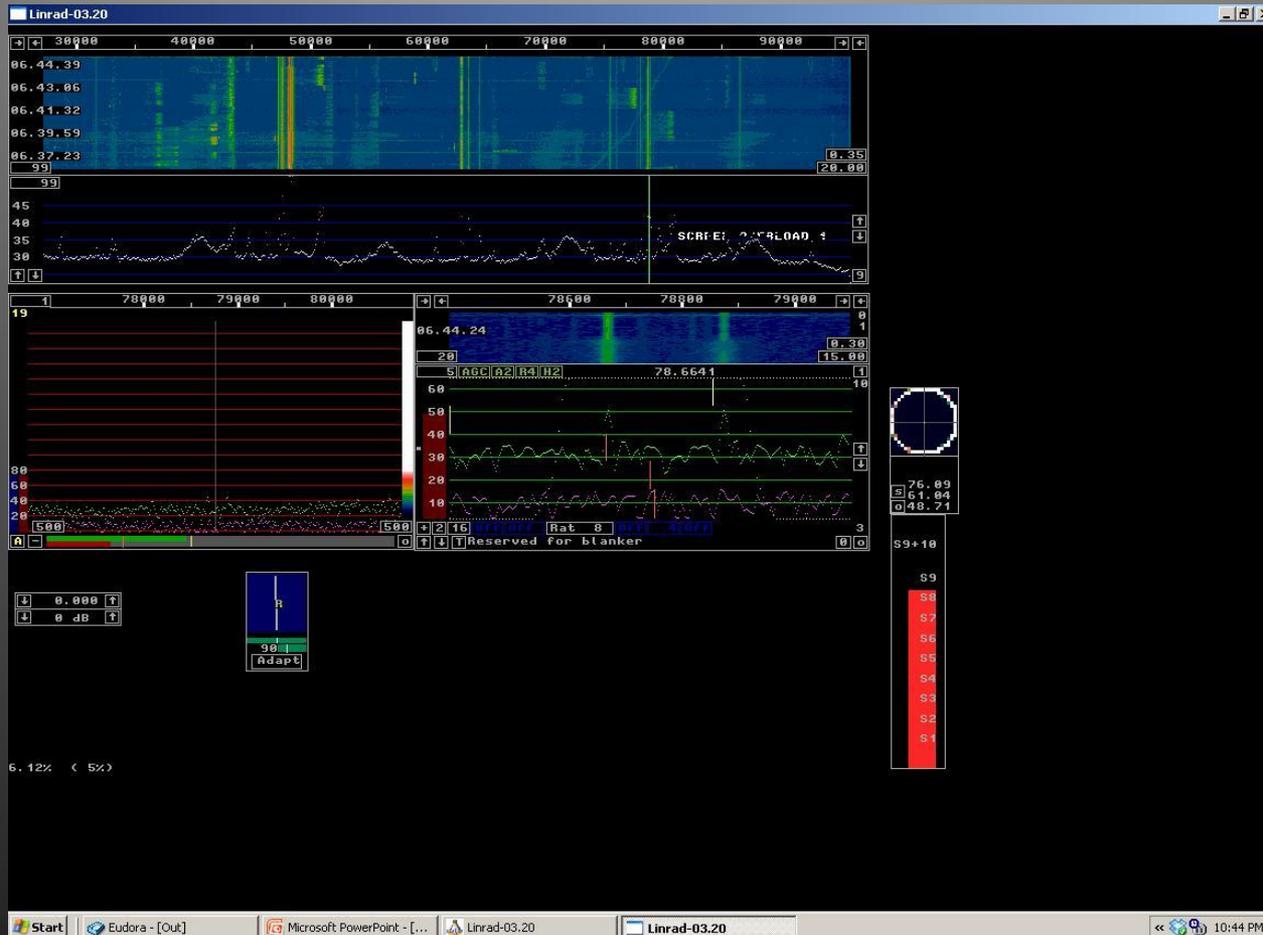


# Adaptive Reception of Dual Polarity EME Signals Using Linrad

By Ed Cole - KL7UW



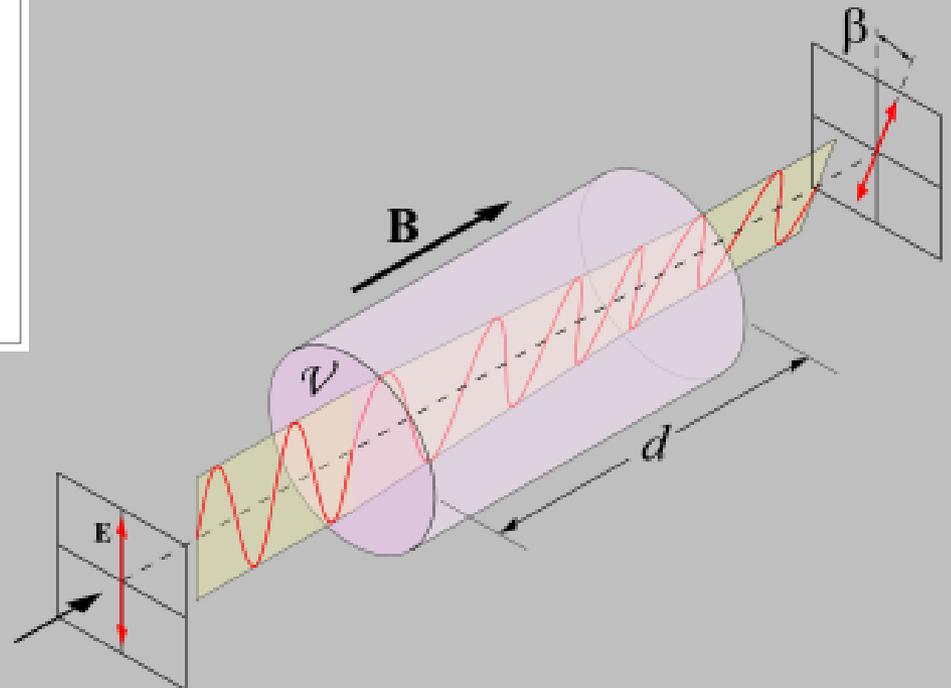
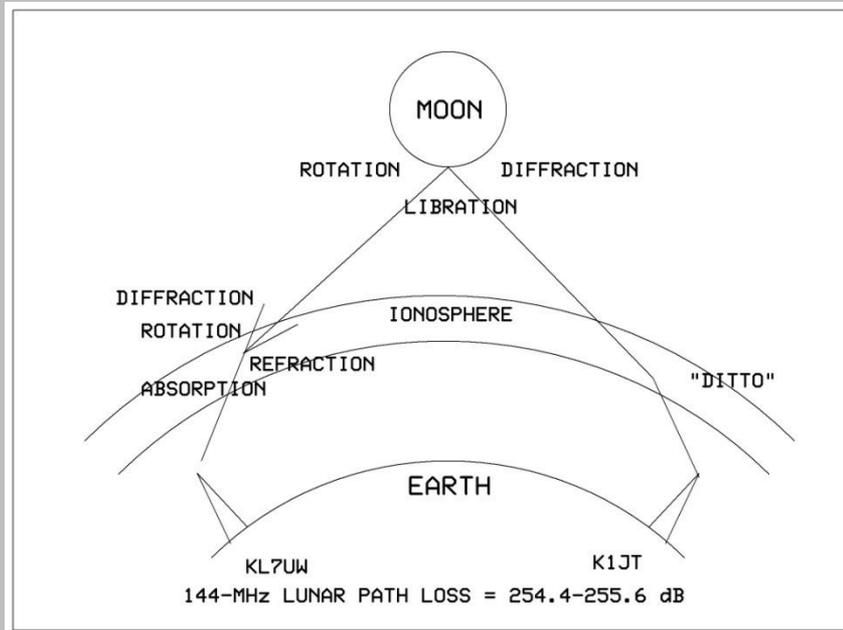
# Introduction

- This paper explores receiving eme signals in two polarities simultaneously, and using the Linrad (**Linux radio**) program for determining the polarization angle and peaking the signal in the direction of polarity. <http://www.k17uw.com/LINRAD.htm>
- Linrad is a software defined receiver (SDR) program, so it uses appropriate hardware that can supply I and Q signals that all SDR require for operation.
- My particular application converts 144-MHz signals down to audio base-band for input to Linrad by use of a high-performance soundcard.
- But before getting into the specifics, lets review some basics about eme reception.

# Signal Polarity and EME:

- EME signals travel thru the ionosphere in transit to the Moon, twice.
- Electrically charged plasma in the Ionosphere interacts with the electromagnetic field of the radio signal to absorb, refract, diffract, and twist it.
- This affects signal reception after it travels to and reflects from the Moon and returns to Earth.
- Not much can be done about most of these effects.
- The one that causes “twisting” (called the Faraday Effect) results in the polarity of a radio signal being rotated and there is something we can do to minimize its effect.
- Faraday varies in strength with solar and geomagnetic activity and results in different impact depending on frequency.
- The effect is stronger at lower VHF frequencies such as 50-432 MHz.

# Signal Polarity and EME:

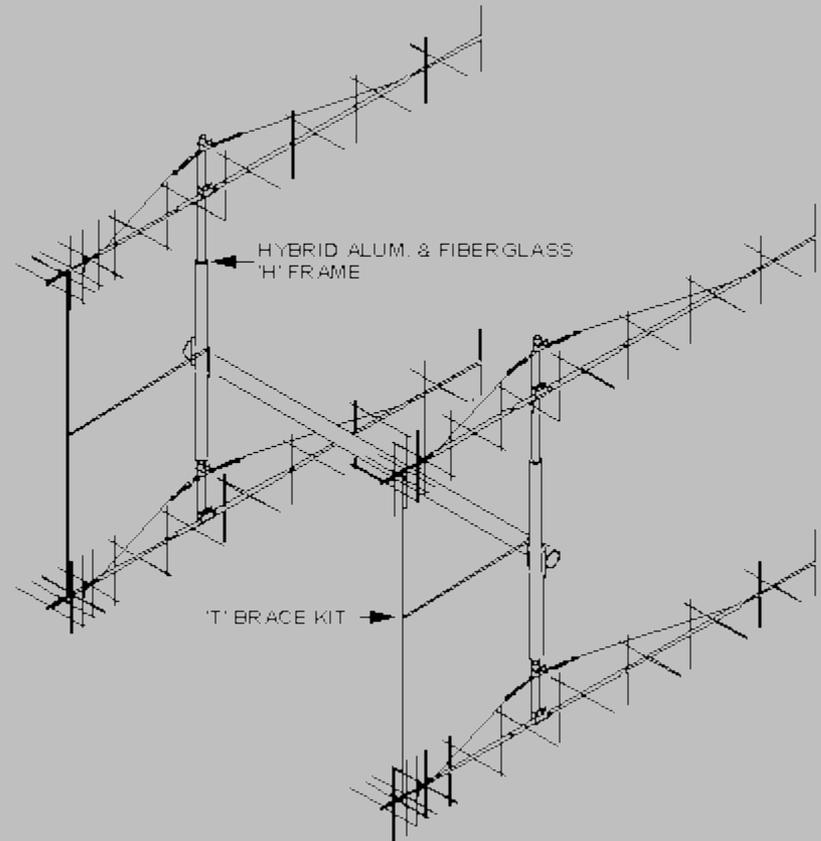


# Signal Polarity and EME:

- At 6m an eme signal will twist very rapidly.
- At 2m typically it will rotate up to 90-degrees in a few minutes.
- At 432-MHz the effect slows to part of an hour up to several hours.
- Above 1000-MHz Faraday is not significant and can be ignored.
- The eme signal returns to Earth at a different polarity angle which results in signal loss called cross-polarity loss.
- At 90 degree rotation loss is >20 dB. At 45 degree it is 3 dB.
- EME is extreme weak-signal operation so any loss is to be avoided.
- Early years of eme they just accepted Faraday.
- In the last decade dual-polarity antennas have become popular.
- On 432 some stations even physically rotate the whole array.
- 1296 and some higher microwave bands circular polarity is used.
- Even using dual polarity loss can still reach 3-dB.
- Is there a better way to handle this?

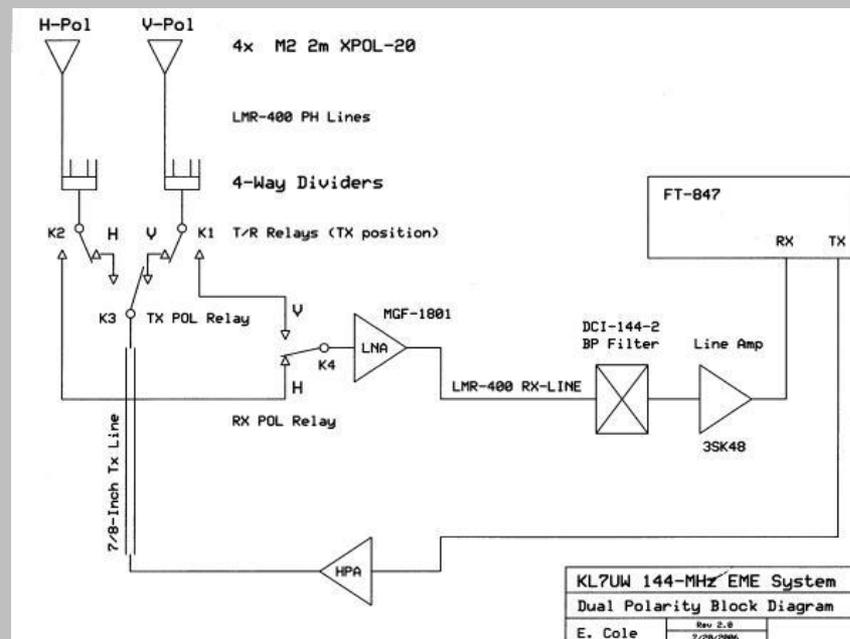
# Hardware of the Dual-Pol Adaptive System

- At KL7UW the M2 2mXpol-20 dual-pol antenna was chosen.
- Each antenna has ten elements in each pol with 13.2 dBd (15.3 dBi) gain. The array has 19.2 dBd (21.3 dBi) gain.
- This array has the minimum gain required for CW-eme using 600w RF output.
- I chose this antenna because it was physically smaller than the typical antenna used for 2m-eme.



# Hardware of the Dual-Pol Adaptive System

- I started building my eme station in 1998 and acquired a FT-847 for my main radio.
- Initially the eme station was fairly simple as I used a 170w amplifier which resulted in about 100w at the antenna. This was QRPp –very weak for CW (I only worked four very-big stations in the first years).
- In 2003 a new digital mode (JT-44) was introduced and I quickly added another 120 contacts.



JT-44 (now JT-65) increases station performance about 10-dB over CW making eme possible with a small antenna system.

# Hardware of the Dual-Pol Adaptive System

- I decided in spring of 2010 to switch from the multi-mode VHF transceiver to using a well-designed HF transceiver with a VHF transverter.
- I chose the Elecraft K3 which has a reputation for superb CW reception.
- It is a hybrid dual-conversion radio using a SDR core.
- Elecraft uses an identical second receiver which could be phase-locked to a single digital VFO for diversity reception.
- K3 offers a transverter interface which provides separate Rx and Tx connections.
- Use of a 10-MHz external frequency reference for very high frequency accuracy. K3 exhibits 2-Hz accuracy at 28-MHz.
- I ordered a custom-made DEMI Transverter with two Rx converter.



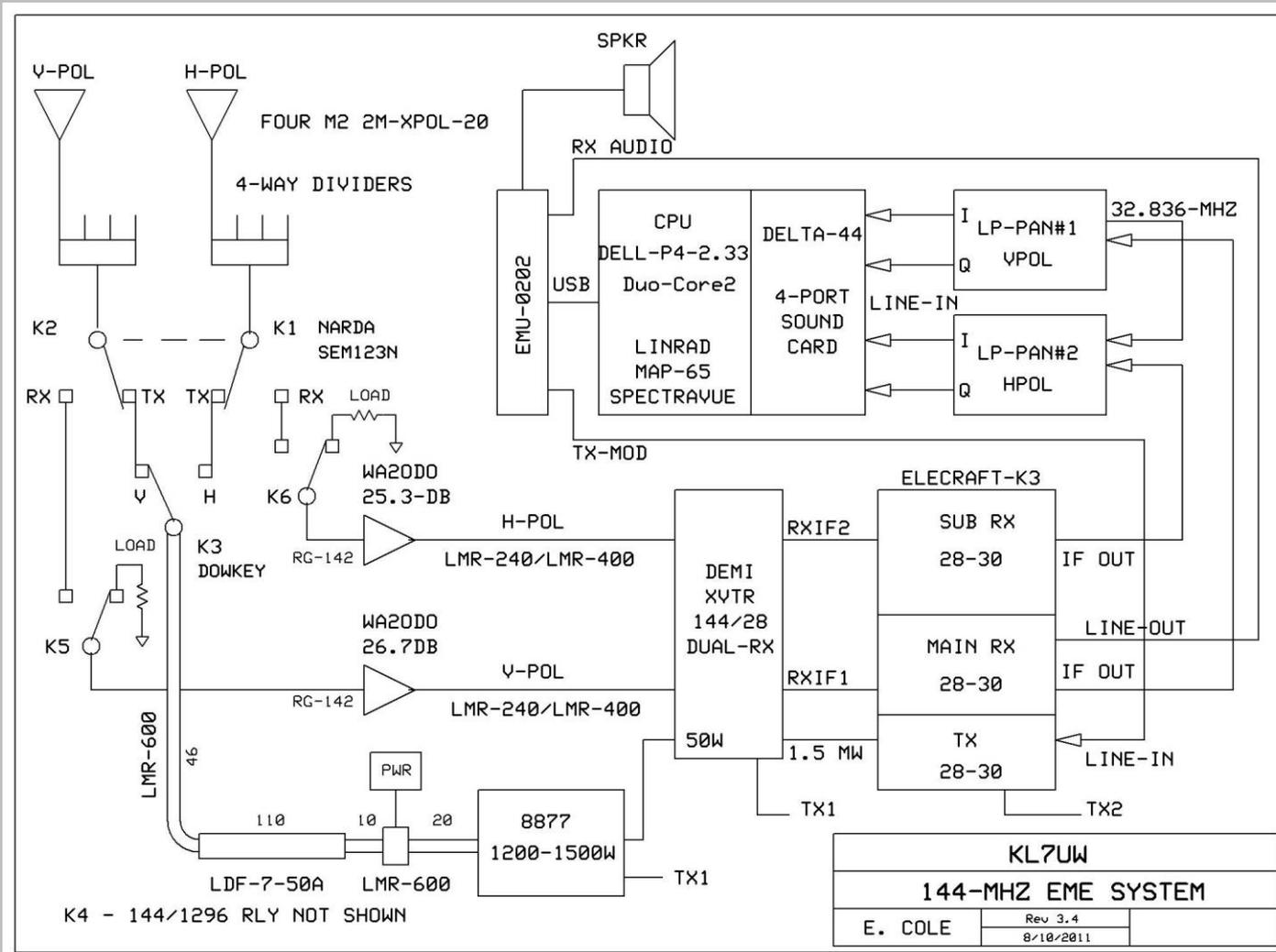
# Down East Microwave dual-Rx Transverter



# Down East Microwave dual-Rx Transverter

- At the 2010 International EME Conference DEMI offered to make a custom-build dual-Rx transverter that I asked about earlier in the year.
- The prototype dual-Rx transverter would be a beta-test for DEMI.
- The transverter is based their new 2010 L-series design. It was designated L144-28HP DRX.
- The second Rx was created from a cut-down transverter pc board.
- A custom enclosure was made to accommodate the extra footprint of adding extra coax connectors.
- I chose the 50w model to directly drive my 8877 linear amplifier.
- Full test specs are on my website:  
<http://www.kl7uw.com/DEMI144-28DRX.htm>
- The dual-Rx in the transverter are fed by two identical preamps made by WA2ODO that exhibit extremely low NF.

# Hardware of the Dual-Pol Adaptive System



<b>KL7UW</b>	
<b>144-MHZ EME SYSTEM</b>	
E. COLE	Rev 3.4
	8/10/2011

# Hardware of the Dual-Pol Adaptive System

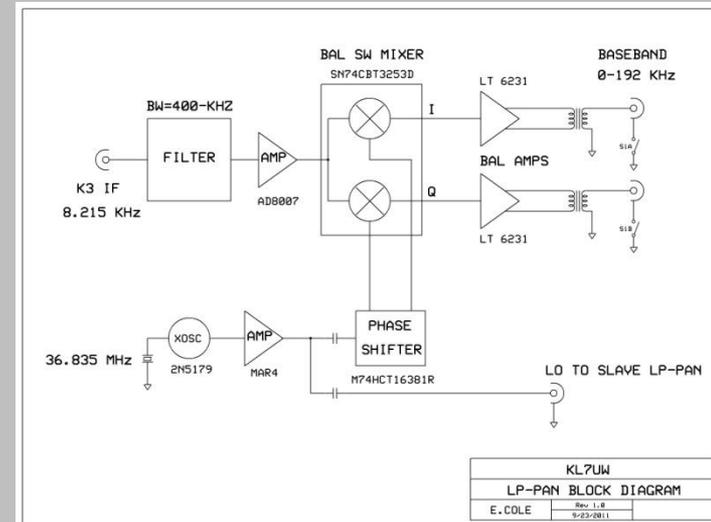
- Audio output of the K3 is limited to a maximum bandwidth of 4-KHz.
- My objective is to use MAP-65 (a variant of JT-65) at 90-KHz of bandwidth.
- Another limitation is the K3 does not provide access to the I-Q signals.
- A different approach suggests using the 8.215 MHz 1<sup>st</sup>-IF of the K3 to feed an external SDR which would offer I-Q output.
- The LP-Pan, made by Telepost, inc., is perfect since it is specifically designed to operate from the 1<sup>st</sup> IF of the K3.
- The LP-Pan was intended to be used as a panadaptor but is a simple SDR and provides both I and Q at audio baseband for input to a stereo soundcard.
- For the dual-receiver system two LP-Pan are required one for the main K3 receiver IF and one for the K3 sub-receiver IF.
- But two modifications were required:
  1. Access to the IF of the sub-receiver in the K3
  2. Running both LP-Pan from a single master LO

# Hardware of the Dual-Pol Adaptive System

- The IF simply requires use of a .001 uF coupling capacitor and a run of RG-174 to a BNC connector on the back of the K3.
- I disabled the LO of one LP-Pan and ran both from the LO in the other LP-Pan (see diagram):

<http://www.telepostinc.com/LPAN.html>

- The I and Q audio outputs are connected to a four port soundcard.
- I chose the M-Audio Delta-44 which can support 96 KHz bandwidth.

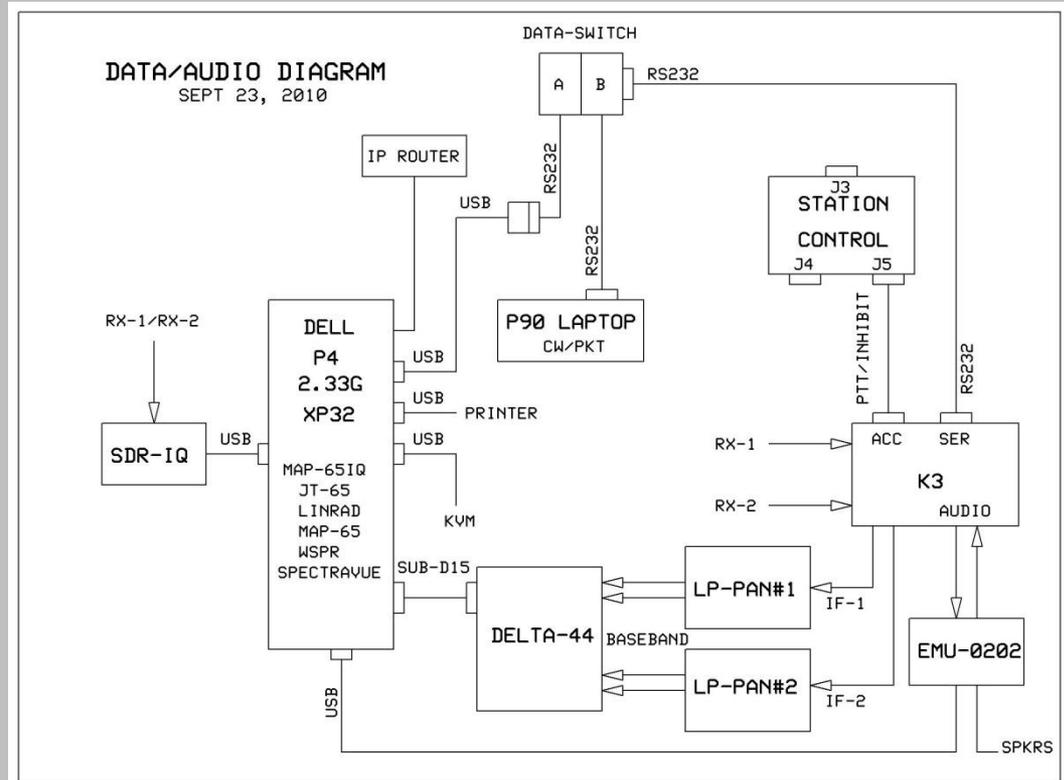


# Software of the Dual-Pol Adaptive System

- Two programs are used:
  1. LINRAD
  2. MAP-65
- Linrad performs the SDR operation of digital filtering, and displaying a spectrum and waterfall screen.
- Linrad is also able to take the input of the two Rx and computes the vector angle of polarization which is displayed and also peaks the output accordance with that polarity, completely eliminating polarity loss.

<http://www.sm5bsz.com/linuxdsp/linrad.htm>

<http://physics.princeton.edu/pulsar/K1JT/>



# Software of the Dual-Pol Adaptive System

- Linrad is the creation of Leif Asbrink, SM5BSZ. Originally written in Linux it is now available in windows.
- MAP-65 is a variation on the popular digital-eme mode, JT-65. This is the creation of Joe Taylor, K1JT. Joe has produced a suite of digital modes called WSJT.
- Linrad performs the SDR processing to provide any mode: CW, SSB. AM, FM, etc. For use with MAP-65 (or JT-65) Linrad is run in USB mode. The output data stream is sent to Map-65 for decoding all JT-65 signals in the 90-KHz baseband. MAP-65 is able to discriminate between valid digital signals and interference (birdies).
- The result is a map of all JT-65 signals listing time, freq., callsign, and signal level for all stations calling within the 90-KHz passband. This is a powerful contest tool and very useful for random eme operation.
- Two photos follow of my station in different stages of development:



Fig. 1 – KL7UW, Spring 2011



Fig. 2 – KL7UW, Summer 2012

# Addendum

- I presented a version of this presentation last year at the Pacific NW VHF Society's conference.
- There are some other hardware approaches: Using the WSE receiver system developed by SM5BSZ (which is out of production so only available used from current owners), and IQ+ which was introduced by HB9DRI this year (a complete 144-MHz dual-receive SDR).
- I chose my approach before the IQ+ was introduced. My approach provides more versatility as the K3 is fully usable for a wide range of HF and VHF operations, while the other two are fairly limited to VHF/EME pursuits.
- Being modular, individual modules can be substituted as one desires.
- The other approaches may perform better and/or be easier to implement. Costs are another factor to consider.
- Next are some images of Linrad:

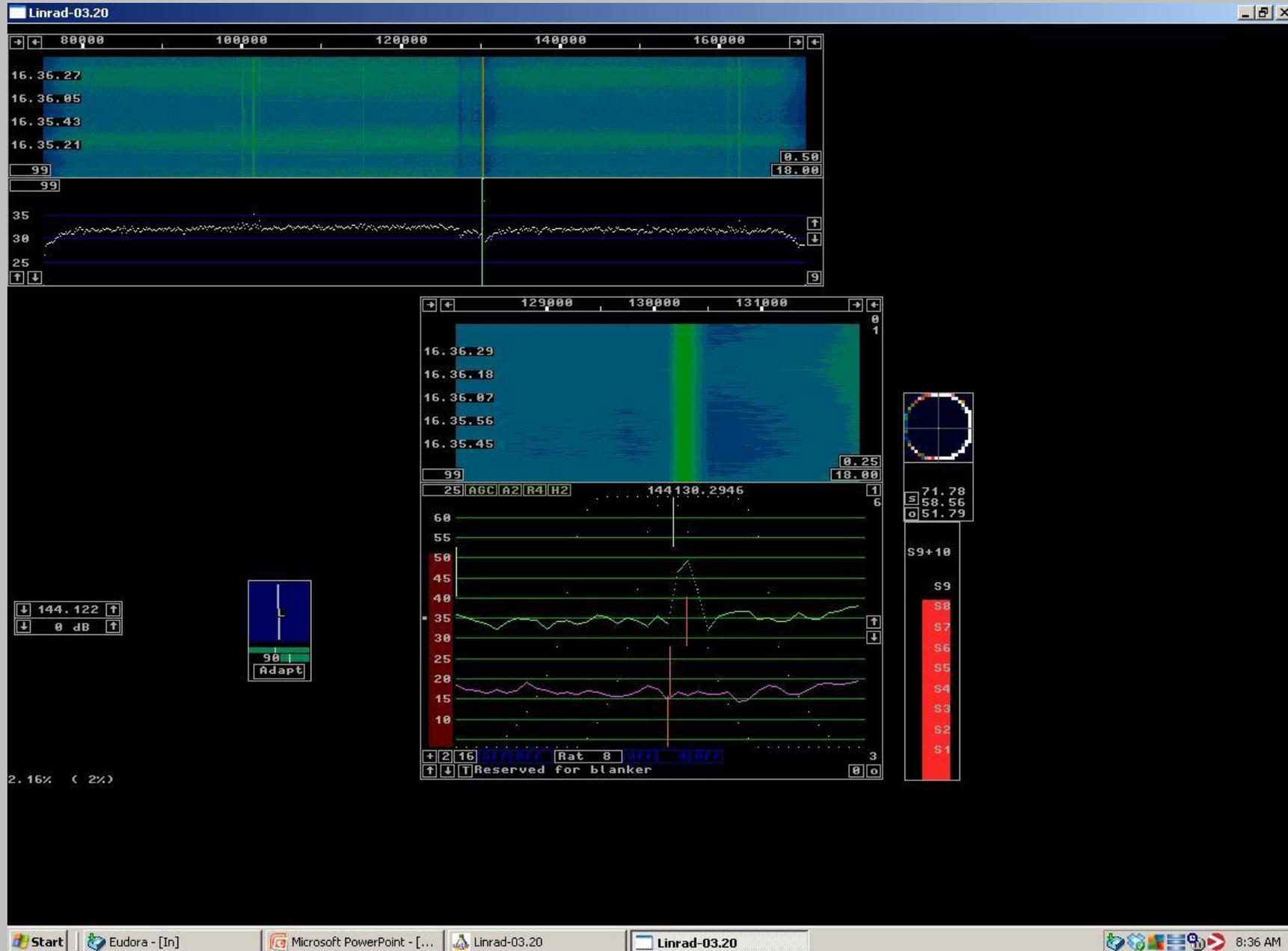


Fig. 3 – Linrad with Adaptive Polarity = 90

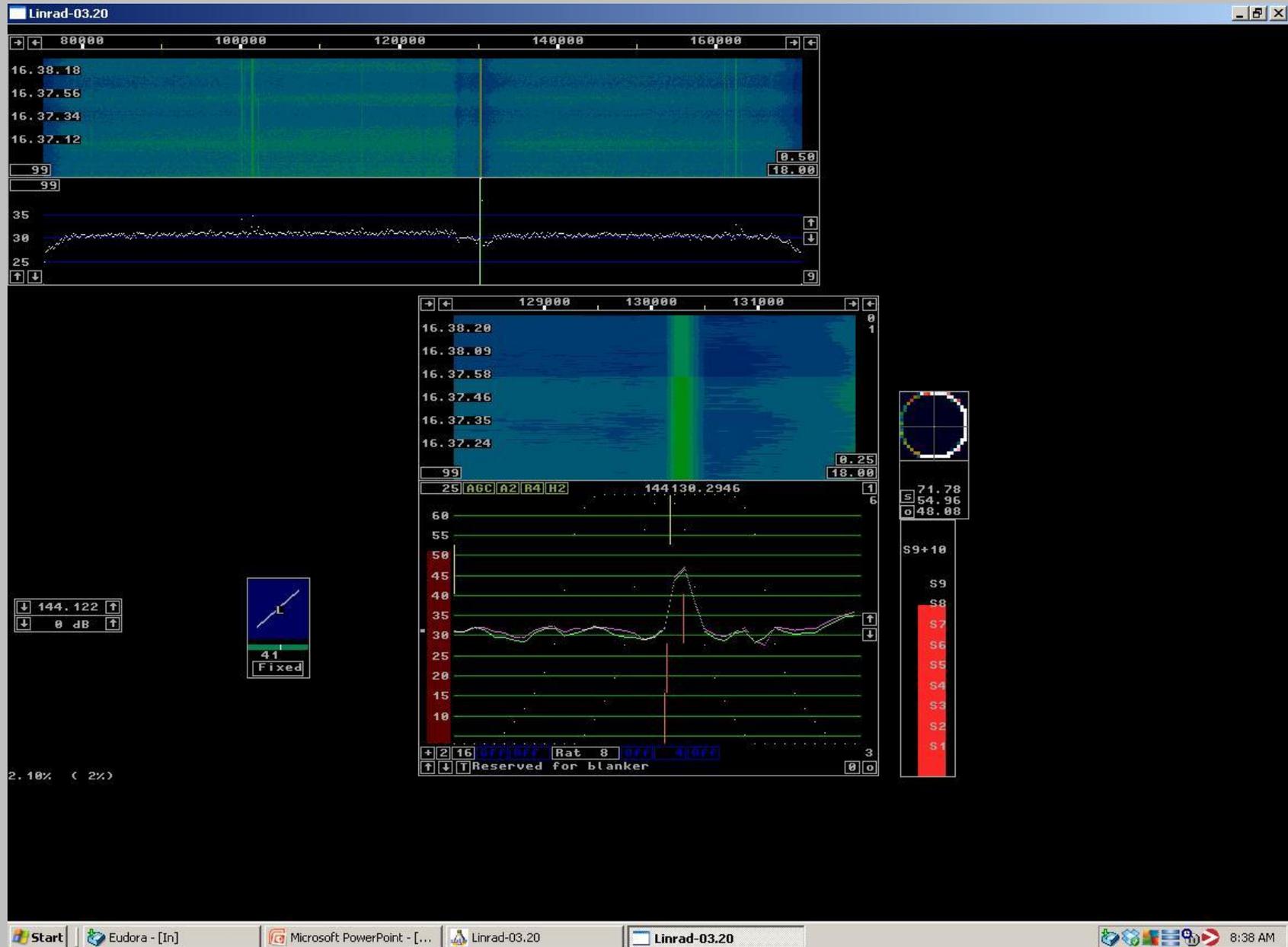


Fig. 4 – Linrad with Adaptive Polarity = 41

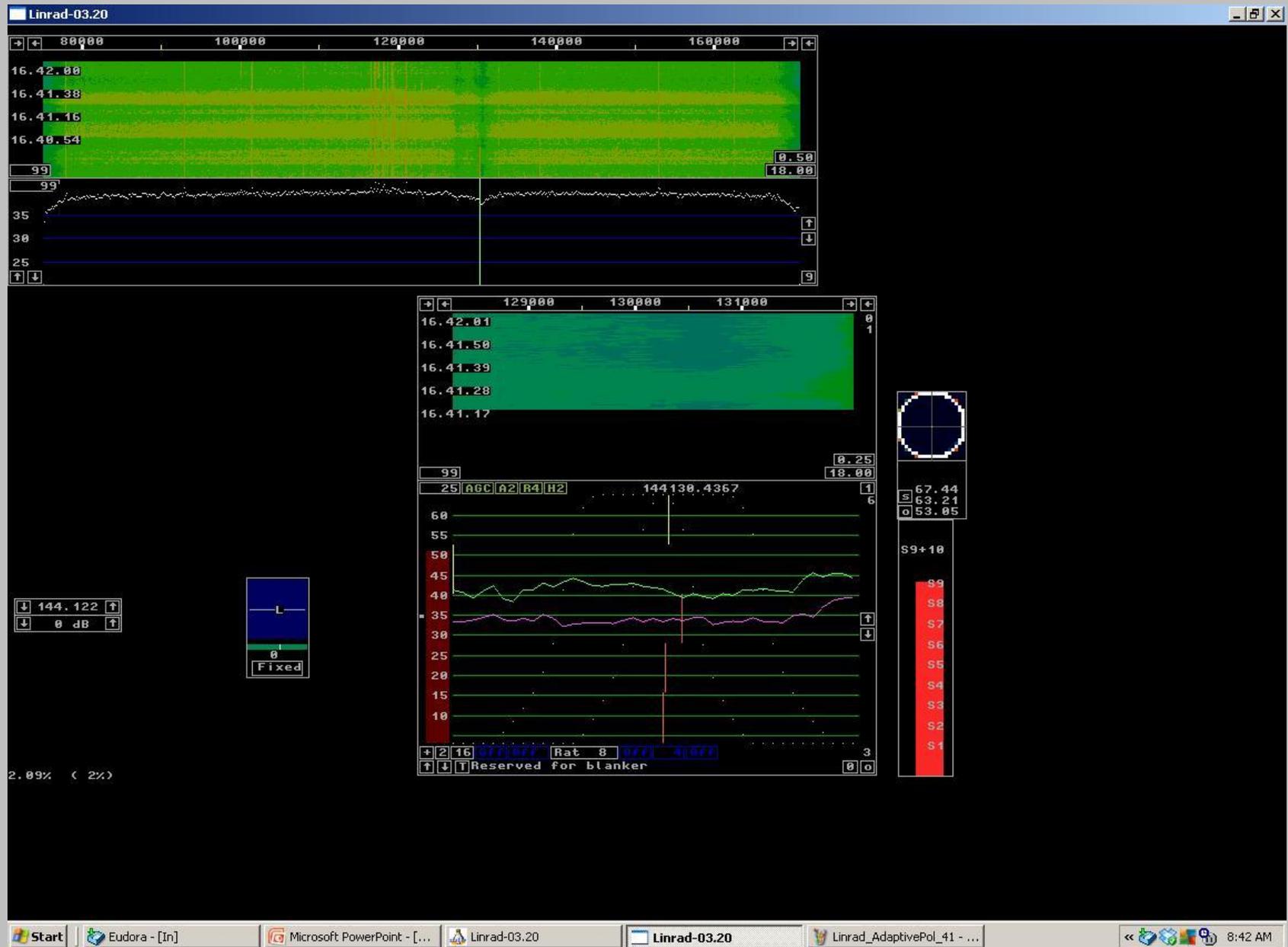


Fig. 5 – Linrad with Adaptive Polarity = 00

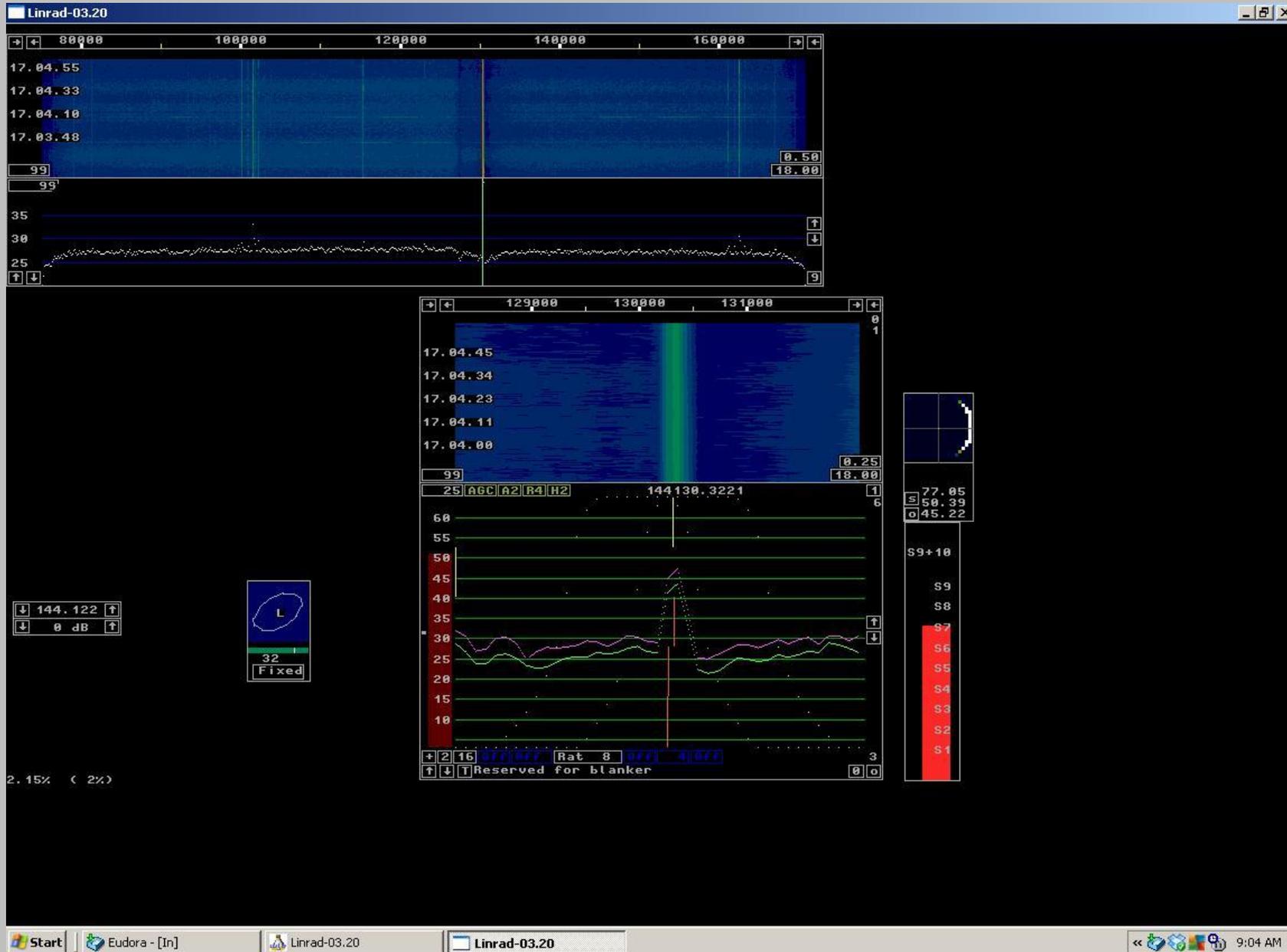
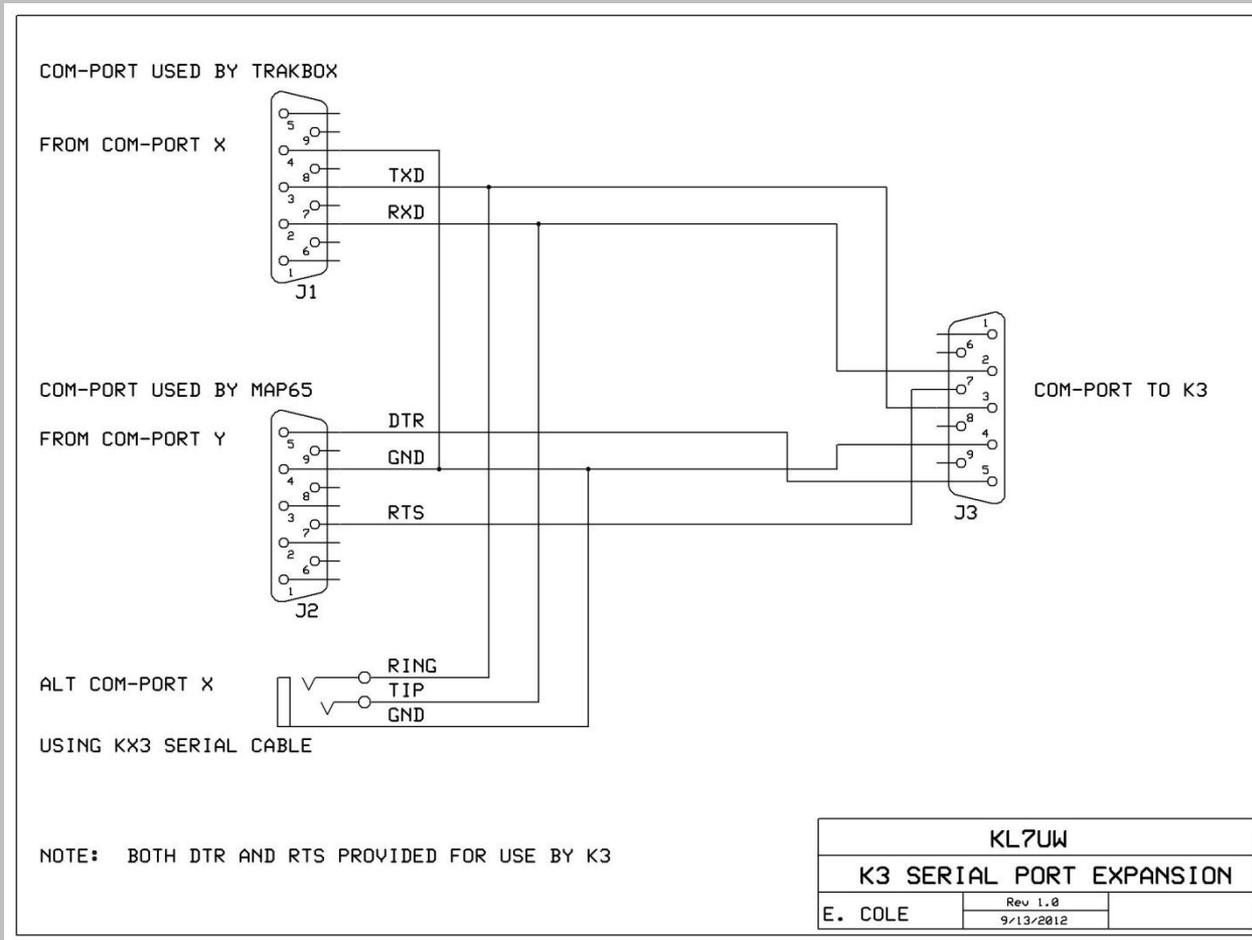


Fig. 6 – Linrad with Adaptive Polarity = Elliptical, 32

# Recent Changes

- Introduction of MAP65 vers 2 makes possible running without use of Linrad. This makes setting up software considerably easier.
- In August, I installed MAP65v2.3 and configured the software to input audio directly into the Delta44 soundcard.
- MAP65v2.3 has a new look and also processes polarity information without aid of Linrad.
- If station grid location is available in CALL3.txt file, MAP65 calculates best transmit polarity using both spacial and signal polarity data.
- Control of the K3 frequency for transmitting requires special software provided by IK7EZN's TRAKBOX program. TRAKBOX reads the azel.dat file created by MAP65 to control VFO-A on the K3 when transmitting.
- TRAKBOX requires access to the RS-232 port on the K3 for this.

# TRAKBOX Interfacing



# Table-I from MAP65 Users Guide (K1JT)

\*Notes: L = *Linrad*, S = *SDR-Radio*, M = *MAP65*

	SoftRock	FUNcube Dongle	SDR-IQ, Perseus	SoftRock × 2	IQ+ VL, V, U	WSE
<b>Input Freq (MHz)</b>	28, 144	144, 432, 1296	28	28, 144	50, 144, 432	144
<b>Polarizations</b>	1	1	1	2	2	2
<b>Soundcard Channels</b>	2	–	–	4	4	4
<b>Digital Interface</b>	USB	USB	USB	USB	USB	Parallel Port
<b>Frequency Control*</b>	L, S, M	L, S, M	L, S	L, M	L, M	L
<b>Front-End Software*</b>	L or S optional	–	L or S required	L optional	L optional	L optional

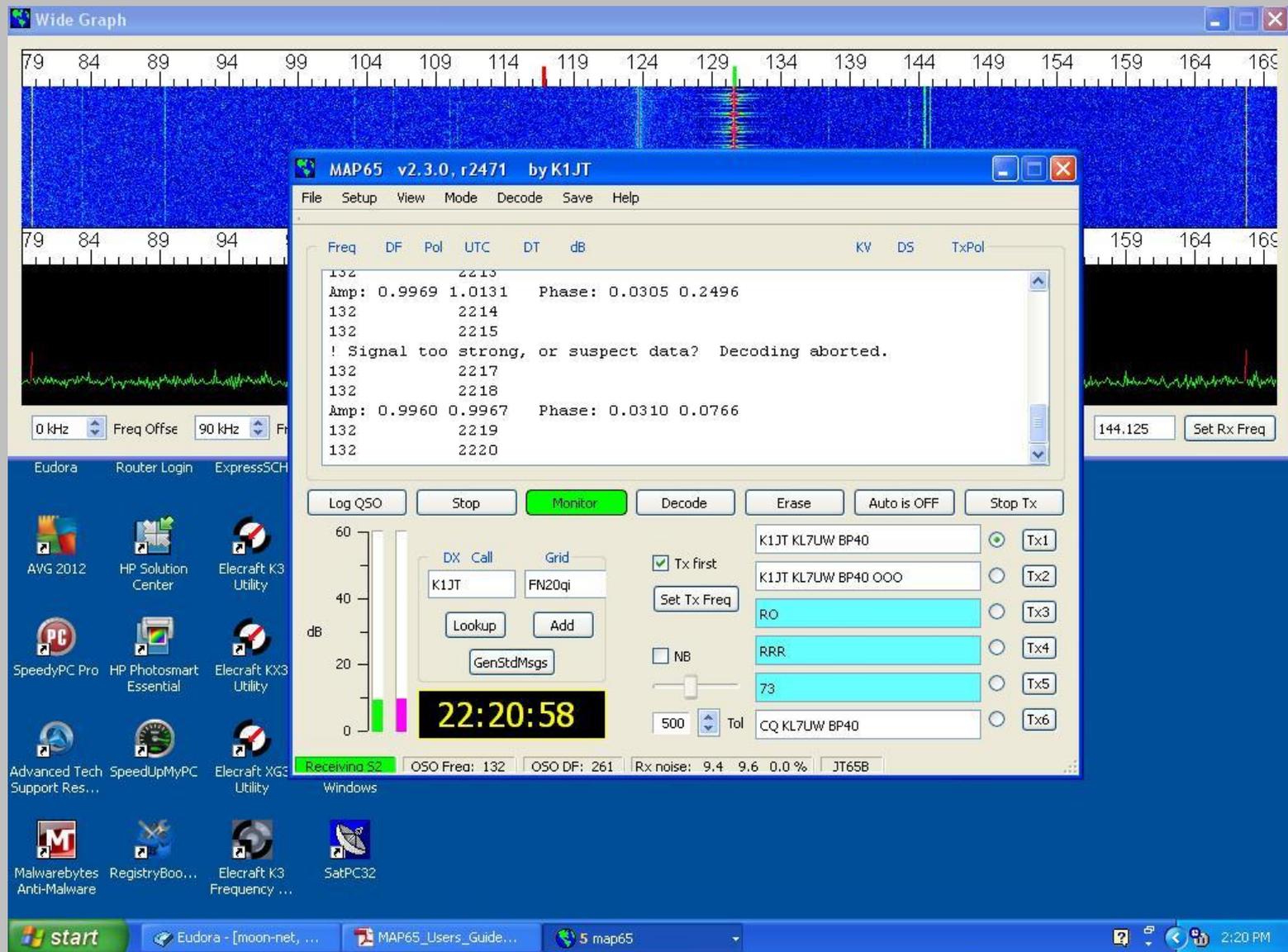


Fig. 7 – MAP-65 ver 2.3 Main Window

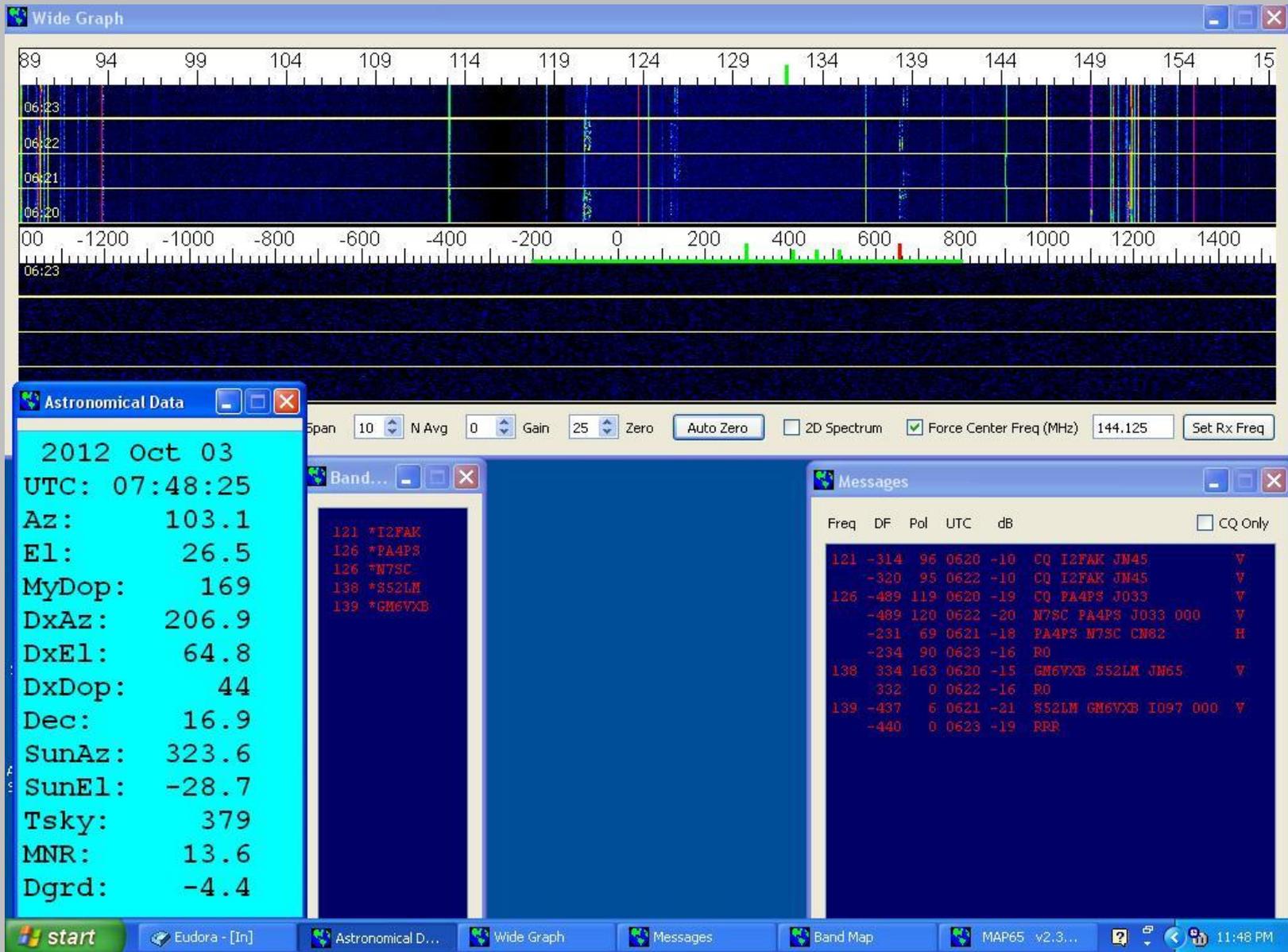


Fig. 6 – MAP-65 ver 2.3

# Closing Remarks

- MAP65 and Linrad provide enhanced reception of VHF/UHF EME signals by adapting dual-polarity signals to maximize reception by better matching of polarity.
- MAP65 scans the entire digital sub-band decoding all JT65 signals providing a quick view of activity on the Moon.
- It is a tremendous asset for contests and precludes using logger “chat-style” websites for spotting stations.
- Setup using MAP65v2 makes the installation process considerably easier.
- My early experience with MAP65 is it improves reception by almost 3-dB, since I no longer have polarity losses.
- This presentation will be available on my website:  
<http://www.kl7uw.com/>