Hamilton Astronomical Society

1420 MHz Radio Astronomy Receiver Notes (2004)

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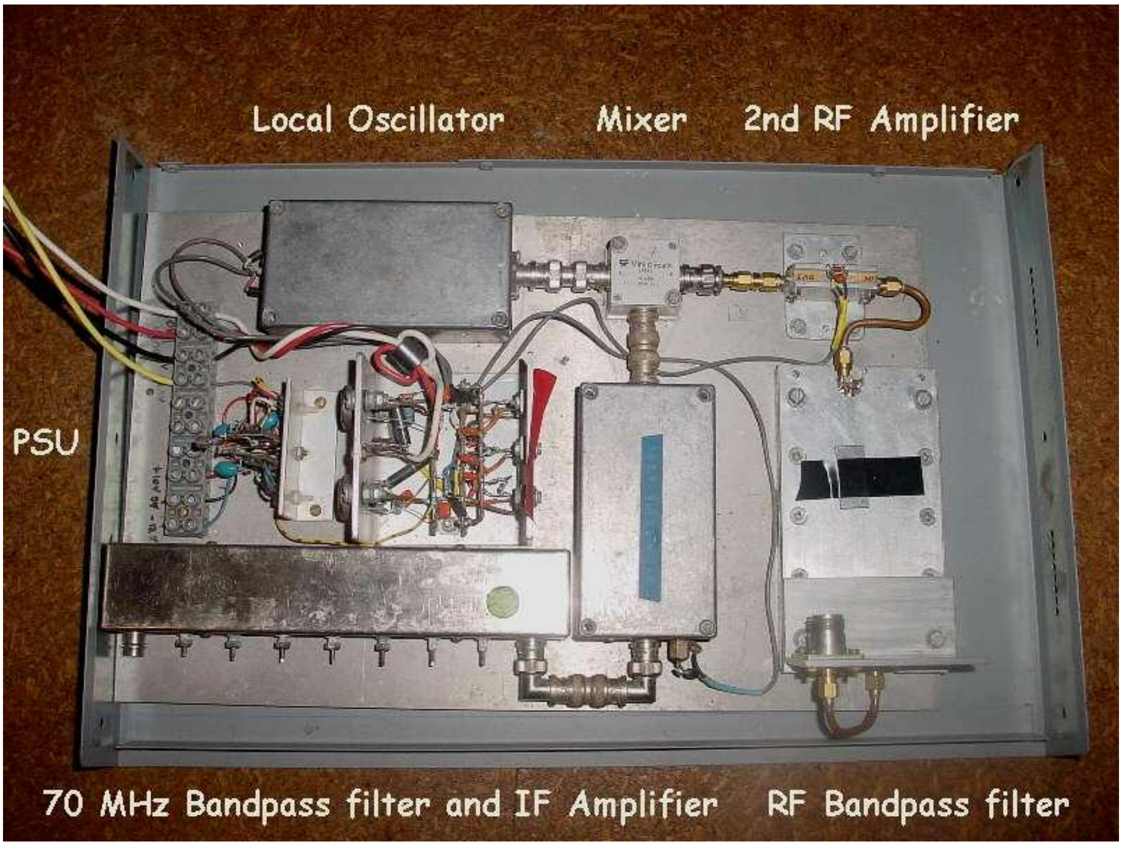
Hamilton Radio Astronomy Receiver



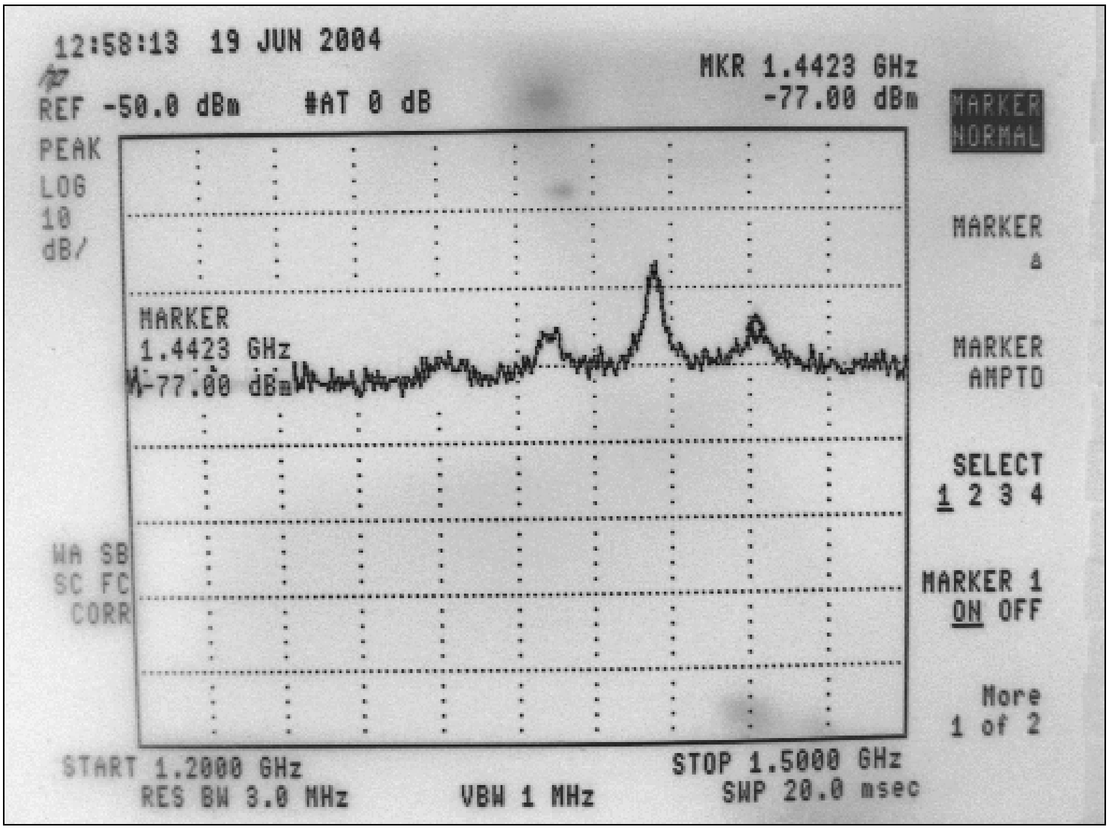
The Receiver is used to receive 1400 to 1427 MHz which is converted to 70 MHz which is then fed into a RF power meter for further processing.
The receiver was previously built in a modular format, on a solid aluminium platform with individual stages either built in commercial enclosures, purpose made fixtures or diecast boxes. The unit was believed to have been designed and built by Waikato University students

The receiver is designed in the following modules
(1)RF amplifier
(2)RF BPF Filter
(3)2nd stage RF amplifier
(4)Mixer
(5)Local Oscillator
(6)70 MHz IF Amplifier
(7)70 MHz IF Filter
(8)Power Supply

There is a following list of comments on each module in turn concerning their suitability or any problems

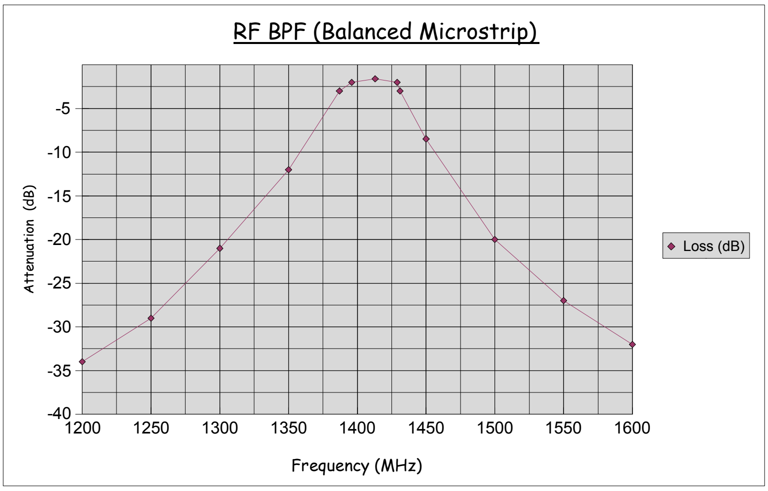
RFAmplifier
This amplifier is external to the Receiver unit shown above and would be fitted close to the Horn feed on the dish. The Amplifier uses a MGF1403 on a Teflon PCB with SMA interconnections. The nominal gain is of the order of 12 dB. The unit suffers from inband (1400 to 1427 MHz) instability with a regenerative gain peak of approximately 11 dB, bringing the gain up to ~ 23 dB in some areas. Analysis with a Spectrum Analyser

shows a major gain peak with 2 smaller adjacent ones The unit requires more investigation to see whether the problem may be resolved. Operating voltage is + XX volts



RF BPF Filter

The Bandpass filter unit, used to pass frequencies between 1400 and 1427 MHz is constructed on a PCB with the filter sandwiched between two PCB earthplanes. The connectors are SMA and the unit has a low loss of 1.6 dB. The following plot shows the response. No further work required



RF Filter Frequency (MHz)	Insertion Loss (dB)
1200	-34
1250	-29
1300	-21
1350	-12
1387	-3
1396	-2
1413	-1.6
1429	-2
1431	-3
1450	-8.5
1500	-20
1550	-27
1600	-32

2nd Stage Amplifier

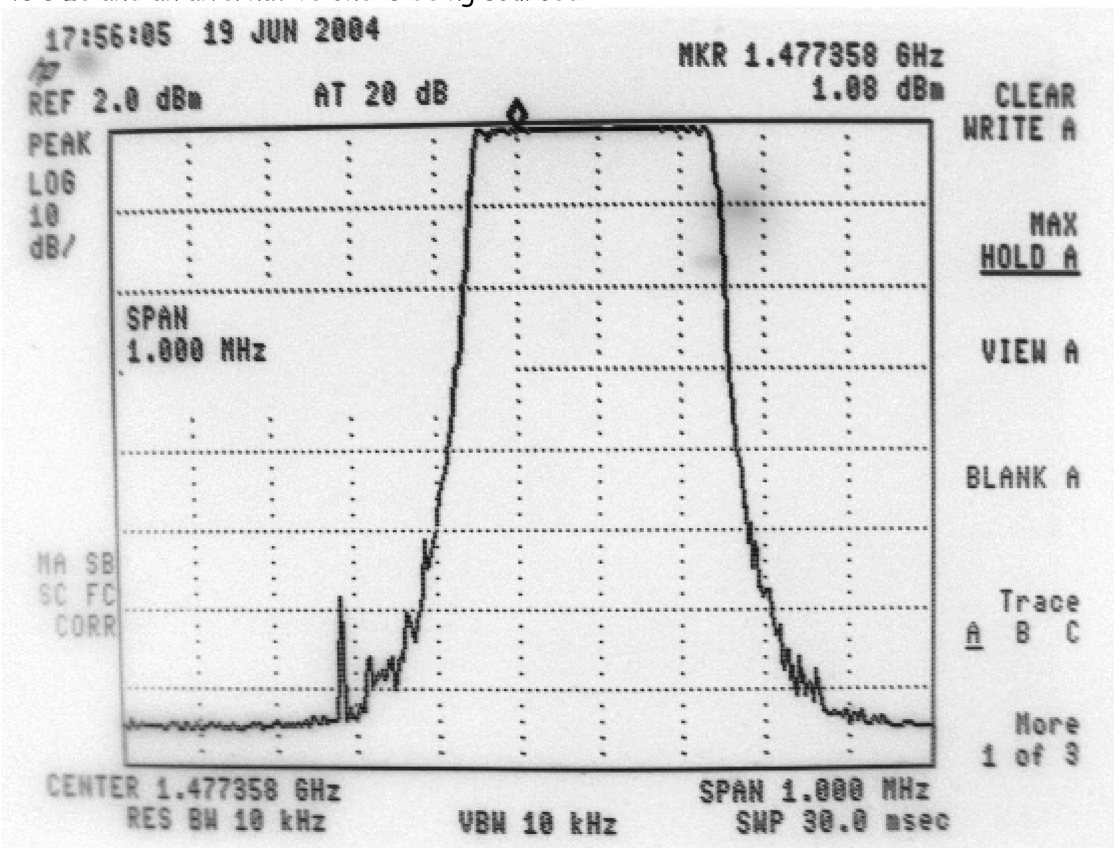
The Amplifier is a commercial MITEQ unit AFD3-1400144 which appears to be optimised for the Astronomy band from comments from Robin Holdsworth. (Data may be available soon). The gain is said to be ~ 30 dB and noise figure ~ 2dB.Operating voltage is +15 volts Age of unit is mid 1980's.

Mixer

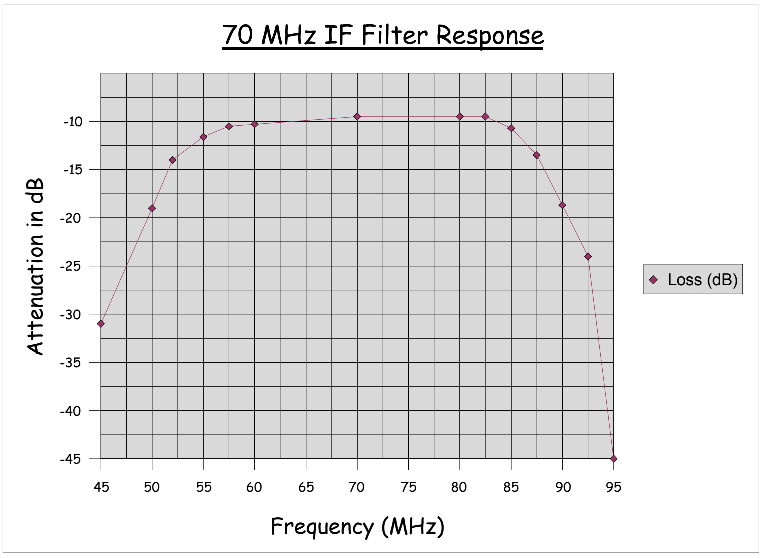
The double balanced mixer is a ZFM-11 with BNC connectors for a + 7 dBm (5 mW) level Local oscillator. This is made by Minicircuits (www.minicircuits.com) rated to 2 GHz. The loss is a nominal – 7 dB with LO to RF port isolation of ~ 33 dB and LO to IF port isolation of 25 dB. VSWR is better than 2.5:1 on all ports at the chosen frequency. Further information may be obtained from the Minicircuits website.

Local Oscillator

The oscillator is a Avantek VCO Model VTO 8090 which operates from 900 to 1600 MHz. The output level was ~ +4 dbm (2.5 mW) The unit runs from a dual supply of +15Volts for the power input and +45 volts for the varicap tuning voltage. The tuning voltage is varied on the PCB with a LM317 voltage regulator, with the common lead going to a single turn preset resistor. Observation on a spectrum analyser shows high level random FM (high phase noise) [See plot below]. This is almost certainly due to the noise coming from the voltage regulator. I have suggested that a crystal oscillator/ multiplier be built to replace the unit. A unit along the lines of a EME65 (www.minikits.com.au) and a frequency multiplier from the Waikato VHF group PCB's has been built as a marker and a unit similar to this will be the LO replacement. The existing box is not suitable due to its size and an alternative one is being sourced



70 MHz IF Filter



IF Filter	
Frequency (MHz)	Insertion Loss (dB)
45	-31
50	-19
52.5	-14
55	-11.6
57.5	-10.5
60	-10.3
70	-9.5
80	-9.5
82.5	-9.5
85	-10.7
87.5	-13.5
90	-18.7
92.5	-24
95	-30
100	-45

This is a surplus Lenkurt filter that has extra attenuation internally to help with termination matching. The response is excellent across the passband with a small slope of ~ 1dB which may be tuned out if necessary. Note the filter –3 dB response exceeds that of the RF filter

PSU

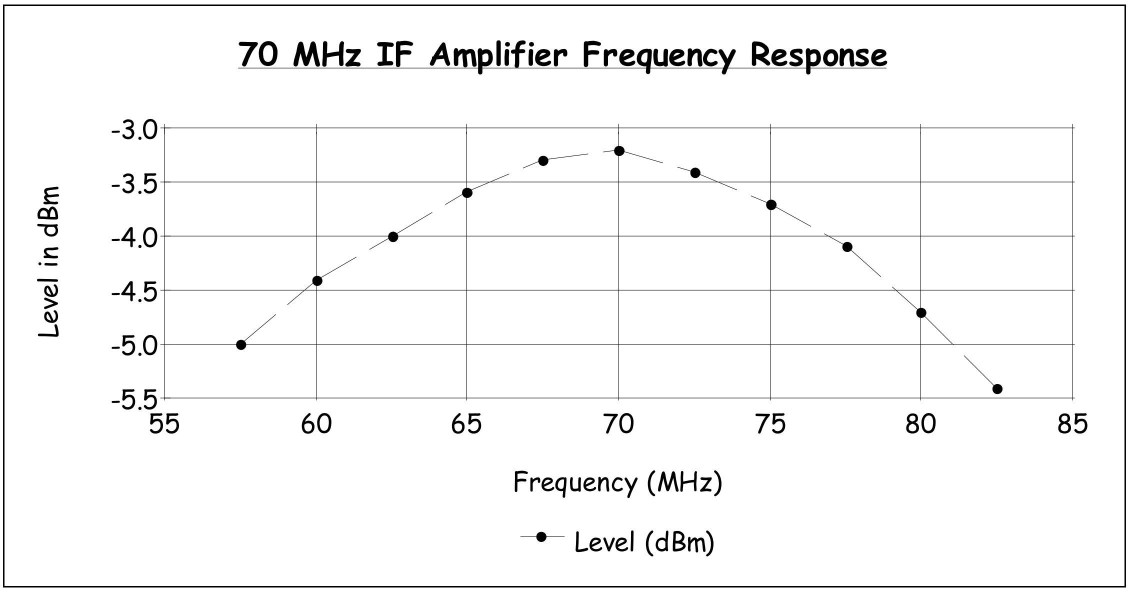
Too many regulators cannot be enough seems to be the motto! I will attempt to rationalise it down to one +15 volt regulator that is fed by ~ +20 volts supplied off board. I would think that ~ 1 amp should be sufficient. The LO unit will be regulated down to +8 volts

70 MHz IF Amplifier

This is a home made unit which has some slope across the 70 MHz (+/- 20 MHz) passband. The transistors are 2n5109 devices. The unit runs off +18 volts. Can the unit run off +15 volts ?

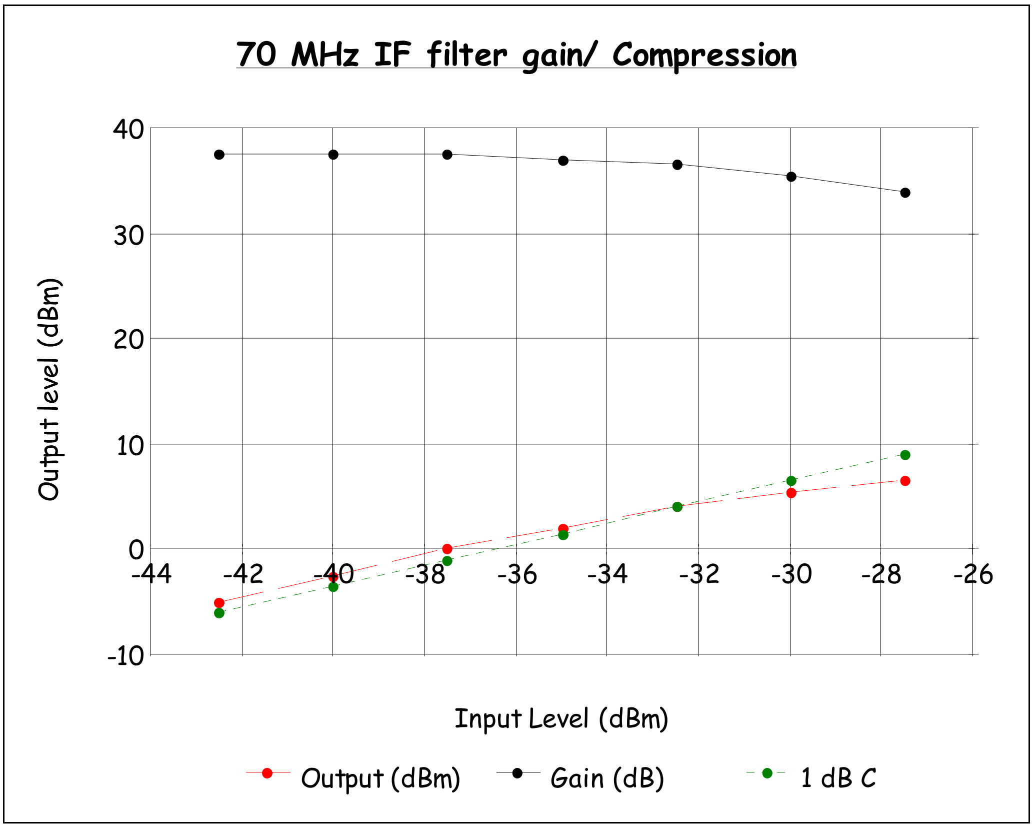
The 70 MHz Amplifier was found to have a frequency response with grater slope above 70 MHz. Adjustments to balance the overall response were made. The nominal gain is +37.5 dB and 1 db gain compression point on the output is +4 dBm (T. Bevan)

IFamp Gain response	
Frequency (MHz)	Level (dBm)
57.5	-5
60	-4.4
62.5	-4
65	-3.6
67.5	-3.3
70	-3.2
72.5	-3.4
75	-3.7
77.5	-4.1
80	-4.7
82.5	-5.4



Tests were also made on the – 1dB Compression Point and gain

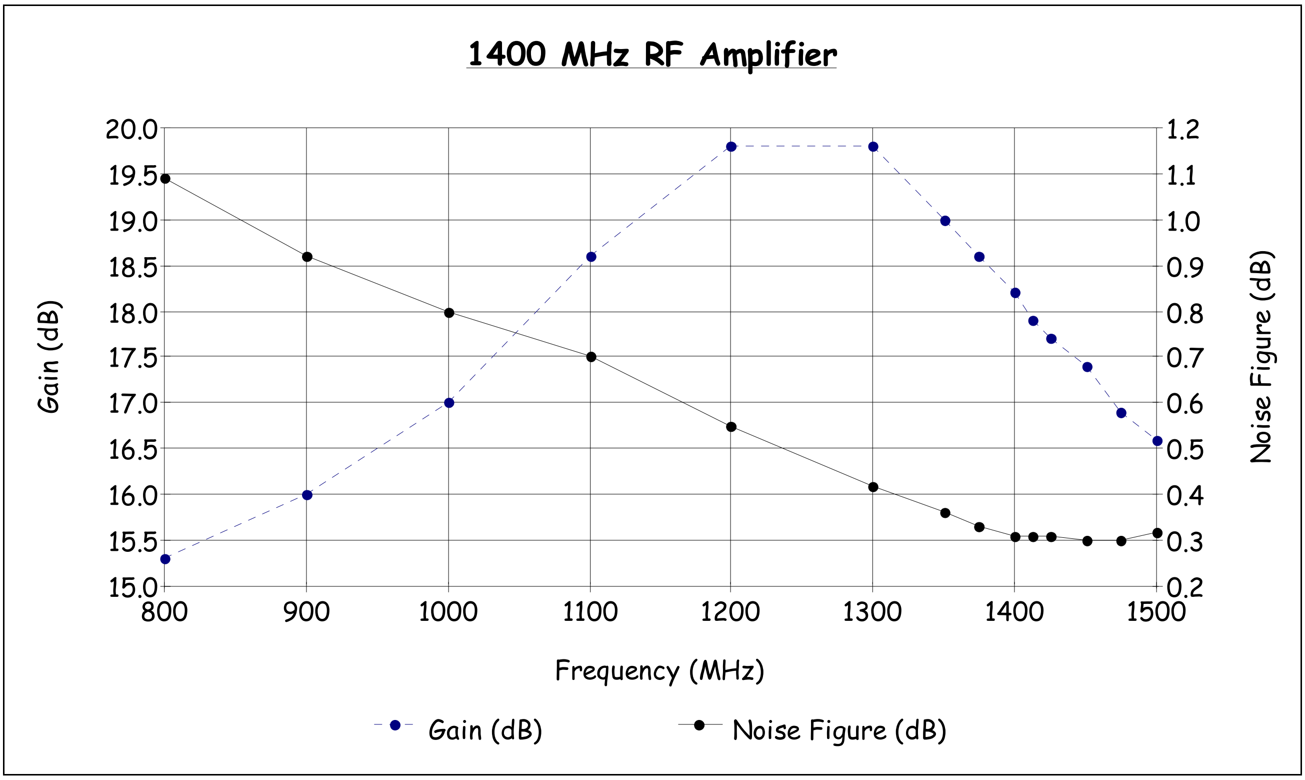
70 MHz Amp		
Input (dBm)	Output (dBm)	Gain (dB)
-42.5	-5	37.5
-40	-2.5	37.5
-37.5	0	37.5
-35	2	37
-32.5	4	36.5
-30	5.4	35.4
-27.5	6.5	34



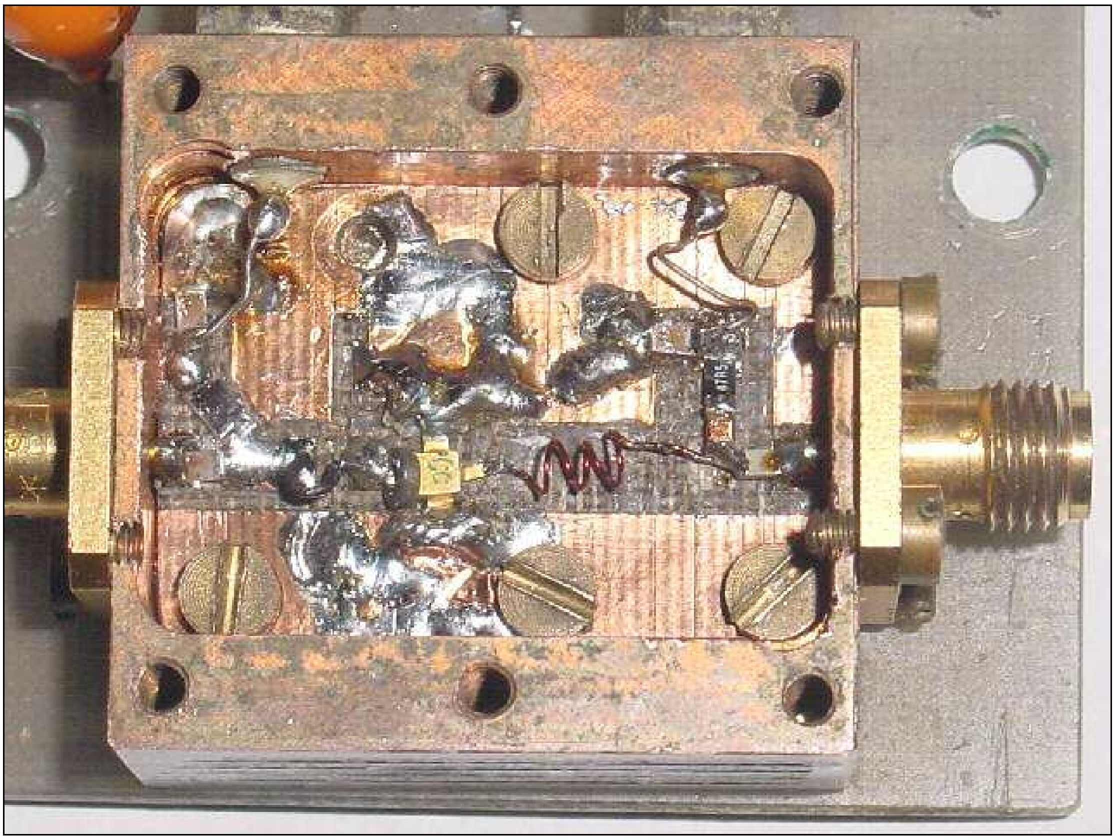
RF Amplifier

The GaAsfet amplifier is built on double sided 1.6mm Teflon (Duroid) PCB. There were no vias and earthing between the two sides relied on the mounting screws. This causes instability as the earth inductance path is higher.
The positive supply is fed via a 100 mA LM317 TO92 type regulator with a voltage setting preset in the common lead. There was no current limiting resistor! This will be fitted to remove the possibility of the FET self-destructing. The negative bias voltage is fed via a 100 mA LM79L05 regulator with a voltage setting preset.
Extra vias are being fitted to the PCB.
The inductors are air wound. SMD inductors will replace some of these to reduce instability.
+15 volts can be used to power the positive regulator and a 7660 dc-dc inverter can be used for the minus side removing the need for a negative supply (T. Bevan)

1400 MHz Preamp		
Frequency (MHz)	Gain (dB)	Noise Figure (dB)
800	15.3	1.09
900	16	0.92
1000	17	0.8
1100	18.6	0.7
1200	19.8	0.55
1300	19.8	0.42
1350	19	0.36
1375	18.6	0.33
1400	18.2	0.31
1413	17.9	0.31
1425	17.7	0.31
1450	17.4	0.3
1475	16.9	0.3
1500	16.6	0.32



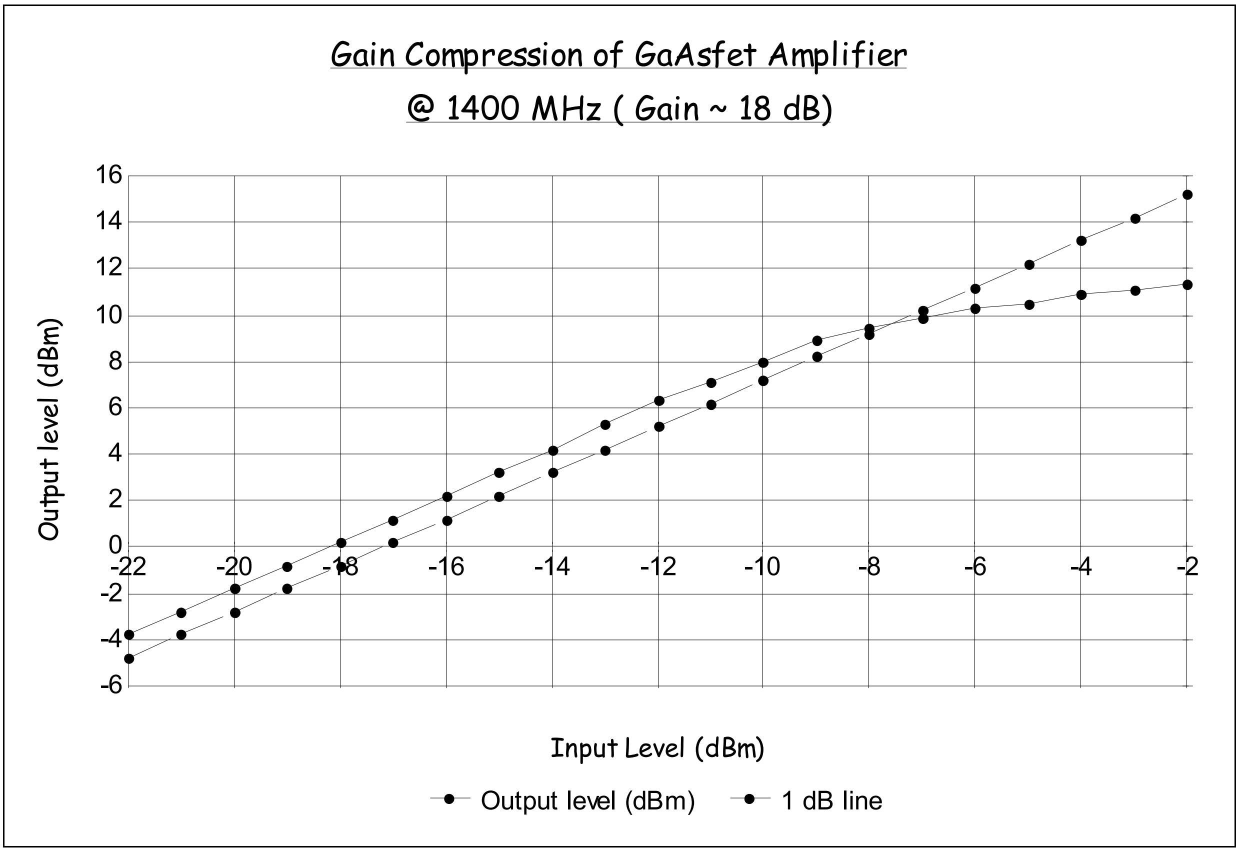
The rework on the 1400 MHz amplifier was successful as can be seen from the results. No sign of instability. The positive supply is +15 volts and an integral –5 volt supply fitted using a 7660 inverter. Positive Voltage regulator o/p is set + 5.5 volts. Current ~ 14 mA. Negative gate volts ~ -0.5 volts. Tantalum capacitors fitted to regulator o/ps for stability
See image of RF portion of amplifier below. (Input on right side)



1400 MHz RF Amplifier Gain Compression Test @ 1400 MHz	
Input level (dBm)	Output level (dBm)
-22	-3.8
-21	-2.8
-20	-1.8
-19	-0.8
-18	0.2
-17	1.2
-16	2.2
-15	3.2
-14	4.2
-13	5.3
-12	6.3
-11	7.1
-10	8
-9	8.9
-8	9.4
-7	9.9
-6	10.3
-5	10.5
-4	10.9
-3	11.1
-2	11.3

At 1400 MHz the amplifier's gain/loss of +18 dB compresses by 1 dB at ~ + 10 dBm output level. The input level at which this gain compression occurs is ~ - 7 dBm.
That is +10 dBm – 17 dB = -7 dBm

The graph below shows a straight line 1 dB below the gain line. As the gain/loss falls by 1 dB the changing slope cuts through the straight line. The crossover is the – 1 dB compression point

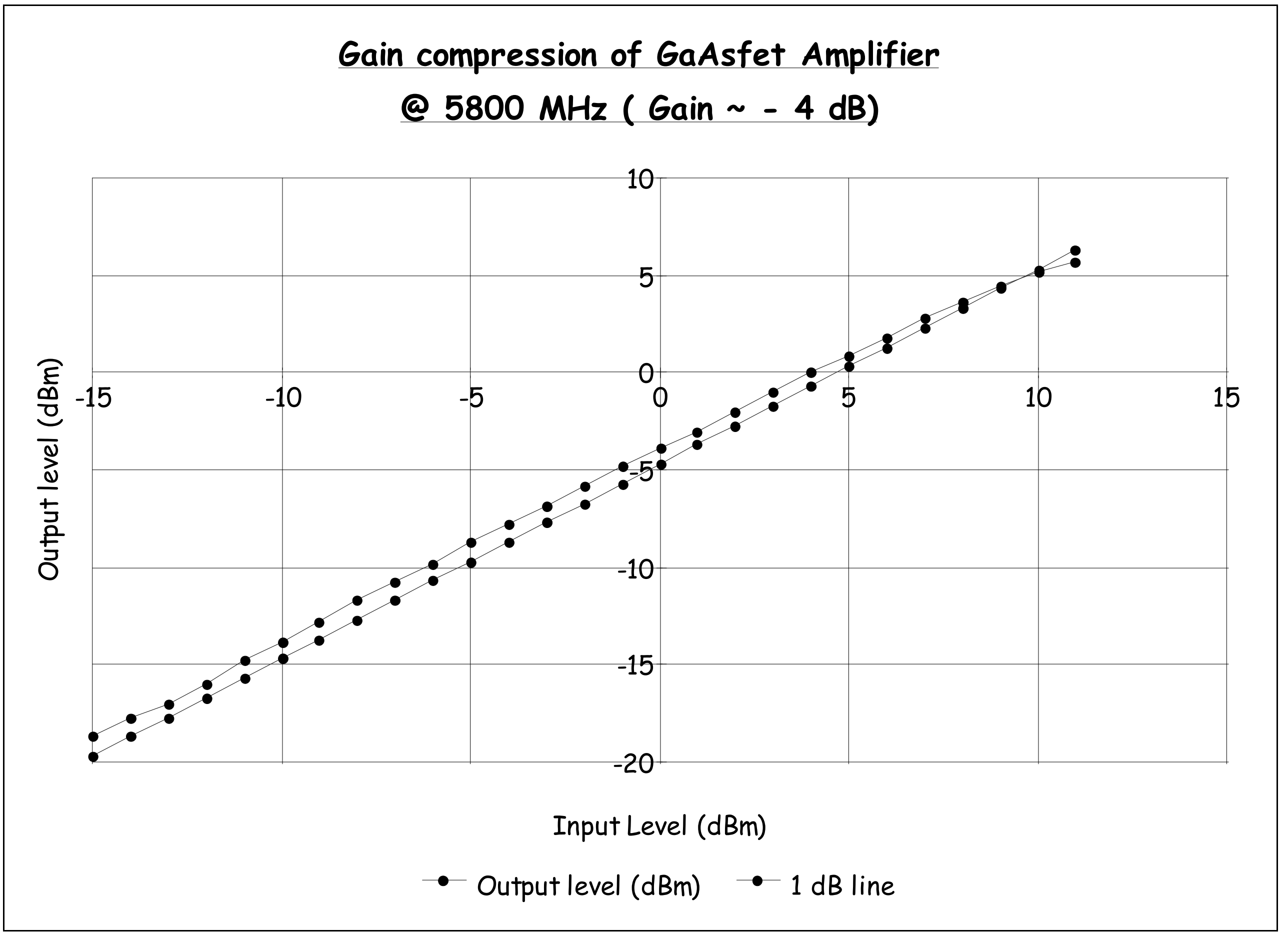


1400 MHz RF Amplifier Gain Compression Test @ 5800 MHz	
Input level (dBm)	Output level (dBm)
-15	-18.7
-14	-17.7
-13	-17
-12	-16
-11	-14.8
-10	-13.8
-9	-12.8
-8	-11.7
-7	-10.8
-6	-9.8
-5	-8.7
-4	-7.8
-3	-6.8
-2	-5.8
-1	-4.8
0	-3.9
1	-3
2	-2
3	-1
4	0
5	0.9
6	1.83
7	2.76
8	3.6
9	4.5
10	5.15
11	5.65

At 5800 MHz the amplifier's gain/loss of -4dB compresses by 1 dB at + 5 dBm output level. The input level at which this gain compression occurs is ~ +10 dBm.

That is +5 dBm – (-5 dB) = +10 dBm

The graph below shows a straight line 1 dB below the gain line. As the gain/loss falls by 1 dB the changing slope cuts through the straight line. The crossover is the – 1 dB compression point

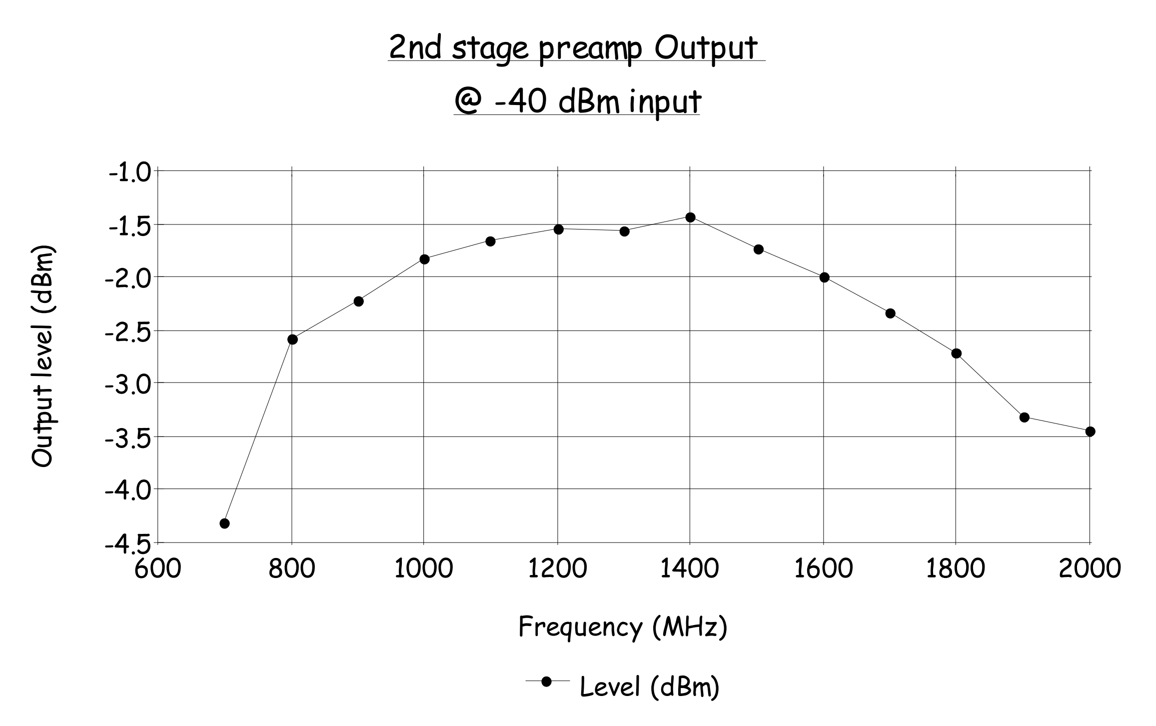


Gain compression of GaAsfet Amplifier
@ 5800 MHz (Gain ~ - 4 dB)
10
5
0
-5
-10
-15
-20
-15
-10
-5
0
5
10
15
Output level (dBm)
Input Level (dBm)
Output level (dBm)
1 dB line

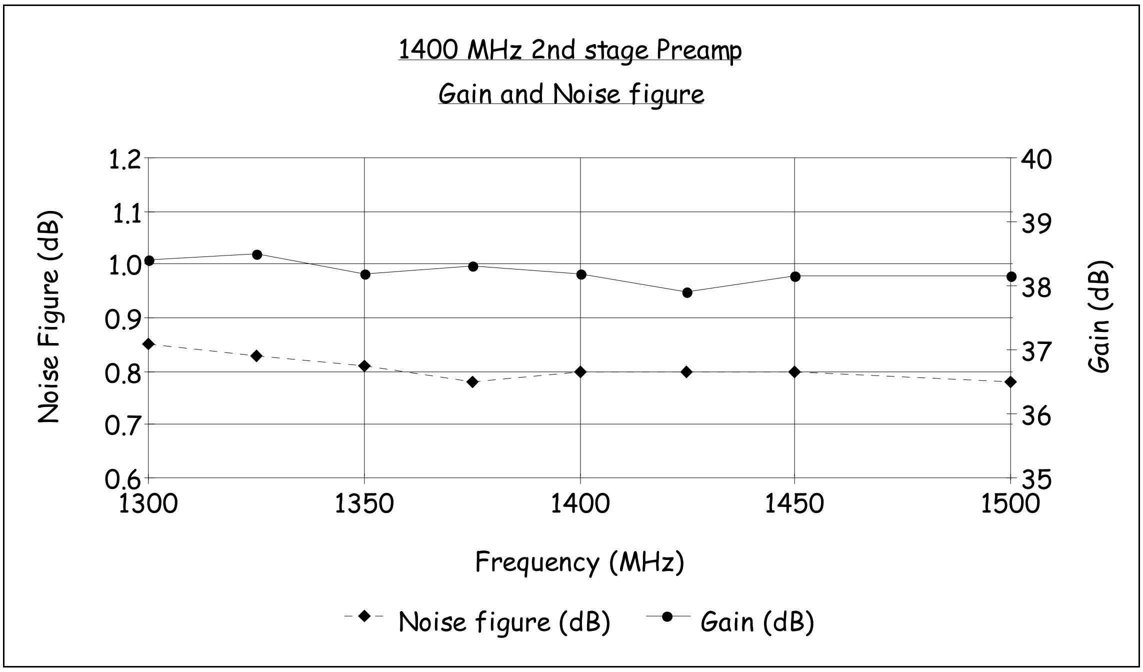
2^{nd} Stage 1400 MHz Preamplifier

2nd stage RF Preamp	
Frequency (MHz)	Level (dBm)
700	-4.32
800	-2.58
900	-2.22
1000	-1.83
1100	-1.66
1200	-1.55
1300	-1.57
1400	-1.44
1500	-1.74
1600	-2
1700	-2.34
1800	-2.72
1900	-3.31
2000	-3.45

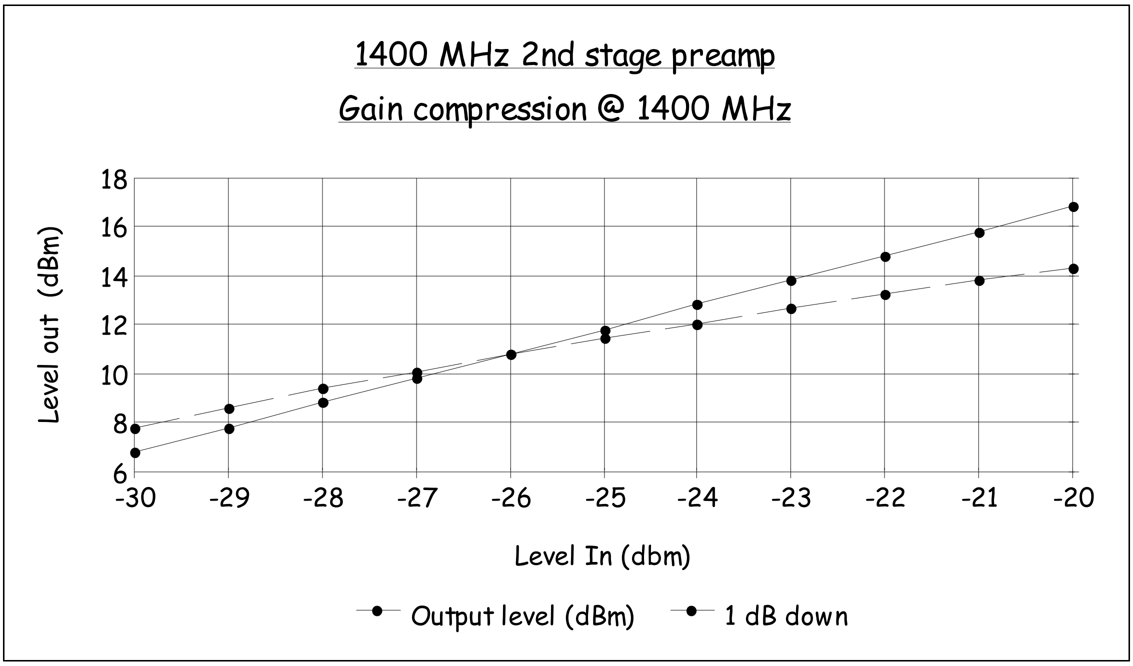
Gain of 1400 MHz 2^{nd} stage Amplifier is ~ 38 dB with –3 dB frequencies of ~ 800 and 2000 MHz.
The noise figure across the 1400 to 1427 MHz band is ~ 0.8 dB
The - 1 dB gain compression occurs at ~ + 11 dBm output. This is ~ -26 dBm referred to its input



1400 MHz 2nd stage preamp Noise figure and gain		
Frequency (MHz)	Noise figure (dB)	Gain (dB)
1300	0.85	38.4
1325	0.83	38.5
1350	0.81	38.2
1375	0.78	38.3
1400	0.8	38.2
1425	0.8	37.9
1450	0.8	38.15
1500	0.78	38.17



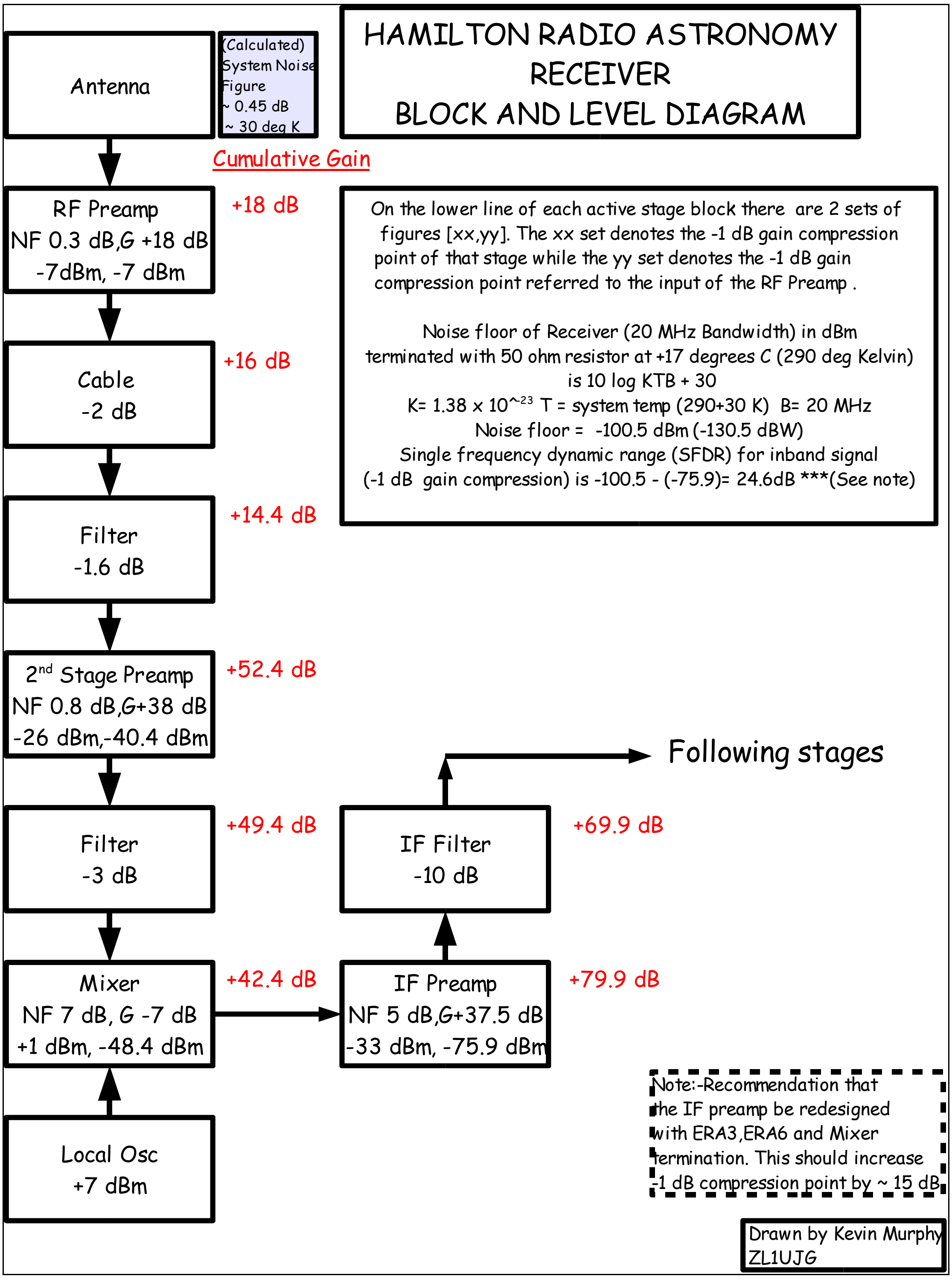
2nd stage preamp Gain compression @ 1400 MHz	
Input Level (dBm)	Output level (dBm)
-30	7.83
-29	8.63
-28	9.4
-27	10.12
-26	10.82
-25	11.46
-24	12.06
-23	12.66
-22	13.25
-21	13.8
-20	14.31



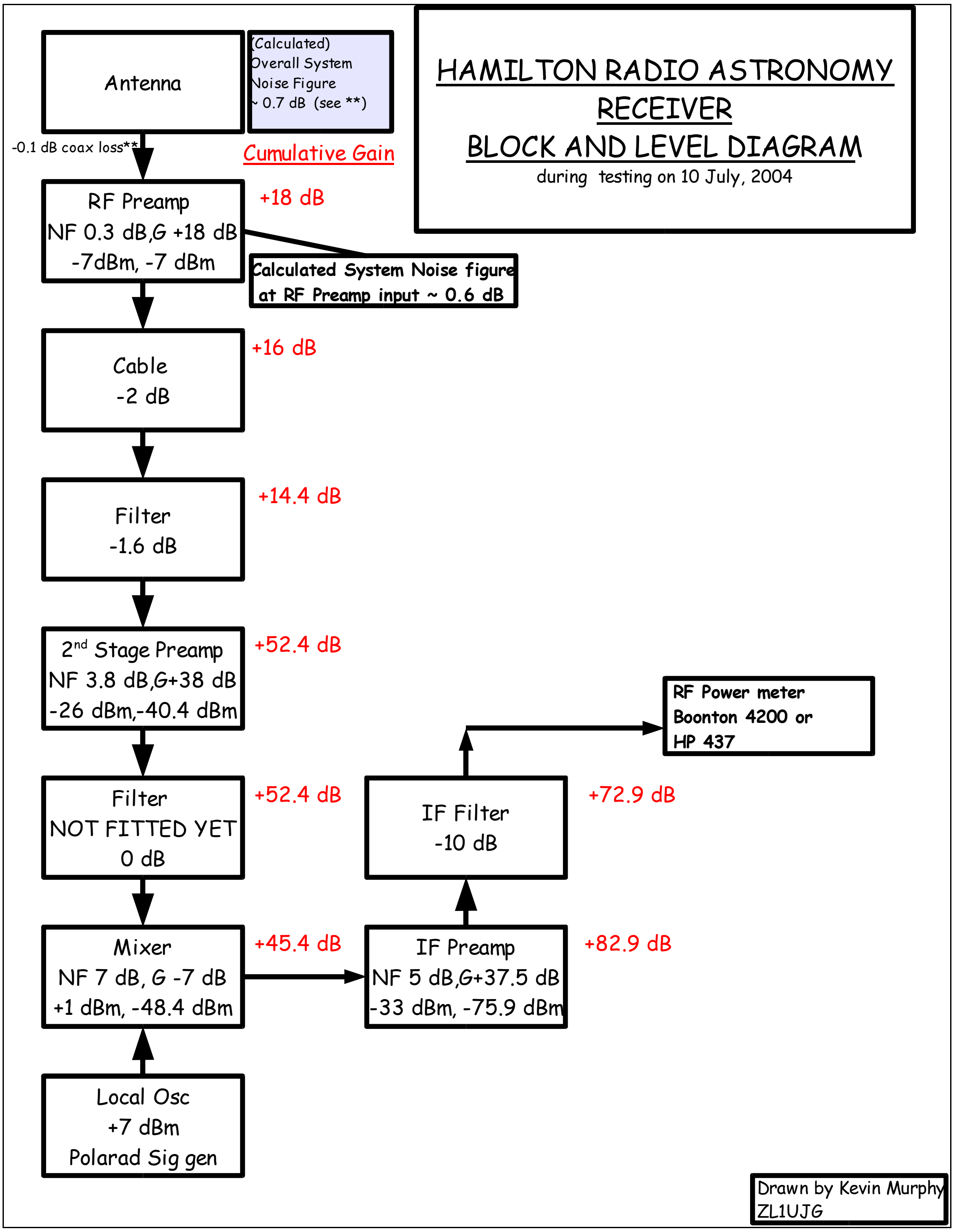
The diagram below is the block and level diagram of the Receiver. In the picture in the first bulletin, there is no 2nd RF filter. A recommendation is that a second RFfilter be fitted for two reasons.

The 1st reason is to increase the image rejection. The primary reception frequency band is 1400 to 1427 MHz. The image is 140 MHz lower between 1260 MHz and 1287 MHz . There is a local 23cm amateur beacon on 1296.256 MHz so extra filtering will further reduce image signals. Currently image rejection is only of the order of 25 dB.

The 2nd reason is that the 2nd RF Preamp will produce noise at both the primary and image frequencies. If the image noise is not filtered before it feeds the mixer, then the noise figure of the 2nd preamp will degrade from 0.8 dB to 3.8 dB!



HAMILTON RADIO ASTRONOMY
RECEIVER
BLOCK AND LEVEL DIAGRAM
Antenna
(Calculated) System Noise Figure
~ 0.45 dB
~ 30 deg K
Cumulative Gain
RF Preamp
NF 0.3 dB,G +18 dB
-7dBm, -7 dBm
+18 dB
Cable
-2 dB
+16 dB
Filter
-1.6 dB
+14.4 dB
2nd Stage Preamp
NF 0.8 dB,G+38 dB
-26 dBm,-40.4 dBm
+52.4 dB
Filter
-3 dB
+49.4 dB
Mixer
NF 7 dB, G -7 dB
+1 dBm, -48.4 dBm
+42.4 dB
Local Osc
+7 dBm
IF Preamp
NF 5 dB,G+37.5 dB
-33 dBm, -75.9 dBm
+79.9 dB
IF Filter
-10 dB
+69.9 dB
Following stages
On the lower line of each active stage block there are 2 sets of figures [xx,yy]. The xx set denotes the -1 dB gain compression point of that stage while the yy set denotes the -1 dB gain compression point referred to the input of the RF Preamp .
Noise floor of Receiver (20 MHz Bandwidth) in dBm terminated with 50 ohm resistor at +17 degrees C (290 deg Kelvin) is 10 log KTB + 30
K= 1.38 x 10^-23 T = system temp (290+30 K) B= 20 MHz
Noise floor = -100.5 dBm (-130.5 dBW)
Single frequency dynamic range (SFDR) for inband signal (-1 dB gain compression) is -100.5 - (-75.9)= 24.6dB ***(See note)
Note:-Recommendation that the IF preamp be redesigned with ERA3,ERA6 and Mixer termination. This should increase -1 dB compression point by ~ 15 dB
Drawn by Kevin Murphy ZL1UJG



This was the equipment setup used on Saturday 10th July, 2004. The RF Power meter was swapped with a Spectrum analyser when required.

The Preamp was wired to some FSJ-4 (1/2 inch heliax cable) The Bias was fed separately via 3 wires. The preamp was first connected to the large horn antenna.The 70 MHz output was fed to the spectrum analyser. It showed that the band (1400 to 1427 MHz) converted to 70 MHz was lumpy. The analyser was then swapped for the power meter and noise measurements taken while the feed was pointed at various objects noted in the chart below

This was then repeated for the EIA twin dipole feed. It was noted that no lumps when viewed on the spectrum analyser

Relative noise measurements(dBm)	Big Horn feed pointed to	EIA Dual dipole feed pointed to
Ground	–37.1	-34.9
Shrub	–37.6	-34.4
Cold sky	–39.13	-39.13
Sun	–38.7	-37.56
Shrub to cold sky Difference	1.53	4.73
Cold sky to sun	0.43	1.56

A Shrub (1 to 2m in diameter) near the building was used as a reference, as pointing the antenna to ground would cause VSWR variations due to proximity to earth. Shrub was ~ 1 metre away from antenna

A 50 Ω termination was connected to the preamp input and this gave –32.8 dBm. Since the impeance of the antenna and 50 Ω may be sufficiently different to cause noise variations this is only included for reference.

Cold sky to ground test is not influenced by antenna size/ gain whereas sun to cold sky test is affected by the antenna gain

The System Temperature Tsys = [Tground – (Y Tsky)]/(Y-1) where Y = ground to cold sky ratio (linear ratio).

T sky assumed to be 10 degrees K. T ground 283 degrees (10 degrees C cold morning)

The Shrub to cold sky ratio is used as the VSWR will change with antennas close to physical ground (ground measurement).

The Horn feed results were suspect as seen on the spectrum analyser (lumpy spectrum). This was possibly due to possible preamp oscillation or incorrect parameters of the feed horn. Discussions with Ken Graham, who visited during Saturday afternoon, indicated that some parameters may have been suspect. Even though the antenna appears to give a good match, the antenna may not have the correct gain. (A 50 ohm load gives a great match but doesn't radiate very well scenario)

The results with the dual dipole were used

When using the EIA feed the Y factor = 4.73 dB (2.97 X)

Therefore T sys = (283 – 29.7)/1.97 = 128.6 degrees K

Subtracting Trx (0.7 dB) (51 degrees K) gives antenna temperature as 77.6 degrees K.

When using the EIA feed for cold sky measurements, the antenna will pick up a certain amount of ground noise due to limited front to back ratio. It was noted that the reflector appeared small. Notes on the W1GHZ website indicate a 1 wavelength square reflector.

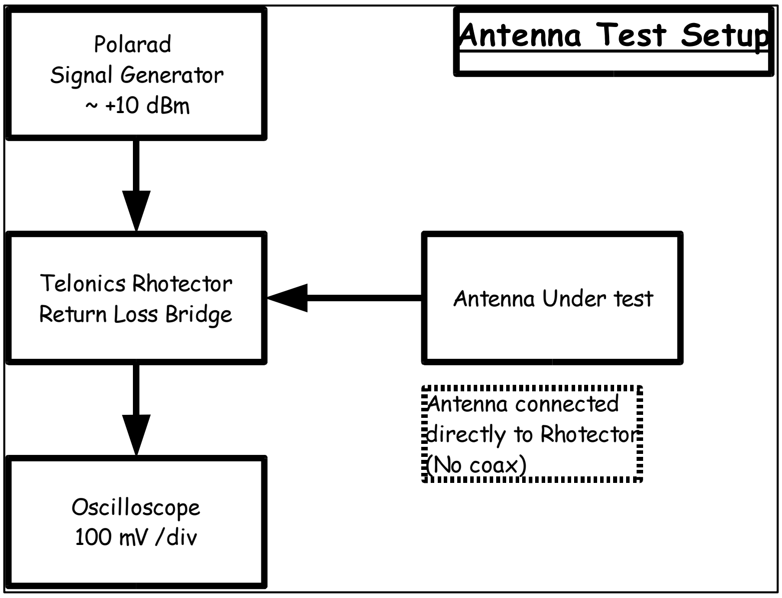
The spectrum viewed on the analyser indicated a –3 dB point spectrum at 70 MHz – 7.5 MHz and + 12.5 MHz. The offset response may have been partly due to ~ 1 dB slope apparent on the IF filter.

The IF power was calculated to be – 27.6 dBm, however measurements indicated –32.8 dBm. This is approximately a 5 dB difference.. This may be partially due to filter shape or how the power meter(Boonton 4200) responded to random noise. Alternatively there may have been a significant gain variation in the RX system.

The dual dipole antenna was swung towards the 1296.256 MHz Beacon in town. It was observed at ~ 45 MHz and at significant strength. At this time only one RF filter is in circuit and this offers ~ 25 dB rejection. A secondary filter will offer a further 25 dB approximately.

The tests at this point indicate that good reception is available on the 1400 MHz to 1427 MHz band

Antenna Testing



Robin has a Telonics Rhotector available. The Rhotector is a return loss bridge which provides a negative going DC signal which provides an indication of antenna match.

The Polarad Signal generator was used as a signal source providing about +10 dBm to the bridge. The generator was then manually tuned to provide test frequencies

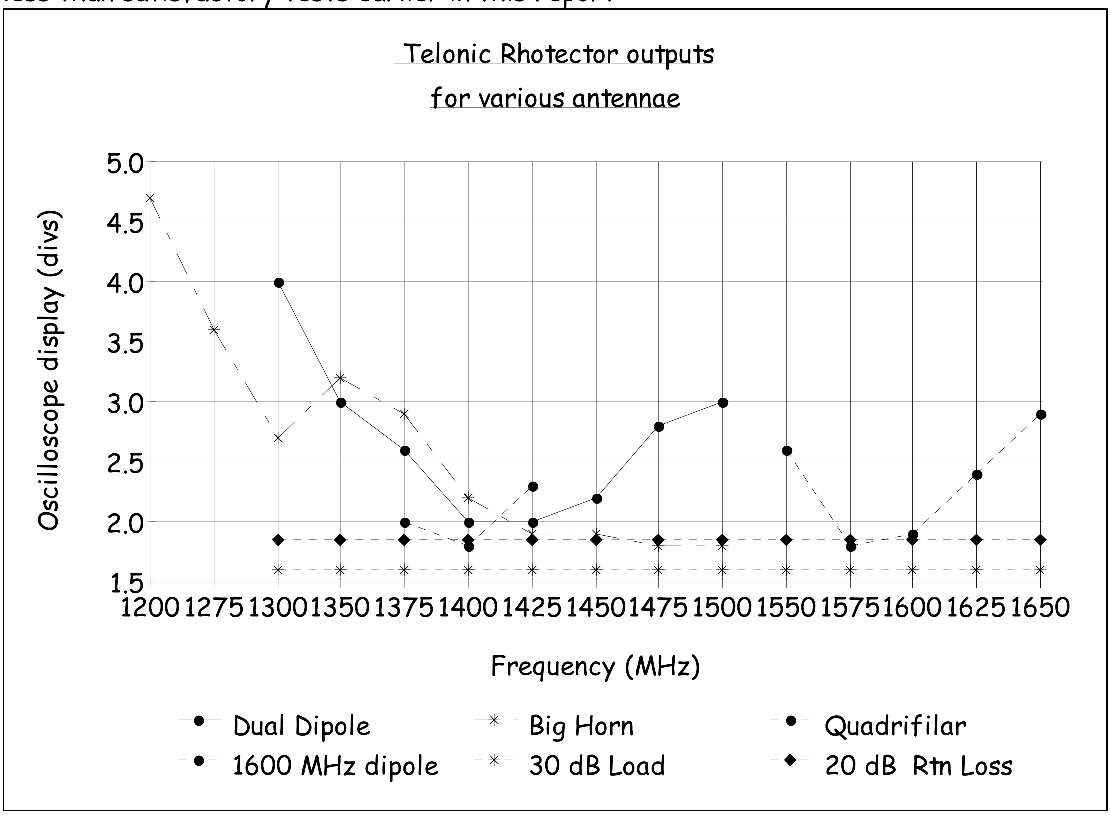
The rhotector was left with the unknown port open circuit/short circuit and FSD was obtained on the Scope using the DC offset control.

A 50 ohm reference load was placed on the unknown port which gave about 1.6 divs indication from the bottom of the screen.

A 10 dB attenuator gave about 1.8/1.9 divs from the bottom of the screen with open port shorted (20 dB return loss)

The attenuator plus 50 ohm load gave 1.6 divs (~ 30 dB return loss)

The chart shows some reasonable matches. The Large horn appears to show a secondary match below 1350 MHz and warrants further investigation. This may be the cause of less than satisfactory tests earlier in this report



Noise measurements (refer to previous update)
Formula was Tsys = [Tground – (yTsky)]/Y-1 Or Y = (Tground + Tsys)/(Tsky + Tsys)
This can be solved differently or more correctly
Note that T sky is made up of the cold sky component and spillover from the feed or dish. (renamed Tant)
T sys or T system is the noise temperature of the receiver/preamp unit (51 degrees K)
Y = (Tground + Trx)/(Tant + Trx)
Therefore if the Y formula is changed around so that Tant is solved it becomes
Tant = (Tground + Trx(1-y))/Y
Then T ant = 283 + 51(1-2.97))/2.97 gives 62 degrees K. This made up of the cold sky noise component (10 to 20 degrees K) and spillover from the feed

Local Oscillator
The original oscillator is an Avantek VCO. Residual FM was many 100's of kHz as shown on a previous update. This was deemed not suitable (!) and a replacement unit is being developed.
The new oscillator is a crystal oscillator based unit multiplied by 12 to the frequency required, which is (Centre of frequency band – 70 MHz) or 1413.5-70 = 1343.5 MHz
The crystal frequency is 111.95833 MHz and is supplied by Hy-Q International in Australia. (www.hy-q.com.au) This crystal is a Hy-Q TT07S Specification and is preaged, the crystal being made to operate at about 55 degrees. The crystal is fitted with a PTC thermistor to operate around this temperature. (PTC-60 thermistors that operate in the region of 55 to 60 degrees Celsius are available from www.downeastmicrowave.com) The crystal is fitted to a VK5EME Oscillator Board, (shown above) which uses a 2 transistor Butler Oscillator, which also multiplies by 3. This is followed by a x 2 multiplier on the same board, then another multiplier (x 2) on a Waikato VHF group Filter board

VK5EME, Minikits (www.minikits.com.au) and Waikato VHF Group (PO Box 606, Hamilton).
These boards are a very cost effective solution for the 1413.5 MHz Oscillator
The whole oscillator unit will have a 7808 voltage regulator, however due to 3 terminal regulators' output noise, the Butler Oscillator will include an active noise reduction system, in an effort to reduce residual FM/ phase noise. See image below (www.wenzel.com)
The 15Ω in the circuit replaces the 78L08 regulator that is normally fitted on the oscillator PCB

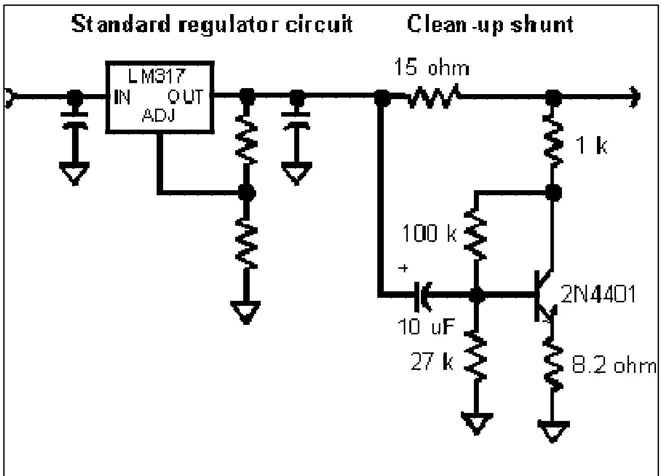
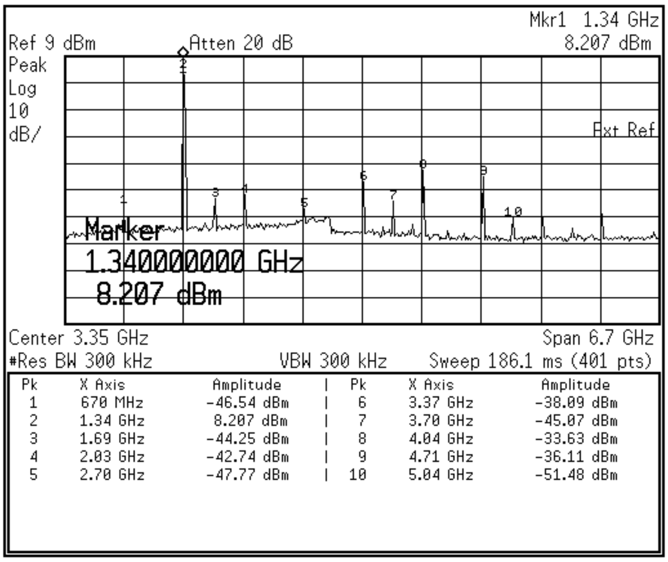


Figure 1: Clean-up circuit for low current loads.

The supply voltage will be +15 volts, so that a common supply can be used. The 7808 regulator is used in preference to a 78L08 due to over dissipation/ thermal shutdown caused by the +15v input and the required current.
The + 8 v on the 7808 regulator output will feed both frequency doublers to reduce frequency variations caused by supply variations changing operating conditions which in turn reflect back to the crystal oscillator circuitry. The units will be placed in a diecast box to some thermal isolation from external influences. DC to the unit will be via a feed-thru capacitor, reducing unwanted signals entering and also exiting the oscillator module.
Other changes to the EME65 module include changing the 10Ω resistor on the collector feed to the 1st doubler, to 100 ohms. This reduces device dissipation and can actually increase output power due to the device coming out of saturation. The 15 pF capacitor feeding the base of that stage is changed for a 4p7 NPO capacitor. (See Option 1 on accompanying Minikits EME65 information.
The capacitor across the primary tuned circuit of the crystal oscillator can be optimised. The circuit will oscillate even though the circuit is not resonant as there is sufficient gain in the oscillator, due to the use of devices with high Ft (unity gain-bandwidth). In the case of this particular unit the capacitor should be 8p2 NPO.
If there is sufficient RF output on the 2nd doubler output, then an attenuator will be fitted on the PCB with SMD resistors to reduce the level to + 7dBm (5 mW). This will provide a better match to the mixer.

1343.5 MHz Oscillator.

The Oscillator was built as described. From switch on @ ambient temperature the unit takes about 5 mins to come within +/- 1 kHz of the nominal 1343.5 MHz. The unit achieves + 9.5 dBm (9mW) output power.

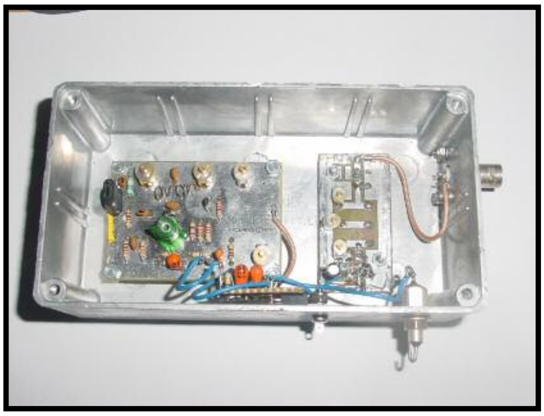


Pk	X Axis	Amplitude	Pk	X Axis	Amplitude
1	670 MHz	-46.54 dBm	6	3.37 GHz	-38.09 dBm
2	1.34 GHz	8.207 dBm	7	3.70 GHz	-45.07 dBm
3	1.69 GHz	-44.25 dBm	8	4.04 GHz	-33.63 dBm
4	2.03 GHz	-42.74 dBm	9	4.71 GHz	-36.11 dBm
5	2.70 GHz	-47.77 dBm	10	5.04 GHz	-51.48 dBm

Spurious frequencies present on the output are due to unwanted harmonics of the crystal frequency (f osc) being multiplied up. The rejection of filters is finite and therefore residual levels of the unwanted frequencies are present. All unwanted frequencies are greater than 40 dB below the wanted signal

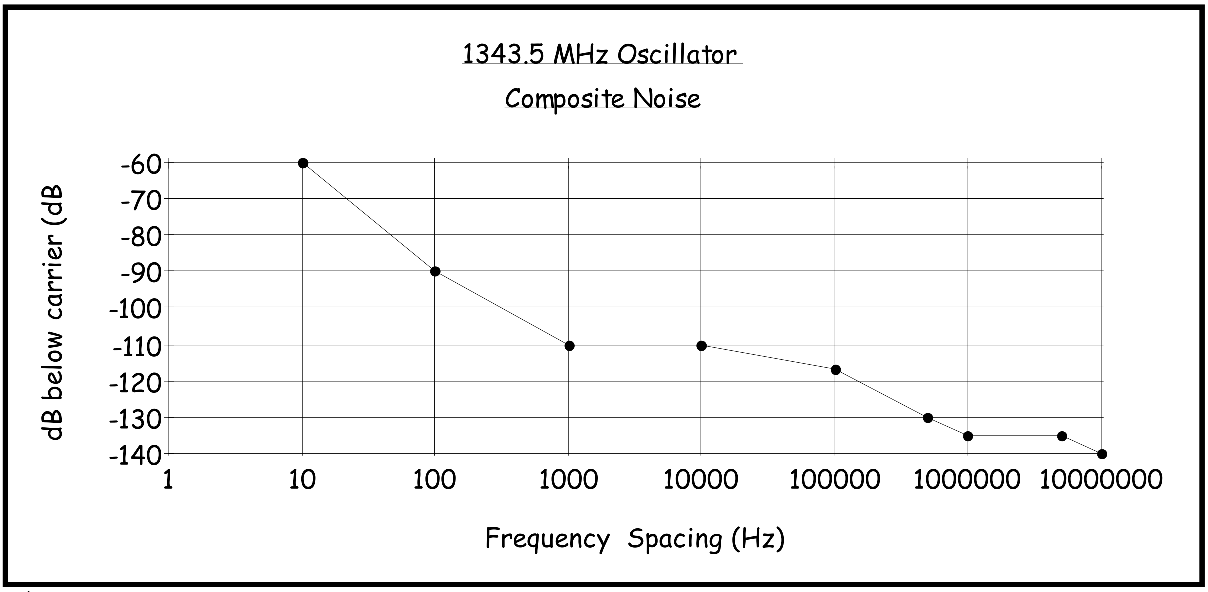
As the signal enters the mixer, the non linear mixing action will generate harmonics of the oscillator frequency 1343.5 MHz

Shown right is the completed oscillator unit. The EME65 PCB is on the left. The noise filter is below that and the 670/ 1340 MHz multiplier is on the RHSide.



Below is a composite noise (phase and AM) graph showing approximate values.

These are values at 1343.5 MHz so the noise at the crystal frequency is ~ 21 dB better.



28th July 2004

The crystal oscillator/multiplier replaced the original VCO and some tests were done at the Observatory

With the preamp terminated with a 50 Ω termination. The 70 MHz IF noise was measured with the Boonton 4200. and diode sensor

This was measured to be –25.3 dBm.

Calculations in update 4 indicated –27.6 dBm

Measurements in update 4 indicated –32.9 dBm
The IF power has increased by 7.6 dB and is much closer to the calculated value. Since some of the values in the chart are approximate then the result is quite close. (The FSJ-4 coax cable is calculated to have less loss than the 2 dB quoted.)
The original oscillator (VCO) was known to have a lower output level (~+4 dBm or 2.5 mW) and there was a wire of about 25mm in length extending to the original connector. This would certainly not be 50 Ω. The VCO rated power is +13 dBm (20mW) and I suspect that considerable power was lost in the VCO/mixer interface as well as having high VSWR. It is a known fact that high VSWR on mixer ports can cause excessive mixer losses and I would surmise that is the reason for the lower level when using the original VCO.
We made two measurements of Shrub/Sky noise

	Test 1	Test 2
Ground (dBm)	-26.4	-26.5
Sky (dBm)	-31.1	-31.4
Diff (dB)	4.7	4.9

The difference in test 1 is close to the reading of 4.73 dB obtained in update 4
The greater reading of 4.9 dB was obtained by searching around the sky for lower sky temperature

Readings for IF noise were also taken with the HP 437 and HP8481D diode sensor. This was at variance with the Boonton by a lesser reading of 3.6 dB (-29 dBm). The readings were made with a 30 dB attenuator still fitted making the power at the sensor around -60 dBm. This is an extremely low level for a power sensor and is only a few dB above its noise floor and may result in incorrect readings due to numerous factors. Further tests with less attenuation (0 or 10 dB may provide different results
We swept the antenna along the buildings and trees across the front of the Zoo and small variances (~ +/- 1 dB) were noted around an IF level of –29 dBm. These were probably due to the antenna seeing different structures (trees/metal roofs/tarseal/one or two cars in the carpark / bright lighting and different amounts of sky). There were no abrupt increases in level. There were also some small changes when the polarisation of the antenna was made which would be due to the beam of the antenna not being symmetrical**

A Icom R100 Wideband scanner was also available and the preamp (18 dB gain) was connected to that via the long feeder(1.5 to 2 dB loss). The RX was tuned to 1420 MHz in AM Mode @ 25 kHz Bandwidth. An increase in noise was apparent (indicating the RX is quite sensitive at 1420 MHz). When the antenna was pointed toward the ground and the sky there was an audible difference via the speaker. The antenna was also pointed along the front of the zoo area and the noise was audibly between ground and sky noise as would be expected from measurements in the paragraph above**. There appeared to be no unusual noises present.

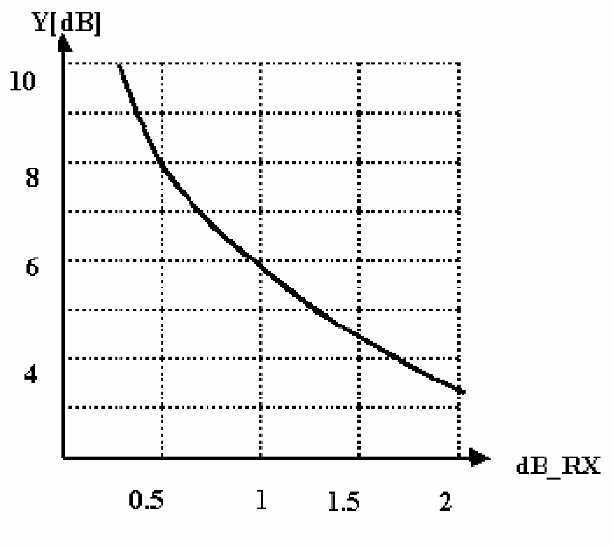
At this point in time,Sunday, 3 September 2006 all the PSU regulators has just been stripped off the Receiver frame and one LM317HVK (TO-3) will be fitted to a bracket and adjusted for +15 volts output. It is the intention to feed this with a +20V input from a remote external PSU.
A right angle bracket will also be fitted to the 70 MHz IF filter to prevent movement. A piece of U channel will also be mounted on rear of the 1400 MHz filter so that the 2nd RF Amplifier can be bolted to it so that a 2nd RF filter can be mounted between the amplifier and mixer

70 MHz IF Amplifier.
I have looked at replacing the existing IF amplifier that uses 2N5109 equivalents, with a MMIC based unit (ERA3 and ERA6). Due to the wide bandwidth of these MMIC's and the probability of LO leakage, it is recommended that a filter should precede these devices. The double balanced mixer operates better if all ports have 50Ω on the ports. Since standard filters only have 50Ω

(or thereabouts) in the passband it is recommended that a diplexer or a constant impedance filter be used.
A commercial unit such as a Minicircuits PIF-70 would be suitable, however considerably more work on a PCB would be needed to fit both this and the MMIC's.(www.minicircuits.com)
I located some information at
http://www.qrp.pops.net/dip2.htm
http://www.qrp.pops.net/DIP_SUP.htm
www.setileague.org/articles/hps_ham.htm then look for UHF, Microwave and Ham radio and view *Interstage 50-ohm Terminator for VHF Converter*
I have calculated values for the diplexer and will purchase some components and will manufacture a diplexer for fitting on the same PCB as the new amplifier.

The effect of 2nd stage Noise figure on the Ground- Cold Sky Y- factor measurement.

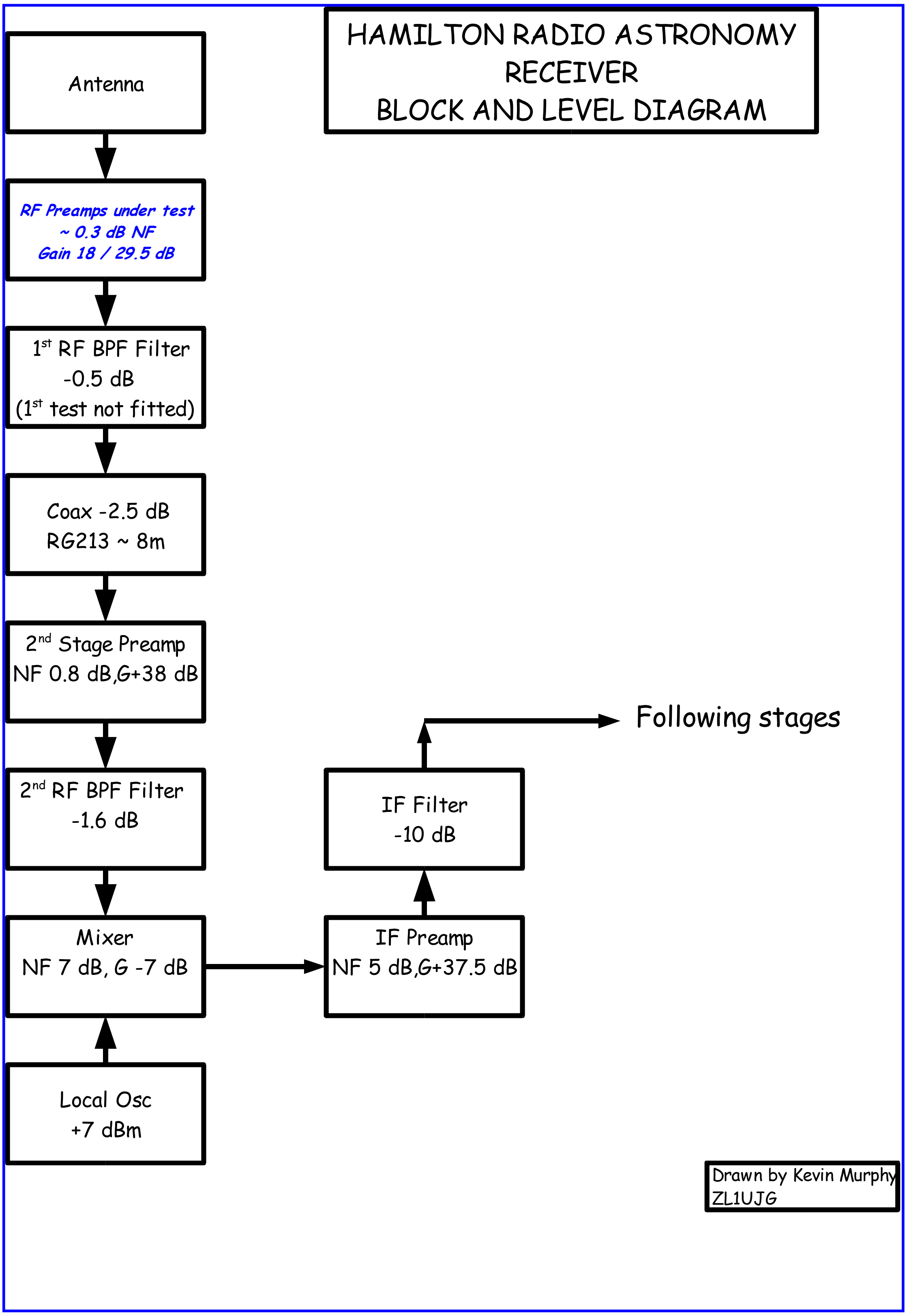
I came across a mention of degradation of the Y factor measurement while looking at this site http://www.qsl.net/oe5jfl/noisefig.htm
While the degradation of the noise figure is small at normal temperatures (eg a noise figure test), the effect of having a high 2nd stage noise figure can be disastrous when used with a low noise preamp and looking at a low sky temperature.
Example
2nd Stage Noise figure 7.6 dB (Equivalent Temp 1380°K)
1st stage Noise figure 0.3 dB (Equivalent Temp 21°K)
Gain 18 dB (63 x)
Overall noise figure 0.59 dB (T rx Equivalent Temp 42 °K)
Calculated Ground/ Cold Sky test
(assuming Ground Temp T_{gnd} 290° K and Cold Sky T_{sky} 10°K)
Y = 10 log ((T gnd + Trx)/(T rx + Tsky))
Y = 10 log ((290 + 42)/(42 + 10)) = 8.05 dB
The noise figure and cold sky and ground figures were close to those of the Astronomical RX yet the practical test showed only 4.7 to 4.9 dB
The noise output of the 1st stage with a 10 °K antenna temp is (21 + 10) x 63 = 1953°K
The noise of the 1st preamp/ sky noise barely overrides the 2nd stage Noise temp of 1380 °K and a so the Trx + Tsky measurement is incorrect due to the influence of the 2nd stage NF
The preamp and sky noise overrides the 2nd stage NF or provides an increase of IF noise by 10 log ((1953)/ (290 + 1380)) = 0.76 dB or IF noise increase)
The degradation of the Y factor is 10 log (1 + $\log_{10}$ (-1 x (IF noise increase)/ 10))
= 2.65 dB
This is subtracted from the calculated Ground /Cold Sky test giving 8.05 – 2.65 giving 5.4 dB.
This figure is quite close to the 4.7 to 4.9 dB measured and may be affected by small differences in Losses/ noise figure/ antenna temperature / antenna spillover/ ambient temp.
On the day/ evening the tests were made the outside temp was 10 degrees C so the ambient was 283 degrees K
This would make the Y factor 7.95 dB with corrections 5.3 dB
Only a fraction of a dB (or a few degrees difference) in the ground/ cold sky measurement due to those losses mentioned in the previous paragraph would make the bring the 5.3 dB corrected Y factor and the measured Y factor closer.



23cm Preamp with W2IMU-Feedhorn

The graph also from the OE5JFL site shows the expected Y factor with a high gain preamp at 1296 MHz.

With the higher gain preamp from WD5AGO it is expected that the Y factor will be significantly higher



The additonal preamp, horn antenna and filter have arrived from the US. The antenna arrived with a damaged N (female) connector. Before repair testing indicated about 9 dB return loss. The connector was replaced and a probe using 0.085 inch semirigid was used. This was cut for an optimum return loss of 15 dB. Internet searching indicate large feed horns, such as those at 1300 to 1400 MHz need a screw of ~ 1.55" from the opposite side of the horn for optimum return loss.

The existing RX setup was reworked so that the 2nd RF preamp and 2nd RF filter were swapped. The gave an RF filter just before the mixer. This changed the measured Noise figure measured at the 2nd RF amplifier input to 1.2 dB, instead of a measured 4.3 dB, no doubt due to filtering of the image noise and loss of the filter before the 2nd RF amplifier

Initial tests were done in the early evening (6 to 7pm) of the 17th September, 2004, at home @ 8 Tamar Place, but without using the new filter. The coax is presently ~ 8m of RG213 instead of the FSJ4. Loss estimated at 2.5 dB. Tests were done just outside the back bedroom window

Antenna	Preamp Gain(dB)	Sky noise (dBm)	Ground Noise (dBm)	Difference (dB)
Dual dipole	18	-32.9	-28.4	4.5
Horn	18	-32.3	-27.8	4.5
Dual dipole	29.5	-20.5	-14.0	6.5
Horn	29.5	-20.8	-15.0	5.8

Comments

It was noticed that very careful alignment of the antenna was necessary to minimise the Sky noise and maximise the Ground Noise. This was done by looking by looking at the power meter through a window and aligning for best advantage. Note that previous pointing of antennas was done by Robin, at the Observatory, without visual feedback of the power meter. I don't know if we are seeing any effects because of the 1296.256 MHz beacon

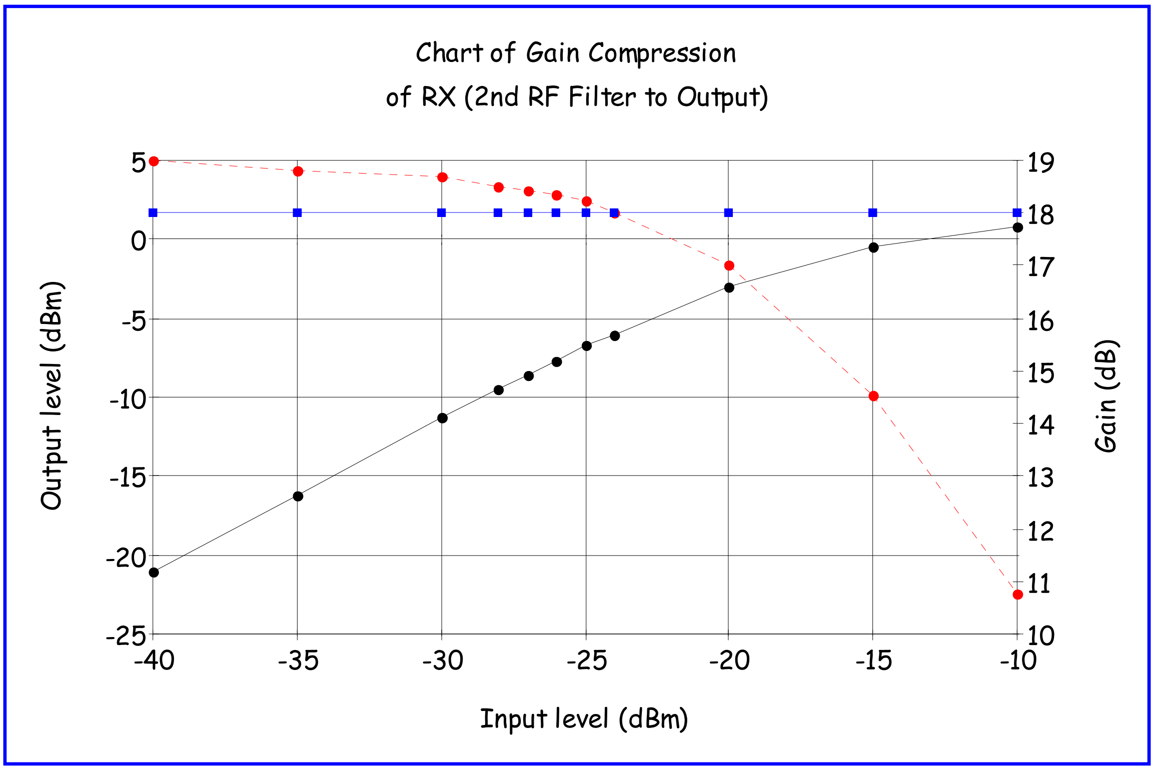
The difference measured using the dual dipole and + 18 dB preamp set-up is slightly lower than before. Possibly due to higher coax losses/ different location/time/part of sky. When tested with the horn antenna, a sensible result was obtained, indicating the horn is more optimum than the previous versions measured at the Observatory site.

Although the two preamps have different gains the noise figure is similar. The difference between the 2 Dual dipole tests (and the horn tests) are probably due to the effect of second stage noise figure on the sky noise measurement. The Dual dipole antenna is still performing slightly better than the horn at present, giving a greater Ground sky noise measurement.

The Cold sky /Ground difference although higher at 6.5 dB, was lower than calculations predict. Rough calculations using a 10 degrees K sky temperature predict 8 to 10 dB using the 18 dB and 29.5 dB preamps It will be interesting to see if there is any difference in readings with the 1st RF filter in circuit.

On Saturday morning, further testing with the 1st RF filter fitted, was less conclusive, although similar results were obtained. There was some initial variation in levels, possibly due to instabilty (which wasn't apparent Friday night) or there may have been close interference such as from a neighbouring PC. It was felt that the single stage preamp was more sensitive to variation. This may be a sign that the IF amplifier is nearing saturation with the high gain 1st RF amplifier in circuit.

Note that gain compression in amplifiers is earlier when noise is used, than when CW is used.



This graph is of the 2nd RF Filter through to the output.

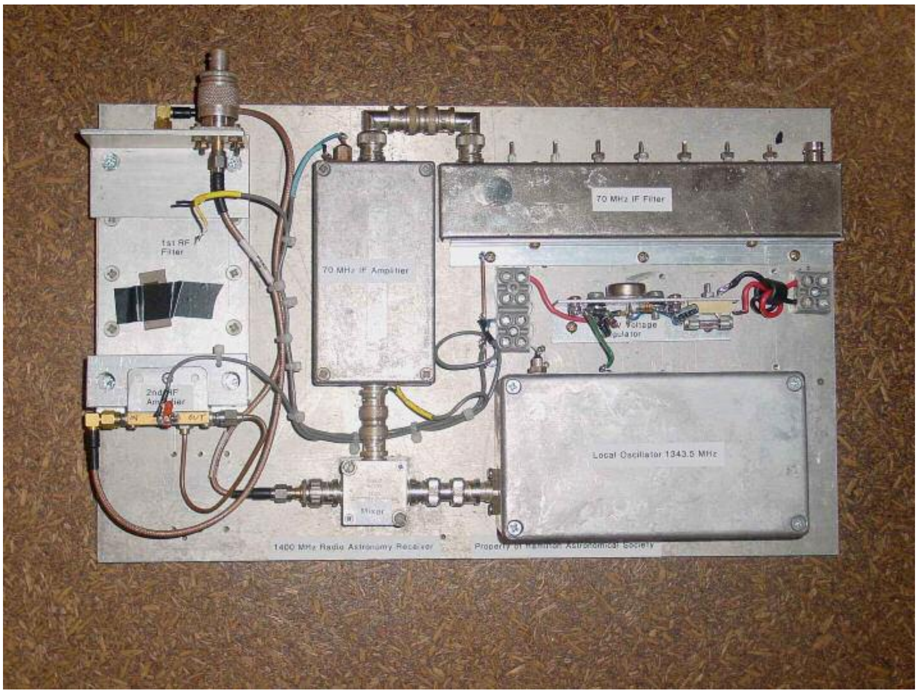
With a CW input signal, there appears to be gain compression occuring starting at –21dBm output (-40 dBm input)

Note that measured noise level has been high as –14 dBm

Equivalent calculated noise at 50Ω input for full RX –100.6 dBm

If we add to the –40 dBm input level the gain and losses of the 1st RF amp, filter, coax and 2nd amp, then gain compression starts at –104.5 dBm (with CW input)!!. This is ~ 4 dB below the equivalent level for a 50 Ω termination…

Further testing and investigation will involve the use of a variable 50Ω attenuator between the 2nd RF filter and the mixer, as there is suitable access and BNC connectors. This may show what effects there are, on the Ground /sky noise as a result of compression



Shown left is the reworked Receiver. The PSU is reworked with a single LM317HVK regulator (~ +18 to 25 v input). The 70 MHz filter is bracketted down on the chassis. A replacement 1343.5 MHz oscillator is fitted. The RF Amp and 1st RF filter are refitted on the PCB. There is suitable labelling to indicate modules.

On the morning of Saturday, 25 September, 2004, further tests were done at the observatory. The weather was wet, while temperature was around 15 degrees C.

The RX was assembled on the tables near the door, and further tests were done with the new preamp and filter. Power measurements were made on the Boonton RF power Meter.

The chart also shows the results of the new amplifiers and antennas, previously obtained at home (with different coax loss RG213). They are included for reference.

The coax FSJ-4 was remeasured and is about 13 metres long.

Tests were done with the R&S 2 GHz Attenuator fitted just before the mixer, to see if any compression effects were apparent.

Ground Sky Noise Tests	Ground Noise (dbm)	Sky Noise (dBm)	Difference (dB)
Dual Dipole (no Attenuator) at home**	-14.0	-20.5	6.5
Dual Dipole (no Attenuator) Grass	-13.6	-21	7.4
Dual Dipole (same) Garden near door	-13.5	-21	7.5
Dual Dipole (Attenuator fitted 0 dB)	-16.4	-23.4	7.0
Dual Dipole (Attenuator fitted 6 dB)	-23.19	-29.86	6.67
Dual Dipole (Attenuator fitted 10 dB)	-27.00	-33.66	6.66
Horn (no Attenuator) at home**	-15.0	-20.8	5.8
Horn (no Attenuator)	-14.53	-21.6	7.07

<u>Comments</u>

1) Higher Ground/ Sky noise measurements were obtained. Different environmental factors may have contributed to this, such as more open space or less local interference such as from PC's. The coax used was also different (RG213 vs FSJ-4)
2) The difference of 7.4 to 7.5 dB for the dual dipole is a good measurement, although there may still be some influence from spillover/ sidelobes of the antennas. For the dual dipole antenna, this equates to an antenna temperature (while looking at the cold sky) of the order of 33 degrees K (including 10 to 15 degrees cold sky.)
3) There is a small difference of 0.1 dB between the ground measurement in the open grass and the garden near the door. This may be slight impedance changes due to distances involved/ concrete in antenna pattern or that the garden was slightly warmer as it was closer to the building.
4) Inclusion of the attenuator decreased the ground/ sky difference. If there was significant compression in the IF amp, then the difference would have increased. Further work on the IF amp is still required however, as sun noise measurements will exceed its capabilities.
5) There was degradation in the differences, when the attenuator was fitted between the 2^{nd} RF filter and mixer. This seemed quite high, even though 60 dB + of gain preceeded it. There was a drop in level, even at 0 dB attenuation, due to inherent losses in the attenuator and associated coax cable.
6) The horn antenna (with 15 dB return loss) also shows an improved result, with a difference of 5.8 dB improving to 7.07 dB.
7) There was fine positioning involved with maximising the ground noise measurement.
8) The new replacement horn probe was received and fitting will be done at a later date. An alternative N (male) single hole fitting (for the horn) will be attempted to be located, as this will reduce the distance between the probe and amplifier. This should enable a shroud to be fitted. At present the preamp extends past the edge of the front reflector. If neccesary the filter can be attached to the RX, reducing the size of the adaptation to the horn antenna. Robin was looking a plastic bucket or similar to fit on the back of the horn antenna.

9) The dual dipole still has an edge in Ground/ Sky noise over the horn. Some documentation indicates that simple horn type antennas at 1.4 GHz may be inferior. W2IMU dual Mode Horns are recommended. (Page 1-17 ARRL UHF/Microwave Projects manual Vol 2) This may change when used in the dish.
10) We are almost at the point of testing with the dish. A clear weekend, both weatherwise and wrt other commitments is needed for this.