*A Beginner's View of*

# *Easy Moonbouncing...*

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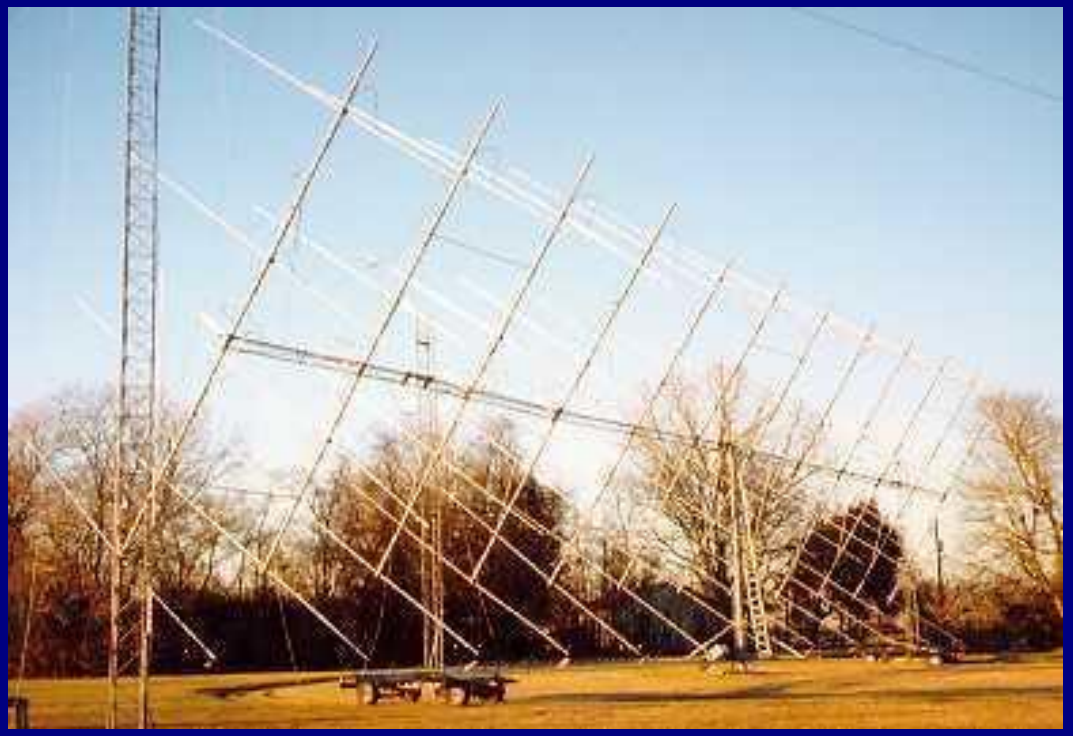
# *My Objective*

- GET YOU INTERESTED IN WORKING EARTH-MOON-EARTH QSOs.
  - Most hams believe exotic equipment, huge antennas, and very high power are needed to work EME.
  - You can enjoy the thrill of moonbounce with a modest setup.
    - Basically the equipment you may already have.


# *This Presentation*

- Why Moonbounce?
- The History
- A real challenge
- The Bands
- How Small a Station
- Visit VE2ZAZ EME
- Some Hints
- Optimize Noise Figure
- JT65
- The Software
- Moon Tracking
- Web References



W5UN – Mighty Big Antenna. 32 x 17 el. Yagis on 2m

# *Why Moonbounce?*

- IT IS EXCITING!
  - Most fun in ham radio is making rare, unusual, or difficult contacts. EME is the pinnacle of ham radio achievement.
- ALLOWS TO WORK WORLDWIDE DX ON ANY BAND - 6M UP.
  - No other unassisted mode provides this capability.
- MOTIVATES YOU TO LEARN MORE ABOUT COMMS THEORY
  - Propagation, noise, antenna phasing, polarization, space object tracking, etc.
- PROVIDES AN INCENTIVE TO BUILD BETTER ANTENNAS.
  - Complete EME arrays are not available commercially.

# A Bit of EME History

- 1946: First experiments by US Mil. in Project Diana. 3,000 watts at 111.5 MHz into dipole array
- Following years, Moon used for Teletype between mainland and Pearl Harbor
- 1953: First Amateur detection between W4AO and W3GK on 2m
- 1960: First EME QSO on 1296 MHz by W1BU club in MA.
- 1965: Arecibo Observatory Mounbounce contacts on 430 MHz with tens of kW !

# *The Anatomy of an EME QSO*

- AVERAGE MOON DISTANCE: 384,000km
  - Average Round Trip: 770,000km!
  - Propagation Path Loss: 250+ dB!
  - Echo delay: ~ 2.4 Seconds
- 93% OF WAVE ABSORPTION BY MOON
  - Only 7% wave reflection
- ANGLES AND BEAMWIDTH
  - Moon is ~ 1 degree wide when seen from earth
  - Antenna is 0.00....1 degree wide when seen from the moon!

# *Impairments in an EME QSO*

- POLARIZATON OFFSET
  - 90-degree polarization offset between stations, forget it!
    - FARADAY ROTATION: Polarization rotation due to Ionosphere and earth's magnetic field. At 432MHz, up to 1.5 complete rotation, at 1296MHz 0.25 rotation. Negligible at higher F.
    - SPATIAL OFFSET: Geometry of the path between two stations.
- LIBRATION FADING
  - Signal fading caused by the movement of the moon and surface imperfections.
  - The higher the frequency, the faster the fading
- COSMIC NOISE, SUN NOISE
  - When Moon has noisy sky in background, forget it!
  - When Sun and Moon line up, forget it!
- QRM, QRN...

# *What Band to use?*

- 50MHz: **Not very popular: Big antennas, lots of QRN, no preamp required, KW+ a must. Difficult.**
- 144MHz: Most popular band, tons of stations work random JT-65 QSOs. A pair of long boom yagis and 500-1000W will keep you active.
- 432MHz: Fewer stations, more difficult to work random. Activity Periods. A pair of long boom Yagis or 4 yagis a good entry point. 400W+ an asset. Preamp is a must. QRN nil!
- 1296MHz: More and more stations, probably more than on 432MHz. A 10+ foot dish is the way to go. 100W+ a must.
- 2304MHz: Fewer stations, must plan skeds. More exotic gear to generate the high output RF power. Skeds only.
- >2304MHz: Experiments, lots of experiments. TWTs, fancy stuff, waveguides. Some activity. Skeds only.

# *Big Guns are an Asset!*

- THEY DO ALMOST ALL OF THE WORK!
- THERE ARE A LOT OF THEM, ESPECIALLY IN EUROPE.

HB9Q Club – 15m Dish (70cm, 23cm, 13cm), 8 x 19 el. Yagis (2m), 11 el. Yagi (6M)

# *How Small Can an EME Station Be?*

- Single long-boom Yagi
- 80W
- No Preamp
- No Elevation Rotor

**Success in JT-65!**

- **4 x long-boom Yagis**
- **45W**
- **Low NF Preamp**

**Success in CW!**

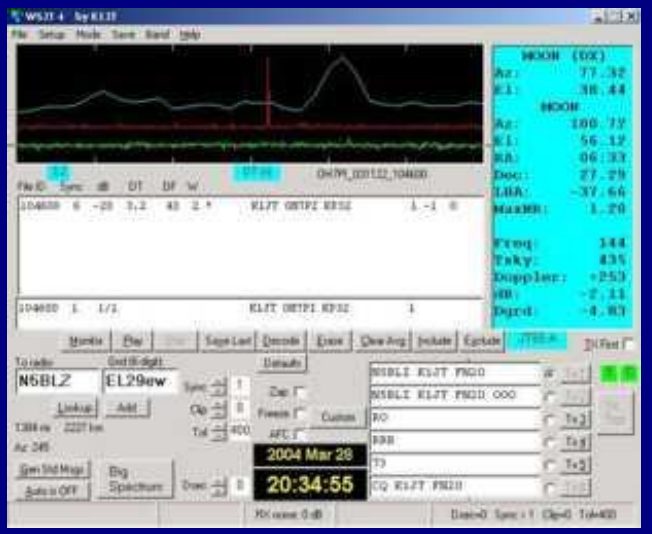
**SIMPLE BASIC QSOs,**
**NOT RAG CHEWING!**

# VA3TO – 2M EME, 112 Countries

# EME at VE2ZAZ... Outside

# EME at VE2ZAZ... Inside

- **Rig: TS-790A (separated Tx and Rx ports)**
- **Amp: Mirage D1010 brick (~100 W).**
  - Future: AM-6155 FAA amp (~400W)
- **Sequencer: "At Last" Sequencer (VE2ZAZ)**
- **Audio Filter: JPS NIR-10 DSP**
- **PC and Sound Card:**
  - WSJT Software
  - Spectran Sound analysis/filter Software
  - Nova For Windows tracking Software
  - N0UK JT-65 EME Logger Website
  - MultiKeyer CW Keyer Software




# *Some Hints for a Small EME Station*

- Minimize Losses Between Antenna and Preamp.
  - Any attenuation is a direct deterioration of the Noise Figure.
    - Best possible coax. RG-214 not good enough. LMR series better.
    - Use N-Type connections everywhere, even at 144MHz.
- Rule out old Yagi designs
  - Constant element spacing not a good indication of modern design.
  - Modern modeled antenna designs are best. K1FO long boom design is a baseline.
- Every Watt Counts. Use the best possible TX feedline.
  - At >432MHz, Heliax or equiv. Is a MUST!

# *More Hints for a Small EME Station*

- At 432MHz and Above, use a preamp with very low NF.
  - NF < 0.5B recommended.
- Transverters Work Great
  - Are Cheaper.
  - Can be located remotely to minimize feedline losses.
- Operate When Moon Conditions are Best
  - The 2dB difference in path loss can “make or break” a QSO.
  - Avoid high sky noise.
- Exploit Ground Gain, up to 6 dB due to ground reflections.
  - Especially applicable to 50MHz and 144 MHz

# *More EME Hints...*

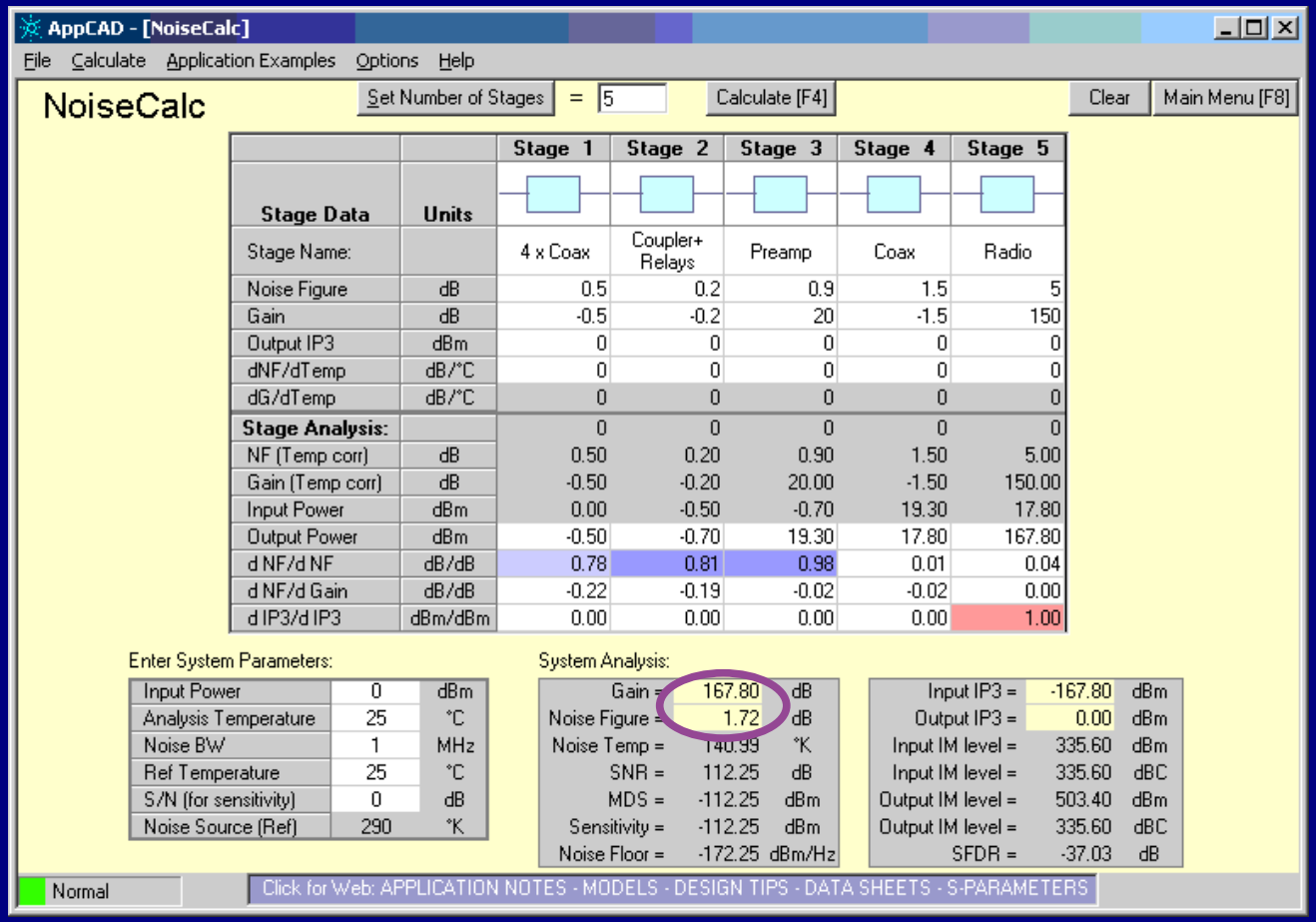
- Be careful about Amplifier Over-Stress from JT65.
  - JT65 runs 50 secs at full power, 70 secs off.
  - Use a fan on linear bricks. 24V fan on 13.8V is quiet and effective.
  - Derate output power (from p.e.p. specs) on tube-type amplifiers.
- Avoid Hot-Switching Coaxial Relays
  - Wears out contacts at much accelerated rate.
- Be on Frequency
  - Measure your TX frequency offset and compensate for it.
  - Use a Frequency Counter with a GPS Reference.
    - Especially applicable to 1296MHz and above.
  - Remember RX Doppler compensation...
    - The higher the F, the larger the Doppler (proportional)
    - At 432MHz Doppler varies +/- 1KHz.

# *Even More EME Hints...*

- Synchronize your PC to UTC Time
  - To the nearest second.
  - Win2K, WinXP, Vista have this built in.
- Polarization Control is an Asset
  - Feedpoint rotation on dishes.
  - Cross-Yagi array
- Watch for Coaxial Cable Power Handling Capability.
  - At 432MHz, surprisingly low.
    - RG-214 = ~ 300W
    - 9913 = ~ 400W
  - Another reason to use Heliax coaxial cable.

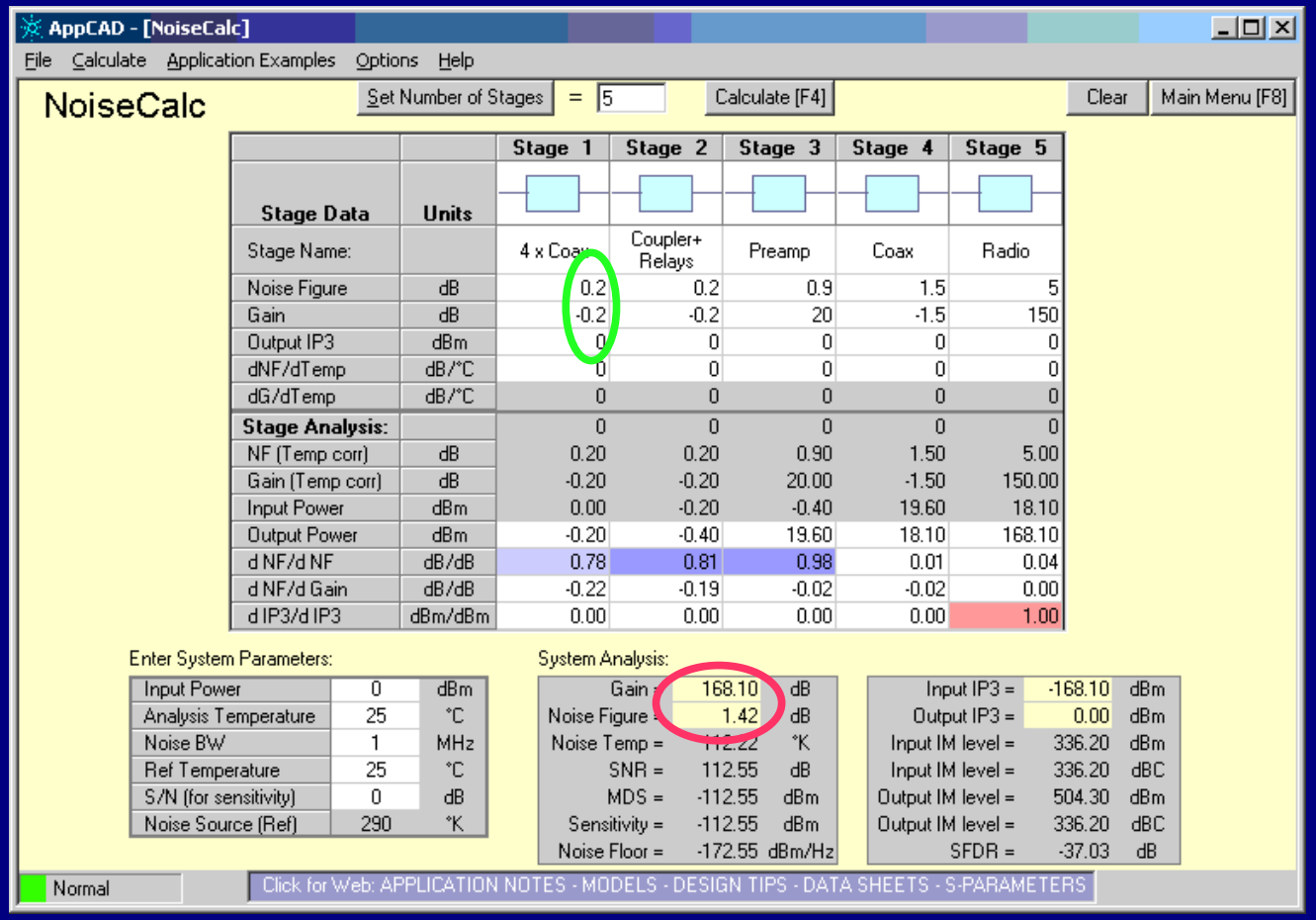
# Optimize your Noise Figure

- A “typical” Setup



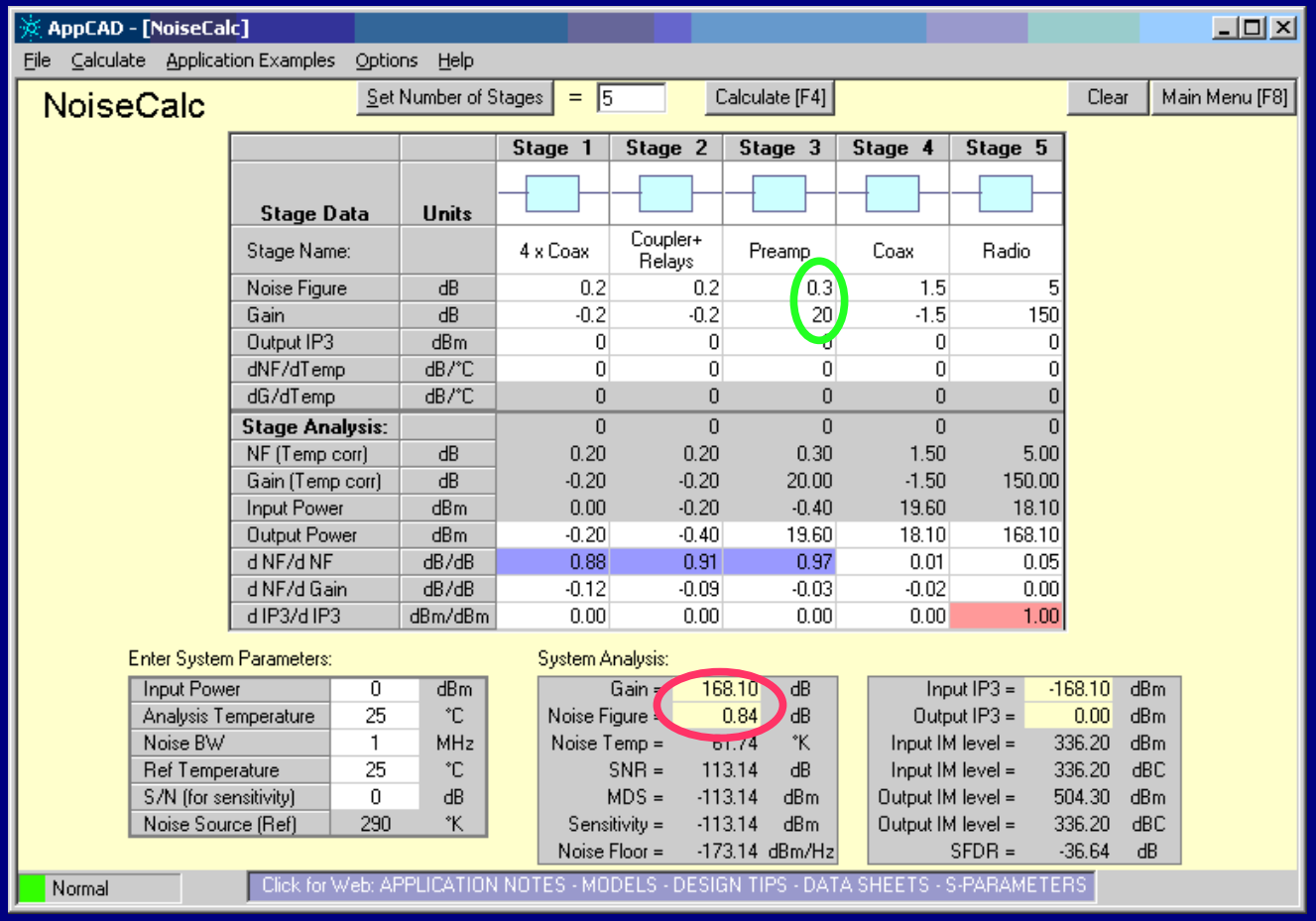
# Optimize your Noise Figure

- A better setup



# Optimize your Noise Figure

- A Much Better Setup




| Stage Data | Units | Stage 1 | Stage 2 | Stage 3 | Stage 4 | Stage 5 |
|---|---|---|---|---|---|---|
| Stage Name: | | 4 x Coax | Coupler+ Relays | Preamp | Coax | Radio |
| Noise Figure | dB | 0.2 | 0.2 | 0.3 | 1.5 | 5 |
| Gain | dB | -0.2 | -0.2 | 20 | -1.5 | 150 |
| Output IP3 | dBm | 0 | 0 | 0 | 0 | 0 |
| dNF/dTemp | dB/°C | 0 | 0 | 0 | 0 | 0 |
| dG/dTemp | dB/°C | 0 | 0 | 0 | 0 | 0 |
| **Stage Analysis:** | | 0 | 0 | 0 | 0 | 0 |
| NF (Temp corr) | dB | 0.20 | 0.20 | 0.30 | 1.50 | 5.00 |
| Gain (Temp corr) | dB | -0.20 | -0.20 | 20.00 | -1.50 | 150.00 |
| Input Power | dBm | 0.00 | -0.20 | -0.40 | 19.60 | 18.10 |
| Output Power | dBm | -0.20 | -0.40 | 19.60 | 18.10 | 168.10 |
| d NF/d NF | dB/dB | 0.88 | 0.91 | 0.97 | 0.01 | 0.05 |
| d NF/d Gain | dB/dB | -0.12 | -0.09 | -0.03 | -0.02 | 0.00 |
| d IP3/d IP3 | dBm/dBm | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 |

| Enter System Parameters: | | |
|---|---|---|
| Input Power | 0 | dBm |
| Analysis Temperature | 25 | °C |
| Noise BW | 1 | MHz |
| Ref Temperature | 25 | °C |
| S/N (for sensitivity) | 0 | dB |
| Noise Source (Ref) | 290 | °K |

| System Analysis: | | |
|---|---|---|
| Gain = | 168.10 | dB |
| Noise Figure = | 0.84 | dB |
| Noise Temp = | 61.74 | °K |
| SNR = | 113.14 | dB |
| MDS = | -113.14 | dBm |
| Sensitivity = | -113.14 | dBm |
| Noise Floor = | -173.14 | dBm/Hz |

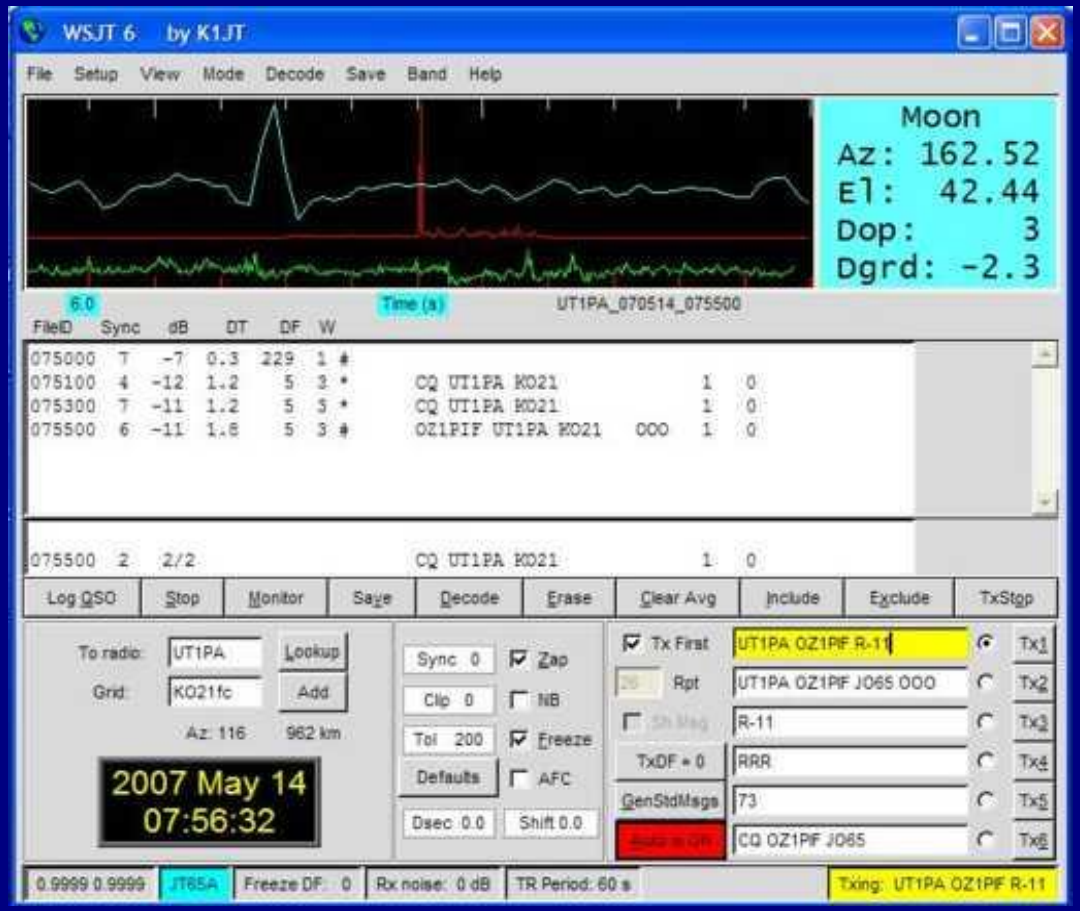
| | | |
|---|---|---|
| Input IP3 = | -168.10 | dBm |
| Output IP3 = | 0.00 | dBm |
| Input IM level = | 336.20 | dBm |
| Input IM level = | 336.20 | dBC |
| Output IM level = | 504.30 | dBm |
| Output IM level = | 336.20 | dBC |
| SFDR = | -36.64 | dB |

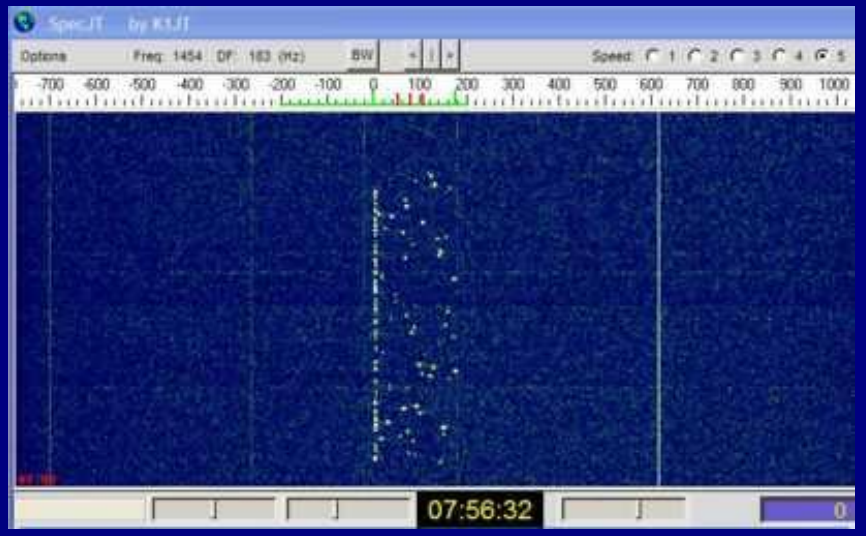
$$F_{sys} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \ldots \frac{F_n - 1}{G_1 G_2 \ldots G_{n-1}}$$

# JT65 – The Small Station's Best Friend

- Modulation mode created by Joe Taylor – K1JT in 2003
- Software actually called WSJT.
- Uses a PC and its sound card, Windows-based.
- DSP techniques optimized for extremely weak but slowly-varying signals (e.g. meteor scatter and moonbounce)
- Uses 63-frequency shift keying with constant phase
  - Single tone and continuous phase: Usable on a non-linear transmitter and power amplifier!
- Decode signals many decibels below the noise floor, even without signals being audible to the human ear.
  - Forward Error Correction (FEC) used. 5.25:1 Redundancy Ratio
  - Fixed and Expected Message, Grid and Callsign Formats
    - CQ VE2ZAZ FN25
    - K2UYH VE2ZAZ FN25
    - O, RO, RRR, 73
  - Does averaging of several Rx messages
  - Uses Deep Search table (list of stations known to do EME)

# WSJT - JT65

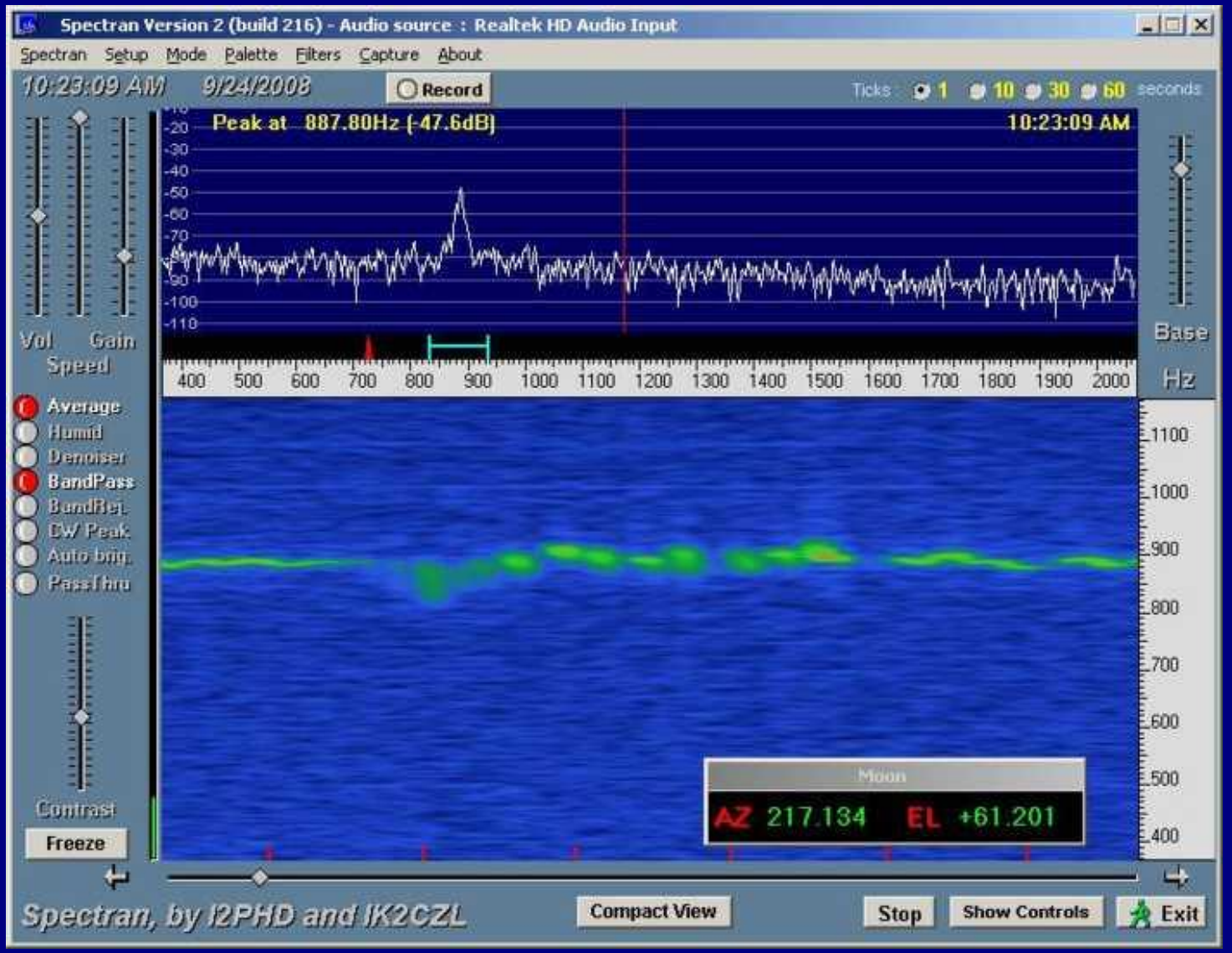

WSJT 6 by K1JT
File Setup View Mode Decode Save Band Help
Moon
Az: 162.52
El: 42.44
Dop: 3
Dgrd: -2.3
UT1PA_070514_075500
FileID Sync dB DT DF W
075000 7 -7 0.3 229 1 #
075100 4 -12 1.2 5 3 * CQ UT1PA KO21 1 0
075300 7 -11 1.2 5 3 * CQ UT1PA KO21 1 0
075500 6 -11 1.8 5 3 # OZ1PIF UT1PA KO21 OOO 1 0
075500 2 2/2 CQ UT1PA KO21 1 0
Log QSO Stop Monitor Save Decode Erase Clear Avg Include Exclude TxStop
To radio: UT1PA Lookup
Grid: KO21fc Add
Az: 116 962 km
2007 May 14
07:56:32
Sync 0 Zap
Clip 0 NB
Tol 200 Freeze
Defaults AFC
Dsec 0.0 Shift 0.0
Tx First UT1PA OZ1PIF R-11 Tx1
Rpt UT1PA OZ1PIF JO65 OOO Tx2
R-11 Tx3
TxDF = 0 RRR Tx4
GenStdMsgs 73 Tx5
CQ OZ1PIF JO65 Tx6
0.9999 0.9999 JT65A Freeze DF 0 Rx noise: 0 dB TR Period: 60 s
Txing: UT1PA OZ1PIF R-11


Options
Freq: 1454 DF: 183 (Hz)
BW
Speed
07:56:32

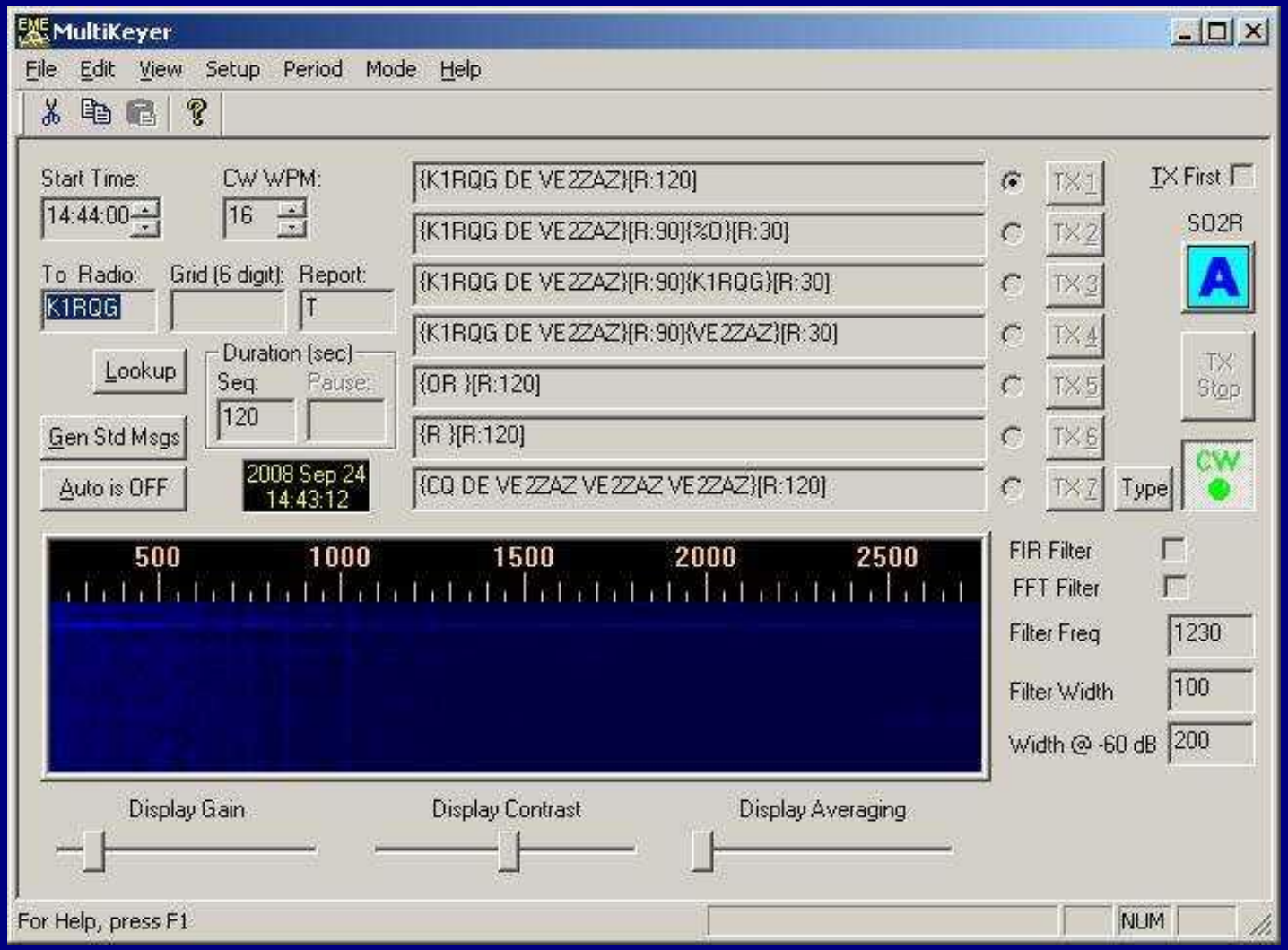
# *The JT65 Controversy...*

- “Deep Search” Lookup Controversy
  - Is it considered a complete copy of info for valid QSO?
- Not a true EME QSO? Too easy!
  - Endless Debate...
  - Solution will be to produce specific award classes for the EME digital modes

# Spectran – Audio SA and Filter SW

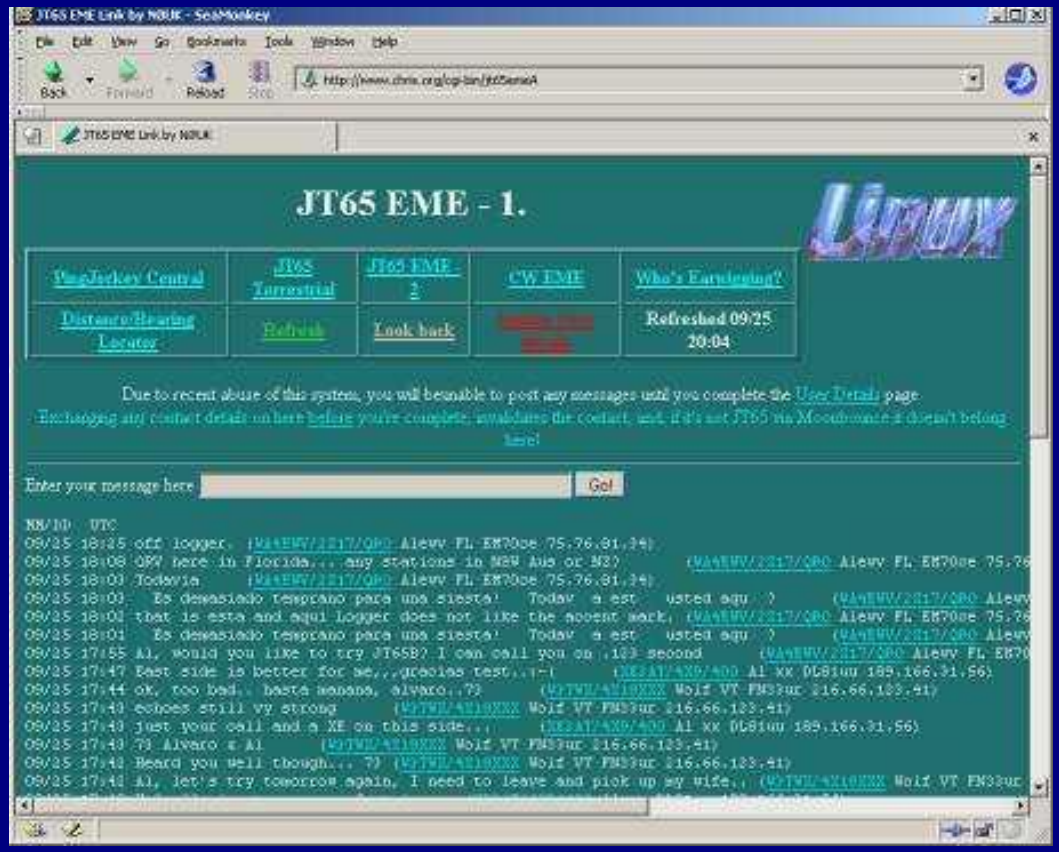


# MultiKeyer – Auto CW Keyer SW



# N0UK JT-65 EME Logger

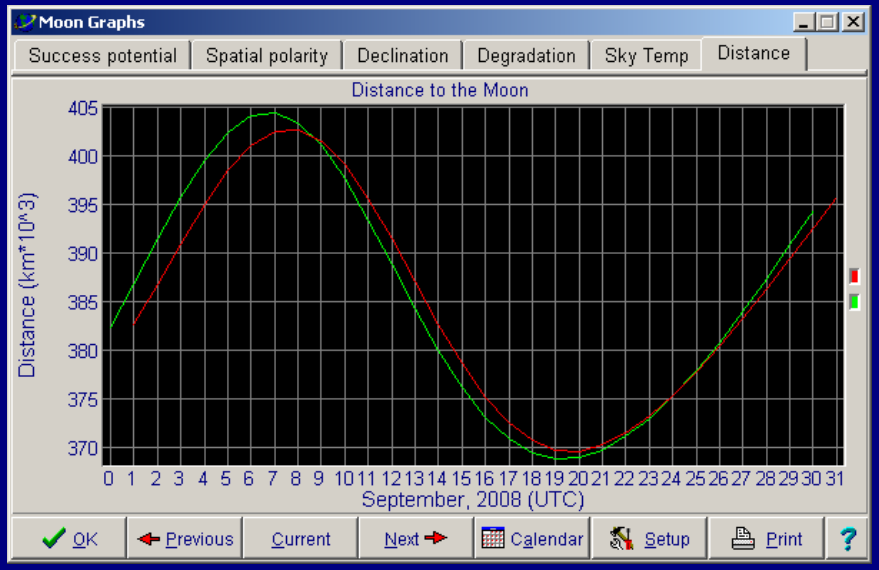
- A Must for both Skeds and Random QSOs
- Mostly 144MHz activity, but all bands are seen
- Other Logger Sites available
  - HB9Q EME Logger
  - ON4KST EME Chat

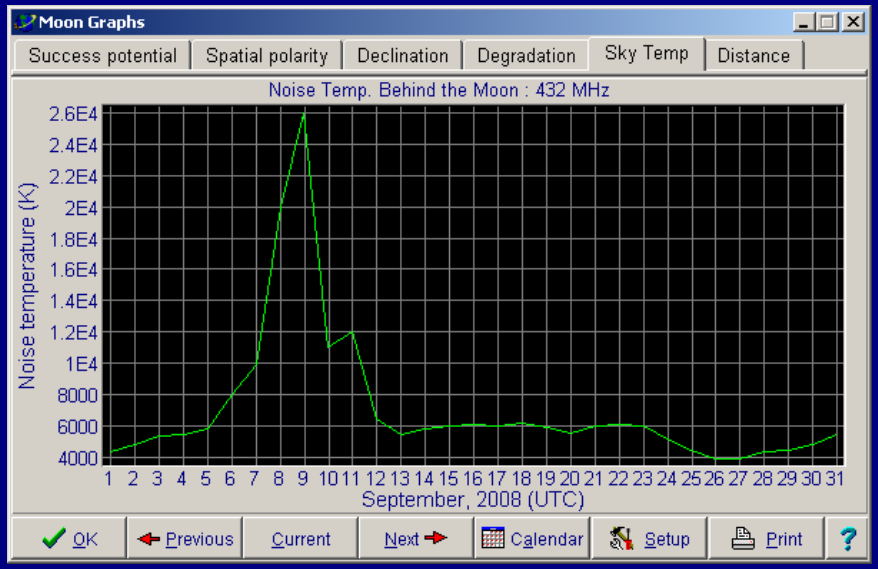


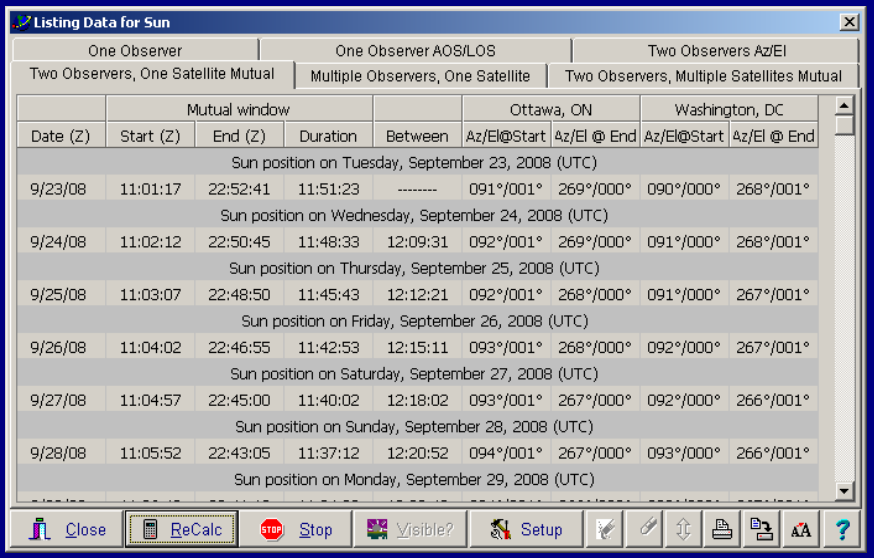
# *Moon Prediction*

- Software (Current Position, Prediction, Sked planning, Mutual Visibility)
  - MoonSked $
  - Nova $
  - EME Systems
  - SatTrack (Linux)
  - Winorbit
  - ...
- Internet Applets (Current Position)
  - Sun, Earth and Moon Applet
    - http://www.jgiesen.de/SME/
  - Sun & Moon Position Calculator
    - http://www.satellite-calculations.com/Satellite/suncalc.htm
  - ...

# Moon Prediction – Nova

# *QSLs are a Must for EME*

- Get your QSL design refreshed!
- Paper QSLs are still very popular within EME community.
- Nice trophies for a Small Station!
- QSL is normally sent Direct, not Via Buro.

# *Some References*

- Moon-Net Email Reflector
  - http://list-serv.davidv.net/mailman/listinfo/moon-net_list-serv.davidv.net
- 144MHz EME Newsletter
  - http://www.df2zc.de/newsletter/index.html
- 432 and Above EME Newsletters by K2UYH.
  - http://www.nitehawk.com/rasmit/em70cm.html
- DUBUS EME Moon Calendar
  - http://www.marsport.org.uk/dubus/eme.htm
- JT-65 Protocol Description
  - http://www.physics.princeton.edu/pulsar/K1JT/JT65.pdf

The WWW IS FULL OF EME STUFF!