EME Talk Notes – C.Rabe - G6NLC

2. FRARS – Flight Refuelling Amateur radio Society founded in 1982

I joined shortly after that when I was first licenced which I think was 1984.
we initially met in the Flight Refuelling rifle range but had the opportunity to take over a changing room building which was much larger and offered us the opportunity to have permanent antennas, operating rooms, storage areas as well as a good size meeting room and tea bar area.

3. Main club activity was VHF/UHF contests
Contesting continued for many years – and we'd have dozens of people turn out for VHF NFD and similar contests. Mostly home made equipment – masts, antennas, 4CX250s PAs for most bands – all good fun.

4. The club did some early EME tests on 432MHz in the 80s

5. Dish acquired by Julian G3YGF in 1985-86

6. Originally is was used on the Post Office Tower at around 2GHz – 3.65m (12ft)

7. In was stored in various locations until we collected it from RSBG HQ in the mid 80s

8. The current project began in 1985 with the dish seen here – 12ft 0.43 f/d

9. The dish weighs around 250KG

10. A further 250KG of mounting hardware has been added.

10. Several years passed and eventually a mount was designed and manufactured The mount is a mobile Versatower base and everything else is mostly from scrap! – Thanks to Jules for some of the bigger machining work.

11. The original system used a satellite jack for elevation and a pair of gearboxes and DC motor for azimuth.

12. Protractors for angle measurement and manual control using a bore sight camera.

13. A circle drawn on the monitor once the moon noise was peaked – doesn't work that well in cloudy conditions!
At 10GHz the gain is around 50dBi with a 0.6° 3dB bandwidth (which is a good match for the sun & moon)

14. 10GHz was our 'starter' band – a fairly basic setup

15. A 20W TWT and two single stage pre-amps gave CW echoes

16. In 1994 our first 10GHz EME contact with Charlie G3WDG followed by an SBB contact with WA7CJO.
At that stage we were seeing 0.5dB moon noise

17. CW Audio Clip

18. SSB Audio Clip

19. A short break of 12 years passed while the Bell Hill beacon complex was build
We have ‘special floating’ beacons – OK we were fitting a damp proof floor membrane and a new skimmed floor

20. You need a guard dog when dealing with beacons…
A funny story – the hut feeds a farmers electric fence and all but a couple of inches of the cable were well insulated – Bugsy here found the only unprotected piece with his tail – when did you last see a Labrador with an unfinished bowl of food!

21 & 22. Maintenance work still goes on today.

Back to EME…

23. Both Az & El drives were updated to stepper motor drives. The Az motor drives a series pair of gearboxes while the El drive rotates a 25mm stainless steel threaded rod.

24 & 25. Jules did most of the larger machining jobs with some ingenious material handling.

26 & 27. Some fairly large lumps of Ali and brass were needed. Finished top & bottom Elevation bearings shows here

28 & 29. The finished Elevation installation with stepper motor drive being fitted.

30 & 31 & 32. Upgrading the feed box assembly to make it easy to change bands with a common ‘sled’ approach

33 & 34. The Az drive suffered from about 6 degrees of backlash in the gearboxes so, as the moon only ever moves East to West some weights have been suspended via stainless wire to apply a torque to pull the dish towards the west against the gears in the gearboxes – backlash eliminated.

35. Various feeds have been built and tested over the years.

In 2017 we worked G4NNS on 3.4GHz who was at Goonhilly. By 2019, we now had a fully working system, complete with 200W TWT (Thompson TH3759A Tube designed for 300W on 14GHz). Since then, we have had many QSOs on 10GHz and it’s been reasonably reliable. When it doesn’t work it’s usually a power supply fault – the TWT PSU is an old technology complex beast.

36. The current 10GHz feed has been profiled and it’s acceptable.

37 & 38. Some 8.5GHz receive experiments with NASA's Juno spacecraft when it was close to Mars at around 120 Million miles which was quite exciting in 2017.

39. An ex-traffic control cabinet makes an ideal ‘outdoor’ box for housing motor drives and cable terminations

40 & 41. Around 2016, John, M5AHQ volunteered to automate the tracking system. The custom dish control software, called Medii after the Moon crater "Sinus Medii", now runs on a Raspberry Pi with suitable driving/interface elements, and allows the dish to be positioned with our custom closed loop software.

42. A web interface displays all dish control options, and a listing of principal objects to track. (Moon, Sun, Park, Load TWT – It's heavy!, QO100)

43. Medii also plots visible moon vs limits for the club locations

44. Medii also has built in hard limits to avoid parts of the mount structure – the black line

45. These have been updated as things have changed around the dish – you can also see the tree line in Blue

46. When the Selsyn decoder unit became unreliable, the replacement home brew decoder showed up some issues around the cardinal points, so, recently, we replaced the Selsyns with two Sick 18 bit (262K point/rev), 360 degree, Ethernet absolute position encoders.

You don't want to buy these new - >£800 each. But are Ebay find sourced a pair for <£150 – bargain – or at least we thought so. These give us better than 0.1degree accuracy.

The problem with these encoders is that they operate using a propitiatory protocol - CIP. After many hours of Internet searching John was able to find enough information to effectively reverse engineer the protocol and we finally had angles being received by Medii.

47. The Elevation encoder is mounted in waste pipe as fittings are cheap and waterproof.

48. As can be seen the dish is mounted on an old Versatower trailer. There's no concrete foundation so we have observed inaccurate pointing as the dish traverses East to West. We found that we had 'lean' and the vertical axis wasn't vertical at certain times of the year. The weight of the whole assembly was causing certain support points to sink. A Theodolite confirmed our suspicions. We now check for verticality periodically and pack the mounting points accordingly.

Before each EME session we calibrate the position on the moon using fine adjustments for maximum moon noise which are then used for that session.

49. Band dependant but lets start with 10GHz which was our first band:

50. We use a modified LNB (Maclean GPS locked) for receive which gives us a 618MHz I/F. Down converted to 144MHz which feeds two SDRs and an Icom IC746. We subsequently added a DU3T 0.6dB NF preamp and pipecap filter before the LNB – It's probably as good as it can get now.

51. The Noise figure of the system has improved, so that we are now seeing:
Moon noise 2.6dB (quite an improvement over the initial 0.5dB)
Sun noise 15.7dB
Ground noise 5.5dB
Room temperature waveguide load 5.7dB

52. the moon beacon DL0SHF is always a good receive performance check providing it's on.

53. On transmit the IC746 feeds a WDG transverter to give us 10368MHz. A shack based 200mW PA then feeds this signal to the 200W TWT that's mounted on the back of the dish. A piece of elliptical waveguide takes the power up to the head plate waveguide switch.

54, 55 & 56. The TWT is mounted on the back of the dish – it needs a pulley to lift it into position as ita round 20KG.

57. The PSU in mounted on the wall in the club house as it’s far too heavy to be moved and you don’t really want to be fiddling around with 8KV cables every time you want to use it.

58. A fairly intricate sequencer is used to ensure the system is reliable.

59. The system block diagram – The simple version….

60. And the full fat version – You probably can’t make out all of the detail in this image.

61. We have a noise meter fed from the 145MHz IF for calibration and checking sun & moon noise.

62. Power monitoring using an ESP32 and web based meters provide feedback on forward and reflected power taken from analogue outputs on the PSU. This is useful when we need to adjust the TWT matching as you can access the web page on a phone close to where the adjustments are needed.

63. All bands are assembled in a similar fashion – the head plates run on wheels that allow the focus point to be adjusted with a small linear jack from the operating position.

All bands use the same 2m I/F so no major changes down at the operating position are required for band switching. Just swap the head plate over – connect the required GPS locked LO signal and off you go.

Some of the head plates contain the complete T/R system – others where the PA’s are either too heavy or too large are split into the receive system on the head plate and the PA and PSU mounted on the back of the dish

Mounting PAs and PSUs on the back of the dish provides reasonable weather protection as it’s generally always pointing at the sky.

A simple plastic barrel cut open at one end can be pushed over the open end of the 14” diameter mount tube to provide weather proofing.

64. So we have the following bands:
    1.3GHz - 80W SSPA
65. 2.4Ghz - 70W SSPA
66. 3.4Ghz - 38W SSPA
67. 5.7Ghz - 40W SSPA
68. 10GHz - 200W TWT with 0.6dB DU3T LNA
69. and we’re close to finishing the 24GHz system – 15-20W RW1127 TWT (originally from Brian G4NNS) with 1.3dB DU3T LNA – probably the most complex system we’ve put together so far.

70. We have a smaller 1,8m offset dish mounted on the ‘back side’ that allows us to work Asia as the large dish is largely pointing through the club house in that direction

70. All bands up to & including 5.7GHz use VE4MA (Kumar) feeds with septum plates to achieve circular polarization. 10GHZ & 24GHz use linear polarization: 10GHz using a Chaparral feed and 24GHz – well – we’re still playing with feed options to get the best performance.

71. Our operating area houses the Transmit & Receive systems along with GPS locked references and changeover sequencing. A number of PCs are used to provide the required control and monitoring.
Left hand Windows PC for secondary receive monitoring, system optimization at the start of the session, TWT output power monitoring (10GHz) and time checks.

Moving to the right – A Linux Box running WSJTX PC for QSO control with CAT control of the Icom IC746

And right again – Access to the HB9Q web page for QSO organisation

And finally – Medii dish control & monitoring (above)

Nearly everybody now uses CFOM – Constant Frequency on the Moon. Where each station compensates for doppler shift of Tx & Rx frequencies to ensure the frequency on the moon is constant.

Libration can affect signal levels & quality – it's the irregular, "fluttery" fading of radio signals caused by the Moon's slightly rough surface and its "wobble" in orbit as seen from Earth.

Fading of EME Signals due to the reflected characteristics of the signal. This is due to the rough surface of the Moon. The Moon actually wobbles in its orbit so when signals are reflected off the Moon, they are reflected across the rough terrain on the moon's surface causing the reflected signals to be inconsistent. This fading becomes extremely pronounced on the higher EME bands.

72. In 2023 the group received the Fraser Shepherd award for 'research into microwave applications for radio communication' – a bit of a mouthful really – Although the award says 'For Advances in 10GHz Moonbounce'

73. Participants: It's been a long and drawn out project with people coming and going but primarily we have from left to right:

Myself Carl Rabe G6NLC
John Goodier M5AHQ
Julian Gannaway G3YFH
John Fell G0API
Rob O'Leary M5RAO

We've had help along the way from Jules G0NZO on the mechanical side and Paul M0EYT who has donated PCs and parts to keep the system operational.

74. Here is an indication of the echo level on 10GHz – just over 16dB above the noise floor.

75. Thanks for listening and hopefully you found something of interest – happy to try and answer any questions.