The N2PK
Vector Network Analyzer
(N2PK VNA)

Original by Paul Kiciak, N2PK, 2007 * (*Pages edited or added by VE7WRS, 2009)

What Does "Vector" Mean?

- Vector: magnitude & direction (angle)
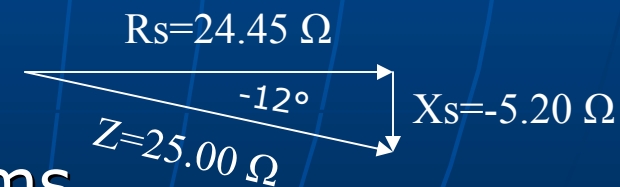
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  - Impedance: 25 ohms @ -12 degrees
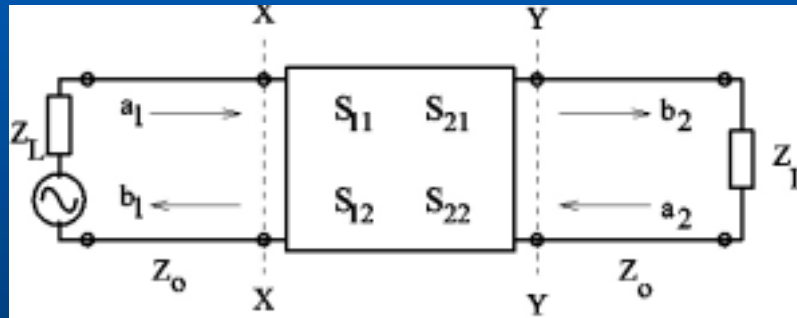 - Reflection: 0.50 @ 155 degrees

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- Vectors:
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  - Reflection: 0.50 @ 155 degrees
- Polar vs. Rectangular Vectors
  - Equivalent representations
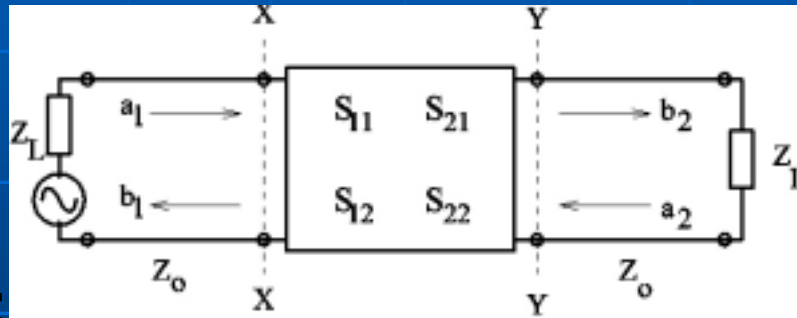 - Polar: 25 ohms @ -12 deg.
  - Rectangular: 24.45-j5.20 ohms

R_s=24.45 Ω

-12°

X_s=-5.20 Ω

Z=25.00 Ω

Some "Networks"

- **General:**
  - Black box: don't care what's inside
  - 'Ports' instead of 'inputs' & 'outputs'
  - Number of Parameters: N*N for N-port
  - DUT: N-Port Device Under Test
  - 2-port:

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- Examples:
  - 1-ports: antenna, R, L, C
  - 2-ports: filters, pair of antennas
  - 4-port: directional coupler

What Does A VNA Measure?

- ## Reflection Parameters:

  - Impedance*, Admittance*, SWR, Return Loss, Reflection Coefficient*
  - Equivalent series & parallel R, L, C
    - Rs, Rp, Ls, Lp, Cs, Cp
  - Q

Admittance = 1 / Impedance

Return Loss (dB) = $10\log_{10}(P_T/P_R)$ "inverse of SWR"

Reflection Coefficient = $\Gamma = (Z_L - Z_s) / (Z_L + Z_s)$

s: source L: load

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* Complex (vector)

What Does A VNA Measure?

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- Transmission Parameters:

  - Gain*, dB
  - Group delay in seconds

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- ## Transmission Parameters:
  - Gain*, dB
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- ## Components:
  - Antennas, coax, …
  - Inductors, capacitors, resistors
  - Filters: crystal, LC, …
  - Amplifiers & attenuators
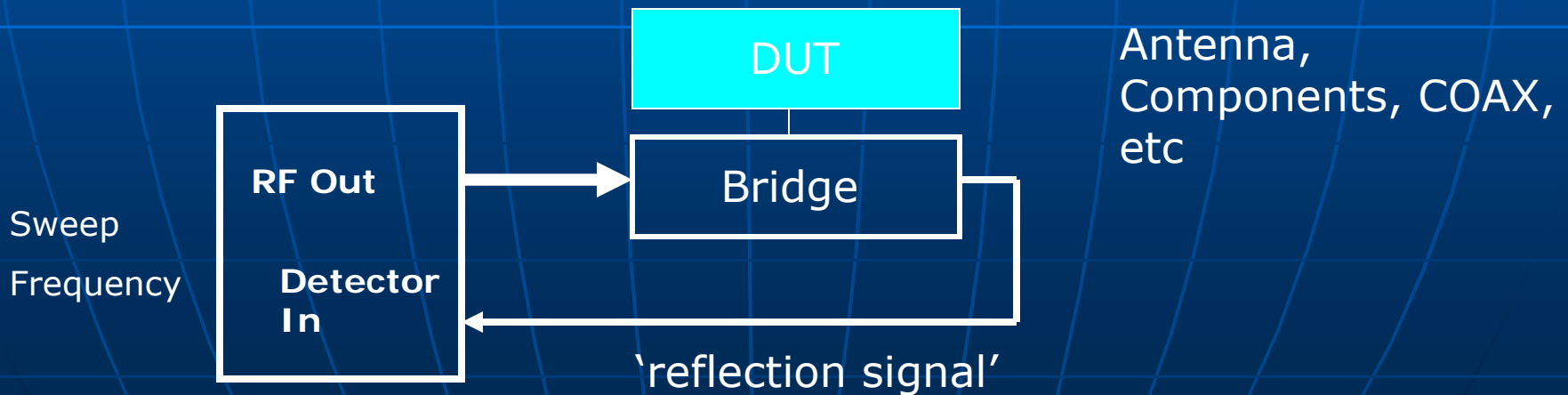 - Duplexers, diplexers, directional couplers, …
  - Diodes, transistors, …

* Complex (vector)

Transmission? Reflection?

Single Detector - **Transmission**

Sweep

Frequency

RF Out
Detector In

→ DUT → 'through signal'

Crystal Filter, Low Pass Filter, COAX, Crystal Test Jig, etc

Single Detector - **Reflection**

Sweep

Frequency

DUT

RF Out
Detector In

→ Bridge → 'reflection signal'

Antenna, Components, COAX, etc

Some VNA History

HP 8410A – late 60's, 110 MHz-12.4 GHz

HP 8753C – late 80's, 300 kHz-6 GHz

Agilent E5071C – current, 9 kHz-3 GHz

N2PK VNA (by VE3MM) – current, 50 kHz-60 MHz

Key Specs of the N2PK VNA

- Frequency Range:
  - VNA: **50 kHz – 60 MHz, 0.034 Hz steps**
  - LO source: <1 Hz with Hi-Z load
- Detectors options:
  - **Single or dual (dual allows simultaneous reflection and transmission)**
  - Slow, single rate (original)
  - Fast, variable rate
- Fast Detector Rates:
  - 10 rates, software selectable
  - 3.5 freqs/sec @ slowest rate
  - 900 freqs/sec @ fastest rate
- Dynamic Range (w/o averaging):
  - **>110 dB dynamic range @ slowest rate**
  - 90 dB dynamic range @ fastest rate
- Effective Detector RF Bandwidth:
  - **7 Hz @ slowest rate**
  - 3.4 kHz @ fastest rate
  - Virtually immune to external signals (antenna testing)
- No adjustments
- PC software controlled via Parallel port or USB port
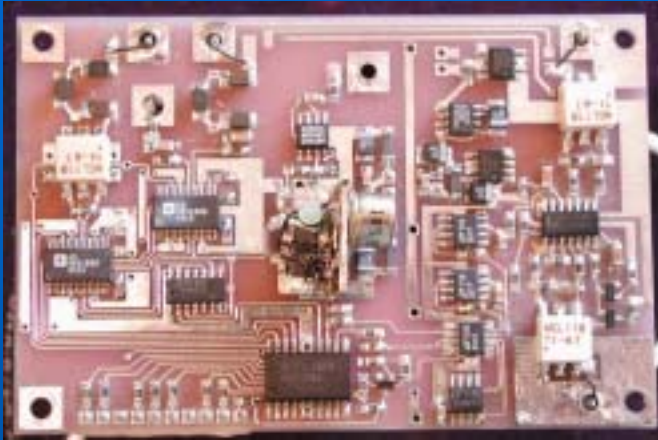
- Homebrew: $250 for a single detector version

How does the N2PK VNA work?

- RF & LO Direct Digital Synthesis (DDS) Sources
- Linear Detector: Synchronous Direct Conversion to DC
- Sequential Quadrature: 0 deg, then 90 deg, & the difference is VERY accurate
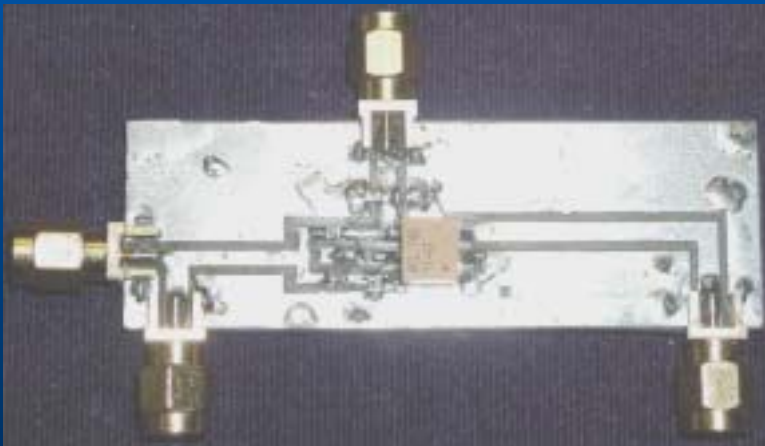- 24 bit Analog to Digital Converter (ADC)

Hardware

Single Detector PCB

VE3IVM Dual Detector PCB

Reflection Bridge PCB

Power Board

Calibration standards

01/22/07 N2PK

Some N2PK VNAs

SM0CFO+SM6PXJ

AG4AY

GM4SEK

W8WWV

OZ1DUG

VE7IT - standalone

Some more N2PK VNAs
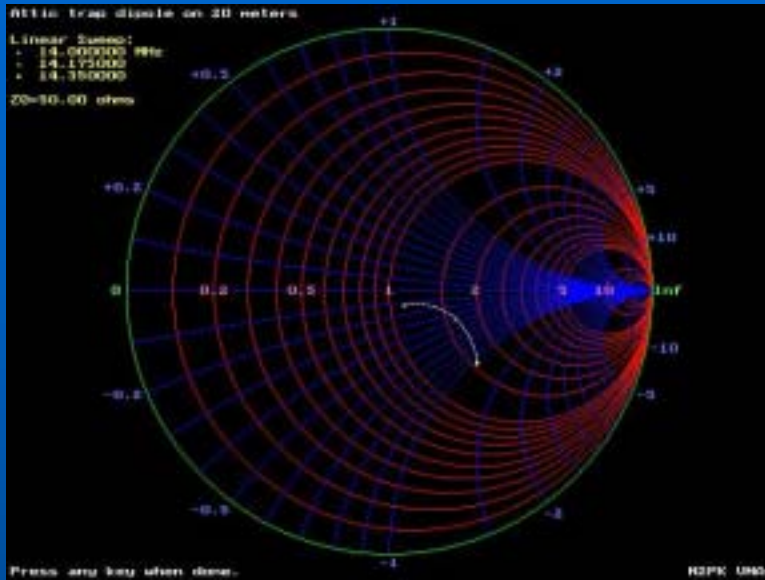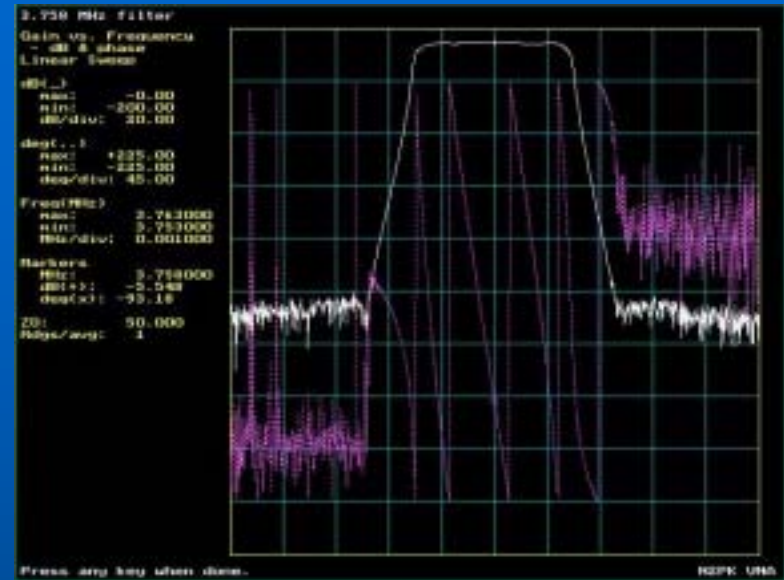
Software

- N2PK **DOS based** (programs function in DOS or Windows)
  - Reflection
    - Open/Short/Load (OSL) calibration
    - Optional Low-Loss Capacitor (LLC) standard for low-loss & Hi-Q DUTs
  - Transmission
    - Through calibration (assumes 50 ohm source and load impedances)
  - Reflection & Transmission
    - OSL and Through – real time simultaneous reflection and transmission
    - Optional 12-term error correction with S-Parameter Test Set
  - Special Test Programs:
    - VNA RF Self-Test (Vs, Zs, Zd)
    - Crystals (Fs, Fp, Rm, Lm, Cm, Co, Q)
    - Coax (Zo, attenuation constants)
    - Component modeling (future)

- **Windows programs** (all do reflection or transmission & good graphics)
  - Exeter (W8WWV)
  - VNA4win (GM4PMK & GM3SEK)
  - WINVNA (OZ1DUG)
  - MyVNA (G8KBB, Dave Roberts) Presently my favorite !!! (WRS)
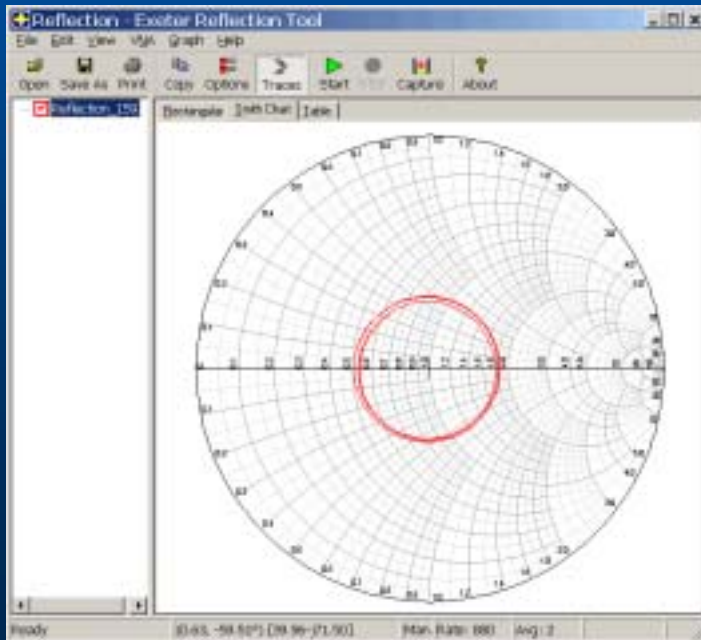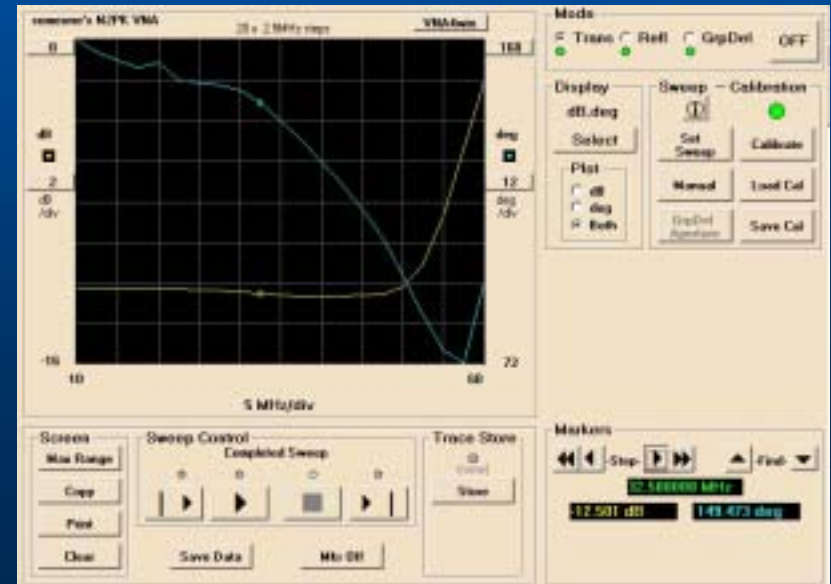
Some Test Results
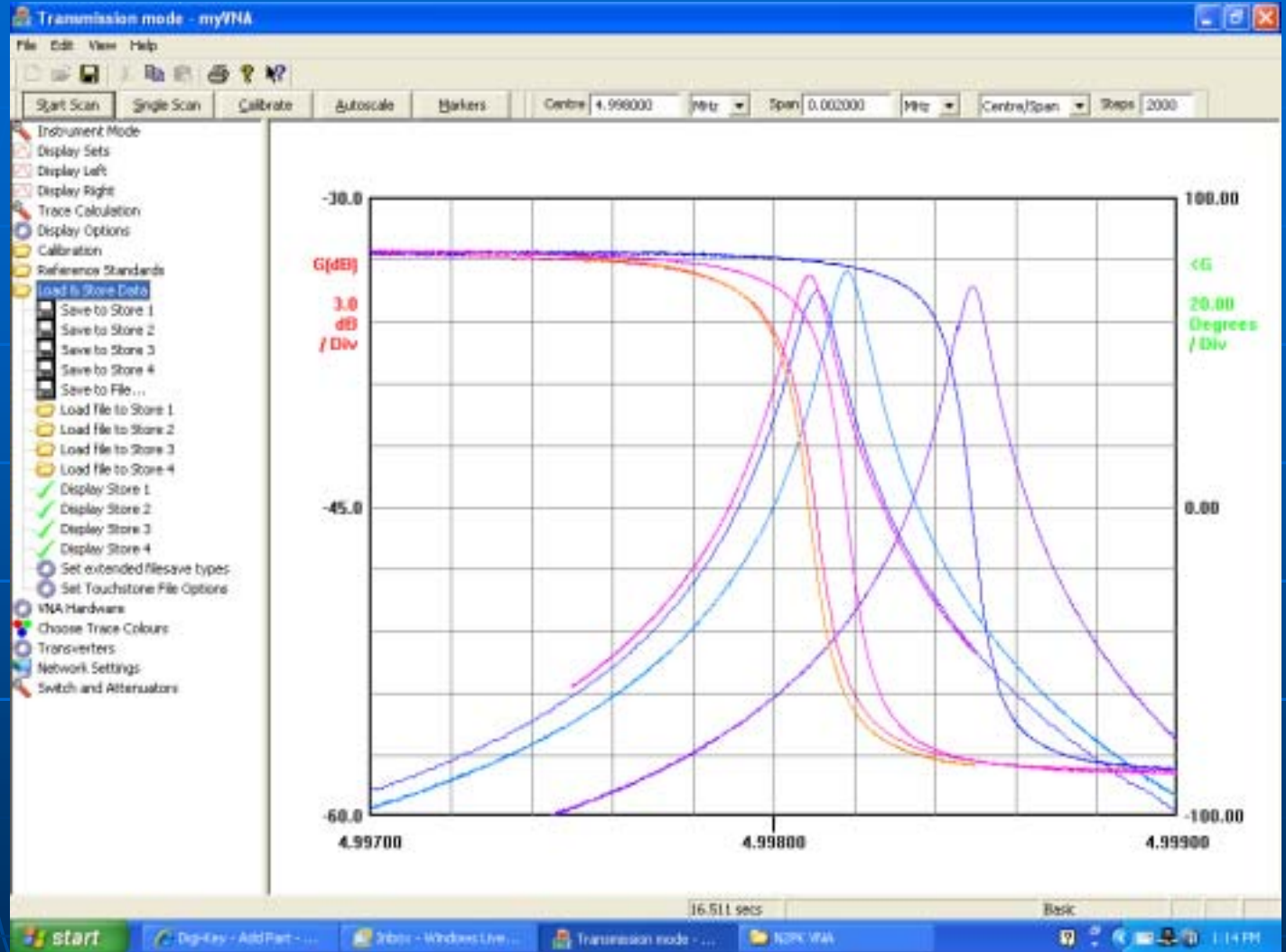
N2PK DOS - Reflection

N2PK DOS - Transmission

Exeter - Reflection

VNA4win - Transmission
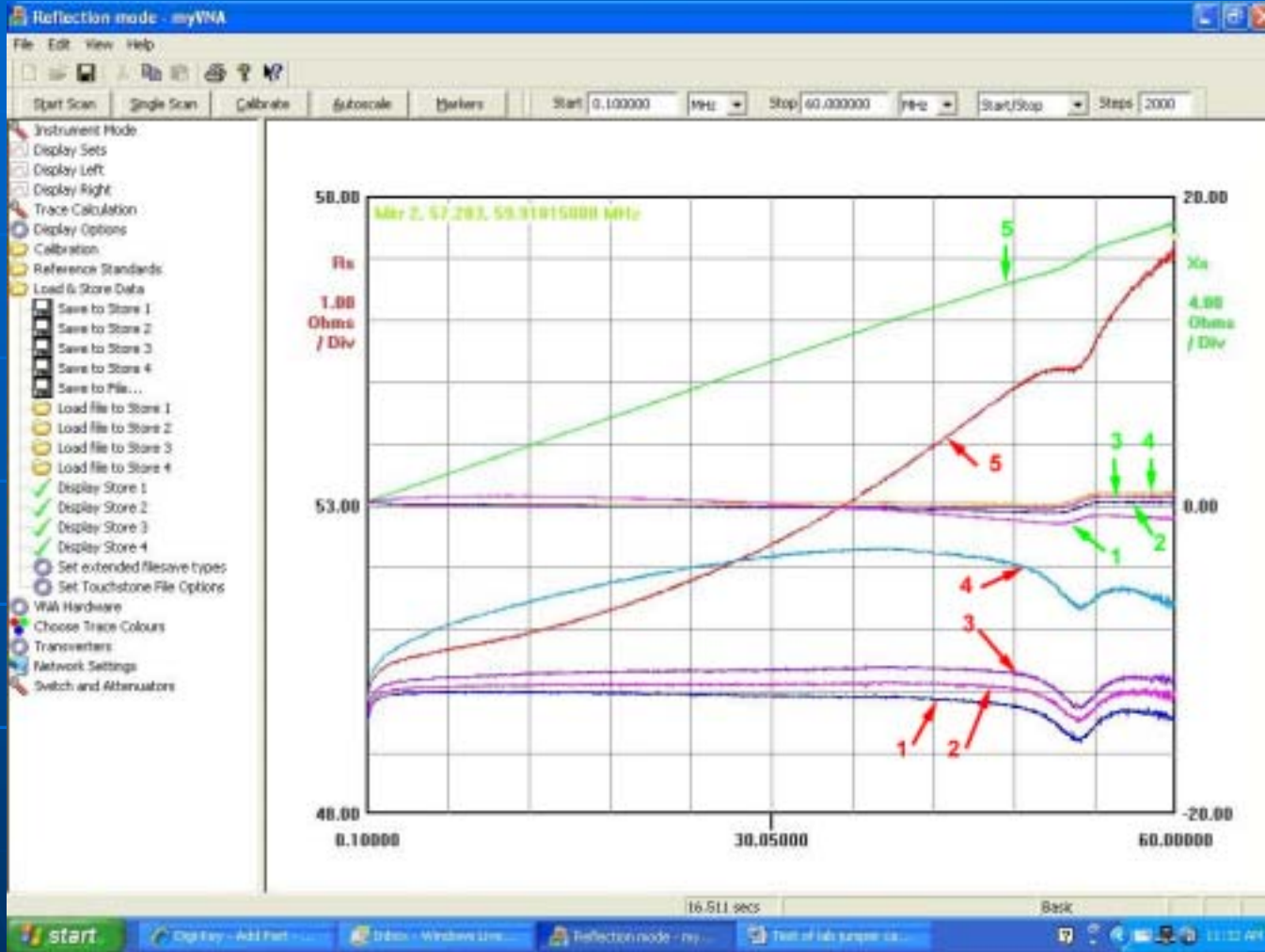
Through Mode: four 5.000Mhz Crystals

Intended for Crystal Lattice Filter

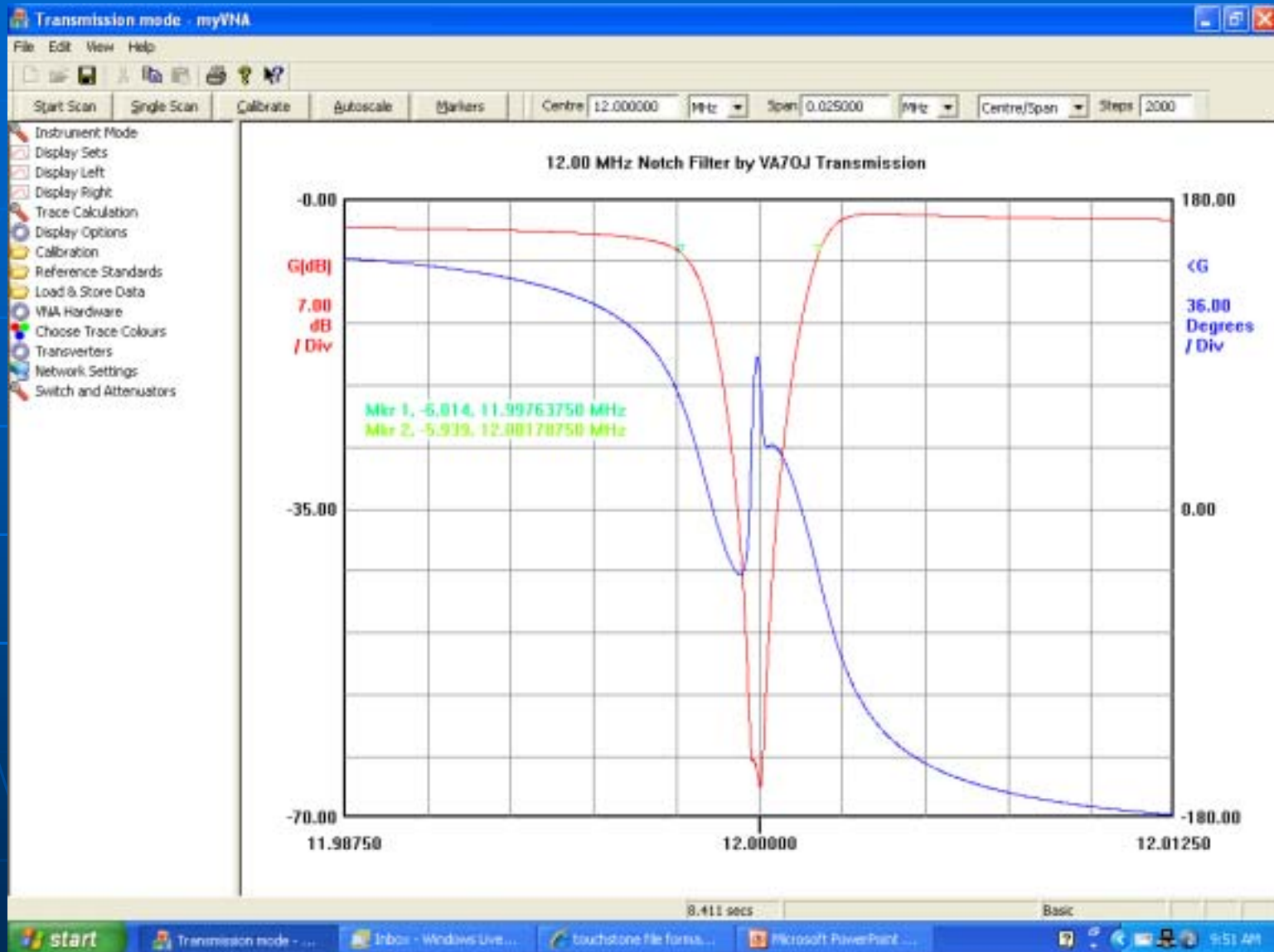Added by WRS

1. 50 ohm calibration
2. Semi rigid jumper SMA to SMA
3. Short jumper SMA to BNC
4. Japanese coax BNC to BNC
5. Swap meet 'lab quality' jumper BNC to BNC

Reflection Mode: testing short jumper cables

Added by WRS

Some Test Results by WRS

Four crystal notch filter built by VA7OJ

Web Resources

- Paul Kiciak, N2PK – documentation, build info, DOS software:
  http://n2pk.com
- Ivan Makarov, VE3IVM - build info:
  http://www.makarov.ca/vna.htm

- Agilent - VNA Fundamentals:
  http://cp.literature.agilent.com/litweb/pdf/5965-7707E.pdf

- Windows software:
  - VNA4win, Roger Blackwell, GM4PMK, & Ian White, GM3SEK:
    http://www.marsport.org.uk/vna4win/index.htm
  - WinVNA, Joakim Soya, OZ1DUG:

    http://www.planker.dk/oz6frs/2004/Projekter/Igang/N2PK/N2PK_VNA.htm
- N2PK-VNA Yahoo group (more than 500 members served):
  http://groups.yahoo.com/group/N2PK-VNA

Google: N2PK VNA

Live Demo