A Beginner's View of

Easy Moonbouncing...

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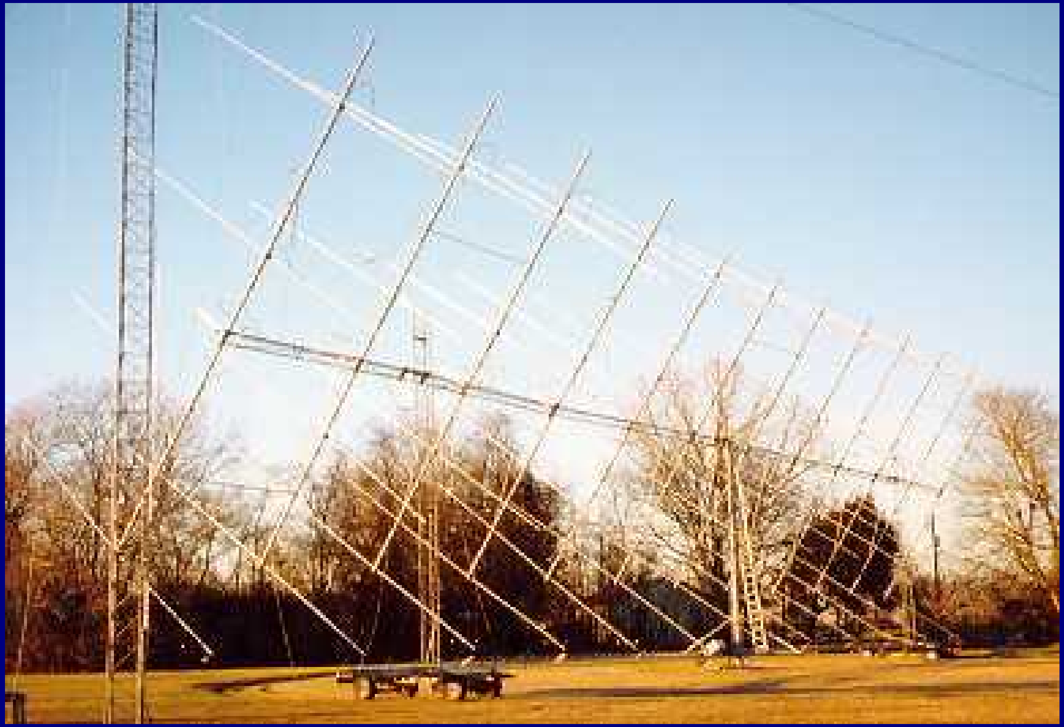
My Objective

- 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 !

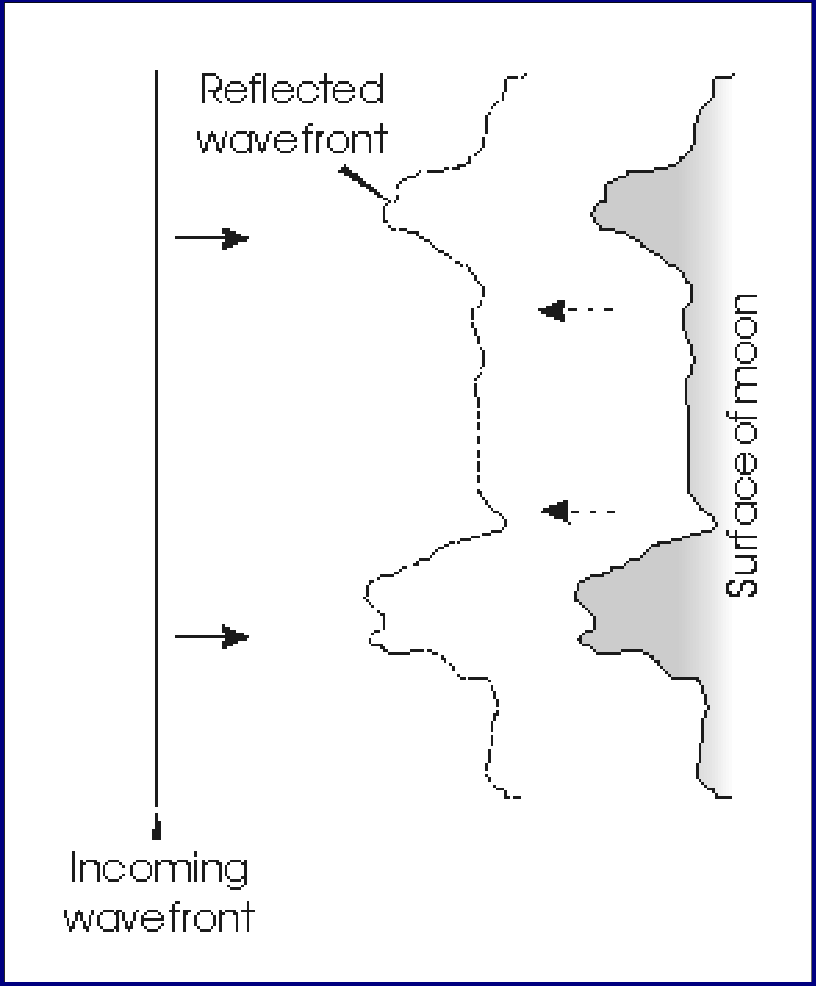
The Anatomy of an EME QSO

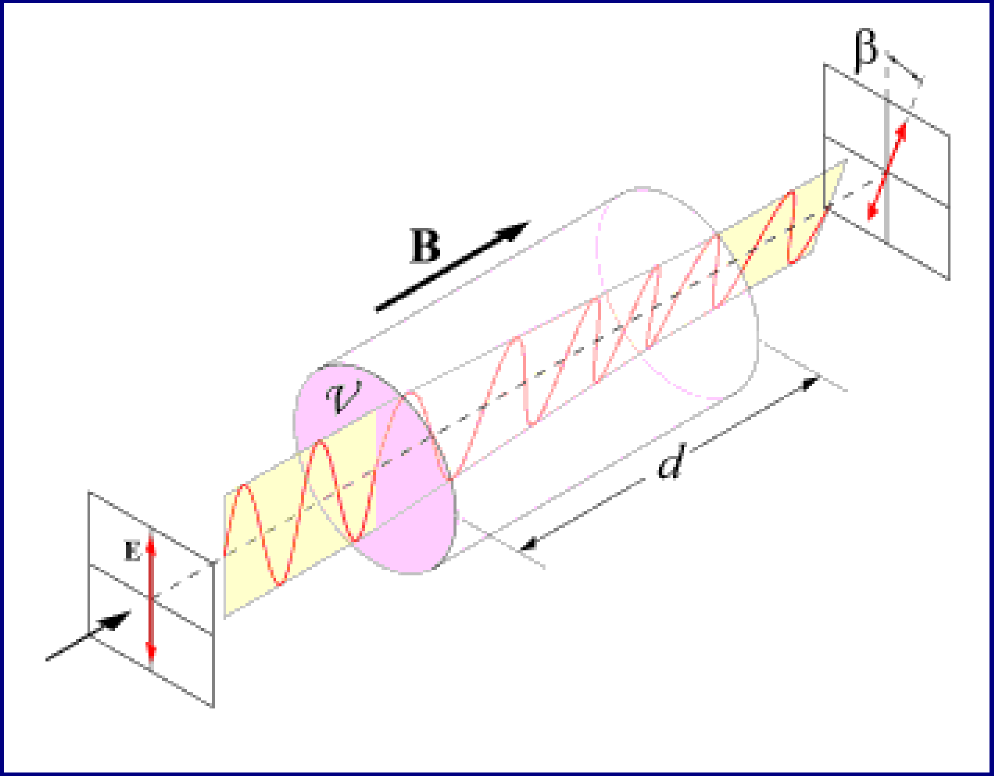
- AVERAGE MOON DISTANCE: 384,000km
  - Average Round Trip: 770,000km!
  - Propagation Path Loss: 250+ dB!
  - Echo delay: ~ 2.4 Seconds
- 93% OF WAVE ABSORPTION BY MOON
  - Only 7% wave reflection
- ANGLES AND BEAMWIDTH
  - Moon is ~ 1 degree wide when seen from earth
  - Antenna is 0.00....1 degree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

Libration And Faraday Rotation





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?

- 422MHz Single long-boom Yagi
- 80W
- No Preamp
- No Elevation Rotor

Success in JT-65!

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

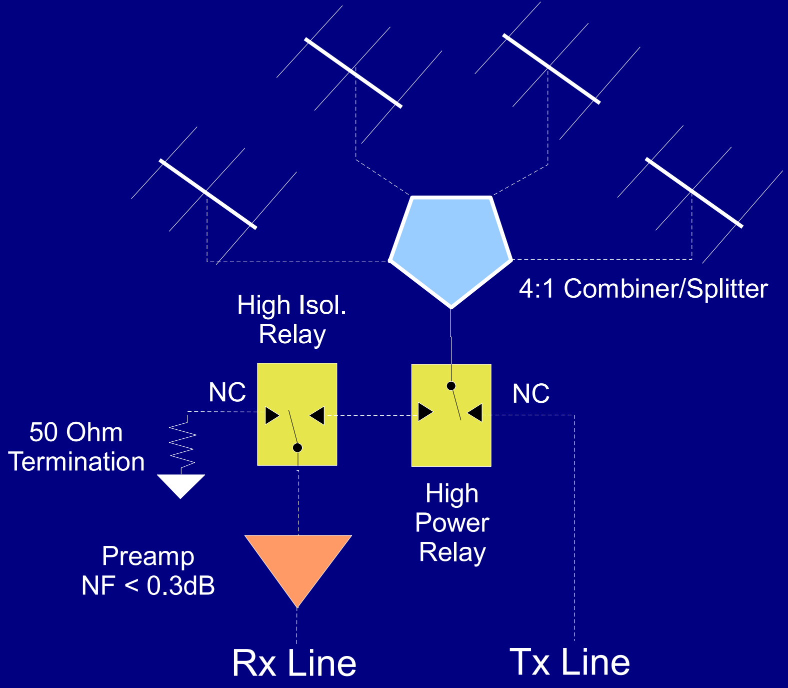
Success in CW!

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

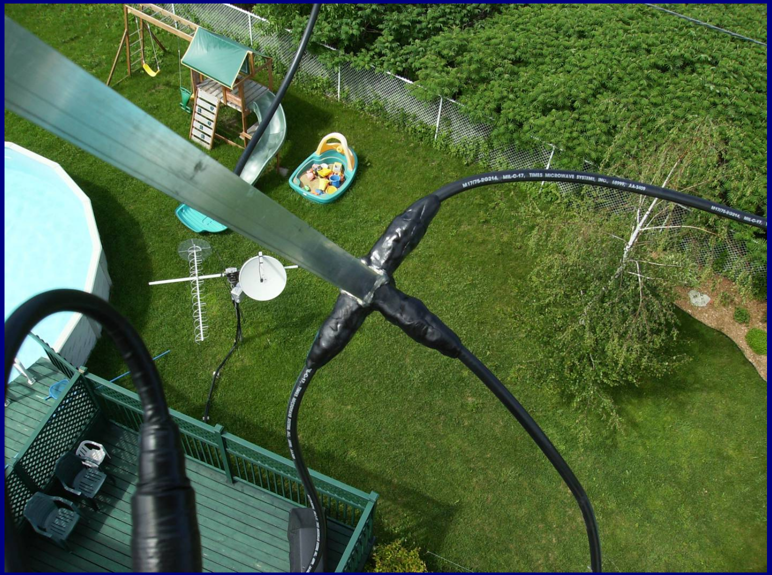
VA3TO – 2M EME, 112 Countries

432 EME at VE2ZAZ... Outdoors

- **ANT:** 4 x 13 element DK7ZB Yagi array (~20 dBd Gain), home-made
- **PREAMP:** 20dB Gain, <0.3dB NF (ATF-54143), home-made
- **FEEDLINE:** Andrew LDF4-50 Heliax (Tx), RG-214 (Rx)
- **SPLITTER:** 4:1 Air dielectric round/square coaxial transformer, home-made
- **ROTORS:** Hy-Gain Tailtwister (azimuth), Yaesu G-550 (elevation)

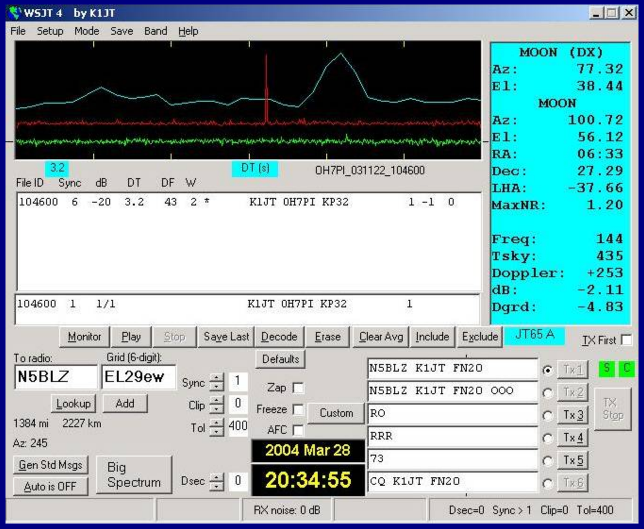


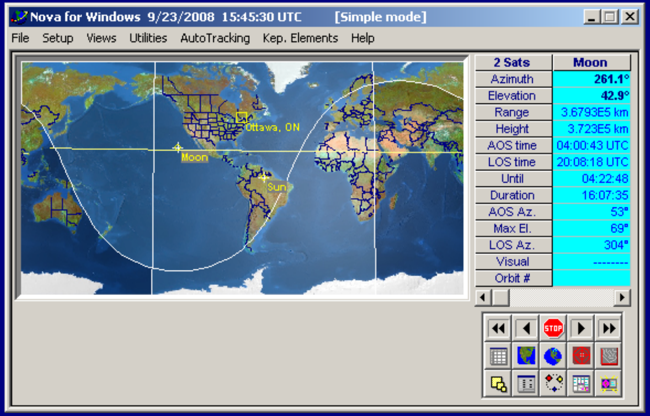
432 EME at VE2ZAZ... Outdoors



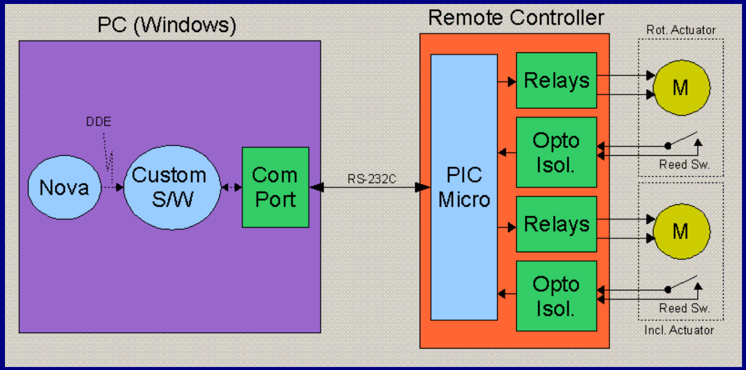
432 EME at VE2ZAZ... Indoors

- **Rig:** TS-790A (separated Tx and Rx ports)
- **Amp:** AM-6155 FAA amp (~300W)
- **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



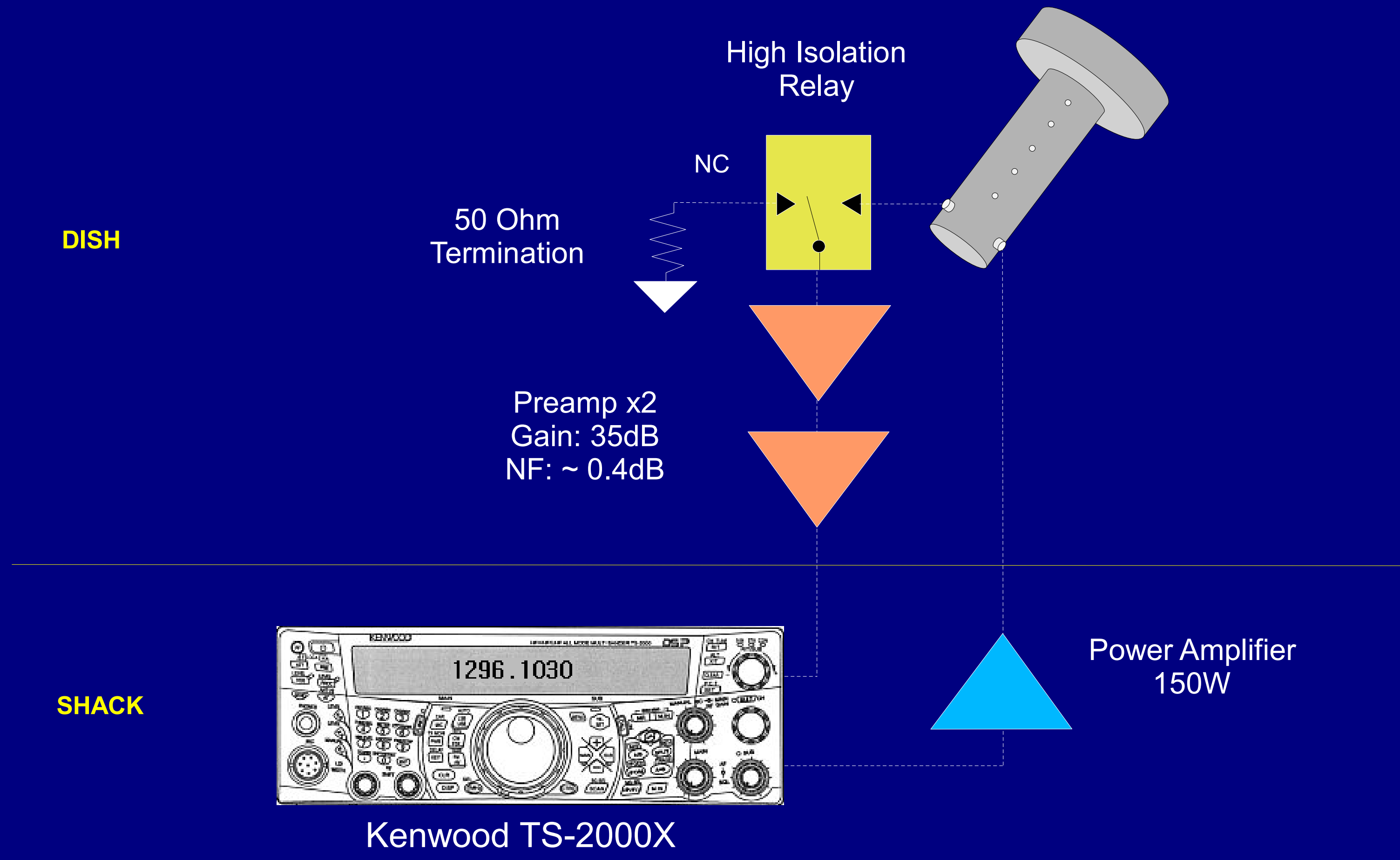


1296 EME at VE2ZAZ... Outdoors



- 3.2m (10.5ft) dish, VE4MA Feed (Super-Scalar Ring), Preamps.
- Azimuth-Over-Elevation Steering. East-to-South Coverage.

1296 EME at VE2ZAZ... RF Chain



NOT SHOWN: T/R Sequencer

Tx Feedline: LDF5-50A 7/8” Heliax (70 ft)
Rx Feedline: LDF4-50A 1/2” Heliax (70 ft)

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.

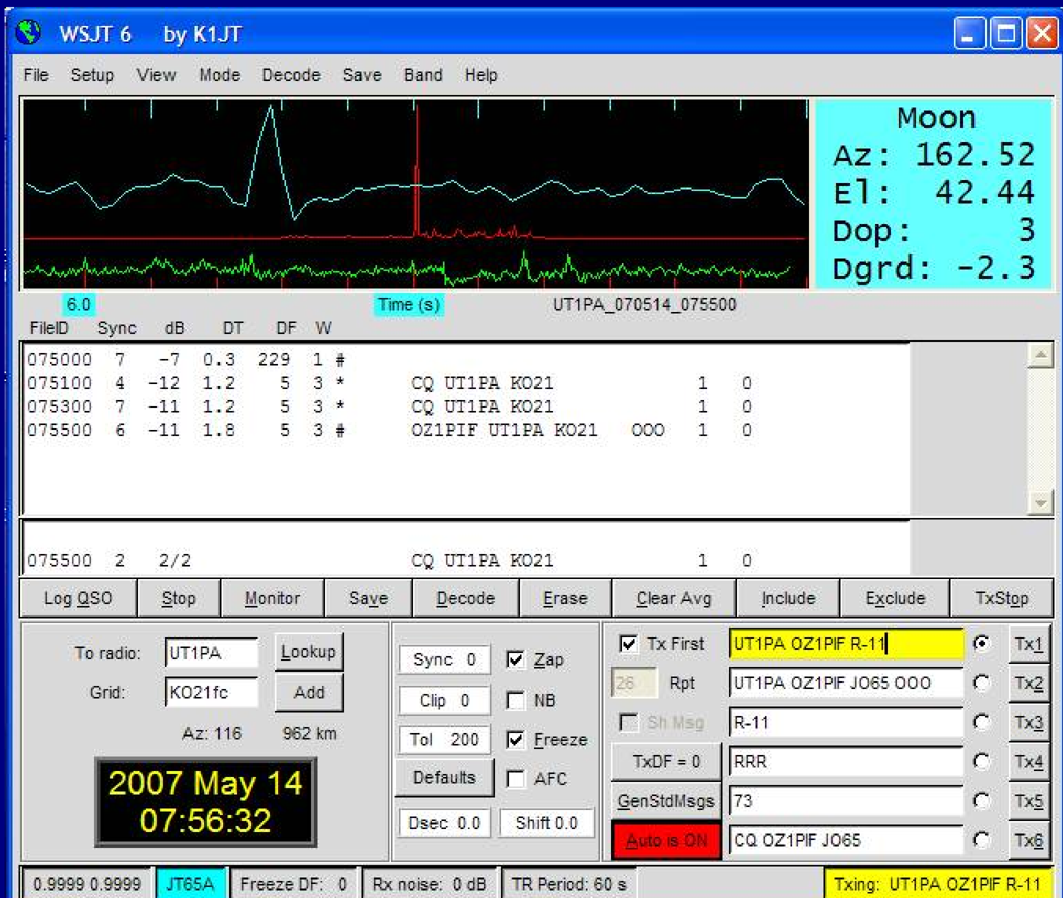
- Polarization Control is an Asset
  - Feedpoint rotation on dishes.
  - Cross-Yagi array

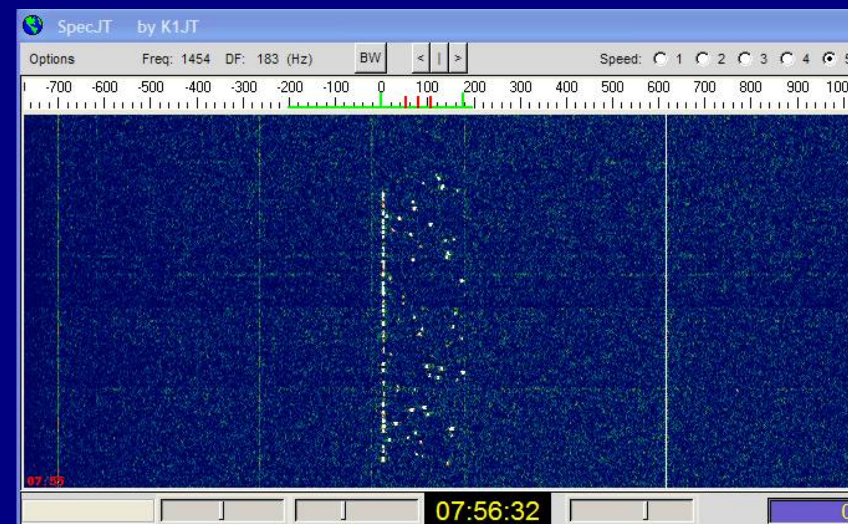
- Watch for Coaxial Cable Power Handling Capability.
  - At 432MHz, surprisingly low.
    - RG-214 = ~ 300W
    - 9913 = ~ 400W
  - Another reason to use Heliax coaxial cable.

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

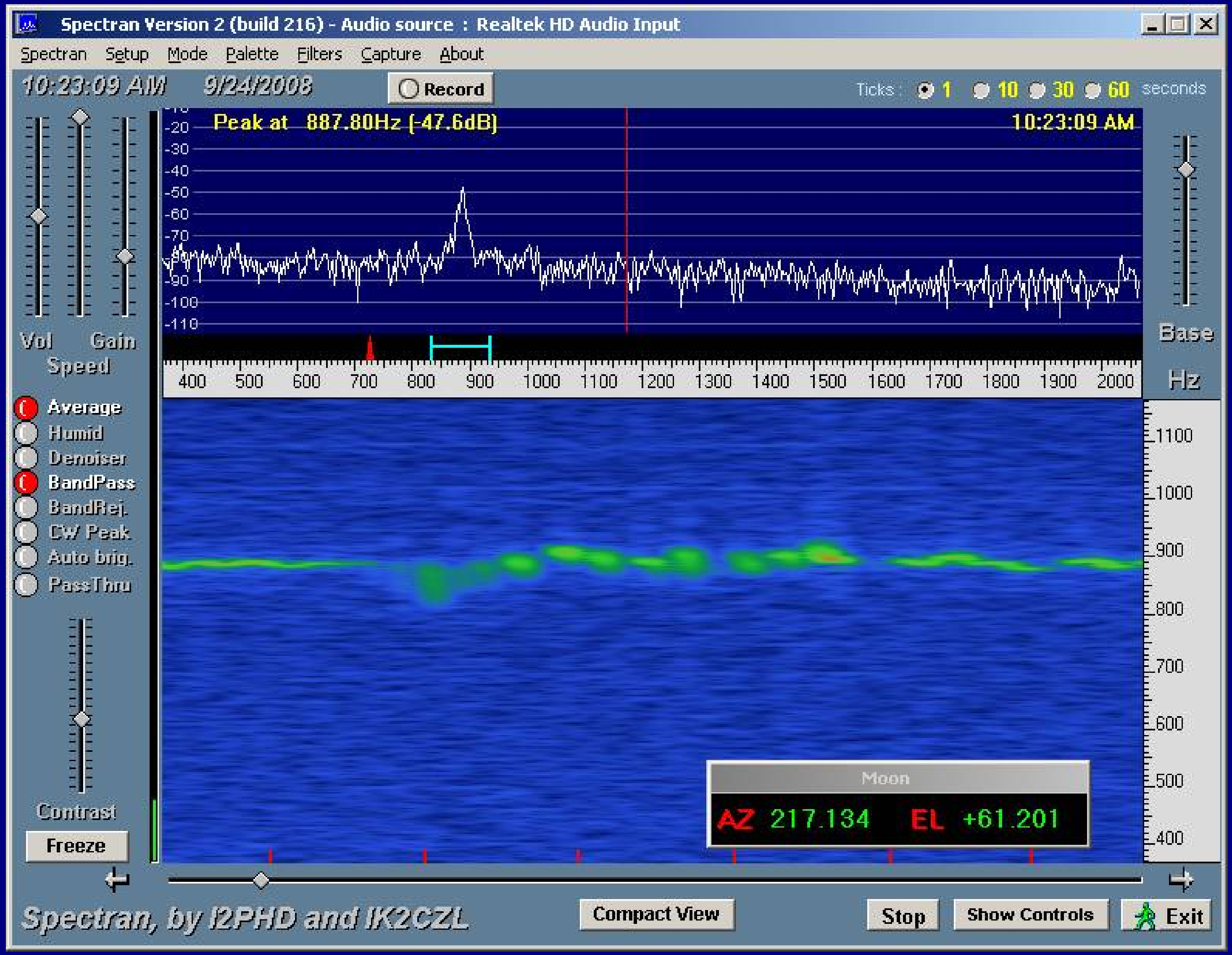

WSJT 6 by K1JT
File Setup View Mode Decode Save Band Help
Moon
Az: 162.52
El: 42.44
Dop: 3
Dgrd: -2.3
6.0
Time (s)
UT1PA_070514_075500
FileID Sync dB DT DF W
075000 7 -7 0.3 229 1 #
075100 4 -12 1.2 5 3 * CQ UT1PA KO21 1 0
075300 7 -11 1.2 5 3 * CQ UT1PA KO21 1 0
075500 6 -11 1.8 5 3 # OZ1PIF UT1PA KO21 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
26
Rpt
UT1PA OZ1PIF JO65 OOO
Tx2
Sh Msg
R-11
Tx3
TxDF = 0
RRR
Tx4
GenStdMsgs
73
Tx5
Auto is ON
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


SpecJT by K1JT
Options
Freq: 1454 DF: 183 (Hz)
BW
Speed: 1 2 3 4 5
-700 -600 -500 -400 -300 -200 -100 0 100 200 300 400 500 600 700 800 900 1000
07:56:32
0

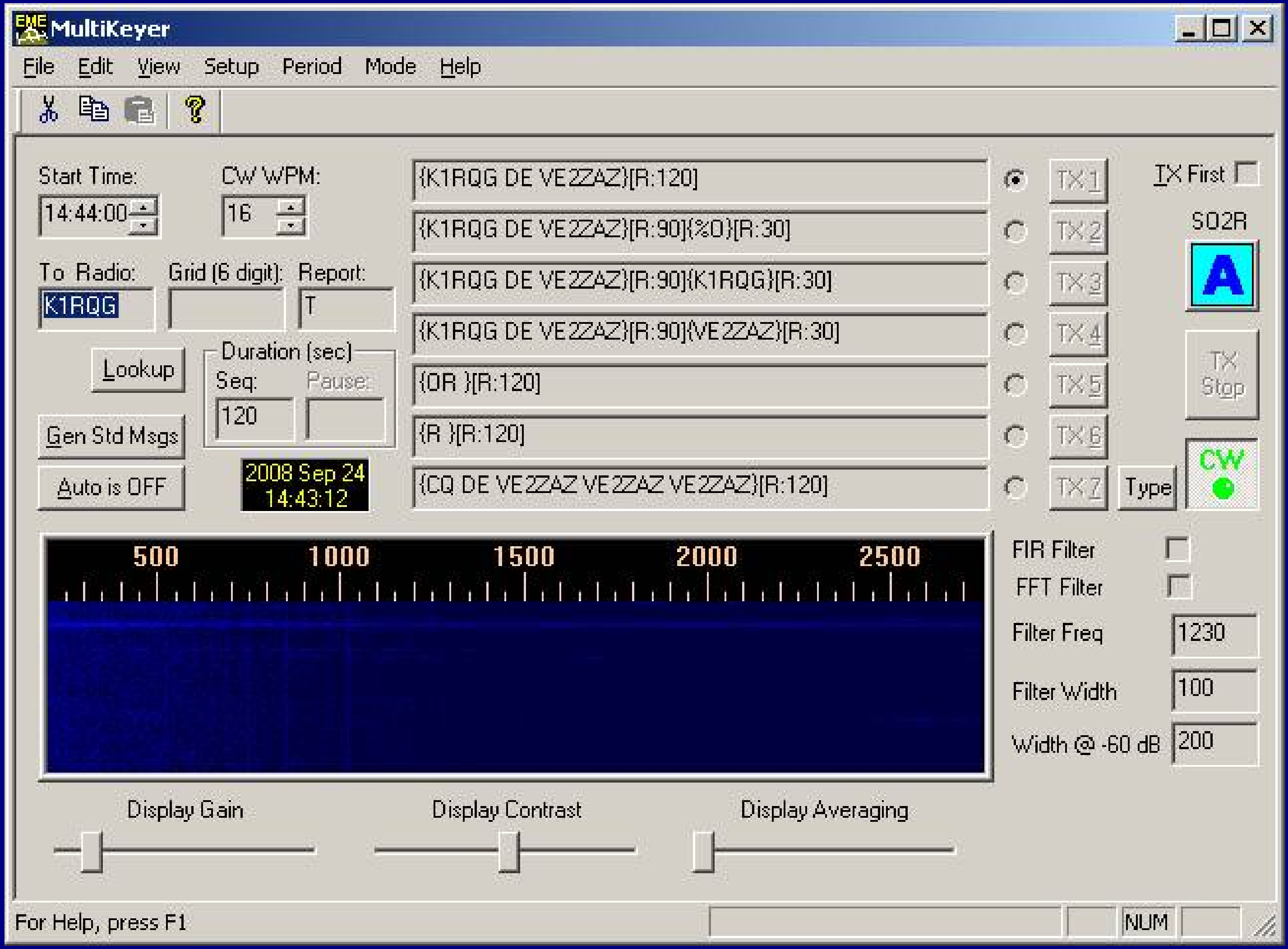
The JT65 Controversy...

- “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

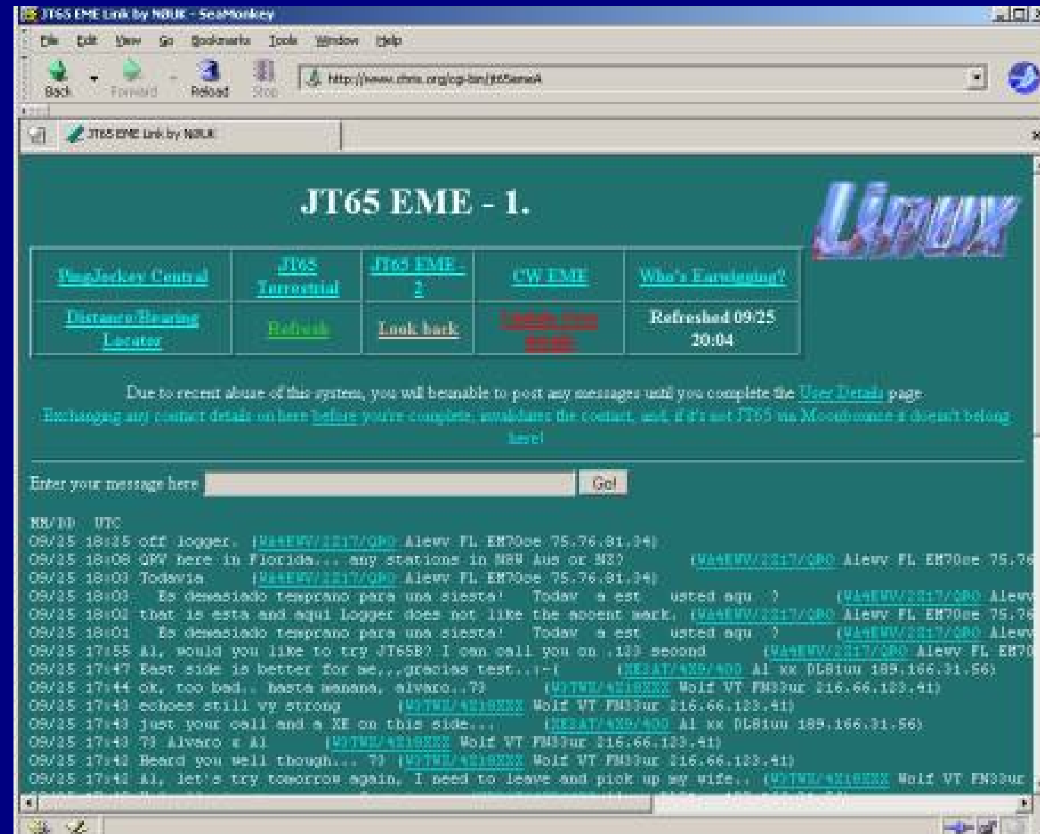


MultiKeyer – Auto CW Keyer SW



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

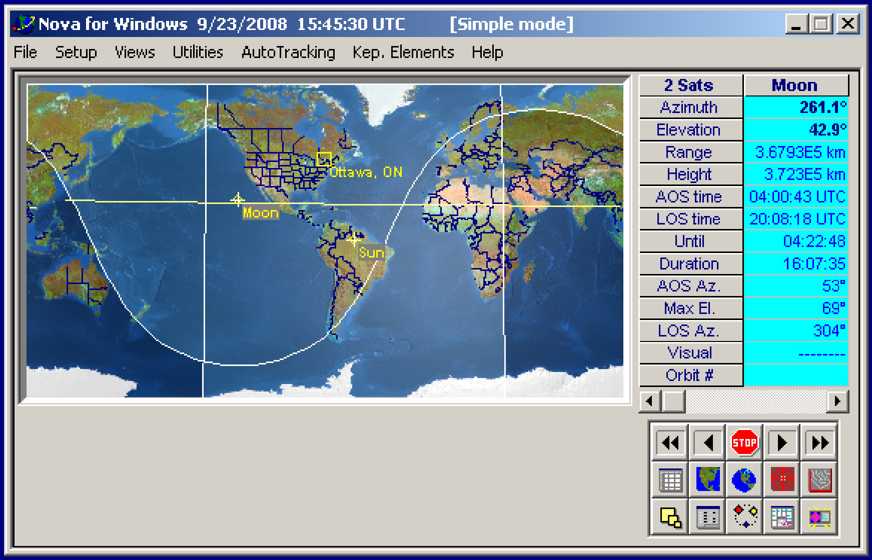


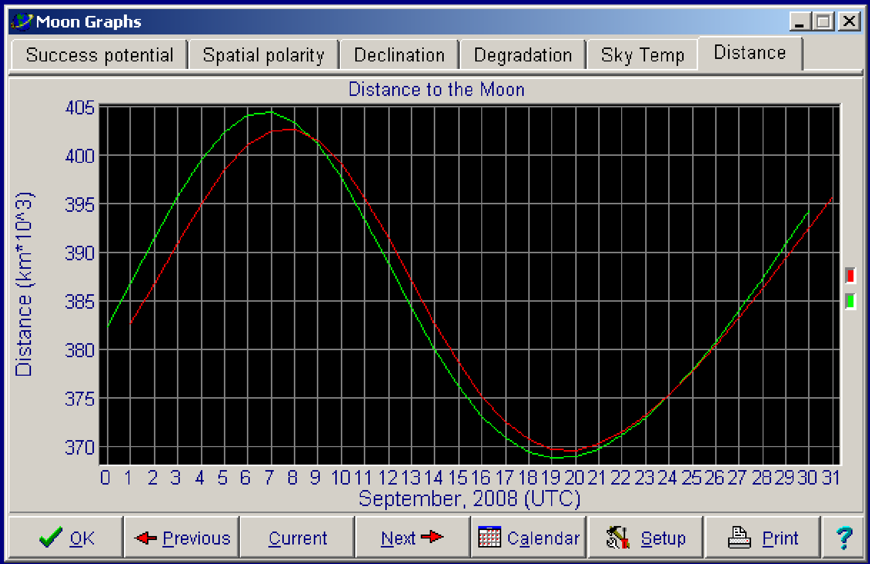
Moon Prediction

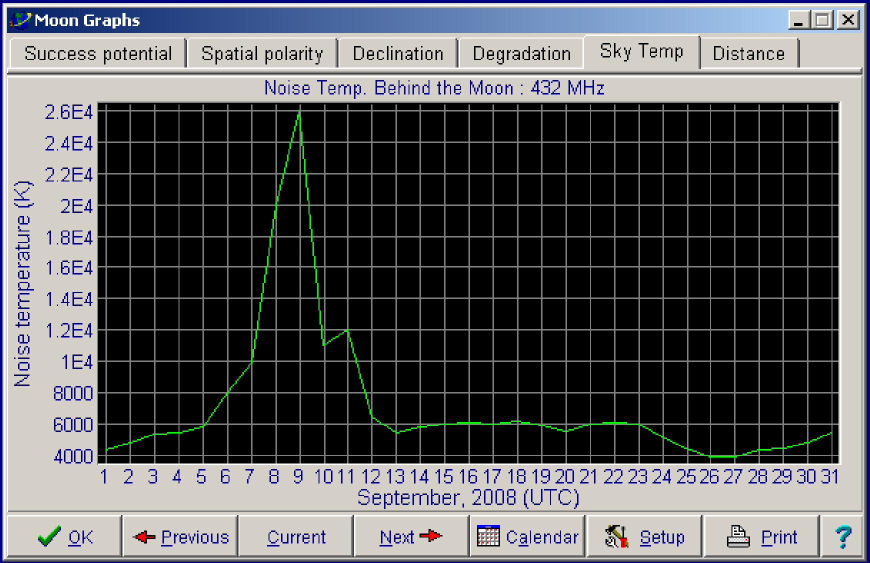
- Software (Current Position, Prediction, Sked planning, Mutual Visibility)
  - MoonSked $
  - Nova $
  - EME Systems
  - SatTrack (Linux)
  - Winorbit
  - ...

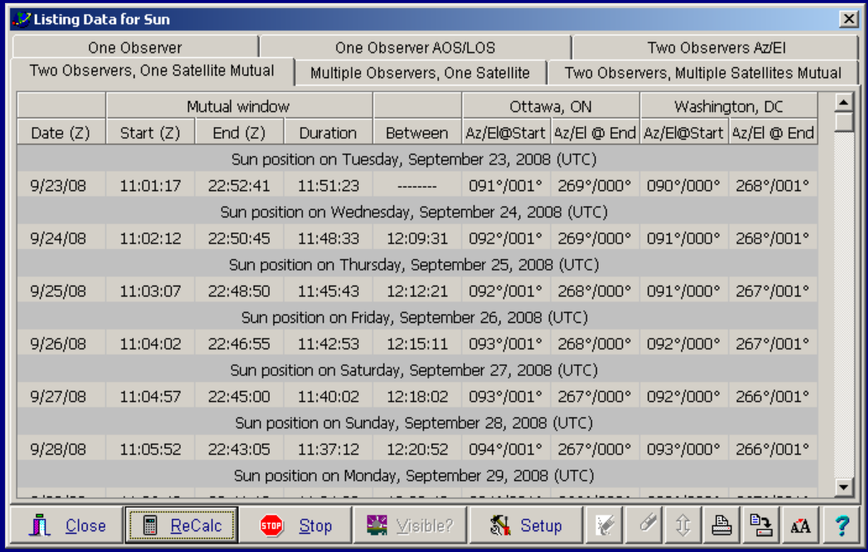
- Internet Applets (Current Position)
  - Sun, Earth and Moon Applet
    - http://www.jgiesen.de/SME/
  - Sun & Moon Position Calculator
    - http://www.satellite-calculations.com/Satellite/suncalc.htm
  - ...

Moon Prediction – Nova









	Mutual window				Ottawa, ON		Washington, DC	
Date (Z)	Start (Z)	End (Z)	Duration	Between	Az/El@Start	Az/El @ End	Az/El@Start	Az/El @ End
Sun position on Tuesday, September 23, 2008 (UTC)								
9/23/08	11:01:17	22:52:41	11:51:23	--------	091°/001°	269°/000°	090°/000°	268°/001°
Sun position on Wednesday, September 24, 2008 (UTC)								
9/24/08	11:02:12	22:50:45	11:48:33	12:09:31	092°/001°	269°/000°	091°/000°	268°/001°
Sun position on Thursday, September 25, 2008 (UTC)								
9/25/08	11:03:07	22:48:50	11:45:43	12:12:21	092°/001°	268°/000°	091°/000°	267°/001°
Sun position on Friday, September 26, 2008 (UTC)								
9/26/08	11:04:02	22:46:55	11:42:53	12:15:11	093°/001°	268°/000°	092°/000°	267°/001°
Sun position on Saturday, September 27, 2008 (UTC)								
9/27/08	11:04:57	22:45:00	11:40:02	12:18:02	093°/001°	267°/000°	092°/000°	266°/001°
Sun position on Sunday, September 28, 2008 (UTC)								
9/28/08	11:05:52	22:43:05	11:37:12	12:20:52	094°/001°	267°/000°	093°/000°	266°/001°
Sun position on Monday, September 29, 2008 (UTC)								

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

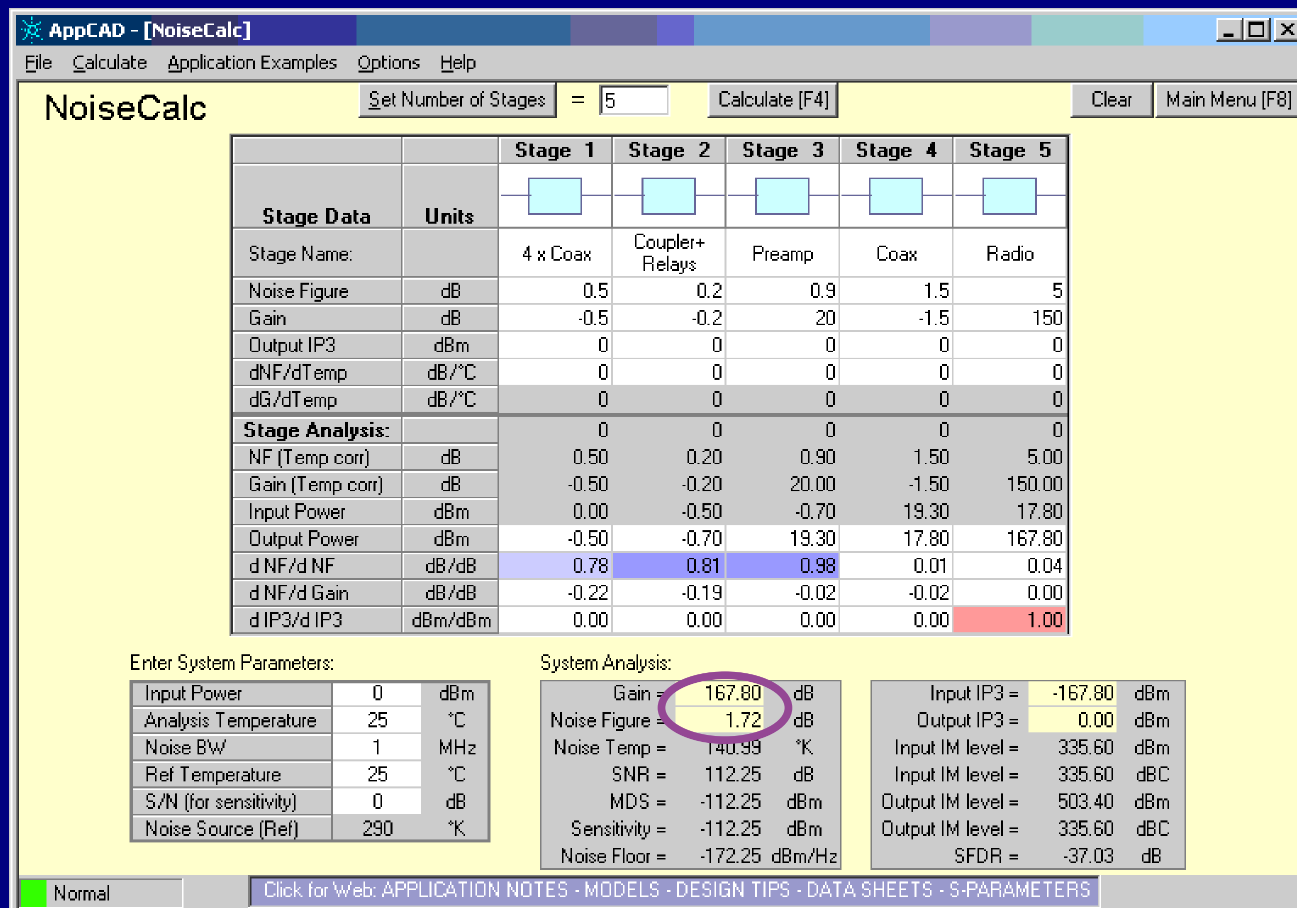
- Moon-Net Email Reflector
  - http://mailman.pe1itr.com/mailman/listinfo/moon-net
- 144MHz EME Newsletter
  - http://www.df2zc.de/newsletter/index.html
- 432 and Above EME Newsletters by K2UYH.
  - http://www.nitehawk.com/rasmit/em70cm.html
- DUBUS EME Moon Calendar
  - http://www.marsport.org.uk/dubus/eme.htm
- VE2ZAZ's 3.2m Dish Project
  - http://ve2zaz.net/3.2m_Dish/3.2m_Dish.htm
- JT-65 Protocol Description
  - http://www.physics.princeton.edu/pulsar/K1JT/JT65.pdf

The WWW IS FULL OF EME STUFF!

Backup Slides

Optimize your Noise Figure

- A “typical” 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	0.5	0.2	0.9	1.5	5
Gain	dB	-0.5	-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	0.50	0.20	0.90	1.50	5.00
Gain (Temp corr)	dB	-0.50	-0.20	20.00	-1.50	150.00
Input Power	dBm	0.00	-0.50	-0.70	19.30	17.80
Output Power	dBm	-0.50	-0.70	19.30	17.80	167.80
d NF/d NF	dB/dB	0.78	0.81	0.98	0.01	0.04
d NF/d Gain	dB/dB	-0.22	-0.19	-0.02	-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

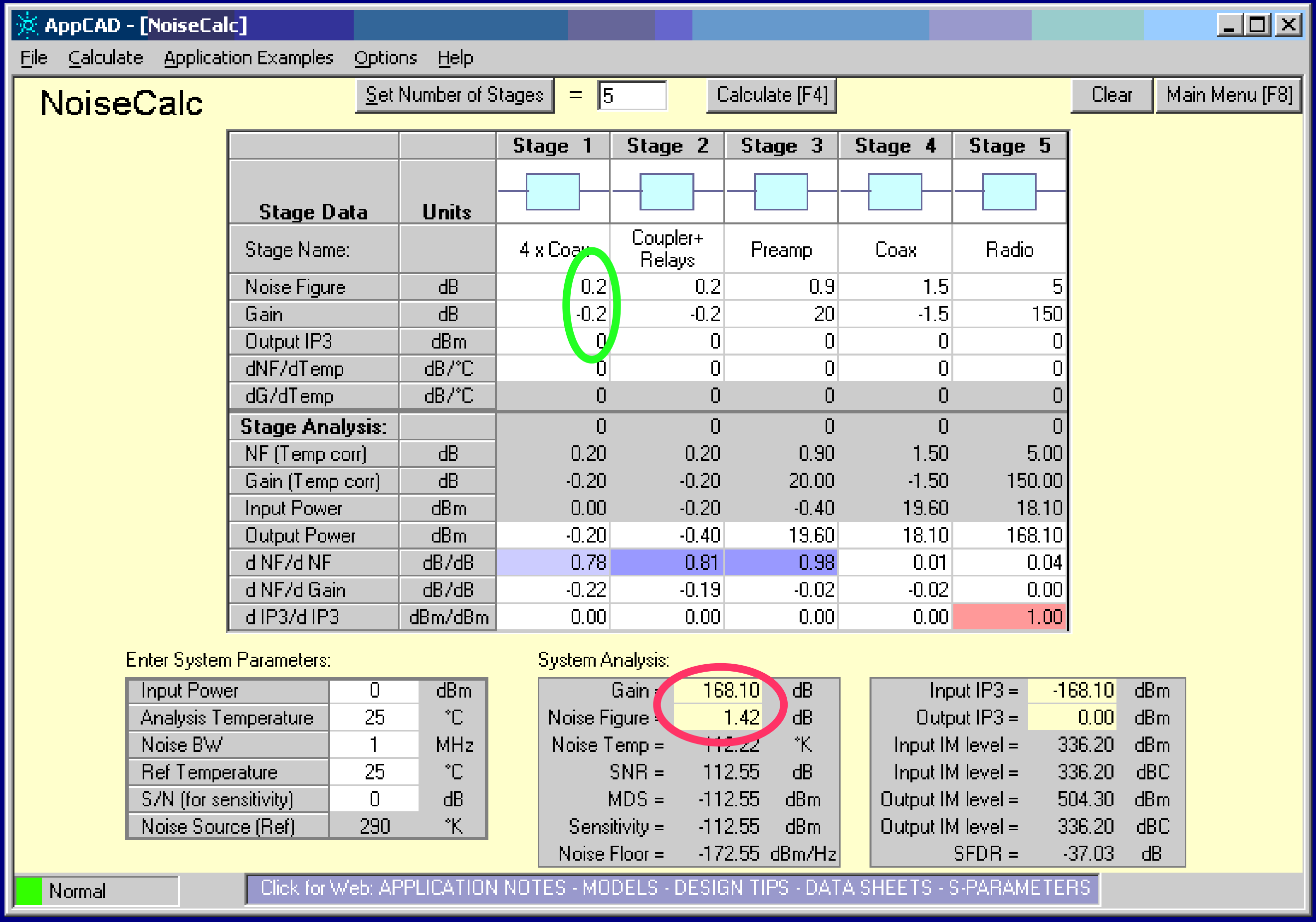
System Analysis:

Gain =	167.80	dB
Noise Figure =	1.72	dB
Noise Temp =	140.99	°K
SNR =	112.25	dB
MDS =	-112.25	dBm
Sensitivity =	-112.25	dBm
Noise Floor =	-172.25	dBm/Hz

Input IP3 =	-167.80	dBm
Output IP3 =	0.00	dBm
Input IM level =	335.60	dBm
Input IM level =	335.60	dBC
Output IM level =	503.40	dBm
Output IM level =	335.60	dBC
SFDR =	-37.03	dB

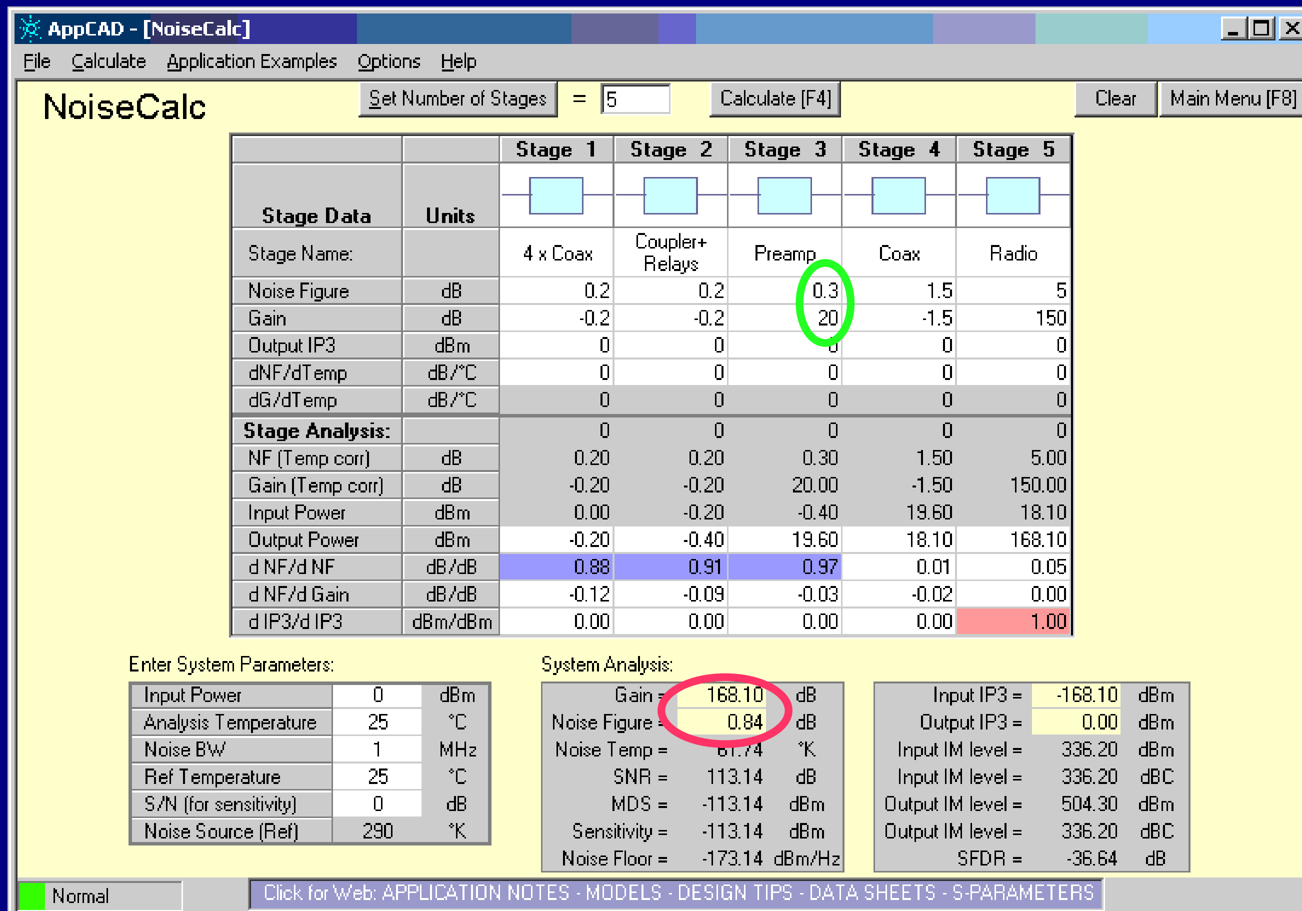
Optimize your Noise Figure

- A better setup



Optimize your Noise Figure

- A Much Better Setup



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