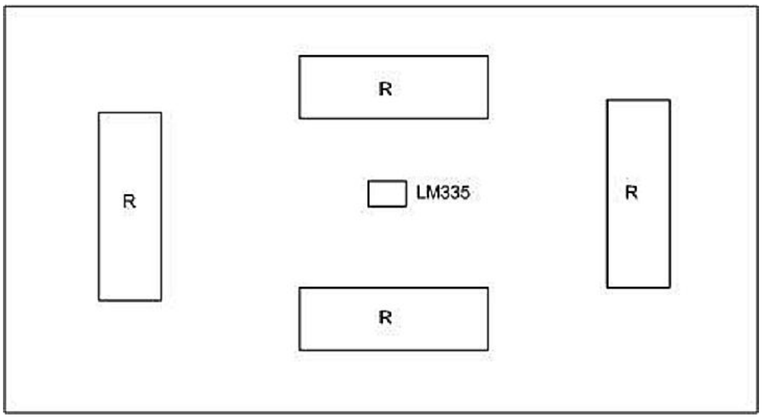


Fig 14 – Concept diagram for resistive heating

Note that the LM335, although specified for operation for up to 100°C only on the datasheets, has shown reliable operation up to almost 200°C in other heater applications, so can be confidently used up to 150°C at least. Do check the temperature ratings of the power resistors you intend to use – the bolt down Welwyn or similar types are a good choice.

The controller circuit described above is suitable for these applications, since none of the temperature critical components is placed on the PCB. To modify the temperature range setting, the value of R1 (6k8?) should be changed, so that the minimum voltage from RV1 slider is still around 2.9v, but the maximum is about 4.4v for a 150°C design. On the output side, consider the combination of resistors in Fig 14 as a replacement for R4, and wire this in the collector circuit of the BDX53, instead of the emitter. Mount the BDX53 on a separate heatsink, not the underside of the hotplate!

Whilst this paper has shown a variable temperature hotplate, which can be used for multiple applications, there are also methods and devices available enabling the simple manufacture of fixed temperature hotplates – one such option is the Dallas Semiconductors DS1620 [5], which has the temperature sensor and control electronics contained in the single chip. It is specified up to 120°C, and requires few external components to make such a heater. It will also operate as a variable temperature sensor and controller, but requires a microprocessor to generate the data it needs.

Other Applications

Although this unit was designed to overcome a specific challenge, some other uses and applications have become apparent since it was built:

- Curing of silver loaded epoxy – such glues are also a method of assembling microwave PCBs onto supports to give mechanical strength and good grounding – they require to be cured at approx 50°C for an hour or so. By placing the assembly on the hotplate, this can be done without intruding into the culinary preparation area which is the protected domain of the XYL!

- The PCB bonding technique can also be applied to power amplifiers – especially at microwave frequencies, it is very important to ensure that the tabs on the device lie flush with the PCB tracks – this can be difficult, since the devices are usually much thicker than the PCB, needing the heatsink plate to be milled out for the device to sit in, or the use of a separate plate between the PCB and the heatsink to bring them into alignment. The first solution is OK for those with access to good machine shops, the second is easier, but results in a more complex assembly. By bonding a copper plate of the correct thickness to the PCB, there is a one-piece board to be assembled, with excellent grounding – but the downside is that more heat will be needed to solder it, since the thin copper plates of 0.5 and 0.7mm recommended for LNA assemblies will not be thick enough for power devices.

PCB's

1:1 artworks of the PCB, and copies of the circuit diagram and component overlay are available on request, for the cost of the postage. Manufactured PCB's can be made available, depending on demand. You can contact me at dl4mup@qsl.net.

Conclusions

This presentation has shown a method for improving the mechanical stability and electrical grounding of PCBs for microwave applications, and has also shown a hotplate accessory to facilitate easy working with the composite assembly resulting from the bonding process.

Acknowledgement

My thanks to Luis, CT1DMK, both for his assistance with my questions about his 10G and 24G designs, and also for permission to publish the bonding method in this paper.

References

[1] 24GHz Modules, Luis Cupido, CT1DMK: Dubus 3/98.

[2] MicroMechanik (inh. Hubert Krause) – Supplier of milled aluminium boxes for 10G and 24G preamps etc. Tel +49 2248 4895/Fax +49 2248 445295.

[3] Oven Stabilised XO for VHF, Uwe Nitschke, DF9LN: Dubus 3/97.

[4] GB3MHS – New 13cm Beacon at Martlesham; Dave Powis, G4HUP, UKW 43, Weinheim 1998.

[5] DS1620 Digital Thermometer and Thermostat – Dallas Semiconductors. http://www.dalsemi.com

Additional Information

Following urls provide leather workers tools

- http://www.theidentitystore.co.uk (UK)
- http://www.eleathersupply.com (USA)
- http://www.tandyleather.com (USA)

You need a 'Drive Punch' - but it seems as if these are being phased out of the catalogues at the moment, and being replaced by more expensive punches and sets, eg single punch is cat 3777-33 at GBP9-00

However, you can make a suitable punch from 'spare parts' for sets – eg from Identity Store (which is UK outlet for Tandy Leather):

- Mini Punch set (cat 3003-00) has 1/16 to 3/16 punch tubes which fit a common handle-cost GBP7-50

- Or just buy the Handle (cat 31767-00) cost GBP2-75 and Minitube size 00 (cat 3798-00) cost GBP1-50

dl4mup@qsl.net

SSETI Express satellite mode S data and voice transmitter

Sam Jewell G4DDK

What is SSETI?

Student Space Exploration and Technology Initiative. Students from twelve different European countries are participating in SSETI. They are building the first pan-European student satellites together. They are all united by their desire to 'launch the dream‘.

Who is behind SSETI?

ESTEC: European Space Research and Technology Centre (Noordwijk, The Netherlands), educational outreach arm of: ESA, the European Space Agency.

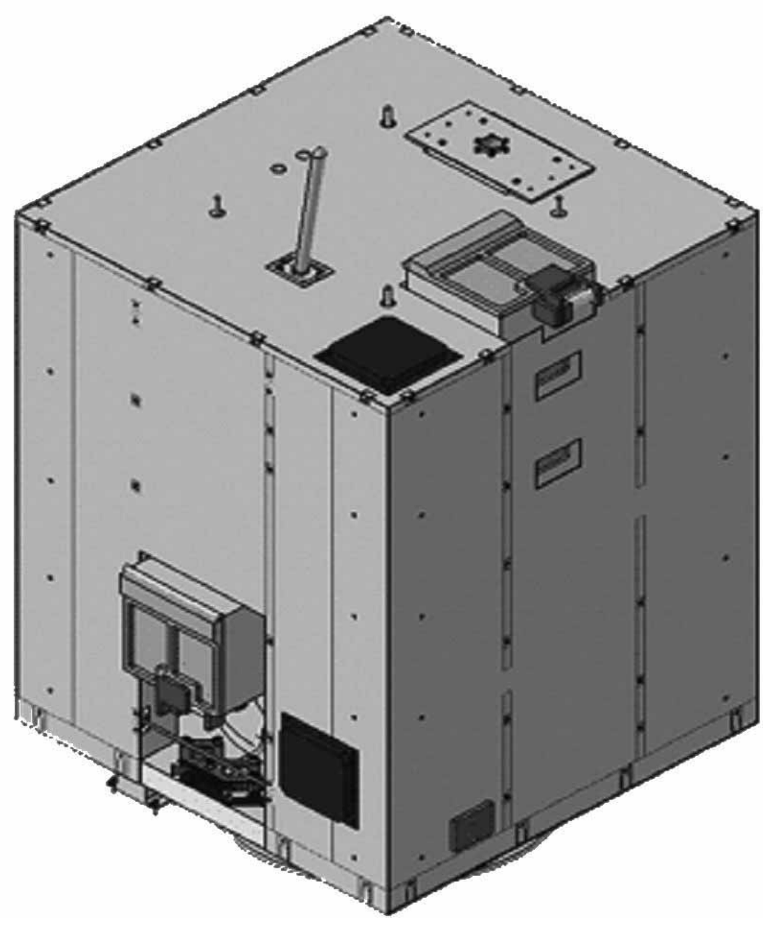
What is SSETI planning?

Mission 0: SSETI Express is planned to be launched in Low Earth Orbit in early 2005. The satellite should serve as a technological demonstration and as a test bed for some of the hardware that will be used for ESEO.

Mission 1: The European Student Earth Orbiter (ESEO) should be launched directly into an geo-stationary transfer orbit using an Ariane 5 launch vehicle. Planned for end 2005.

Mission 2: After the first mission has succeeded, the next step will be the development of a Moon Orbiter to prepare a final Moon landing.

Mission 3: The last step is the final Moon landing. This includes to drop a Moon Rover which will explore the Moon.



SSETI Express

Why and how are we involved?

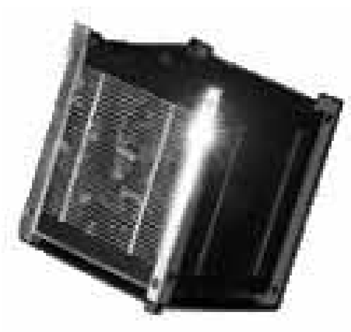
To create a network of students, educational institutions and organisations (via the internet) to perform the distributed design, construction and launch of (micro)-satellites and other spacecraft is the main objective of the SSETI initiative.

SSETI Express

The SSETI Express mission is an educational mission that shall deploy CUBESAT pico-satellites developed by universities, take pictures of Earth, act as a test-bed and technology demonstration for hardware of the complementary project: the European Student Earth Orbiter, and function as an radio transponder for the rest of it's mission duration.

SSETI Express passengers

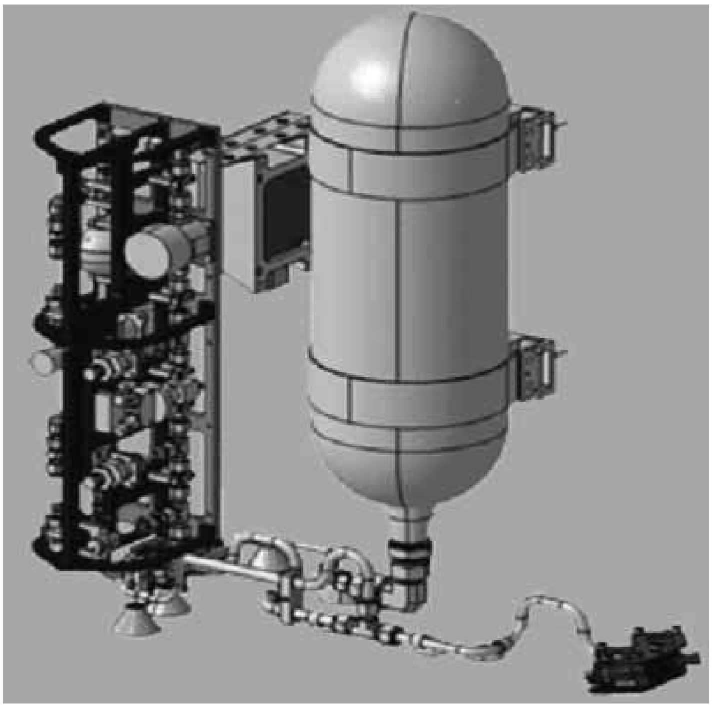




- XI-V from Japan, University of Tokyo
- UWE-1 from Germany, University of Würzburg
- Ncube-2 from Norway, Andoya Rocket Range

They will be deployed from a T-Pod developed by UTIAS Space Flight Laboratory, Toronto

SSETI Express payload

SSETI Express parameters

- The satellite is approximately 60*60*70cm and weighs 80kg.
- SSETI Express is planned to fly on the DMC-3 Cosmos launch vehicle from Plesetsk in Russia.
- The main passengers of this launch are two commercial satellites from Surrey Satellite Technologies Limited (SSTL), United Kingdom.
- Launch is planned April 2005 by Polyot in Plesetsk
- The orbit is circular SSO : 686km, 98.3deg 11:00AM LTAN
- The period of the orbit is around 90min

SSETI Express communications

Primary communications will be simplex 9.6kb/s on 437MHz using a specially qualified T7F transceiver produced by Holger Eckart, DF2FQ.

The S Band package consists of

- 3W, 2401.840MHz single channel, directly modulated FM transmitter.
- TNC7
- SMPSU
- Logic and interface board
- Sensor board
- 3-way antenna splitter

S Band modes

Data or voice configuration

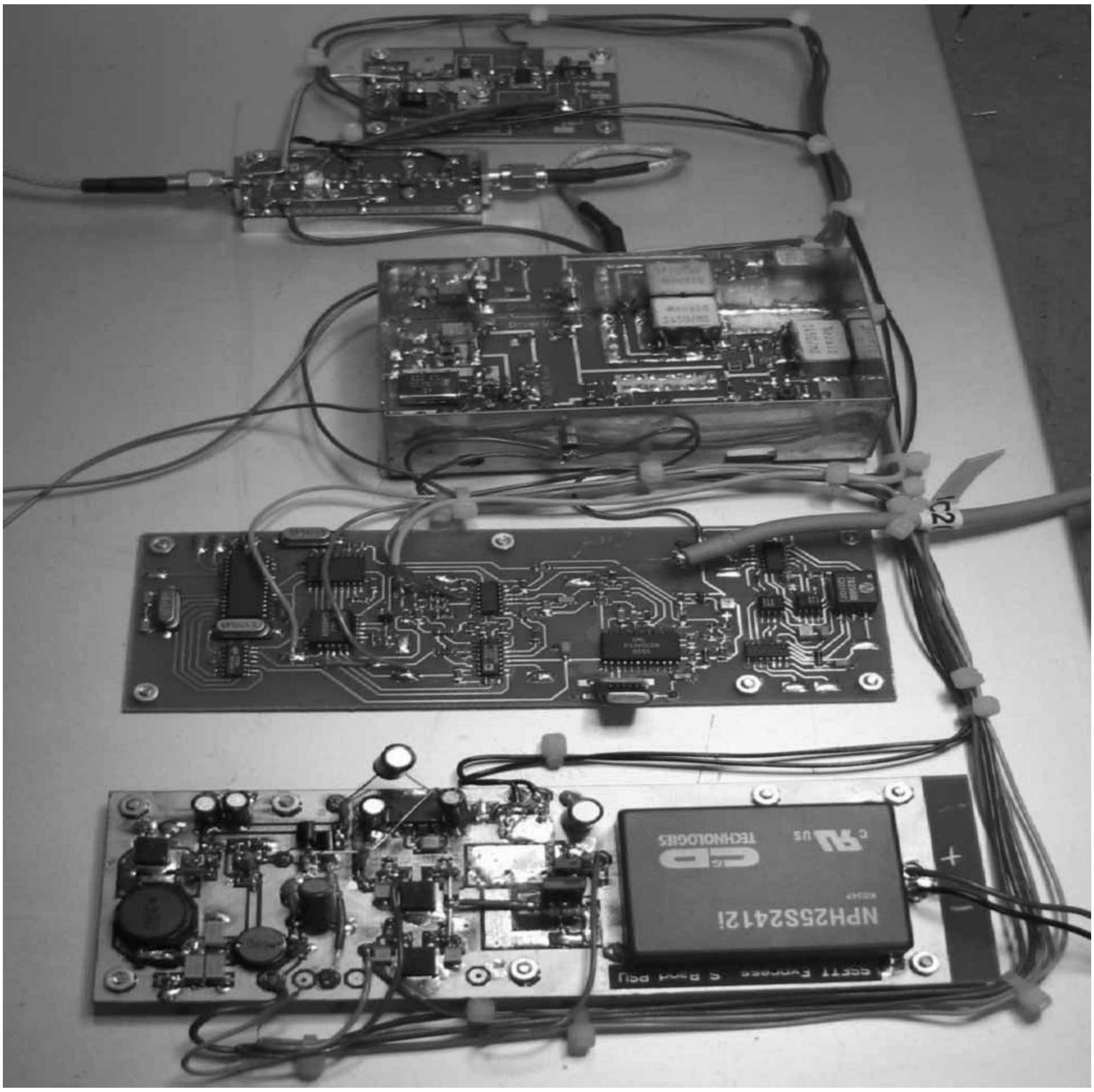
Data:
- 38.4kbit/s from the TNC7.
- Relays satellite experiment data and camera data stream

Voice:
- Relay of the 437MHz voice uplink
- CTCSS enabled
- DTMF-based telemetry frame every 2 minutes

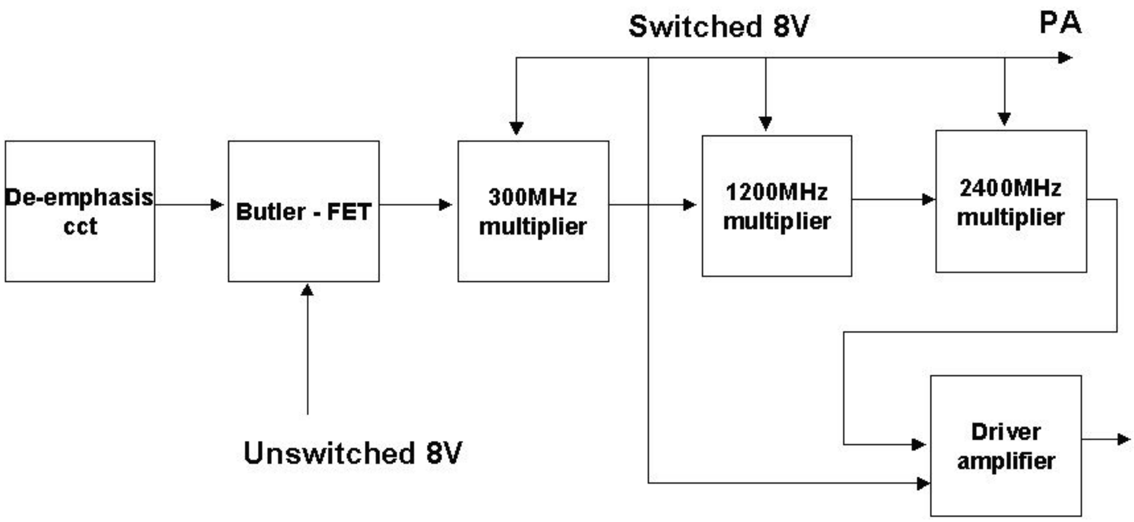
The S Band Transmitter

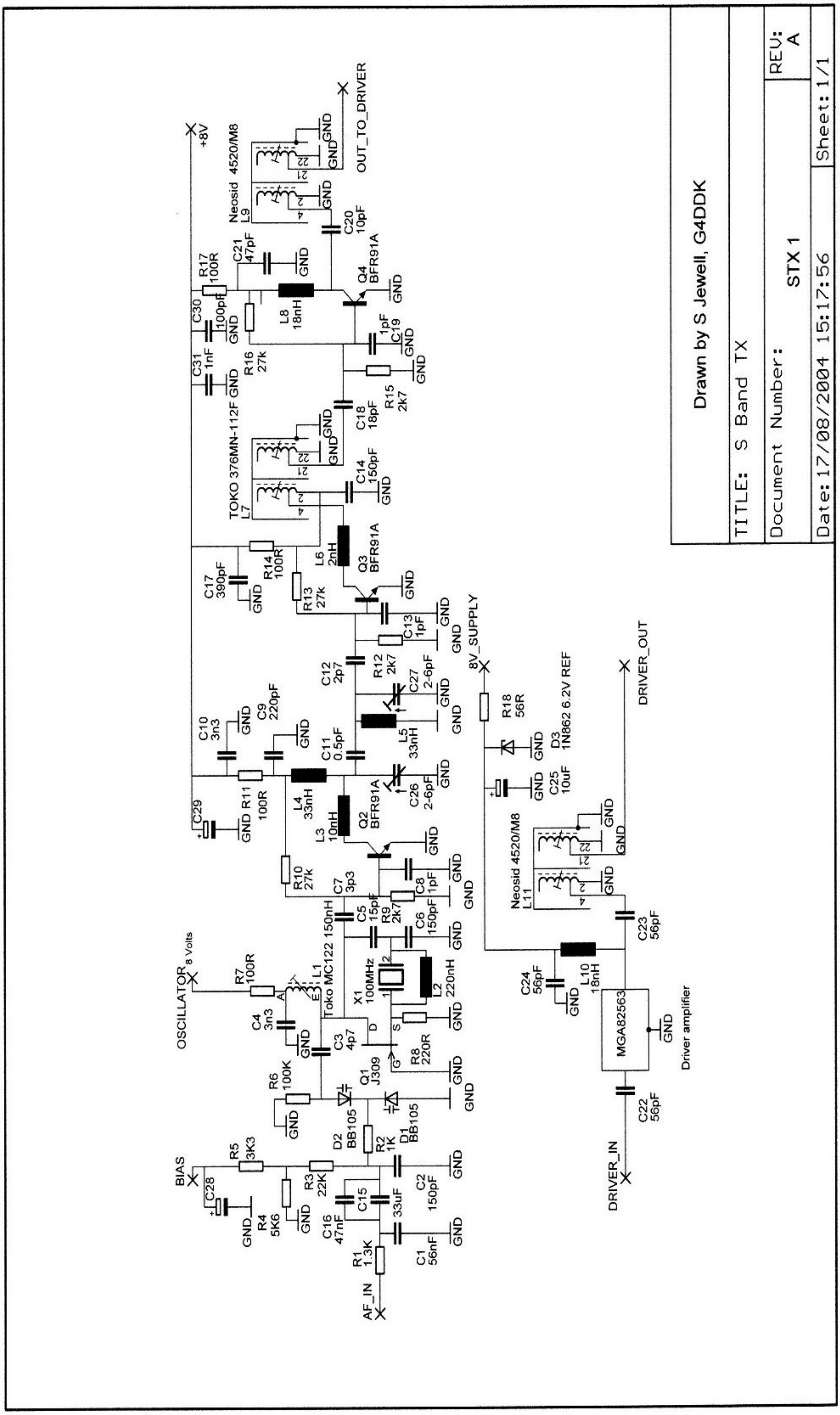
- Express – 8 weeks to produce a working prototype.
- Direct FM modulation using 'G3RUH' data stream shaping (filtering)
- Existing, flight proven (ECHO) PA from G3WDG
- PA monitoring for power output, heatsink temperature and supply current (maybe RSSI)
- Tight spectral mask – lots of filtering.
- 12kHz peak deviation with high linearity for data
- 5kHz peak deviation for voice and DTMF telemetry
- Low current consumption <10W for the entire module.

SSETI Express S band test bed



The S Band Modulator

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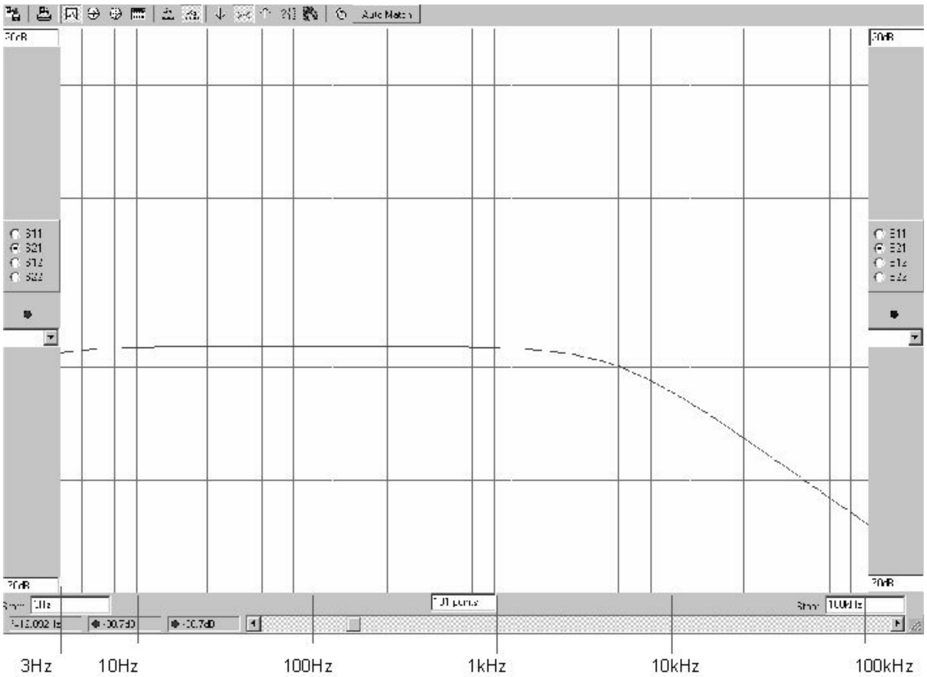
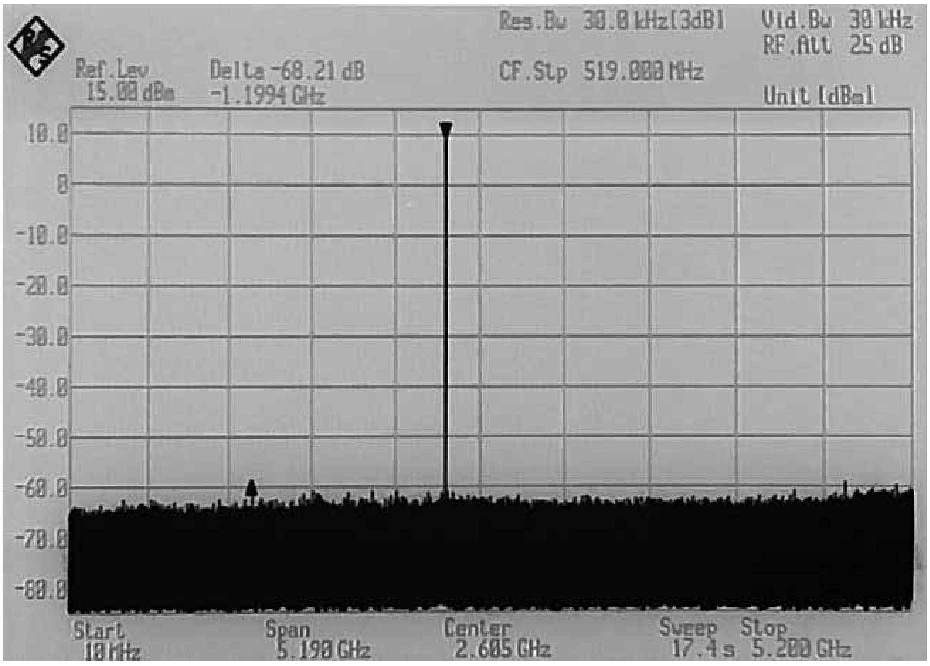
OSCILLATOR 8 Volts
+8V
OUT_TO_DRIVER
8V_SUPPLY
DRIVER_IN
DRIVER_OUT
MGA82563
Driver amplifier
Toko MC122 150nH
X1 100MHz
Q1 J309
Q2 BFR91A
Q3 BFR91A
Q4 BFR91A
TOKO 376MN-112F
Neosid 4520/M8
D3 1N862 6.2V REF



S Band modulator de-emphasis



Spectral purity

Acknowledgements

Jason Flynn, G7OCD
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David Bowman, G0MRF
Howard Long, G6LVB
Charlie Suckling, G3WDG
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Amsat-UK
SSTL
ESTEC

2.4GHz WLAN in Amateur Radio

Paul Marsh – M0EYT

About the author

Paul M0EYT lives in Poole, Dorset (IO80XR) and is active on 2.4GHz, 3.4GHz, 5.7GHz, 10GHz and HF! He is a committee member at FRARS (www.frars.org.uk) and has been 'active' on microwave bands since around 1990.

Paul has been working for IBM UK, in the area of computer security, for the last 4 years, and before that, at an IBM business partner. Most of his work involves helping customers track down security breaches and implementing technology to prevent hackers getting into networks, including WLAN networks.

What is WLAN?

WLAN is an acronym for '**W**ireless **L**ocal **A**rea **N**etwork', and WLANs are direct replacements for wired networks such as Ethernet. In most applications WLAN should work as well as wired networks – subject to the type of network traffic.

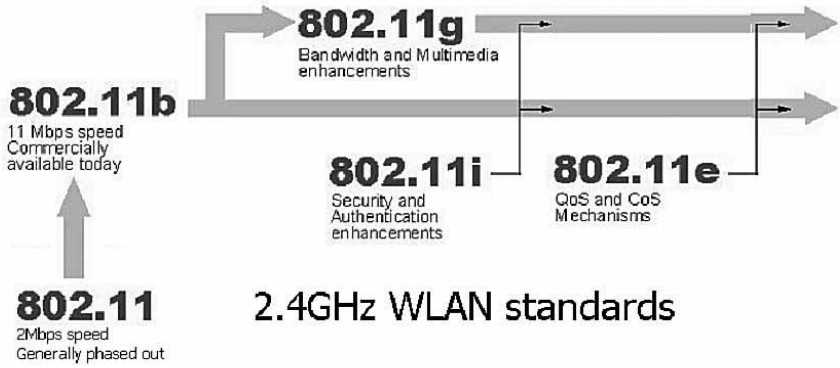
The most popular type of wireless network can transfer data at a rate of 11,000,000 bits per second (802.11b). Several manufacturers have improvements that can increase the speed to over 100 Mbps in the 2.4GHz band. Hardware which conforms to the 802.11b/g spec can interoperate.

History

Around 1997, a standard was ratified by the IEEE called '802.11' which proposed a 2Mbps data communications protocol for use over a wireless link. Then, in 1998, technology advanced and we saw the first 11Mbps wireless standard – '802.11b'. Around the start of 2003, '802.11g' equipment saw the light of day, and it offers a massive 54Mbps of data transfer.

There are manufacturer specific solutions offering 108Mbps over the air speed! (US Robotics); there are also lower speed solutions (1.6Mbps) such as HomeRF that are generally not used any more.

Standards



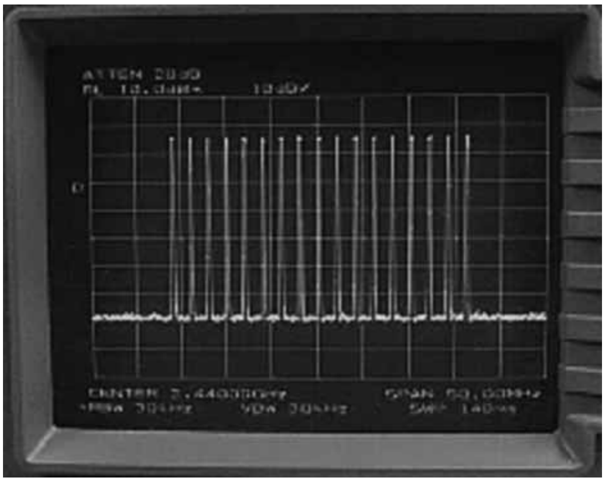
Modulation schemes

The following modulation schemes are used:

- 802.11 – FHSS – 1.6 / 2 / 3 Mbps over the air
- 802.11b – DSSS – 11Mbps over the air
- 802.11g – DSSS / OFDM – 54Mbps over the air

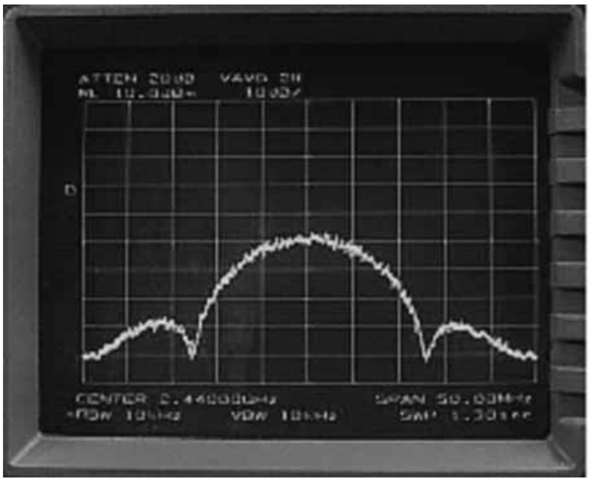
802.11 – FHSS – 1.6 / 2 / 3 Mbps

There are 79 slots, 1MHz wide. The hopping sequence is preset in the cards, but can be varied slightly to create different WLAN networks operating in the same band.



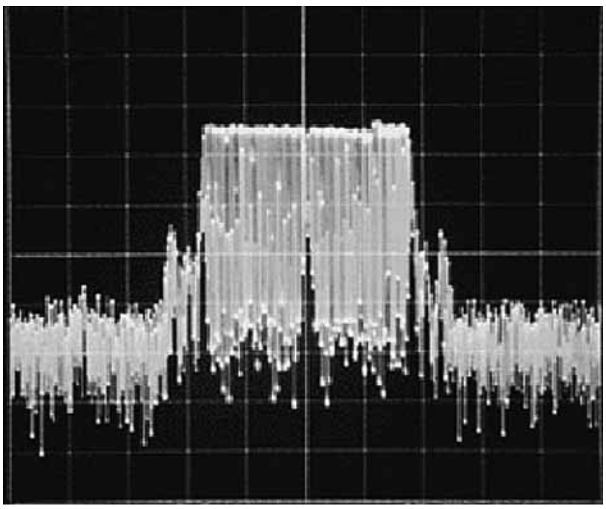
802.11b – DSSS – 11Mbps

Direct Sequence Spread Spectrum is used by 802.11b – the spreading code is fixed in hardware and cannot be altered. Channels can overlap with only a small amount of degradation. Typical RF bandwidth is 22MHz



802.11g – OFDM – 54Mbps

This standard uses a combination of DSSS and OFDM (orthogonal frequency division multiplexing) – approximately 30MHz of RF used for 54Mbps data rate.



Possible uses in Amateur Radio

- Remote control of a PC that controls a radio or dish.
- Data collection from remote site (i.e. a uWave beacon).
- Internet access from microwave sites for contest support – on4kst / DX cluster / email / VoIP.
- Onsite text chat for the larger contest stations.
- Centralised logging for contest stations.
- Community high-speed data network.
- Long term study of propagation effects at 2.4GHz.

WLAN Hardware

Wireless LAN devices can generally be divided into 2 types – infrastructure equipment and clients.

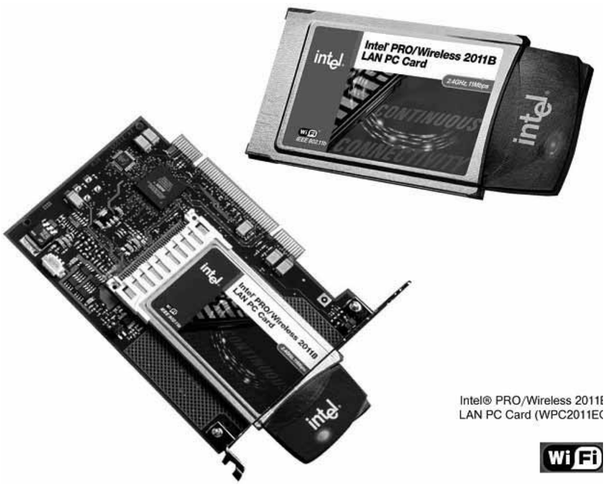
Infrastructure equipment connects to wired networks and provides the wireless interface, while clients are the devices that connect to the infrastructure via wireless.

Infrastructure

The most common infrastructure device is called an Access Point. It is a radio <> Ethernet bridge. For 'shack' use, ADSL routers can allow broadband internet to be distributed around the shack to other PC's, laptops or printers. Most access points have a typical range of a few 100m.

Wireless clients

The most common type of wireless card is the pc-card. Pc-cards fit most modern laptops. PCI Wireless cards are available for desktop PC's. Ethernet <> radio bridges are also available to allow PC's with Ethernet to connect over the air to wireless devices.



Wireless clients

The cards we have found that have the best receive sensitivity are made by Senao; They are suitable for long distance WLAN links because they have adjustable link timing.

Sensitivity:

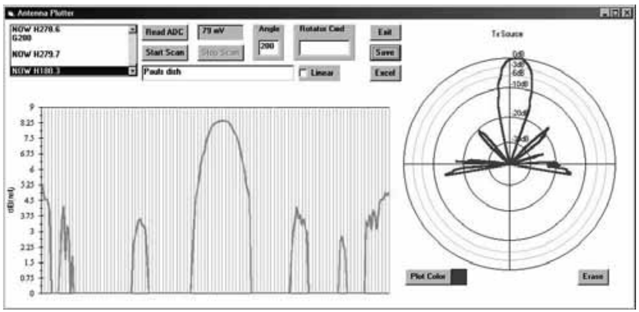
-86dbm @11 Mbps
-88dbm @5.5 Mbps
-90dbm @2 Mbps
-92dbm @1 Mbps

Antennas

Since 2.4-2.483GHz is in use, 13cm amateur band antennas work very well. Many commercial 2.4GHz antennas are available, but it is simple to build your own. An EIRP limit of 100mW does apply if you are operating as ‘license exempt’. You can use more power / higher EIRP if you operate under the amateur radio license, but they are drawbacks – you are not allowed to transmit public data.

Here are two examples of antennas we have built at FRARS, one is a Sky mini-dish, the other is a short back fire. A link over a 14Km path was achieved @ 5.5Mbps.

Each time we build an antenna, we test it on our antenna test range, in order to plot its polar diagram.



WLAN Data security

As you know, any traffic that is transmitted over the air is subject to interception; WLAN is no different.

- Out of the box – most WLAN devices are insecure.
- Many tools are available on the Internet to 'sniff' WLAN traffic.
- There are now many different methods of securing wireless networks, including WEP, WPA, and 802.1x.
- For the 'home' user of WLAN, WEP or WPA have sufficient protection against all but the most determined hacker.
- Operating WLAN under the amateur license means you cannot encrypt your data.

UK legal position on WLAN usage

When operating WLAN as 'license free' the following must be observed

- 100mW EIRP is the maximum you are allowed to radiate no matter which WLAN standard you use, i.e. FHSS, DSSS or OFDM.
- You can attach larger antennas and gasfet preamps to the receive side to increase link distances, but the transmit antenna must not exceed 100mW EIRP.
- WLAN networks must accept interference from other users of the band.
- Data encryption is allowed.

Example: Bell Hill beacon telemetry

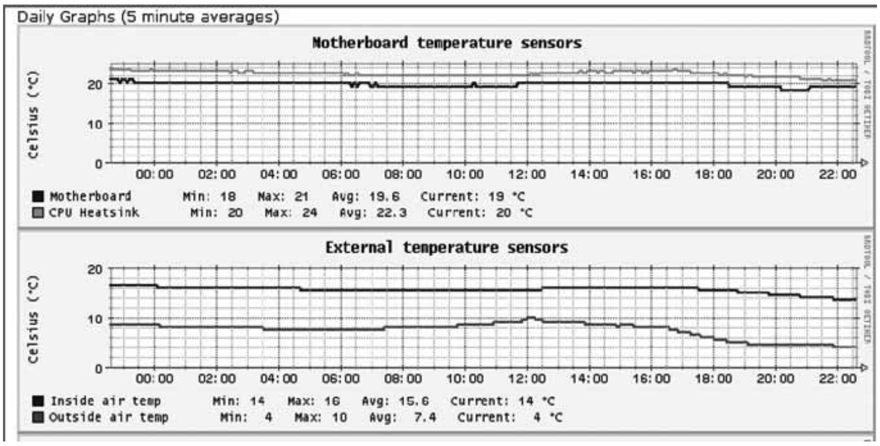
Since early 2004, we have been experimenting with a long distance WLAN link to the Bell Hill beacon site. The purpose is to study link reliability and propagation effects at 2.4GHz.

We use a dish antenna with pre-amp for receive and a patch antenna for transmit, keeping to the 100mW EIRP rules. The link is 22Km long.

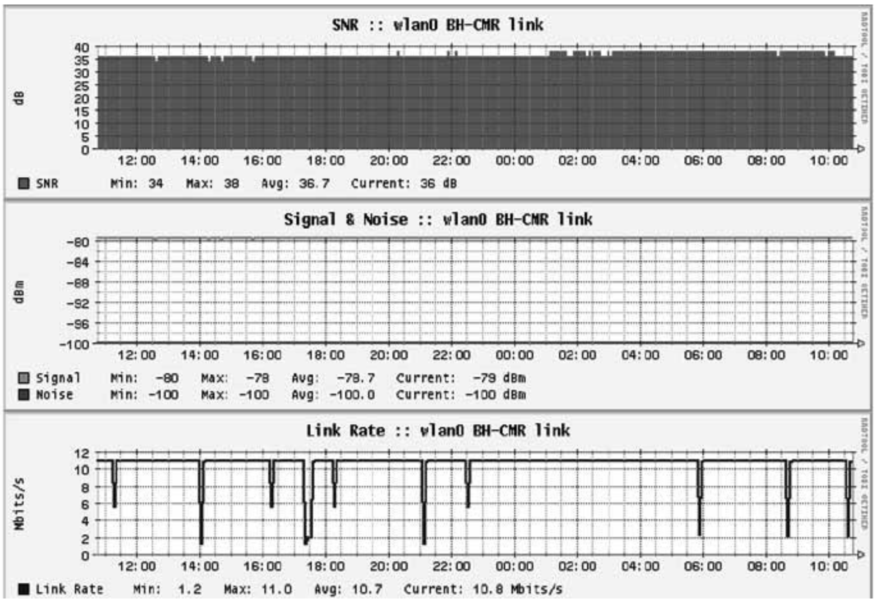
The equipment hut contains a low-spec PC which acts as a wireless router – one interface connects to the two link antennas and the other is Ethernet which connects to a hub. A low-light video camera monitors the environment.

The hut PC also has a variety of interfaces – facilities exist to control 16 relays, 32 TTL I/O devices and sense 16 opto-coupler inputs, all via a web page.

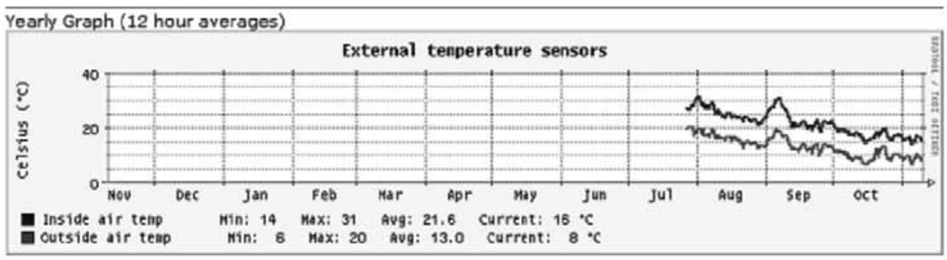
Internal and external temperatures are also monitored and recorded from external i2c sensors.

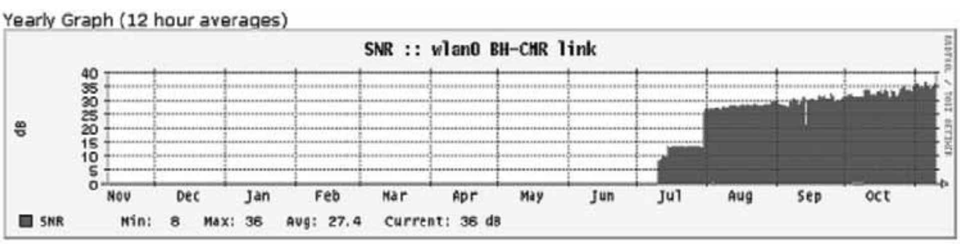


In addition to temperature, WLAN link statistics are also monitored; SNR, received signal strength and bit rate.

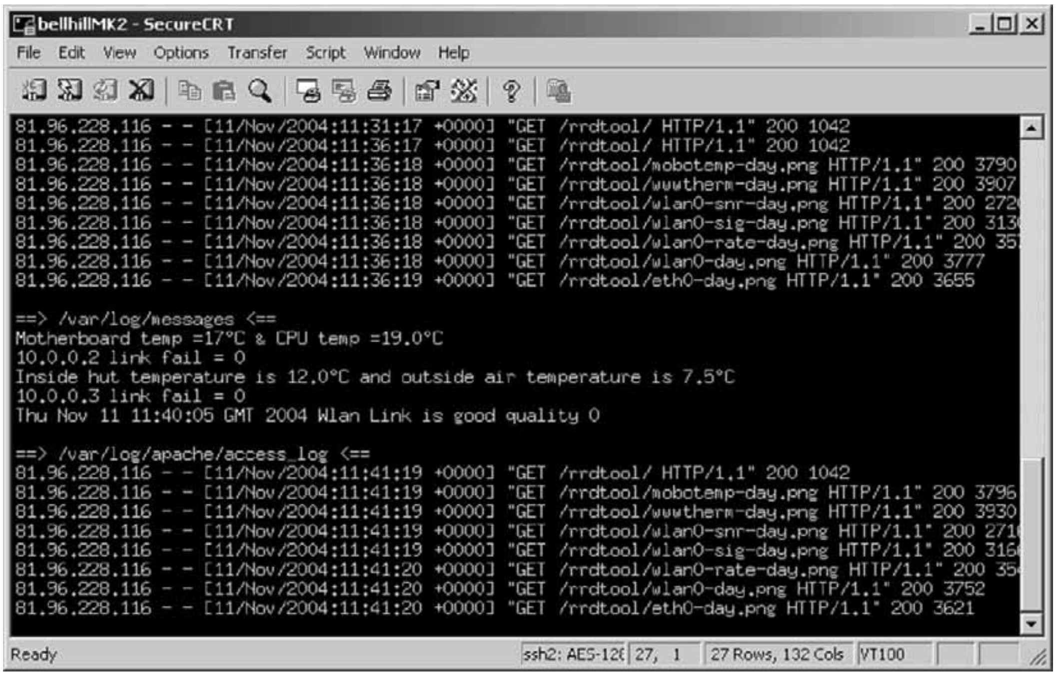


An interesting trend has been noticed in the received SNR as the year has gone on – as the average external temperature falls, the SNR improves. At the end of July the SNR was 25dB, it is now 36dB. We have also noticed tropo enhancements where signals have peaked up to 10dB over nominal.





The hut PC is Linux based and can be accessed from any Internet connected PC with SSH, this allows for general system admin tasks to be performed remotely.



Several enhancements to the current system are planned

- Mains voltage and current monitoring.
- Perhaps a wide band receiver that can be remotely tuned with audio streamed back from the site.
- A steerable video camera with zoom.
- More weather sensors, wind speed, humidity, etc.
- Interfacing to the current beacon status telemetry such that information can be rendered on a web page.

Example: VHF NFD Internet access

During the VHF NFD event this year, G4RFR and G4BRA thought it may be useful to have Internet access on site for the purposes of DX cluster, ON4KST and e-mail. We made a portable hot-spot that was planted in the field we were using for the contest. All equipment ran from a 12V leisure battery.

One WLAN hop was made from Little Minterne Hill to Bell Hill which is about 12Km – this used a pair of antennas at Bell Hill, and an omni at Little Minterne Hill.

The on site WLAN was distributed using a corner reflector antenna and an access point. This was connected to the Linux laptops that were providing routing and address assignment services.

Each station had a laptop that provided:

- Broad band Internet access. For browsing WWW and checking tropo forecasts etc.
- Site wide IRC chat (text chat room).
  Inter station chat was used to notify all stations of QSY freq as well as schedule requests – text chat was used because it is simple to type and read when compared to using usual 2m FM talkback.
- ON4KST chat access.
- Usual logging facilities

The on-site WLAN signal is good enough to be used around 400m radius from the onsite access point – this means that in most cases, the internal antennas in the wireless cards are sufficient.

Any questions, please email me:
m0eyt@ntlworld.com
pjmarsh@compuserve.com

Frequency Standards

Practical improvements in Frequency Stability, Resolution and Accuracy

Written and presented by : David Wrigley – G6GXK
Martlesham Microwave Round Table – November 2004

Contents

About the author

David has spent most of his life in the management of design for the manufacturing industry, mainly for Ferranti, but also with Siemens and with GEC-Marconi. He took early retirement in 1994 and since then has been helping out part-time with a family business, the IEE and the University of Manchester. David got his Amateur licence in 1980 and renewed his interest after retirement by getting involved in Microwaves. He is a Committee member of UKuG and NW elmer.

Basics

Definitions

- **Accuracy** –closeness to what it should be. We measure by comparison with another reference whose accuracy is known.
- **Stability** –the variation of frequency with time. Provided that the mechanical aspects are robust, the main cause of this variation is temperature. In order to achieve high accuracy we must first have high stability.
- **Resolution** – this is the minimum freq step in adjustment or display, this relates to the fineness of adjustment. However many oscillators may indicate great precision, but they do not necessarily have it. Put simply it is only the number of digits on the display or the number of divisions on the pot. and may have nothing to do with accuracy.

Frequency Sources

- **Frequency References** – Are local sources which depend for their accuracy on local frequency dependant devices, usually a quartz crystal. These can be very stable but are not necessarily precise and will inevitably drift with time.
- **Frequency Standard** –These are usually signals which have some reference to National Standards and that means that they have credible precision.

What are we trying to achieve?

- In order to achieve reliable and repeatable communication, we need to reduce the number of variables. Assuming that we have an antenna, which is stable and can be pointed in any desired direction with some degree of confidence. The next step is to ensure that we are on the right frequency.
- Good Frequency Accuracy and Stability will minimize the time taken to establish a contact.
- To enable better weak signal performance
- Will permit very narrow bandwidth techniques
- But - it needs both ends to be both accurate and stable!

What sort of stability is that?

The accuracy of the Local oscillators both in the transceiver and the transverter will affect the result. However, at 10GHz, using a 144MHz IF, the transverter LO is about 60 times more important in terms of stability and most of us have noticed that!

A simple crystal oscillator will probably have a stability of a few parts per million across its temperature range which could be -40 to +80 degC, but in practical terms this translates to say 10KHz or so drift at 10GHz, this is too lively for easy working and most of us have used the simple Murata positive temp coefficient resistor on a spring metal clip over the crystal can. This stabilizes the temperature to within a few degrees and the frequency drift is correspondingly reduced to around 1KHz or so when conditions up on a hilltop can vary from sun to overcast with a cold wind.

A further improvement can be made by taking the Quartz crystal out of the LO and into a separate oven controlled crystal oscillator (OCXO). OCXOs vary in quality but we are now talking about a hundred Hz or less of variation, which is very acceptable as a basis of reliable communications at 10GHz. I should mention at this point that these frequency reference OCXOs should be left running all the time to get the best from them in terms of stability.

Continuing along our quest, there are some adventurous souls who wish to push on to higher frequencies or to use data transmission which relies on extreme stability. In these cases even higher levels of stability and accuracy are required. These can involve an even more complex double oven controlled crystal oscillator (DOXCO), Rubidium or to lock the LO to a National Frequency Standard in order to get better accuracy.

Over this next part I want to show the sort of useful devices that are around and how they fit into the overall framework of frequency stability and accuracy.

Local Frequency References

- Quartz Xtal Oscillator
- Temperature Compensated XtalOsc
- Quartz Xtalwith Murata PTC heater
- Oven Controlled XtalOscillator
- Dual Oven Controlled XtalOscillator
- Rubidium Source

Oscillatek TCXO

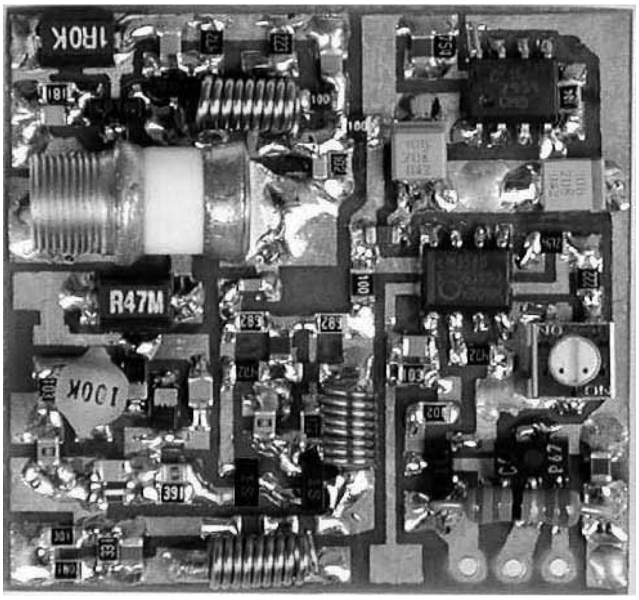
One type I haven't mentioned so far is the temperature compensated crystal oscillator. They are compact, low power consumption and of course they don't get hot. In these devices the temperature is sensed and an appropriate compensating voltage is applied to correct the frequency. This one (below) is a 10MHz device which, is used as the reference for a Qualcomm PLL giving out 1152MHz.I got this from Chuck Haughton WB6IGP. The sort of stability achieved is usually around 100Hz at 1GHz – similar to the Murata PTC heater. More modern ones use internal digital controllers and can be more effective.

TOYOCOM 613 OCXO

This is the unit which is inside the Pye HS400. This one did not have electrical frequency control (EFC), so it was added later (ref 1) to enable it to be locked to GPS.

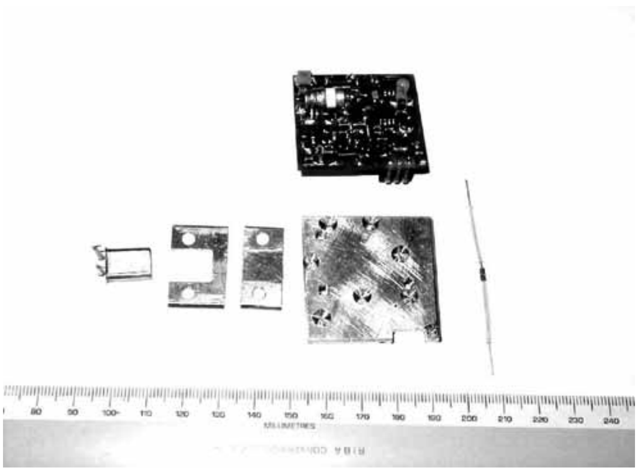
G8ACE OCXO

This is a higher frequency (100MHz) home built OCXO. This particular unit was assembled by Lorenz, DL6NCI – and I have to say it is much neater than mine – I bought an ultrasonic cleaner after seeing this! There is also a 10MHz version. They work well, are compact and inexpensive. (ref 14)



G8ACE provided the PCB. The G6GXK interpretation of the metal work is shown below. The main heatsink is a piece of solid copper busbar of 2 inch by 0.25 inch section. This has a hole drilled lengthways through the centre to take the thermistor. Also provided are the pocket and clamp plate for the crystal. The cut-out at the bottom RHS is to provide space for the three power transistor leads which is the main source of heating. It important that the thermal impedance between the heater, crystal and thermistor is very low. Hence the copper block.

G8ACE OCXO Components



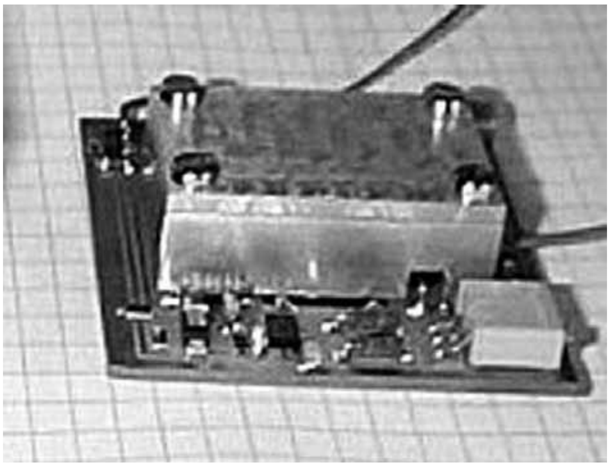
P 10811 OCXO

The HP10811 is the standard for OCXO's and is a much sought after unit. This one is a single oven

OCXO (108011-60111), but there are units looking much like this one which are double oven units – see later.

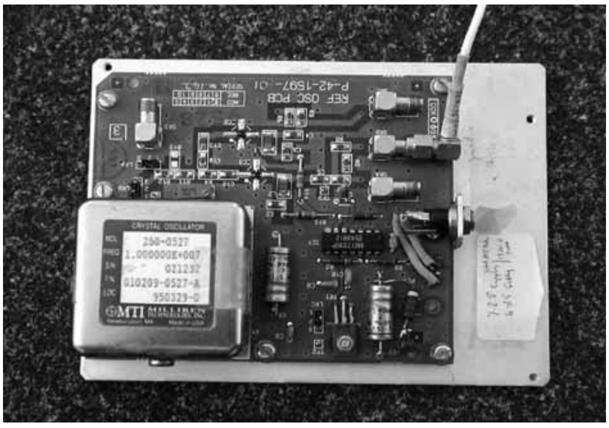
DC9UP OCXO

Because the HP10811 is getting scarce, DC9UP has designed this unit which is claimed to have similar characteristics. Note the metalwork which surrounds the crystal to give it thermal stability.



Milliren OCXO Assembly

This is the 10MHz Milliren 250 OCXO obtained from a rally as an assembly. It has a series of external buffers which conveniently provides the multiple outputs required for locking a both a transverter and transceiver to 10MHz. This unit has EFC and can be adjusted by a 10T pot. The later Milliren 260 unit has a performance which rivals a Rubidium source.

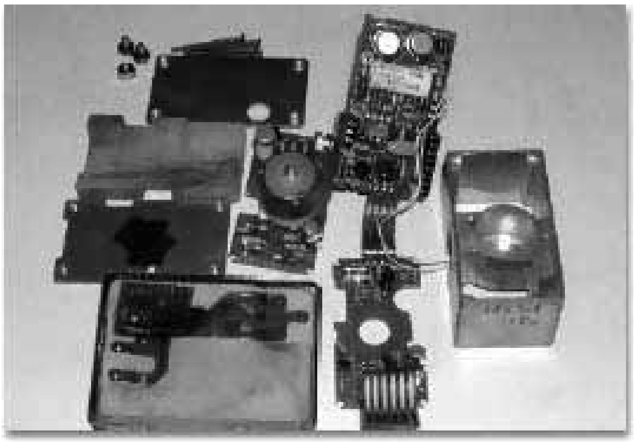


DOXCO

The double oven controlled crystal Oscillator, stabilizes the temperature and also stabilizes the offsets due to thermal flow within the metal mass.

The following shows the construction of the HP 10811-60158 DOCXO (Steve Smith G8LMX, Ref 7)

HP DOCXO inner parts



Peltier Temperature Controller

To improve an existing OCXO, it might be thought that converting it to a DOCXO by adding an external oven is easy – it may not be!.

Adding an external oven will increase the effective ambient of the existing (internal) oven and if the existing oven is of a low temperature (40 degC) the effect may be to turn off he internal oven or to reduce the effectiveness of it.

A way of avoiding this problem is to use a Peltier effect heat pump which will permit the external surface of the existing OCXO to be maintained at a “normal” ambient of say 20 degC. The price we pay for this is a fairly hefty power consumption of 2A at 12V. And of course this is accompanied by a need for further heat dissipation (a bigger heat sink and/or fan).

The use of such a device can transform a reasonably stable OCXO from perhaps a few parts in 10^10 to a few parts in 10^11. This particular system, shown below, was designed and built by G6GXK and consists of a Peltier device arranged between two push pull high current amplifiers.

There is a temperature sensor in the copper block and the amplifier passes current one way or the other in order to heat or cool the block as required to maintain a constant temperature. The copper block is then clamped to the external surface of the OCXO and the rest of the surface covered with plastic foam to help keep all the surface at the same temperature.

Frequency Standards

Frequency Standards are a reference to national standards to provide some basic accuracy as well as stability. They can be obtained from the following sources.

- TV Line freq-VHF BBC1 (Not official Std)
- DroitwichR4 198kHz carrier
- Rugby MSF 60kHz carrier
- MainflingenDCF77 77.5kHz
- W5OJM GPS system
- CT1DMK GPS -3 types of PLL
- G4JNT –Jupiter GPS

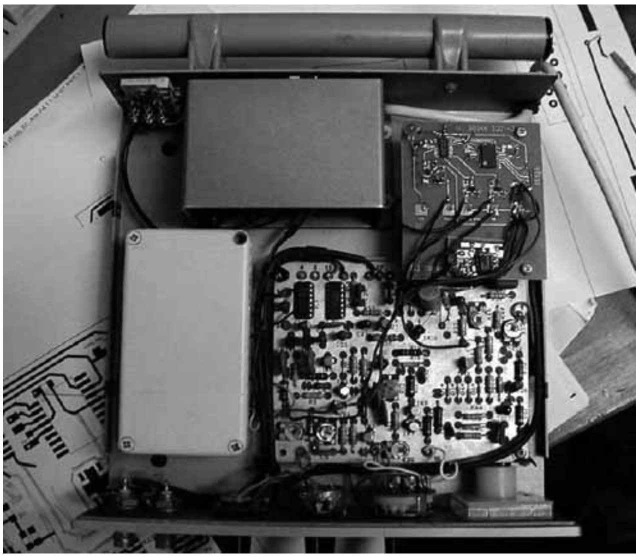
TV line freq std

This unit uses the UHF receiver from a VCR and the sync sep and PLL design from RAD Com's– "Poor man's Caesium Clock" (ref 2)- and a similar design published by BATC (ref 3). The results from BBC1 are very good on average –but there is a slight oscillation on the 10MHz output – lasting over a few seconds. I was never sure whether this was from the transmitter or because the PLL was slightly unstable. It should be noted that it is the UK government's intention to close down analogue TV transmissions over the next few years.

Advance Off Air Frequency Standard

This was a piece of test gear picked up at local rally. Clearly the unit was unusable because the Droitwich frequency has been shifted from 200KHz to 198KHz. In order to get the unit working on the new frequency an almost complete rebuild was necessary. This unit still uses the original TRF receiver concept, and because of this and the attached ferrite antenna, the gain is limited and signal strength must be reasonable for it to work. With hindsight a superhet design would have been better.

The following internal view shows the new PLL pcb at the top RHS, which replaces almost all the original circuitry on the ocb below it. The new receiver pcb is contained within the screened box on the LHS.



W5OJM GPS system

Also known as the Brooks Shera system (ref 9). This is essentially an inexpensive GPS disciplined OCXO. The publishing of this design caused such a demand for the HP OCXOs that they have become scarce.

- This is a digital PLL design based on a PIC microcontroller
- The measurement of phase difference is performed digitally by counting the cycles of a 24MHz oscillator and averaging them.
- Its main advantage is the very long and well defined time constant that can be applied to smooth out the jitter on the 1 second pulse
- With a Rubidium Freq source it is capable of a very high accuracy and stability
- Disadvantages are the lack of auto-holdover on GPS loss and auto restart procedure in the event of power down

The mode links on the Brooks Shera system are:

N=1, 30 sec averaging time
N=2, 1500 sec averaging time (25 mins)
N=3, 3000 sec averaging time (50 mins)
N=4, 6000 sec averaging time (1.6 hrs)
N=5, 12000 sec averaging time (3.3 hrs)
N=6, 24000 sec averaging time (6.7 hrs)
N=7, 48000 sec averaging time (13.3hrs)

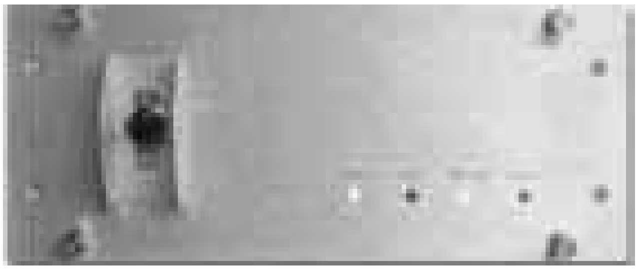
The G6GXK version was built into a HS400 case using the internal Toyocom OCXO. This can achieve an accuracy of a few parts in 10^10 when kept in a temperature controlled room. The mode is usually N=3 because higher modes have been found to become unstable due to the temperature sensitivity of the Toyocom OCXO. It was found that using a Peltier controller on the OCXO case, N=5 was OK and the stability was raised to a few parts in 10^11. (Ref 8).

Z3801A GPS Std

This is a professional version of a GPS disciplined OCXO.

Z3816A GPS Std

This is a later version. The unit I tested had an automatic restart after power failure and also a holdover arrangement where the frequency was held fixed if the satellite signal was lost. Note that an alarm comes up unless the antenna takes a minimum of 21mA.



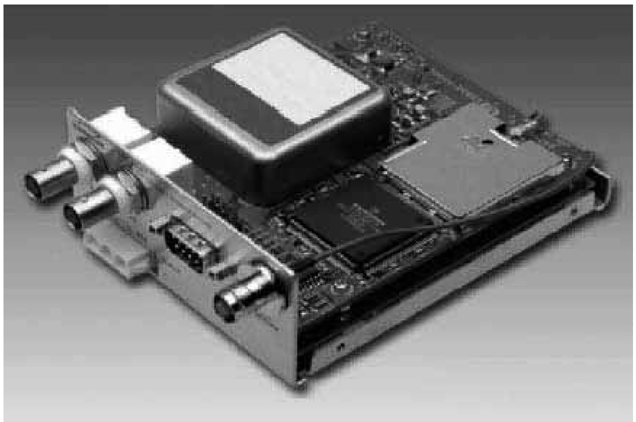
Inside the Z3816A GPS Rx. The MIlliren type 260 which has a very high order of stability. It is said to compete with a Rubidium source.

For further information on these HP GPS receivers (see ref 4).

48540A GPS Freq Standard.

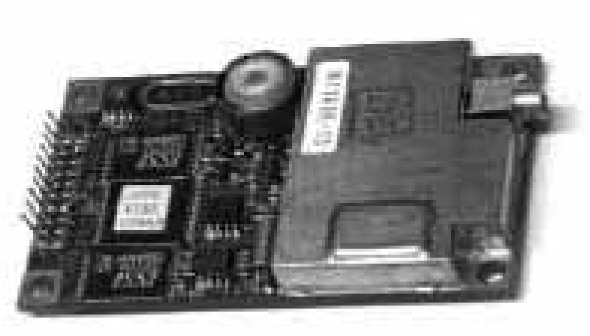
This is a current model from Symmetricom which is also starting to appear on Ebay

Inside the 48540A GPS Freq Standard:



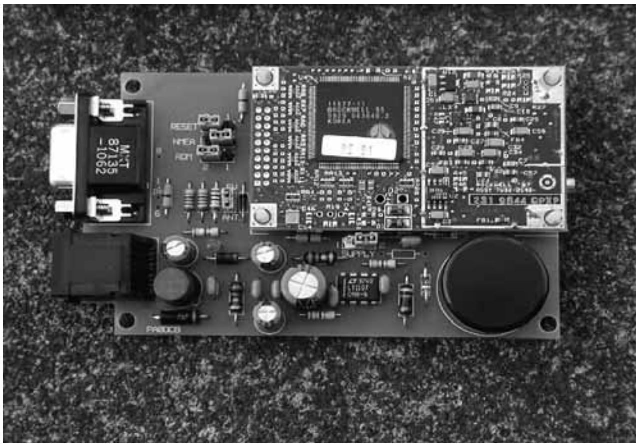
Jupiter GPS Rx

Many of these units have been sold recently (2004) The really useful feature of this receiver is that as well as a 1sec pulse they have a 10KHz output. The control of the 10KHz output appears to be stabilized over a few seconds or so, because it doesn't jitter as much as the the normal GPS 1 sec output.



An interface pcb is available – see below, and Andy Talbot (G4JNT) has produced a very simple PLL to provide just about the least expensive GPS Frequency Standard. (Ref 5).

Jupiter Assembly (mounted on the interface pcb)

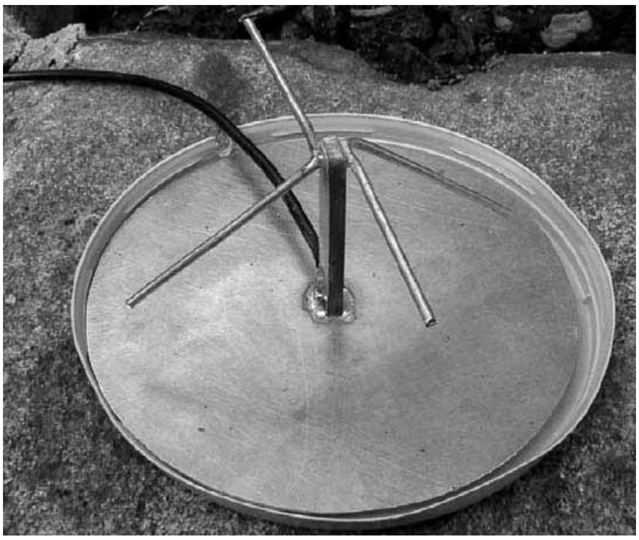


Antennae for GPS

There are several types of antenna which can be used with GPS.

MK-76 Low Cost Commercial – about £25 includes a magnetic base

N7KKQ (a simple home made design which due to its large size gives just as good a signal as the commercial active one– ref 6) The ray dome is 300g “Kraft” cheese tub.



Commercial “anti bird” design

It can be disconcerting to lose the GPS signal because of a bird perching on the antenna. There are a number of commercial designs of GPS antennae - they usually have pointed tops which clearly discourage birds from perching on them.

Rubidium frequency sources.

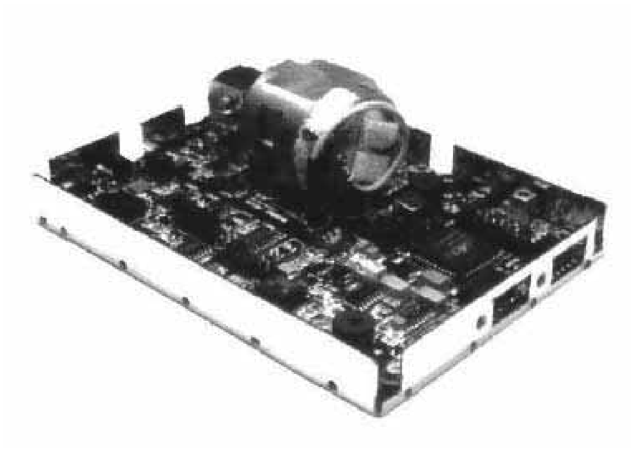
These are a secondary source with a means of frequency adjustment. Although as a local source they have the ability to quickly get on frequency from about 4 minutes or so from switch-on.

These units have been getting smaller, more reliable and having a longer life. Their stability is a few parts in 10^11. But disciplined by a GPS system could be a few parts in 10^12.

Low Profile RbOsc(LPRO) –many of these units have been sold on Ebay

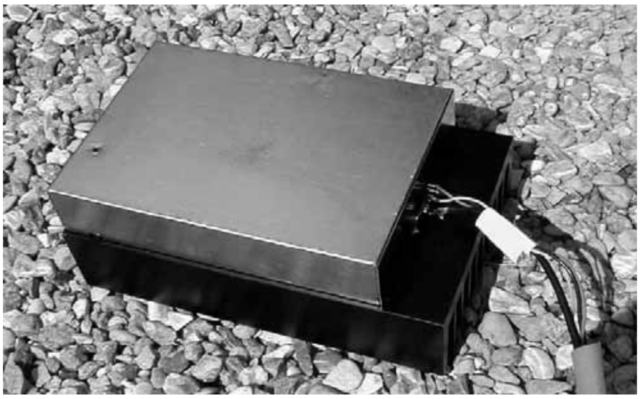
Inside the LPRO

The physics package can be seen as the largest component.

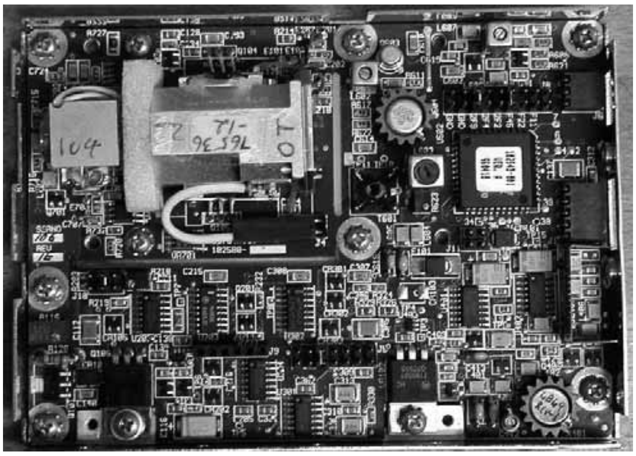


Slim Line Compact Rb(SLCR)

This later lower profile version has also been sold in significant numbers on Ebay. This one was purchased by G6GXK and mounted on a heat sink. They run on 24V and dissipate quite a bit if heat.

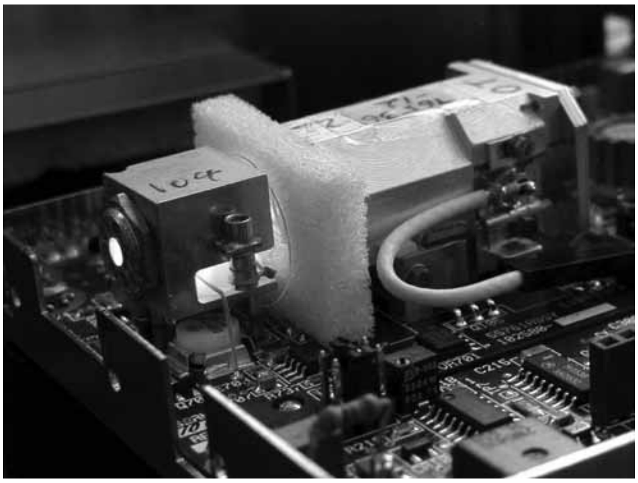


Inside the SLCR



Rb SLCR Physics Package

The rubidium gas plasma initiated by the microwave energy at 6.8GHz causes a pink glow to be seen.



X72 Rubidium Osc

This is the latest unit to appear and is even more compact and integrated.

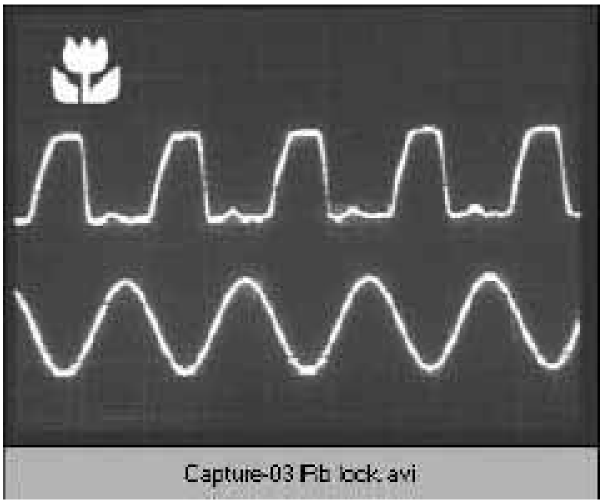
Measurement

In order to measure or compare frequency standards, apart from specialized equipment there are two main methods:

- Counter Timer – which is time consuming, due to counting whole cycles only. To see 1pp10^10 error requires a counting period of 1000secs (17mins)
- Scope – is much faster because one can see phase differences directly. It takes only 10 seconds to see 1pp10^10 difference (1ns).

Rbstart up +4min

This is a frame from a video showing how the SLCR Rubidium source (bottom trace) snaps into lock after only 4 minutes warm up. It is being compared to a GPS disciplined OCXO (top trace).



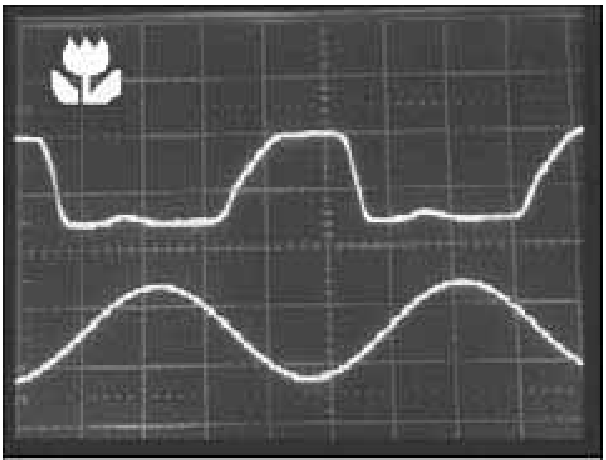
50ns/div freq comparison

Because of the difficulties of measurement, we will lock th scope to the sine wave trace and then check the phase drift using the sharper edged trace. Each division is 50ns. So we could easily see a phase change of say 25ns and for 1 part in 10^10 the required time period would be 250 sec (4 min 10 sec). There was no apparent difference over the short term.

This measurement can be speeded up and/or made more sensitive by expanding the timebase.

20ns/div freq comparison – 4pp10^10

This is the same pair of signals soon after first locking of the Rb, but using trace expansion we are better placed to measure small changes. Set at 20ns per large division (4ns per small division). Over the period of 10 seconds of this video the upper trace moves by 1 small division to the left. This indicates that the lower trace (Rb) is slower by 0.4ns per second than the GPS (4pp10^10).

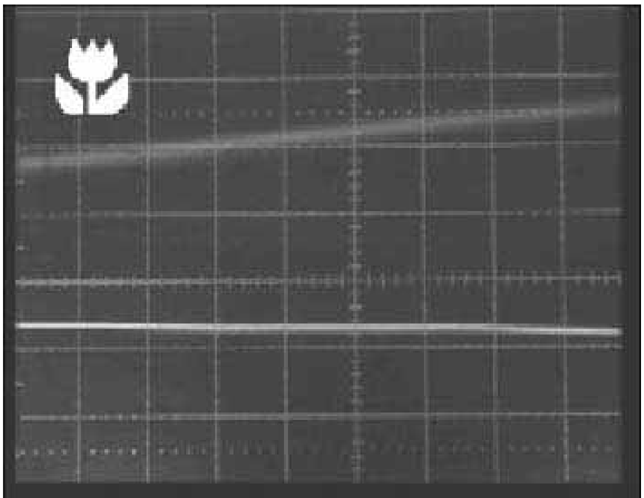


Capture-04-20ns.avi

1ns/div freq comparison – 3pp10^11

This is the same pair of signals after 30 minutes of warm-up, and by using even more trace expansion we can measure at 1ns per large division. Over the period of 15 seconds of this video the upper trace moves by 0.4 large divisions to the left.

This indicates that the lower trace (Rb) is slower than the GPS by approx 3pp10^11. The Rb is is settling down with time to be closer to the nominal frequency of 10MHz.



Capture-07 Rb - 30mins

Clearly the Rubidium Frequency Standard is a useful source in that it will come up close to frequency in about 30 mins from switch-on. The measured values of drift cannot be relied upon due to the fact that the GPS source with which it is being compared has a similar level of stability to the Rubidium.

Overview of Frequency Standards

- All the primary sources are absolute in the long term. However due to the propagation aspects, the short term accuracy may well be in error.
- Every source has some problems to overcome
- It boils down to a question of longer averaging time for better accuracy. For example MSF would need to be averaged over 24 hrs to eliminate the daily variations.
- And that means that we need a very stable oscillator to avoid drift between corrections.

Practical issues

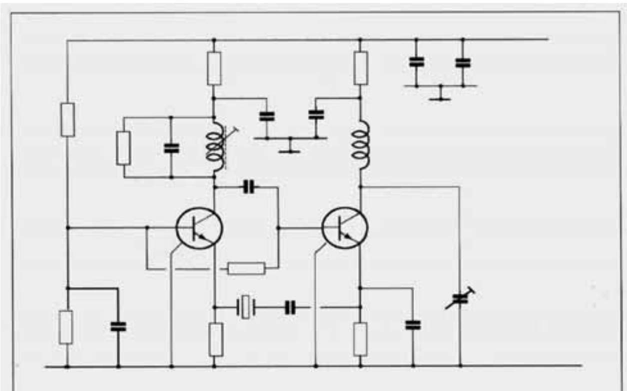
- Interface OCXO to Transverter
- OCXO to DDK004 LO
- OCXO to DB6NT LO
- Freq Std to lock OCXO
- WA6CGR PLL
- Commercial PLL IC
- CT1DMK CPLD –Ref Lock

Transverter interface

The frequency determining circuits of the LO are the objects of control. Two of the most popular circuits currently used in the UK are shown below (G4DDK LO and the DB6NT LO).

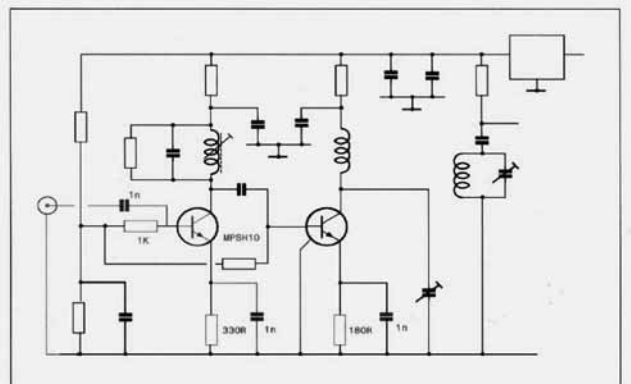
G4DDK-004 LO

This circuit was not originally designed for use with an external oscillator but many people have modified it to achieve that. The original circuit uses two devices in a Butler oscillator.



BUTLER OSCILLATOR SECTION OF THE DDK004

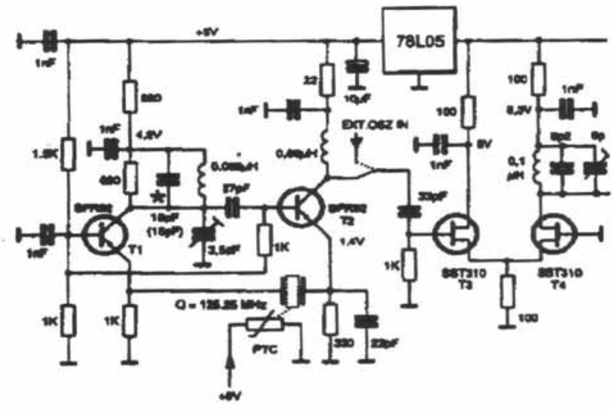
This can be fairly easily modified as shown below to permit an external source to drive it.



MODIFICATIONS TO THE DDK004 FOR EXT OSC FEED

DB6NT LO

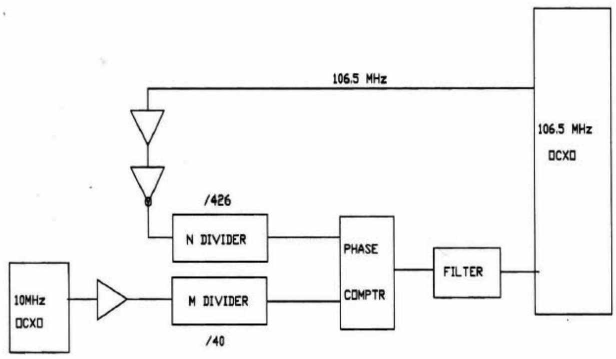
The DB6NT LO already has some provision for an external input, and requires only the existing circuit to be isolated by cutting the track -or not fitting the components - and soldering a connection to a new SMA connector for the external OCXO.



OSCILLATOR CIRCUIT OF THE DB6NT 12GHZ LO

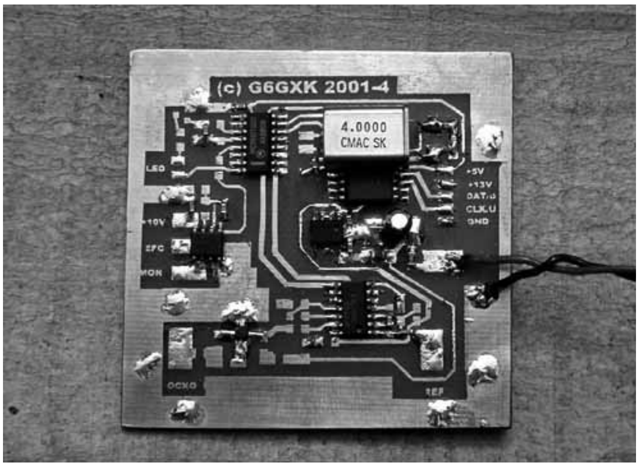
Standard PLL scheme

If it is required to lock the LO source to a 10MHz Frequency Standard, this is achieved through the use of a Phase Locked Loop, shown diagrammatically below. The dividers are so arranged as to divide the Reference and the LO source to get the same frequency at the phase comparator. The output of the phase comparator is filtered and used to control the frequency of the LO source.



PCB for standard PLL IC

The pcb shown below achieves this through the use of a modern PLL IC (LMX series).



WA6CGR PLL

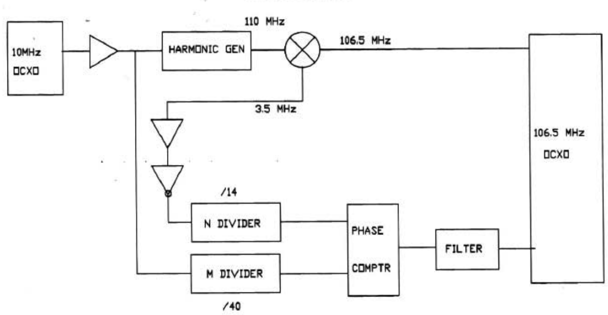
Many of us who have built beacons which are on very odd frequencies would like to lock these to a 10MHz frequency standard. However with the commercially available IC's the available division ratios are often not sufficient.

In order to overcome that, the WA6CGR arrangement uses a clever frequency differential technique to reduce the required division ratio. The reference frequency is multiplied up to the nearest harmonic to the LO and then mixed with it.

The difference freq is selected by means of a tuned circuit and squared up for division. This difference frequency is now much smaller and easier to divide down to a common comparison frequency.

Whilst the original chips are now unobtainable is should be possible to use modern equivalents to achieve the same result. (Ref 10)

WA6CGR PLL



CT1DMK PLL

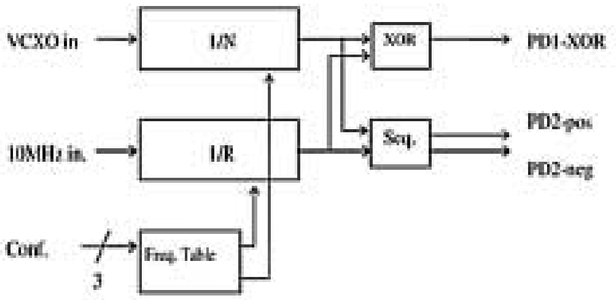
Over the last year or so there has been considerable interest in using the modern CMOS Programmable Logic Device (CPLD) and Luis Cupido (CT1DMK) has programmed such a device to achieve a high performance PLL. This is limited by the high frequency performance of the CPLD to around 150MHz max LO frequency.

Several variations of the original program have been written and Luis has a web page on which all this information is available. (Ref 11).

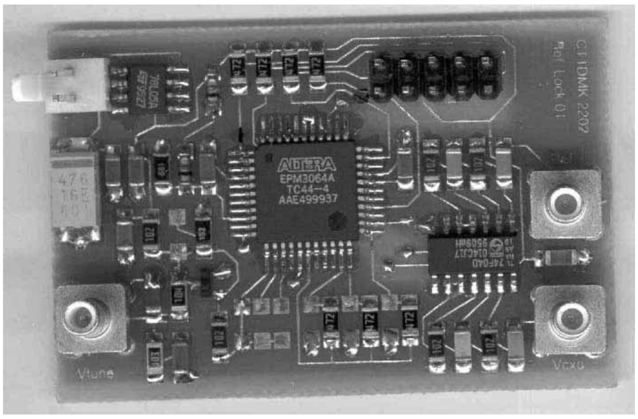
There have been many variations of the mechanical construction and also the interface to the CPLD to incorporate additional facilities for buffering the reference and LO inputs.

CT1DMK PLL Scheme

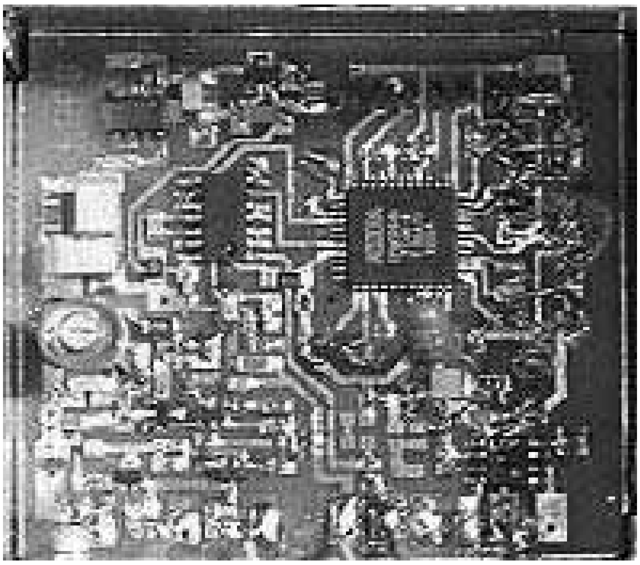
Below is the basic design showing the alternative outputs available.



CT1DMK PLL –original pcb

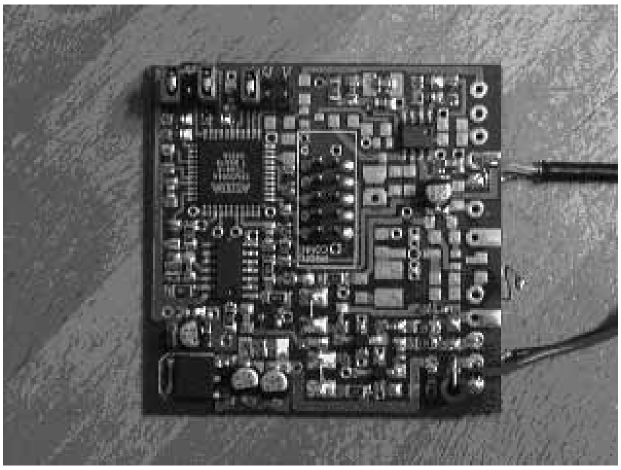


G8BKE version of the CT1DMK PLL

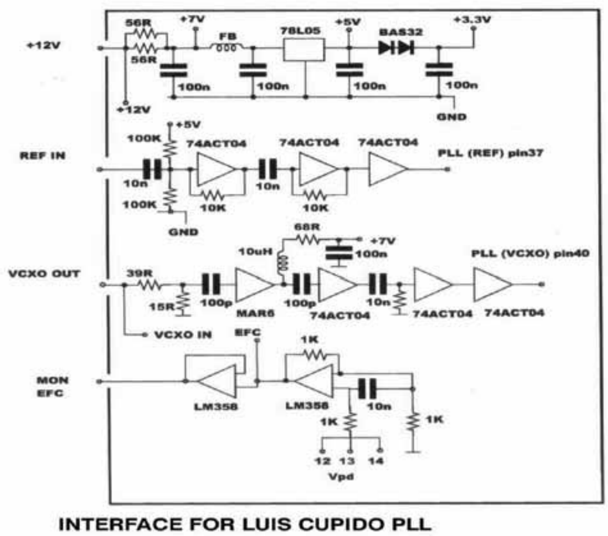


G8ACE version of the CT1DMK PLL

This pcb is designed to fit inside the OCXO box

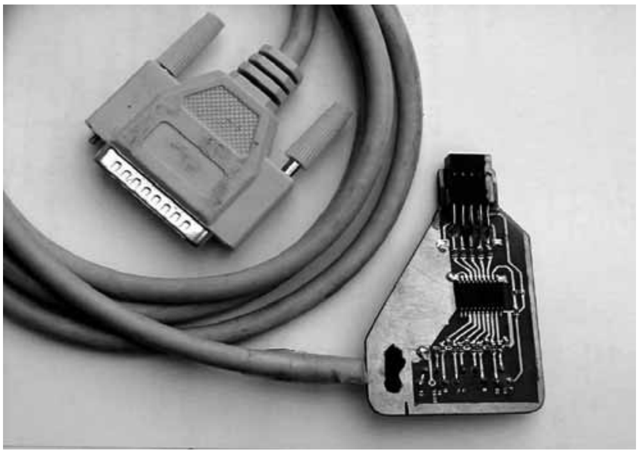


Interface for CT1DMK PLL



Programming Cable – G6GXK

Details can be downloaded from the Altera site – ref 15.



Changing a CPLD

When you fix the chip on the wrong way round – you have to remove it.

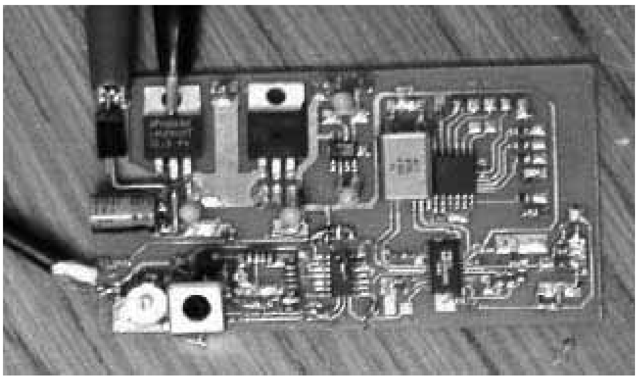
The pcb is held in a croc clip device which is located over a damp cloth placed over the waste disposal outlet. A hot air paint stripper is then cautiously applied until the solder glistens (appears melted) and then a sharp tap on the pcb with a metal tool removes the chip (along with perhaps a few others). The chip survived this treatment and was successfully re-used!

CT1DMK update - latest info

- Luis has now provided a new .pof file which permits the 10kHz Jupiter output to be locked to a 10MHz OCXO –using the same PCB and CPLD as before. This will permit a very compact and reasonably priced GPS freq std to be built.
- Darrel VE1ALQ has designed a flexible and useful version of the CT1DMK PLL (ref 12)

DDS

Some mention should be made of Direct Digital Synthesis (DDS) as a means of using a frequency reference or standard to drive a DDS IC and produce an accurate sine or square wave output of up to 130MHz or so. An experimental board designed to produce 24MHz is shown below (G6GXK) – however the output is somewhat spikey – it varies according to the frequency settings. These can be troublesome when multiplied to the higher microwave frequencies.



In order to overcome that problem, John Miles KE5FX (Ref 13) has designed a scheme where the DDS is used to generate a narrow range of a relatively low frequency which is then fed as the reference frequency via a narrow filter to control a PLL/VCO in order to derive a much higher frequency. The narrow filter has the effect of removing the close-in spikes yet permitting an adequately fine adjustment of the final frequency. This should be an interesting development.

References

Thanks and credits to numerous sources of material, including:

Ref 1. Modification to the HS400/Toyocom OCXO to add EFC –G6GXK -Scatterpoint

Ref 2. Poor man's Caesium Clock – Dave McQue G4NJU, RadCom

Ref 3 TV Off-Air Freq Std – Circuit Notebook No 62–Lawrence, CQTV 180 (BATC)

Ref 4 further info on HP GPS receivers from K8CU at http://www.realhamradio.com

Ref 5 Low cost GPS disciplined freq std - Andy Talbot G4JNT – Scatterpoint (and MUD 2004 proceedings)

Ref 6 N7KKQ low cost GPS antenna see ARRL QST article http://www.arrl.org/tis/info/pdf/0210036.pdf

Ref 7 Steve Smith G8LMX on site of K8CU http://www.realhamradio.com

Ref 8 http://www.microwave.fsnet.co.uk/projects/projects-2.htm

Ref 9: http://www.rt66.com/~shera/

Ref 10 WA6CGR PLL http://www.ham-radio.com/wa6cgr/mwpll.html see also VK5KK version http://members.ozemail.com.au/~tecknolt/Projects/vk5kk48.htm

Ref 11 CT1DMK PLL web page, http://w3ref.cfn.ist.utl.pt/cupido/reflock.html

Ref 12 VE1ALQ web site http://www.ve1alq.com/clpd_pll/clpd_pll.htm

Ref 13 KE5FX and VK6BRO– A versatile Hybryd Synthesizer –QEX Mar-Apr 2004 www.qsl.net/ke5fx/synth.html

Ref 14 G8ACE OCXO http://www.microwaves.dsl.pipex.com/

http://www.microwaves.mcmail.com/

Ref 15 Altera web site http://www.altera.com

http://www.altera.com/products/devices/max3k/m3k-index.html

Potential Interference To Galileo From 23cm Band Operations

Peter Blair G3LTF

1. Contents.

2. Introduction

This paper describes the proposed Galileo system design and its applications with particular reference to the E6 (1260-1300MHz) band. It covers some of the issues driving the programme and the frequency allocation situation. It describes the operation of typical receivers and their ability to deal with interference and gives practical illustrations of these effects. The likely effect of the Galileo transmissions on 23cm receivers is analysed and found negligible. However there is the potential for 23cm transmissions to interfere unless the Galileo receivers are designed and built to withstand them. In order to work robustly in the expected electromagnetic environment Galileo receivers will need to use the most advanced technology available. Finally the likely course of events is discussed and arguments that we might use to continue our use of the band are presented.

3. Galileo, History and Background

The Galileo programme is intended to provide the European Union (EU) with its own Global Navigation Satellite System (GNSS). Currently there are two major systems, the USA's Global Positioning System (GPS) and the Russian GLONASS. GPS was designed as a military system and, until 2000, the open signal's accuracy was intentionally degraded. The US has now pledged to maintain the full capability, free, open service signals and will give 6 years notice of any change to this position. Although essentially a military system, the civil applications have been wide ranging and are the basis of many businesses as well as supplementing and improving many existing navigation systems even though the users recognise that the US could degrade or jam the services should it judge that necessary for its security. GLONASS will not be discussed further, as it does not overlap our allocation and its future status is unclear.

Two programmes have been implemented to overcome some of the deficiencies of GPS as they affect the civil aviation industry, these are the USA's Wide Area Augmentation System (WAAS) and the EU's European Geostationary Navigation Overlay System (EGNOS). Their purpose is to monitor the accuracy and quality of the GPS signals and provide an instantaneous warning via geostationary satellite and data link should they degrade.

The EU view is that having its own GNSS is essential to its economic and infrastructure development, and that it cannot rely on GPS for reasons of availability and reliability of the signals. Furthermore, GPS gives no performance guarantee. There is a benefit to both GPS and Galileo in having more satellites in space, particularly in situations such as cities where the view of the sky is restricted. Because both systems would operate in the same frequency band and with comparable modulation schemes, it will be relatively easy to build receivers to use all the satellites in view.

In 1999, after many years of studies of candidate systems the EU launched the Galileo programme. The definition phase ran from1999 to 2001 and covered the definition of the architecture and services to be provided and the development and validation phase started in 2002. In this phase, the European Space Agency (ESA) will procure and launch two satellites, the first of which will be launched at the end of 2005. In 2007 the plan is to launch a mini constellation of four satellites to test the system in orbit. The cost of this phase is estimated as €1.1Bn and will be EU funded. The deployment phase, building and launching 26 satellites and building and deploying the ground segment is estimated as €2.1Bn with two thirds coming from industry and the rest from the EU. Commercial operation is planned to begin in 2008. The four principal countries involved in the work are France, Italy, Germany and the UK all of whom will benefit under "juste retour" with jobs and the housing of ground facilities.

Independent observers find this timescale unrealistic even without the usual funding delays and full operation in 2010 is probably more realistic. The Galileo Joint Undertaking is, in essence, a body set up to organise the funding, the business plan and the risk sharing arrangements. Organisations of other nations outside the EU have been joining this body, most significantly from China and Israel. This will, of course, help with the arrangements for hosting ground facilities outside the EU. In 2005 the Galileo Supervisory Authority will be set up as an agency of the EU Commission to control and manage all aspects of the project including security and all technical matters.

4. Galileo System Description

The system will operate in essentially the same way as GPS. Thirty satellites in 23,600 km orbits will carry atomic clocks and transmit accurate time signals using spread spectrum modulation together with orbit data and other messages. A receiver synchronises itself to the satellites in view and by measuring the range to four of them can determine its position in three dimensions and obtain standard time. Higher quality receivers will use two or more frequencies making separate measurements to correct for ionospheric delay. The ground system, fully duplicated to provide resilience, will control the satellites through a series of uplink stations around the globe.

The services planned to be offered by Galileo are the following:

1. **The Open Service (OS)** provides position and timing free of user charge.

2. **The Safety of Life Service (SoL)** improves the open service by providing warnings to users when the OS fails to meet service standards.

3. **The Commercial Service (CS)** provides access to two additional signals, which can provide higher data rate throughput and help to improve accuracy. It also provides a limited broadcast message capability from service centres to users.

4. **The Public Regulated Service (PRS)** provides position and timing to specific users requiring high continuity of service with controlled access. Two PRS signals with encrypted ranging codes and data will be available.

5. **The Search and Rescue Service (SAR)** will enhance the international search and rescue system by broadcasting globally the messages emitted from distress beacons.

There is little more than this available about the services because of course what is actually offered will by decided by the competitors for the concession to develop and run Galileo.

The latest published information, reference [1], on the mapping of the services to the frequency bands is from June 2003.

The three Galileo bands are as follows:
E5 1164 - 1215 MHz carrying CS, OS and SoL
E6 1260-1300 MHz carrying CS and PRS
E1-E2-L1 (sometimes called L1) 1559 - 1591 MHz carrying CS, PRS and SoL

5. Galileo Funding Mechanism

It is important to understand a few of the key issues around the development and deployment of this system. It is being strongly backed by the European Commission who wish to have a GNSS which is independent of the USA, but because of its high cost (Currently estimated as €3.2Bn to get it up and working and, of course, the running costs are additional to this figure), it is essential to have industry involved in the funding in a Public-Private Partnership (PPP). The competition to choose the concessionaire to undertake the development and running of the system is on going and the final decision is now scheduled for May 2005. Obviously there is currently no information on what the two competitors will offer; however, it is envisaged that there will be two income streams, one from the IPR involved in equipment licensing and one from the two subscription services, the CS and the PRS.

There is a free service already available from GPS, used by many companies to offer enhanced services for profit (e.g. differential GPS for oil prospecting, car navigation systems, etc), . The open GPS signals to be are be enhanced by the addition of a second civil signal, called L2C, which will reach full operational capability (FOC) in 2010 and eventually a third wide bandwidth civil signal will be added. The existence of these GPS based products means that the selected Galileo concessionaire will have to offer a superior service, security and/or availability. It will be important to understand what this will be in order to assess what the impact will be on the E6 Channel.

For civil aviation , the existence of EGNOS and WAAS enhances the reliability of basic GPS and gives it much of what it wants without needing to contribute to the costs of Galileo. Everybody would like the Galileo satellites to be available so that for example the coverage of GNSS in urban canyons would be improved; but will the user be prepared to pay for that enhancement?

6. Galileo PRS Applications

The principal users of the PRS, according to the EC/ESA proponents, are likely to be European national government agencies such as customs and immigration or by the police and paramilitary. They take the view that PRS will offer a more secure service to them than is currently provided by the open GPS and that in the event that the open services of both Galileo and GPS were jammed in order to prevent their use by a hostile power, there would still be a service available to key government agencies. The encryption and other tricks on the PRS signal would also give protection against spoofing or meaconing (see later). There is a cost involved however; both in new equipment and in user charges and the agencies will have to assess the costs against the risks. The complexity of the issue should not be underestimated, for example if the navigation system of a police helicopter is changed to take inputs from Galileo as well as GPS this could affect the certification.

A factor often overlooked in the discussion of the PRS is that to make the system robust requires much more than just protection of the signal in space, it requires secure ground support facilities in whatever part of the world it is to be used; this is costly.

There are persistent stories that some countries would wish to use the PRS for military purposes . Whilst there would be no objection to using the Galileo signals for tracking materiel or for logistics purposes by peacekeeping forces, the application to weapon guidance, for example, would raise serious issues

The recently published report of the UK House of Commons Transport Committee, reference [2], voiced serious concerns about the PRS - "The uses described for the PRS are hazy; the UK government has said it does not want to use it… The Committee urges the UK government to ensure that there is a real demand, that access can be properly controlled, and that it would not allow the use of PRS for military applications".

This situation will not be resolved or even clarified until the selected concessionaire(s) offer is available for examination.

7. The Frequency Allocation Situation

At the World Radiocommunication Conference in 2003, (WRC-03) a **Primary status allocation** was approved with no power flux-density (pfd) limits for the radio navigation satellite service (RNSS) in the 1260 -1300 MHz band.

The allocation was a result of studies conducted since WRC-2000 on sharing between RNSS and the radiolocation service in this band. The WRC invited interested parties to continue appropriate technical, operational and regulatory studies (including an assessment of the need for a pfd limit) on RNSS systems in the 1215 to 1300 MHz band. The purpose of the studies was to ensure that the RNSS would not cause harmful interference to the radiolocation (radar) service. All studies were to be conducted as a matter of urgency and in time for WRC-07. They are reported under WP 8B. There is a possibility for radar targets to be obscured by the signal from a Galileo satellite because the high gain of the radar antenna and tests carried out in the USA on working radars have demonstrated the potential problem, reference [3]. Some proposed measures to achieve compatibility include tailoring the RNSS signal to reduce overlap with the radar band, pfd limits on the RNSS signal and frequency separation. It is clear from the material already submitted to WP 8B that the USA is concerned about interference to its L-band ATC radar network, however many countries operate ATC and defence radars in this band so it is a much wider problem. Wind profiling radars operate in the band 1270 to 1290 MHz and a recent study examined the level of protection that these would require in the presence of Galileo E6 signals.

It should be noted that the WRC appears to wish to achieve a mode of operation and spectrum sharing in which up to five separate satellite GNSS systems can operate in the allocated spectrum 1215 to 1300 MHz. The Galileo organisation's stated essential requirement is to have the same regulatory regime in the whole of the band and to achieve regulatory protection of all radars through a footnote in the Radio Regulations. The position of the International Civil Aviation Organisation (ICAO) is "To support the incorporation of a single regulatory mechanism applicable to RNSS in the whole band 1215-1300 MHz as a necessary protection for important radars used for civil aviation purposes, and to support the incorporation of the agreed mechanism within an adequate regulatory framework having full mandatory force for current and future RNSS systems"

Galileo has to get a satellite up and running by April 2006 in order to claim the frequency allocation, and it is unclear which frequencies will be radiated by this satellite. It is likely that this will be the satellite built by Surrey Satellite Technology Ltd. (SSTL) although I understand that they are not responsible for the payload.

8. Potential interference from Galileo to 23cm amateur operations

The Galileo signal at the earth's surface is very weak and spread over a wide bandwidth, and will only be a source of interference to stations with large antennas who are communicating via EME (Earth-Moon -Earth) . As a typical 23cm EME system uses a relatively large, typically >3m, antenna, the satellite will only be present in the beam for a short time. Virtually all 23cm EME communication uses circular polarisation

The Galileo PRS signal is planned to be -128dBm as received by a ***right hand circular polarisation*** (RHCP) antenna and spread over 40MHz. A 3m dish has 30dBi gain and a typical receive sensitivity would be -152dBm for a 500 Hz bandwidth. The bandwidth restriction means that the received power is -128dBm - 49dB = -177dBm. The antenna gain increases this to -147dBm. However, fortunately the EME standard is for ***left hand circular polarisation*** (LHCP) ***on receive*** and so there is an additional attenuation of the cross polarisation performance of the dish and feed, typically 20dB. Thus the operator will not experience a noise increase. With a 10m dish the increase will just be noticeable. There is a further factor to be considered and that is the spectrum shape of the Galileo signal: this tapers towards the band edges and so there is a further (estimated) 6dB reduction in the noise received. Systems using noise measuring receivers to measure moon noise (for dish pointing or system calibration) or to observe radio stars in this band will be more adversely affected. For example a 500kHz wide receiver with a 10m dish and receive system would see a noise increase of about 30dB as a satellite went through the beam which would make it virtually useless.

9. The operation of GNSS receivers and their typical response to interference.

In order to assess how amateur transmissions might interfere with Galileo receivers it is essential to understand a little about how these receivers might operate and about their capability to reject interference.

The signal structure of GPS and Galileo is similar and so the receiver characteristics of both will also be similar.

A receiver has to lock onto the satellite's carrier frequency, with correction for the Doppler shift, and synchronise its code generator to that of the particular satellite that it is receiving. The code is modulated onto the carrier by a process of phase reversals. When the receiver has achieved carrier lock and code synchronization, it is able to effectively make a measurement of the distance (called a "pseudo-range"), between the satellite and the receiver. A separate signal (in Galileo) also carries data giving the satellite orbit and other essential information which the receiver then decodes.

When the receiver has gone through this process with four satellites, it is able to calculate its 3D position and velocity, and its clock is synchronised to the system standard time. Measurements to additional satellites will improve the accuracy of the measurements and provide resilience against intermittent loss of signal. Modern GPS receivers perform some of this process in digital form: in 5 years time virtually all of it will be digital. When a receiver is tracking a signal from a satellite the bandwidth of the code and carrier tracking loops can be very narrow. The code loop might be as low as 0.1Hz, the carrier loop 1kHz or less. The satellite's motion is highly predictable and so a stationary receiver, once the carrier is locked on, can easily follow the Doppler change. However, if the receiver is moving, for example in a vehicle, then a sudden change of direction could cause the carrier loop to lose lock. To prevent this, either the receiver must allow the loop to operate at a wider bandwidth or the tracking loop must be "aided" by inputs form another sensor. In a fighter aircraft, for example, this aiding comes from the inertial reference system, in a vehicle it could come from a much simpler low cost gyro or dead reckoning system. These forms of coupled sensors are expensive. It is obvious from the foregoing that while a receiver is in tracking mode with the carrier and code operating as narrow bandwidth loops, it has a high ability to reject interference due to the narrow bandwidths. The loop characteristics are similar to a flywheel and a short interruption of one or more signals can be accommodated by the receiver.

There are many techniques that can be used to extend the ability of the receiver to keep tracking the satellite(s) in the presence of interference. Some examples are:

1 Tracking the code alone if the carrier lock is lost.
2 A dual frequency channel receiver may continue to track if the second channel is not affected by the interference.
3 A narrow band filter can be automatically steered in the processor to reduce the effect of a CW interferer.
4 Pulsed interference can be reduced by pulse blanking.
5 The use of multiple correlators, some new receiver chip designs use over 2000 to enable the signal to be tracked through fades and interference
6 Antenna nulling - a further significant increase in the ability of a receiver to withstand interference comes from the use of an adaptive antenna which can automatically steer nulls onto multiple sources of interference. It is possible to obtain 30dB of improvement with this technique.

Where receivers are most vulnerable is in the acquisition phase. If a receiver starts absolutely from scratch, i.e. unknown position, velocity and time (PVT), then it will have to search with wide loop bandwidths in order to find the signal and lock to the code. The more information it has about its PVT the faster it can acquire and the narrower the loops can be. Once a receiver is giving good PVT data then it is more difficult to interfere with, or jam. Where problems can arise is when the receiver is forced into a re-acquisition mode and where interference prevents it from then re-acquiring.

There is, obviously, a vast difference in receiver performance between those designed for leisure walking and those designed for civil aviation or for the most demanding military environments. A simple small receiver does not have the room for quality front end filtering or high dynamic range for example.

Finally spoofing must be mentioned, this is a technique for interfering with GNSS operation by transmitting either a simulated signal or a delayed version of a real signal with the aim of making the receiver display an incorrect position. In the proposed PRS it is intended to include cryptographic techniques to prevent this abuse.

10. Practical Interference Scenarios

This section will examine some interference scenarios.

The Galileo E6 signal is -128dBm as received by an isotropic circularly polarised antenna and in total has a 20MHz bandwidth That means it is roughly 30dB below thermal noise before signal processing. The Martlesham beacon on 1296.835MHz has an quoted erp of 700W (58dBm) referenced to a dipole The code modulator in the receiver operating at 5 Mchips/sec effectively turns this CW signal into a noise spectrum at its output so that if the receiver is tracking with, say, a 100Hz bandwidth, there is a processing gain (2x chip rate/tracking loop bandwidth) of 50dB. The tracking loop will continue to operate with an interferer about 5dB above the wanted signal. We will assume that as the beacon is near the upper E6 band limit and that the receiver matched filter attenuates it by 6dB. There is a further 3dB attenuation as the Galileo receiver has a CP antenna.

The margin required to continue operating is then -128 +5 - (58-50-6-3) = -122dB. This attenuation occurs at a range of 18 km. The approximate radio horizon of this beacon is 35km (there are a number of assumptions in this calculation but it indicates the scale of the potential problem).

A pertinent question, (perhaps even an FAQ) is …"so why hasn't this problem occurred with GPS which has been in use for a decade or more?" The answer is that the simple GPS L1 (1575.42MHz) receivers are, indeed, vulnerable to interference but that their (approximately) 2MHz wide frequency channel is clear because it is protected to aeronautical standards. These receivers can be disrupted by relatively simple jammers designs for which are available over the internet but there are few reported instances of problems.

The study in 2001 of the vulnerability of the US transport system to GPS failures by the USA DoT's John A. Volpe Transportation Systems Center, reference [4], states that a 1W CW airborne jammer would break lock in a typical receiver at 10km and prevent lock at 85km. A jammer which more accurately mimicked the GPS waveform would be effective to > 900km. Other potential sources of interference are the harmonics of VHF/UHF base stations and mobiles which are stated to have been shown to deny operation out to 9km. It is noted that the fourth harmonic of the new Tetra deployment at 390MHz falls in band and these transmitters will be present in most police and emergency service vehicles.

A study of interference to Civil GNSS applications by out of band interference has been undertaken for the Australian Global Navigation Satellite System Coordination Committee, reference [5]. Testing of the performance of typical GPS receivers in the presence of potential interference sources was carried out using commercial receivers. The study concentrated on interference affecting the GPS L1 signal and it looked, in particular, at the possibility of interference from the harmonics of UHF TV transmitters to GNSS. By a mixture of measurement and simulation the study determined that the typical third harmonic radiated from a 480kW TV Transmitter would disrupt GPS operation over a 3.5 km radius. There are plenty of high power TV transmitters in the UK who's second and third harmonics fall on the L1 frequency, but the writer has not heard of problems being reported.

At the other end of the scale there is a report of a 2mW jammer disrupting GPS operation over a 1nautical mile radius in a sea trial. This would represent about -100dBm at the receiver, exactly the level predicted by theory. In the lower part of the GNSS band both GPS and GNSS have to cope with the pulsed signals from the aeronautical distance measuring equipment (DME) and from TACAN and JTIDS / MIDS which are pulsed navigation systems and data links respectively. In addition Galileo receivers will have to cope with the navigation radars in the E6 band and their out of band transmissions as well. In a paper, reference [6], to be presented at the 2005 ION NTM Conference, the problem is highlighted but the solution is not obvious. For an excellent description of the GPS C/A code receiver jamming issue see reference [7].

11. What is likely to happen?

There is no doubt that GNSS will play an increasingly important, role in the transport infrastructure operation in both Europe and the USA. The EU seems determined to possess its own system, independent of the USA and GPS.

However it still remains to be seen whether it can get the private sector to finance and run it for profit, or whether it will have to heavily subsidise its operation. All NATO countries have access to military quality GPS and so, in the light of other priorities for military equipment spending, it seems very unlikely indeed that there would be pressure from the European military for an independent system, especially when the US have said they would jam it, (or worse!) if it were perceived as a threat. The Galileo funding issue is not yet settled for development or for operation.

If Galileo goes forward as planned, perhaps with a year or two's delay, then as its usage becomes a more integrated and critical part of the infrastructure, the demand to have greater security, availability and reliability from the service will grow. This is happening already in the USA as the planned use of GPS for aircraft precision approach and landing comes closer to realisation. Air transport is more important in their infrastructure and so there is a need to see a way through to a highly robust civil GPS system.

The report by John A. Volpe, Transportation Systems Center, **reference [4**], reviewed this area and made many recommendations for improving robustness and availability, including research into interference mitigation and interference location. Everyone is beginning to recognise that the current GNSS ***does*** have vulnerabilities and that interference mitigation has to be an important and necessary component of the receiver system design.

Even if Galileo does not proceed, we have to recognise that the 1260-1300MHz band will be used ***at some time*** for GNSS and that these systems will always have a rather weak signal at the earth's surface. Sharing the allocation with radar is/was relatively painless for the Amateur Services. Radars, even civil ones, are designed to cope with interference, both accidental and deliberate, by employing a whole library of techniques developed over many years.

Furthermore, because the number of radars is small and they are large installations and easily physically protected, the techniques can be kept secret where necessary. Although there are some who are calling for the GNSS bands to be effectively swept clear of interference sources that could affect Galileo this is (in my own view) impractical, especially where they are not protected by the stringent aeronautical regulations. Therefore if it is required to have a robust, high availability, PRS service in the E6 channel then those receivers will have to incorporate ***very extensive*** interference rejection measures. These measures must be able to cope with both accidental and deliberate interference. The limit will be set by what can be released from military anti-jam technology into this para-military area, bearing in mind the virtual impossibility of keeping large numbers of the PRS equipments secure.

One technique which could be particularly valuable is the adaptive antenna because of its ability to automatically form simultaneous deep nulls on several interferers. As the GNSS signals are below thermal noise in their own bandwidth, the antenna does not have to recognise them in its processing, which is a major simplification. It would seem entirely feasible to fit a police or fire vehicle with a 4-6 element adaptive antenna, greatly reducing its vulnerability to interference.

12. What can the Amateur Services do about it?

While Galileo might be delayed, it is unlikely to be abandoned, even if it were, then at some time (probably post-2007) another GNSS will take the allocation.

Non-continuous signals such as ssb/cw ought not to present a major problem to a properly designed and robust PRS receiver and one can argue that 23cm amateur transceivers will be available for many years to come and probably constitute the largest quantity of potential jammers available to any person or illegal organisation wishing to cause disruption. Therefore the PRS receivers should protect themselves against them as a matter of good design and therefore we should be allowed to continue our occupancy of the band.

We can further argue that, to a moving vehicle, the signal from a typical amateur ssb/cw transmission will be very intermittent (the transmitting antenna is narrow beam, typically 30 degrees, and the signal received by a car will be subject to terrain shadowing) and therefore the receiver should be little affected by it. It would be useful to take some measurements of these sorts of signal levels. Obviously the terrain masking effect would be less for the police helicopter scenario but it would still be present to a degree.

EME operations are typified by a higher erp than normal "tropo" stations. However, the beam widths are smaller and so the duration of interference is short and a well designed receiver in a police helicopter for example should “flywheel” through it. The side lobe levels are about the same erp as a tropo station and the antennas, being large, are at low height, which considerably increases the intermittency of the signal at a distance.

Transmissions below 1300 MHz which are more continuous such as beacons, TV repeaters and FM repeaters and which are often on higher masts and with wider pattern antennas might have to be limited.

A lot will depend on what arrangement is worked out to protect the radar operations and what is worked out at WRC-07 in order for both radar and Galileo E6 receivers to continue to operate. As someone said to the writer, “the radar guys will do the heavy work on this issue.”

The IARU does not appear, as yet, to have grasped all the implications. To quote from the Region 1 WRC-03 report “The GALILEO allocation between 1260 and 1300 MHz (approved at WRC 2000) overlaps our amateur and amateur satellite allocations, but to date does not pose much of a threat. However, other spectrum users such as airborne and ground based radars are more concerned……. it was agreed that existing GPS systems put into operation before 2000 would not be subject to constraints, but that limits would be imposed on all new systems. From an amateur point of view, these new constraints will just provide a little ***extra protection”*** (added emphasis) “for us as well, and so this decision was a positive one from our point of view.”

13. References

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Buying & Selling Microwave Bits on eBay

Steve Davies G4KNZ

Introduction

Since early in 2004, I've Increasingly made use of eBay both to sell some surplus radio items and to buy a few things (radio and otherwise). I know quite a few other readers do as well, but maybe some of you are not really so aware, or you've had a look but not actually bought or sold anything yet.

There is enough help on the eBay pages that I don't need to go into too much detail about getting started. It is fairly painless, though you will need to give a credit card - to pay any selling fees - but also it helps establish your identity is real. See www.ebay.co.uk for all this basic information. What follows are a few hints and tips on some less obvious points.

US vs UK site

If you are searching for bits, you can look at both the UK and the US site. Using the UK site, you can also view items that are available to the UK - in the main from the US, but also I notice quite a few from Germany. If you use the US site (www.eBay.com), you can see everything on offer in the US - many times what is available in the UK - but do be aware many sellers in the US can't be bothered with shipping overseas - you need to check every item (whereas it should only appear via the UK site if the seller will ship there).

If you have friends/relatives in the US who will allow use of their address and forward stuff on, you can get round that, and it gives you access to a much wider selection. The advantage of looking on the US site is that it is useful to see everything else on offer, even if you can't buy it - to get an idea of prices, how many of the same are around, etc.

Importing

There are plenty of interesting items on the US site, often at better prices than you'll find in the UK. If you have it shipped direct from the US seller, a problem, though, is that UK customs might intercept your package and decide you need to pay VAT and maybe also duty. In theory, this applies to items above £18 (or gifts above £36) though practice is not 100% consistent!

To add to this, the delivery agent can also make a service charge for collecting VAT (and duty) - and for example, with Parcel Force this charge is £8 (minimum). I have already been caught out once with this, it cost me a total of £18 added on to a £50 item from the US before I could have the package.

Shipping costs

It does sometimes seem some sellers are adding quite high shipping costs, beyond what you think reasonable. You can sometimes see quite expensive handling on very cheap items - eg a software CD, where £5, or more shipping is required - and you know you could post it yourself for under a pound.

In some countries, (e.g. the US), it seems there is not always the same culture of going to the post office when you have a package to post. Instead they pick up the phone and ask FedEx, DHL or whichever courier they use to call and collect it. So it is not surprising that shipping can then be £10 to £20.

As an example, for a light weight Bird element, I was quoted around $35 to ship to the UK, and when I queried this, I was give an excuse about the value of the item and that ordinary post was not permitted ... but I know I could post this to the US from the UK for about £2, so why not the other way? It seems some US sellers are just not interested in trying to offer economical shipping.

Another recent trend is a large number of electronic items sold by Hong Kong sellers (and others in the region), often appearing on the UK site as if they are local. Shipping on these can also be quite high.

Terminology

If you are using the search facility, bear in mind that different terminology is often used for the same thing, especially between the UK and US. For example, a bird "element" is sometimes called a "slug". Coaxial "relays" might be called coaxial "switches".

Waveguide is more commonly referred to by its WR number outside the UK - WG20 is known as WR42, WG22 is WR28, and so on. And of course spellings - e.g. analyser or analyzer. If you are listing something that you want to be noticed in the US, for example by the search engine, make sure you include terms that will be familiar - so if there are different spellings, perhaps deliberately use at least one of each.

Dubious Deals

There are a few about, for example selling links to web sites when you could find them for free. During 2004, a common example was selling a link where you register for a mobile phone and send £20, then persuade others to register - if enough people you've referred have registered, you get your phone for £20.

These sites claim they are legal - but sometimes people selling the links don't quite make it obvious they are only offering a link - it can be hidden near the bottom. I've seen one of these auctions go up to about £70 - when at least one poor soul thought they were competing to buy a great value phone - and all the winner got is a URL!

By and large, in the area of RF components, equipment, etc, most people are honest and reliable.

However, in recent months, there have been a few auctions for test equipment that I suspect did not exist. These were new/current Agilent models, for example a network analyzer or spectrum analyser, offered with a low starting price of maybe $5k or so and no reserve. Often from Canada, requiring payment only by bank draft, by a newly registered seller with no feedback, and the ads were just cut/pasted from the Agilent catalog.

I also noticed in several cases, eBay suspended the auctions before the end, and de-registered the user concerned. If something looks too good to be true, perhaps it is!

Personally I always try to include a real picture of the actual item for sale, to try and give people some confidence I really do have it ready to ship.

Classification

As a seller, you need to make sure you list your item under the right classification, for maximum visibility. Sometimes it is easy & obvious, sometimes there are a few choices and it is not.

For example, some RF connectors/adapters - they could be listed under test & measurement, under ham radio, under commercial radio, under components. You can list under two categories, but insertion fees are doubled.

As a buyer, sometimes you notice things that don't really belong in the category you are browsing though. Sometimes it is deliberate - you'll see memory cards all over the place - or sometimes the seller doesn't really know what it is. I've noticed all sorts of things pop up under 'aviation' including pieces of waveguide (well, they came out of some aviation installation)! Sometimes, you can find a great bargain this way!

PayPal costs

PayPal is quite popular, though I have noticed negative comments from some people, for example concerning suspension of accounts when a dispute arises. PayPal was bought by eBay some while ago now, and they actively promote and encourage it. I suspect since this there are now less complaints, but I've not checked.

PayPal enables a buyer to pay immediately via credit card - the money appears instantly in the sellers account, and I have found it very convenient. There are charges - circa 3%, depending on the amount - so you may see some sellers wanting extra for PayPal to cover this - this tends to be those who are selling low value items on quite low margins. Personally, for the surplus bits I've sold, I've been quite happy to absorb the 3% or whatever myself, and I really do prefer to pay this way when buying - you can complete the admin within seconds of the auction end, then just wait for the goods to turn up - it makes it all so easy.

Ending times

As a seller, think carefully when you list an item - the ending time can be quite important. Many items are only bid up to a nice (to the seller) price at the last minute, so you want the auction to end when there are likely to be plenty of interested buyers around. Not at 6am in the morning!

Consider who you are aiming at. Fellow amateurs, or small businesses etc? In the UK or overseas? Sunday evening is quite a popular time for items to end, and I have found it works well - it is the end of the weekend, many people have the time to site down and browse/bid - and as a bonus, it is early Sunday afternoon in the US, reasonably convenient for many of them.

Conversely, quite a few US items seem to end during their Sunday evening - when it is now 3 or 4am Monday morning here - not so very convenient for us. Since you can choose from a 5, 7 or 10 day listing, that means starting the auction on Tuesday, Sunday or Thursday. Or you can always delay the start of an auction, it only costs an extra 12 pence.

As a buyer, Sunday evening is a popular time for auctions to end, and there is lots to look at. But everyone else is looking too! Sometimes it can pay to look at less convenient times, for example early Saturday or Sunday morning. There are less items about to end, ... less buyers about ... and sometimes quite cheap bargains can be had.

Prices

I am often surprised at how expensive or cheap something sells for, and often it depends on how well (or poorly) it was promoted, and how available it is compared to demand. Sometimes the same seller has several (often lots) identical lots for sale, and the prices can vary by a factor of two or more. I know which price I'd rather pay!

It can pay to check the sellers other items - several times I have seen a seller list identical items with different Buy-it-now prices - if you want it, you just choose the cheapest. Or they may have a number of auctions, with different start prices and different end times - if you can watch them all, maybe you can pick up the item on one of the cheaper ones.

Bid Sniping

It is amazing sometimes how the price of an item can increase right at the last minute. People wait almost to the end to bid, to try and avoid pushing up the price too high in a competitive auction. I know some sellers seem to disapprove of this, and even sometimes say they will end the auction a little early to try and stop it - personally think it's part of the fun! Be wary though if your internet connection is not so fast or reliable - you don't need it to hang for a couple of minutes right at the end, just as you were about to bid! I've lost one or two items this way!

Steve G4KNZ