Coaxial Transmitting Chokes

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Don’t Bother Taking Notes

These slides (and a lot more) are at

http://k9yc.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
It's an Antenna

ANT TUNER OR TRANSCEIVER

EARTH UNDER ANTENNA

ANTENNA

Common Mode
This feedline carries both differential and common mode current
Ham Antennas and Balance

- Most ham antennas are unbalanced by their surroundings, 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 unbalanced by their surroundings, 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
Common Mode
Common Mode

BUILDING

ANTENNA

ANT TUNER OR TRANSCEIVER
Common Mode Current
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 buy (W2DU, W0IYH Baluns)
Much better chokes you can build

4 turns RG8

5 turns RG8

5 turns Big Clamp-On RG8X

7 turns RG8X
Much better chokes you can build
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
Common Mode Current

RF in the Shack

Receive Noise

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 increases the current
• A cable longer than $\lambda/4$ (and shorter than $3\lambda/4$) is inductive
  – Series capacitance resonates with it and increases the current
• Resistance always 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, Dexter Magnetics, Kreger
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 (\( \mu \)) 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

2.4” o.d.

1” i.d.

0.25” i.d.
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!

Parallel Resonance!
$R_s$ and $X_s$ vary with frequency!

[Graph showing $Z$, $R_s$, and $X_L$ varying with frequency from 1 MHz to 1 GHz, with a peak at around 100 MHz indicating parallel resonance.]
A Ferrite for UHF Suppression

Parallel Resonance!

0461164281

Z, R_s, X_L(Ω)

1 MHz 10 MHz 100 MHz 1 GHz
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!
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 is a dielectric!)
“Strings of Beads” (W2DU, W0IYH Baluns)
A String of Different Beads
Small bead used in W2DU Choke
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 W0IYH choke

• Many more beads are needed
  – They’re small and cheap (good)

• #73 only made to fit RG58 or RG303
Impedance, Resistance of W2DU Baluns
50 - #73 0.19" long on RG-303

Choke is 10" long

Inductive  Resistive  Capacitive

Impedance (Ohms)

Series Resistance

Frequency (MHz)
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
#43 Bead used in W0IYH Choke

HF Bands
Inductive

Z, Rs, X_L (ohm)

1 MHz  10 MHz  100 MHz  1 GHz
W0IYH Choke

- Also a “string of beads” choke
- Predominantly **inductive** 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

HF Bands
Inductive

Z, Rs, XL (ohm)

1 MHz  10 MHz  100 MHz  1 GHz

0  60  120  180  240  300  360
Using #31 Beads in the String

#31 Bead Baluns for RG8X, RG6 (W2DU-Style)

(4 ft) 40 Beads
20 Beads (2 ft)
10 Beads 1 ft long

Series Resistance (Ohms)

10,000

1000

100

10

1

Frequency (Mhz)

And it’s Inductive! (Bad)
Inductive
Capacitive
Resistive

Choke is 10" long

Impedance, Resistance of W2DU Baluns
50 - #73 0.19" long on RG-303

Impedance (Ohms)

Frequency (MHz)
Using #31 Beads in the String

#31Bead Baluns for RG8 (W2DU Style)

And it’s **Inductive!** (Bad)
Some Commercial Products
(Not Measured – From Datasheet)

Inductive (BAD)
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

The Power of $N^2$!

Impedance (Ohms)

Frequency (MHz)

- 1 turn
- 2 turns
- 3 turns
- 4 turns
- 5 turns

$2x = 4x$

$30$

$120$

$480$
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

![Graph of Impedance vs. Frequency for Toroid Chokes]

- **14 turns**
- **3 turns**
- **2 turns**
- **1 turn**

**Y-axis:** Impedance (Ohms)

**X-axis:** Frequency (MHz)
Measured Data for #31 Toroid Chokes

[Graph showing impedance versus frequency for different numbers of turns (1, 2, 3, 4, 14) on a log-log scale.]
K9YC Chokes
(Improvements on W1JR, W2DU Designs)

4 turns RG8

5 turns Big Clamp-On RG8X

5 turns RG8

7 turns RG8X
RG8 Chokes on #31 Toroids
5" Diam Turns, Wide Spacing except as noted

Impedance (Ohms)

Frequency (MHz)
RG8X Chokes on 2.4" #31 Toroids

Impedance (Ohms)

Frequency (MHz)
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 **below** 10 MHz
• Wide spacing usually best **above** 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 **average** power
  - With CW, ~ 3 dB less than PEP
  - SSB **without** speech processing or clipping ~ 14 dB less than PEP
  - SSB **with** 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 a reasonably well matched antenna with reasonably good balance, $R = 5,000$ ohms keeps dissipation low.
Failures From Excessive Voltage

- \( P = \frac{E^2}{R} \)

- **Causes of excessive voltage**
  - Antenna systems that make \( E \) very large
  - Feedline length near \( \lambda/2, \lambda, 3\lambda/2, 2\lambda, \text{ etc.} \)
  - 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)

<table>
<thead>
<tr>
<th>Legs (Ft)</th>
<th>Power</th>
<th>Volts</th>
<th>PEP</th>
<th>Constant CQing</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 - 36</td>
<td>30 W</td>
<td>387 V</td>
<td>8 W</td>
<td>4 W</td>
</tr>
<tr>
<td>27 - 39</td>
<td>80 W</td>
<td>632 V</td>
<td>24 W</td>
<td>12 W</td>
</tr>
<tr>
<td>24 - 42</td>
<td>150 W</td>
<td>866 V</td>
<td>40 W</td>
<td>20 W</td>
</tr>
<tr>
<td>20 - 46</td>
<td>253 W</td>
<td>1125 V</td>
<td>80 W</td>
<td>40 W</td>
</tr>
</tbody>
</table>
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 $\lambda/2$ combined with strong antenna imbalance
• Insufficient air circulation
• Choking impedance too low
How Much Choking Z is Enough?

• If your antenna is well matched and balanced, 5,000Ω is plenty
• If your antenna has severe imbalance, 10,000Ω may not be enough
• Chokes on Windom antennas (badly unbalanced) 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

- 12 Turns #12 Wire on 1 - #31 core
- 8 Turns #12 Wire on 2 - #31 cores

Graph showing impedance (Ohms) versus frequency (MHz).
Bifilar Chokes

• I’m looking for a low cost choke that anyone can build cheaply
• Enamelled 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

THHN insulation does something quite nice for impedance curve!
$Z_0$ of Bifilar Windings

- Winding is a balanced transmission line
- $Z_0$ depends on spacing, wire size, and dielectric
- $Z_0$ For #12 - #14 wire
  - Close spaced enameled wire $\sim 50$ ohms
  - Close spaced THHN $\sim 100$ Ohms (Sevick)
  - My measurements $\sim 80$-90 Ohms
Impedance of THHN Windings

• Does the mismatch matter?
• It’s a short length of line
  – 12 turns ~ 40 inches of line
    • Less than $\lambda/20$ at 14MHz, $\lambda/10$ at 28 MHz
  – 16 turns ~ 50 inches of line
    • Less than $\lambda/50$ 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!
Impedance of THHN Windings

• The mismatch does matter at the feedpoint of some tri-band Yagis like the Force12 C3SS
  – A THHN choke de-tunes the coupling between elements for the three bands
  – We use bifilar-wound enameled #12 copper, Zo ~ 50 Ohms for the C3SS antennas we use for Field Day, 7QP, and CQP county expeditions
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 on #31 (lossy) toroid

- 12 Turns #12 THHN on 1 - #31 core
- 14 Turns #14 THHN on 1 - #31 core
- 16 Turns #14 THHN on 1 - #31 core

Impedance (Ohms)

Frequency (MHz)
Bifilar Chokes Work in Coax Lines

• Much lower cost, much more compact
• Can handle ~ 700W with reasonably well balanced antennas
• De-rate to 100W - 300W for poorly balanced antennas (off-center fed)
• 14 turns of #14 THHN on #31 toroid covers 80M - 10M
• 16 turns of #14 THHN on #31 toroid covers 160M – 30M
• Add second choke for higher power
Using Bifilar Chokes At High Power

- A bifilar choke on a single #31 core reduces weight
- Power rating only about 700W for well balanced, well matched antenna
- Add second choke for higher power
  - Can be anywhere along the feedline
  - Can be bifilar, or
- Turns of coax wound through cores
- See the Cookbook – Chapter 7 in k9yc.com/RFI-Ham.pdf
W6GJB's Dipole Insulator

- Smaller choke reduces weight
- Exposed to air for better heat transfer
- Good for ~ 700W
- Use second choke for higher power
- k9yc.com/RFI-Ham.pdf
Power Handling for Chokes

- Differential losses – copper losses in conductors, only a factor if high SWR
- Common mode losses – $I^2R$ losses in resistive part of choking Z
- Higher choking Z reduces current
- Additional choke divides loss
- NEC model can predict loss (heat)
Using NEC To Predict Loss

• Add transmission line to antenna model as a single wire from antenna feedpoint to ground
  • Physical length multiplied by $V_p = 0.98$
  • Current is outside the feedline, so $V_p$ is for insulated wire with o.d. of coax
• Add choke as a Load on that new wire
• Place at actual position along line
  • Chokes change current and voltage distribution on the line
Modeling The Choke in NEC

• Use values of $R_p$, $L_p$, and $C_p$ if known
  • Provides greatest accuracy
  • From curve-fitting measured data
• Use only $R_p$ if $L_p$ and $C_p$ are not known
  • Provides rougher approximation
See K9YC’s Choke Cookbook (Chapter 7 in the RFI Tutorial) for specific recommendations

http://k9yc.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

• Buy in full box quantities from industrial distributors listed on the Fair-Rite website
  – Newark, Allied, Dexter Magnetics, Lodestone Pacific, Kreger, DigiKey

• Don’t be a cheap ham
  – Think big – it costs more to think small!
  – Spend your money wisely
  – The more you buy, the cheaper they are
How to Buy Ferrites In Quantity

• Get part numbers and suggested quantities from Appendix One of my tutorial

• Select only 2-3 of most useful parts
  – 2.4-in o.d. #31 toroids
  – 1-in i.d. #31 “largest clamp-on”
  – ½-in or ¾-in i.d. #31 clamp-on (¾-in best)

• Combine your needs with neighbor hams and members of local ham clubs
How to Buy Ferrites In Quantity

• Get quotations from vendors for the quantities you can buy

• Pay with credit card, ship to one address
  – Or second address for widely separated members of wide area clubs

• Add shipping costs and tax to price quoted to group buyers

• I let buyers pay by check when received
  – Usually in time to pay credit card bill
How to Buy Ferrites In Quantity

• Do not re-ship them to distant members
  – Shipping and packing is expensive and time-consuming
  – Ferrites are brittle, break easily, are difficult to pack well
  – Fair-Rite packing is excellent, breakage is rare
DX Engineering 50Ω Choke Balun

$140
DX Engineering 200Ω – 50Ω

$130  Bifilar Choke Balun
DX Engineering 300Ω – 50Ω
Bifilar Choke Balun
$130
Two $130 Baluns

50:50 Coax

50:200 Guanella
Some Commercial Products
(Not Measured – From Datasheet)

Inductive (BAD)
What we can do for $25 - $40

RG8 Chokes on #31 Toroids
5\text{"} Diam Turns, Wide Spacing except as noted
What we can do for $25 - $40

RG8X Chokes on 2.4" #31 Toroids
What we can do for $15 - $45
What we can do for $6
Handles 700W in well balanced 50 Ohm system
What we can do for $6
Up to 700W in well balanced
50 Ohm system
What we can do for $10
For a Beverage, 16-20 turns on two cores
Or 24 turns of one pair from CAT5
See K9YC’s Choke Cookbook (Chapter 7 in the RFI Tutorial) for specific recommendations

http://k9yc.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 don’t
- A lot of smart people have missed all this!
What are we Trying to Measure?

56 µH
0.9 pF
4,400 Ω

#31

C

Fixture
What are we Trying to Measure?

#61

![Image of a coil with a circuit diagram showing 75 µH, 100K Ω, and 0.3 pF with C_{STRAY}.

\[ 75 \mu H \]
\[ 100K \Omega \]
\[ 0.3 \text{ pF} \]
What are we Trying to Measure?

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

- 56 µH
- 4,400 Ω
- 0.9 pF
- 0.4 pF
The Measurement Problem

- **56 uH**
- **0.9 pF**
- **4,400 Ω**
- **Q = 0.54**
- **1.3 pF**
Measuring Coax Chokes

RF GENERATOR

50 ohms

Z x

50 ohms

RF VOLTMETER

HP 8590D SPECTRUM ANALYZER

50 ohms
Curve Fitting

Compare to 5 Turns RG8 on 7 #31 Cores

Parallel Resonance Curve

- $L_p = 320 \, \mu H$
- $C_p = 4 \, \text{pF}$
- $R_p = 6,600 \, \Omega$
- $Q = 0.73$

Impedance (Ohms)

Frequency (MHz)
Curve Fitting

Parallel Resonance Curve

Compare to 7 Turns RG8X on 5 #31 Cores

- $L_P$: 590 uH
- $C_P$: 4.3 pF
- $C_{STRAY}$
- $R_P$: 7,800 Ω
- $Q = 0.7$

Impedance (Ohms)

Frequency (MHz)
The Measurement Problem

Stray Capacitance

Compare to 4 Turns RG8 on 5 #31 Cores

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

Impedance (Ohms)

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

Total Field

* Primary
Vert80MTopLoadFeedlines

With Chokes

No Chokes

EZNEC+

3.55 MHz
W1HIS Coaxial Choke

#43 cores
Two Clamps on RG8

3T on 2 Clamps Wide-Spaced
3T +2T on Clamps Close Turns (W1HS "Binocular")

Binocular is not better!
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!
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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

• *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 at k9yc.com/publish.htm
Coaxial Transmitting Chokes

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