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

Common Mode

ANT TUNER OR TRANSCEIVER
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

• **Imbalanced 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 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
Much better chokes you can build

RG400 – Dipole Center Insulator
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
Receive Noise

Common Mode Current

RF in the Shack

ANT TUNER OR TRANSCEIVER
So coax won't be a passive reflector for a nearby vertical.

**GOOD**

So RX noise picked up on coax won't get to receiver.

**GOOD**

So coax won't be a passive reflector for a nearby vertical.

A choke here does not reduce RX noise, may reduce RF in shack.
Design of Transmitting Chokes

• Higher impedance is better!
  – Reduces common mode current
  – Reduces noise
  – Reduces interaction
  – Reduces RF in the shack
  – Reduces dissipation (overheating)

• Resistance is better than reactance
Why is Resistance Better?

- We want to reduce the current
- A cable shorter than $\lambda/4$ is inductive
  - Series inductance reduces the current
  - Series capacitance resonates with it and increases the current
- A cable longer than $\lambda/4$ (and shorter than $\lambda/2$) is capacitive
  - Series inductance 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 have discounts for quantity!
  – Arrow, Allied, Newark, Kreger, Dexter Magnetics, Lodestone Pacific, Digikey
Why Is Fair-Rite My Example?

• Their parts are the most useful for ham applications
• They are easy to buy in North America
• They are the only manufacturer of #31 material or any material like it
• Stick to the industrial distributors listed on previous slide
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 VHF, but #31 is much better on the HF bands
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!

Parallel Resonance!

- 1 MHz
- 10 MHz
- 100 MHz
- 1 GHz

$Z, R_s, X_L (\Omega)$
A Ferrite for UHF Suppression

Parallel Resonance!
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!

Parallel Resonance!
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

HF Bands

$Z, R_S, X_L$ (ohm)

$X_C$

$1$ MHz $10$ MHz $100$ MHz $1$ GHz
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
Inductive Capacitive Resistive

Choke is 10” long

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

Impedance (Ohms)

Series Resistance

Frequency (MHz)
Newer (and Inferior) Designs

- W2DU’s design is 50 years old
- That’s old fashioned -- certainly something newer must be better!
- He measured 50, 100, and 200 bead chokes
- 200 beads best, 4x impedance of 50 beads
  - Much better noise suppression, better power handling
  - Commercial W2DU balun only 50 beads (or less)
- W2DU’s beads are tiny
- W0IYH tried something bigger
- BIG beads that fit on RG8
New Understandings of Chokes

• Before 2006, chokes were thought of as preventing pattern distortion from the imbalance caused by coax
  – 500Ω was considered “good enough”

• In 2006, W1HIS showed that a much higher choking impedance could prevent noise picked up on the coax from reaching the receiver
  – 5,000Ω was his recommendation
  – Chuck did not realize the significance of the resistive component of the impedance around resonance, and saw resonance as a problem
New Understandings of Chokes

• My 2005 AES paper on RF interference to audio systems k9yc.com/AESPaperFerritesASGWeb.pdf
  – Cited E. C. Snelling’s 1969 analysis of dimensional resonance in ferrite materials
  – Developed equivalent circuit for a ferrite choke as two parallel resonant circuits in series
    • Dimensional resonance
    • Circuit resonance of the winding around the core
  – Showed the importance of the resistive component of the impedance near resonance
  – Provided extensive measured data for small wire chokes wound on #31, #43, #61, #77, and #78 materials
New Understandings of Chokes

• That 2005 AES paper included extensive measured data for small wire chokes wound on #31, #43, #61, #77, and #78 materials
  – For each material, chokes of 1 – 14 turns were measured, producing families of data for each material demonstrating both resonances
  – These data were produced by a collaborator with access to precision measurement gear in an engineering lab where he worked
  – That collaborator has chosen to remain anonymous
New Understandings of Chokes

• My 2005 AES paper was the first to analyze Fair-Rite’s #31 material
  – It was a relatively new material, developed after 2001
  – For that research, I obtained (in 2004) five samples from the first prototype run of 2.4-in o.d. toroids, and shared them with the collaborator who did the measurements

• The ham community was unaware of #31 material until my first RFI tutorial for hams in 2007  k9yc.com/RFI-Ham.pdf
#43 Bead used in W0IYH Choke

HF Bands
Inductive

Z, R_s, 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
Using #31 Beads in the String

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

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

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)

Series Resistance

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

And it’s Inductive! (Bad)
Some Commercial Products
(Not Measured – From Datasheet)
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 $N^2$!

Frequency (MHz)

Impedance (Ohms)

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

$2x = 4x$

$2x = 4x$

$30$

$120$

$480$
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
Measured Data for #31 Toroid Chokes
Earlier K9YC Chokes (No Longer Recommended)

- 4 turns RG8
- 5 turns RG8
- 5 turns Big Clamp-On RG8X
- 7 turns RG8X
Why No Longer Recommended?

• Poor repeatability due to variations in winding
  – Turn diameter
  – Turn spacing
  – Turns not wound in order cancel ("Cross-over turns")
  – Coax diameter and dielectric affect both inductance and parallel capacitance
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, digital modes, 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, $R = 10,000$ 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 $\frac{\lambda}{2}$, $\lambda$, $\frac{3\lambda}{2}$, $2\lambda$, 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>PEP Power</th>
<th>Volts</th>
<th>Constant CQing CW, FM, RTTY, PSK</th>
<th>SSB</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 Must Be Exposed to Air Flow For Good Power Handling
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 balanced, 10,000Ω is plenty
• If your antenna has severe imbalance, 30,000Ω may not be enough
• Chokes on Windom and other Off-center fed 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

Impedance (Ohms)

Frequency (MHz)

12 Turns #12 Wire on 1 - #31 core

8 Turns #12 Wire on 2 - #31 cores
Bifilar Chokes

• I was 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 2-wire 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)
- Study k9yc.com/2018Cookbook.pdf for detailed recommendations
Impedance of THHN Windings

• Does the mismatch matter?
• It’s a short length of line
  – 12 turns ~ 30 inches of line
    • Less than $\lambda/20$ at 14MHz, $\lambda/10$ at 28 MHz
  – 16 turns ~ 40 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!
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
• See k9yc.com/2018Cookbook.pdf for detailed recommendations per band
  • #12 THHN solid pair
  • #12 Teflon stranded silver-coated copper
• RG400 (50Ω, silver coated stranded copper center, double silver-coated copper braid shield)
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)
See K9YC’s New Choke Cookbook

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 invented 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 **quantity** from distributors listed on the Fair-Rite website
  - Arrow, Newark, Allied, Lodestone Pacific, Kreger, Dexter Magnetics

- 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

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

$130
Two $130 Baluns

- 50:50 Coax
- 50:200 Guanella

Impedance (Ohms) vs Frequency (MHz)
Some Commercial Products
(Not Measured – From Datasheet)
See K9YC’s Choke Cookbook for specific recommendations

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!
Finding the Equivalent Circuit

• It’s a parallel resonant circuit
  – $R_p$ is the peak value of measured $Z_{MAG}$
  – $L_p$ is the value that causes the computed curve to match the measured data below resonance
  – $C_p$ is the value that resonates with $L_p$ at the measured $F_{RES}$
  – Plot $R_p$, $L_p$, and $C_p$ on same axes as measured data
  – Tweak $L_p$ and $C_p$ for best curve fit
My Current Test Setup

- VNA replaces HP gear
- Same measurement circuit
- Measures S21 (complex)
- DG8SAQ software computes and plots $Z_{\text{MAG}}$, $R_s$, $X_s$
- It takes ~3 minutes to make a measurement and save it
- VNWA 3EC

https://www.sdr-kits.net
What are we Trying to Measure?

Image of a fixture with the number #31.

Diagram showing a circuit with the following components:
- 56 µH
- 4,400 Ω
- 0.9 pF
- C Fixture
What are we Trying to Measure?

75 µH
0.3 pF
100K Ω
C_{STRAY}
What are we Trying to Measure?

Typical “good” analyzers

75 µH
0.3 pF
100K Ω
2 pF
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 2008 measurement setup
The Measurement Problem

- $L_p = 56 \, \text{uH}$
- $R_p = 0.9 \, \text{pF}$
- $C_p = 4,400 \, \Omega$
- $Q = 0.54$
- $C_{\text{STRAY}} = 1.3 \, \text{pF}$
My 2008 Test Setup

- RF GENERATOR
- 50 ohms
- Zx
- 50 ohms
- HP 8590D SPECTRUM ANALYZER
- RF VOLTMETER
- 50 ohms
2008 Test Setup
2008 Test Setup
RG8 Chokes on #31 Toroids
5" Diam Turns, Wide Spacing except as noted

- 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

Impedance (Ohms)

Frequency (MHz)
Finding The Equivalent Circuit of a Choke
Curve Fitting

Parallel Resonance Curve

Compare to 5 Turns RG8 on 7 #31 Cores

- \( L_P = 320 \text{ uH} \)
- \( C_P = 4 \text{ pF} \)
- \( C_{STRAY} \)
- \( R_P \)
- \( Q = 0.73 \)
- \( 6,600 \Omega \)

Impedance (Ohms)

Frequency (MHz)
Curve Fitting

Compare to 7 Turns RG8X on 5 #31 Cores

Parallel Resonance Curve

- $L_P = 590 \, \text{uH}$
- $C_P = 4.3 \, \text{pF}$
- $R_P = 7,800 \, \Omega$
- $Q = 0.7$

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
So coax won't be a passive reflector for a nearby vertical.

So RX noise picked up on coax won't get to receiver.

A choke here does not reduce RX noise, may reduce RF in shack.
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
Chokes Used As "Egg Insulators"

#12-2 THHN also works well, slightly more loss, slightly less power handling
Choke As End Insulator of A Vertical Dipole
Choke As End Insulator

• A very demanding application, because the end of a wire is a high voltage point
  – Very high choking impedance is required
  – May need multiple chokes in series to achieve, depending on power level

• Feedpoint Z of a vertical dipole is close to 75Ω
  – 75Ω coax best for feedline

• Choke impedance not critical
  – RG400, Teflon 12-2, THHN 12-2 all work
Choke As End Insulator

- Detailed advice in k9yc.com/VerticalDipole.pdf
W1HIS Coaxial Choke

#43 cores
Two Clamps on RG8

Binocular is not better!

Impedance (Ohms)

Frequency (MHz)
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!
We Were Both Wrong About #43

• #43, #52, #61 are a very poor choice for HF chokes because
  – All ferrite products have wide production tolerances (> 20%)
  – #43, #52, #61 are high Q mixes, so resonance is narrow
  – Wide tolerances can move high-Q resonance out of range of where we want them
  – In other words, designs are not repeatable
Why #31 Is The Only Choice For HF

• In a #31 choke, dimensional resonance combines with its circuit resonance to give it a much lower-Q (broader) resonance

• I measured hundreds of #31 cores, picked cores at tolerance limits, wound and measured chokes

• Recommendations are based on “worst case” of those measured data
  – That is, any #31 core (of the specified size) will be at least as good as the performance spec
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- The NCCC crew, for lots of antenna help.
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](http://www.fair-rite.com)

• *Ferroxcube Catalog and Applications Notes*  More online from another great manufacturer of ferrites.  [http://www.ferroxcube.com](http://www.ferroxcube.com)
References

• These tutorials and applications notes are on my website for free download  k9yc.com/publish.htm

• *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*

• *A Ham’s Guide to RFI, Ferrites, Baluns, and Audio Interfacing*

• *A New Choke Cookbook for the 160–10M Bands*

• *Build Contesting Scores by Killing Receive Noise*
Coaxial Transmitting Chokes

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