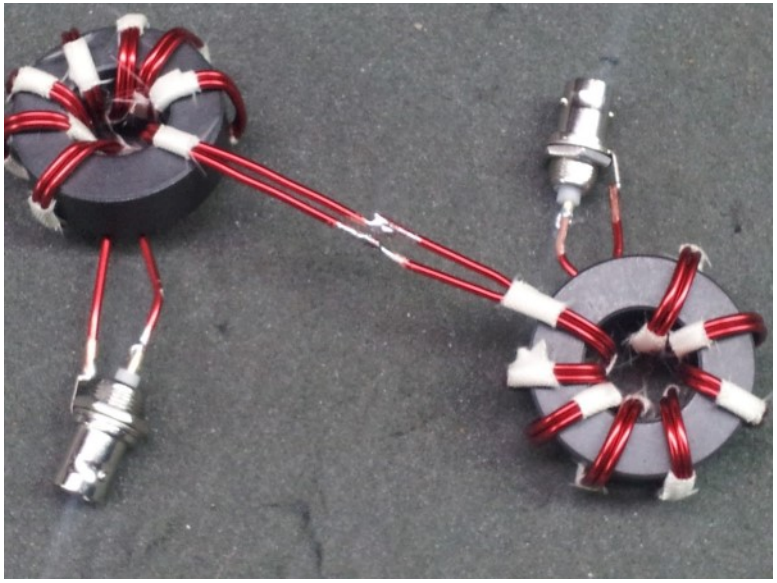
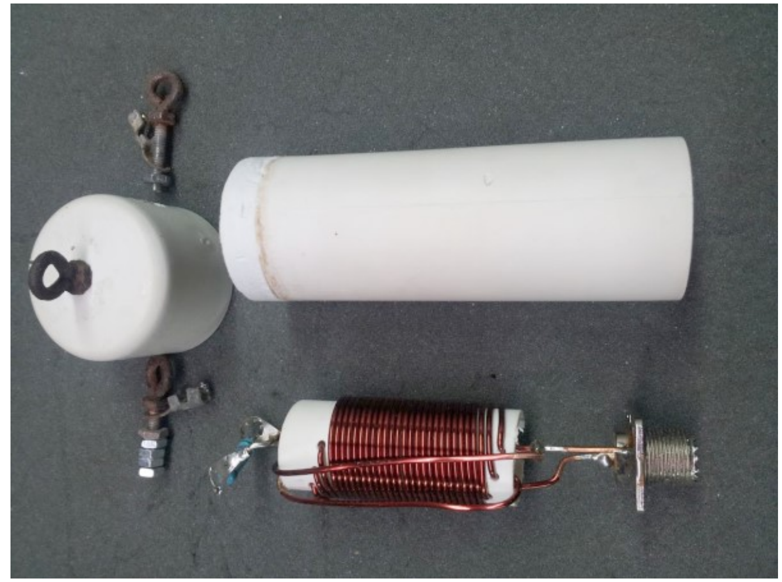




Baluns, Ununs, and Related Topics

W7KVI, HARC

Original: 3/26/16

This Presentation

- Informal & brisk - 52 slides (too many unless you're an enthusiast!)
- Discussion encouraged if not extensive, interrupt me freely
- My motivation – commercial, popular balun kit, inexpensive, insufficient instructions – installed on a 75m dipole, poor resulrs

Major Topics

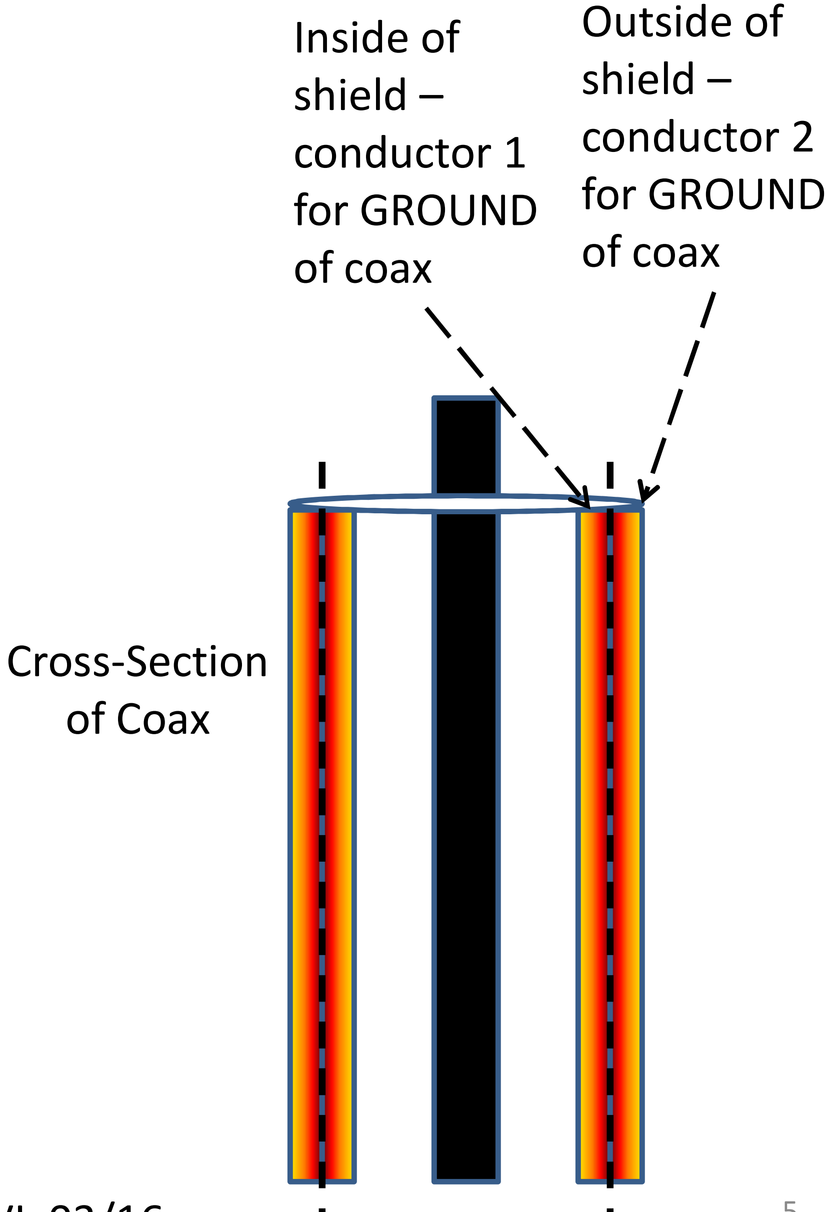
- Why Baluns?
- Applications
- Types of Baluns
- Examples

Why & Where?

- Why do we need baluns and ununs?
  - Prevent current on outside of coaxial cable shield, which causes radiation pattern distortion
    - Due to Skin Effect
  - Convert impedances
    - Reduce need for, or demand on, antenna tuner
    - Prevent transmitter "foldback" at ~2:1 SWR
- Typical applications
  - Connect balanced and unbalanced structures
    Dipole to coax
    - Balanced feedline to coax
    - Use antenna on non-resonant frequencies

Skin Effect

- Property of AC current to flow mostly near the surface of a conductor
  - Skin Depth – thickness containing 63% of current
  - At 10 MHz, skin depth = 21 µm, or 0.000021m
  - Coax shield thick enough that it actually represents 2 separate conductors – inside and outside of shield
- Allows using pipes or tubes to reduce conductor cost



Unbalanced Coax connected to Balanced Antenna

- <u>REASON #1 for BALUNS…</u>
- Current from coax shield to dipole conductor (or reverse) has available 2 paths – inside and outside of coax shield.
- Now have current on OUTSIDE of coax – undesired!
- Feedline now radiates and is part of antenna – changes the radiation pattern, may place RF in the shack when touching "ground."

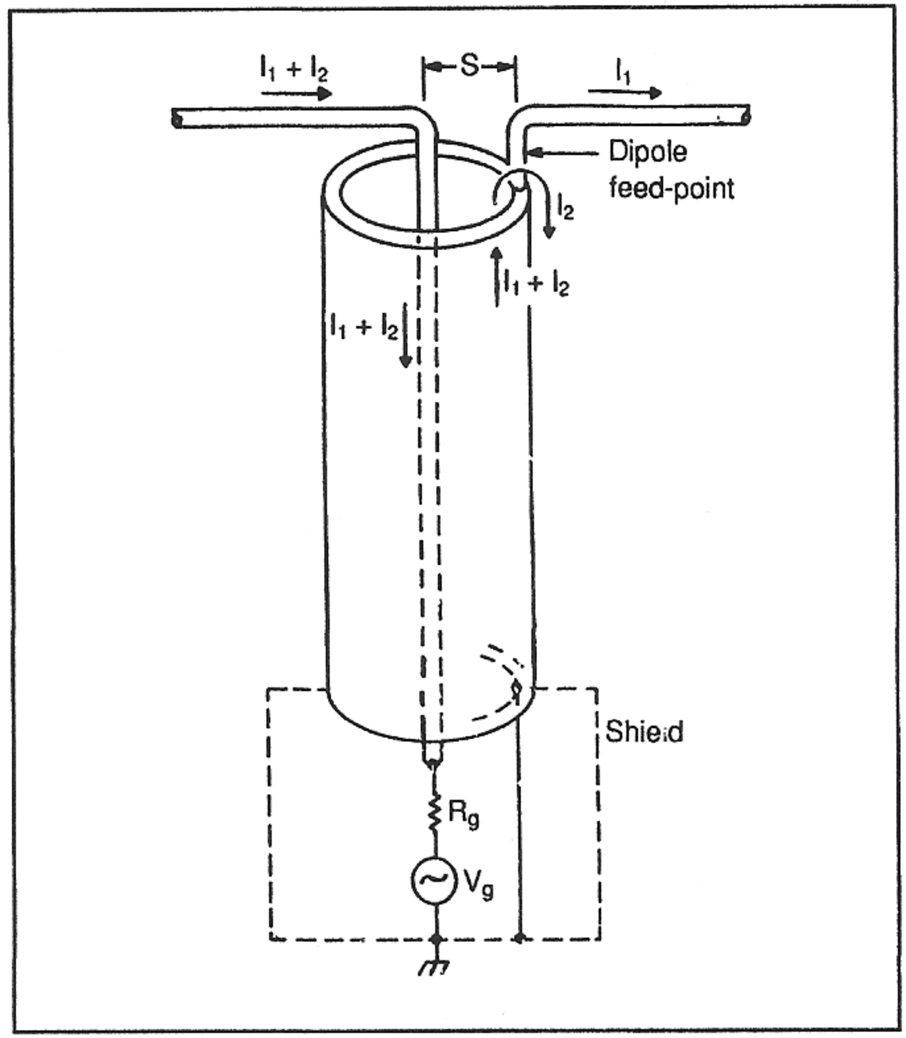


Figure 7-1. *An illustration of the various currents at the feedpoint of a dipole. I_1 is the dipole current and I_2, the inverted L (imbalance) current.*

Why Impedance Transformation?

- REASON #2 for BALUNS…

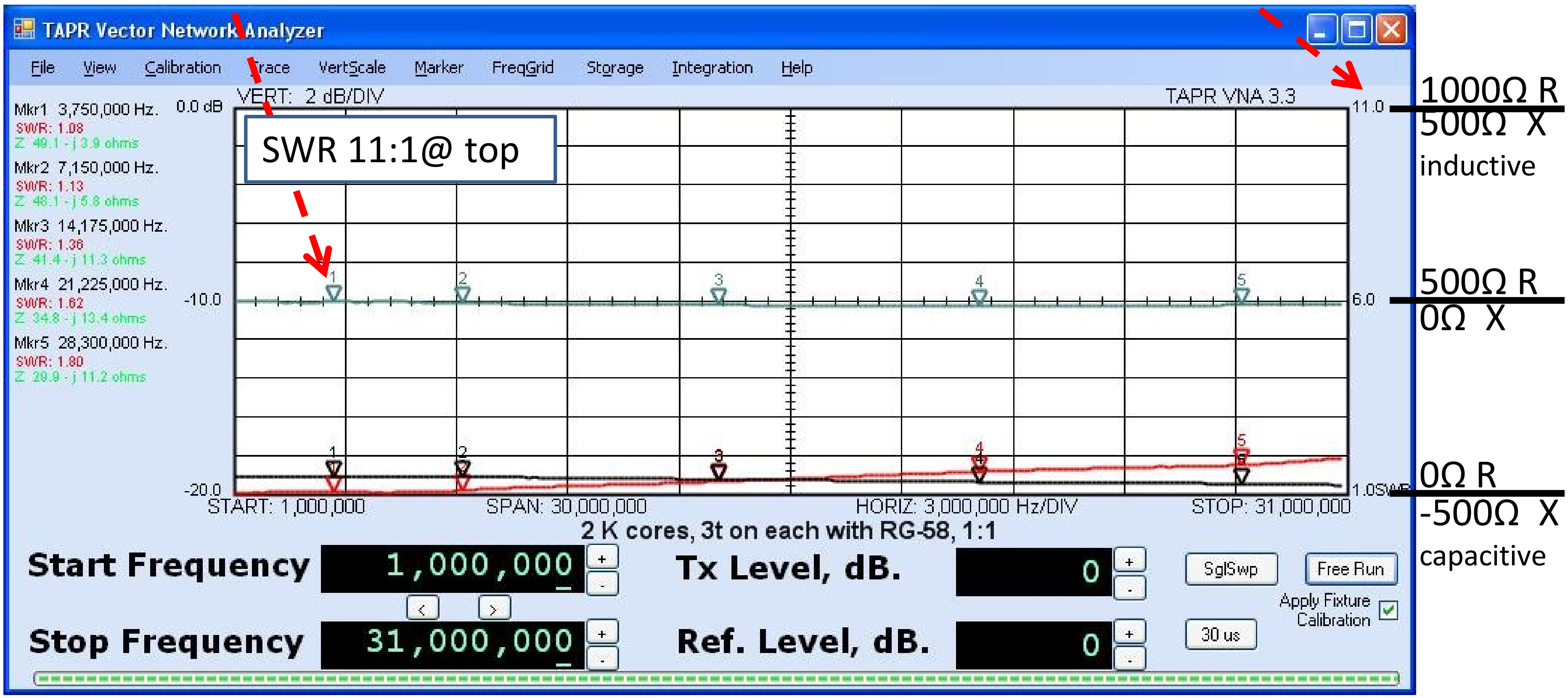
- Antennas aren’t usually 50 or 72 ohms, even though theory (properly) states a dipole is 72 ohms (only in free space, far from earth).

- Antenna impedances are highly dependent on proximity of the earth, and other objects such as trees and buildings.

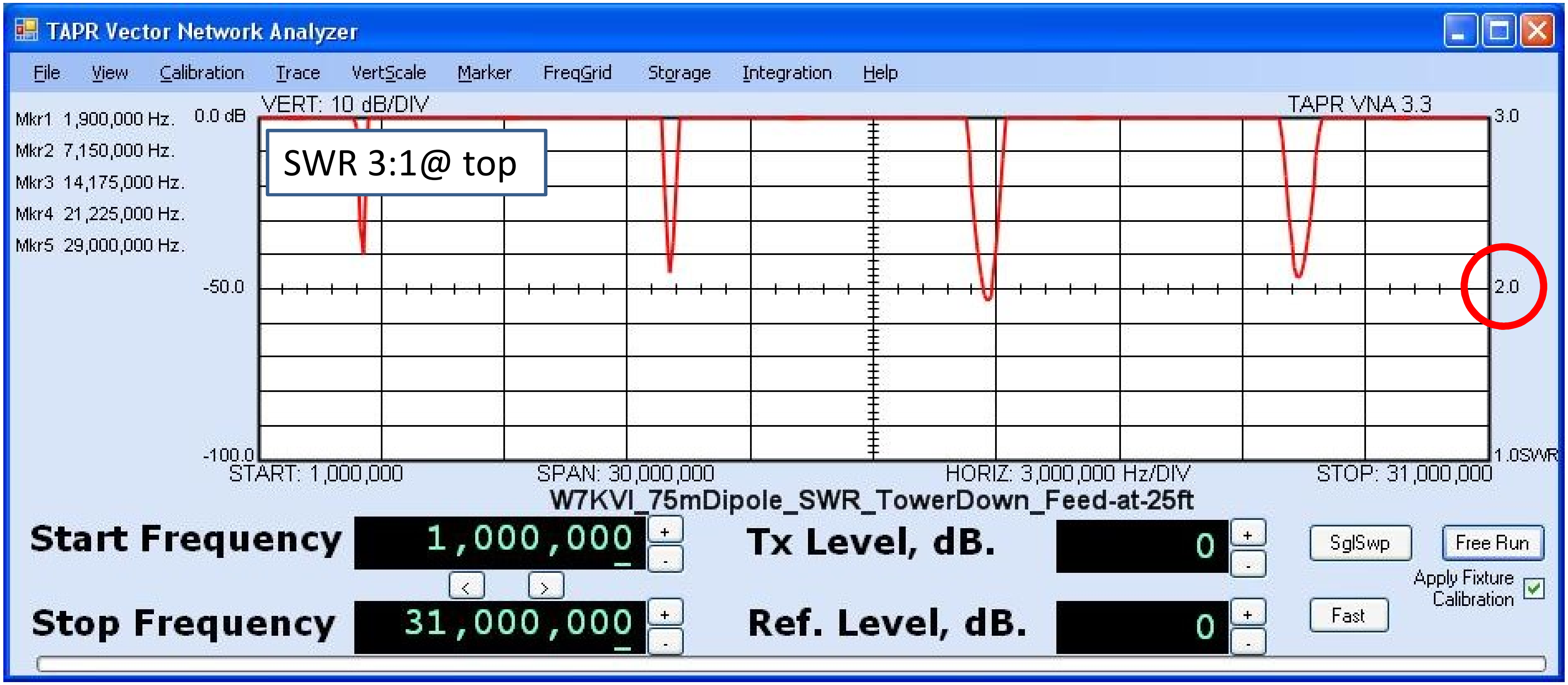
Antenna Impedance Examples

First, How to Read Analyzer Data

- Typical traces – SWR (red), R (black), X (gray)
  - SWR scale at right – 1:1 to 11:1 or 1:1 to 3:1
  - X and R plotted 100 ohms/div, X centered (10 ohms/div in some plots)
- Markers in 160/80-10m ham bands



Antenna Sweep – 75 m Dipole, tower down
SWR (only) plotted on 3:1 max scale



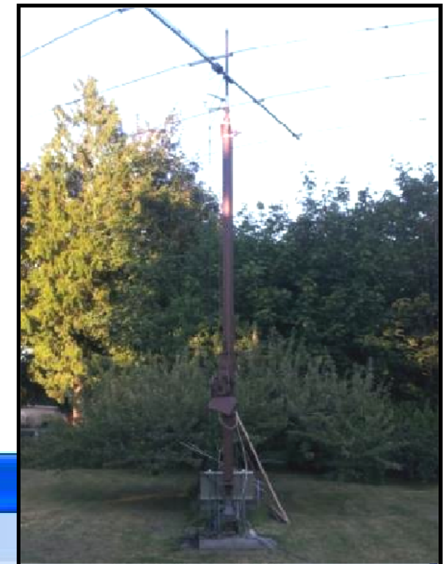
Antenna Sweep – 75 m Dipole, tower down
R&X plotted at ± 100 ohms/div

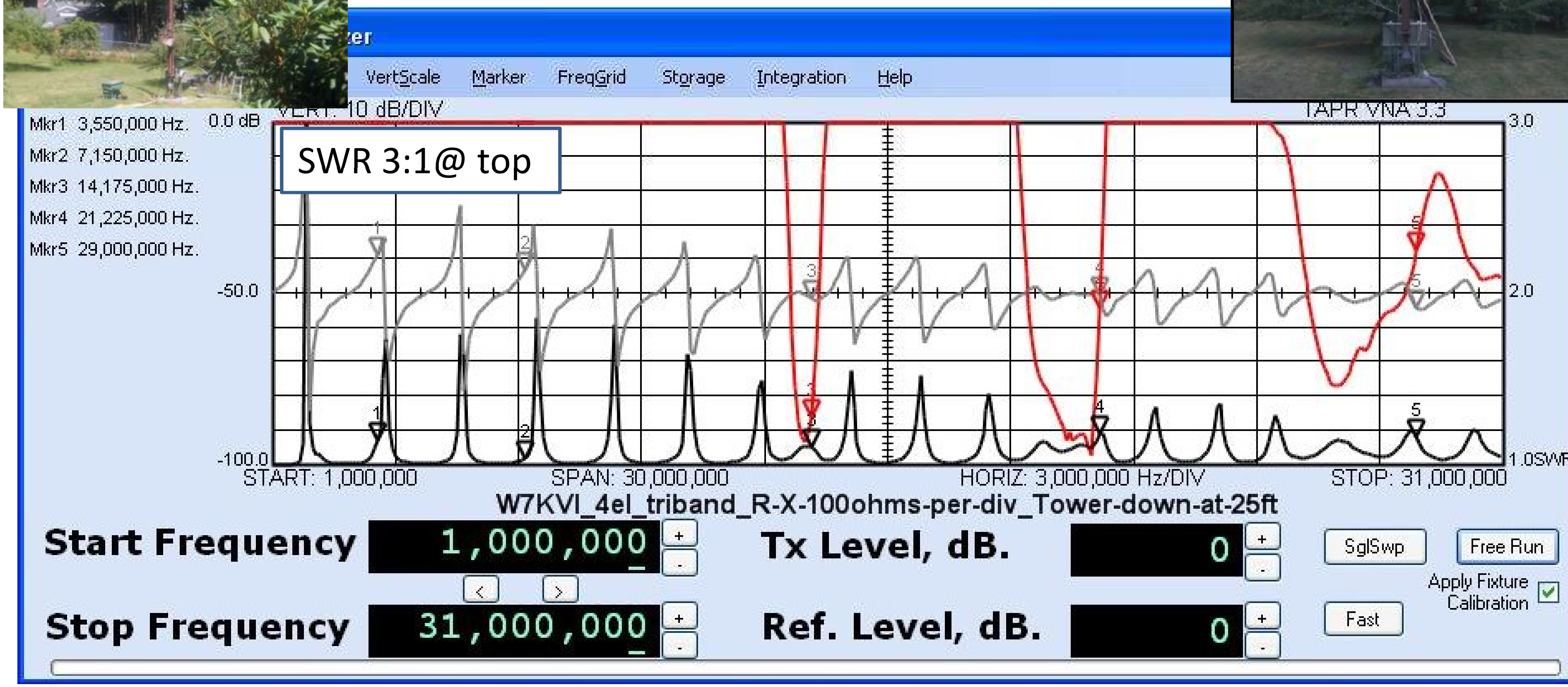
80m: ~20 ohms, ~2.3:1 SWR
40m: ~0 ohms, Vy Hi SWR

20m: ~10 ohms, ~5:1 SWR
15m: ~205 ohms, ~4:1 SWR

10m: ~10 ohms, ~5:1 SWR
30, 17, 12m - ????

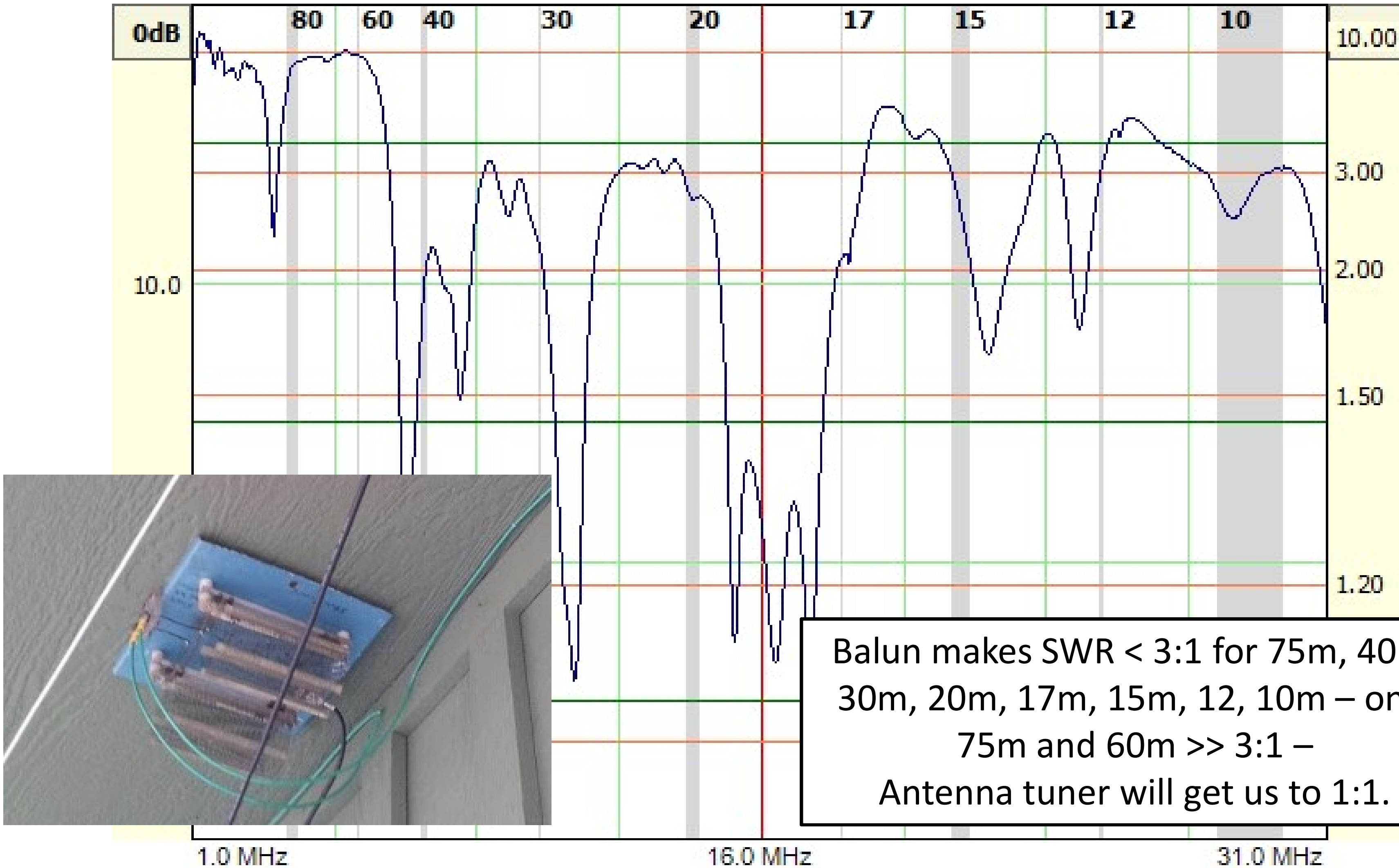
Antenna Sweep – Triband Beam
R&X plotted at ± 100 ohms/div





Antenna Sweep – Eaves Loop

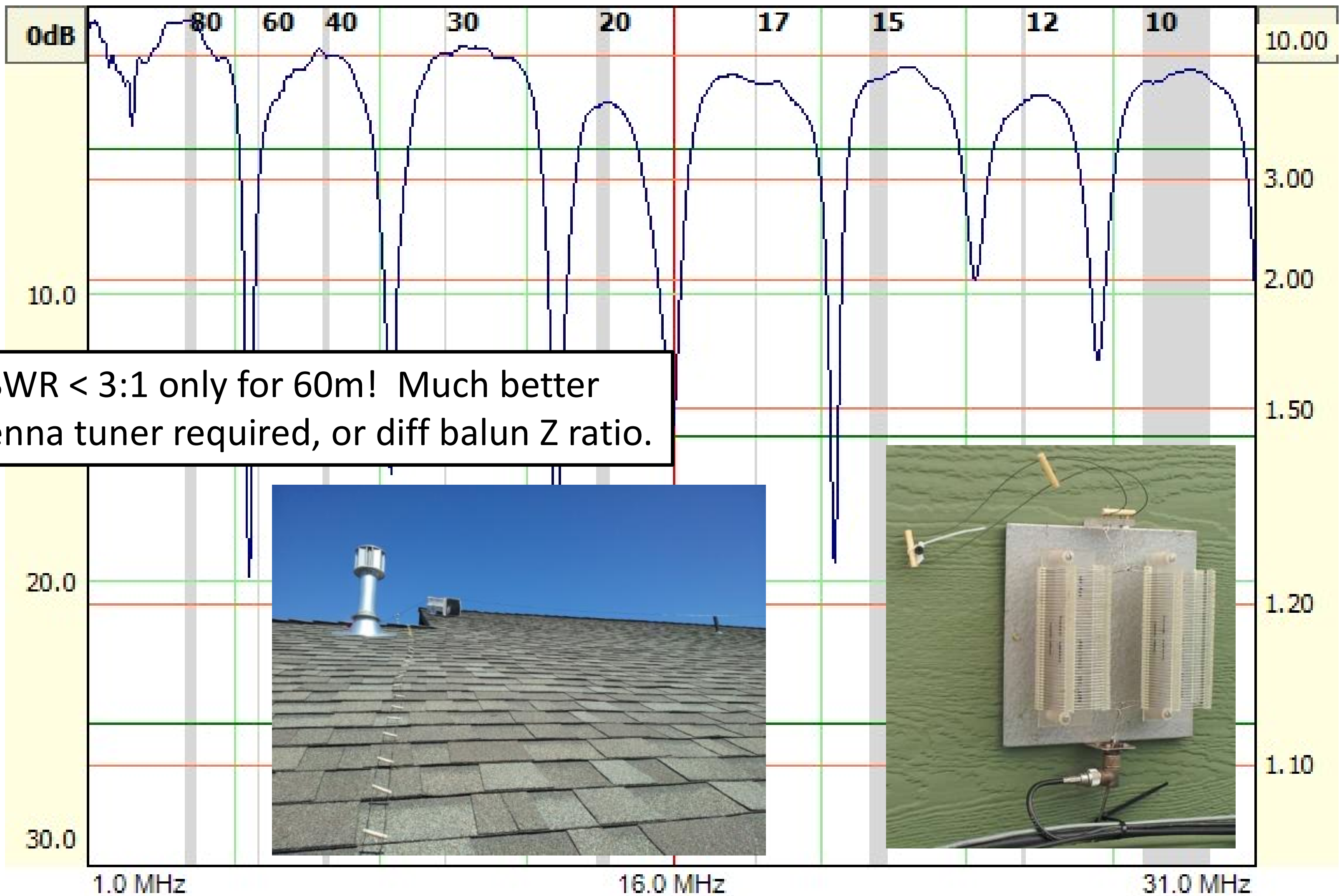
265' #12 wire, 4:1 air balun, antenna 14' AGL



Balun makes SWR < 3:1 for 75m, 40m, 30m, 20m, 17m, 15m, 12, 10m – only 75m and 60m >> 3:1 –
Antenna tuner will get us to 1:1.

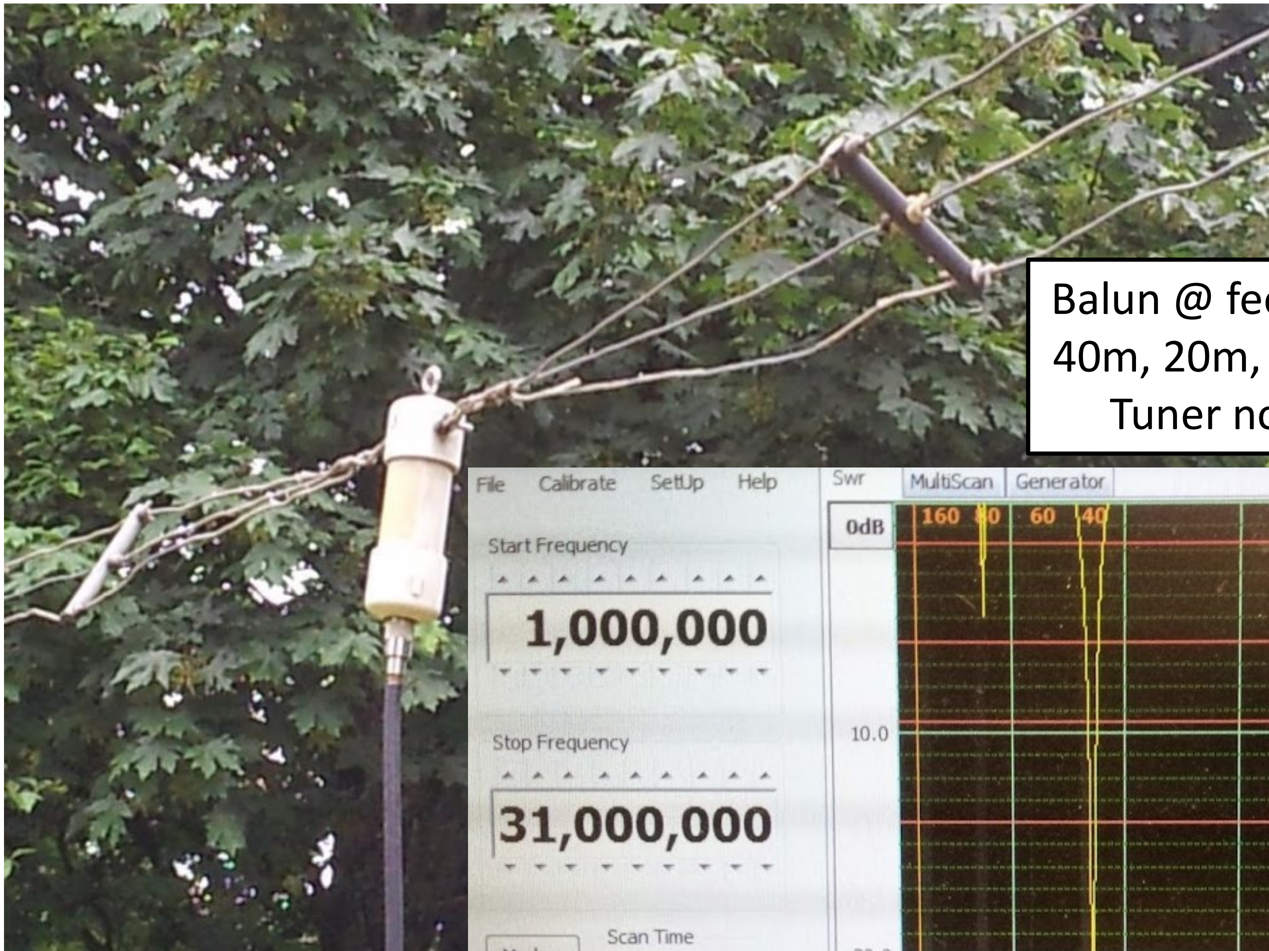
Antenna Sweep – 97’ FlatTop

450 ohm ladder line, 4:1 air balun, 20’ AGL, center on roof (temp)

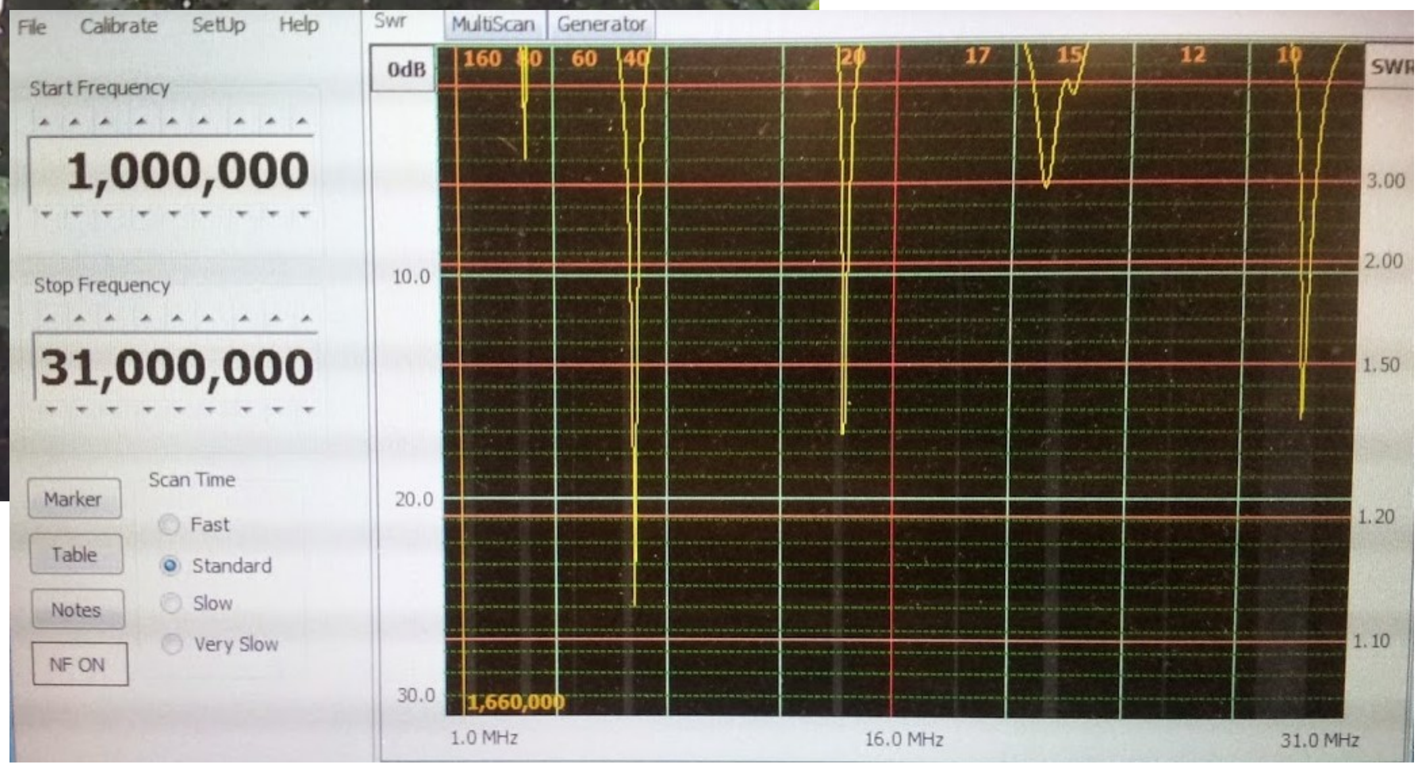


SWR < 3:1 only for 60m! Much better antenna tuner required, or diff balun Z ratio.

Fan (Multi-band) Dipole, 12’ AGL



Balun @ feedpoint, SWR < ~3:1 for 80m, 40m, 20m, 15m, 12, & high part of 10m. Tuner not needed for 40, 20, 10m.



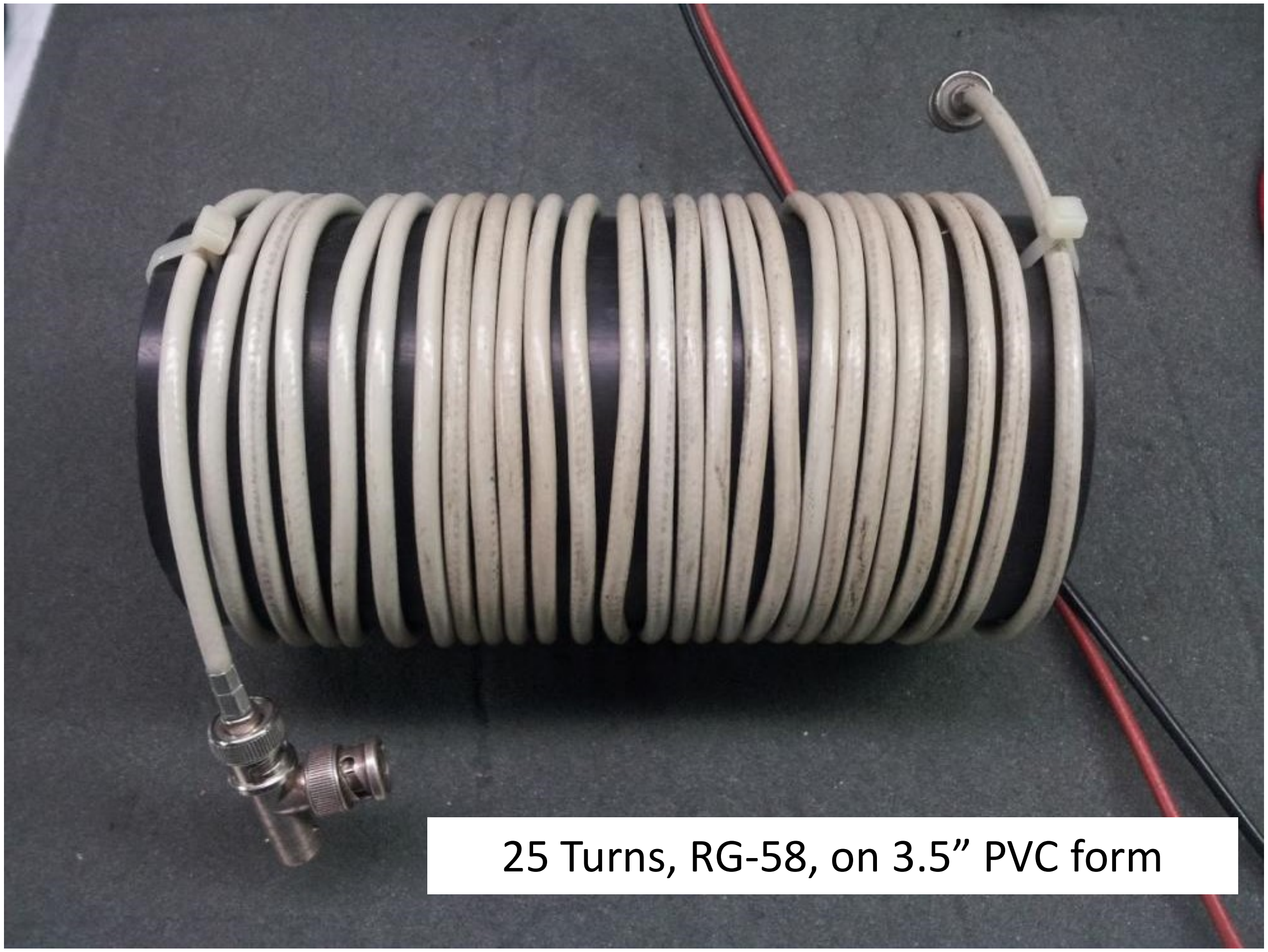
Types of Baluns and Ununs

- Choke (coiled feedline)
  – Merely an additional length of feedline
  – Presents high Z to current on outside of coax shield
- Flux-coupled (via a core material, incl air)
  – Relies on coupling between windings by flux in a metallic or ferrite core [typ. Ruthroff or voltage balun]
- Transmission-line (wound on a core material)
  – Uses parallel or coaxial transmission line, wound on a ferrite for choking action [Guanella or current balun]

Choke Balun (1:1)

Choke Unun

Inserted in existing coaxial line, coil provides an inductive reactance to resist flow of common-mode currents (e.g., power line noise) on outside of shield – Unbalanced to Unbalanced



25 Turns, RG-58, on 3.5” PVC form

Choking Action

- Measure Z from shield to shield, 2’ RG-58

- Several ferrite materials
  - Mix 31 beads
    - 3t, 2 beads ➔ 1700 Ω
    - 1t, 4 beads ➔ 350 Ω
  - Large Mix 43 toroids
    - 2t, 4 cores ➔ 825 Ω
    - For connectorized cables

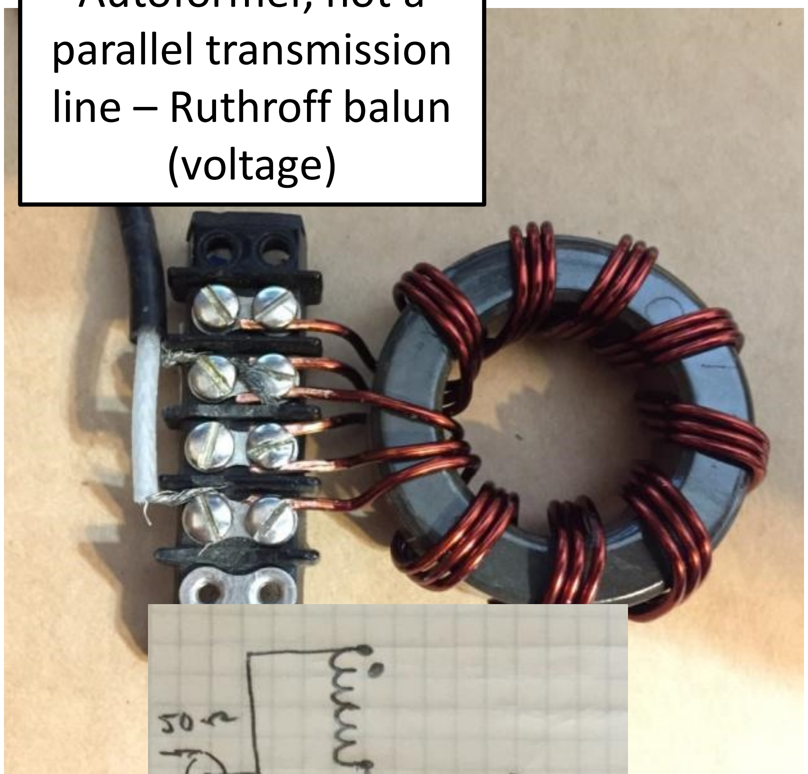
Choking Results

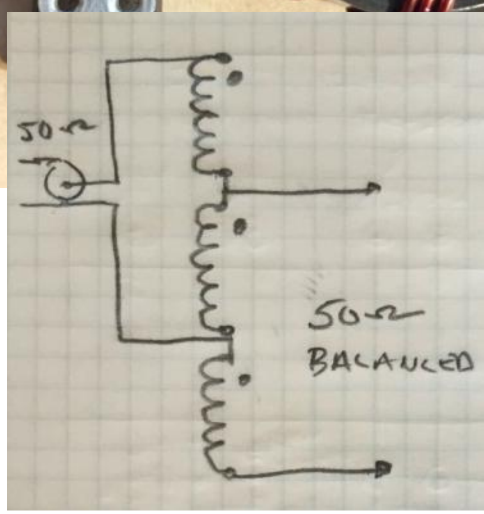
24" of RG-58, connect ends of SHIELD across Autek Antenna Analyzer to measure Z of the shield, which represents it common mode resistance Then add various ferrites over the coax to increase the Z of the shield					
	Z, ohms, of shield on coax				
Config	2 MHz	3.7 MHz	7.1 Mhz	16.1 MHz	29.6 MHz
No Ferrite	10	15	30	72	150
1t on K core	12	23	42	90	180
2t on K core	22	44	86	163	370
3t on K core	40	80	160	310	540
1t on 4 ea K cores	26	50	105	250	420
2t on 4 ea K cores	83	160	410	970	340
4t on 3 ea K cores	240	520	>1K	730	310
1t on 4 ea Mix 31 beads	270	380	480	590	350
2t on 4 ea Mix 31 beads	1240	1575	1290	580	285
1t on 8 ea Mix 31 beads	560	815	950	690	330
1t on 4 ea Mix 43 cores	62	95	140	270	440
2t on 4 ea mix 43 cores	230	360	575	822	368

Good choice for low HF band noise

Flux-coupled and Transmission Line Baluns
(Voltage and Current Baluns)

Autoformer, not a parallel transmission line – Ruthroff balun (voltage)

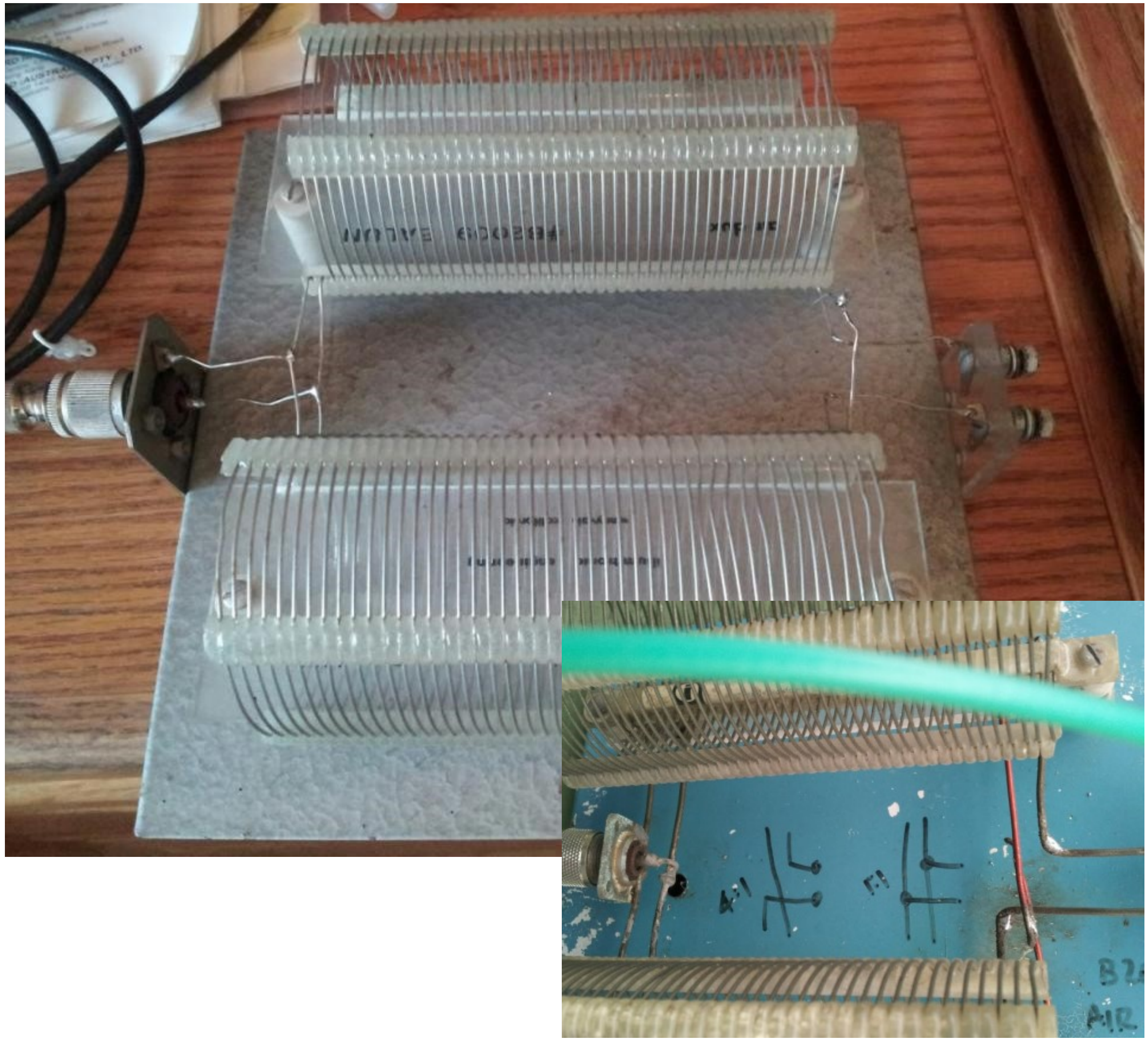




One or more parallel transmission lines, connected various ways – Guanella balun (current) – core is used solely for choking action

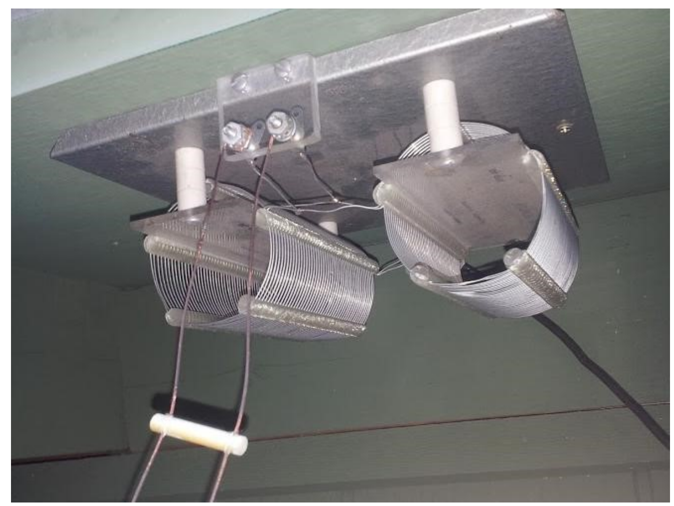
Air Core Balun

- Classic balun using Airdux material
- 2 conductors in each coil, adjacent turns are different conductors!
- Configurable for 1:1 and 4:1



Classic Air-Core Balun - Application

- Convert parallel feedline to coax
- Types of Parallel Line
  - **Open Feeder** or **Ladder line**
    - Typ 450 and 600 ohm
  - **Twin Lead**
    - Common for (old) outdoor TV antennas
  - **Window line**
    - Commonly available today



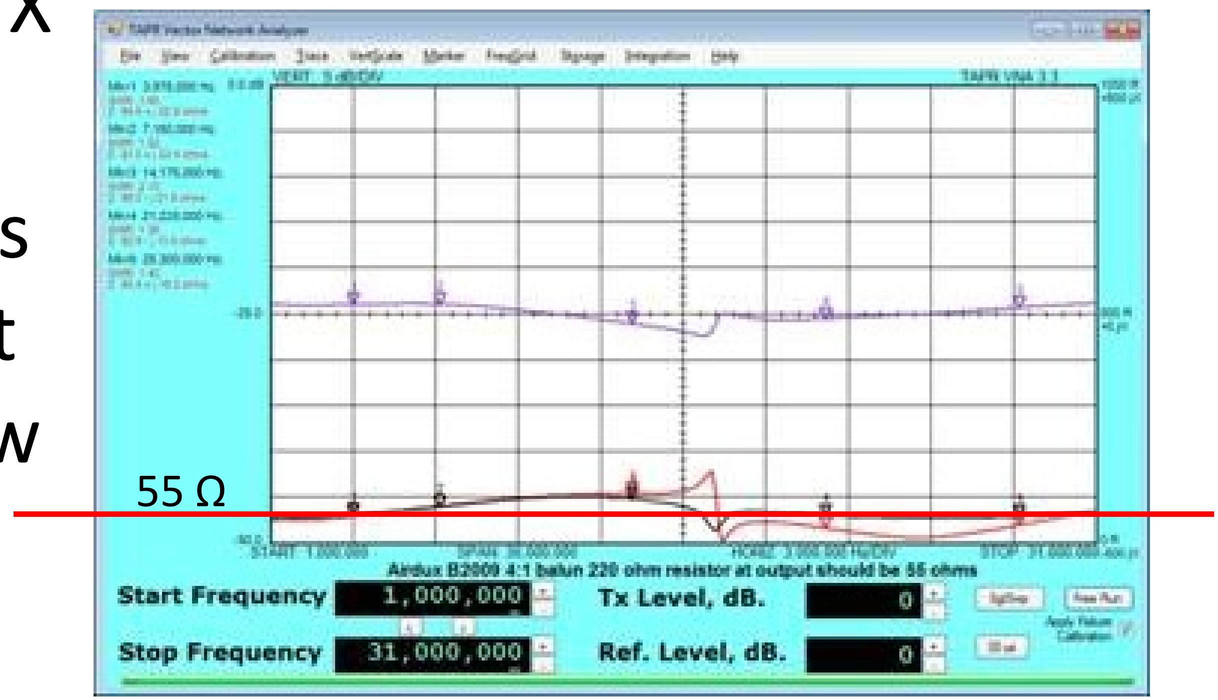
How Well Does it Work (4:1 Air-Core)?

- 300 Ω load ➔ s.b. 75 Ω input, 1.5 SWR, zero X

- Looks great except for resonance @ ~ 17 MHz

How Well Does it Work (4:1 Air-Core) @ a Lower Impedance?

- 220 Ω load ➔ s.b. 55 Ω input, 1.1 SWR, zero X
- Looks OK, lines not as flat, but resonance now larger



How Well Does it Work (4:1 Air-Core) @ a Still-Lower Impedance?

- 150 Ω load ➔ s.b. 37.5 Ω input, 1.33 SWR, zero X
- Large resonance effects

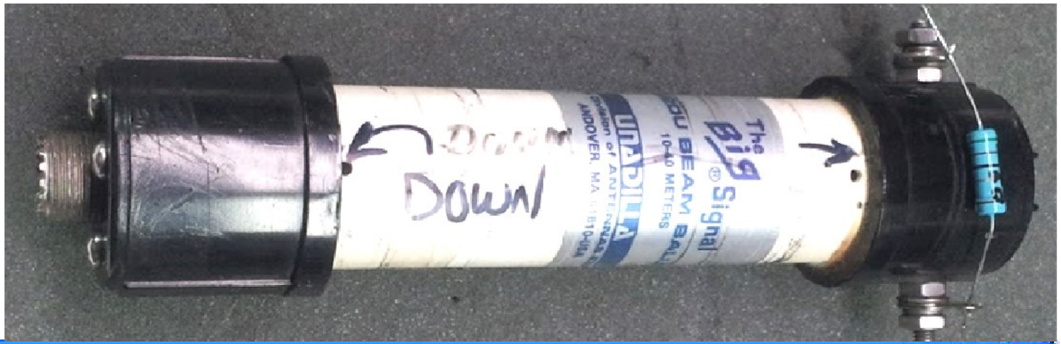
We see that baluns (at least this one) have a DESIGN IMPEDANCE at which they work best – for this air core balun, it's 300/75 Ω or higher – this makes sense, since 300 and 450 Ω lines were common in tube-type equipment days.

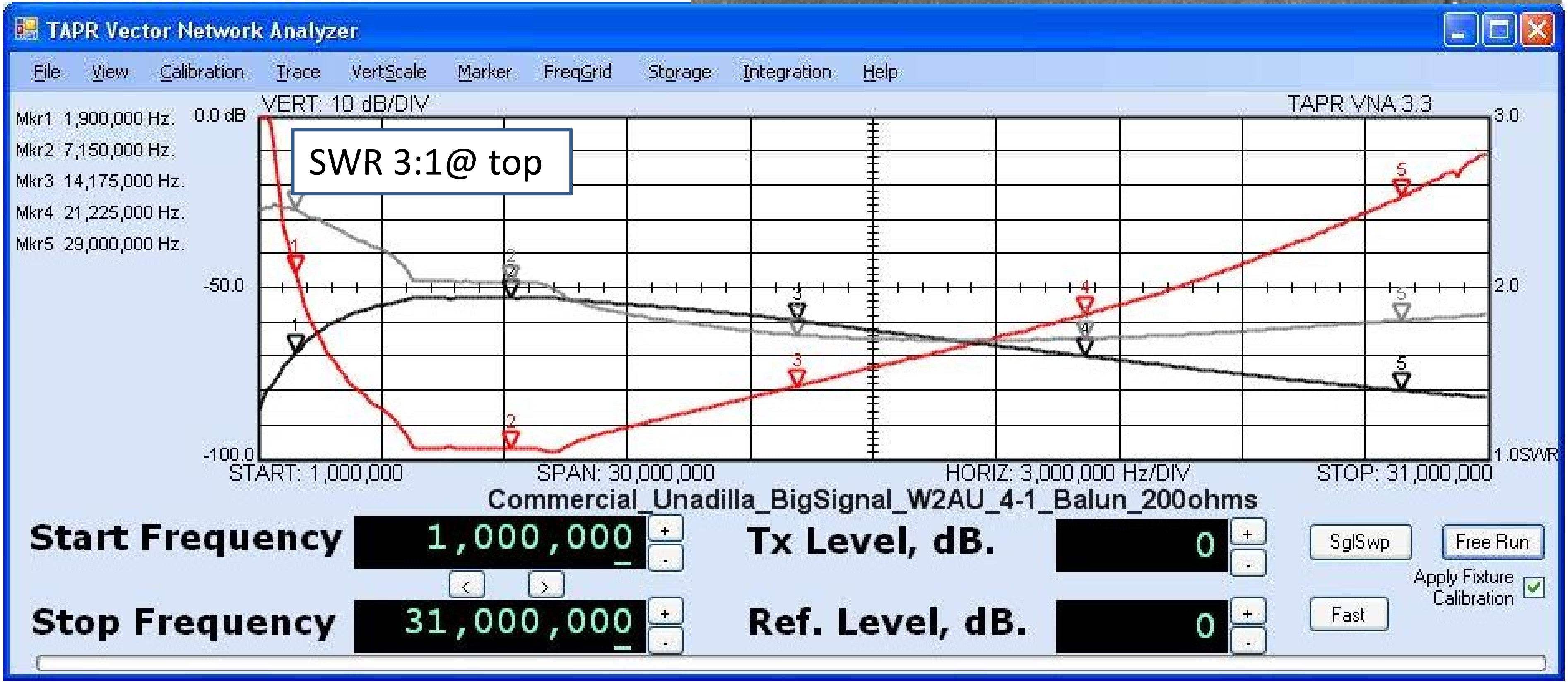
Some Commercial Baluns

- Mixture of choke, ferrite, and air-core baluns
- Some 1:1, others 4:1
- <u>**Caution**</u> – the specific examples in most cases are used baluns, with unknown service – these may not be representative of new examples.
- In some cases, corrosion had to be removed to obtain the results shown.

Commercial Balun #1

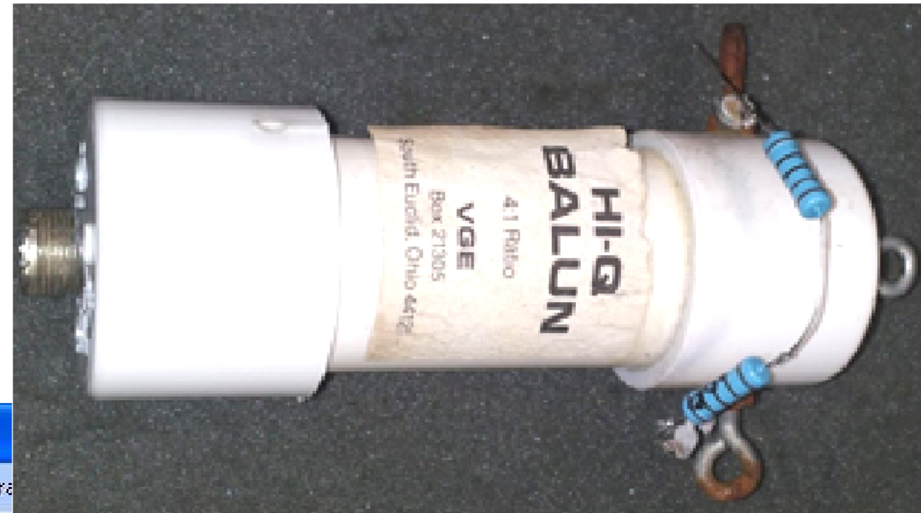
- 4:1 - Not great!
- 2.5:1 @ 10m & 1.8:1 @ 15m

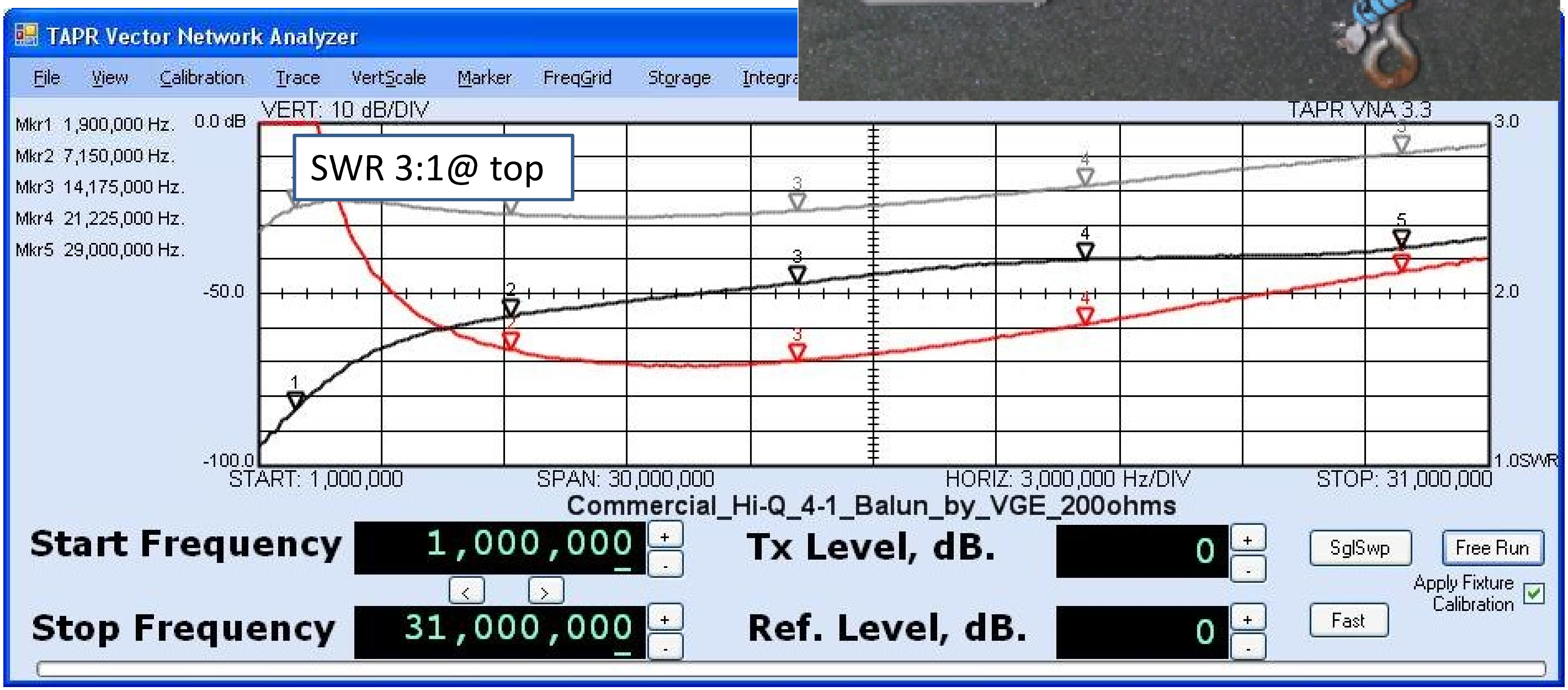




Commercial Balun #2

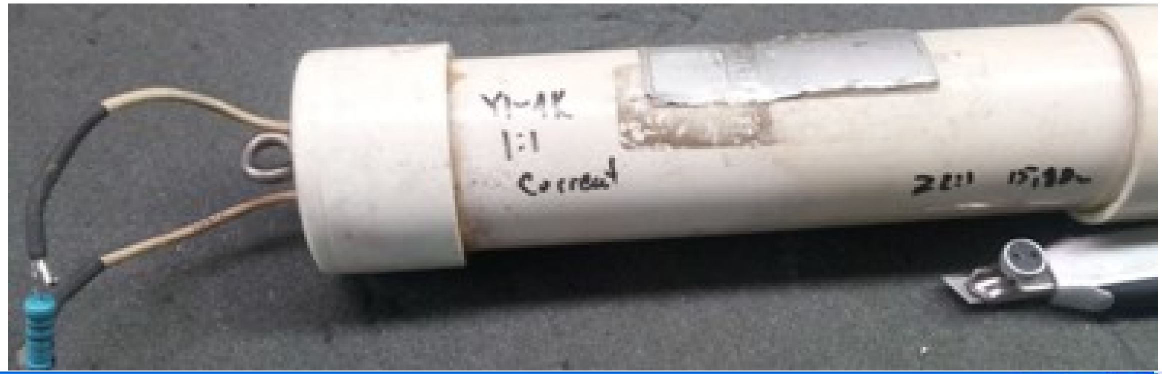
- 4:1 – Not great!
- 1.6:1 @ 40,20m & 2.1:1 @ 10m

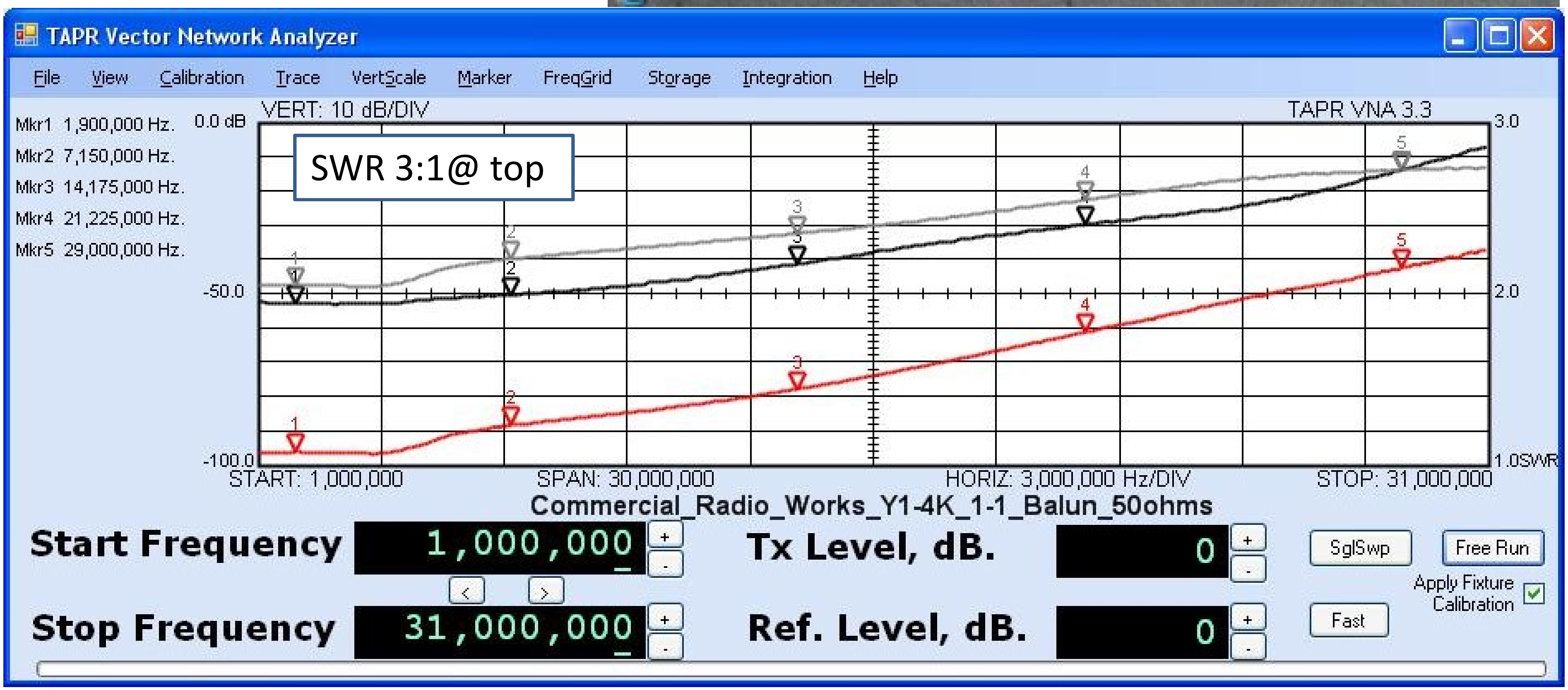




Commercial Balun #3

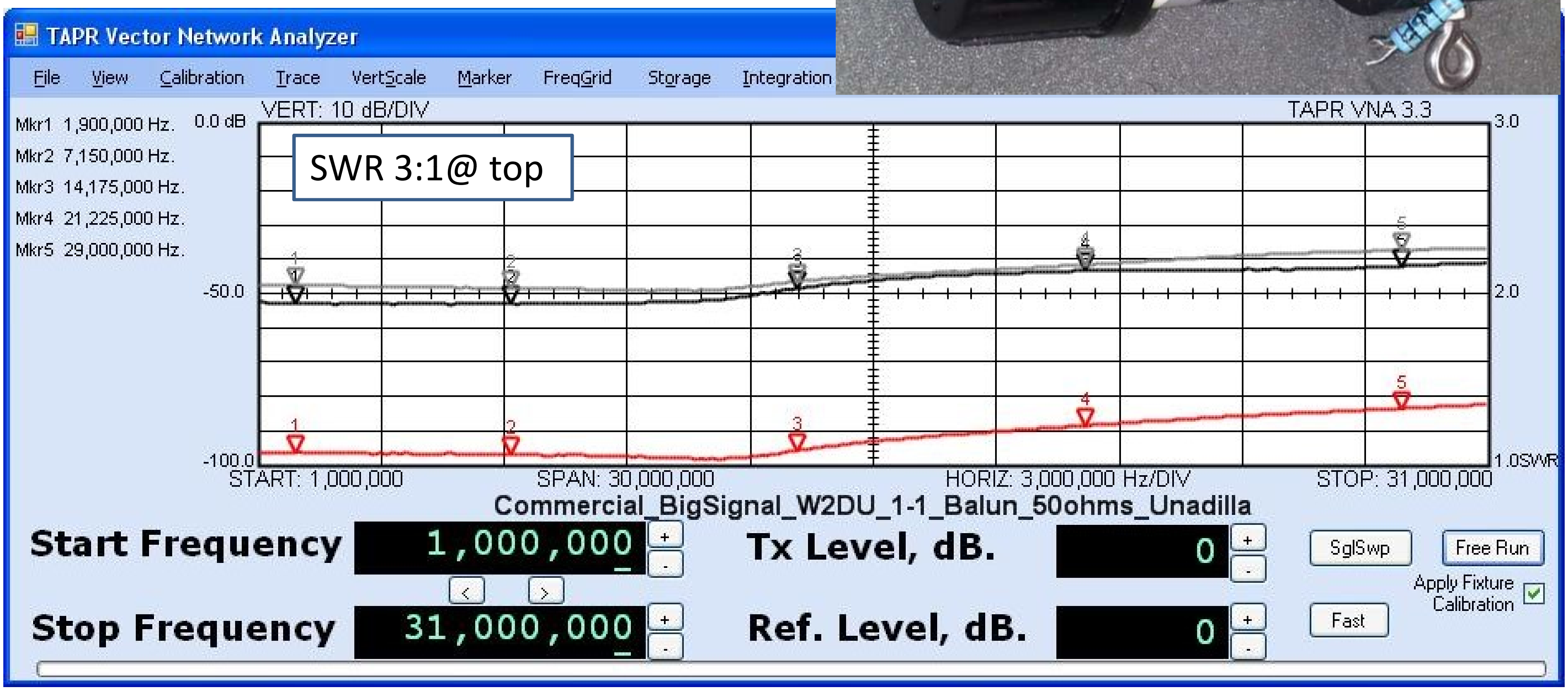
- 1:1 - Not great!
- 2.1:1 @ 10m & 1.8:1 @ 15m





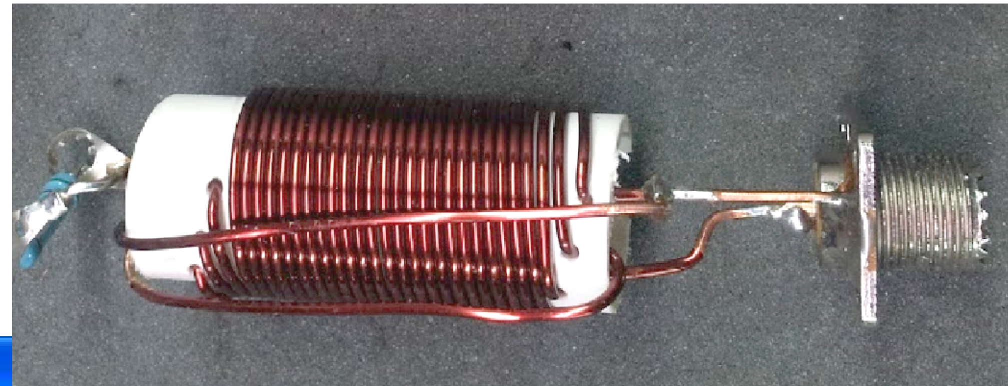
Commercial Balun #4

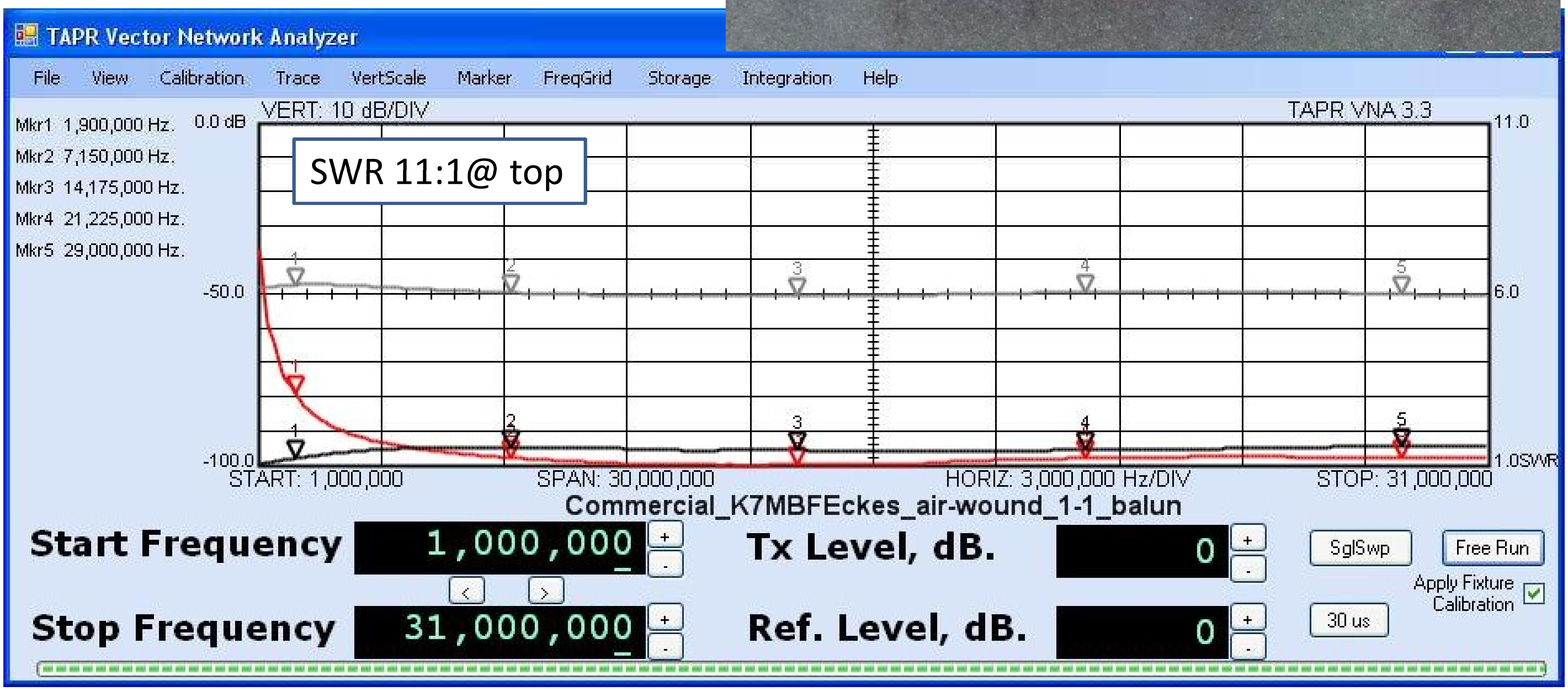
- 1:1, Much Better!
- 1.4:1 @ 10m & 1.2:1 @ 15m



Commercial Balun #5, Unknown Source

- 1:1, Best so Far!
- ~1.7:1 @ 80m, but ~1.3:1 through 10m!





Home-Brew Examples

- Ruthroff (voltage) baluns – rely on flux in a ferrite
- Guanella (current) baluns – transmission lines, nearly zero flux, on a ferrite which is used to provide a choking impedance to shield currents

My Resources

- Understanding, Building, and Using Baluns and Ununs, Theory & Practical Designs, by Jerry Sevick, W2FMI, CQ Communications, Inc
- Transmission Line Transformers, by Jerry Sevick, W7FMI, Noble Publishing, Atlanta

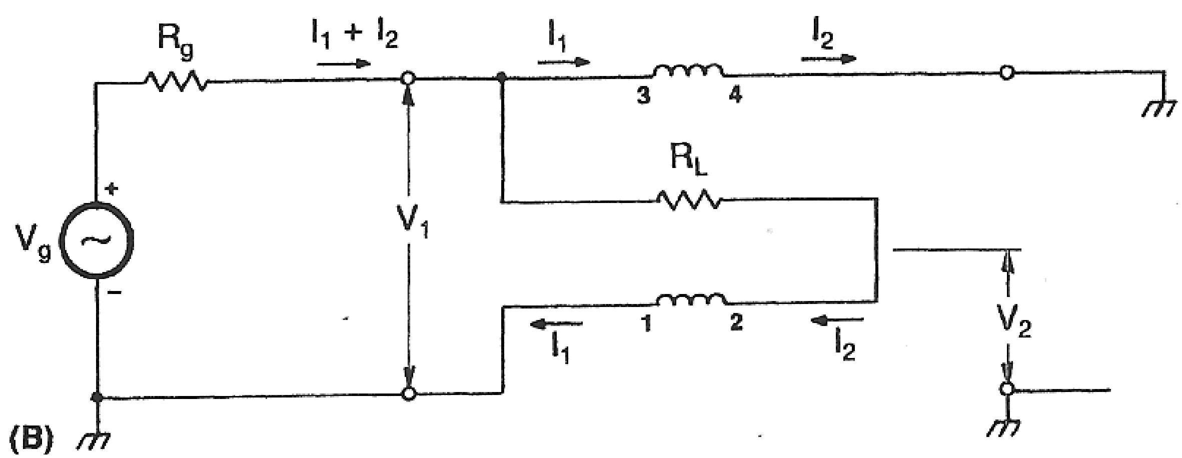
My Materials (mostly per Sevick)

- Cores/Beads
  - T-200-2 (perm µ 10), powdered iron, large dia, part of $6 kit
  - K (perm µ 290), NiZn ferrite,
    - 1.25" $1.75
    - 1.5" $7.00
    - 2" $11.50
  - Mix 43 (perm µ 800), NiZn ferrite,
    - 1 3/8" $1.52
    - 2 3/8" $3.94
  - Mix 31 (perm µ 1500), MnZn bead
    - $1.69

- Wire & Tape
  - #14 Copper wire, Imideze insulation
  - #16 Copper wire, enamel insulation
  - #18 Hookup wire (stranded)
  - Scotch 27 Glass electrical tape, maintain parallel lines
  - 3M Polyimide Type 97 tape, provide desired line impedance

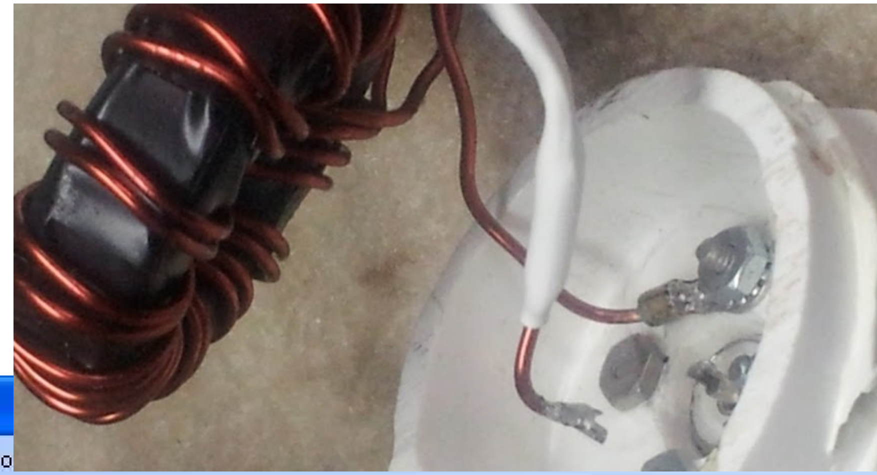
Ruthroff (voltage) Baluns/Ununs

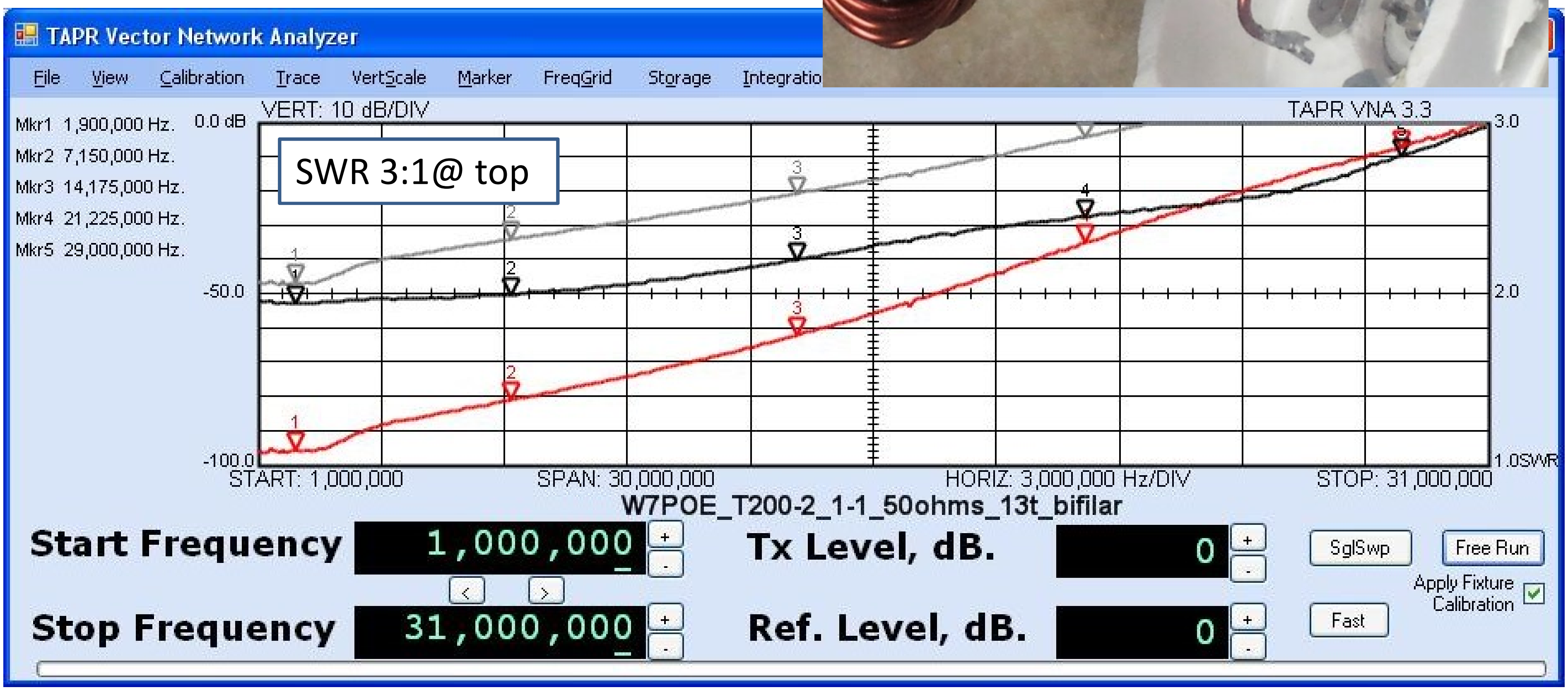
- Rely on flux in the core to couple between windings
- Generally add delayed to direct signals (4:1 shown)
- More susceptible to saturation (harmonics) and overheating
- Bifilar and Trifilar windings



Commercial Kit, Ruthroff 1:1 Balun

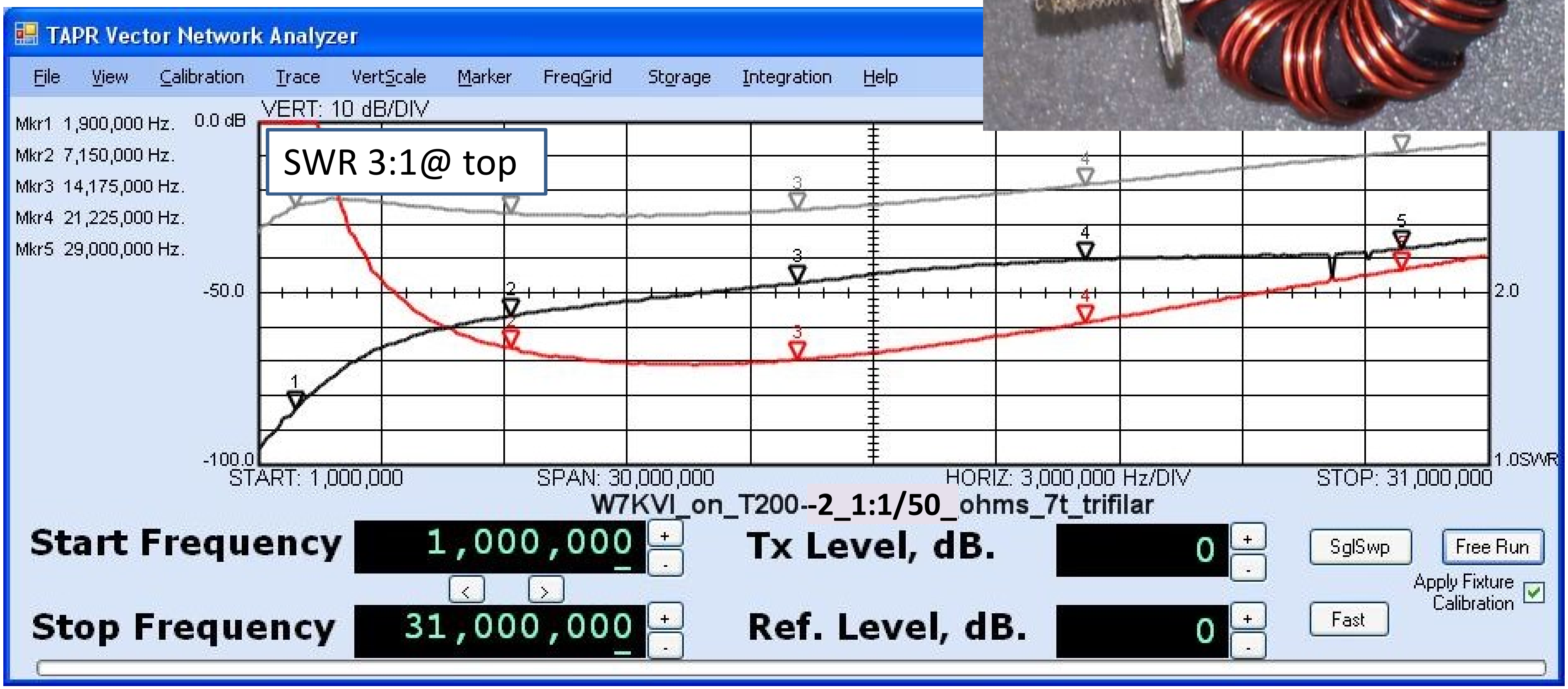
- T-200-2 core (µ 10), bifilar, flux-coupled
- Poor performance 20m (1.8:1) & above





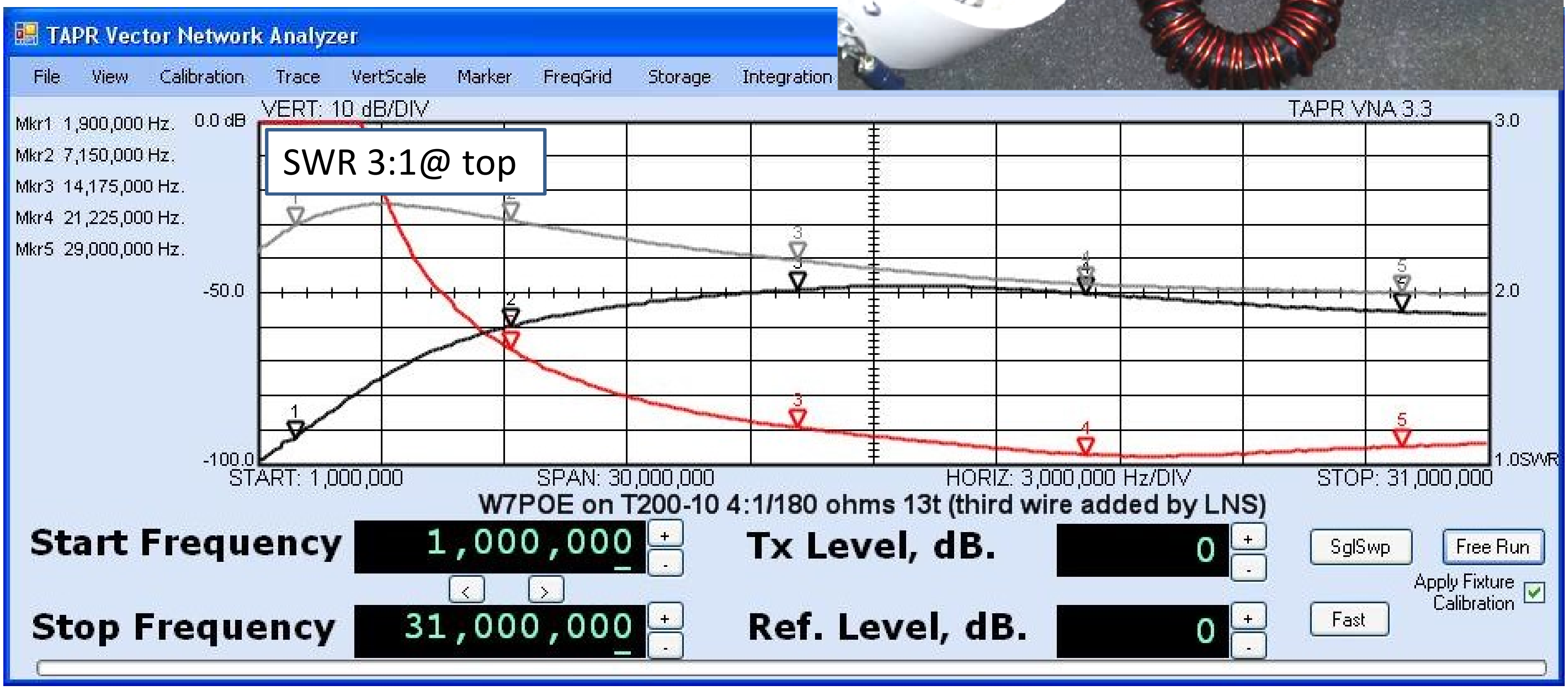
Commercial Kit, 2nd ver Ruthroff 1:1 Balun

- T-200-2 core (µ 10), Trifilar, flux-coupled, 7 turns
- Best SWR 1.6:1, generally poor – insufficient turns and/or µ



Commercial Kit, Ruthroff 4:1 Balun

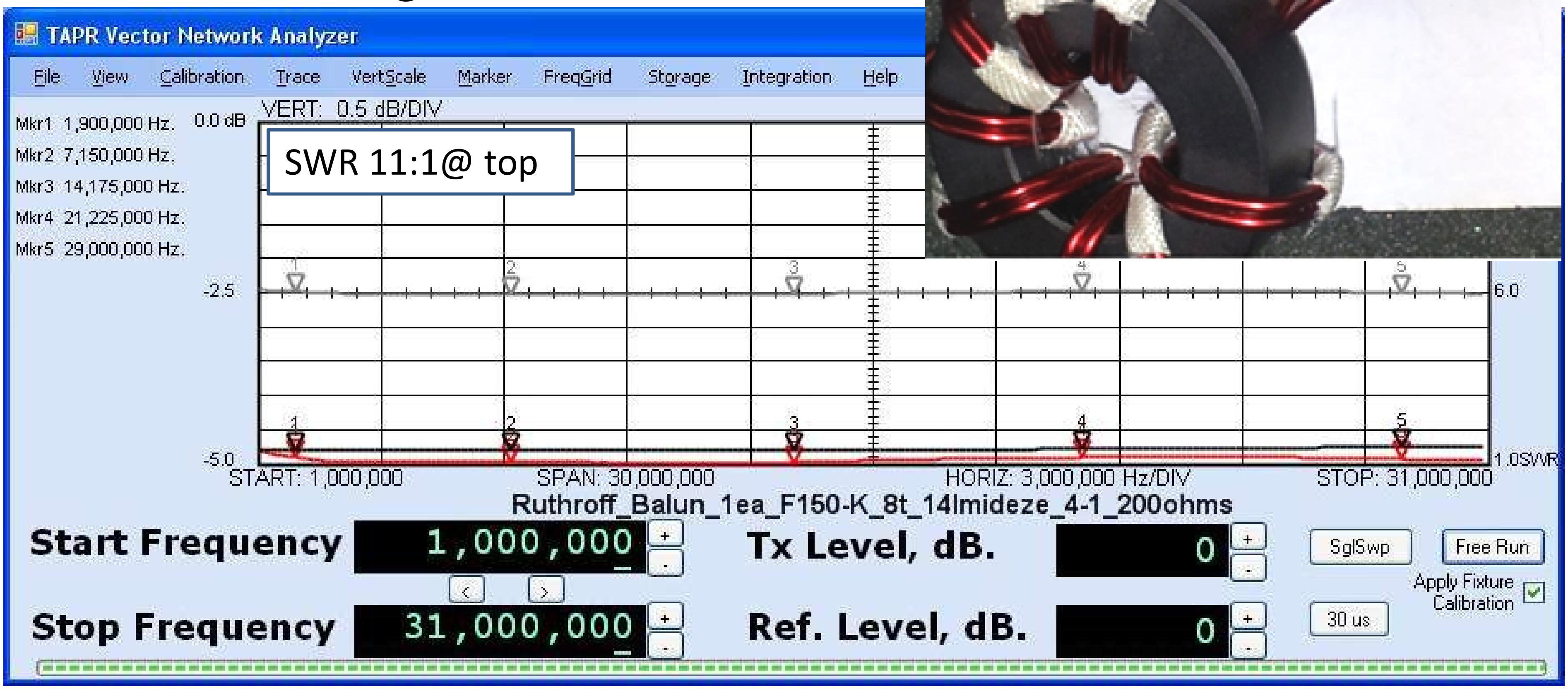
- T-200-2 core (μ 10), Trifilar, flux-coupled, 13 turns
- Poor @ 3:1 80m, 1.7:1 40m, OK 20m & above



4:1 Ruthroff Balun

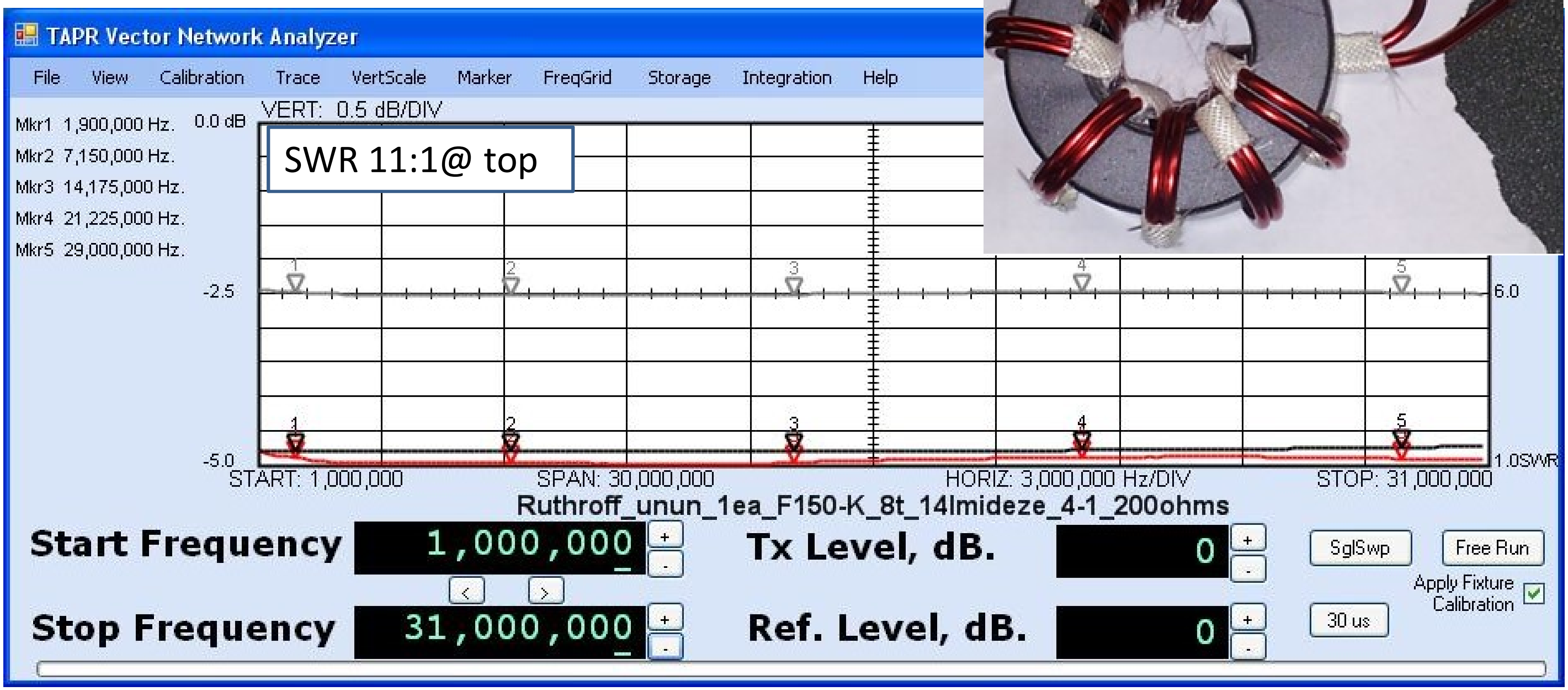
- 1.5” K core (µ 290), flux-coupled, much better core

- Outstanding!



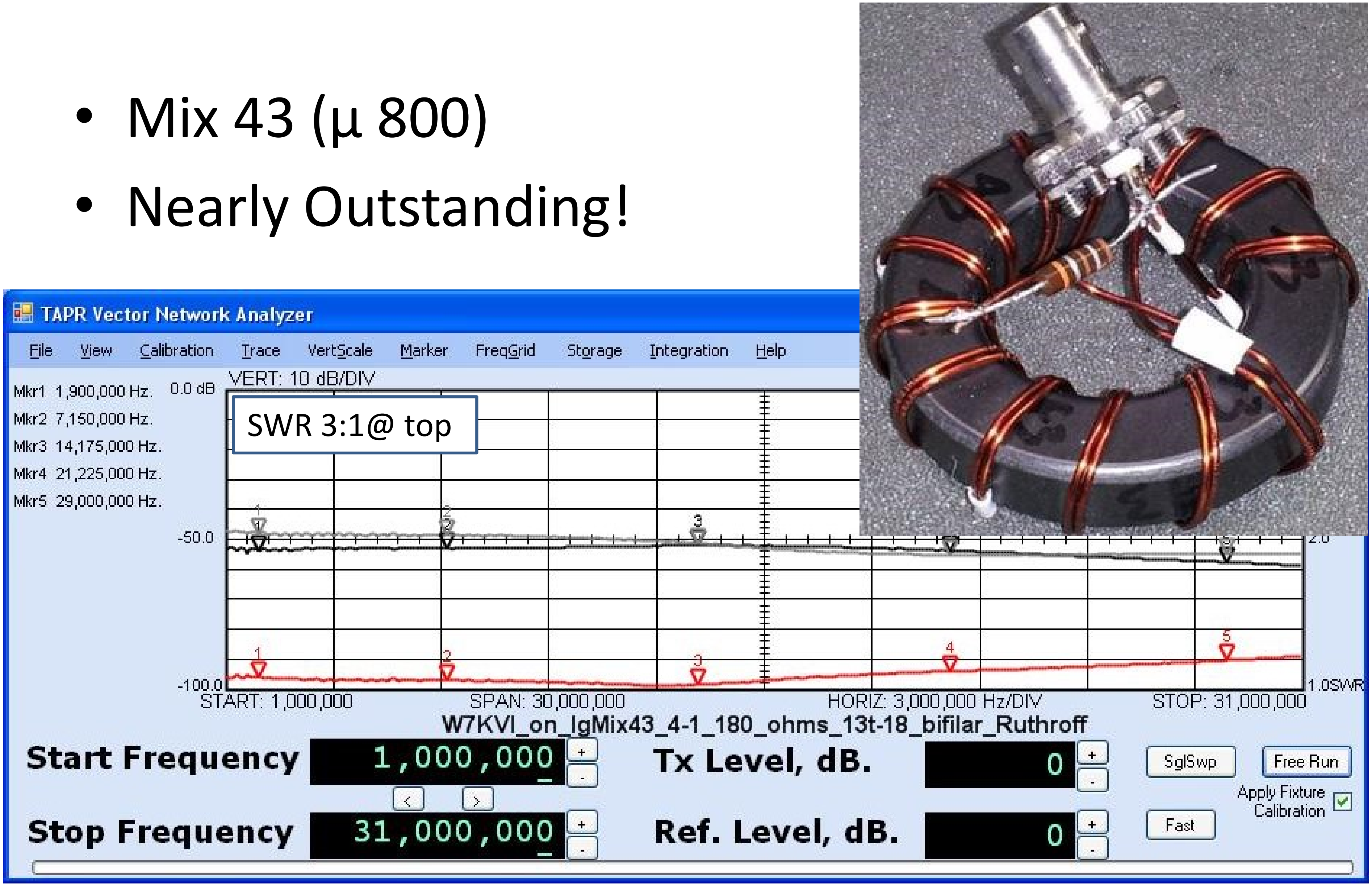
4:1 Ruthroff Unun

- 1.5” K core (µ 290), flux-coupled, much better core
- Outstanding!



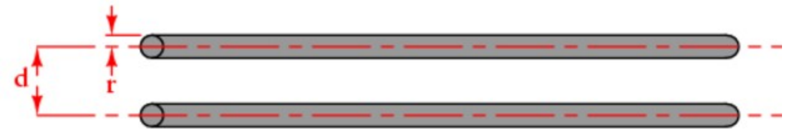
4:1 Ruthroff Balun, Large Mix 43 Core

- Mix 43 (µ 800)
- Nearly Outstanding!



Guanella (current) Baluns/Ununs

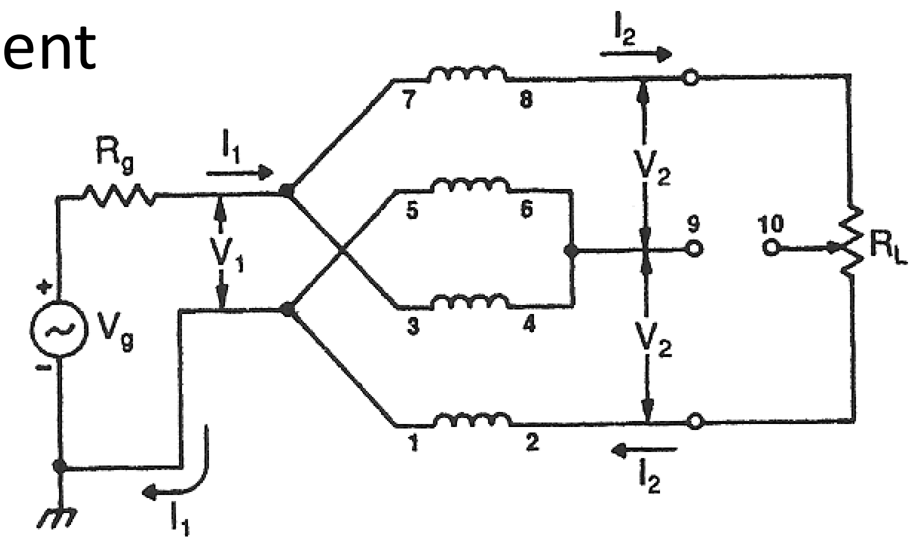
- Rely on parallel transmission lines rather than flux in core
- As a result, very little concern about saturation (harmonics) and overheating
- Reasonably high µ core required to provide sufficient choking action
- Generally add in-phase signals (4:1 shown)



$$Z_0 = \frac{276}{\sqrt{k}} \log \frac{d}{r}$$

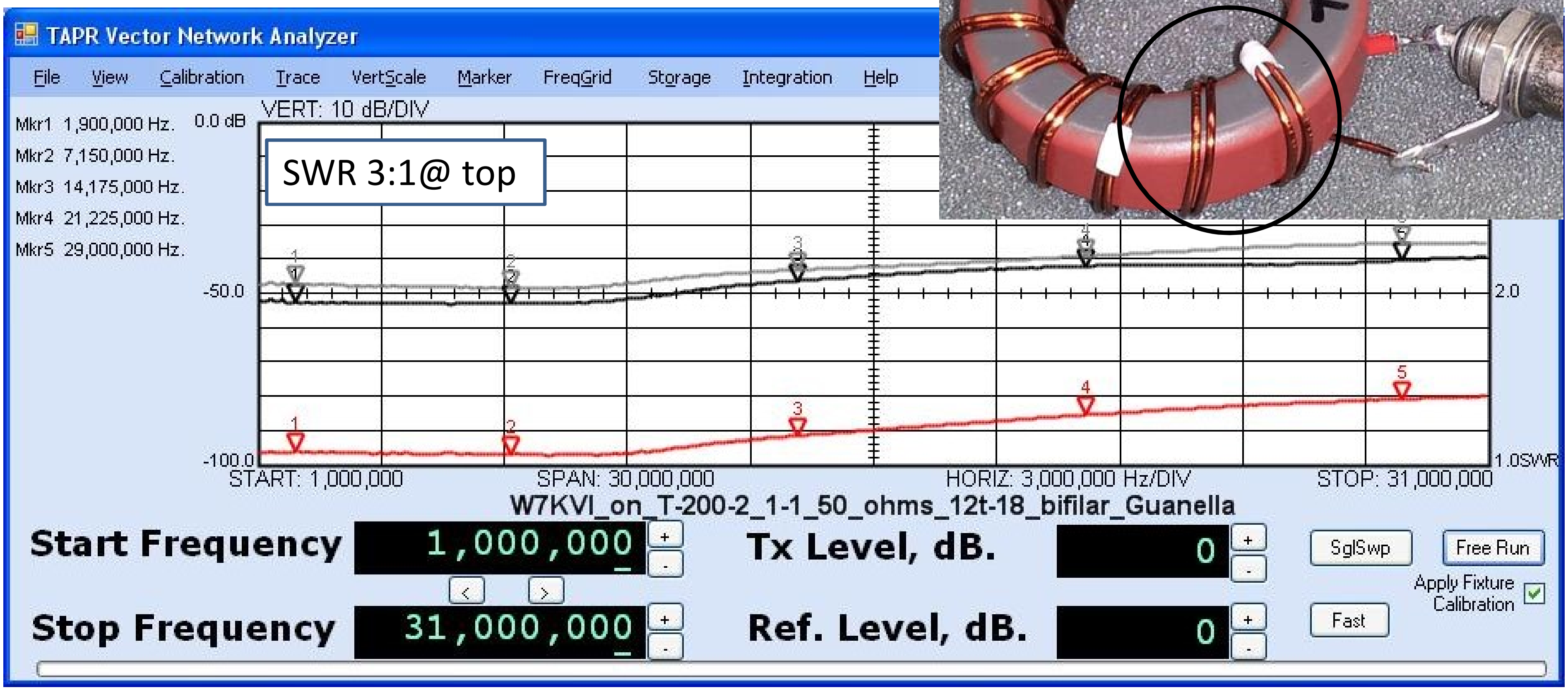
Where,

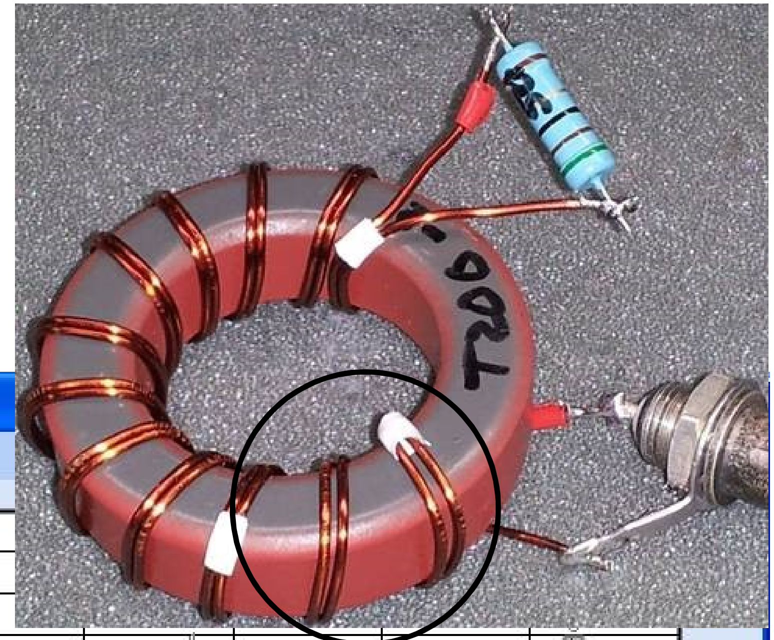
Z_0 = Characteristic impedance of line
d = Distance between conductor centers
r = Conductor radius
k = Relative permittivity of insulation between conductors



1:1 Guanella, T-200-2 core

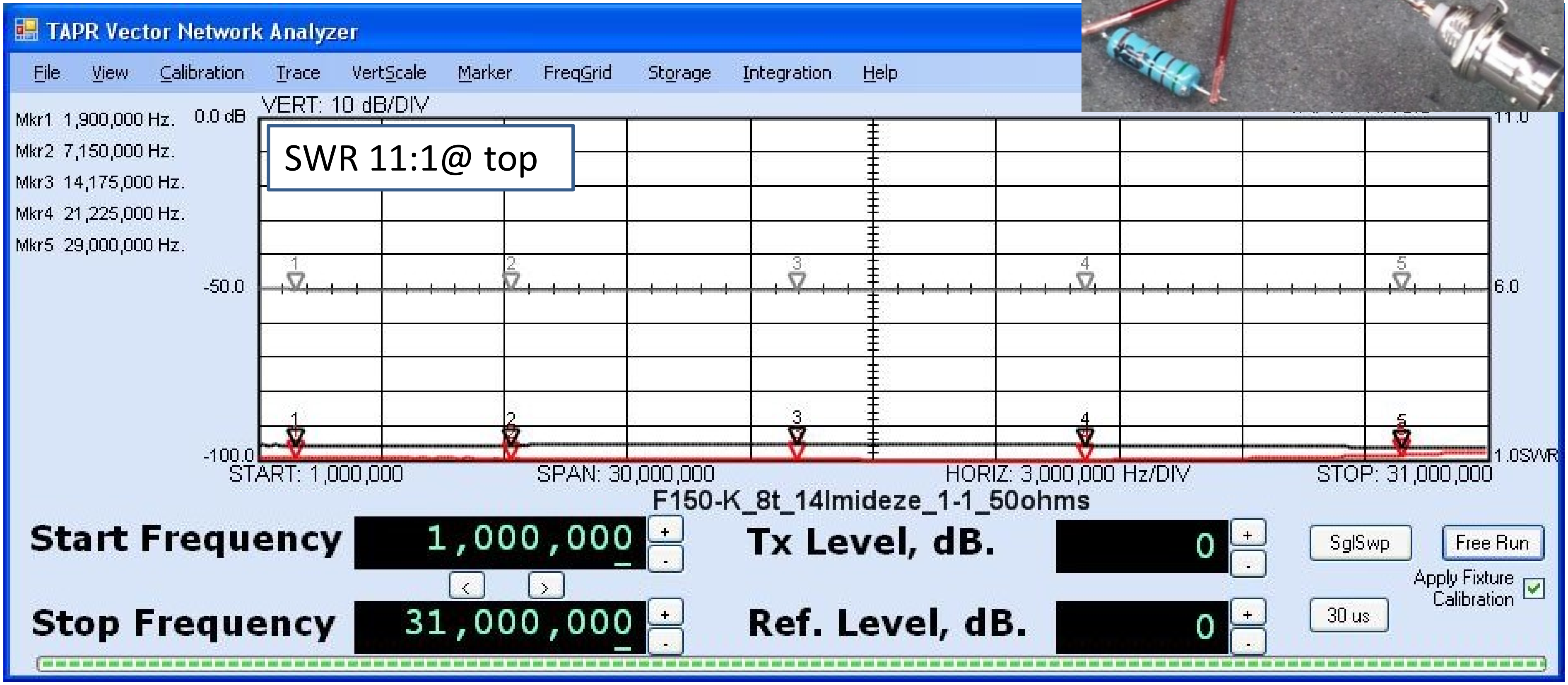
- T-200 (µ 10), transmission line (no/low flux), spacing not well maintained
- Amazing for low perm core!
  1.4 SWR @ 10m
- Insufficient choking, due low µ





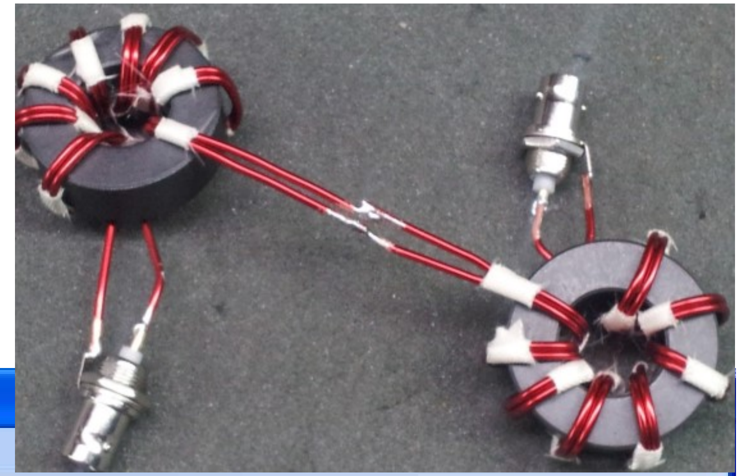
1:1 Guanella, K core - #1 of 3

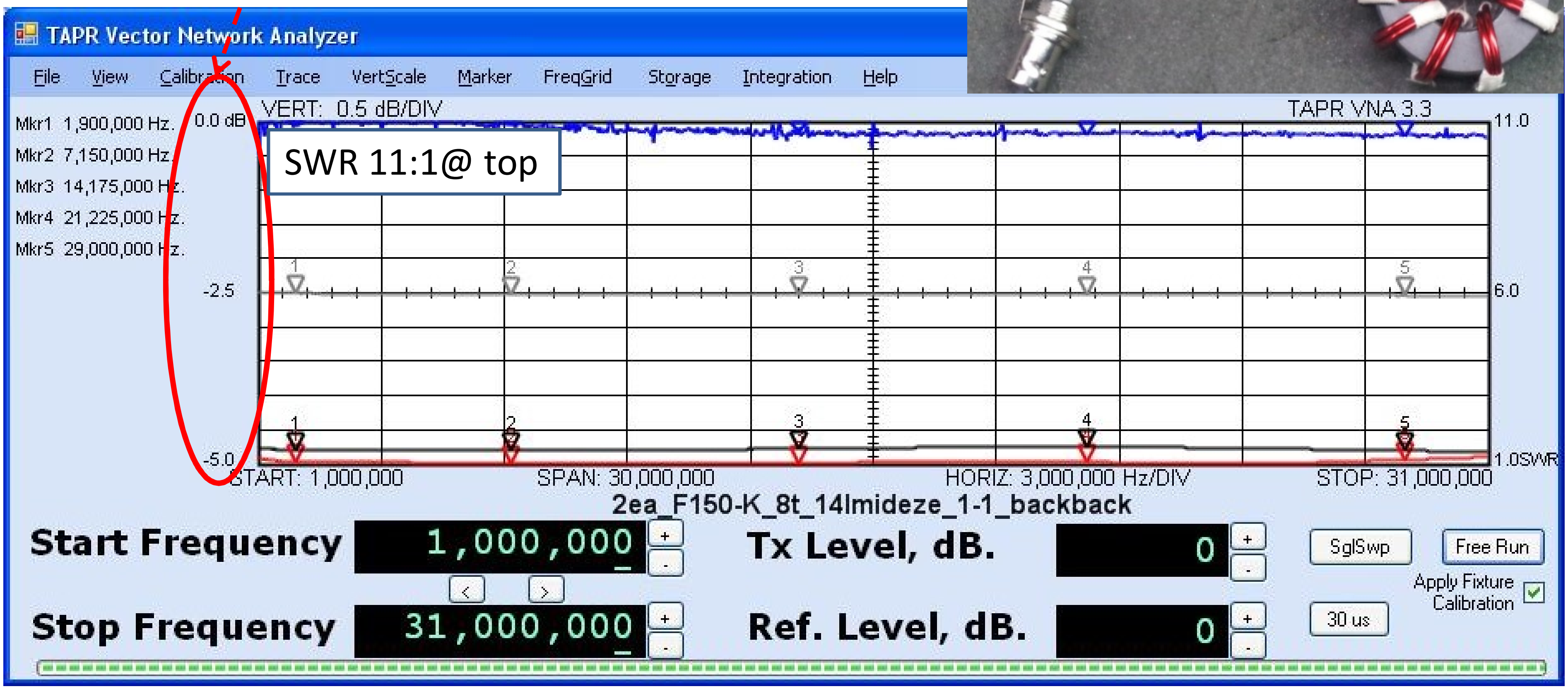
- Medium K core (µ 290), #14 wire, transmission line (no/low flux)
- Zline 25 ohms impedance very good (flat SWR, R, X)



1:1 Guanella, Back-back, loss measurement - #2 of 3

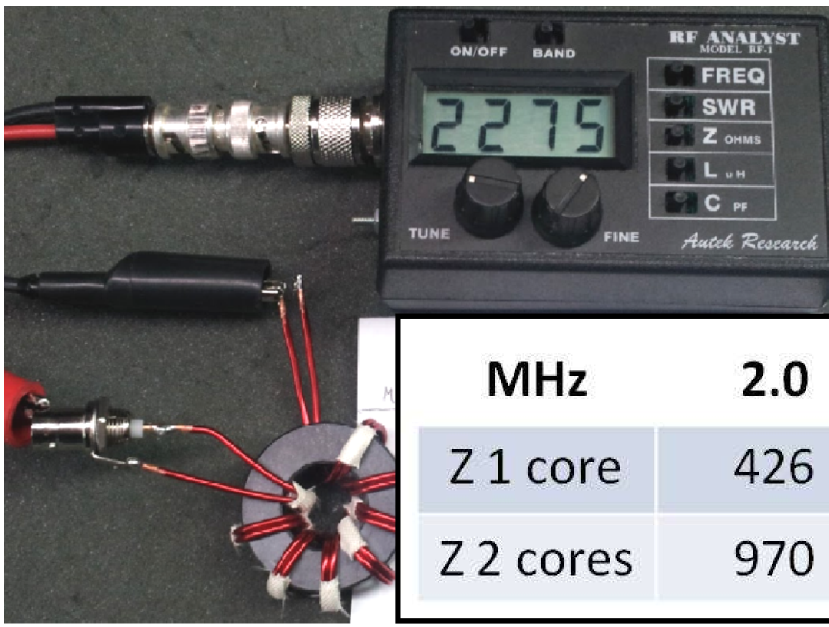
- 2 identical cores as previous slide for loss measurement
- New blue trace on graphic – loss for 2 cores at 0.5 dB per division
- @ 10m, ~0.1 dB loss per core or ~98% eff.!





1:1 Guanella, K core – Sufficient choking? #3 of 3

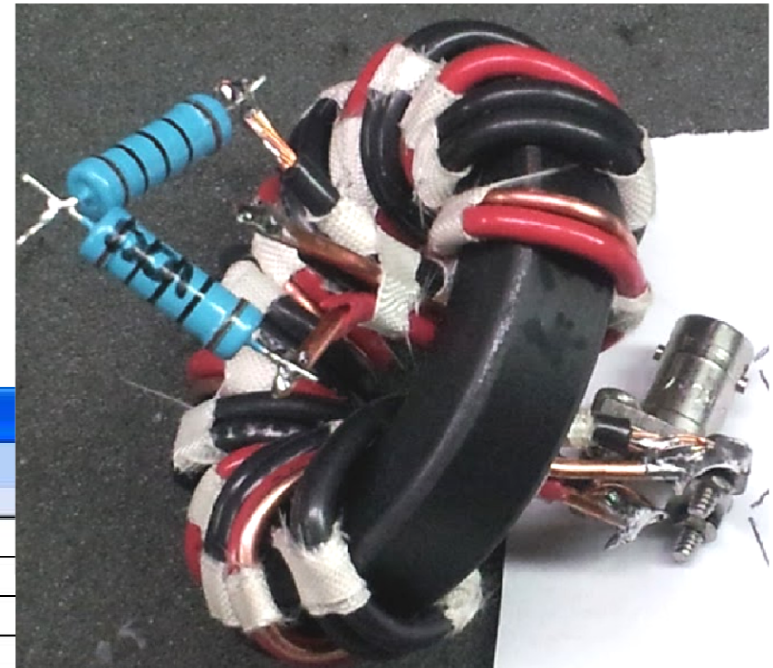
- Measure input shield to (balanced) output lead
- Z ≥ ~500' (10 times characteristic impedance) except for 10m, use more turns for better 10m choking performance

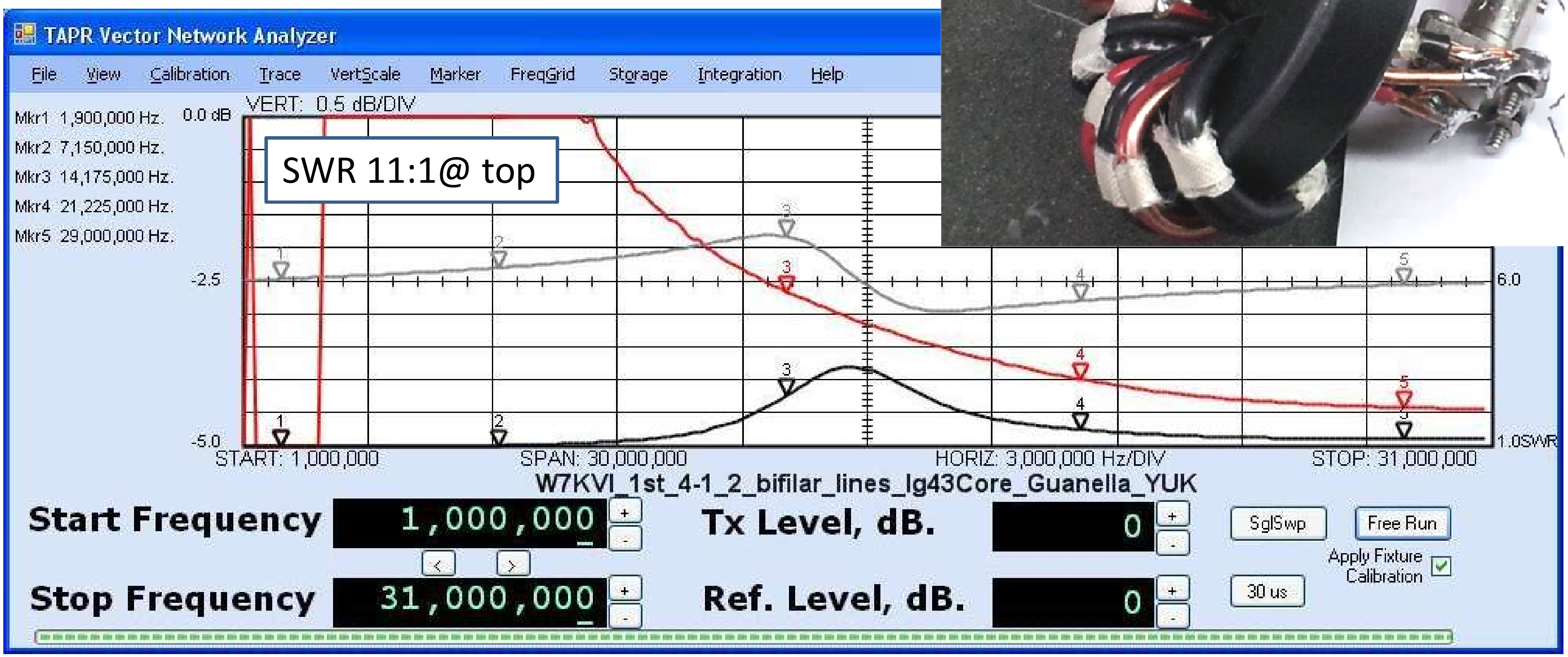


MHz	2.0	3.7	7.1	15.6	29.0
Z 1 core	426	1180	2360	625	290
Z 2 cores	970	>>1K	1720	557	280

4:1 Guanella, 1st Effort - YUK

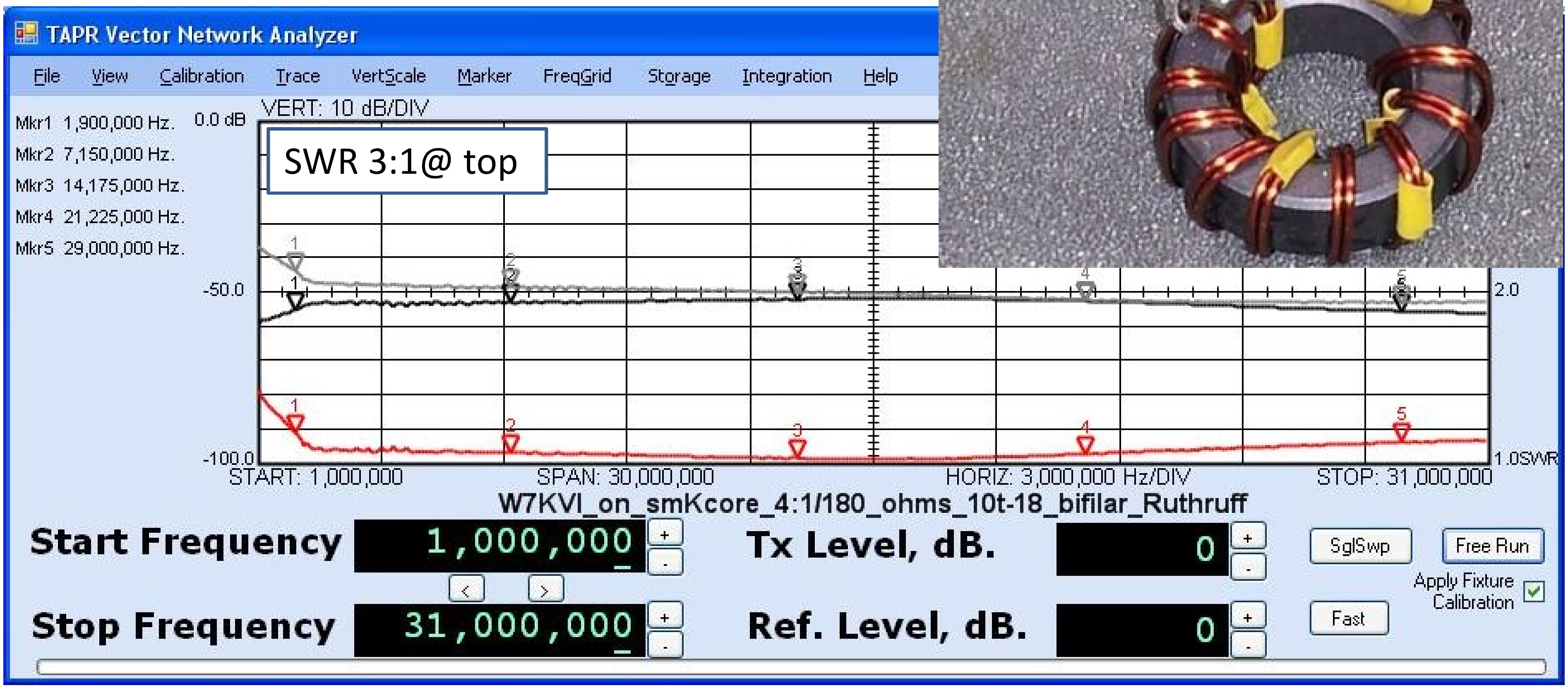
- Mix 43 core (µ 800), intended transmission line Z100 - #12 house wiring, but one line solid, one stranded, removed one insulation to lower Z
- Something major wrong! Stranded wire too flexible – difficult to maintain spacing





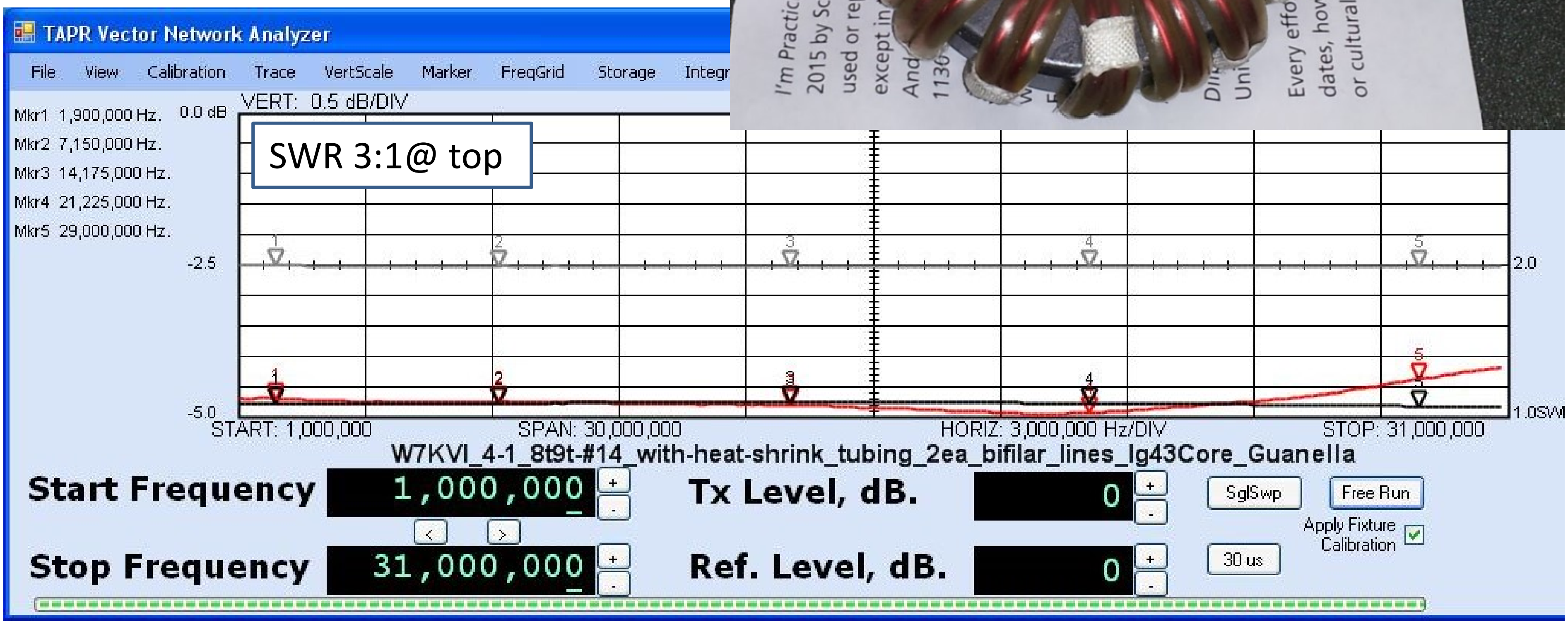
4:1 Guanella Balun, K core

- Medium K core (μ 290), transmission line Z100
- Nearly Outstanding! Wire dia a bit too small, R sags a bit @ 10m



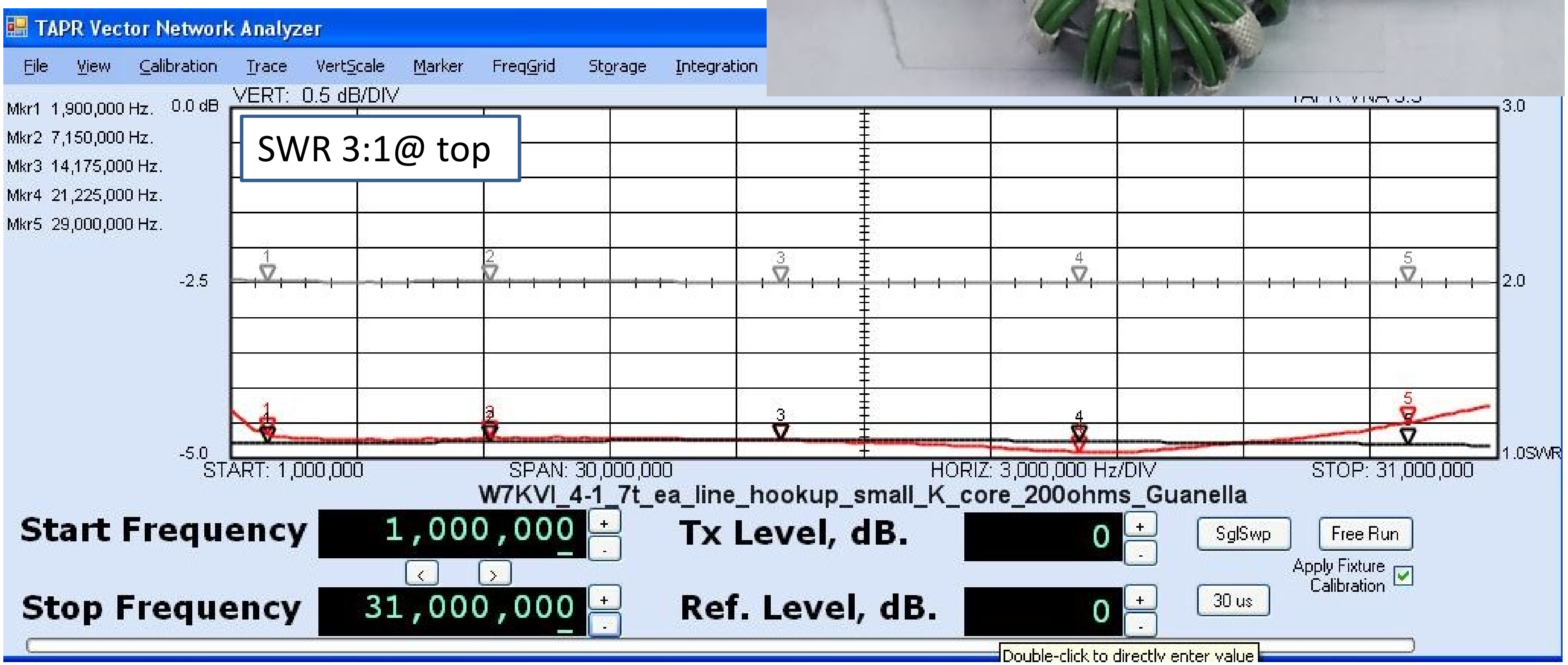
4:1 Guanella, “High-power” Mix 43

- Large 43 (µ 800), transmission line (no/low flux), #14 wire with sleeving for Zline = 100 ohms
- Nearly Outstanding! 1.1:1 except 1.3:1 10m



4:1 Guanella, "Low-Power"

- Smallest K (µ 290), transmission line (no/low flux), hookup wire
- 1.2:1 or better, 160-10m
- 100w continuous, 300w peak
- Very small, light, inexpensive



Some Conclusions

- Commercial baluns may have poor or mediocre performance – testing required
- Ruthroff (voltage) baluns work well if core has sufficiently high permeability (well above 10!)
  - Flux-based, can be saturated (harmonic generation) and overheat
- Guanella (current, transmission line) baluns always worked well, even on low-perm cores
  - No/low flux, so saturation (harmonic generation!) and heating are likely not an issue
  - But….low-perm cores not likely to provide sufficient choking action
- Choosing the right core is key!
- Baluns are easy and inexpensive to make.

End

- Thanks for listening!
- Q & A, More Discussion
- Next Steps?
  - – Balun-measuring session - bring any baluns not in the air!
  - – Balun-building session – Interest?

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