BALUNS AND FERRITES

Radio Talk 2013

Jacques Audet
VE2AZX Sept. 2013

VE2AZX@amsat.org

- REASONS FOR USING A BALUN
- TYPES OF BALUNS
- CHECK YOUR BALUN WITH AN SWR ANALYZER
- RESULTS
- MESURING THE IMPEDANCE OF A NUMBER OF FERRITES
- IMPEDANCE MEASUREMENT RESULTS
- USING FERRITES ON A FEEDER AND HOUSE CONDUCTORS

REASONS FOR USING A BALUN ?

BALUN = BALanced to Unbalanced - It’s a transformer

Used to feed a balanced load, Ex: dipole

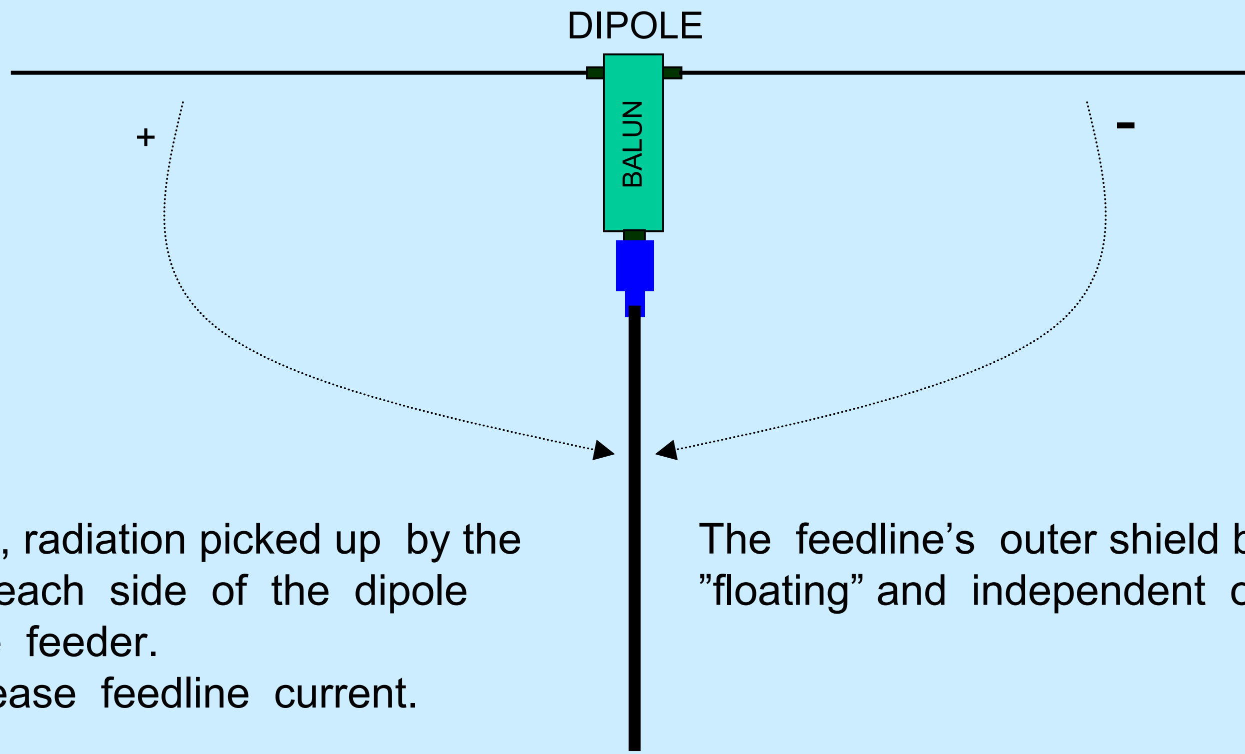
Decreases feeder radiation

The feed line becomes independent of the antenna:

We can change its length … move it around

<u>Without causing SWR change</u>.

REASONS FOR USING A BALUN ?



With a balun, radiation picked up by the feeder from each side of the dipole cancels at the feeder.
This will decrease feedline current.

The feedline's outer shield becomes "floating" and independent of the antenna.

The feedline should run away from the dipole at right angle.
The dipole should be parallel to the ground.

A non symetrical antenna Ex: Windom… Will require the use of a current balun

BALUN TYPES

VOLTAGE

- TRANSFORMER WITH WINDINGS GIVING A BALANCED OUTPUT
- IN-OUT IMPEDANCES ARE DETERMINED BY THE TURNS RATIO. A WIDE RANGE OF RATIOS IS POSSIBLE.
- OPERATES OVER A SOMEWHAT LIMITED BANDWIDTH (100 TO 1)

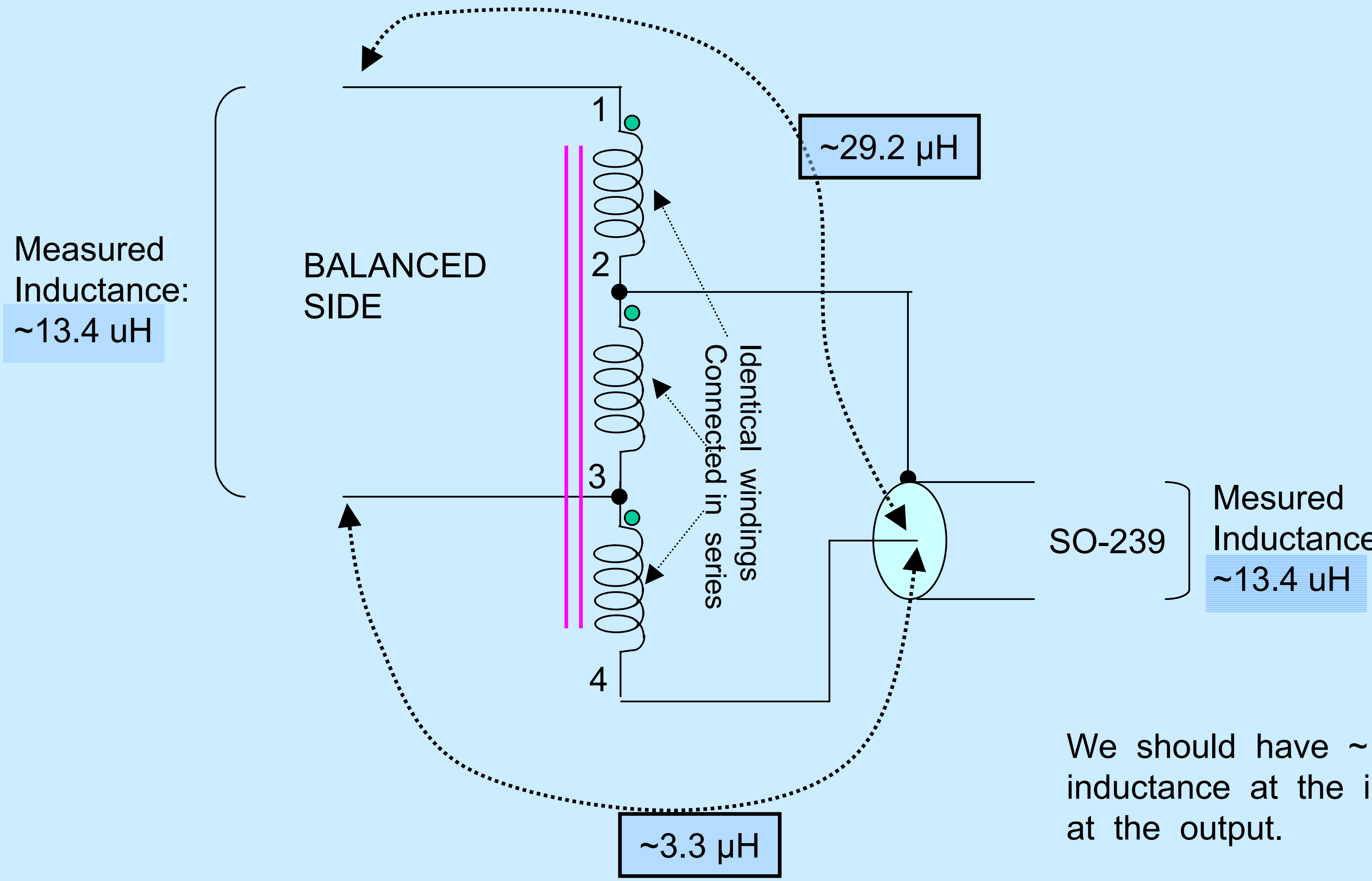
CURRENT

- USES TRANSMISSION LINES WOUND ON A CORE
- MAY USE A COAXIAL CABLE OR A PARALLEL WIRE LINE WITH OR WITHOUT FERRITES.
- COMMON IMPEDANCE RATIOS: 1:1 AND 4:1
- OPERATE OVER A MUCH WIDER BAND OF FREQUENCIES

1:1 VOLTAGE BALUN

- 3 IDENTICAL WINDINGS

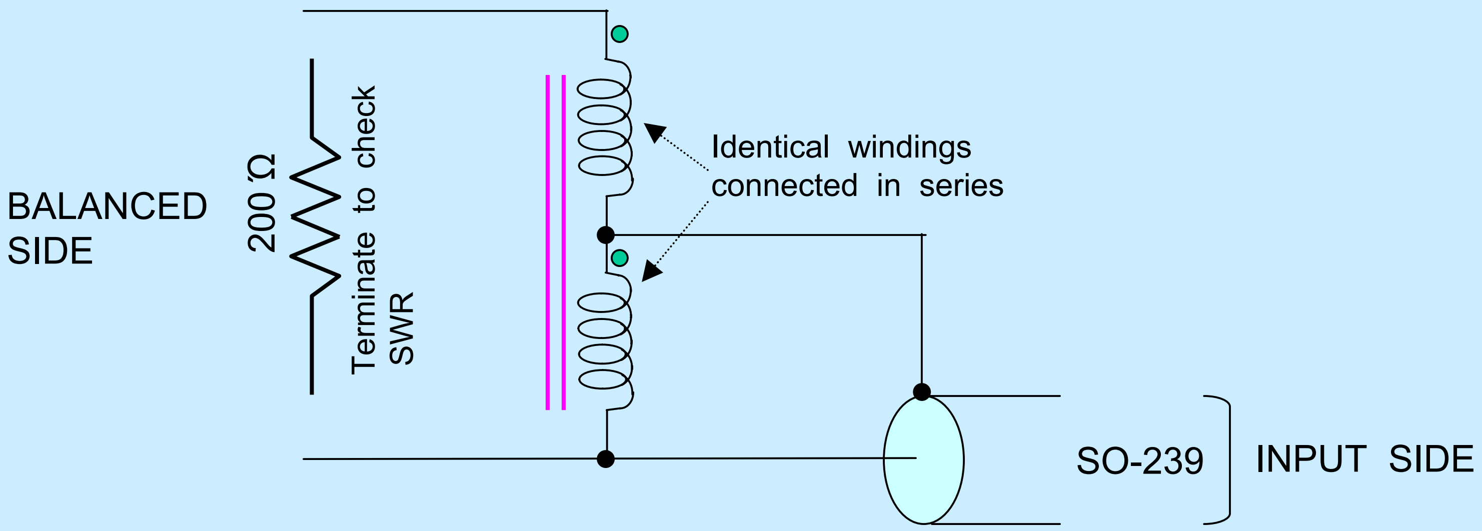
- GENERALLY 50 : 50 ohms



We should have ~ the same inductance at the input and at the output.

VOLTAGE BALUN 4:1

- 2 IDENTICAL WINDINGS

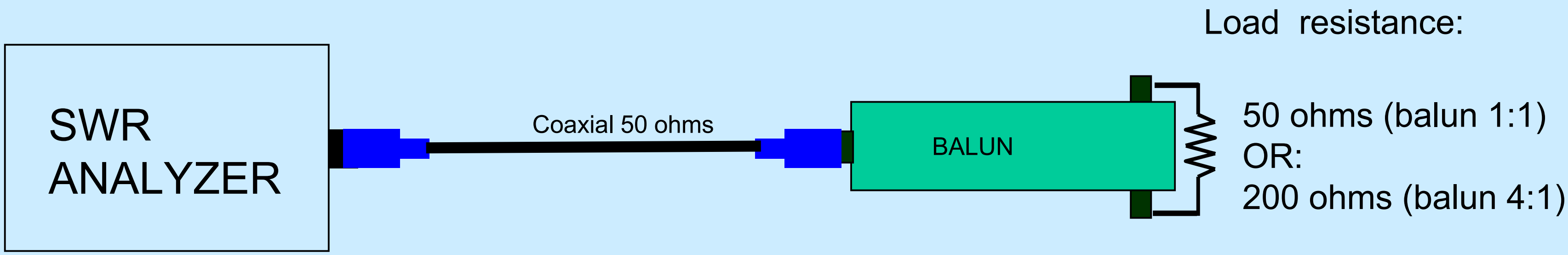


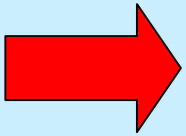
The measured inductance at the output is ~ 4X the input inductance as a result of inductance coupling.

TESTING A BALUN WITH AN SWR ANALYZER

These tests verify:

- Winding inductance
- Winding distributed capacitance
- The quality of the insulation between conductors

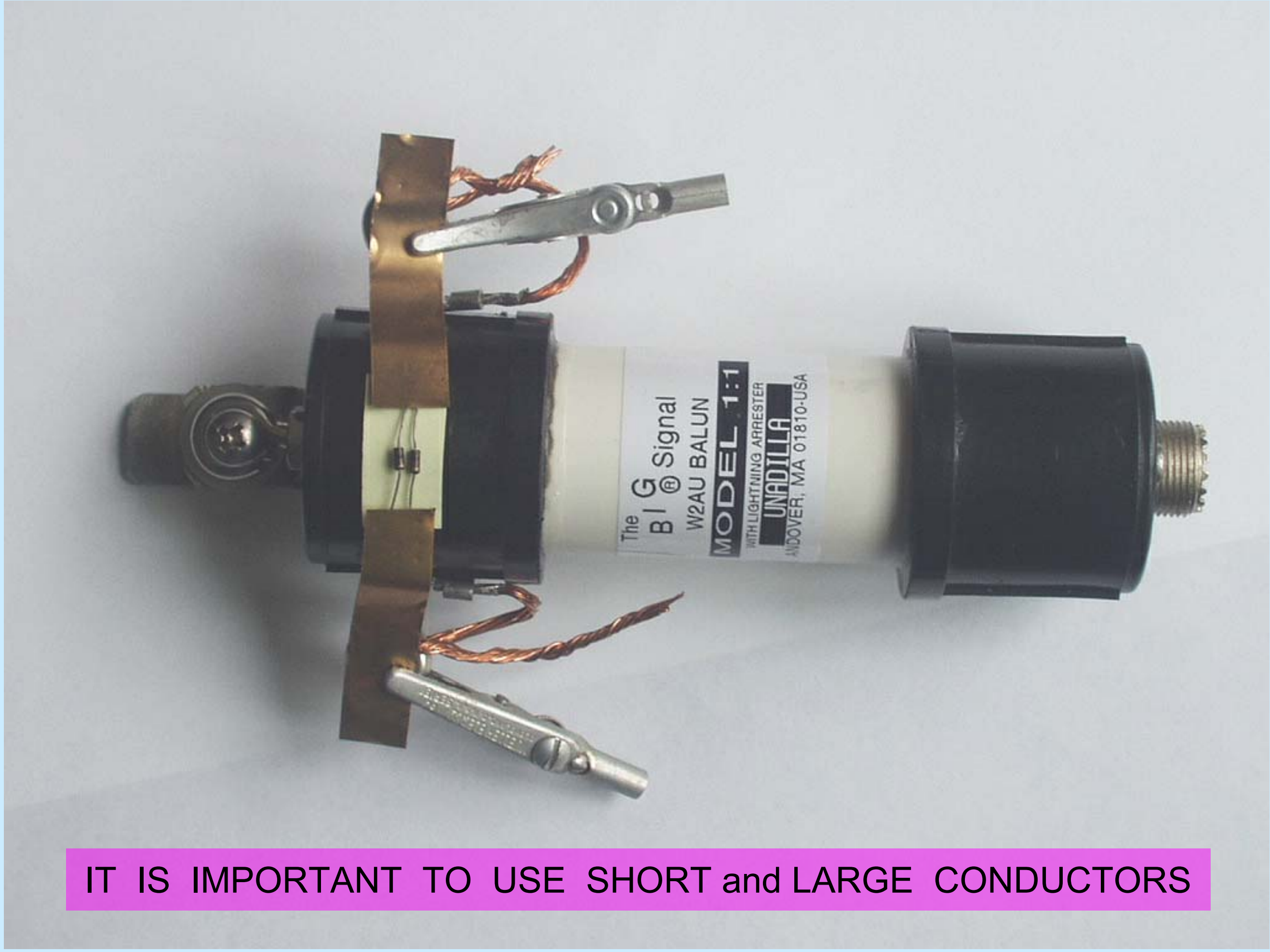


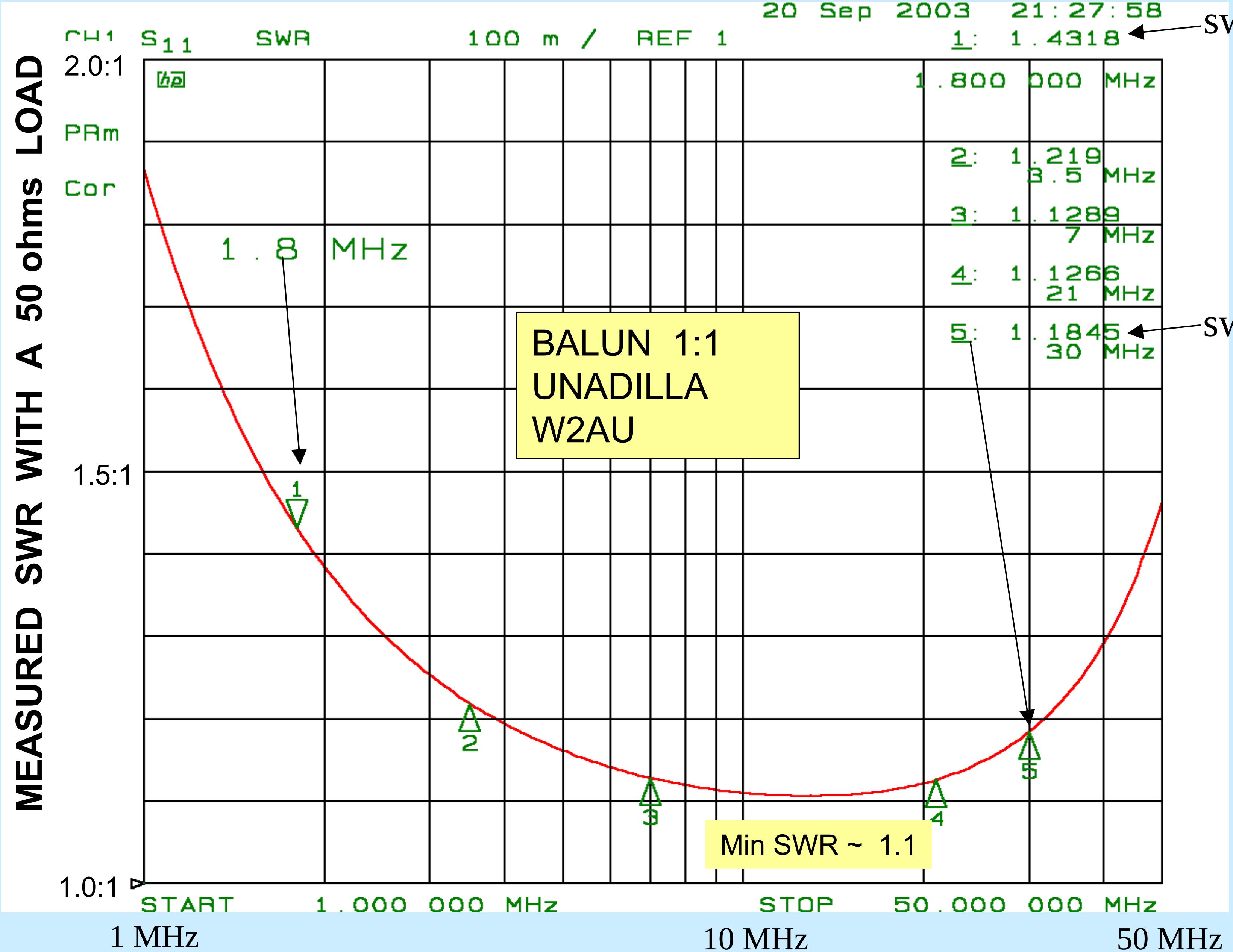


The minimum SWR should be below 1.5
In the middle of the balun's frequency range

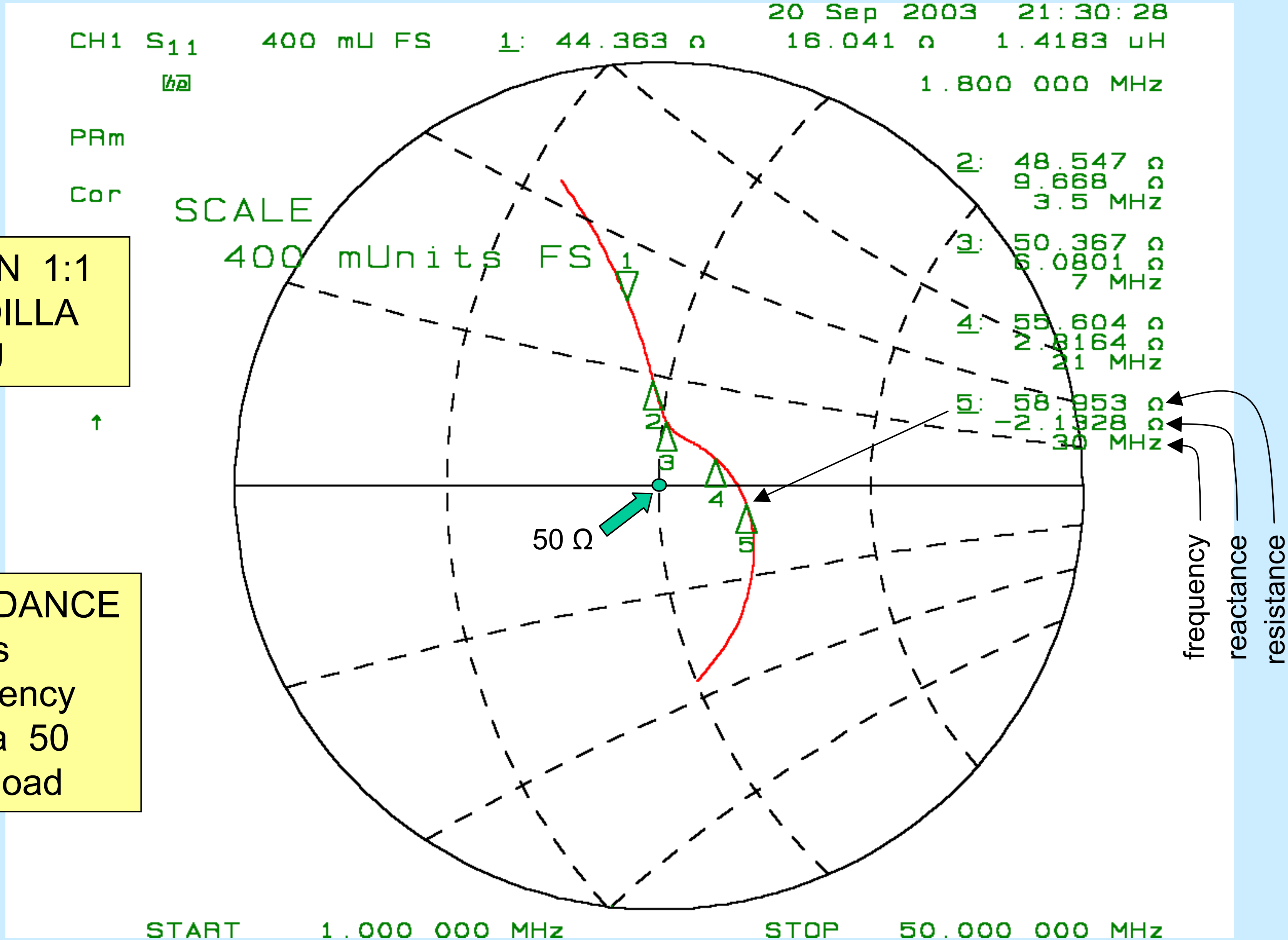
Indicates low losses

CONNECTING THE LOAD RESISTANCE 50 Ω HERE

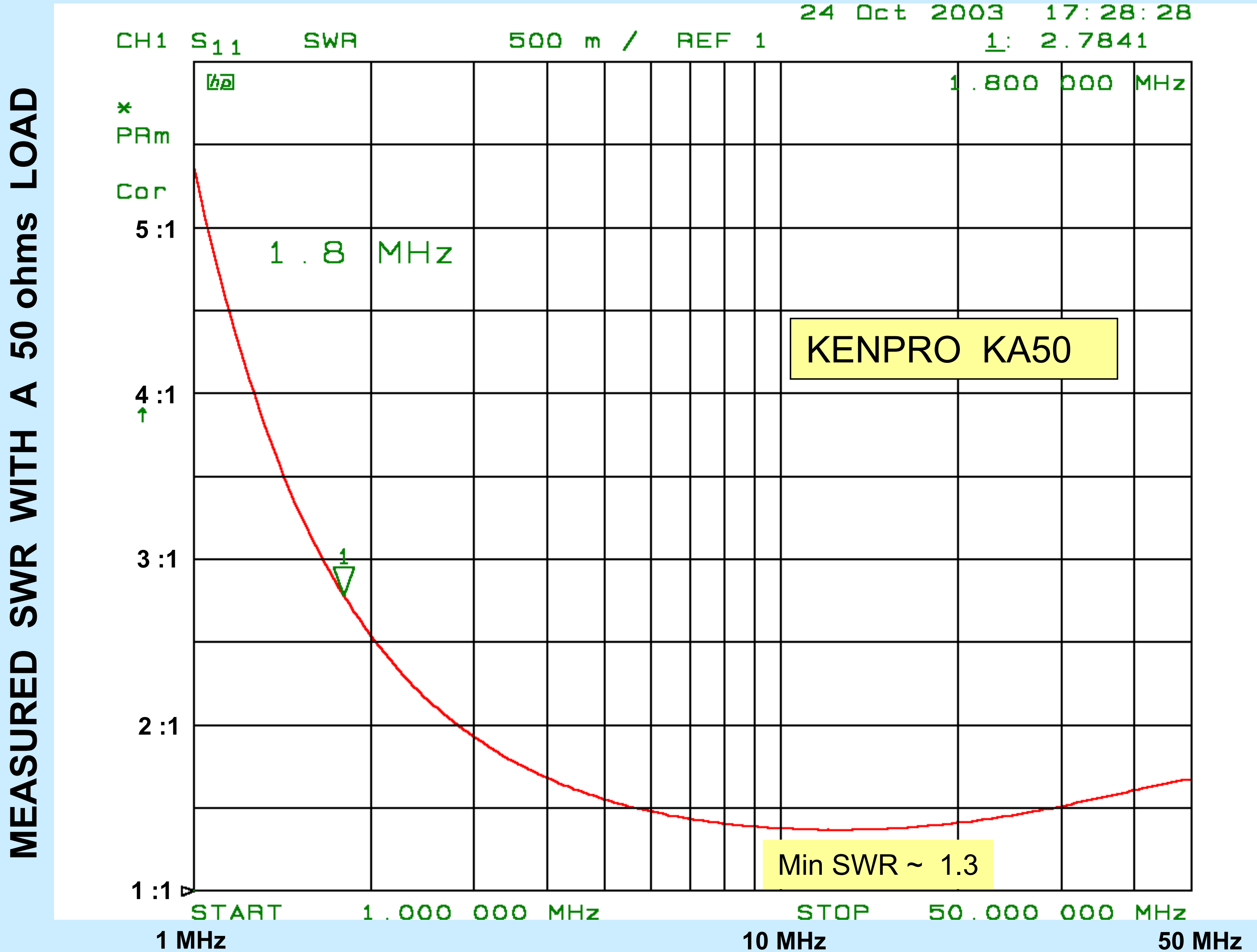



MEASURED SWR WITH A 50 ohms LOAD
20 Sep 2003 21:27:58
CH1 S11 SWR 100 m / REF 1
1: 1.4318
1.800 000 MHz
swr
2.0:1
PRm
Cor
1.8 MHz
2: 1.219
3.5 MHz
3: 1.1289
7 MHz
4: 1.1266
21 MHz
5: 1.1845
30 MHz
swr
BALUN 1:1
UNADILLA
W2AU
1.5:1
Min SWR ~ 1.1
1.0:1
START 1.000 000 MHz
STOP 50.000 000 MHz
1 MHz
10 MHz
50 MHz

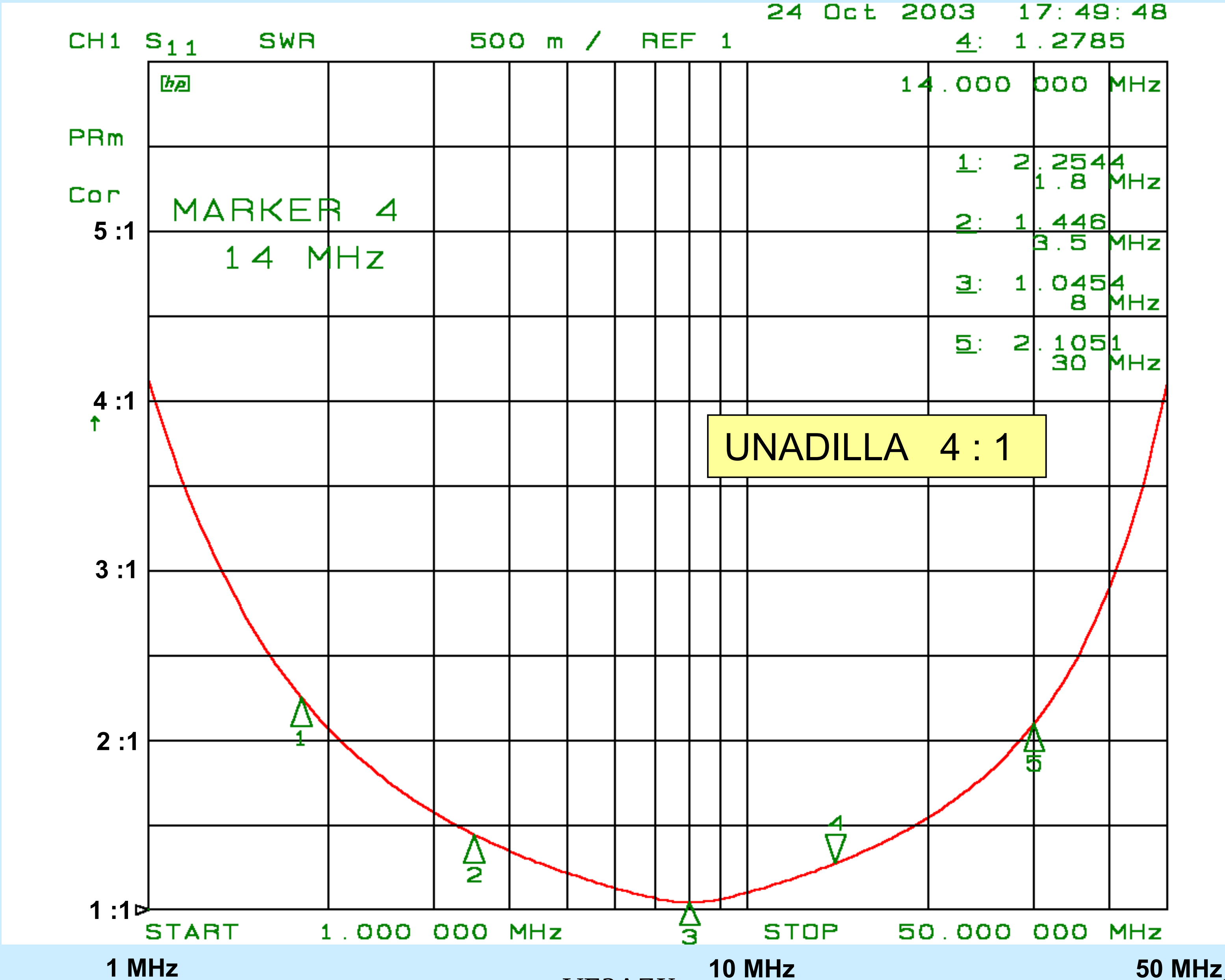
BALUN 1:1
UNADILLA
W2AU



IMPEDANCE
vs
Frequency
with a 50
ohm load


MEASURED SWR WITH A 50 ohms LOAD
24 Oct 2003 17:28:28
CH1 S11 SWR 500 m / REF 1 1: 2.7841
1.800 000 MHz
PRm
Cor
5 :1
4 :1
3 :1
2 :1
1 :1
1.8 MHz
KENPRO KA50
Min SWR ~ 1.3
START 1.000 000 MHz
STOP 50.000 000 MHz
1 MHz
10 MHz
50 MHz

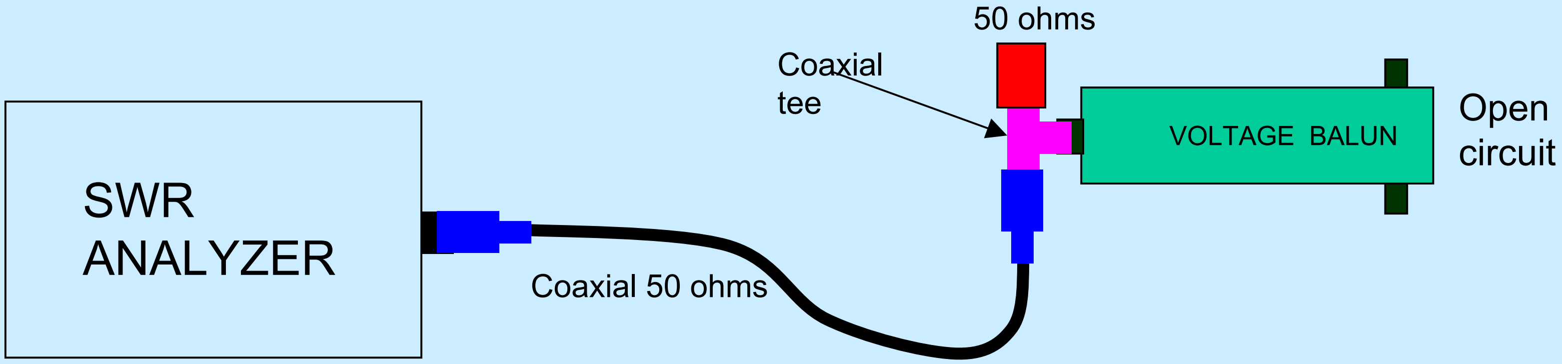
MEASURED SWR WITH A 200 ohms LOAD

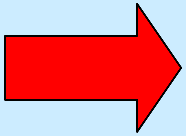


OPEN CIRCUIT TESTS WITH THE SWR ANALYZER

These tests verify:

- Winding inductance
- Winding distributed capacitance
- Quality of the winding insulation

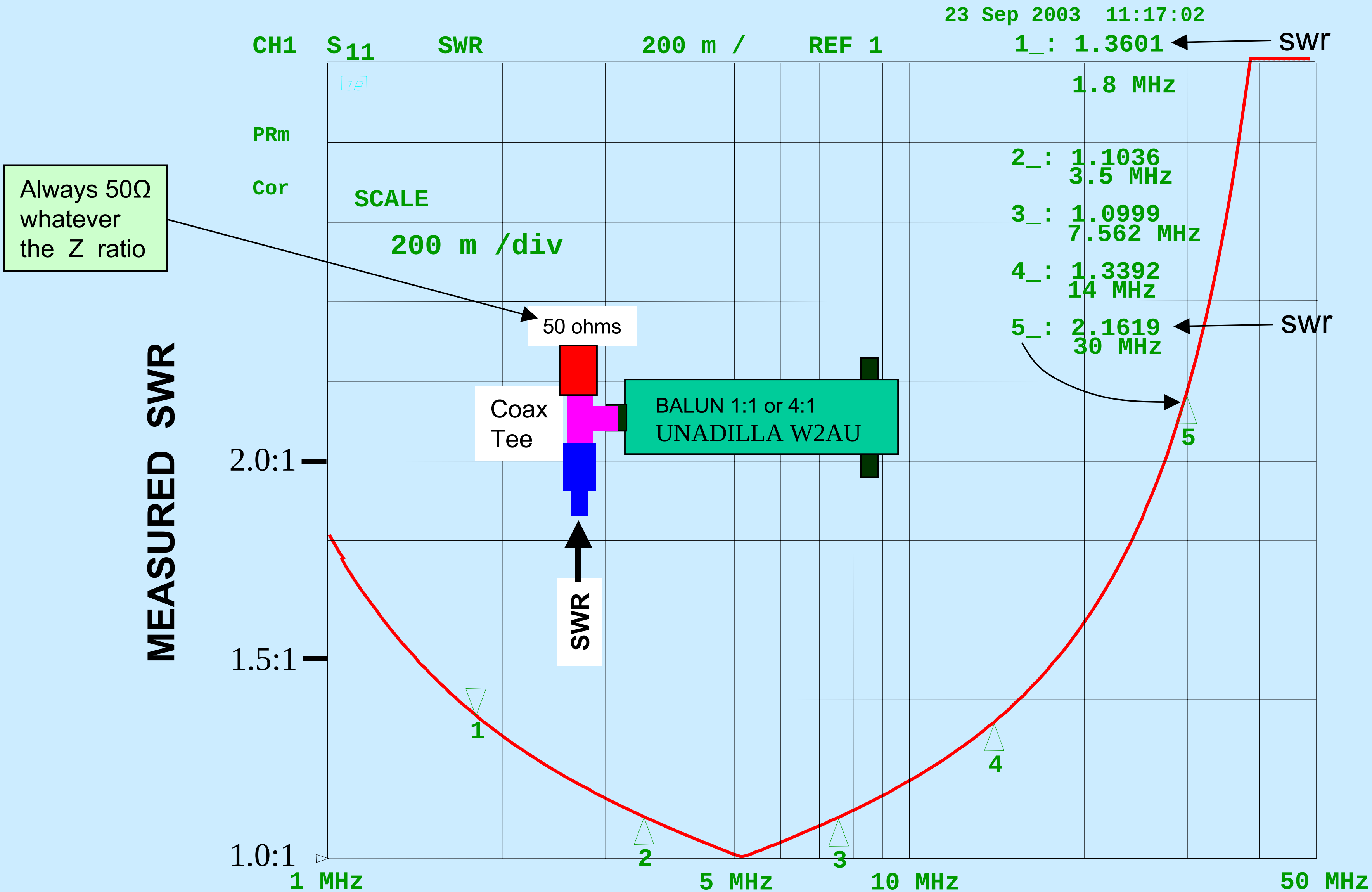




The minimum SWR should be below 1.1
in the middle of the balun's frequency range

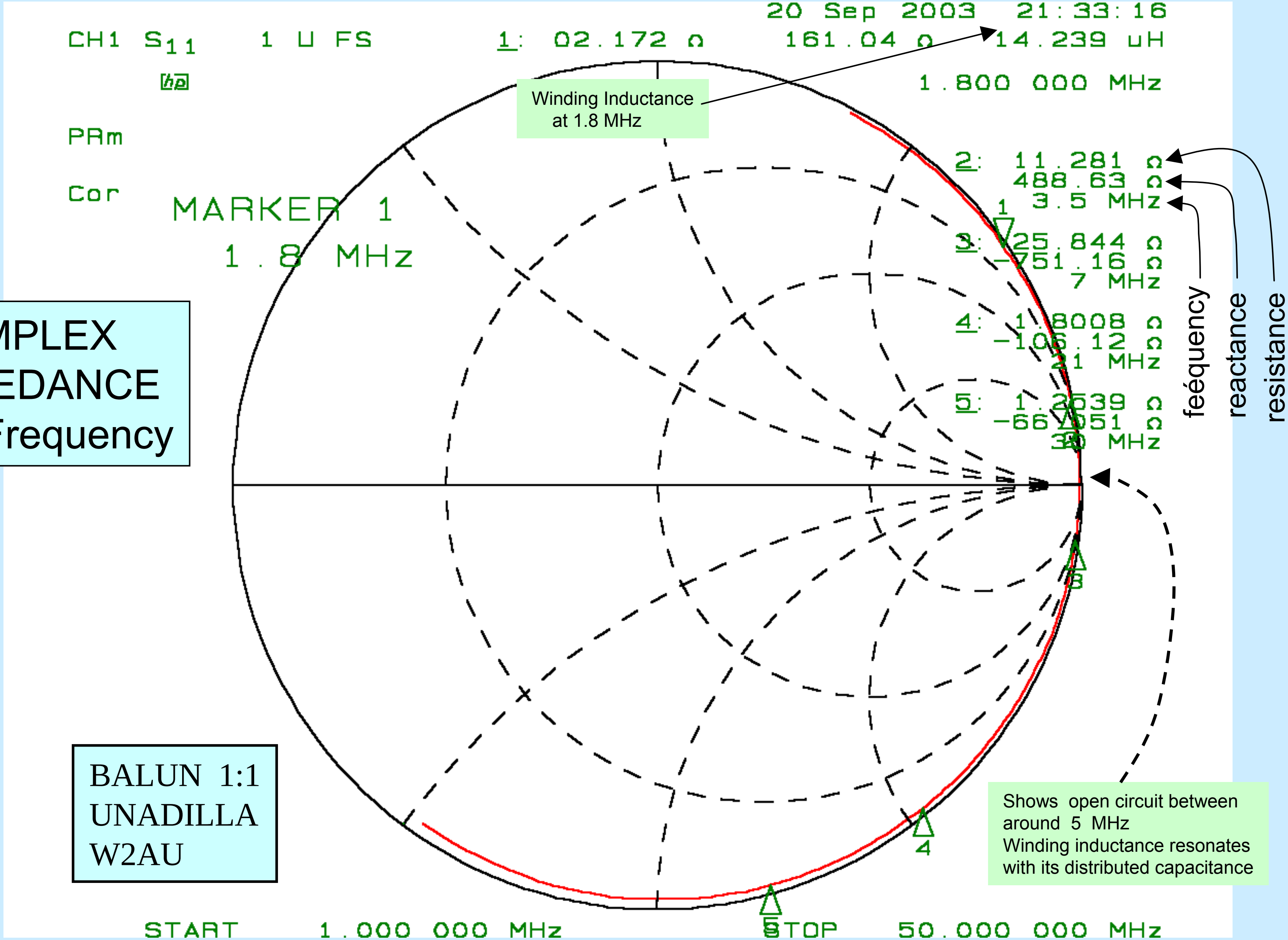
Indicates low losses

OPEN CIRCUIT TESTS WITH THE SWR ANALYZER



OPEN CIRCUIT TESTS WITH A VNA

COMPLEX IMPEDANCE vs Frequency



BALUN 1:1
UNADILLA
W2AU

CURRENT BALUNS

QUESTION: How many independent conductors at RF frequencies do we have in a coaxial cable ? 1, 2, 3 or 4 conductors ?

There are 3 independent conductors:

- The center conductor
- The inner surface of the shield
- The outer surface of the shield

Note that the RF current that flows on the outer surface of the shield is <u>independent</u> of the inner shield current.

This is so because at RF frequencies, the current penetrates very little inside the conductors. This is called SKIN EFFECT.

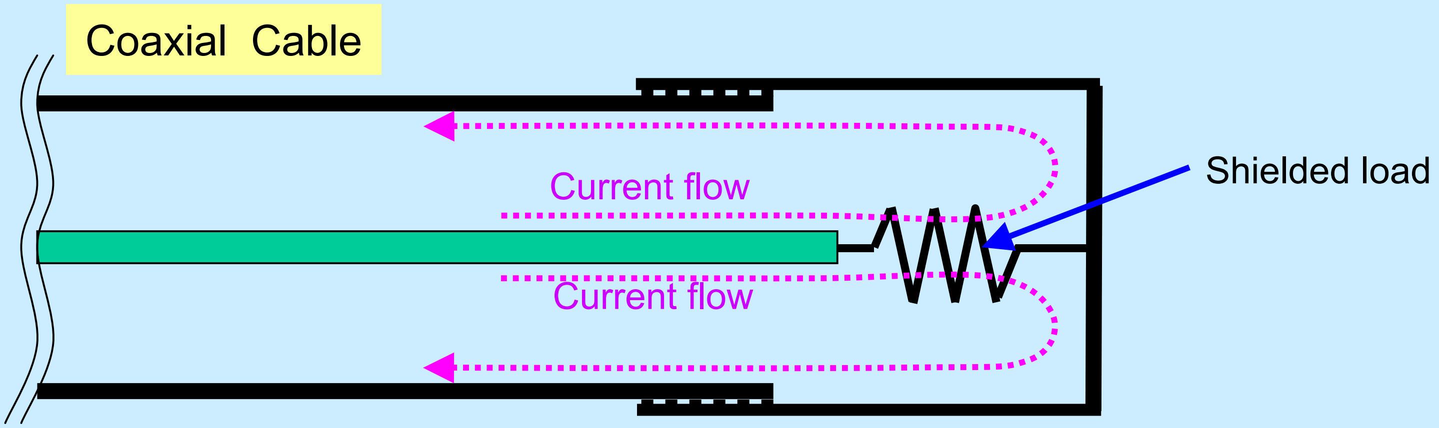
Note also that the <u>SWR only applies to the inner shield currents (and center cond). The SWR is basically independent of the outer shield currents.</u>

SHIELDED LOAD

With a shielded load, the current stays inside the coax

There is no current on the outside of the coax, <u>whatever the load</u> (open, short or terminated)

Adding ferrites on the outside of the coax has NO effect, since no current flows on the outside of the shield.

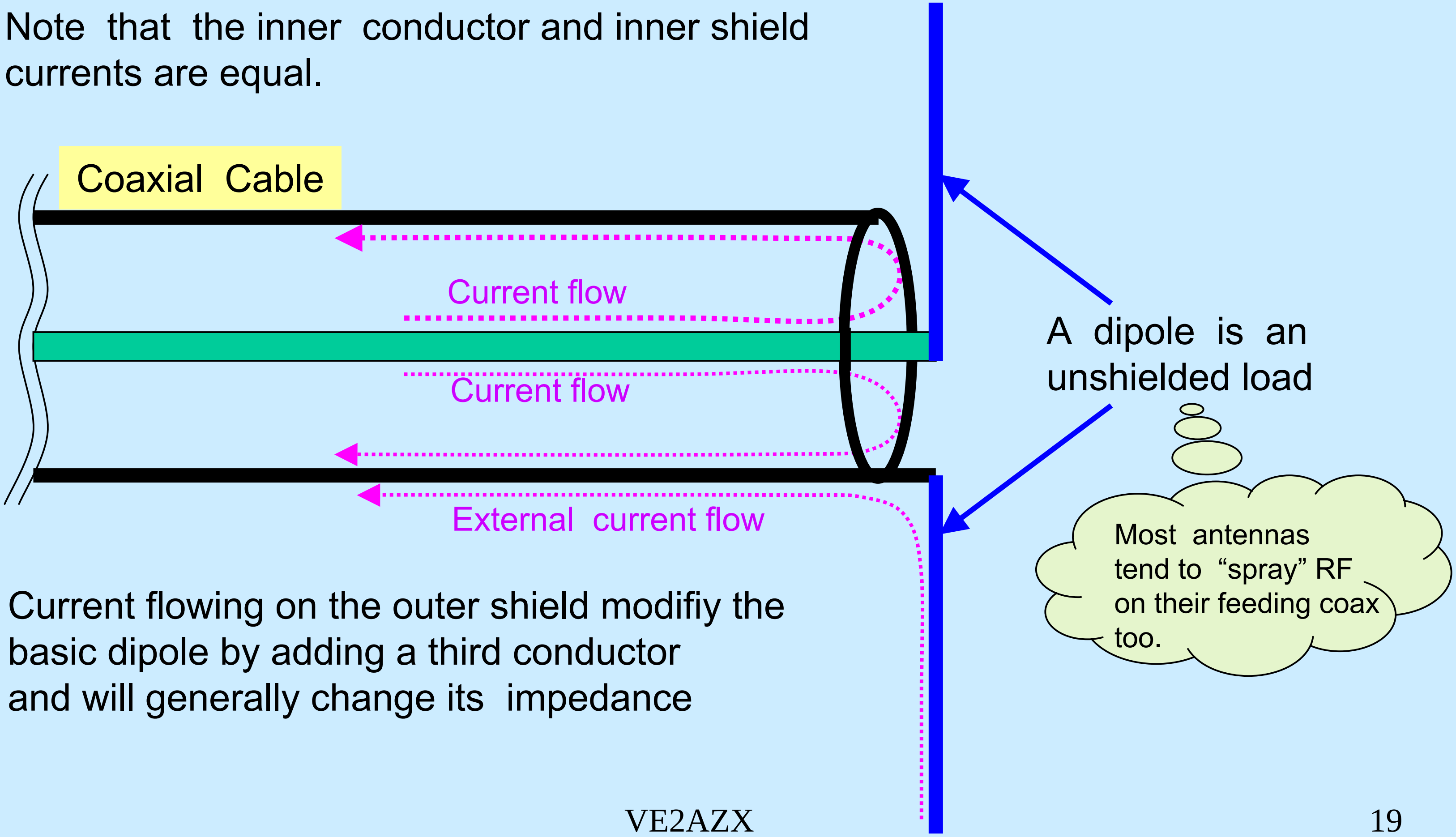


UNSHIELDED LOAD

A dipole is an unshielded load

An unshielded load causes current to flow on the outer surface of the coax, since it picks up radiated currents. In fact <u>it is part of the antenna.</u>
The radiation pattern changes.

Note that the inner conductor and inner shield currents are equal.



Current flowing on the outer shield modifiy the basic dipole by adding a third conductor and will generally change its impedance

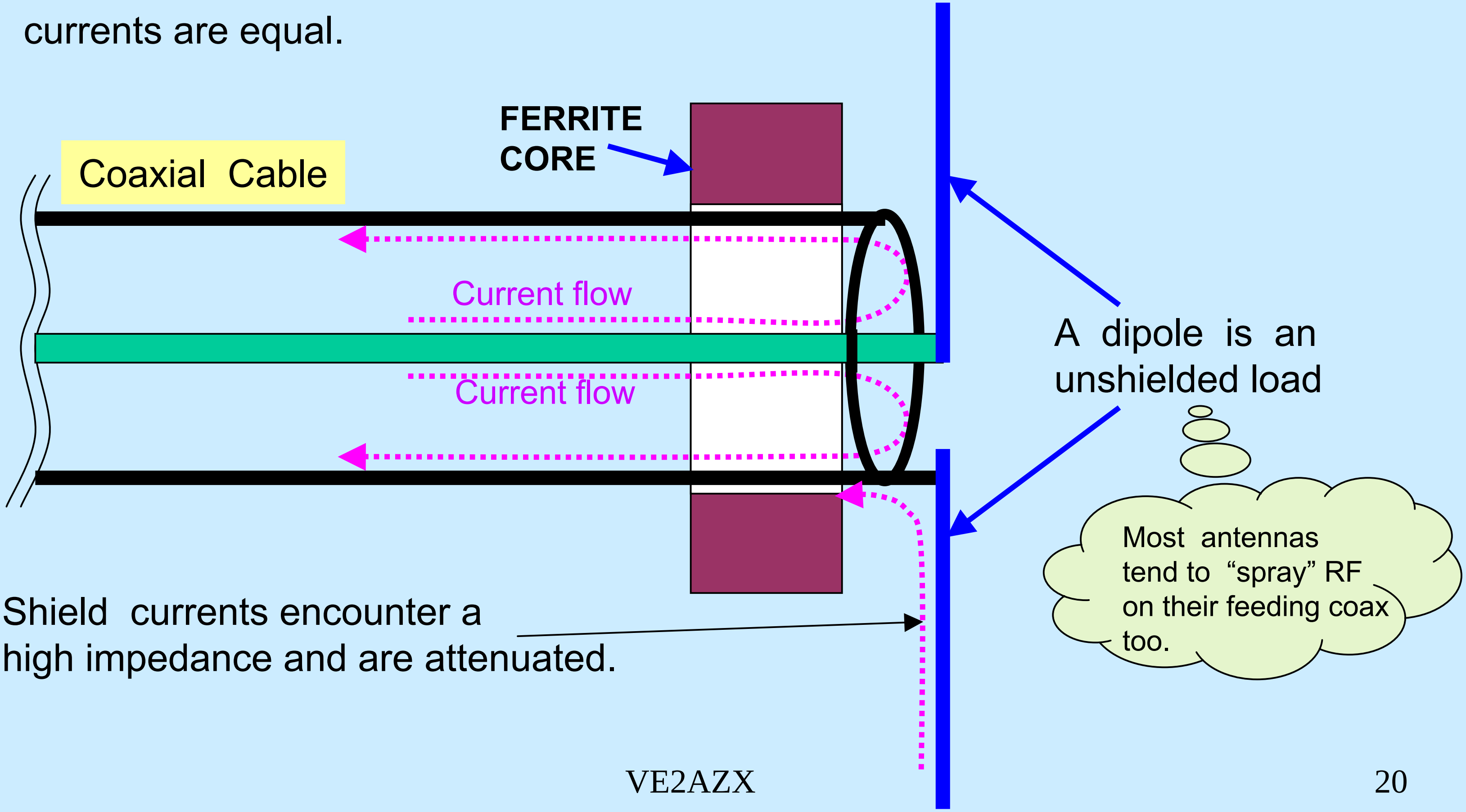
UNSHIELDED LOAD

Adding a ferrite core adds resistance (at RF) only on the OUTSIDE of the coax.

The ferrite core reduces the shield currents

The ferrite core has NO effect on the internal coax currents, besides restoring the dipole impedance and normal radiation pattern.

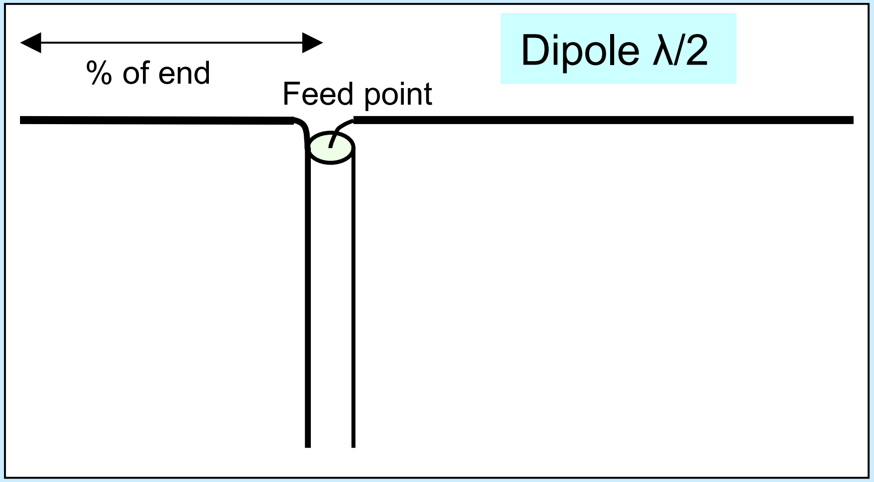
Note that the inner conductor and inner shield currents are equal.

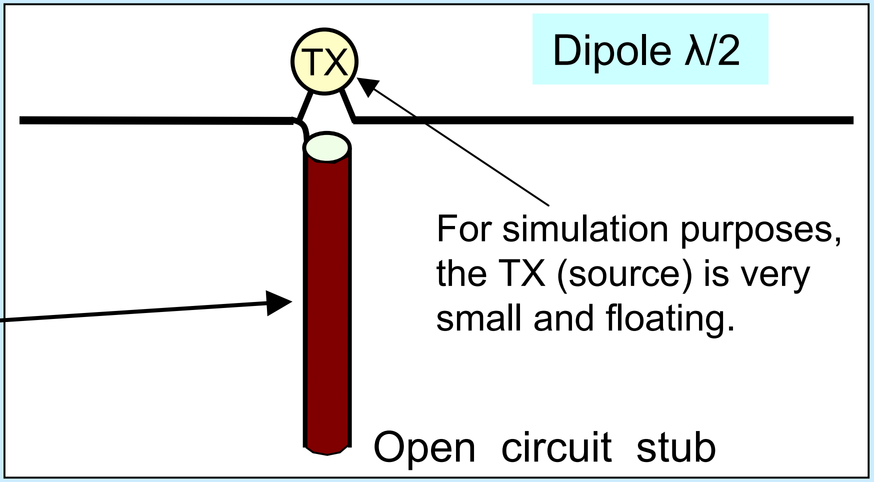


CURRENT BALUNS

How much Resistance is Required when
Feeding a dipole with a coaxial cable ?

A coax cable feeds a dipole at its center, or with an offset





Equivalent Circuit

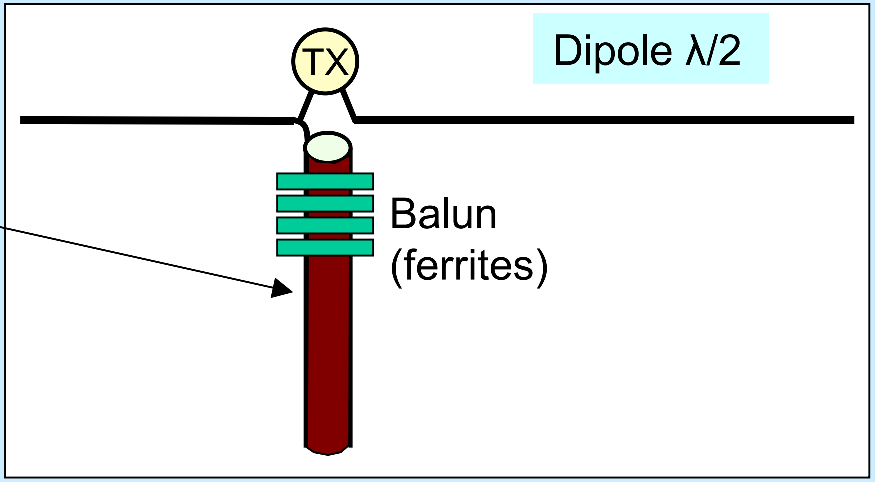
The coax is part of the antenna

λ/4 open stub Is the WORST length – since it reflects a short

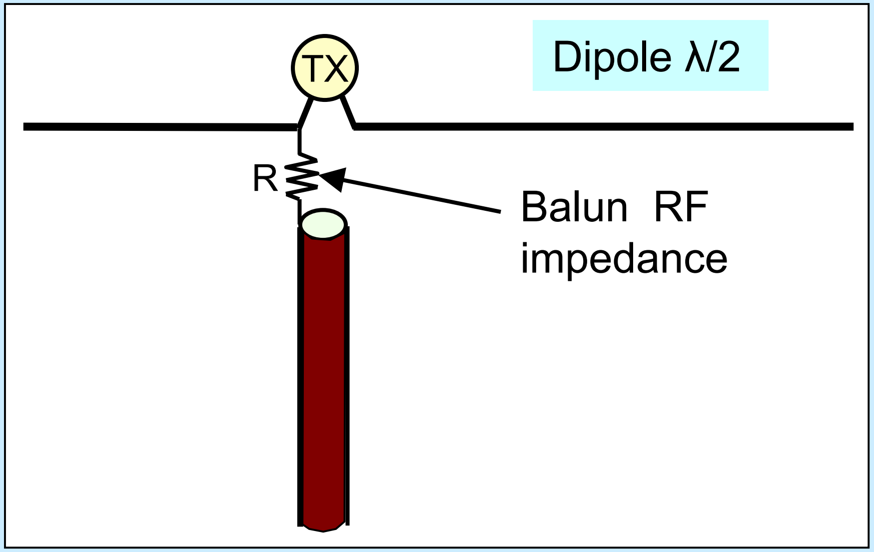
CURRENT BALUNS

Feeding a dipole with a coaxial cable

To decrease the stub current:
A current balun is inserted.
It adds a series impedance
on the outside of the coax.



Balun Equivalent Circuit

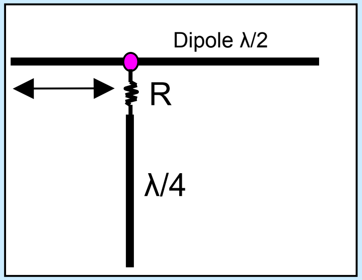


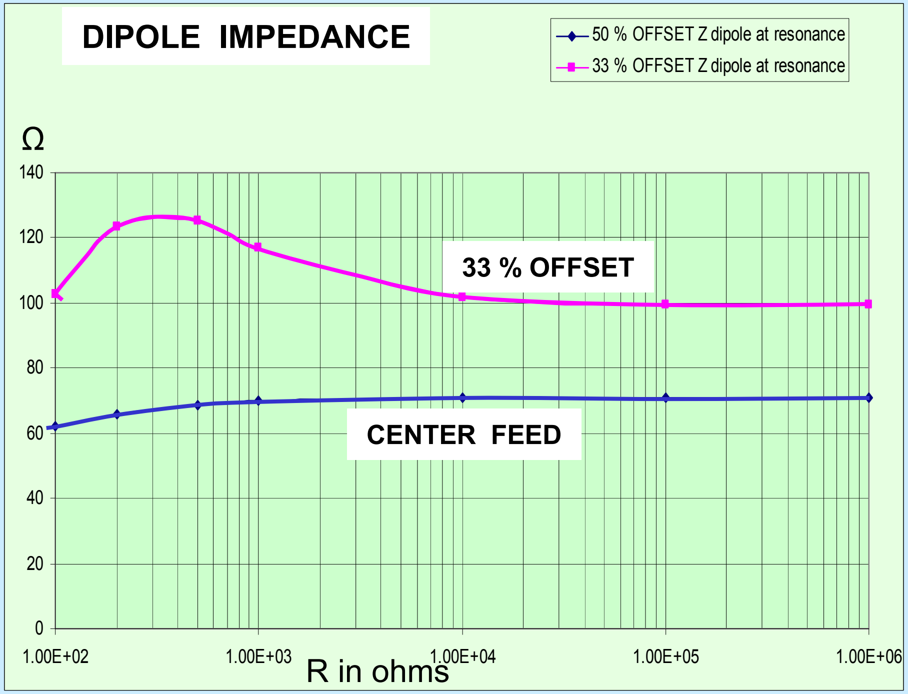
What is the minimum value of
Impedance that I can have …

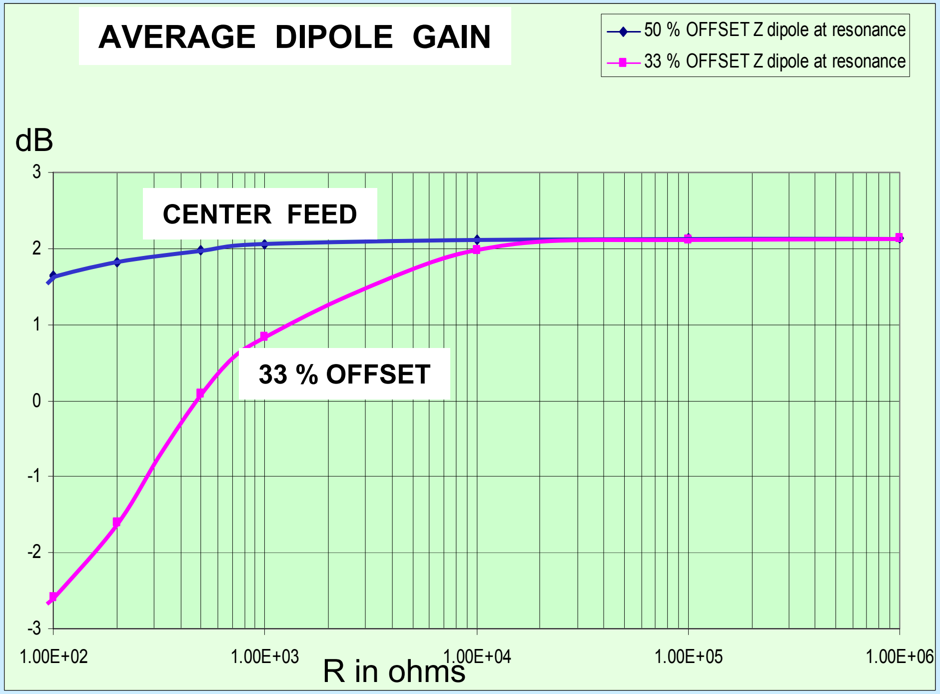
That will have little effect on
the <u>gain</u> and <u>impedance</u> of
the dipole antenna ?

CURRENT BALUNS

Feeding a dipole with a coaxial cable





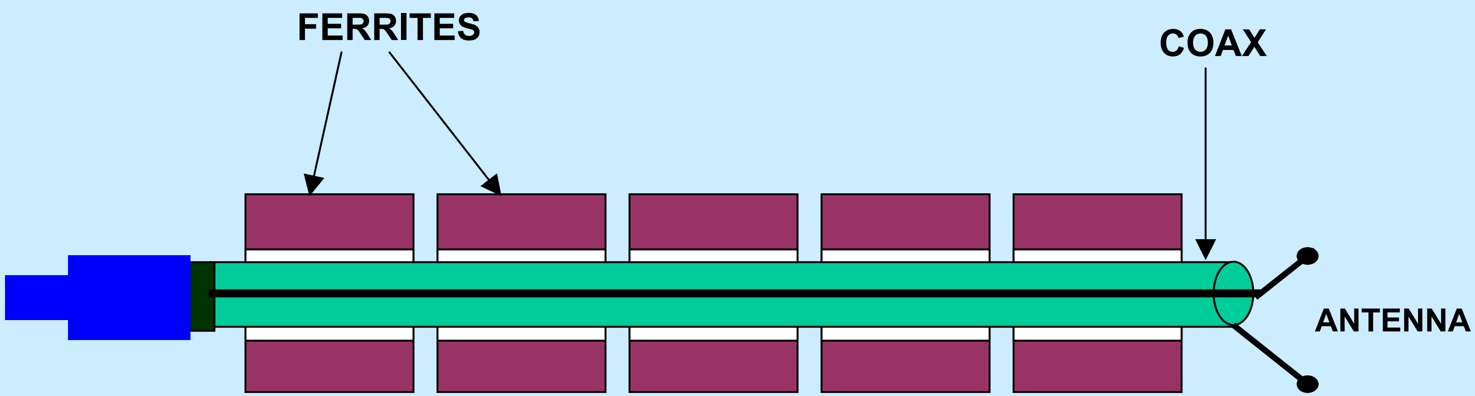


If feeding at the center (50%): R > 1000 ohms
If feeding at 33% from end: R > 10000 ohms

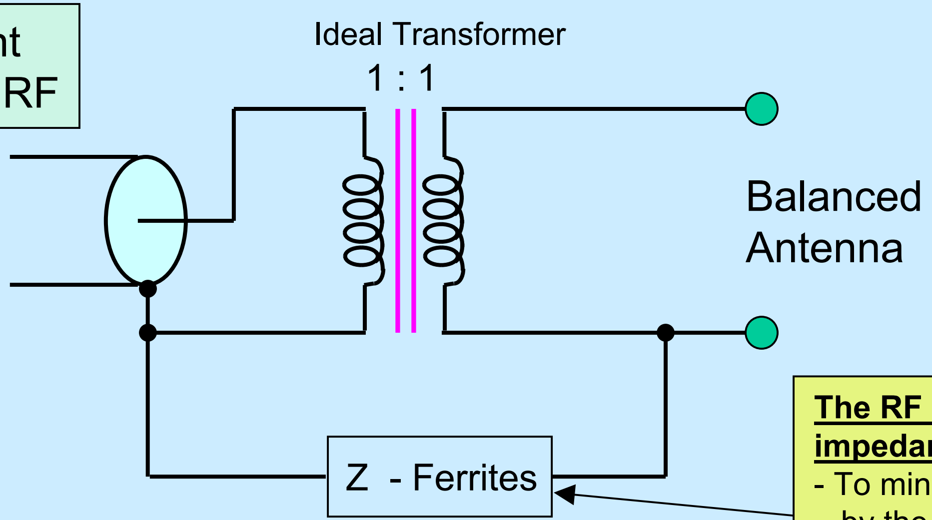
It's easier to feed at the center

CURRENT BALUNS

1:1 CURRENT BALUN



Equivalent Circuit at RF



<u>The RF resistance caused by the ferrite impedance should be high (> 1000 ohms)</u>

- To minimize the RF transmitted and received by the feeder.
- Minimize temperature increase in the ferrite at high power by using Z ferrite > 5000 ohms.

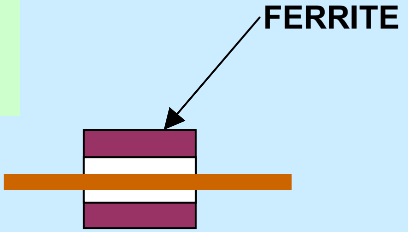
FERRITE IMPEDANCE

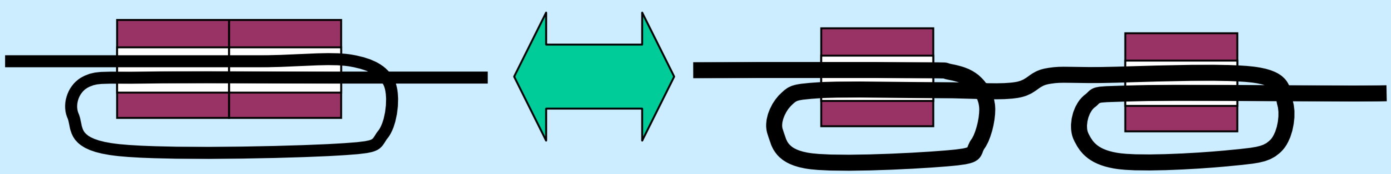
DEPENDS ON…

- MATERIAL
- LENGTH
- VOLUME OF MATERIAL
- VARIES WITH FREQUENCY
- **TO CALCULATE THE IMPEDANCE Z: (approx.)**

  IMPEDANCE OF ONE TURN FOR ONE FERRITE
  multiplied by…
  NUMBER OF FERRITES
  multiplied by …
  (NUMBER OF TURNS) squared

- NOTE: 1 TURN = FERRITE ON A STRAIGHT WIRE





8X Impedance

8X Impedance

FERRITE IMPEDANCE

- **FERRITES VS IRON POWDER … TWO DIFFERENT MATERIALS**

- **FERRITE**: HAS A HIGH PERMEABILITY (10 to 15000)
GIVING A HIGH INDUCTANCE FOR A SMALL NUMBER OF TURNS

BUT THE INDUCTANCE OBTAINED IS NOT STABLE AND Q FACTOR IS LOW

OK FOR TRANSFORMERS AND BALUNS

- **IRON POWDER**: LOWER PERMEABILITY … LOWER INDUCTANCE,
GIVES A STABLE, HIGH Q INDUCTANCE (EX.: VFO, FILTERS, TUNERS)

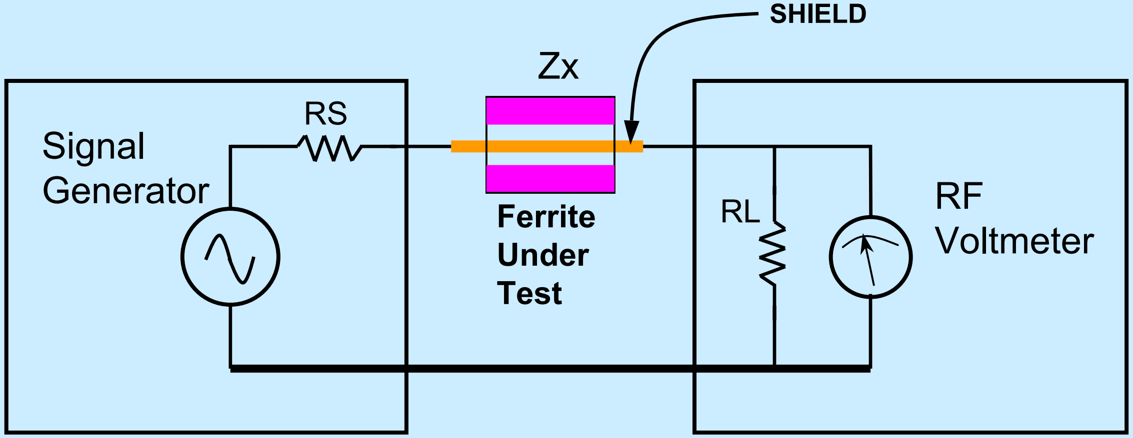
EXAMPLE: AMIDON -> FERRITES and IRON POWDER

PART # - EXAMPLE: FT240-43
FT: FERRITE
240: External diam in inches X 100 (here 2.4 in.)
43: TYPE OF FERRITE, PERMEABILITY = 850

IMPEDANCE MEASUREMENTS

FREQUENCY RESPONSE MODE

- Does NOT allow measuring separately the Resistive and Inductive components
- Ease of sweeping the frequency
- Reference level = 0 dB = short in place of ferrite



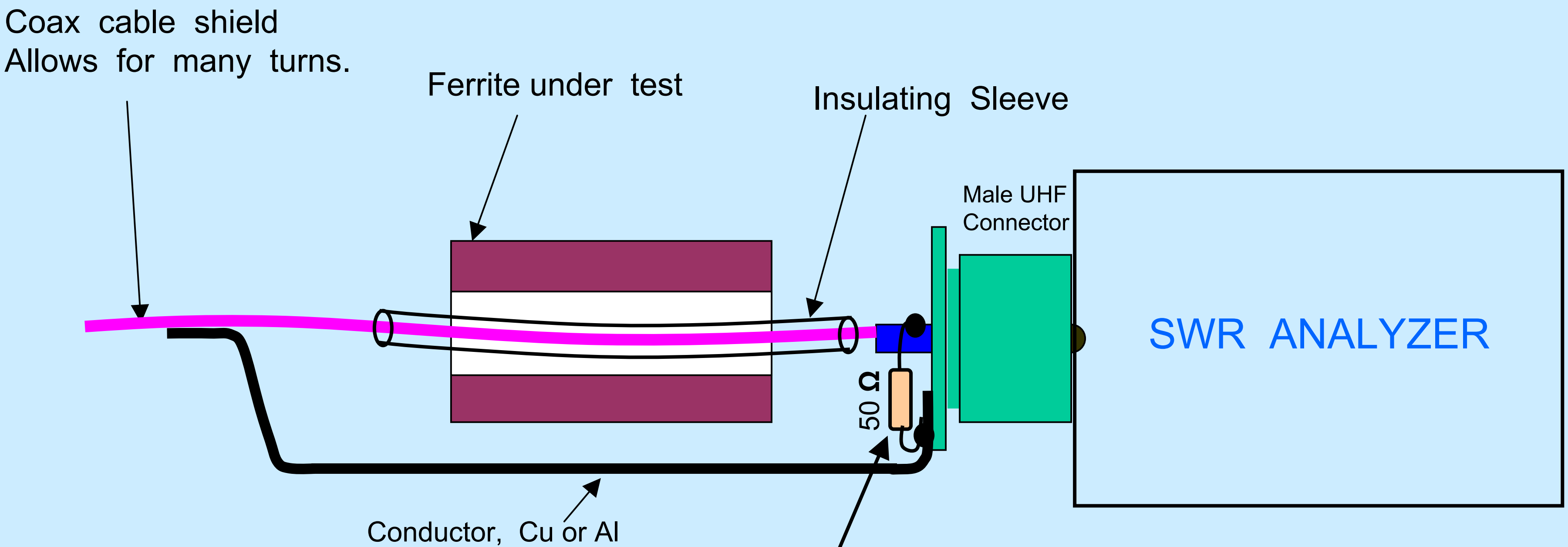
RS and RL are generally 50 ohms

To calculate Zx from attenuation readings in + dB's:
(assumes that Zx is resistive)

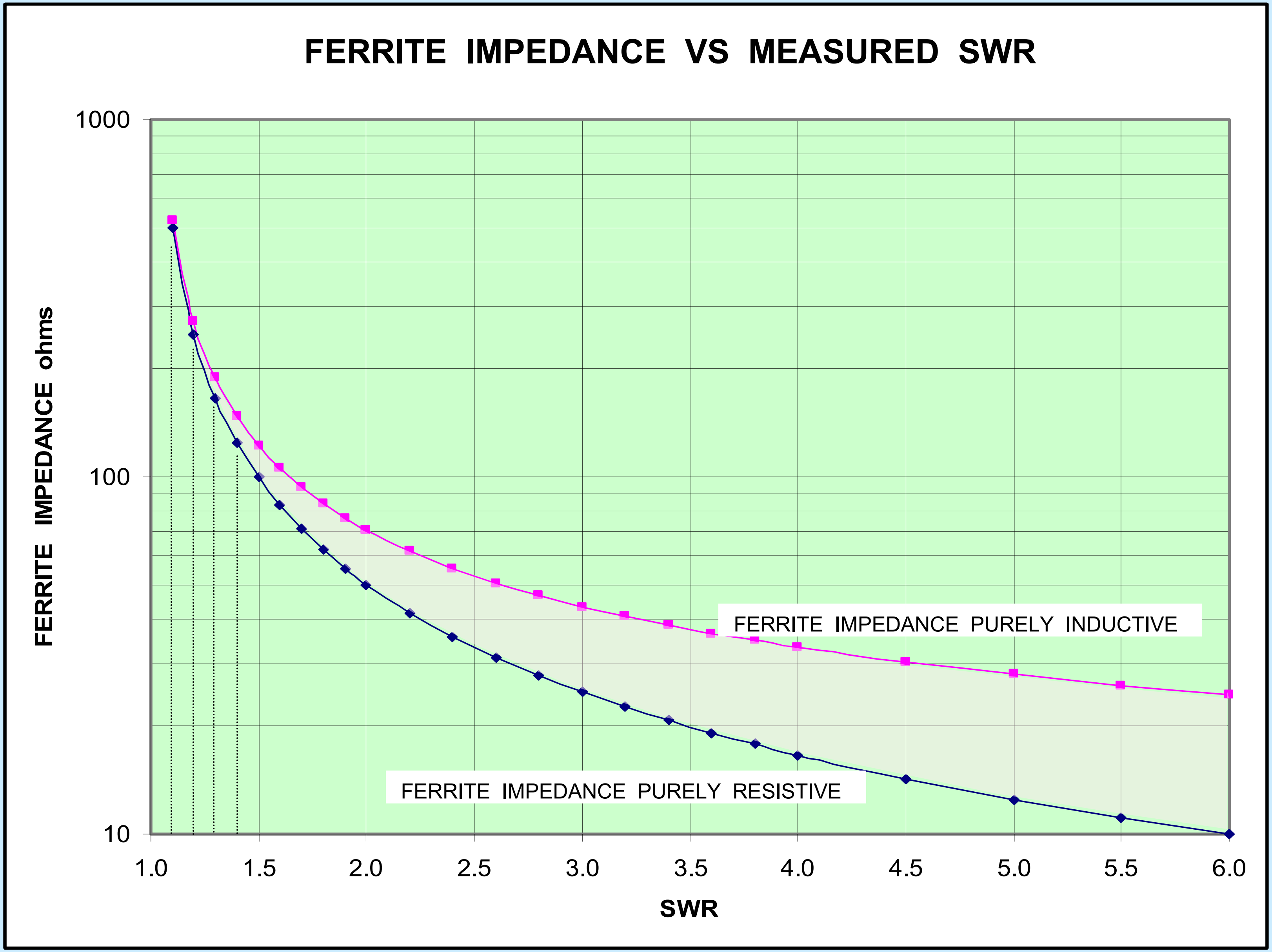
$$Zx = (RL + RS) \cdot \left(10^{\left[\frac{dB}{20}\right]} - 1\right)$$

CHECK YOUR FERRITES WITH YOUR SWR ANALYZER

FROM SWR MEASUREMENTS



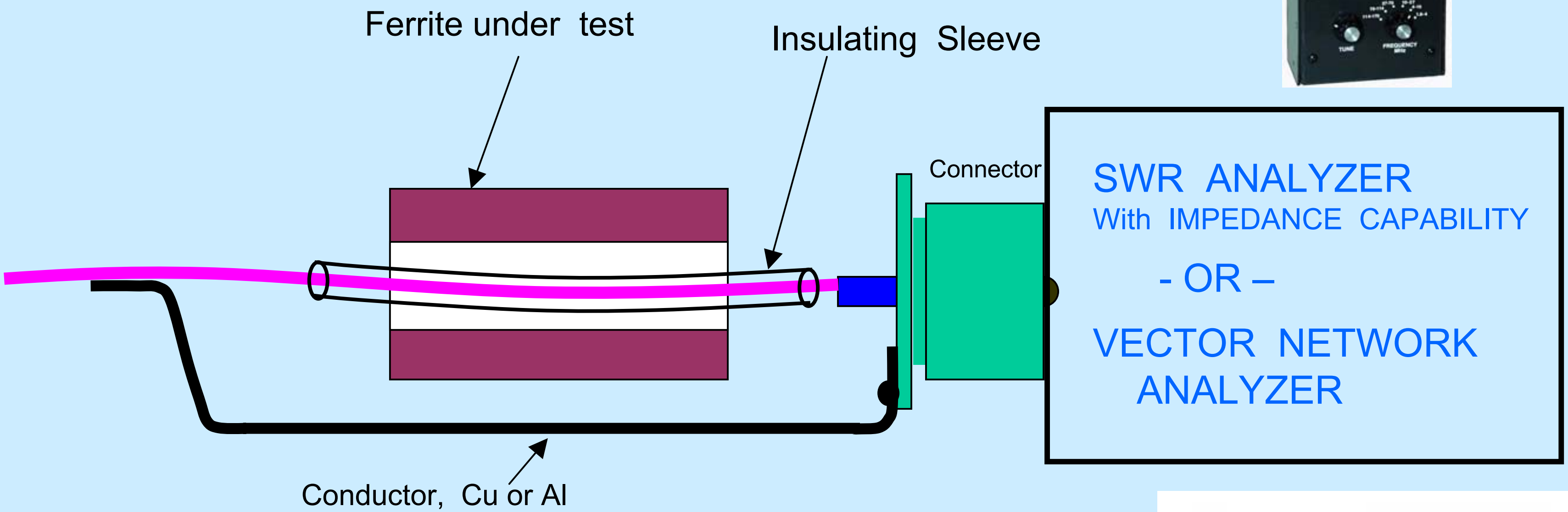
The ferrite is in parallel with the 50 ohms (1%) termination


FERRITE IMPEDANCE VS MEASURED SWR
1000
100
10
FERRITE IMPEDANCE ohms
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
SWR
FERRITE IMPEDANCE PURELY INDUCTIVE
FERRITE IMPEDANCE PURELY RESISTIVE

MEASUREMENT OF FERRITE IMPEDANCE

USING AN SWR ANALYZER OR A VECTOR NETWORK ANALYZER

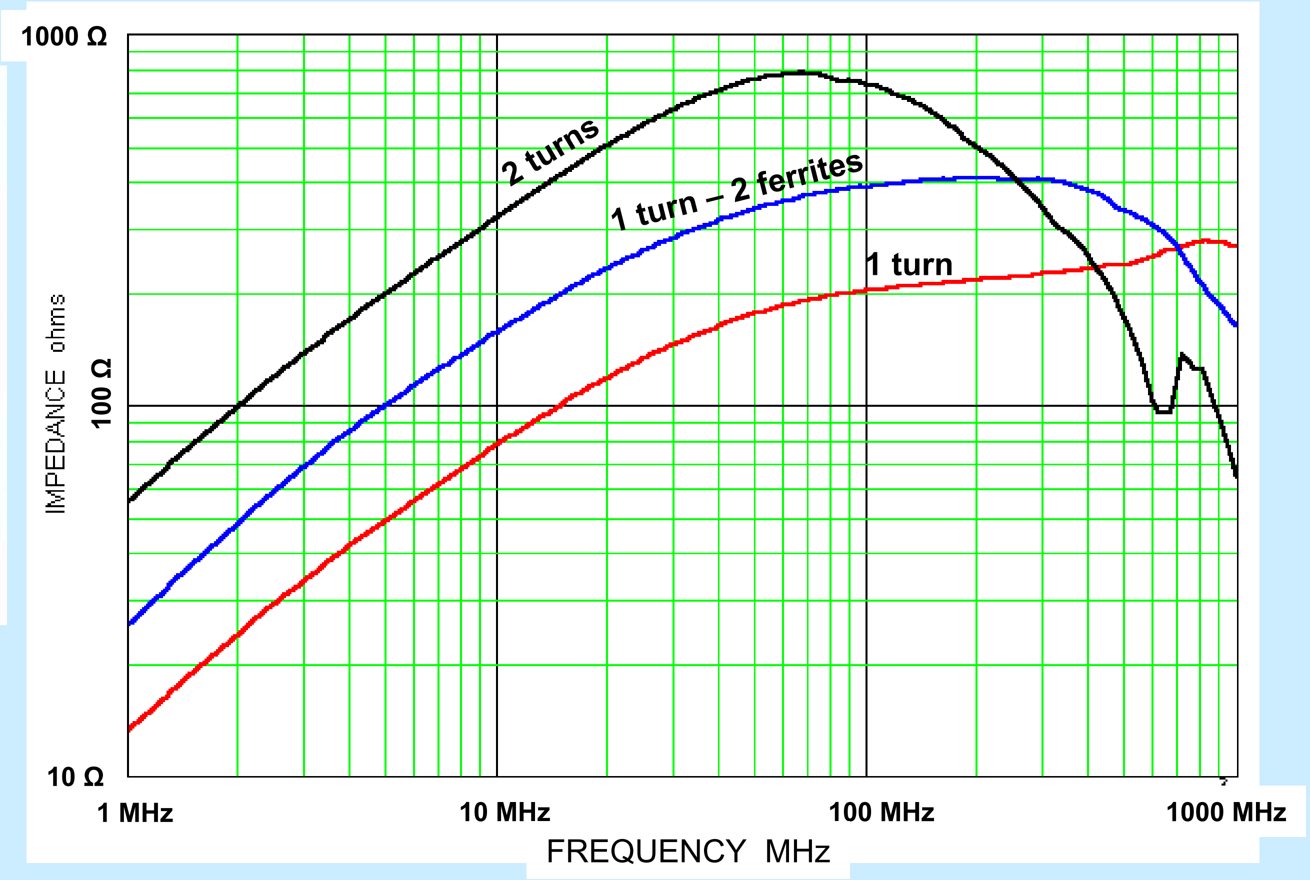
Allow measuring separately the Resistive and Inductive Components



VE2AZX

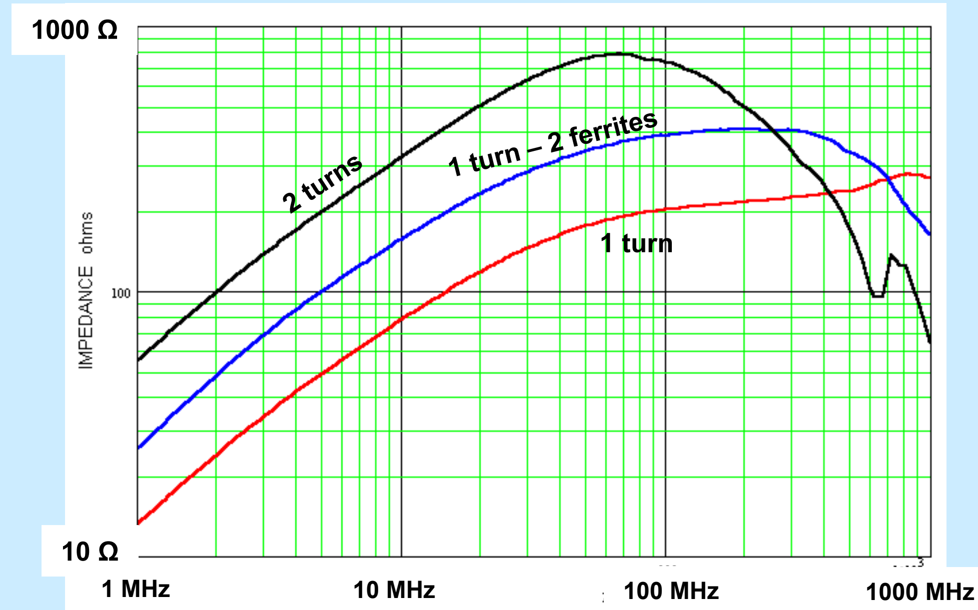
IMPEDANCE MEASUREMENTS

CLAMP ON FERRITE
FOR RG-8

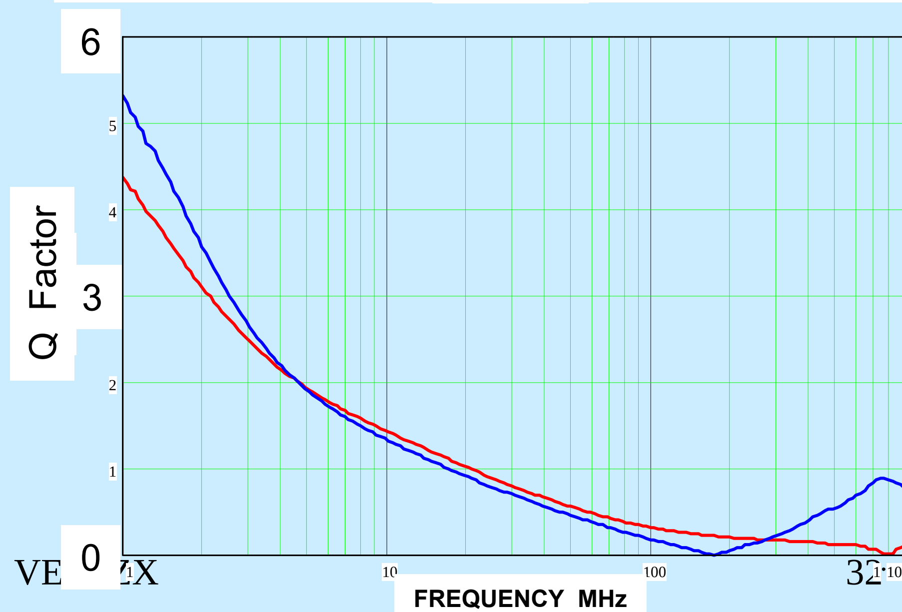


YIELDS 80 ohms at 10 MHz for 1 turn

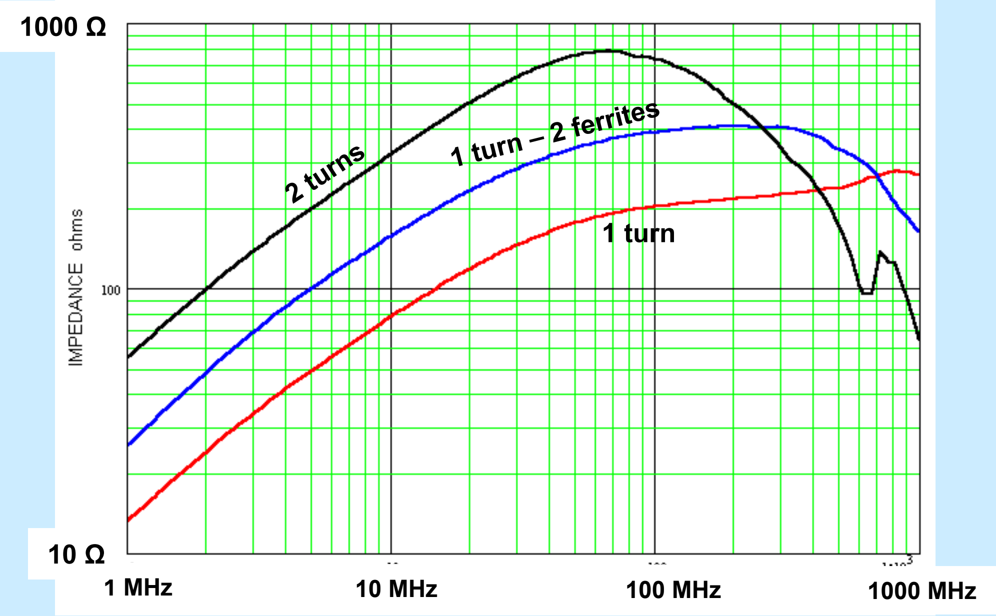
IMPEDANCE MEASUREMENTS

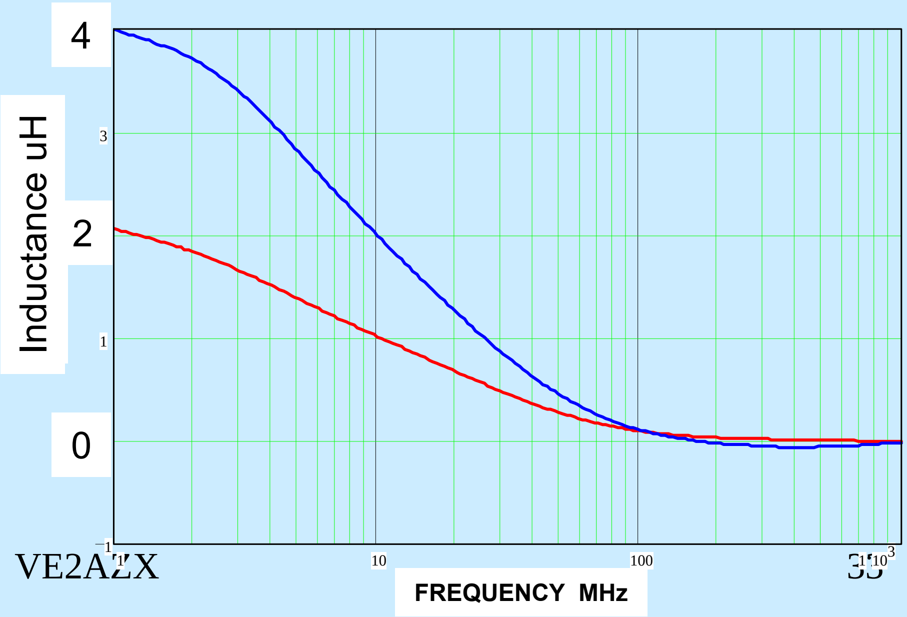


- ABOVE 20 MHz THE Q FACTOR < 1
THE IMPEDANCE BECOMES RESISTIVE



IMPEDANCE MEASUREMENTS

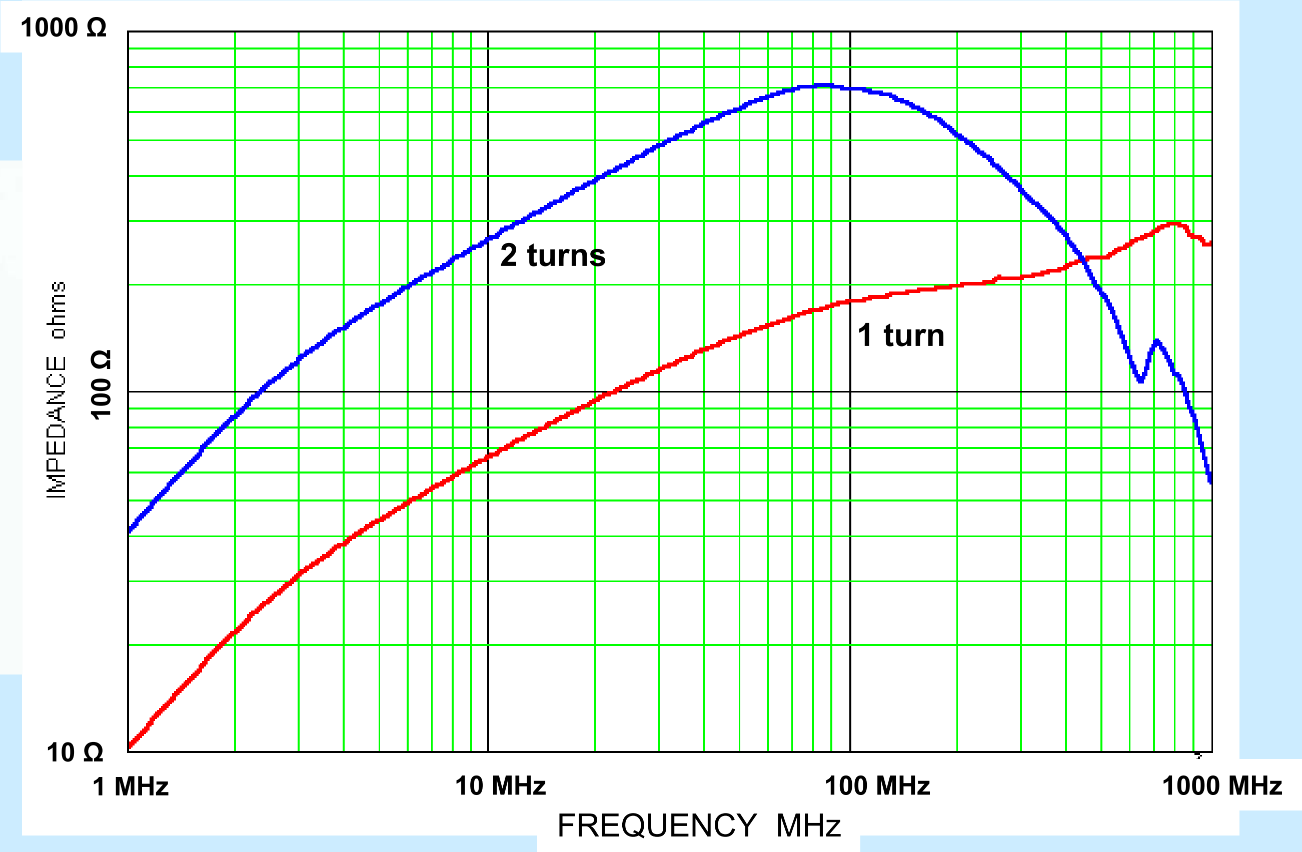




- THE INDUCTANCE DECREASES AS THE FREQUENCY IS INCREASED

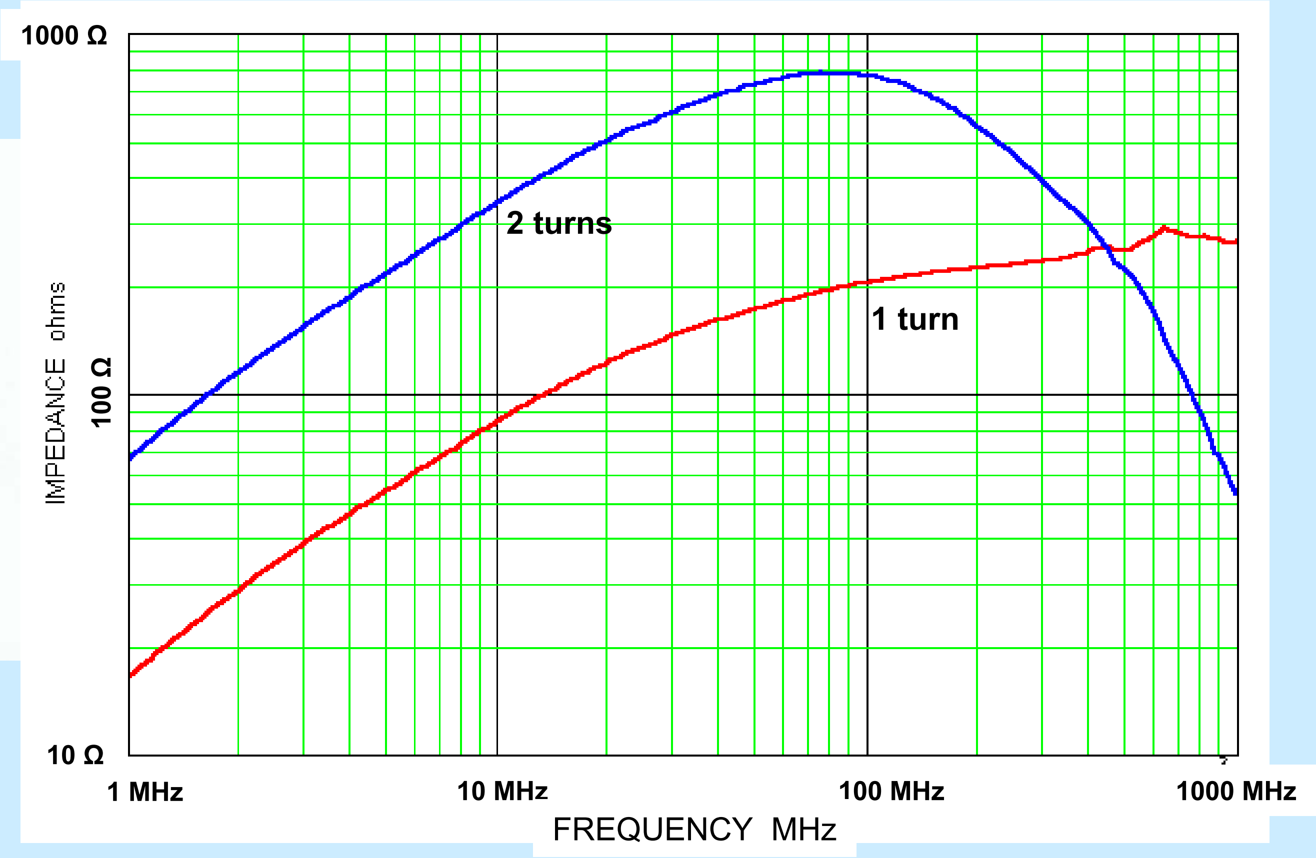
- THE INDUCTANCE DISAPPEARS WHEN F > 100 MHz

IMPEDANCE MEASUREMENTS



- THIS IMPEDANCE CURVE IS SIMILAR TO THE PREVIOUS CORE

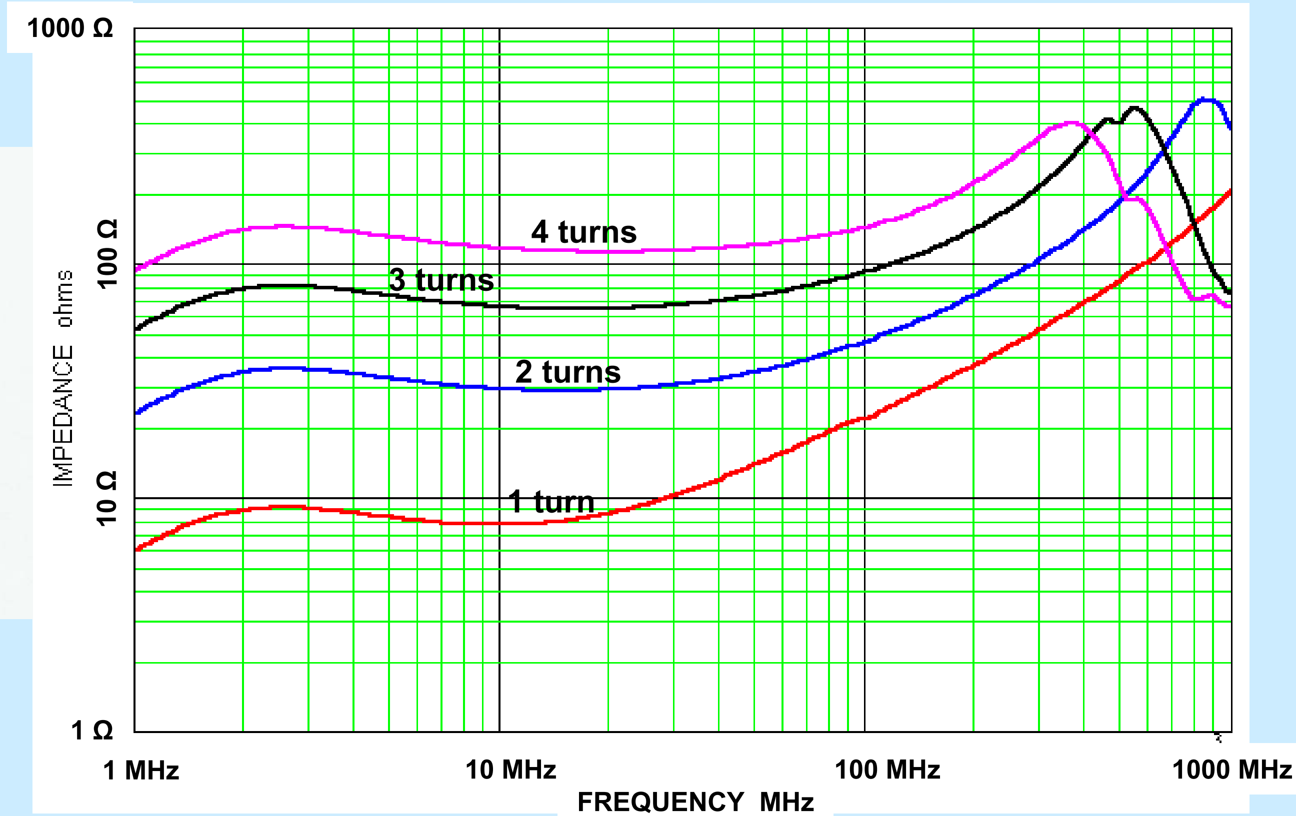
IMPEDANCE MEASUREMENTS



- THIS IMPEDANCE CURVE IS SIMILAR TO THE PREVIOUS CORE

IMPEDANCE MEASUREMENTS

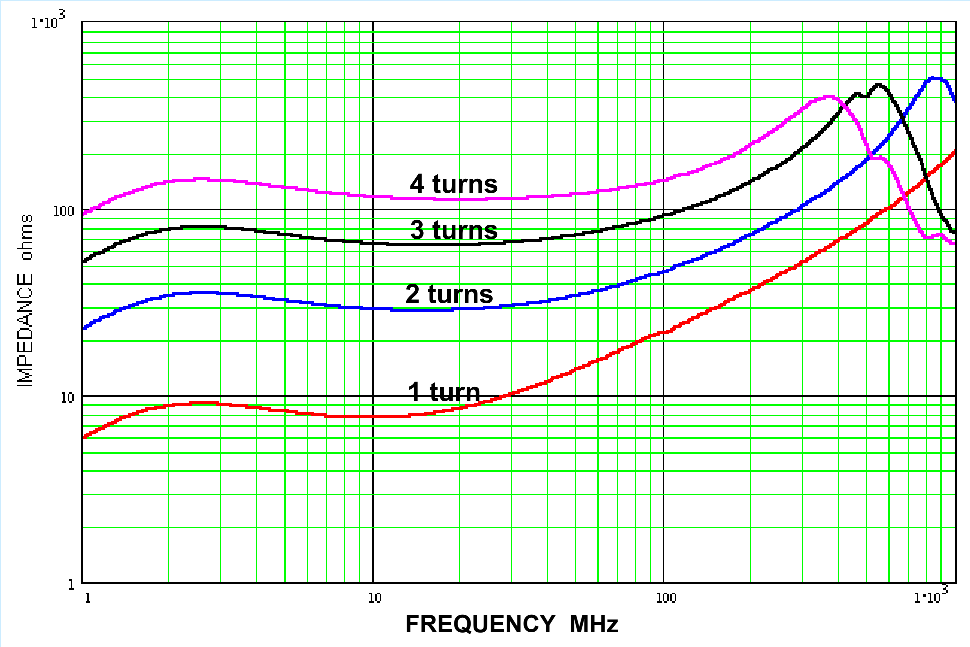
RECTANGULAR
CLAMP-ON FERRITE

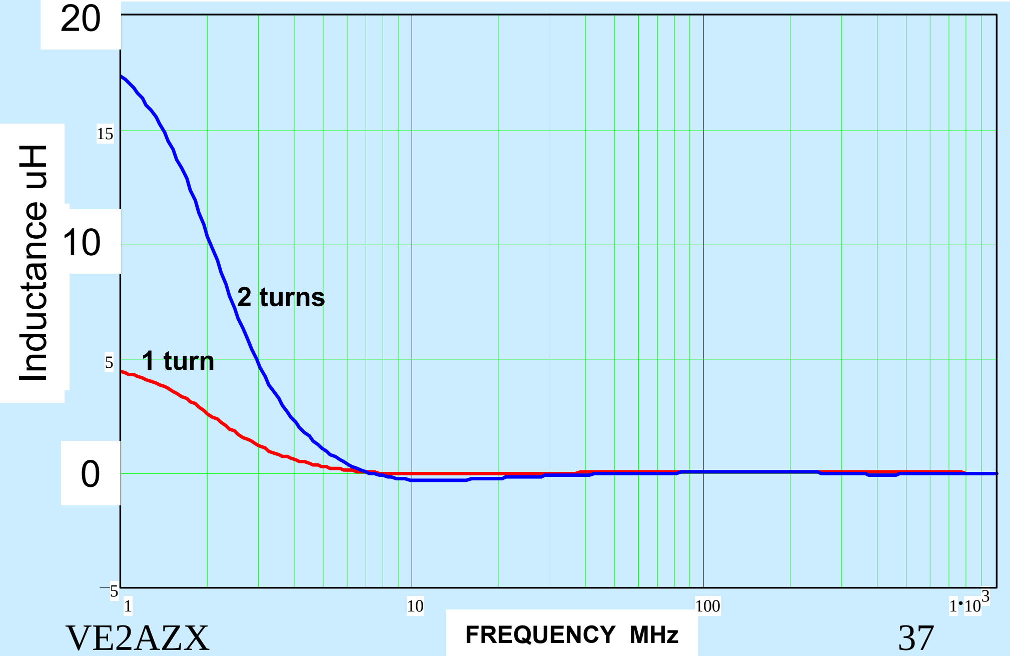


- GIVES ~ 10% IMPEDANCE OF PREVIOUS CORES (8 ohms at 10 MHz for 1 turn)
- COVERS MUCH WIDER FREQUENCY RANGE
- SHOULD USE MANY TURNS: 10 TURNS GIVE 800 ohms AT 10 MHz

IMPEDANCE MEASUREMENTS

RECTANGULAR
CLAMP-ON FERRITE

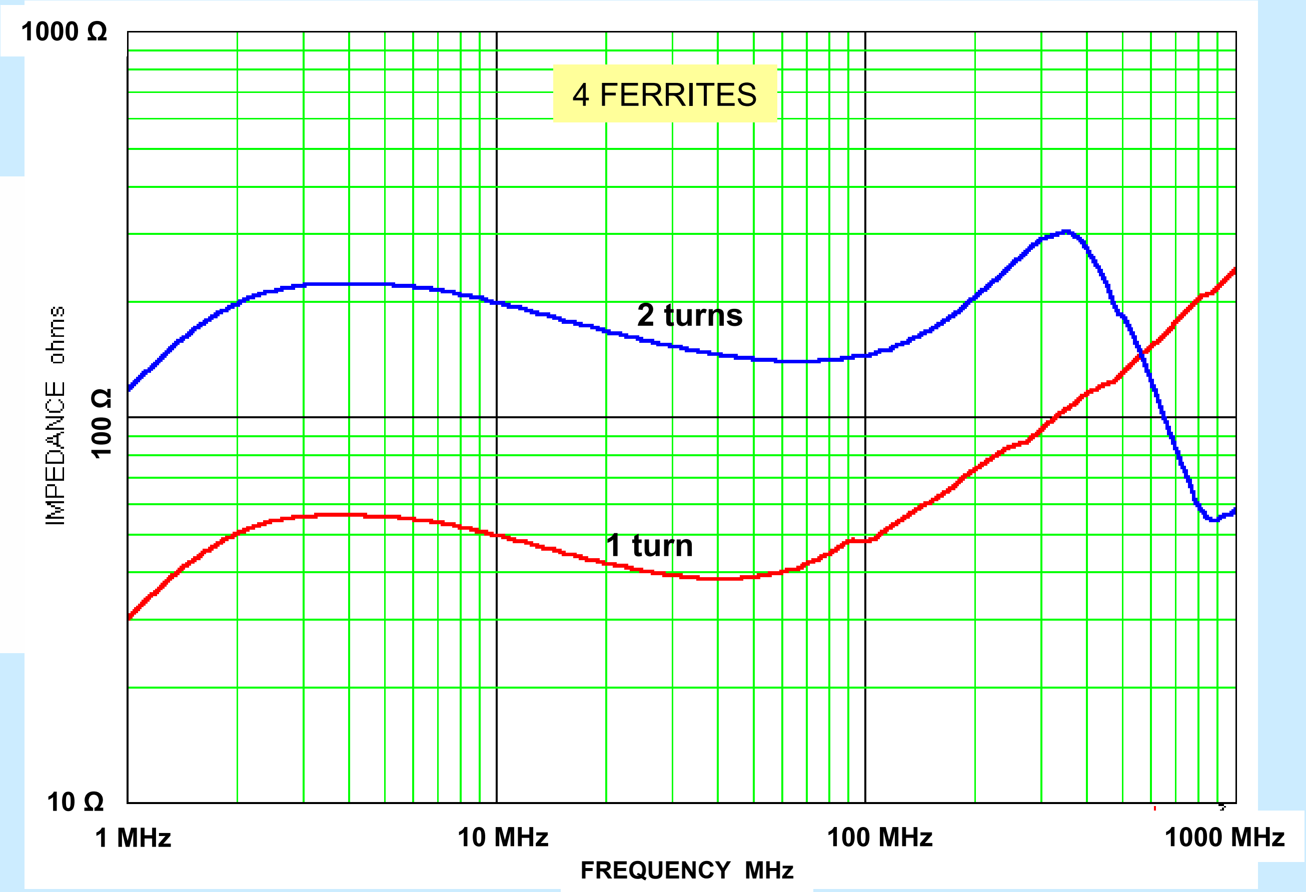




- THE INDUCTANCE DISAPPEARS ABOVE 6 MHz

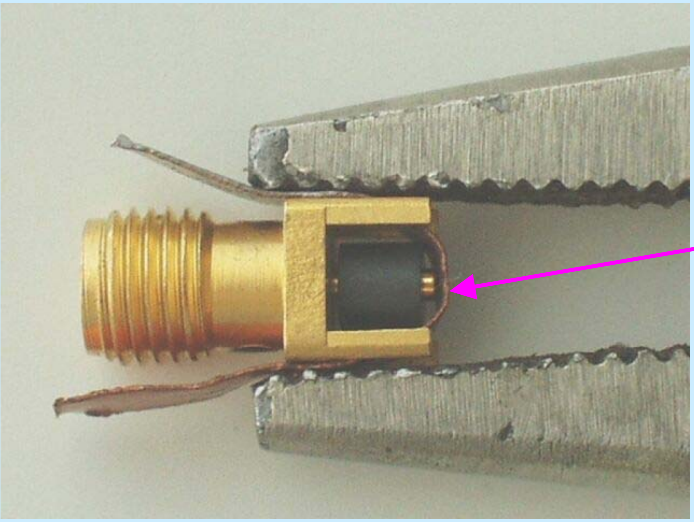
IMPEDANCE MEASUREMENTS

STACKED
RECTANGULAR
CLAMP-ON FERRITE



4 TURNS WILL YIELD ~ 800 ohms

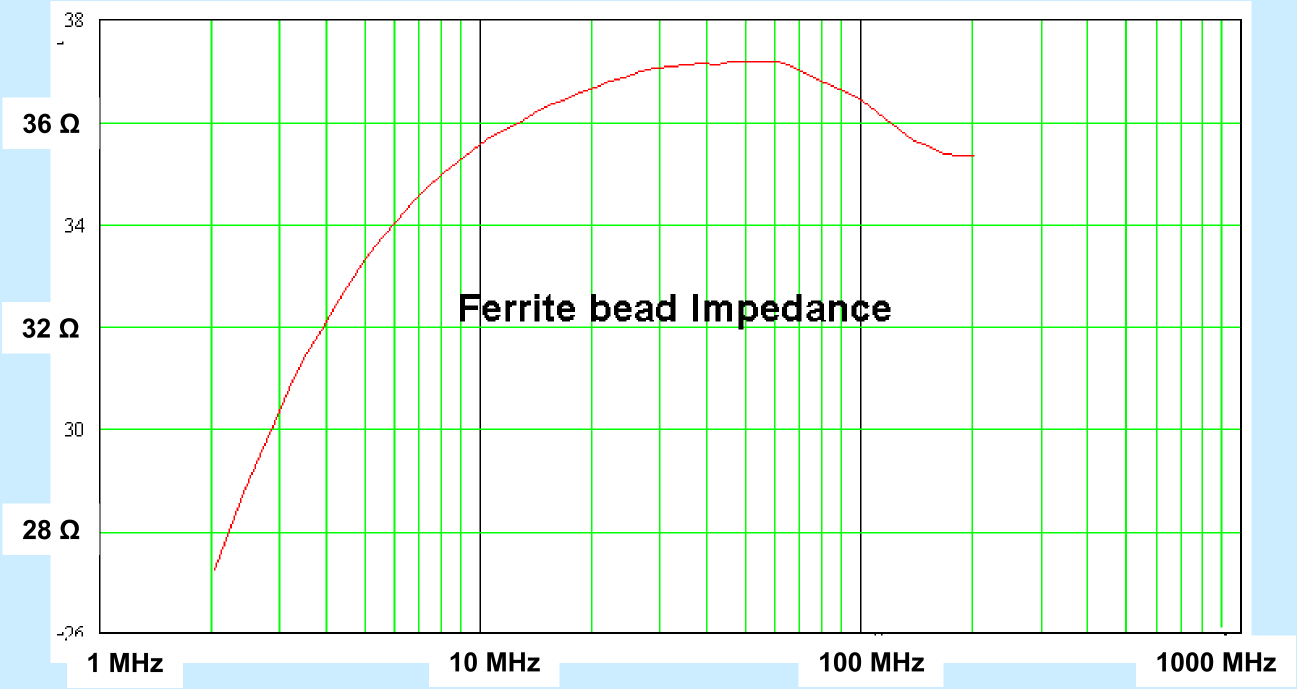
TESTING A FERRITE BEAD



FERRITE BEAD

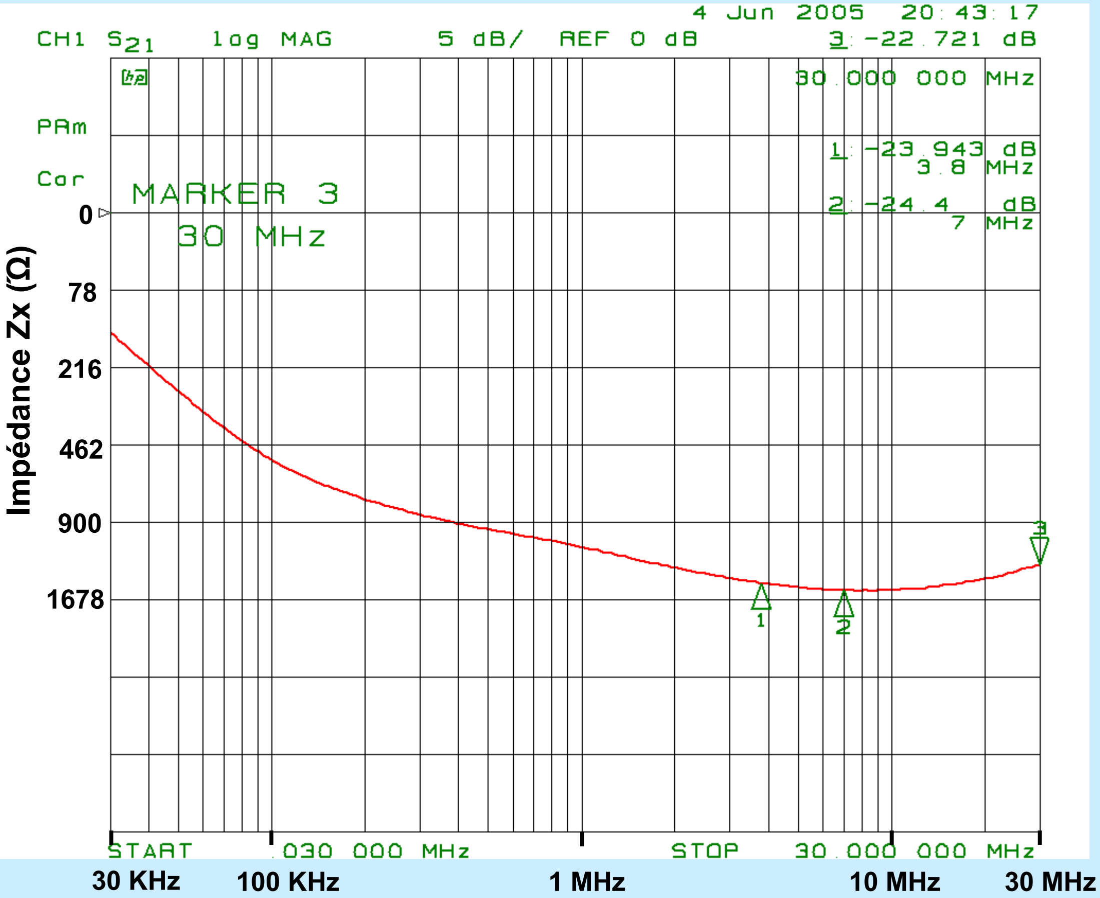
APPROX. 0.1 PO. LONG.

ohms



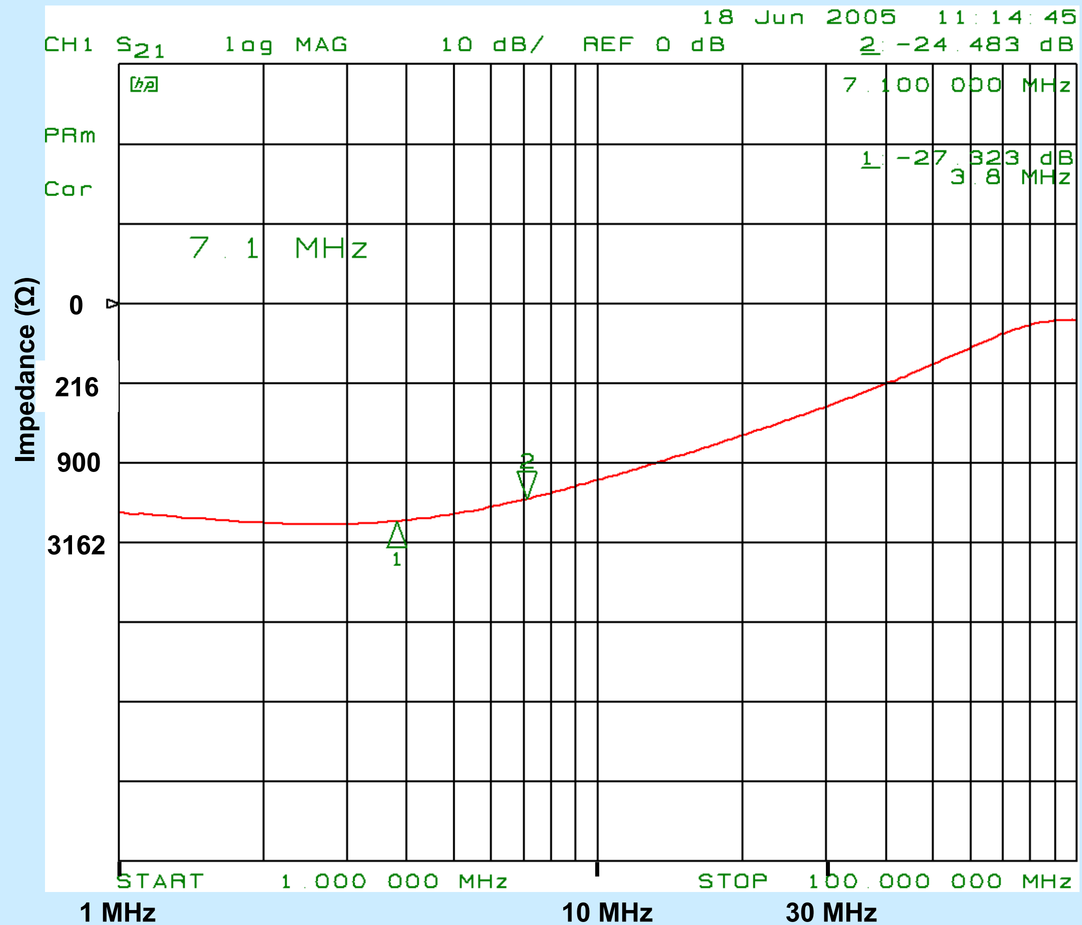
IMPEDANCE MEASUREMENTS (Done in frequency response mode)

6 toroids 4 turns



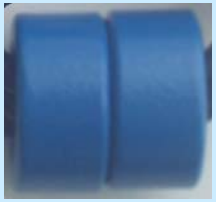
IMPEDANCE MEASUREMENTS (Done in frequency response mode)

6 toroids 6 turns

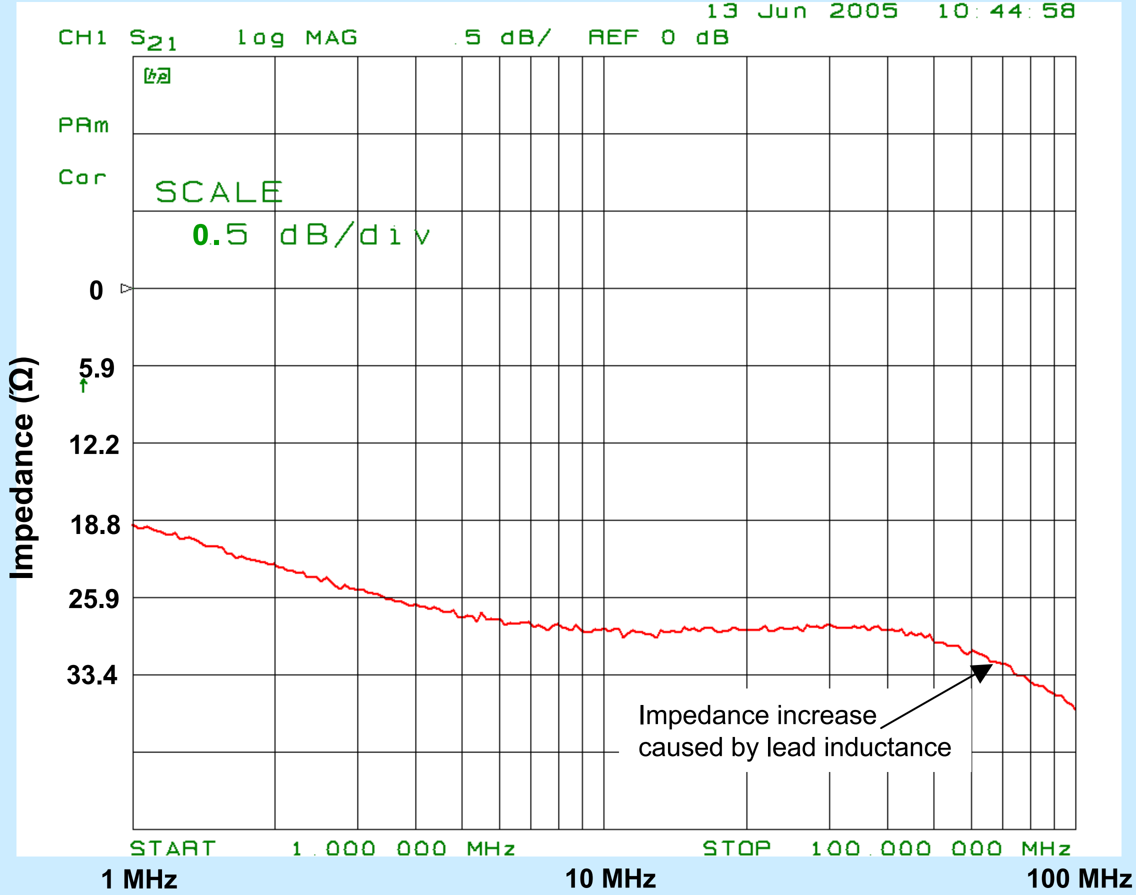


IMPEDANCE MEASUREMENTS

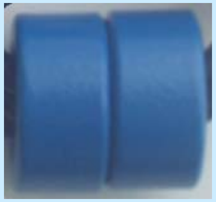
(Done in frequency response mode)



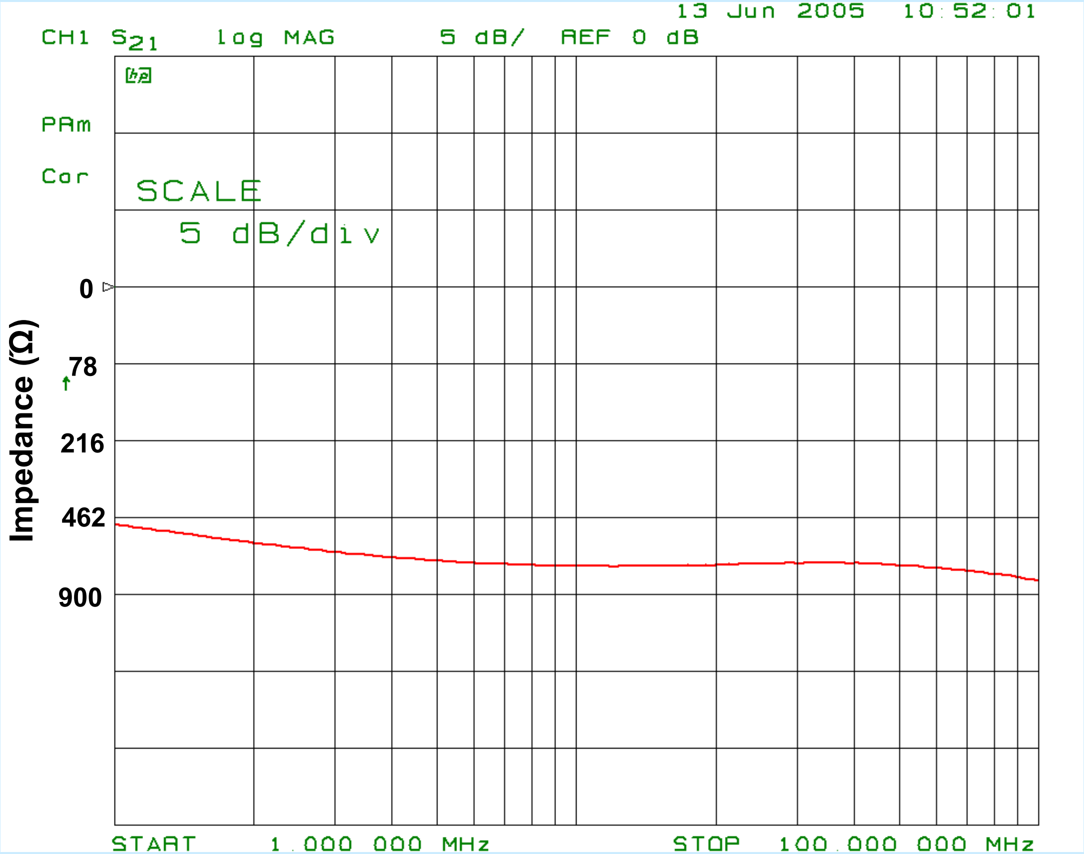
2 toroids
1 turn



IMPEDANCE MEASUREMENTS (Done in frequency response mode)



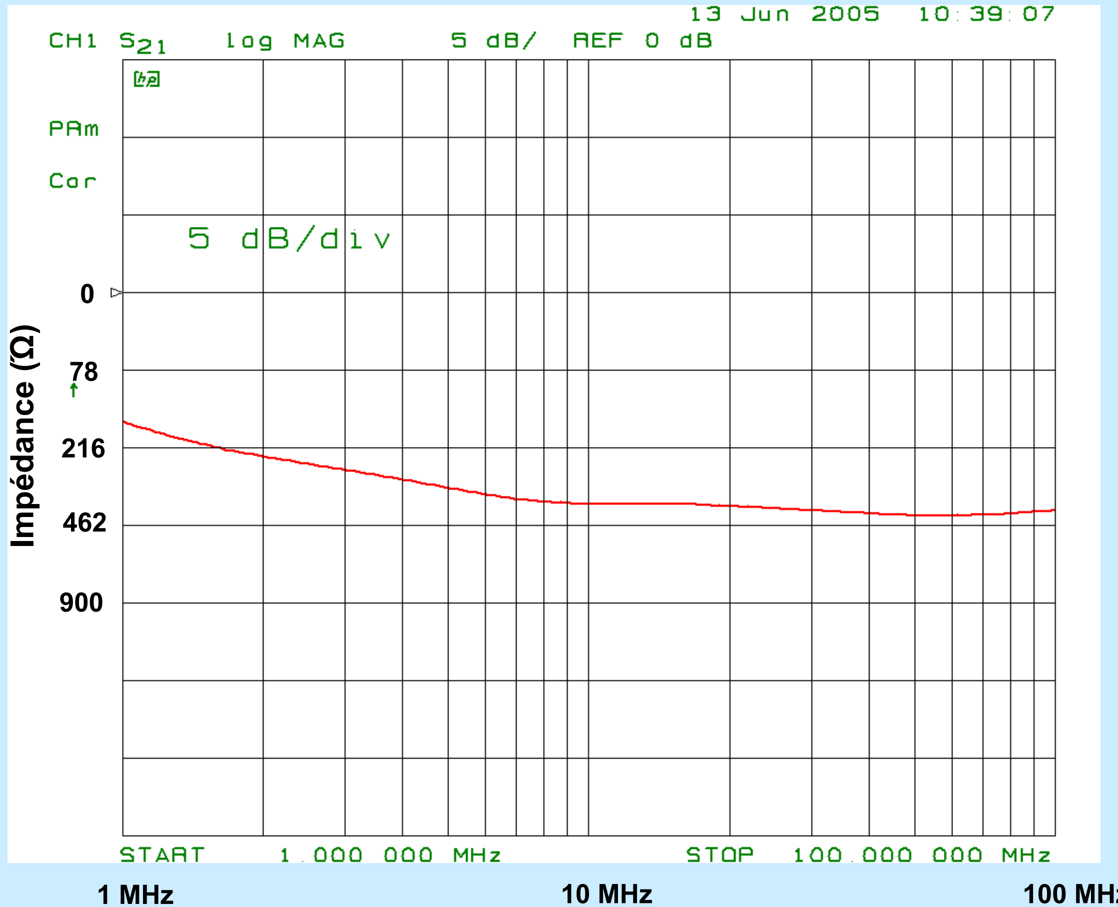
2 toroids 5 turns



IMPEDANCE MEASUREMENTS

(Done in frequency response mode)

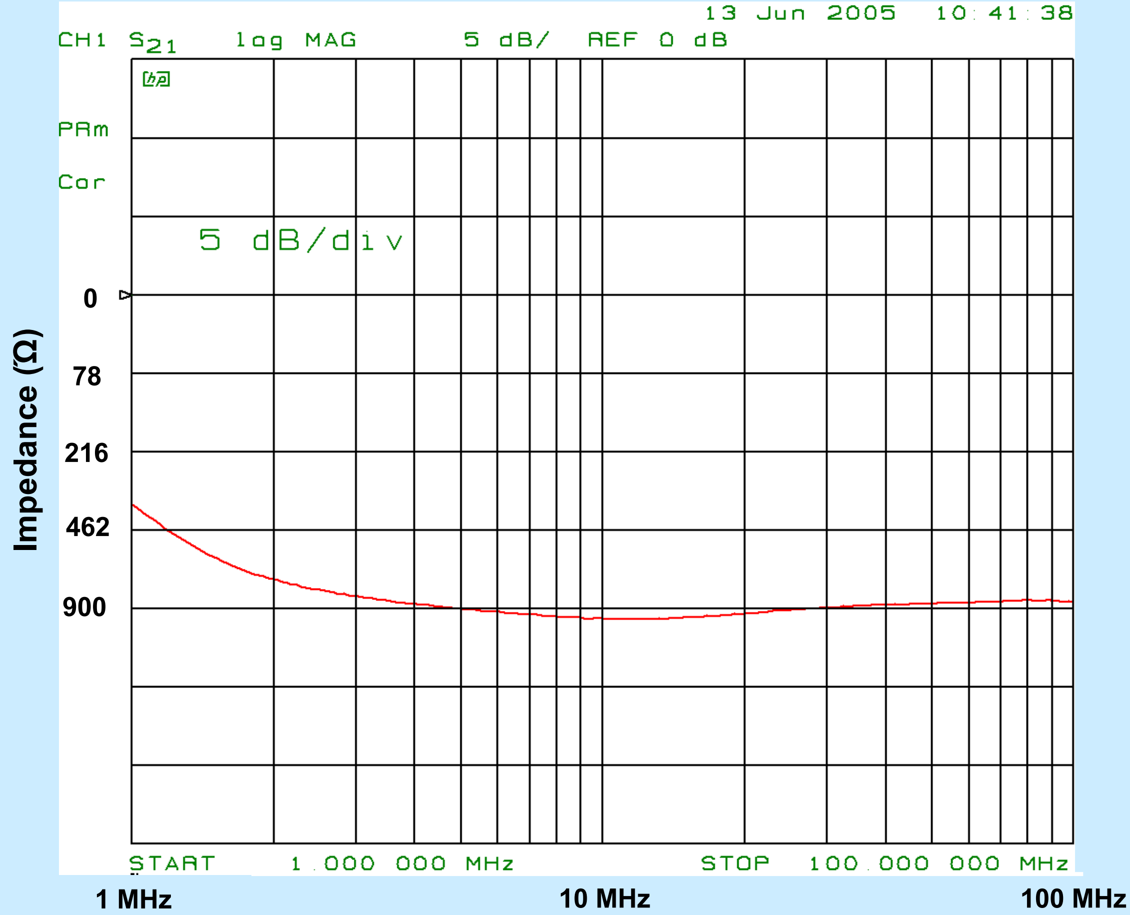
Coax with 25, #43 beads



IMPEDANCE MEASUREMENTS (Done in frequency response mode)

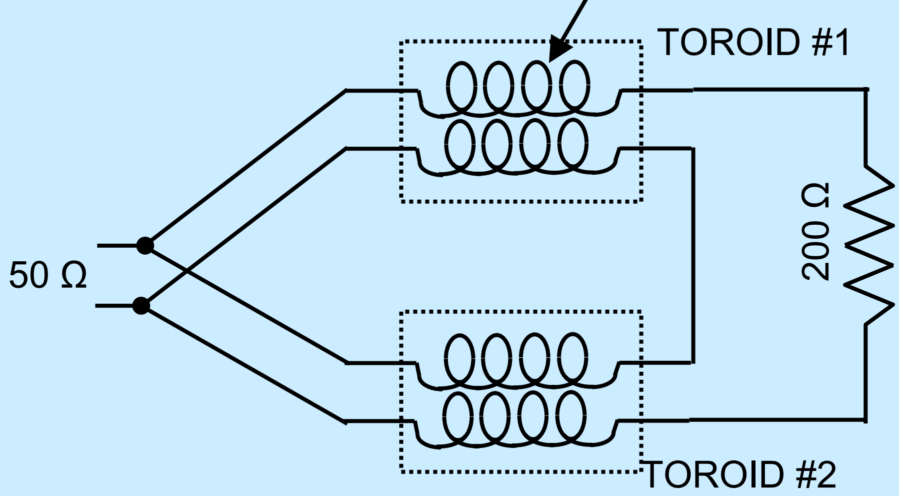
#14 Wire with 50 beads #73

Excellent at HF



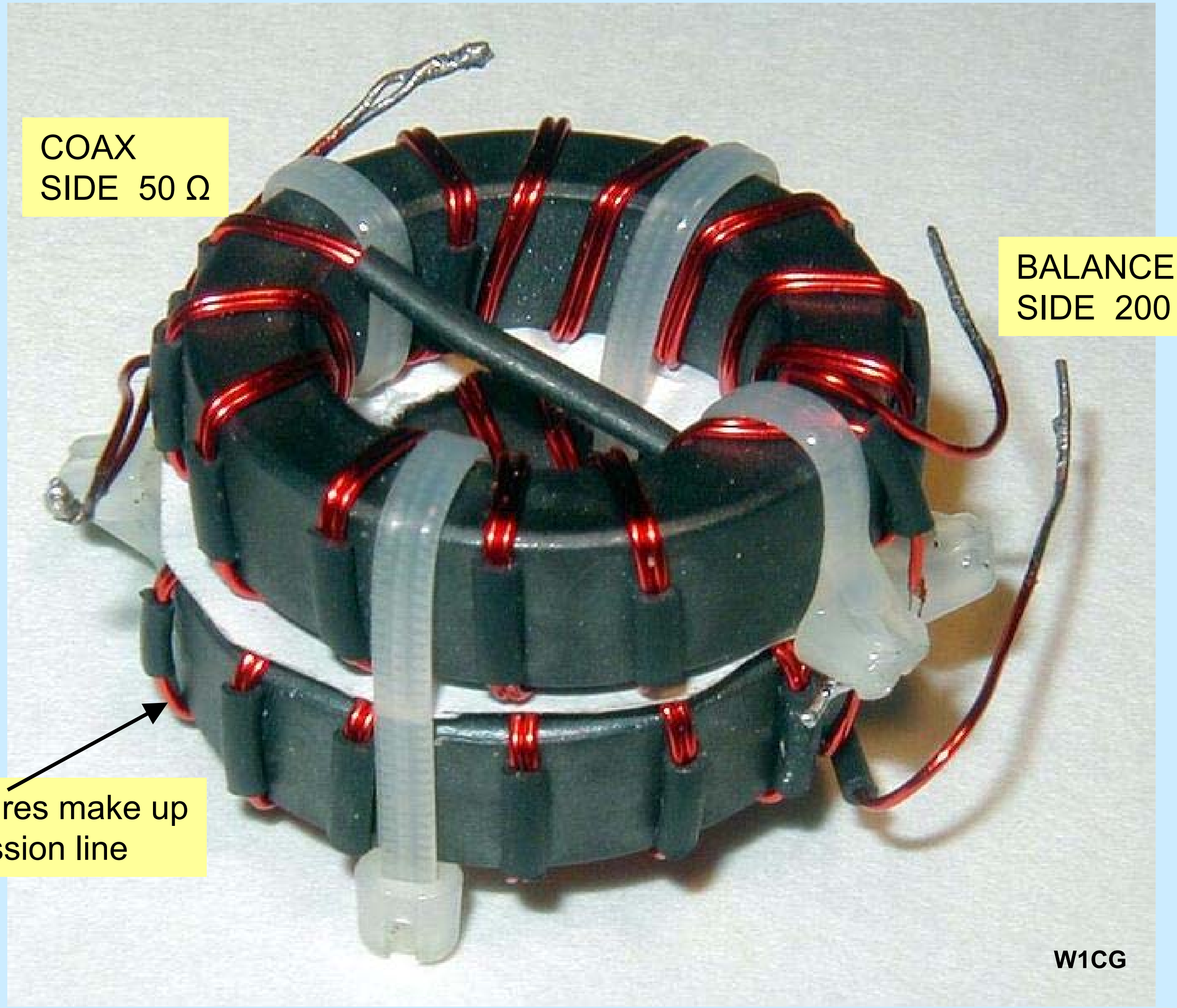
CURRENT BALUN GIVING A 4:1 IMPEDANCE RATIO

- USES 2 PARALLEL WIRES INSTEAD OF A COAX
- MAKES A COMPACT <u>TRANSMISSION LINE</u>

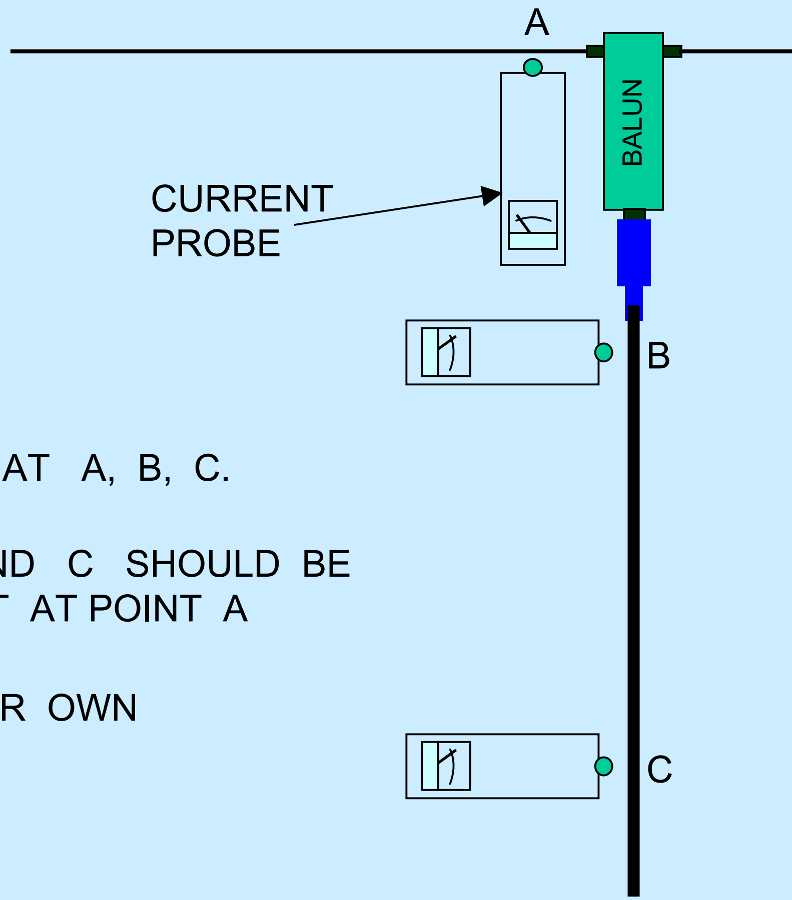


NOTE: THIS 4:1 CURRENT BALUN
IS SUPERIOR TO THE 4:1 VOLTAGE BALUN

CURRENT BALUN GIVING A 4:1 IMPEDANCE RATIO



CURRENT MEASUREMENTS



MEASURE CURRENT AT A, B, C.

CURRENTS AT B AND C SHOULD BE < 10% THE CURRENT AT POINT A

YOU CAN MAKE YOUR OWN CURRENT METER

MFJ-206

FERRITES MAY BE USED WITH A VOLTAGE BALUN

- MESURE THE SHIELD CURRENT

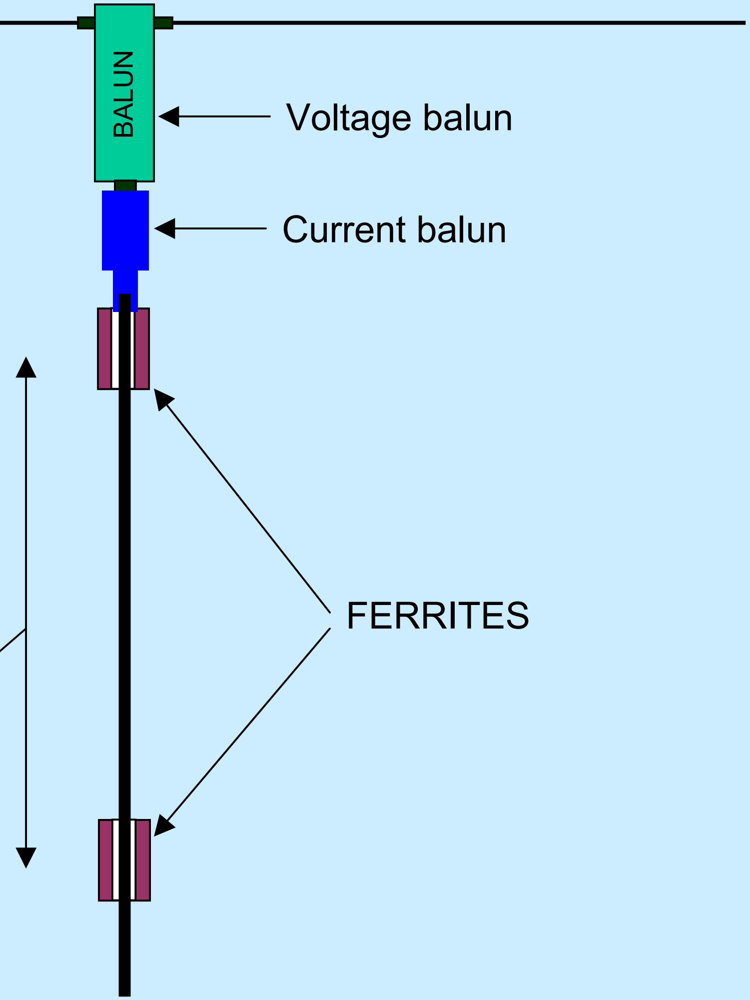
- PUT THE FERRITES AT POINTS OF MAXIMUM CURRENT

- WILL FURTHER ISOLATE THE FEEDER FROM THE ANTENNA

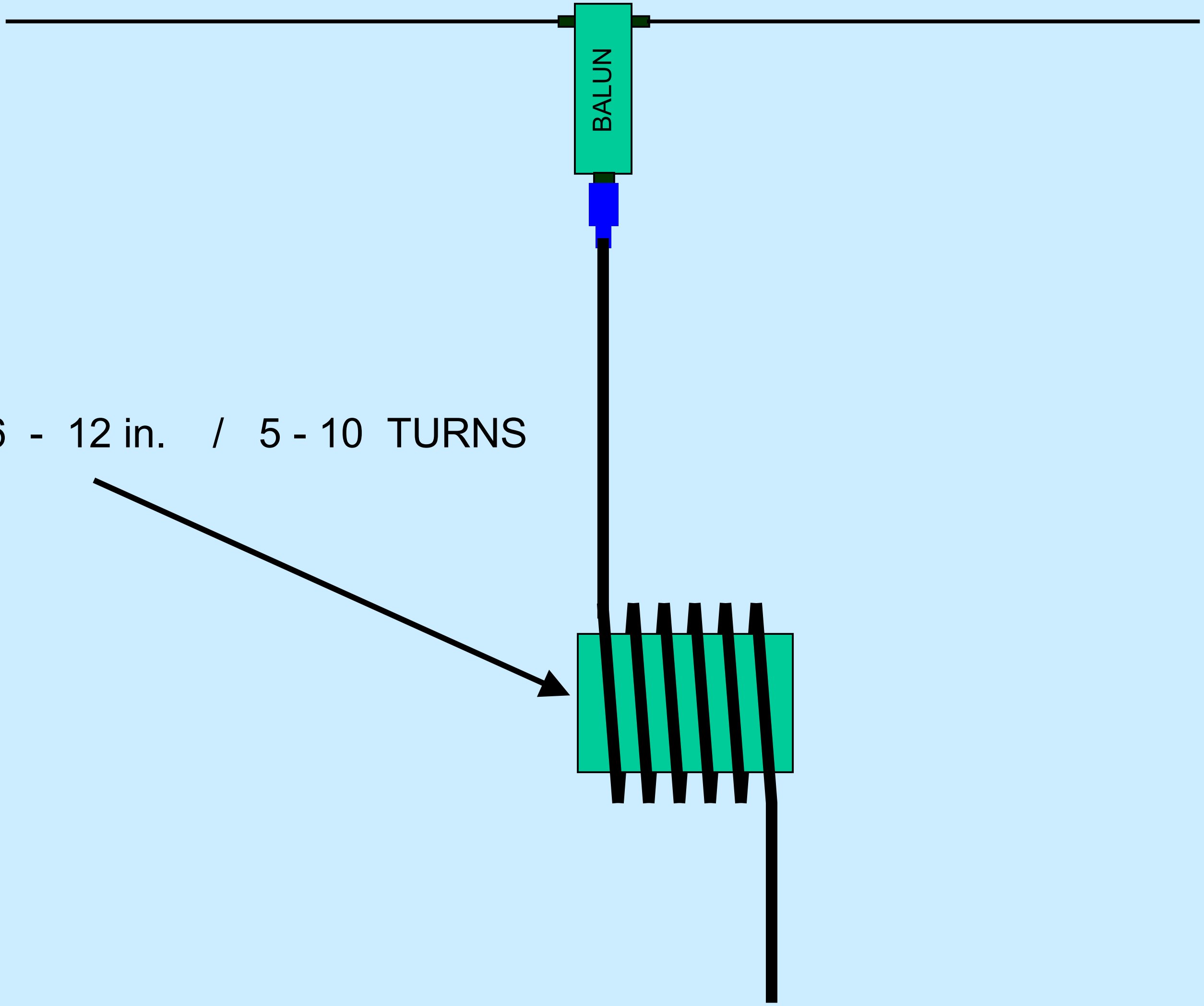
- WILL STABILIZE THE ANTENNA IMPEDANCE

- MAY REDUCE THE NOISE PICK-UP BY THE FEEDER

- USE FERRITES AT EVERY QUARTER WAVELENGTH OR AT CURRENT MAXIMA

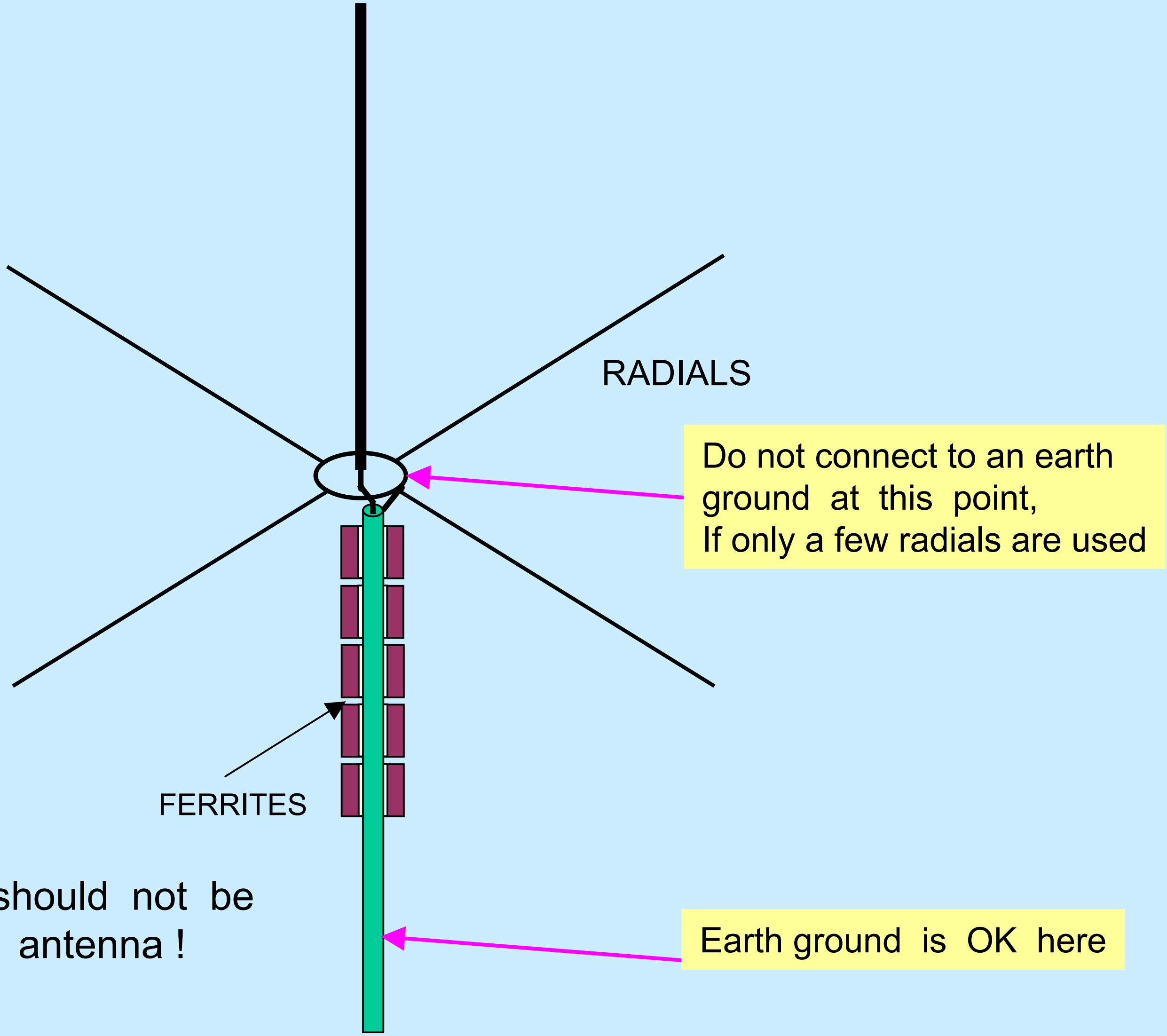


CURRENT BALUN MADE UP OF COAX CABLE



- COIL DIAMETER 6 - 12 in. / 5 - 10 TURNS

USING A BALUN ON A VERTICAL ANTENNA

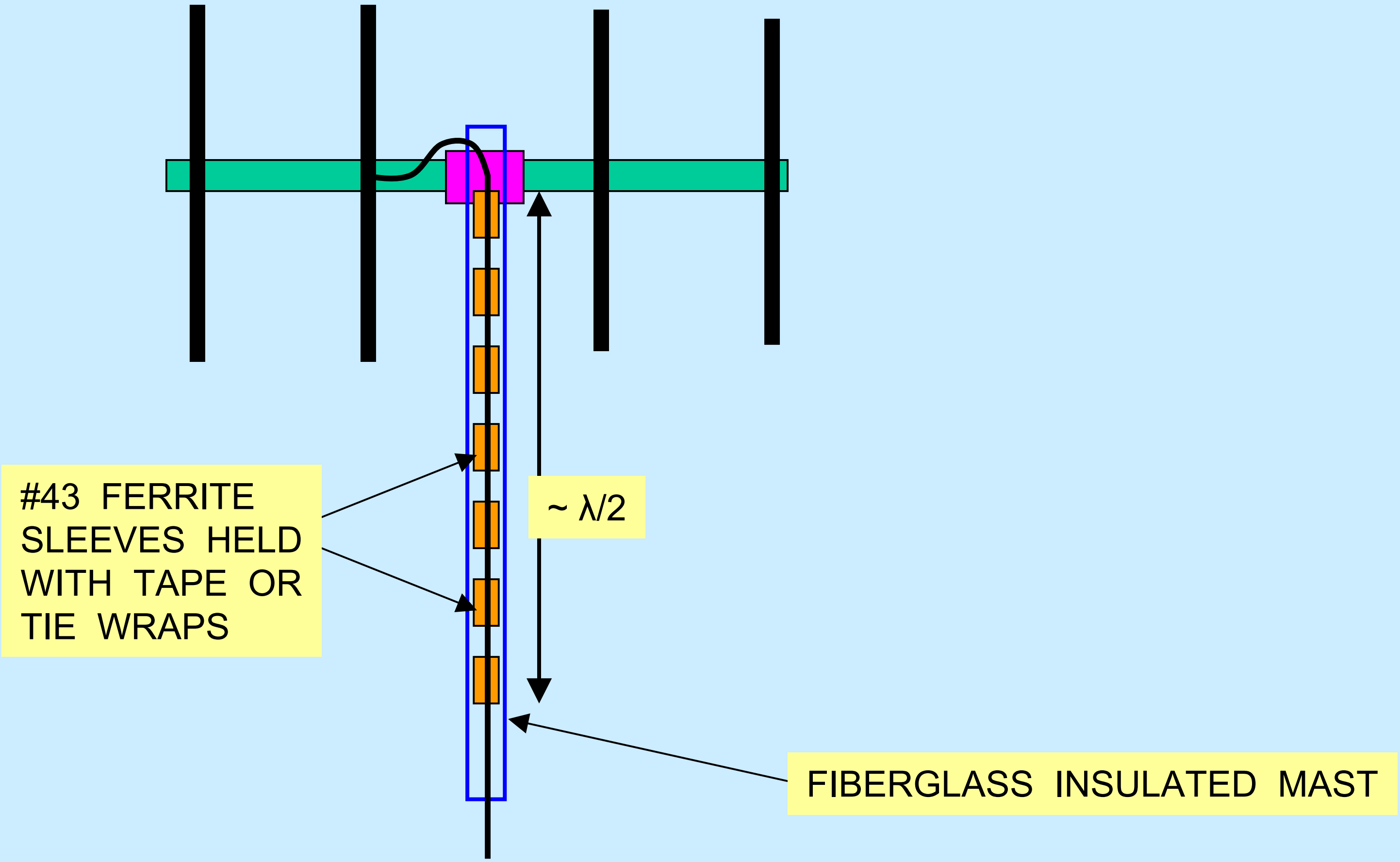


The coax should not be part of the antenna !

USING FERRITES ON THE FEEDER OF VERTICAL YAGI

PREVENT INTERACTION BETWEEN COAX + MAST WITH YAGI

Ref: QEX Sept – Oct. 2006



NOTES

- **USING A BALUN UNDER HIGH SWR:**

- VERIFY HEATING OF THE CORE
- DECREASE THE POWER
- USE MIX 73 (μ=2500) OR 31 (μ=1500)
  FOR HIGH POWER USE MIX 43 (μ=850) See Ref. 4
- BALUN LOSSES MAY / WILL INCREASE UNDER HIGH SWR
- VOLTAGE BALUN NOT RECOMMANDED IF SWR > 5:1 UNLESS
  DESIGNED FOR HIGH SWR

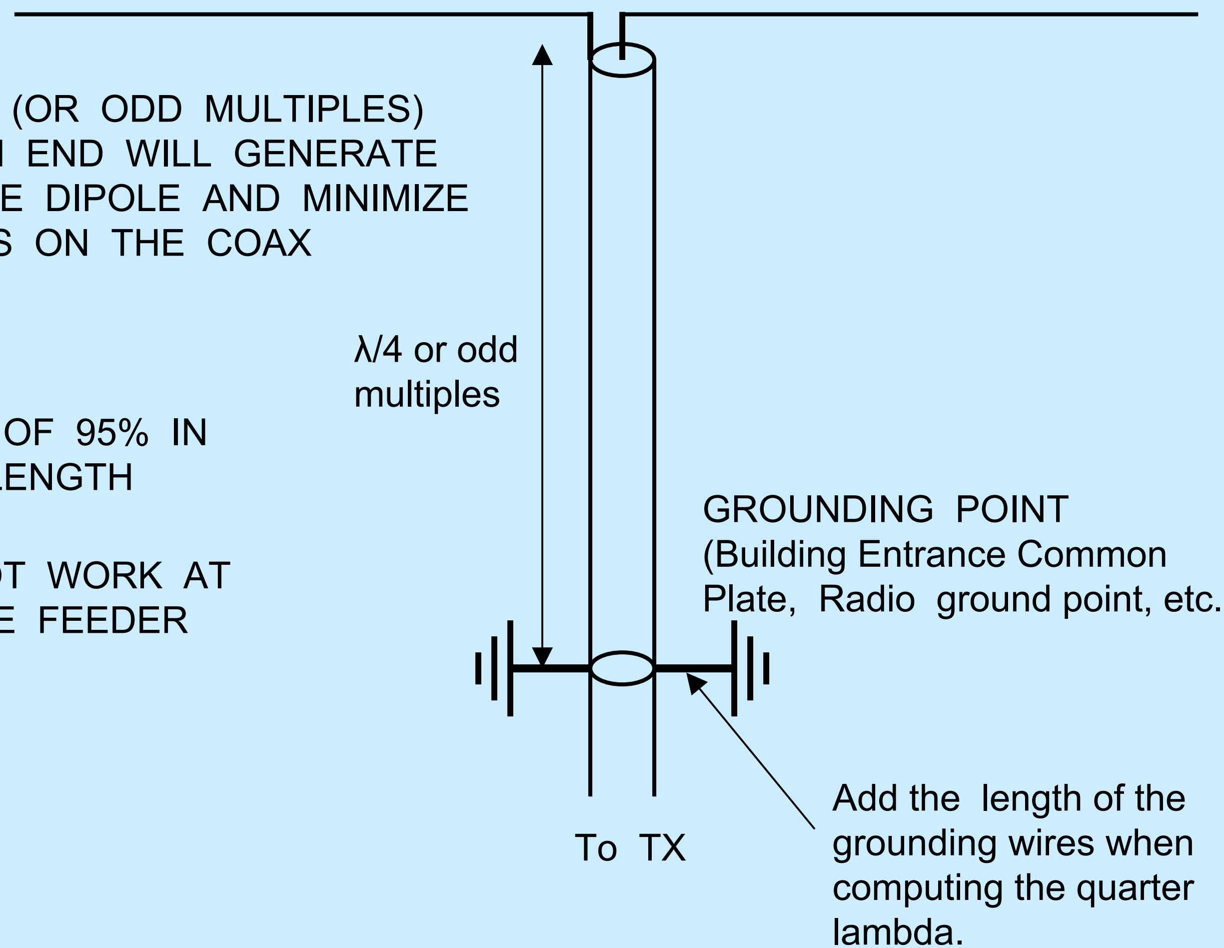
- **BALUNS NORMALLY PROVIDE A VERY LOW ATTENUATION,
  NORMLLY < 0.3 dB … WHEN THE LOAD IS MATCHED**

QUARTER WAVE BALUN

- A QUARTER WAVELENGTH (OR ODD MULTIPLES) SHORTED AT THE BOTTOM END WILL GENERATE A HIGH IMPEDANCE AT THE DIPOLE AND MINIMIZE COMMON MODE CURRENTS ON THE COAX OUTER SHIELD.

- USE A VELOCITY FACTOR OF 95% IN CALCULATING THE COAX LENGTH

- THIS TECHNIQUE WILL NOT WORK AT FREQUENCIES WHERE THE FEEDER IS A MULTIPLE OF λ/2



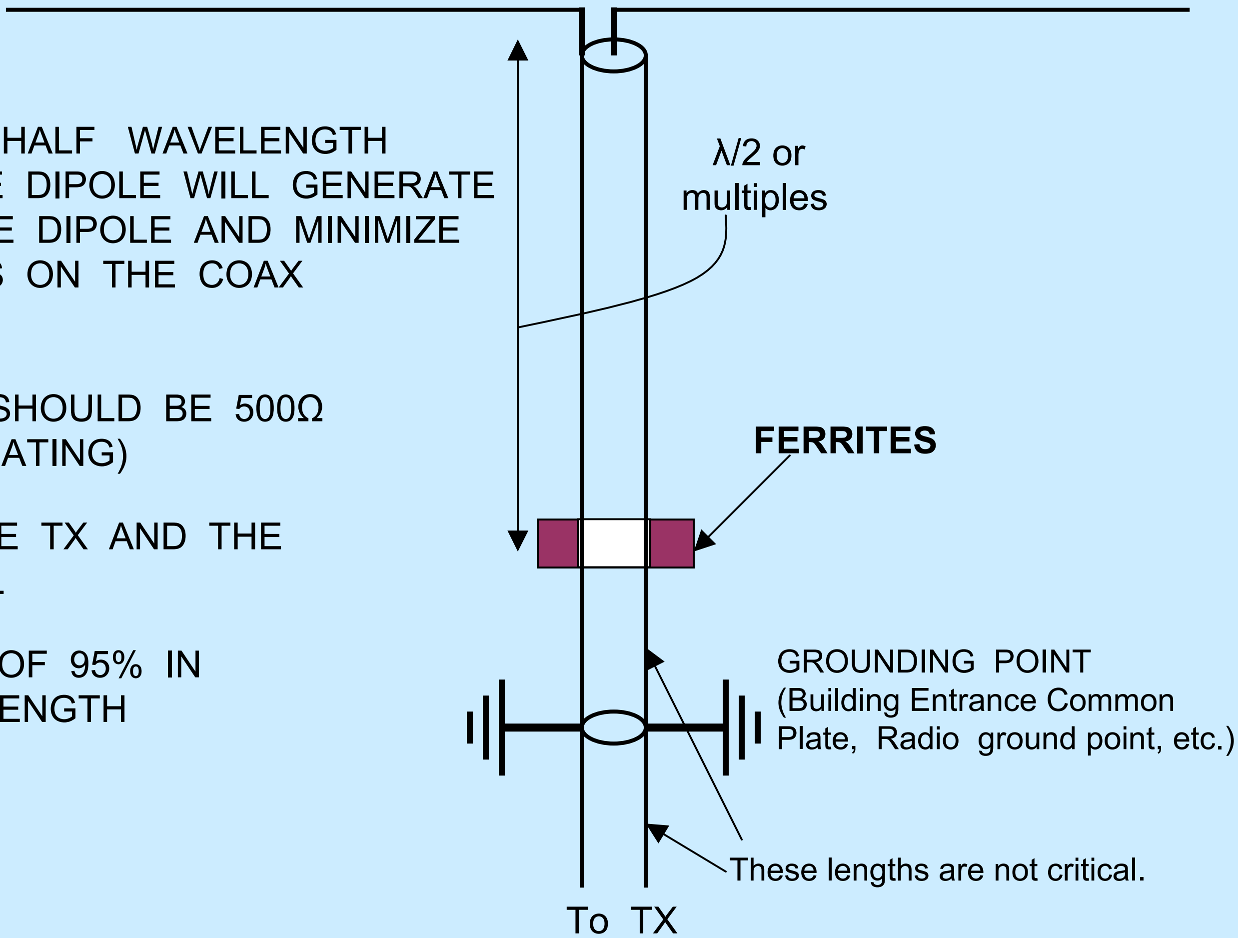
CANNOT LOCATE BALUN AT DIPOLE FEEDPOINT: TOO HEAVY !

- SETTING THE FERRITES A HALF WAVELENGTH (OR MULTIPLES) FROM THE DIPOLE WILL GENERATE A HIGH IMPEDANCE AT THE DIPOLE AND MINIMIZE COMMON MODE CURRENTS ON THE COAX OUTER SHIELD.

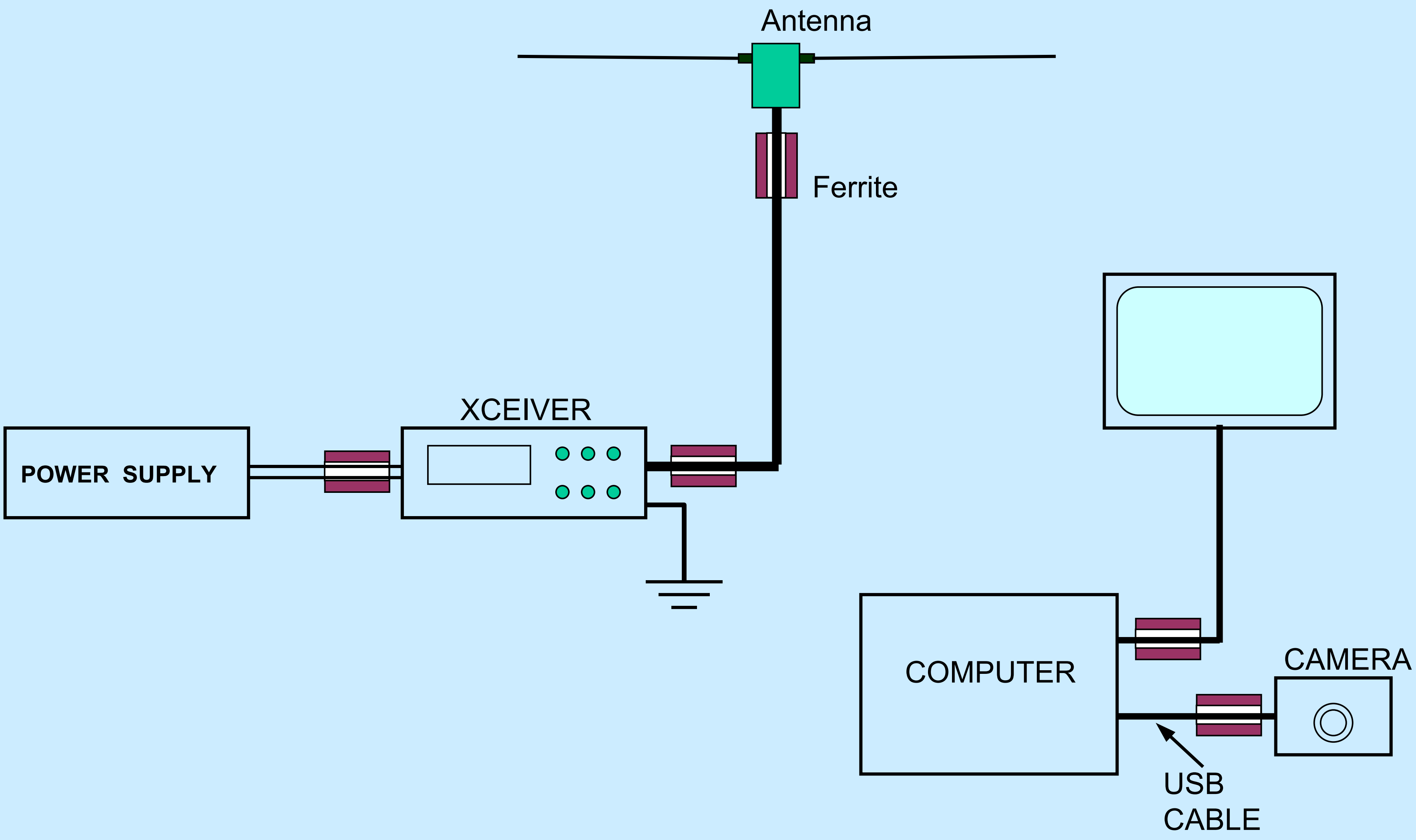
- THE FERRITE IMPEDANCE SHOULD BE 500Ω OR MORE. (CHECK FOR HEATING)

- THE LENGTH BETWEEN THE TX AND THE FERRITES IS NON CRITICAL

- USE A VELOCITY FACTOR OF 95% IN CALCULATING THE COAX LENGTH



FERRITES ARE USED EVERYWHERE



THINGS TO REMEMBER…

- **VOLTAGE BALUNS** COVER A VERY WIDE RANGE OF IMPEDANCES
- SET EQUAL VOLTAGES AT THE OUTPUT
- GENERALLY PROVIDE NO PROTECTION AGAINST CURRENTS FLOWING ON COAX EXTERIOR
- MAY BE COMBINED WITH A CURRENT BALUN

- **CURRENT BALUNS** CREATE A AN IMPEDANCE ON THE OUTSIDE OF THE COAX (OR ANY CONDUCTOR)
- ALSO CALLED COMMON MODE CHOKES
- DECREASE COAX RADIATION AND PICK-UP
- STABILIZE THE ANTENNA IMPEDANCE
- GENERALLY 50:50 ohms RATIO (ALSO 50:200 POSSIBLE)

THINGS TO REMEMBER…

- DECREASE COAX RADIATION ON TRANSMIT

- AND PICK-UP ON RECEIVE

Extract from Ref. 4:

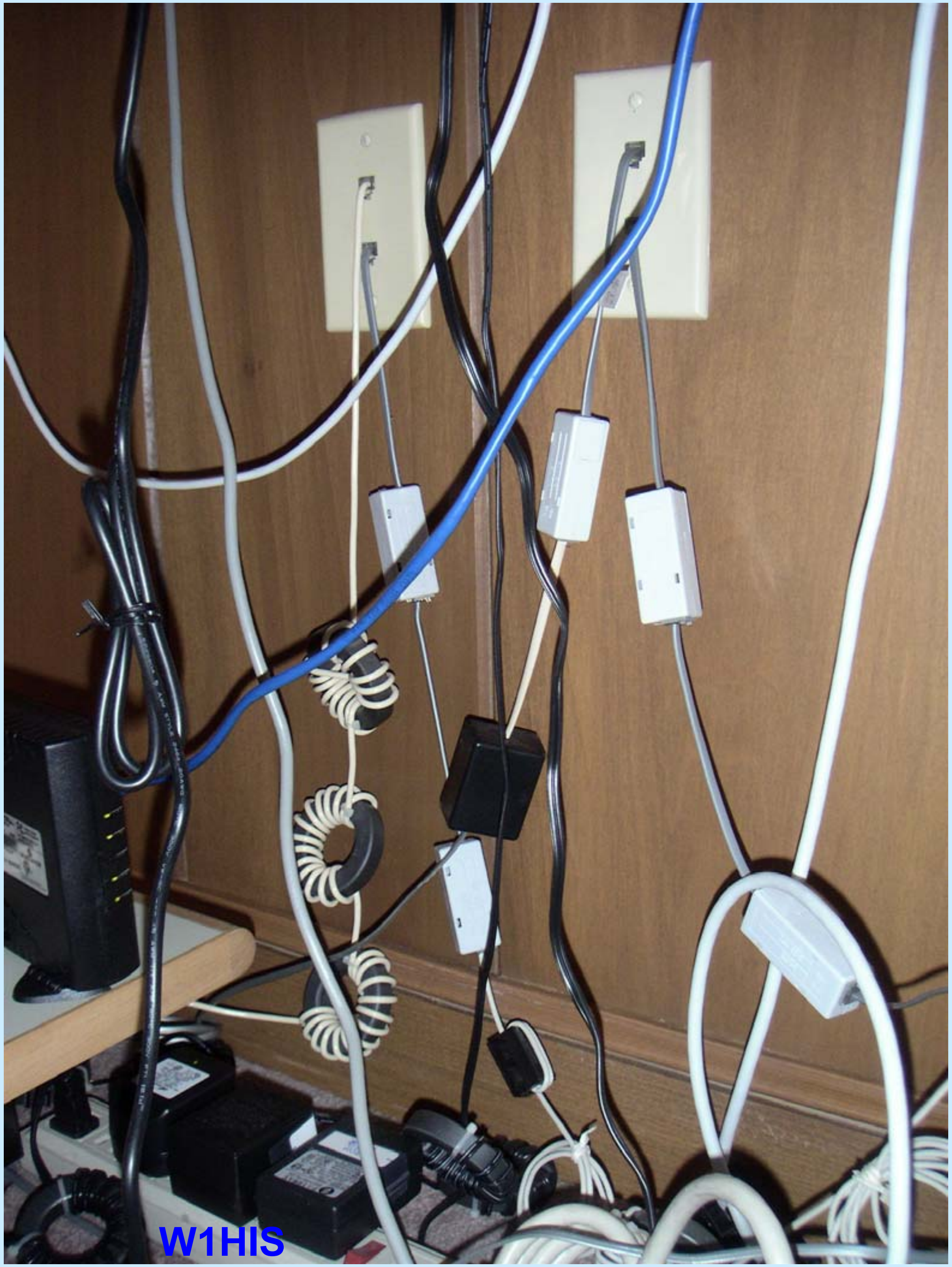
The most common reasons for using common-mode chokes are:

(1) to reduce the fraction of the RF power that is fed to your antenna from your transmitter, but then is conducted back to your shack *via* common-mode current on your feedline, causing RFI trouble in the shack or elsewhere in your house;

(2) to keep the transmitted RF power that 60-Hz power, telephone, TV, and other cables in the field of your antenna pick up, from bothering susceptible devices connected to these cables in your own and neighbors' houses

Extract from Ref. 4:

(3**)** to keep the RF noise that all the electronic devices in your house generate, from being conducted *via* 60-Hz power, telephone and other cables to the outer shield of your radio, and from there along your feedline(s) to your antenna(s), in common-mode.



REFERENCES

1- General informations on baluns – Index of good articles:
http://www.nonstopsystems.com/radio/frank_radio_baluns.htm

2- Transmission Line Transformers, by Jerry Sevick W2FMI

3- Cost effective ferrite chokes and baluns
http://www.nonstopsystems.com/radio/article-cost-effective-chokes.pdf

4- Reducing interferences inside the house: Chuck Counselman W1HIS.
http://www.yccc.org/Articles/W1HIS/CommonModeChokesW1HIS2006Apr06.pdf

5- FERRITE SUPPLIERS
Digikey http://www.digikey.com
Fair-Rite http://www.fair-rite.com
Aimdon http://www.amidoncorp.com
ByteMark http://www.cwsbytemark.com/prices/toroidal.php
The Toroid King http://www.kitsandparts.com/index.php