# ATV on the microwave bands

Noel Matthews – G8GTZ

Topics

- **What is ATV?**

- **Transmission Modes**

- **Current Trends**

- **FM ATV on 5.6 GHz**

- **Digital ATV**

- **ATV on 10 GHz, 24 & 76GHz**

- **Satellite ATV**
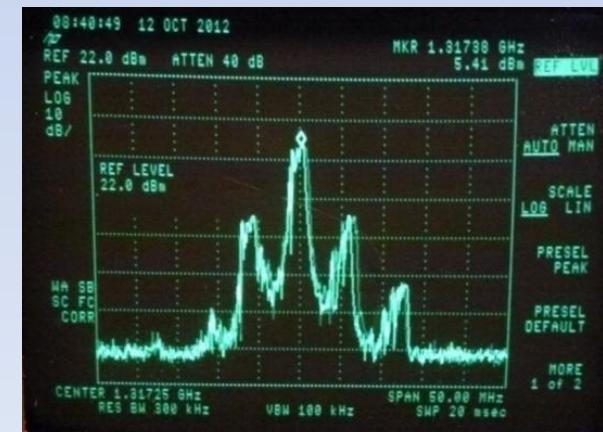
What is Amateur Television?

- Includes video production, editing and transmission
- Covers classic camera restoration right through to transmitting live pictures from a Raspberry Pi on a tethered drone.
- Real freedom to experiment
- ATV generally refers to fast-scan TV

Transmission Modes

- **Amplitude modulation (DSB/VSB)**
  - Now rarely used due to bandwidth
- **Frequency Modulation**
  - Lower Deviation still used on 23cms and 3cms
  - Higher Deviation used on 6cms
- **Digital DVB-S and DVB-S2**
  - All bands, various bandwidths
- **Digital DVB-T and GMSK**
  - Rarely used in UK
- **Internet Streaming**

Band-by-Band

- **71 & 146 MHz**
  - The "new" ATV bands
  - RB-TV
- **70cms**
  - Digital only on 437MHz
- **23cms**
  - Analogue and digital
  - Activity on repeaters and simplex
- **13cms**
  - Still room after PSSR!
  - Repeaters and simplex
  - Oscar 100 uplink

- **3.4 GHz**
  - Digital only
  - Repeater outputs
- **5.6 GHz**
  - FM ATV for under £20
  - Repeater inputs
- **10 GHz**
  - Repeaters and simplex
  - FM and DATV
  - Oscar 100 downlink
- **24 / 47 / 76GHz**
  - DATV
  - 120 kms is the goal

Low cost 5.6 GHz FM ATV

- **Using tx and Rx made for drone FPV use**
  - Tx = 600 Milliwatts out
  - Rx = -85 dBm
  - 27MHz wide
- **Available on ebay!**
- **Cover UK amateur Band**
  - 5665 MHz
- **They just work out of the box!**
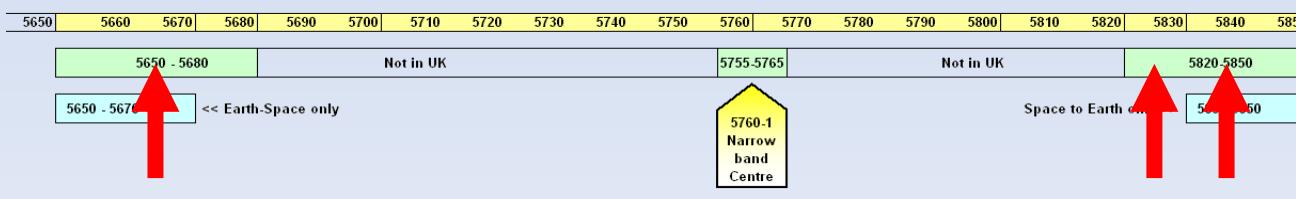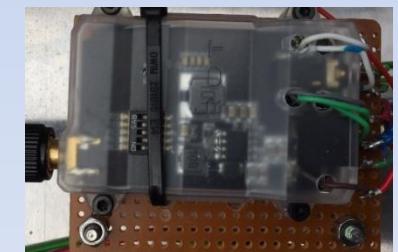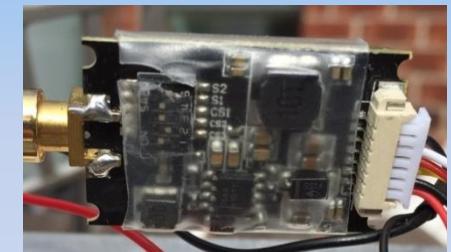
| 5650 | 5660 | 5670 | 5680 | 5690 | 5700 | 5710 | 5720 | 5730 | 5740 | 5750 | 5760 | 5770 | 5780 | 5790 | 5800 | 5810 | 5820 | 5830 | 5840 | 5850 |

| 5650 - 5680 | Not in UK | 5755-5765 | Not in UK | 5820-5850 |

5650 - 5670   << Earth-Space only

5760-1 Narrow band Centre

Space to Earth

The system

- **Wire up power, video and audio**
  - Beware blue screen and Reverse SMA!
- **Connect antennae**
  - 5.8 Ghz wi fi or Sky dish (available from the local tip!)
  - SMA relay is the most expensive bit!
 - Single or 2 ant working

5.6Ghz on the air

- Clear line of site paths
  - 50Km is easy
 - Best DX so far = >153 Km
    - 350Km with tropo!
- Also used for WB voice
  - PW Siren project
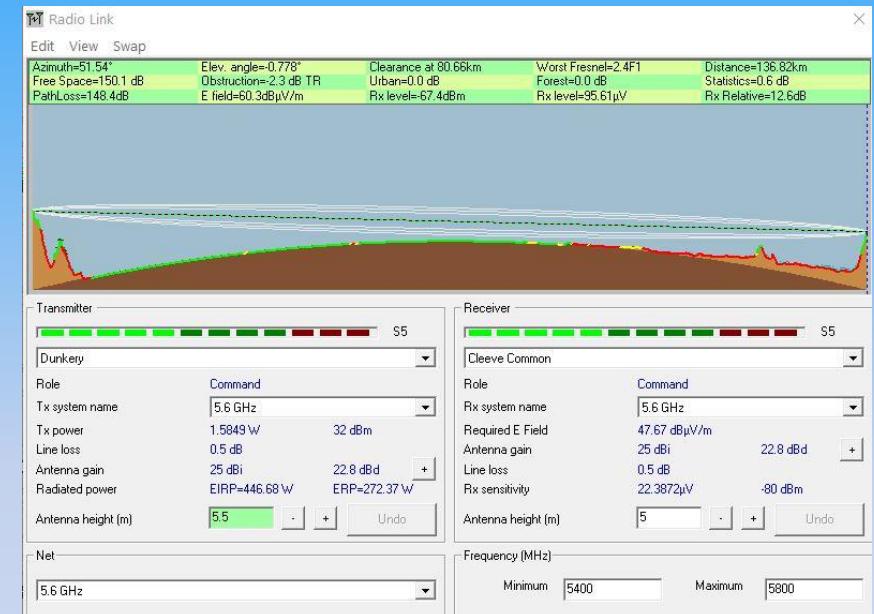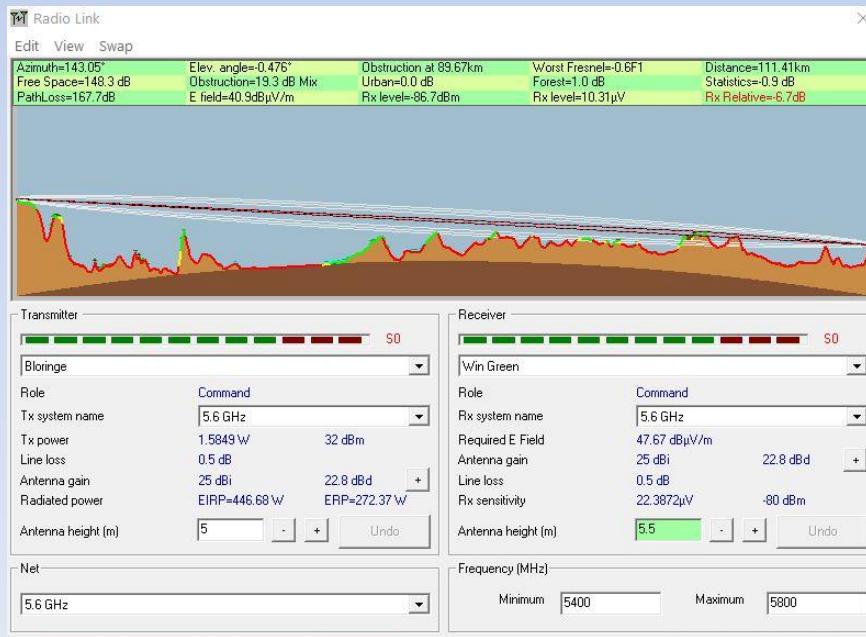
- Great club project
  - Backpack /p!

Paths

Blorenge to
Win Green
111 km
obstructed

Radio Link (top right — Dunkery to Cleeve Common)

Azimuth=51.54°	Elev. angle=-0.778°	Clearance at 80.66km	Worst Fresnel=2.4F1	Distance=136.82km
Free Space=150.1 dB	Obstruction=-2.3 dB TR	Urban=0.0 dB	Forest=0.0 dB	Statistics=0.6 dB
PathLoss=148.4dB	E field=60.3dBµV/m	Rx level=-67.4dBm	Rx level=95.61µV	Rx Relative=12.6dB

Transmitter — S5

Dunkery

Role	Command	
Tx system name	5.6 GHz	
Tx power	1.5849 W	32 dBm
Line loss	0.5 dB	
Antenna gain	25 dBi	22.8 dBd +
Radiated power	EIRP=446.68 W	ERP=272.37 W
Antenna height (m)	5.5	- + Undo

Net

5.6 GHz

Receiver — S5

Cleeve Common

Role	Command	
Rx system name	5.6 GHz	
Required E Field	47.67 dBµV/m	
Antenna gain	25 dBi	22.8 dBd +
Line loss	0.5 dB	
Rx sensitivity	22.3872µV	-80 dBm
Antenna height (m)	5	- + Undo

Frequency (MHz) — Minimum 5400 Maximum 5800

Radio Link (bottom left — Blorenge to Win Green)

Azimuth=143.05°	Elev. angle=-0.476°	Obstruction at 89.67km	Worst Fresnel=-0.6F1	Distance=111.41km
Free Space=148.3 dB	Obstruction=19.3 dB Mix	Urban=0.0 dB	Forest=1.0 dB	Statistics=-0.9 dB
PathLoss=167.7dB	E field=40.9dBµV/m	Rx level=-86.7dBm	Rx level=10.31µV	Rx Relative=-6.7dB

Transmitter — S0

Blorenge

Role	Command	
Tx system name	5.6 GHz	
Tx power	1.5849 W	32 dBm
Line loss	0.5 dB	
Antenna gain	25 dBi	22.8 dBd +
Radiated power	EIRP=446.68 W	ERP=272.37 W
Antenna height (m)	5	- + Undo

Net

5.6 GHz

Receiver — S0

Win Green

Role	Command	
Rx system name	5.6 GHz	
Required E Field	47.67 dBµV/m	
Antenna gain	25 dBi	22.8 dBd
Line loss	0.5 dB	
Rx sensitivity	22.3872µV	-80 dBm
Antenna height (m)	5.5	- + Undo

Frequency (MHz) — Minimum 5400 Maximum 5800

Dunkery to
Cleeve
Common
136 km LoS

ATV is going Digital

- **The move to digital is happening**
  - First tests in ~ 2000
  - Pressure on spectrum eg 13cms
  - A new challenge
- **Broadcast standards are being adopted and adapted**
- **DVB-S at 66KS > 4 MS**
  - 100 KHz > 6 MHz Bandwidth
- **Significant bandwidth gains and better pictures**
- **DVB-S2 and H265 give even more gain**

Analogue vs Digital ATV
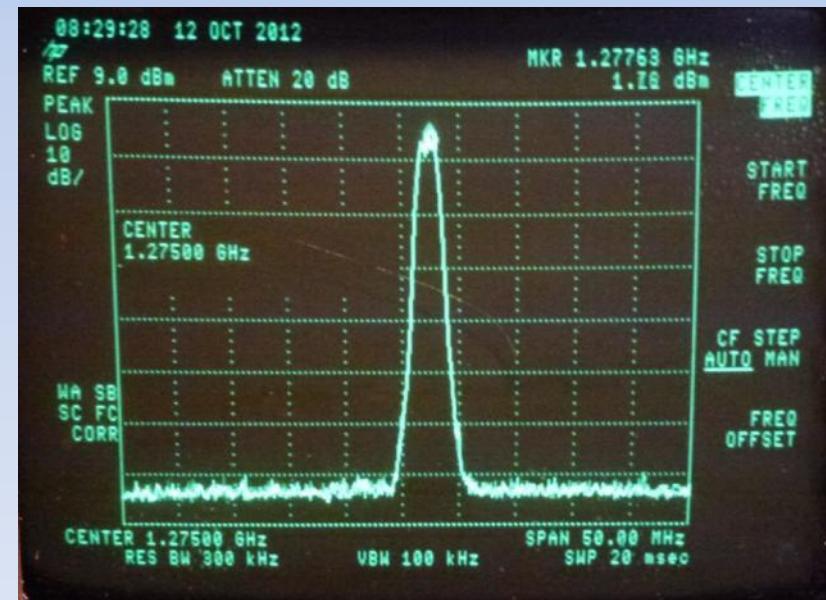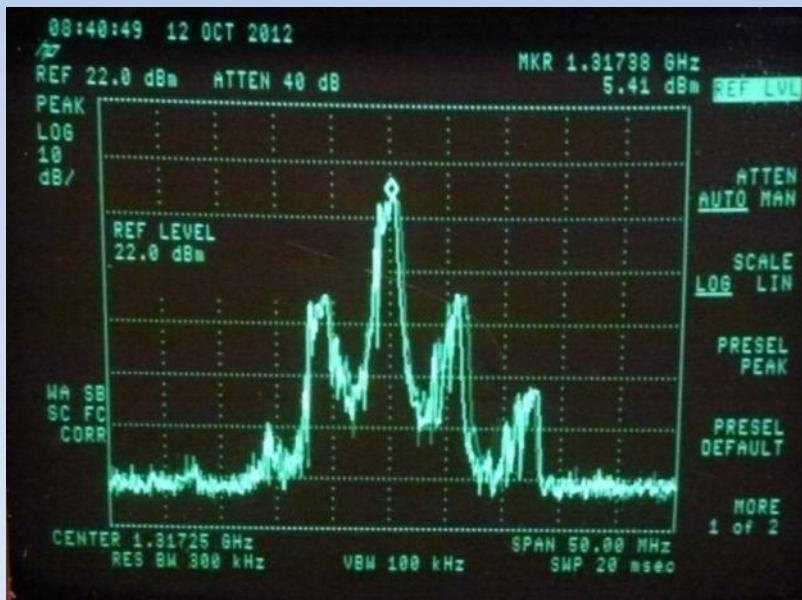
FM analogue
- 16 MHz deviation
- ~ 16 MHz

DVB-S QPSK,
- 1.6 MS, ½ FEC
- ~ 2 MHz

Analogue vs Digital ATV
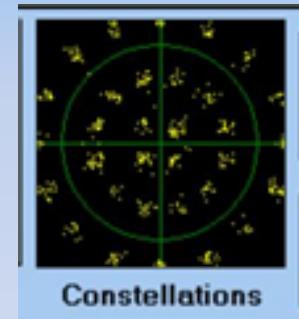
Reduced Bandwidth (RB-TV)

- Not enough space for "normal" DVB-S on the lower bands so we invented RB-TV
- RB-TV is "normal" fast scan DATV at <1 MS
- Live TV in ~450Khz bandwidth (333 Kbit/s video)
- Based on DVB-S standard BUT...
  - Benefits from MPEG-4 / H265 encoding for transmit
  - "Normal" satellite RX won't work below 1 MS
- So the ATV community has developed TX and RX products
  - Portsdown DATV TX
  - MiniTiouner RX
- Significant power/bandwidth gains
  - DVB-S2 in 500KHz decodable <5 dB above noise
  - RB-TV will go when FM signals are S9
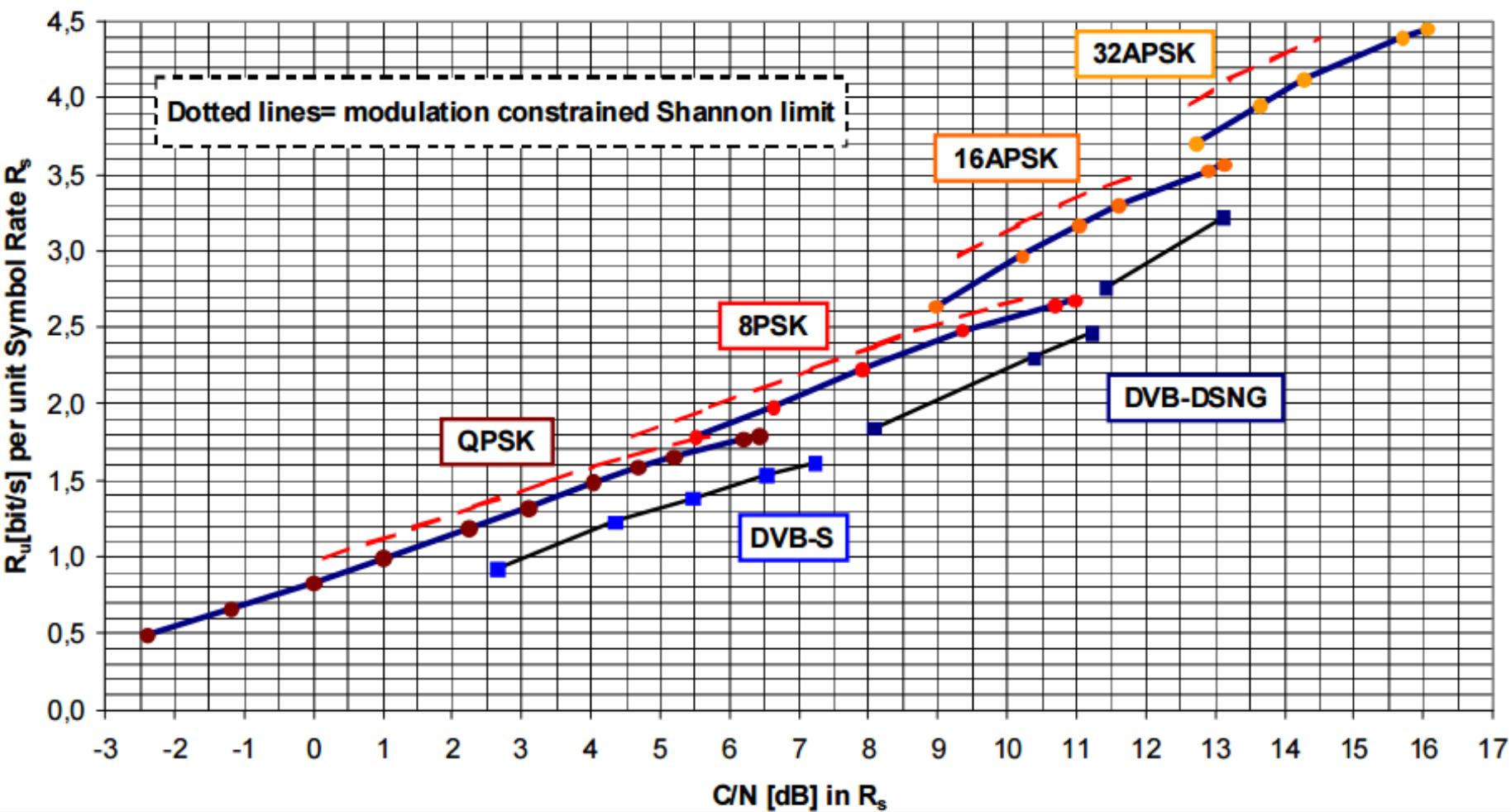
DVB-S2

- DATV has used DVB-S for last 10 years but equipment is now available to tx and rx DVB-S2
- Originally deployed on satellites as it is capable of carrying more bits/hz
  - HD in the same bandwidth as SD
- Operates closer to the Shannon Limit
  - 2 -3 dB gain over DVB-S
  - Proven in on-air tests
  - Significant when limited to 50 watts erp
  - Helps achieve 50+ dB spectral re-growth!
- Enables higher bit rates in reduced bandwidth

Constellations

DVB-S2 vs DVB-S

Spectrum efficiency versus required C/N on AWGN channel

DVB-S2 results

- **BATC** **Tests on Oscar 100 show S2 does give some valuable gains**

- **BATC** **At 1/2 FEC 2 MS**
  - DVB-S2 needs 3 dB less power than DVB-S
  - going from 1/2 to 1/4 FEC needs 4 dB less power

- **BATC** **Or can be used to provide higher payload**
  - DVB-S2 with 32APSK, 7/8 FEC gives 1.4 Mbit/s in 500Khz
  - Enough bit for 1920 * 1080 High Definition video on 146 MHz!

- **BATC** **Also experimenting with H265 codecs**
  - 50% bit rate saving!
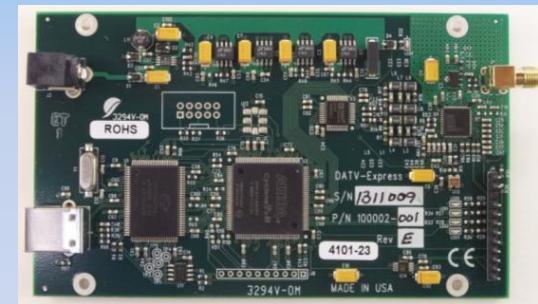
Generating DATV

- Ex-commercial encoders

- Amateur Market:

  - SR Systems Equipment

  - BATC DTX-1

  - DATV Express

- "Homebrew"

  - DigiLite – PC-based, external modulator

  - DigiThin – RPi-based RB-TV only

  - Portsdown – RPi-based, full bandwidth

Portsdown 2019

- **BATC project to bring DATV to everyone**
  - All the common modes and bandwidths
  - 28MHz to 3.4GHz
- **Based around RPi3 and Lime SDR Mini**
  - MPEG 2 / 4 encoding
  - Touch screen control
- **Requires some hands on construction**
  - "I made that!"
- **Easy way to get on air at low cost**
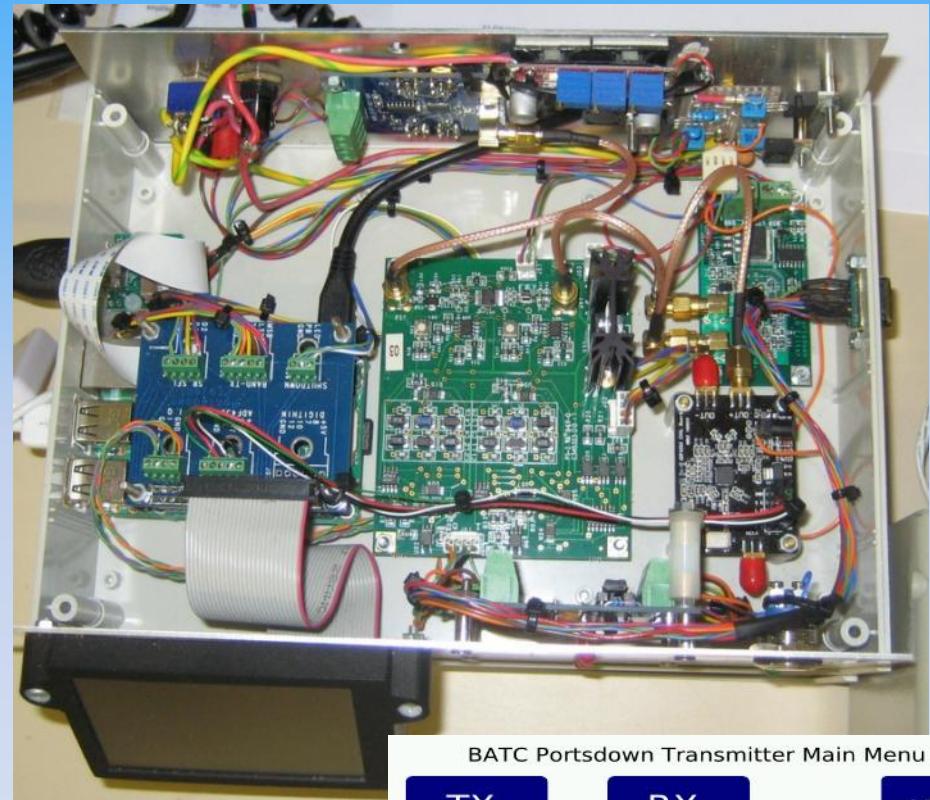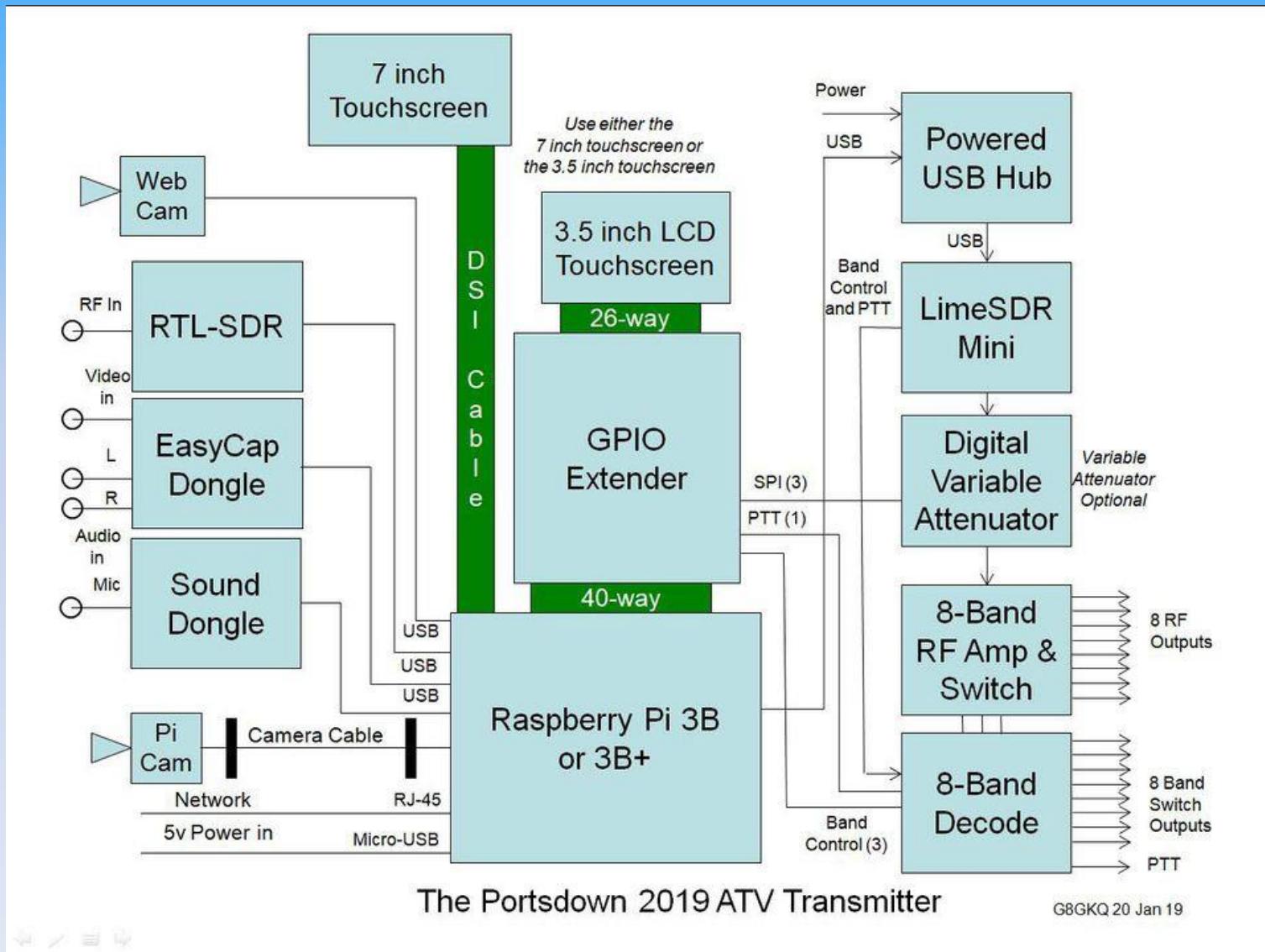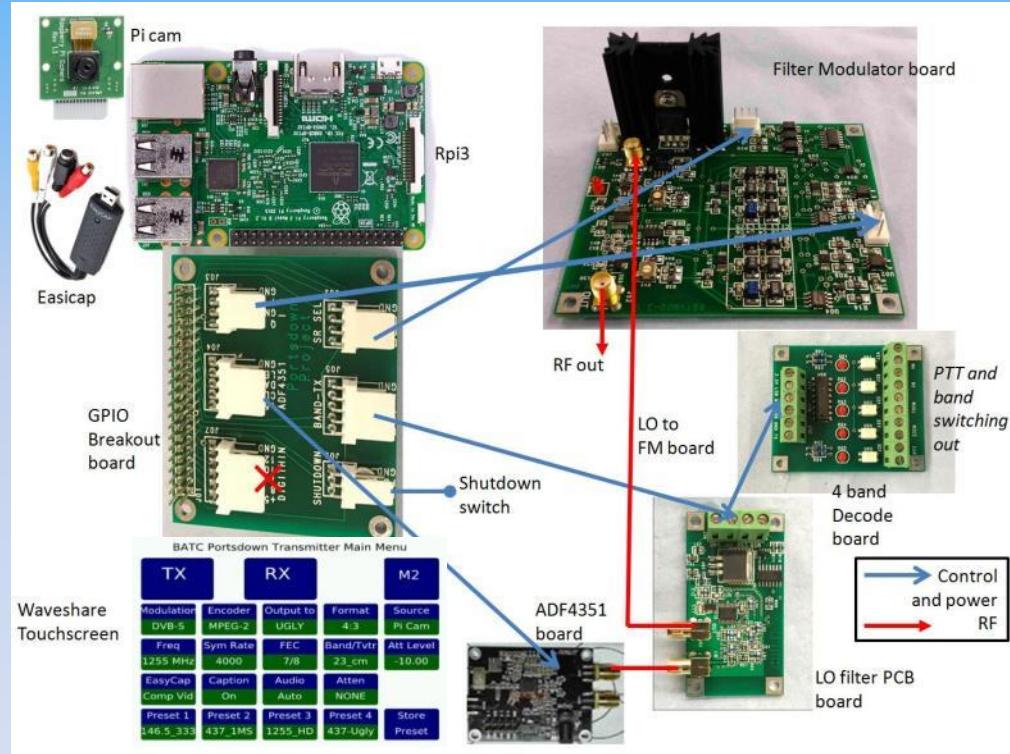
BATC Portsdown Transmitter Main Menu

TX	RX			M2
Modulation	Encoder	Output to	Format	Source
DVB-S	MPEG-2	UGLY	4:3	Pi Cam
Freq	Sym Rate	FEC	Band/Tvtr	Att Level
1255 MHz	4000	7/8	23_cm	-10.00
EasyCap	Caption	Audio	Atten	
Comp Vid	On	Auto	NONE	
Preset 1	Preset 2	Preset 3	Preset 4	Store
146.5_333	437_1MS	1255_HD	437-Ugly	Preset

Portsdown 2019 system

The Portsdown 2019 ATV Transmitter
G8GKQ 20 Jan 19
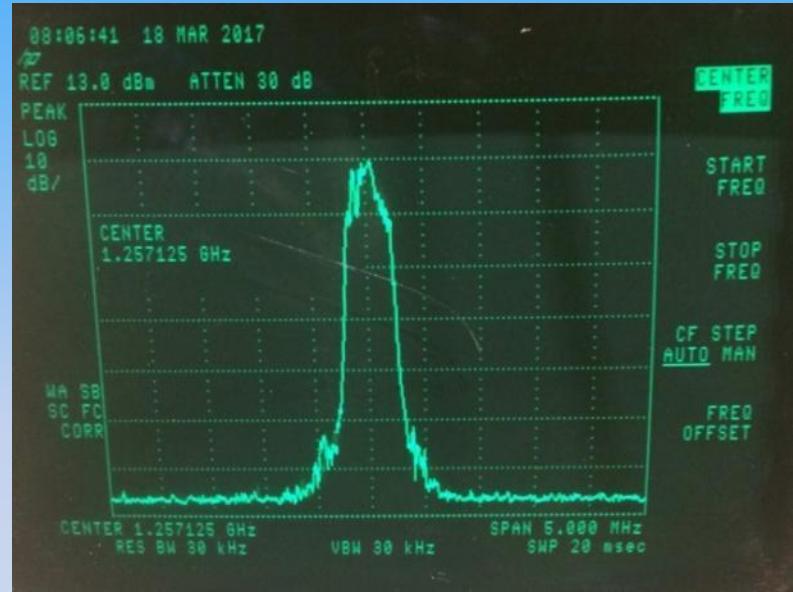
Portsdown made easy

- All hard to get or critical components in BATC shop
- Full set of PCBs and LimeMini from BATC shop
- Pre-programmed SD Card from BATC shop or self-build
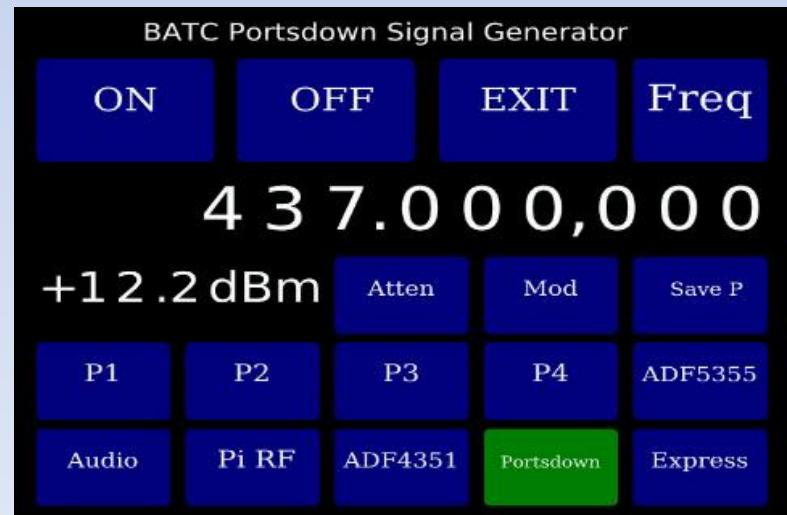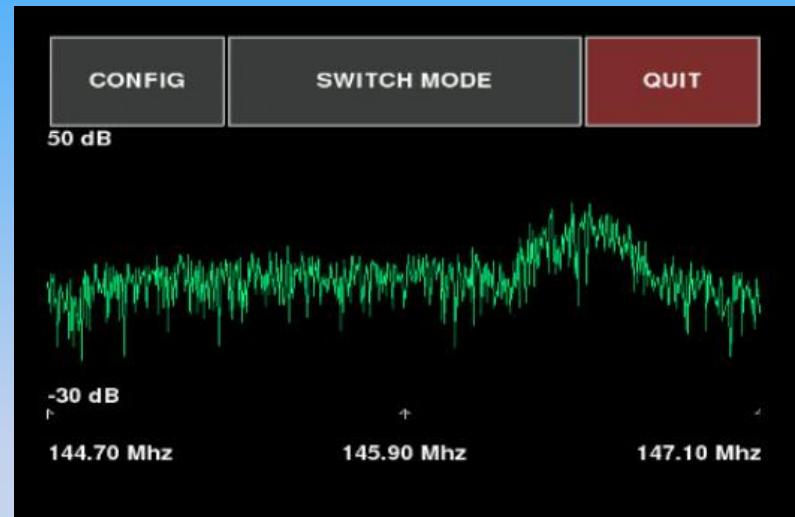
Portsdown Specs

- 30Mhz to 3.5GHz

- 88KS to 1 MS

- MPEG-2 and MPEG-4 encoding

- Touch screen or PC control

- PTT and band switching control

- Analogue Video out with test patterns

Portsdown 2019

- Not just a DATV system!
- Portsdown is being developed by the ATV community
  - Code is on Git Hub
- Latest developments include:
  - Microwave transverter switching
  - Spectrum monitor
  - FM receiver
- All from the standard software!

MiniTiouner

- Satellite TV tuner with USB interface
- Receiver / analyser software by F6DZP
- Tunes 144 – 2600 MHz
- Symbol Rates 66 KS – 30 MS
- Kit or ready-built

Minitioune s/w

Forget the S meter!

MER 18dB -----RF level -36dBm ----VBER 0% not bit corrected →TS OK
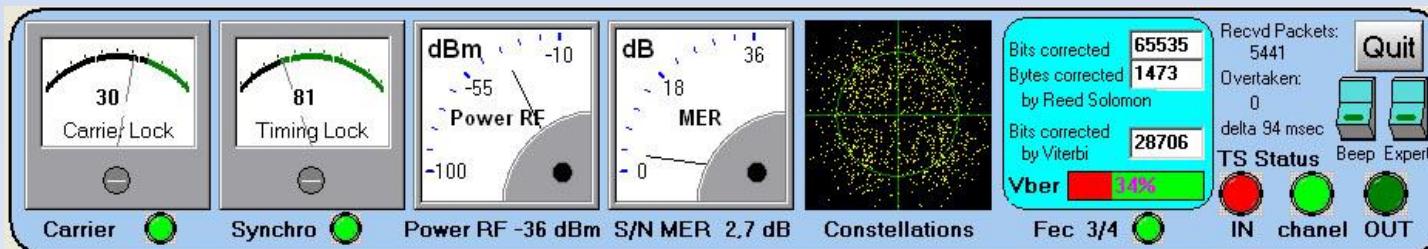
MER 5.8dB -----RF level -36dBm ----VBER 4% bits corrected by Viterbi →TS OK

MER 4dB -----RF level -36dBm ----VBER 18% bits corrected by Viterbi and Reed Solomon →TS OK
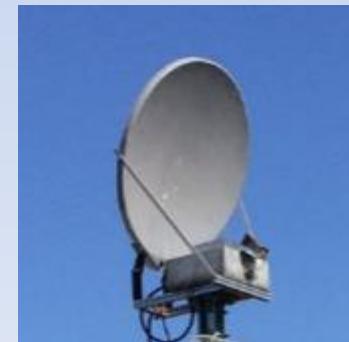
MER 2.7dB -----RF level -36dBm ----34% bits corrected by Viterbi and Reed Solomon →TS NOT OK

Microwave DATV
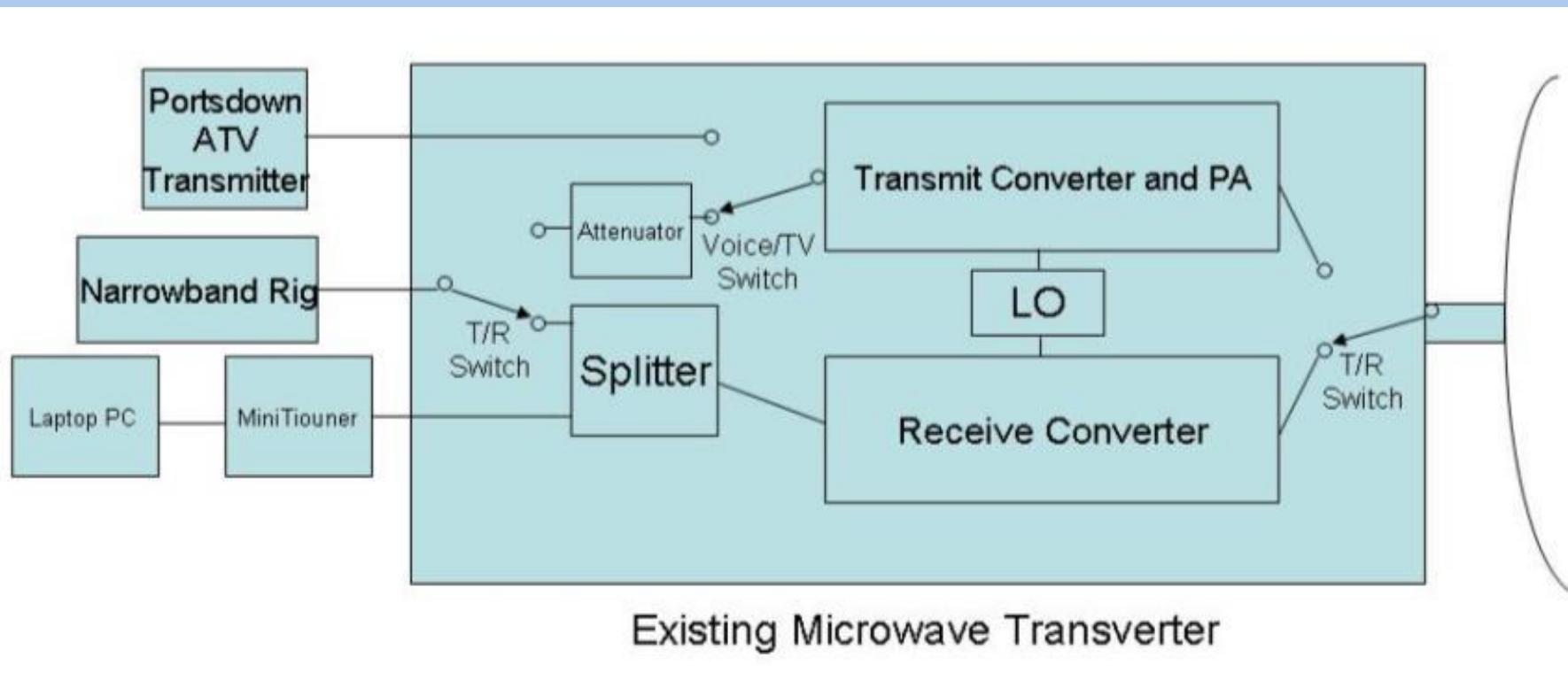
- DATV needs linear transverter Tx
  - FM ATV can be multiplied up
- Microwave transverters use 144 or 432 as an IF
  - 2.3, 3.4, 5.6, 10GHz, 24 GHz
- Portsdown covers 144 and 432MHz
- MiniTiouner covers 144 and 432MHz for receive
- So what happens if we drive the transverter with DATV?
  - It just works on Tx and Rx ☺
- Just a few system issues
  - Switching issues (DC on Tx and Rx!)
  - Drive levels
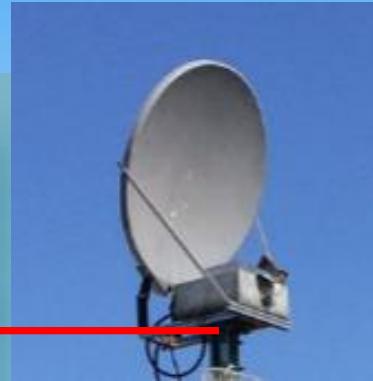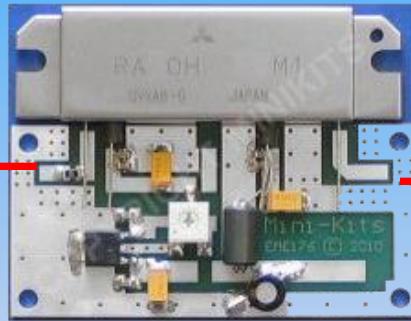
DATV on Microwaves

- Lime SDR covers up to 3.4GHz
- Higher bands via NB transverter
- Used successfully on 10, 24, 47 and 76 GHz

Existing Microwave Transverter
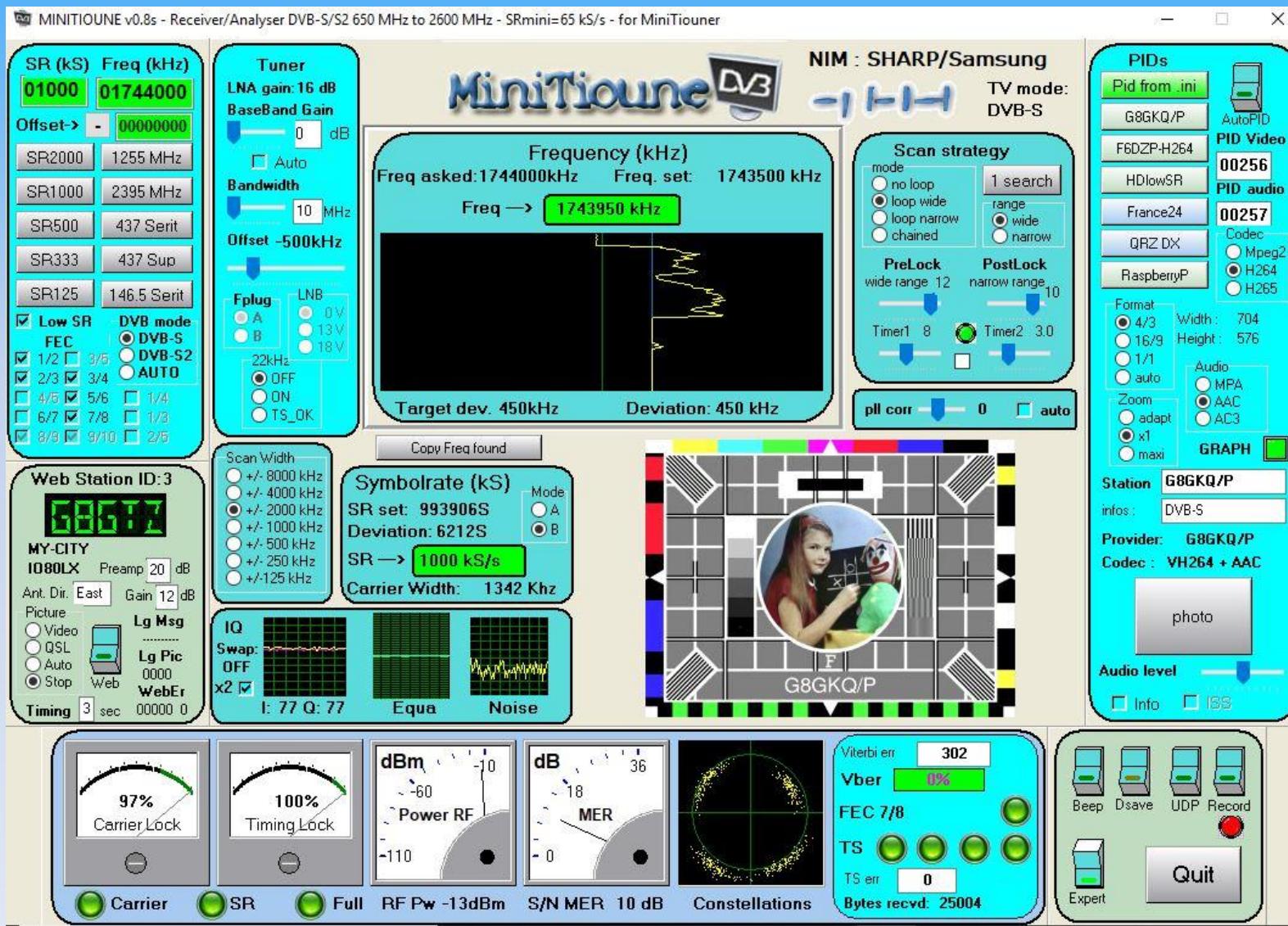
10GHz DATV system

Phase Noise

- DVB-S is vulnerable to phase noise
- Initial assumption was SSB was more critical proved to be incorrect
  - Readable SSB, but no-go on DVB-S
- ADF5355 (x2) as a 24 GHz LO works but..
  - Internal supply smoothing with 2000uF +
  - High Reference frequency
  - High charge pump current
- Problem is worse on higher bands
  - Multiplied LO multiplies the phase noise

Phase noise on 3.4GHz

10 GHz DATV

- **First tests in 2016**
  - 92KM
- **RB-TV and DATV**
  - Best DX was 138KM
  - Dunkery to Cleeve
  - 2Ms (~2 MHz) with 23dB MER!
- **Lot of margin in hand**
  - 200+Km should be easy!
  - Under flat band condx
- **October 2018 tropo**
  - M0DTS/P > G4UVZ
  - 407Kms!!
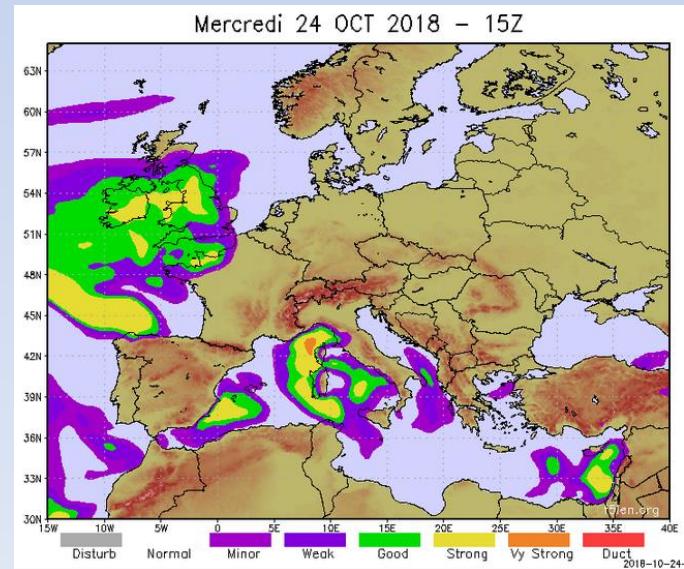
24GHz

- Same architecture as 10GHz
- Power levels < 1 watt
- Current UK Dx record = 85Kms
 - IO90LX > IO80WP
- World record only 120Kms
  - Can be beaten!
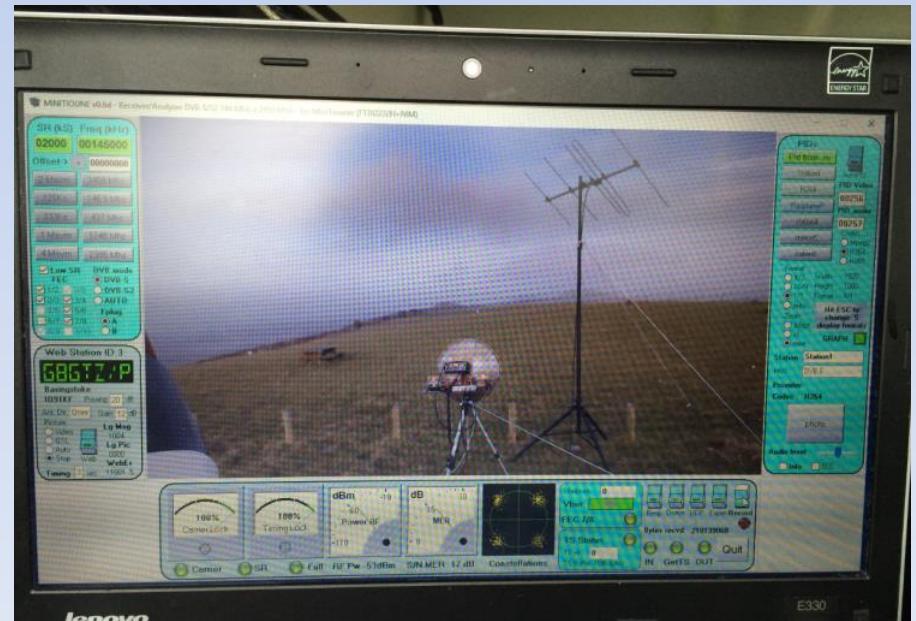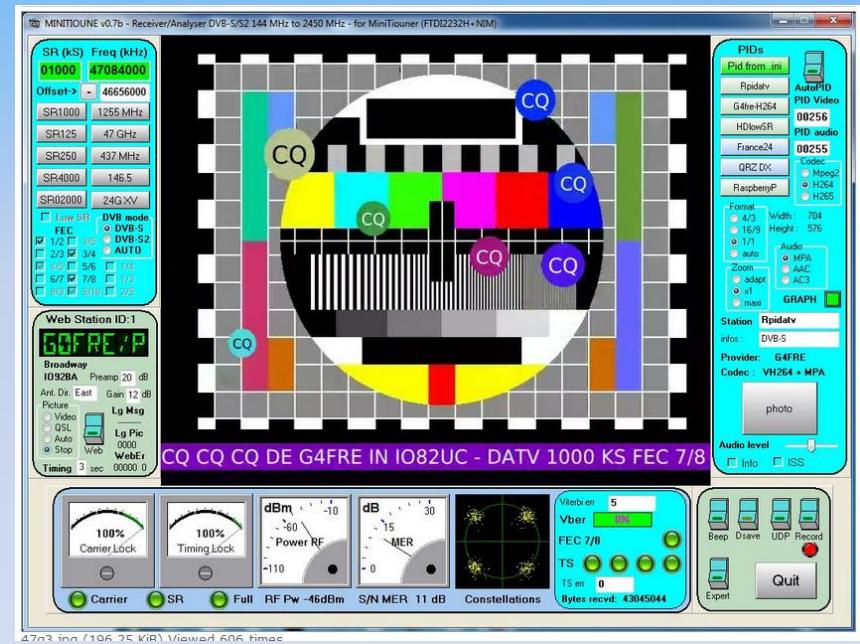
47GHz

- Only one station active!

- G4FRE has had a one way QSO from /p back to home
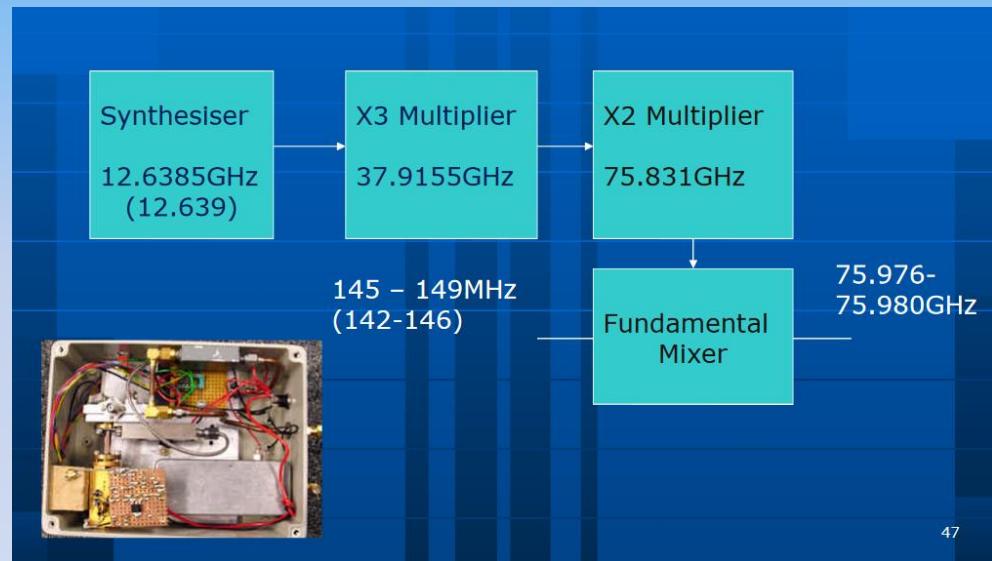
- Broadway > Malvern = 34.9Km

- .2mw > Paso link rx
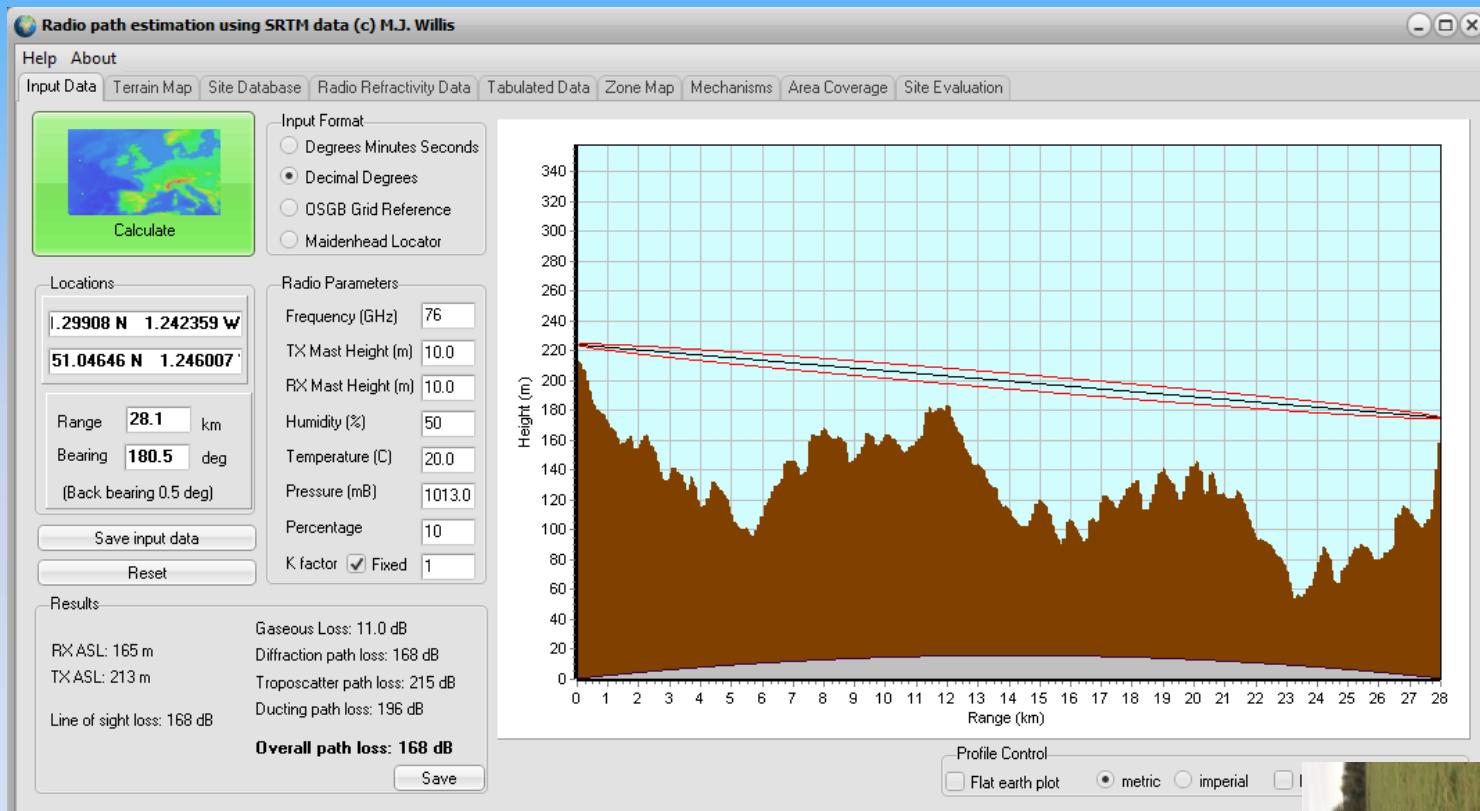
76GHz

- G4LDR and G8GTZ have been experimenting with 76Ghz DATV for 18 months
- Ukmicrowave loan kit
- ~ 5 milliwatts – NF ??
- Very critical on atmos phase distortion and equipment phase noise
- Current (world / UK) record is 35Kms
- A 38Km LoS path would not go

Synthesiser

12.6385GHz
(12.639)

X3 Multiplier

37.9155GHz

X2 Multiplier

75.831GHz

145 – 149MHz
(142-146)

Fundamental
Mixer

75.976-
75.980GHz

47
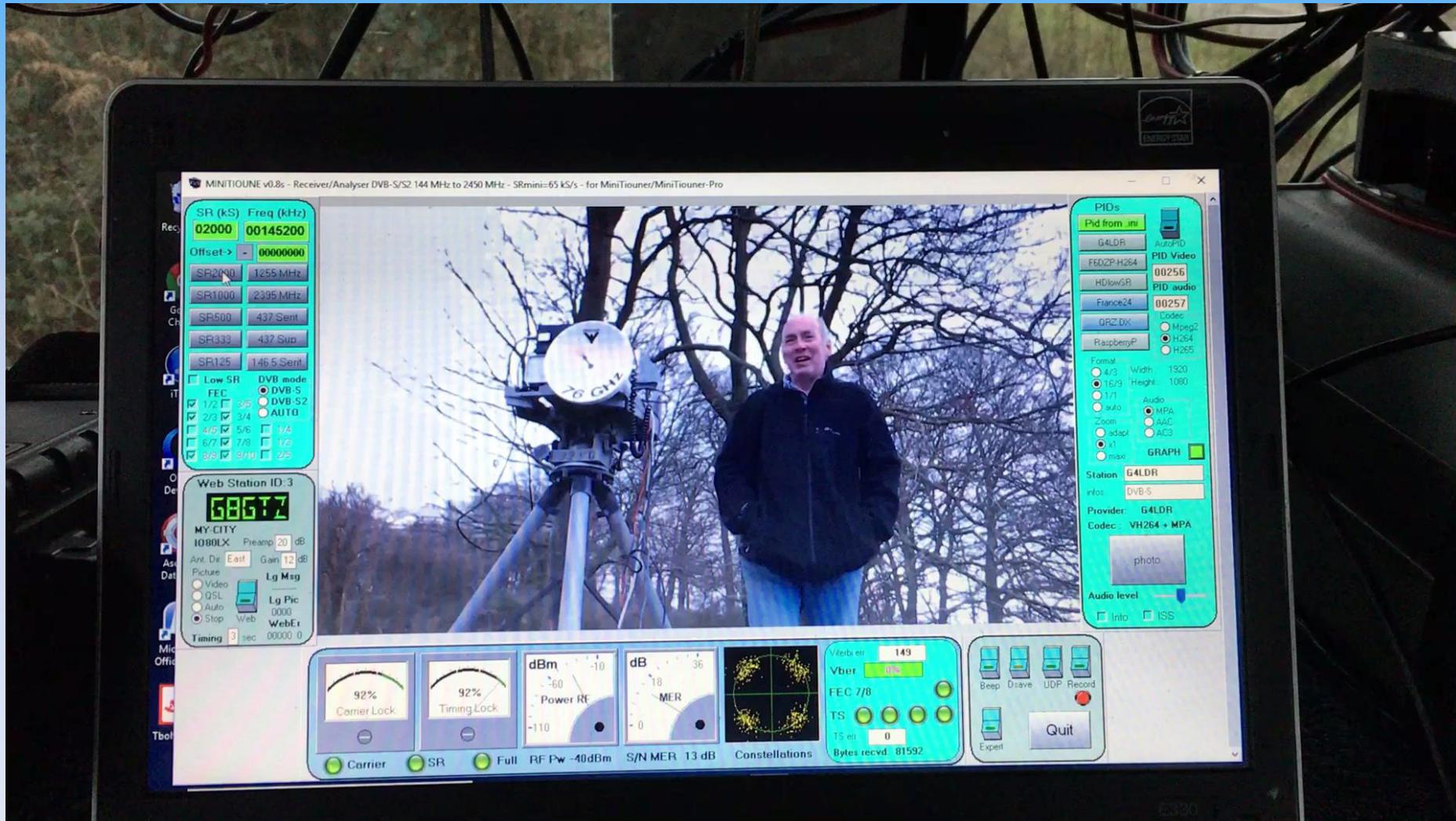
Hannington > Cheesefoot
28.1Km
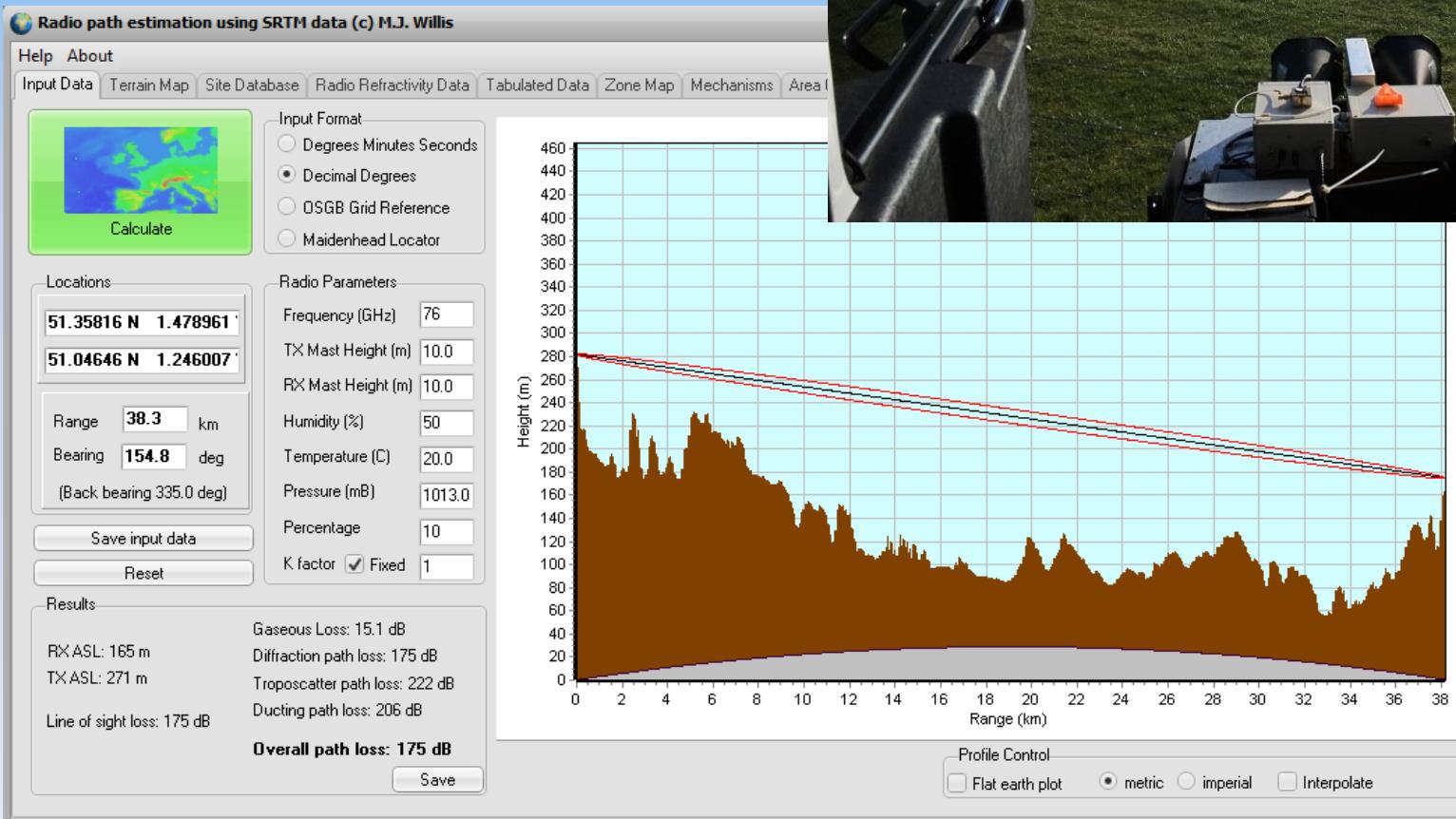
Video – 76GHz @ 28.1Km
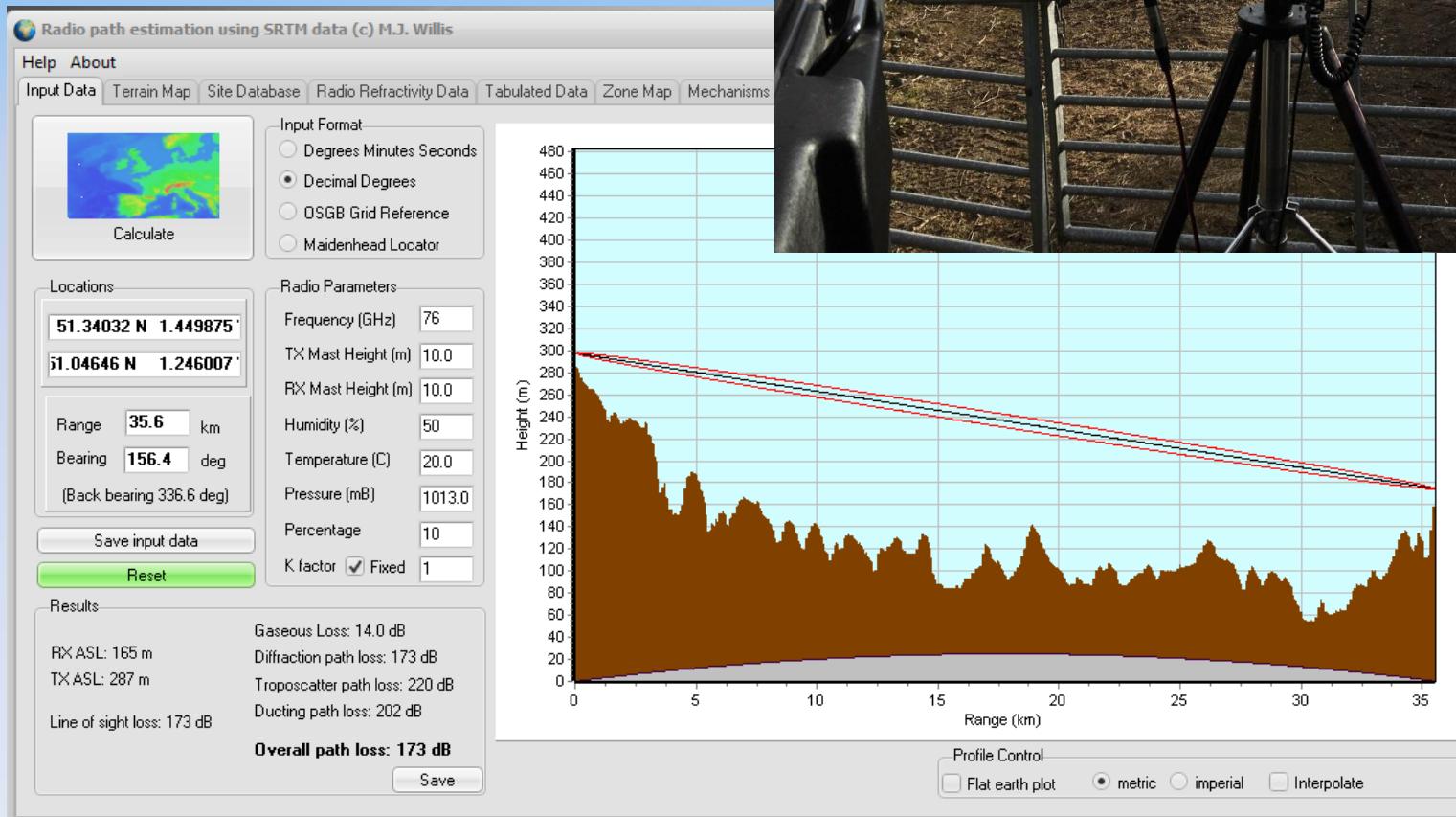
Coombe Gibbet > Cheesefoot

38.3Km LoS
175dB
Did not go on TV!

Coombe PMR > Cheesefoot

35.6Km LoS
173dB
Did go on TV!

76GHz video @ 35Km

76GHz – what next?

- **Try a longer path**
  - 45Km to Butser
- **Improve the gear**
- **Neil is adding an image filter**
  - 3dB more power / Rxr NF?
- **Improve phase noise on LO??**

Oscar 100
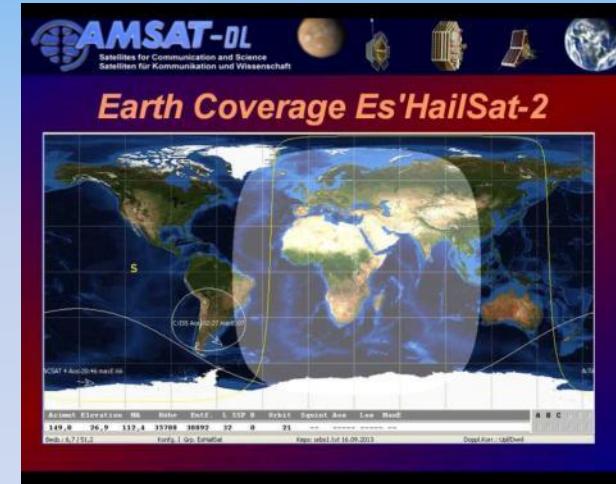
- A real game changer
- Es'Hail-2 wideband is an "8 MHz bent pipe" transponder
  - 2.4 GHz up, 10.49 GHz down
  - No spot beams – covers 1/3 of the earth!
  - Dedicated to DATV use
- DVB-S2 is preferred modulation
  - 88Ks > 2Ms
  - 100 KHz > 2.5MHz
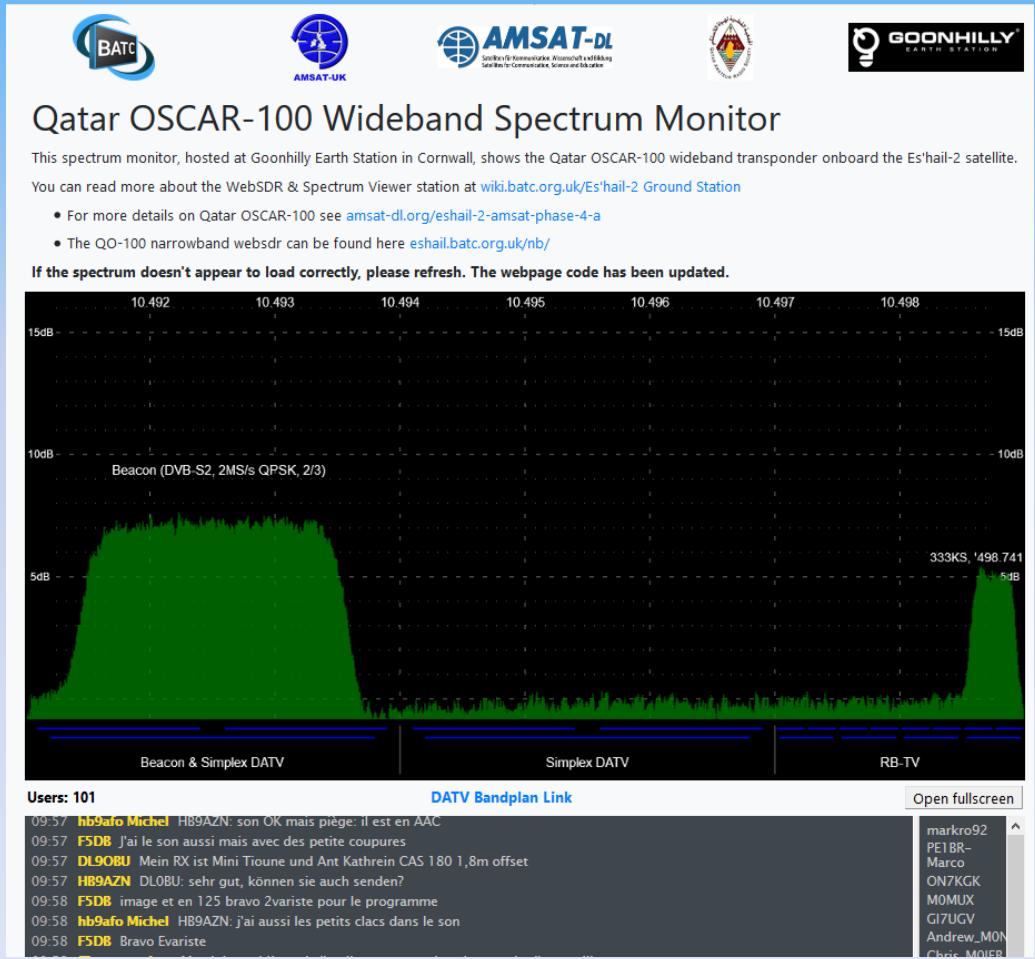
Oscar 100 DATV

Spectrum monitor and chat for coordination

Beacon on 24/7

– Invaluable for dish alignment and dish checking in high winds!

Oscar 100

- Typical DATV rx station:
  - 1mt dish
  - PLL LNB
  - MiniTiouner USB receiver
- Typical DATV Tx station
  - Portsdown2019 > Lime Mini
  - DVB-S2 88Ks – 2Ms
  - 30 watts on 2406MHz
  - 1.2mt dish
- MJW dual band patch feed
- Come to Bristol CAT on 31st March to learn more

The new golden age for ATV!

- ATV is undergoing a real revival
- Last area of real amateur radio
  - No commercial equipment
  - You have to build and experiment
  - Real open source
- Covers all skill levels from beginner to seasoned professional
  - propagation, antennas, RF design, studio, video editing,
- BATC is thriving
  - 25% increase in last 3 years
  - Growing a real ATV community
  - Sharing the knowledge and growing together
- Do some real radio today – get involved in Amateur TV!

More information

- BATC wiki: https://wiki.batc.tv/BATC_Wiki
- 5.6GHz: https://wiki.batc.tv/5.6_GHz
- Portsdown: https://wiki.batc.tv/The_Portsdown_Transmitter
- See you at CAT19 Bristol on 31st March