# IMPROVED MATCHING OF

# A SEVEN BAND ZS6BKW TYPE ANTENNA

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## SUMMARY


The ZS6BKW antenna is an improved multi band version of the G5RV.  It is a shortened dipole on 80m.

The ZS6BKW antenna needs two feeder lengths to cover 80, 40, 20, 17, 15, 12, 10m bands.

The shorter feeder is required on 80m and 15m, while the longer feeder is required to cover the other bands.

This means switching in an additional feeder length to cover the 40, 20, 17, 12, 10m bands.

Here I designed an inverted Vee version of the ZS6BKW that implements the additional feeder length using a Tee circuit:  It uses two series inductors and a shunt capacitor connected in the middle. The Tee circuit is optimized to limit the SWR to less than 2:1 on 40, 20, 17, 12m bands. On 10m the SWR is less than 3:1 over the full band of 28 MHz to 29.7 MHz.

The Tee matching circuit is connected between the ladder line and the 50 ohm coax balun. It is switched in/out using two DPDT relays which are operated via DC voltage on the coax feeder. SWR losses are minimized since the matching circuit is connected at the end of the ladder line.

The 80m band does not use any matching and was set to provide the minimum VSWR at 3750 KHz. This SWR minimum is around 3.5:1, when measured at the end of a 50 foot length of RG-8. Simulations show that it is possible to add the 80m band to the 40, 20, 17, 12, 10m bands by adding a series capacitor, as shown on pages 22 and 23.

The 15m band uses an optional correction circuit that shifts the resonance slightly at midband. The L – C – L circuit must be bypassed for this band.

This is a well balanced antenna that minimize the RX noise and the TX shield currents.

# SIMULATIONS using Eznec+ V6.0

Wires — Ref: G5RV-Inverted Vee NO TRL 2x 39.5pi.ez

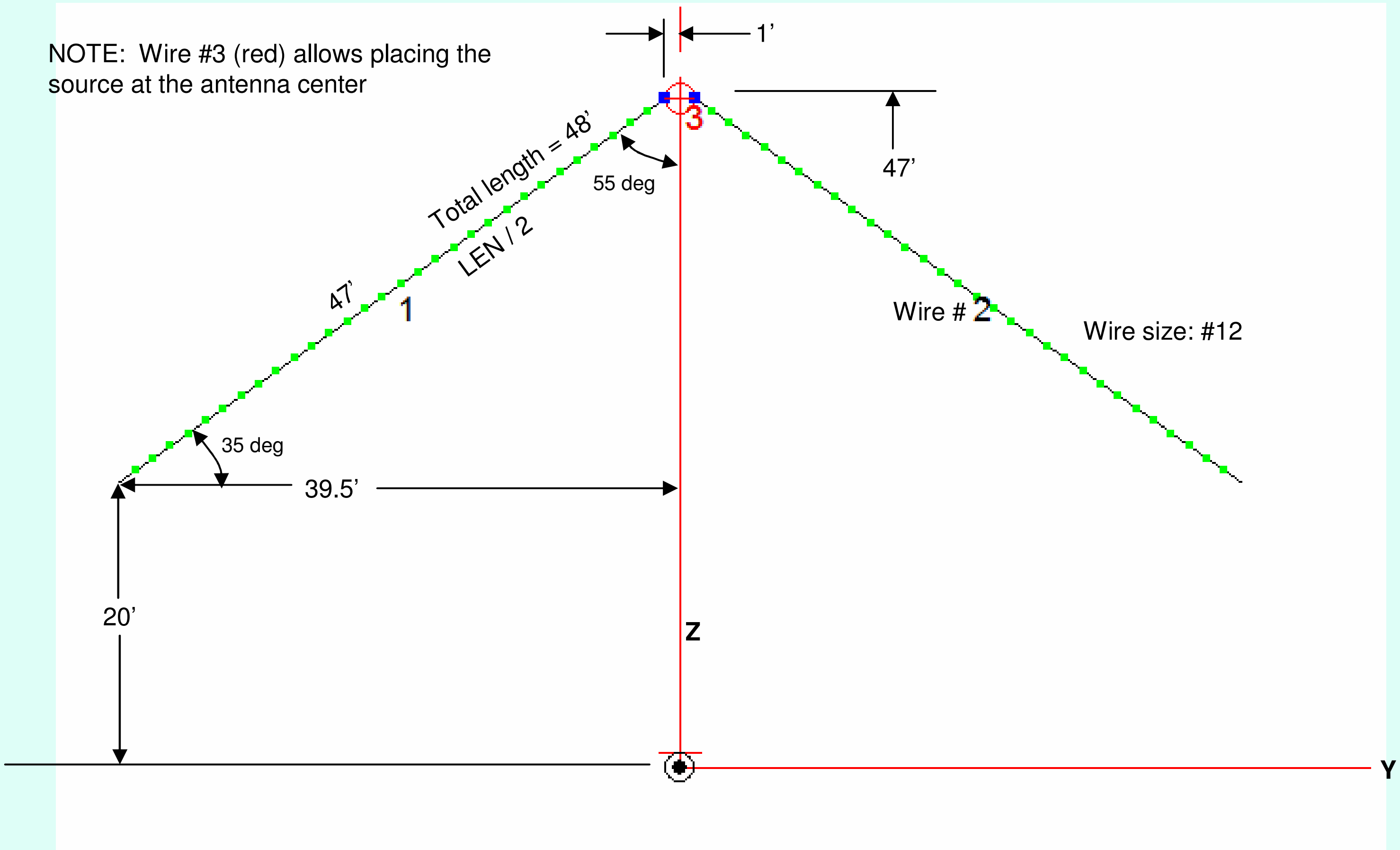
Wire Create Edit Other

☐ Coord Entry Mode ☐ Preserve Connections ☑ Show Wire Insulation

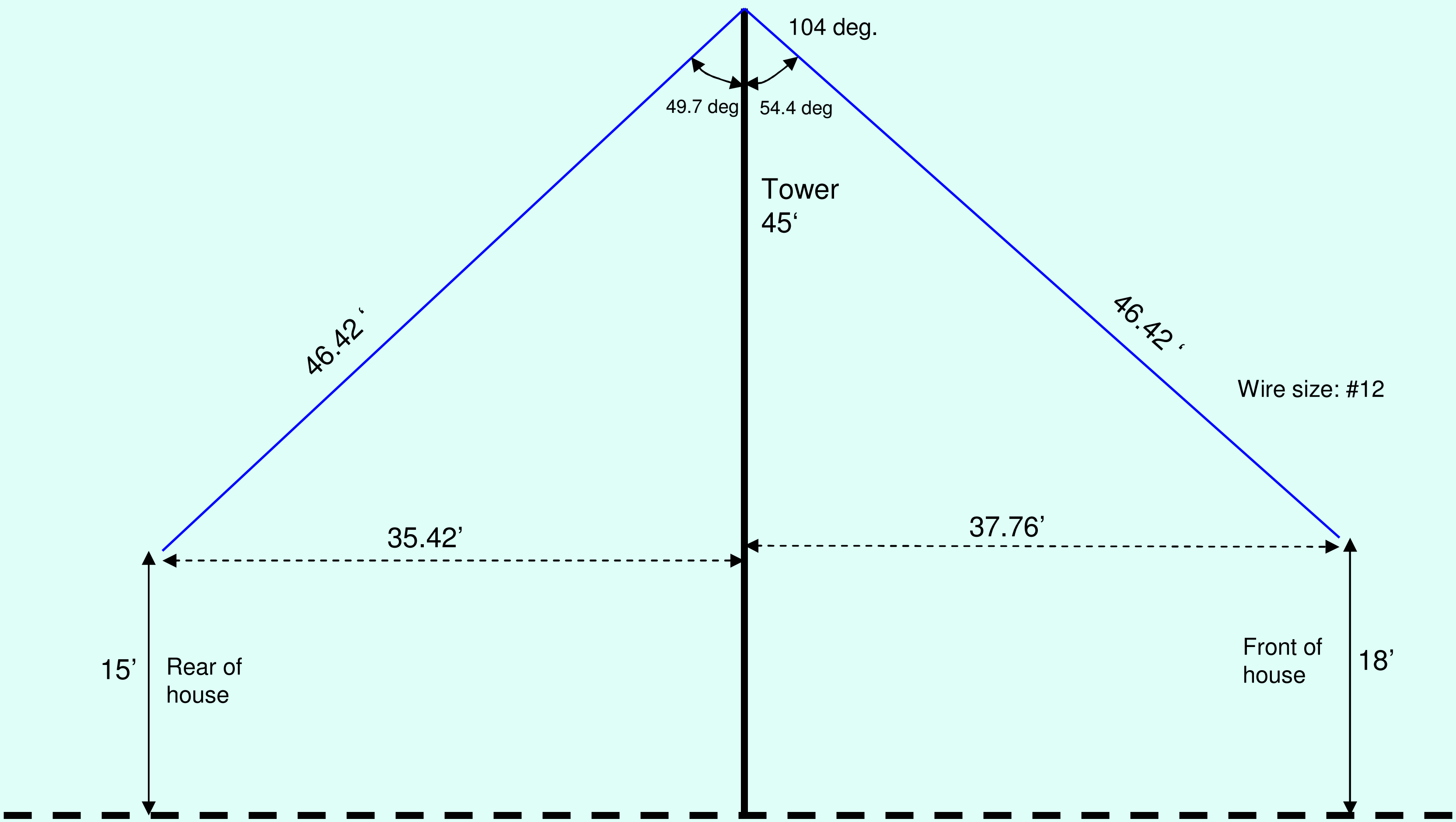
Wires

| No. | End 1 | | | | End 2 | | | | Diameter | Segs | Insulation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | X (ft) | Y (ft) | Z (ft) | Conn | X (ft) | Y (ft) | Z (ft) | Conn | (in) | | Diel C | Thk (in) |
| 1 | 0 | -1 | 47 | W3E1 | 0 | -39.5 | 20 | | #12 | 31 | 1 | 0 |
| 2 | 0 | 1 | 47 | W3E2 | 0 | 39.5 | 20 | | #12 | 31 | 1 | 0 |
| 3 | 0 | -1 | 47 | W1E1 | 0 | 1 | 47 | W2E1 | #12 | 1 | 1 | 0 |

NOTE: Wire #3 (red) allows placing the source at the antenna center

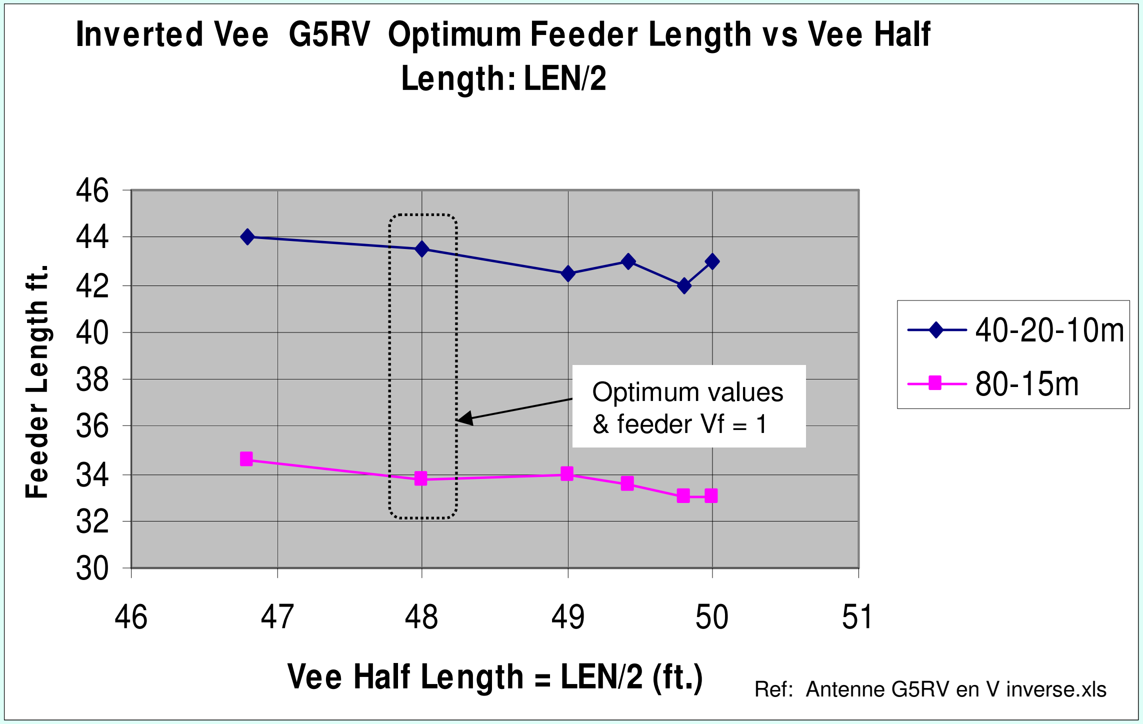


# INVERTED VEE as BUILT




Delhi Tower: 48' - (6 sections * 6") = 45'
Antenna wire length = 50' - 43" = 46.42' after adjustment with short feeder to give SWR minimum at 3.75 MHz.

# SIMULATIONS RESULTS




- The optimum combination of Vee half length and feeder length is found first at 80 and 15m.
- Then the feeder length is increased to optimize VSWR on 10, 12, 17, 20, 40m.
- The feeder impedance used in the simulations was 400 Ω.

**Optimum Values found from simulations,**
**Giving best VSWR** from 10, 12, 15, 17, 20, 40, 80m

Vee Half Length = LEN/2 = 48 ft.
Feeder = 33.7 ft @ 15m and 80m (Vf=1)
Feeder = 43.5 ft @ 10, 12, 17, 20, 40m (Vf=1)

Note that the dipole first resonance (Fo) occurs at 4.875 MHz
The second resonance (3.Fo) occurs at 14.625 MHz
The third resonance (5.Fo) occurs at 24.375 MHz

The 33.7 ft feeder quarter wave resonance occurs at 7.3 MHz, 21.9 MHz
The 33.7 ft feeder half wave resonance occurs at 14.6 MHz.

The 43.5 ft feeder quarter wave resonance occurs at 5.6 MHz, 17 MHz
The 43.5 ft feeder half wave resonance occurs at 11.3 MHz.

## Velocity Factor Measurement on my ‘400’ ohms Transmission Line

Z = SQRT(L/C) Where L measured with line shorted, C is measured with line opened.

L = 10.457 µH C = 62.025 pF measured @ 100 KHz with my UT612 LCR Meter.

Z = 410.6 Ω This value will be used in the simulations.

c = speed of light λ=wavelength f in Hz Vf = velocity factor len = length of TRL in feet

$c = 3 \cdot 10^{8} \ \frac{m}{sec}$ $c = 9.84 \cdot 10^{8} \ \frac{feet}{sec}$ $c := 9.84 \cdot 10^{8}$

$\lambda \cdot f = c \cdot Vf$

$Vf = \frac{\lambda \cdot len \cdot f}{c}$ λ = 2 for 180 deg resonance, Test in series transmission mode
λ = 4 for 90 deg resonance Test in shunt transmission mode

$len := 22.167$ $\lambda := 2$ $f := 19.89$ MHz

$Vf := \frac{\lambda \cdot len \cdot f \cdot 10^{6}}{c}$ $Vf = 0.896$

$len := 22.167$ $\lambda := 4$ $f := 9.9$ MHz

$Vf := \frac{\lambda \cdot len \cdot f \cdot 10^{6}}{c}$ $Vf = 0.892$

Averaged Vf used = 0.894

TRL = 33.7*0.894 = 30.13 ft = 30 ft + 1.5 in.

**NOTE**: 33.7 ft is the value used for antenna simulations with Vf = 1
Initial feeder length = 30 ft + 1.5 in.

**The revised feeder length is 29 ft + 9.6 in. after substracting 4 in. (from the matching circuit)**

# REPLACING THE 9.8 FT FEEDER BY L – C CIRCUITS

Feeder = 33.7 ft @ 15m and 80m (@ Vf=1)
Adding 9.8 ft is required to obtain the 43.5 ft below to cover the five additionnal bands.
Feeder = 43.5 ft @ 10, 12, 17, 20, 40m (@ Vf=1)

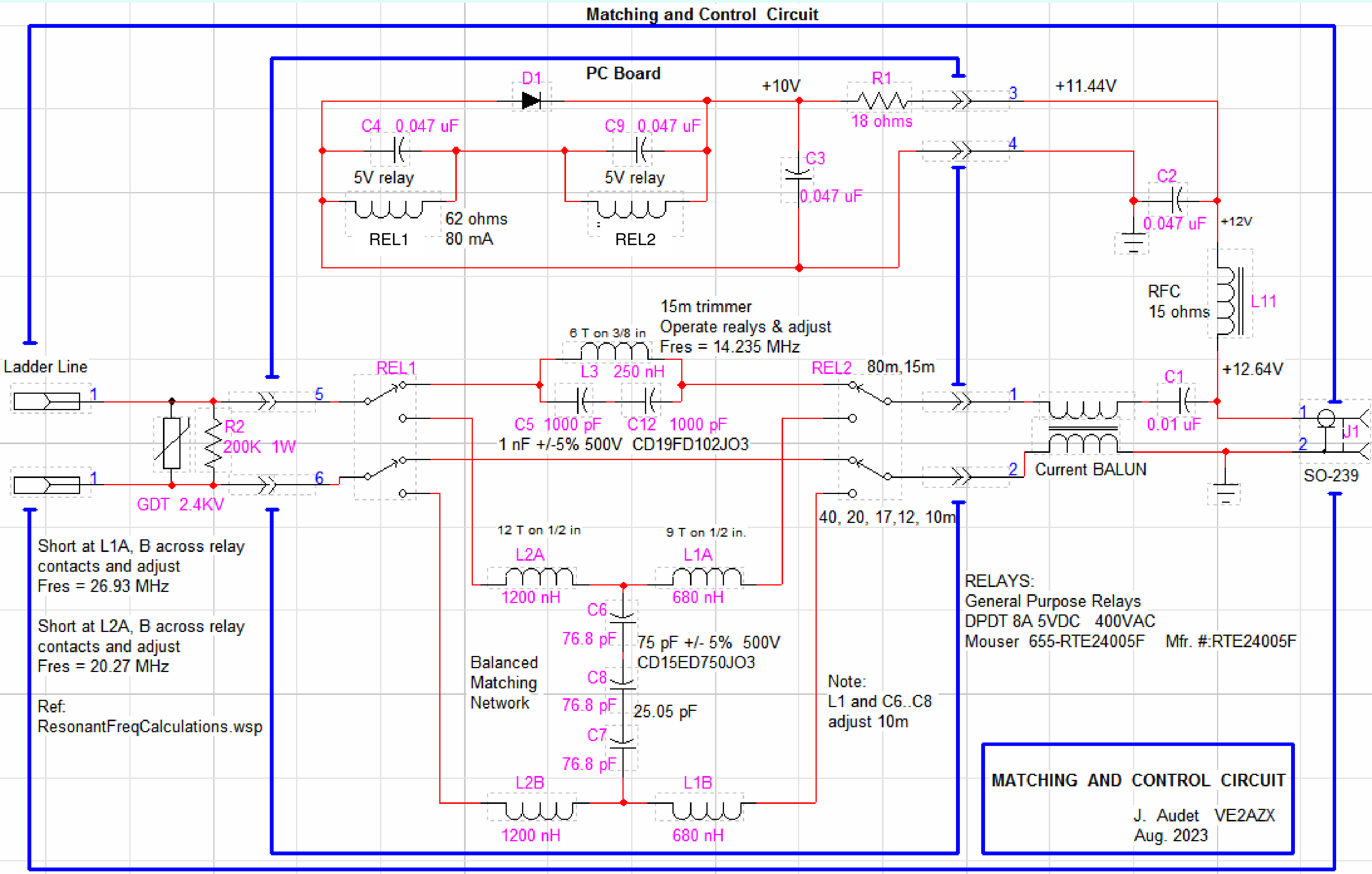
The additional 9.8 ft may be realized using a double PI circuit using 3 shunt caps and 2 series inductors.
The VSWR will remain unchanged when the 9.8 ft line or the double PI is switched in.
It was found that a double PI which behaves like a 550 ohms line will further improve the VSWR.

Is this an optimal solution ?
**NO !**

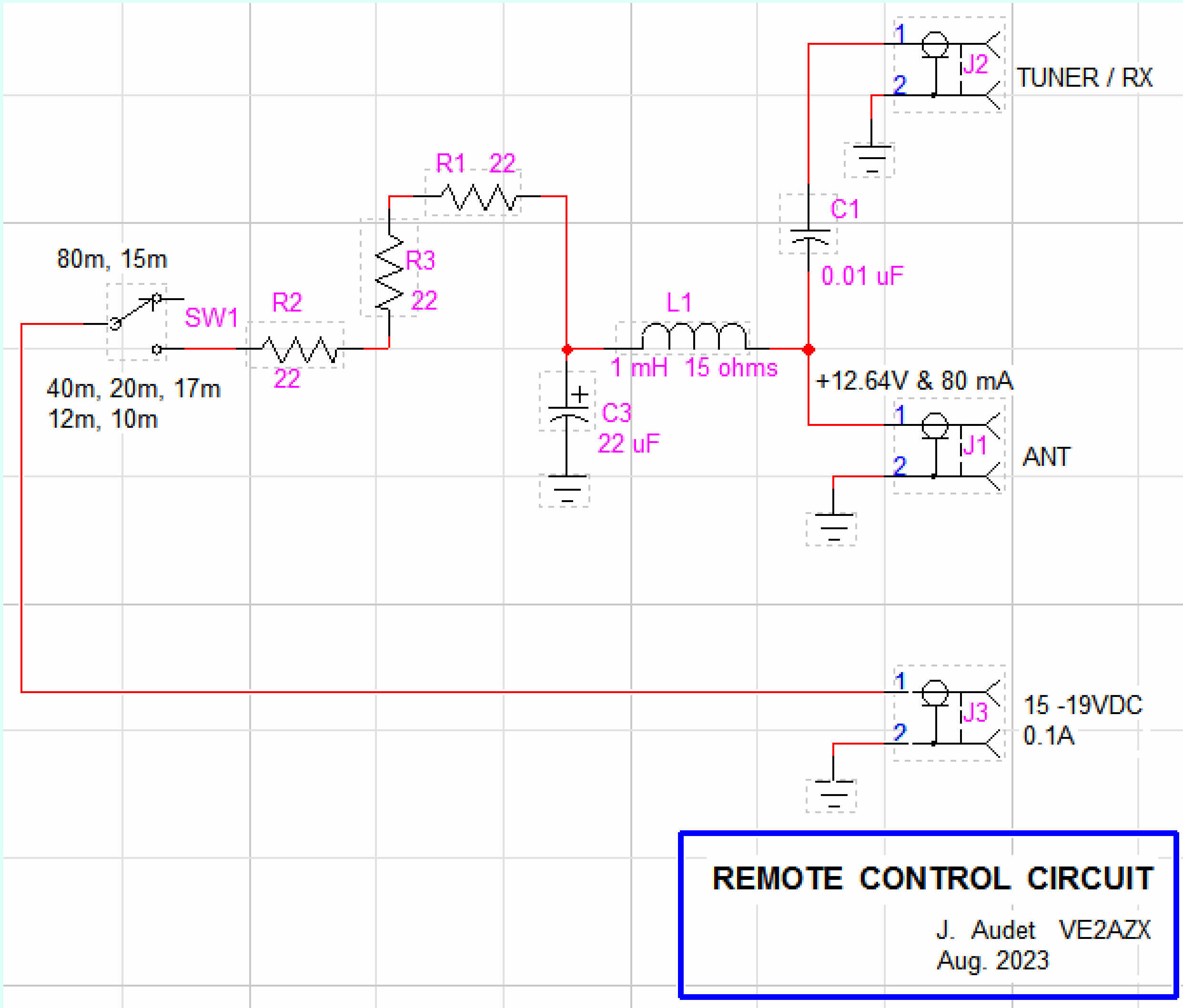
The double PI components values may be optimized to improve VSWR on 10, 12, 17, 20, 40m bands.
The result is a circuit having a Tee configuration, where we have:
L series … Cshunt …Lseries
Three components instead of five are now required to optimize matching.
And the VSWR is below 2:1 and centered on the 12, 17, 20, 40m bands and below 3:1 on 10m !

For the 10, 12, 17, 20, 40m bands, the new matching circuit is switched in with two DPDT relays using DC voltage sent on the coax feed line.
For the 80m and 15m bands the matching circuit is bypassed.

# OPTIMIZED MATCHING CIRCUIT

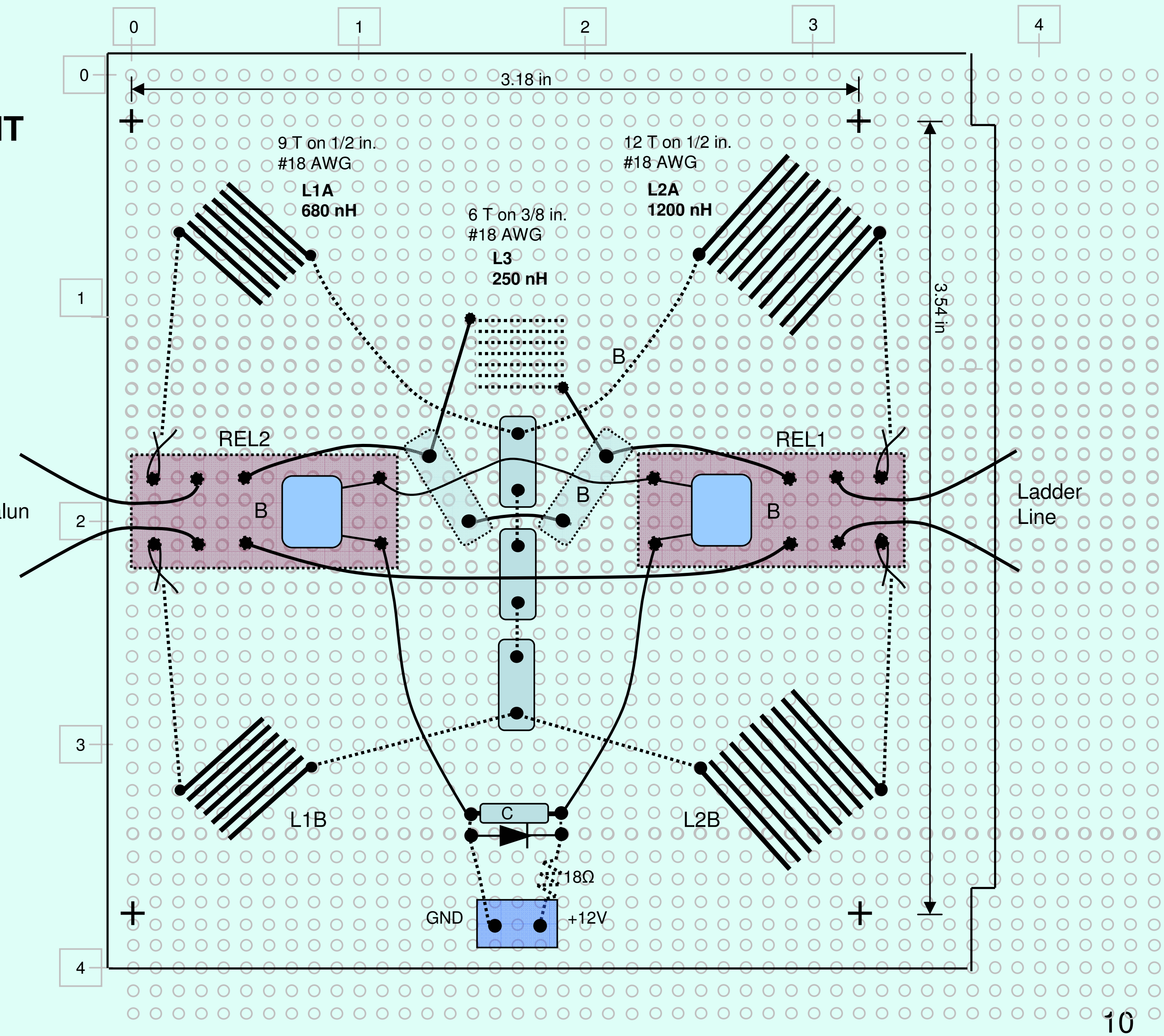


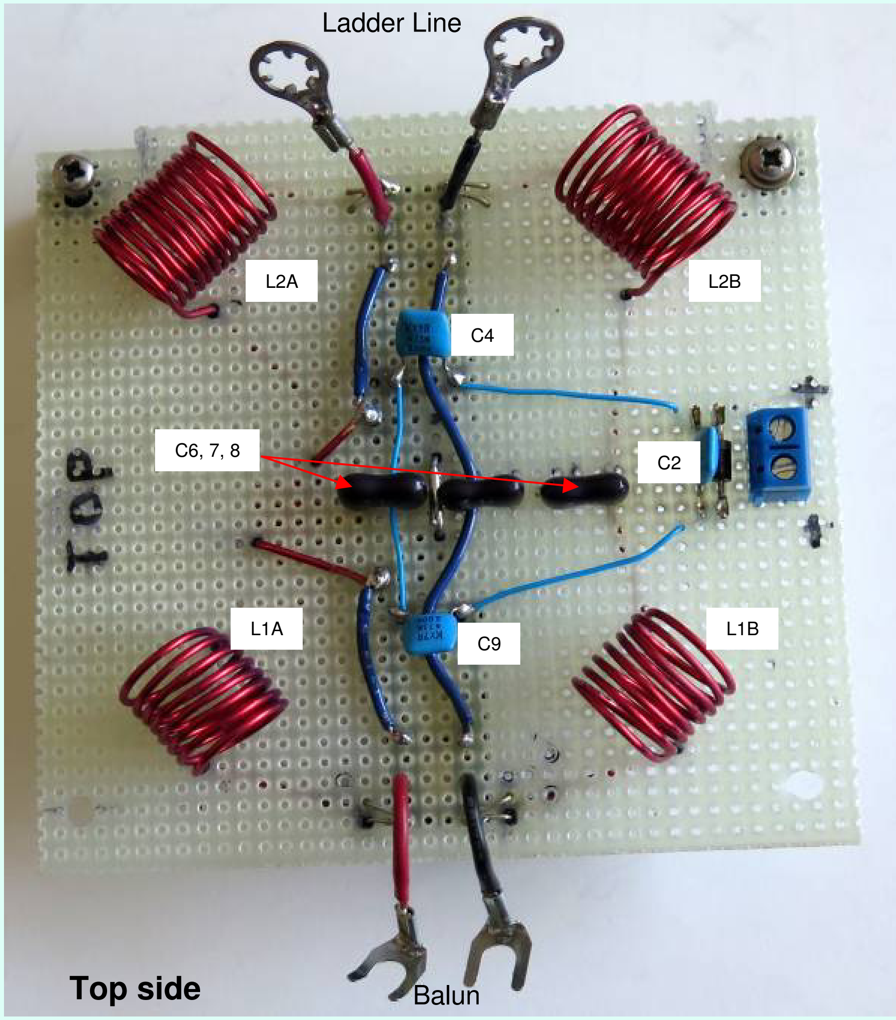

Ref.: Inverted Vee 80m to 10m-39.5_NO TRL.wsp
Ref.: Inverted Vee 80m to 10m-39.5_NO TRL-Revised-TRL-Loss-50ohmFeederAdded-Compare w Mesures.wsp

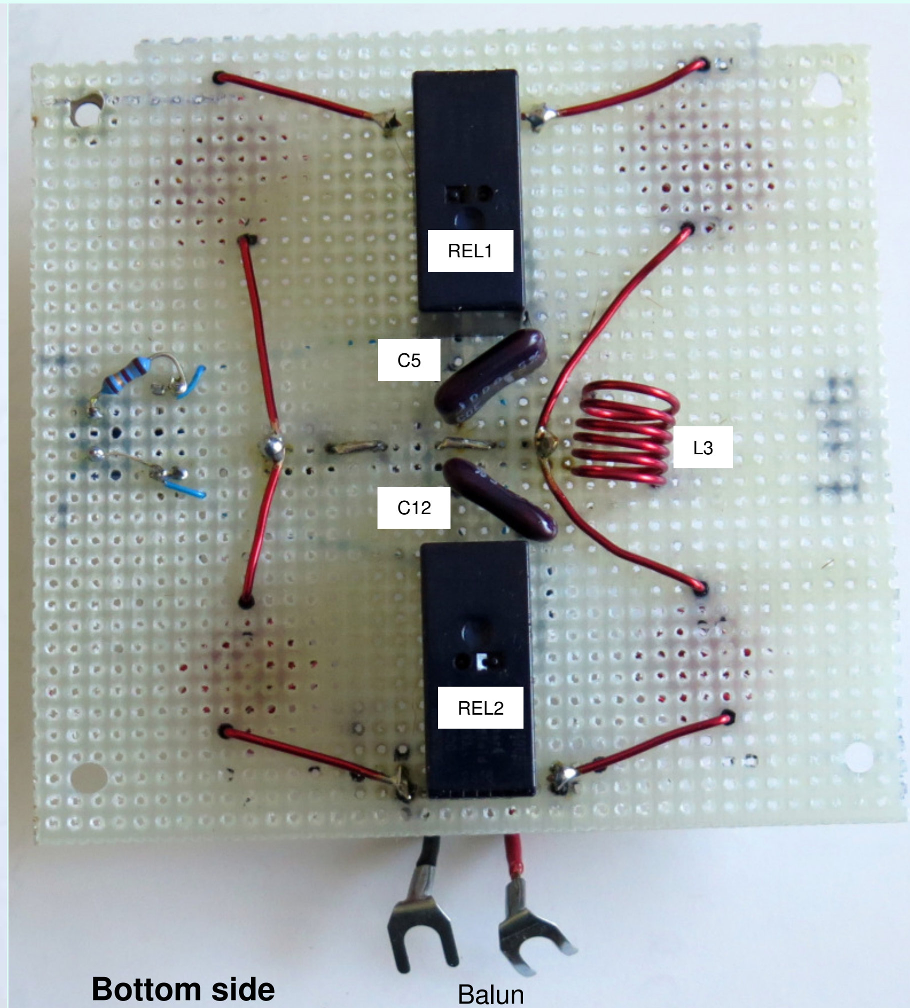


TUNER / RX
J2
1
2
R1 22
C1
0.01 uF
80m, 15m
R3
22
SW1
R2
L1
22
1 mH 15 ohms
+12.64V & 80 mA
40m, 20m, 17m
12m, 10m
C3
22 uF
J1
ANT
J3
15 -19VDC
0.1A
REMOTE CONTROL CIRCUIT
J. Audet VE2AZX
Aug. 2023

# COMPONENT LAYOUT



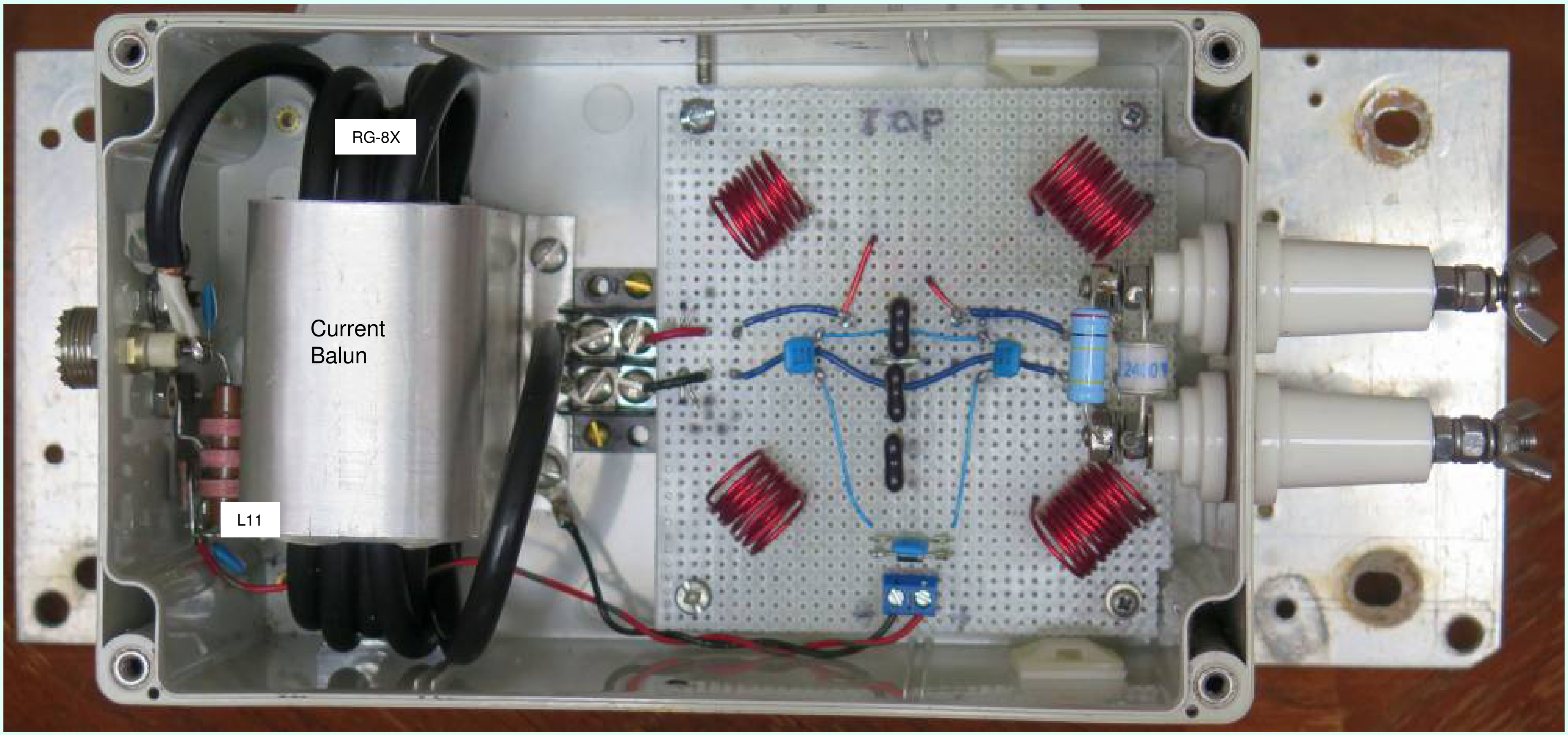



**NOTE:** The board was sprayed with silicone conformal coating to keep the moisture out.

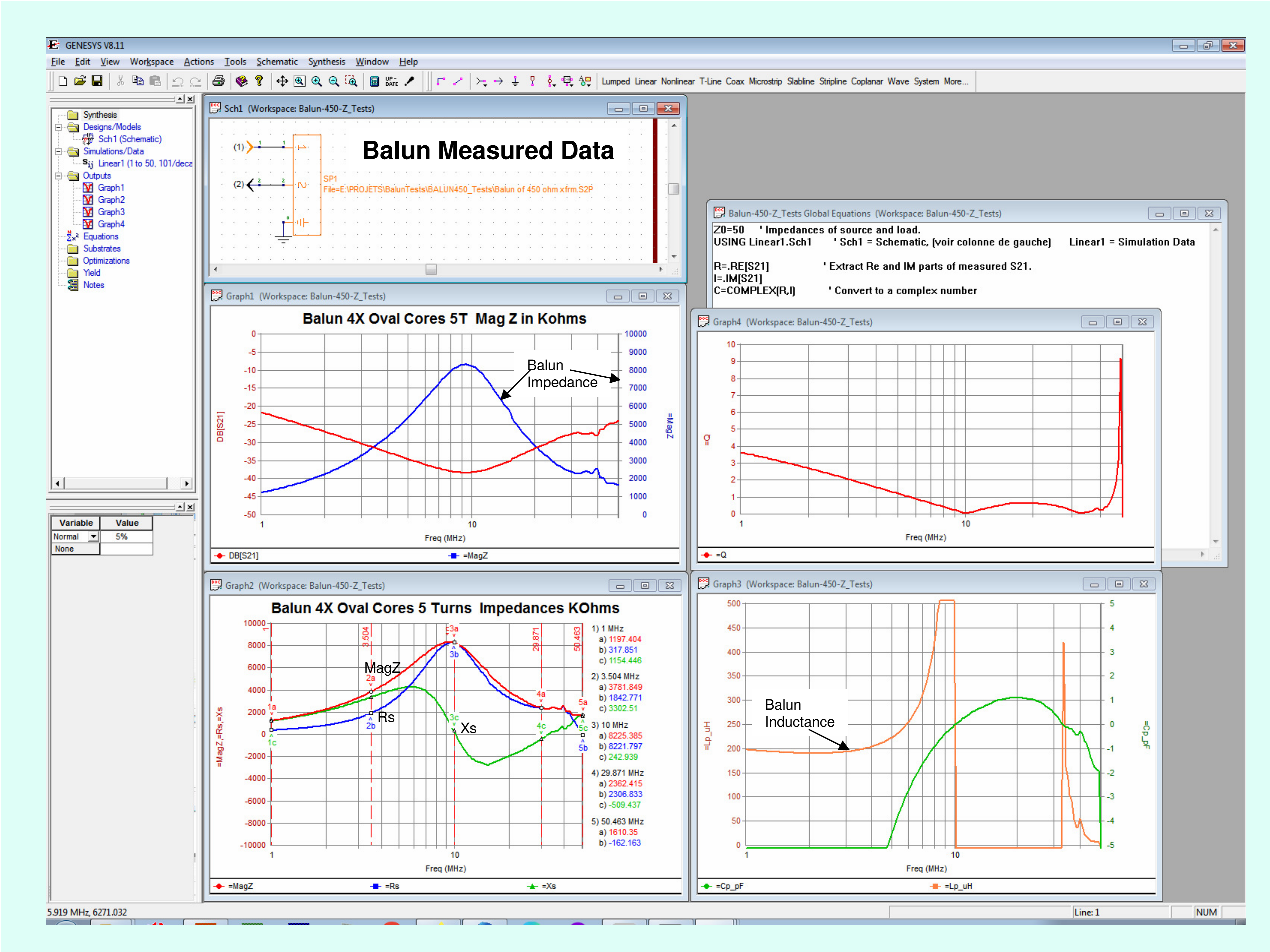
# BALUN, RELAYS and FILTER

Grey ABS plastic watertight enclosure Hammong Mfg. #1554UGY or 1554U2GY

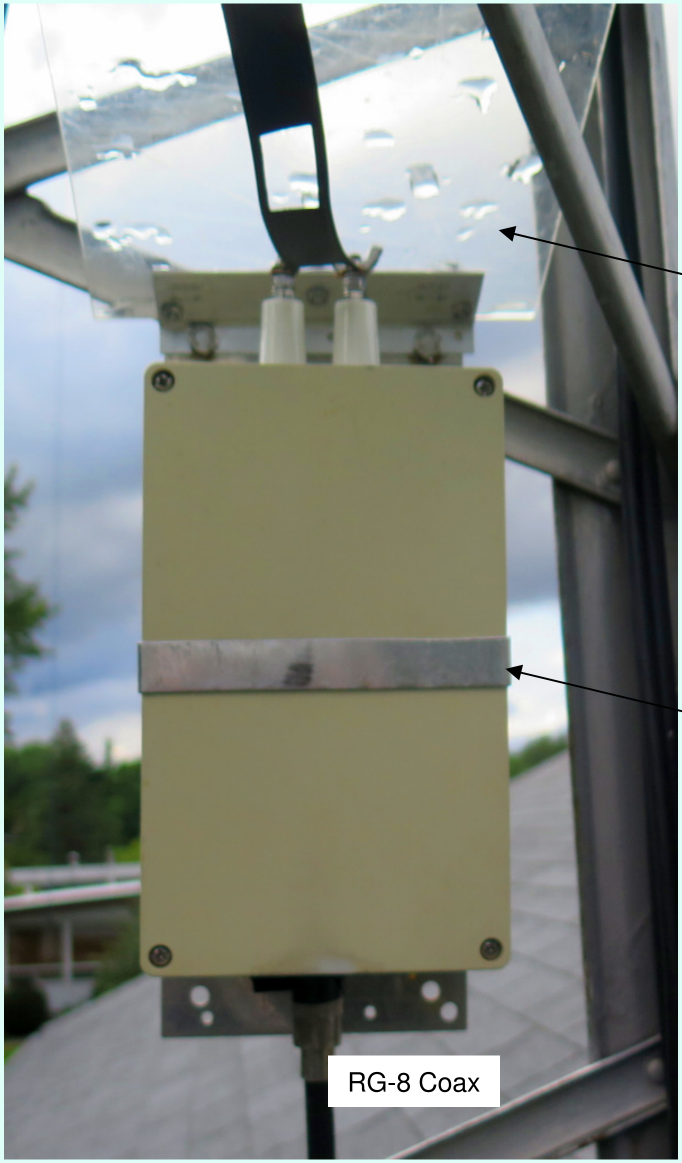


## 1:1 Current Balun

Provides 2500 Ω to 8000 Ω over 3.5 to 30 MHz


GENESYS V8.11
File Edit View Workspace Actions Tools Schematic Synthesis Window Help
Lumped Linear Nonlinear T-Line Coax Microstrip Slabline Stripline Coplanar Wave System More...
Synthesis
Designs/Models
Sch1 (Schematic)
Simulations/Data
Linear1 (1 to 50, 101/deca
Outputs
Graph1
Graph2
Graph3
Graph4
Equations
Substrates
Optimizations
Yield
Notes
Variable
Value
Normal
5%
None
Sch1 (Workspace: Balun-450-Z_Tests)
Balun Measured Data
SP1
File=E:\PROJETS\BalunTests\BALUN450_Tests\Balun of 450 ohm xfrm.S2P
Balun-450-Z_Tests Global Equations (Workspace: Balun-450-Z_Tests)
Z0=50 ' Impedances of source and load.
USING Linear1.Sch1 ' Sch1 = Schematic, (voir colonne de gauche) Linear1 = Simulation Data
R=.RE[S21] ' Extract Re and IM parts of measured S21.
I=.IM[S21]
C=COMPLEX[R,I] ' Convert to a complex number
Graph1 (Workspace: Balun-450-Z_Tests)
Balun 4X Oval Cores 5T Mag Z in Kohms
Balun Impedance
DB[S21]
=MagZ
Freq (MHz)
Graph4 (Workspace: Balun-450-Z_Tests)
=Q
Freq (MHz)
Graph2 (Workspace: Balun-450-Z_Tests)
Balun 4X Oval Cores 5 Turns Impedances KOhms
MagZ
Rs
Xs
=MagZ,=Rs,=Xs
1) 1 MHz
a) 1197.404
b) 317.851
c) 1154.446
2) 3.504 MHz
a) 3781.849
b) 1842.771
c) 3302.51
3) 10 MHz
a) 8225.385
b) 8221.797
c) 242.939
4) 29.871 MHz
a) 2362.415
b) 2306.833
c) -509.437
5) 50.463 MHz
a) 1610.35
b) -162.163
Freq (MHz)
=MagZ
=Rs
=Xs
Graph3 (Workspace: Balun-450-Z_Tests)
Balun Inductance
=Lp_uH
=Cp_pF
Freq (MHz)
5.919 MHz, 6271.032
Line: 1
NUM

# Installed Matching and Control Circuit




Plexiglass panel to keep bird droppings out

Added clamp to keep the cover tightly closed.

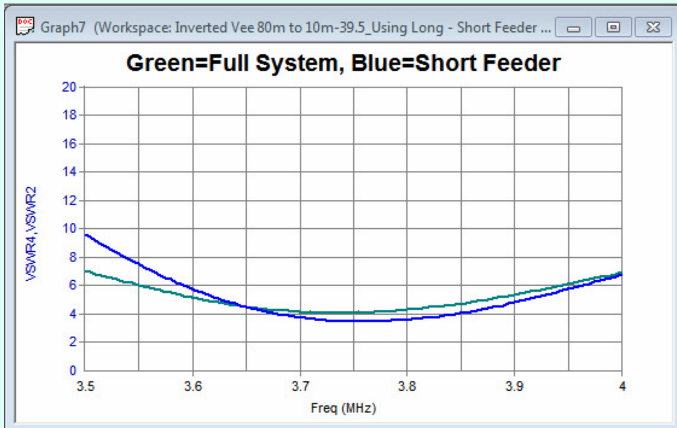
## NOTE: INITIAL ANTENNA TESTS:

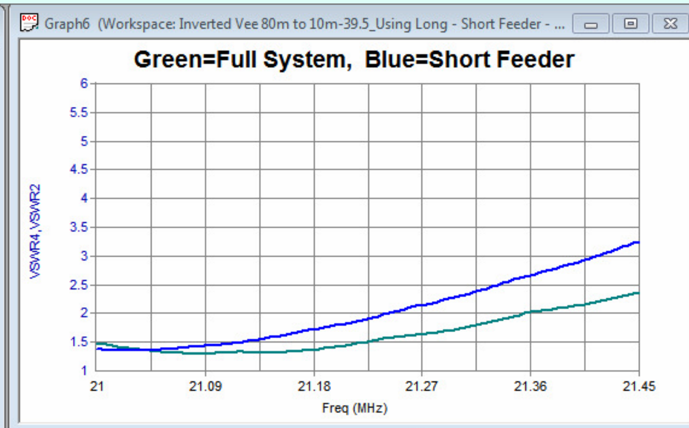
The Impedance at the end of the ladder line was measured: (33.7 ft @ Vf = 1)
The calibration was done using the balun connected to the high voltage insulators.
The calibration plane was at the high voltage insulators.
OSL type calibration was done (Open, Short, Load).

The antenna length was adjusted to “resonate” at 3750 KHz, that is at the point of minimum SWR.
The 15m resonance should produce acceptable SWR. (below 2:1)

**NOTE:** Reducing the antenna length wire will increase the resonant frequency.
The % frequency increase was less than than the decrease in % length.
This is not a problem however.

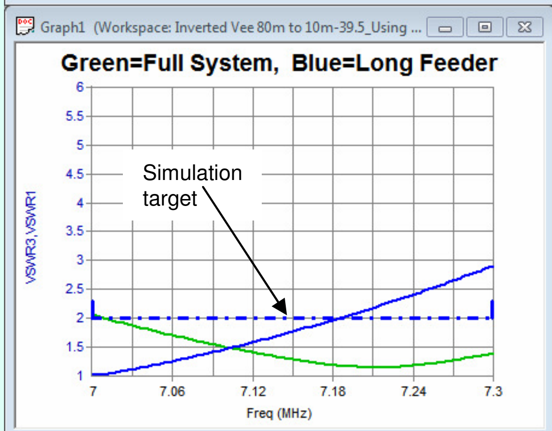
# VSWR MEASUREMENTS

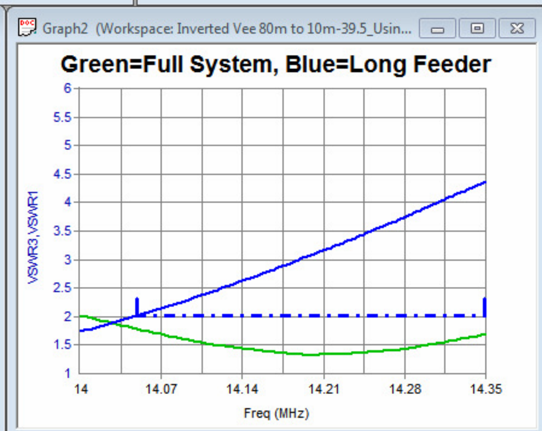


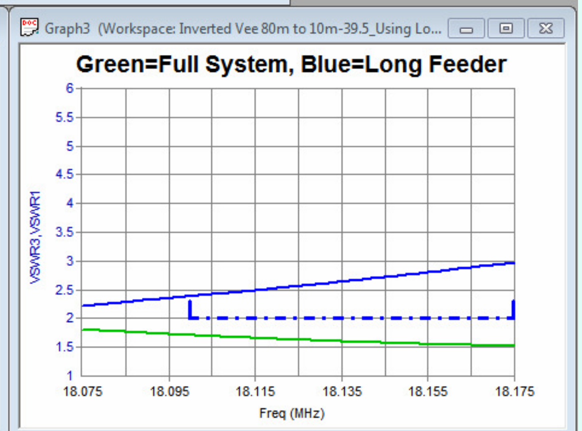



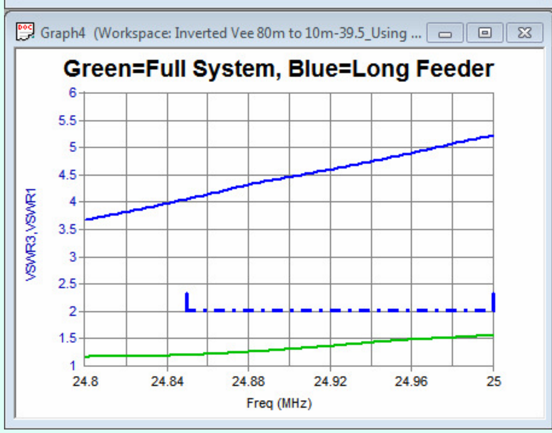

Full System uses the matching circuit and the short feeder

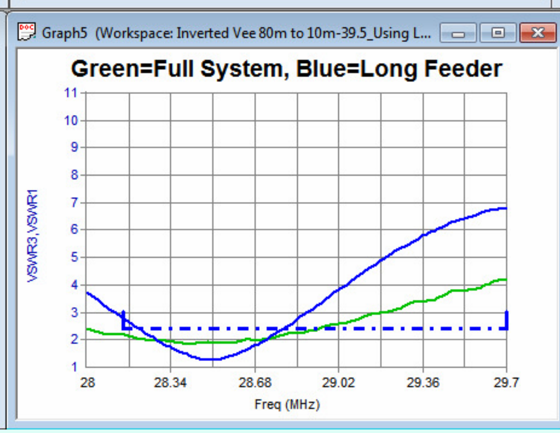
Short Feeder (410Ω) = 29 pi 8.5 in.




All blue curves use the short or long feeder

Full System uses the matching circuit and the short feeder

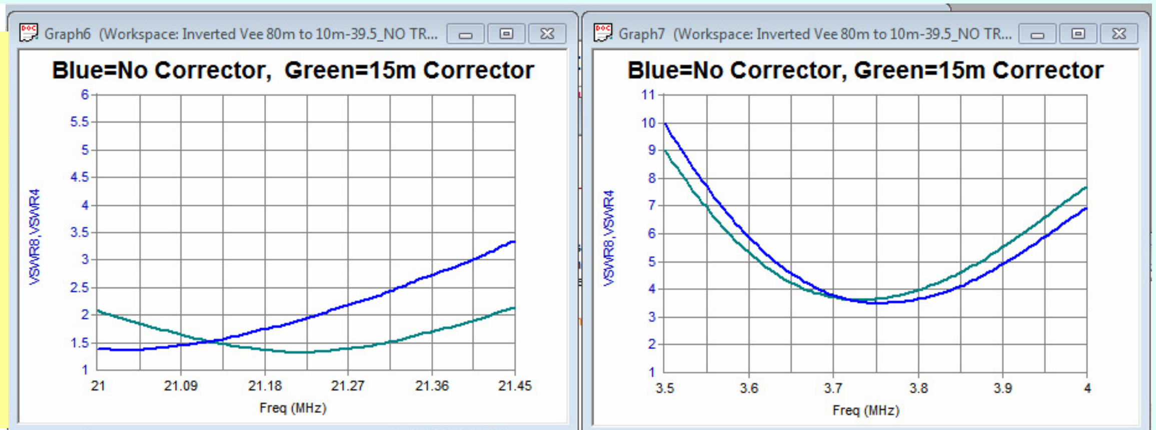
Long Feeder (410Ω) = 38.89 ft (38 ft 10.7 in.)
Used on: 10, 12, 17, 20, 40m

# ANTENNA MEASUREMENTS & SIMULATIONS

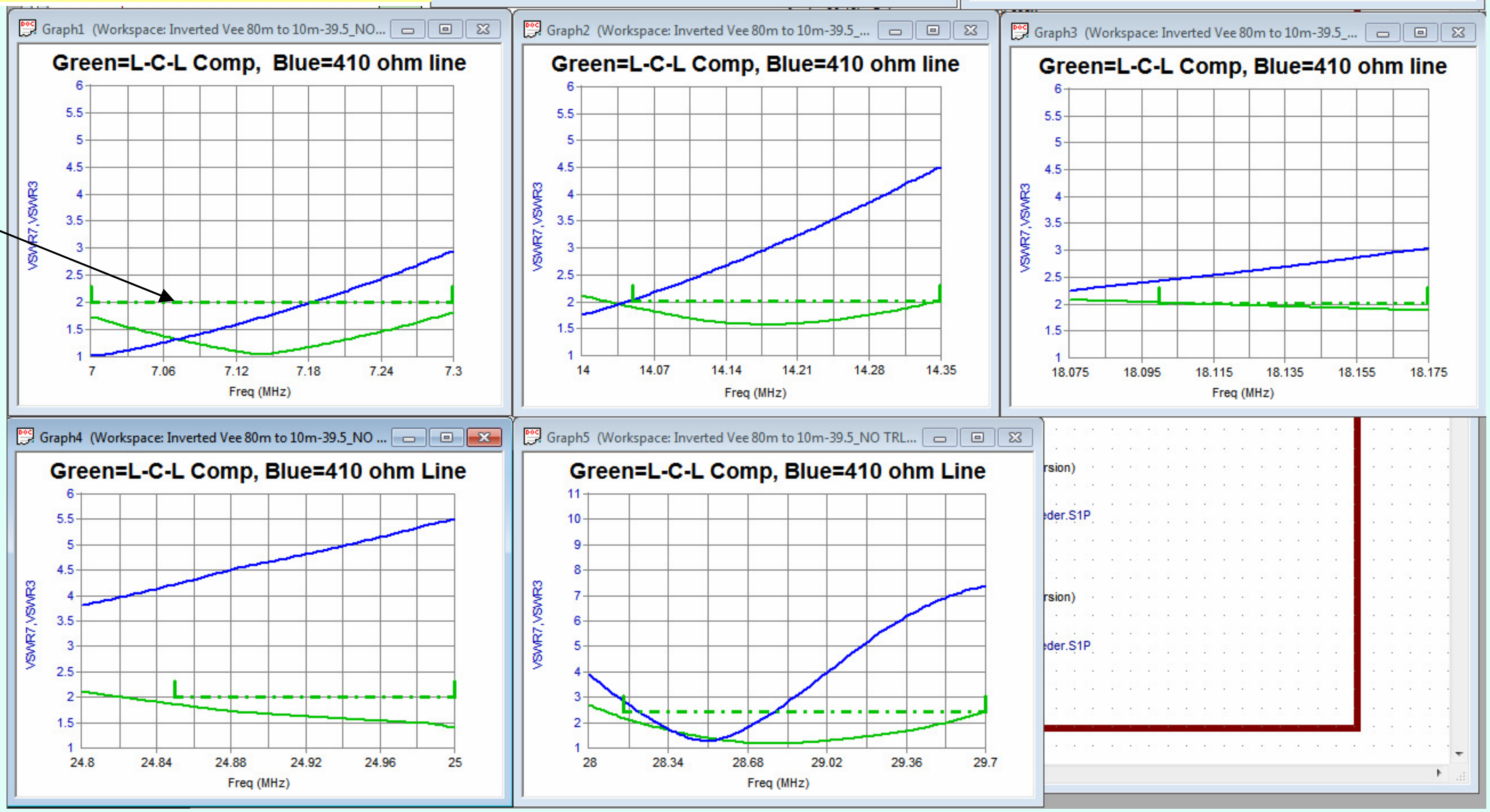
Includes about 50 ft of RG-8 cable

**For 40, 20, 17, 12, 10m bands:**
Blue= Measured VSWR using additional 410Ω line.
Green= The additional line is replaced by a simulated and optimized L-C-L circuit.

**For 80, 15m bands:**
Correction done for the 15m band only.
Blue= Measured VSWR without correction.
Green= Simulated L-C parallel added in series.




Simulation target



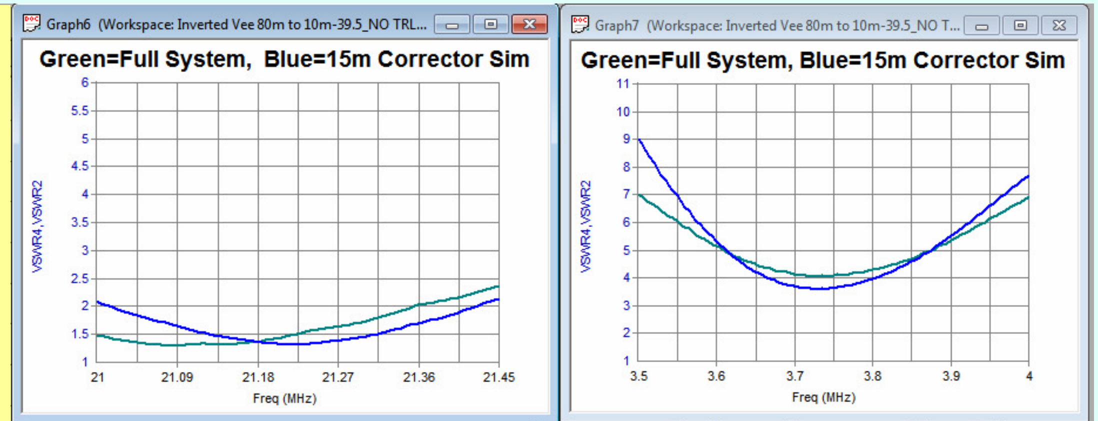

Ref: Inverted Vee 80m to 10m-39.5_NO TRL-Revised-TRL-Loss-50ohmFeederAdded-Compare w Mesures.wsp

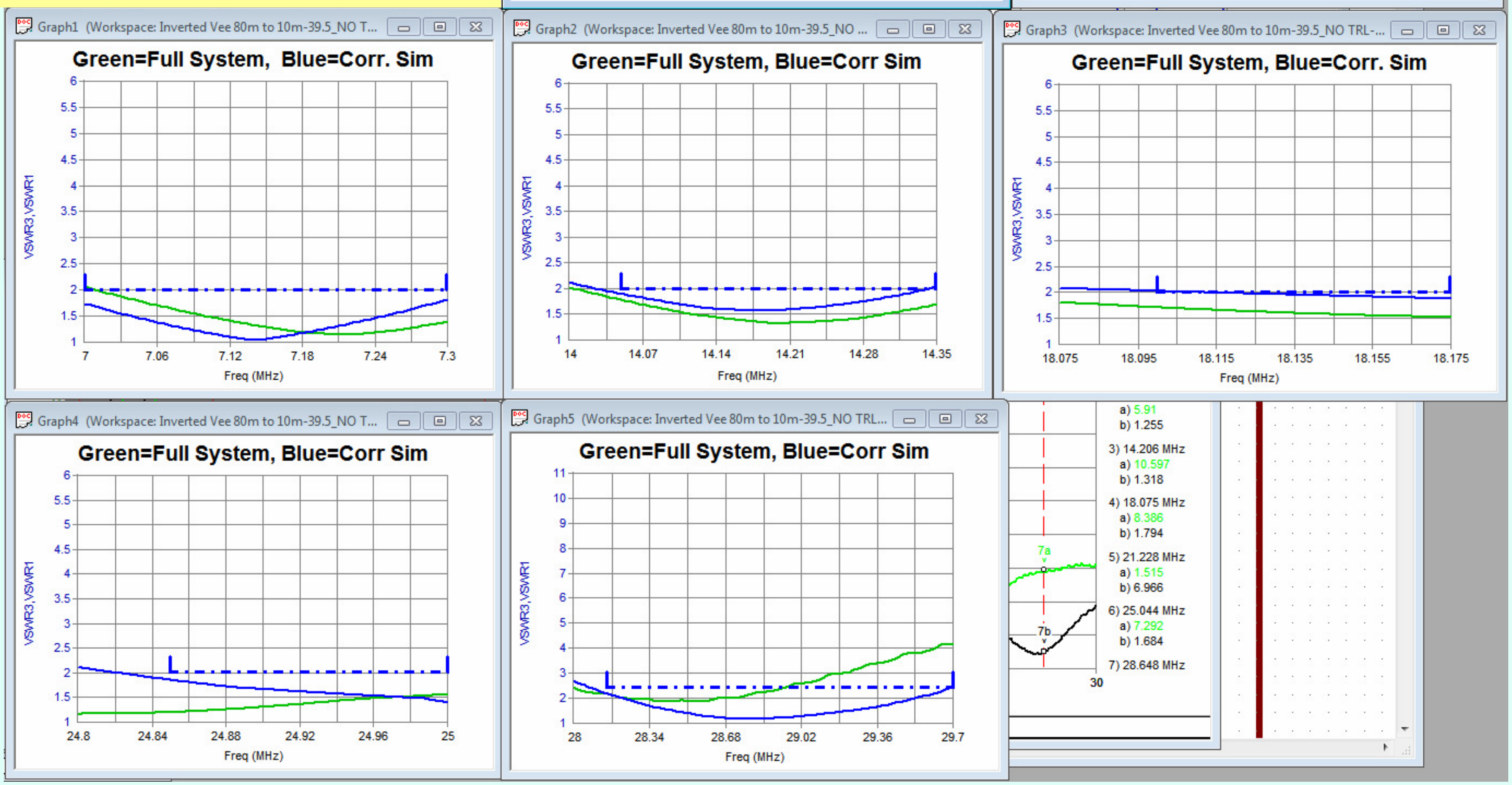
# ANTENNA MEASUREMENTS & SIMULATIONS

**<u>The feeder length has been reduced by 4 in.</u>**
Includes about 50 ft of RG-8 cable.

**For 40, 20, 17, 12, 10m bands:**
Green= Measured VSWR using optimized matching circuit. Completed system.
Blue= The additional line is replaced by a simulated and optimized L-C-L circuit.

**For 80, 15m bands:**
Green= Measured VSWR with L-C parallel circuit for 15m band. Completed system.
Blue= Simulated L-C parallel added in series.

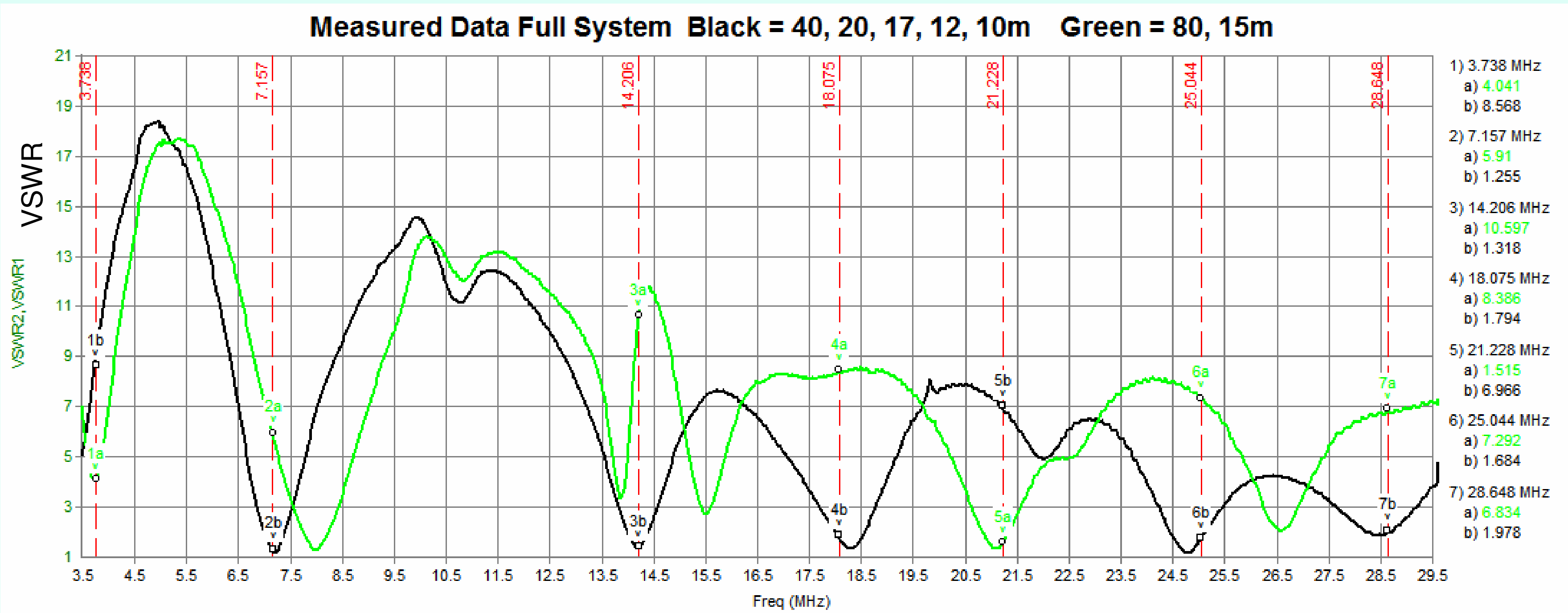



Ref: Inverted Vee 80m to 10m-39.5_NO TRL-Revised-TRL-Loss-50ohmFeederAdded-Compare w Mesures-FullSystem-Feeder-4po.wsp

# MEASURED VSWR FROM 3.5 TO 30 MHz

**Completed system, using the matching circuit as previously described for 40, 20, 17, 12, 10m.**




NOTE: Measurements includes about 50 ft of RG-8 cable

The above curves corresponds to the green curves in previous pages.

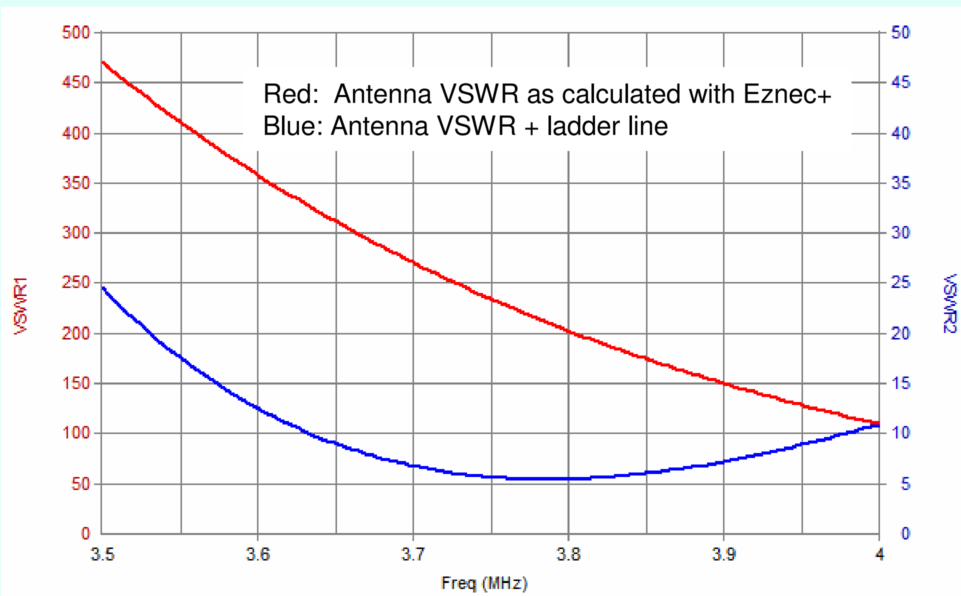
Ref: Inverted Vee 80m to 10m-39.5_Using Long - Short Feeder - Compare w Mesures-FullSystem-Feeder-4po.wsp

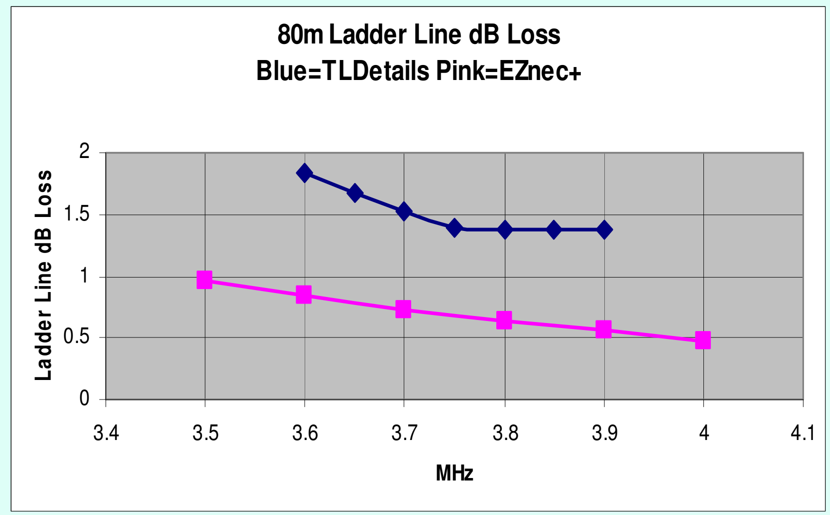
# Ladder Line dB Loss on 80m Band

Extremely high VSWR at the antenna gives reflection losses in
the 410Ω ladder line. (VSWR = 234 @ 3.75 MHz)
The ladder line 'matches' these wild antenna impedances.
At the end of the 'short' ladder line the minimum VSWR is about 5.5.

**BLUE:**
Ladder line losses as calculated with TLDetails.
Losses include:
- Conductor + Dielectric Losses = 0.08 dB
- Reflection losses vary from 1.3 to 1.76 dB

**PINK:**
As calculated with EZnec+ V6.0
Decreased level in the radiation pattern caused by losses in the ladder line

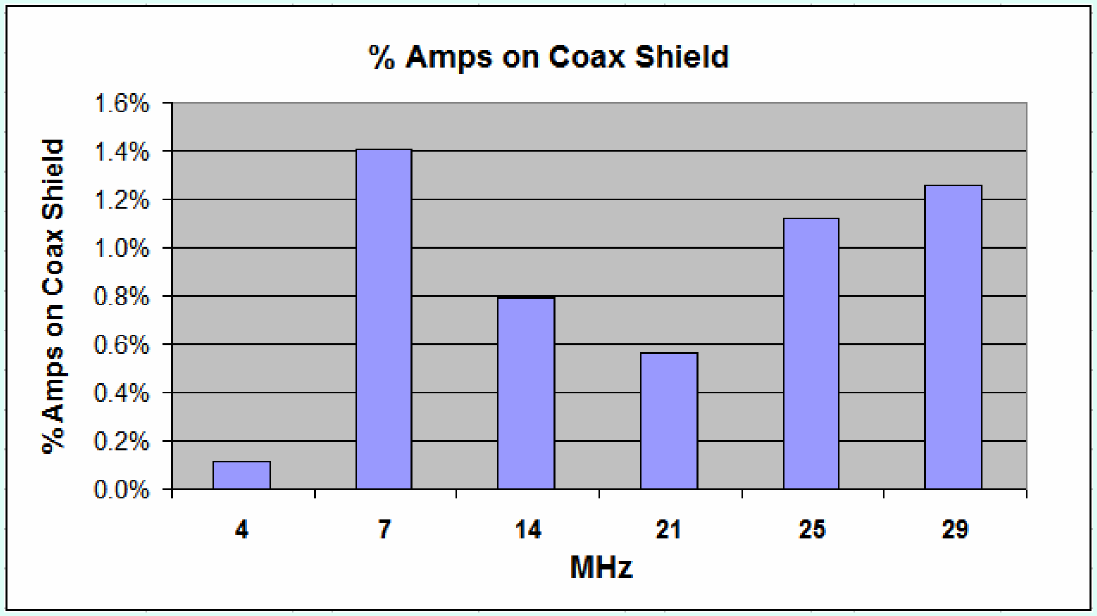



Ref: TRL Losses -33 ft.xls
Antenna Impedance-NO TRL.wsp

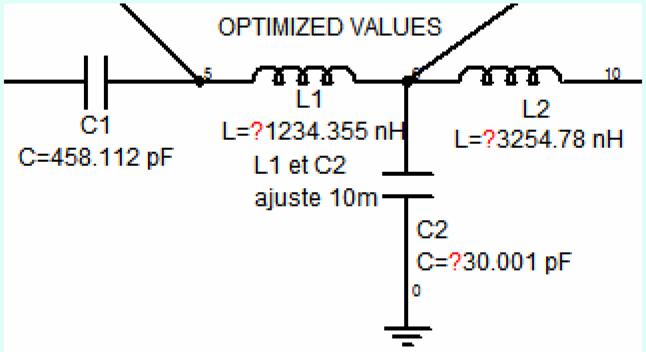
## Current on the coax shield vs differential current inside the 50 Ω coax

This is a well balanced antenna that minimizes the unbalanced currents on the feeder.

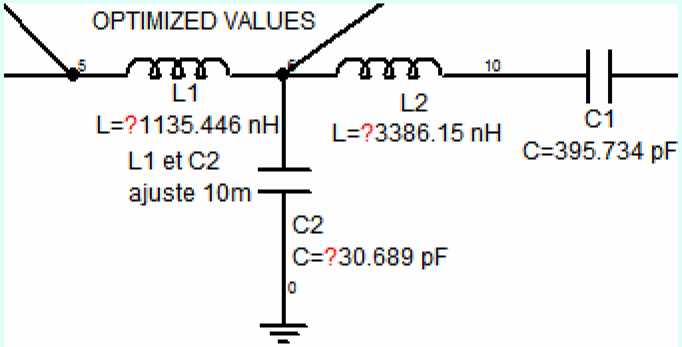



Ref: Current probe tests.xls

## USING A SERIES CAP TO BRING 80m IN WHEN THE L – C – L NETWORK IS USED




C1 at input




C1 at output

**NOTE:** In the balanced configuration L1 and L2 values are divided by 2 and the C1 values are multiplied by 2. The balanced configuration was used as shown on the shematic page 8.

## SUMMARY of SWR READINGS

**NOTE:**
- The red SWR readings are done with the L-C-L network.
- The blue SWR readings are done <u>without</u> the L-C-L network.

| As Built No C1 | C1 at Input | C1 at output | |
|---|---|---|---|
| 1) 3.738 MHz<br>b) 3.583 | 1) 3.738 MHz<br>a) 3.477 | 1) 3.738 MHz<br>a) 3.491 | 80m OK now with C1 |
| 2) 7.104 MHz<br>a) 1.155 | 2) 7.104 MHz<br>a) 1.687 | 2) 7.104 MHz<br>a) 1.683 | Slightly worse w/r No C1 |
| 3) 14.206 MHz<br>a) 1.577 | 3) 14.206 MHz<br>a) 1.89 | 3) 14.206 MHz<br>a) 1.789 | Slightly worse w/r No C1 |
| 4) 18.075 MHz<br>a) 2.065 | 4) 18.075 MHz<br>a) 2.31 | 4) 18.075 MHz<br>a) 2.102 | Slightly worse w/r No C1 |
| 5) 21.228 MHz<br>b) 1.309 | 5) 21.228 MHz<br>b) 1.309 | 5) 21.228 MHz<br>b) 1.309 | The L - C – L network is bypassed |
| 6) 25.044 MHz<br>a) 1.15 | 6) 25.044 MHz<br>a) 1.361 | 6) 25.044 MHz<br>a) 1.352 | Slightly worse w/r No C1 |
| 7) 28.648 MHz<br>a) 1.204 | 7) 28.648 MHz<br>a) 1.969 | 7) 28.648 MHz<br>a) 2.075 | Worse w/r No C1 |