How to Blow Up Your Balun

(and other things too…)

Fig 36 – Coaxial Chokes Wound to Minimize L and C

Fig 37 – A Bifilar Choke

By Dean Straw, N6BV

Sea-Pac June 7, 2014

Photos courtesy Jim Brown, K9YC

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- I will examine stresses placed on common-mode chokes (aka, “baluns”) as hams use/abuse them.
- I will examine the efficiency of simple dipole multi-band antennas and their feed systems.

Stressing a Balun

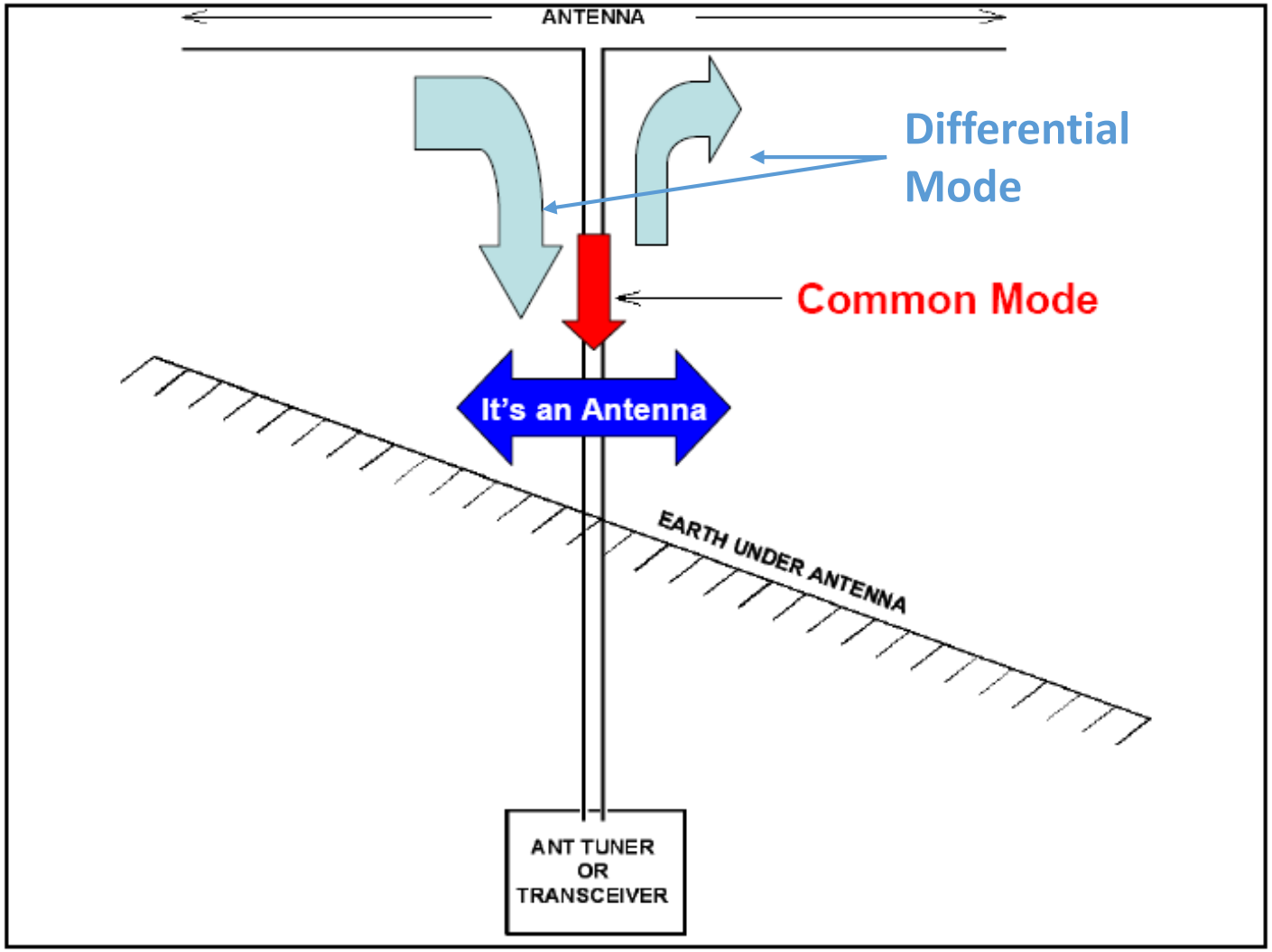

Figure courtesy K9YC

What's a Common Mode Choke?

- A circuit element that reduces common mode current by adding a high impedance in series with the common mode circuit
  - Reduces radiation from the cable
  - Reduces reception by the cable

Slide courtesy K9YC

Current-Mode Chokes

- Impedance is assumed high enough to “choke off” undesired common-mode currents, preventing radiation from the transmission line. This is the best case, with the least power lost in the choke balun due to common-mode current. (More on this later in discussing OCF dipoles.)

Current-Mode Chokes

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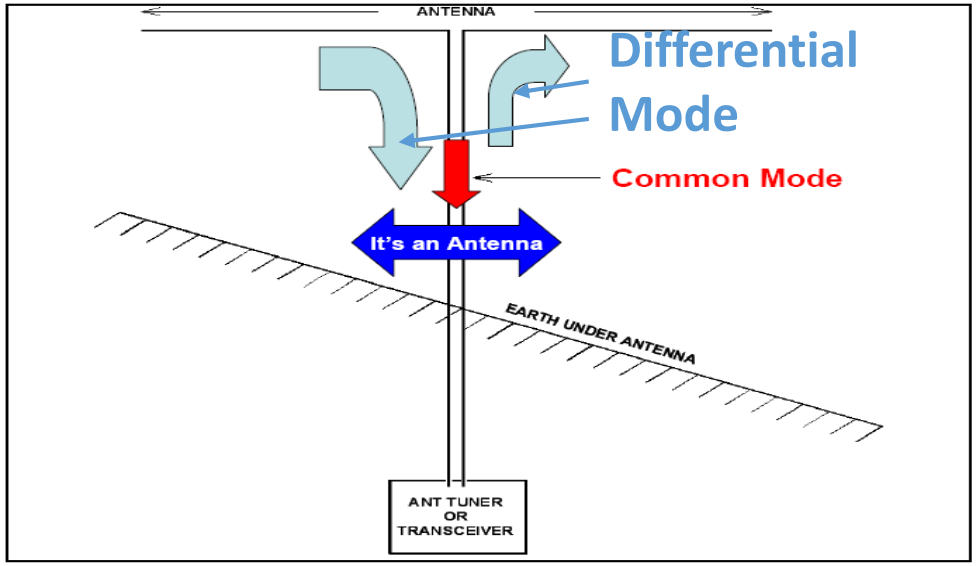
- The desired differential-mode current flows in opposite directions on the inside of a coax cable. The field around the transmission line is cancelled.



Current-Mode Chokes

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- The desired differential-mode current flows in opposite directions on the inside of a coax cable. The field around the transmission line is cancelled.
- The desired differential-mode currents also flows in opposite directions on balanced transmission line. The far field around the transmission line is cancelled.

Fig 36 – Coaxial Chokes Wound to Minimize L and C

Fig 37 – A Bifilar Choke

Example of current-mode transmission-line chokes, also known commonly as “choke baluns.” *Photos courtesy Jim Brown, K9YC*.

Stresses on Common-Mode Chokes

- The common-mode chokes shown in the previous slide are designed by K9YC for 50-Ω antennas, and can handle SWRs up to about 10:1 without self-destructing at a 1.5 kW power level.

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- They show wideband common-mode impedances of more than 5000 Ω, effectively choking off almost any kind of common-mode currents over more than three octaves of frequency.
- The length of the RG-303 type Teflon-insulated coax used is about 1 foot per turn through the ferrite donuts, for a total of about 6 feet of RG-303 for 5 turns.

The Quest for Multiband Operation with a Single-Wire Dipole Antenna

- Operating a dipole at even harmonic frequencies can be rough: e.g., 40 meter dipole operated on 20 meters, or on 10 meters.

Feed-point impedances for a 66-foot long, center-fed inverted-V dipole, apex at 50 feet high over ground with dielectric constant of 13, conductivity of 5 mS/m.

Freq. Feed-Point
MHz Impedance

1.83 MHz: 1.6 − j 2257 Ω
3.8 MHz: 10.3 − j 879 Ω ← Even worse!
7.1 MHz: 64.8 − j 40.6 Ω
10.1 MHz: 21.6 + j 648 Ω
Bad → 14.1 MHz: 5287 − j 1310 Ω
18.1 MHz: 198 − j 820 Ω
21.1 MHz: 103 − j 181 Ω
24.9 MHz: 269 + j 570 Ω
28.4 MHz: 3089 + j 774 Ω ← Pretty bad

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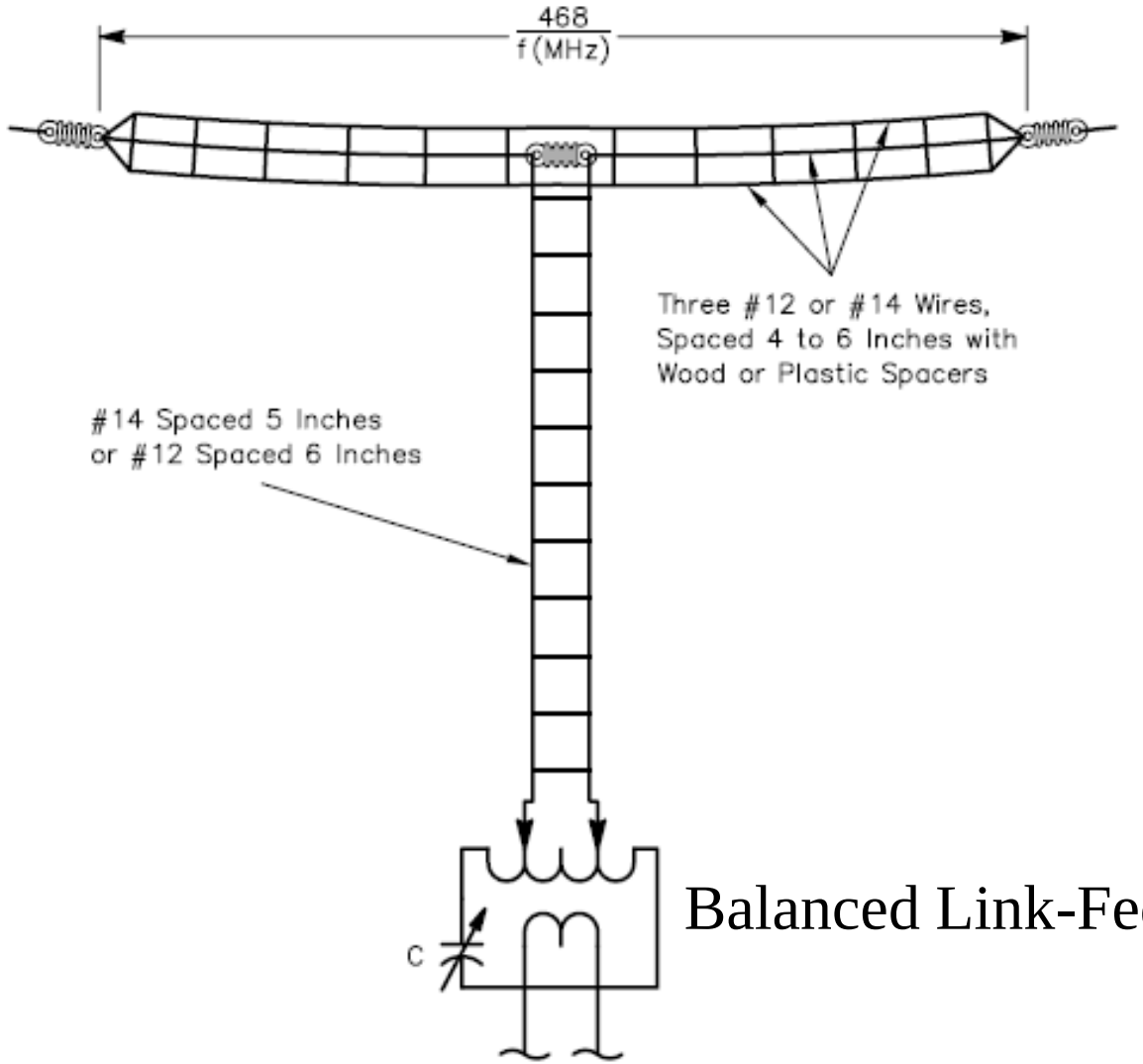
- Operating a dipole at even harmonic frequencies can be rough: e.g., 40 meter dipole operated on 20 meters.
- Single feed line—coax or open-wire line?
- Where should the common-mode choke balun go? I'll go through several worst-case scenarios. But first…

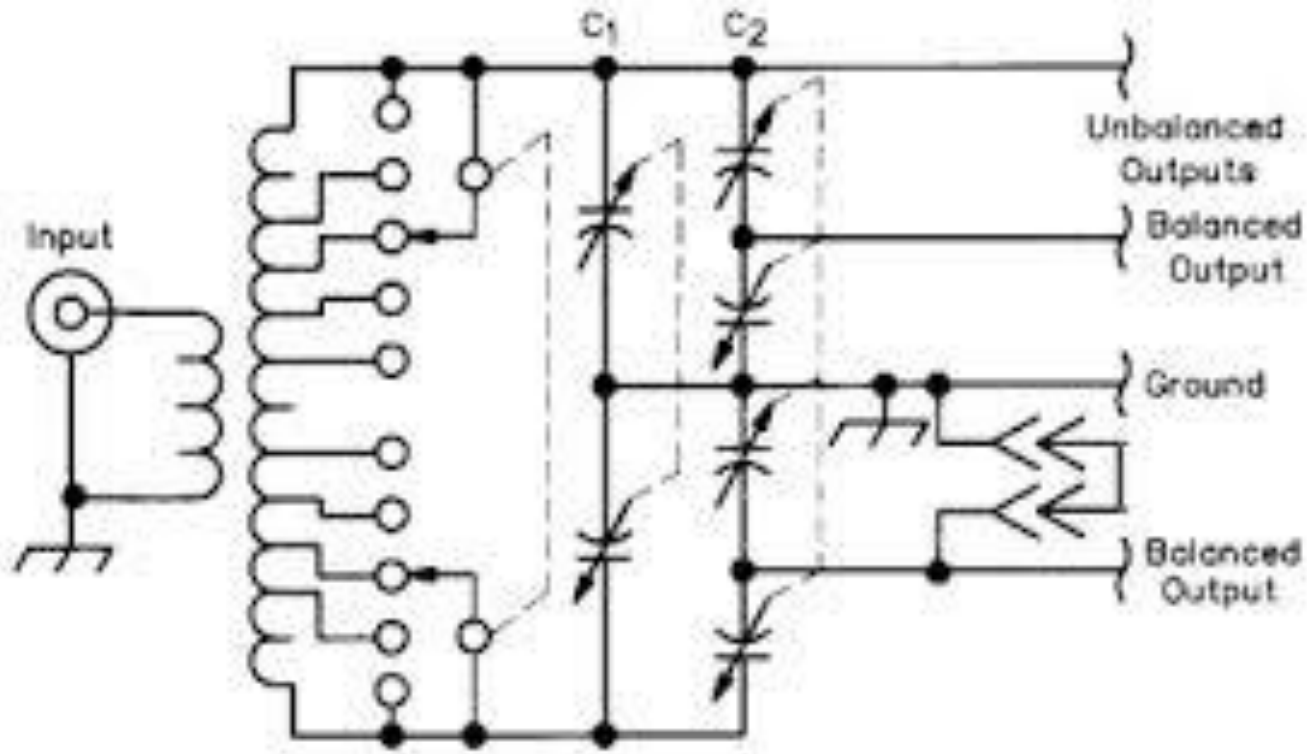
Back in the Good Ole Days…



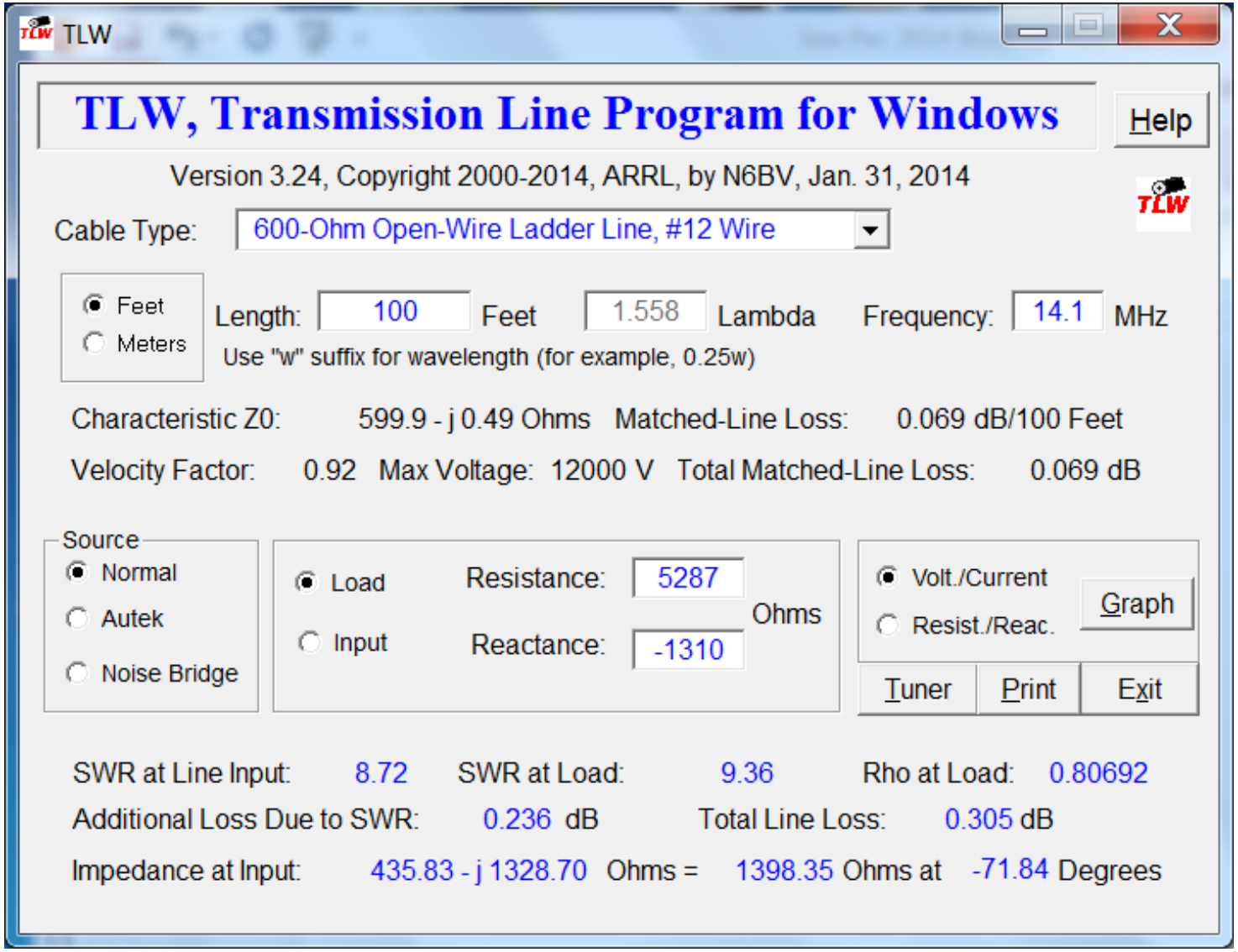
Balanced Link-Fed Tuner

Balanced Antenna Tuner

- An intrinsically balanced antenna tuner, such as a Johnson Matchbox, uses no lossy coax inside as a balun. It is link fed.

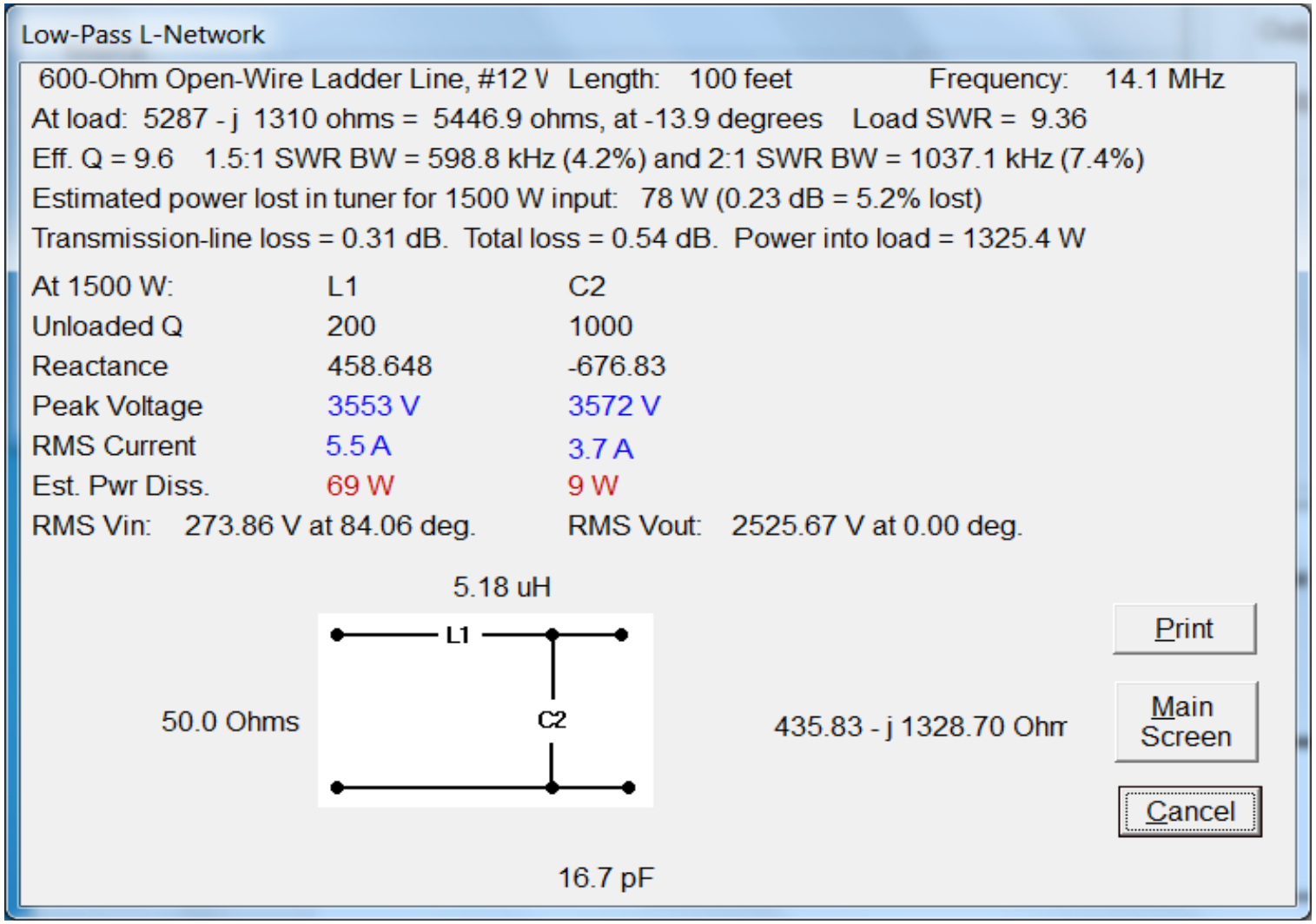

C1
C2
Input
Unbalanced
Outputs
Balanced
Output
Ground
Balanced
Output

TLW, the "Swiss Army Knife" of Transmission Lines



The latest version of *TLW* updates the matched-line losses of "Window" lines with new measurements made by the ARRL Laboratory.

Losses in a Simple L-Network Tuner



Ex. 1: Balanced Antenna Tuner with Open-Wire Line

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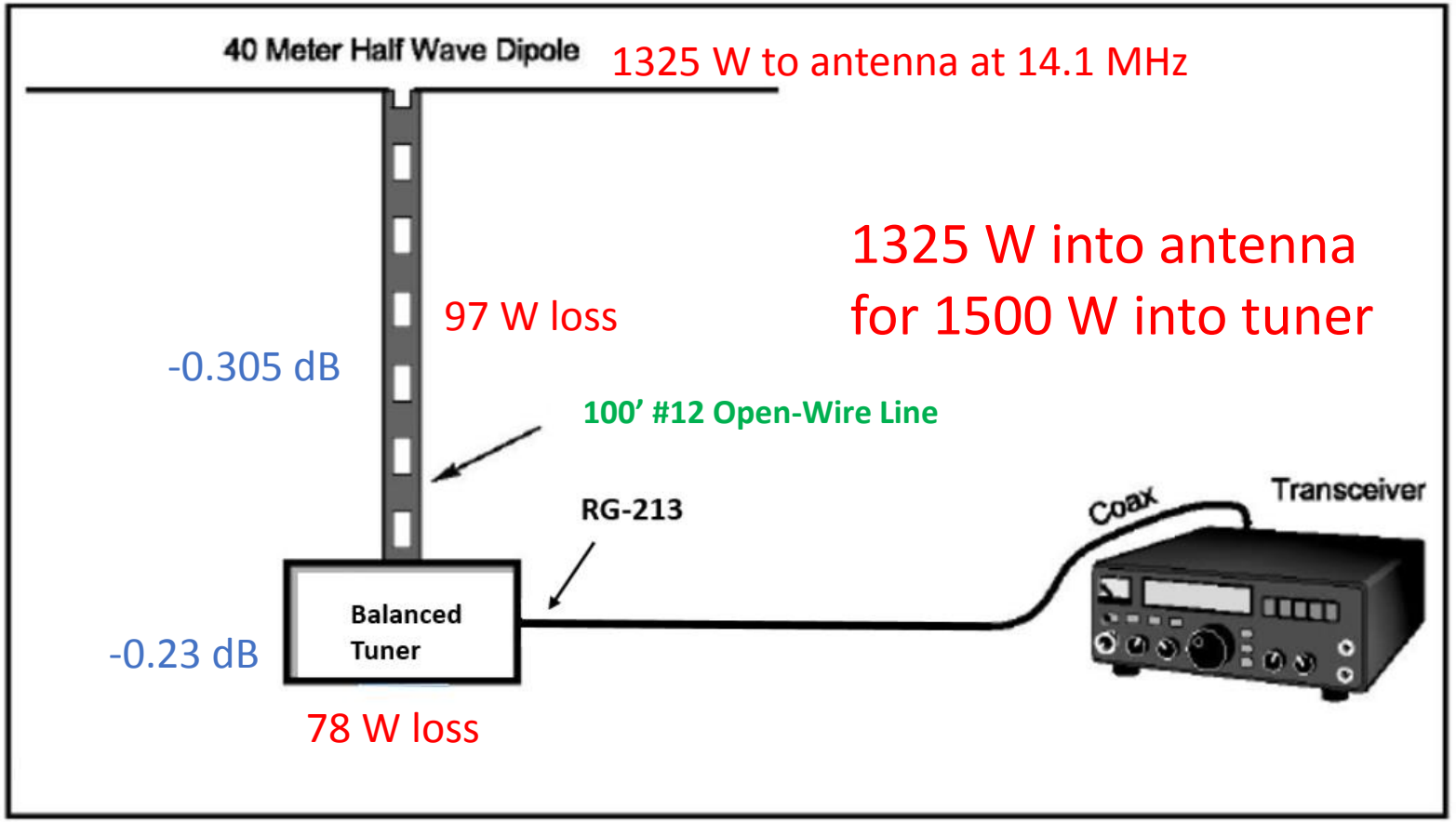
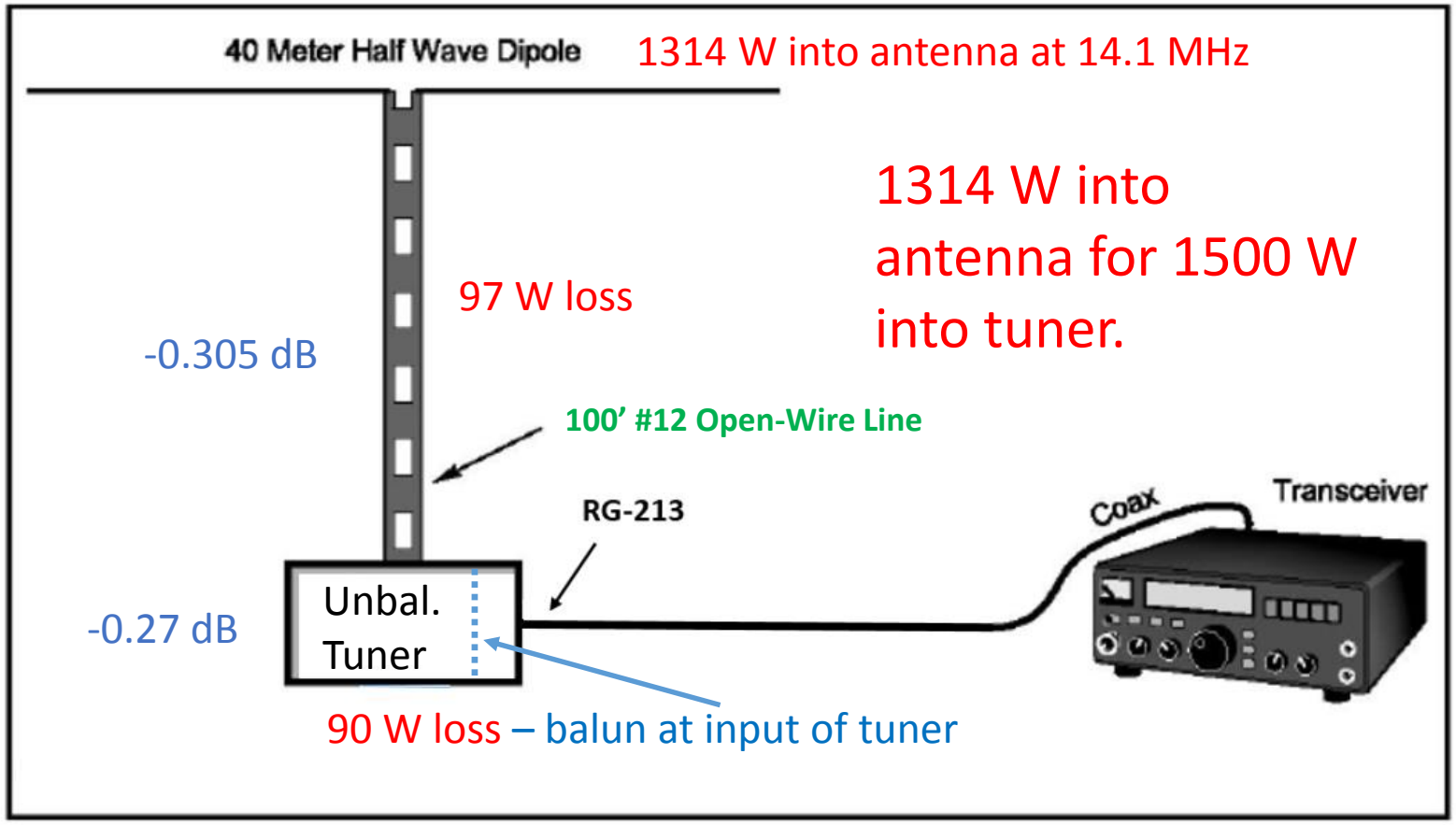


Ex. 2: Unbalanced Tuner With Choke Balun at Input

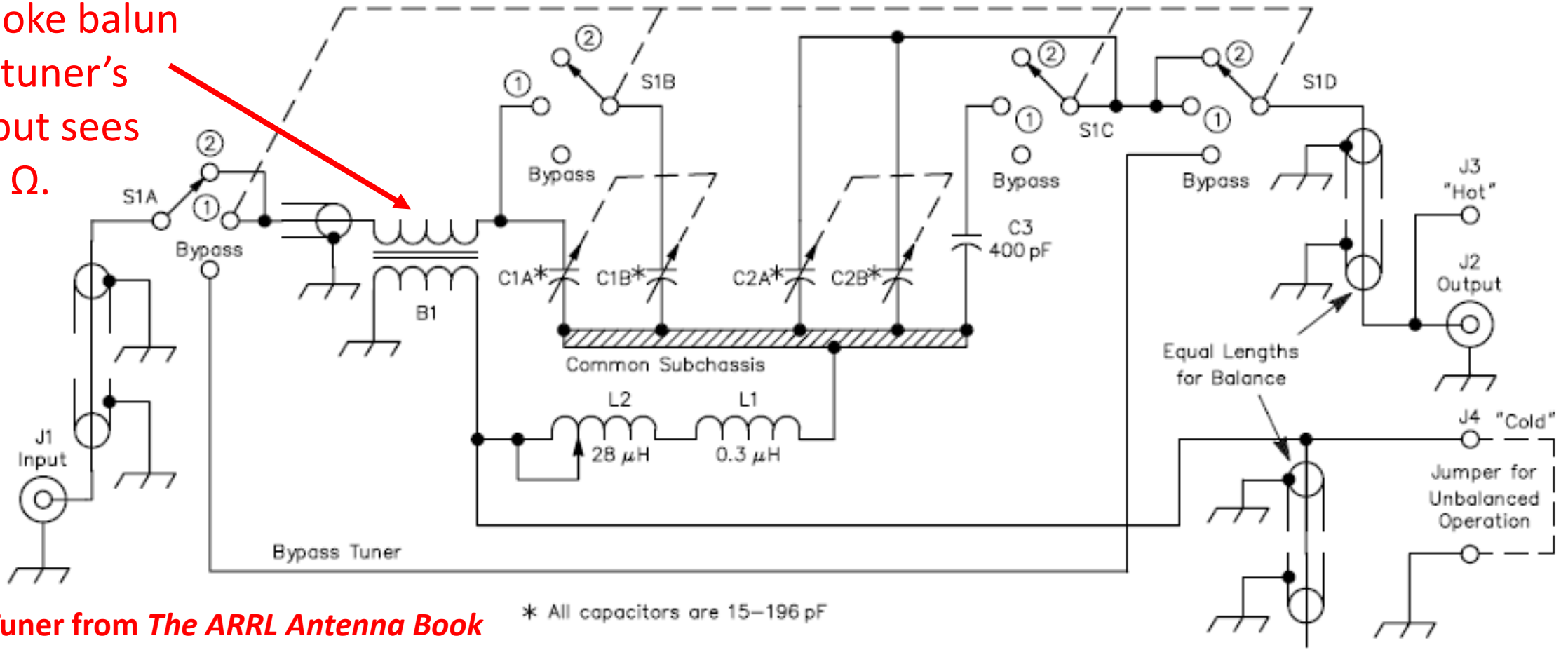
- If the choke balun is put at the 50-Ω input of an unbalanced tuner, the differential-mode loss due to SWR can also be low.



Ex. 2: Unbalanced Tuner With Choke Balun at Input

- If the choke balun is at the 50-Ω input of an unbalanced tuner, the differential-mode loss due to SWR will be low.

Choke balun at tuner's input sees 50 Ω.

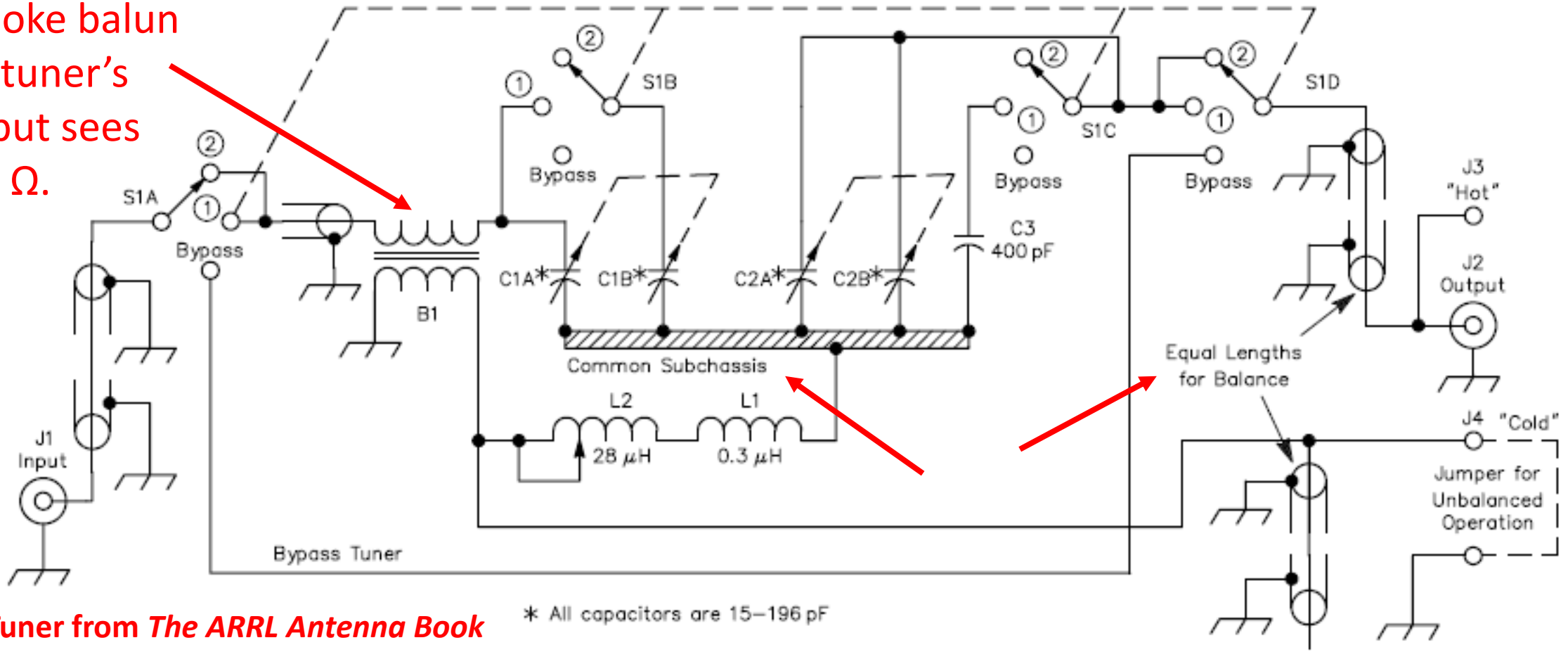


Tuner from *The ARRL Antenna Book*

Ex. 2: Unbalanced Tuner With Choke Balun at Input

- However, the mechanical configuration is more complex for a choke balun at the tuner's input.

Choke balun at tuner's input sees 50 Ω.



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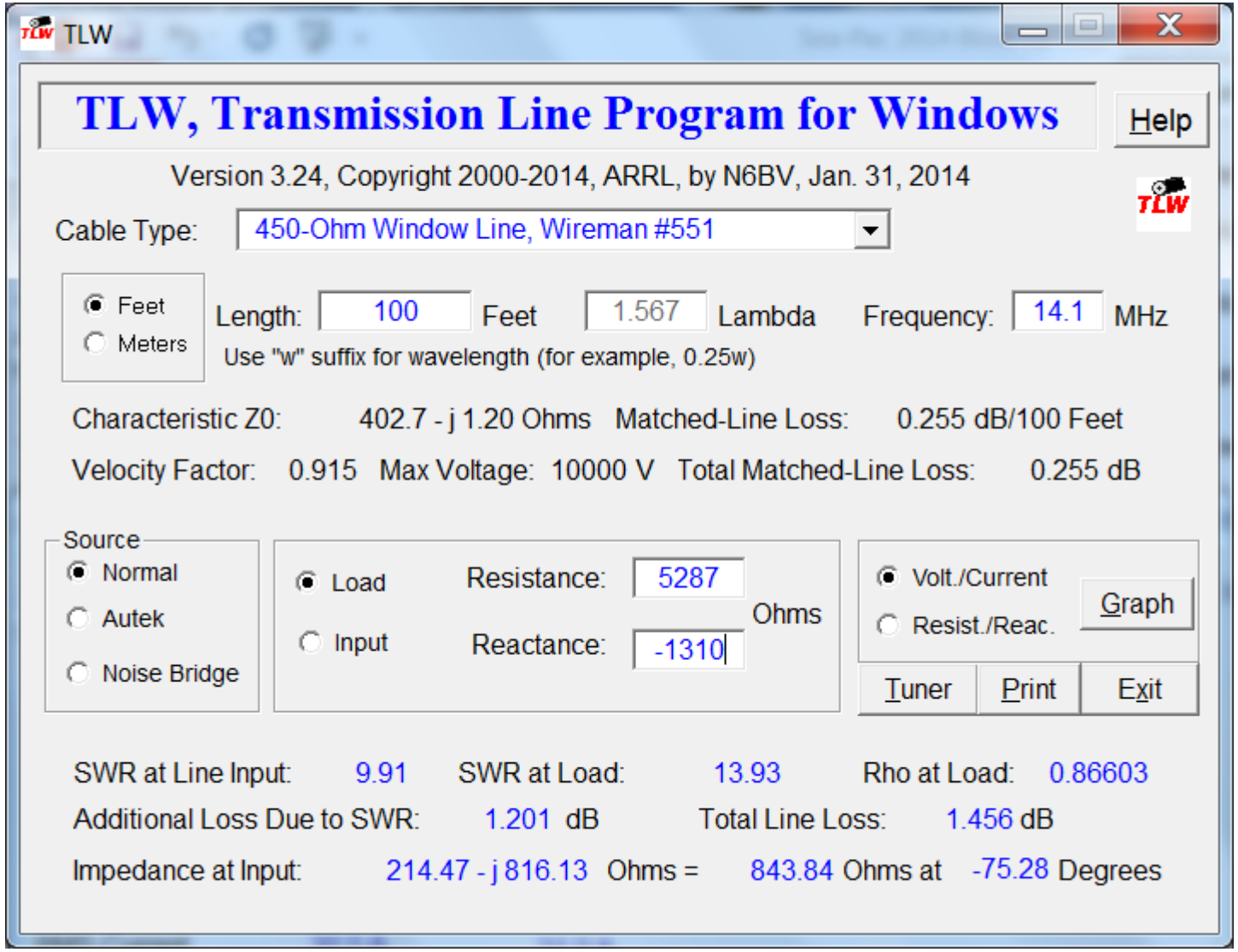
Ex. 3: Using “Window Line”



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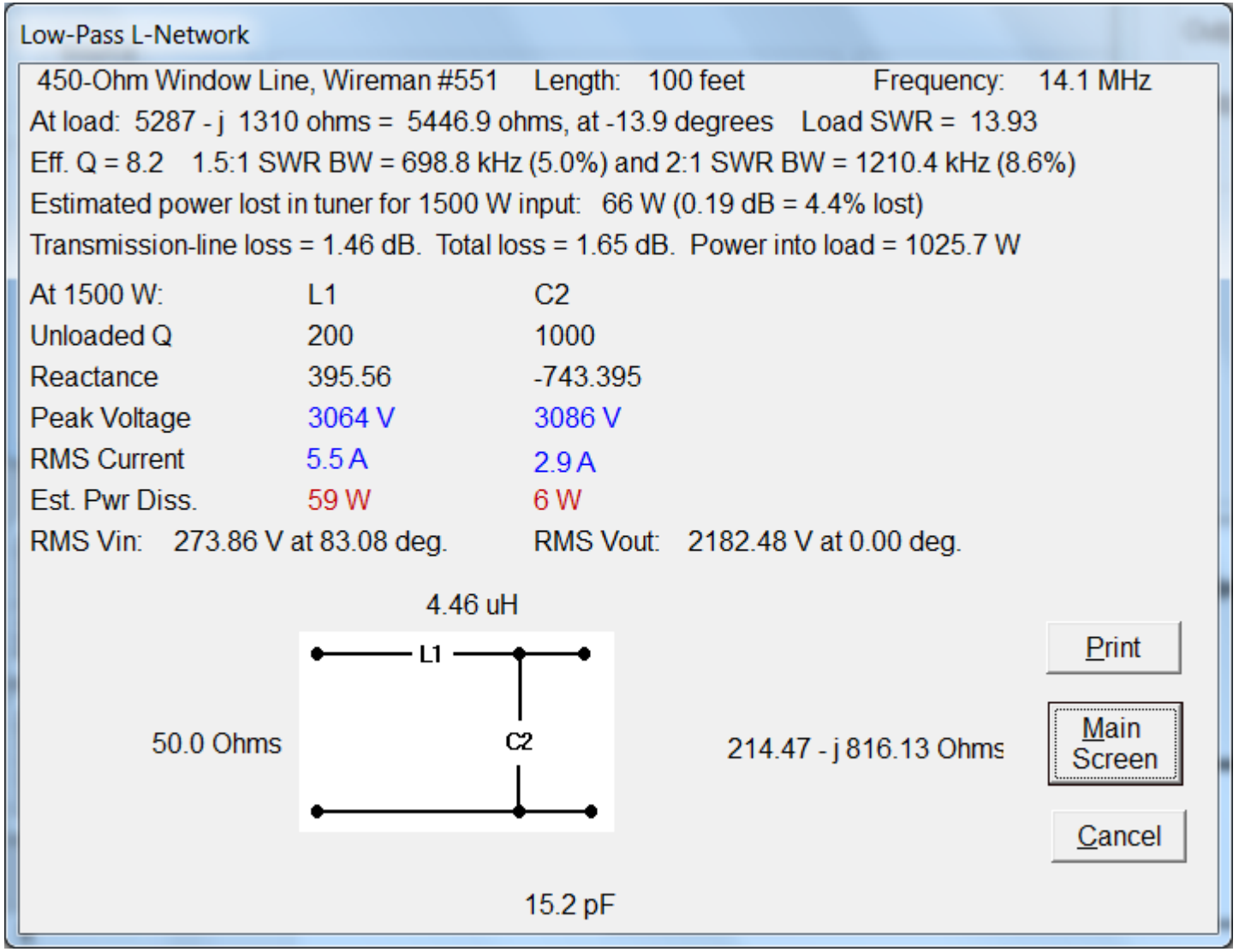

Ex. 3: Johnson Matchbox With "Window Line"

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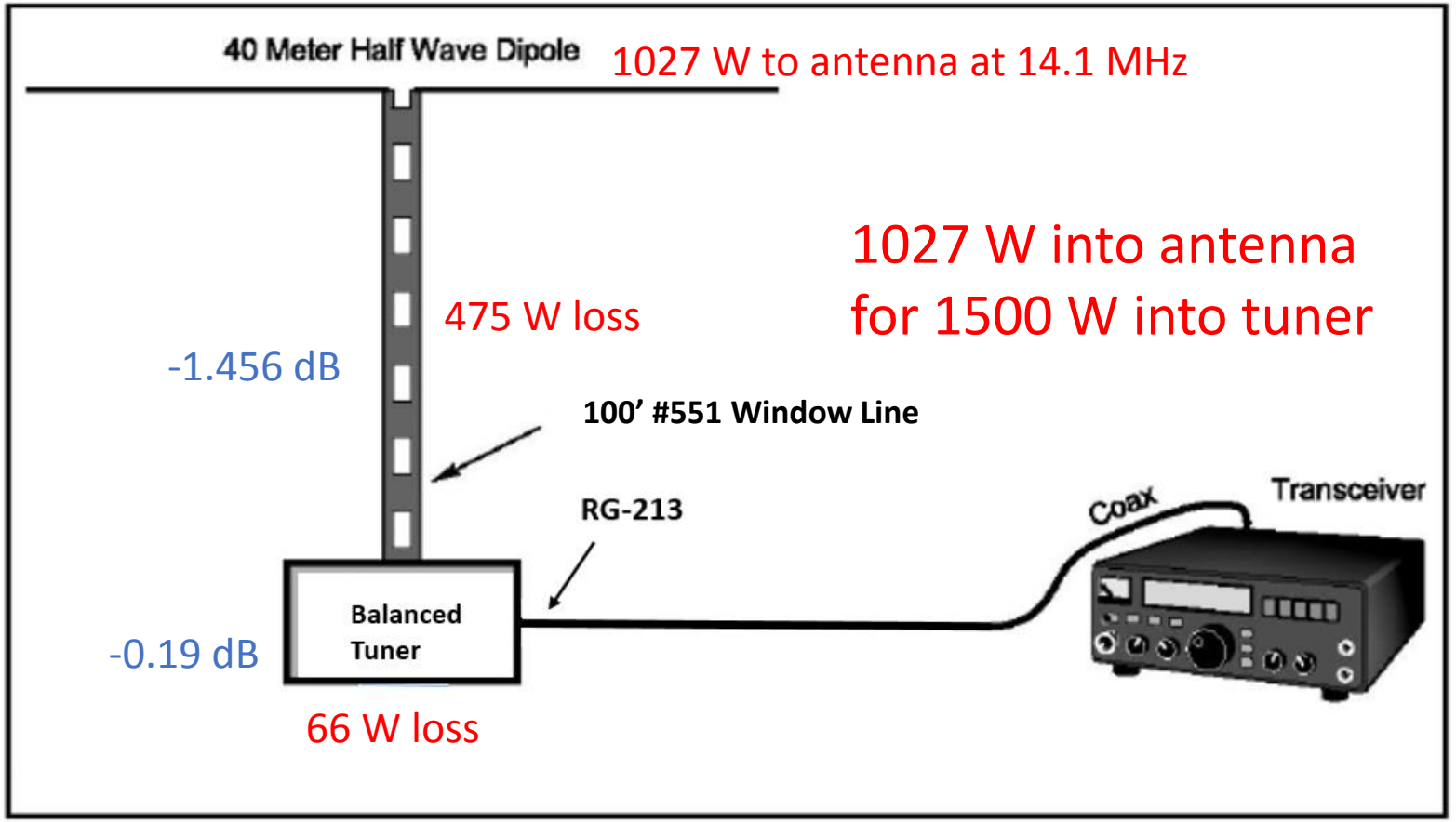
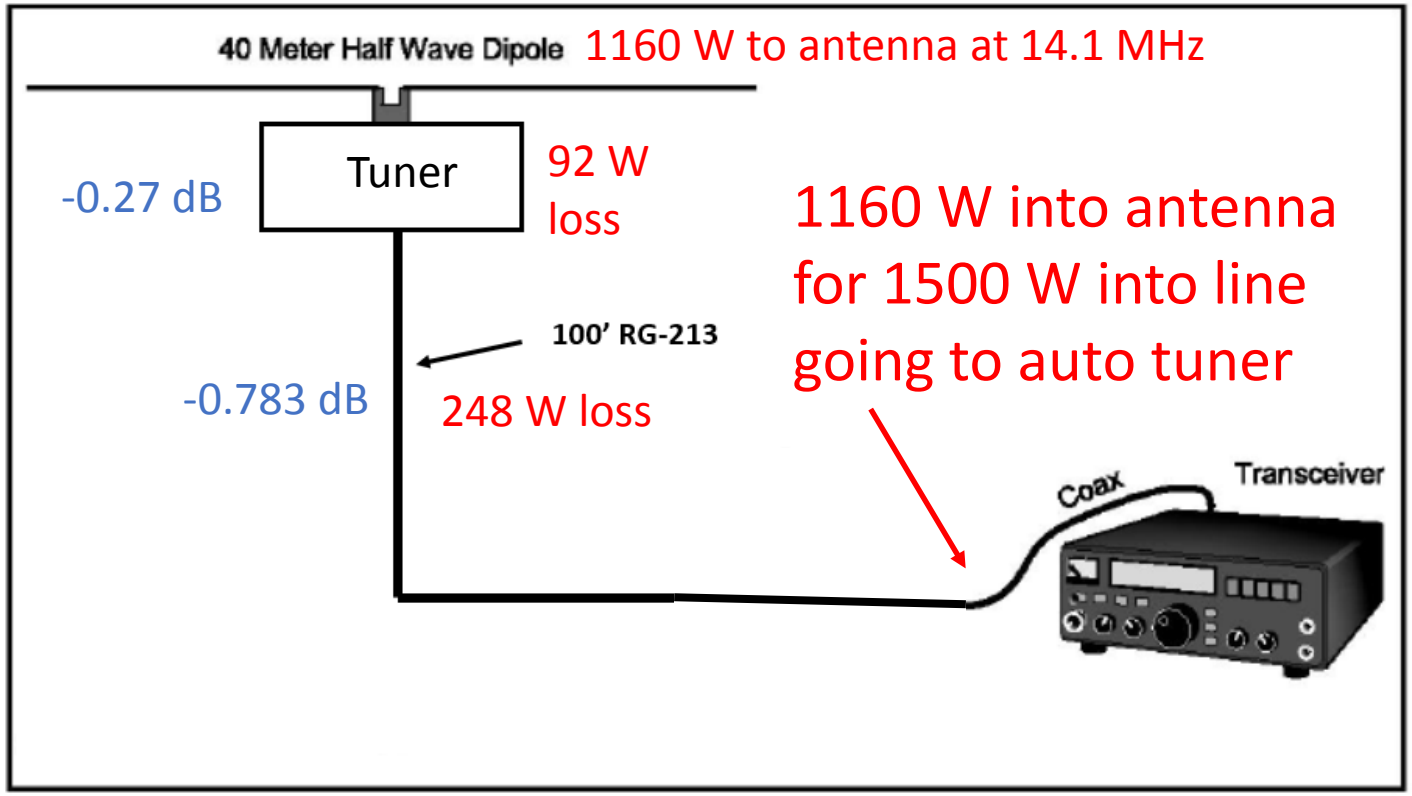


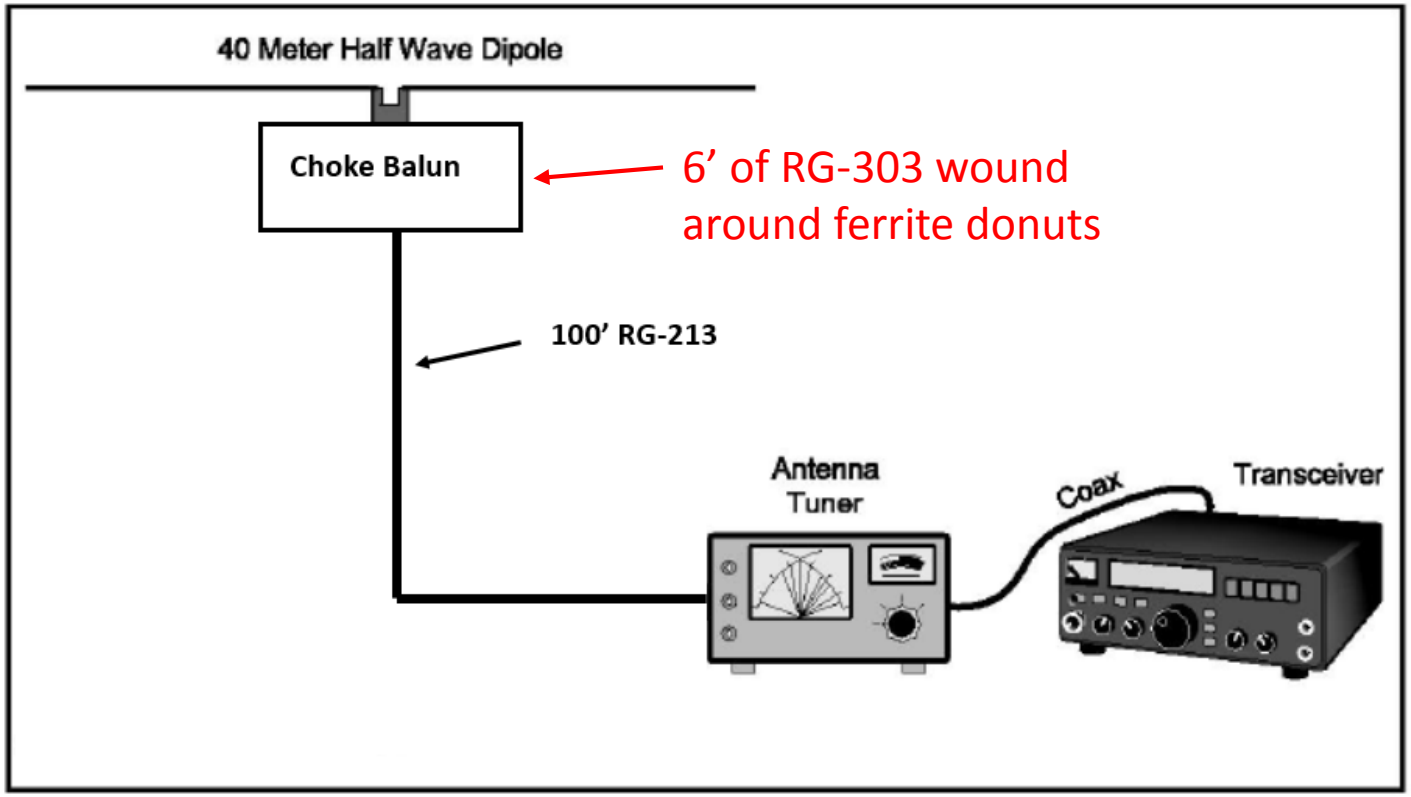
Ex. 4: Balanced Antenna Tuner

- The loss is also low if an auto tuner is located up at the antenna feed point.



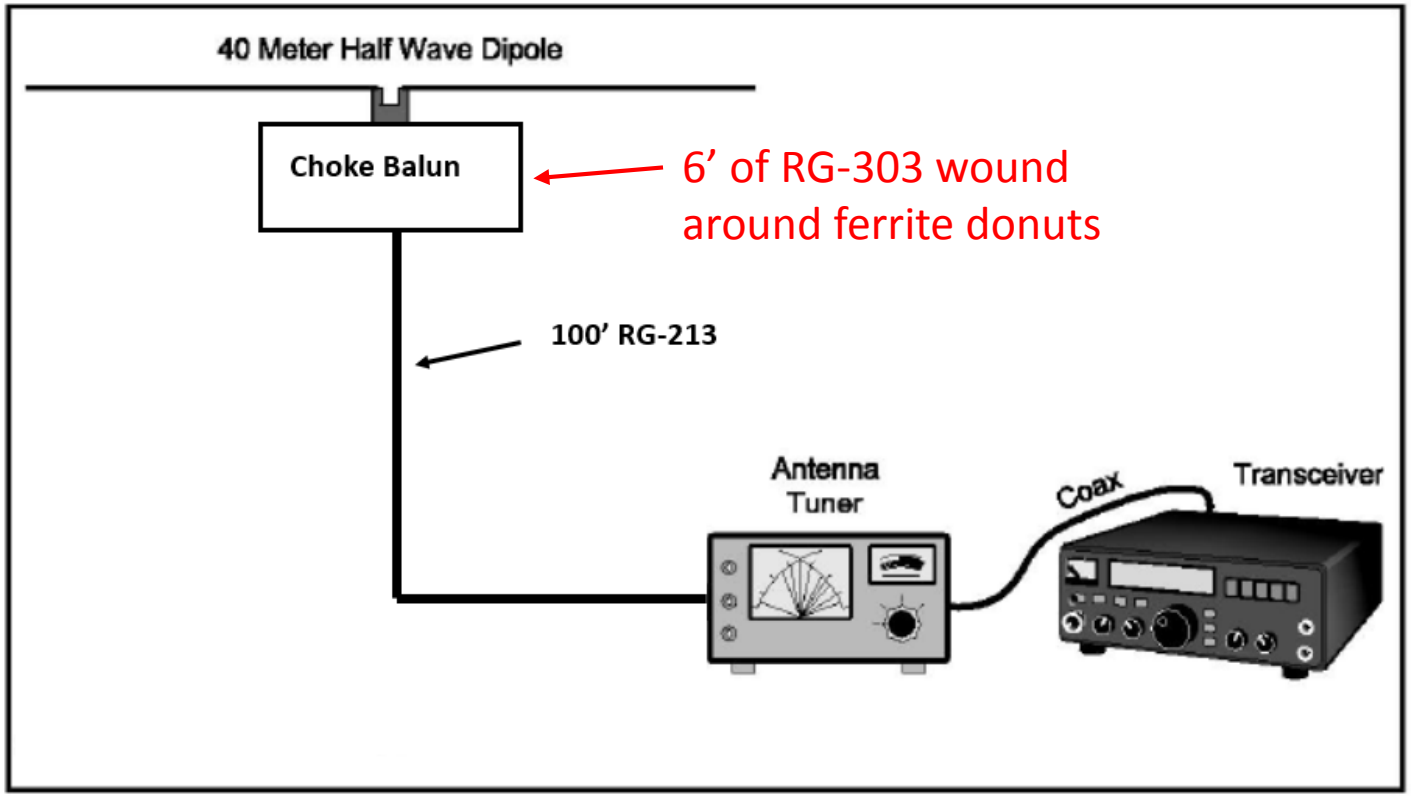
Ex. 5: Common-Mode Choke at Feed Point

- Assume antenna is a 40-meter dipole set up as an Inverted-Vee and operated at a worst-case frequency of 14.1 MHz.



Ex. 5: Common-Mode Choke at Feed Point

- Assume antenna is a 40-meter dipole set up as an Inverted-Vee and operated at a worst-case frequency of 14.1 MHz.
- Jim, K9YC, calls this my “train wreck” scenario!



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- *EZNEC* says the feed-point Z at 14.1 MHz is 5287 – *j* 1310 Ω.

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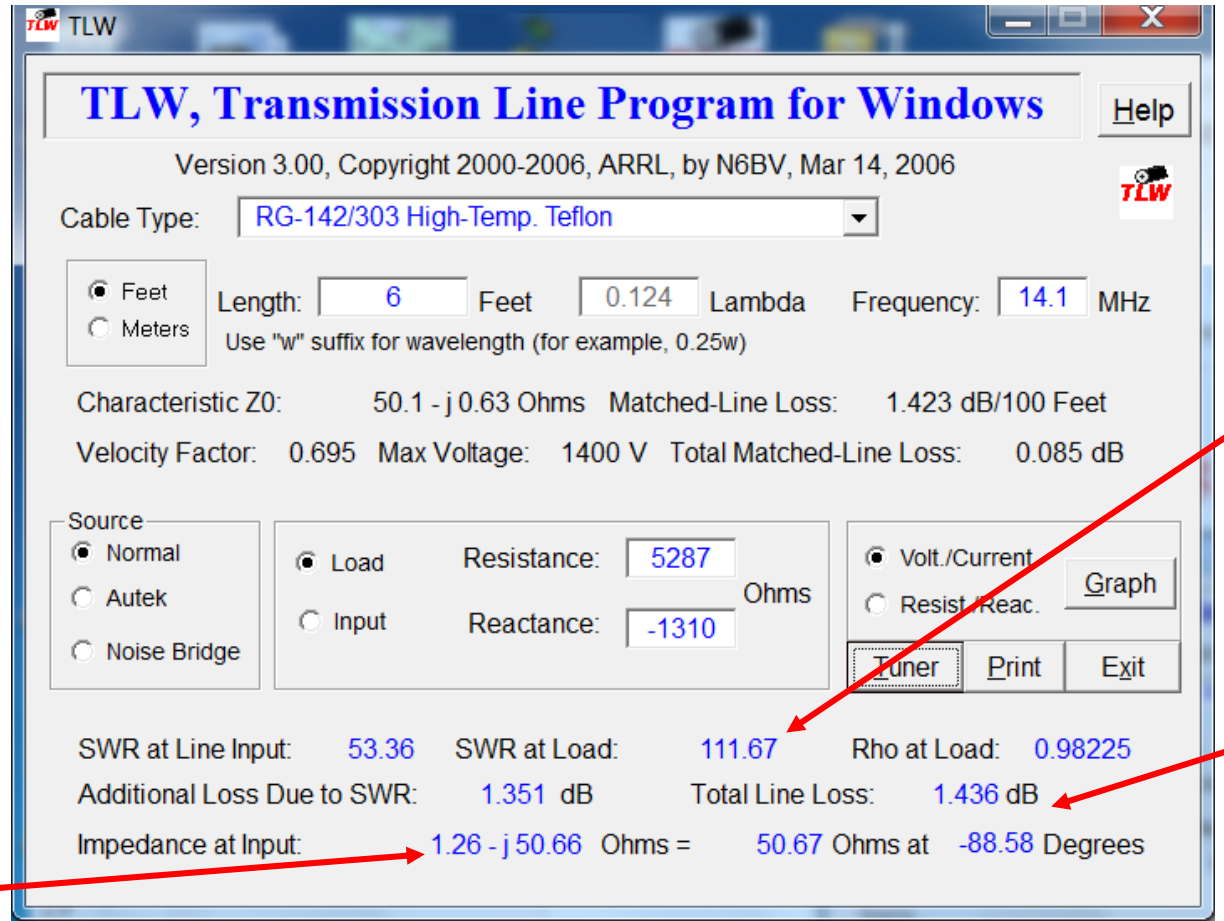
- *EZNEC* says the feed-point Z at 14.1 MHz is 5287 – *j* 1310 Ω.
- *TLW* computes the loss in 6’ of RG-303 making up the choke balun as 1.436 dB. Now, we “daisy chain” coax to coax.



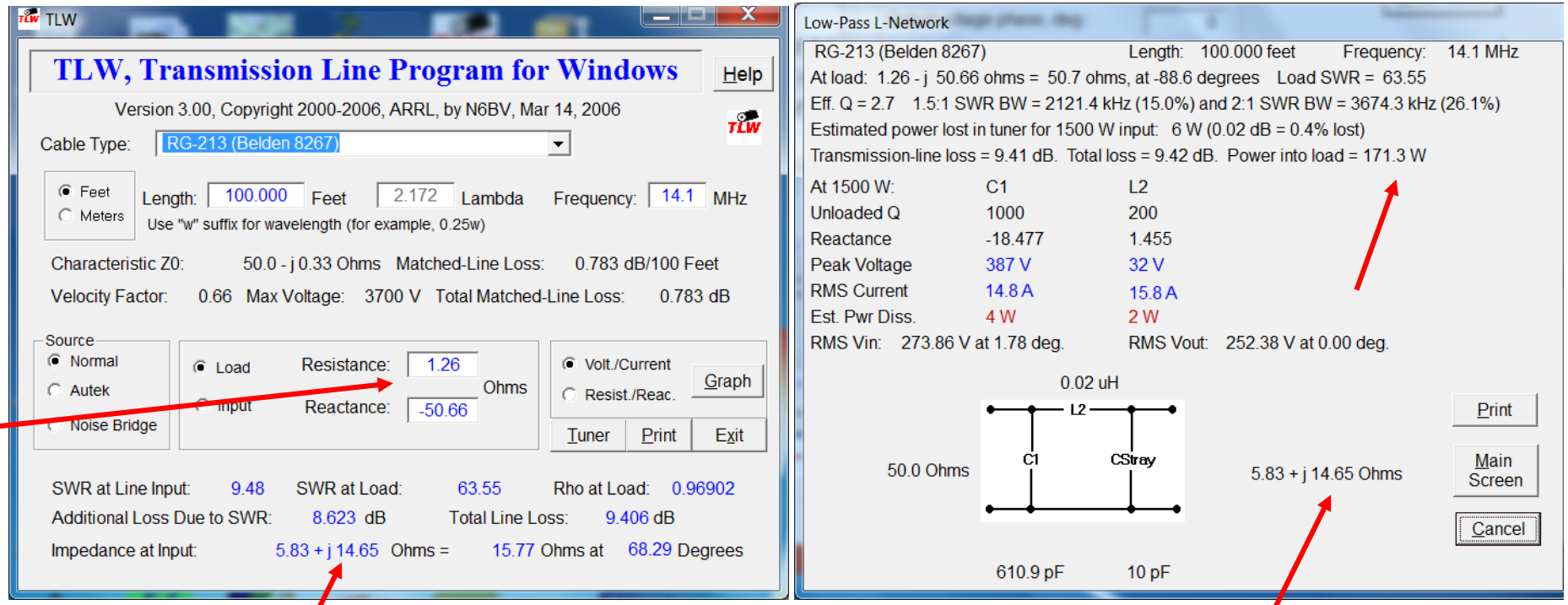
SWR!

Loss in choke balun

Z seen by 100’ of RG-213

Ex. 5: Common-Mode Choke at Feed Point

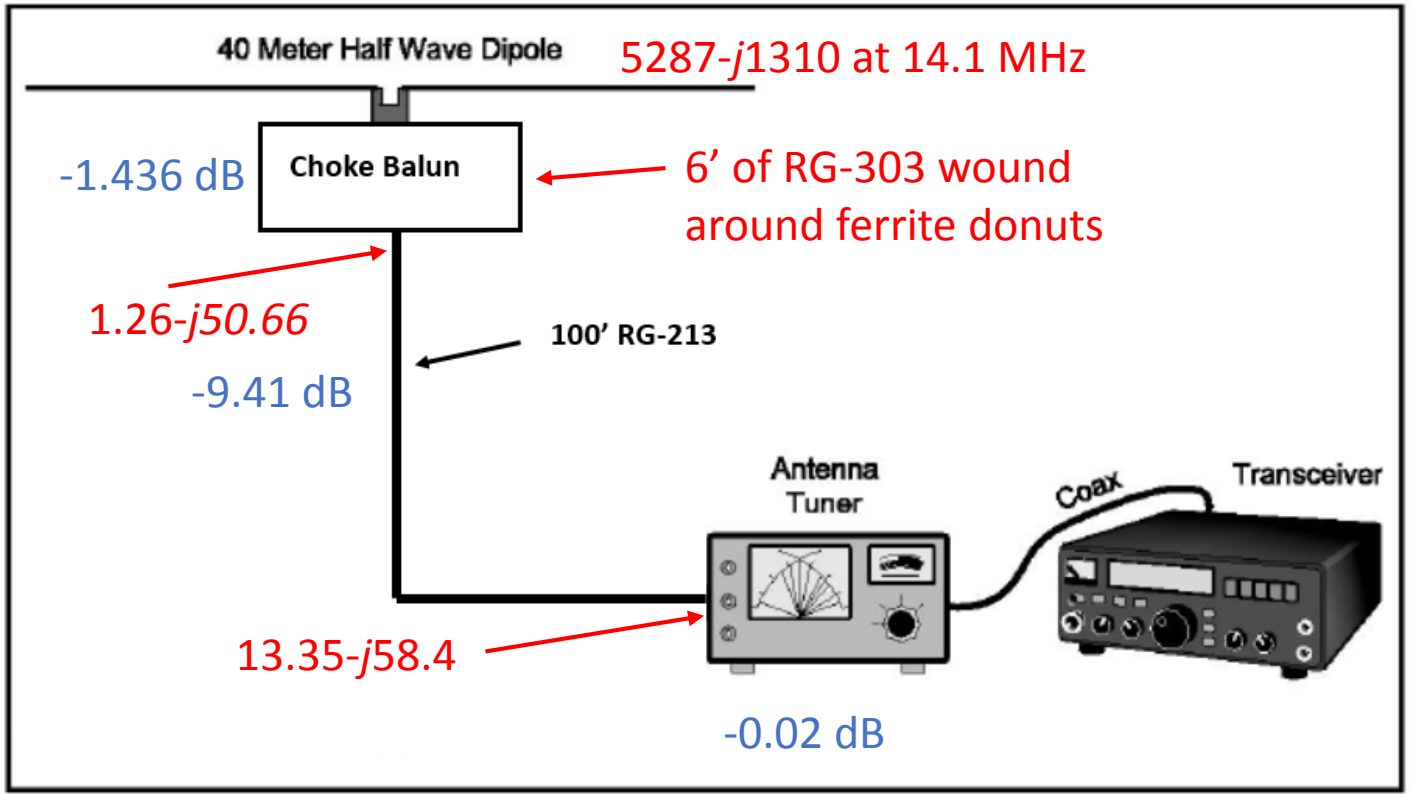
- *TLW* calculates that 100’ of RG-213 seeing 1.26 – j 50.66 Ω plus an efficient tuner will have a loss of 9.41 dB, giving an input to the choke balun of 1500 W – 9.41 dB, or 171 W.



Input of choke

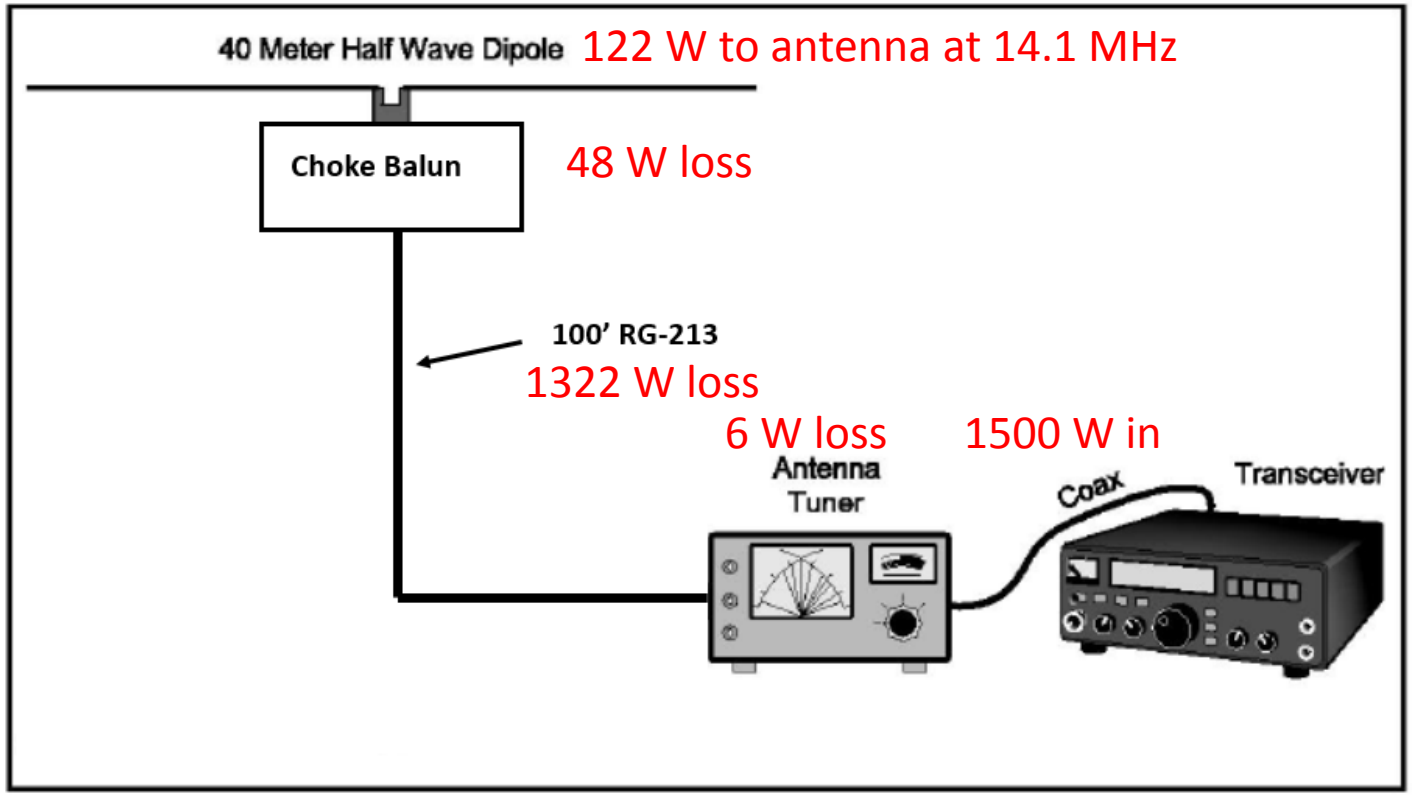
At tuner

Ex. 5: Common-Mode Choke at Feed Point



Ex. 5: Common-Mode Choke at Feed Point

- Loss in choke balun = 48 W, which is 8 W/ft; should not fry the small choke balun, even if airflow is restricted. The overall system loss is 10.87 dB. The antenna thus receives 122 W for 1500 W power into the tuner.



Note that the high loss in the RG-213 coax is "protecting" the balun.

Stresses on Common-Mode Chokes

- Now what sort of dimwit would try to feed a 40-meter half-wave dipole on its full-wave resonance, through coax?

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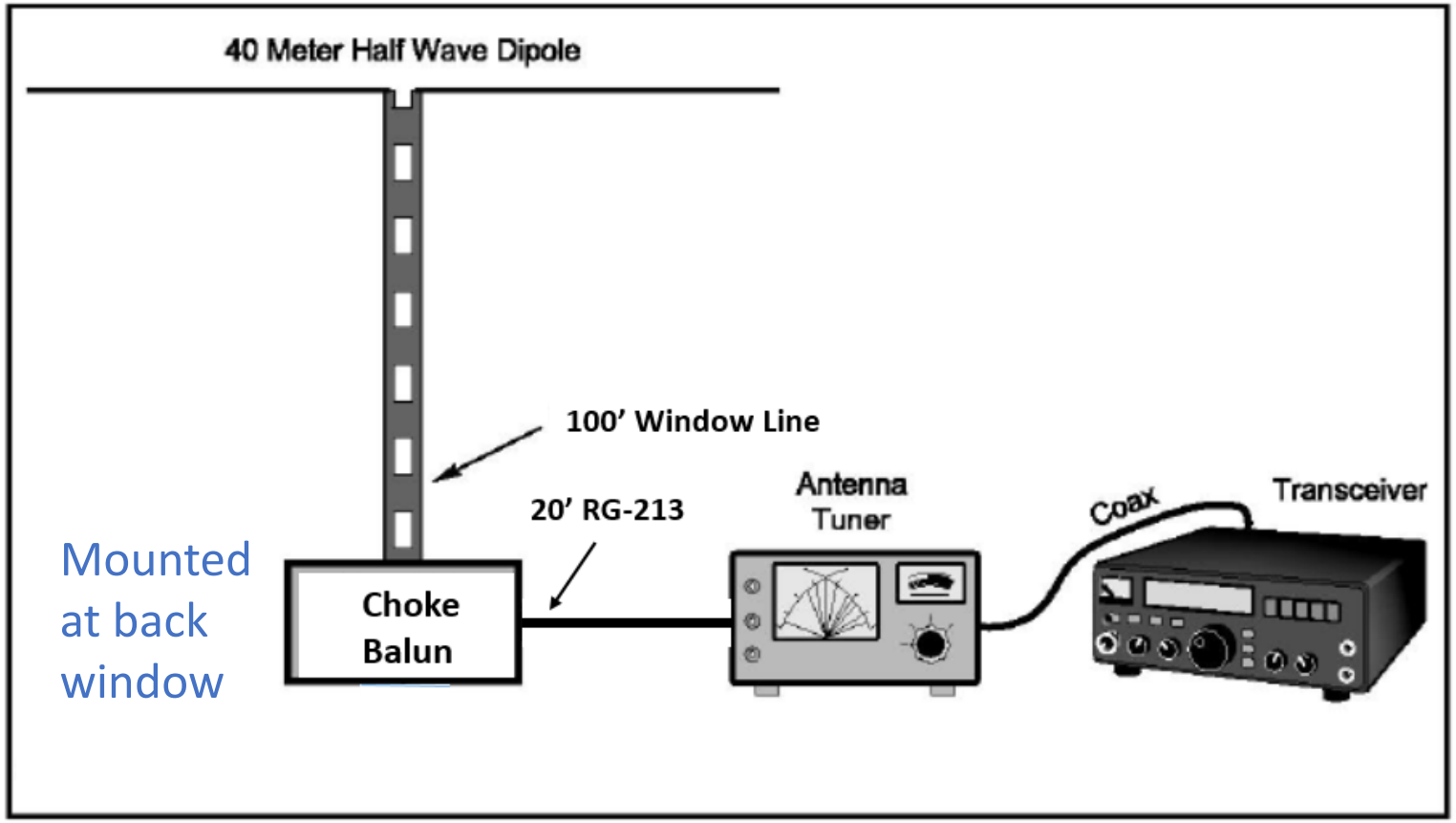
- Now what sort of dimwit would try to feed a 40-meter half-wave dipole on its full-wave resonance, through coax? Don't ask me how I know…

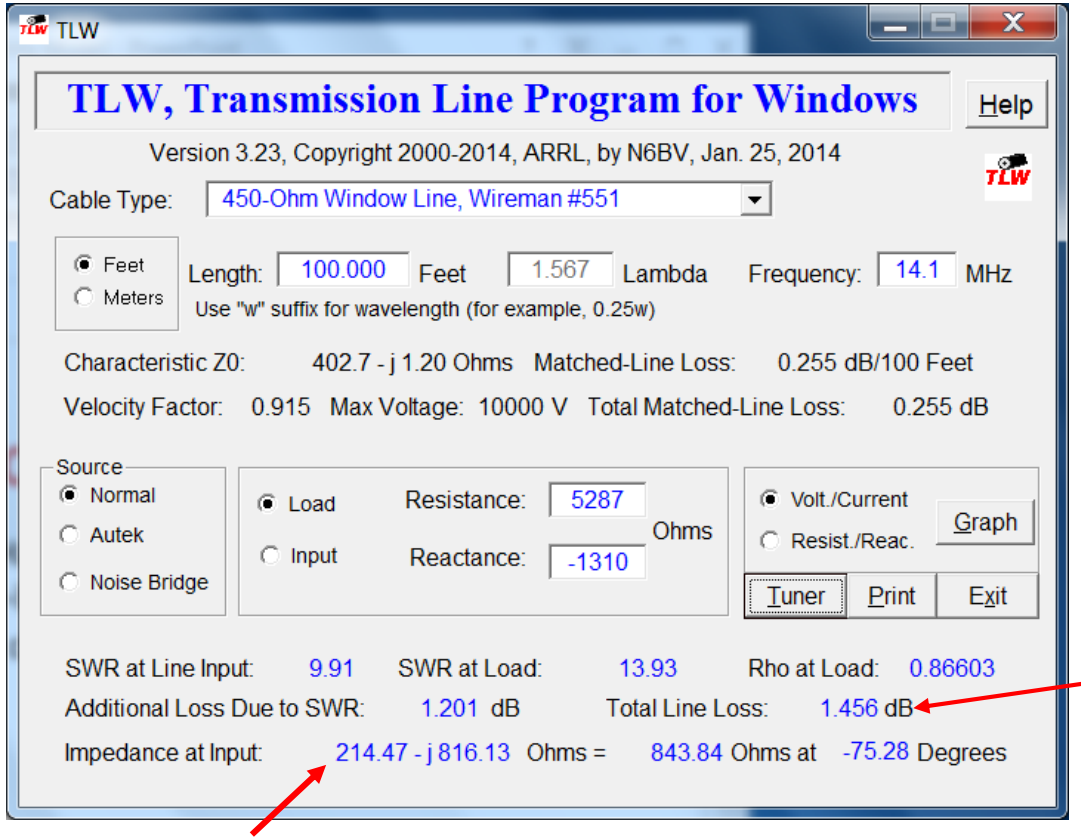
Ex. 6: Common-Mode Choke in Shack

- A common installation, where open-wire feed line goes to a choke balun placed at a rear window in the shack and then, say, a 20’ coax jumper goes from the choke to the Antenna Tuner.



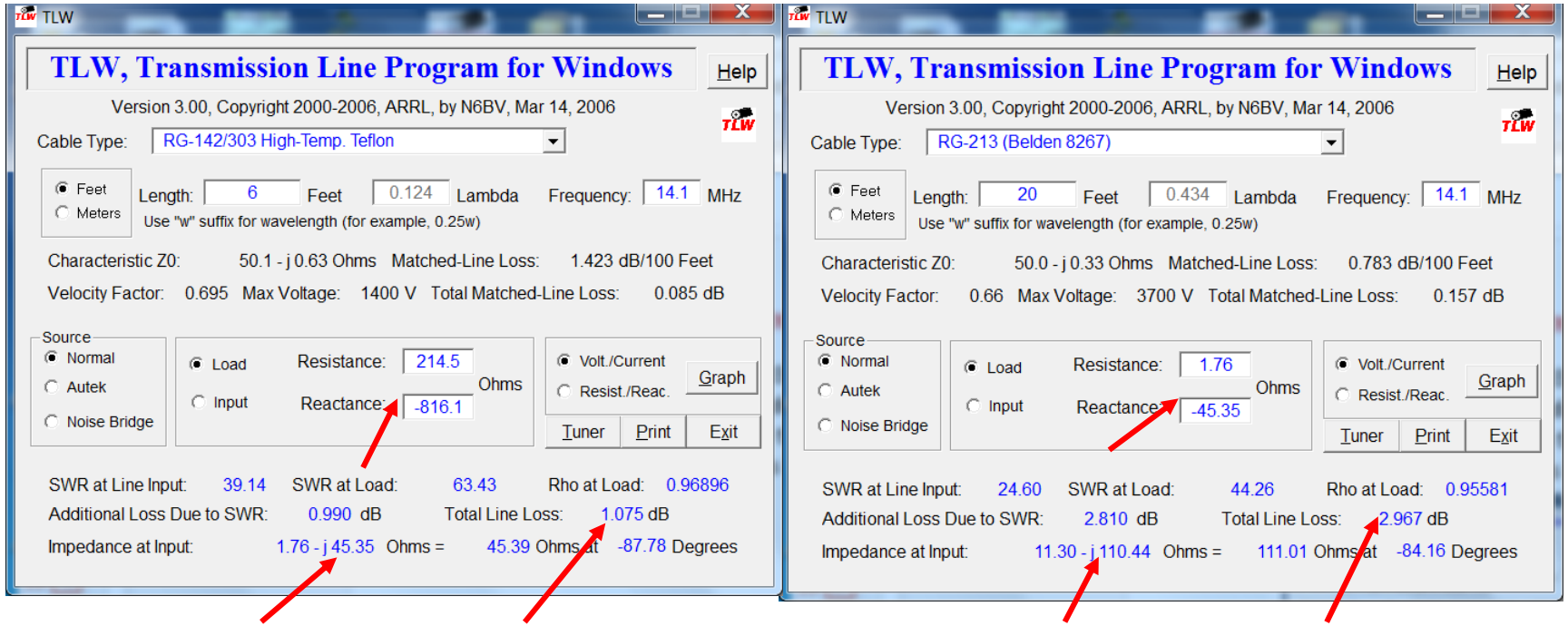
Ex. 6: Common-Mode Choke in Shack

- At the full-wave frequency of 14.1 MHz for this 40-meter half-wave dipole, the total window ladder-line loss is 1.456 dB. Not too bad! Now, daisy chain Zin to the choke balun load.



Ex. 6: Common-Mode Choke in Shack

- The loss in the 6’ of RG-303 making up the choke balun at the bottom of the 100’ of window line is 1.075 dB. The loss in 20’ of RG-213 from the choke to the tuner is 2.967 dB; the tuner loses about 0.28 dB. Overall loss is 1.456+1.075+2.967+0.28=5.78 dB.



This is the choke balun

20’ jumper from tuner to balun

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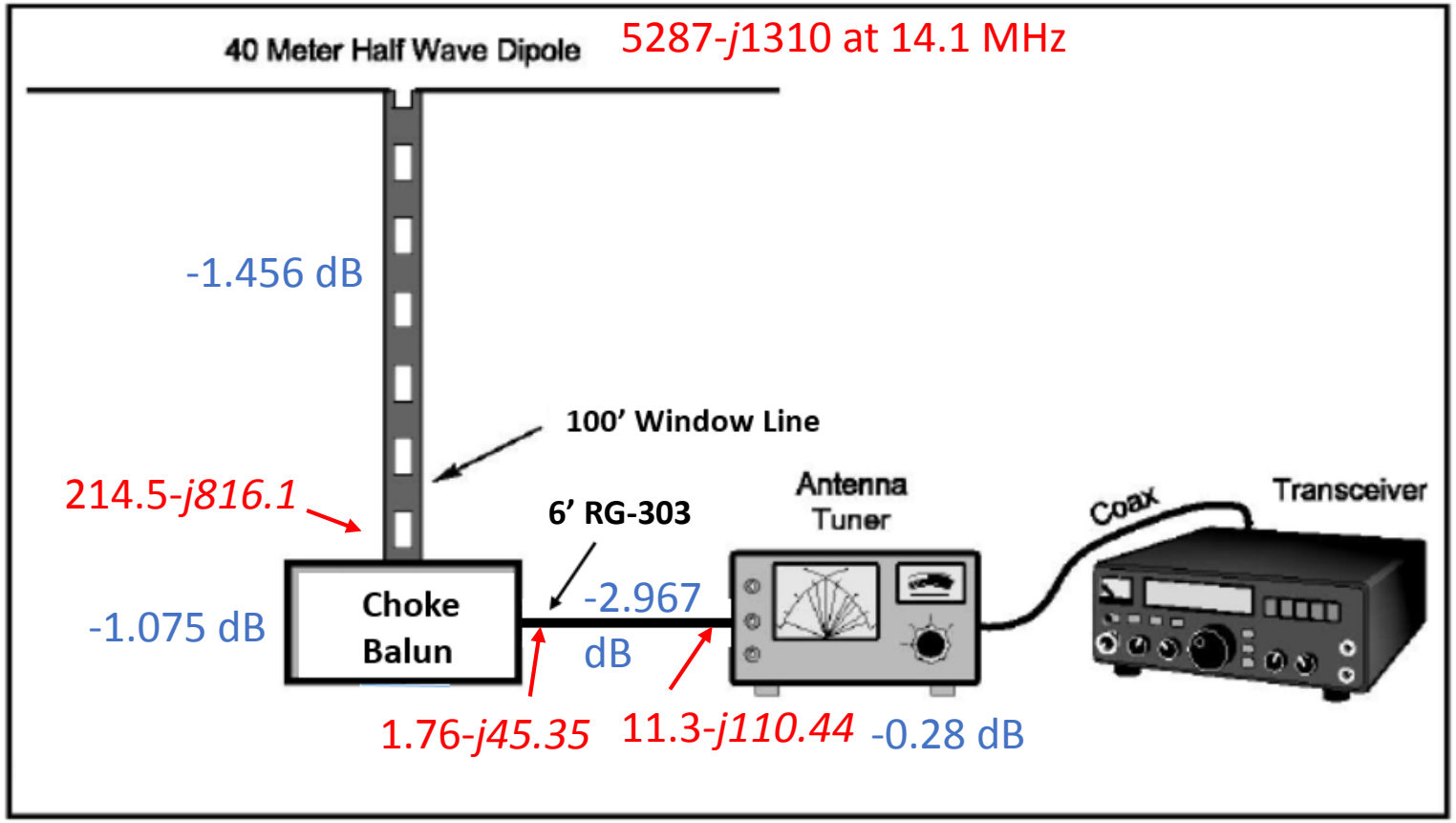
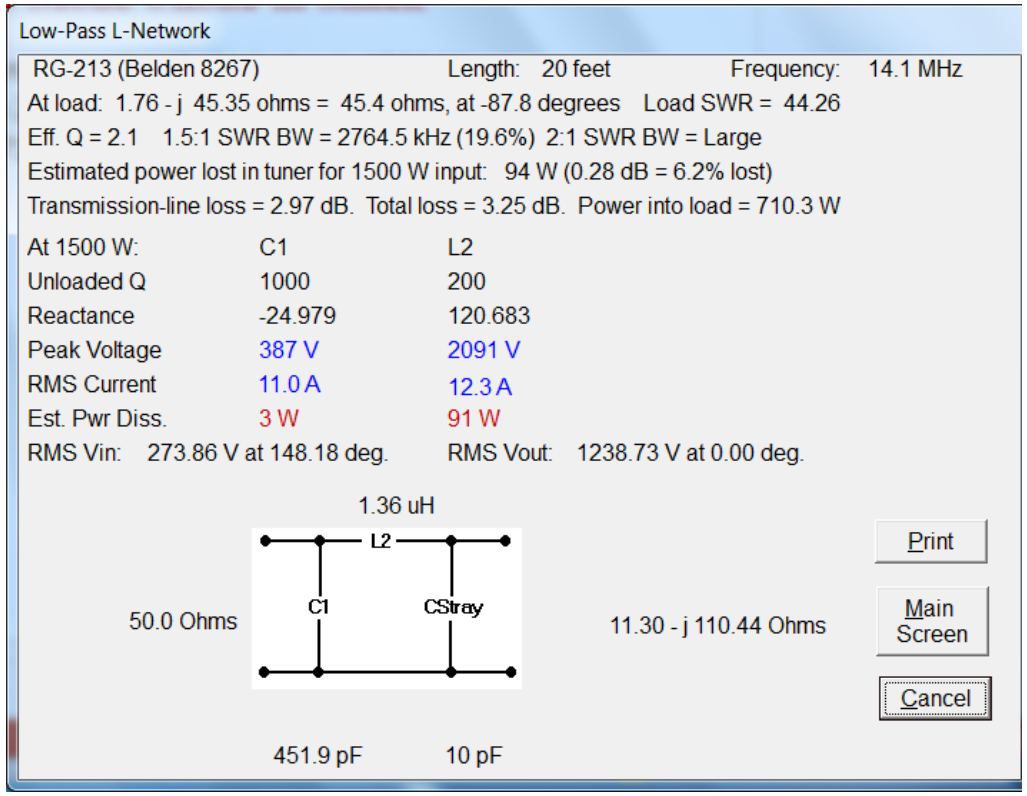


Ex. 6: Common-Mode Choke in Shack

- The power available at the input to the choke balun is 1500 W minus loss in antenna tuner and in 20’ of RG-213 jumper from antenna tuner to the choke balun = 710 W at balun. The 696 W lost in the 20’ jumper is 35 W/ft. Goodbye jumper!



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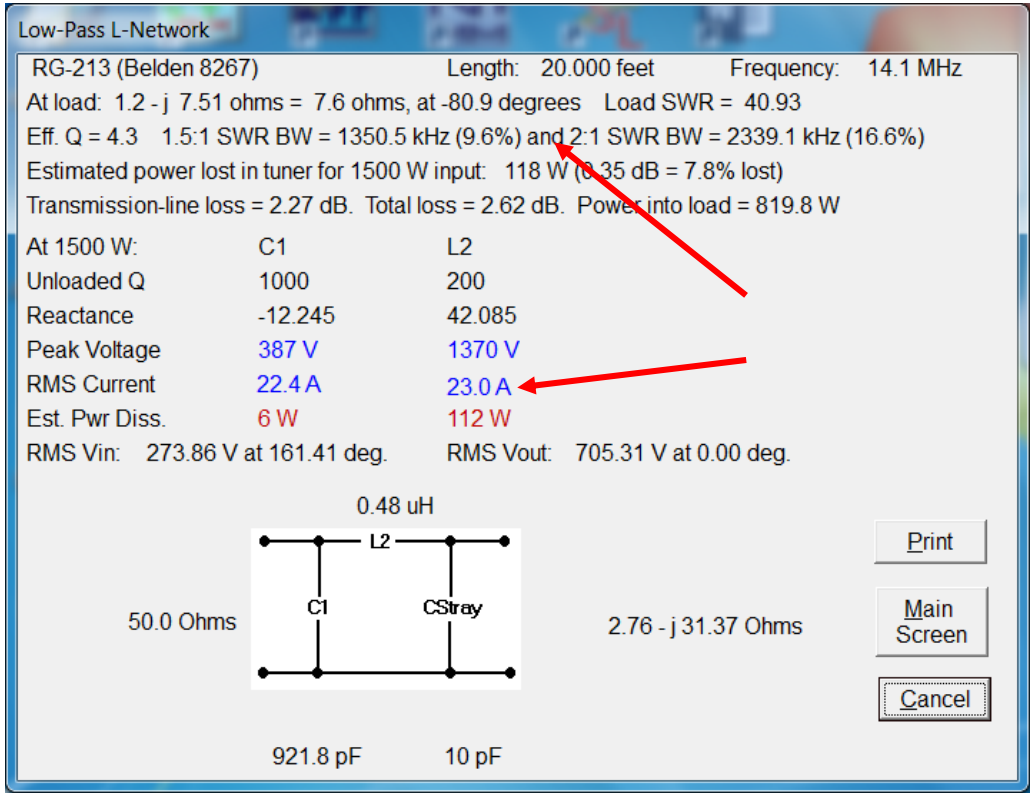
- The power lost in the choke balun is 710 W - 554 W = 156 W, 26 W/ft., a dangerous level for a balun.
- Note tuner loss: 118 W, 112 W in the coil.



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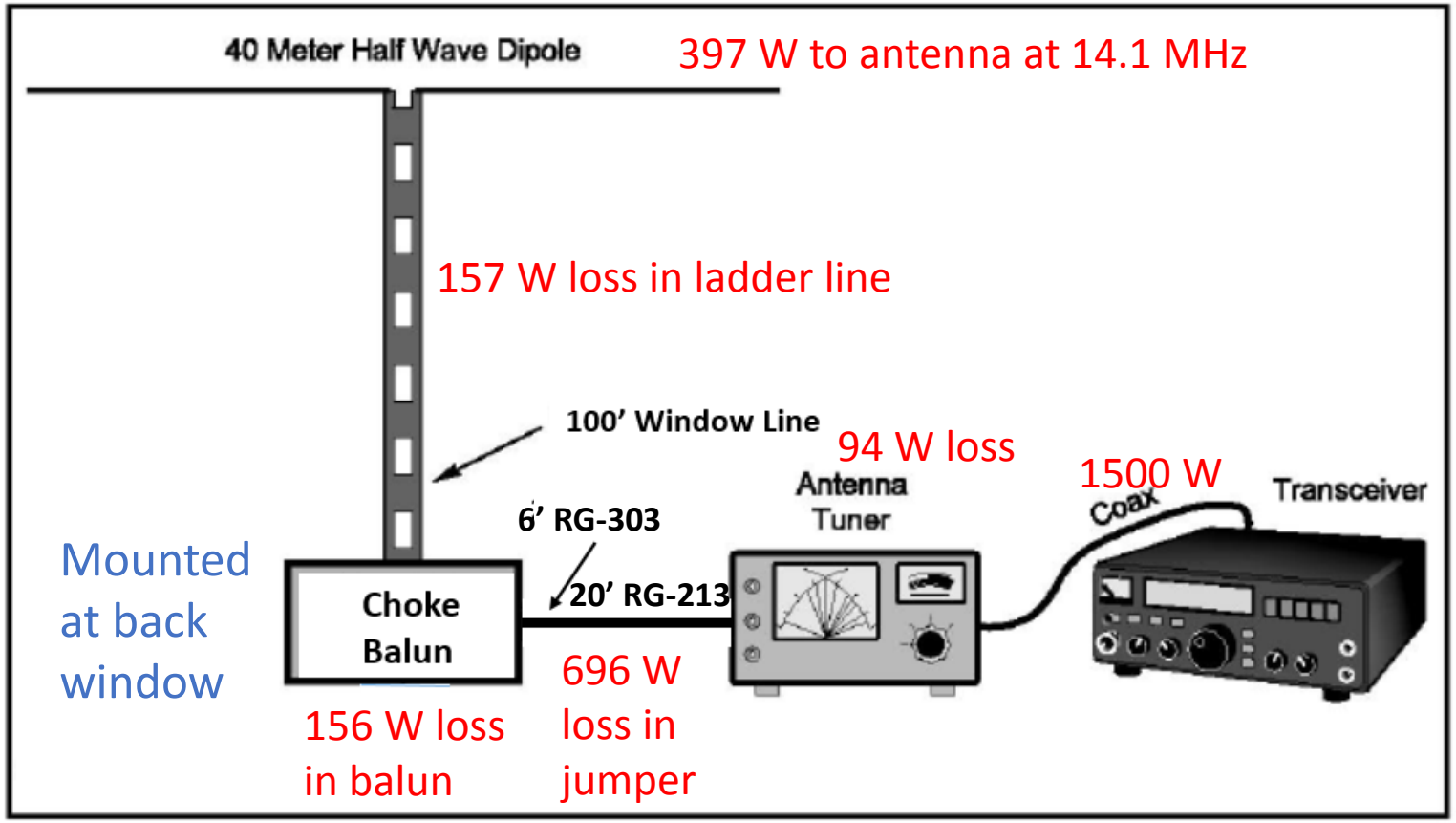
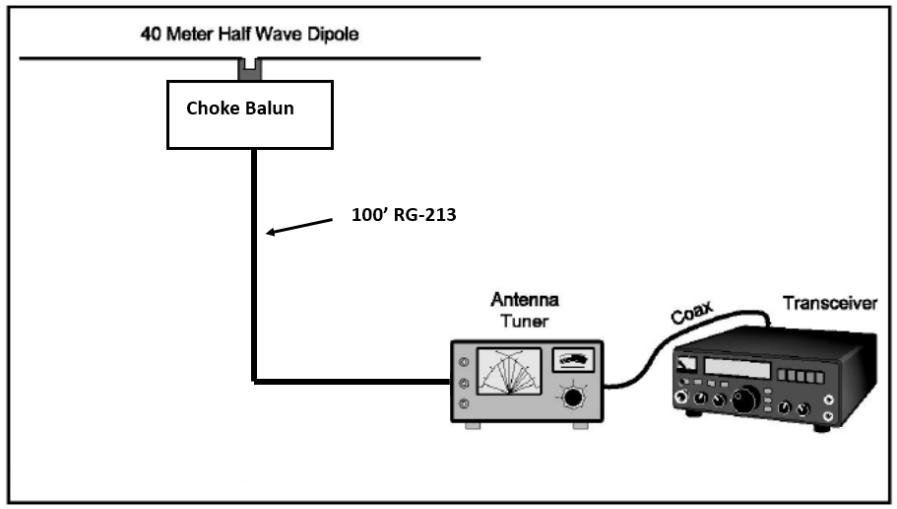
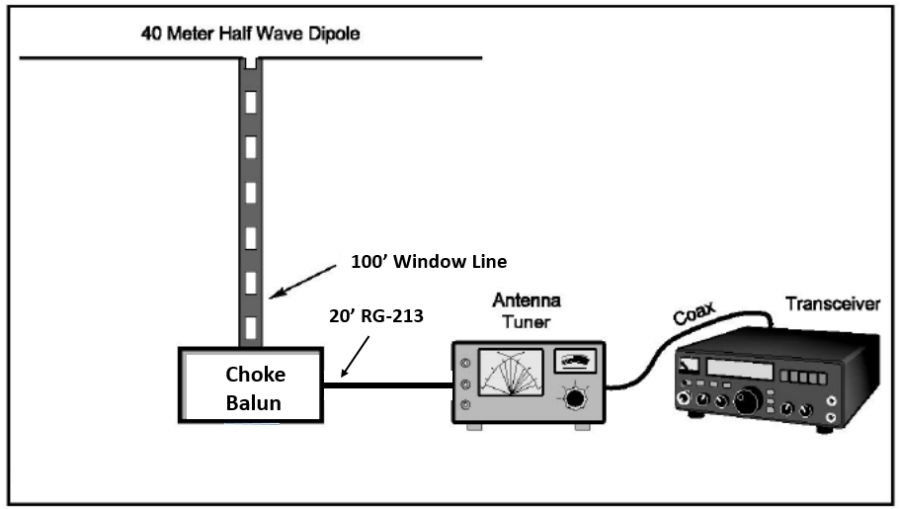


Stresses on Common-Mode Chokes

- An overall feed-line loss of 5.68 dB is better than the previous loss of 10.87 dB, but it still isn't anything to write home about. And the choke-baluns probably won't survive QRO power.





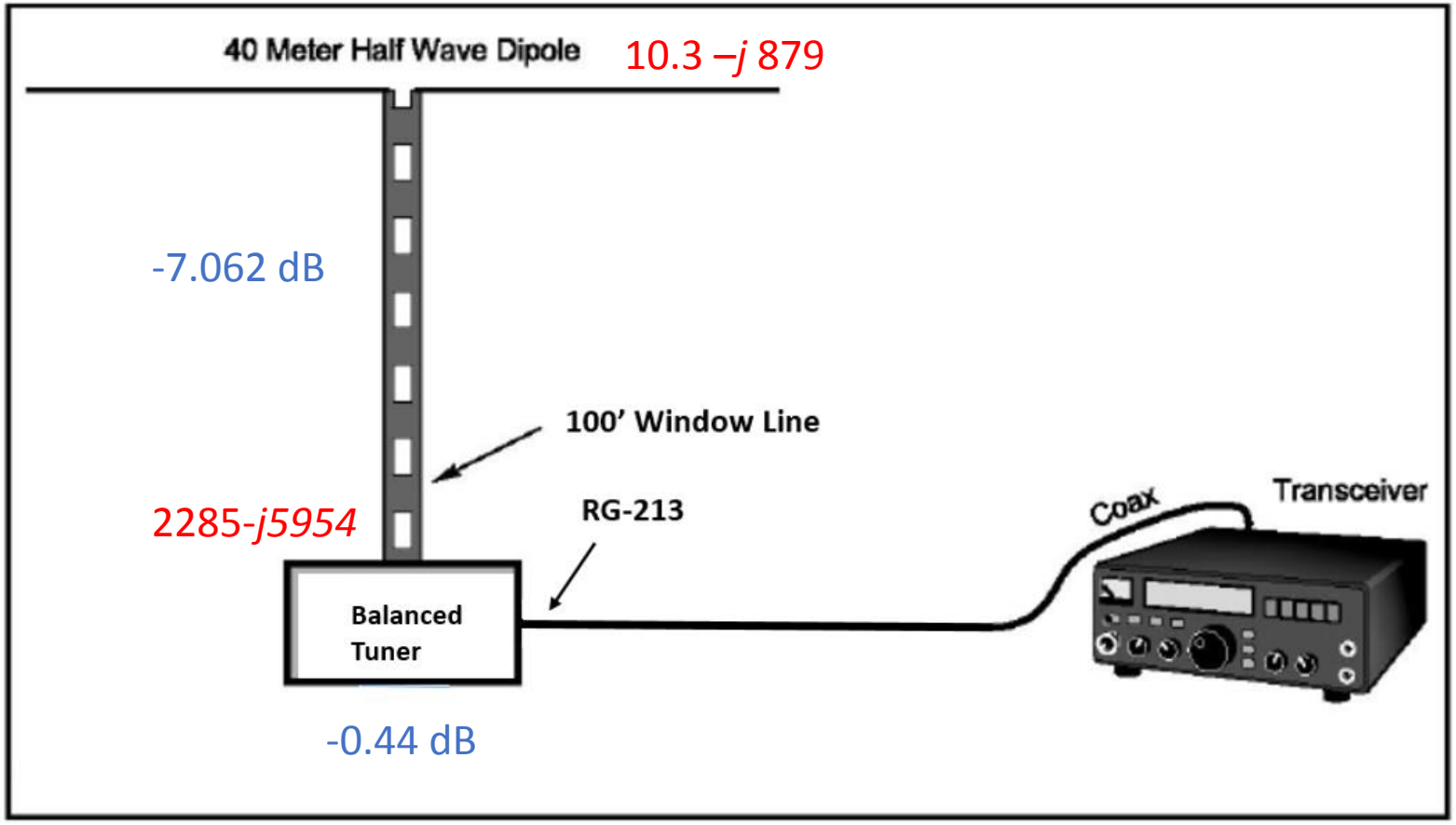
10.87 dB total system loss: 122 W gets to antenna for 1500 W input; not very efficient use of RF.

5.87 dB system loss: 397 W at antenna for 1500 W input; we have smoke inside the tuner, the jumper and in the choke balun.

Setup: Inv. V 40-m Dipole used at 14.1 MHz	Power in Tuner	Power in Balun	Power in Feed Line	Power in Antenna
Classic 100’ long #12 open-wire line Ex. 1	78 W, Johnson Matchbox	NA	97 W, in #12 OWL	1325 W
Classic 100’ long #12 open-wire line Ex. 2	90 W, balun at unbalanced tuner’s input	12 W balun in tuner	97 W, in #12 OWL	1314 W
Balanced tuner at dipole’s feed point; 100’ RG-213; Ex. 4	92 W, in autotuner	NA	248 W, in 100’ RG-213	1160 W
#551 100’ window-line; Ex. 3	66 W, Johnson Matchbox	NA	475 W, in 100’ #551 window line	1027 W
Balun in shack; 100’ #551; Ex. 6	94 W	156 W in balun; 696 W in 20’ RG-213 jumper	157 W, in 100’ #551 window line	397 W
Choke balun at dipole’s feed point; 100’ RG-213; Ex. 5	6 W	48 W	1322 W in 100’ RG-213	122 W

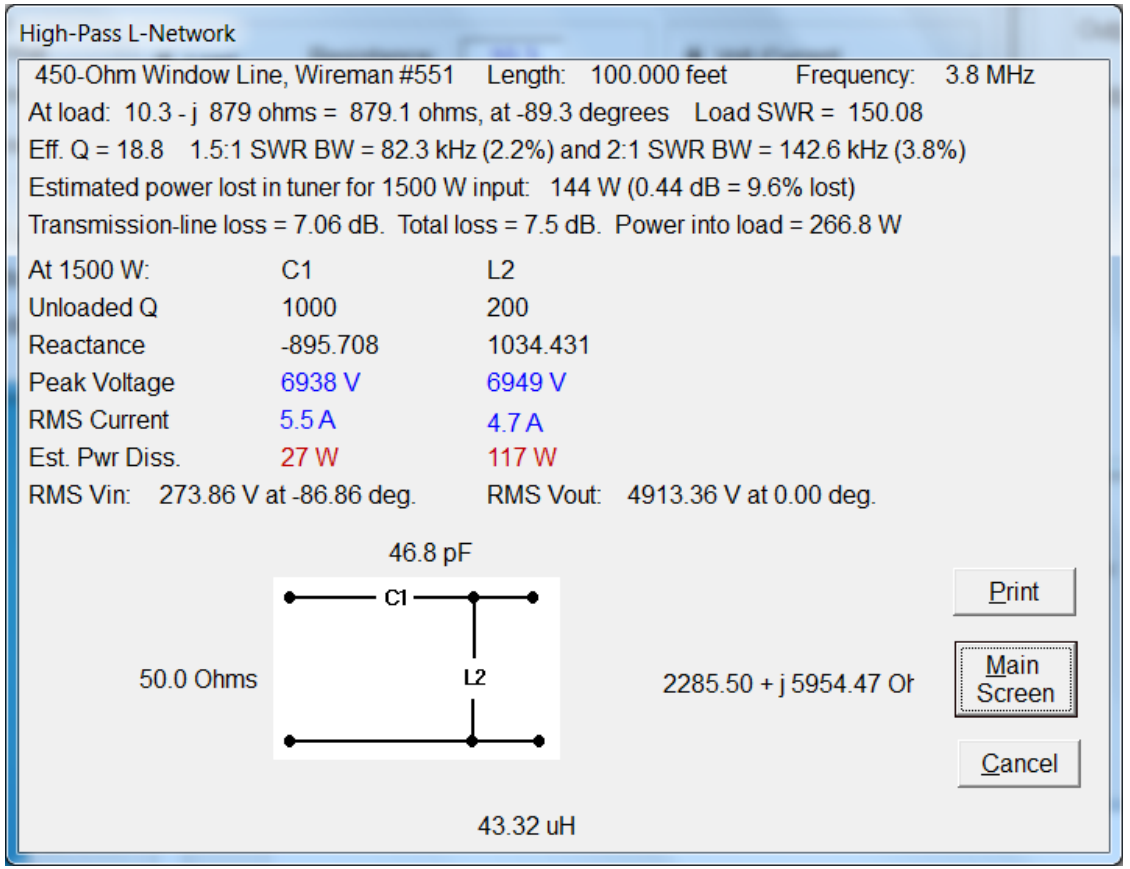
Ex. 8: 40-Meter Dipole Used on 80 Meters

- Loss in ladder-line at 3.8 MHz (where antenna feed point is 10.3 –*j* 879) is 7.062 dB, surprisingly high for window line.
- Loss in balanced tuner is 0.44 dB. Overall loss is 7.50 dB.



Ex. 8: 40-Meter Dipole Used on 80 Meters

- Loss in balanced tuner is 0.44 dB. The loss is mainly in the coil (117 W) but 27 W is in the tuning capacitor.
- The peak voltages inside the tuner are close to 7000 V peak.



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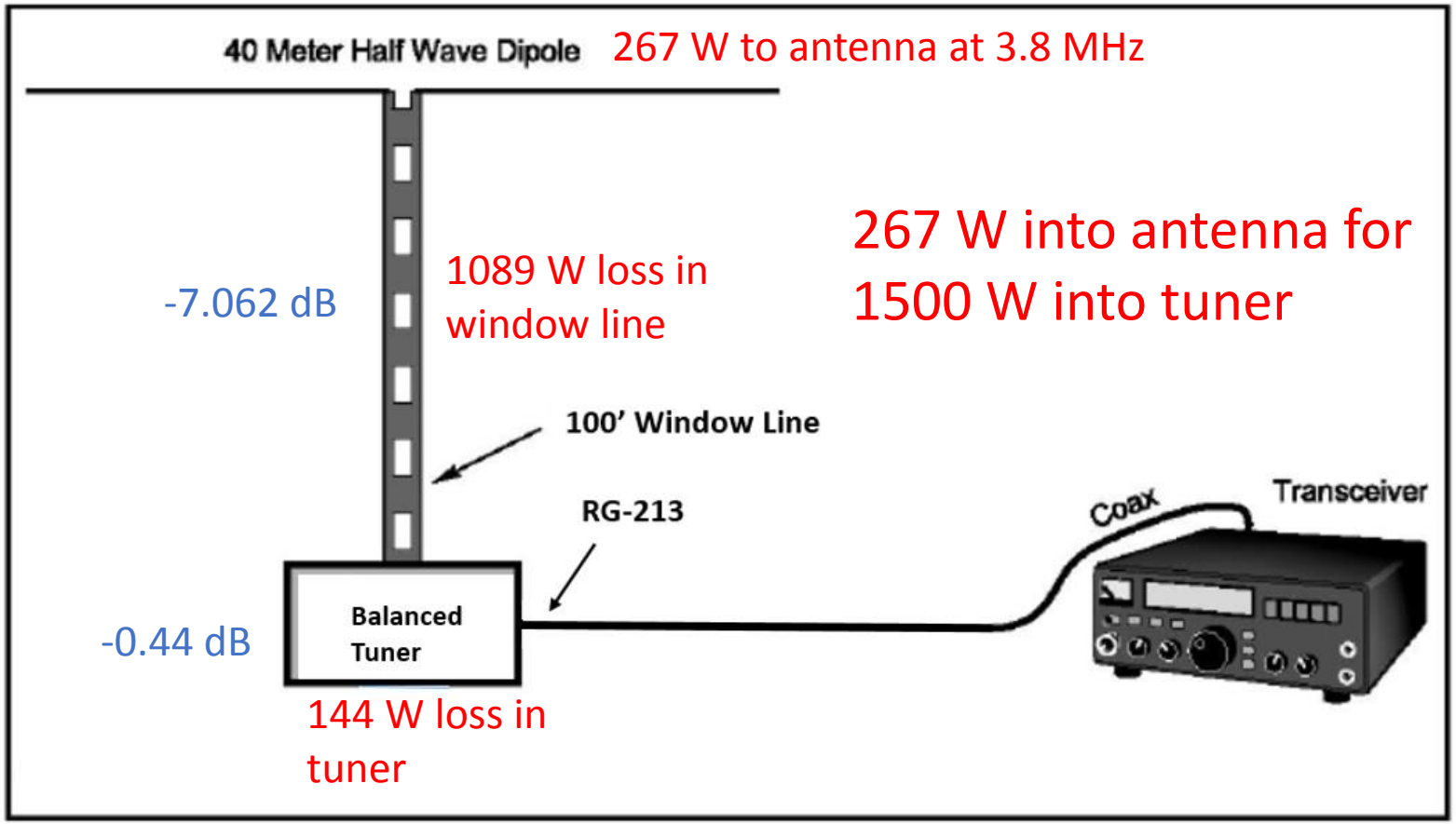

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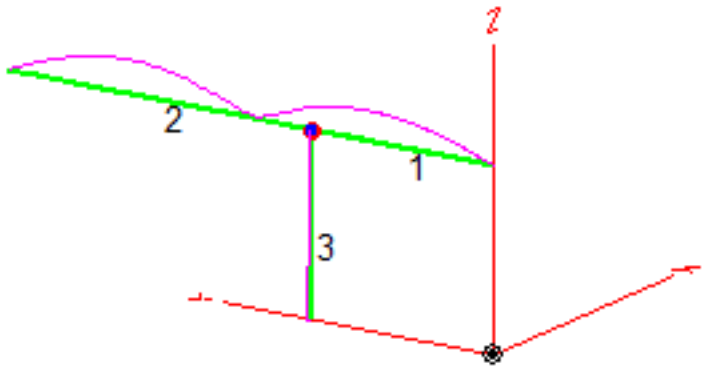

EZNEC Pro/4

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- Common-mode currents are unavoidable due to asymmetric feed, even with high values of common-mode choke resistance.
- For a typical 80-meter OCF fed 37.5% from one end, *EZNEC* calculates a choke balun loss of 326 W for a 5000-ohm choke resistance at 7.1 MHz at 1500 W.

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- Common-mode currents are unavoidable due to asymmetric feed, even with high values of common-mode choke resistance.
- For a typical 80-meter OCF fed 37.5% from one end, *EZNEC* calculates a choke balun loss of 326 W for a 5000-ohm choke resistance at 7.1 MHz at 1500 W.
- This is guaranteed to fry the choke balun! OCFs have a reputation for blowing up baluns.

Summary, Common-Mode Choke Balun Stresses

- Loss due to high SWR can fry a choke balun, especially when an operator tries to achieve multiband QRO operation on a single-wire antenna. Some frequencies have large losses!

Summary, Common-Mode Choke Balun Stresses

- Loss due to high SWR can fry a choke balun, especially when an operator tries to achieve multiband QRO operation on a single-wire antenna. Some frequencies have large losses!
- You should make sure there is air circulation inside a choke balun, especially on high-duty-cycle modes — like RTTY.

Summary, Common-Mode Choke Balun Stresses

- Loss due to high SWR can fry a choke balun, especially when an operator tries to achieve multiband QRO operation on a single-wire antenna. Some frequencies have large losses!
- You should make sure there is air circulation inside a choke balun, especially on high-duty-cycle modes — like RTTY.
- Even at low transmitter power that allows a choke balun to survive, the system losses build up surprisingly high. After all, 11 dB down from 5 W QRP is 0.4 W QRPp.

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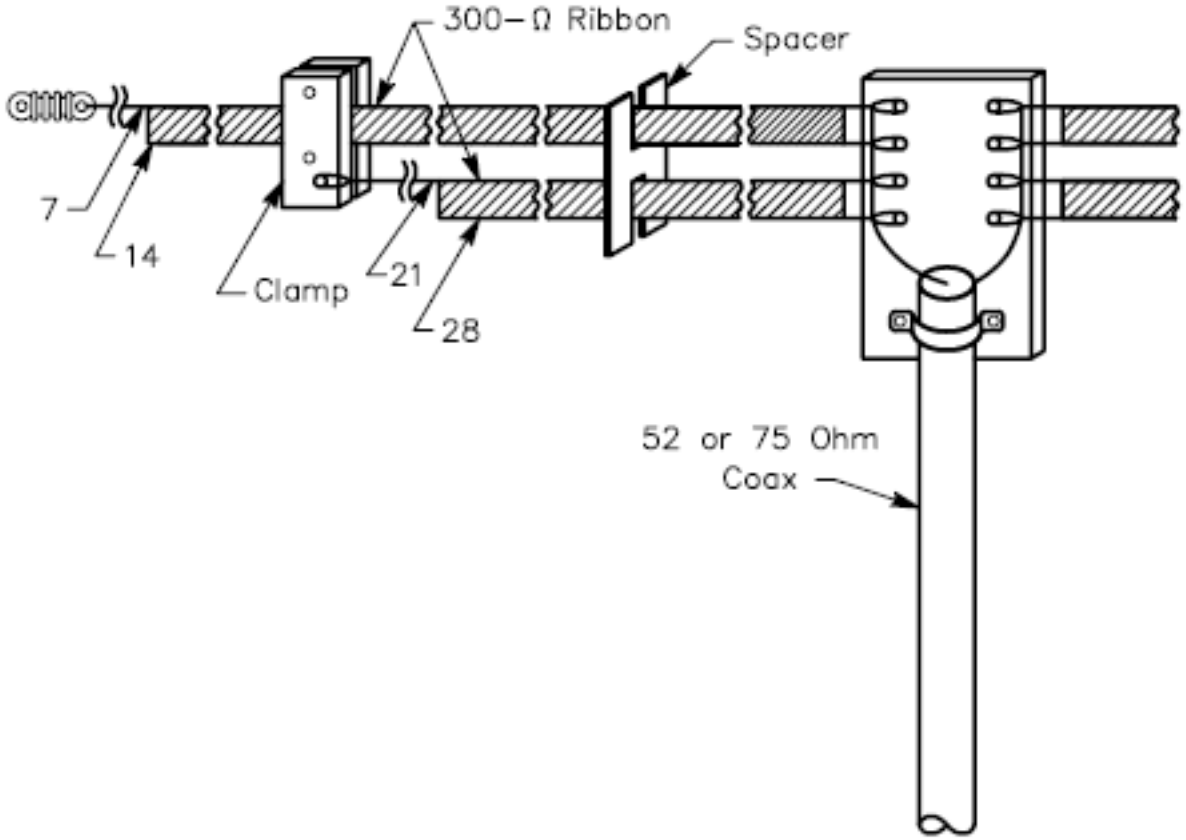
Multiple Parallel Dipoles at Common Feed Point



To Tuner

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- Read K9YC's treatise "RFI, Ferrites and Common Mode Chokes for Hams." http://audiosystemsgroup.com/publish.htm.