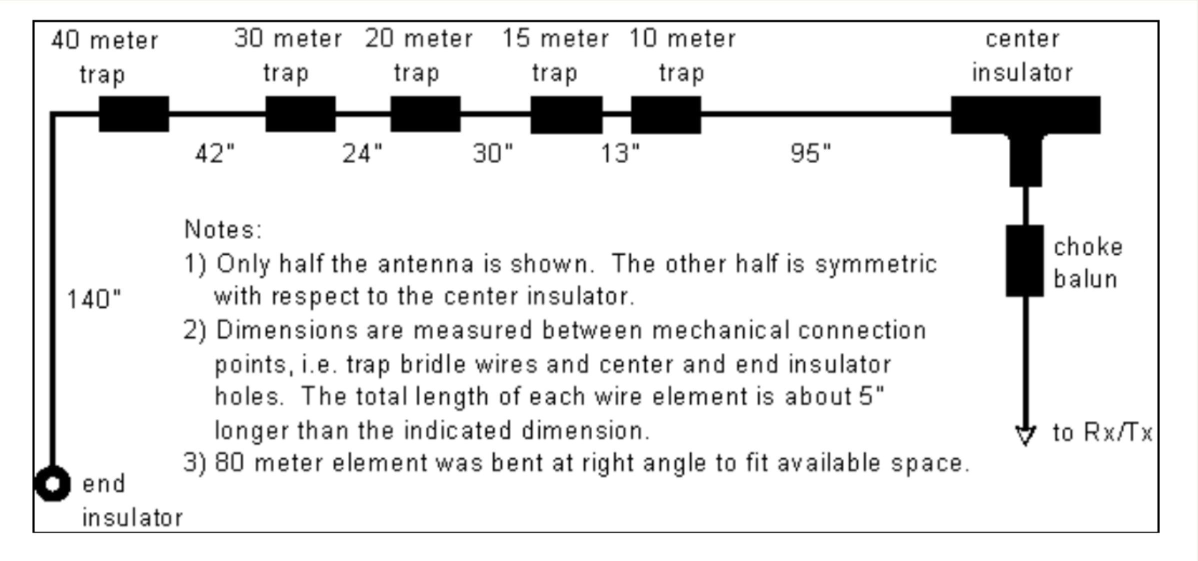
# OFF Center Fed/Loaded HF Antennas
# VE3KL

- **Searching for the elusive 40,30,20 m Short Antenna**
- **Small, no bulky traps, minimum of components**
- **Leads to a general design approach for a broad class of HF Antennas**

**1:1 Balun RG316 Ferrite Core**

**Loading Coil Powdered Iron**
**High Q: 20 m monoband antenna**

# Typical Trapped Dipole
# Ten Traps…Six Bands…not portable
# Hard to get good SWR on All Bands
# Commonly Used in Fixed Applications
# Trap L/C not adjustable in coax type traps

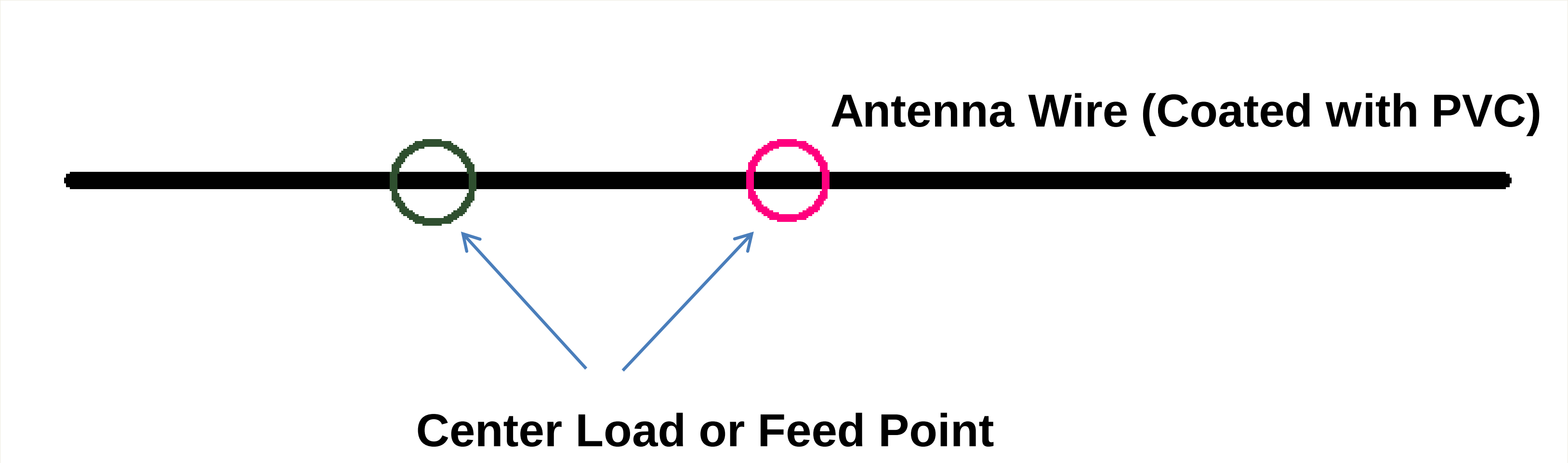



**http://degood.org/coaxtrap/**

# Outline

- **Theory of Resonance..the vibrating string**
- **Selecting the Length: $\lambda$ @ 14.1 MHz**
- **The Design Process**
- **Synthesizing the loading networks**
- **Building/Testing**
- **More work to be done**
- **Many More possibilities: QRP/QRO/Bands**

# Antenna Configurations



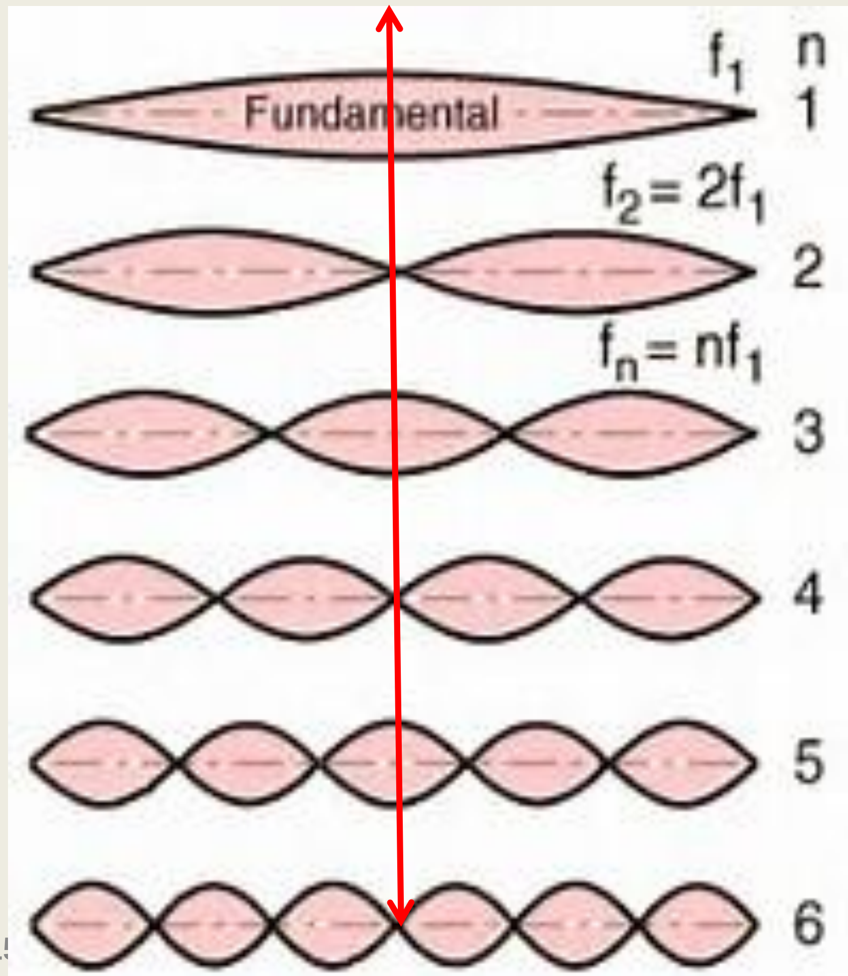

- Antenna Length usually one wavelength at a the highest band (20m)
- Some Antennas Off-Center fed and Center loaded
- Some Antennas Center Fed and Off-Center loaded (small monoband)
- Balun and Line Isolator always used.  (Gives predictable performance)

# A Vibrating String Analogy

## A Vibrating String has many natural frequencies

## Example: Full Wavelength @ 14 Hz

**No Vibration at 10 Hz**




**7 Hz**

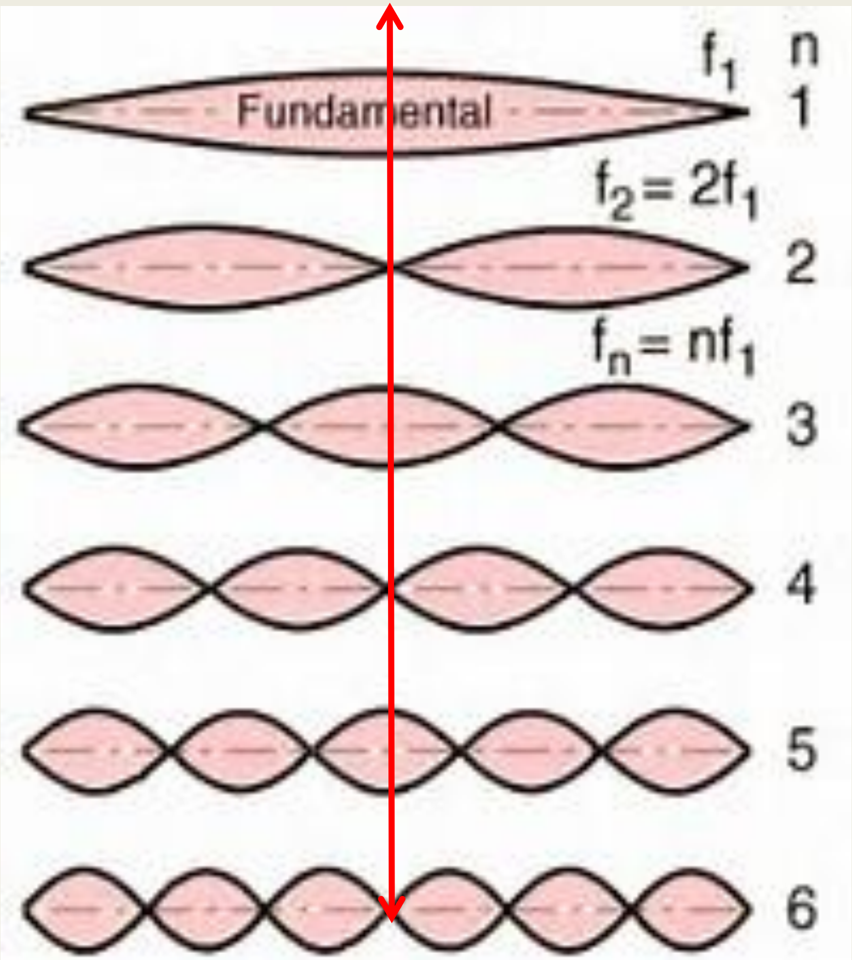
**14 Hz (No vibration at the center)**

**21 Hz**

**28 Hz (No vibration at the center)**

# A Vibrating String Analogy

**Placing a load at the center "does not" affect 14 or 28 Hz Vibration…..But it impacts 7 and 21 Hz**




**7 Hz**

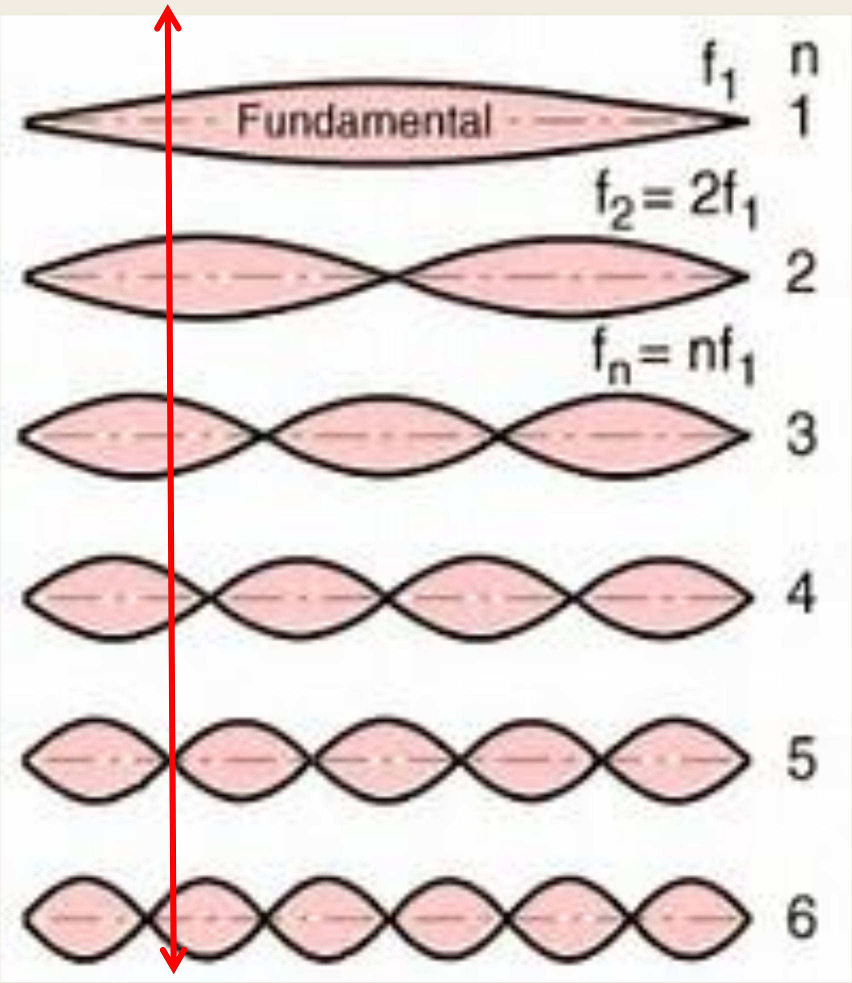
**14 Hz (No vibration at the center)**

**21 Hz**

**28 Hz (No vibration at the center)**

# A Vibrating String Analogy

**Plucking the string Off-Center produces vibrations a 7, 14 , 21 and 28 Hz**




**7 Hz**

**14 Hz**

**21 Hz**

**28 Hz**

# Summary so Far

- A full wavelength (14 Hz) string with center fed plucking only works on 7 and 21 Hz

- No natural vibration at 10 Hz

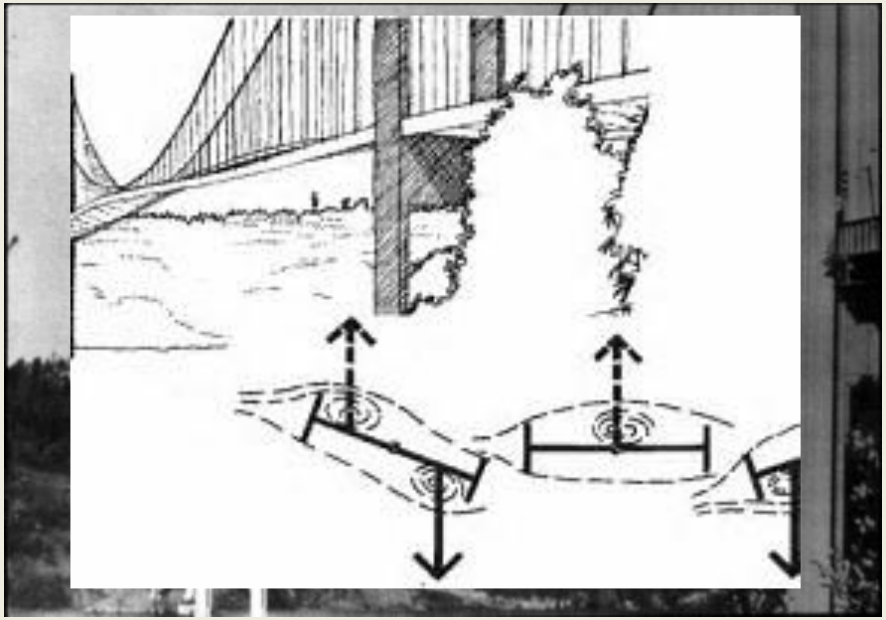
- Off Center plucking: 7,14, 21, 28 Hz operation. Still no vibration at 10 Hz

# A note on Terminology

- **In the field of vibrations (Bridges, CNTower, Air Craft, Car Engines..)**

**The term natural resonant frequency is called an Eigenvalue**
**The excitation of natural resonant frequency is an Eigenvector**

**This means that you can pluck a string at certain points (more than one) where only one frequency exists: say the third harmonic.**

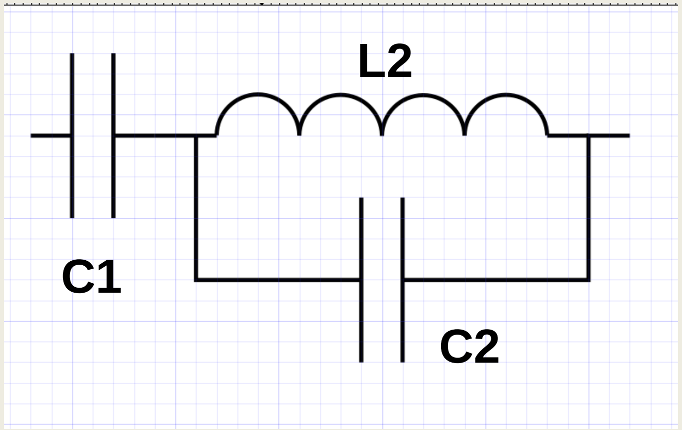


**Tacoma 1940**

# 40, 30, 20 Antenna Design Process
# Full Wavelength at 14.1 MHz

- Use 4nec2 antenna simulator/optimizer
- Model the PVC coated wire, use average ground: h = 7 to 12m
- Adjust the antenna length (no loading) to resonate at 14.1 MHz
- Add center loading network to control the 40 and 30 m bands

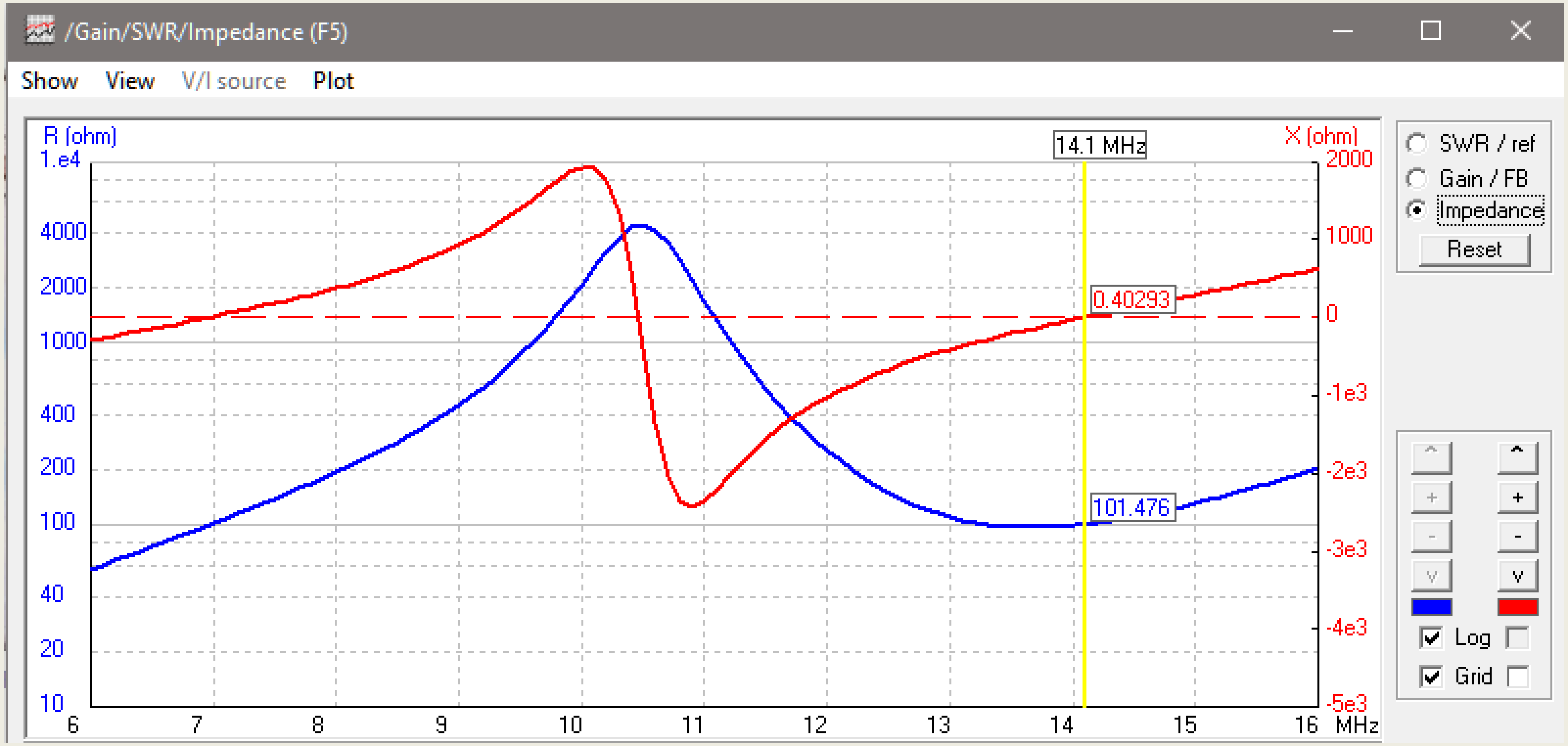
**C1 = 38pF C2 = 100 pF L2 = 3.6 uH**



# 40,30,20 Antenna Design

## Step #1. Resonate the antenna at 14.1 MHz

## Z = 101 –j0.4 Ω at 14.1 MHz   L = 20 m




**The Length sets the resonant Frequency**
**The Feed Point sets the impedance (Fed Off Center in this test)**

# Step# 1 Results

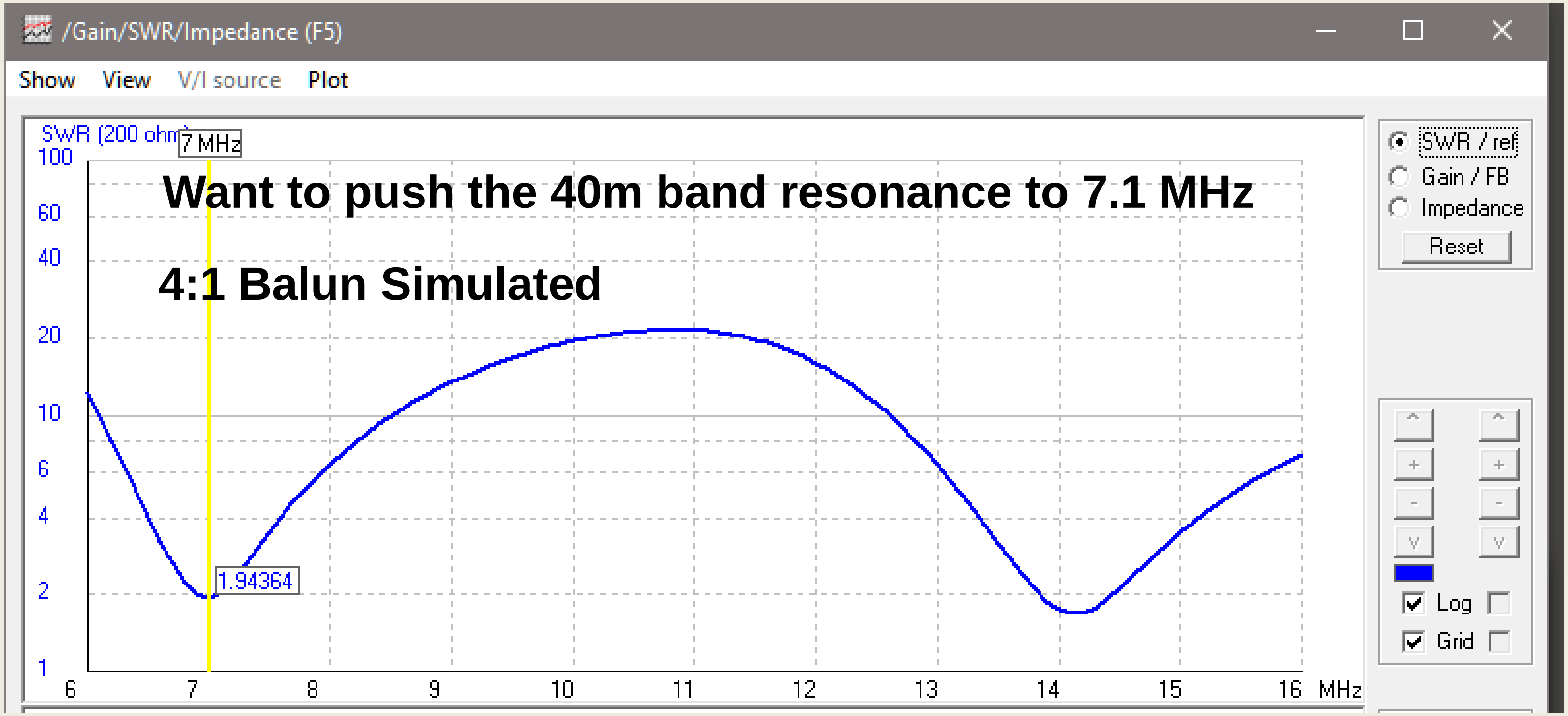
## Off Center Fed @0.33L  No Loading

## Resonant @ 14.1 MHz  GOOD

## Resonant @ 6.9 MHz  Too Low (not adjustable)

## No Operation at 10.1 MHz

SWR




Frequency [MHz]

# Step# 2

## Add a Center L-C network

## Adjust the network to resonate antenna at 7.1 and 10.1 MHz

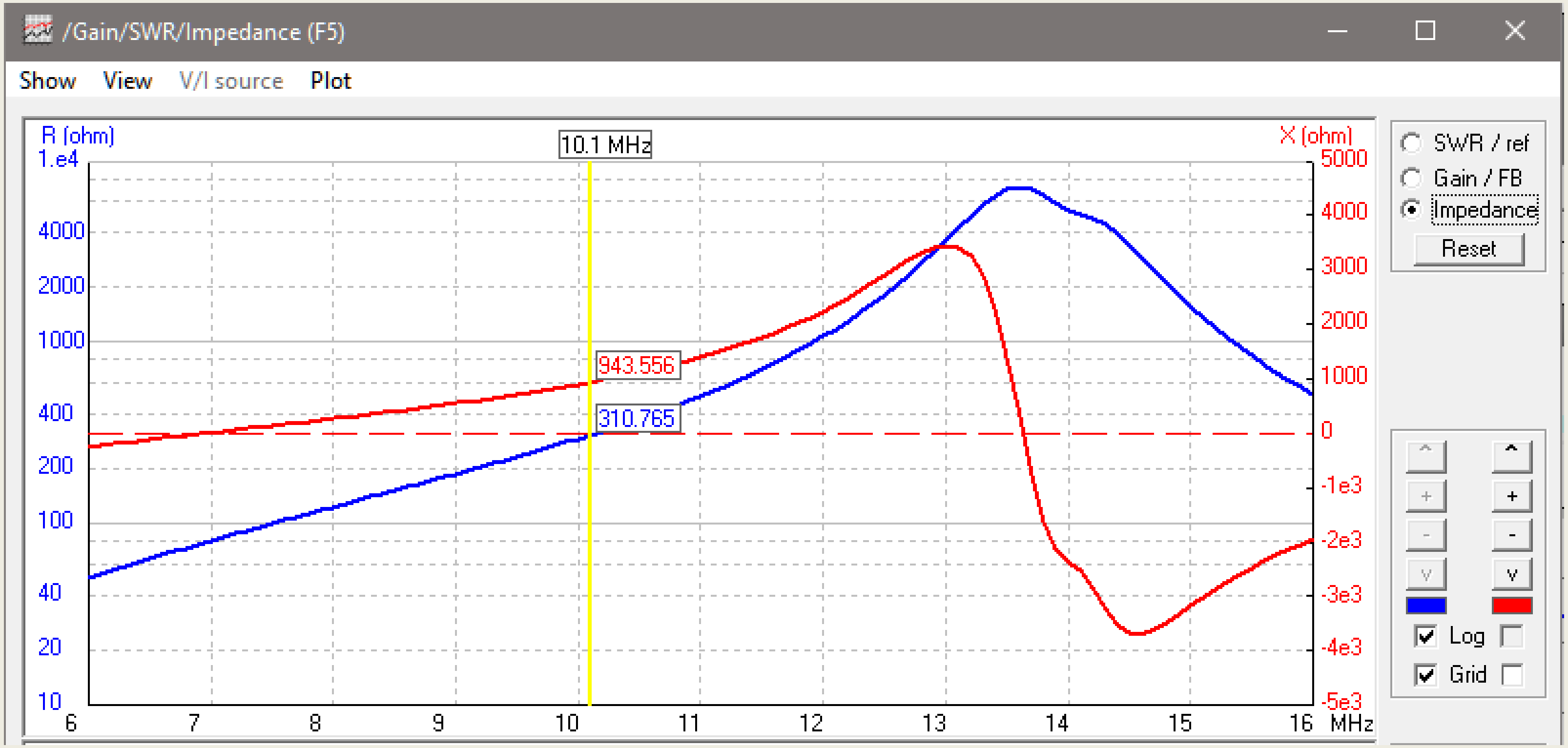
- **What Network?**
- **How to find the element values**
- **Notice: Center loading has no impact on the 14.1 MHz performance**

1. **Measure the antenna reactance, Xa, at its center: 7.1 and 10.1 MHz**
2. **To resonate the antenna the complex conjugate,-Xa, must be added to the basic dipole at its center**
3. **Find a single network that fits the requirement**
4. **Write/Solve equations to find all element values**
5. **Build and test**

# Impedance at Antenna Center
# Needed to design the matching network

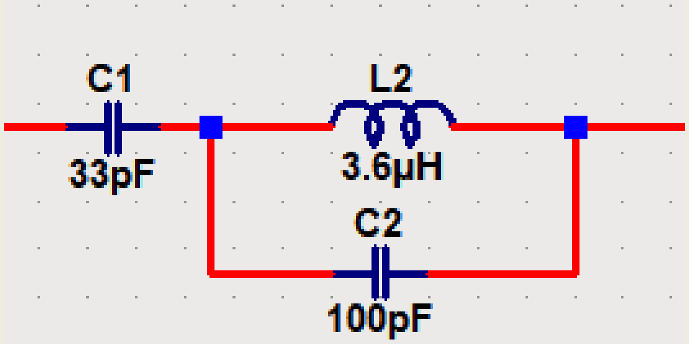
**Xa @ 10.1 MHz = 943Ω     Xa @ 7.1 MHz = 35 Ω**

**Xload @ 10.1 MHz = -943 Ω   Xload @ 7.1 MHz = -35 Ω**



# The Matching Network

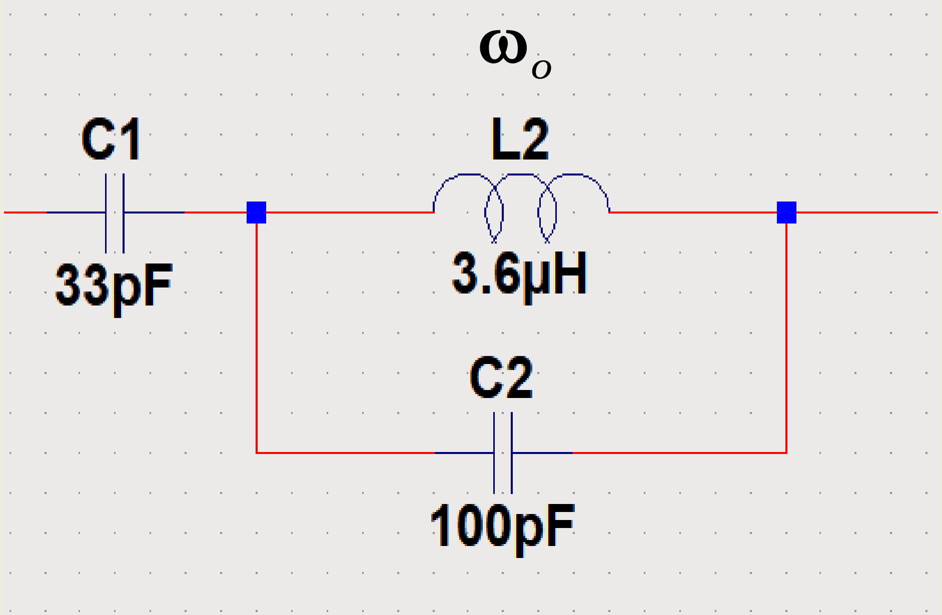
**C1 = 33 pF  L2 = 3.6 uH  C2 = 100 pF**

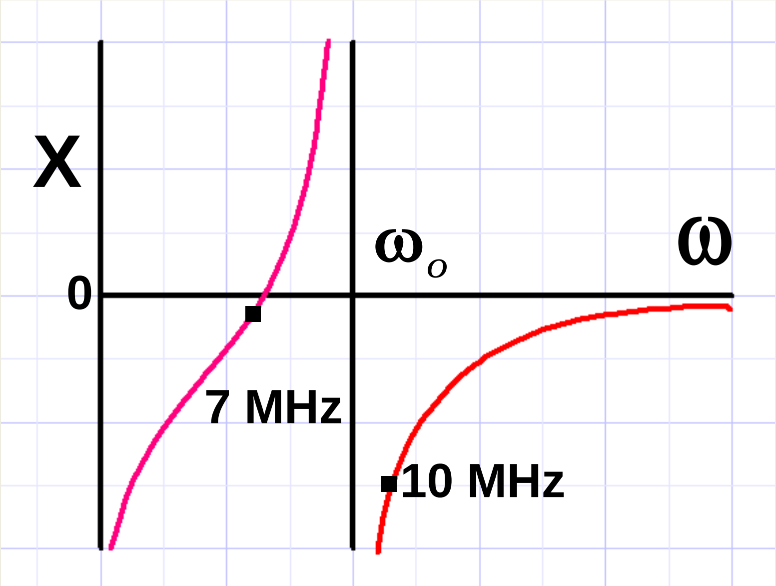



$$\omega_o^2 = 1 / L_2 C_2$$

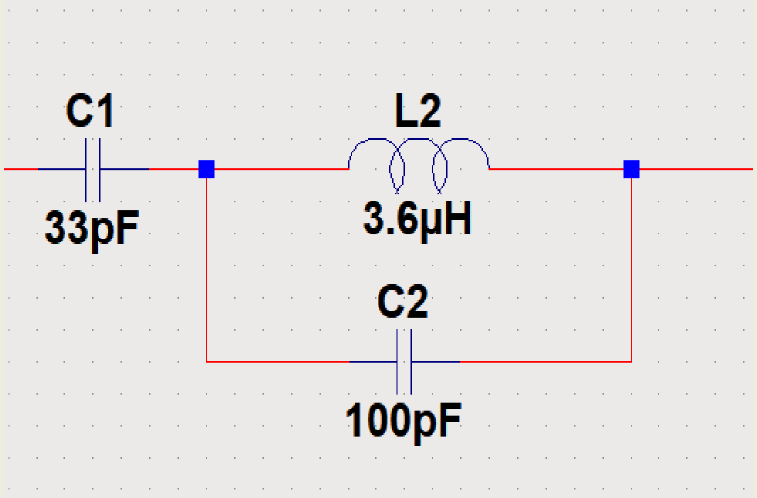
# Designing the Loading Network

- Select a suitable circuit……back-of-the-envelope
- Use circuit analysis to find the impedance….equations
- Solve the equations and find components values



# The Equations




$$Z = Z_1 + Z_2$$

$$= \frac{1}{j\omega C_1} + \frac{j\omega L_2}{1 - \omega^2 L_2 C_2}$$

**Solve this equation for two frequencies: 7.1 and 10.1 MHz.**
**Notice: three variables, two equations…..one arbitrary definition allowed**

# Matching Network Values
# (General for any Three Band Antenna)

$$\omega_o^2 = \omega_7 \omega_{10}$$

**Arbitrary definition**

$$\eta_x = 1 - (\omega_x^2/\omega_o^2)$$

**A simplifying definition**

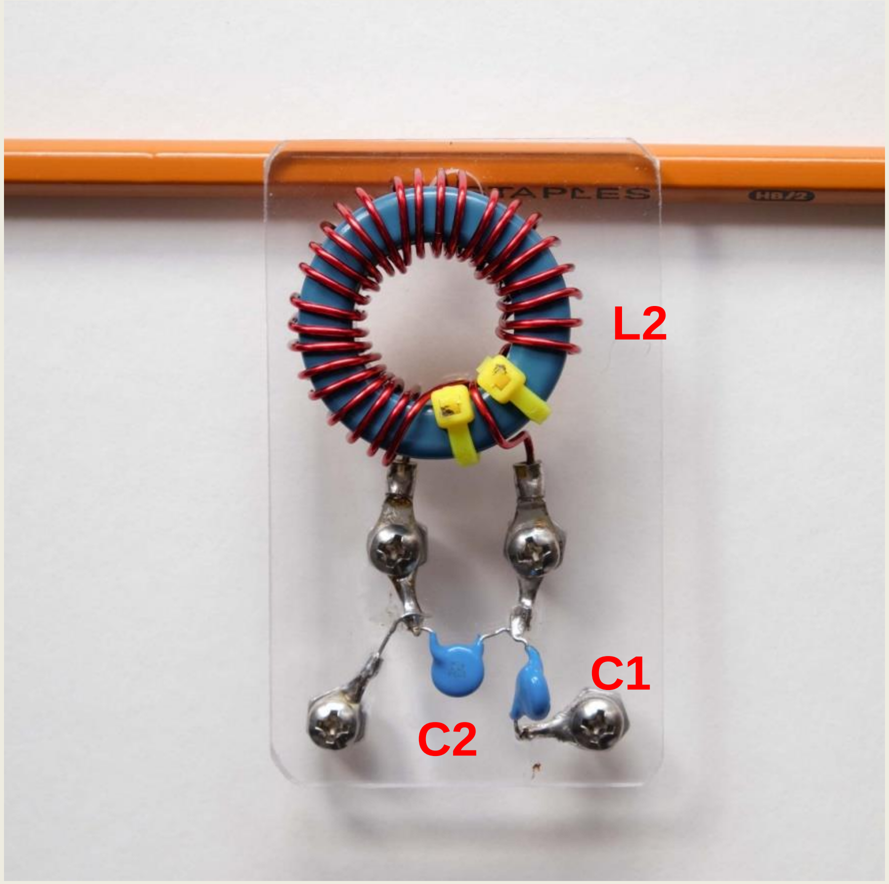
$$L_2 = (\omega_7 X_{Load,7} - \omega_{10} X_{Load,10})/(\omega_7^2/\eta_7 - \omega_{10}^2/\eta_{10})$$

$$C_1 = -(1/\omega_{10} + 1/\omega_7)/(X_{Load,7} + X_{Load,10})$$

$$C_2 = 1/(\omega_o^2 L_2)$$

# The Matching Network

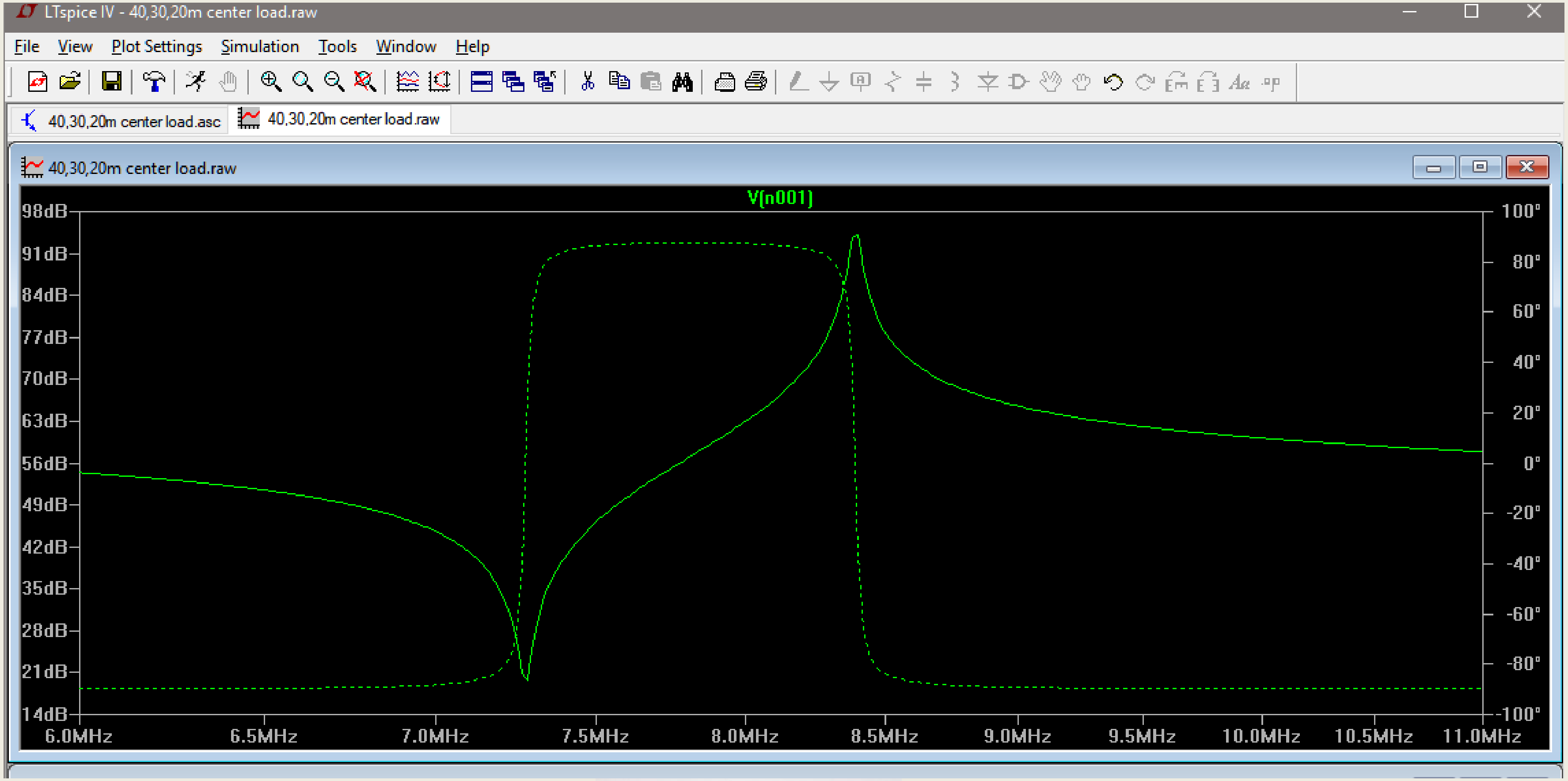
**C1 = 33 pF  L2 = 3.6 uH  C2 = 100 pF**




**T130-17**
**29 - 30 Turns**
**3.6 uH**

**C2,C3 3kV TDK Ceramic**

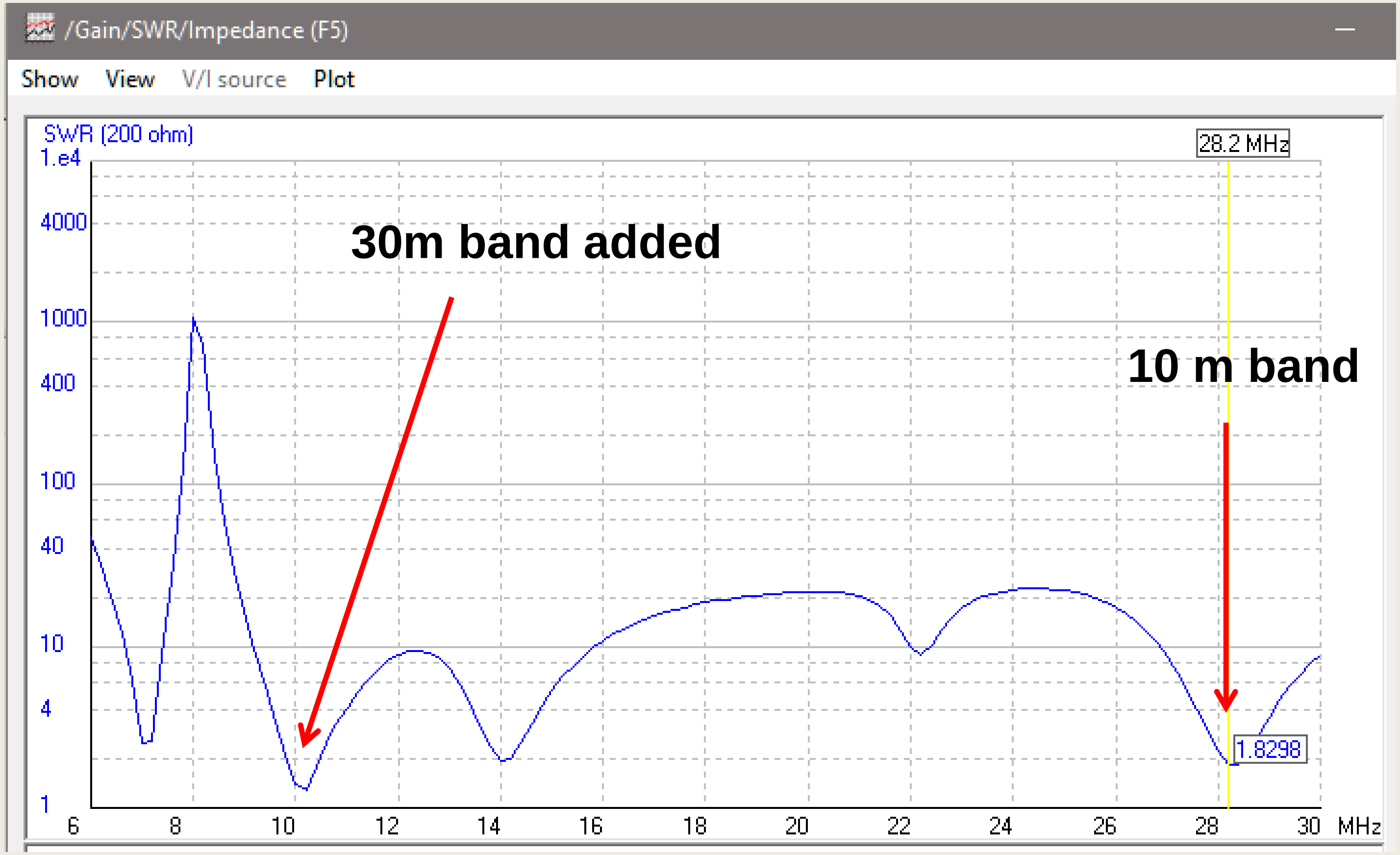
# LTSPICE..Matching Network



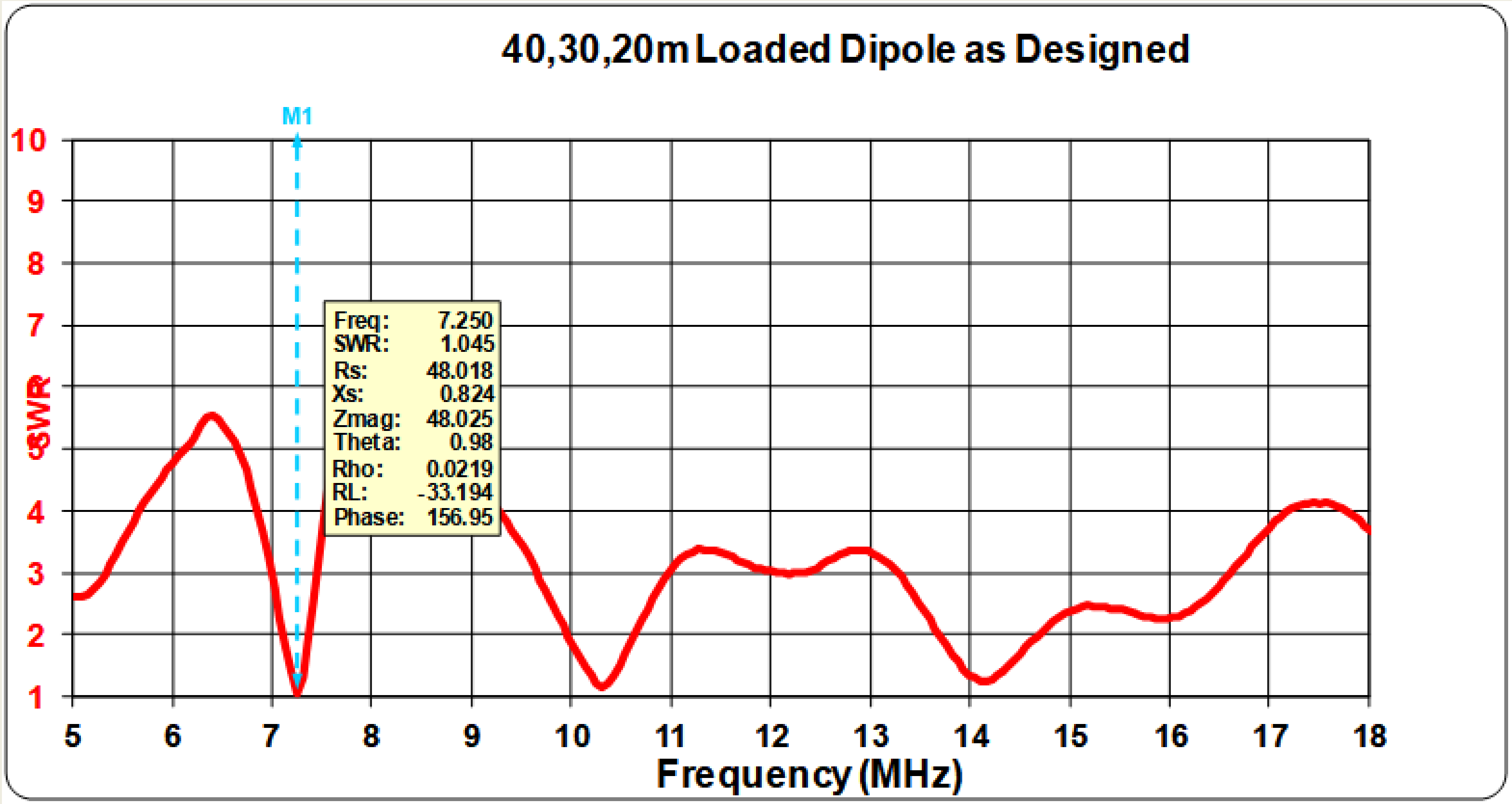

# The Design Process
# (40,30,20 m Antenna)

- **Now select a place to feed the antenna for best SWR on 40,30,20 m**
- **This is a compromise: cannot get 1:1 SWR on all bands**
- **Use 4nec2 simulator: Selected Feedpoint 0.33L**

# 4nec2 Simulation
# 40,30,20 m as Designed
# SWR < 2 on 7,10,14 and 28 MHz
# Poor performance between 16 and 26 MHz



# Measurements: AIM 4170
# 40,30,20 m as Designed




**Home Brew 4:1 Balun and Line Isolator**

# Two Band Design
# Same Process as Before
# Consider a 17 and 30 metre Antenna

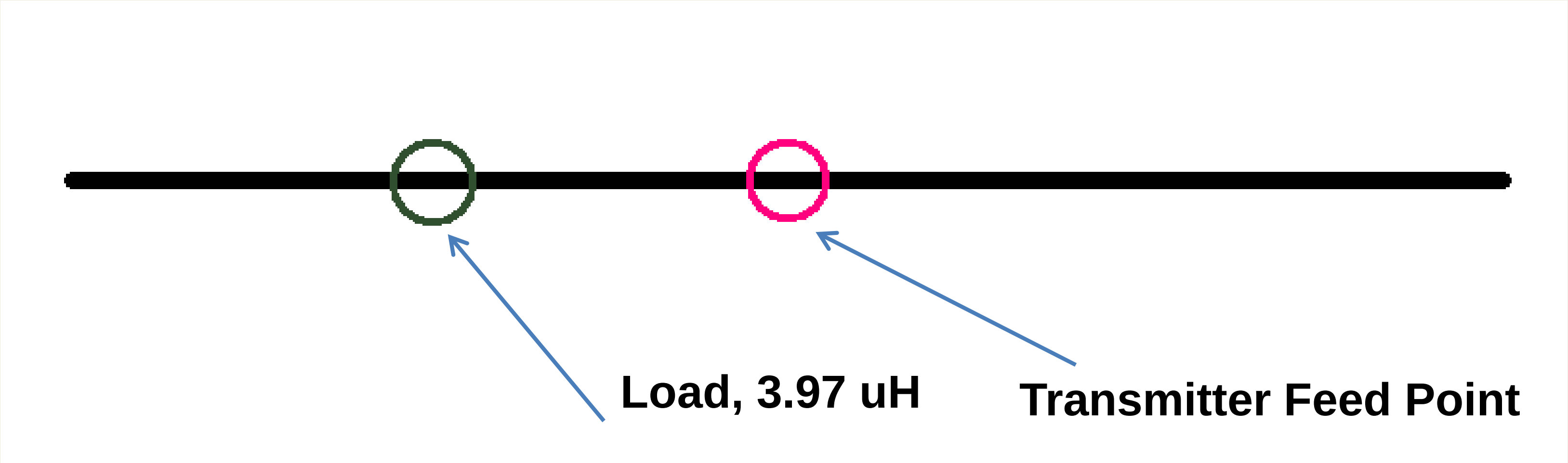
- Start with a full wavelength 17 m antenna: L ≅ 17m
  Optimize L for resonance

- Measure the reactance at the center of the antenna

- Find the matching network

- Find a “suitable feedpoint”

# Monoband Band Design
# Short 20m...L = 8.2m
## Two built...VE3KL, VE3NA

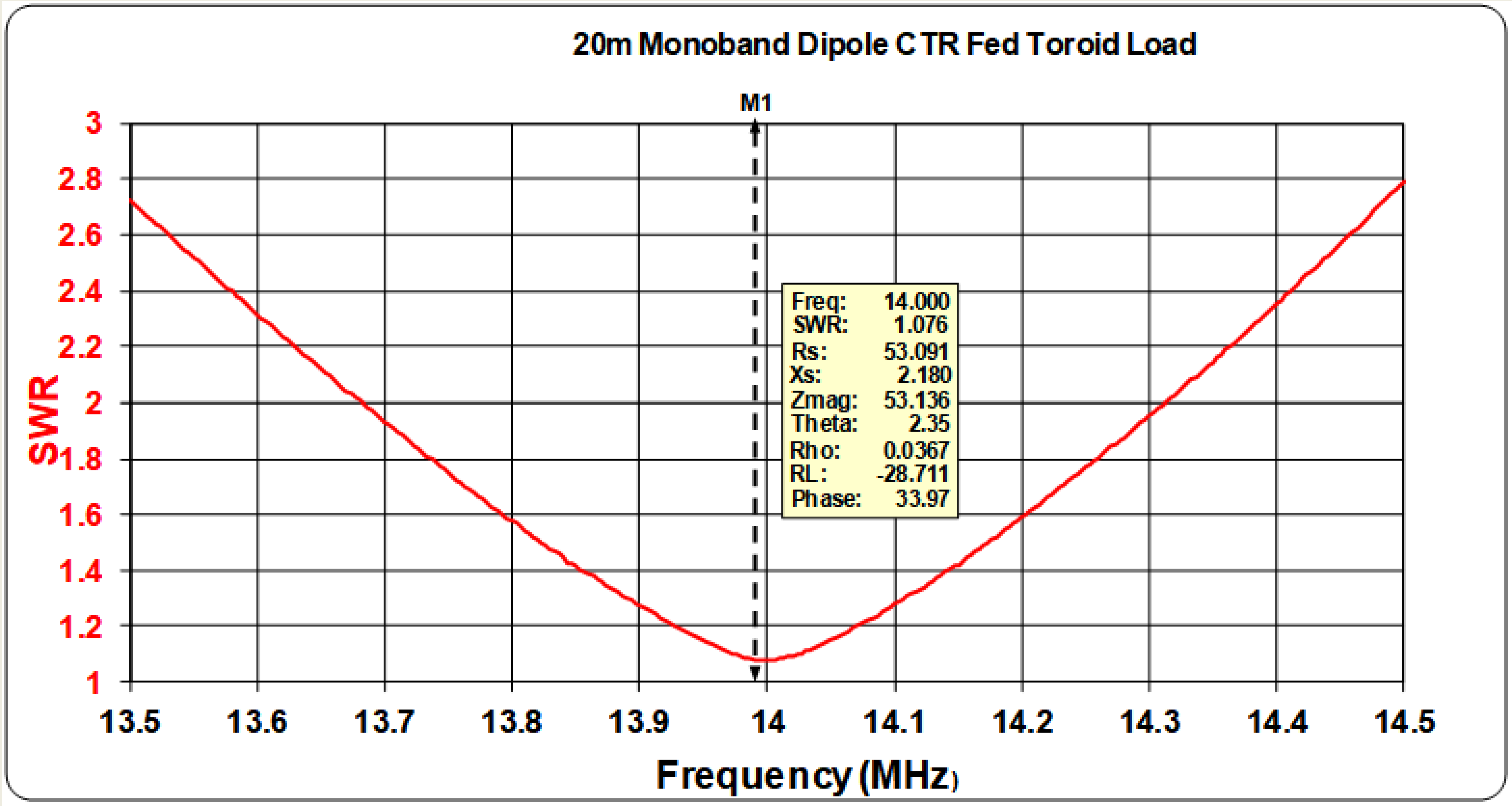



- OCL   0.25 L
- Center Fed
- L = 8.2 m (78%)

# Monoband Band Design
# Same Process as Before

- Set the length to some value: say L= 0.7$\lambda$/2 (arbitrary)
- Measure the reactance at the chosen point for loading..usually at L/4 where the current is high.
- Find the load reactance...no complex equations
- Find a "suitable feedpoint"

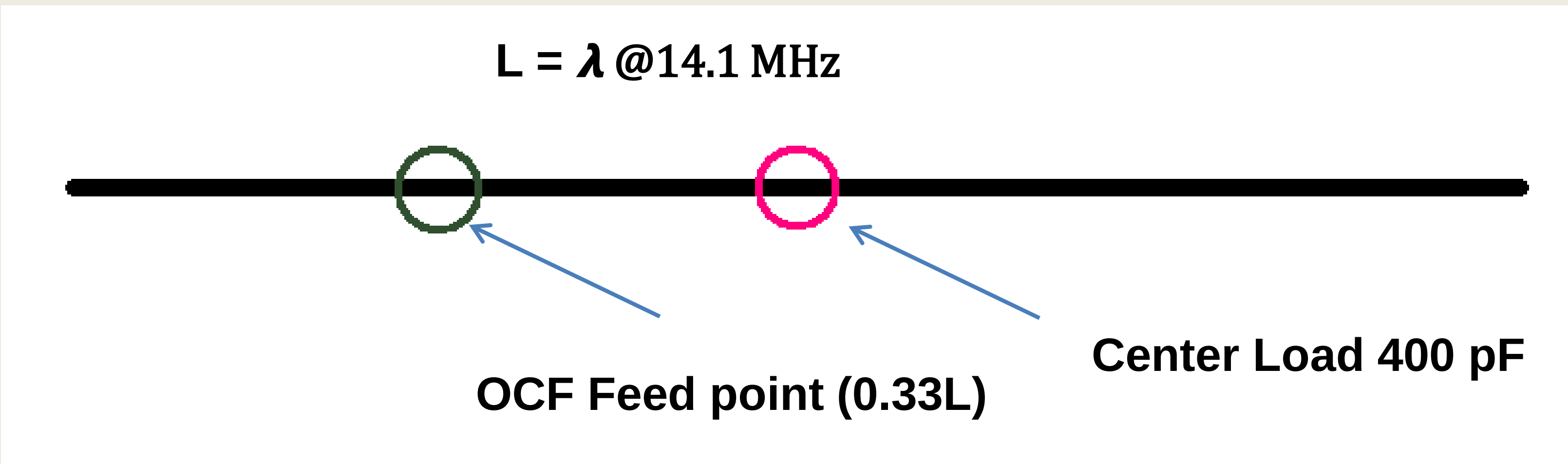
# Measurements
# 20 m as Designed
## Center Fed OCF Load   SWR 1.08 Measured




**Home Brew 1:1 Balun**

# 40,20 Dual Band

## my workhorse antenna

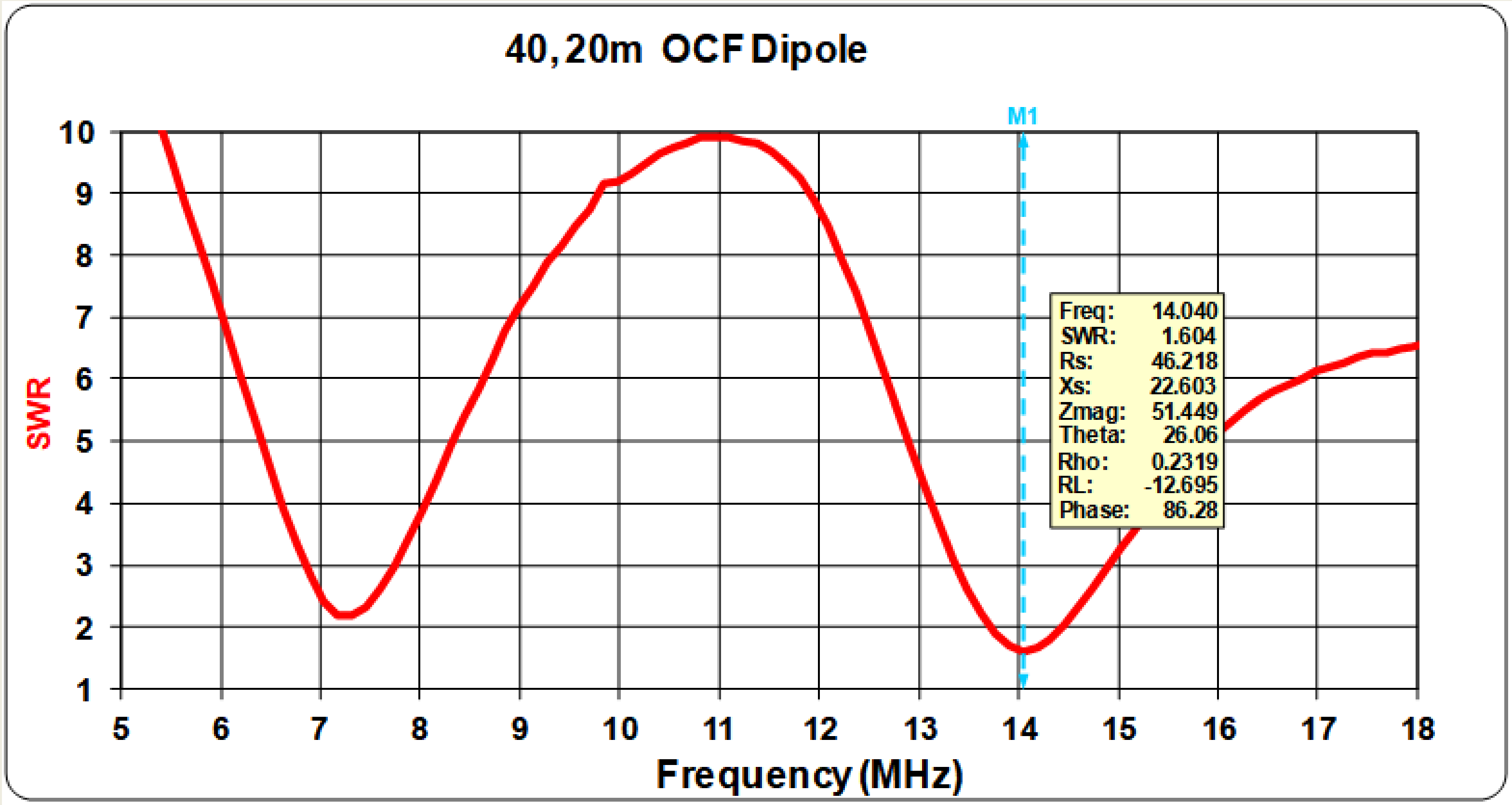



Home Brew 4:1 Balun

# Measurements
# 40,20 m as Designed

**Capacitive Load pushes the 40 m response up to 7.2 MHz**

**No Impact on 20m.**




**Home Brew 4:1 Balun....used with antenna tuner.**

# What’s Next

- Engineer the 40,30,20 m load for 150W Operation

- Design an 80,60,40m antenna for next year’s NVIS Experiment*

* Needed to simplify operation.
At least two antennas previously needed for NVIS Experiments

# References

1. Six Band Center Loaded http://hamwaves.com/cl-ocfd/en/index.html

2. John Belrose, VE2CV, Peter Bouliane, VE3KLO. The off-center-fed dipole revisited: A broadband, multiband antenna. *QST*. 1990;74(8):28-34. Available at: http://www.arrl.org/files/file/protected/Group/Members/Technology/tis/info/pdf/9008028.pdf.

3. Gene Preston, K5GP. A broadband 80/160 meter dipole. 2008. Available at: http://www.egpreston.com/K5GP_broadband_80_meter_antenna.pdf

# Summary

- A design approach for a class of HF antennas has been presented
- Case studies have been presented to demonstrate the process
- All designs have an intuitive (back-of the-envelope) starting point

73 Dave VE3KL

73  Dave VE3KL

# 4:1 Balun VE3KL


- **Two Ferrite Cores 4:1 Plus High CMR**
- **FT 114-43 11 or 12 Turns**
- **Zip Cord (Zo = 100 Ω, 16 AWG)**

**Note: Single Core construction gives 4:1 transformation: But Zero CMR**