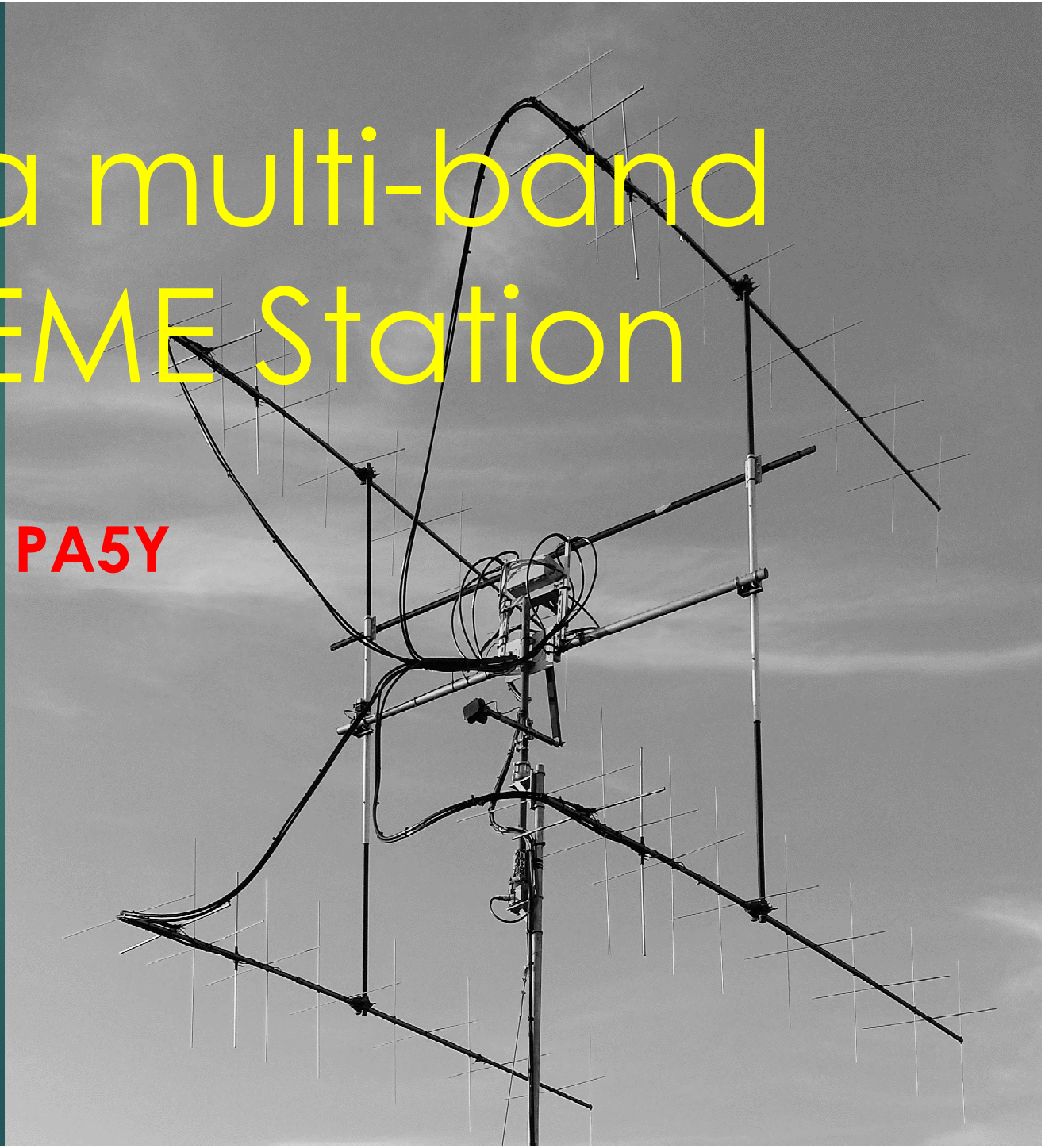
Building a multi-band Tropo & EME Station

CONRAD FARLOW PA5Y



Introduction

- Show the evolution of my successful multiband eme and tropo station – None of it is rocket science!
- Mechanical ideas on a budget
- Discuss system optimisation including RX/TX path
- Choice of antennas
- Discuss the tools used for optimisation
- Discuss avoiding noise from your own shack
- Station configuration for EME and Terrestrial DX/Contests
- A few operating hints that work for me especially in activity contests
- Future plans

Who am I?

- Came here from the UK to work as an RF Engineer in May 2015
- EME and VHF Dxer since 1988, first CW EME contact 24/03/1991
- First 70cms CW EME contact 26/11/94
- 198 DXCC on 6m
- Location is farm with not many neighbours – only 3 in 800m radius
- First QRV as PA5Y on 2m with a 8 ele LFA and IC746 09/06/2015
- Humble beginnings – preamp in shack -100W first QSO CT1HZE!
- Added 3CX800 amplifier loaned to me by PA2CHR
- First EME with this system no elevation ZL2ADU! I was amazed!

Stage 1 Humble beginnings

- Found the location and took a small radio and 6m/2m/70cms and triband yagi as a 'sniffer'
- Blame PA1BVM he actually found the house on the internet ☺
- Mmm no noise RX must be deaf
- Went back 2nd time with a preamp – still no noise
- Property was rented – made 100% sure antennas OK, no neighbours, no problem!
- Nearest neighbour has a manitou loader and helps with antennas
- House is huge 6 bedrooms – just me – was hard to manage – more later

Humble beginnings

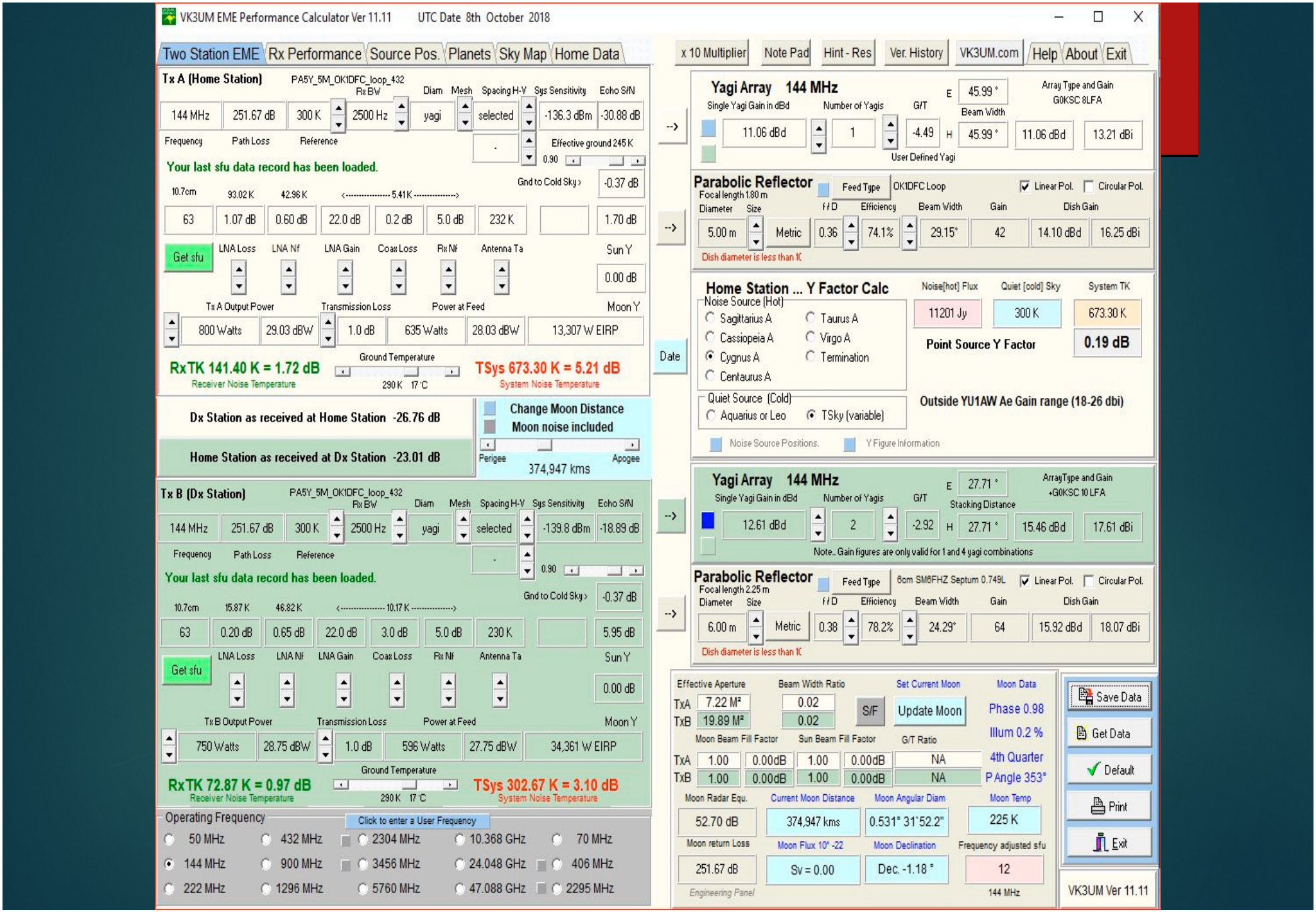
- Single 8 ele LFA bought from a guy in Zwolle first time out of N

Humble beginnings getting ready for system analysis

- 20m of Ultraflex 10
- ARR Gaasfet LNA in the shack 0.6dB Noise Figure
- IC746
- 3CX800
- No elevation at all
- Amazingly with ground gain I could work stations when moon up to 20 deg
- Most impressive for me was HV0A when moon was 22 deg elevation!
- Lets look at the system details with an optimisation tool

Humble beginnings – Analysis tool

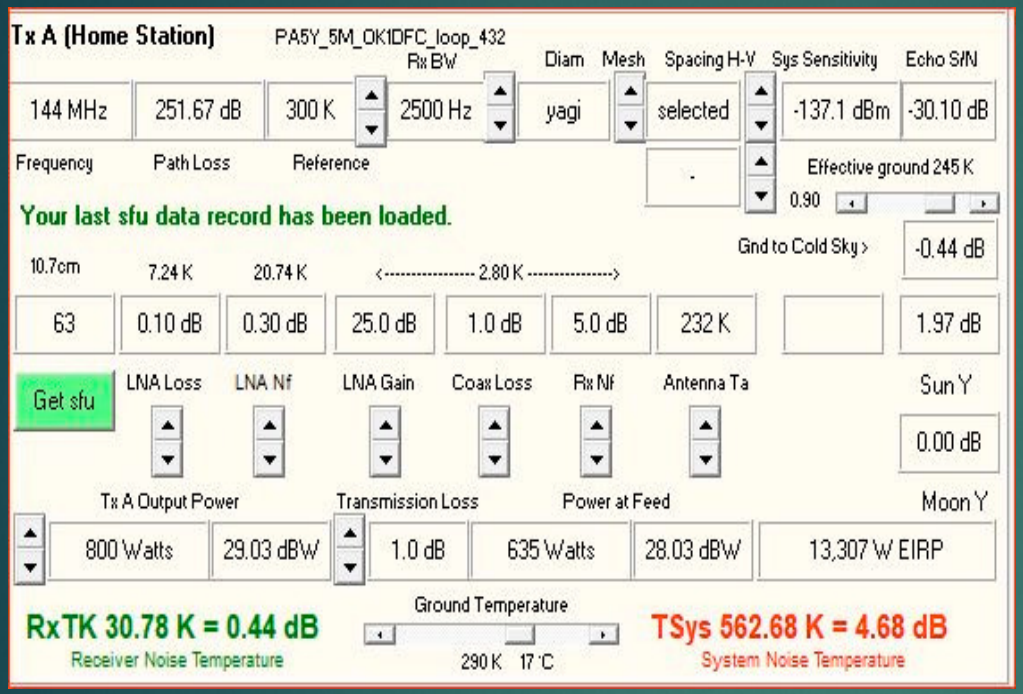
- VK3UM my friend Doug now SK wrote great tool called EME Calc
- Important info
  - Coax loss – 20m of Ultraflex 10 is 0.97dB
  - Loss of relay and connectors 0.1dB
  - LNA noise figure 0.6dB
  - TX Power 3CX800 – ahem 800 watts
- Not really system design just what I had available - surprising
- Next slide shows analysis


VK3UM EME Performance Calculator Ver 11.11
UTC Date 8th October 2018
Two Station EME
Rx Performance
Source Pos.
Planets
Sky Map
Home Data
x 10 Multiplier
Note Pad
Hint - Res
Ver. History
VK3UM.com
Help
About
Exit
Tx A (Home Station)
PA5Y_5M_OK1DFC_loop_432
144 MHz
251.67 dB
300 K
2500 Hz
yagi
selected
-136.3 dBm
-30.88 dB
Frequency
Path Loss
Reference
Rx BW
Diam
Mesh
Spacing H-V
Sys Sensitivity
Echo S/N
Effective ground 245 K
Your last sfu data record has been loaded.
Gnd to Cold Sky >
-0.37 dB
10.7cm
93.02 K
42.96 K
5.41 K
63
1.07 dB
0.60 dB
22.0 dB
0.2 dB
5.0 dB
232 K
1.70 dB
Get sfu
LNA Loss
LNA Nf
LNA Gain
Coax Loss
Rx Nf
Antenna Ta
Sun Y
0.00 dB
Tx A Output Power
Transmission Loss
Power at Feed
Moon Y
800 Watts
29.03 dBW
1.0 dB
635 Watts
28.03 dBW
13,307 W EIRP
Ground Temperature
RxTK 141.40 K = 1.72 dB
Receiver Noise Temperature
290 K 17 °C
TSys 673.30 K = 5.21 dB
System Noise Temperature
Dx Station as received at Home Station -26.76 dB
Home Station as received at Dx Station -23.01 dB
Change Moon Distance
Moon noise included
Perigee
Apogee
374,947 kms
Tx B (Dx Station)
PA5Y_5M_OK1DFC_loop_432
144 MHz
251.67 dB
300 K
2500 Hz
yagi
selected
-139.8 dBm
-18.89 dB
Your last sfu data record has been loaded.
Gnd to Cold Sky >
-0.37 dB
10.7cm
15.87 K
46.82 K
10.17 K
63
0.20 dB
0.65 dB
22.0 dB
3.0 dB
5.0 dB
230 K
5.95 dB
Get sfu
0.00 dB
Tx B Output Power
Transmission Loss
Power at Feed
Moon Y
750 Watts
28.75 dBW
1.0 dB
596 Watts
27.75 dBW
34,361 W EIRP
RxTK 72.87 K = 0.97 dB
TSys 302.67 K = 3.10 dB
Operating Frequency
Click to enter a User Frequency
50 MHz
144 MHz
222 MHz
432 MHz
900 MHz
1296 MHz
2304 MHz
3456 MHz
5760 MHz
10.368 GHz
24.048 GHz
47.088 GHz
70 MHz
406 MHz
2295 MHz
Yagi Array 144 MHz
Single Yagi Gain in dBd
Number of Yagis
G/T
Beam Width
Array Type and Gain
11.06 dBd
1
-4.49
45.99 °
11.06 dBd
13.21 dBi
User Defined Yagi
Parabolic Reflector
Feed Type
OK1DFC Loop
Linear Pol.
Circular Pol.
Focal length 1.80 m
Diameter
Size
F/D
Efficiency
Beam Width
Gain
Dish Gain
5.00 m
Metric
0.36
74.1%
29.15°
42
14.10 dBd
16.25 dBi
Dish diameter is less than 1C
Home Station ... Y Factor Calc
Noise Source (Hot)
Sagittarius A
Cassiopeia A
Cygnus A
Centaurus A
Taurus A
Virgo A
Termination
Quiet Source (Cold)
Aquarius or Leo
TSky (variable)
Noise[hot] Flux
Quiet [cold] Sky
System TK
11201 Jy
300 K
673.30 K
Point Source Y Factor
0.19 dB
Outside YU1AW Ae Gain range (18-26 dbi)
Noise Source Positions.
Y Figure Information
Yagi Array 144 MHz
Single Yagi Gain in dBd
Number of Yagis
G/T
Stacking Distance
ArrayType and Gain
12.61 dBd
2
-2.92
27.71 °
15.46 dBd
17.61 dBi
+G0KSC 10 LFA
Note.. Gain figures are only valid for 1 and 4 yagi combinations
Parabolic Reflector
Feed Type
6cm SM6FHZ Septum 0.749L
Linear Pol.
Circular Pol.
Focal length 2.25 m
Diameter
Size
F/D
Efficiency
Beam Width
Gain
Dish Gain
6.00 m
Metric
0.38
78.2%
24.29°
64
15.92 dBd
18.07 dBi
Dish diameter is less than 1C
Effective Aperture
Beam Width Ratio
Set Current Moon
Moon Data
TxA 7.22 M²
TxB 19.89 M²
0.02
0.02
S/F
Update Moon
Phase 0.98
Illum 0.2 %
Moon Beam Fill Factor
Sun Beam Fill Factor
G/T Ratio
4th Quarter
P Angle 353°
Moon Radar Equ.
Current Moon Distance
Moon Angular Diam
Moon Temp
52.70 dB
374,947 kms
0.531° 31'52.2"
225 K
Moon return Loss
Moon Flux 10^-22
Moon Declination
Frequency adjusted sfu
251.67 dB
Sv = 0.00
Dec. -1.18 °
12
144 MHz
Engineering Panel
Save Data
Get Data
Default
Print
Exit
VK3UM Ver 11.11
Date

Stage 1: System analysis

- Mmm echoes are -30.88dB threshold for detection on JT65B is -30 dB more like -29 dB
- Yet I could often see my own echo at -25 at moonrise and moonset optimally when moon was at 6 deg elevation – why?
- **Ground Gain** – the Netherlands is flat !
- This makes for excellent ground gain in my case around 6dB
- Lets see if putting a better preamp at masthead would help?
- Noise figure 0.3dB (easy nowadays) loss before preamp 0.10dB

Stage 1: System analysis



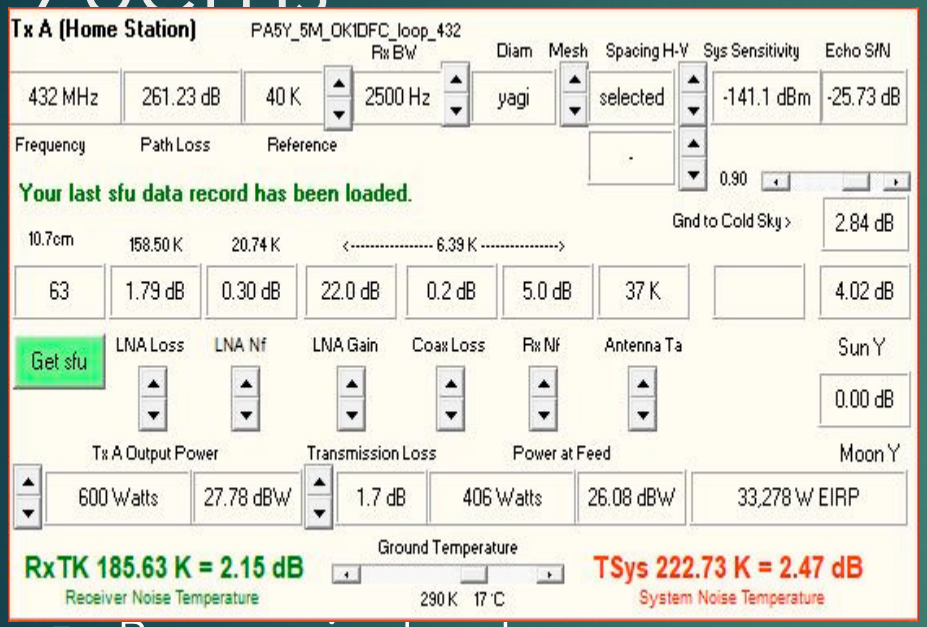
- Answer HARDLY at all! But on EME this might be considered worth it
- Personally I think for casual single yagi EME don't bother
- However keep coax losses close to 1dB and noise figure around 0.6
- Use analysis and ignore ham radio 'folk lore' or marketing hype

System analysis – new scenario 70cms

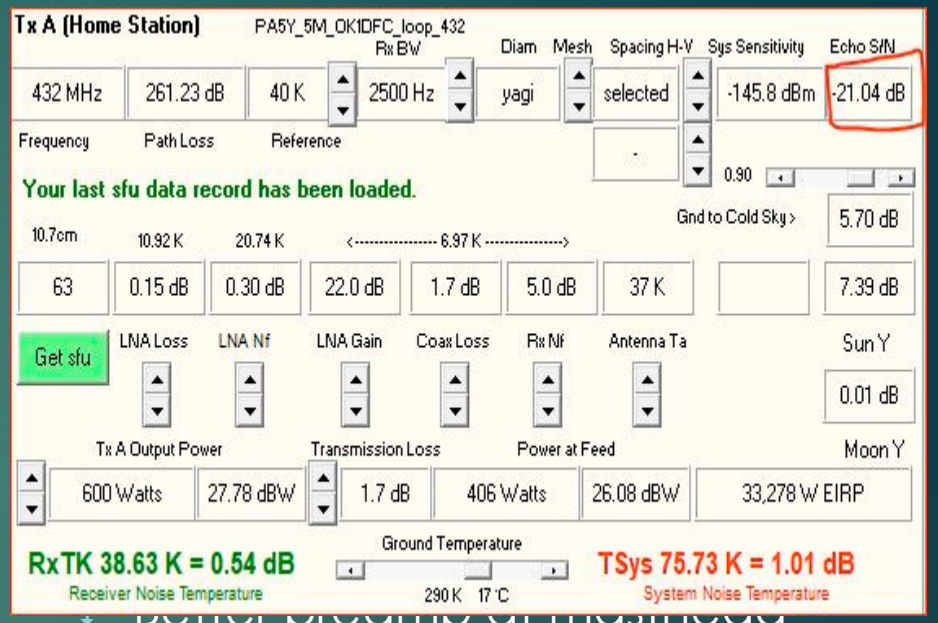
- 20m of Ultraflex 10 – now loss is 1.74dB
- HA8ET Xtra 70 LNA 0.6dB Noise Figure OK
- TS2000
- 3CX800 now 600W
- Antenna now an 8.5wl yagi on a 6m boomlength much more gain
- No elevation at all

Lets look at the system details with same tool

System analysis – new scenario 70cms



- Preamp in shack
  - That's pretty good, 6m long yagi and 600W echo is -25.7dB



- Better preamp at mastHead
  - WOW what a difference over 5dB better echoes
- Definitely Worthwhile but why?

Time to get serious about 2m EME

Time to get serious about 2m EME

- I was on a tight budget and was offered 2 used I0JXX 8 ele Xpols
- Xpols and an adaptive RX were essential – more later
- 2 antennas not enough so I bought 2 more new ones – 4 yagis
- Xpols need fiberglass – no metal close to the antenna
- For medium light yagis the well known green 38mm GRP poles are perfect
- Used metal in the middle for strength
- Plastic plugs in the end so antennas do not crush the fibreglass
- Split aluminium tube so that clamps can be tightened
- Not high only 5,3m to top antennas – on a trailer

Some details about the GRP tubes

- The fiberglass poles are well known here, every single hamfest 1.25m long, 38mm OD, strong! 30 EUR for 6

- Thanks to Eric PE1RLF the pole inserts were made

Some details about the GRP tubes

- 30cm is inside the aluminium tube bored out to be a tight fit for GRP, again the work of PE1

- More cheap solutions

Detail – Ugly yes but it works!

- Important keep metal away from antennas – coax is metal
- Ecoflex 15 has very low loss but its heavy - again it was available
- It goes to the back of the antennas then grouped together
- This definitely helps reduce pattern distortion array behaves well
- I TX circular, linear stations see me same signal H & V
- Adaptive RX stations see me 45 or 135 deg except at low elevations
- Low elevations H component has ground gain so TX elliptical
- Or of course there is something wrong with their set up!

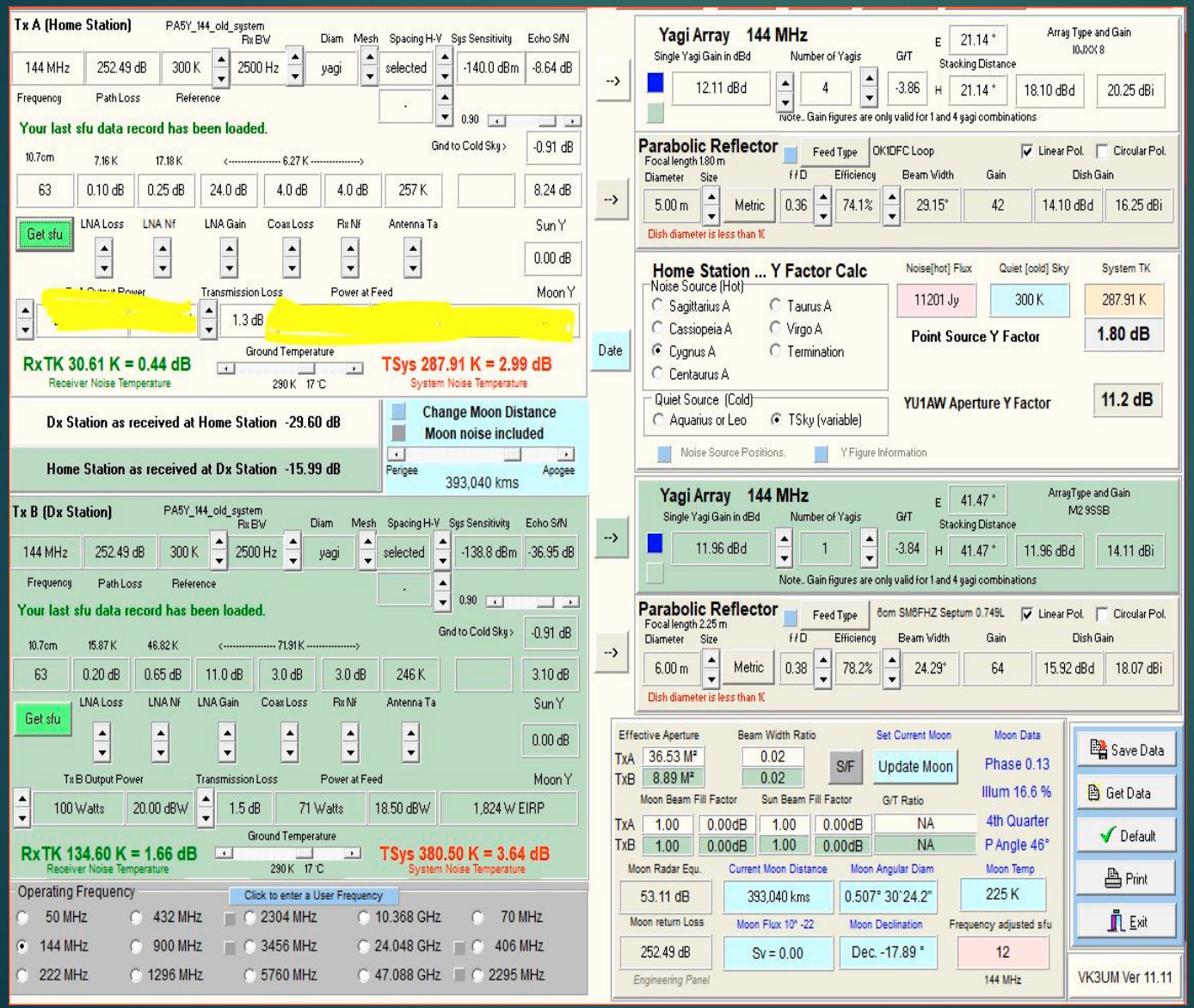
A little discussion about TX pol

- Faraday rotation is a problem on 2m.
- Many stations TX linear H pol and RX linear H pol
- Some stations appear once then go away – how to maximise your chances?
- What if you could TX at all angles from 0 - 360 deg at the same time?
- You can – TX circular
- You lose no more than 3dB MAXIMUM but on EME that is a LOT
- So increase power by 3dB?
- Most of the time you lose more like 1.2 – 1.6dB polarisation is seldom perfectly aligned

What about RX polarisation?

- Polarisation is constantly changing on 2m sometimes fast sometimes not so fast – you can get locked out and cannot hear anyone
- How can you catch it all?
- MAP65 allows adaptive RX that optimises signal to noise
- Not great for weak signals but most signals with 4 yagis are not weak
- What about the weak stuff?
- For signals near the noise you can RX at 0, 45, 90 and 135 deg
- You must be very close to optimum
- Aim for me was to make the most of my time on air

Lets analyse this Ugly system



Lets analyse this Ugly system

- The slide is an accurate representation of performance
- Except when it rains heavily and then my TX suffers
- Circularity becomes elliptical due to uneven radiation H and V
- The DX station is a single 9 ele yagi with 100W
- Its marginal until I see ground gain
- Smallest station worked 8 ele 40W and it was easy at the time
- New system must be better to get to the next layer of the onion
- SHOW OFF TIME – 2m DXCC in 1 year from starting
- Total 2m DXCC right now = 124
- 2m Squares 791

Really Showing off #1

- I won the ARRL international EME contest in 2016 with 4 medium yagis
- Beat 8 yagi stations with twice the boomlength
- Why because I can hear them – you must copy who is calling
- Will not do it again for a few years – it's exhausting

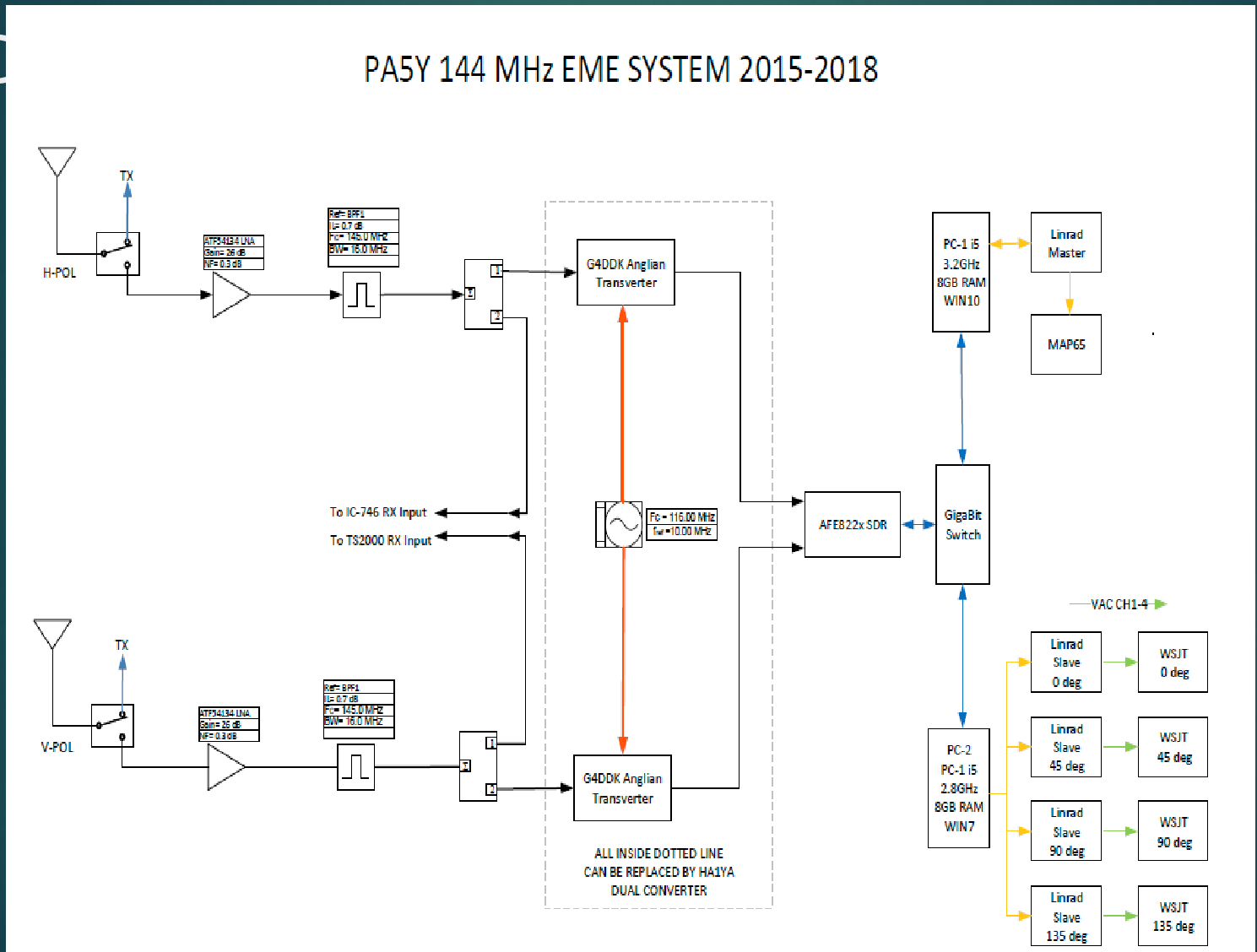
SINGLE OPERATOR, ALL MODE, 144 MHZ			
PA5Y	1,684,900	203	83
OK1DIX	1,482,000	190	78
SM4GGC	762,500	125	61
LZ1DP	701,800	121	58

Really Showing off #2

Shack and station configuration

- More on the EME setup because it is the most sophisticated
- I will talk about reducing noise later – own section
- Hardware HA1YA dual channel coherent transverter
- Afedri AFE822x dual channel SDR
- TX IC746 locked to 30 MHz tripled from 10MHz
- Linrad – masters and slaves – for NB and network distribution
- Linrad the BEST for weak CW EME
- MAP65
- WSJT10, WSJT-X, MSHV on 0 and 90 deg (H and V)
- WSJT10 on 45 and 135 as well
- VAC or lately Voice Meter banana for virtual audio distribution
- Also TS2000 and UMC402HD soundcard 1 channel TS2000 other IC746
- I like a REAL radio as well – one of them is sure to decode

Shack and station c



This is fine but what about terrestrial

- All my contest success has been achieved with this system
- TX circular , RX H and V
- EA8 type tropo plus MS and Es changes polarisation!
- In contest all the guys using verticals hear me
- I listen one ear H and one ear V, Airplanes cause Pink Floyd effects!
- There seems to be some advantage on the horizon with noise
- Noise varies at different Azimuths – sometimes it is weak on V allowing things to be heard
- You have to experiment.

Activity Contests

- Why do them?
  - Set yourself small goals, great to test system improvements
  - Get back to the magic of just having QSOs
  - Don't be a DX snob
  - We need to use the bands!
  - The bloody Brits have 200 QSOs in 2.5hrs on Tuesday evenings
  - We must get the activity levels up
  - Maybe little contest groups
  - Don't have to win just have to be part of it
  - We can't all win, there are DX snobs in the room who could beat me!

Activity contests activity levels

- With a medium sized single yagi station you can work these distances
  - 800-1000km every week on 2m - more with a few MS QSOs
  - 700-800km on 70cms
  - 500-650km on 23cms
  - 800-1700km on 6 and 4m with MS more with summer Es
- QSO numbers:
  - 50 -100 QSOs on 2m
  - 40-70 QSOs on 70cms
  - 20 -35 QSOs on 23cms harder but great fun
  - 30-35 QSO on 6m
  - 30-40 QSO on 4m because we are quite rare ☺

Contest tips – equipment

- You must get a band scope these are essential
- I use SRP2 Pro on 4m, 70, 23cms
- I use Afedri AFE822x with transverter from EME system on 2m
- I use another Afedri AFE822x in undersampling mode on 6m
- HDSDR is a nice bandscope – with Omnirig to move the main radio
- 50 is IC7300 bandscope is a waste of time use the above
- 70MHz is an IC7300
- 144 is an IC746
- 432 is a TS2000
- 1296 is a TS2000

Contest tips operating

- It varies by band but there are a lot of UK stations on later
- Hungry for QSOs if we make noise they will beam this way
- Of course they also have noise problems and HUGE QRM
- Be persistent
- Be QRV regularly then people come looking for you
- Determine CQ and Search and Pounce by practice
- Do call CQ
- Do use CW – LEARN IT or LEARN it again ☺ On 23cms MOST DX is that way
- Lots of DLs to work some are a good distance
- I wish KST was not necessary but it is, strike a balance? Hard!
- Use MS on 6 and 4m especially – less so on 2m
- Use MSHV it's more contest friendly
- FT8 produces illegal QSOs rules expect FULL locator do not do it!
- Produce good TX audio – this is not always easy but try

Noise

- I have a quiet location but trust me – we create a LOT of noise ourselves
- We like the convenience of our DX spotting tools, KST, Digi programs
- We have audio to radio interfaces, PC to radio interfaces
- Some people use switch mode PSUs – I DO NOT GENERALLY
- Well I have telecom approved ones for SSPAs they are off during RX
- You must be methodical about it
- Start running LNA and Radio from a battery all lights off all internet off
- Map the Azimuth – turn AGC off use an AC voltmeter attached to speaker out
- Start to introduce things one by one

Noise

- **Main noise sources and what to do**
- Microham interfaces – all types – they are very badly designed from an EMC perspective, thankfully I found this out before I bought any
- Use a simple audio interface, transformer coupled and in a shielded enclose – don't ground both sides of the transformer!
- USB connections – use high quality cables the expensive ones from Media Markt are good
- Use a wireless mouse and keyboard these radiate a lot
- Ham type SMPSU they are AWFUL all of them I tried 6 brands
- PC SMPSUs are very very BAD! Don't use them
- Meanwell have a good reputation, in my experience they are not great

Noise (continued)

- For ethernet use shielded twisted pair make sure connectors are grounded – the ones supplied by KPN are excellent!
- Make sure router is metal and uses grounded sockets
- Monitors – oh boy fixing this is hard, Dell seem to be best, LG are BAD
- I had one that was clean except on 70cms
- Buy LOTS of clip on ferrites – the Wurth Electronik ones are good
- Fit them at each end of the cable use multiples I have over 100 clip on ferrites!
- Have a ground floor shack and shield it completely if this is viable
- You will find your main problems quite quickly
- I guarantee that you will be surprised
- Use shielded cables and metal boxes for anything up the

Noise continued

- Use RG142 or Ultraflex 7 for interconnects in the shack including 10 MHz reference signals
- You need 100dB screening efficiency from 50MHz to 2.5GHz
- RG58 is NOT GOOD ENOUGH
- Remember you have to hear stuff before you can work it
- Go through this and I will be surprised if you do not see significant improvements
- Learn how to properly set your gain for your situation
- For EME mount your antennas low down
- Do you need a band pass filter – I use them on all bands
- In my case AFTER the preamp without I have problems from De Mortel

Noise from external sources

- OK you did all that and you still have terrible noise
- There are still some things that will help
- System gain – turn off your AGC and measure the audio level
- Look for the worst case turn on AGC if your S meter is moving then your sensitivity is being reduced
- I NEVER use AGC on EME or MS
- Now reduce gain until turning the AGC on does not change your audio amplitude this is now your BEST sensitivity for your situation
- Chose an antenna with a clean pattern
- This reduces the noise floor from directions that you are not interested in
- This does not help if you are beaming at the noise source
- Consider higher bands – the problems are less

Existing band by band summary

- 50 MHz – Antenna PA5070-11-6 – 6m boom length Xtra6 LNA in the shack – band pass filter from antennas amplifiers, IC-7300
- Afedri AFE822x SDR for band-scope
- QRV from May 2017
- DXCC in 13 weeks last summer!
- Not QRV since May 2018
- Current score 108 DXCC
- 6 DXCC on EME
- 372 squares

Existing band by band summary

- 70 MHz – Antenna PA5070-11-6 – 6m boom length Xtra4 LNA in the shack – band pass filter from antennas amplifiers, IC-7300
- Not QRV since May 2018
- Current score 37 DXCC
- 147 squares
- Not super active on 4m but like the band

Existing band by band summary

- 144 MHz – Antenna 4 x 8X8JXX2– 6m boom length masthead LNAs, 0.3dB NF band pass filters from DD7MH , IC-746 and TS-2000
- HA1YA dual channel transverter and Afedri AFE822x
- Not QRV since May 2018 apart from 4L ‘lash up’
- Current score 124 DXCC
- 791 squares
- My main band or at least was…..

Existing band by band summary

- 432 MHz – Antenna BV OPT70 8.5WL– 6m boom length
  VHF design LNA 0.3dB NF
- band pass filter from DD7MH, TS2000
- SDR Play RSP2Pro
- Current score 28 DXCC
- 124 squares
- Almost all from contests – some EME
- Most notable QSOs TG9CHR single yagi EME and 3DA0MB
  2 yagis

Existing band by band summary

- 1296 MHz – Antenna PA1296-70-6– 6m boom length VHF design LNA 0.3dB NF
- band pass filter from Tweedehands.nl PA built excellent!
- TS2000
- SDR Play RSP2Pro
- Current score 14 DXCC
- 66 squares
- Almost all from contests – only 5 EME QSOs
- I can always work OK stations in the contest EVERY week
- My new favourite band??

Where did I go?

- Owner of house returned from USA with family I had to move 60m
- Renovated small adjacent farmhouse for me – was some workers living there
- Built me a brand new shack and machine room for things with blowers
- I have about 50 x 25m to put up antennas
- I have a new Versatower BP60HD
- No concrete use ground screws
- Its up and I am QRV on 6m in time for C21GJ – worked him
- Some noise from neighbours 266-275 deg but not bad
- North through to South open fields
- Perfect moonrise!

Versatower

Versatower with antenna

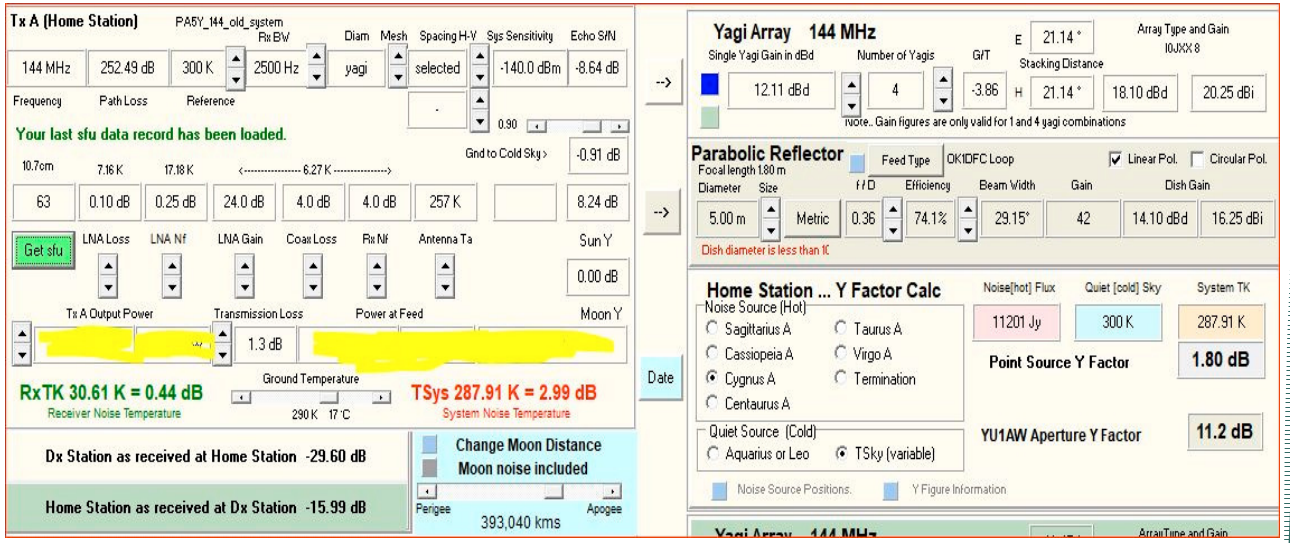
Shack – when brand new

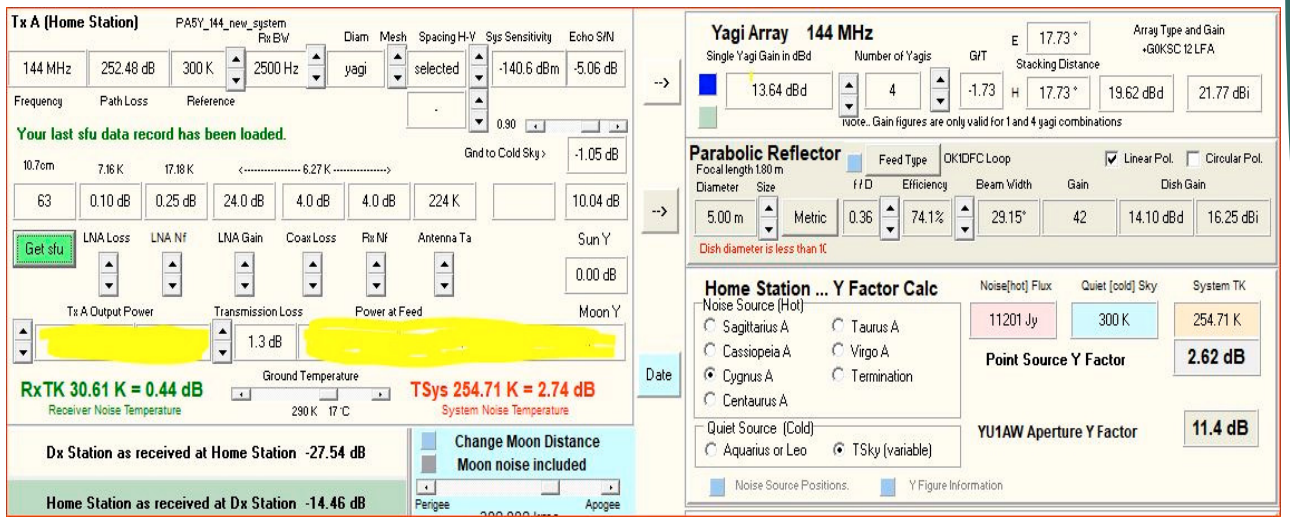
Future plans in order of completion

- Versatower this will be VERY soon
  - PA5070-11-6
  - PA144-12-7
  - PA432-27-7 this will have elevation for a little EME fun
- New 12m HD Kokermast
  - Stage 1 – 2m dish dual band ring feed for 23 and 13cms , 120W
  - Stage 2 add 1m offset dish, WG feed, 0.6dB NF LNA, 20W
- 9m Bouwlift new EME system for 2m
  - 4 x PA144-XPOL-26-8 later slide shows improvement
- 12m Hazer mast
  - PA50-XPOL-14-9 Xpol 6m EME with adaptive RX

Future plans in order of completion

- 5m Prime Focus dish
  - 23cms first SM6FHZ
  - 70cms with exciting new feed from SM6FHZ





New 2m system improvement

Questions

- Any questions?

- Thankyou to Hans, DKARS and ASTRON for hosting the event
- Thanks for listening

- 73
- Conrad PA5Y