Moonbounce - part II

Building a small high performance station

Mick Price - HADARC April 2024

Part II

The Low Down

- Why 70cm
- Background - why
- Design choices
- Results

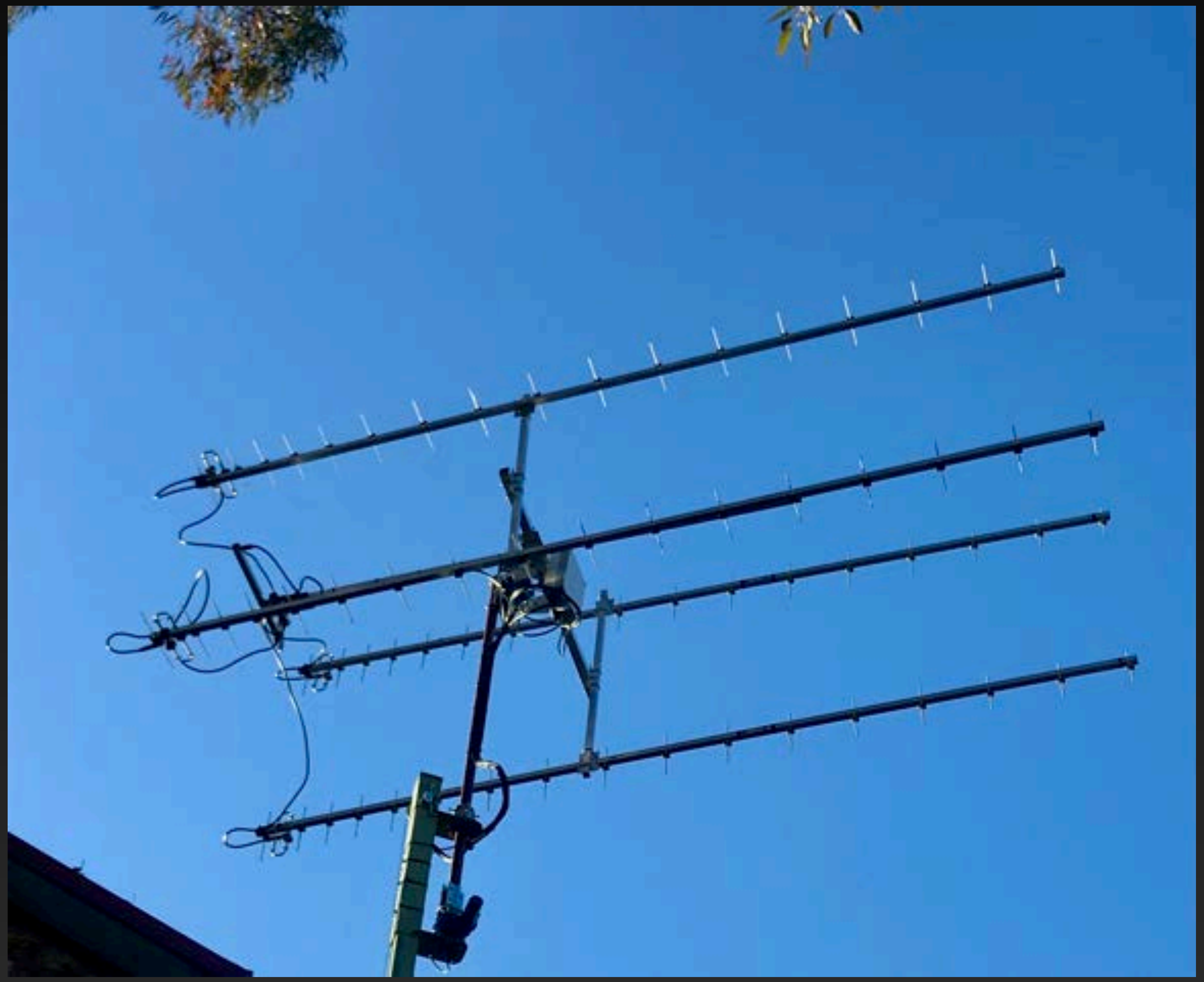
Why 70cm

'Living in the city..'

- High gain array vs 2m for size
- No room for a dish (23cm)
- There are good X-pol 70cm yagi available i.e. YU1CF
- Adaptive polarisation provides benefit to small stations

Bigger is better?

Or the quest to work more DX



- 2H+2V 18element LFA
- Gain ~21dbi
- 2018

- 4x 15element X-pol
- Gain 21.4dBi
- 2021

- 4x 21 element X-pol
- Gain 24.1dBi
- 2022

Part II

The Low Down

- Background - to making good design choices

$$Pr = Pt - L + Gt + Gr$$

What's the goal here?

Getting a signal to the moon and back

RX signal in dB

Path loss is ~261dB

Gain of RX

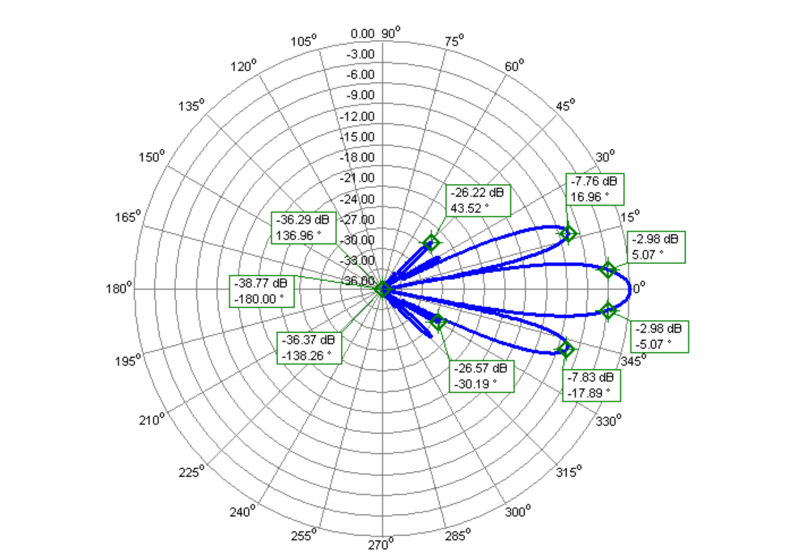
$$P_r = P_t - L + G_t + G_r$$

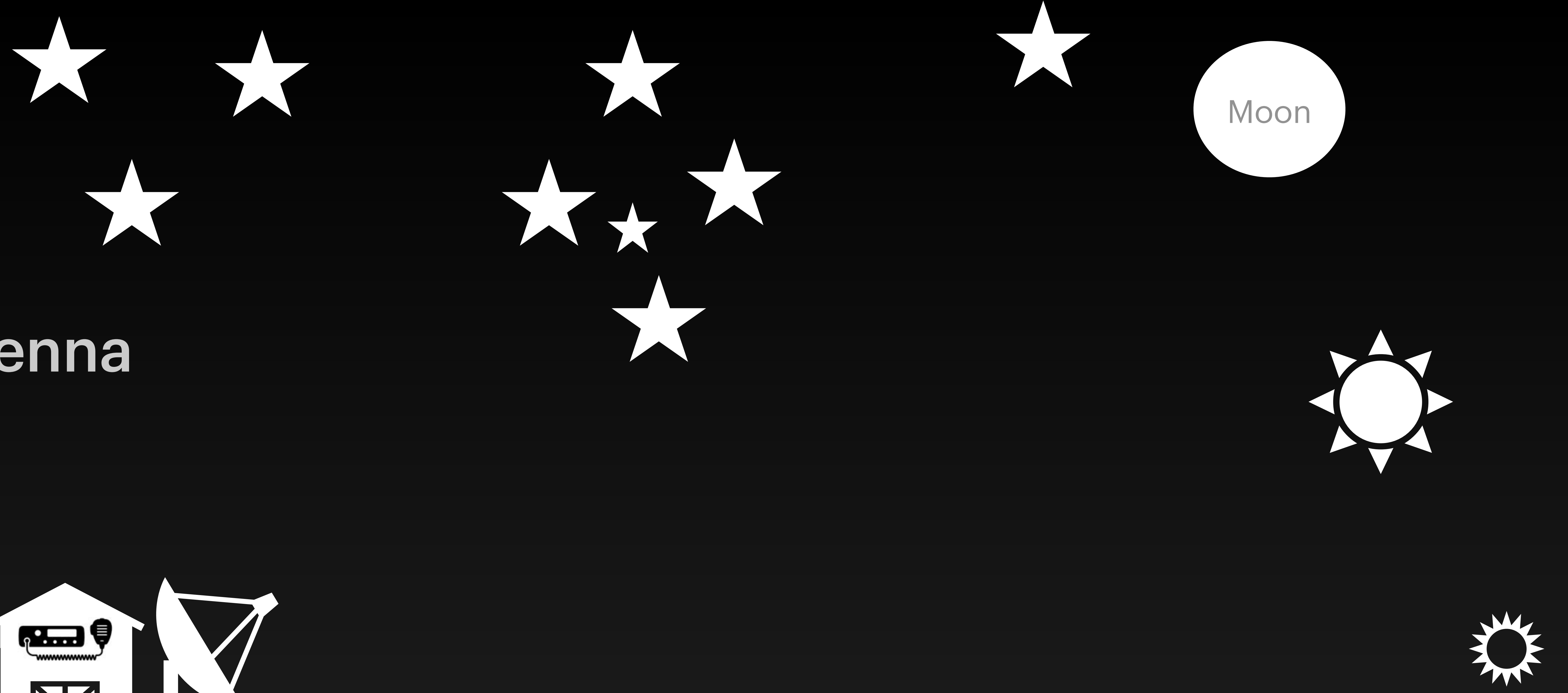
TX power in dBW

Gain of TX antenna

Its not just DX your antenna is picking up

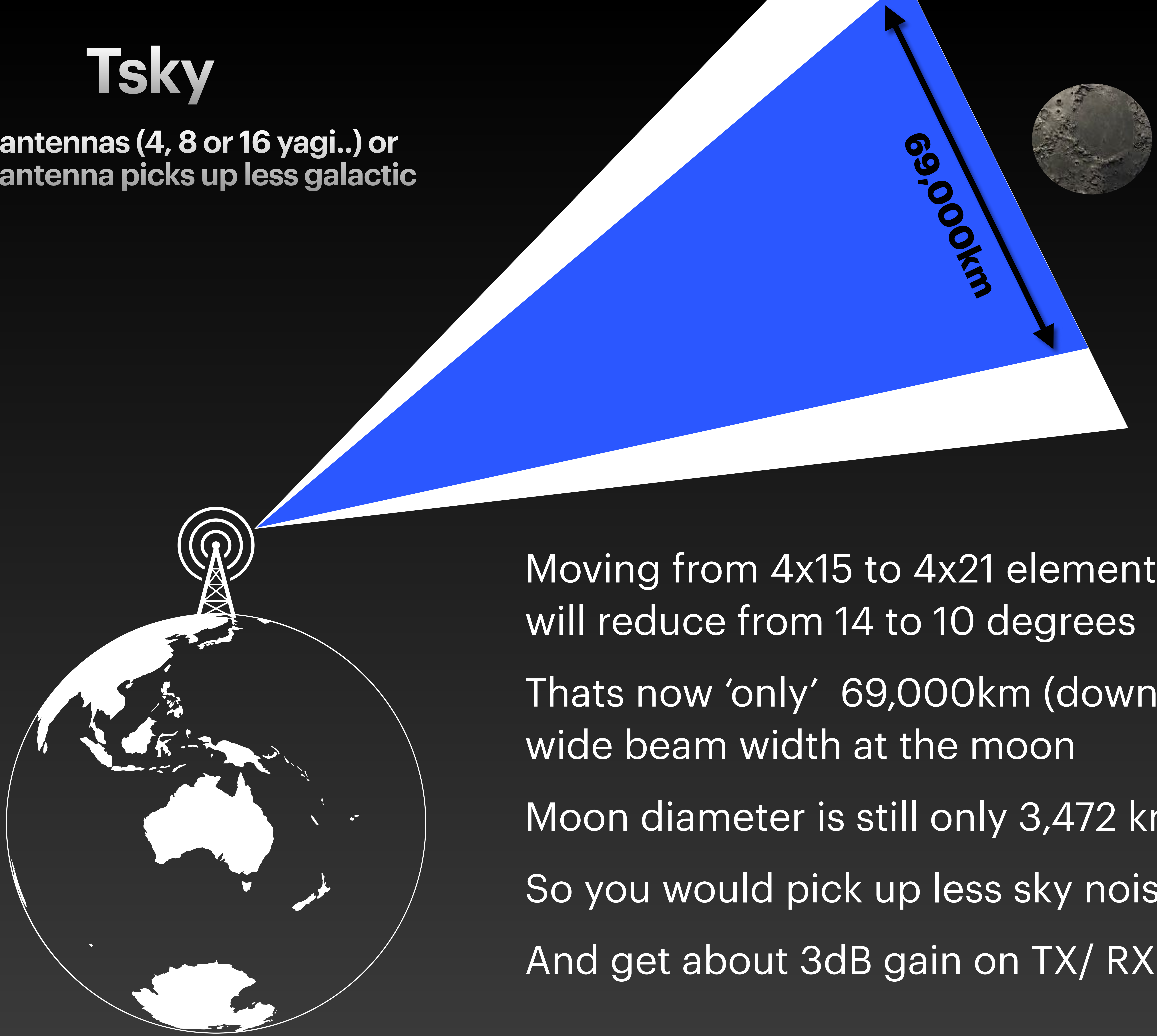
The moon is 0.5 degree wide but my antenna 3dB beam width is 10 degrees…….





Tsky

More antennas (4, 8 or 16 yagi..) or longer antenna picks up less galactic



Moving from 4x15 to 4x21 element yagi the beamwidth will reduce from 14 to 10 degrees

Thats now ‘only’ 69,000km (down from 104k km) wide beam width at the moon

Moon diameter is still only 3,472 km

So you would pick up less sky noise

And get about 3dB gain on TX/ RX


Neighbours make more noise than you think....
33KV High Voltage distribution line
VK2CMP - when I win lotto I'm buying an antenna farm


There are now 11 solar panel installations <120m (circle) from VK2CMP as at 2023
www.nearmaps.com - 2023


No. Solar Installations <120m
12
9
6
3
0
1
2
4
4
4
7
9
10
11
2015
2016
2017
2018
2019
2020
2021
2022
2023
In 2009 there was only 1 solar panel installation <120m (circle) from VK2CMP
www.nearmaps.com - 2015

$SNR = Pr - Pn$

Its the noise that stops you making that contact. This can be from space, atmosphere, neighbour hood QRM, your RX chain and even from within your house and shack

Signal to Noise Ratio

=

Power receive signal - Power noise

- Have you ever missed out on a station because he/she was in the noise?
- AT VK2CMP I can not work stations off the moon below 7 degrees elevation unless they are a big gun. Yet using the same antenna I can work them at 8 degrees

$$SNR = P_r - P_n$$

$$SNR = (P_t - L + G_t + G_r) - P_n$$

What if we design with two aims in mind;

1) the best possible RX signal and

2) least possible noise

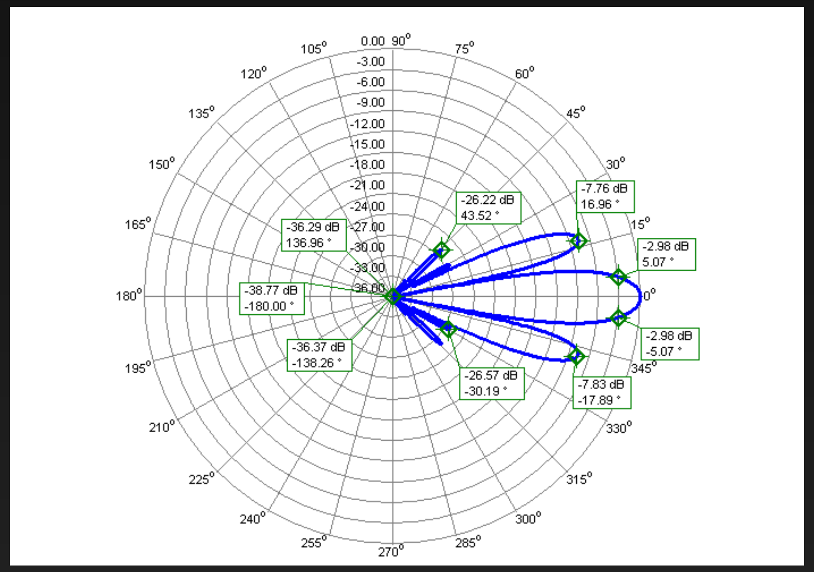
Deadset - so if I decrease my noise then I will hear smaller stations? Its like having a bigger antenna!

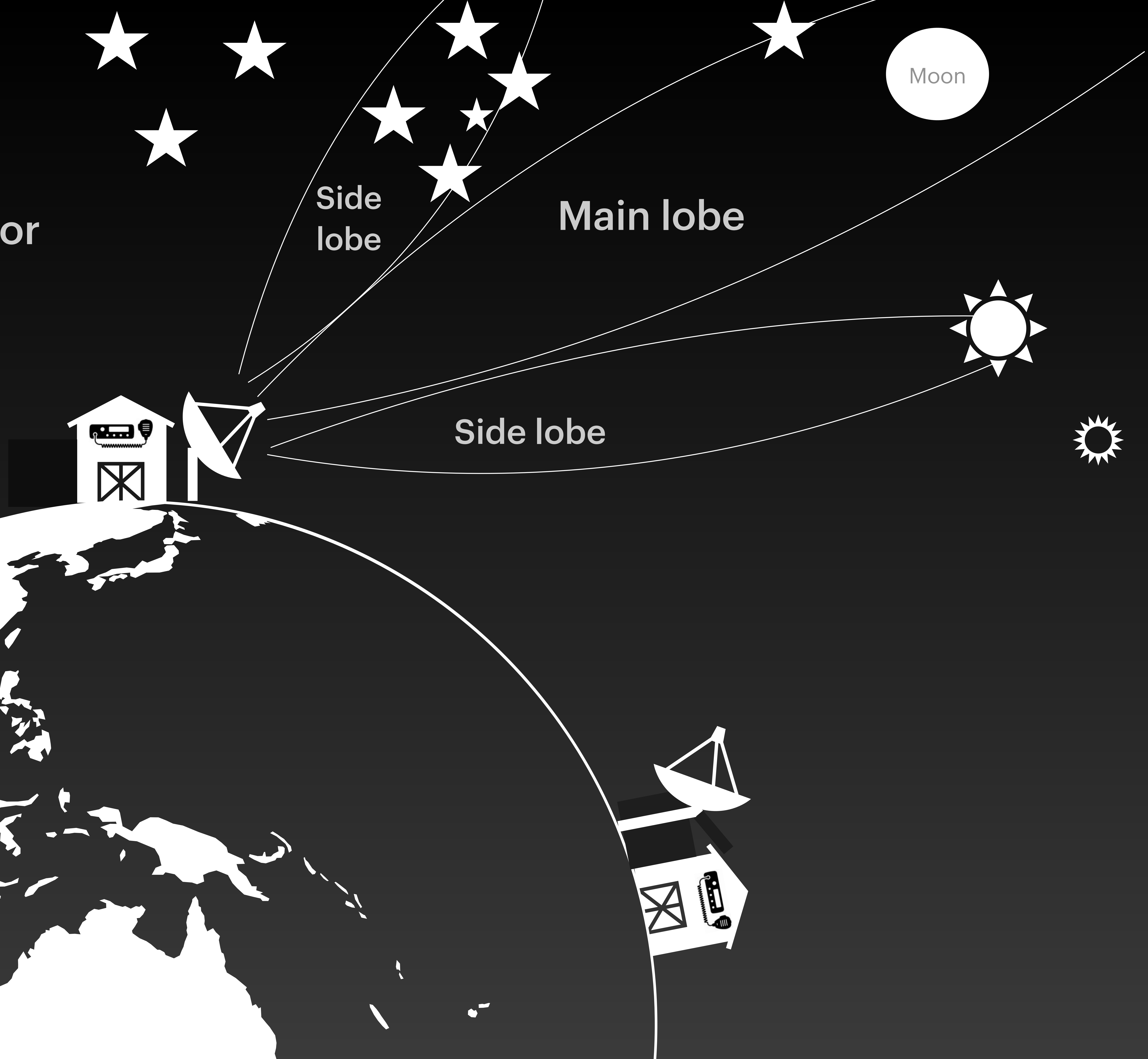
$$SNR = Pt - L + Gt + Gr - Pn$$

- RX signal to noise ratio in dB
- TX power in dBW
- Path loss is ~261dB
- Gain of TX antenna
- Gain of RX antenna
- RX noise power In dB

SNR=Pr-Pn

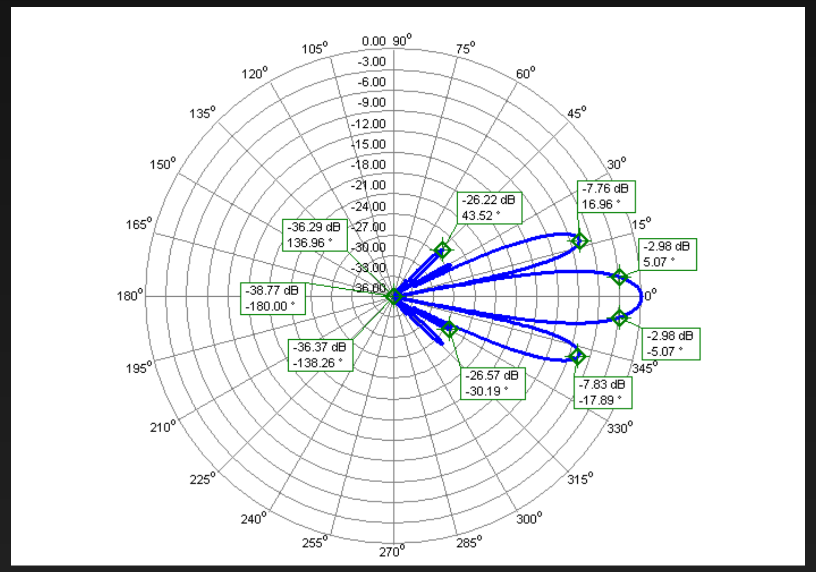
The side lobes are a big contributor to system noise





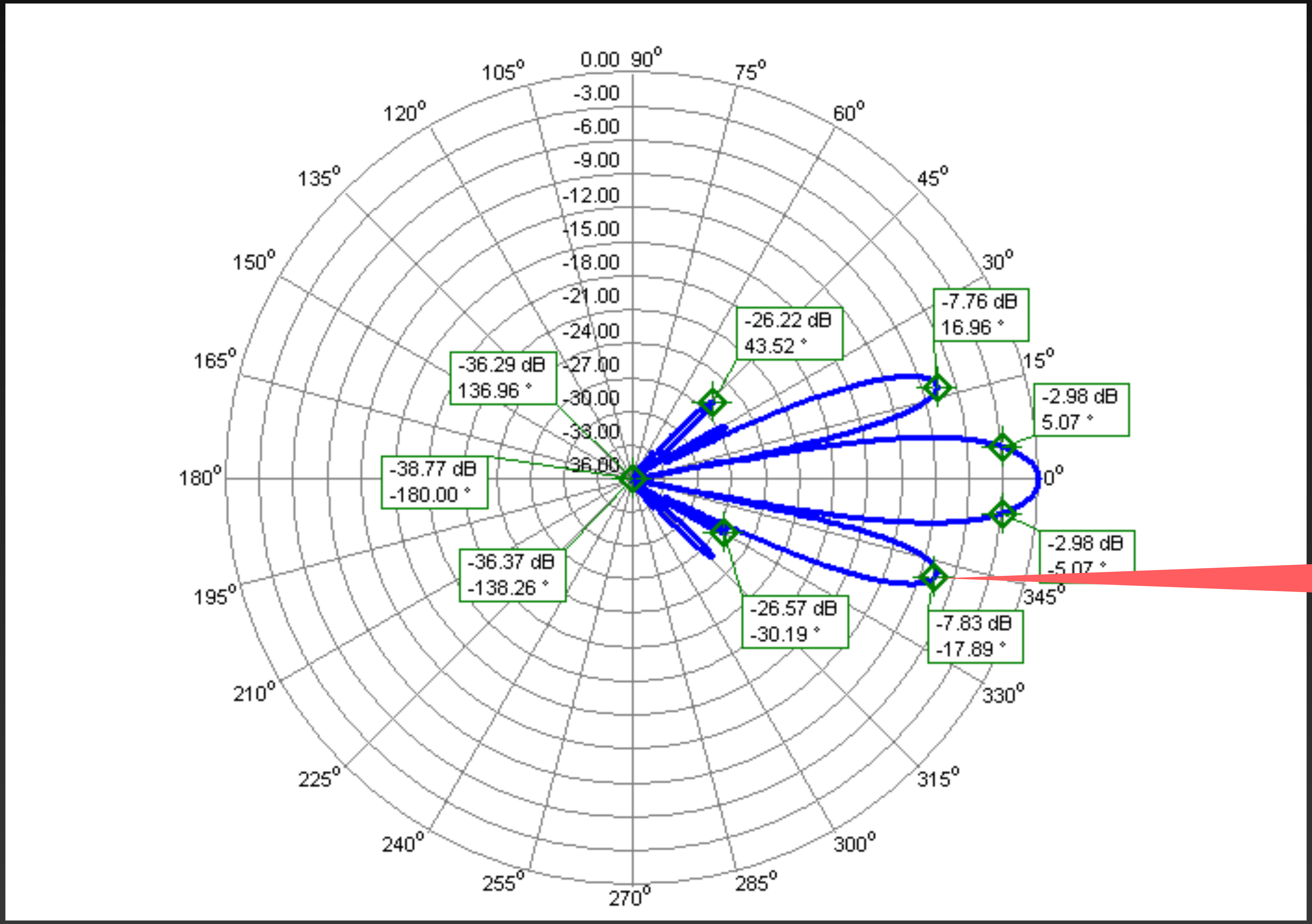
SNR=Pr-Pn

Your side lobes also point to your neighbours and the earth (ground)



Antenna G/T

Its not just gain its also how much noise the antenna design picks up



The size of the side lobes is crucial as these pick up noise - man made, ground noise and sky noise

G/T

Its not just gain its how much noise the antenna contributes to your rx chain

Issue: Jan 25, 2024

VE7BQH Antenna Table

Old Reference: Tsky=20K Tearth=350K
New Reference: Tsky=27K

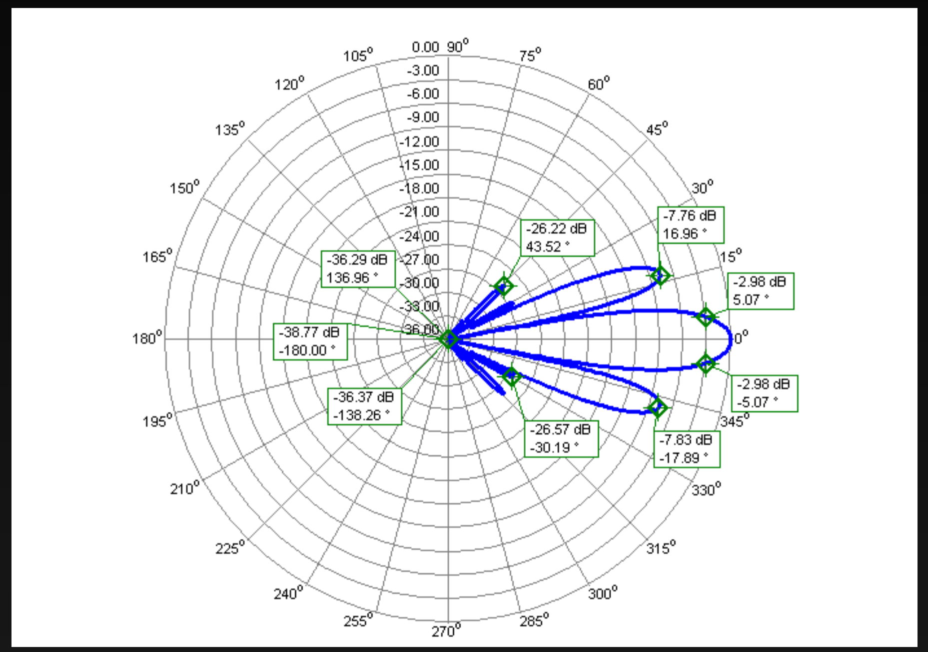
Reference: Estimated Values for man made noise (Tearth) on 432.1 MHz:

Rural =	760
Residential =	1800
City =	8200

Man-Made Noise in Our Living Environments
U.R.S.I. Radio Science Bulletins No. 334, 09.2010

Enter Tsky > 27 K | Enter Tearth, K > 1800 | Enter Receive System NF > 0.75 dB

					DL6WU Optimal Stacking					1 Ant.					
		1 Ant.			4 Antennas					< H Plane >					
TYPE OF ANTENNA	Length (m)	GAIN (dBi)	E (m)	H (m)	GA (dBi)	Tloss (K)	TA (K)	G/T (dB/K)	S/N (dB)	F/R (dB)	1st SL (dB)	2nd SL (dB)	Z (ohms)	VSWR Bandwidth	Feed System
Tonna 21 DX	4.58	17.91	1.67	1.61	23.80	6.81	117.11	1.52	-16.87	20.48	14.5	18.2	58.4	2.32:1	Folded Dipole
KF2YN Boxkite 22	4.65	19.26	1.99	1.90	25.14	11.16	95.14	3.49	-14.90	29.00	16.2	21.2	52.1	1.17:1	Bent Dipole
DG7YBN GTV70-21n	4.69	18.82	1.68	1.63	24.68	7.25	53.37	3.80	-14.59	32.35	14.8	21.1	48.3	1.48:1	Bent Dipole
InnoV 20 LFA	4.85	18.28	1.73	1.67	24.31	5.11	50.90	4.11	-14.28	35.15	15.1	20.7	50.5	1.09:1	LFA-LOOP
InnoV 20 LFA 2019	4.86	18.44	1.76	1.70	24.38	5.98	49.95	4.23	-14.16	30.00	14.7	22.4	48.0	1.53:1	LFA-LOOP
+YU7XL QY721104D14	4.88	18.42	1.88	1.82	24.47	3.44	52.37	4.20	-14.19	27.68	18.5	22.8	201.1	1.28:1	LFA 200
RA3AQ AQ70-21f	4.95	18.54	1.73	1.67	24.41	7.11	58.82	3.91	-14.48	27.87	16.8	21.3	52.3	1.07:1	Folded Dip
BVO70-7.2 WL modified	4.97	18.49	1.76	1.70	24.42	3.85	81.82	3.10	-15.29	22.56	14.9	19.1	49.5	1.06:1	Dipole
Directive DSEFO432-25	5.13	18.57	1.74	1.69	24.47	5.18	66.58	3.68	-14.72	25.39	15.9	20.5	198.2	1.38:1	T Match
*Directive DSEFO432-25	5.13	18.57	1.78	1.68	24.47	4.98	66.35	3.68	-14.71	25.39	15.9	20.5	198.2	1.38:1	T Match
Directive DSEFO432-25XPOL H	5.13	18.57	1.73	1.73	24.48	5.20	66.07	3.70	-14.69	25.40	15.9	20.5	198.2	1.38:1	T Match
Directive DSEFO432-25XPOL V	5.13	18.57	1.73	1.73	24.48	5.50	65.86	3.71	-14.68	25.40	15.9	20.5	198.2	!.38:1	T Match
InnoV 22 LFA 2019-2	5.18	18.84	1.82	1.76	24.74	6.85	45.95	4.76	-13.63	31.15	14.0	28.0	46.2	2.67:1	LFA Loo
InnoV 21 LFA 2019	5.21	18.53	1.82	1.76	24.58	6.58	48.98	4.47	-13.92	28.19	14.1	26.4	47.9	1.53:1	LFA Loo
+DG7YBN GTV70-23m	5.24	18.65	1.76	1.70	24.51	3.85	54.05	4.18	-14.22	32.30	15.7	21.8	48.4	1.56:1	Bent Dipo
YU7EF EF7021B-5	5.27	18.66	1.74	1.68	24.50	8.02	62.83	3.86	-14.53	29.60	20.3	21.7	50.2	1.33:1	Dipole
EA1DDO 22 Quad V3	5.44	17.54	1.52	1.50	22.93	3.76	76.44	1.78	-16.61	22.22	14.8	20.8	50.9	1.23:1	Dipole
I0JXX 25JXX70	5.49	18.53	1.74	1.68	24.41	5.72	73.52	3.38	-15.01	23.91	21.3	24.8	198.6	1.12:1	T Match
InnoV 22 LFA 2019	5.52	18.84	1.85	1.80	24.77	6.92	44.85	4.84	-13.55	32.00	13.9	28.5	46.2	2.66:1	LFA Loop
KF2YN Polly 24 CR	5.65	19.15	1.90	1.90	25.11	3.75	71.86	4.12	-14.27	29.50	13.1	19.1	51.8	1.14:1	Multi-Pol loop
*Antennas-Amplifiers PA432-23-6A	5.69	18.88	1.90	1.90	24.90	6.86	47.95	4.84	-13.56	36.26	17.0	26.9	49.1	1.09:1	Hair Pin
+YU7XL QY724104D17	5.79	19.01	2.00	1.90	24.99	3.44	51.83	4.74	-13.65	31.67	18.7	22.8	199.0	1.23:1	LFA 200 Ω
+DG7YBN GTV70-25m	5.82	18.97	1.80	1.74	24.84	3.24	48.82	4.71	-13.68	32.60	16.3	22.1	41.2	1.25;1	Bent Dipole
InnoV 23 LFA	5.83	19.16	1.87	1.82	25.08	5.70	48.84	4.97	-13.42	31.75	15.9	21.7	45.2	1.23:1	LFA-LOOP
*InnoV 23 LFA	5.83	19.16	1.89	1.85	25.06	5.70	48.84	4.95	-13.44	31.80	15.9	21.7	45.2	1.23:1	LFA-LOOP
DJ9BV BVO70-8.5wl	5.85	19.14	1.95	1.90	25.13	5.09	100.12	3.28	-15.11	24.25	14.9	17.8	203.9	1.45:1	Folded Dipole
InnoV 23 LFA 2019	5.85	19.02	1.87	1.82	24.94	6.54	43.99	5.04	-13.35	32.19	14.4	27.6	47.4	1.32:1	LFA-LOOP
DJ9BV OPT70-8.5wl	5.86	19.04	1.80	1.75	24.87	4.96	83.04	3.52	-14.87	23.22	15.8	20.1	186.1	1.56:1	Folded Dipole
EAntenna 432LFA23	5.86	18.96	1.90	1.84	24.89	8.28	47.08	4.87	-13.52	31.99	14.2	30.9	47.8	3.99:1	LFA-LOOP
YU7EF EF7023B-5	5.88	18.98	1.79	1.73	24.78	6.53	56.67	4.36	-14.03	30.47	19.6	21.9	48.6	1.21:1	Dipole
RA3AQ AQ70-24f	5.91	19.22	1.87	1.82	24.82	6.20	51.47	4.61	-13.78	30.00	15.1	21.0	52.0	1.13:1	Folded Dipole
InnoV 24 LFA	6.17	19.32	1.92	1.87	25.25	5.99	46.95	5.22	-13.17	33.42	15.3	22.1	46.4	1.19:1	LFA-LOOP
*InnoV 24 LFA	6.17	19.32	1.89	1.84	25.22	5.99	46.40	5.21	-13.18	33.40	15.3	22.1	46.4	1.19:1	LFA-LOOP
YU7EF EF7024B-5	6.17	19.19	1.84	1.79	25.02	7.70	59.06	4.52	-13.87	30.30	20.5	22.4	50.1	1.60:1	Dipole
Innov 24 LFA 2019-b	6.21	19.20	1.89	1.83	25.11	6.29	44.08	5.21	-13.18	33.23	30.6	29.4	50.1	1.60:1	LFA-LOOP
M2 432-9WLA	6.38	19.40	2.02	1.96	25.33	7.40	122.00	2.93	-15.46	23.24	15.8	18.1	167.2	2.09:1	Folded Dipole
*M2 432-9WLA	6.38	19.40	1.83	1.88	25.23	7.15	104.57	3.28	-15.11	23.24	15.8	18.1	167.2	2.09:1	Folded Dipo
+YU7XL QY728107D21	6.94	19.64	2.22	2.06	25.65	3.44	52.37	5.38	-13.01	28.60	19.1	24.1	198.1	1.29:1	LFA 200
Antennas-Amplifiers PA432-26-7BGP	6.96	19.60	1.95	1.95	25.49	7.56	45.42	5.54	-12.85	36.30	16.2	28.2	47.9	1.07:1	HairPin



Different antenna designs offer similar gain but provide better figure of merit

http://www.dg7ybn.de/GT_Tables/432_MHz_GT.htm

G/T

Its not just gain its how much noise the antenna contributes to your rx chain

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U.R.S.I. Radio Science Bulletins No. 334, 09.2010

Enter Tsky > **27** K — Enter Tearth, K > **1800** — Enter Receive System NF > **0.75** dB

		1 Ant.			DL6WU Optimal Stacking 4 Antennas					1 Ant. < H Plane >					
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InnoV 20 LFA															LFA-LOOP
InnoV 20 LFA 2019															LFA-LOOP
+YU7XL QY721104D14															LFA 200
RA3AQ AQ70-21f															Folded Dip
BVO70-7.2 WL modified															Dipole
Directive DSEFO432-25															T Match
*Directive DSEFO432-25															T Match
Directive DSEFO432-25XPOL H															T Match
Directive DSEFO432-25XPOL V															T Match
InnoV 22 LFA 2019-2															LFA Loo
InnoV 21 LFA 2019															LFA Loo
+DG7YBN GTV70-23m															Bent Dipo
YU7EF EF7021B-5															Dipole
EA1DDO 22 Quad V3															Dipole
I0JXX 25JXX70															T Match
InnoV 22 LFA 2019															LFA Loop
KF2YN Polly 24 CR															Multi-Pol loop
*Antennas-Amplifiers PA432-23-6A															Hair Pin
+YU7XL QY724104D17															LFA 200 Ω
+DG7YBN GTV70-25m															Bent Dipole
InnoV 23 LFA															LFA-LOOP
*InnoV 23 LFA															LFA-LOOP
DJ9BV BVO70-8.5wl															Folded Dipole
InnoV 23 LFA 2019															LFA-LOOP
DJ9BV OPT70-8.5wl															Folded Dipole
EAntenna 432LFA23															LFA-LOOP
YU7EF EF7023B-5															Dipole
RA3AQ AQ70-24f															Folded Dipole
InnoV 24 LFA															LFA-LOOP
*InnoV 24 LFA															LFA-LOOP
YU7EF EF7024B-5															Dipole
Innov 24 LFA 2019-b															LFA-LOOP
M2 432-9WLA															Folded Dipo
*M2 432-9WLA															Folded Dipo
+YU7XL QY728107D21															LFA 200
Antennas-Amplifiers PA432-26-7BGP	6.96	19.60	1.95	1.95	25.49	7.56	45.42	5.54	-12.85	36.30	16.2	28.2	47.9	1.07:1	HairPin

Only Antennas that have actually been built are posted in these Tables, except for the F5FOD Isotropic Lossless Radiator.

Thanks to Vladimir, UR5EAZ for establishing the Interactive Mode in the 144 and 432 Tables
Thanks to Hartmut, DG7YBN for his ongoing support and many inputs to the Tables

Legend:

1. L = Length in Wavelengths

2. Gain = Gain in **dBi** of a single antenna

3. E = E plane (Horizontal) stacking in Meters.

4. H = H plane (Vertical) stacking in Meters.

5. Ga = Gain in **dBi** of a 4 bay array

6. Tloss = Noise temperature due to ohmic losses in the antenna (K) at an actual antenna temperature of 290 K.

7. Ta = Noise temperature of the antenna array (K) is the mixture of the antenna array pattern, the sky temperature, ground and the ohmic losses in the antenna array.

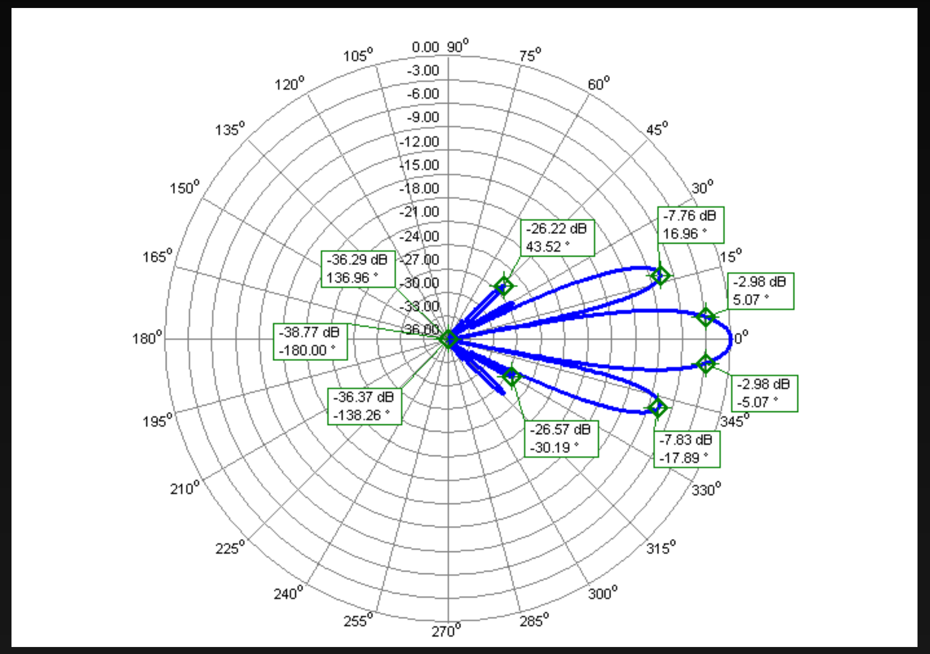
8. F/R = Front to Rear in dB over the rear 180 degrees of an antenna using either E or H plane.

9. Z ohms = The natural impedence of a single antenna in free space.

10. VSWR = VSWR Bandwidth is based a single antenna over 432.000 - 435.000 MHz with a reference at 432.300 MHz. This parameter gives an indicator of the antenna "Q" and what to expect with with stacking and wet weather.

11. G/T = Figure of merit; a system parameter used to determine the receive capability of the antenna or array as part of the radio receiving system. The more positive value the better.

12. S/N = Figure of merit; a system parameter used to determine the receive capability of the antenna or array as part of the radio receiving system. The more positive value the better.



Different antenna designs offer similar gain but provide better figure of merit

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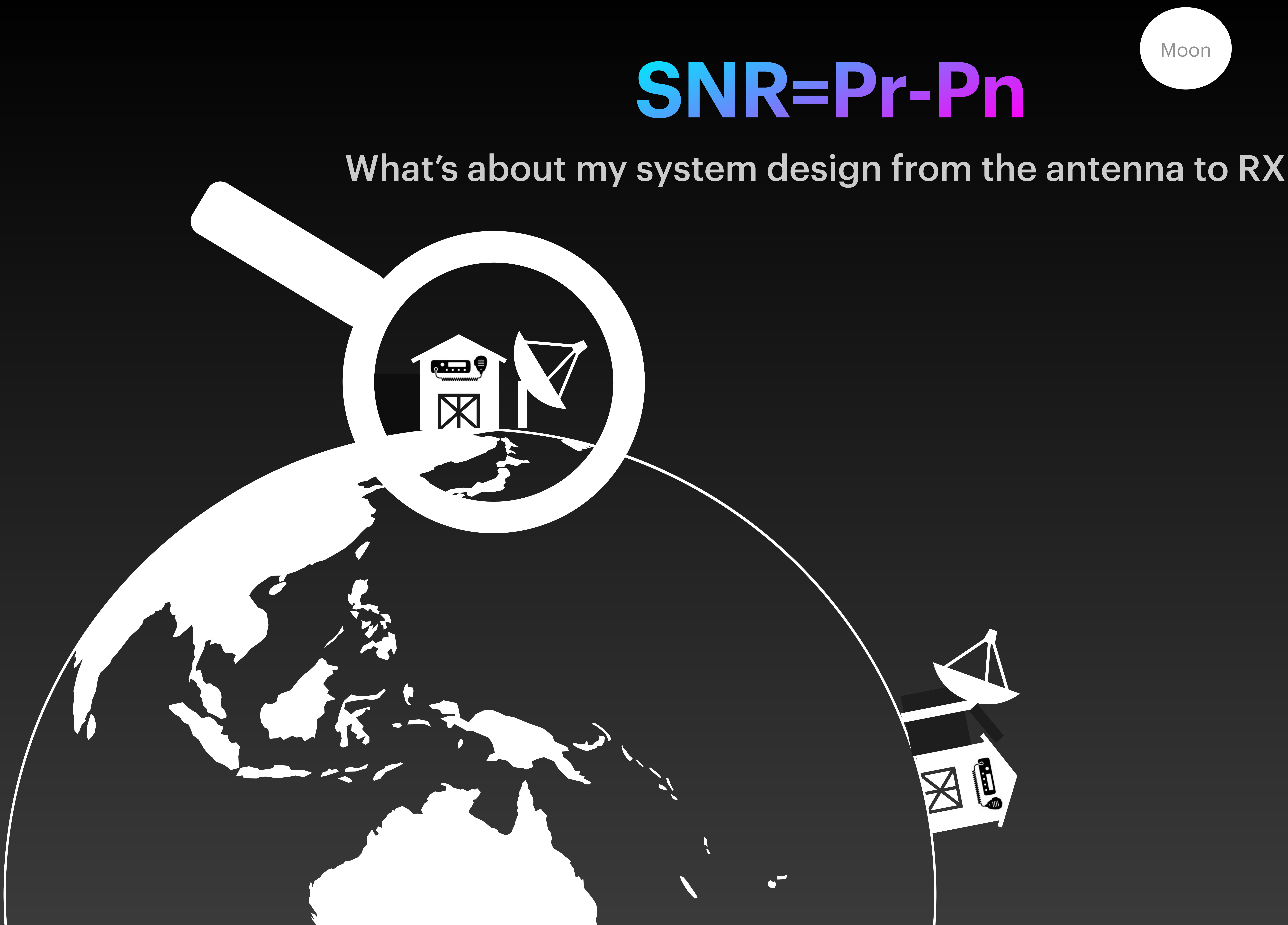
SNR=Pr-Pn

What's about my system design from the antenna to RX



$SNR = P_r - P_n$

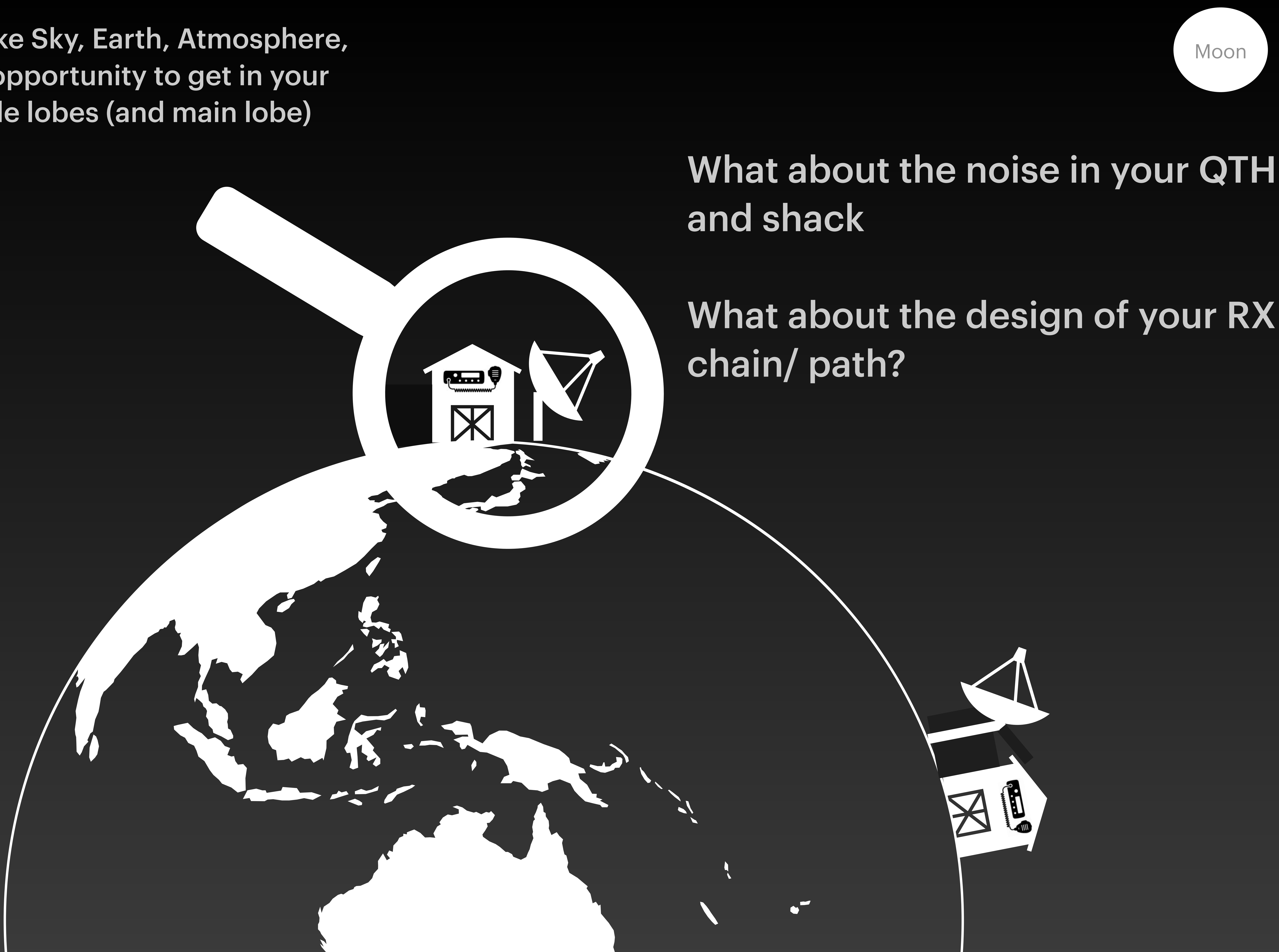
Moon

What's about my system design from the antenna to RX

$$T_{system} = T_{ant} + T_{rx}$$

This includes everything from the antenna connector to and including the receiver

The external noise like Sky, Earth, Atmosphere, Solar, HV has a big opportunity to get in your RX chain via your side lobes (and main lobe)



What about the noise in your QTH and shack

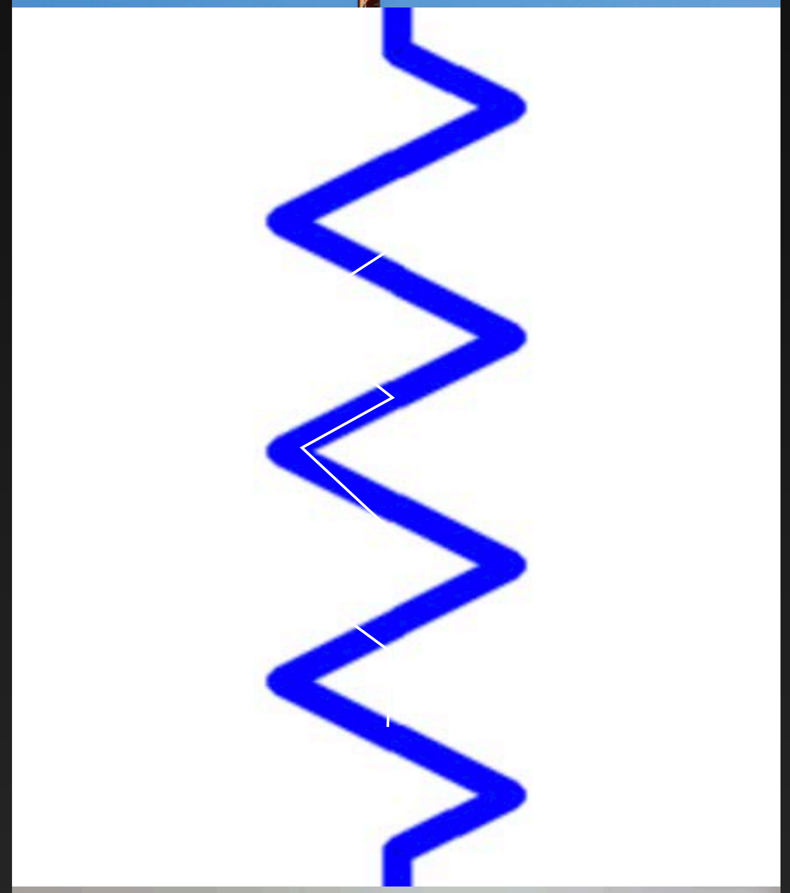
What about the design of your RX chain/ path?

Minimising the losses down before the LNA
Why all the fuss (without the math)?

- Overall System Noise performance is largely determined by the 1st stage.

- Any resister (or conductor) generates a noise voltage (proportional to the resistance, temperature and bandwidth)

- Any losses before the LNA will attenuate the DX signal.
- But the same losses will increase the noise level
- So the Signal to Noise ratio decreases by much more than just the value (dB) of the losses


Optimising the RX chain

7/16 DIN connectors from 1st LNA to antenna power combiner - low IL

N connectors from 1st LNA output to receivers

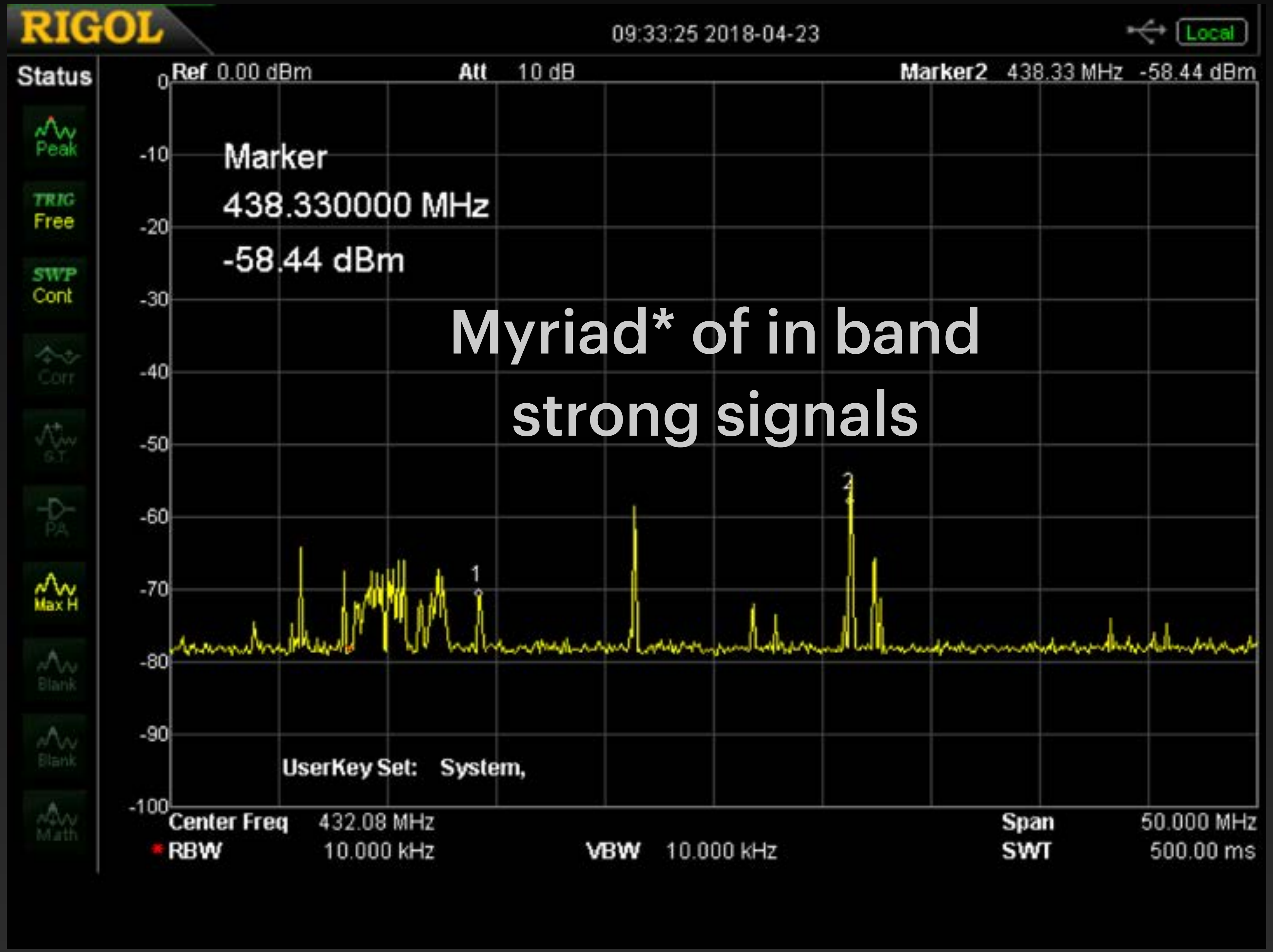
Low LNA Noise Figure and high P1dB

The 1st stage of the RX chain is high performance cavity LNA with gain of 20.5dB and NF 0.26dB. Its has its 2nd amplifier stage on the PCB replaced with Bandpass and Elliptic filters. The LNA is from Radio Astronomy Supplies and was made by Tommy WD5AGO and has P1dB +12dBm and was chosen due to my high noise city location.

The 2nd stage LNA is Kuhne LNA. Its gain is 20.4dB and NF 0.31dB. Its got good IP3 specifications (typ =27dBm) and Helical filters for good selectivity.

Optimising the RX chain

Living in the city there is a myriad of signals in the LNA's BW that you may not see in your receiver. However you will experience the impact of these signals to the LNAs performance hence receive performance.



- We often just do the math just using the desired signal
- However to obtain a good NF the LNAs typically are wide BW
- In metropolitan areas there are lots of signals that the LNA picks up that you may not see in your receiver

* = sh!t tons of signals (XYL said I was not around to use the technical description)

Feedlines

4x15LFA Xpol

4x21 XPol

Less feedline loss results in less system noise

Feedlines

4x15LFA Xpol

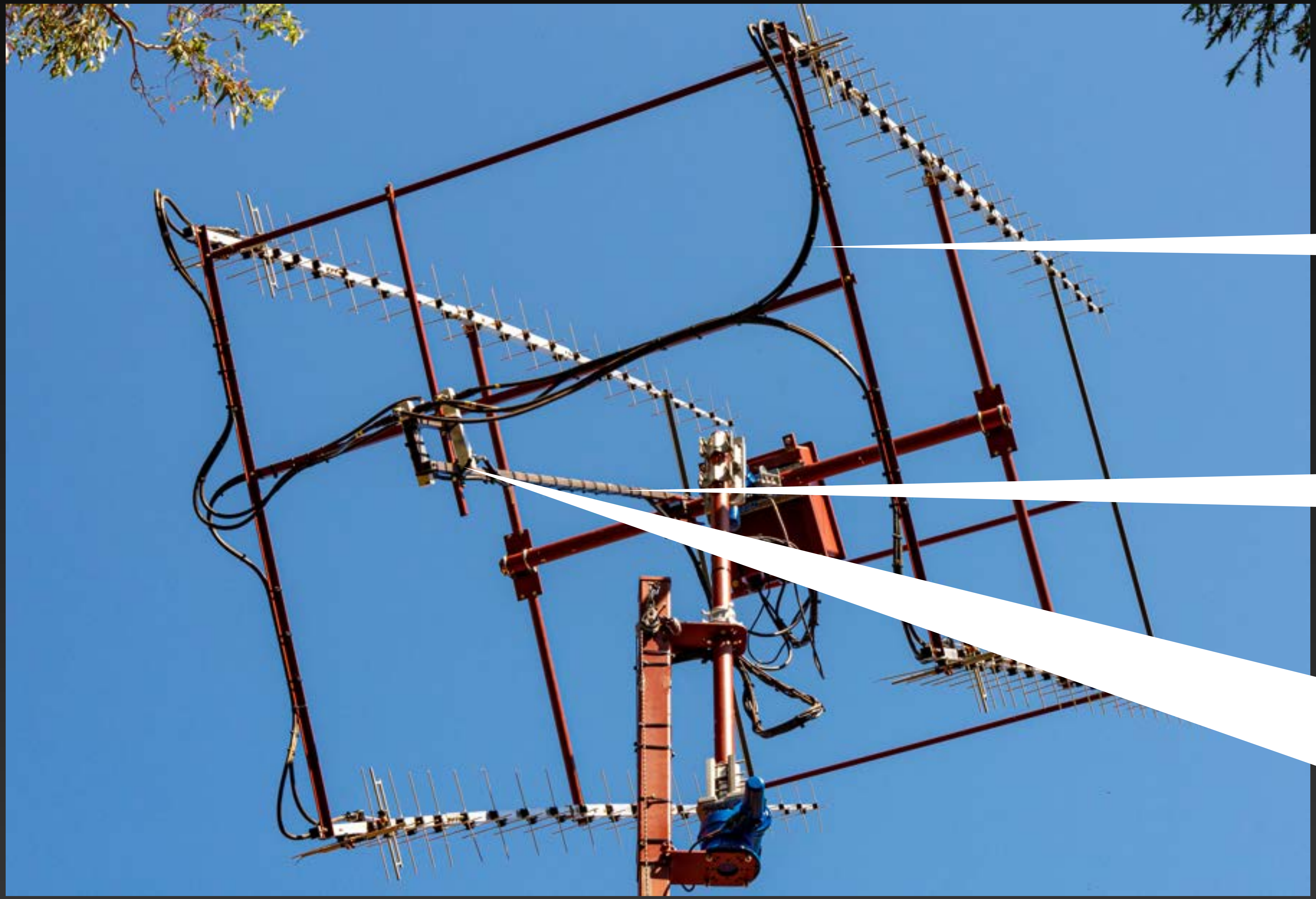
3/2 wavelength power divider reduces feed line length

Using Times 5.2mm SFT-205 instead of RG142 gains 0.1dB per cable

4x 15LFA-JT H frame is spaced at 1.2m to optimise low noise design

Feedlines

4x21 XPol



10mm M&P Hyperflex - Antenna to Power Divider

13mm Hyperflex - Power Divider to Relay

Using 7/16 DIN from power divider down to shack (slighter less insertion loss & better power rating)

High quality power dividers from Antenna Amplifiers have very low loss and excellent return loss

Not all power dividers are equal

Insertion loss of Power Dividers relates to Quality

Divider	IL (dB)	RL (dB)
Current 4:1	6.1	30
3/2 wavelength 4:1 (V2 - high power model)	6.1	31
3/2 wavelength 4:1 (V1 - low power model)	6.3	26
Old 4:1	6.2	28
2:1	3.5	14
2.:1	3.4	23

Not all relays are equal

Power and IL
All relays and connectors on TX chain are 7/16 DIN from PA to input of 4:1 power divider

@ 432Mhz
> 80dB isolation
0.1 insertion loss
N - type
700 watts
0.1kg

@ 432Mhz
> 100dB isolation
0.02 insertion loss
7/16 DIN
2 kW
1.3kg!

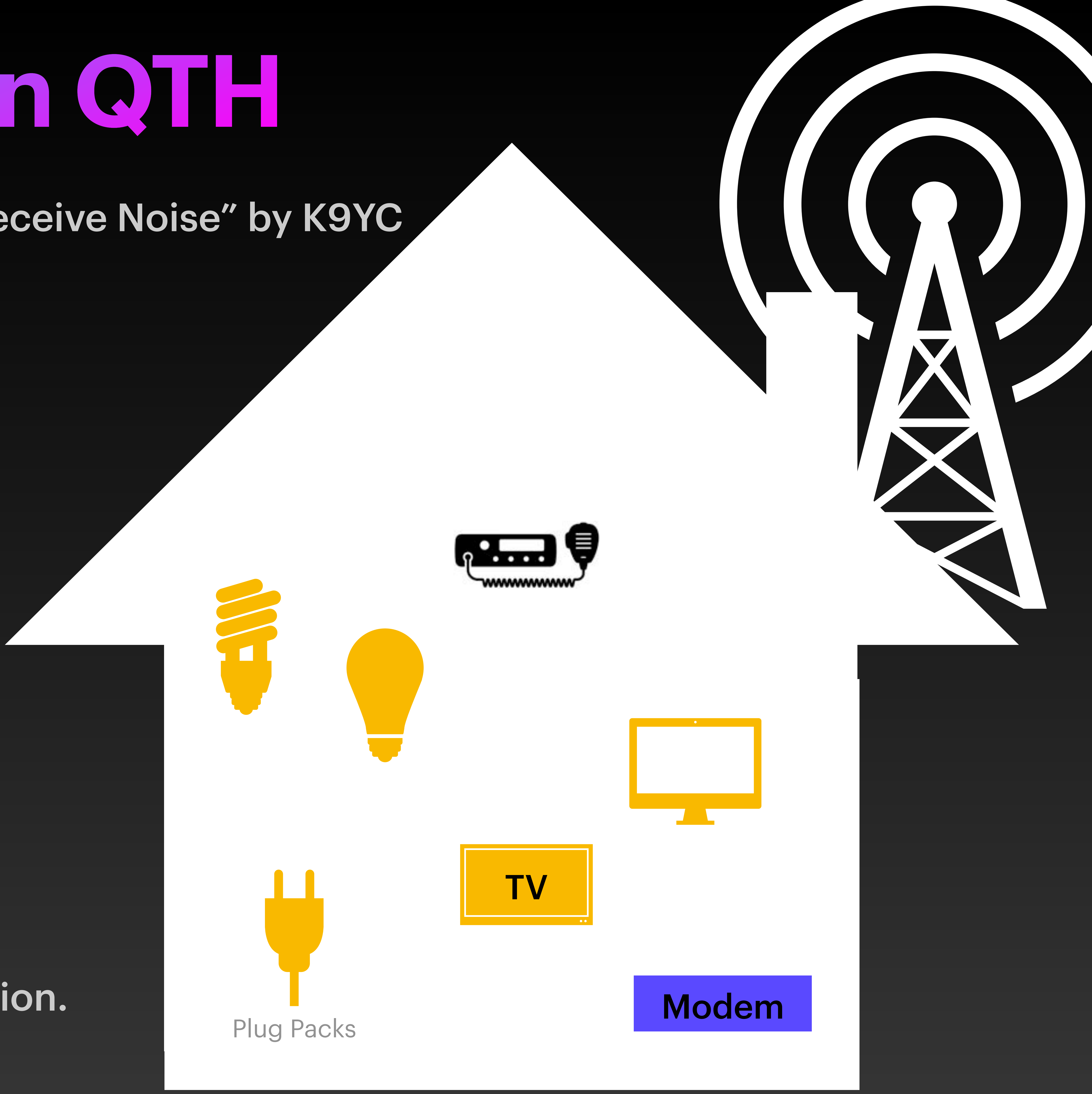
QRM from within own QTH

Have a read of “Building Contest Scores by Killing Receive Noise” by K9YC

I put a ferrite on every cable (buy in bulk) to:

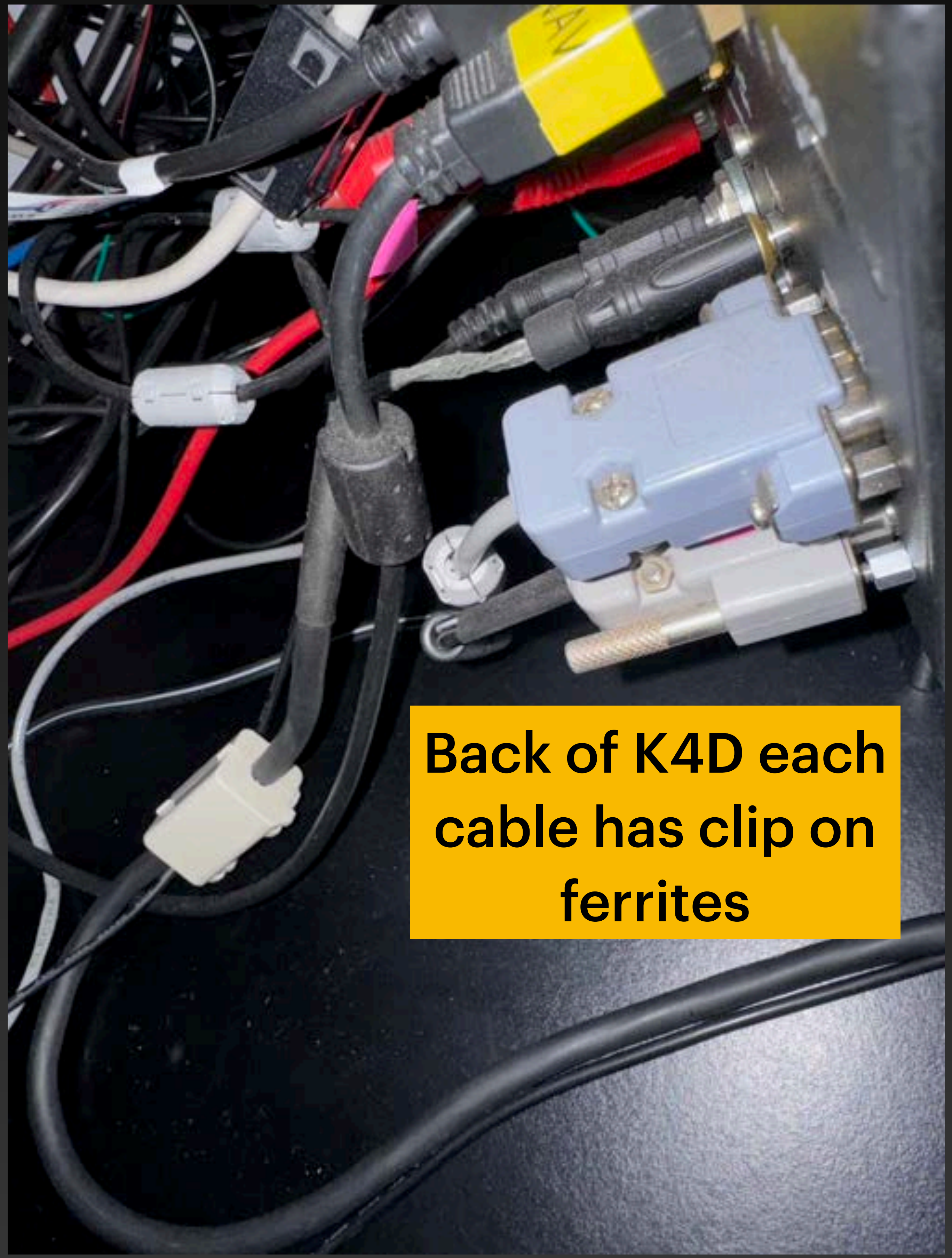
- PC
- Transceiver
- Transverters
- Receivers
- Sound cards
- PC
- PA
- LAN switch
- Power Supply

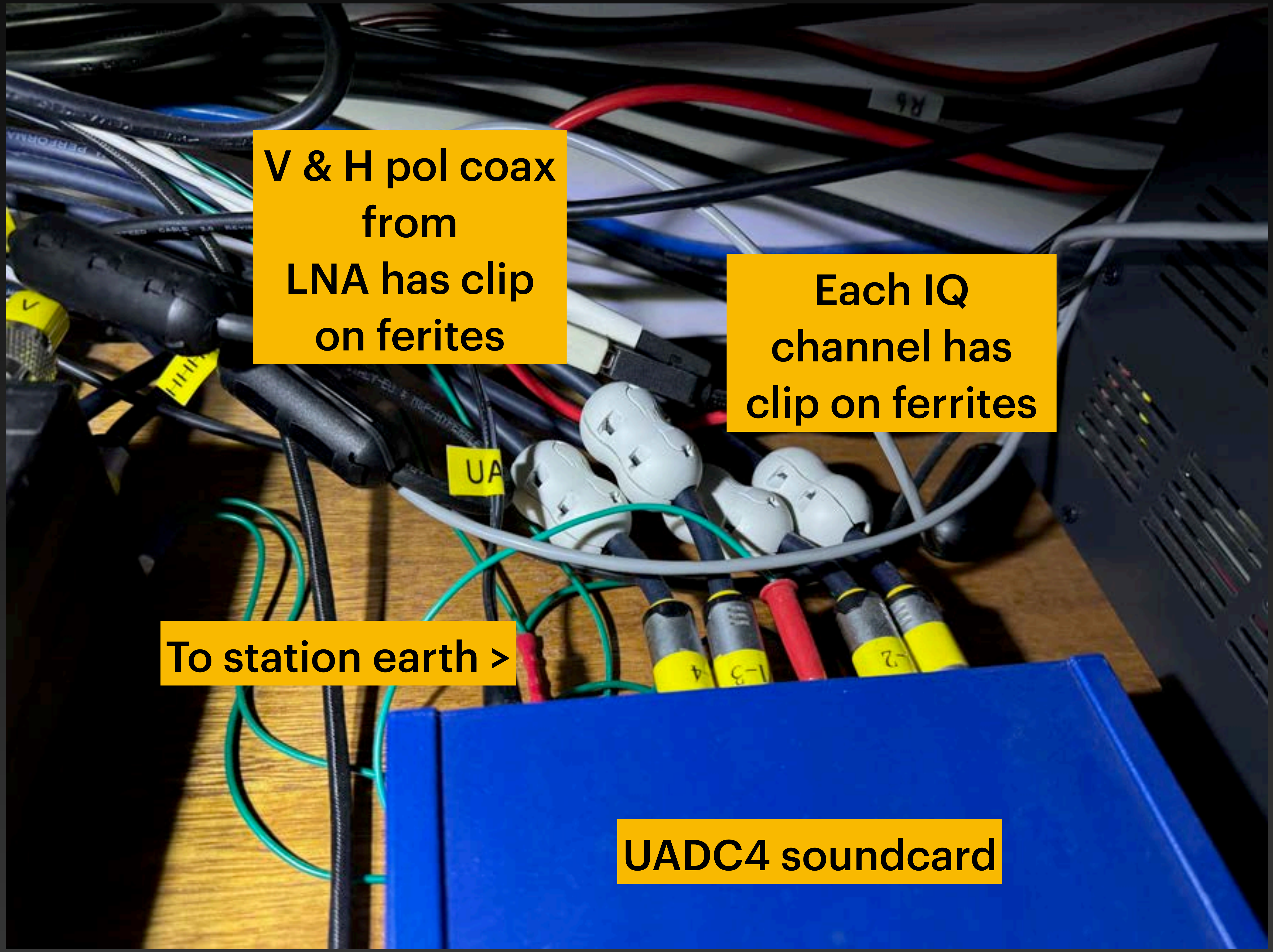
Implement proper bonding and earthing of your station.



PC, Soundcards, Radio anything that moves noise

If it moves choke it!

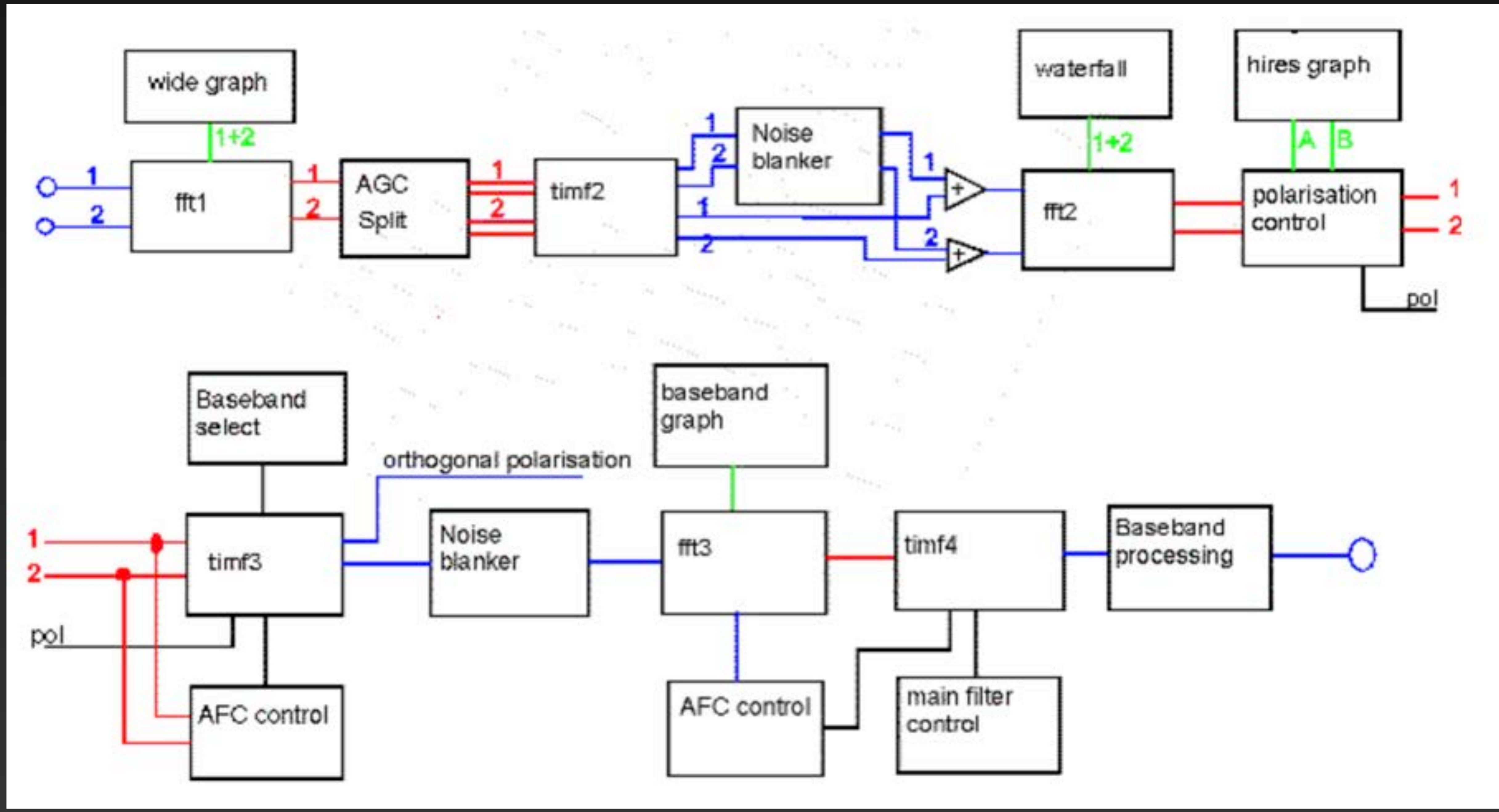




Linrad smart noise blanker

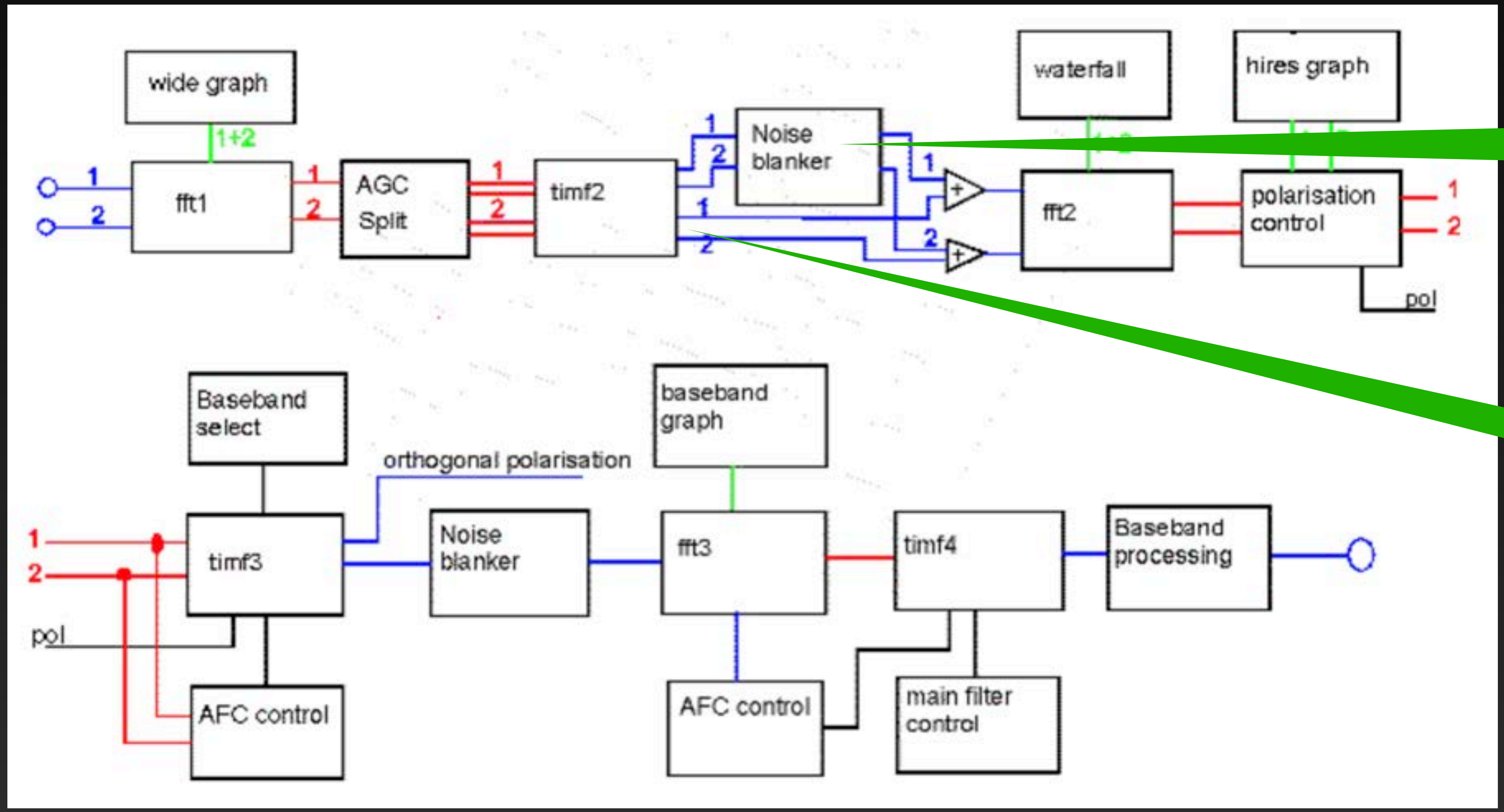
‘So I designed the best station ever but I still have QRM…’

SM5BSZs Linrad SDR software is amazing freeware available to ham community



Linrad smart noise blanker

'So I designed the best station ever but still have QRM..'



Strong signals - QRM gets 'blanked'

Weak signals - the desired weak signals off the moon

Then both are combined in fft2

SM5BSZs Linrad has many uses apart from EME including HF

So I did all that and still have noise

- On HF trial a ANC-4 (or similar)

- Time of day - interference often is not 24/7
- Direction/ elevation - antenna choices
- Remote operation - more and more people are doing this
- Move house!

Making a small station bigger

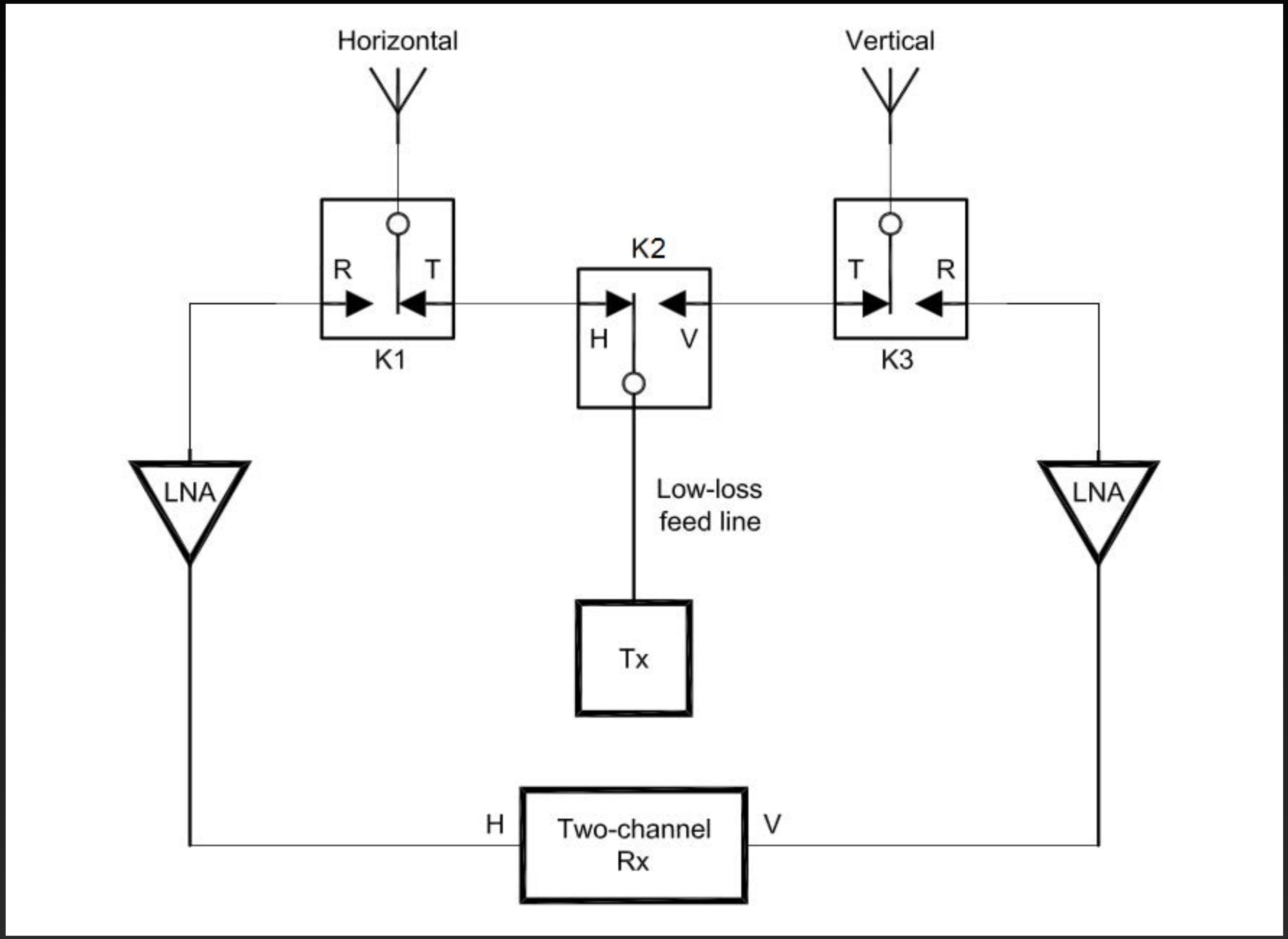
Recap from EME part 1...
70cm EME signals change polarisation due to the other stations location (Geometric Polarisation) as well a Faraday rotation when the signals pass thru the earths atmosphere.


When is H pol really V pol?
Its a matter of perspective!
Photos from nasa.gov

Adaptive polarisation

High performance small stations

- TX relay enables V or H transmit
- 2x Antenna relays switch between TX and RX feeds
- Requires 3 coax runs
- No relay required in PA
- Combats Faraday lockout by using two receivers.
- Can use Linrad (& coherent receiver) to RX DX station using correct polarisation for the DX station

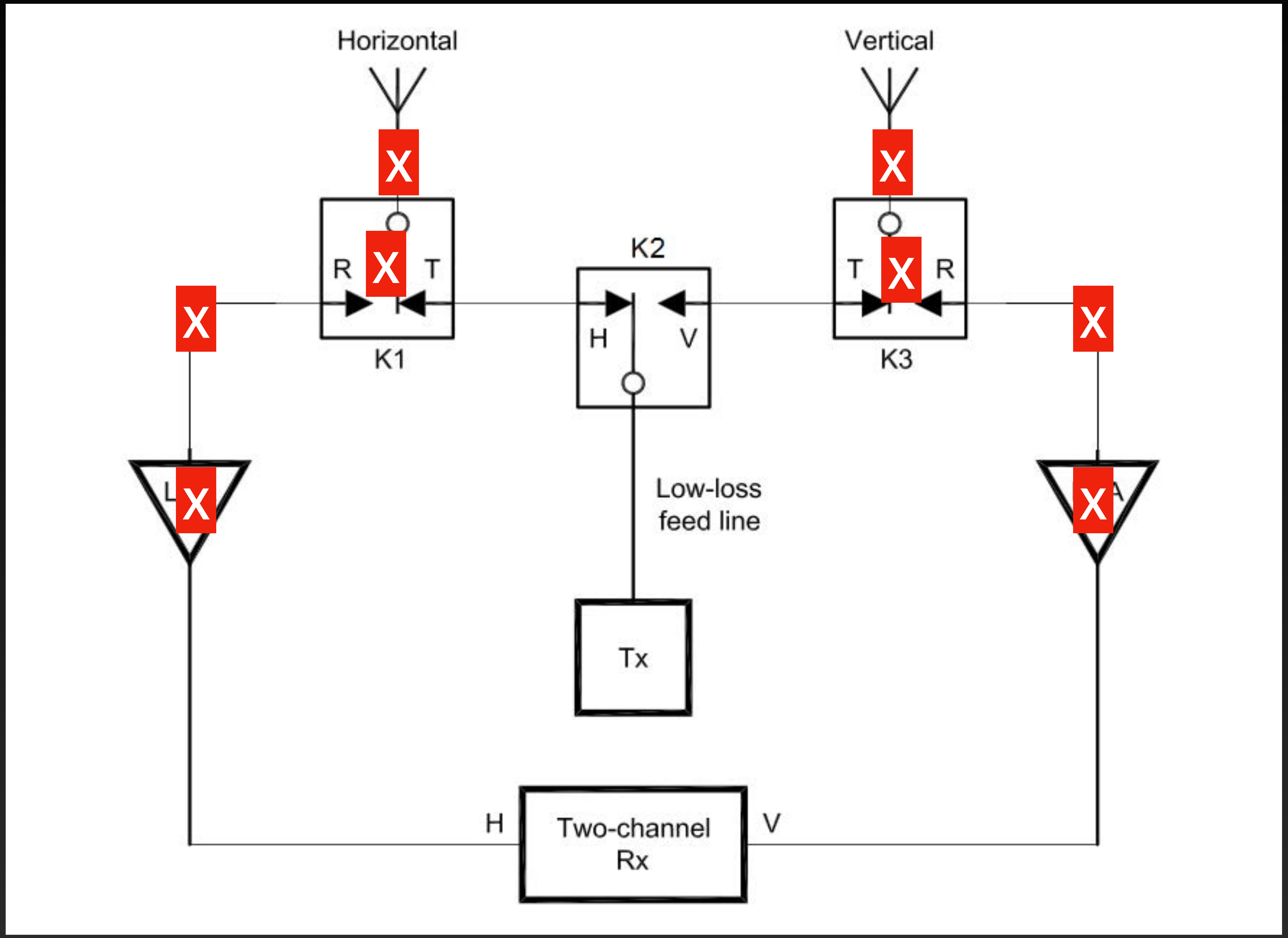


Feedline arrangement using 3 relays and 2 channel receiver.

Focus areas X

To minimise system noise (and increase the number of stations received)

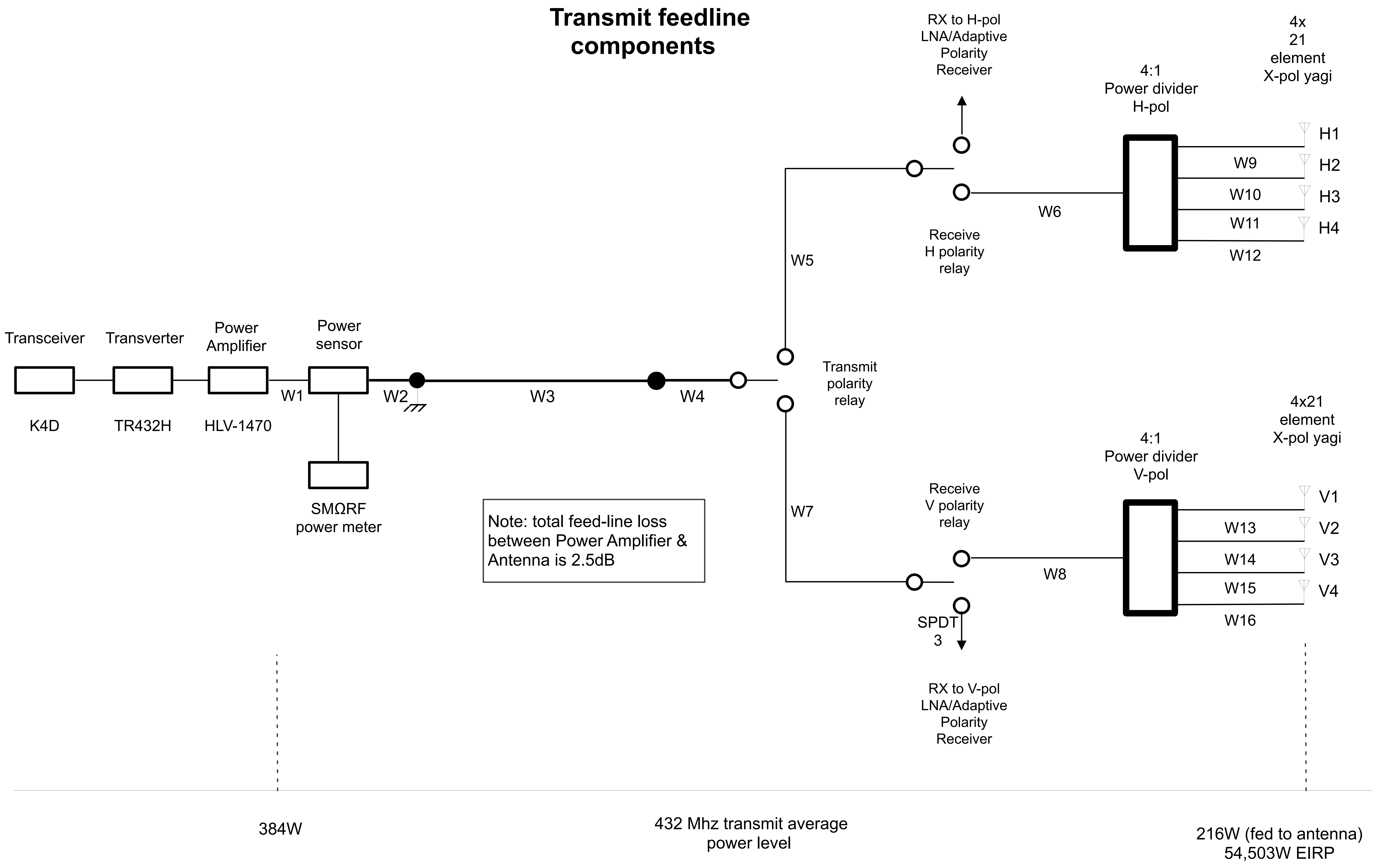
- Minimise ALL losses before the LNA. This includes;
  1. Feedlines
  2. Dividers
  3. Relays
- Use LNA with low Noise Figure, filters and good IP3 performance

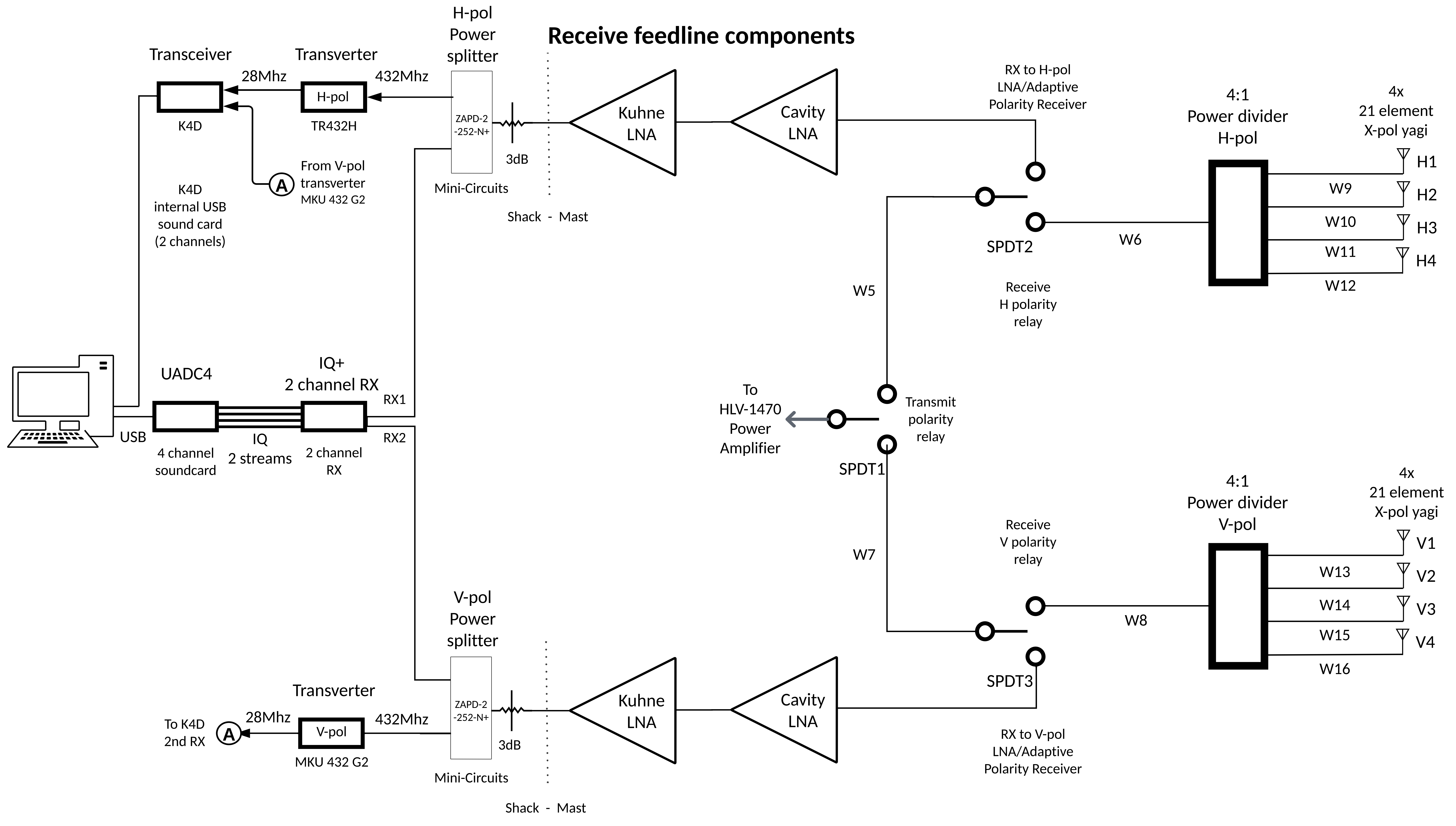


H & V Power dividers are not shown

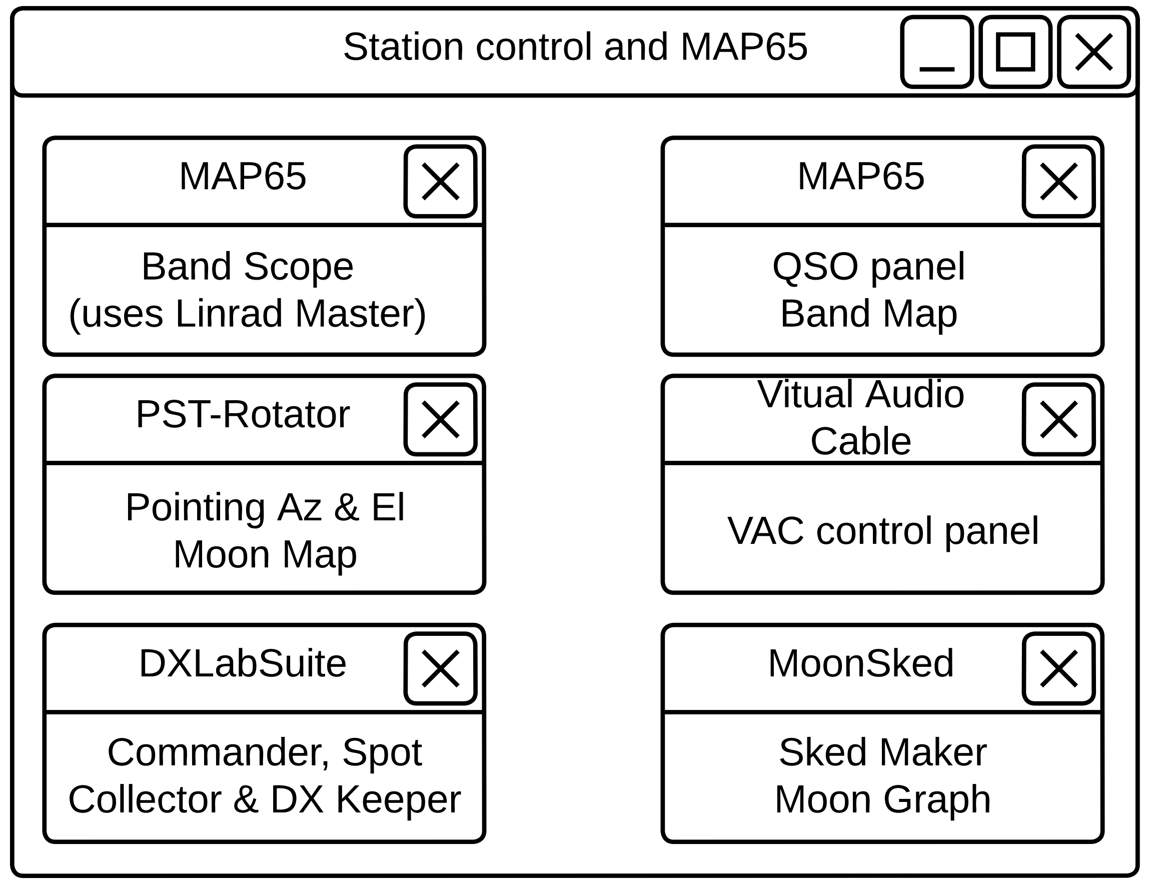
VK2CMP

Building a high performing station
- putting it all together

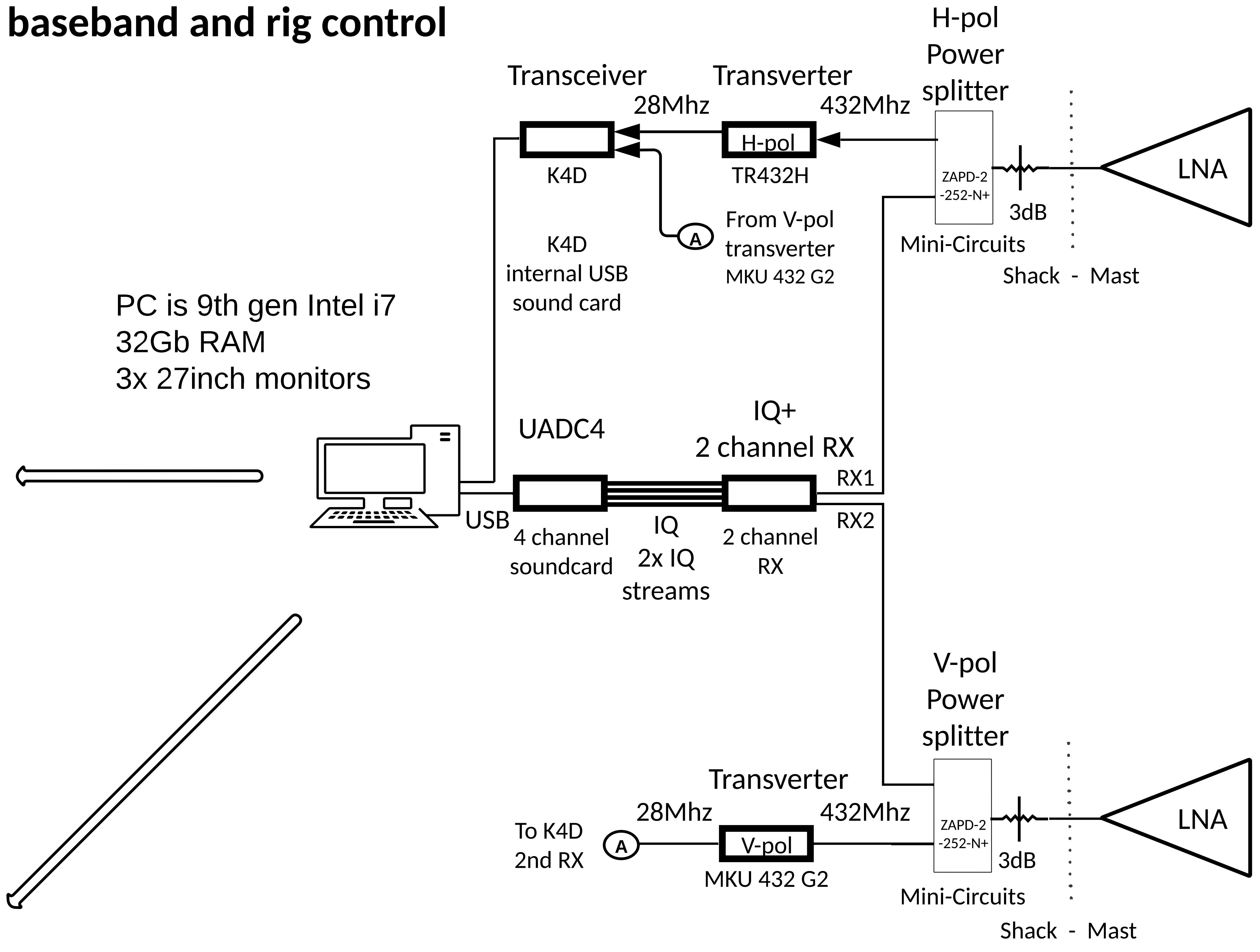

Transmit feedline components
Transceiver
K4D
Transverter
TR432H
Power Amplifier
HLV-1470
Power sensor
SMΩRF power meter
W1
W2
W3
W4
Transmit polarity relay
W5
W7
RX to H-pol LNA/Adaptive Polarity Receiver
Receive H polarity relay
W6
4:1 Power divider H-pol
4x 21 element X-pol yagi
H1
H2
H3
H4
W9
W10
W11
W12
Receive V polarity relay
SPDT 3
RX to V-pol LNA/Adaptive Polarity Receiver
W8
4:1 Power divider V-pol
4x21 element X-pol yagi
V1
V2
V3
V4
W13
W14
W15
W16
Note: total feed-line loss between Power Amplifier & Antenna is 2.5dB
384W
432 Mhz transmit average power level
216W (fed to antenna)
54,503W EIRP

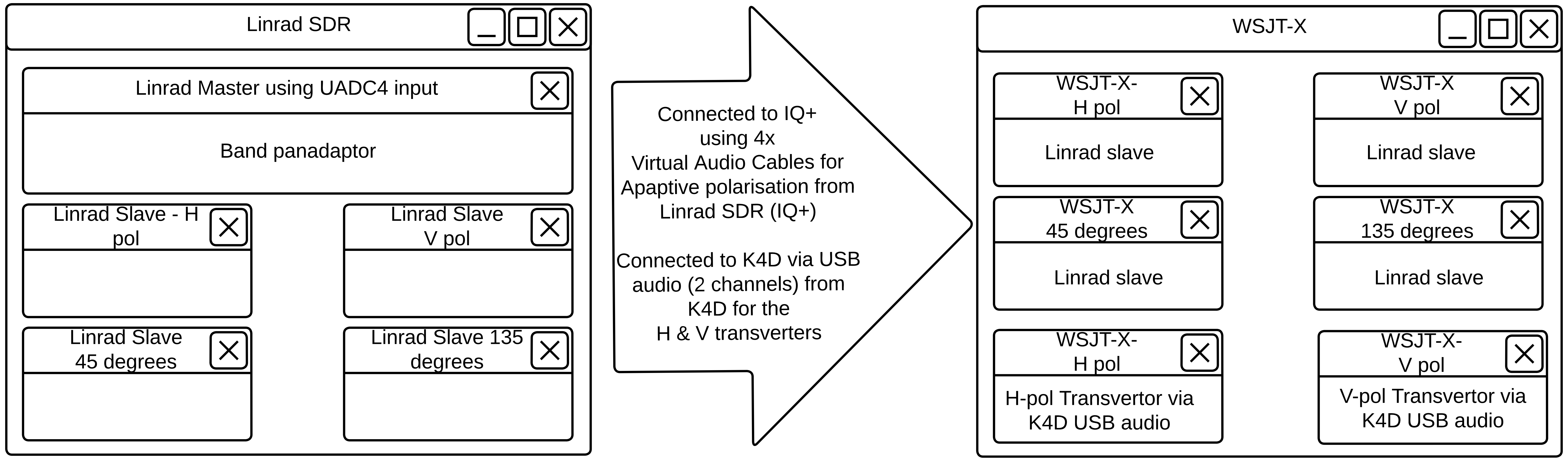

Receive feedline components
Transceiver
28Mhz
Transverter
H-pol
432Mhz
H-pol
Power
splitter
ZAPD-2
-252-N+
K4D
TR432H
3dB
Mini-Circuits
Shack - Mast
Kuhne
LNA
Cavity
LNA
RX to H-pol
LNA/Adaptive
Polarity Receiver
4:1
Power divider
H-pol
4x
21 element
X-pol yagi
H1
H2
H3
H4
W9
W10
W11
W12
W6
SPDT2
W5
Receive
H polarity
relay
A
From V-pol
transverter
MKU 432 G2
K4D
internal USB
sound card
(2 channels)
UADC4
IQ+
2 channel RX
RX1
RX2
USB
IQ
2 streams
4 channel
soundcard
2 channel
RX
To
HLV-1470
Power
Amplifier
Transmit
polarity
relay
SPDT1
W7
Receive
V polarity
relay
4:1
Power divider
V-pol
4x
21 element
X-pol yagi
V1
V2
V3
V4
W13
W14
W15
W16
W8
SPDT3
V-pol
Power
splitter
Transverter
To K4D
2nd RX
A
28Mhz
V-pol
432Mhz
MKU 432 G2
ZAPD-2
-252-N+
3dB
Mini-Circuits
Shack - Mast
Kuhne
LNA
Cavity
LNA
RX to V-pol
LNA/Adaptive
Polarity Receiver

Receive baseband and rig control



Station timing using Dimension 4
Station frequency standard 10Mhz Rubium Standard

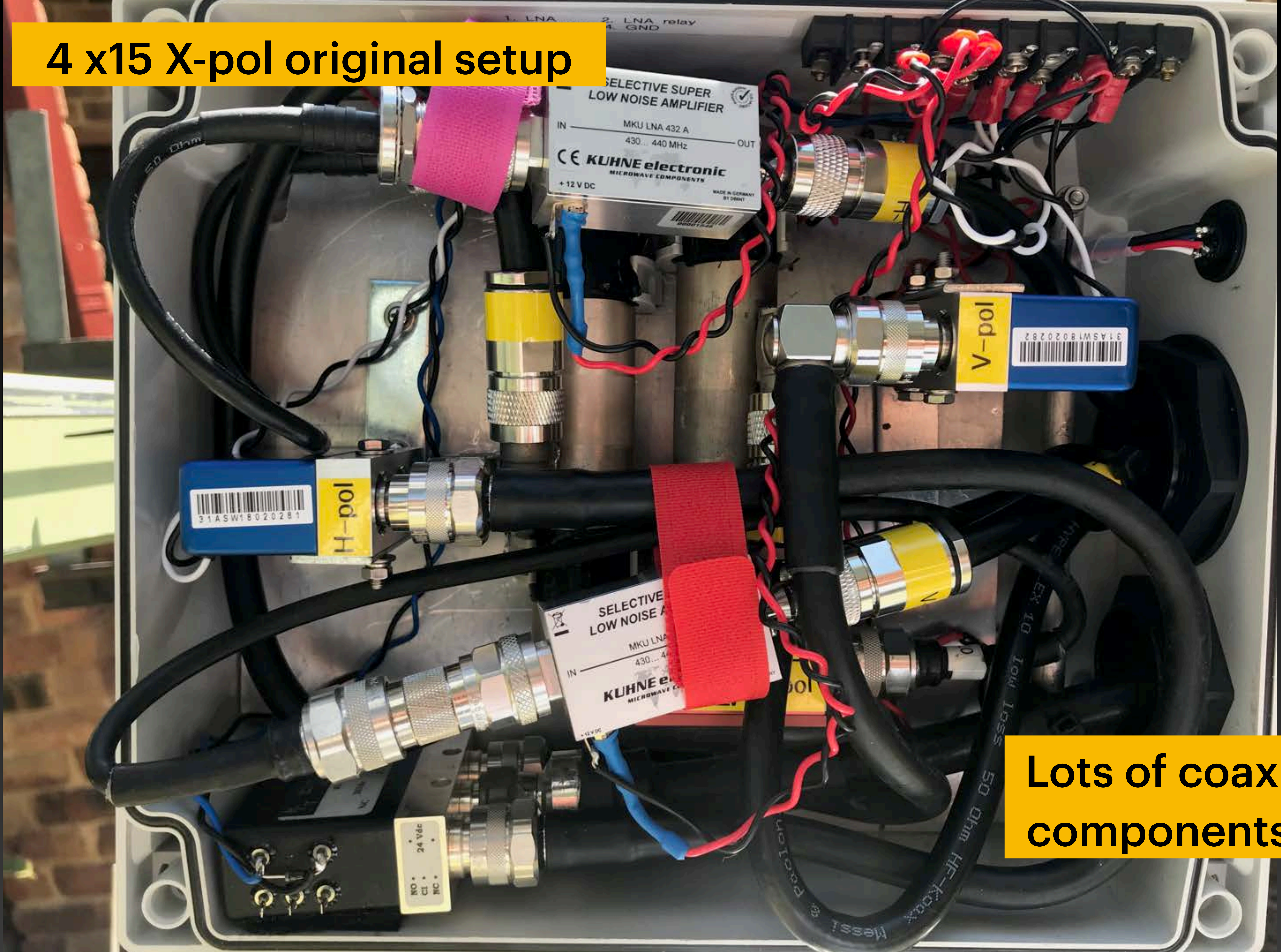




H & V polarisation IQ streams via USB input to Linrad Master
Linrad Master drives 4 Linrad Slaves
Frequency of operation selected on Linrad Master panadaptor
Linrad Slaves feed WSJT-X intances using 4 VAC

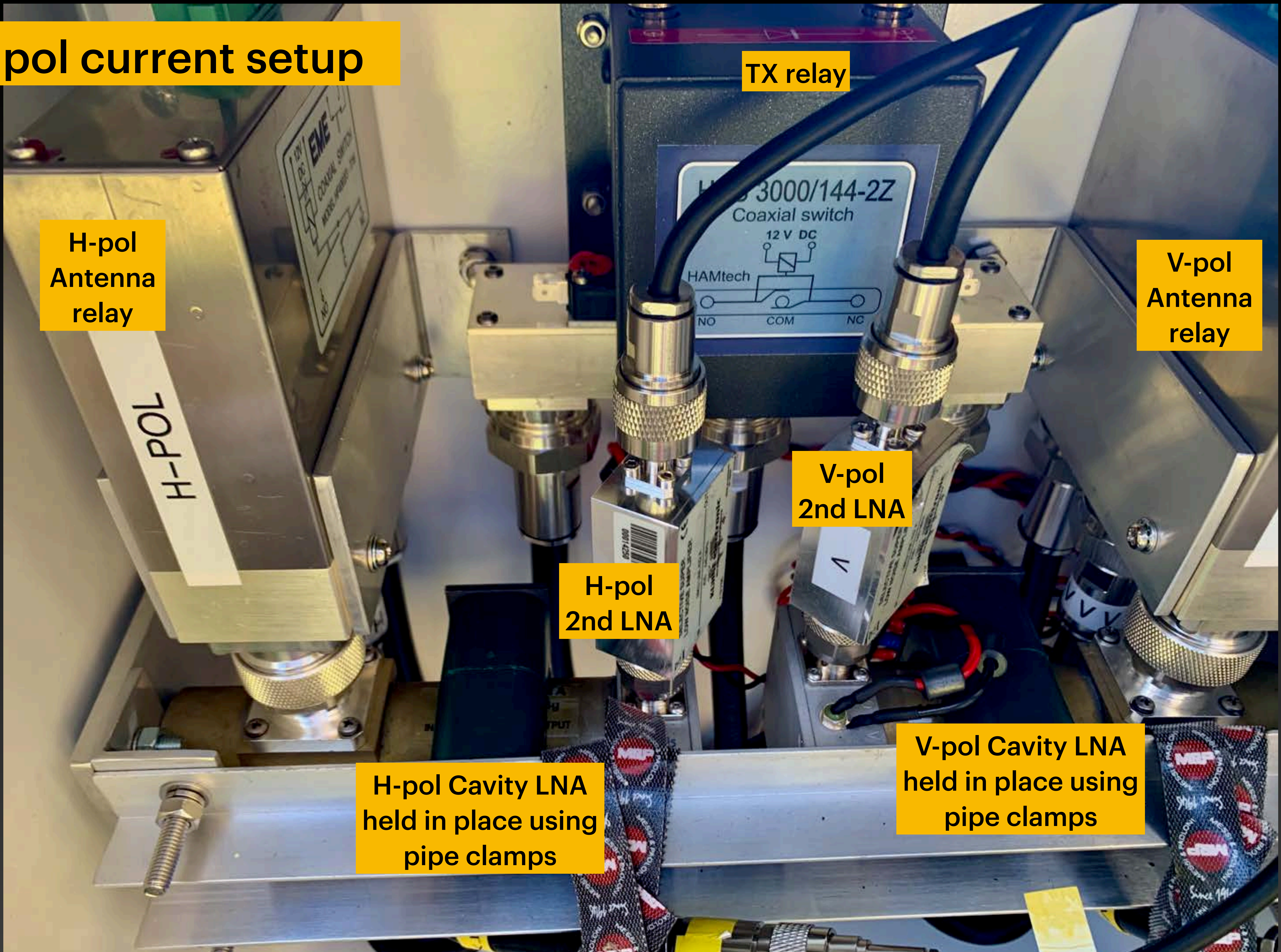
Adaptive polarisation using IQ+, UADC4, Linrad and 4 instances of WSJT-X
Two WSJT-X instances (H & V-pol) using H & V Transvertors and K4D
WSJT-X instances control via DXLabSuite Commander
WSJT-X receive audio via VAC or K4D USB audio (left channel for H-pol from Receiver A & right channel for V-pol from Receiver B)
WSJT-X transmit audio via K4D USB audio

4 x15 X-pol original setup



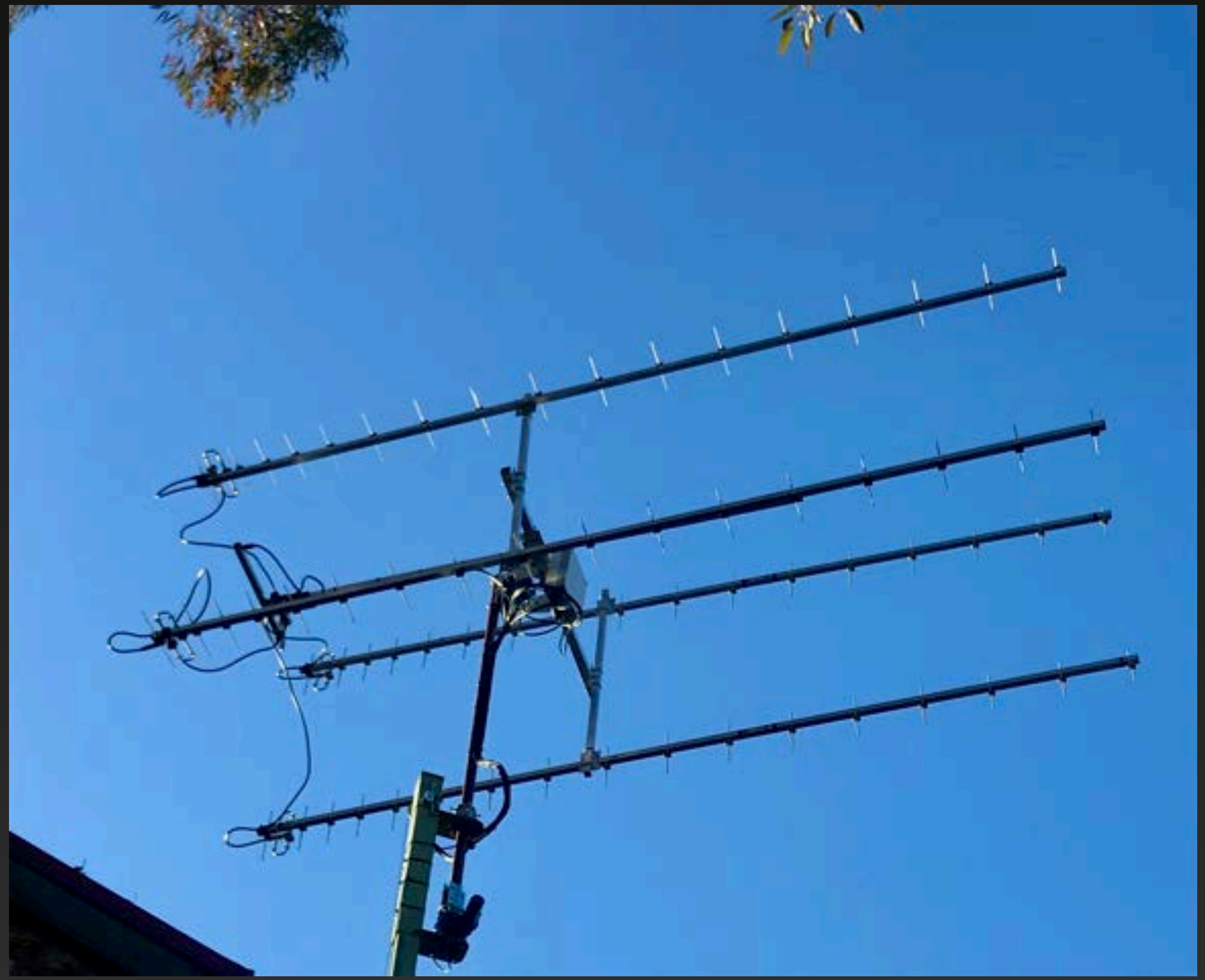
Lots of coax cables linking components and adapters

4 x21 X-pol current setup



From just participating to the podium

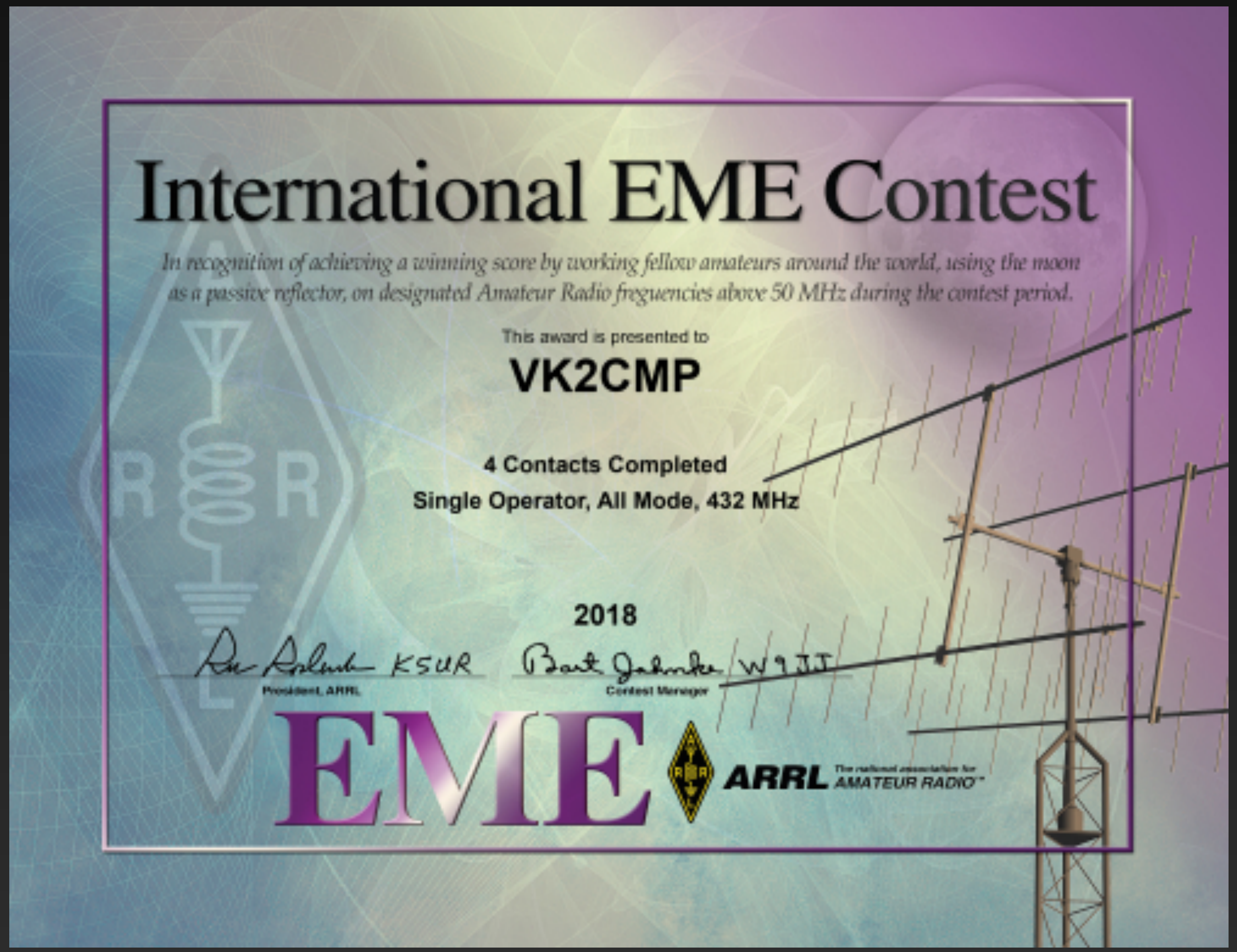
It all started in 2018

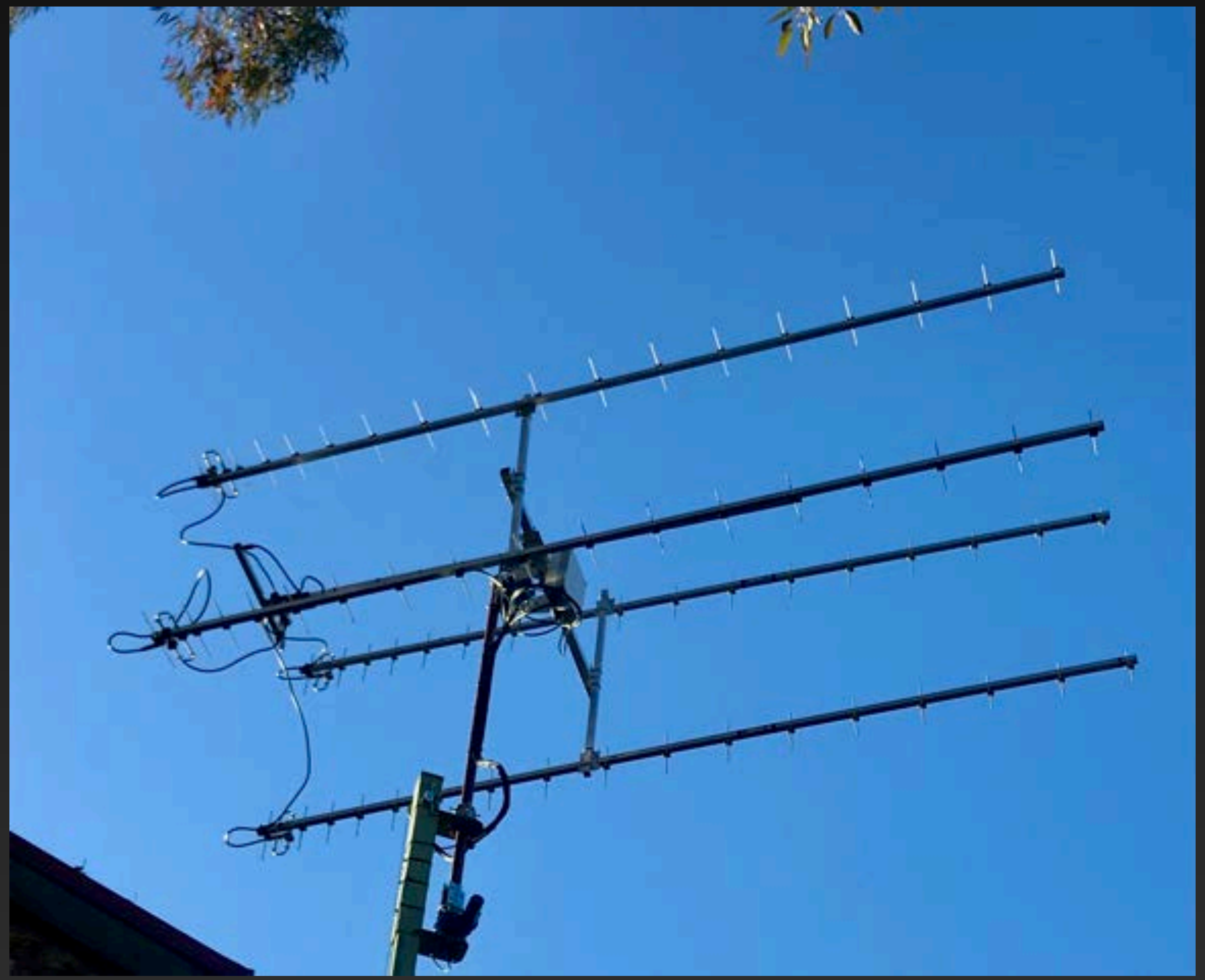


- Wide beam width picks up a lot more noise
- Long feeder cables - big loss before LNA
- OK relays - Insertion loss of 0.15dB
- Very under performing power dividers - poor return loss and large insertion loss

From just participating to the podium

I really had no idea but gave it a bash





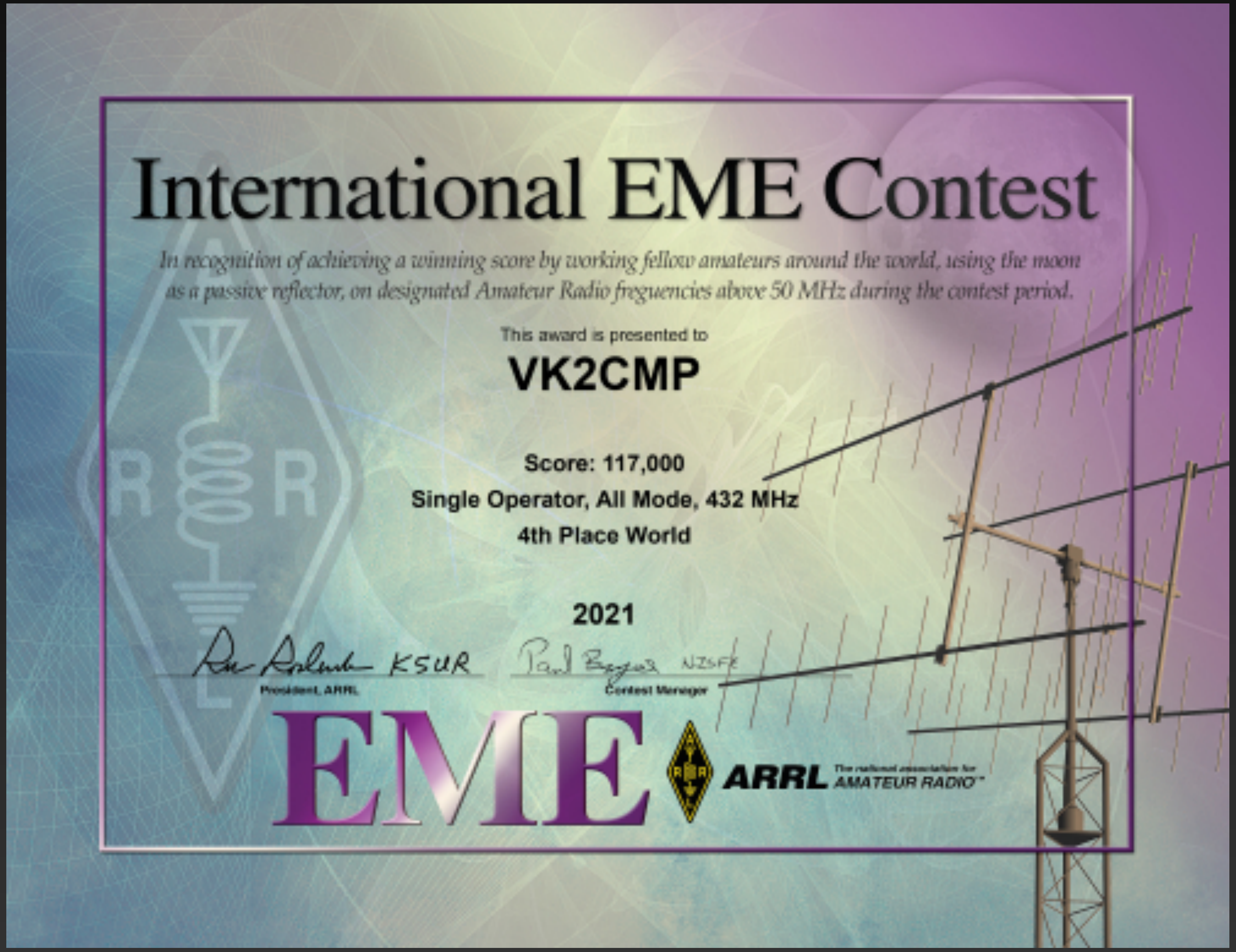
From just participating to the podium

4 yagi stations make a massive difference

- 4 yagi's reduced beam width to 14 degrees - lots less QRM and QRN
- 4ft feeder cables
- Times SFT-205 instead of RG142
- 3/2 wavelength power dividers - enable shorter (4ft) feeder cable
- Very high performing power dividers - excellent return loss and very small insertion loss (6.1dB)
- Ducks guts relay IL of 0.02dB

From just participating to the podium

4 yagi make a massive difference



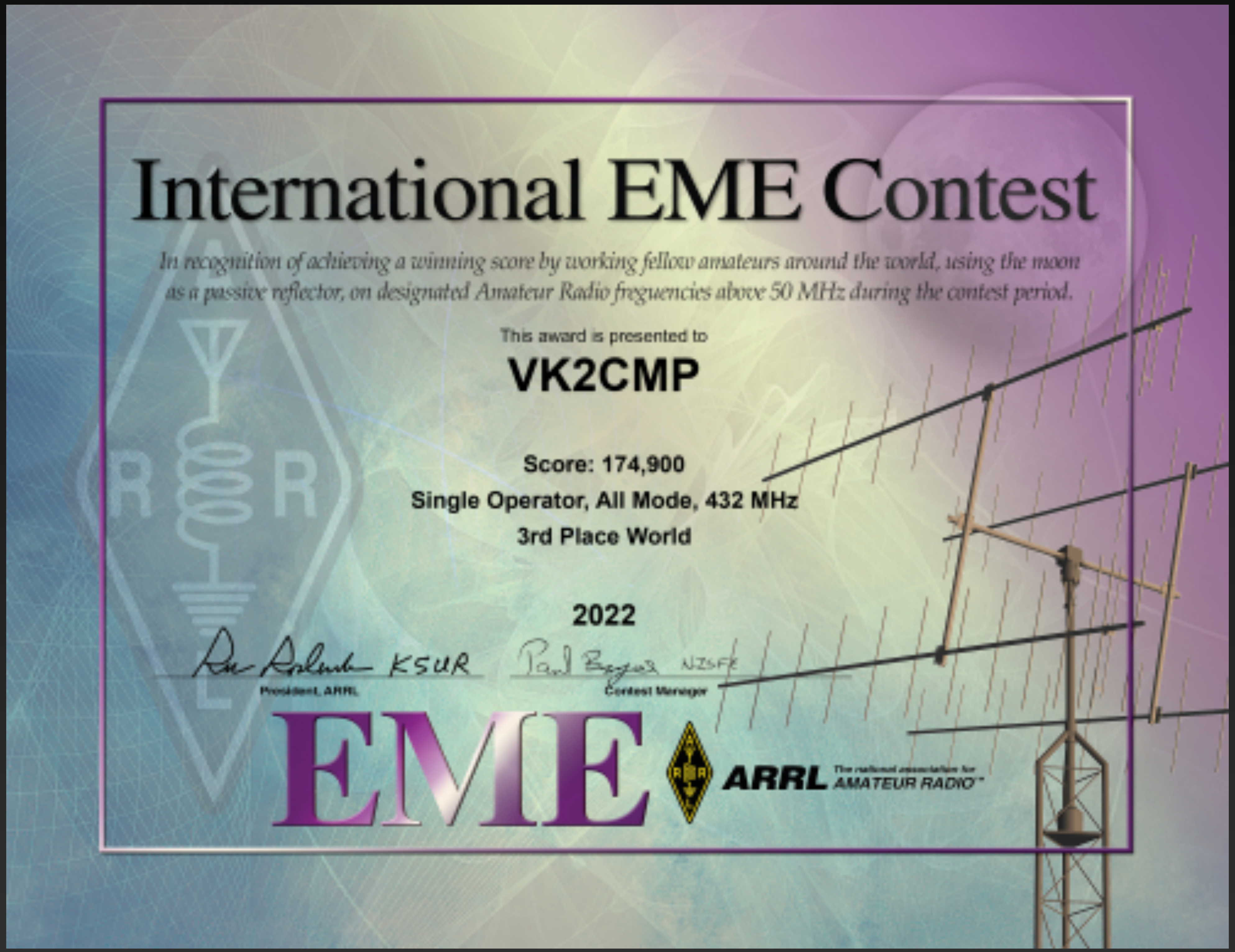
From just participating to the podium

Changed from 4x15 to 4x21 element X-pols (21H +21V)

- Reduced beam width from 10 to 14 degrees
  - even less QRM and QRN
- M&P 10mm Ecoflex low loss feeder cables
- Very high performing power dividers - excellent return loss and very small insertion loss (6.1dB)
- Ducks guts relay IL of 0.02dB

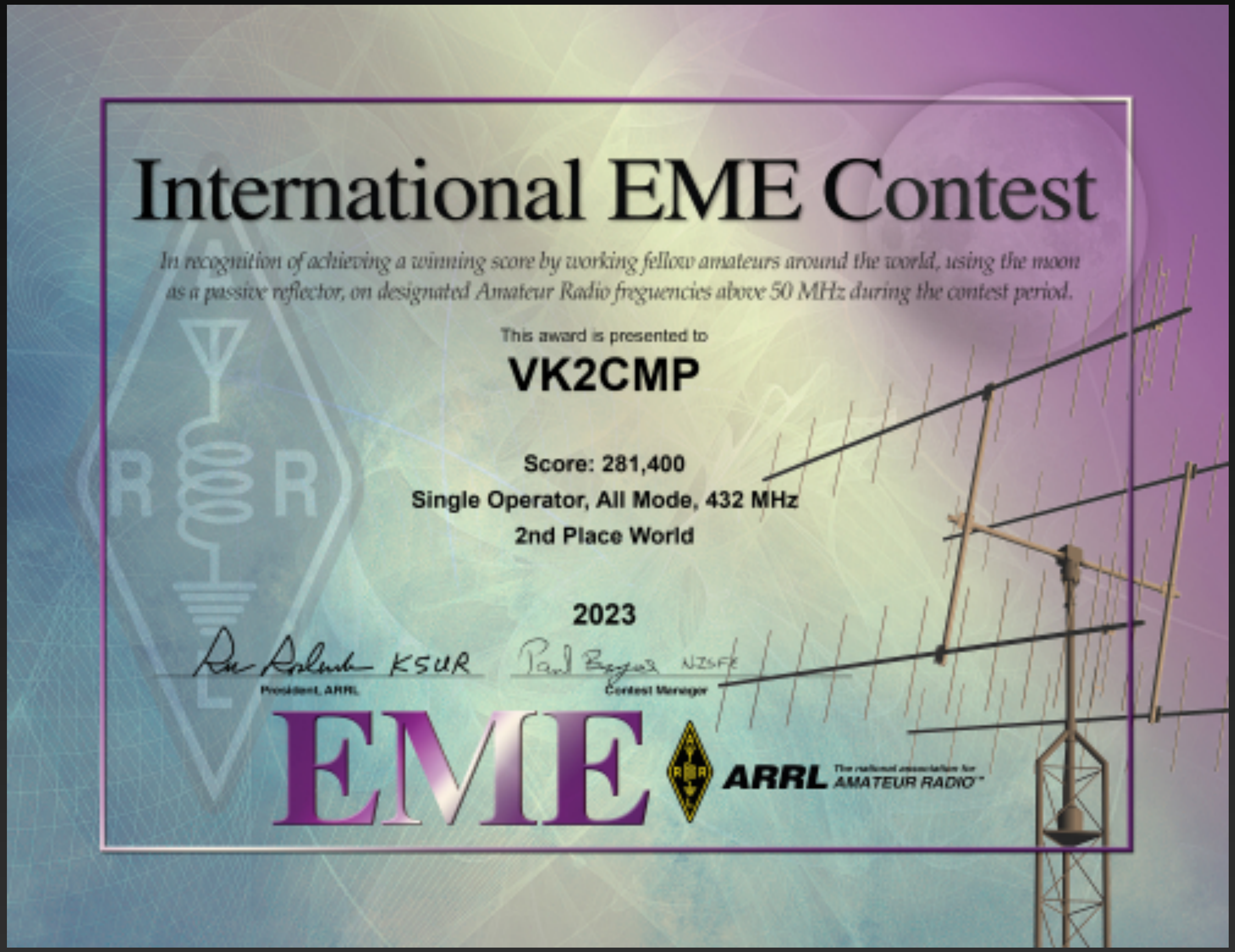
From just participating to the podium

Podium - at last!



From just participating to the podium

Soooo close!




Moon
Entrance panel
V-pol transverter
& sequencer
Az/El
HF beam
Pwr meter
HF Az
H-pol transverter
4:1
432Mhz PA
HF PA
K4D & Heil amp
SDR receivers are under bench >
Shack PC

Part II

The Low Down

- Select antenna that picks up more signals and less noise
- Minimise the losses before the LNA - optimise choice of feed line, power divider and relays to improve SNR (minimise losses and improve NF)
- Choose a LNA with good NF and high P1dB specs
- If possible have some sort of filtering before the LNA i.e low IL cavity
- Receiver — SDR
- Minimise the noise in the shack - ferrites, check plug packs, lights
- Noise Reduction using Linrad dumb and smart NB
- Implement good earthing and bonding practices

Pn - Noise power

- the often ignored in station design

- You have more influence over these design elements than you might think!

- Think of your station design required to receive the desired signal AND then think of the same design to minimise noise.

- Tsky
- Tantenna
- Man made noise - environment
- Man made noise - QTH
- Noise in RX chain - design choices
- Tsystem

Appendix

T system worksheet example

W2PU as built

	A	B	C	G	H
1	**Tsys Worksheet**	Gain	Noise Figure	Noise Contribution	
2		(dB)	(dB)	(K)	% Total
3	4 ft RG-142	-0.32		22.2	18.7%
4	Power splitter	-0.05		3.6	3.1%
5	3 ft LDF 4-50A	-0.04		2.9	2.5%
6	T/R relay	-0.05		3.7	3.1%
7	LNA1 (DB6NT)	23.00	0.40	30.8	26.0%
8	10 ft LMR400	-0.27		0.1	0.1%
9	100 ft LMR240	-5.20		3.9	3.3%
10	10 ft RG58	-1.00		1.5	1.2%
11	LNA2 (ARR)	20.00	0.50	0.9	0.7%
12	LinkRF IQ+		9.00	0.5	0.4%
13					
14	Tr at antenna feedpoint		**0.94**	**70.0**	59.2%
15					
16	Antenna and feed losses	0.06		4.0	3.4%
17	Sky noise (main beam, on ecliptic)			20.0	16.9%
18	Side and rear lobes			25.0	21.1%
19	Total antenna noise, Ta			48.4	40.8%
20	System noise temperature, Ts			**118.4**	100.0%
21					
22	Frequency (MHz)	432			
23	Lossless antenna gain (dBi)	22.40			
24	Solar Flux at 432 MHz (SFU)	44.0			
25	Tx power at antenna (W)	100			
26					
27	EME path loss (dB)	261.6			
28	G/Ta (dB/K)	5.5			
29	G/Ts (dB/K)	**1.6**			
30	Y Sun (dB)	**9.9**			
31	EME S/N in B=2500 Hz (dB)	**-23.0**			
32	EME S/N in B=50 Hz (dB)	**-6.0**			

W2PU K1JT worksheet

T system worksheet example

VK2CMP as built

	A	B	C	G	H
1	**Tsys Worksheet**	Gain	Noise Figure	Noise Contribution	
2		(dB)	(dB)	(K)	% Total
3	4 ft Times SFT-205	-0.22		15.1	16.6%
4	Power splitter	-0.05		3.5	3.9%
5	3 ft LDF 4-50A	-0.04		2.9	3.1%
6	T/R relay	-0.02		1.4	1.6%
7	LNA1 & DB6NT (both at antenna)	40.00	0.26	19.1	21.1%
8	10 ft LMR400. 20m	-1.85		0.0	0.0%
9	100 ft LMR240	0.00		0.0	0.0%
10	10 ft RG58	0.00		0.0	0.0%
11	LNA2 (ARR)	0.00	0.00	0.0	0.0%
12	LinkRF IQ+		9.00	0.3	0.4%
13					
14	Tr at antenna feedpoint		**0.59**	**42.4**	46.7%
15					
16	Antenna and feed losses	0.06		4.0	4.4%
17	Sky noise (main beam, on ecliptic)			20.0	22.0%
18	Side and rear lobes			25.0	27.6%
19	Total antenna noise, Ta			48.4	53.3%
20	System noise temperature, Ts			**90.7**	100.0%
21					
22	Frequency (MHz)	432			
23	Lossless antenna gain (dBi)	22.40			
24	Solar Flux at 432 MHz (SFU)	44.0			
25	Tx power at antenna (W)	100			
26					
27	EME path loss (dB)	261.6			
28	G/Ta (dB/K)	5.5			
29	G/Ts (dB/K)	**2.8**			
30	Y Sun (dB)	**11.0**			
31	EME S/N in B=2500 Hz (dB)	**-21.8**			
32	EME S/N in B=50 Hz (dB)	**-4.8**			

W2PU K1JT worksheet

Useful references - In no particular order

- This presentation and more about VK2CMP at https://farout.ai/
- Building Contest scores by Killing Receive Noise - Jim Brown K9YC, May June 2016 NCJ (ARRL)
- Space Communications, Chapter 25, ARRL Handbook 2023
- Noise, Chapter 5, ARRL Handbook 2023
- Receiving, Chapter 12, ARRL Handbook 2023
- Receivers, Chaper 5, RF Design Basics, John Fielding ZS5JF
- Antenna Amplifiers, https://antennas-amplifiers.com/
- Linrad and and host of other RF stuff from SM5BSZ http://www.sm5bsz.com
- WSJT-X, MAP65 & WSPR home page https://wsjt.sourceforge.io/
- VK3UM's EME calculator and other good oil https://www.vk5dj.com/doug.html