# Microwave EME

(Trials, Tribulations & Triumph “Downunder”)

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VK3NX (VK3FMD)

# Presentation Outline

My EME History

Current EME Activity

Some Technical Aspects

(Future Plans)

# The "Early Days"

- First EME contact – On 144 MHz with W5UN using an IC-746 and 100W into a 15 element DL6WU Yagi.
- On to 70cm…120 W into 2 @ 27 element Yagis with another "Big Gun" DL9KR.
- Several stations were then worked on 70cm and 2m with mixture of CW and then "Digital" modes.

# The "Early Days"

- With NO Elevation control the limit was quickly reached!
- But which Band to focus on?

# …But a pre-requisite

**I wanted to hear my own echoes!**

# 144 - 432 - 1296

- Reasonably easy in terms of generating power…….High power permit required
- Antennas…large – medium sized
- Noise levels in the city…high
- For CW Capability: EMR compliance on a “city” block……NO CHANCE

# *Microwave bands?*

- Smaller Antennas……Dish
- Dish is multi-band capable
- Medium (but attainable) power required
- More readily EMR compliant
- Hence more realistic for ME….**but which band to start with?**

# Crunching numbers.

- With my Microwave transverters, I had a choice of any band from 2.4 - 24 GHz
- World wide band allocations for 2.4 and 3.4 GHz need to be considered
- Utilizing F1EHN and VK3UM software and consideration of the numbers, showed 5.7 GHz as the most likely band to start with the intended dish size of 2.3m

# Initial Setup
## "A Fool Jumps In"

- Chose Joysat 2.3m mesh dish
- Linear feed. Coax-W/G transition with VE4MA feed. Simple!
- Tracking with Sat. actuator for El. and standard rotator for Az.
- Simple manual Tracking system built around PicAxe software designed by VK3HZ.
- Accurate tracking built around "Noise meter"
- PA upgraded to 24 W output….still VERY low power for chasing echoes!
- Feed assembled with DB6NT preamp
- Xvtr modified for EME use. Sep Rx / Tx lines. Ext LO input.
- Feed position optimised on Sun noise.
- Reasonable Sun and Moon noise BUT ...No echoes !
- Maybe a QSO is still possible?

# Initial Disappointment

- Tried with OK1KIR , F2TU and CT1DMK

  …….Unsuccessful.
- Over approximately 6 months I tried to make improvements to the system, each time hoping to hear echoes.
- Meanwhile, about this time VK3XPD had a few of us around at his shack for a demo on his 10 GHz EME system. Hearing his echoes in the "loudspeaker" was very motivating.
- 3M dish tried…… Still no success with echoes or with a QSO.
- ALL Eu stations on 5.7 GHz were running CP. This -3dB could no longer be tolerated!
- Built CP feed. Screw Polariser variety.
- With a lot of help from F2TU , I had a tuned and working model on the test bench.
- ……THEN……..

# *"So Close ,Yet, So Far…"*

- In August 2005 my wife (and I) decide it's time to move QTH.

- After 6 months of planning and 8 months of work, the dish was taken down and the house put on the market and subsequently sold!

# New QTH.. New Opportunities

- With Help from the “locals”  2 towers and a “dish” pole were installed on “the farm”
- Bigger IS Better…….A 3.7M Joysat dish was acquired and installed.
- Soon after his success on 10 GHz, Alan, VK3XPD completed the 1st VK EME contact on 5.7 GHz with OK1KIR

# New QTH.. New Opportunities

- I decided that the dish will eventually be used for other microwave bands so I would take the time to build in “Band-Changeability”.
- Inspired by G4FRE I built a “Cage” setup

# Nearing Success?

CP feed installed.

Sun / Moon Noise were optimised over a couple of weeks / months.

In Early Aug 2006 I arrived at the following 5.7 GHz Performance:

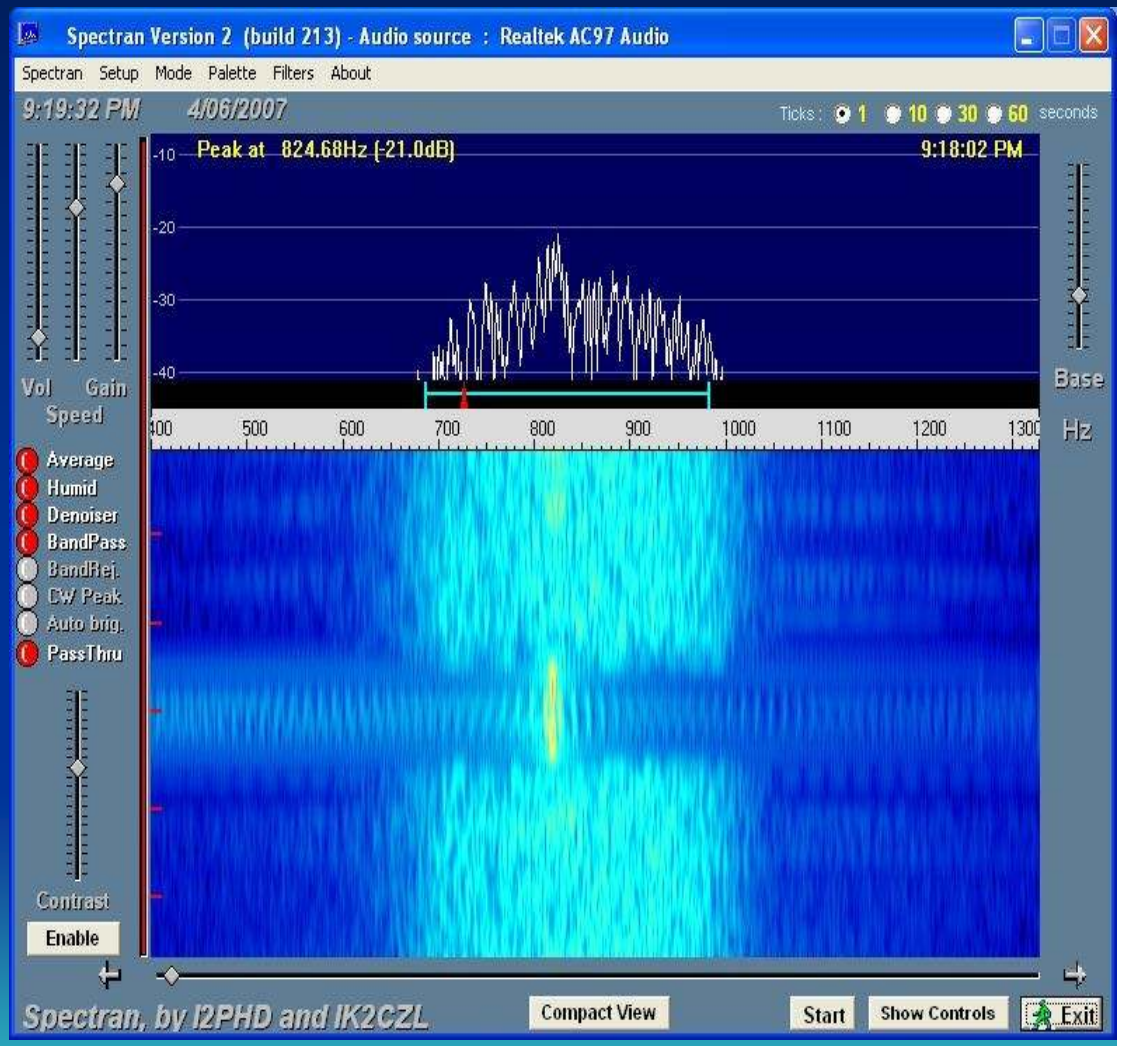
Sun Noise = 12.2 dB*

Moon Noise = 0.8 dB

(* SFU = 80)

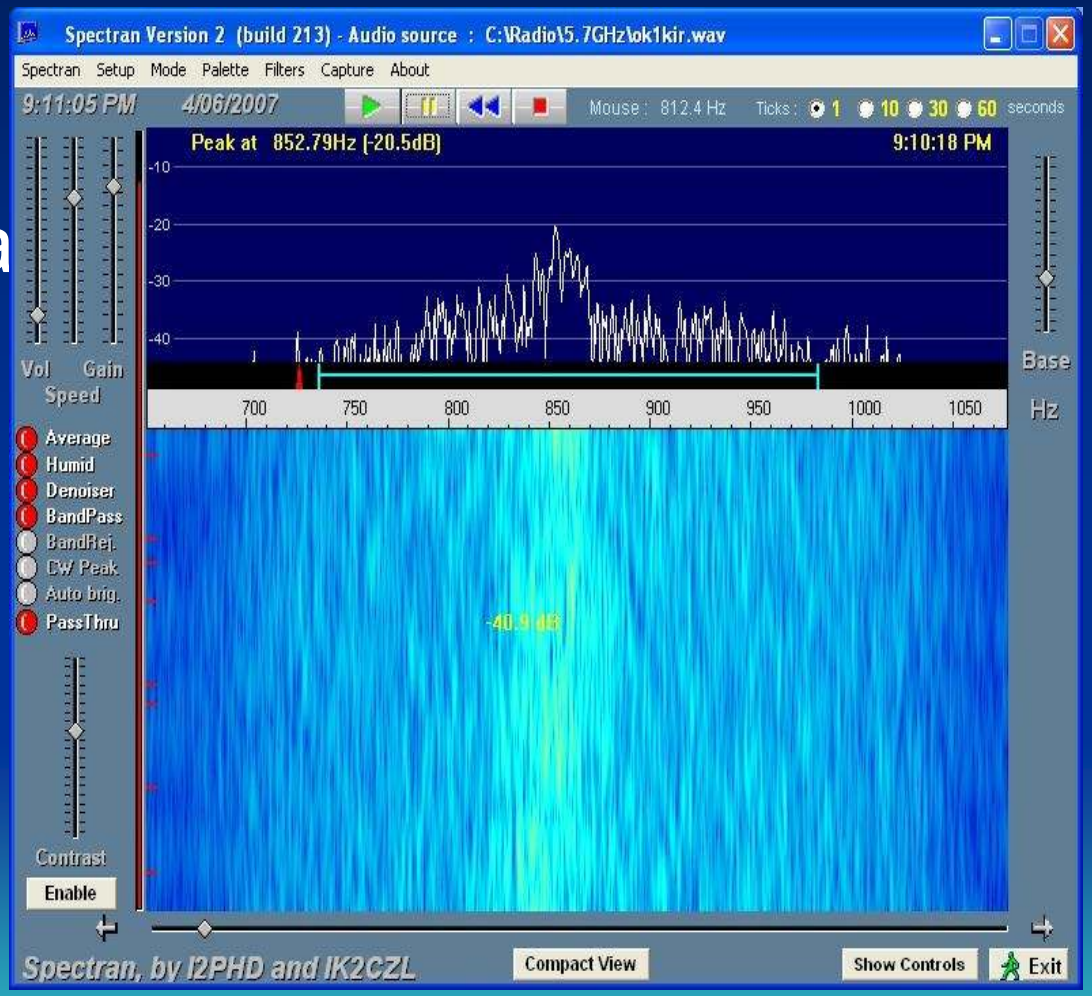
# Sweet Success !

- On 3rd August 2006 I FINALLY heard my own CW echoes for the first time via EME



# Time For A QSO

- On 10th August 2006 I worked the OK1KIR team. Vladimir, Tonda and Jan have a 4.6 m dish and ~ 60 W at the feed.
- Exchanged O/O



# Stations worked so Far on 5.7

***As End of June 2007***

OK1KIR CW O/O

F2TU CW 559/529

RW1AW CW & SSB 559/539 52/44

OE9ERC CW 549/449

W5LUA CW O/O

IK2RTI CW 519/0

LX1DB CW 559/449

8N1EME CW SSB (FM) 599/579

# Moving on to other bands.

## As End of June 2007

**Stations worked on 10 GHz:** # 10

F2TU O/O
OK1KIR 559/549
RW1AW 559/559
F5VKQ O/O
W5LUA O/M
WA6PY O/M
IQ4DF 559/519
OK1CA O/O
DF9QX 549/0
LX1DB 529/449

**Stations worked on 3.4 GHz:** # 4

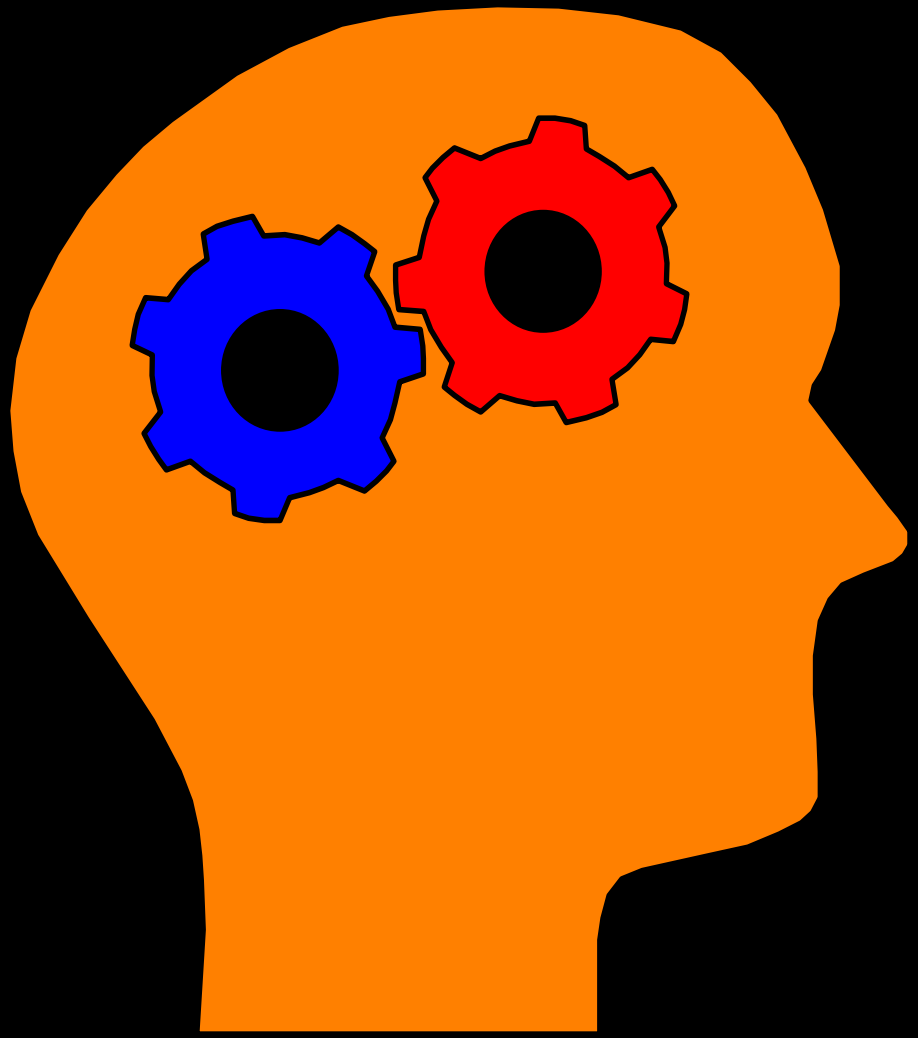
LX1DB 529/559
W5LUA M/O
G3LTF M/O
OK1CA M/O

# Technical Details

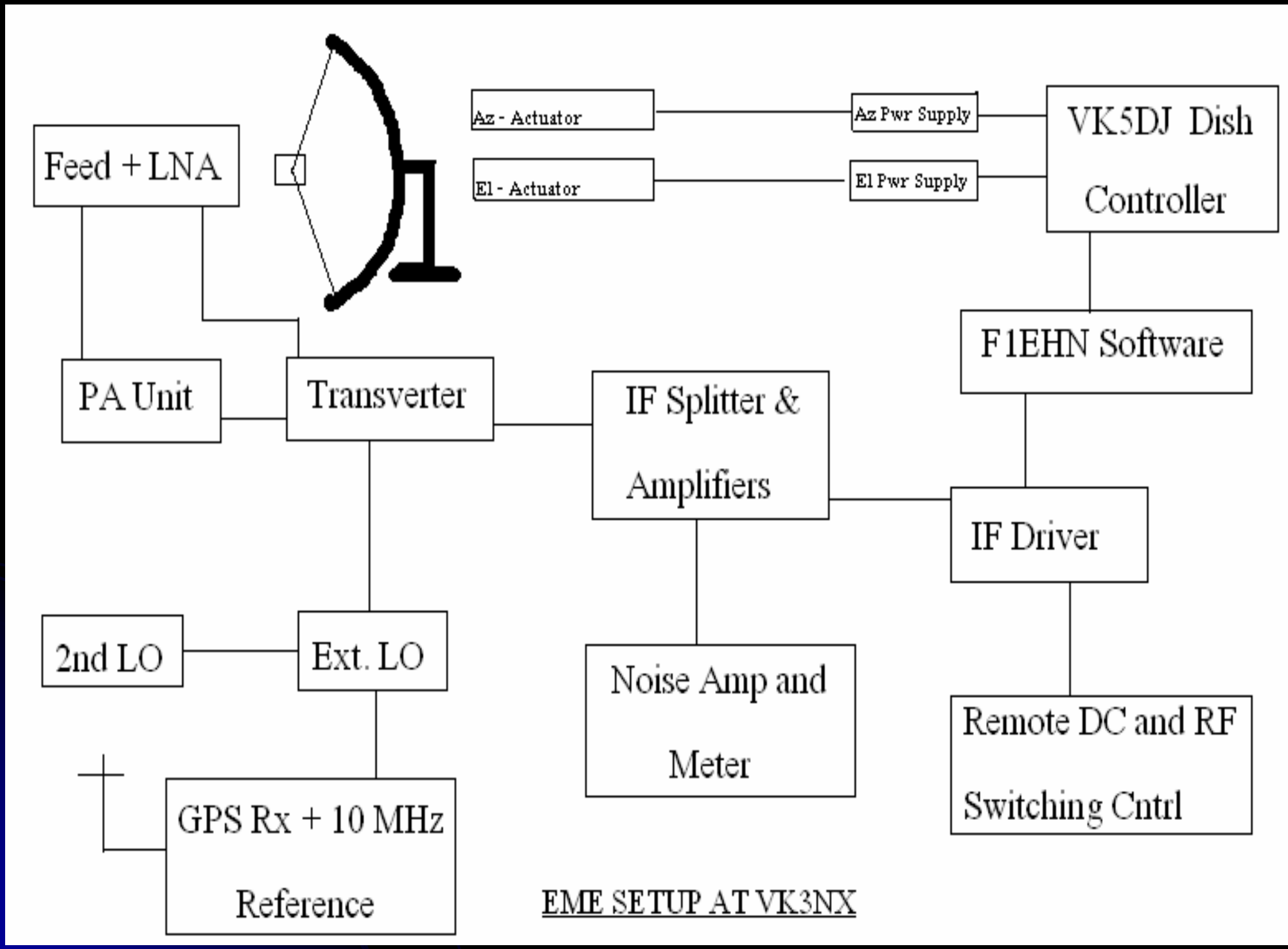
## Of EME STATION VK3NX

# Considerations for EME on the Microwave Bands

- Dish size ?
- Dish installation?
- Mechanics of Tracking?
- Feed design?
- RF Power?
- LNA and Rx?
- Transverters?
- System co-ordination?



Knowledge acquisition?


Feed + LNA
Az - Actuator
El - Actuator
Az Pwr Supply
El Pwr Supply
VK5DJ Dish Controller
F1EHN Software
PA Unit
Transverter
IF Splitter & Amplifiers
IF Driver
2nd LO
Ext. LO
Noise Amp and Meter
Remote DC and RF Switching Cntrl
GPS Rx + 10 MHz Reference
EME SETUP AT VK3NX

# Path Loss

3.4 GHz = 278.6 dB – 280.9 dB

5.7 GHz = 283.0 dB – 285.3 dB

10 GHz =288.1 dB – 290.4dB

* Extra 2.3 dB b/w Perigee & Apogee

# The Dish

- 3.7 M mesh dish from Joysat
- Powder coated
- Mesh size: 1mm wire with ~4mm spacing
- Gain @ 3.4 GHz* = 37.8 dBd
- Gain @ 5.7 GHz* = 42.2 dBd
- Gain @ 10 GHz* = 47.3 dBd
- Az / El or Polar mounting….
  Az / El chosen

* Assuming 55% feed efficiency

# Dish Control

- Az / El control with 24” Actuators.  24 VDC motors
- Variable speed control with PWM DC
- Achieves >93 degrees of elevation movement
- Achieves >114 degrees of Az movement
- 2 Positions used on Az setup to cover >200 degrees in Az travel of the moon
- Utilise VK5DJ “Screwjack” solution… VERY accurate but careful calibration required
- “Cage” setup at feed point for QUICK band change

# Dish Mechanics

# 10 GHz Feed Assembly

Linear Polarisation

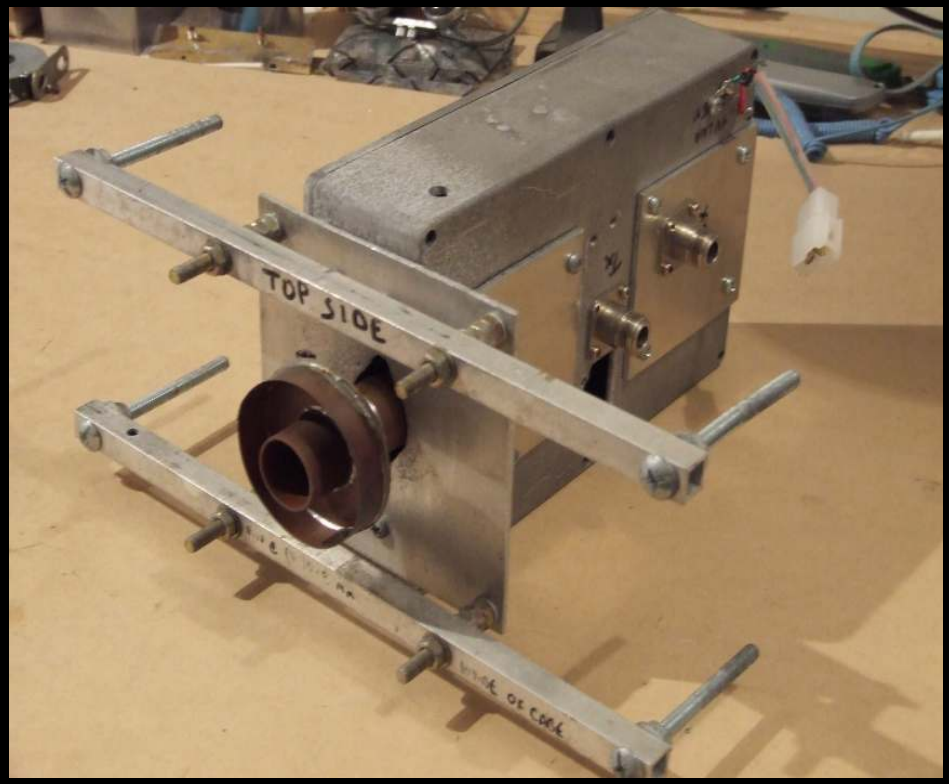
VE4MA Choke Flange

Initially 23mm ID

(Now rebuilding using 20.5 mm ID)

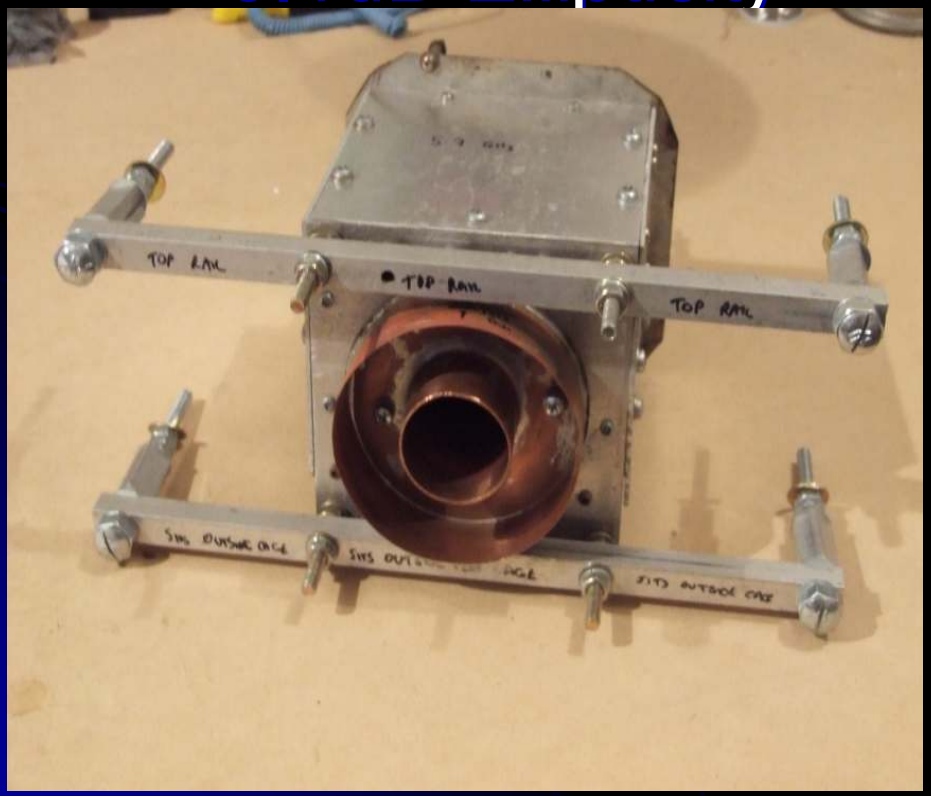
DB6NT LNA - coaxial!

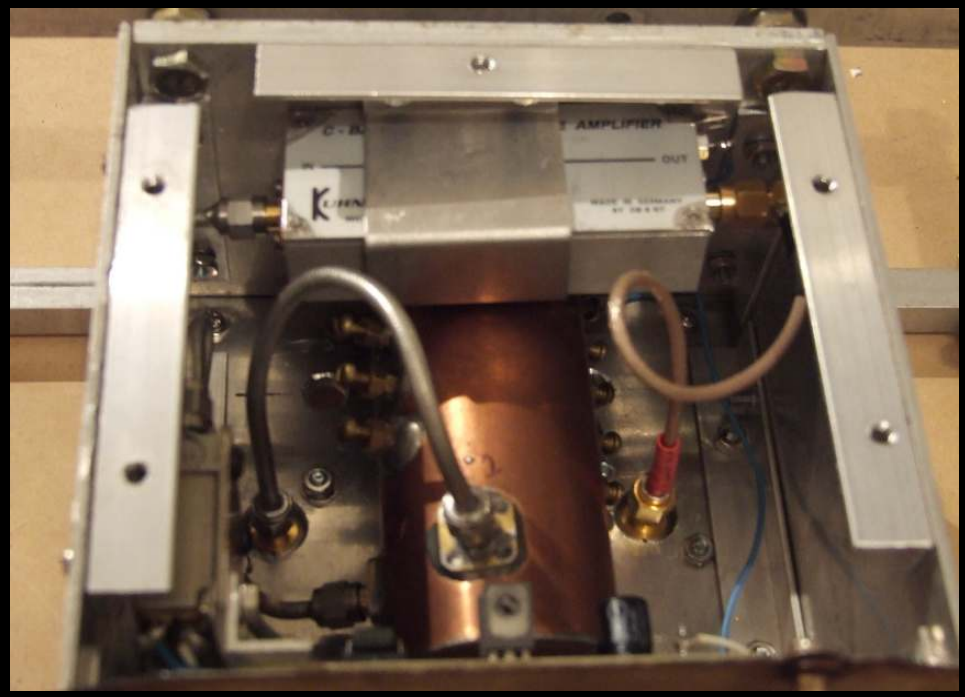
0.7dB Gain = 28.5dB



# 5.7 GHz Feed Assembly

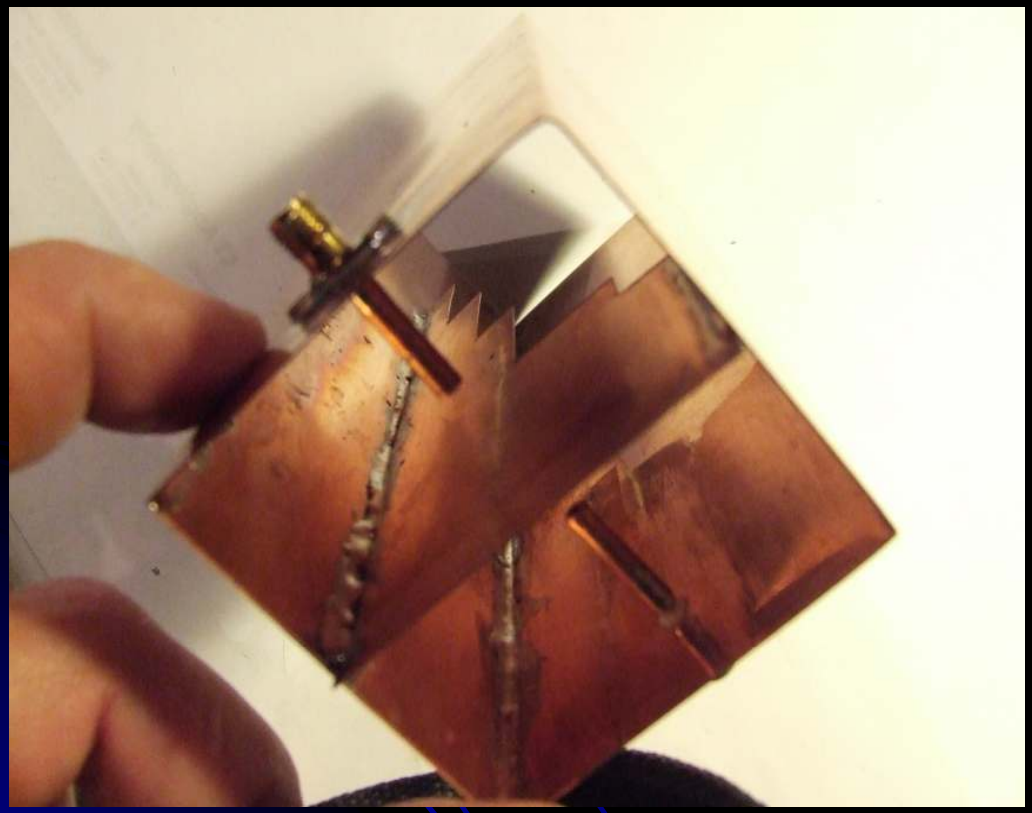
Circular Polarity
Screw Polariser
V and H < 2dB =
<0.1dB Ellipticity



VE4MA Choke Flange
(0.5 wL @ 0.5 wL)
DB6NT LNA 0.7dB NF
G ~ 28dB

# 3.4 GHz Feed Assembly



- Initially started with Screw polariser version.
- Rolled my own tube.
- Circularity seemed poor >6dB diiference V /H
- Echoes Barely detectable

- New Feed- RA3AQ Version of Septum polariser.
- Optimised for f/d 0.39 – 0.4
- Flange is “Super VE4MA”
- Measurements scaled from 1296
- Ellipticity <0.1 dB (<2dB V/H)
- Echoes NOW LOUD !

# Current Sun & Moon Noise

3.4 GHz :

Sun Noise 11.3 dB (SFU=67)
Moon noise ~0.68 dB (mid dist.)

5.7 GHz :

Sun Noise 12.2 dB ( SFU=72)
Moon Noise 0.80 dB

10 GHz :

Sun Noise 12.6 dB (SFU=70)
Moon Noise 1.2 dB

Echoes Good – Very good currently on all bands despite some feed inefficiencies!

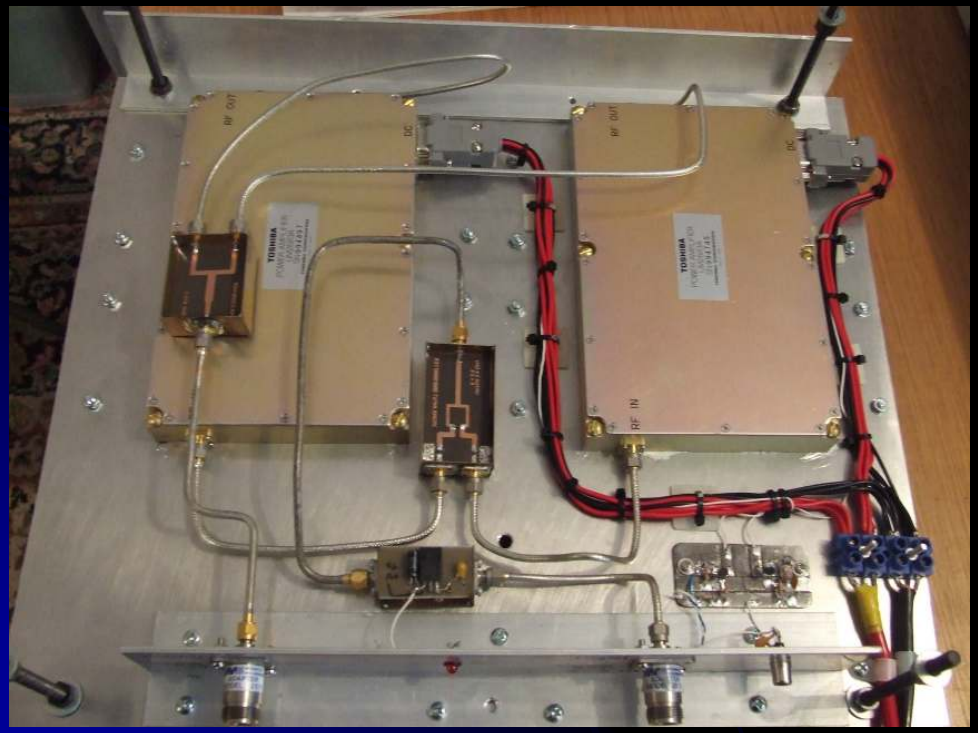
# POWER AMPLIFIERS

## 5.7 GHz

4 @ 5964-8 FETS
28 W out ( TO BE IMPROVED)
~20 W @ the feed

## 3.4 GHz

2 @ Toshiba 55W modules giving 120W
~90 W @ feed



## 10 GHZ

Modified 14 GHz TWT
Produces >40 W out for 0dBm input
Tx Cable loss = <2dB ~26 W @ feed

# Transverters

All modified for external LO inputs and for separate Rx and Tx Lines.

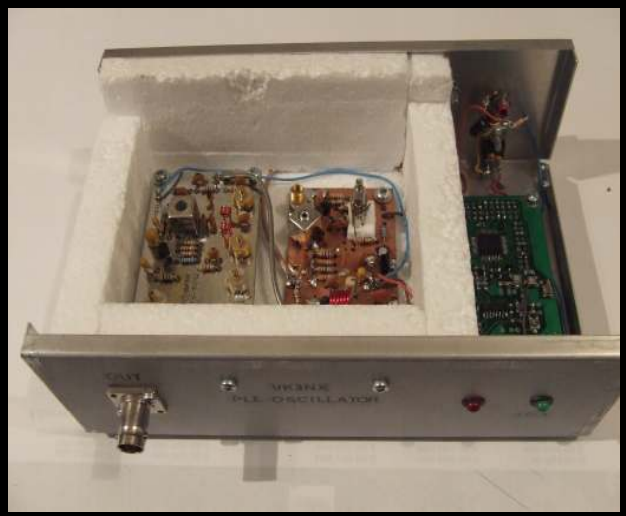
10 GHz based on W1GHZ design (DEMI)

5.7 GHz based on N1BWT design (MiniKits)

3.4 GHz based on KH1CP design (MiniKits)

# Local Oscillators

- 10 MHz Reference is GPS derived/locked
- LO's are PLL locked to this reference or "free running"
- PLL based on "VE1ALQ" design. Easy to get working!
- 10 GHz LO based on SM6VFZ running @ 1136 MHz
- 5.7 GHz LO based on VK3NX and VK5EME designs running at 561.6MHz
- 3.4 GHz LO based on VK3NX and VK5EME designs running at 542 .666 and 552 .0 MHz

# IF Splitter


- Splits Rx path into 2 and provides switching between common IF for Rx and Tx
- 1 Rx signal goes to IF the other is bandpass filtered and amplified ~ 20dB and sent to “noise meter”.
- Band pass filtered around 140-144 MHz

# Noise Meter – WHY?

Beam widths are extremely small on the upper microwave bands.

With 3.7M dish, -3dB Beam width:

3.4 GHz = 1.6 deg.

5.7 GHz = 1.0 deg.

10 GHz = 0.5 deg.

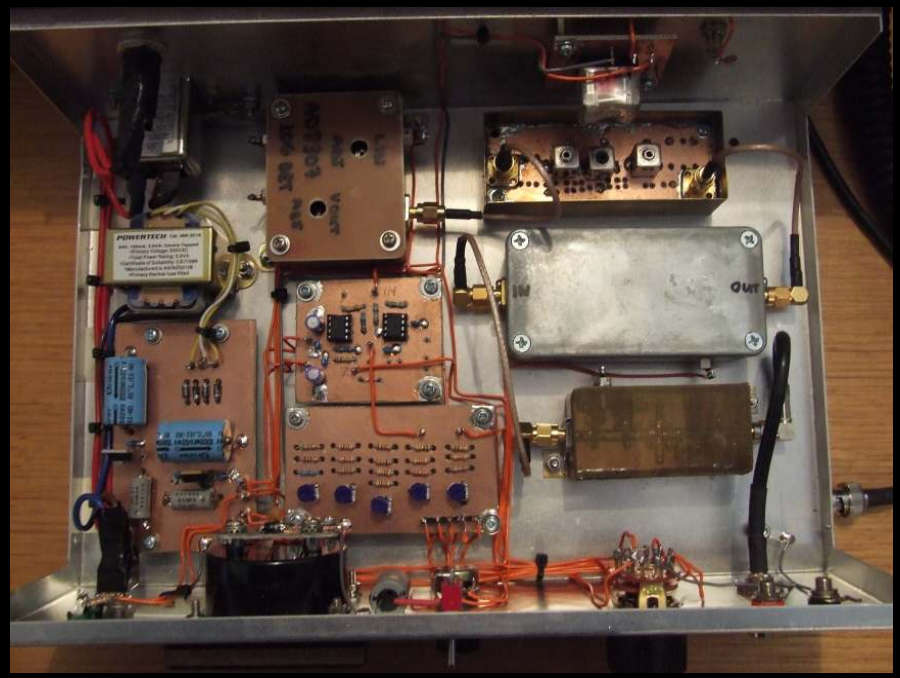
MOON subtends ~0.5 degrees

DISH MOVEMENT NEEDS TO BE SLOW!

**MUST TRACK VIA MOON NOISE!**

# Noise meter

- 40dB total amplification with filtering @ 141 MHz
- Accurate (<0.005 dB) relative measurements for Sun & Moon noise measurements
- Logarithmic Detector…..  AD 8307
- By Utilizing OP amps an expanded scale is achieved.
- 5 scales used for the meter :  FSD = Full, 10dB, 2dB, 1dB and 0.5dB

# Control

- IF driver - IC746 with both 250 Hz CW filters and 1.8 KHz SSB filter installed as well as TCXO.
- F1EHN software for Doppler and timing control as well as co-ordinating skeds.
- “Spectran” and “Spectrogram” used for recording and analysing signals

# Microwave EME compared to the lower bands?

# (The good, bad and ugly)

# Polarity

- Faraday Rotation:
  - Function of Ionization Density

- Protocol for Linear on 10 Ghz NA - Horiz. Pol
  Eu – Vertical

  VK?.....Have to be able to switch or go CP and lose 3dB!
  (Strength In numbers)
- Circular Polarization dominates on 5.7 GHz and Slowly becoming the standard on 3.4 GHz
- CP IS DIFFICULT for the newcomer but with a little experience tuning a Screw polariser is manageable. Septum Feed makes it easier!
- Dielectric polarisers may make it easier.

# Atmospheric and Tropospheric effects

## -Tropospheric ducting:

-can seriously effect EME on the lower bands at low elevations.

- Less likely an effect at the higher microwave frequencies at anything but very LOW elevations.

## -Atmospheric effects:

-Very thick cloud cover has been observed to reduce sun noise on 3.4 GHz by as much as 1dB

# Accuracy!

On the microwave bands (esp. 5.7 and 10 GHz), everything is measured in mm!

Feed positioning

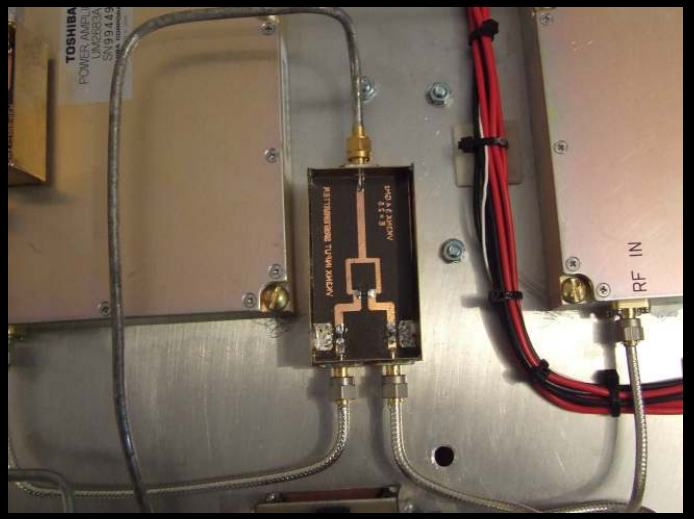
Feed aiming

Dish Inaccuracies

Circuit board techniques

Feed fabrication

Adjustments




# Doppler

- Doppler shifts are large

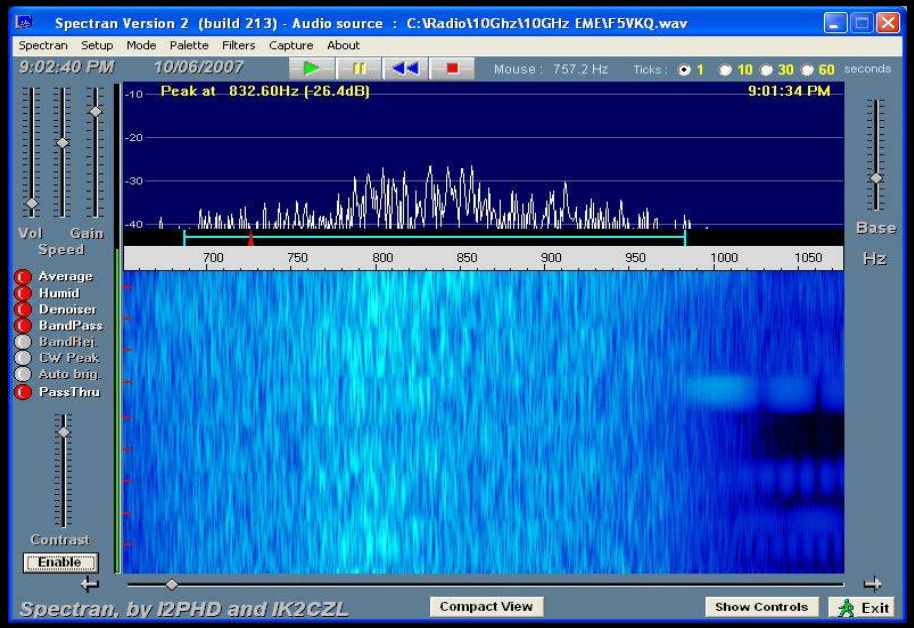
  10 GHz : ~ +/- 26 KHz

  5.7GHz: ~ +/- 15 KHz

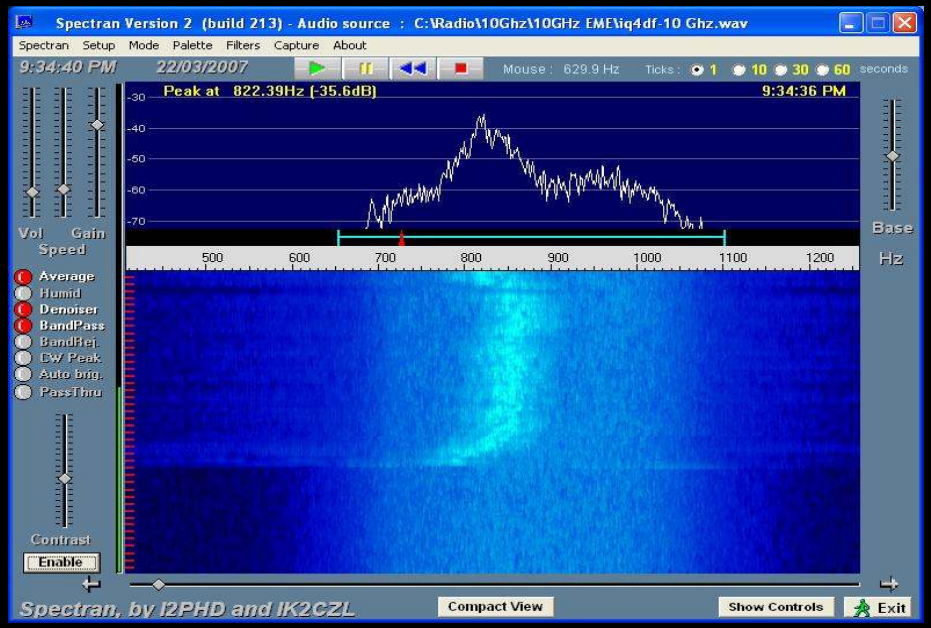
  3.4 GHz: ~ +/- 9 KHz

- Doppler shift on Echoes can change by as much as ~1.5 Hz / sec .
- “mutual doppler” to be considered with QSO partners
- Different techniques required for sked & random procedures
- Most programs predict Doppler accurately. “EME System” by F1EHN within 1-2 Hz @ 10 GHz

# Doppler Smear




F5VKQ 3.1 M dish ~ 30 W

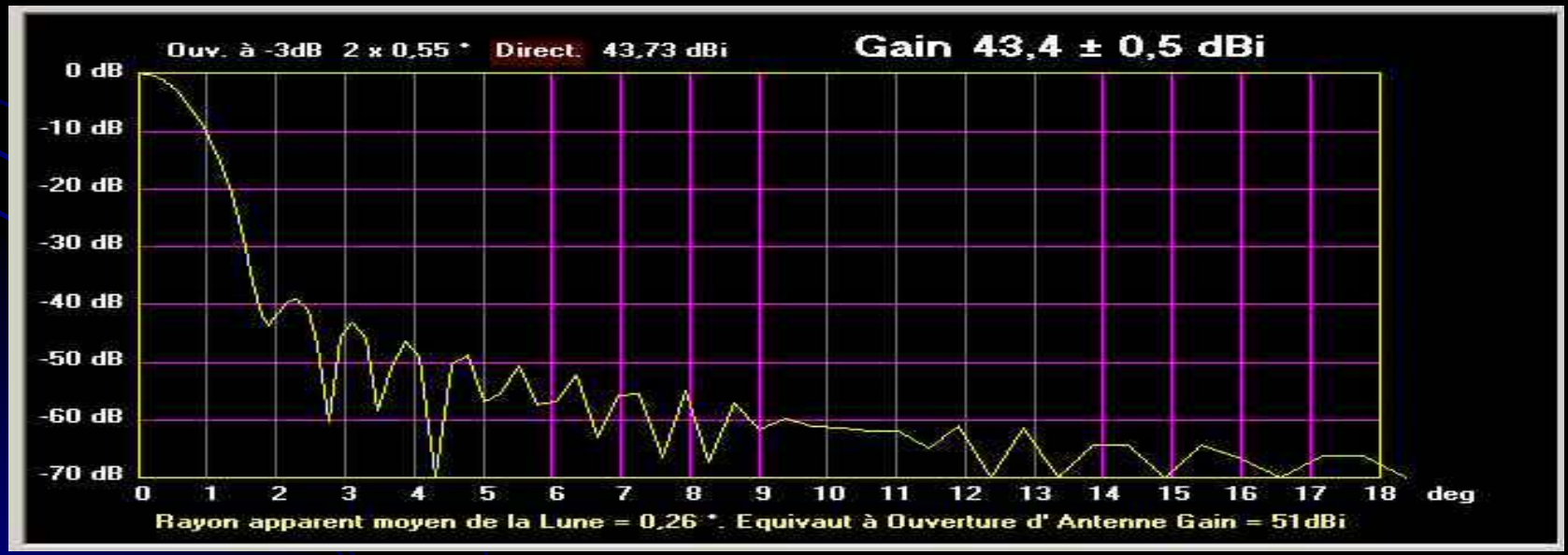



IQ4DF

Caused by the fact that different areas of the moon (edge Vs centre) have different relative velocities compared to the also revolving earth underneath. Therefore the doppler created is different from these different areas. The result is an echo that that is "spread" or "smeared"

# Advantages

- Quieter environment with respect to “Man Made” noise …. QSOs at low elevations limited by “real ground” temperature
- Sky Temp much lower
- Narrow Beam widths so even if Sun is close to the moon ( only a few degrees away), QSOs can still be had.



# Dish Gain

- Because of small beam width involved, larger size stations may not illuminate the whole moon surface on the higher bands
- Signals can actually be Weaker B/W large stations due to pointing errors
- Moon Noise becomes the LIMIT for Rx Noise Floor…If QSO partner does not generate a signal > moon noise…..No QSO ! (bigger is not always better)

# Next on the list

Bigger dish !  (5-6 m)

Full and accurate Auto Track

More Power on 10 GHz  And 5.7 GHz

Feed experimentation / optimisation

CP on 10 GHz….RA3AQ Septum ?

13 cm capability…very soon

24 GHz !  (PA wanted : any offers!)

# Summary – A lot of fun!

- A lot of construction is required for Microwave EME….both mechanical and electrical (RF & DC!)
- There is information, but you need to dig deep!
- Generating POWER is still the hardest aspect.
- Some parts of the required electronics CAN be bought in "plug'n'play" style (for a price), BUT, building the gear has been the most pleasing aspect.
- A lot of the equipment is purpose designed and built.
- Meticulous and painstaking changes need to be experimented with in the search for that extra fraction of a dB ……..It Takes A Lot of Time!!
- Start with a plan of the overall system and build upon each system component methodically and incrementally
- Be prepared for that 3 or 4 AM sked ….part of living at the "arse end of the earth"

# Acknowledgements

Many thanks to the people below who have at different stages contributed to my pursuit into Microwave EME in different ways:

Geraldine (my wife)

| | |
|---|---|
| VK4AFL | VK3HZ |
| VK5DJ | VK3XPD |
| CT1DMK | F2TU |
| OK1KIR | F5VKQ |
| W5LUA | LX1DB |
| VK3PY | VK3QM |

Many Tnx for your attention
73 de VK3NX