

Transmitting Chokes for the 630M Band

Jim Brown, K9YC

k9yc.com

k9yc@arri.net

**Don't Bother Taking Notes –
These slides will be on my
website next week**

k9yc.com/publish.htm

Acknowledgement

**Thanks to Wayne Burdick, N6KR,
Elecrafft co-owner, who provided the
ferrite cores used for this work, and for
work on chokes and transformers for
receiving antennas**

Common Mode vs Differential Mode

- Differential mode current is the normal transmission of power inside the coax, or between paired conductors
- Common mode current is carried on the outside of the coax shield, or as the difference of unequal currents on the two conductors of 2-wire line

Why Common Mode Current is Bad

- When common mode current flows, the feedline becomes part of the antenna**
- If the antenna is not perfectly balanced (few are), common mode current flows putting RF in the shack and coupling local RF noise to the antenna**
- Common mode current radiates**
 - Into your living room (and your neighbor's)**
- Antennas receive like they radiate**
 - Noise from you and your neighbors**

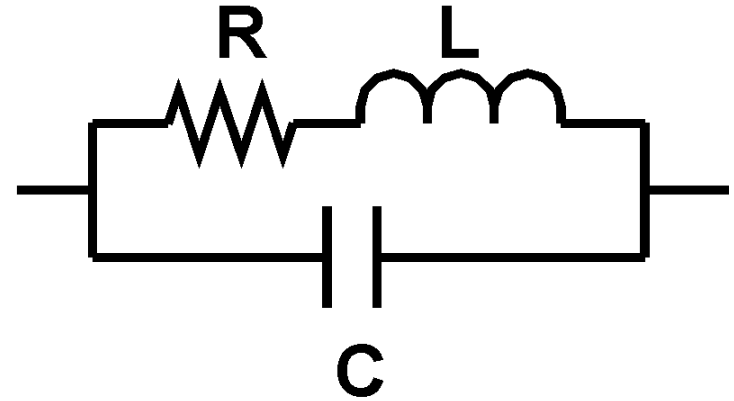
Choking Impedance

- **Ferrite chokes work by adding a large impedance in series with the common-mode circuit**
- **We achieve high values of common mode impedance by winding multiple turns of a transmission line onto a suitable ferrite core to form a parallel resonant circuit at the frequency(ies) where we want to use the choke**

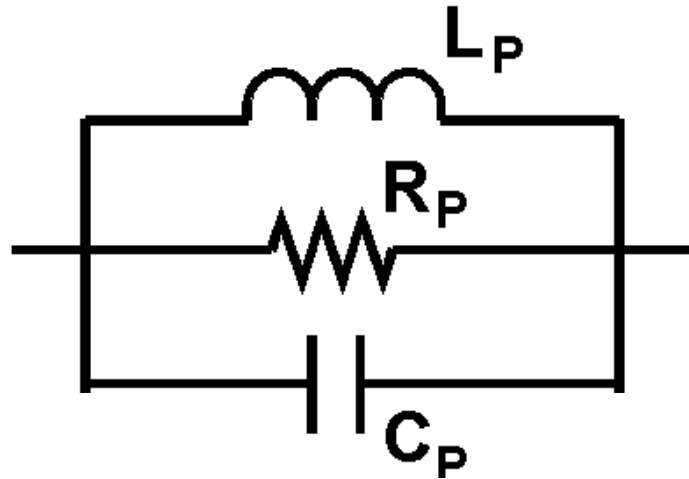
Equivalent Circuit of a Ferrite Choke



Low Frequencies

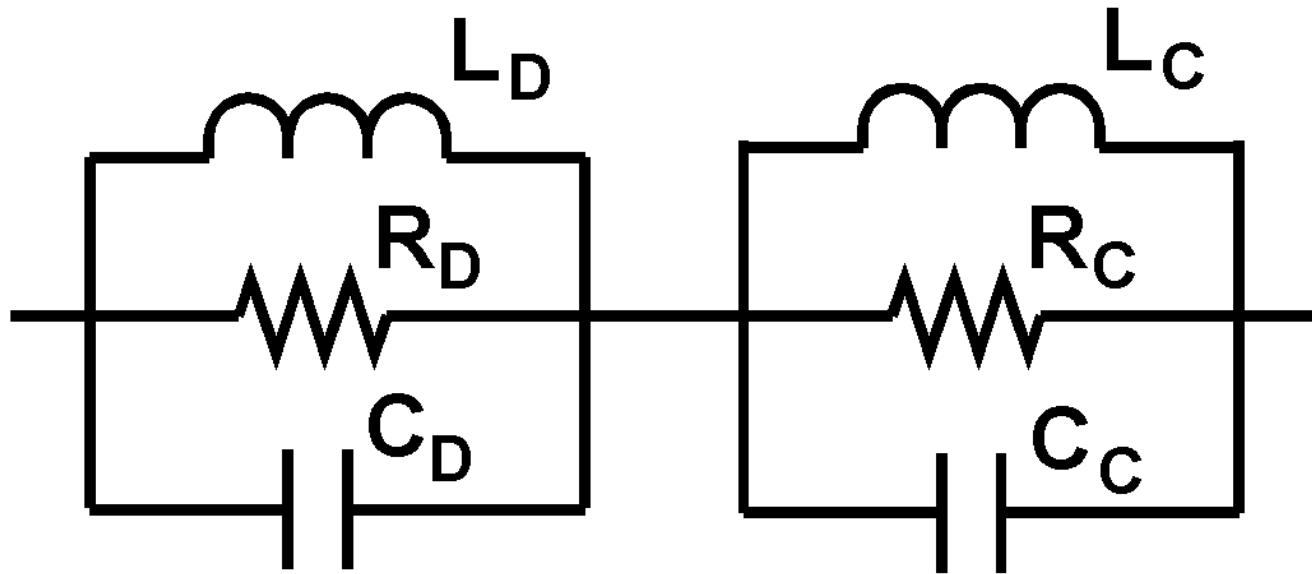


Mid-Frequencies



Near Resonance

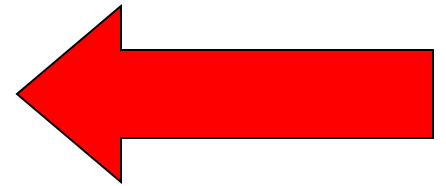
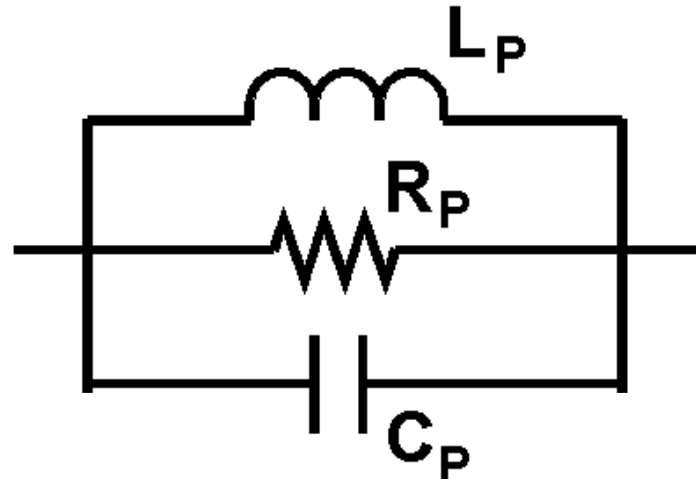
More General Equivalent Circuit



Including Dimensional Resonance

(more about that later)

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



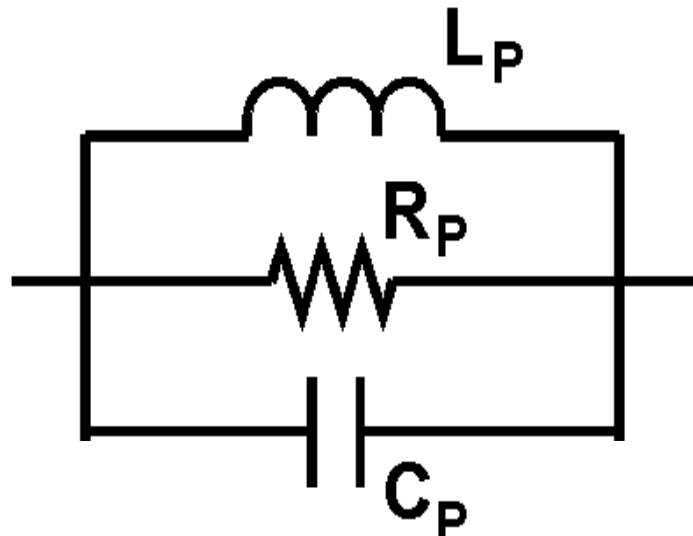
Data Sheets Use This Equivalent Circuit to Graph the Impedance



Rs and Xs Are What We Can Measure



We can use a graph of R_s and X_s values to compute L_p , R_p , and C_p



Rs and Xs

- **Ls and Rs are the inductance and loss (resistance) coupled from the core**
- **Ls and Rs are multiplied by the N^2 (the number of turns through the core)**
- **Cp is the total stray capacitance between turns, and between the turns and the core**
- **As we wind turns, the resonance moves down in frequency and the choking impedance increases**

Tuning the Choke

- **We put the resonance where we want our choke to work well by varying the number of turns and by choosing the “right” ferrite mix**
- **A “right” ferrite mix is lossy at frequencies where we want the choke to work**
- **The “right” ferrite mix for 630M is Fair-Rite #75**

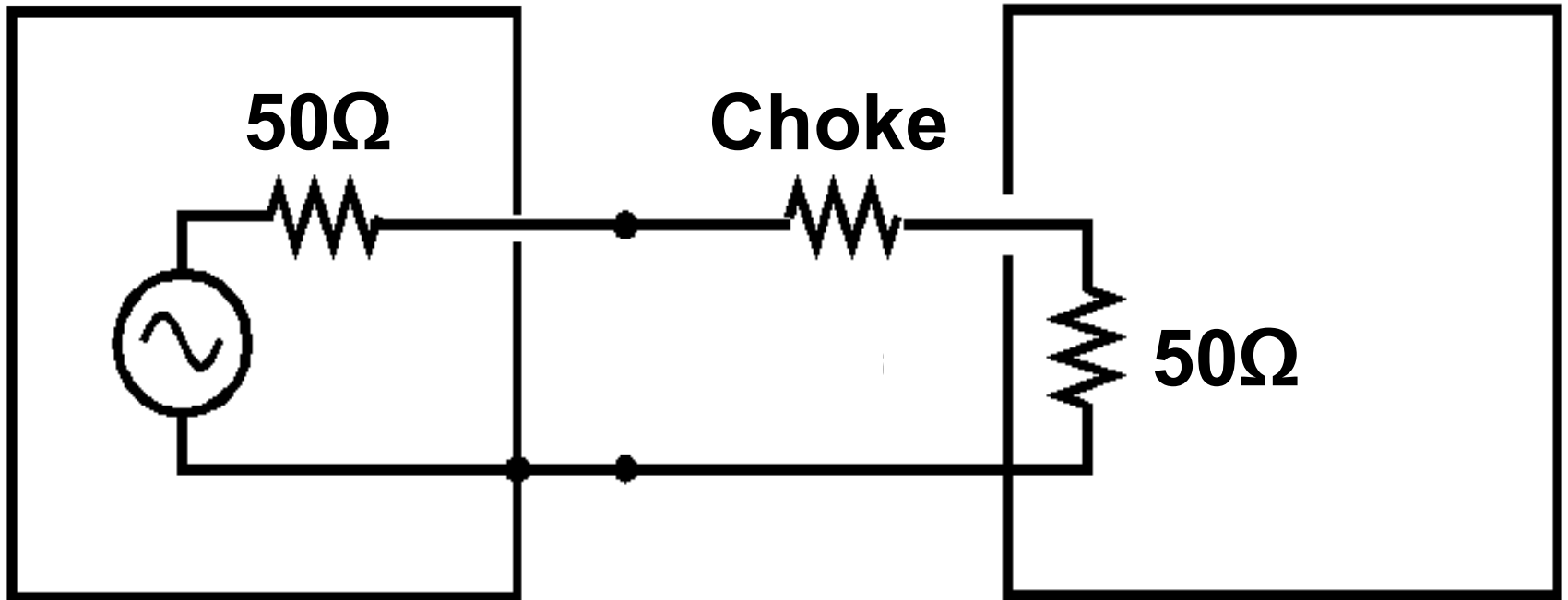
Rs and Xs

- **$Z_{MAG} = \text{sqrt} [(Rs)^2 + (Xs)^2]$**
- **$Z = Rs + j Xs$**
- **We measure Z_{MAG} , Rs , and Xs**
- **Or, more precisely, we place the choke in series between a 50Ω generator and 50Ω voltmeter, forming a voltage divider**
- **The generator and voltmeter take the form of a Vector Network Analyzer**
 - **VNWA3EC, designed by German EE prof DG8SAQ, sold by SDR Kits in the UK**

Measuring Coax Chokes

Swept RF
Generator

RF Voltmeter



R_s , X_s , R_p , C_p , L_p

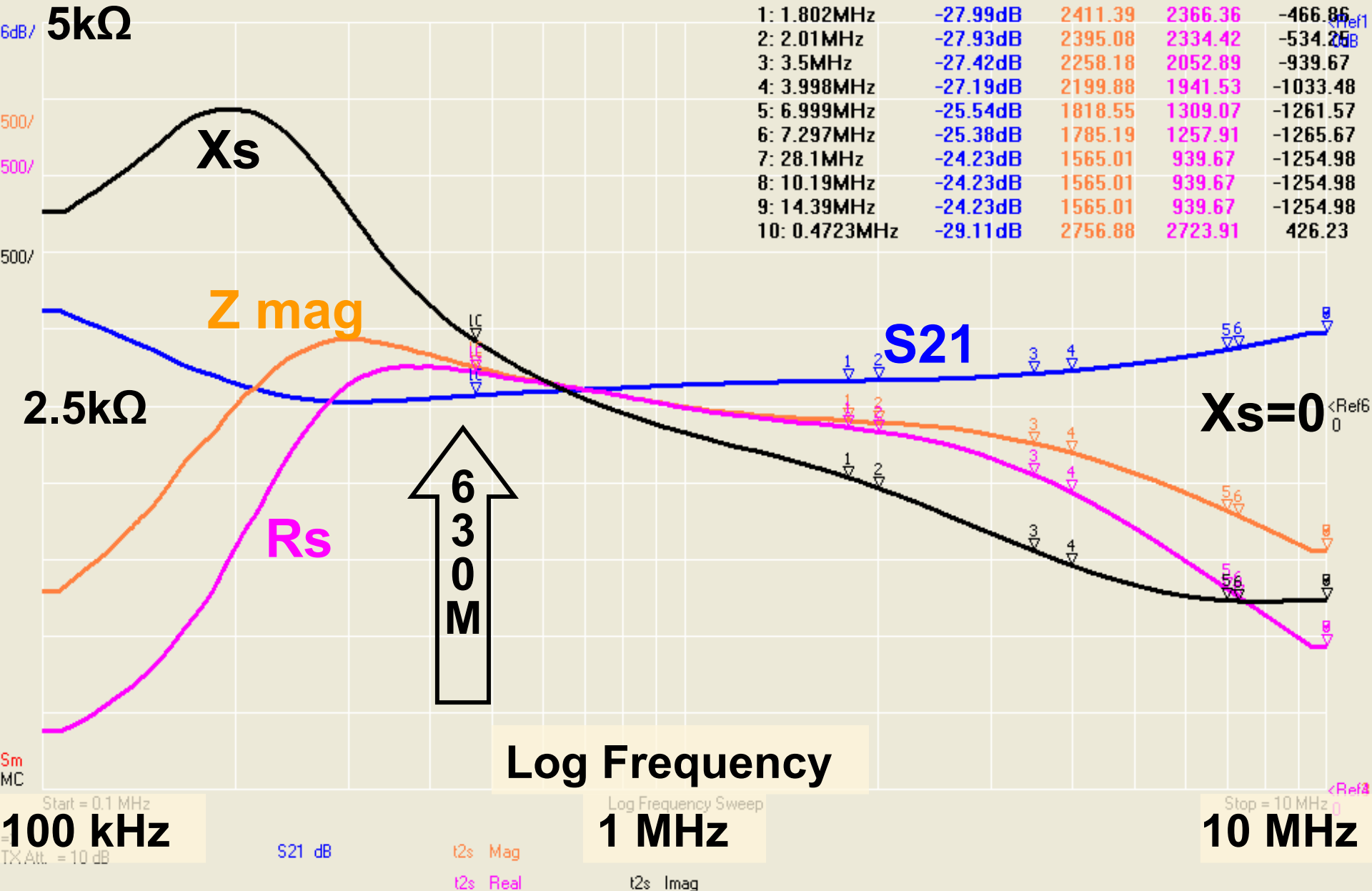
- **R_p , C_p , and L_p are approximately constant with frequency**
 - **They describe the physical properties of the choke**
- **R_s and X_s have different values for every frequency**
- **At resonance, $R_s = R_p$**
- **L_p is the inductance we would measure far below resonance**
- **C_p is the value that resonates with L_p**

Rs and Xs

- **We measure S21 (the voltage divider ratio) and solve the voltage divider equation backwards to find Z of the choke**
- **The control software for the VNWA does the math and plots the data you will see later**
- **S21 is the blue curve in the plots of choking impedance**

Choking Z RG400 18 Turns

10/18/2018 4:39:01 PM 18 Turns rg400 on Fair-Rite 2.4-in Toroid #75-3 Full, no overlap



Why Choking Resistance (R_s) Matters

- The common mode circuit includes the antenna, the feedline, and whatever the feedline is connected to (usually ground via the transmitter)**
- The antenna, feedline, and connection at the far end have some impedance by virtue of their combined electrical length**
- That impedance can be inductive or capacitive at any given frequency**

Why Choking Resistance (R_s) Matters

- That impedance can be inductive or capacitive at any given frequency**
- When it is inductive, the inductance of an inductive choke adds to it, and common mode current is reduced**
- When it is capacitive, it cancels the inductance of an inductive choke, leaving only the resistance of the choke, R_s to reduce the current**
- A choke with a high value of R_s works independent of feedline length**

Using Transmitting Chokes

- **Most 630m antennas are (very short) verticals working against some form of counterpoise or radial system**
- **One or more chokes at the feedpoint prevents the feedline (and house wiring) from becoming part of the counterpoise or radial system**

630m Power Requirements

- We can run 5w EIRP on the 630m band
- $EIRP = \{X_{mtr} \text{ Power}\} \times \{\text{Antenna Efficiency}\}$
- Because any antenna/counterpoise/radial system we can build will be very short as a fraction of a wavelength, 630m antennas are very inefficient, so:
- Efficiencies of 1% - 10% are common
- This corresponds to 50 – 500W transmitter power to radiate 5W
- A choke with $R_s = 5k\Omega$ should handle 500W
- $R_s = 2.75K\Omega$ should handle 250W

Good Stuff On 630M Antennas

- **antennasbyn6lf.com**
- **Rudy Severns, N6LF has done lots of great work on antennas and radial systems for the low bands**
 - **He's shown how to compute efficiency for real world 630M antennas**
- **It's all on his website**
- **He's an ARRL Handbook and Antenna Book contributor**

Power Handling and Choking Impedance

- **Power in the choke is I^2R where I is the common mode current and R is the choking resistance, R_s**
- **Common mode current is $E/(R_s)$, where E is the common mode voltage**
- **We want the choke to reduce common mode current to near zero**
- **Because power is current squared, the power falls with increasing R_s**

Winding the Chokes

- **When counting turns, count the number of times the cable passes through the inside of the toroid**
- **Turns must be wound sequentially, and conductors must not be twisted**
 - **A twisted or reversed order turn cancels another turn, reduces choking impedance**
- **17-18 turns of RG400 or pairs of #12/2 Teflon, NM, or THHN fill a 2.4" i.d. core**
- **It is OK for one end of the winding to overlap the other end to fit more turns**

Winding RG400 Chokes

- **While winding, it helps to hold the starting end tight to the toroid using two small ty-wraps, the first going around the core, the second looped between the first ty and the core and around the cable being wound (see photo of RG400 choke)**
- **It can also help to ty-wrap turns in several places – RG400 tends to want to un-wind**

18 Turns RG400 on Fair-Rite #75 2.4-in o.d. Toroid



Winding Teflon Chokes

- **It's also a good idea to tywrap the start of Teflon windings – the teflon wire is slippery**
- **When cutting the coax or wire, allow 3.75-in per turn, plus whatever lead length is needed for termination to antenna and feedline**
- **Winding with different colors makes it easier to spot twists and reverse order turns**

17 Turns #12-2 Teflon on Fair-Rite #75 2.4-in o.d. Toroid



Winding the Chokes

- On 650m, 18 turns of RG400 or a #12 pair of Teflon wire yields about 2.7k Ω Rs
- THHN and NM (black and white from Romex) will choke about the same as Teflon
 - Less expensive
 - Less able to withstand high temperature

Recommendations

- **A single 18-turn choke will handle 200W**
- **For maximum suppression and greater power handling, use two 18-turn chokes wired in series**
- **Chokes wound on #31 cores can be added in series to use the same antenna to cover higher frequency bands**

W6GJB's Dipole Center Feed



- Here's one way to connect two chokes in series
- Easily adapted to feed a vertical
- The tube is well sealed against moisture to protect wiring

The Wire

- **RG400 is 50Ω Z_0 , the size of RG58**
 - **Stranded silver-coated copper center**
 - **Two silver-coated copper braid shields**
 - **Teflon dielectric and outer jacket**
- **The paired windings (Teflon, THHN, NM) form a transmission line with Z_0 near 100Ω**
- **The length of wire in two chokes is so short (about 0.005λ) that any mismatch to an antenna doesn't matter**

Why RG400 and not RG142?

- The center conductor of
 - RG400 is stranded silver-coated copper
 - RG142 is silver-coated copper-clad solid steel
- Their shields are the same – double shields, each silver-coated copper braid
- RG400 center is more flexible, less likely to migrate close to the shield when wound tightly around the ferrite core

Enameled Wire Works Too

- Zo is near 50Ω**
- Fair-Rite #75 material is optimum for 630m, but is also a good conductor**
- Enameled wire is easy scraped, can short to the core, which defeats the choke**
- Cores wound with enameled wire should have a wrap of tape to insulate the wire from the core**

Buying The Cores

- **Fair-Rite part number 5975003801**
 - **\$7.50 at Kreger Components (1-49 qty)**
 - **\$11.08 at Mouser (1-9 qty), \$9.23 (10 qty)**
 - **\$10 at Digikey (1-9 qty), \$8.50 (10 qty)**
 - **These are industrial vendors, with good discounts for quantity**
 - **Buy larger quantities when you can**
 - **Arrow is good for Fair-Rite that they stock, but don't stock this one**

Don't Buy Ferrites From Ham Vendors

- **They have invented their own part numbers (FT240, for example) so you don't know what to order from industrial vendors, who offer great discounts for quantity**
 - **Amidon**
 - **Palomar**
- **This allows them to sell at very high markups**

Some Good Vendors

- **Arrow Electronics**
- **Lodestone Pacific**
- **Dexter Magnetics**
- **Krieger Components**
- **Newark**
- **Allied**
- **Digikey**
- **Mouser**

Buying Cores

- **Not everyone stocks everything**
- **Call around – most will be cheaper for what they have in stock, and that can vary**
- **Build quantity by combining an order with other hams**

Buying The Coax

- **I buy Harbor Industries RG400 on ebay**
 - **\$230 for 100ft**
 - **Others sell shorter lengths**

Buying The Wire

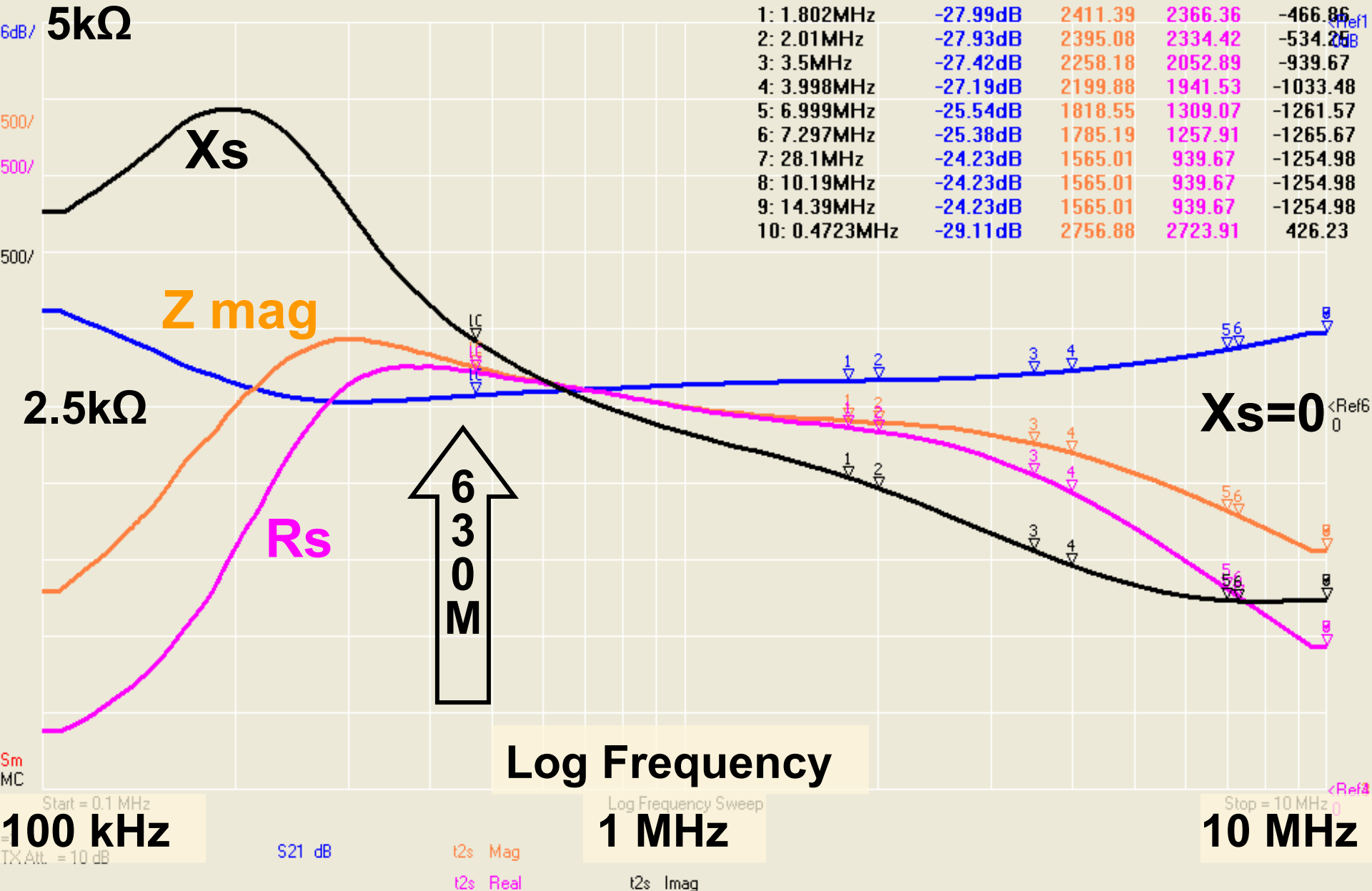
- **Buy #12 stranded, silver coated copper Teflon on ebay (new, surplus)**
 - \$12 for 20 ft from seller parelectronics
 - He has multiple colors
- **Buy THHN or Romex at the big box store**
 - Solid winds better than stranded

Buying Enameled Wire

- **I found very good enameled wire from Temco on ebay (their brand, new)**
 - **Sold by weight**
 - **10 lb (315 ft) AWG #10 for \$102**
 - **#12 is good enough, costs less**
 - **Shorter lengths are available**
- **Pay attention to voltage breakdown rating of what you're buying**
 - **That's why I bought Temco – specs are on their website**

Choking Z RG400 18 Turns

10/18/2018 4:39:01 PM 18 Turns rg400 on Fair-Rite 2.4-in Toroid #75-3 Full, no overlap

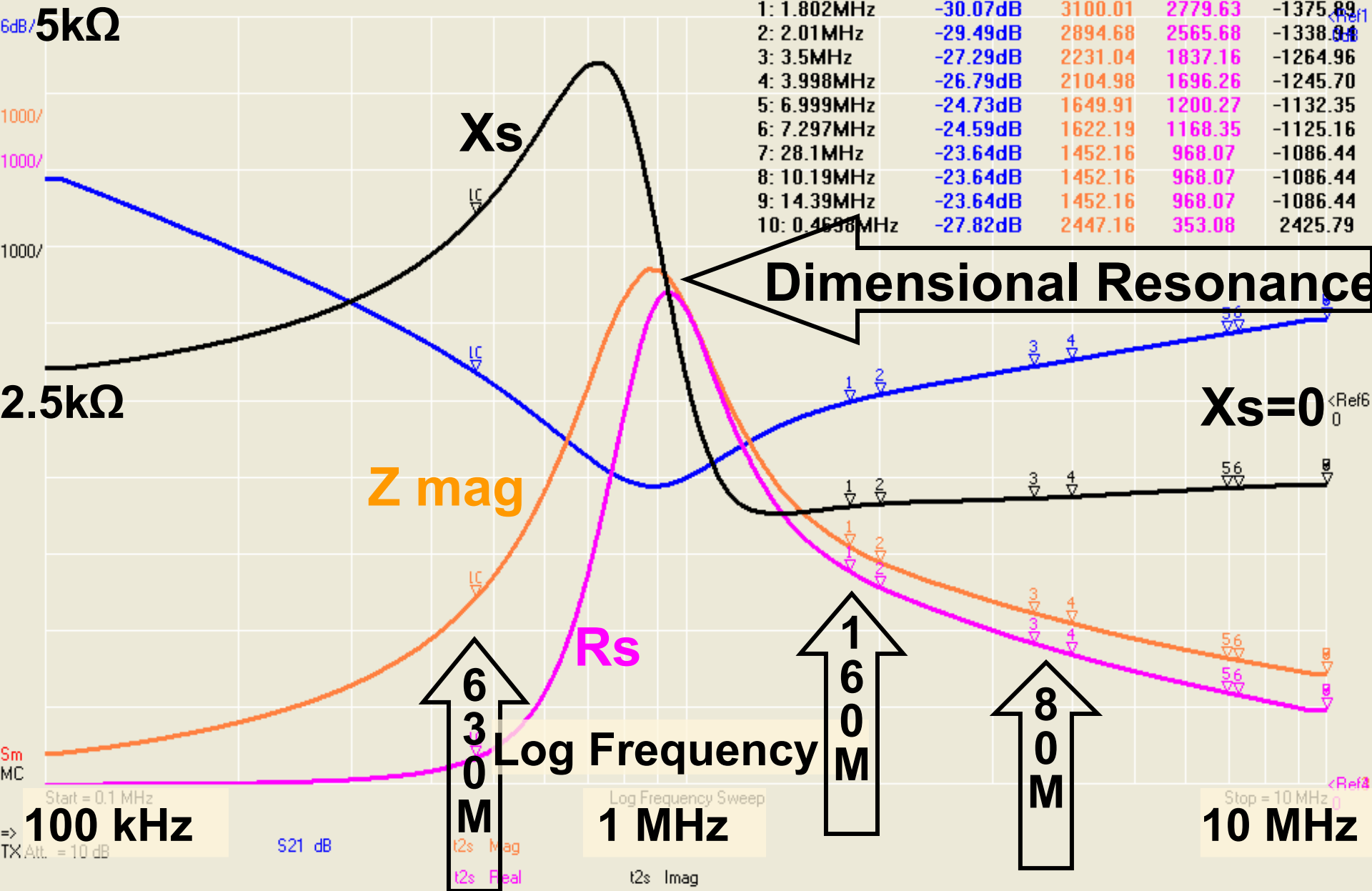


What About #77 Core Palomar Sells?

- **#77 and #78 are almost the same**
- **I have some #78 cores, but not #77**
- **So I measured #78**
- **It's a terrible choice for any ham bands!**
- **#77 has the same problem**
- **Fair-Rite does not advise using 77 or 78 for chokes – they are inductive parts**
 - **Used in power circuits in the 20-100 kHz range**

14 Turns Teflon #12/2 on #78 Core

10/14/2018 3:01:58 PM 14 Turns Teflon #12-2 on Fair-Rite 2.4-in Toroid #78-3



Dimensional Resonance

- **A limitation of MnZn ferrite materials**
 - **#31, #75, #77, #78**
- **A high Q resonance caused by standing waves within the cross section of the core**
- **Frequency set by dimensions of the core and properties of the ferrite**
- **Ferrite cores are wide tolerance parts (+/- 25% is typical) so frequency varies between cores with the same part number**

Dimensional Resonance Is Why:

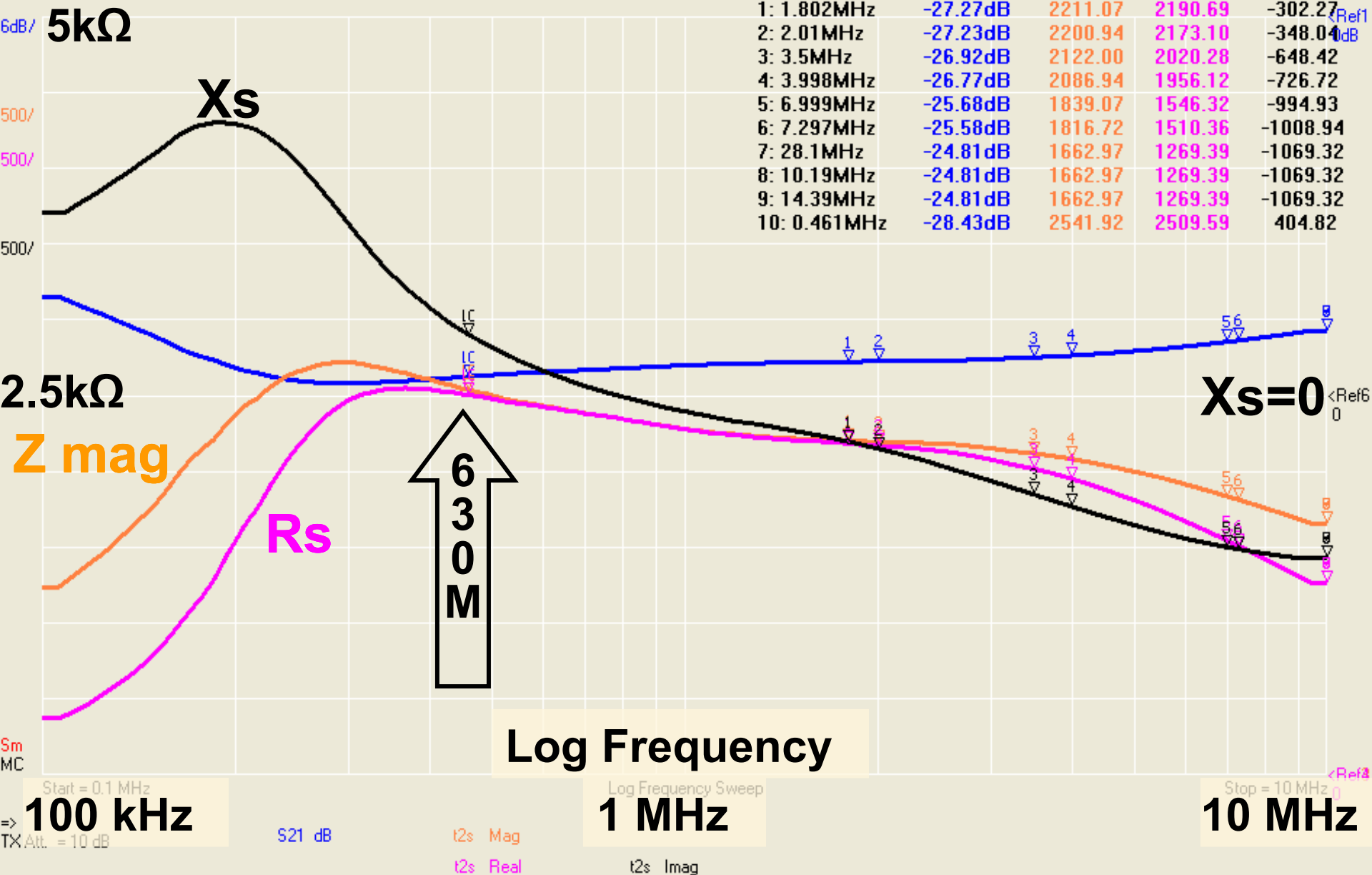
- #75 is good for 630M but not below about 300 kHz**
- #31 is good for 160M-6M, but not below 160M**
- #77 and #78 (almost the same) are not good for chokes at all**

Dimensional Resonance Is Not All Bad

- It can combine with circuit resonance (number of turns) to broaden the useful range of a choke**
- The next three chokes are examples**
 - Two of the #75 chokes in series cover 630, 160, and 80 pretty well for about 400W**
 - The #31 choke covers 80, 40, 30, and 20 (note the different vertical scale) for that same power level**

Choking Z RG400 17 Turns

10/11/2018 1:51:05 PM 2.4-in #75 Toroid #4 17 Turns RG400



14 Turns Teflon on #31 Toroid

9/27/2018 8:52:20 PM Teflon 12-2 on High Rs Low Xs #31 Core GA2 14 Turns

12.5kΩ

Note different vertical scale

1: 1.802MHz	-33.73dB	4783.85	3484.19	3289.46
2: 2.01MHz	-34.24dB	5073.47	3948.81	3190.57
3: 3.5MHz	-35.81dB	6075.33	5808.60	1769.81
4: 3.998MHz	-35.96dB	6182.36	6044.81	1282.24
5: 6.999MHz	-36.01dB	6219.26	6177.16	-717.55
6: 7.297MHz	-36.02dB	6222.09	6162.40	-855.60
7: 28.1MHz	-32.36dB	4114.82	1408.86	-3862.81
8: 10.19MHz	-35.95dB	6180.65	5814.50	-2092.07
9: 14.39MHz	-35.54dB	5901.67	4840.59	-3375.78
10: 21.29MHz	-33.98dB	4943.23	2770.66	-4088.63

6.25kΩ

Sm
MC

Start = 1 MHz
=> 1 MHz
TX Att. = 10 dB

160M

80M

40M

30M

20M

Log Frequency

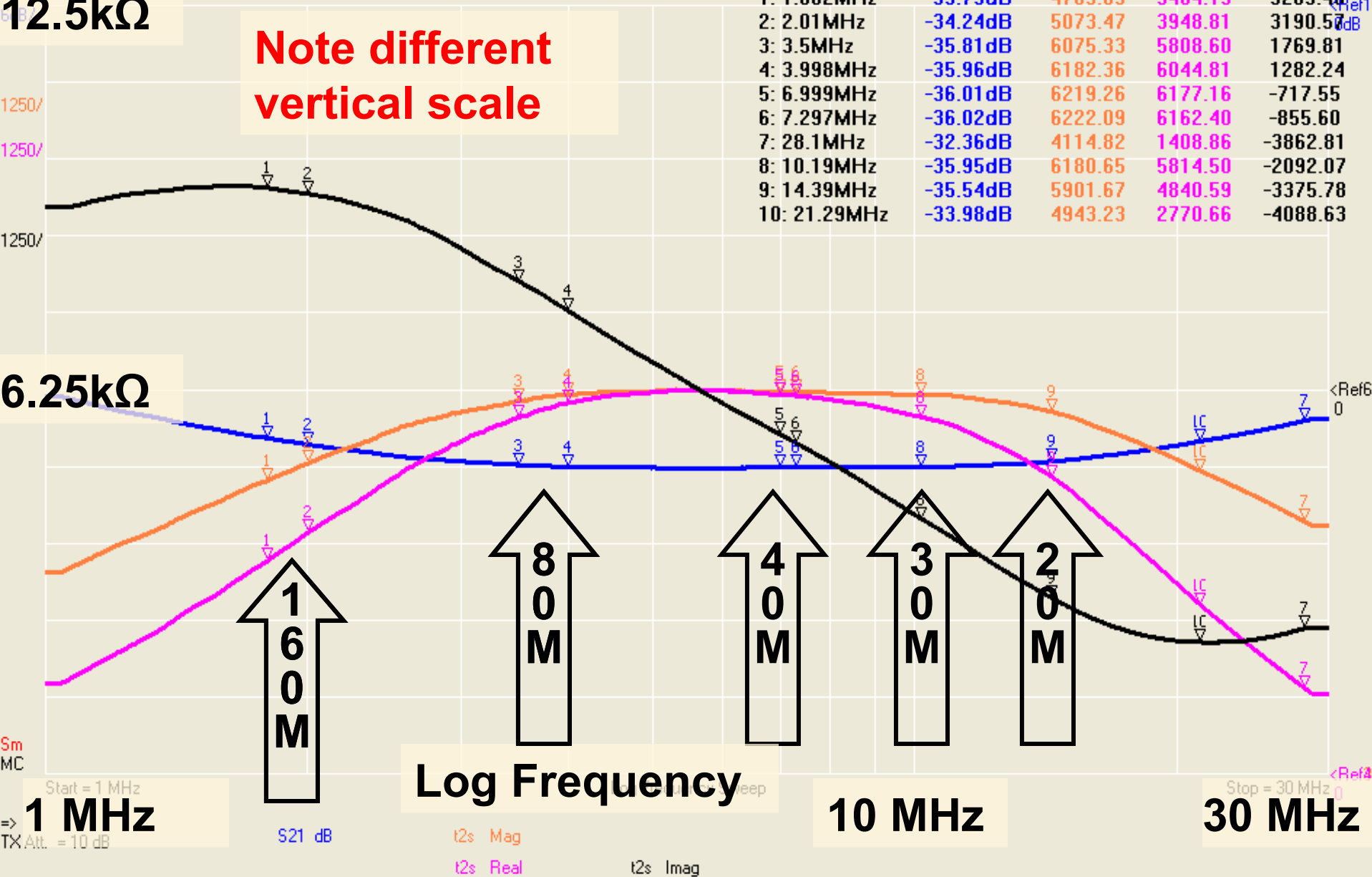
10 MHz

Stop = 30 MHz

t2s Mag

t2s Real

t2s Imag

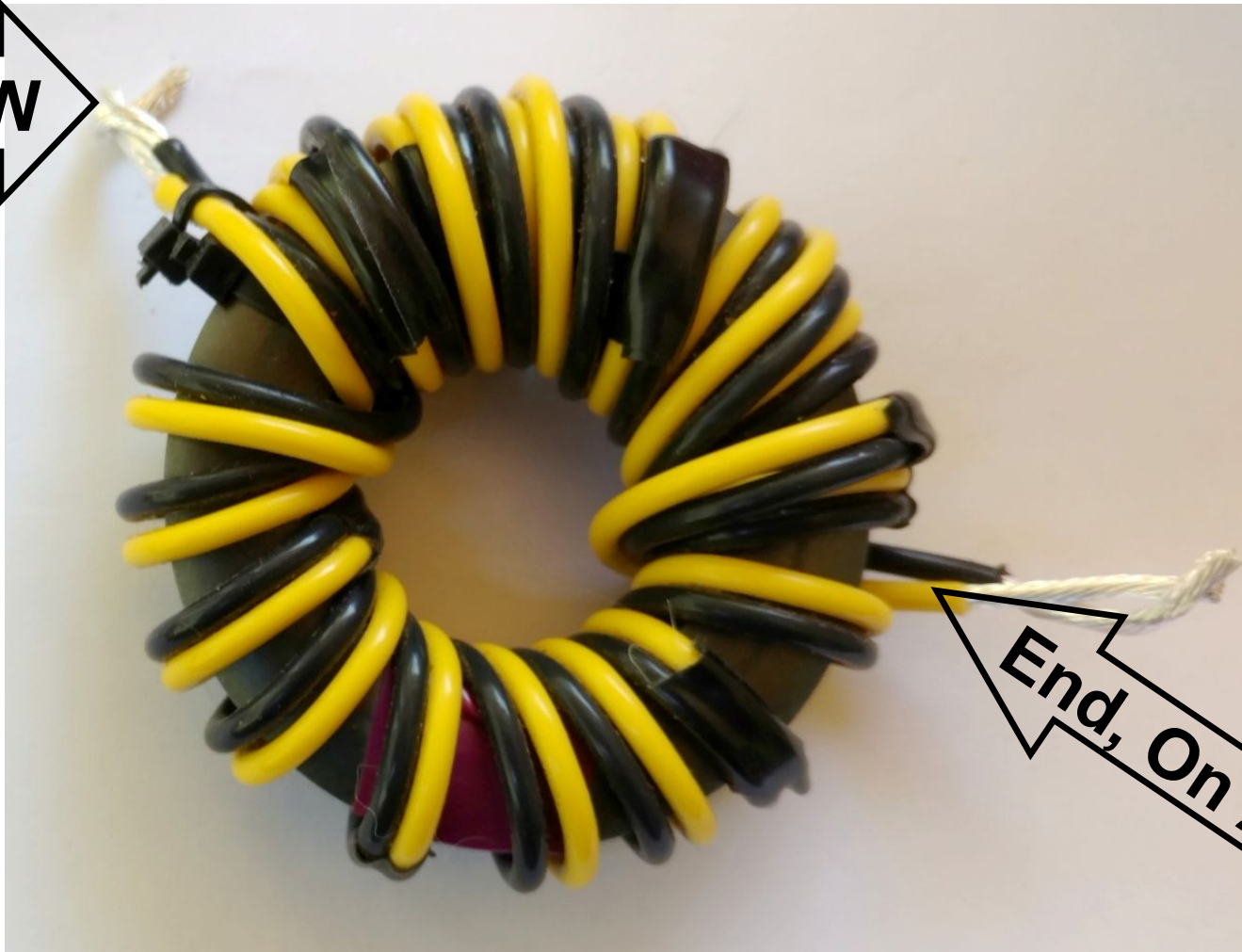


Winding More Turns On Second Layer

- **Choking Z can be increased by adding turns on a second layer**
- **Increased capacitance moves resonance down, sacrificing higher bands**

22 Turns #12-2 Teflon on Fair-Rite #75 2.4-in o.d. Toroid

Start, CW



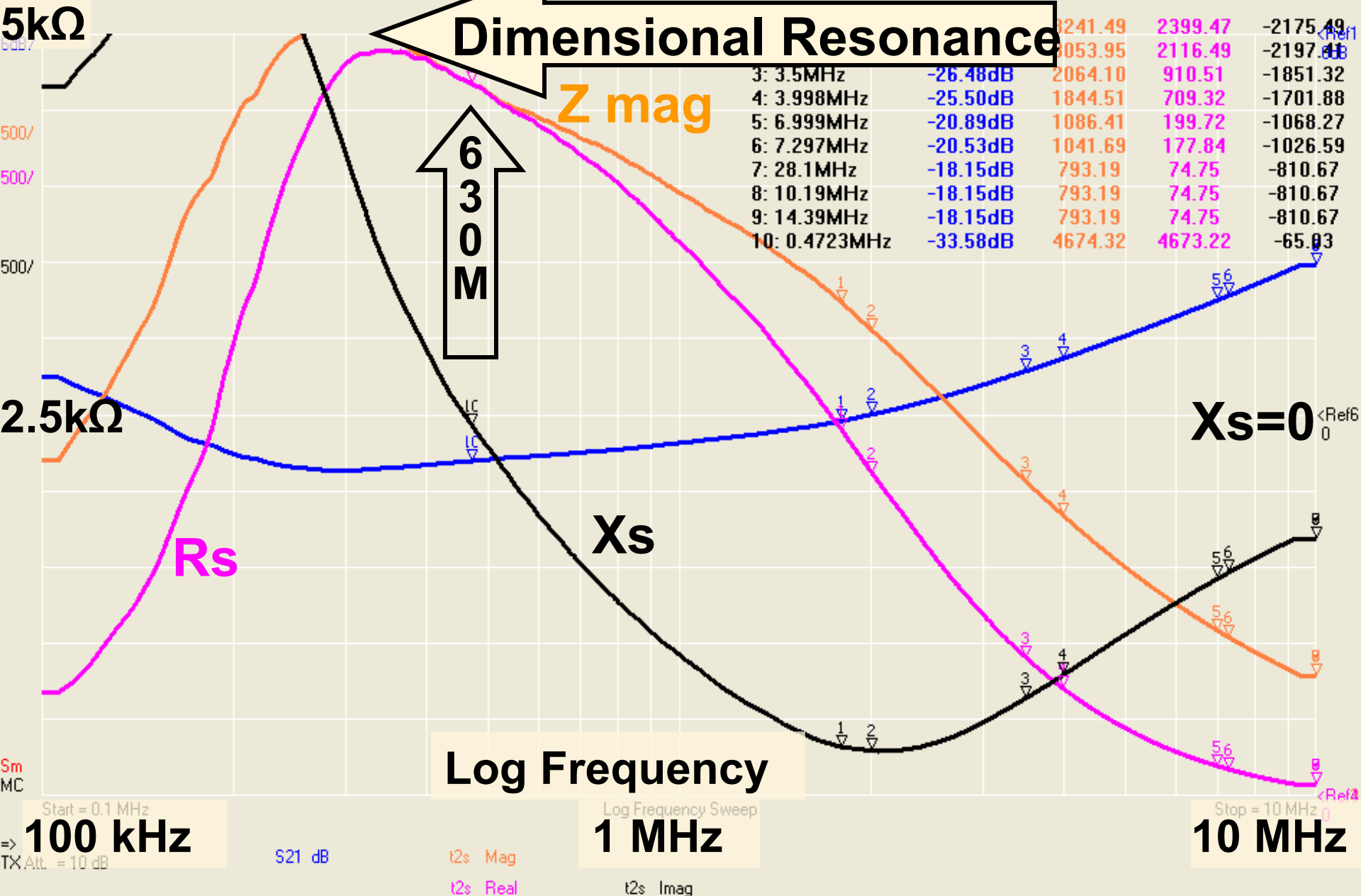
End, On 2nd Layer

Winding More Turns On Second Layer

- **For this 22 turn choke (5 turns overlapped)**
 - **Choking $Z \sim 4.5\text{k}\Omega$ on 630M**
 - **Almost doubles choking Z with a single core**
 - **Added turns excite dimensional resonance around 300 kHz**

Choking Z Teflon #12/2 22 Turns

10/16/2018 1:05:11 PM 22 Turns Teflon Yel/Blk #12-2 on Ferrite 1.4-in Toroid #75-2



Be Careful About Taking This Too Far

- Component tolerances (+/- 25%) can vary frequency of dimensional resonance, moving it too far from 630M**
- Two chokes with fewer turns may be a safer choice**

K9YC's BS Filter

- Some vendors who don't understand chokes are selling hams the wrong materials, and at crazy markups**
- Palomar got a spot at Visalia to give hams wrong advice (to sell hams the wrong stuff)**
- I couldn't get on the program!**

Fair-Rite Toroids For Chokes

- **#43 is useless below about 10 MHz**
- **#61 is useless below VHF**
- **Dimensional resonance makes**
 - **#31 useless below about 1.5 MHz**
 - **#77 and #78 almost useless on any band for multi-turn chokes**
 - **#75 useless below about 400 kHz**
- **Palomar is selling #77 and #61 for chokes**

Ferrites Have Multiple Uses

- Nearly all ferrite materials have low loss at low frequencies, and a lot of loss at high frequencies**
- “Low” and “high” depends on the ferrite chemical mix (the number)**
- Fair-Rite, a US company with factories in the US and in China, manufactures virtually all ferrite cores used by hams**

Range of Commonly Used Ham Ferrites

Ferrite Mix	Low Loss (Power, Xfmrs)	High Loss (Chokes)
#31	Not useful	1.5 – 150 MHz
#43	Not useful	12 – 300 MHz
#61	Good to 15 MHz OK to 30 MHz	200 MHz – 2 GHz
#67	Good to 50 MHz	Not useful
#75	Below 100 kHz	0.4 – 20 MHz
#77	Below 100 kHz	Not useful
#78	Below 200 kHz	Not useful

Chokes Wound on Various Fair-Rite Core Materials

- **#43 is a good choice above 10 MHz**
- **#31 is best for 160M – 30M, useful up to 6M**
- **#75 is best for 630M**
- **I haven't yet found a good material for the 2200M (135 kHz band)**

Transmitting Chokes for the 630M Band

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