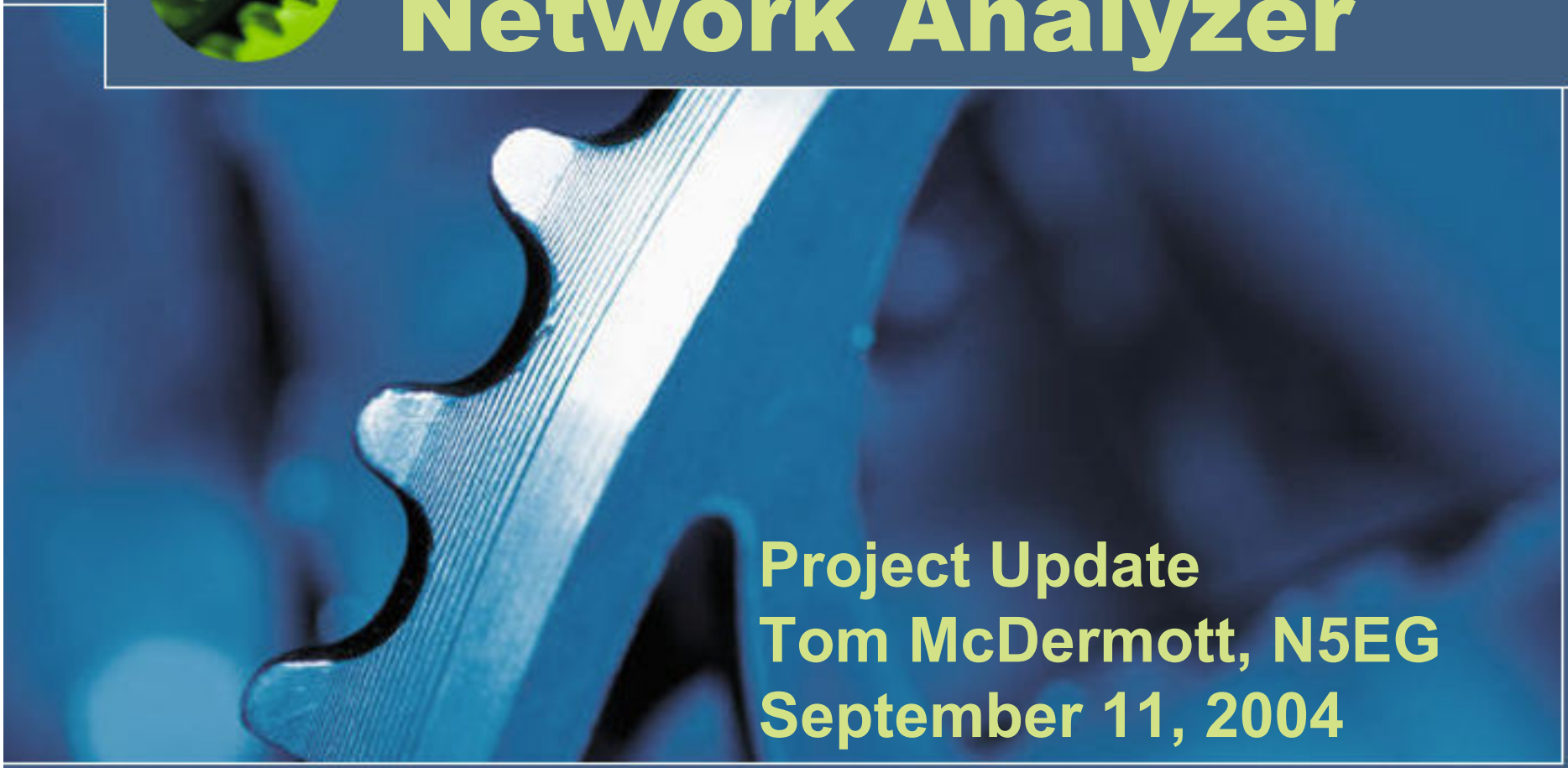
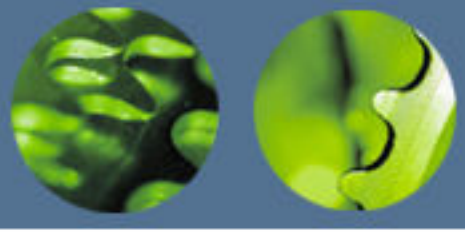


# TAPR Vector Network Analyzer

Project Update

Tom McDermott, N5EG

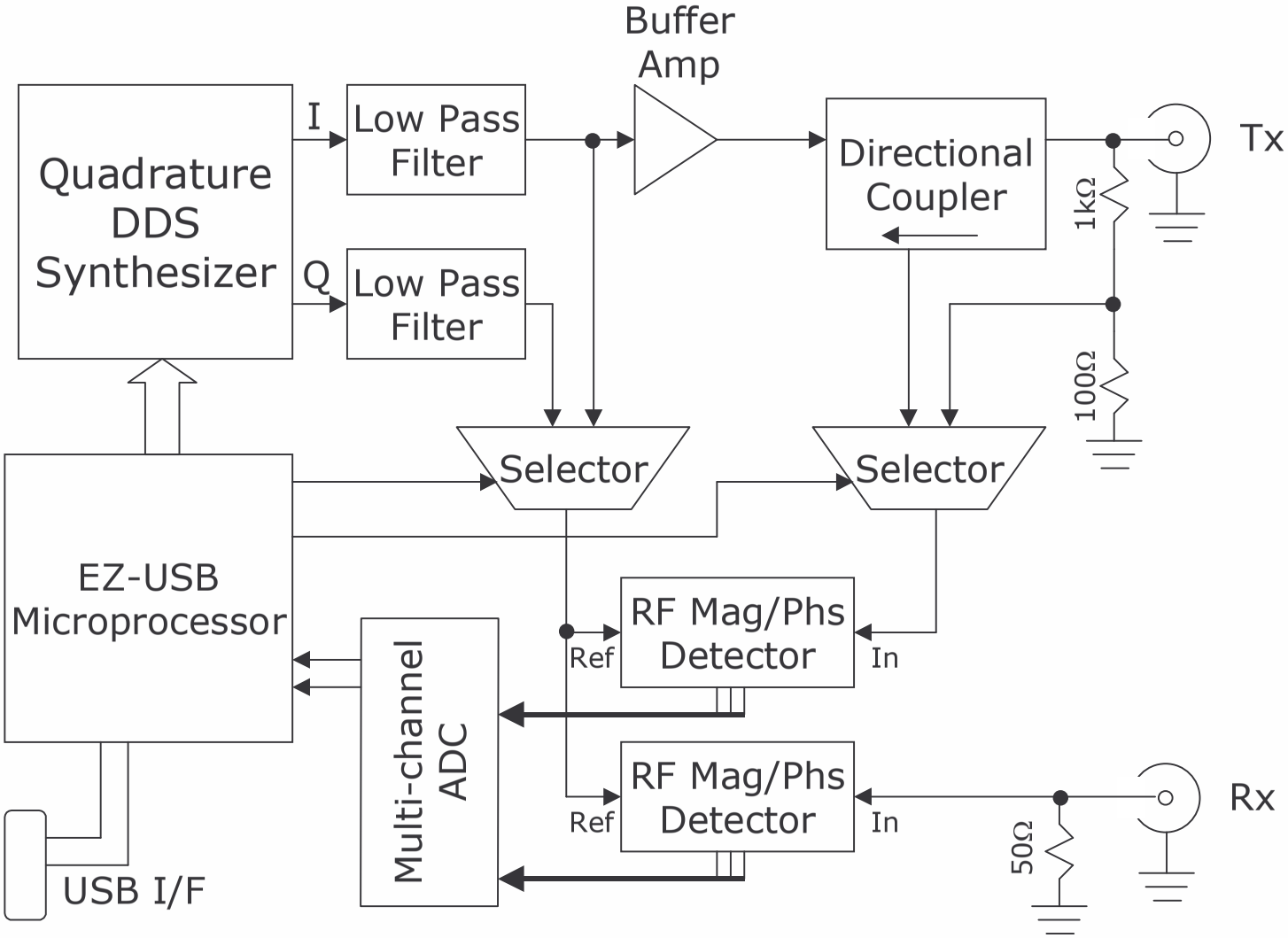
September 11, 2004



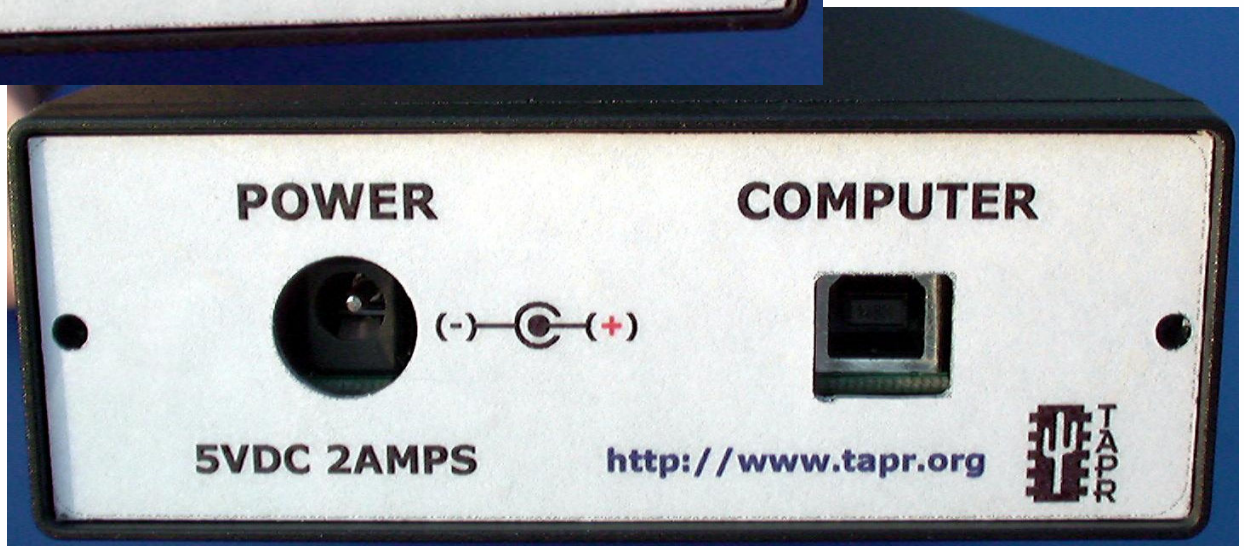
# VNA Project

- Open Source Vector Network Analyzer
- Low-cost, simple hardware
- Software released under GNU GPL
- Uses USB to interface to host
- Target software downloaded by host
- Target processor is Cypress EZUSB (8051 with additions)
  - Written in C with Keil tools.
- Host is Windows 98 – Windows XP
  - Written in Microsoft C++ .NET 1.1.

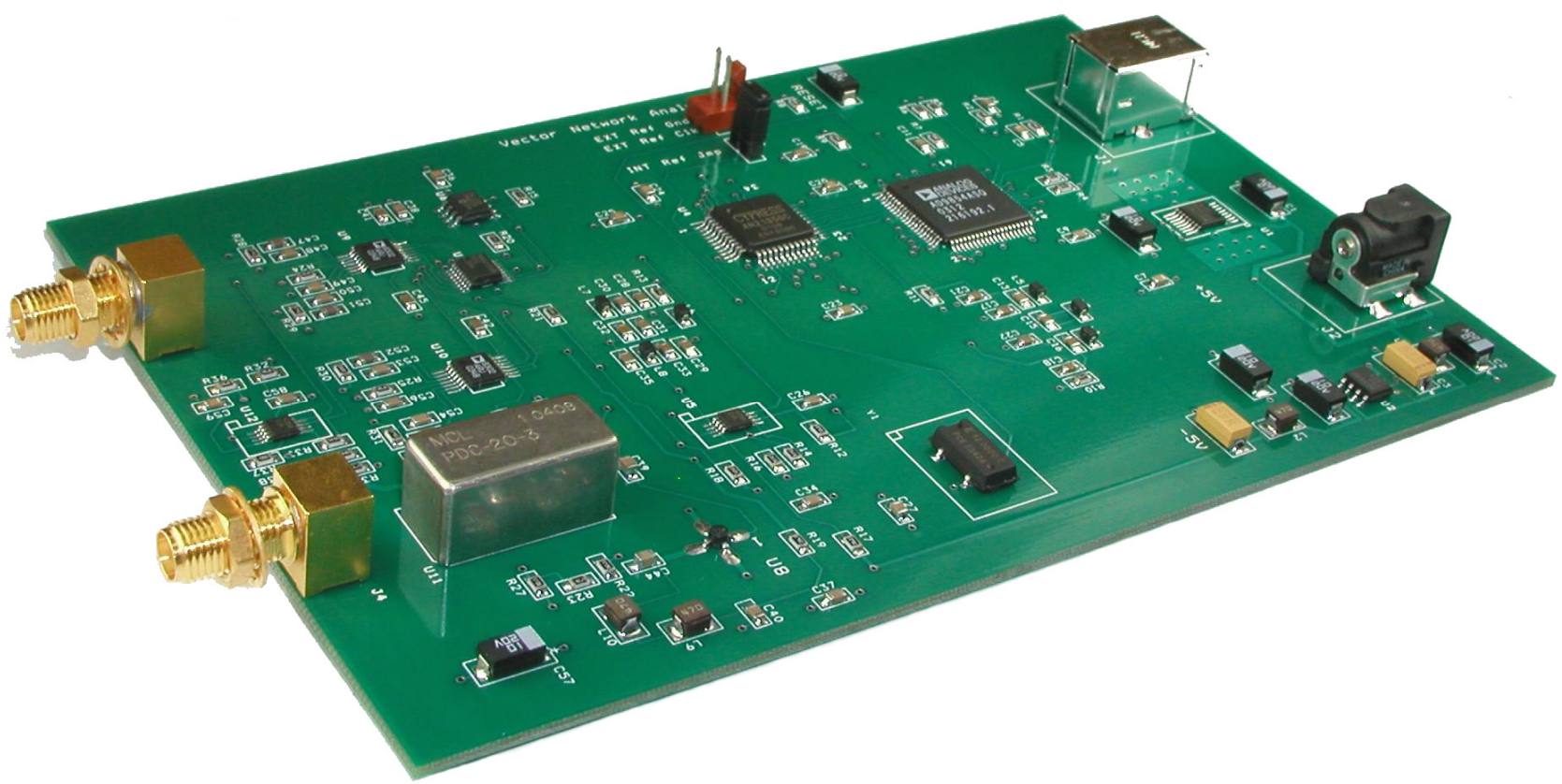
# Block Diagram

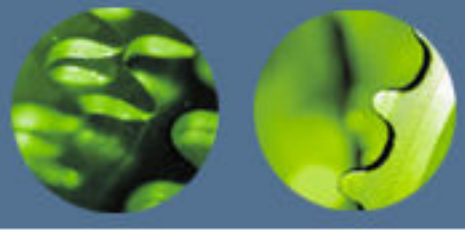


# VNA Front & Rear

# R2 Circuit Board

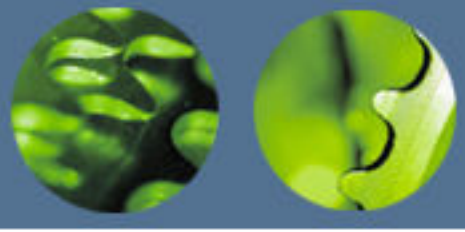




# Beta Test Team

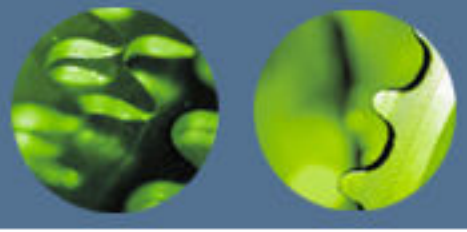
- 10 Beta Testers
  - Assembled units, made modifications, installed and tested software
  - Provided Feedback on Software Functionality, guidance for new features, assembly problems
  - Excellent Feedback

| | |
|---|---|
| John Ackermann, N8UR | Steve Bible, N7HPR |
| Francesco Ledda | Karl Ireland |
| Joe Everhard, N2CX | Mike Dishop, N8WFF |
| Roger Hayward, KA7EXM | Frank Perkins, WB5IPM |
| George Heron, N2APB | Johan Forrer, KC7WW |



# Problems Encountered

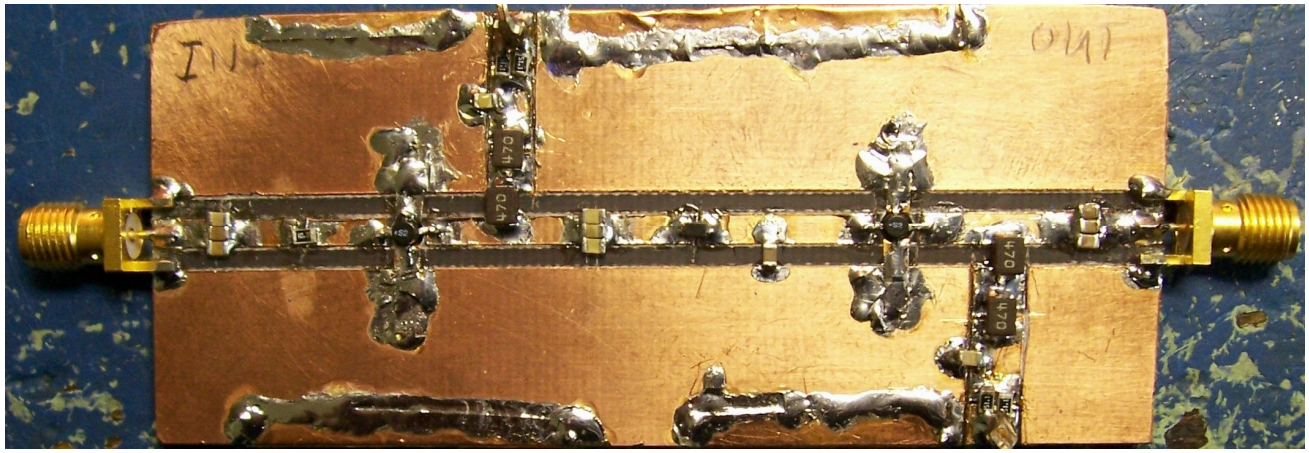
- Primarily Hardware
  - Required 4 reworks to fix
  - Caused by noise coupling into wideband detectors, grounding on buffer amplifier
  - Will require a new board layout (R3)
- Very few Software Problems
  - Mostly feature requests, additions
  - Beta team provided great feedback



# HW Design Enhancement

- AD8302 has ~58 dB dynamic range
  - Theoretically limits S21 dynamic range to 58 dB, actually achieved about 50-52 dB.
- Improvement: low-noise Rx preamplifier, programmable VNA Tx output level
  - 32 dB gain wideband low noise preamp
  - -87 dBm noise calculated, about -84 dbm achieved (could be improved with better roofing filter)
  - Resulted in measured S21 dynamic range of 80-82 db.
- Enhancement will be folded into R3 board redesign

# Pre-amplifier



Uses 2 Sirenza SNA-286 amplifier blocks

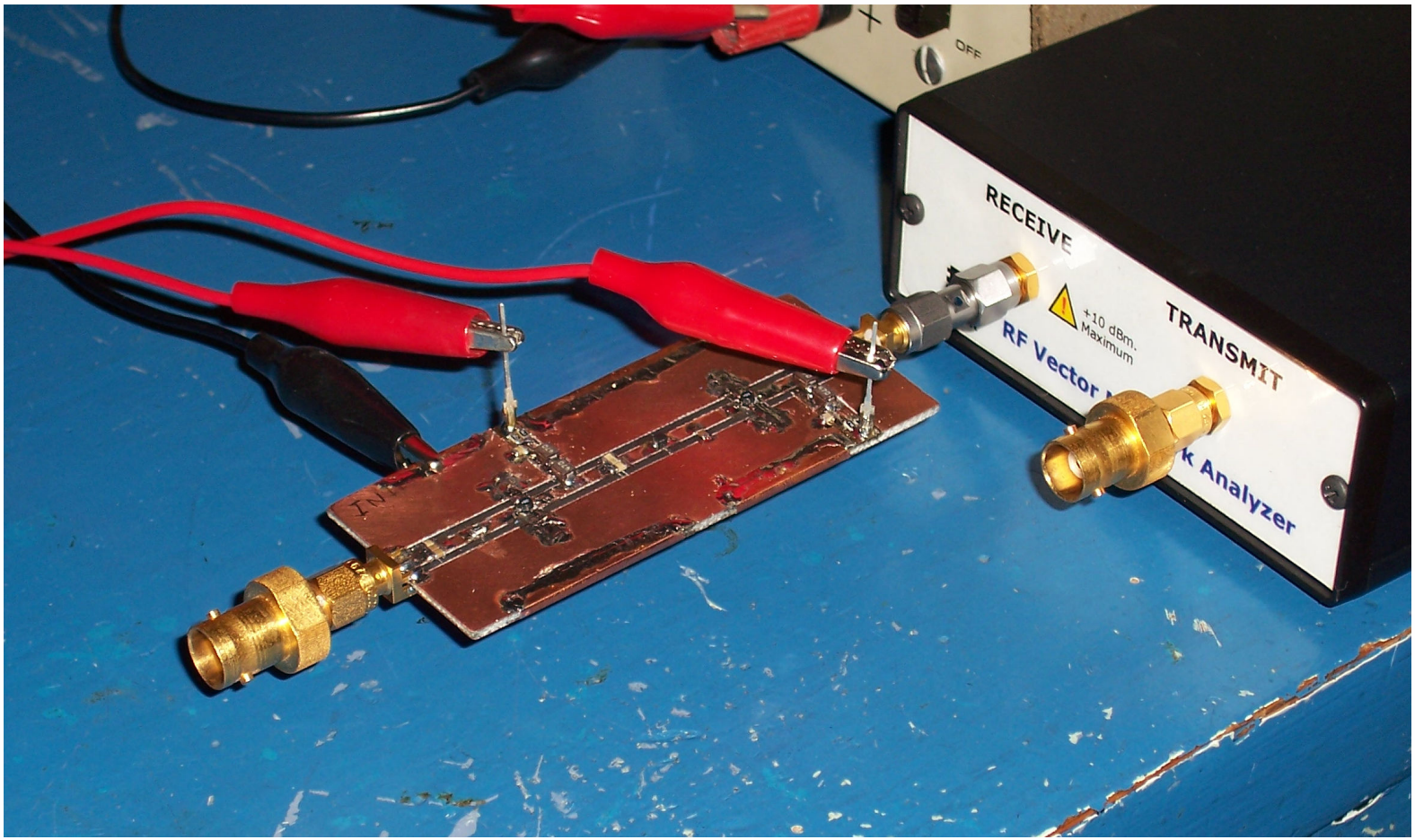
- 16 dB gain per amplifier, 6 dB NF

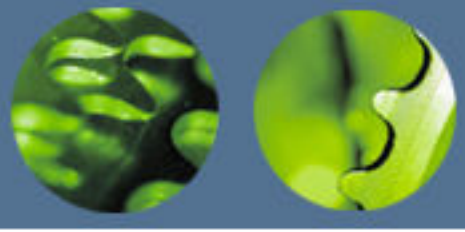
100 MHz noise roofing filter between gain stages

+5 VDC required

Could use a post-amp roofing filter

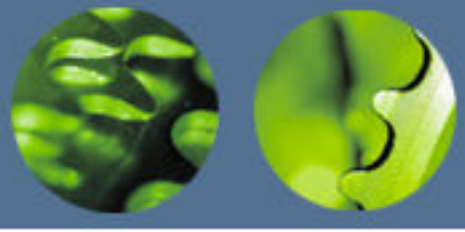
# Pre-Amp & VNA





# Software Enhancements Added

- Added SWR display modes
- Left- and right- scales change with scale factor and trace offsets, right scale is selectable (time, phase, SWR)
- Selectable group delay aperture 1 to 64 samples
- Markers
  - Drop and drag with the mouse, marker number on top of the markers
  - Parametric values dB, SWR, Mag/Phase, Impedance R + jX, color coded to screen traces

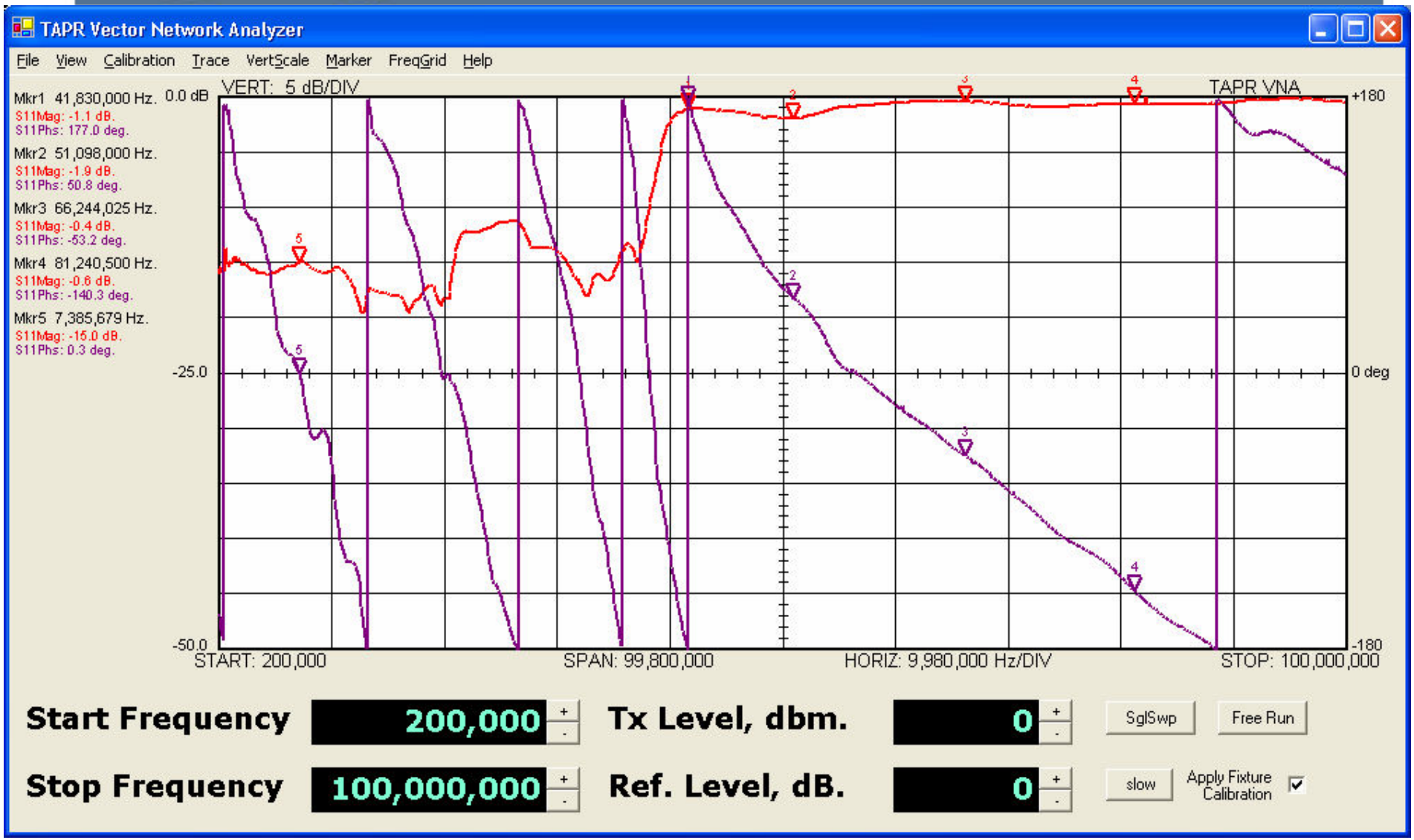


# Software Enhancements

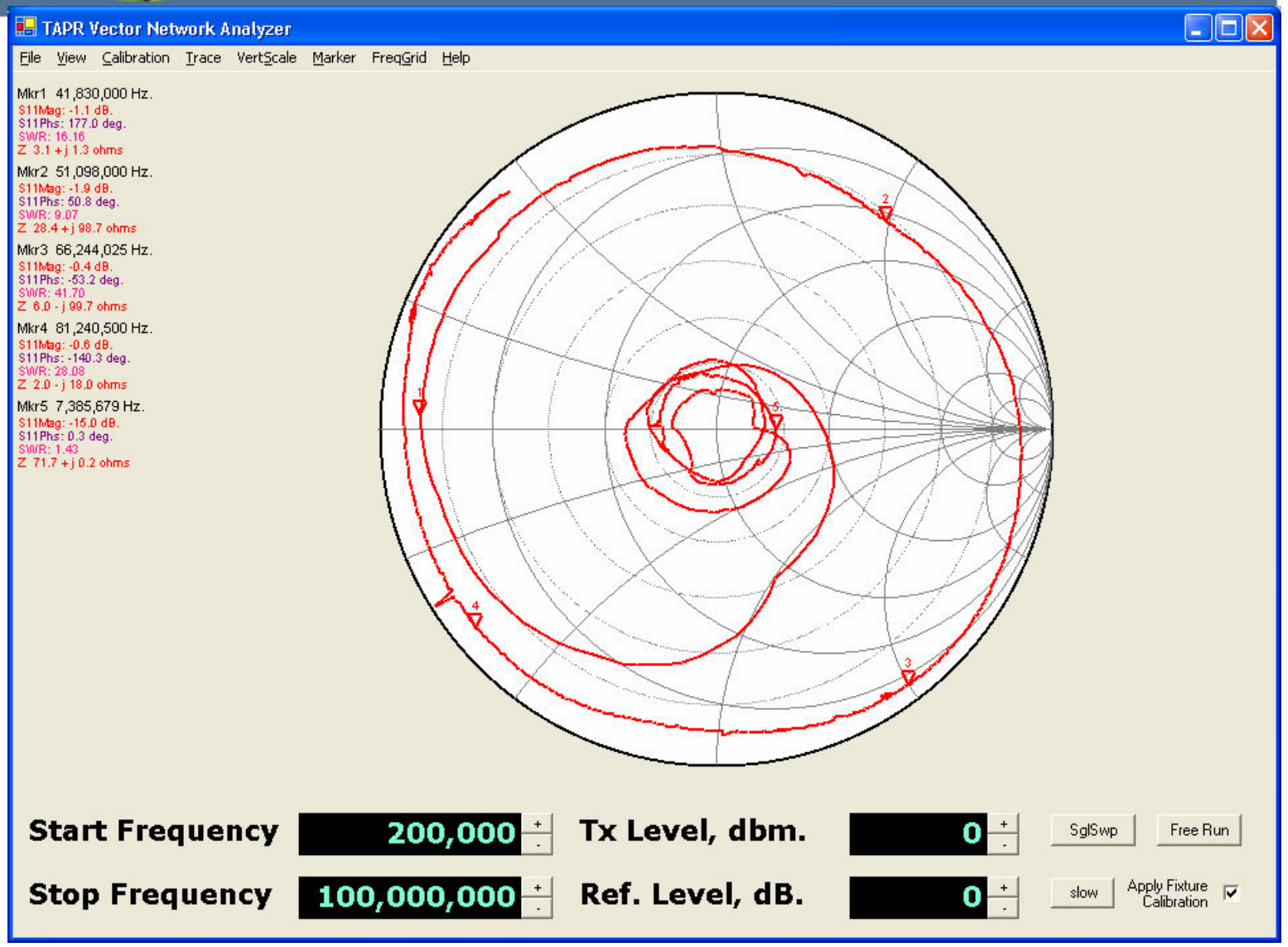
- Pop-up displays cursor coordinates
  - Rectangular mode: Frequency, Magnitude + Phase, and SWR
  - Polar mode: Magnitude + phase of S11, SWR, and impedance in R + jX format
- Fast measurement mode: about 2½ full sweeps per second (permits tuning of filters in real-time)
- Plot Titles
- Direct print to PDF file

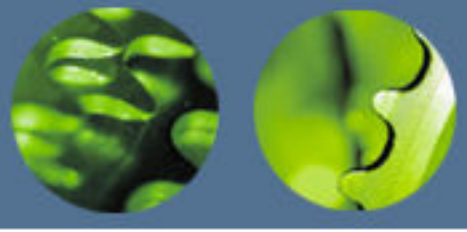
# Rectangular Display

# Rectangular Display



# Polar Display

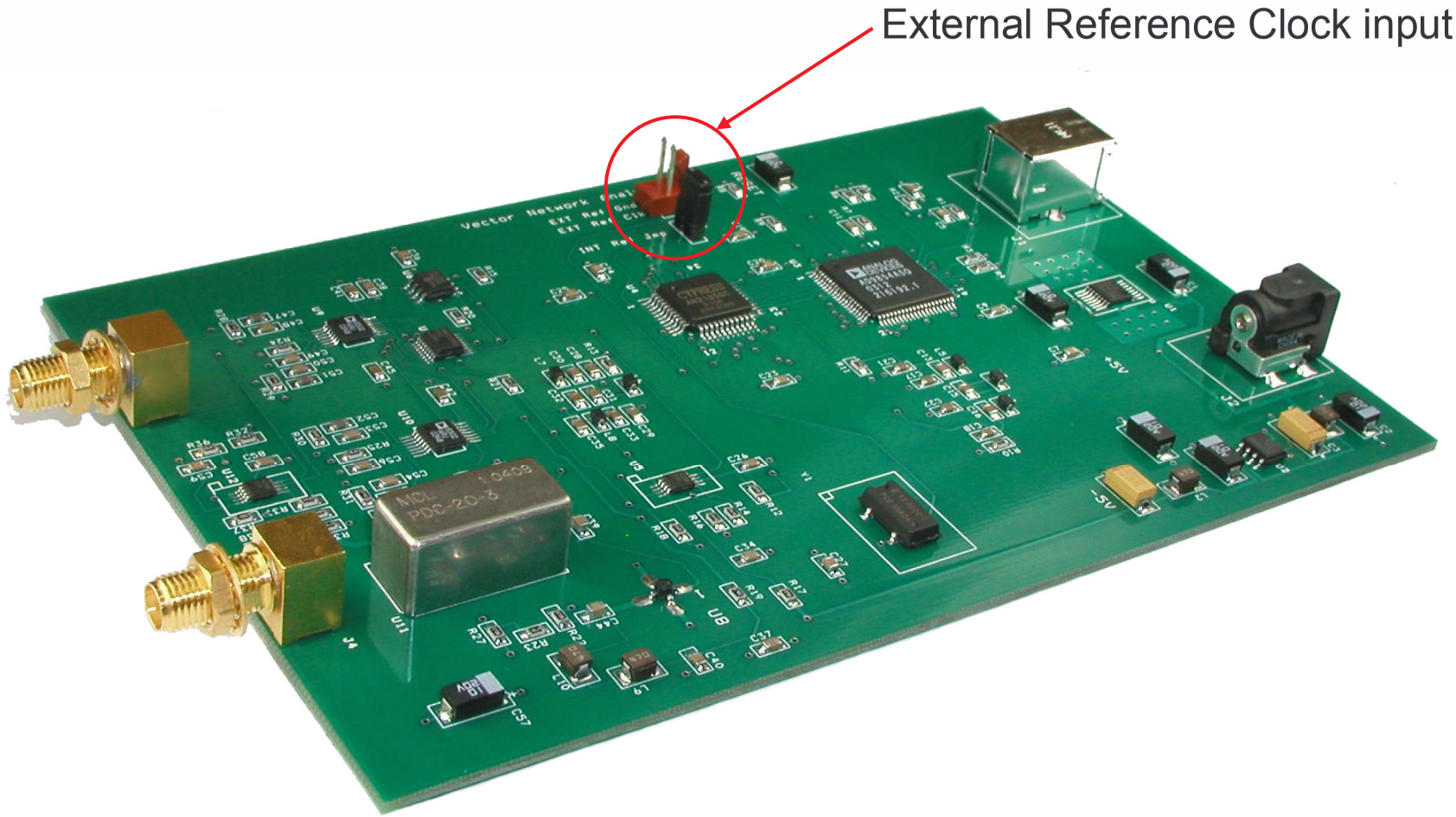


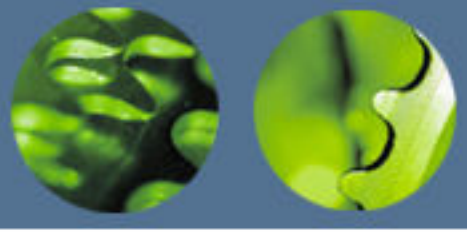


# A Few VNA Applications

- S21
  - Filter transmittance
  - Attenuators (flatness, delay)
  - Power splitters
  - Baluns
  - Phasing networks
  - Crystals, resonances, impedances
  - Amplifier gain, delay
  - Cable electrical length, velocity factor
- S11
  - Antenna measurements
  - Complex load impedance
  - Power splitters, diplexers
  - Filter return loss
  - Amplifier return loss
  - Cable impedance

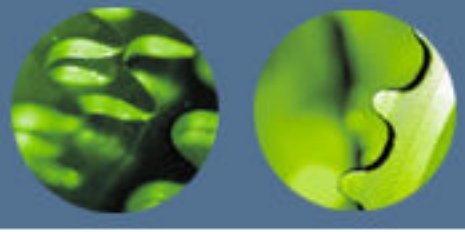
# External Ref Clock





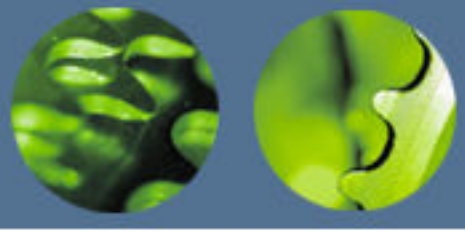
# Other Applications

- Existing R2 hardware provides for reference clock to be strapped ‘External’
- This allows using a GPS-derived external 10,000,000.000 Hz. reference clock
- New application software could provide precision frequency synthesis and level setting
  - Different downloadable image than VNA
  - Different host image than VNA
  - Not yet designed or coded
  - 48-bit DDS accumulator would determine resolution (~ very fine)



# Resources

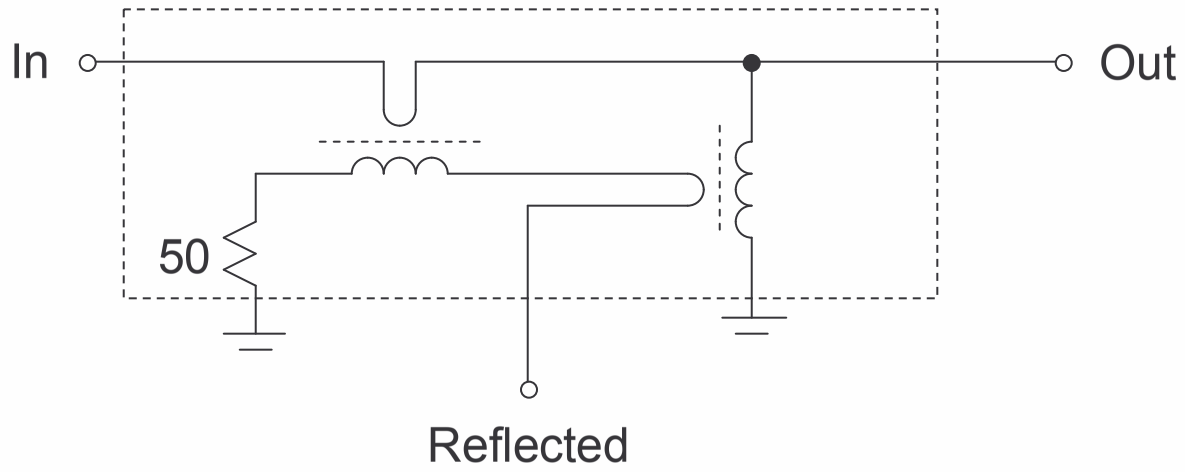
- R1.1 Schematic & Software Source
  http://www.arrl.org/qexfiles
- Current parts list, build docs, schematic, updated source, help files, Windows binary executable, *this presentation*
  ftp://ftp.tapr.org/pub/n5eg
- Project Status
  http://www.tapr.org/kits/vna
- R2 Beta Test Page – maintained by George Heron, N2APB
  http://www.amqrp.org/vna



# Backup Slides

- How a transformer-type directional coupler works
  - Contains a voltage and a current sensor.
    - Current sensor output proportional to 50 volts/amp.
    - Voltage sensor output proportional to 1 volt/volt.
    - Two sensor outputs are wired in series opposition
    - Thus output is the vector sum of the two sensors.
  - Sensors cancel (null) when load is 50 +j0
  - Output is maximum when load = 0
  - Output is maximum (but opposite sign) when load = open
  - Output does not cancel for reactive load because V and I are out of phase

# Lumped-element Directional Coupler

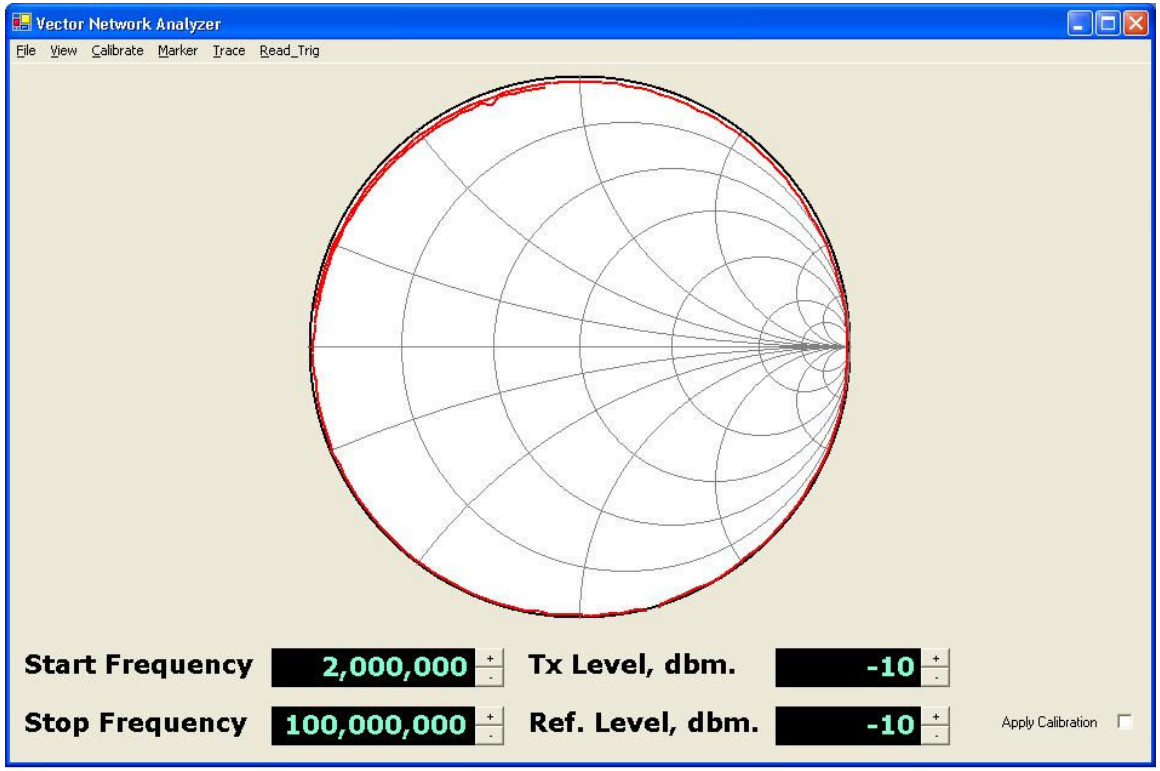



*"The Lumped-Element Directional Coupler"* William E. Sabin, W0IYH, QEX March 1995, pp 3-11.

*"Designing the Toroid Transformer for the Directional Coupler"* William, E. Sabin, W0IYH, QEX May 1995, pp 8-12.

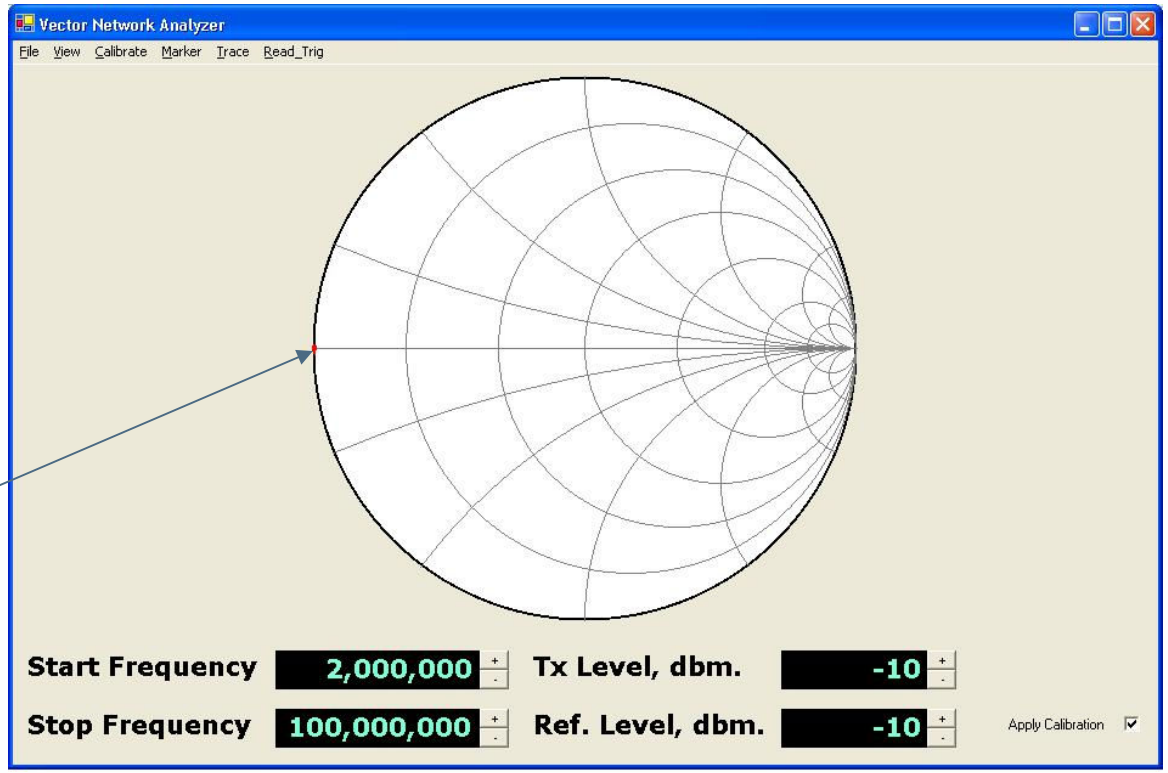
# Shorted Line

- Reflection magnitude = 1, but the phase rotates at 2x (go and return path along the cable).



# After Fixture Calibration

- Fixture calibration adjusts amplitude and phase at each frequency sample point



# Bandpass Filter