Coaxial Transmitting Chokes

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Don’t Bother Taking Notes

These slides (and a lot more) are at

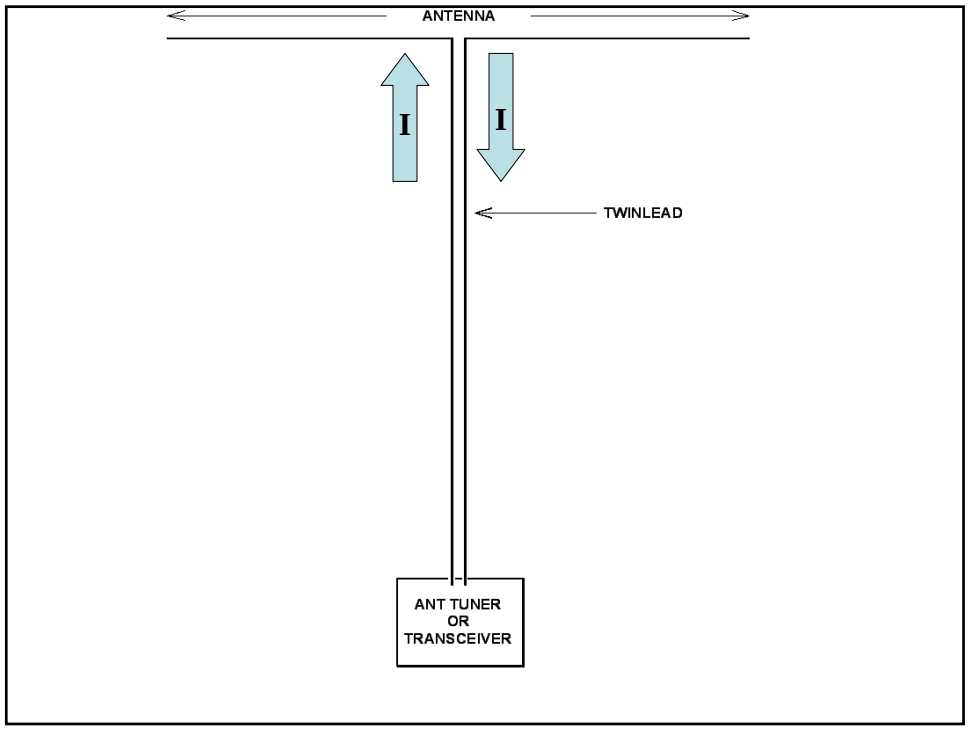
http://audiosystemsgroup.com\publish.htm

Why Do We Need Chokes?

Understanding Common Mode and Differential Mode Currents on Transmission Lines

Differential Mode Current

- Transmission line carrying power from transmitter to antenna, or from antenna to receiver
- Signal is voltage between the two conductors
- Current flows out on one conductor and returns on the other
- Currents are equal and opposite in polarity



Differential Mode Current

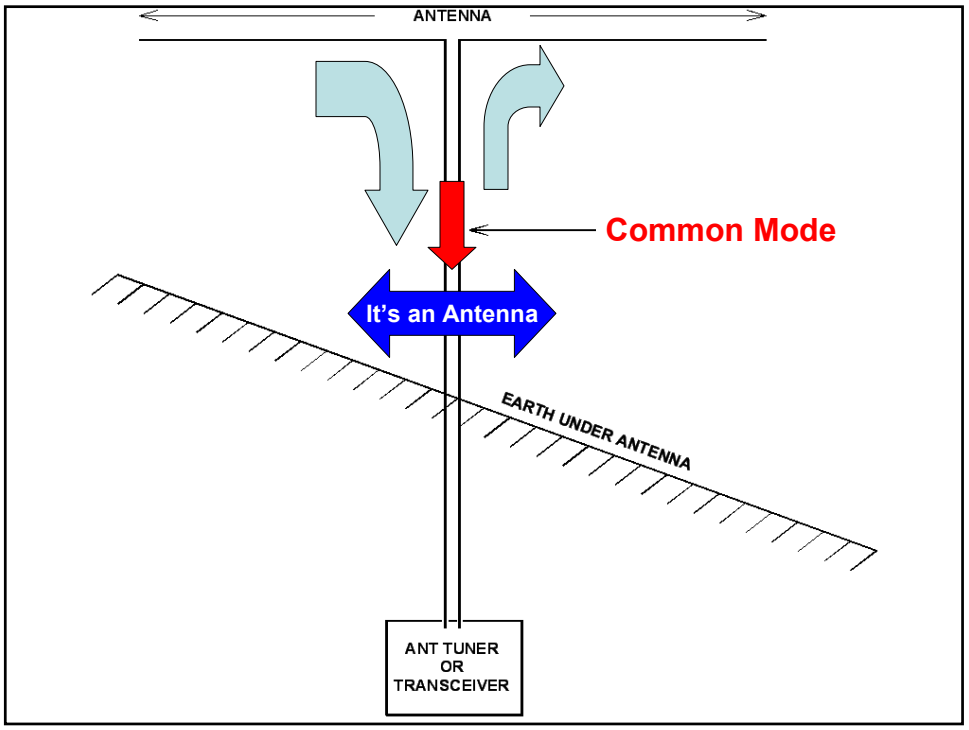
- Transmission line carrying power from transmitter to antenna, or from antenna to receiver
- Signal is voltage between the two conductors
- Current flows out on one conductor and returns on the other
- Field exists between the two conductors
- No radiation from ideal line
  - At a distance, field of one conductor cancels field of the other conductor

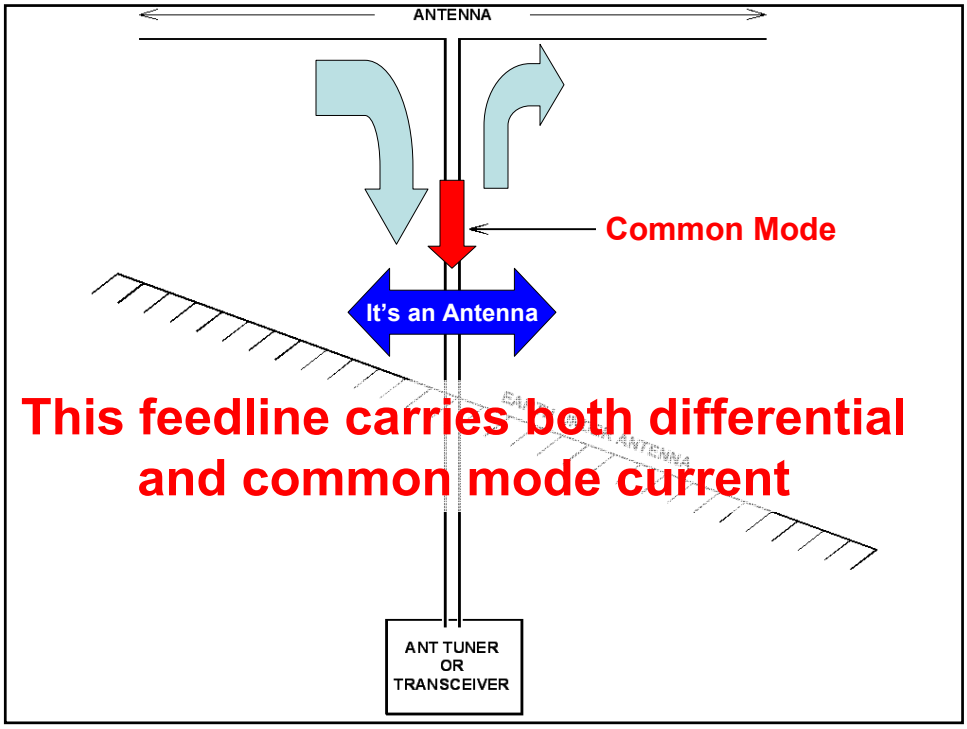
Differential Mode Current

- Currents are equal and opposite in polarity
- Field mostly between the two conductors
- No distant radiation from ideal line
  - At great distance, field of one conductor cancels field of the other conductor
- In the near field of an ideal line, the fields do not cancel
  - Most observers will be slightly closer to one conductor than the other, so cancellation will not be perfect

Common Mode Current

- Equal and flowing in the same direction on all conductors of the transmission line
- Current flows lengthwise on the line
  - No cancellation of one current by another, because they're in polarity
- Line acts as long wire antenna
  - It radiates and it receives





Ham Antennas and Balance

- Most ham antennas are <u>unbalanced</u> by their <u>surroundings</u>, even when fed by a balanced source and line

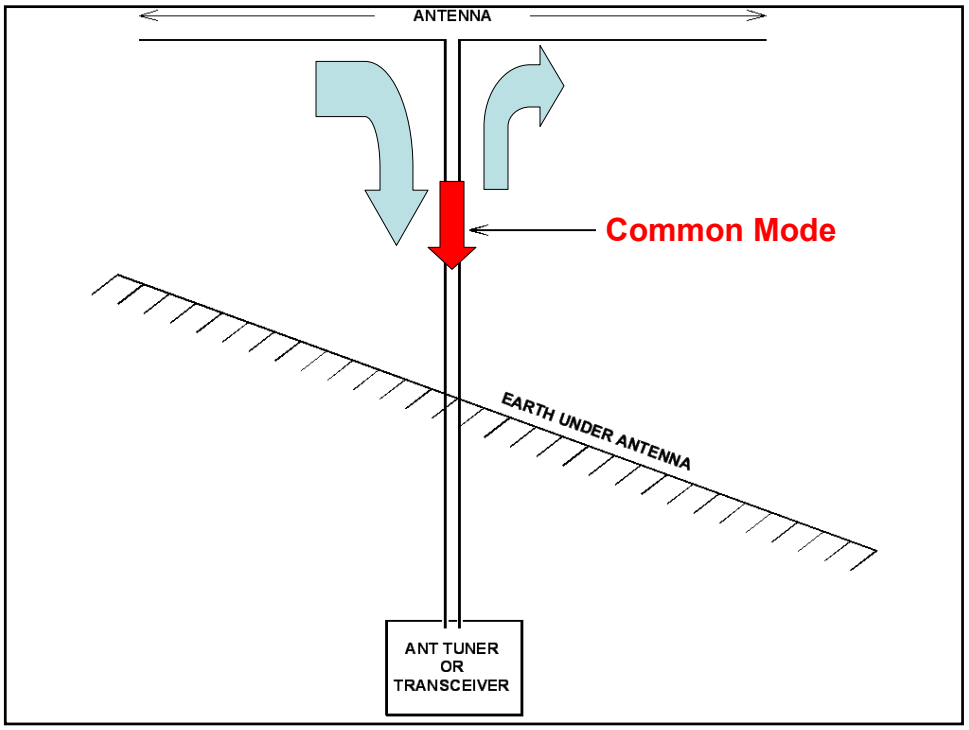
What Makes a Circuit Balanced?

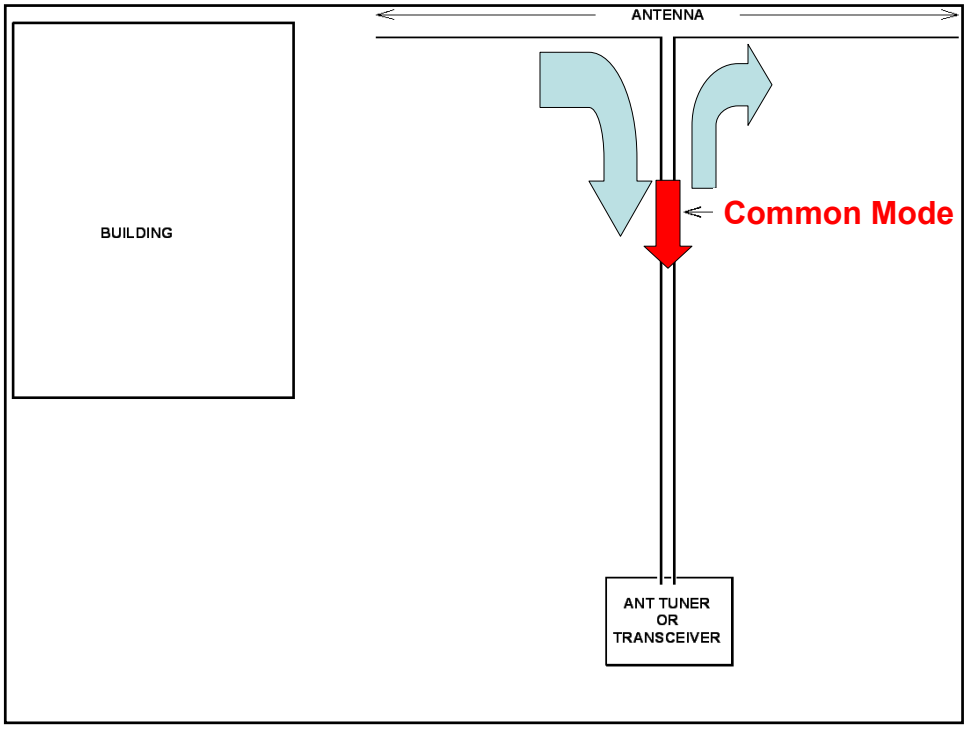
What Makes a Circuit Balanced?

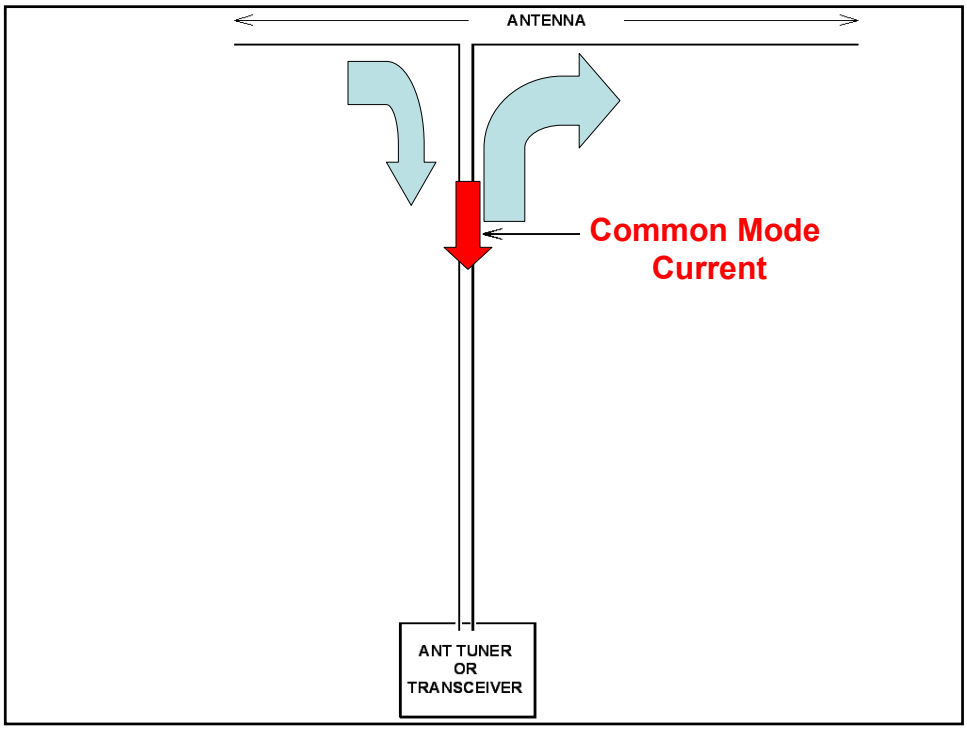
- The impedances of each conductor to the reference plane are equal
- Balance is not defined by voltage or current
- Imbalance impedances cause unbalanced currents

Ham Antennas and Balance

- **Most ham antennas are <u>unbalanced</u> by their <u>surroundings</u>, even when fed by a balanced source and line**
  - **Unequal capacitances to nearby conductors**
  - **Unequal inductive coupling to nearby conductors**
  - **Trees, buildings, towers, terrain**
  - **Feedline comes off at an angle**
  - **Coax is not a part of these imbalances**




ANTENNA
BUILDING
Common Mode
ANT TUNER
OR
TRANSCEIVER


ANTENNA
Common Mode
Current
ANT TUNER
OR
TRANSCEIVER

Unbalanced Antennas and Lines

- If the antenna is unbalanced
  - Unequal voltage and current to earth
  - Unequal currents on the feedline
  - The difference is common mode current, and it radiates from the line
- Coax did not cause the imbalance in these antennas!
- Coax simply adds to the imbalance

The Fields around Coax and Twinlead are Very Different

Coax is Special

- All the differential power (and field) is confined inside the coax
- All the common mode power (and field) is outside the coax
- A ferrite core surrounding coax sees only the common mode power (and field)
- No differential mode radiation

Coax is Special

- Skin effect splits the shield into two conductors
  - Inner skin carries differential mode current (the transmitter power)
  - Outer skin carries common mode current (the current due to imbalance)

Now We Can Talk About Common Mode Chokes!

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

Some Common Mode Chokes

- A coil of coax at the antenna
- A string of ferrite beads around coax (Walt Maxwell, W2DU)
- Multiple turns of transmission line through a toroid (Joe Reisert, W1JR) or stack of toroids (W1HIS, K9YC)
- Most 1:1 “baluns” are common mode chokes

Chokes you can <u>buy</u> (W2DU, W0IYH Baluns)

Much better chokes you can <u>build</u>

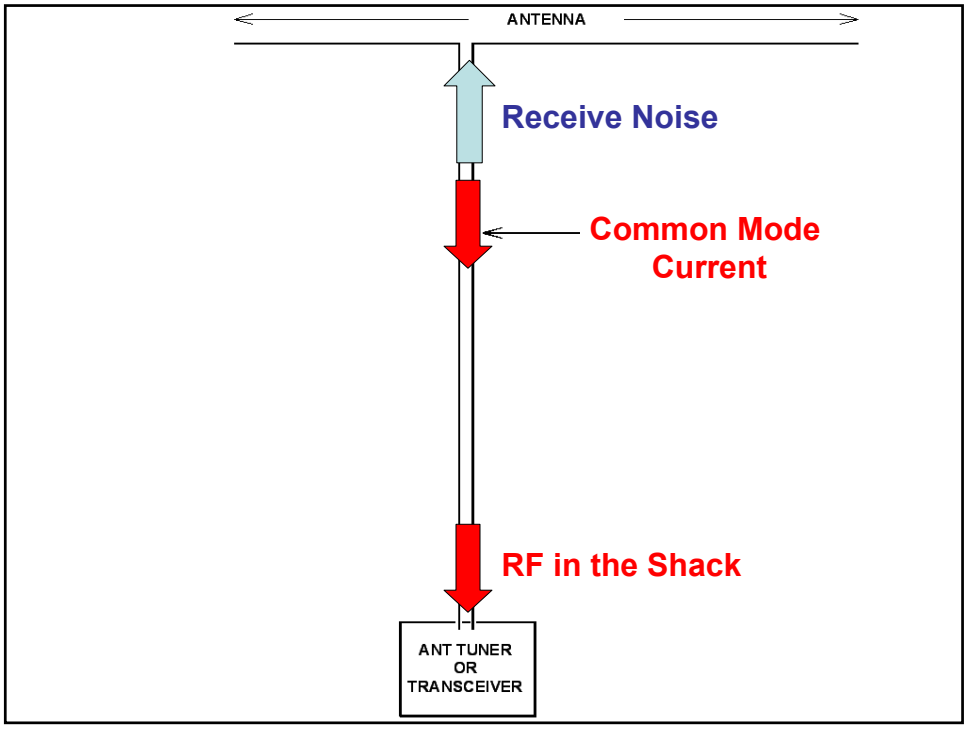
Much better chokes you can <u>build</u>

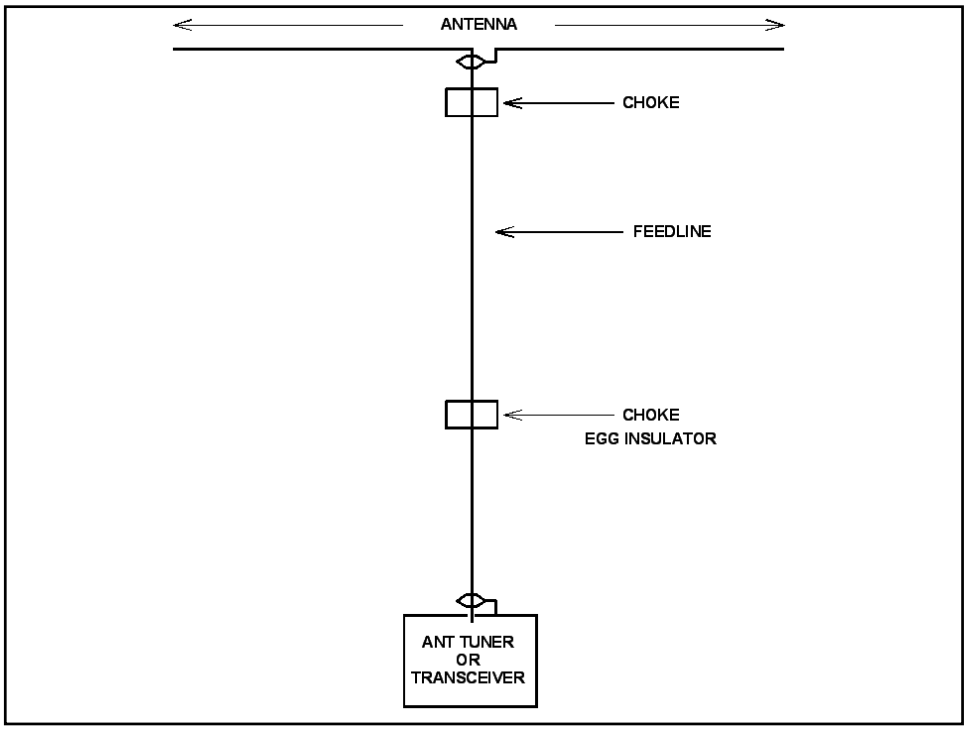
Some Common Mode Chokes

- Some 2:1, 3:1, and 4:1 "baluns" are also common mode chokes
  - Guanella balun
  - But the few I've measured aren't very good common mode chokes

Why Transmitting Chokes?

- Isolate antenna from its feedline
- Reduce receive noise
- Keep RF out of the shack (and your neighbor's living room stereo)
- Minimize antenna interaction
  - Field Day, CQP Expeditions
  - SO2R, Multi-multi
  - Dipole feedline and vertical antenna


ANTENNA
Receive Noise
Common Mode Current
RF in the Shack
ANT TUNER OR TRANSCEIVER


ANTENNA
CHOKE
FEEDLINE
CHOKE
EGG INSULATOR
ANT TUNER OR TRANSCEIVER

Design of Transmitting Chokes

- Higher impedance is better!
  - Reduces common mode current
  - Reduces noise
  - Reduces interaction
  - Reduces RF in the shack
  - Reduces dissipation
- Resistance is better than reactance

Why is Resistance Better?

- We want to reduce the current
- A cable shorter than $\lambda/4$ is capacitive
  - Series inductance resonates with it and <u>increases</u> the current
- A cable longer than $\lambda/4$ (and shorter than $3\lambda/4$) is inductive
  - Series capacitance resonates with it and <u>increases</u> the current
- Resistance <u>always</u> reduces current

Why is a Simple Coil of Coax a Lousy Choke?

- Because it's just an inductor
  - Can resonate with the line and increase the current
- Will resonate with its own stray capacitance (between turns)
- Above resonance it's a capacitor
  - Can resonate with the line and increase the current

Ferrite Chokes are the Answer!

Why is Fair-Rite My Example ?

- Their published data is FAR better than any of their competitors
- You can study it and understand
  - How ferrites work
  - How one part is different from another
  - How one mix is different from another
  - How each part will work in your circuit
- The numbers I'm using are those that describe parts made by Fair-Rite

Why Is Fair-Rite My Example?

- Most ferrites sold by ham distributors are actually made by Fair-Rite
- Ham distributors charge HUGE markups (typically 5X their cost)
  - Palomar, Amidon, Wireman, DX Engineering, etc.
- Industrial distributors don't!
  - Allied, Newark, Lodestone Pacific, Digikey

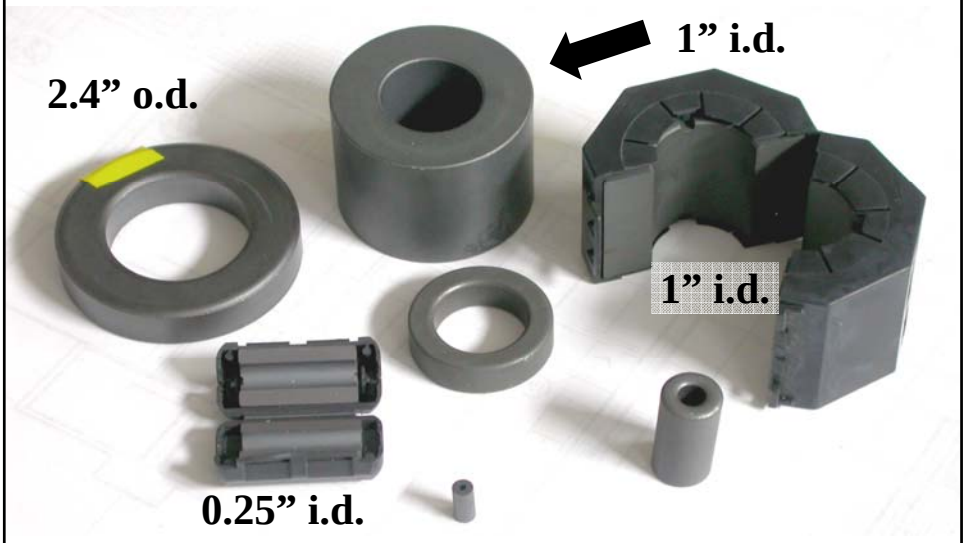
Why Is Fair-Rite My Example?

- They're a great company to deal with
- Their parts are the most useful for ham applications
- They are easy to buy in North America
- Stick to the industrial distributors

What's a Ferrite?

- A ceramic consisting of an iron oxide
  - manganese-zinc
  - nickel-zinc
- Has permeability (μ) much greater than air
  - Better path for magnetic flux than air
  - Multiplies inductance of a wire passed through it
- Is increasingly lossy at higher frequencies

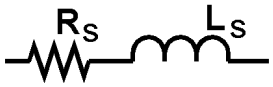
Different sizes and shapes

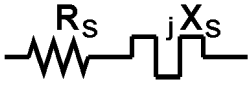


What’s Do the Numbers Mean?

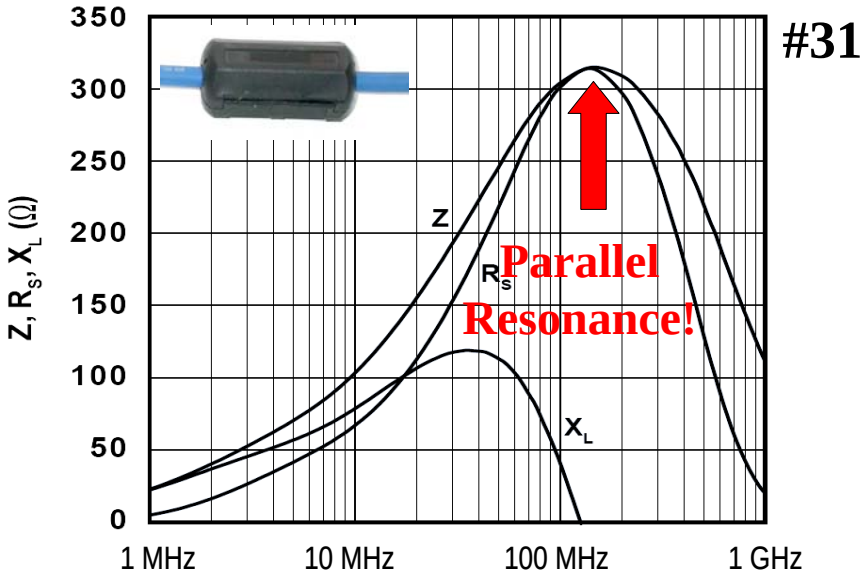
- The “*MIX*” − the chemical formula of the iron oxide!
- A ceramic consisting of an iron oxide
  - manganese-zinc (MnZn) – 1-30 MHz (AM broadcast, hams) #31, #77, #78
  - nickel-zinc (NiZn) – 30 MHz-1 GHz (FM, TV, cell phones) #43, #61, #67
- #31 is a new MnZn *mix* that behaves like #43 at HF and VHF, but is much better below 5 MHz

A simple equivalent circuit of a wire passing through a ferrite



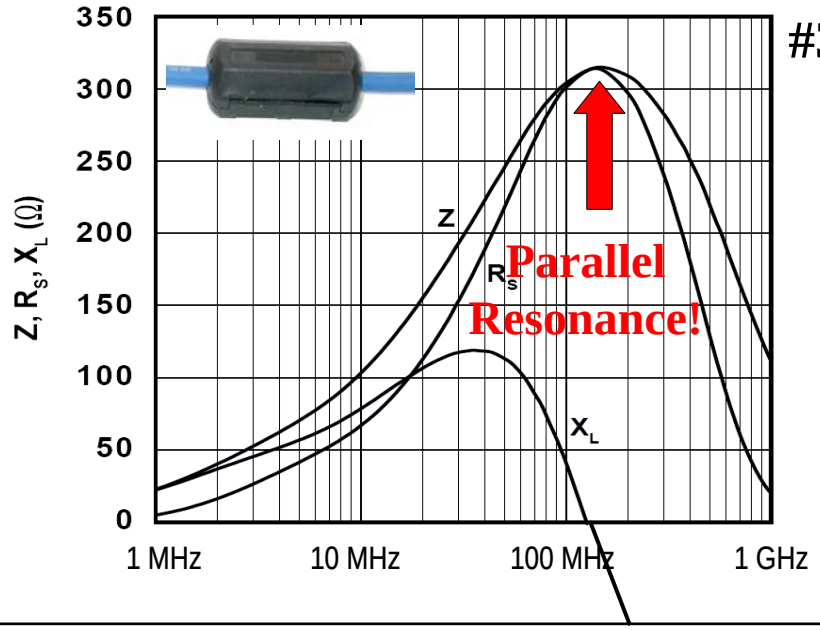


R_S and X_S vary with frequency!



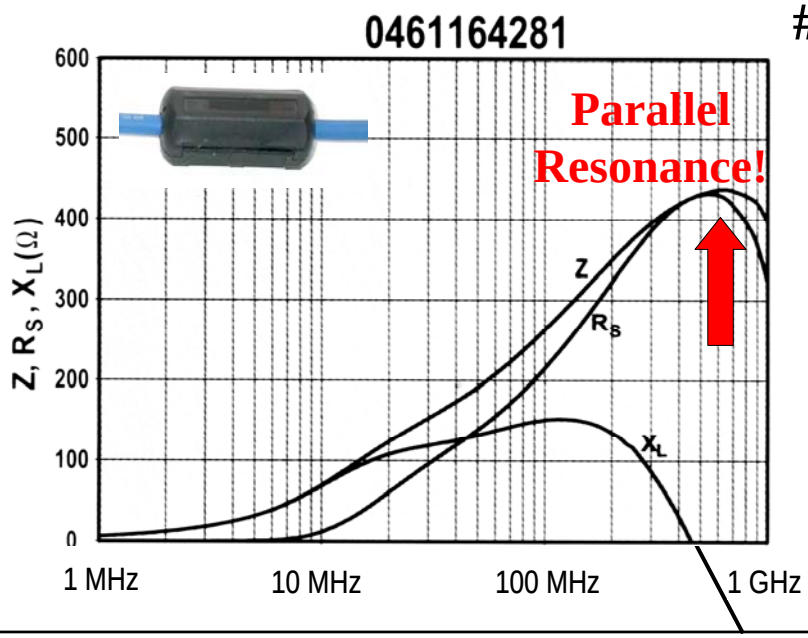
R_S and X_S vary with frequency!

#31



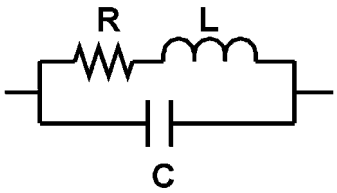
A Ferrite for UHF Suppression

#61

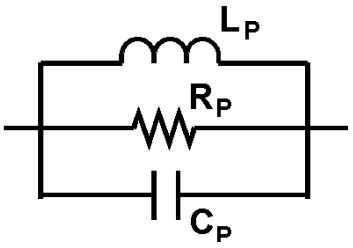


Equivalent Circuit of a Ferrite Choke

Low Frequencies

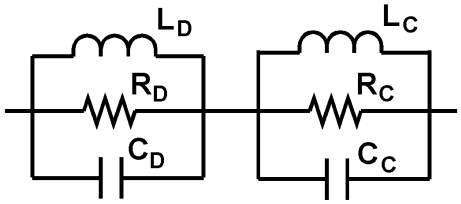


Mid-Frequencies



High Frequencies

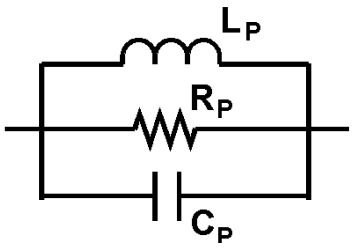
More General Equivalent Circuit



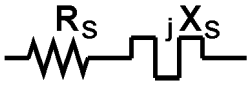
Including Dimensional Resonance

(more than we have time to talk about today)

We'll Use This Physical Equivalent Circuit to Understand the Choke

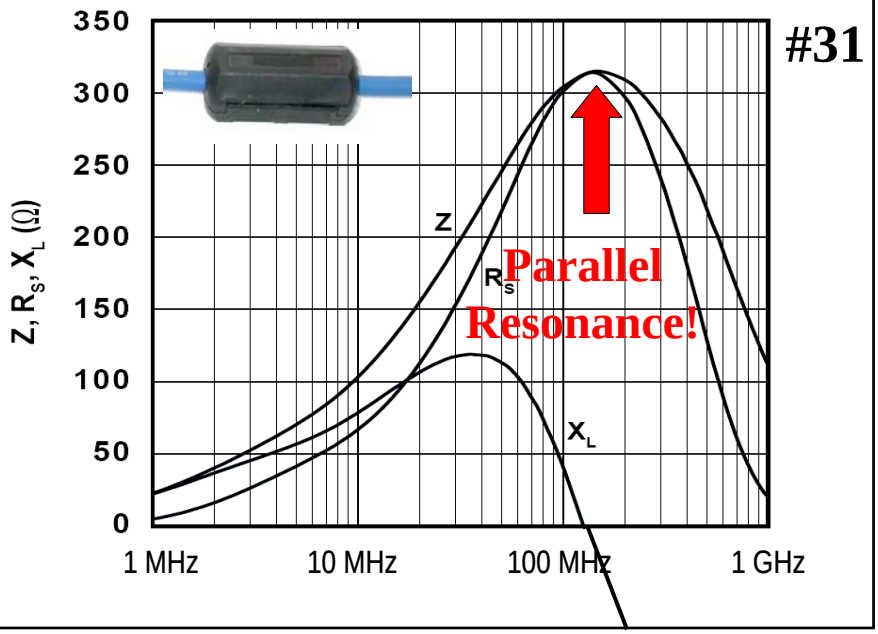


Data Sheets Use This Equivalent Circuit to Graph the Impedance



R_S and X_S vary with frequency!

#31



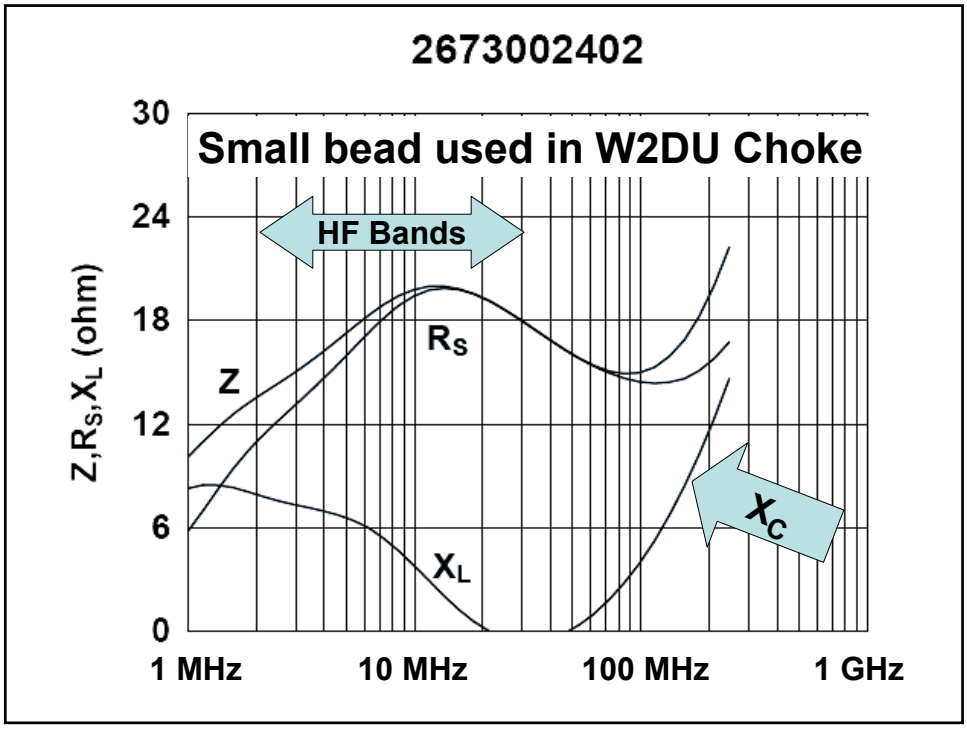
Where's the Capacitance here?

Where's the Capacitance here?

From the wire at one end of the choke to the wire at the other end, through the permittivity of the ferrite (it <u>is</u> a dielectric!)

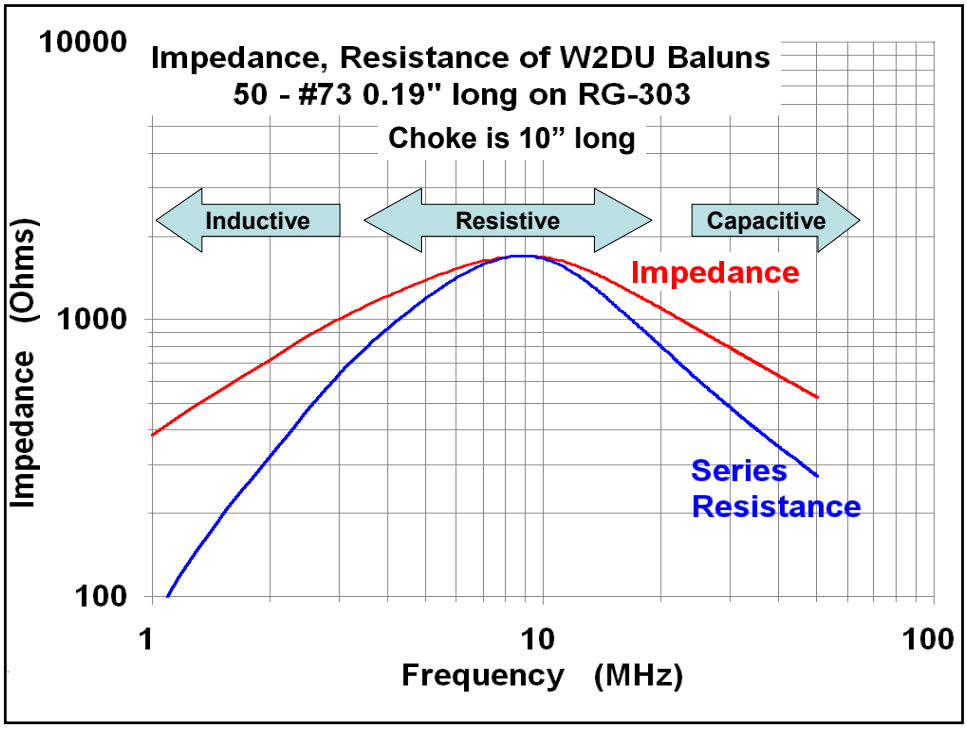
“Strings of Beads” (W2DU, W0IYH Baluns)

A String of Different Beads



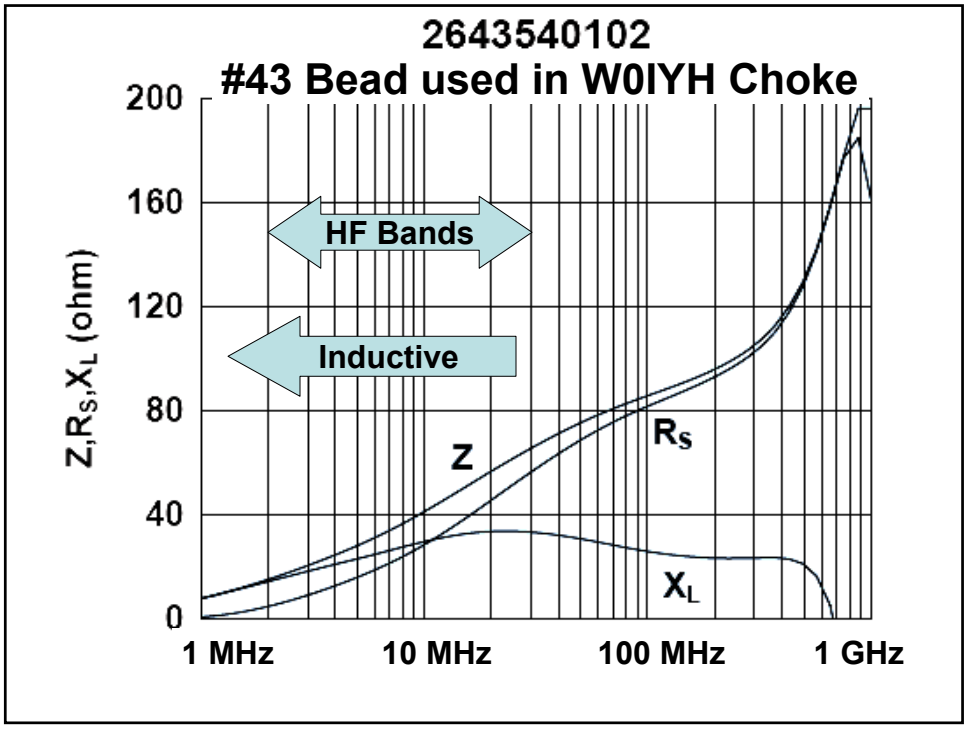
W2DU Choke

- A "string of beads" choke
  - Impedances in series add
  - 50 beads = 50 x Z of one bead
- W2DU used #73 mix (a very good choice)
- Increasingly resistive above 3 MHz
  - Less sensitive to feedline length
- Much better than bead of WØIYH choke
- Many more beads are needed
  - They're small and cheap (good)
- #73 only made to fit RG58 or RG303



Newer (Poor) Designs

- W2DU's design is 40 years old
- That's old fashioned -- certainly something newer must be better!
- W2DU's beads are tiny
- W0IYH tried something bigger
- BIG beads that fit on RG8



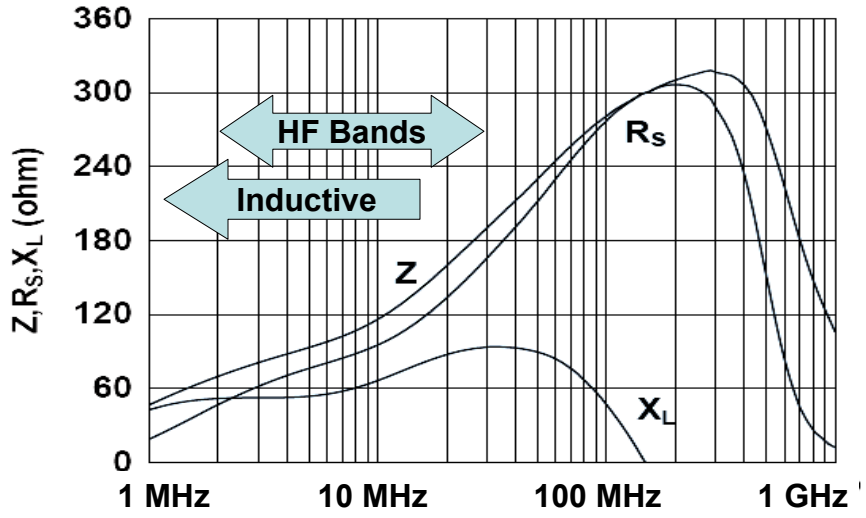
W0IYH Choke

- Also a "string of beads" choke
- Predominantly <u>inductive</u> below 25 MHz
  - Very sensitive to feedline length
  - Inductance resonates with a capacitive line
- Increasingly resistive above 25 MHz
  - Much less sensitive to feedline length
- Not very effective below 15 meters!

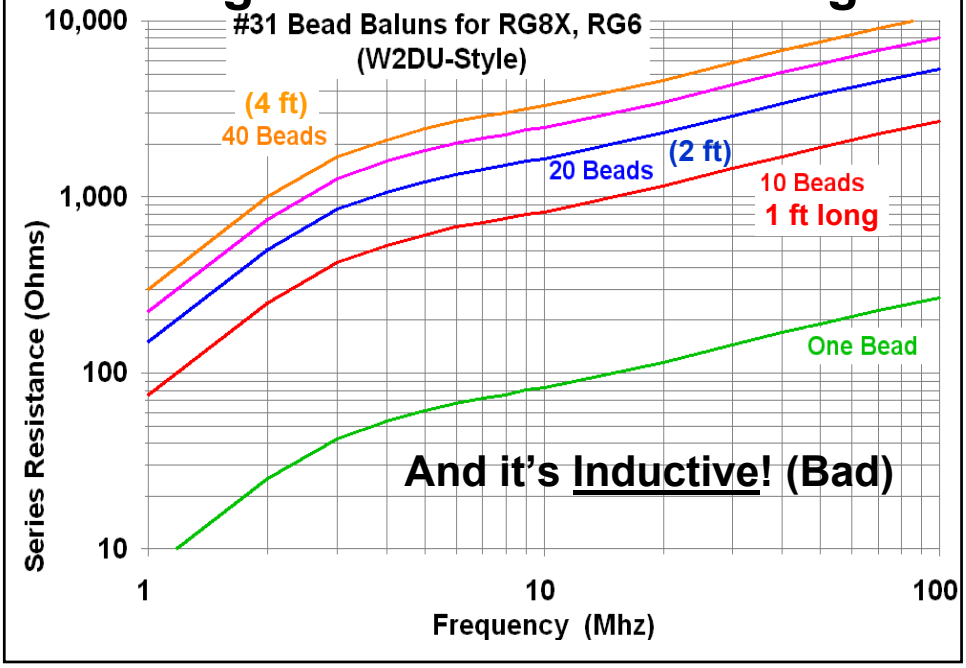
A #31 Bead for the String

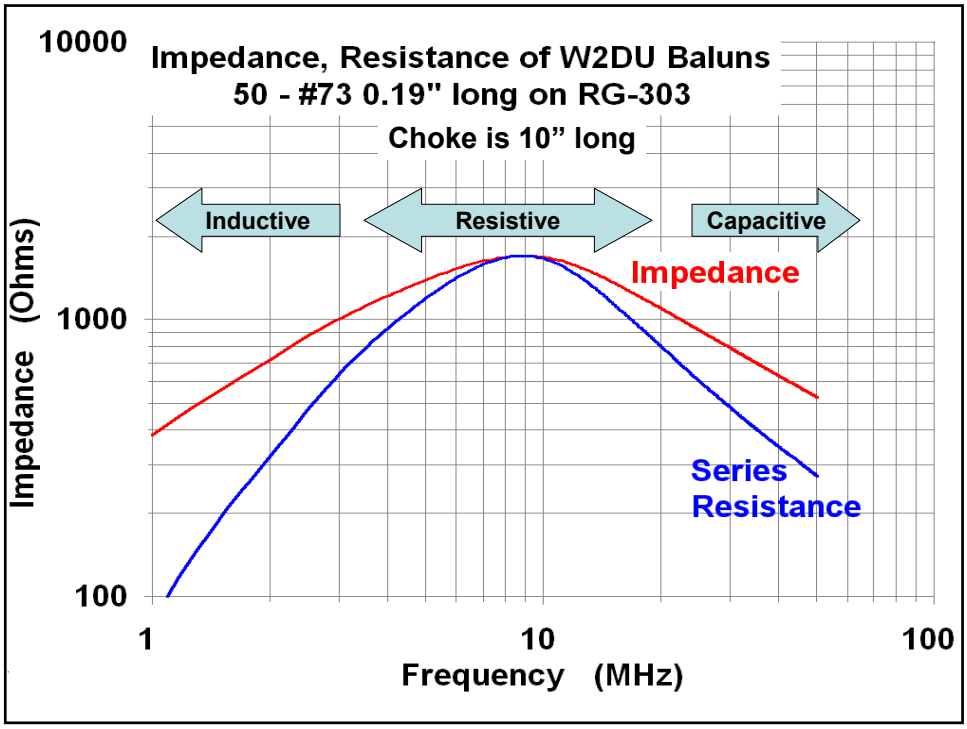
1" o.d. x 1.125" long (Fits RG8)

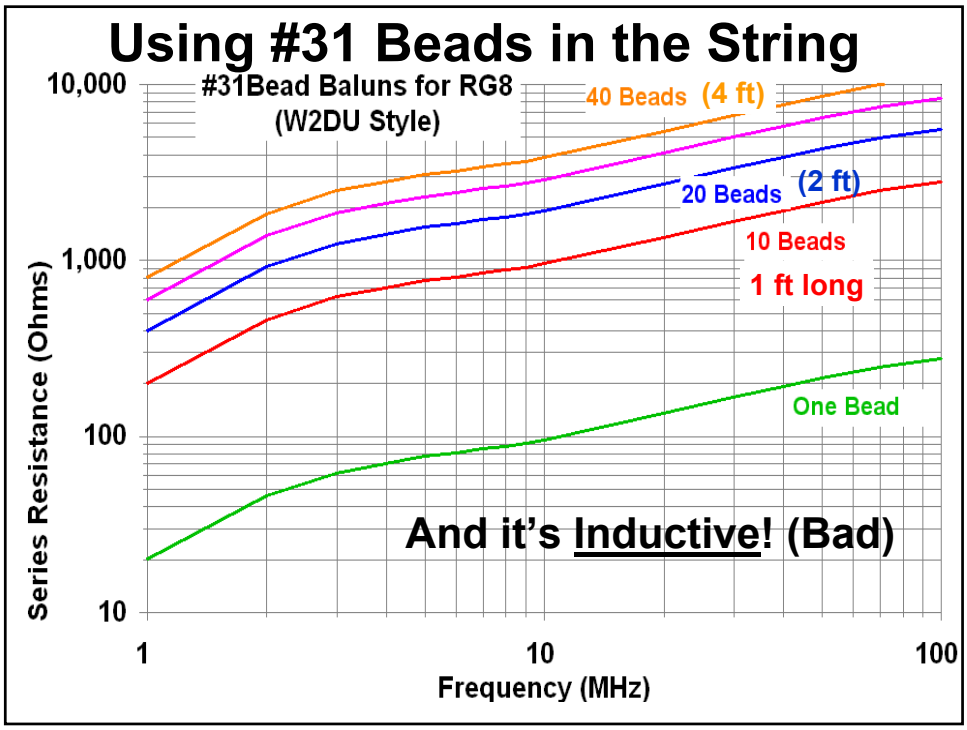
2631102002

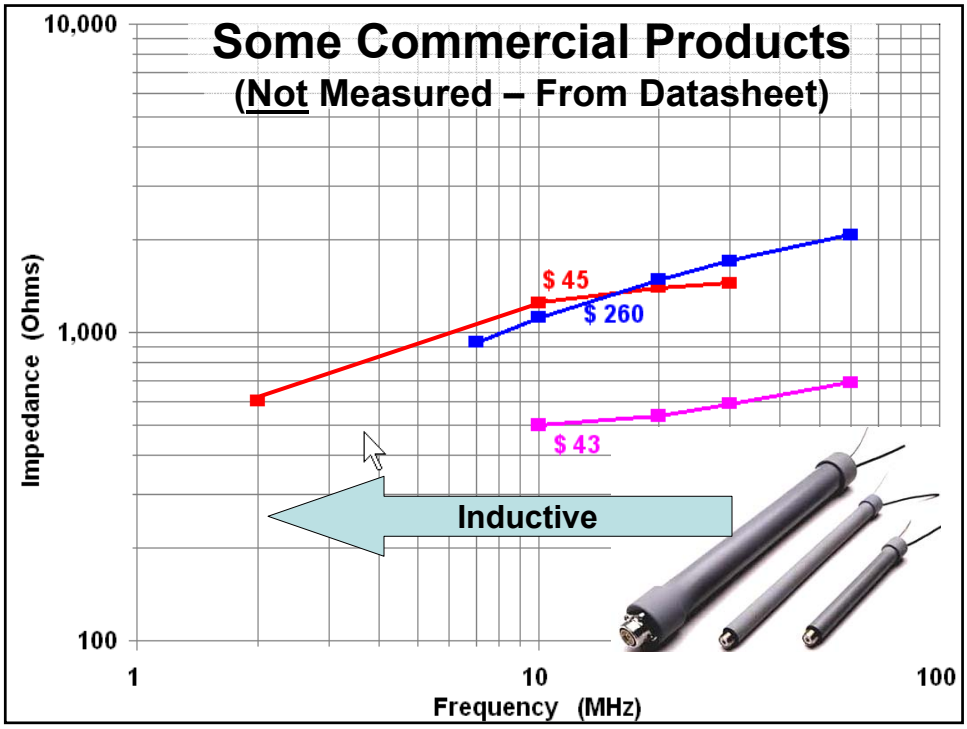


Using #31 Beads in the String




Impedance, Resistance of W2DU Baluns
50 - #73 0.19" long on RG-303
Choke is 10" long
Inductive
Resistive
Capacitive
Impedance
Series Resistance
10000
1000
100
Impedance (Ohms)
1
10
100
Frequency (MHz)

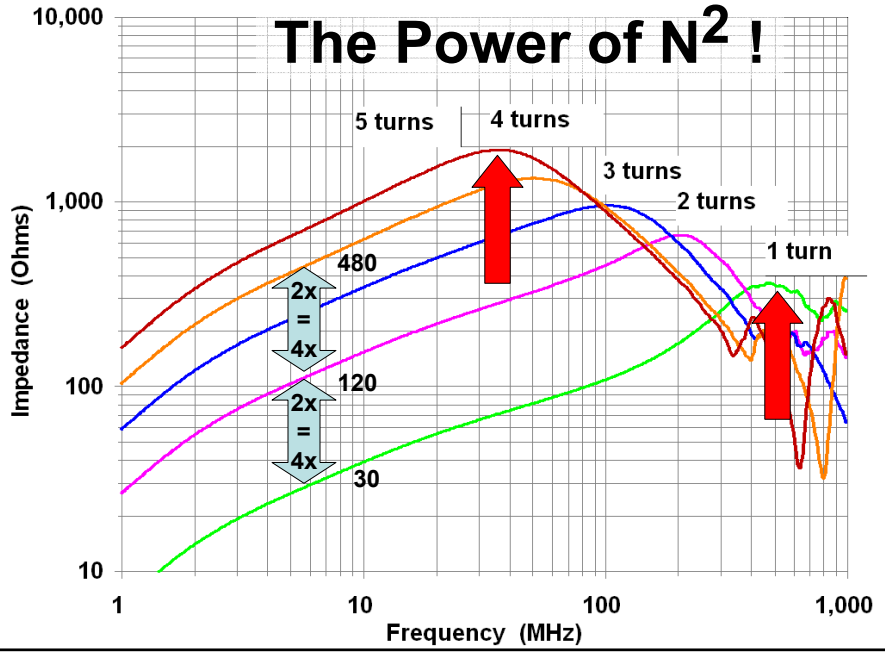

Using #31 Beads in the String
#31Bead Baluns for RG8
(W2DU Style)
40 Beads (4 ft)
20 Beads (2 ft)
10 Beads
1 ft long
One Bead
And it's Inductive! (Bad)
10,000
1,000
100
10
Series Resistance (Ohms)
1
10
100
Frequency (MHz)



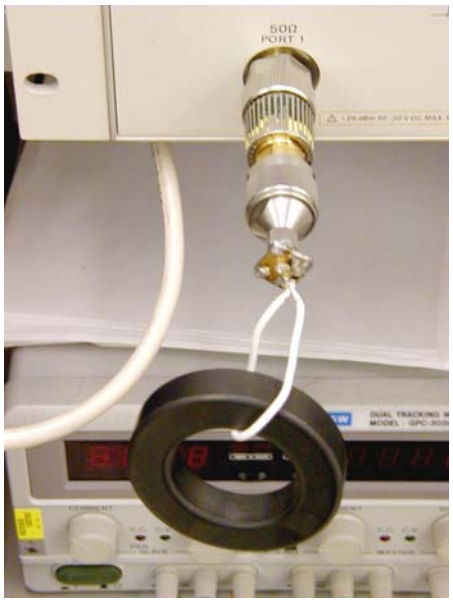
There's A Much Better Way to get Higher Impedance

- Inductance increases as N^2
- Inductively coupled resistance increases as N^2

Measured Data for #43 Toroid Chokes



HP8753C w/HP85046A S-parameter Test Set (by my anonymous collaborator)



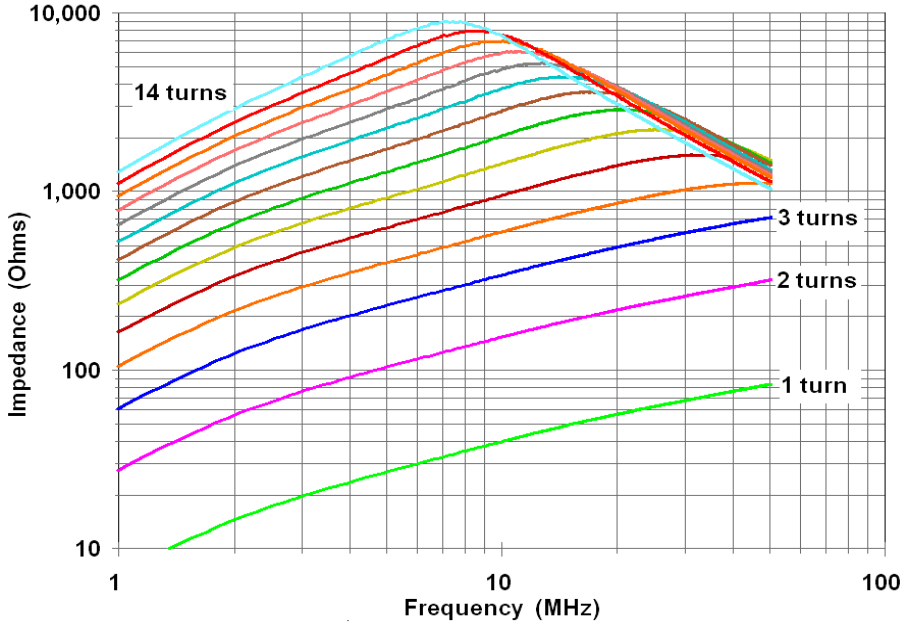
Why the Resonance Moves Down

- Inductance increases as N^2
- Inductively coupled resistance increases as N^2
- Capacitance increases with N
  - Capacitance between turns
  - Capacitance through the ferrite core
  - A bit more capacitance with much bigger wire (like coax)

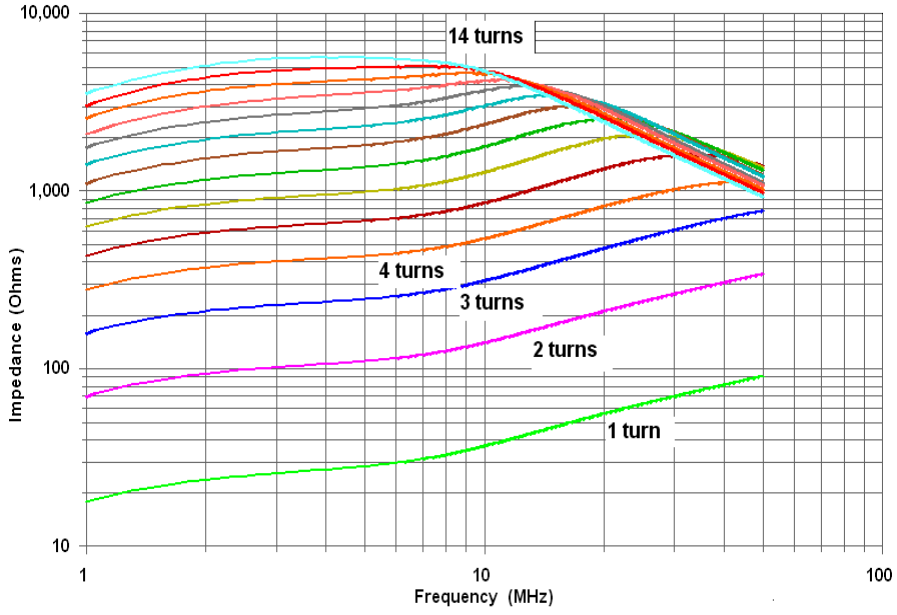
The Power of Turns at HF and MF

- Moves the resonance down from VHF to HF
  - More inductance
  - More capacitance
- Multiplies impedance at resonance
  - But not by N^2, because resonance has moved lower in frequency

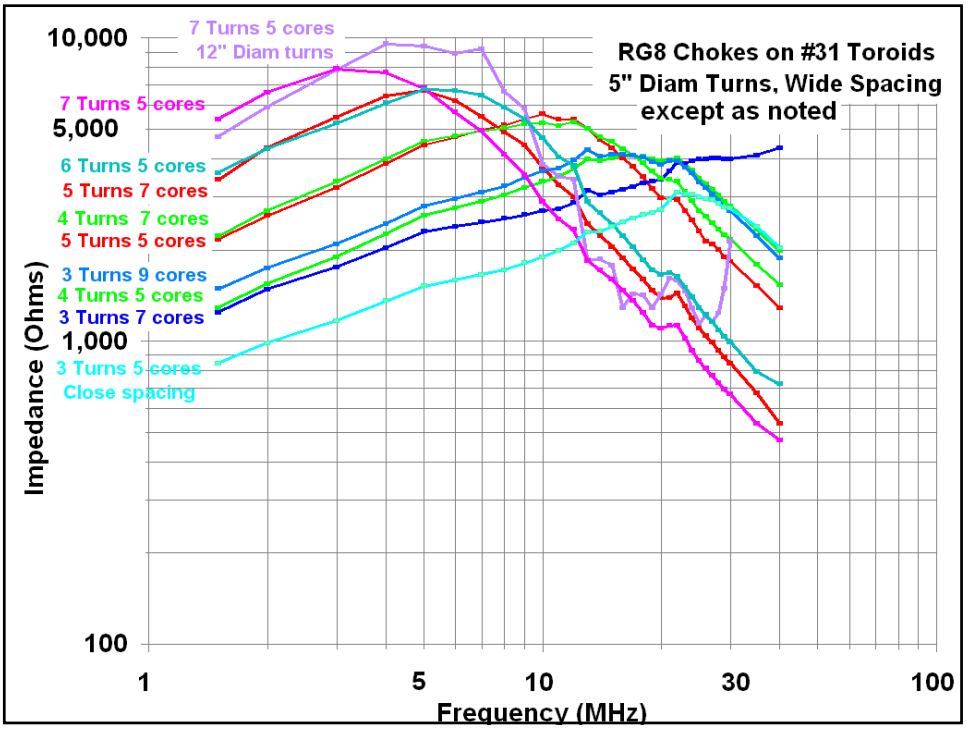
Measured Data for #43 Toroid Chokes

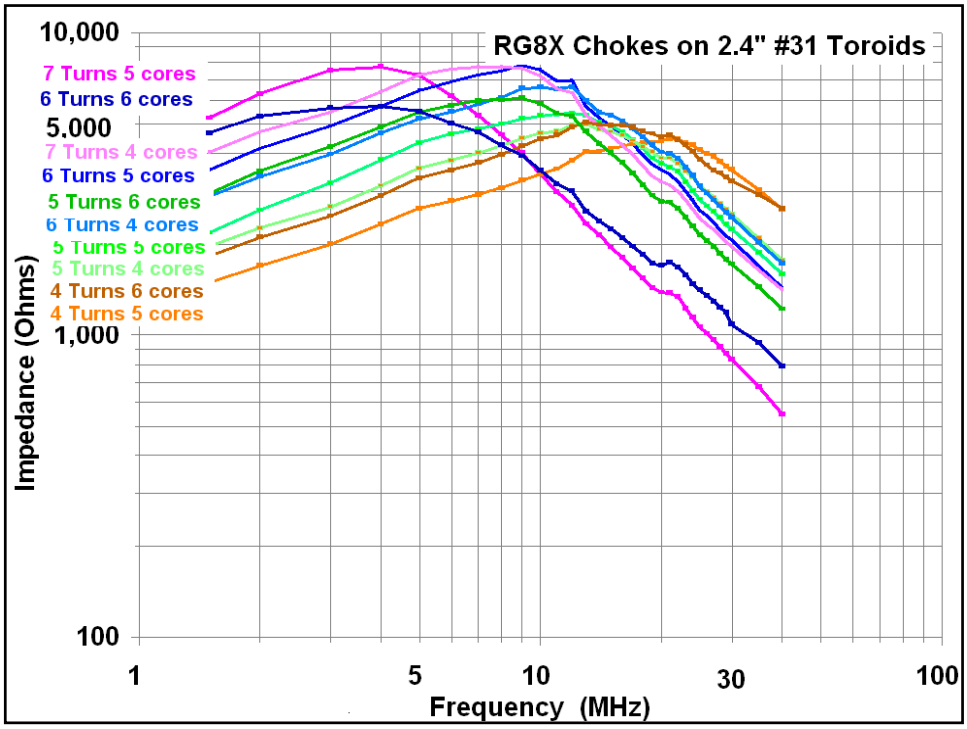


Measured Data for #31 Toroid Chokes

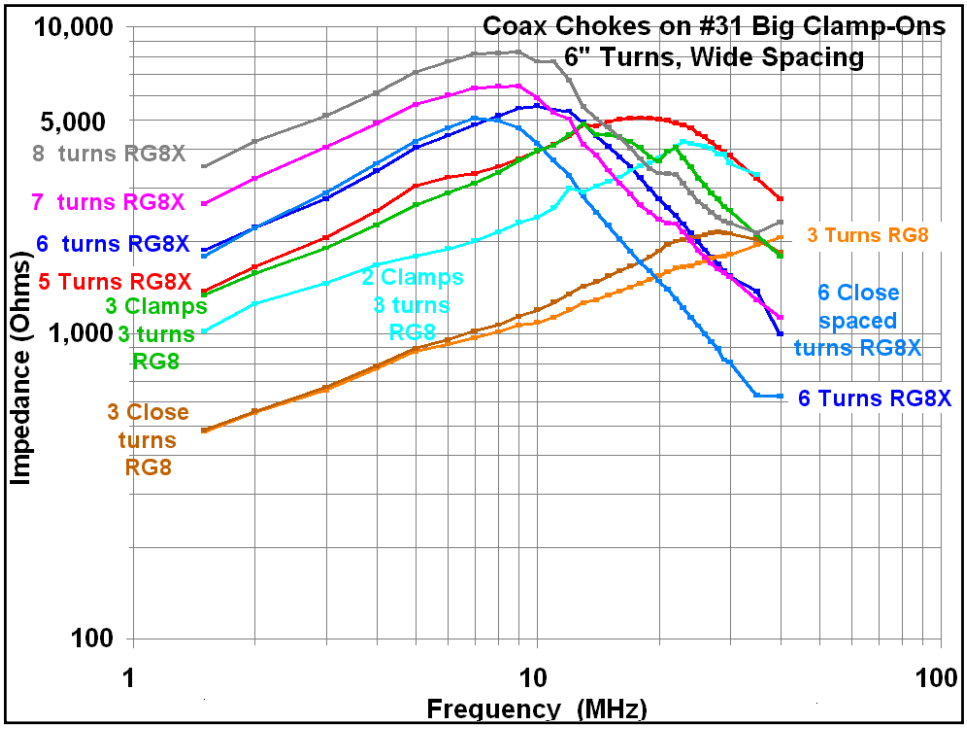


K9YC Chokes (Improvements on W1JR, W2DU Designs)





The "Big Clamp-On" When You Can't Easily Take the Connector Off



Wide or Close Spaced Turns?

- Close spacing lowers resonant frequency
  - More capacitance
  - More inductance
- Close spacing often better <u>below</u> 10 MHz
- Wide spacing usually best <u>above</u> 10 MHz
- Study the K9YC data and Cookbook for specific applications

Let's Talk About Dissipation (Heat, Power Handling)

Dissipation and Form Factor

- 1,500 W in 50 ohms = 275V @ 5.5A PEP
- Heat produced by the <u>average</u> power
  - With CW, ~ 3 dB less than PEP
  - SSB <u>without</u> speech processing or clipping ~ 14 dB less than PEP
  - SSB <u>with</u> heavy processing ~ 6 dB less than PEP
- Most power amps must be de-rated by 3 dB for RTTY, PSK, FM, AM

Dissipation and Duty Cycle

- We've got to listen sometime, so subtract another 3 dB (50% listening)
- Real world average ham power levels for intense contesting and DXing
  - ~ 6 dB less than PEP for CW
  - ~ 9 dB less than PEP for SSB
  - ~ 6 dB less than PEP for RTTY, PSK, FM

Heat in Common Mode Chokes

- Heat (Power) is $I^2 R$
  - I and R are common mode values
  - Make R very large
  - I falls in proportion to R
  - P falls as I^2 so power (heat) falls twice as fast as R increases
  - Obtain current from the NEC model of the common mode circuit

What About Heat?

- Heat is not a problem in coax chokes if R (the choking impedance) is large enough
- How large is enough?
- For an antenna with reasonably good balance, R = 5,000 ohms keeps dissipation low

Failures From Excessive Voltage

- $P = E^2 / R$
- Causes of excessive voltage
  - Antenna systems that make E very large
  - Feedline length near λ/2, λ, 3λ/2, 2 λ, etc.
  - Antenna tuners that step voltage up to high impedance lines
  - Severe imbalance
- Let's study an example in NEC

A Real Antenna, Unbalanced

- NEC Model of 40M dipole, fed by 67 ft of coax (half wave), 5,000 ohm choke (Vf ~ 0.98 for common mode)

	PEP		Constant CQing	
Legs (Ft)	Power	Volts	CW, FM, RTTY, PSK	SSB
30 - 36	30 W	387 V	8 W	4 W
27 - 39	80 W	632 V	24 W	12 W
24 - 42	150 W	866 V	40 W	20 W
20 - 46	253 W	1125 V	80 W	40 W

Chokes Exposed to Air Flow Can Handle More Power

A choke in a closed box is much more likely to overheat

Causes of Choke Failures

- Feedline near λ/2 combined with strong antenna imbalance
- Insufficient air circulation
- Choking impedance too low

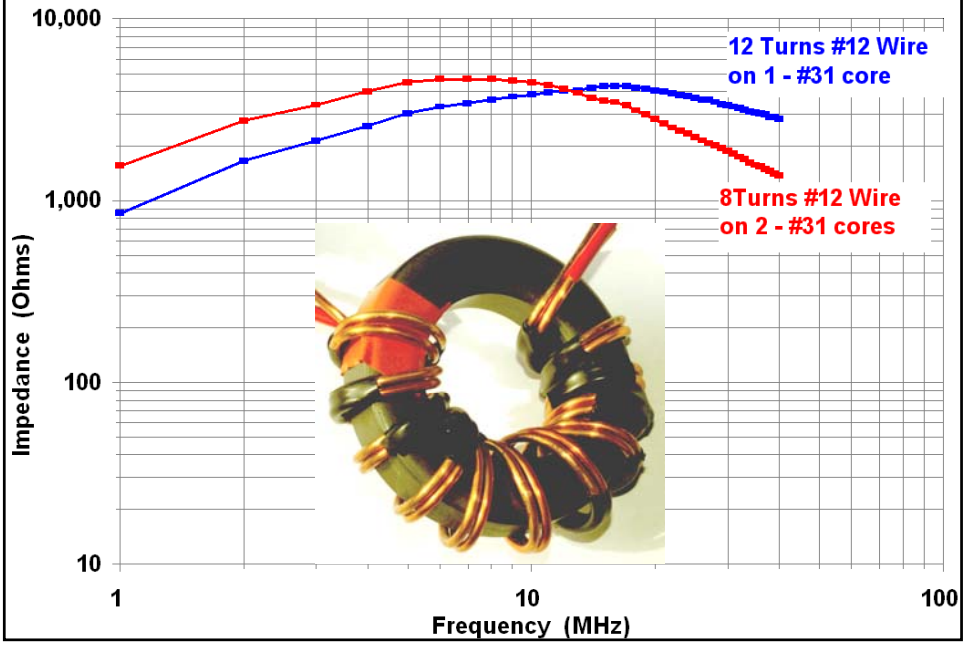
How Much Choking Z is Enough?

- If your antenna is well balanced, 5,000Ω is plenty
- If your antenna has severe imbalance, 10,000Ω may not be enough
- Chokes on Windom antennas are notorious for failing

What About Bifilar Chokes?

- These bifilar chokes are wired simply as a short section of balanced line wound around one or two cores

Bifilar chokes on #31 (lossy) toroid

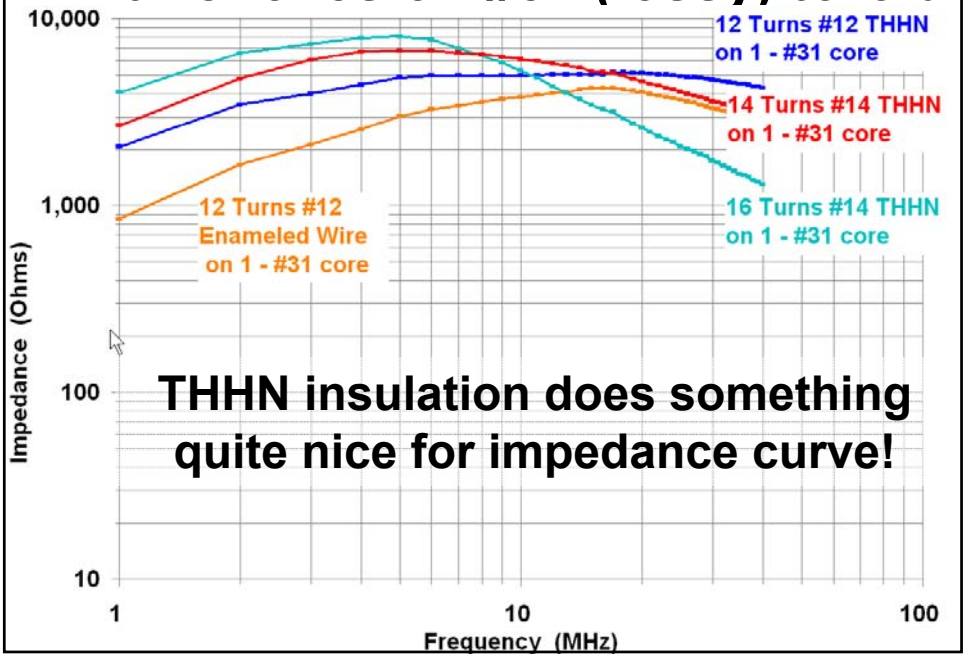


Bifilar Chokes

- I'm looking for a low cost choke that anyone can build cheaply
- Enameled wire is hard to find and not cheap
- Voltage rating depends on enamel coating, varies widely
- How about THHN? (House Wire)

Chokes wound with #14 THHN (ordinary house wire)

Bifilar chokes on #31 (lossy) toroid



Z_O of Bifilar Windings

- Winding is a balanced transmission line
- Z_O depends on spacing, wire size, and dielectric
- Z_O For #12 - #14 wire
  - Close spaced enameled wire ~ 50 ohms
  - Close spaced THHN ~ 100 ohms (Sevick)

Impedance of THHN Windings

- Does the mismatch matter?
- It's a short length of line
  - 12 turns ~ 30 inches of line
    - Less than λ/20 at 14MHz, λ/10 at 28 MHz
  - 16 turns ~ 40 inches of line
    - Less than λ/50 at 4 MHz
- These small mismatches don't affect loss, easily matched by antenna tuner
- A small price to pay for high choking impedance and bandwidth!

Can They Handle High Power?

- Patched in series with my Titan amp at 1.5kW, they barely got warm!
  - Choke saw only differential power
  - All the heat was in the wire where it was wound around the core
  - No heating in the core itself!
  - No heating in the wire away from the core
- Like any other choke, dissipation due to common mode will be small if the antenna has reasonable balance

Bifilar Chokes

- Leakage flux is quite small with a good bifilar winding
  - Very good symmetry and uniformity
- Loss shows up as heating in the wire, not the core
  - Large wire (#14, #12) for high power
- Use same cores and winding guidelines as for small wire

How Much is Current Reduced?

- NEC Model of 80M dipole @ 129 ft, fed with 129 ft of coax (Near half wave – Vf ~ 0.98 for common mode)
- Without choke, feedline current is 1/3 of antenna current (-10 dB)
- Adding 5,000 ohm choke reduces feedline current by an additional 24 dB

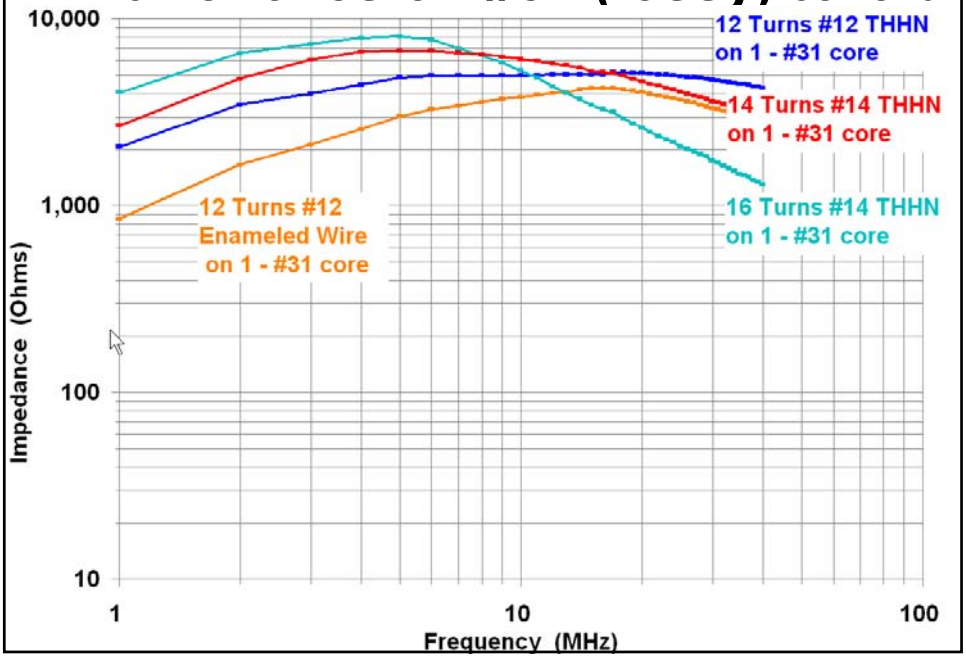
How Much is Current Reduced?

- NEC Model 80M dipole @ 66 ft, fed with 66 ft of coax (near quarter wave)
- Without choke, common mode current at TX end is 1/12 of antenna current (-22 dB), -38 dB at feedpoint
- Adding 5,000 ohm choke has no effect on feedline current

Bifilar Chokes Work in Coax Lines

- Much lower cost, much more compact
- Can handle full legal power with reasonably well balanced antennas
- De-rate to 500W for poorly balanced antennas (windoms)
- 14 turns of #14 THHN on #31 toroid covers 80M - 10M
- 16 turns of #14 THHN on #31 toroid covers 160M – 30M

Bifilar chokes on #31 (lossy) toroid



See K9YC's Choke Cookbook (Chapter 7 in the RFI Tutorial) for specific recommendations

http://audiosystemsgroup.com/RFI-Ham.pdf

How About Commercial Products?

We Can Build At Least as Good As We Can Buy, and for the cost of the cheapies!

- We must stock up on the right parts, buying in quantity

Who Makes Ferrites?

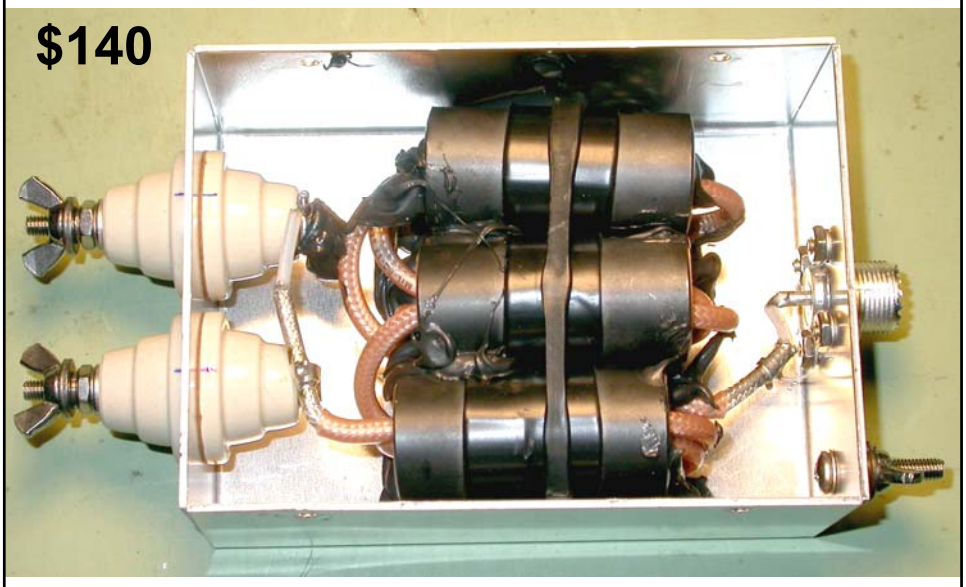
- Most ham ferrite parts are made by Fair-Rite
  - A big company in upstate NY
- Ham distributors simply resell them
  - Disguised by new part numbers (FT240-61)
  - Very high markups (typically 3-5x cost)
  - Palomar, Amidon, The Wireman
  - Often the "wrong" parts for best performance!

How to Buy Ferrites?

- Get part numbers from my tutorial
  - http://audiosystemsgroup.com/RFI-Ham.pdf
- Buy in quantity from distributors listed on the Fair-Rite website
  - Newark, Allied, Lodestone Pacific, Kreger
- Buy in large quantities direct from Fair-Rite
- Don't be a cheap ham
  - Think big – it costs more to think small!
  - Spend your money wisely

DX Engineering 50Ω Choke Balun

$140

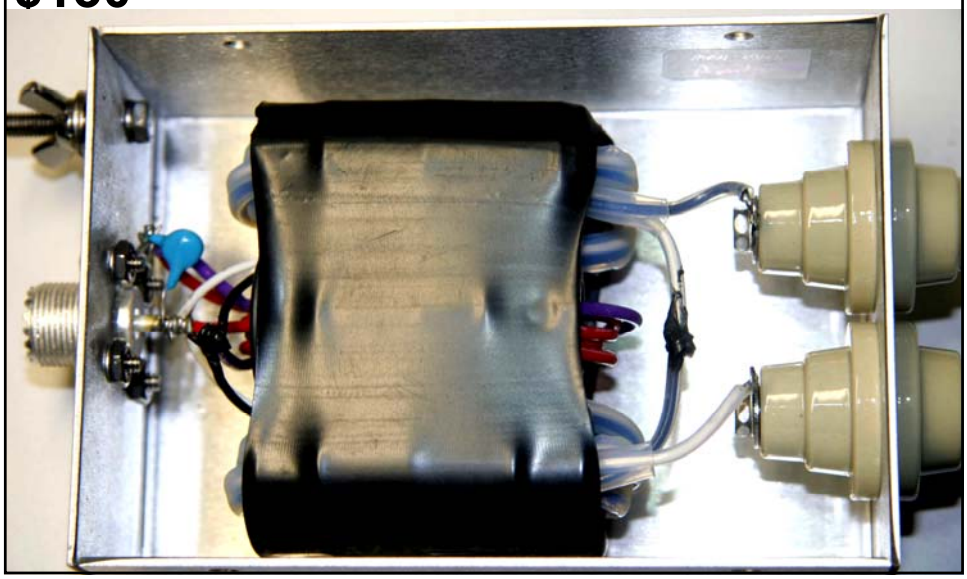


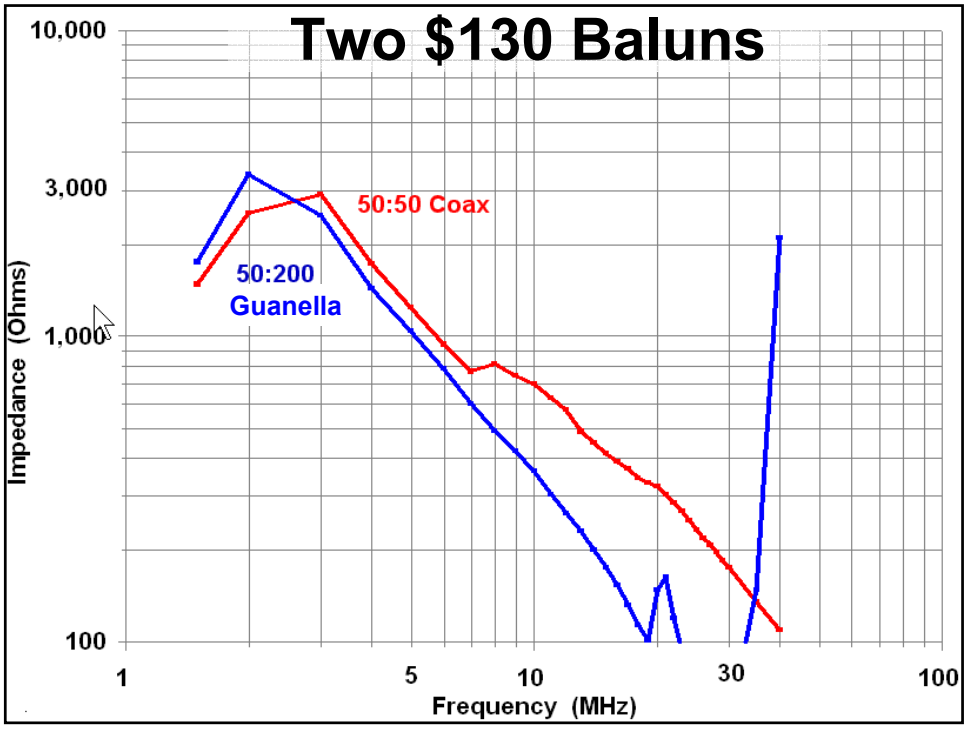
DX Engineering 200Ω – 50Ω Bifilar Choke Balun

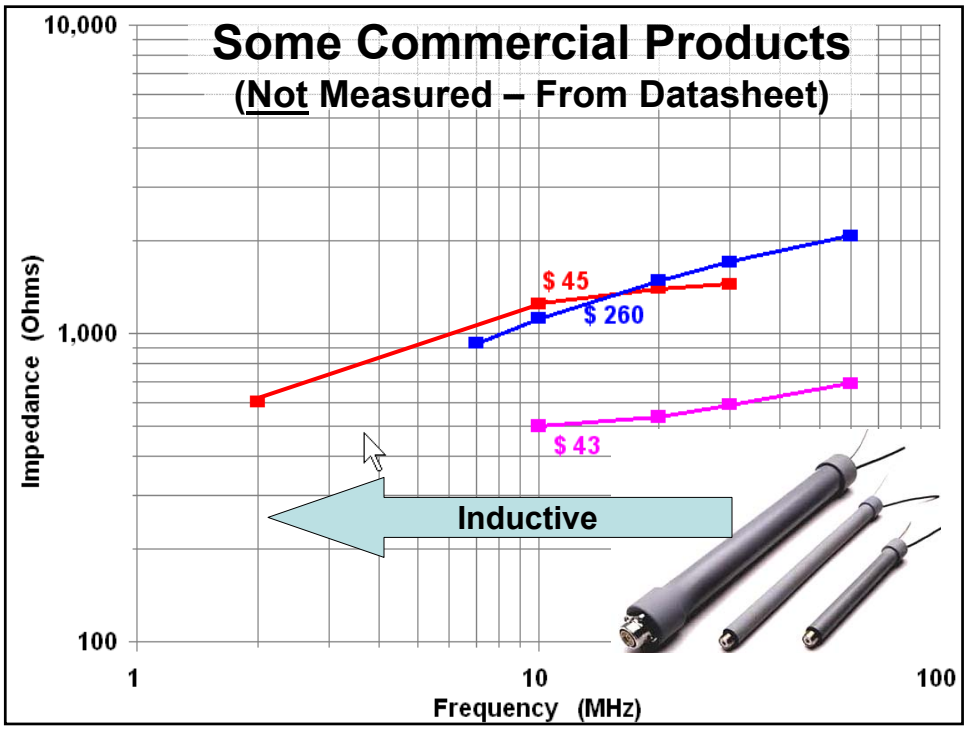
$130

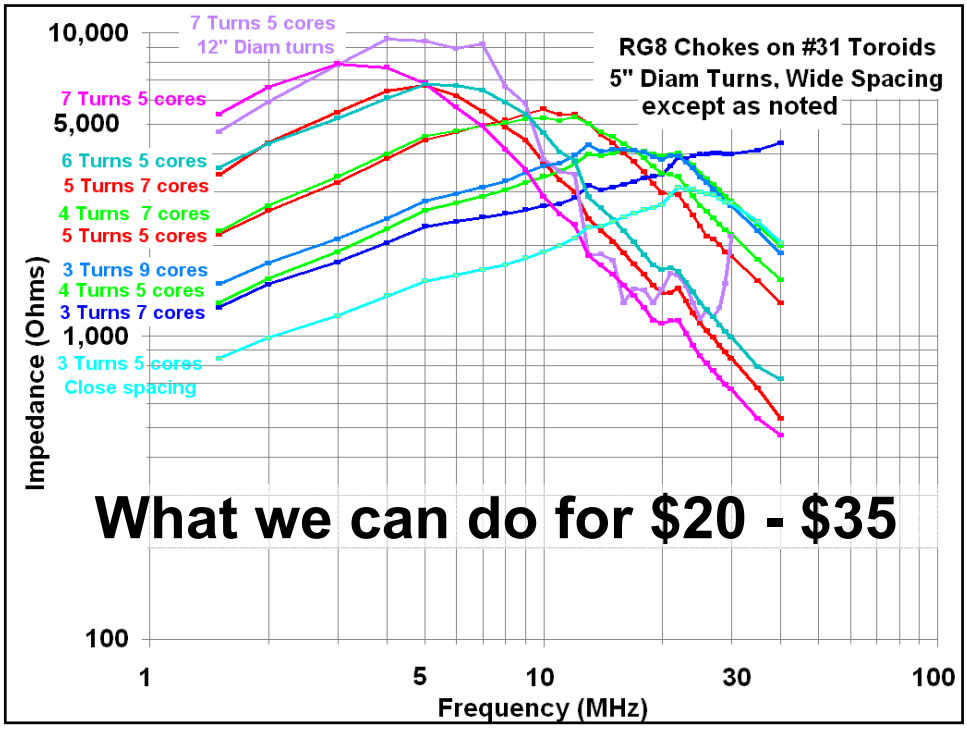
DX Engineering 300Ω – 50Ω Bifilar Choke Balun

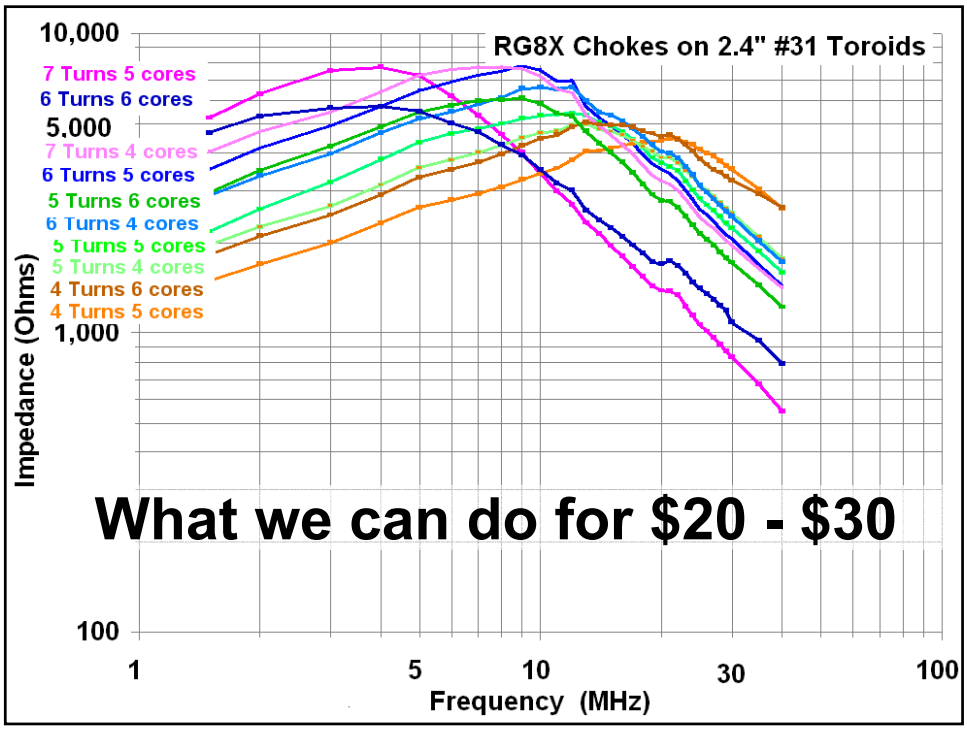
$130

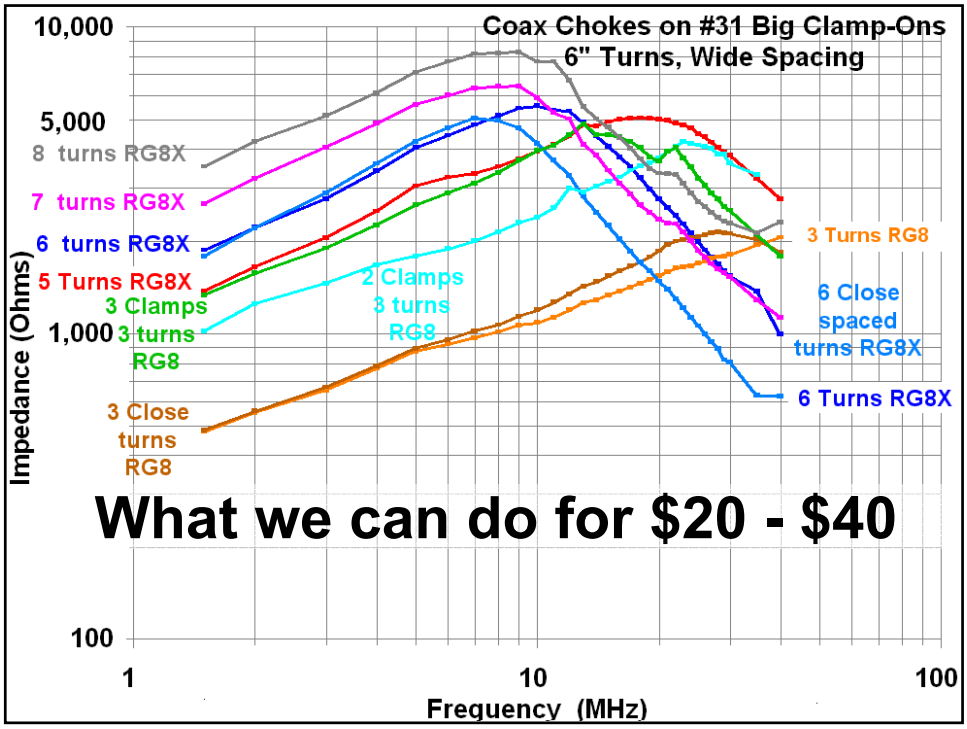


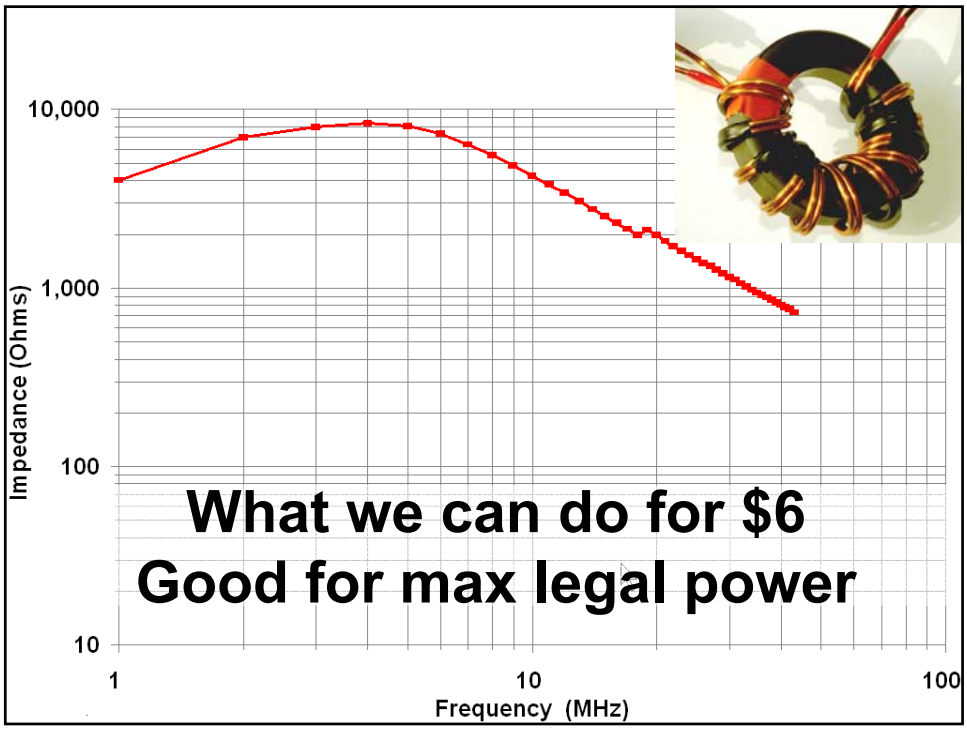

Two $130 Baluns
10,000
3,000
1,000
100
Impedance (Ohms)
50:50 Coax
50:200
Guanella
1
5
10
30
100
Frequency (MHz)

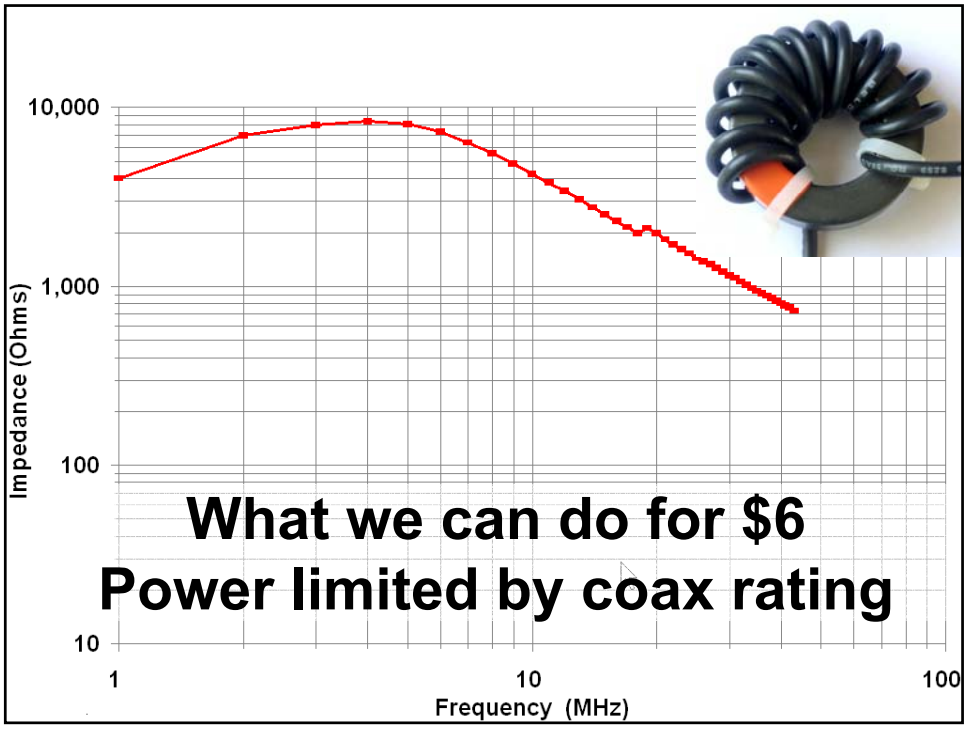

Some Commercial Products
(Not Measured – From Datasheet)
10,000
1,000
100
Impedance (Ohms)
$ 45
$ 260
$ 43
Inductive
1
10
100
Frequency (MHz)

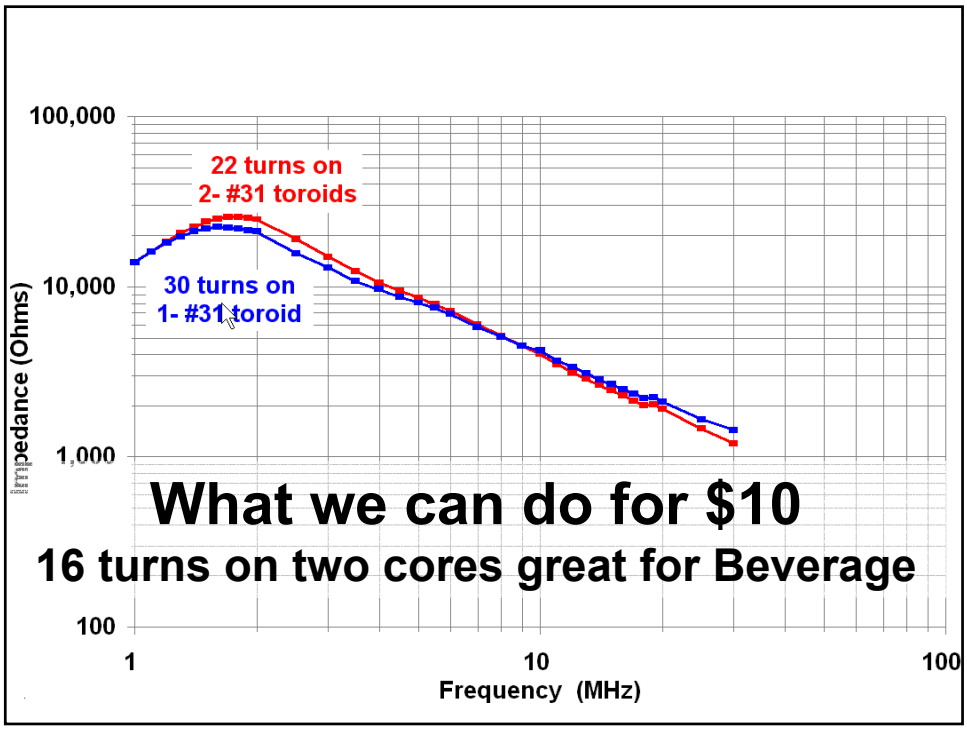

RG8 Chokes on #31 Toroids
5" Diam Turns, Wide Spacing
except as noted
7 Turns 5 cores
12" Diam turns
7 Turns 5 cores
6 Turns 5 cores
5 Turns 7 cores
4 Turns 7 cores
5 Turns 5 cores
3 Turns 9 cores
4 Turns 5 cores
3 Turns 7 cores
3 Turns 5 cores
Close spacing
What we can do for $20 - $35
Impedance (Ohms)
10,000
5,000
1,000
100
1
5
10
30
100
Frequency (MHz)


RG8X Chokes on 2.4" #31 Toroids
7 Turns 5 cores
6 Turns 6 cores
7 Turns 4 cores
6 Turns 5 cores
5 Turns 6 cores
6 Turns 4 cores
5 Turns 5 cores
5 Turns 4 cores
4 Turns 6 cores
4 Turns 5 cores
What we can do for $20 - $30
Impedance (Ohms)
10,000
5,000
1,000
100
1
5
10
30
100
Frequency (MHz)


Coax Chokes on #31 Big Clamp-Ons
6" Turns, Wide Spacing
10,000
5,000
1,000
100
Impedance (Ohms)
8 turns RG8X
7 turns RG8X
6 turns RG8X
5 Turns RG8X
3 Clamps
3 turns
RG8
3 Close
turns
RG8
2 Clamps
3 turns
RG8
3 Turns RG8
6 Close
spaced
turns RG8X
6 Turns RG8X
What we can do for $20 - $40
1
10
100
Frequency (MHz)


10,000
1,000
100
10
Impedance (Ohms)
What we can do for $6
Good for max legal power
1
10
100
Frequency (MHz)


10,000
1,000
100
10
Impedance (Ohms)
1
10
100
Frequency (MHz)
What we can do for $6
Power limited by coax rating


100,000
10,000
1,000
100
22 turns on
2- #31 toroids
30 turns on
1- #31 toroid
1
10
100
Frequency (MHz)
What we can do for $10
16 turns on two cores great for Beverage

See K9YC's Choke Cookbook (Chapter 7 in the RFI Tutorial) for specific recommendations

http://audiosystemsgroup.com/RFI-Ham.pdf

An 80/40 Fan Dipole

Closely Spaced Turns for an 80/40 Fan Dipole

Wide Spaced Turns for an 20/15/10 Fan Dipole

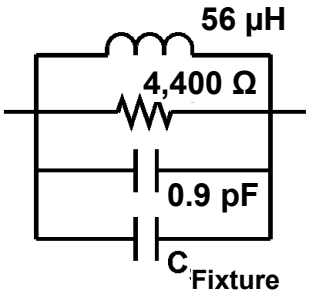
The Measurement Problem

Measuring Coax Chokes

- Very difficult to measure
- Traditional "reflection" measurements give wrong results
  - Poor accuracy if 5 ohms > Zx > 500 ohms
- Stray capacitance of fixture causes additional errors
  - Some VNA's and other analyzers that claim to subtract it out <u>don't</u>
- **A lot of smart people have missed all this!**

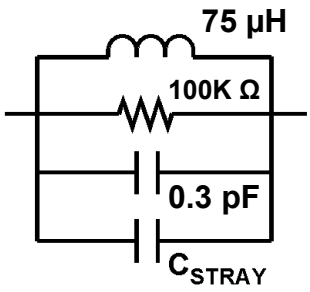
What are we Trying to Measure?

#31



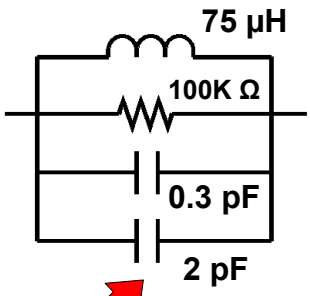
What are we Trying to Measure?

#61



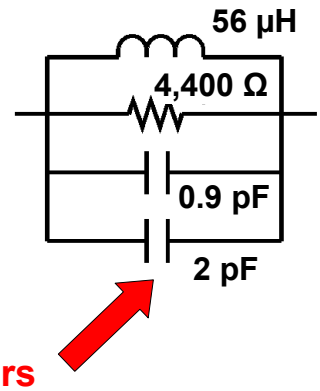
What are we Trying to Measure?

#61



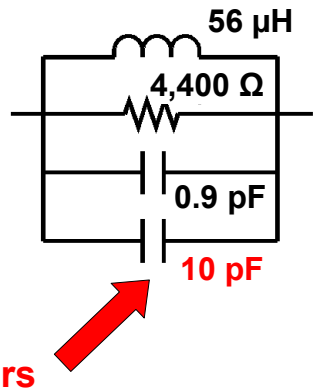
Typical “good” analyzers

What are we Trying to Measure?



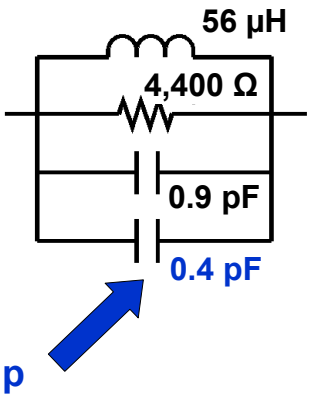
Typical "good" analyzers

What are we Trying to Measure?



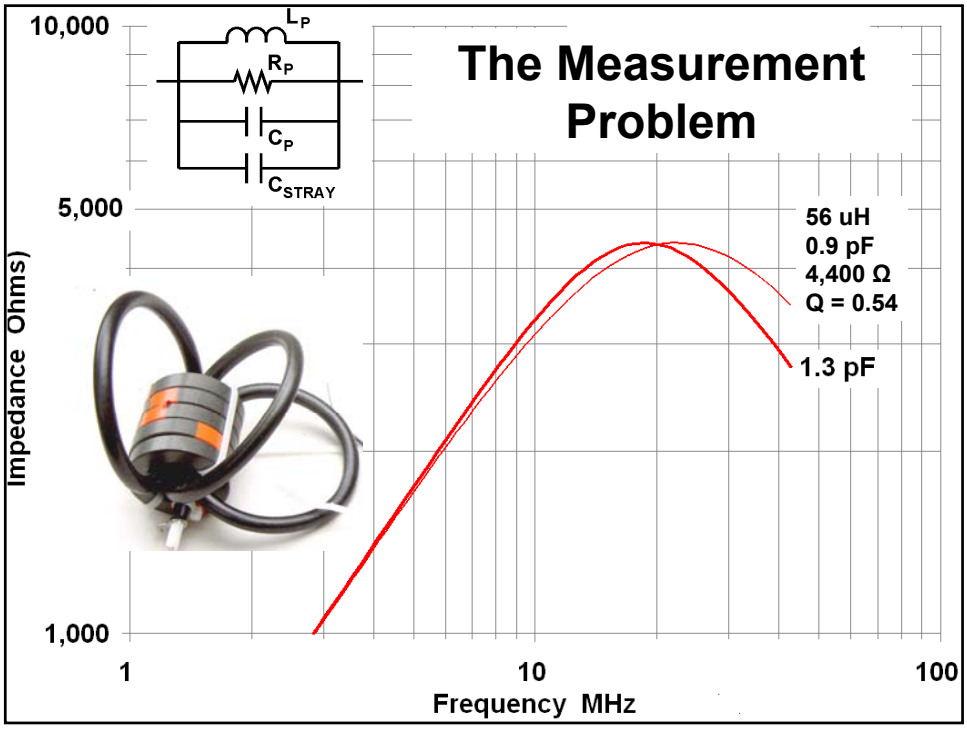
Typical "antenna" analyzers

What are we Trying to Measure?

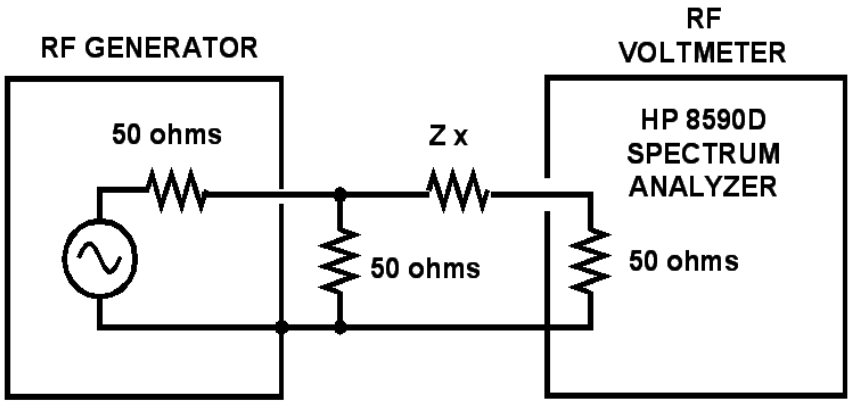


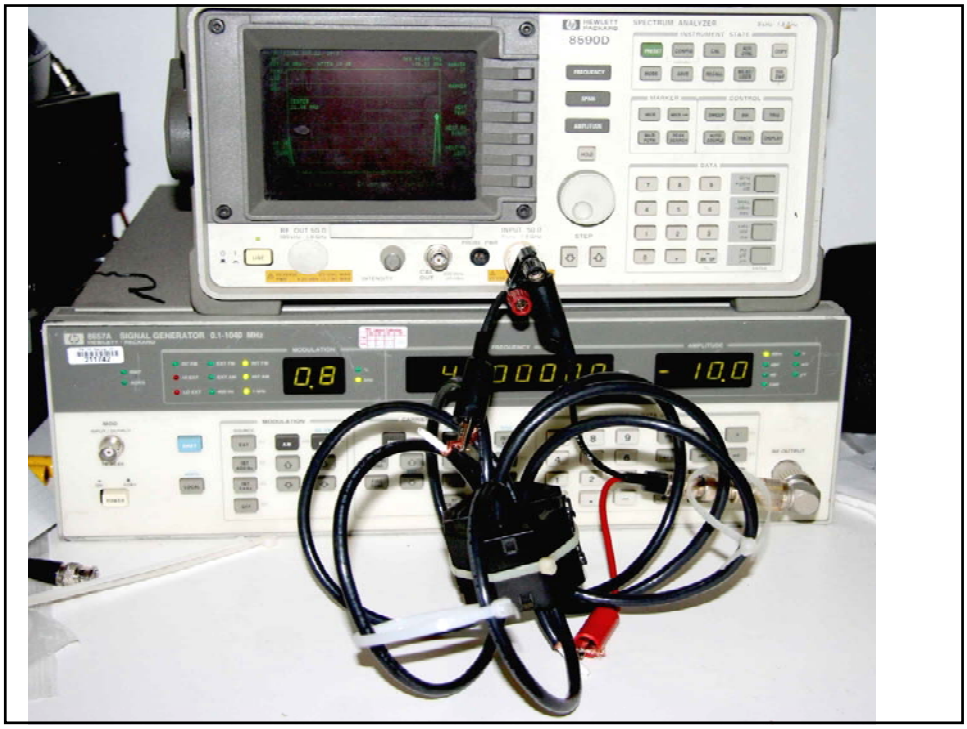
My measurement setup

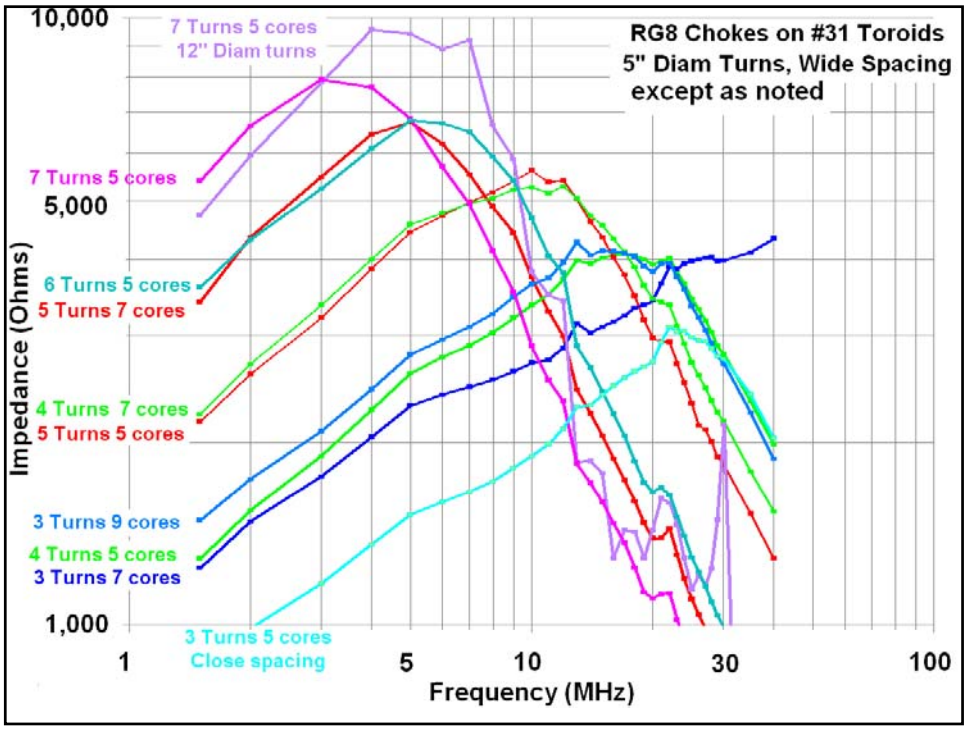
The Measurement Problem

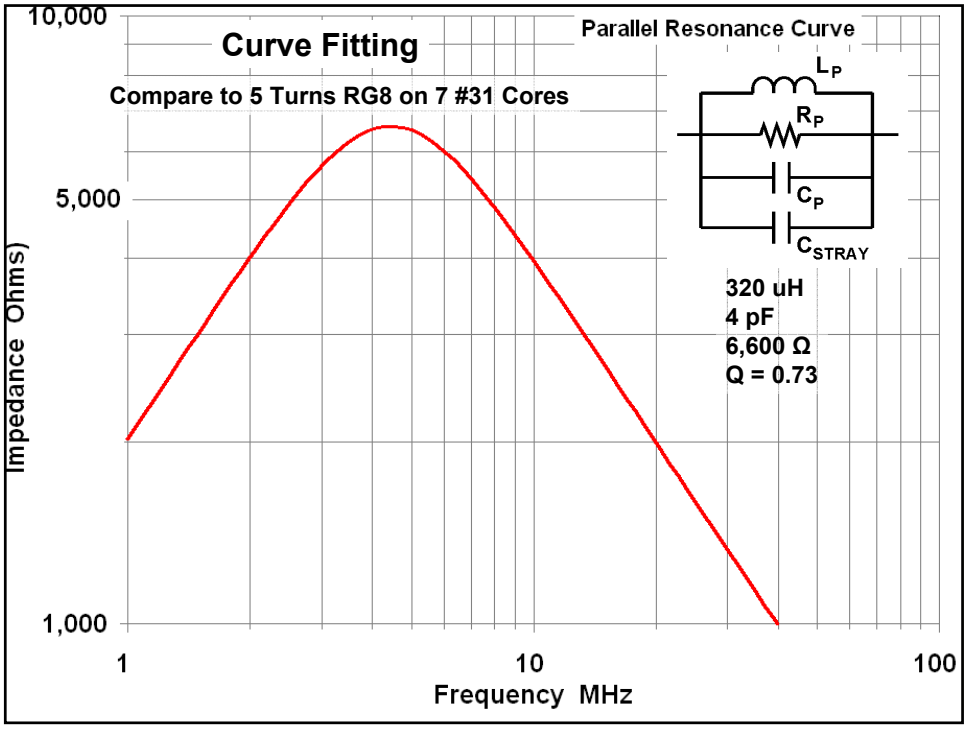


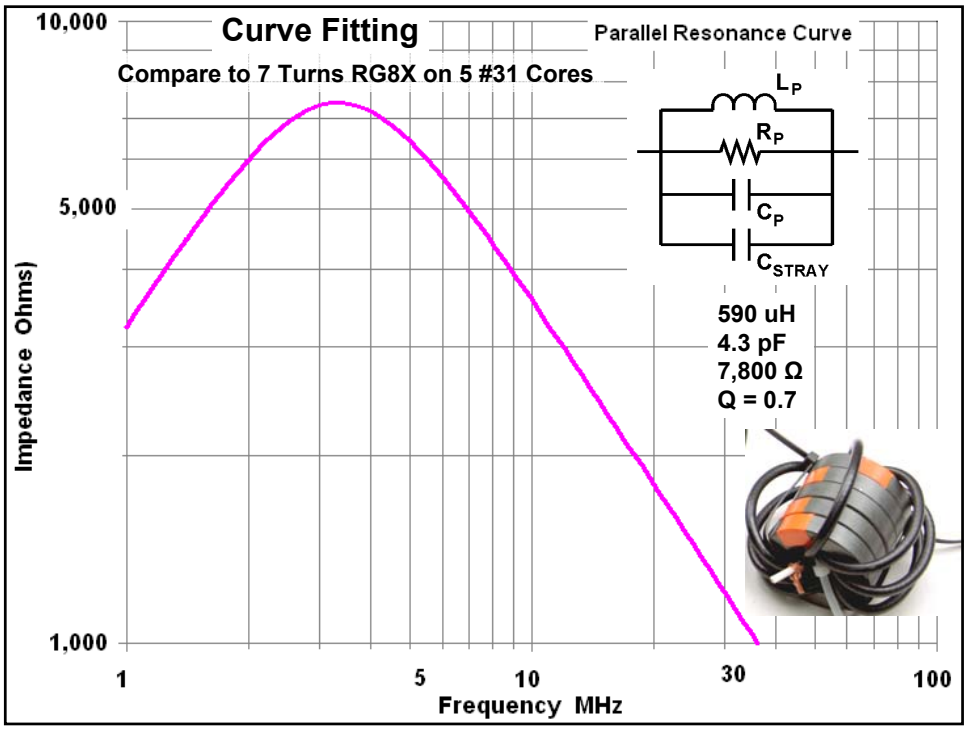
Measuring Coax Chokes

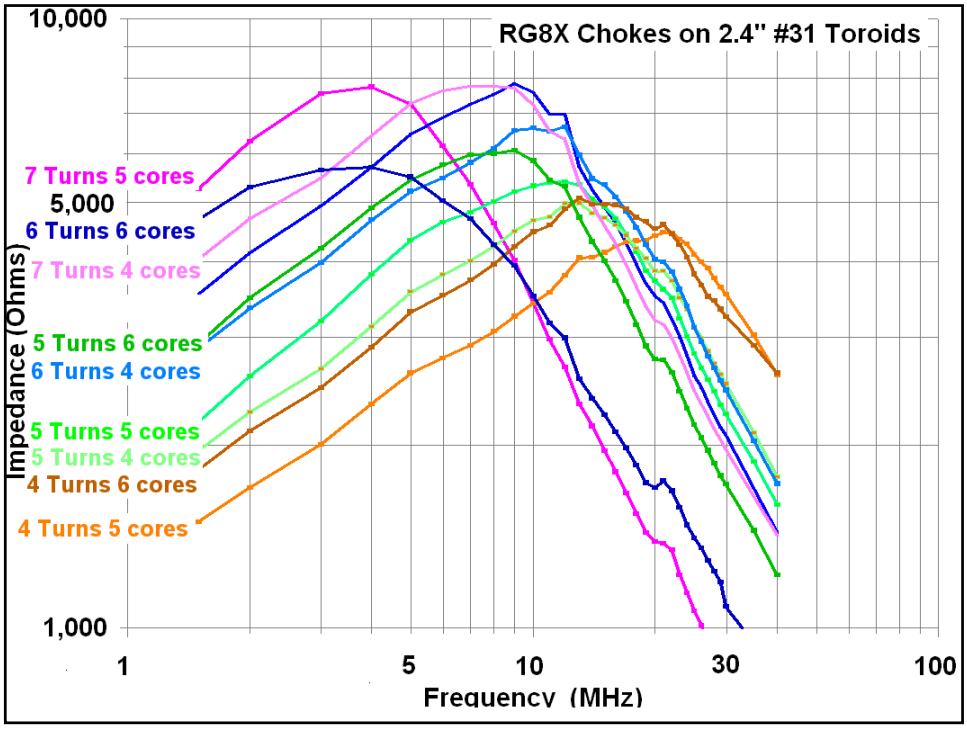


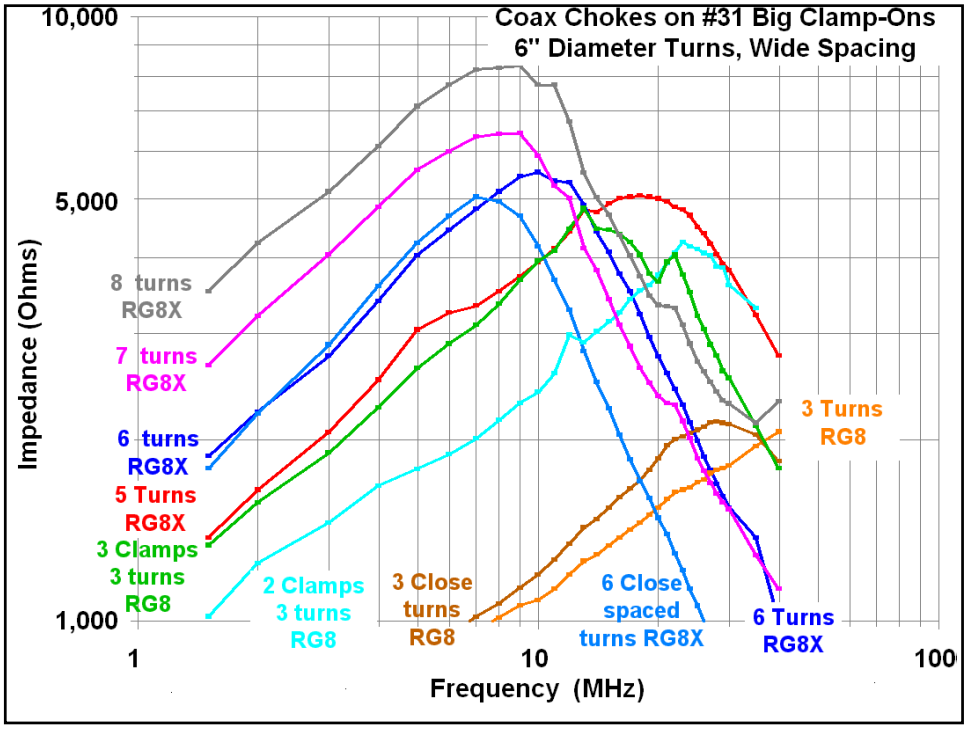


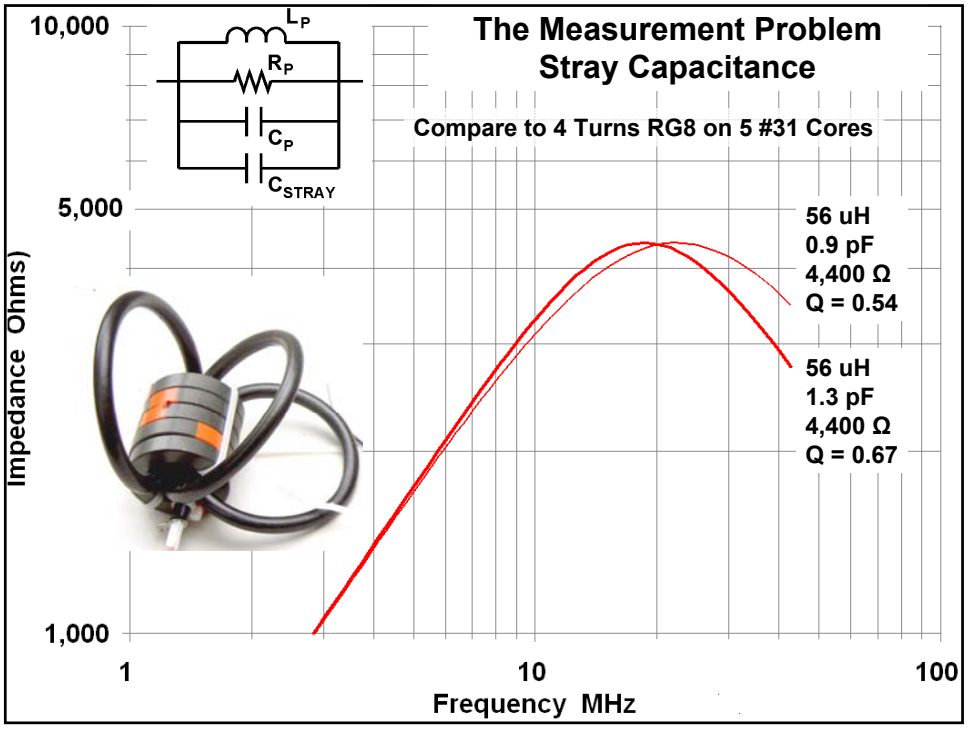

RG8 Chokes on #31 Toroids
5" Diam Turns, Wide Spacing
except as noted
10,000
5,000
1,000
Impedance (Ohms)
7 Turns 5 cores
12" Diam turns
7 Turns 5 cores
6 Turns 5 cores
5 Turns 7 cores
4 Turns 7 cores
5 Turns 5 cores
3 Turns 9 cores
4 Turns 5 cores
3 Turns 7 cores
3 Turns 5 cores
Close spacing
1
5
10
30
100
Frequency (MHz)

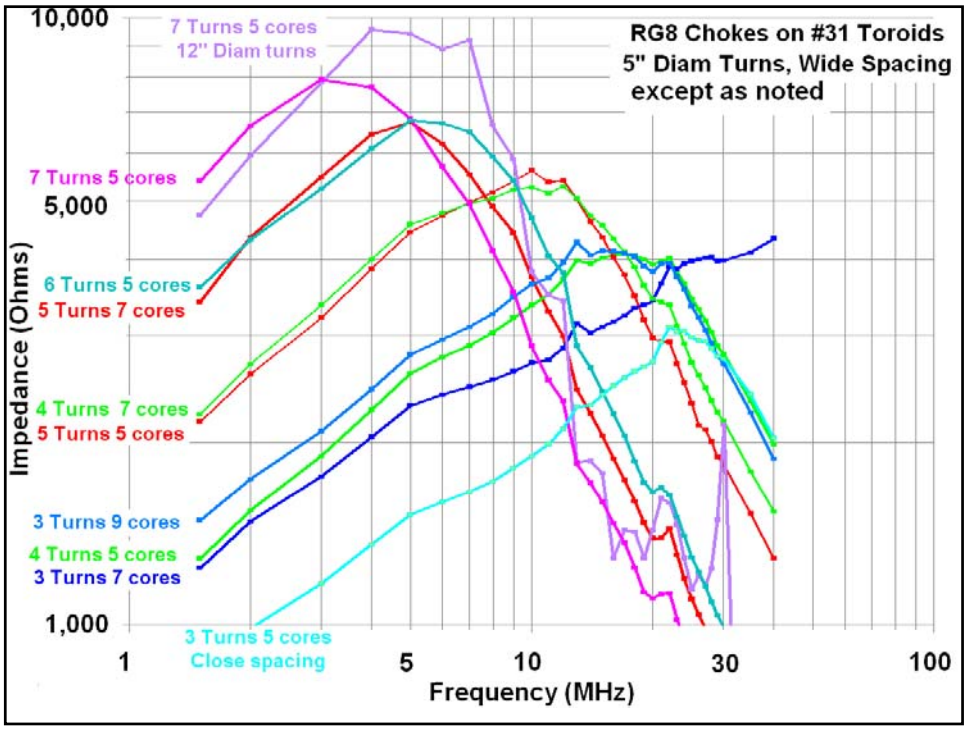

Curve Fitting
Compare to 5 Turns RG8 on 7 #31 Cores
Parallel Resonance Curve
L_P
R_P
C_P
C_{STRAY}
320 uH
4 pF
6,600 Ω
Q = 0.73
10,000
5,000
1,000
Impedance Ohms)
1
10
100
Frequency MHz


Curve Fitting
Compare to 7 Turns RG8X on 5 #31 Cores
Parallel Resonance Curve
L_P
R_P
C_P
C_{STRAY}
590 uH
4.3 pF
7,800 Ω
Q = 0.7
10,000
5,000
1,000
Impedance Ohms)
1
5
10
30
100
Frequency MHz

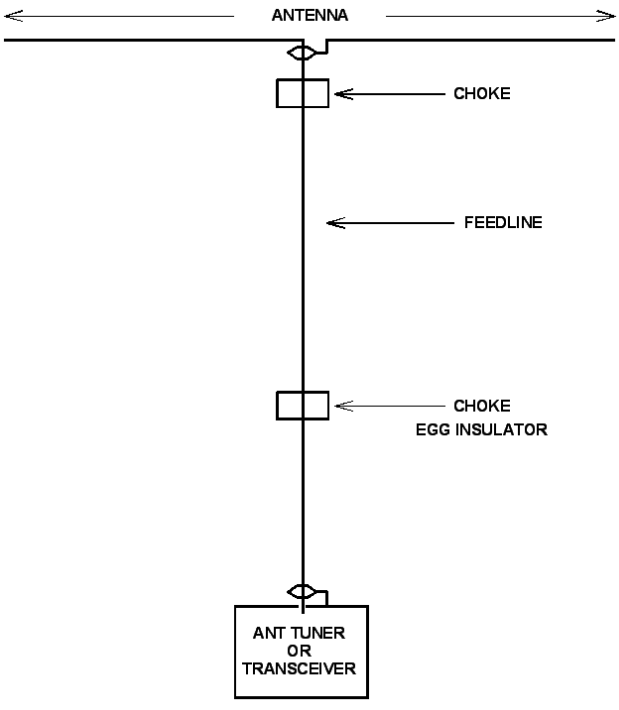

RG8X Chokes on 2.4" #31 Toroids
10,000
5,000
1,000
Impedance (Ohms)
7 Turns 5 cores
6 Turns 6 cores
7 Turns 4 cores
5 Turns 6 cores
6 Turns 4 cores
5 Turns 5 cores
5 Turns 4 cores
4 Turns 6 cores
4 Turns 5 cores
1
5
10
30
100
Frequency (MHz)


Coax Chokes on #31 Big Clamp-Ons
6" Diameter Turns, Wide Spacing
10,000
5,000
1,000
Impedance (Ohms)
8 turns RG8X
7 turns RG8X
6 turns RG8X
5 Turns RG8X
3 Clamps 3 turns RG8
2 Clamps 3 turns RG8
3 Close turns RG8
6 Close spaced turns RG8X
6 Turns RG8X
3 Turns RG8
1
10
100
Frequency (MHz)

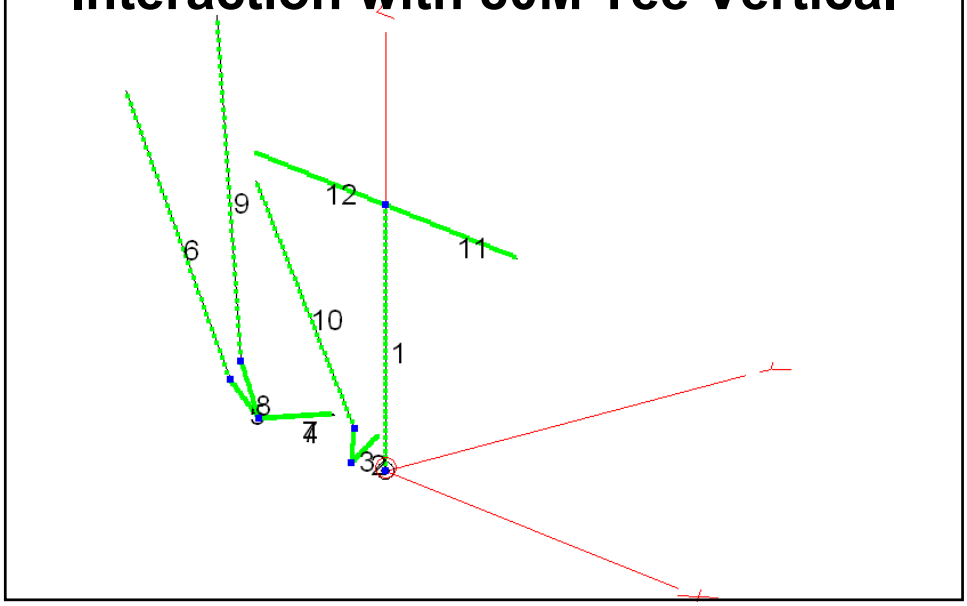

The Measurement Problem
Stray Capacitance
Compare to 4 Turns RG8 on 5 #31 Cores
L_P
R_P
C_P
C_{STRAY}
10,000
5,000
1,000
Impedance Ohms)
1
10
100
Frequency MHz
56 uH
0.9 pF
4,400 Ω
Q = 0.54
56 uH
1.3 pF
4,400 Ω
Q = 0.67


RG8 Chokes on #31 Toroids
5" Diam Turns, Wide Spacing
except as noted
7 Turns 5 cores
12" Diam turns
7 Turns 5 cores
6 Turns 5 cores
5 Turns 7 cores
4 Turns 7 cores
5 Turns 5 cores
3 Turns 9 cores
4 Turns 5 cores
3 Turns 7 cores
3 Turns 5 cores
Close spacing
10,000
5,000
1,000
Impedance (Ohms)
1
5
10
30
100
Frequency (MHz)

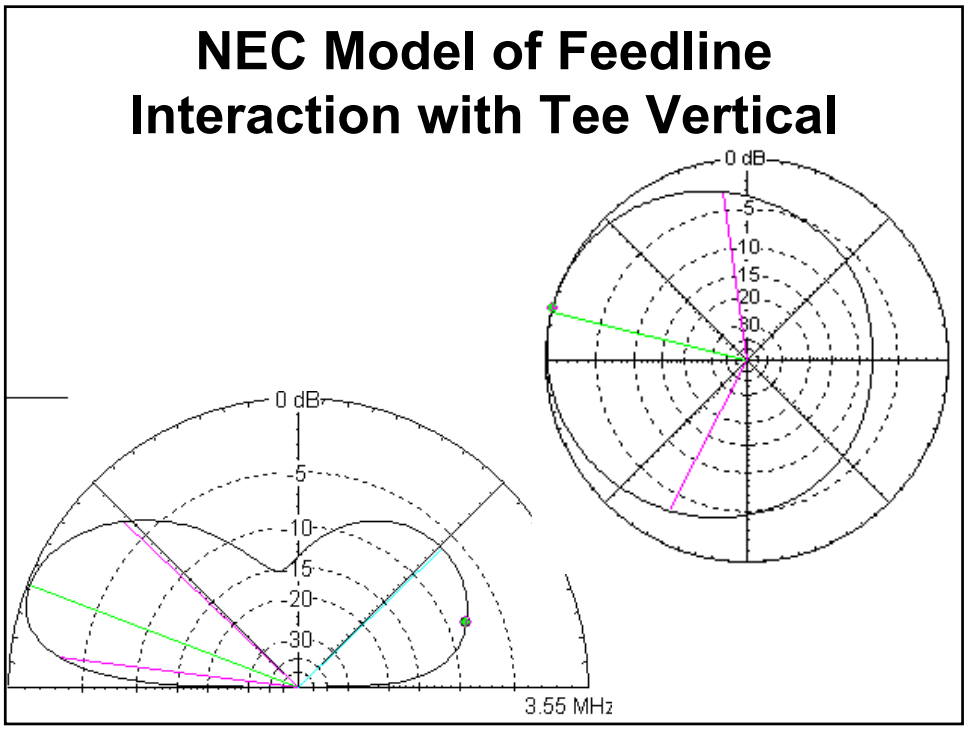
Chokes as “Egg Insulators to Break Up the Feedline



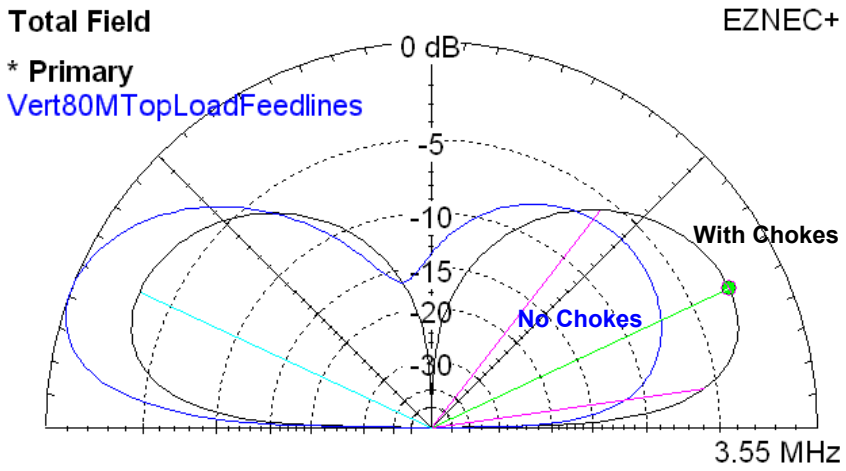
NEC Model of Feedline Interaction with 80M Tee Vertical



NEC Model of Feedline Interaction with Tee Vertical

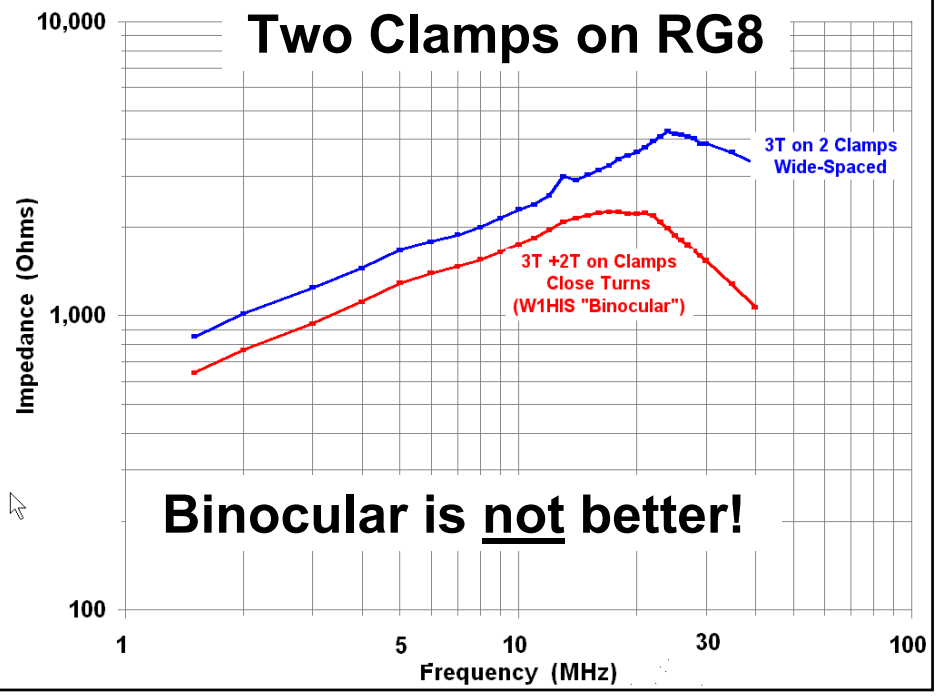


Add Choke in Each Feedline



W1HIS Coaxial Choke

#43 cores



Thanks to Kevin, K6TD

- **Helped me verify my suspicions about reflection-based measurements, and get good S21 data using his HP Network Analyzer**

  (Unfortunately, we didn't have the extra hardware needed to get complex data out of the analyzer into a spreadsheet.)

Thanks to Chuck, W1HIS

- **Chuck was right about using 5,000Ω chokes to minimize receive noise**
- **Chuck was wrong about how to build 5,000Ω chokes, because he (and his friends) didn't know how to measure them correctly!**

More Thanks

- **Walt Maxwell, W2DU, for his great writing, and for his kind words.**
- **Danny, K6MHE, for prodding me to participate in a measurement roundtable that confirmed my work**
- **Henry Ott, WA2IRQ, for his insights, criticism, advice, and great teaching.**
- **Ron Steinberg, K9IKZ, for lots of help at critical times.**
- **The NCCC crew, for lots of antenna help.**

Thanks to Richard Heyser

Dick's "day job" was at JPL, where he worked on underwater communications and communications for the space program, but audio was his hobby.

Dick invented Time Delay Spectrometry (TDS), which revolutionized audio by revolutionizing acoustic measurements. He was an articulate writer and teacher, teaching us how to always think about what we were measuring, to always question both the accuracy and the meaning of the data on the screen, and to use new ways of looking at the data to learn more from it.

References

- **Henry Ott, *Electromagnetic Compatibility Engineering,* Wiley Interscience, 2009**
- **Henry Ott, *Noise Reduction Techniques in Electronic Systems,* Wiley Interscience, 1988**
- **E. C. Snelling, *Soft Ferrites, Properties and Applications,* CRC Press, 1969**
- **E. C. Snelling and A. D. Giles, *Ferrites for Inductors and Transformers,* Research Study Press, 1983**
- ***Fair-Rite Products Catalog* This 200-page catalog is a wealth of product data and applications guidance on practical ferrites. http://www.fair-rite.com**
- ***Ferroxcube Catalog and Applications Notes* More online from another great manufacturer of ferrites. http://www.ferroxcube.com**

References

- ***New Understandings of the Use of Ferrites in the Prevention and Suppression of RF Interference to Audio Systems* , J. Brown** (AES Preprint 6564)
- ***Understanding How Ferrites Can Prevent and Eliminate RF Interference to Audio Systems*, J. Brown** Self-published tutorial (on my website)
- **A Ham's Guide to RFI, Ferrites, Baluns, and Audio Interfacing** Self-published tutorial (on my website)

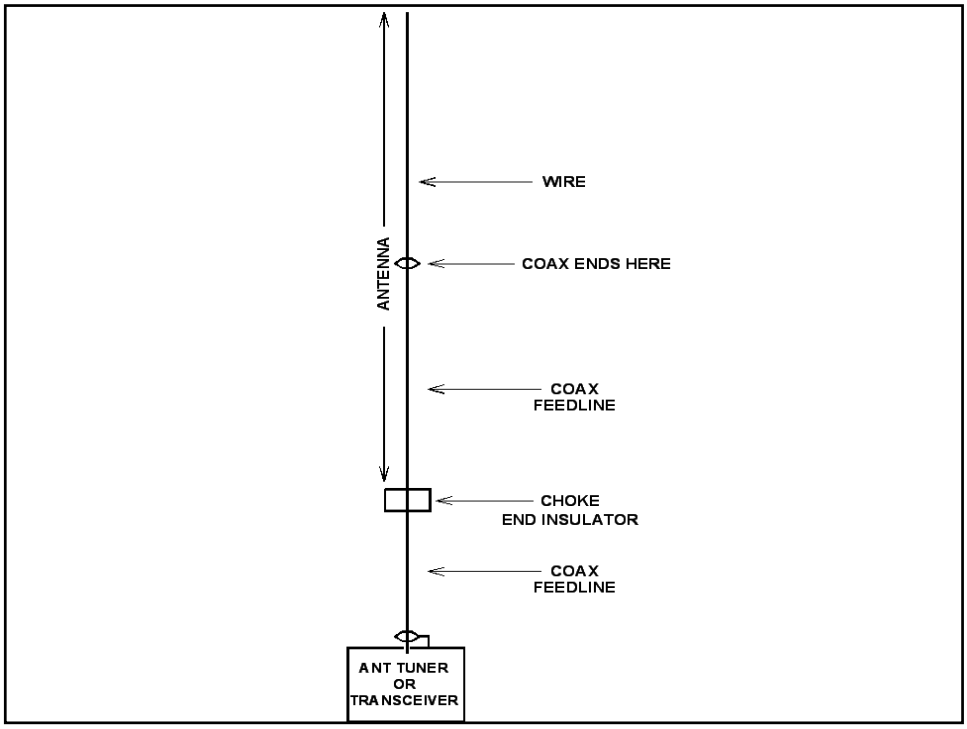
Applications notes, tutorials, and my AES papers are on my website for free download
http://audiosystemsgroup.com/publish.htm

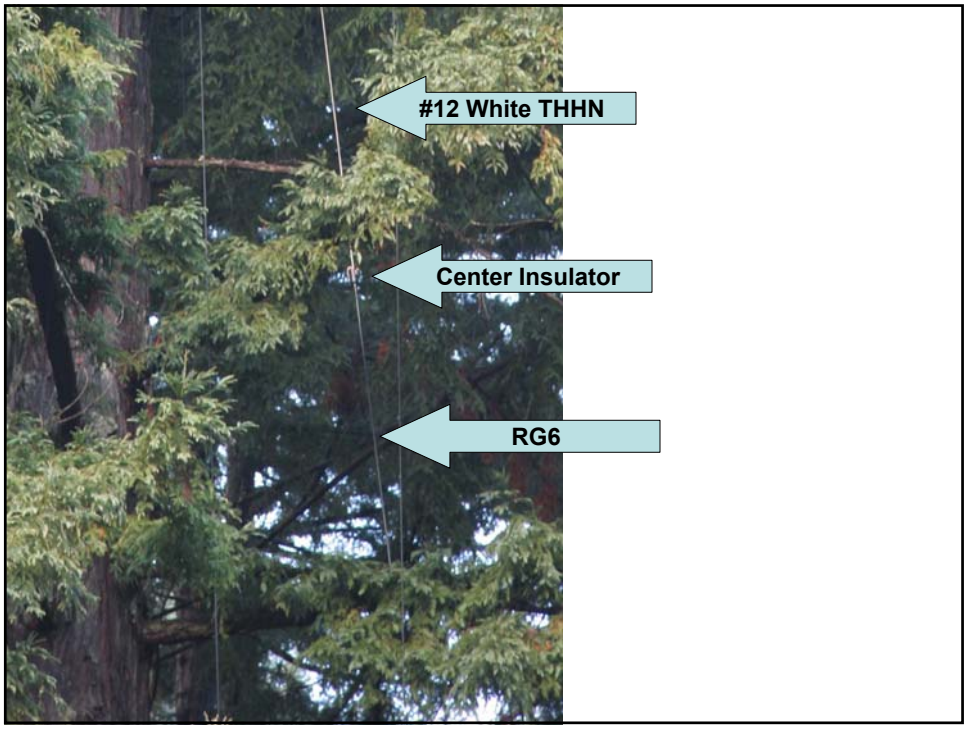
Coaxial Transmitting Chokes

Jim Brown K9YC
Santa Cruz, CA

http://audiosystemsgroup.com

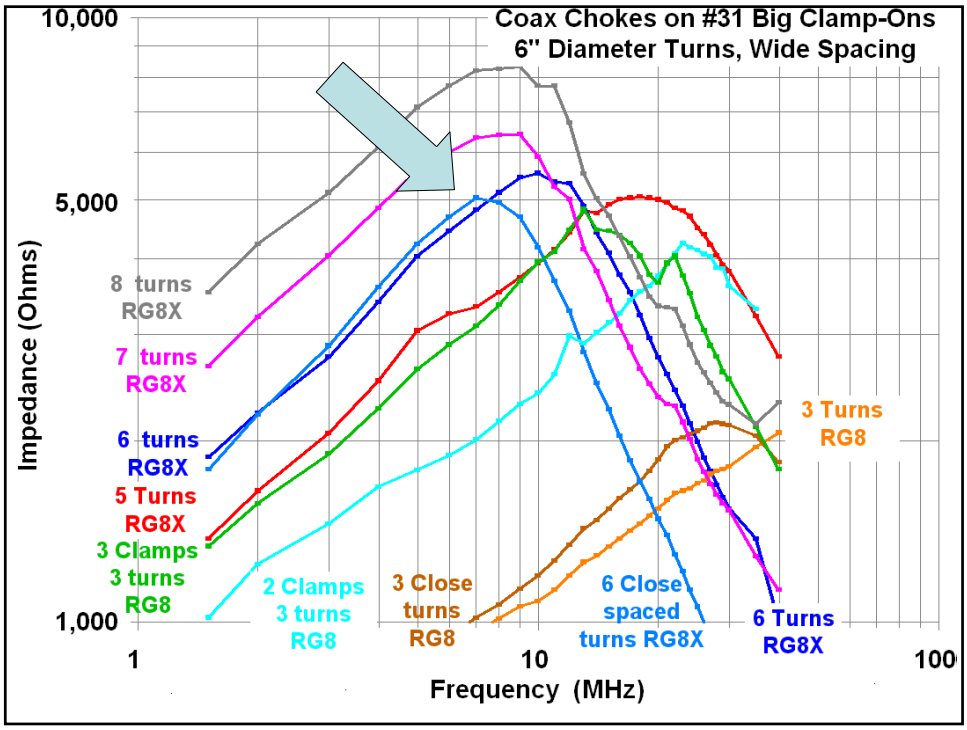
A Choke as the End Insulator of a Vertical Dipole


WIRE
ANTENNA
COAX ENDS HERE
COAX
FEEDLINE
CHOKE
END INSULATOR
COAX
FEEDLINE
ANT TUNER
OR
TRANSCEIVER

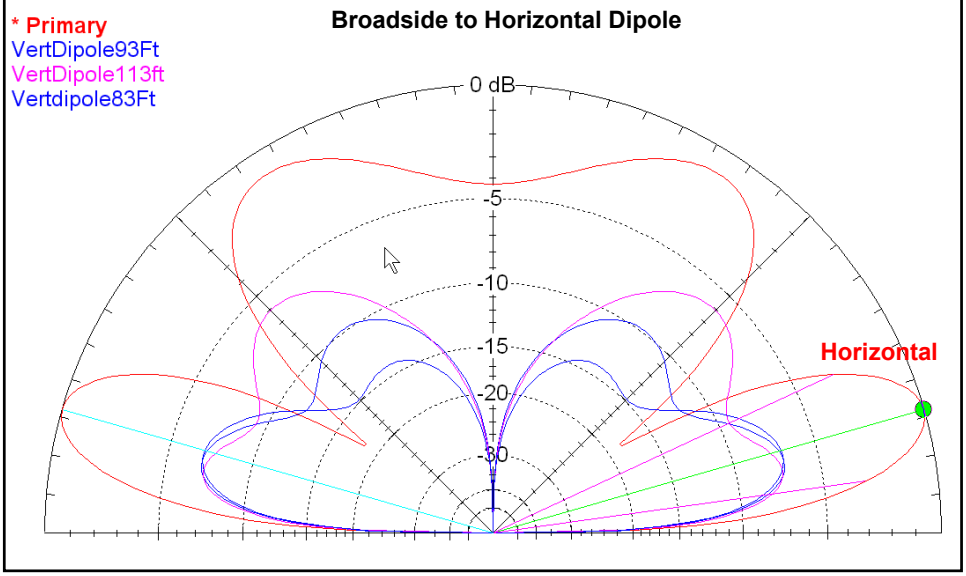


End Insulator for a 40M Dipole

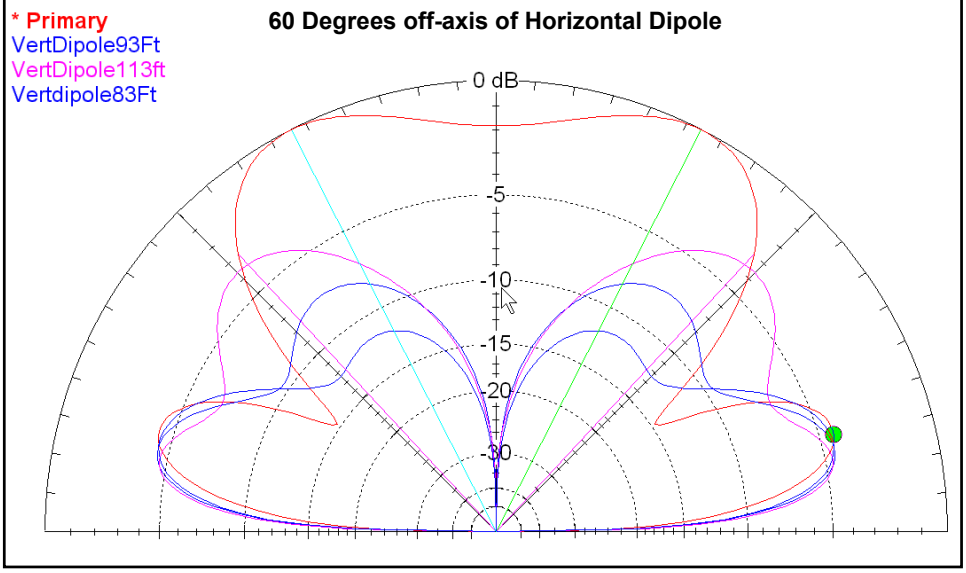
- 6 turns of RG6 around a “big clamp-on” is enough for 500 watts of serious contesting
  - About 5,000Ω resistive impedance
- Two of these 6-turn chokes are needed for 1.5kW
  - About 10,000Ω resistive impedance


Coax Chokes on #31 Big Clamp-Ons
6" Diameter Turns, Wide Spacing
10,000
5,000
1,000
Impedance (Ohms)
1
10
100
Frequency (MHz)
8 turns RG8X
7 turns RG8X
6 turns RG8X
5 Turns RG8X
3 Clamps 3 turns RG8
2 Clamps 3 turns RG8
3 Close turns RG8
6 Close spaced turns RG8X
6 Turns RG8X
3 Turns RG8

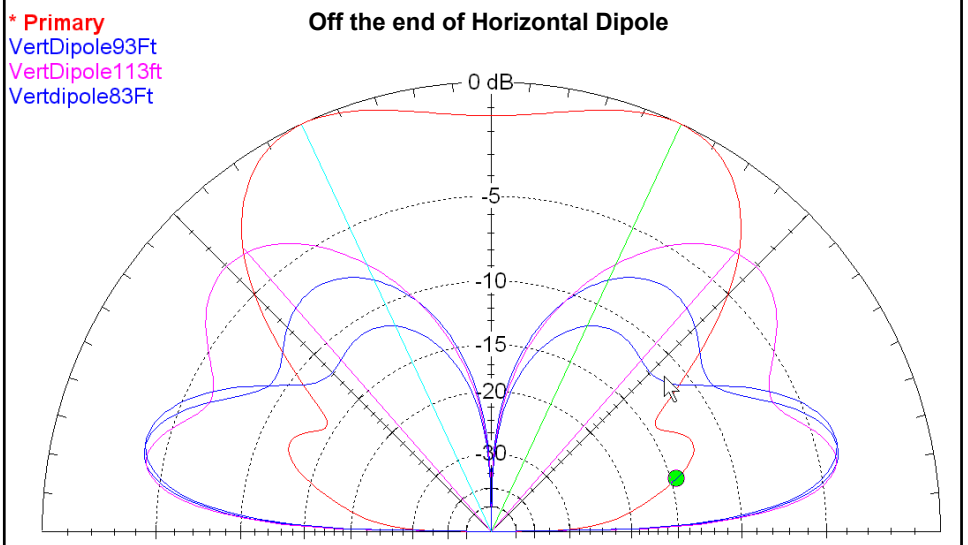
Before you fall in love with a vertical dipole, compare it to a horizontal dipole!



Before you fall in love with a vertical dipole, compare it to a horizontal dipole!



Before you fall in love with a vertical dipole, compare it to a horizontal dipole!

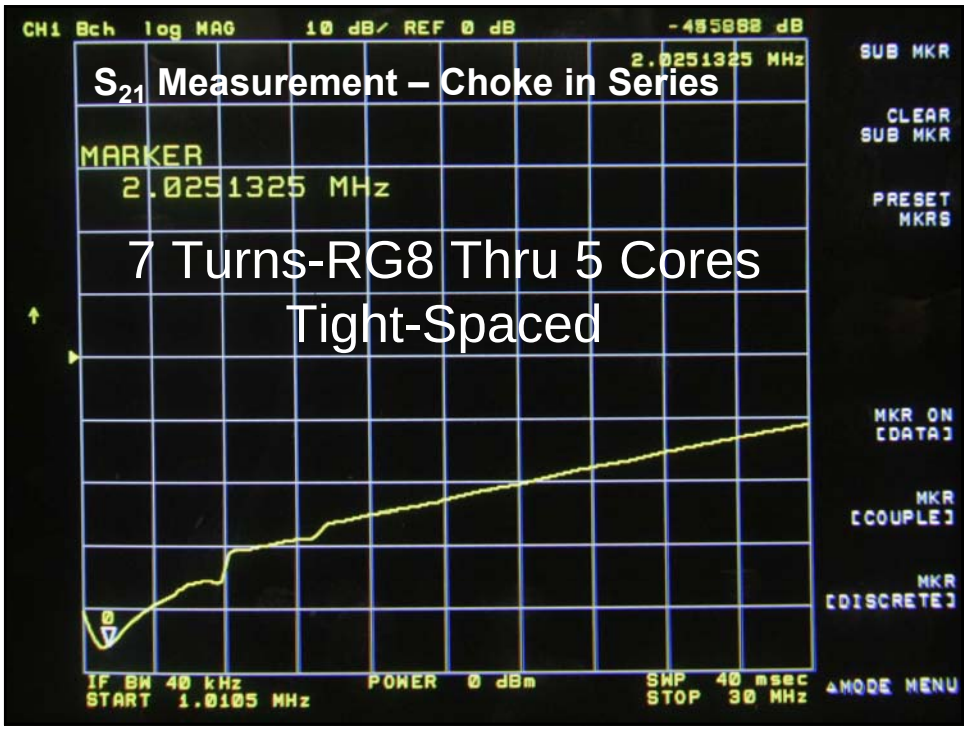


Thanks to Kevin, K6TD

- Helped me verify my suspicions about reflection-based measurements, and get good S21 data using his HP Network Analyzer

  (Unfortunately, we didn't have the extra hardware needed to get complex data out of the analyzer into a spreadsheet.)

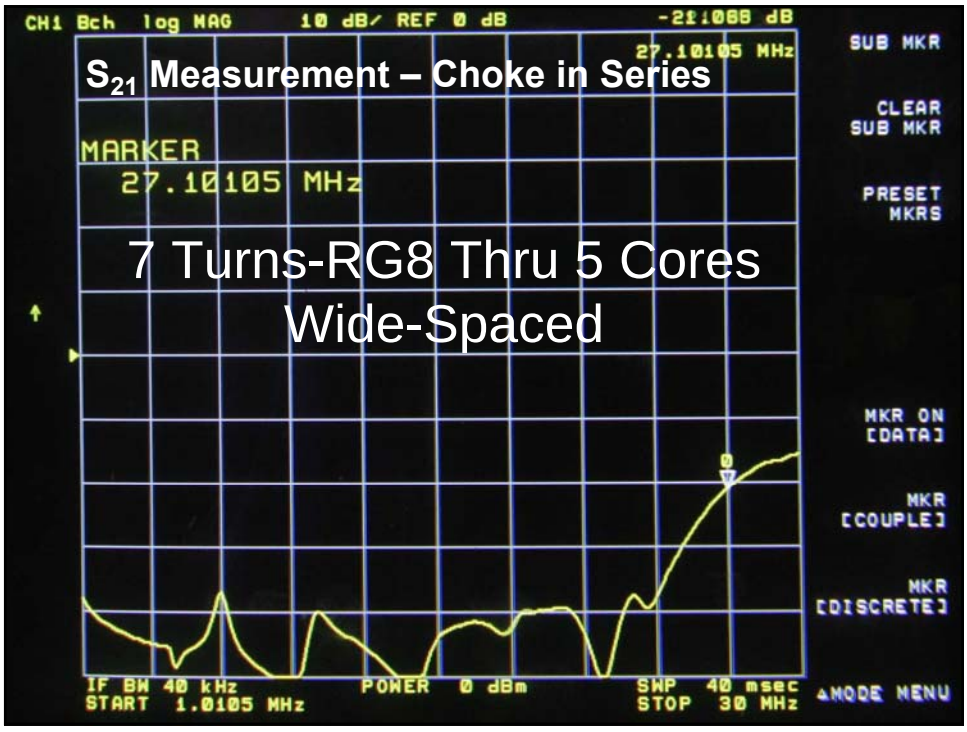
7 Turns-RG8 Thru 5 Cores Tight-Spaced



S_{21} Measurement – Choke in Series

7 Turns-RG8 Thru 5 Cores Tight-Spaced

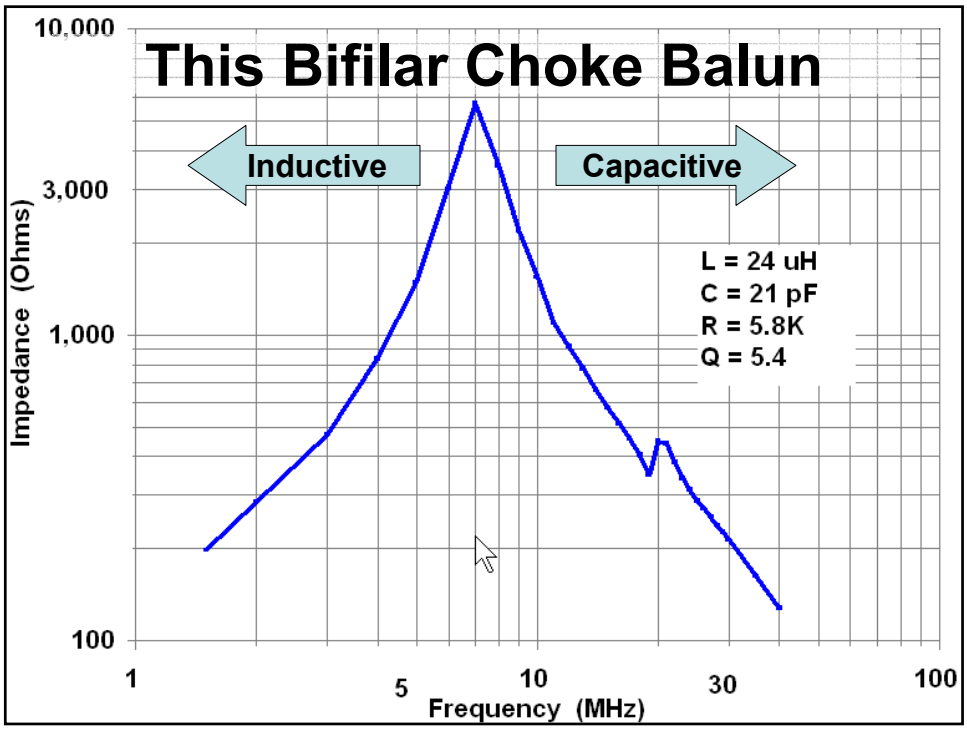
7 Turns-RG8 Thru 5 Cores Wide-Spaced



S_{21} Measurement – Choke in Series

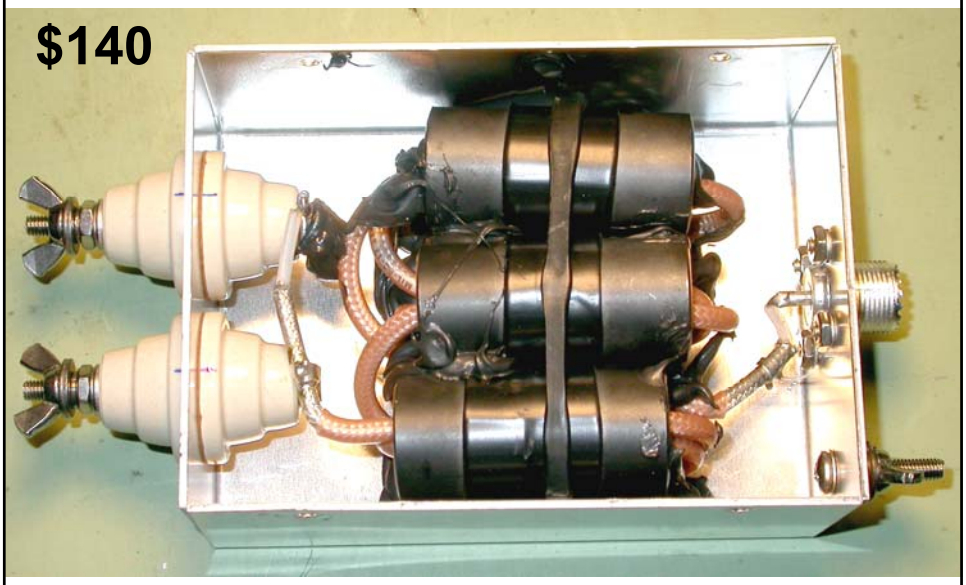
7 Turns-RG8 Thru 5 Cores Wide-Spaced

Bifilar Choke Balun on low loss core (Discontinued by DX Engineering)



DX Engineering 50Ω Choke Balun

$140

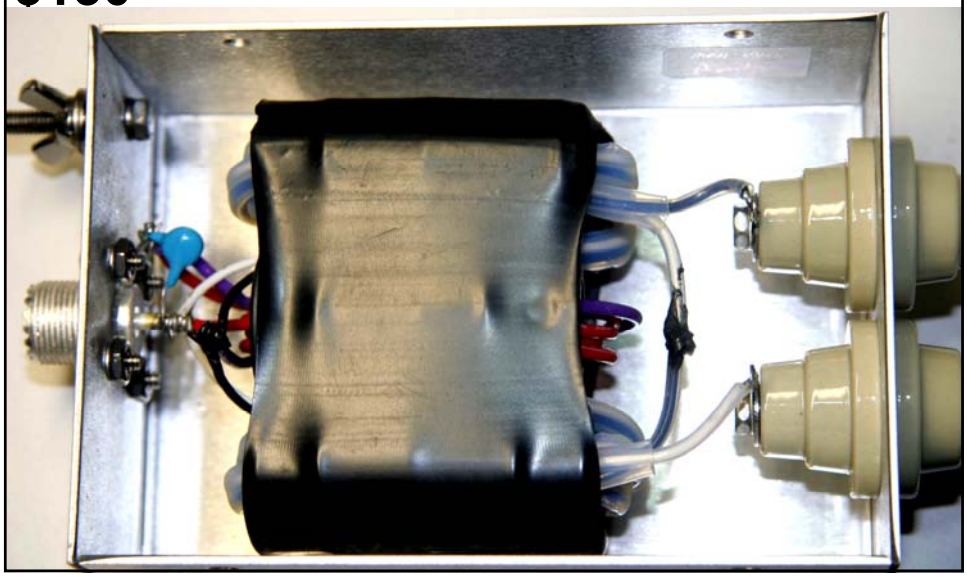


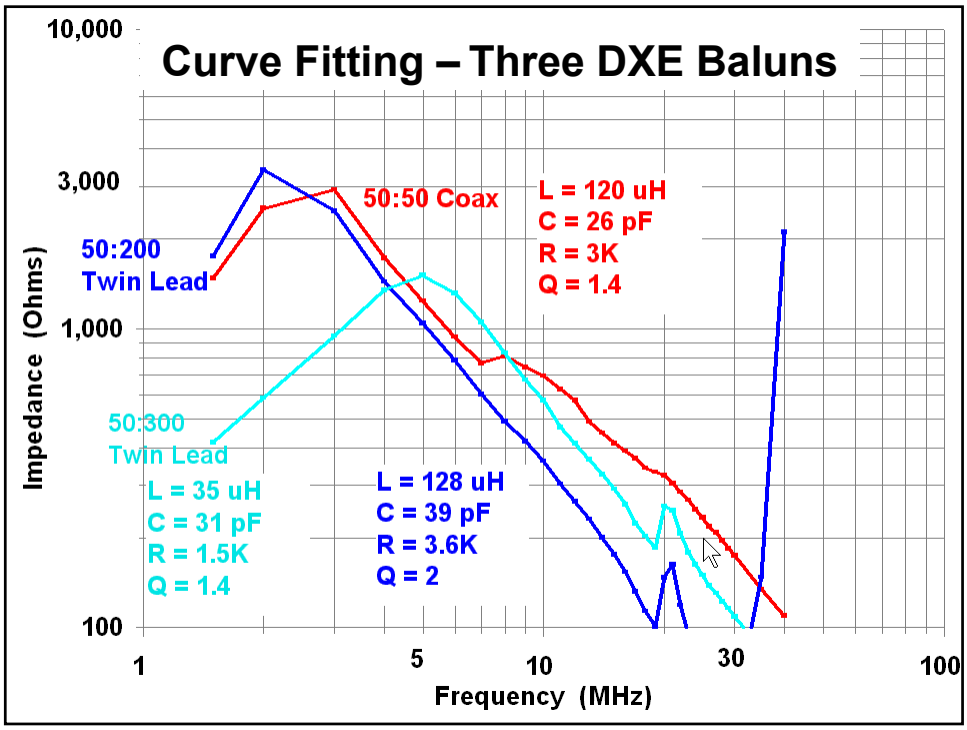
DX Engineering 200Ω – 50Ω Twin Lead Choke Balun

$130

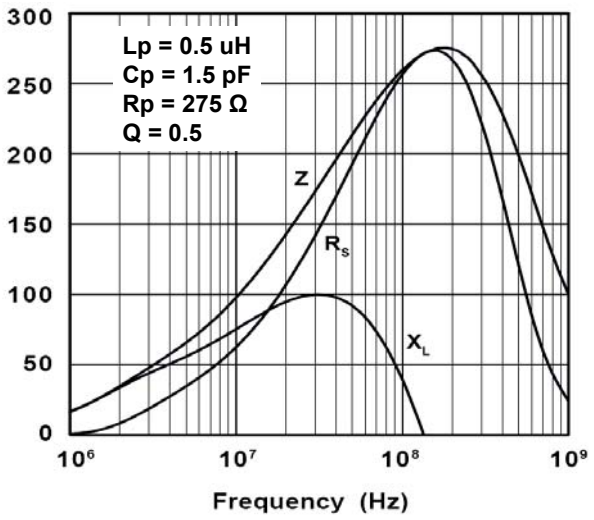
DX Engineering 300Ω – 50Ω Twin Lead Choke Balun

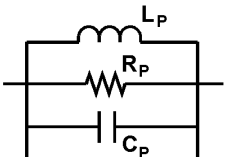
$130





Curve Fitting – #31 HF-VHF Clamp-On Fair-Rite 0431164281





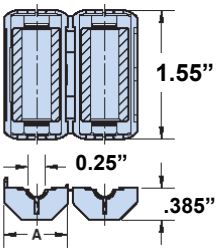
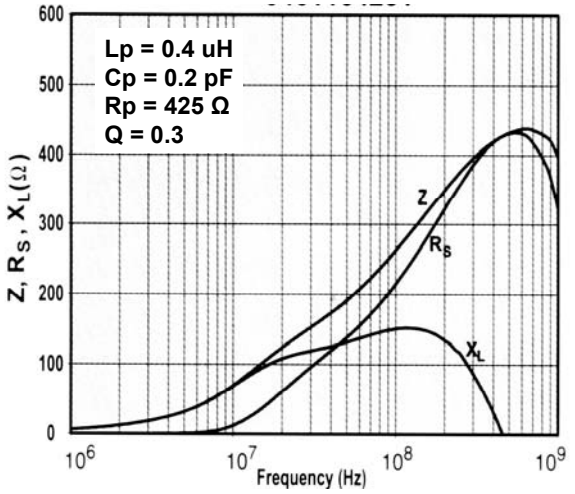
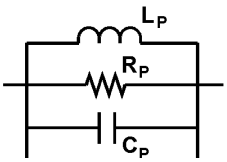


Figure 1

Curve Fitting – #61 UHF Clamp-On Fair-Rite 0461164281





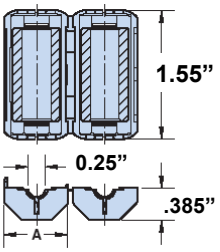
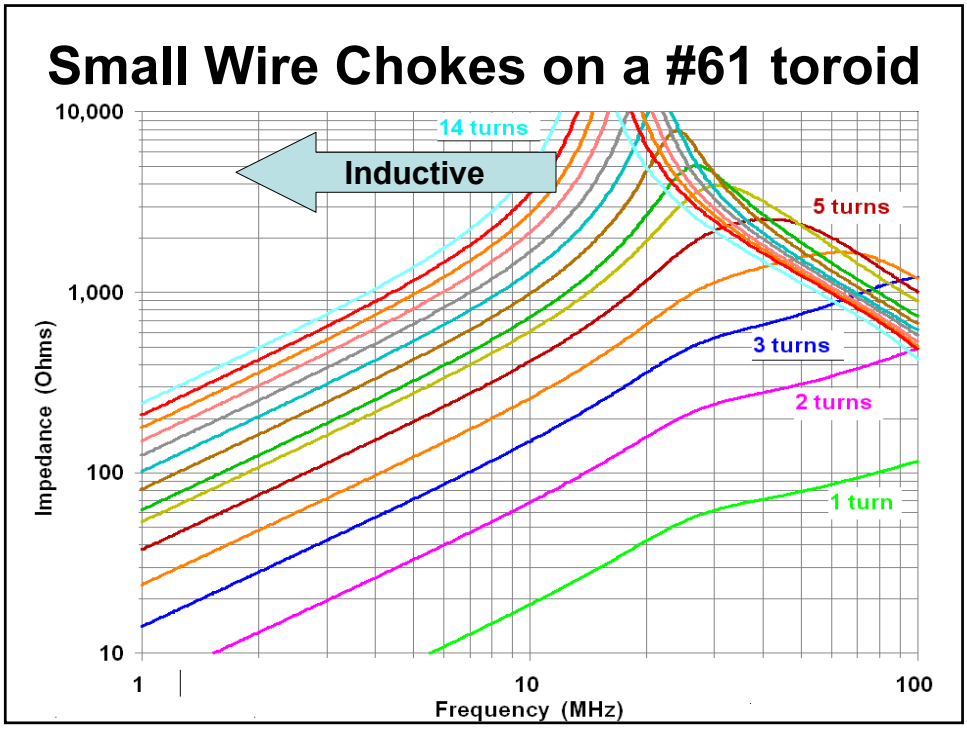


Figure 1


Small Wire Chokes on a #61 toroid
10,000
1,000
100
10
Impedance (Ohms)
14 turns
Inductive
5 turns
3 turns
2 turns
1 turn
1
10
100
Frequency (MHz)