49:1 UNUN Transformer Designs

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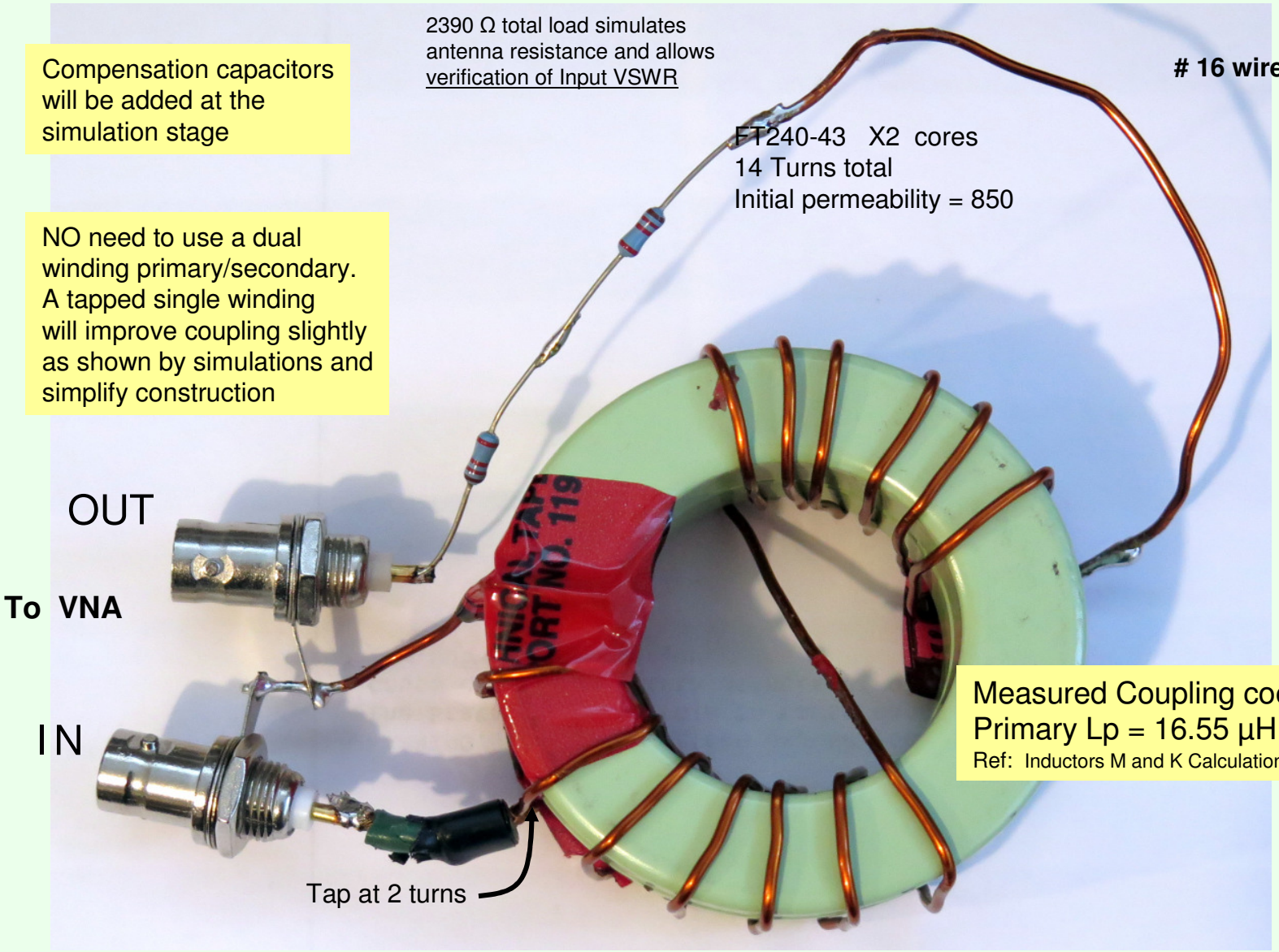
Oct. 2023

49 to 1 Standard UNUN (FT240-43) Tap at two turns

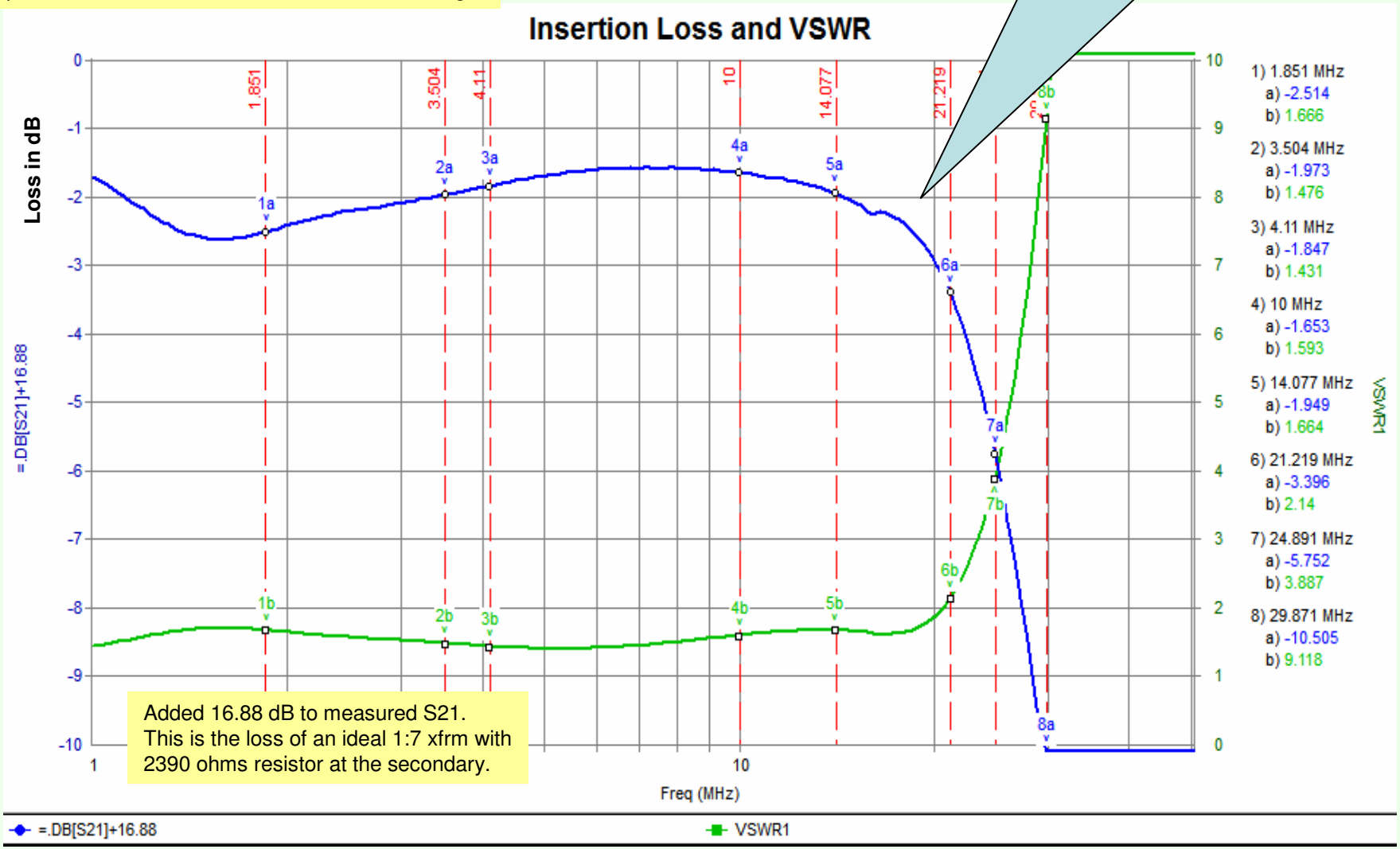
Measurement SET-UP



All transmission tests done with HP8753D VNA, using full two port calibration.

Added 150 pF Cap across input
optimizes VSWR and losses above 10 MHz
The measured primary inductance of 16.55 µH
improves SWR below 3 MHz, but losses are still high.

FT240-43 gives high insertion loss, at least with 2 to 14 turns.
BUT VSWR is low (1.4 to 2.0) from 1 to 20 MHz even with coupling coeff = 0.99



Ref: FT240-43-2cores-16wireVer1-NoCap-Tap-Rewond.wsp

MEASURED RESPONSE

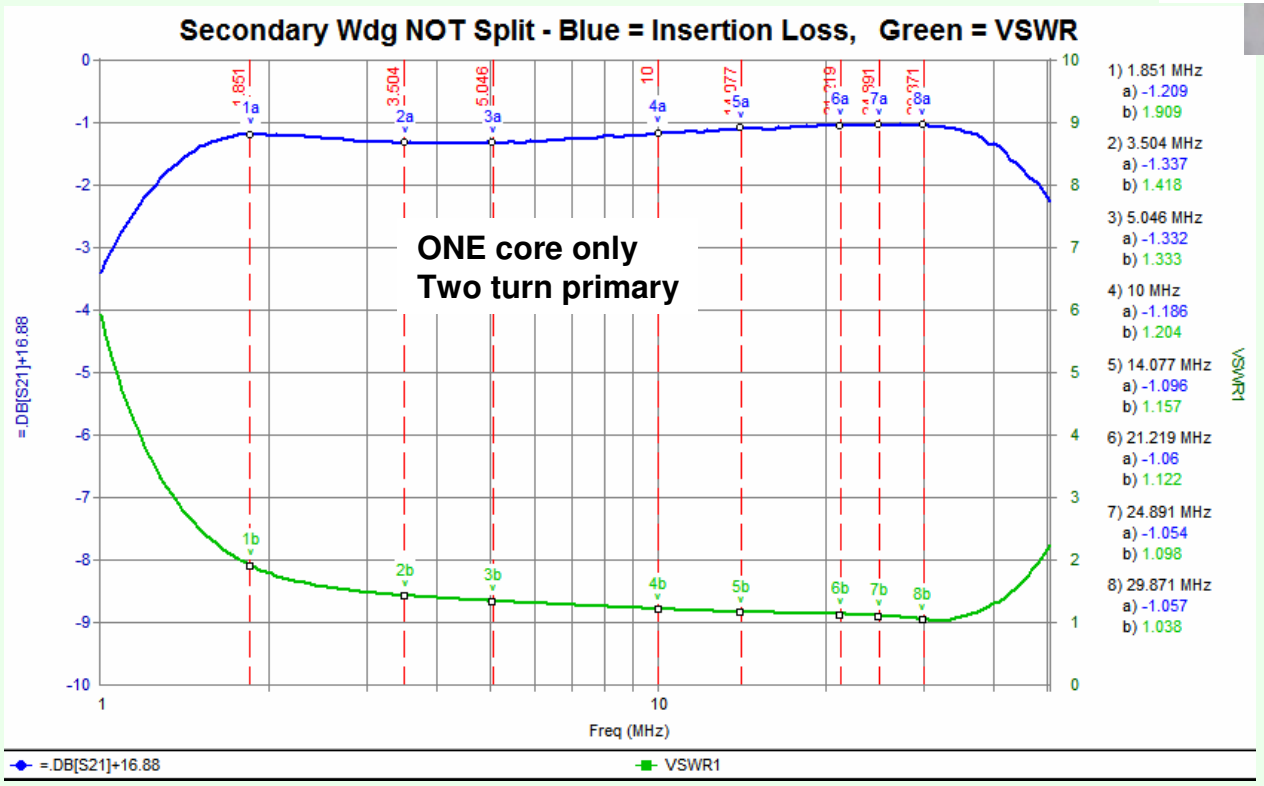
FAIR-RITE FT140-43

Fair-Rite calls it an ‘inductive component’

68 pF in shunt on primary
3900 pF in series

Max power: one core, 2 pri. turns = 12W @ 3.5 MHz,
Max power: two cores, 3 pri. turns = 104W @ 3.5 MHz

Fair-Rite core
5943002701
1.4 x 0.906 x 0.5 in.
43 material μ = 800



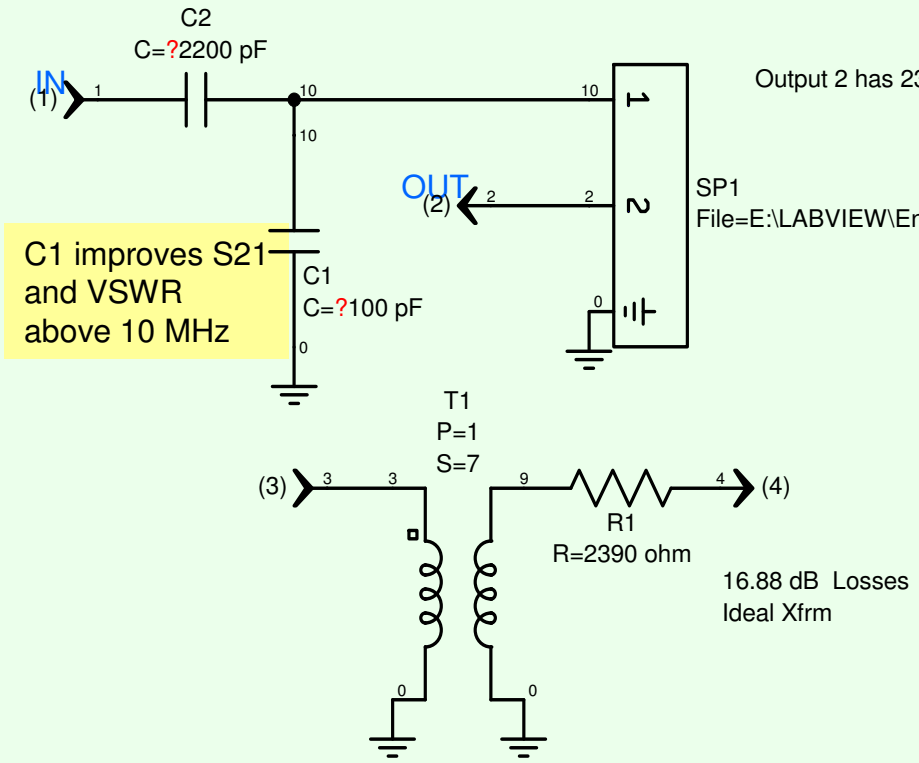
Too much losses at both low and high frequencies

Not Recommended !

Ref: UNUN 49to1-1cores-26wire-14a2Tours-NoSplitSecondary-FT140-43.wsp

Circuit used for Simulations

Improving VSWR and losses at the low frequencies.
C2's reactance cancels the primary inductance.



Output 2 has 2390 ohms in series

s2p file of measured data

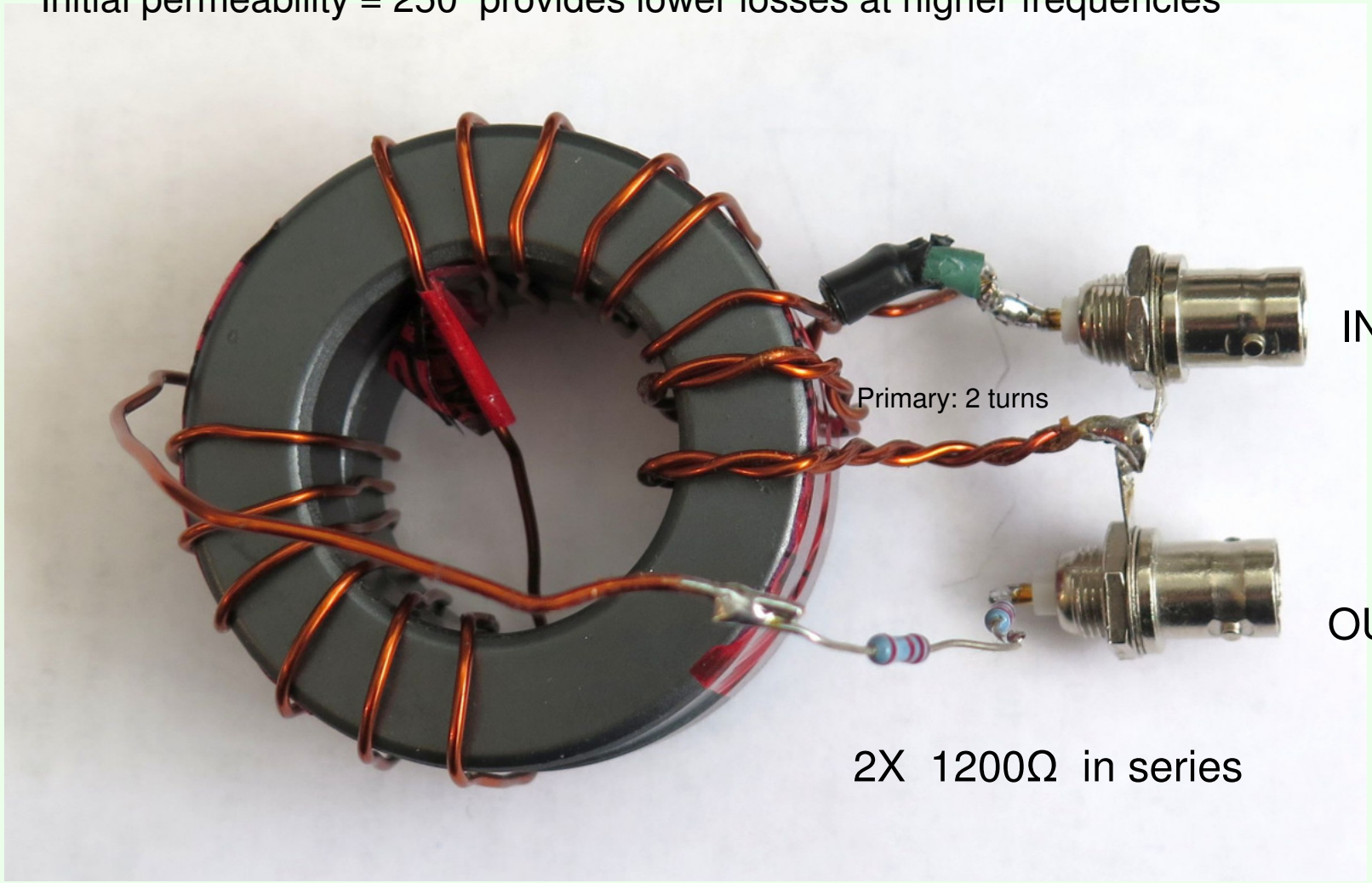
Value added to measured S21
to compute actual losses

16.88 dB Losses
Ideal Xfrm

49 to 1 Standard UNUN # 16 wire separate primary/secondary

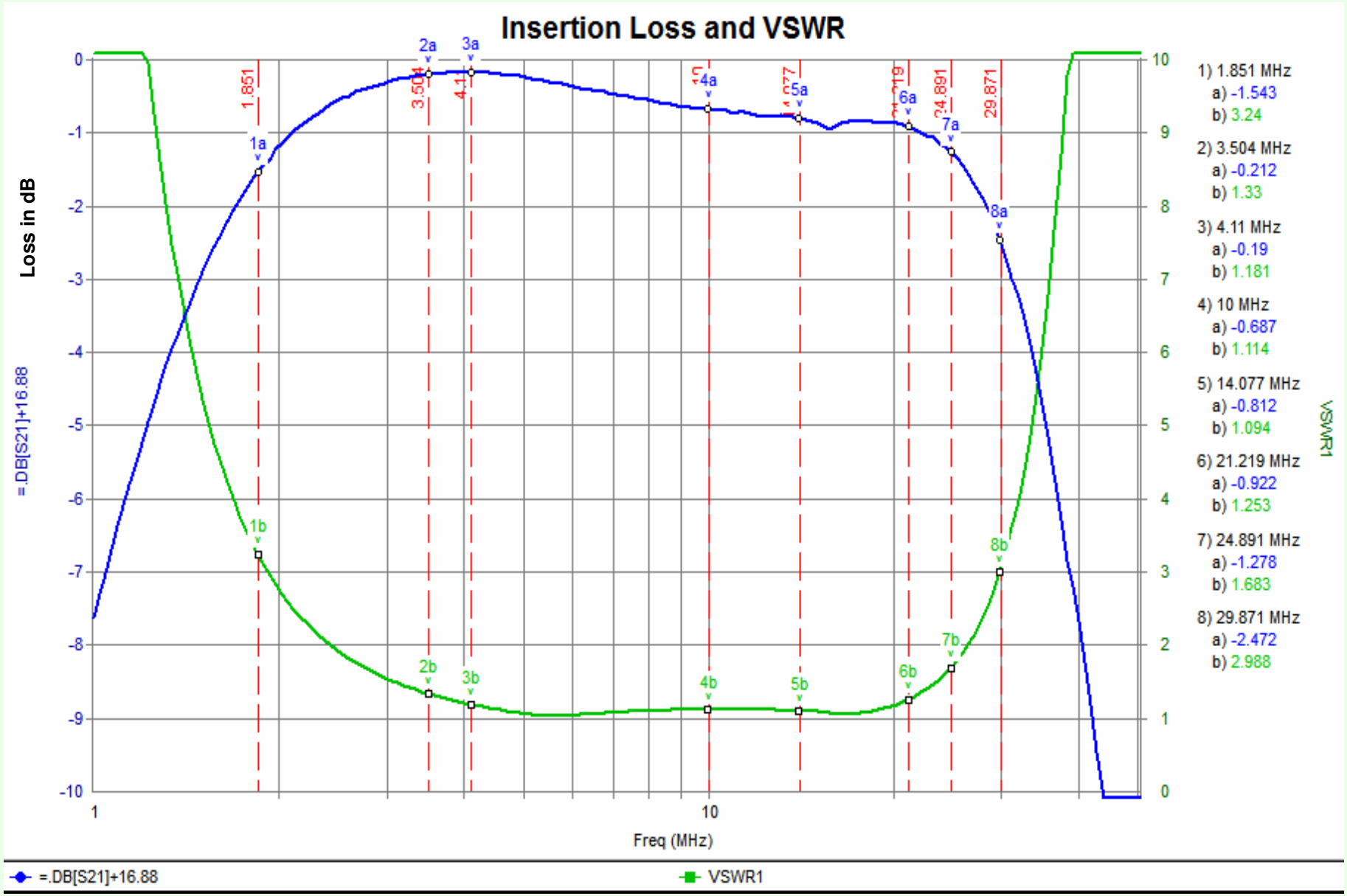
FT240-52 X2 cores 2/14 turns

Initial permeability = 250 provides lower losses at higher frequencies



Added 69 pF cap. across input and 2200 pF in series with the input

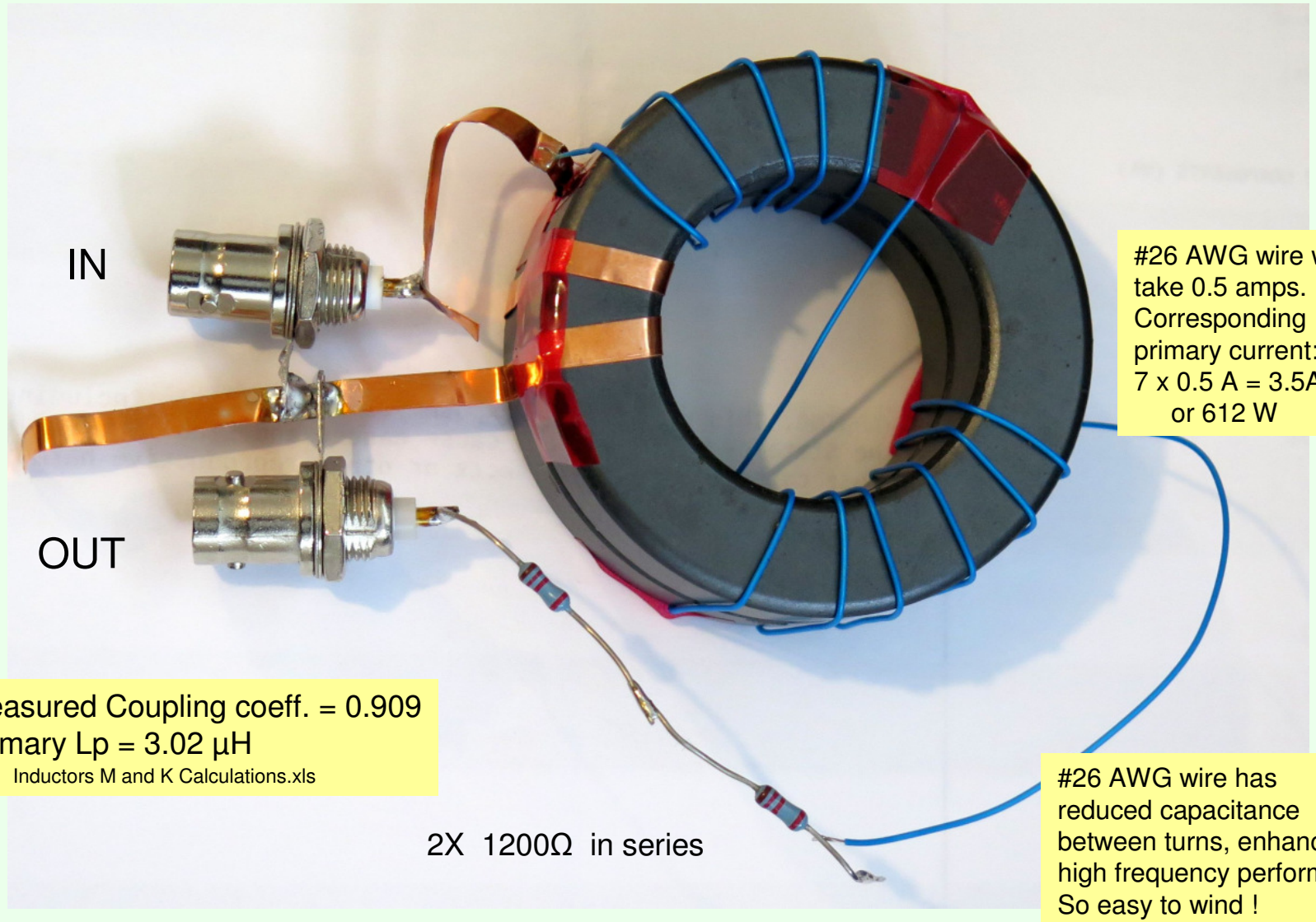
FT240-52 gives much lower insertion loss at least with 2 to 14 turns.



Ref: Unun-1 to7-TransformerFT240-52_Ver1.wsp

49 to 1 Auto Transformer 140 mil wide Cu strip on primary, # 26 wire secondary

FT240-52 X2 cores



#26 AWG wire will take 0.5 amps. Corresponding primary current:
7 x 0.5 A = 3.5A
or 612 W

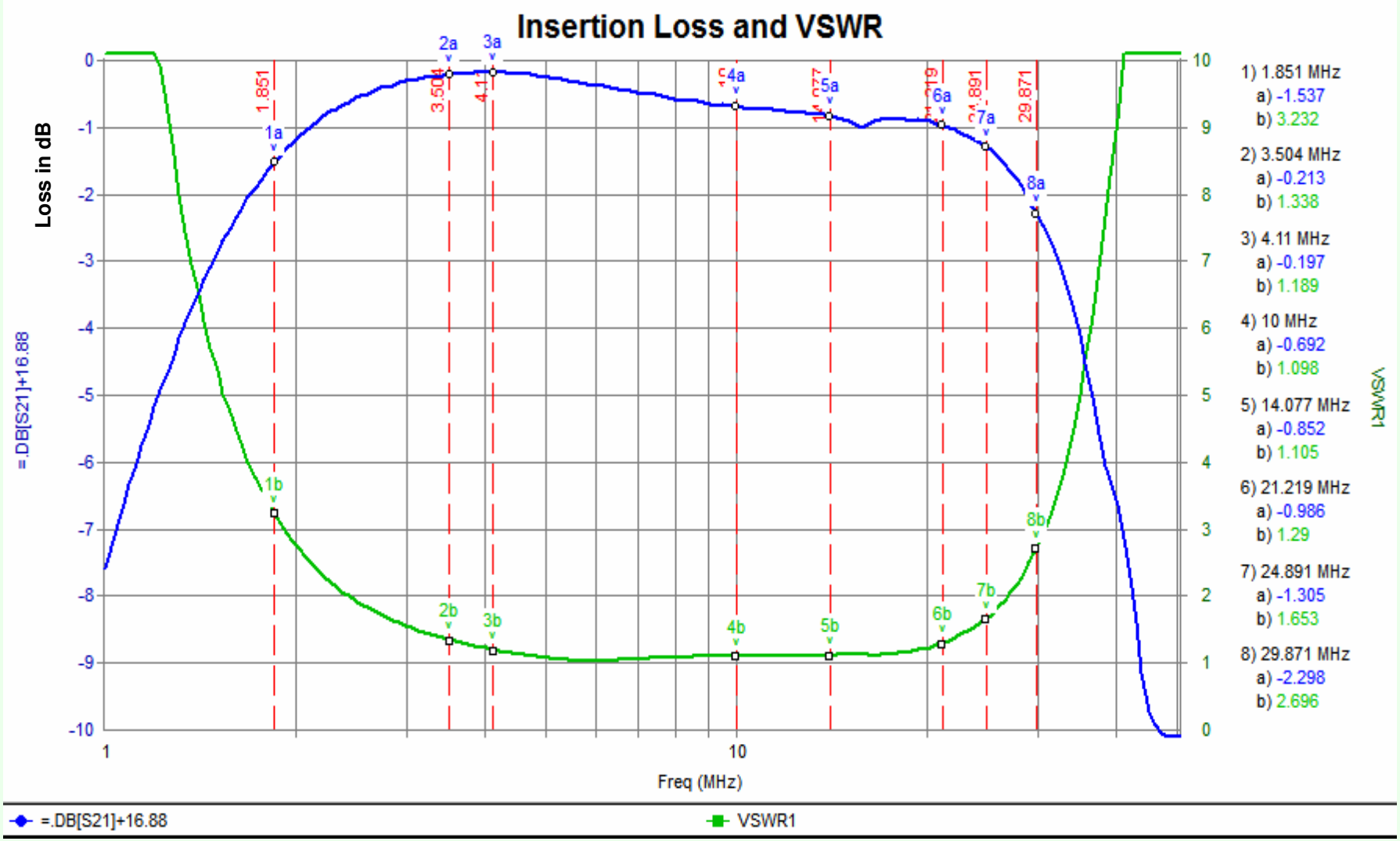
Measured Coupling coeff. = 0.909
Primary Lp = 3.02 µH
Ref: Inductors M and K Calculations.xls

#26 AWG wire has reduced capacitance between turns, enhancing high frequency performance
So easy to wind !

Ref: Unun-1 to7-TransformerFT240-52_26wire-Ver2.wsp

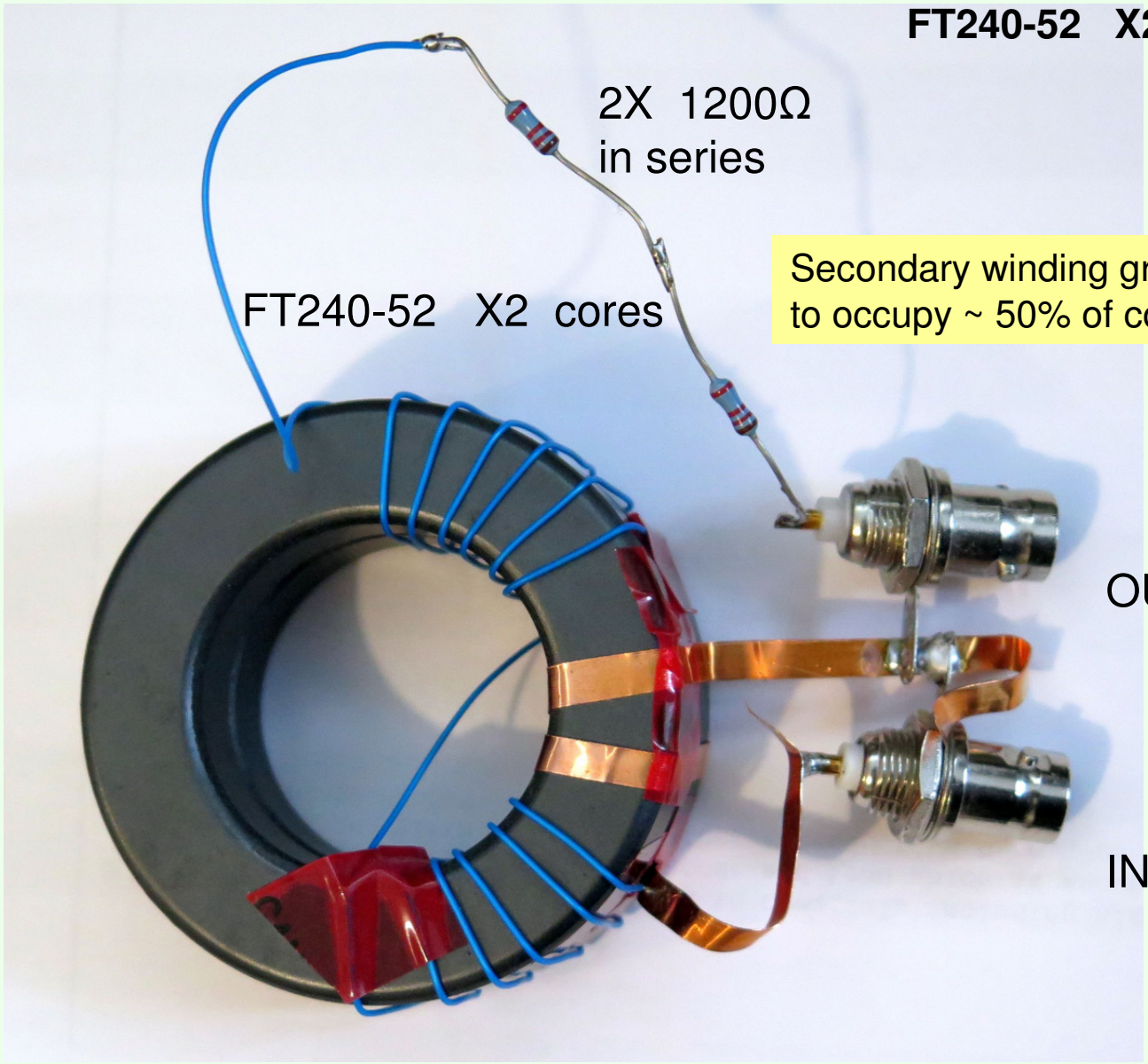
Added 88 pF Cap across input and 2200 pF in series with the input

Coupling coeff. K is too low = 0.909
Attenuation above 20 MHz increases.

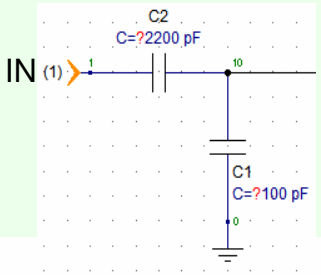


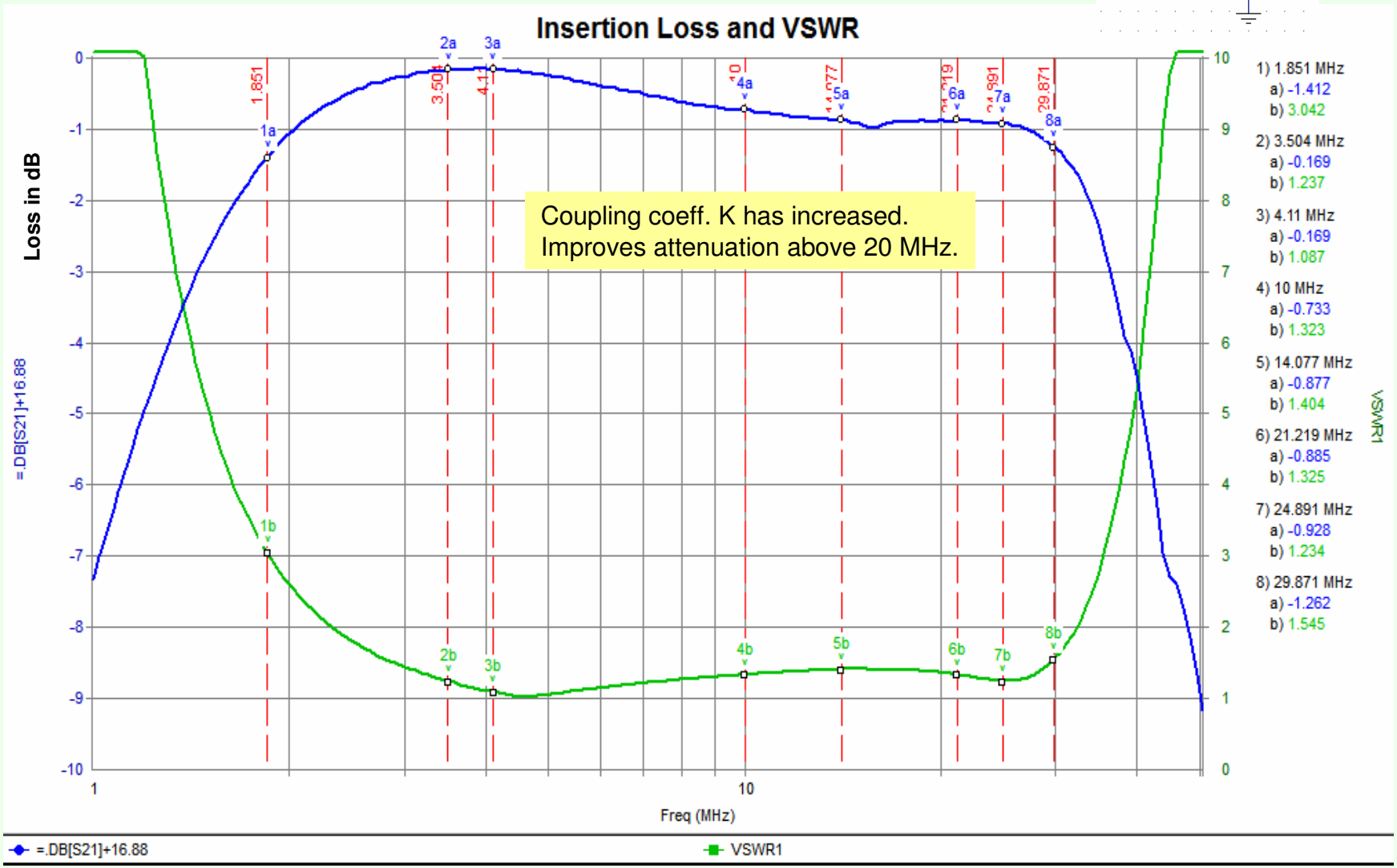
Ref: Unun-1 to7-TransformerFT240-52_26wire-Ver2.wsp

49 to 1 Auto Transformer 140 mil wide Cu strip on primary, # 26 wire secondary



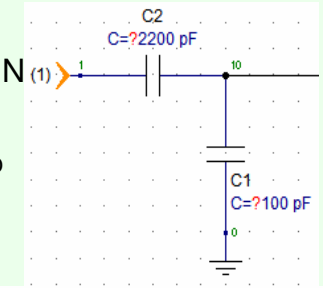
Added 100 pF Cap across input and 2200 pF in series with the input





Ref: Unun-1 to7-TransformerFT240-52_26wire-Ver2-Secondary_Wound-on-FirstHalf-of-Core.wsp

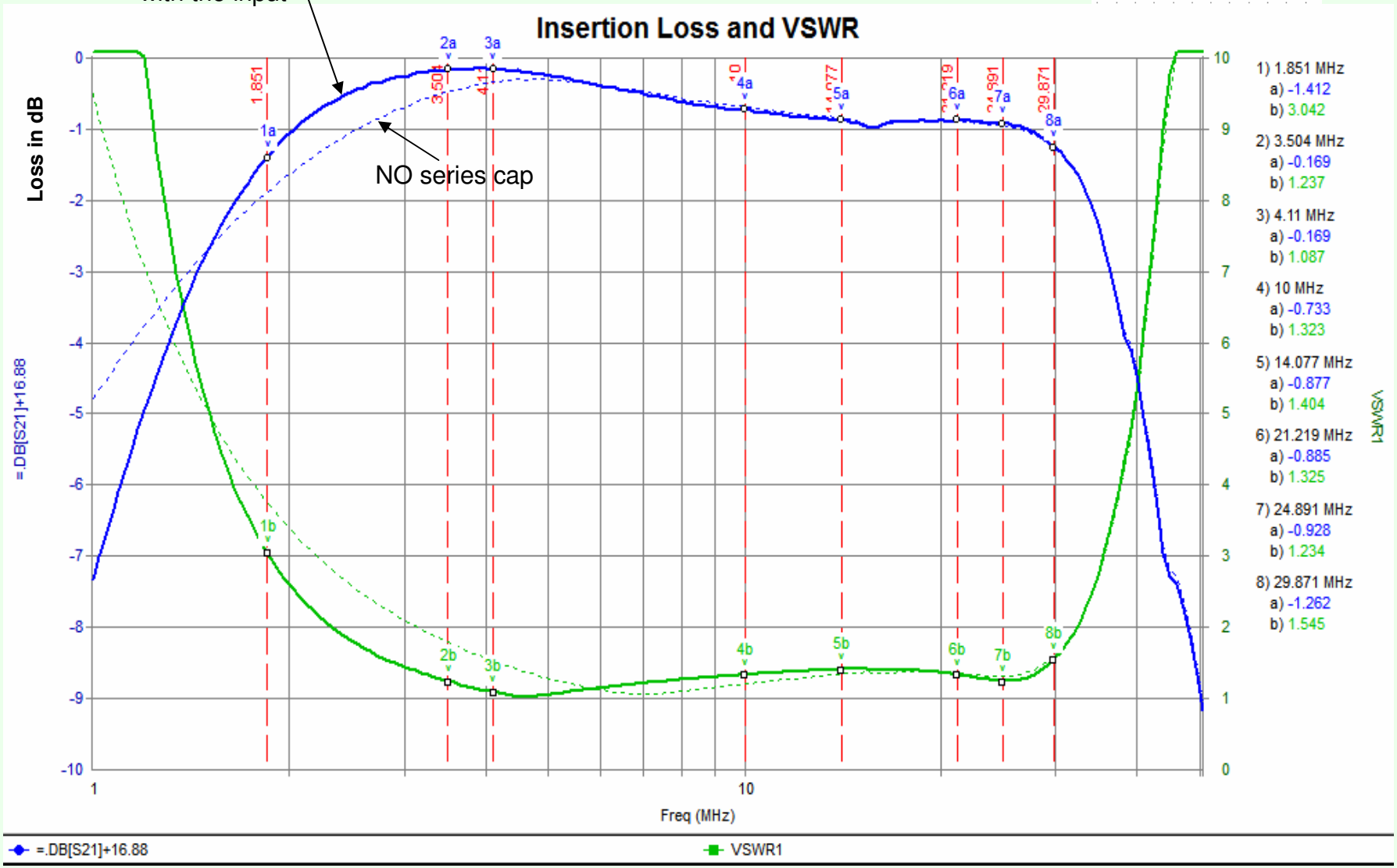
EFFECT of Series Capacitor at input



Added 100 pF Cap
across input

2200 pF in series
with the input

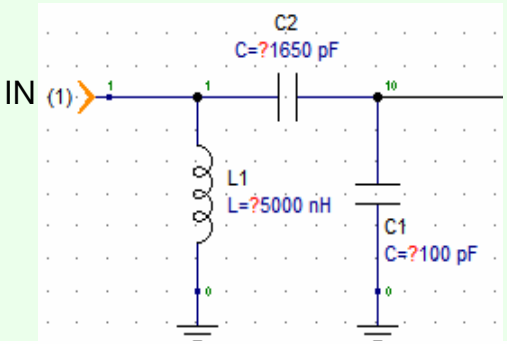
NO series cap



Ref: Unun-1 to7-TransformerFT240-52_26wire-Ver2-Secondary_Wound-on-FirstHalf-of-Core.wsp

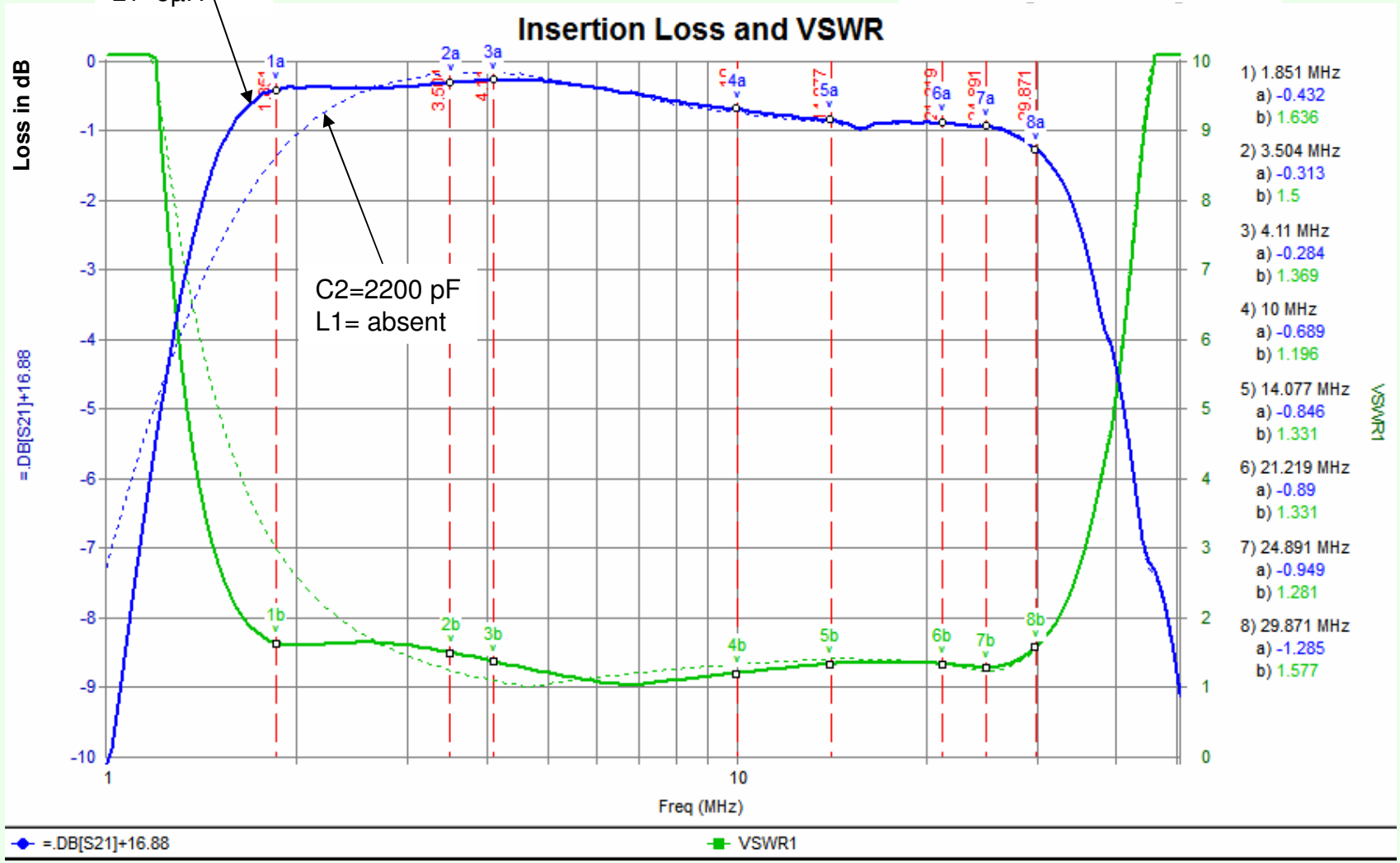
Improving performance on 160m.

Added shunt 5µH Inductor + 1650 pF in series with the input



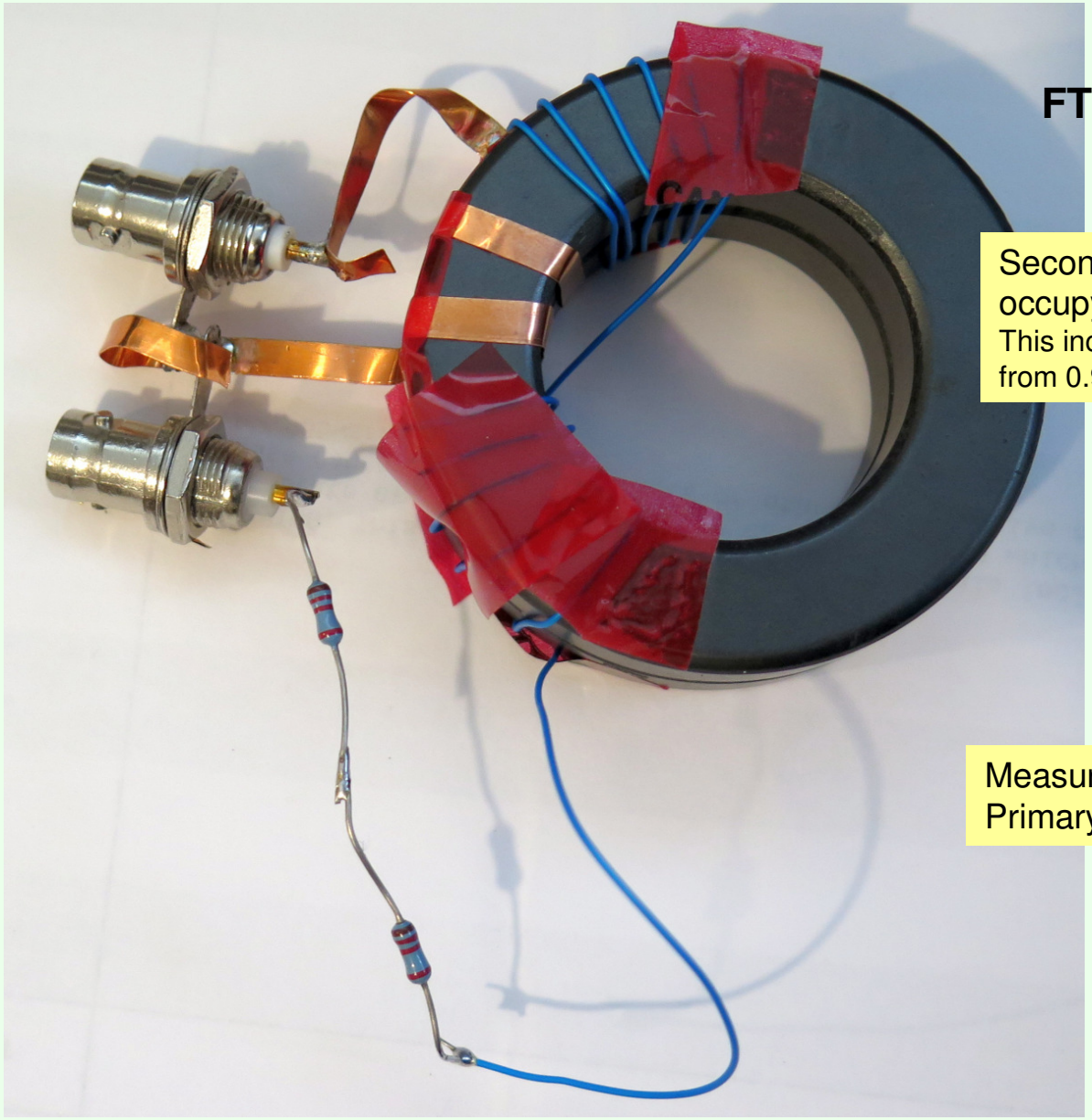
C2=1650 pF
L1=5µH

C2=2200 pF
L1= absent



Ref: Unun-1 to7-TransformerFT240-52_26wire-Ver2-Secondary_Wound-on-FirstHalf-of-Core-160m_Comp.wsp

49 to 1 Auto Transformer 140 mil wide Cu strip on primary, # 26 wire secondary

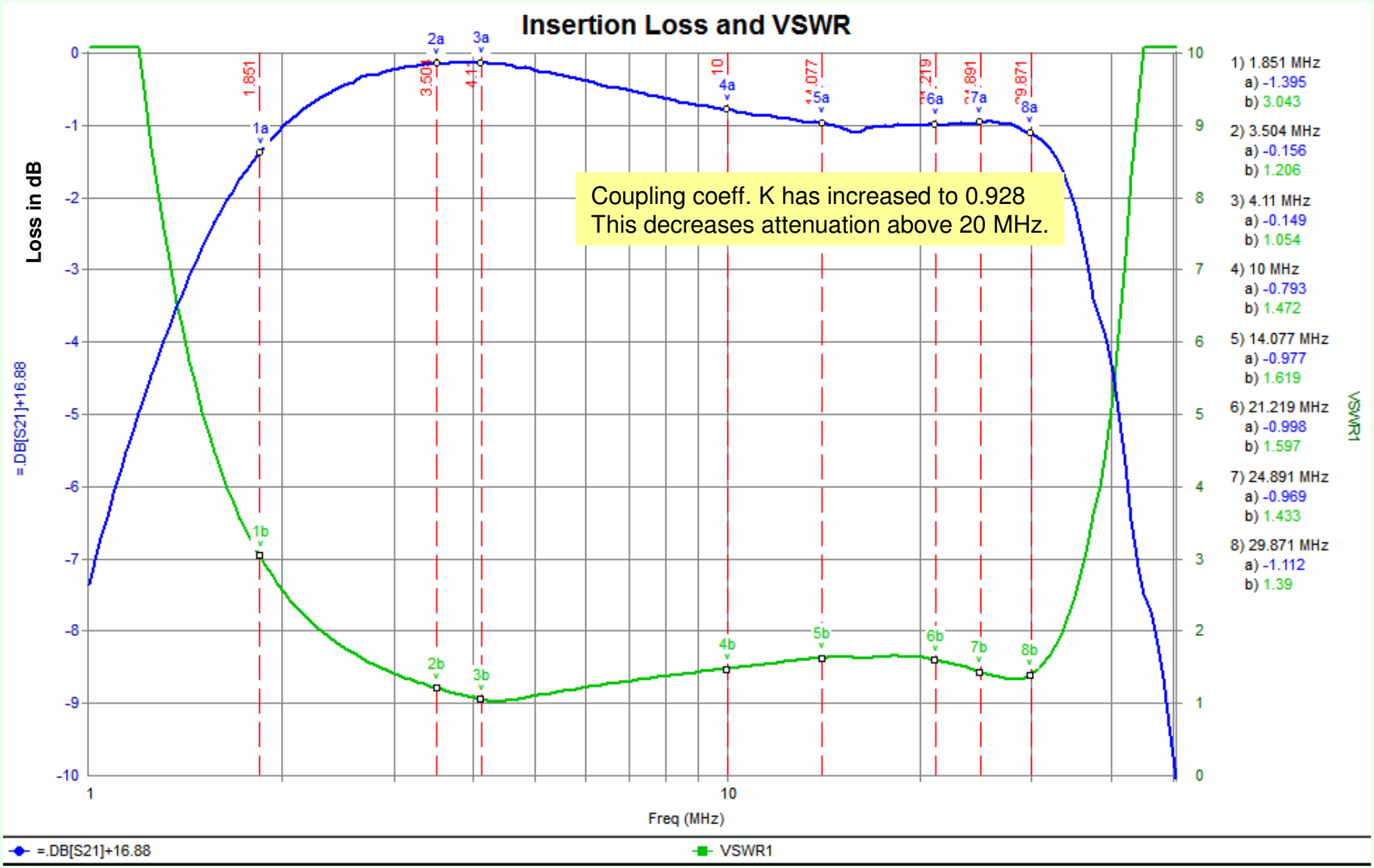


FT240-52 X2 cores

Secondary winding grouped to occupy ~ 40% of area.
This increased the coupling coeff. from 0.909 to 0.928 (See slide 6)

Measured Coupling coeff. = 0.928
Primary Inductance = 3.03 µH

Added 112 pF Cap across input and
2200 pF in series with the input



Ref: FT240-52-2cores-26wireVer2-NoCap-Tap-WdgsTighter.wsp

49 to 1 Auto Transformer 140 mil wide Cu strip on primary, # 26 wire secondary

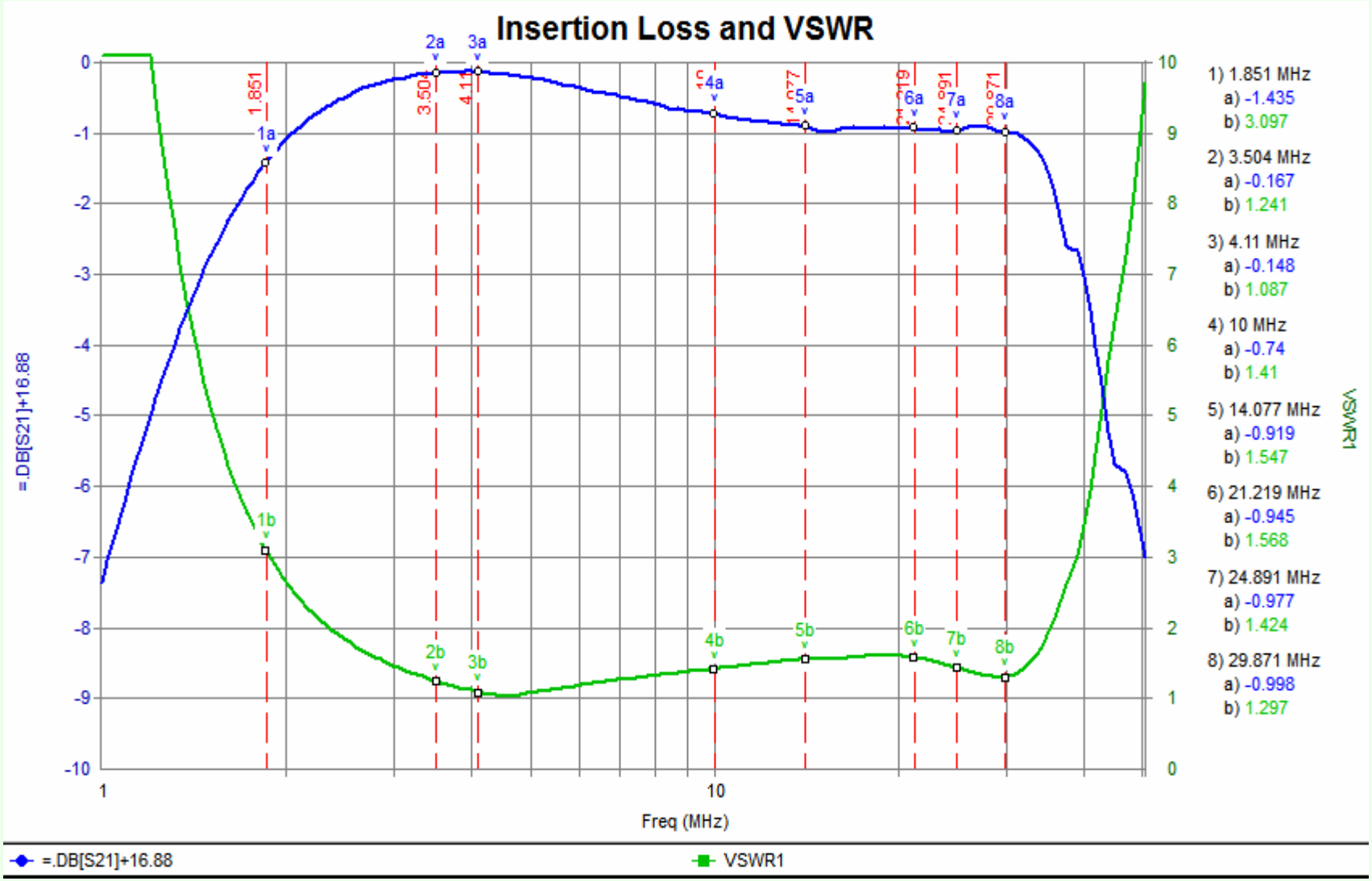
FT240-52 X2 cores

Tape added on last 7 turns

Secondary winding grouped to occupy ~ 35% of area.
This increased the coupling coeff. from 0.909 to 0.938 (See slide 6)

Measured Coupling coeff. = 0.938
Primary Inductance = 3.0 µH

Added 100 pF Cap across input and
2200 pF in series with the input

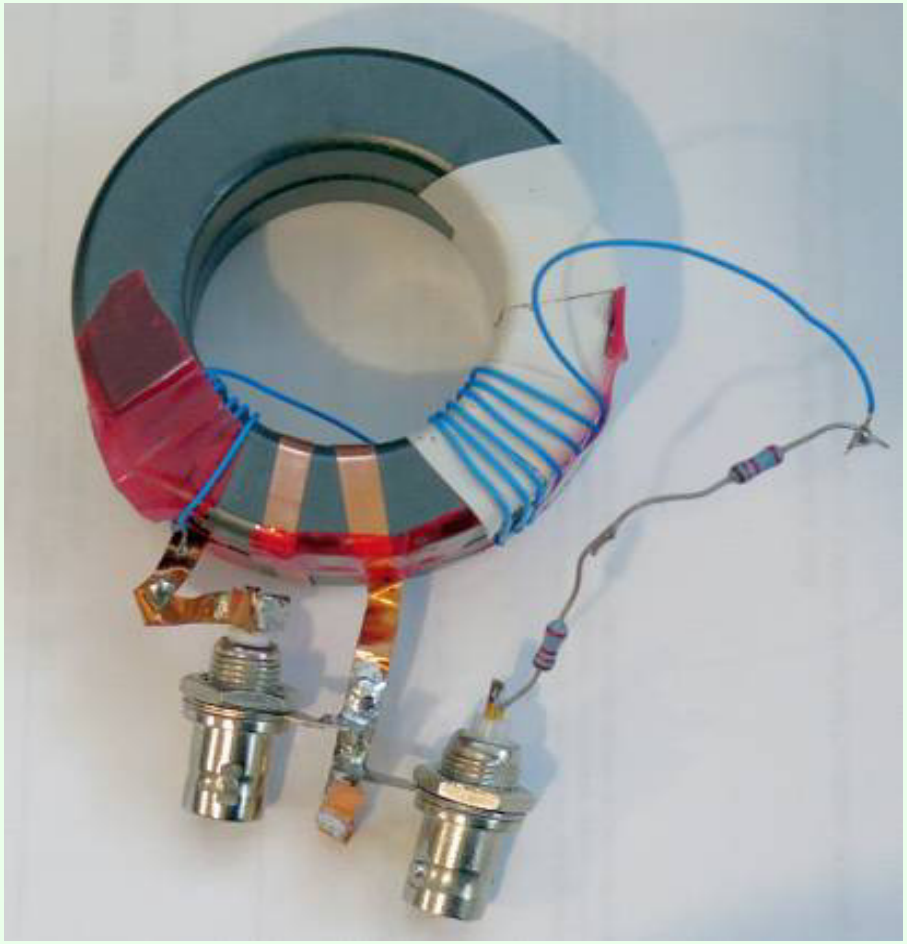


Ref: FT240-52-2cores-26wireVer2-NoCap-Tap-WdgsTighter-TapeLast7T.wsp

49 to 1 Auto Transformer 140 mil wide Cu strip on primary, # 26 wire secondary

FT240-52 X2 cores

Tape added on last 7 turns



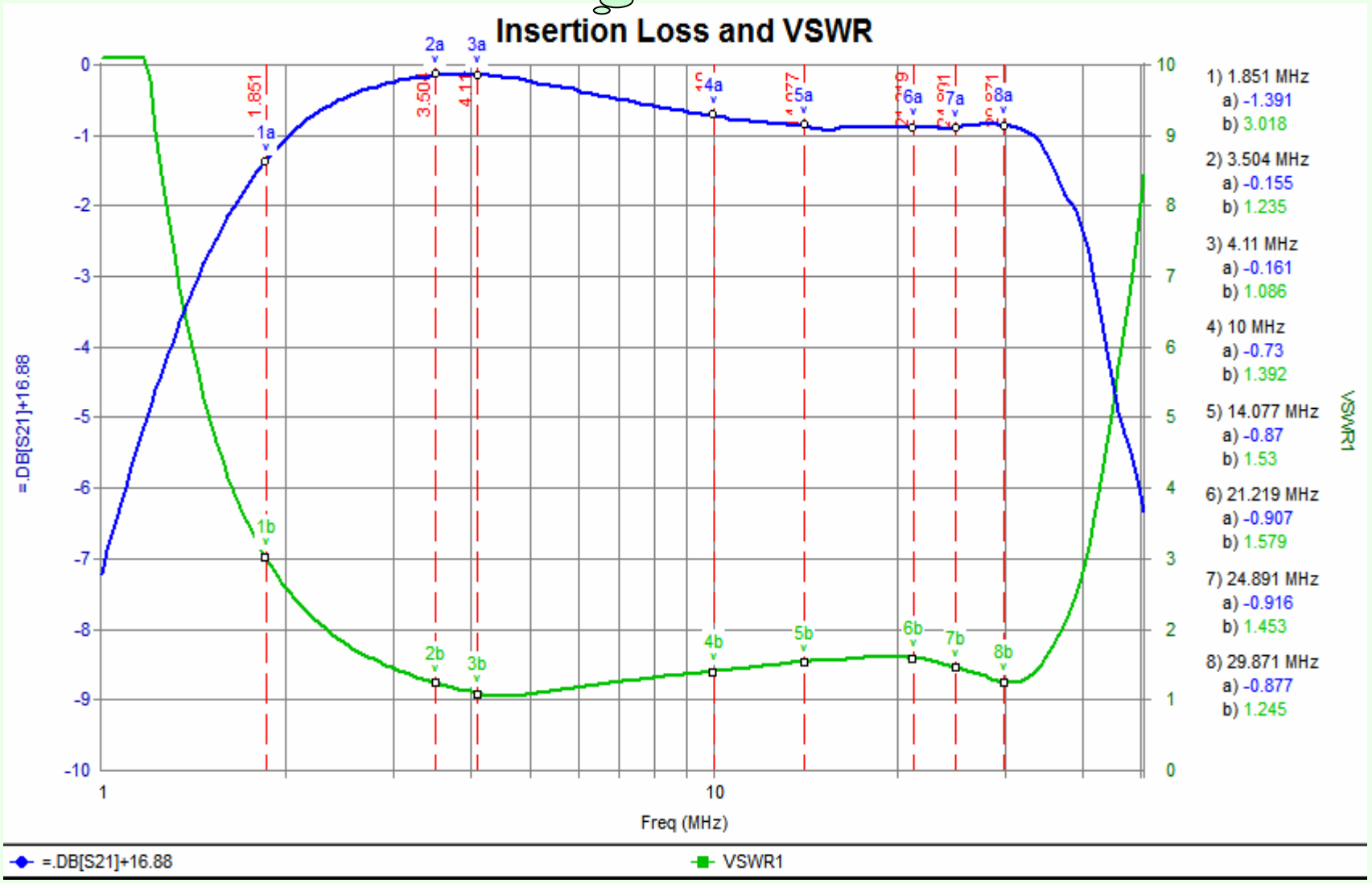
Secondary winding grouped to occupy ~ 30% of area.
This increased the coupling coeff. from 0.909 to 0.957 (See slide 6)

Measured Coupling coeff. = 0.957
Primary Inductance = 3.12 µH

Added 100 pF Cap across input and 2200 pF in series with the input

This is the best so far…

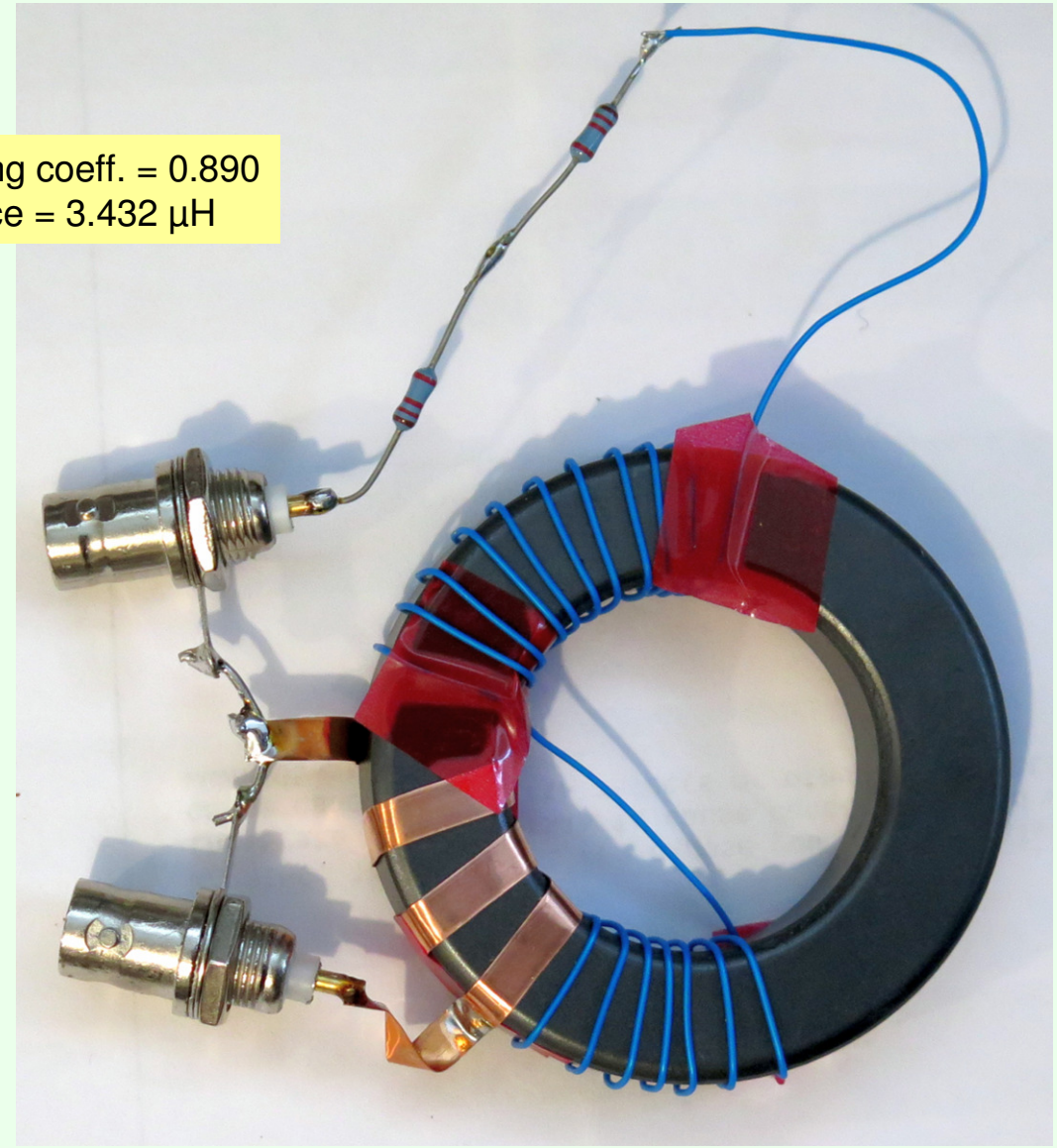
- **Higher coupling decreases loss slightly and gives loss margin at 30 MHz.**
- **Close wound has no visible effect**
- **The tape has no effect.**



Ref: FT240-52-2cores-26wireVer2-NoCap-Tap-WdgsTighter-TapeLast7T-TightWindg.wsp

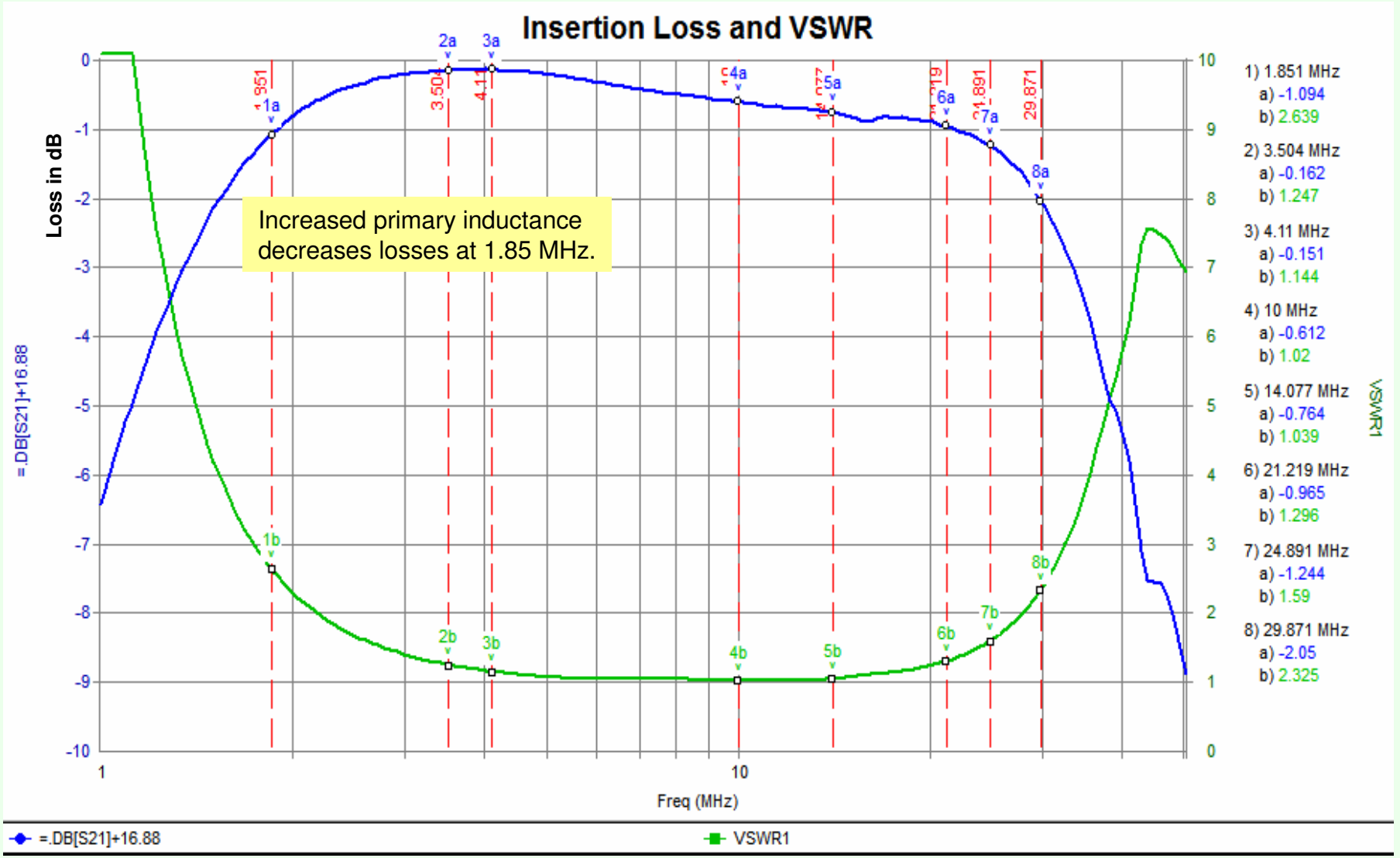
49 to 1 Auto Transformer 140 mil wide Cu strip on 3T primary / 21T secondary
<u>One</u> FT240-52 Core

Measured Coupling coeff. = 0.890
Primary Inductance = 3.432 µH



Added 80 pF Cap across input and 2200 pF in series with the input

Using one core increases losses at the high end, since coupling is reduced to 0.890



Ref: FT240-52-1cores-26wireVer3-NoCap-Tap-21a3Tours.wsp

49 to 1 Auto Transformer 140 mil wide Cu strip on 3T primary / 21T secondary

One FT240-52 Core Tight Winding

Measured Coupling coeff. = 0.949
Primary Inductance = 3.568 µH

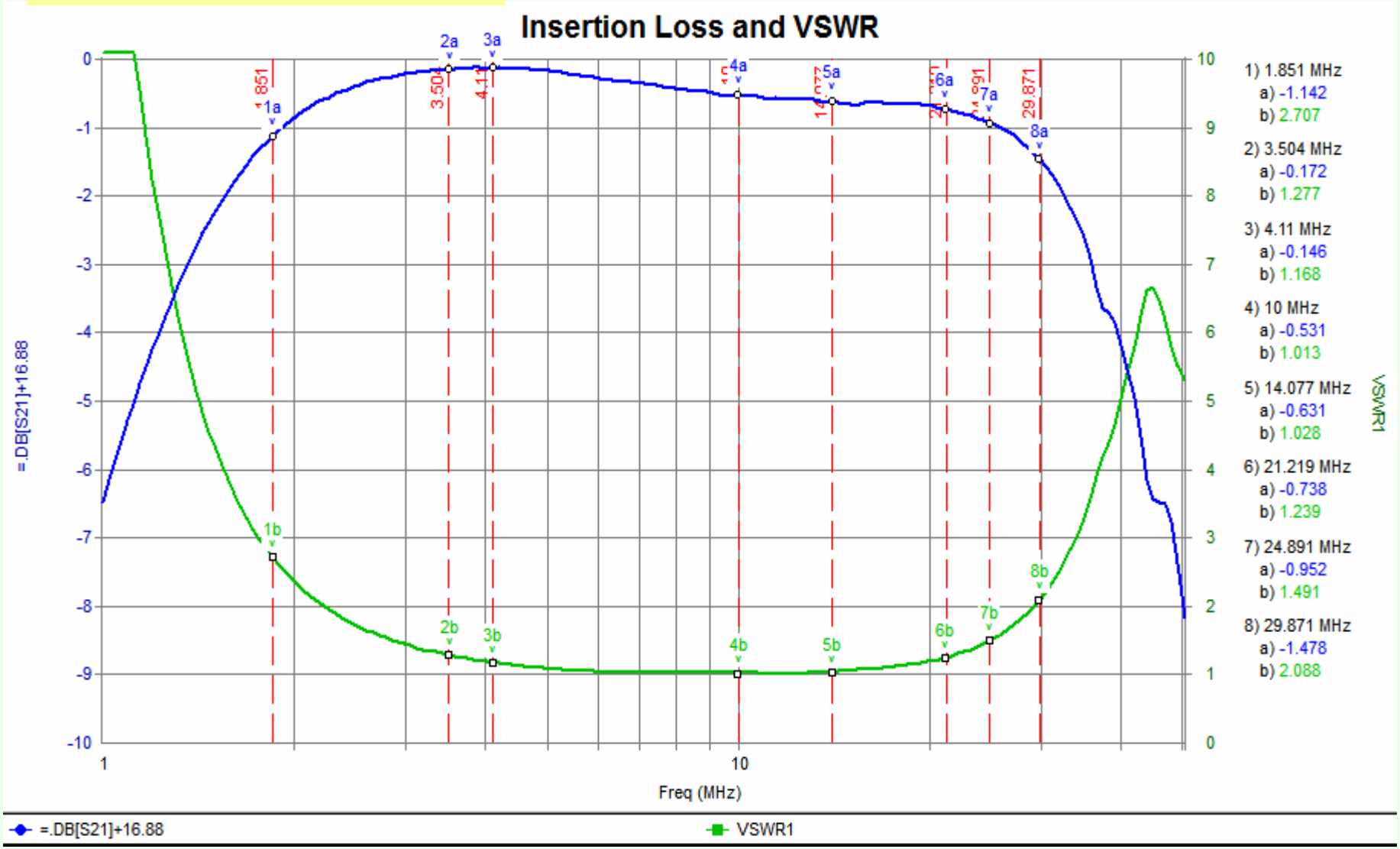
49 to 1 Transformer 140 mil wide Cu strip on 3T primary / 21T secondary

One FT240-52 Core Tight Winding

Added 80 pF Cap across input and 2200 pF in series with the input

Good choice using only one core

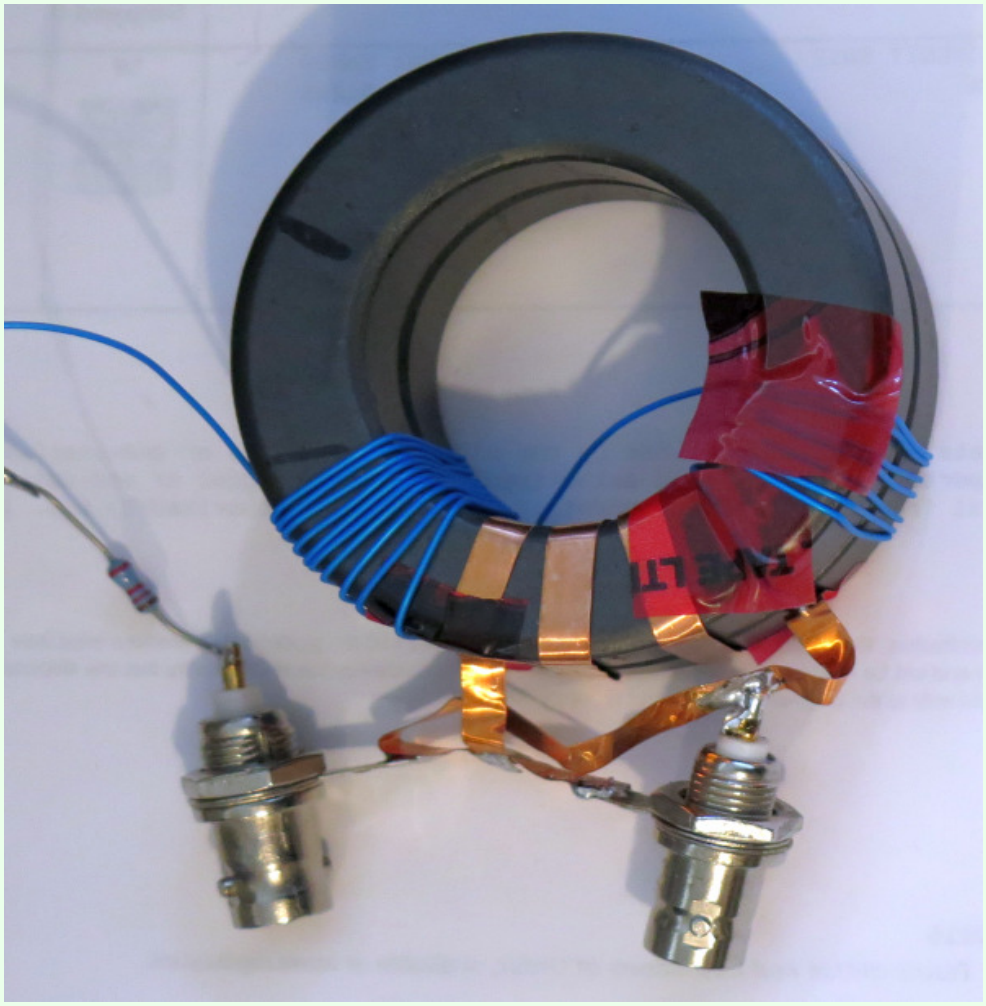
Increased coupling gives…
Slight loss reduction above 20 MHz



Ref: FT240-52-1cores-26wireVer3-NoCap-Tap-21a3Tours-TightWdg.wsp

49 to 1 Auto Transformer 140 mil wide Cu strip on 3T primary / 21T Total
Two FT240-52 Cores Tight Winding

Measured Coupling coeff. = 0.948
Primary Inductance = 6.919 µH

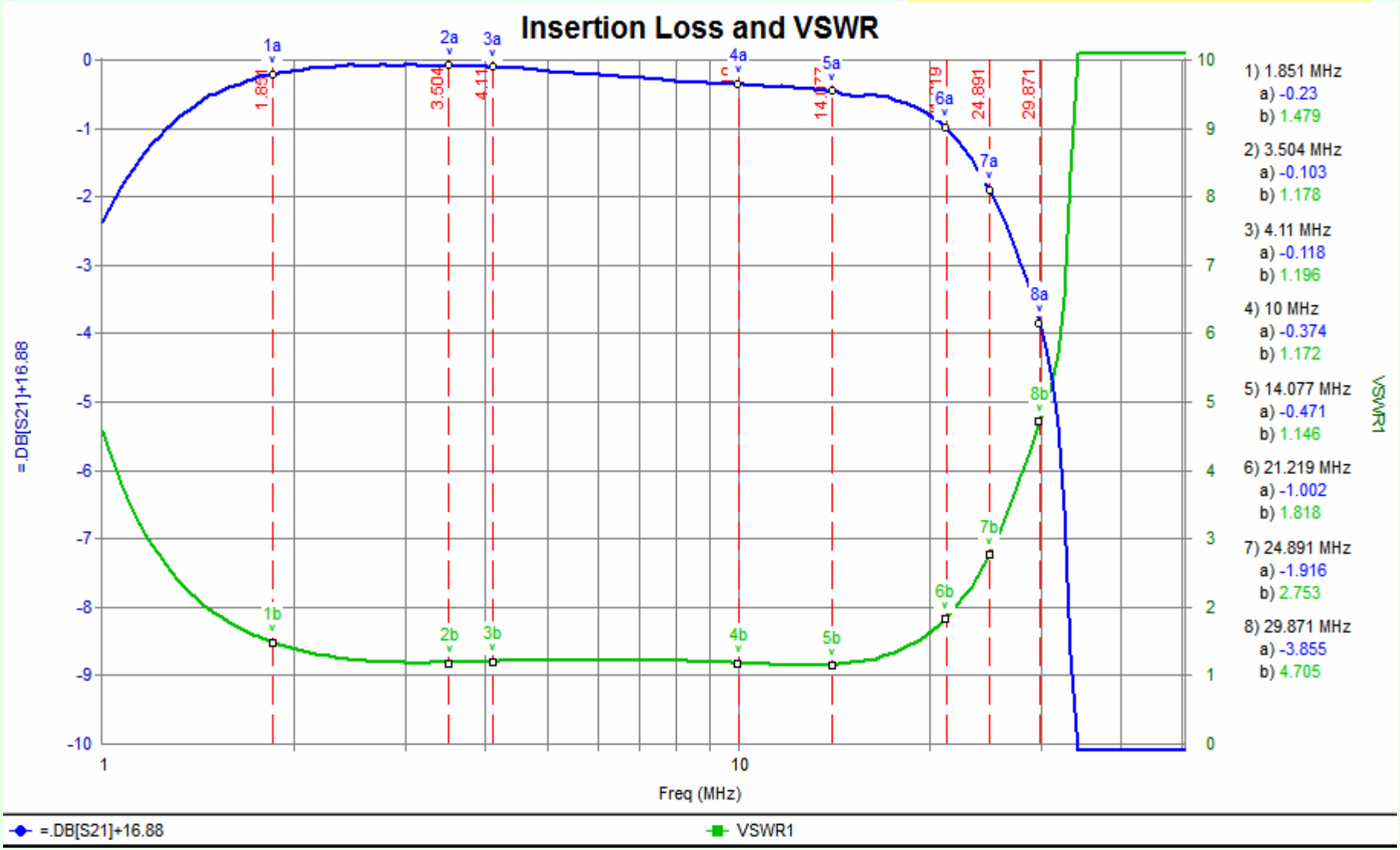


49 to 1 Transformer 140 mil wide Cu strip on 3T primary / 21T Total

Two FT240-52 Cores Tight Winding

Added 100 pF Cap across input and 2200 pF in series with the input

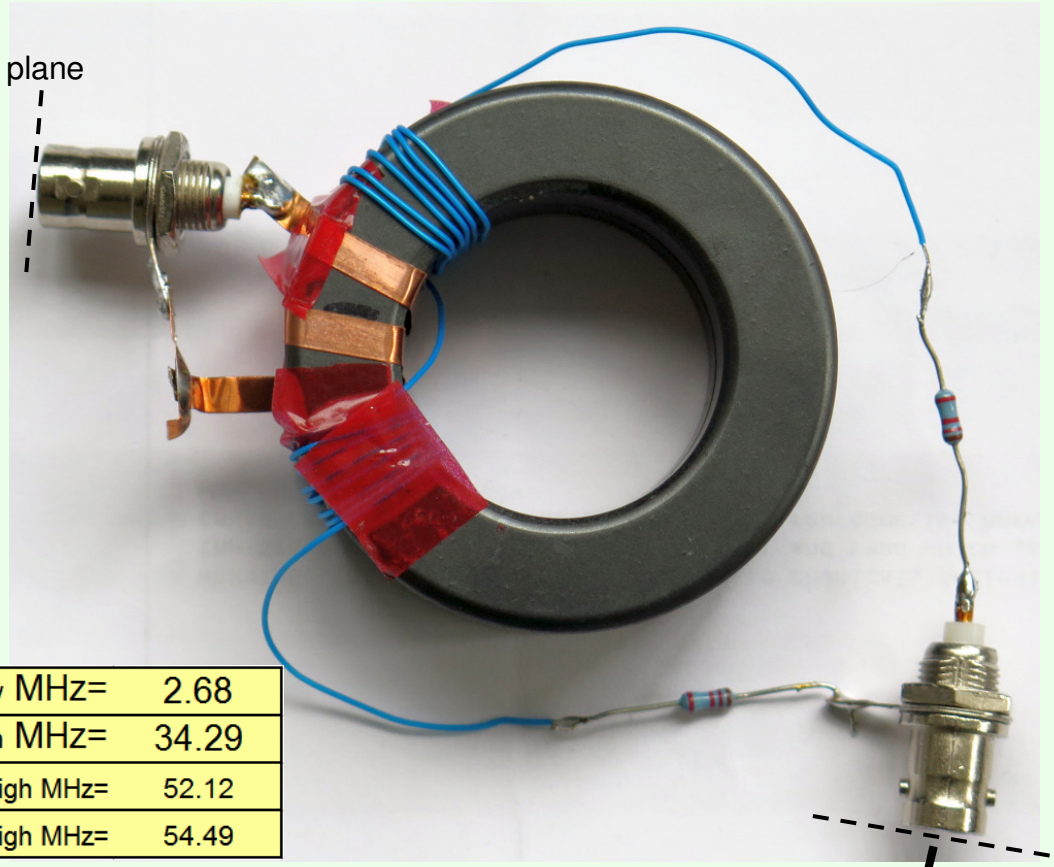
Increased coupling gives…
- Much increased losses above 20 MHz coming from higher pri. inductance: not optimum
- But … Low loss/VSWR on 160m



Ref: FT240-52-2cores-26wireVer3-NoCap-Tap-21a3Tours-TightWdg.wsp

49 to 1 Transformer 140 mil wide Cu strip on 2T primary / 14T Secondary

Two FT240-52 Cores Isolated Secondary Tight Winding



Measured Coupling coeff. =0.949
Primary Inductance = 3.056 µH

M =	**19.26**	Mutual inductance	F3 dB Low MHz=	2.68
K =	**0.949**	Coupling Coeff.	F3dB High MHz=	34.29
	0.153	Primary leakage Inductance	F3dB High MHz=	52.12
	7.156	Secondary leakage Inductan.	F3dB High MHz=	54.49

Ref.: Inductors M and K Calculations.xls

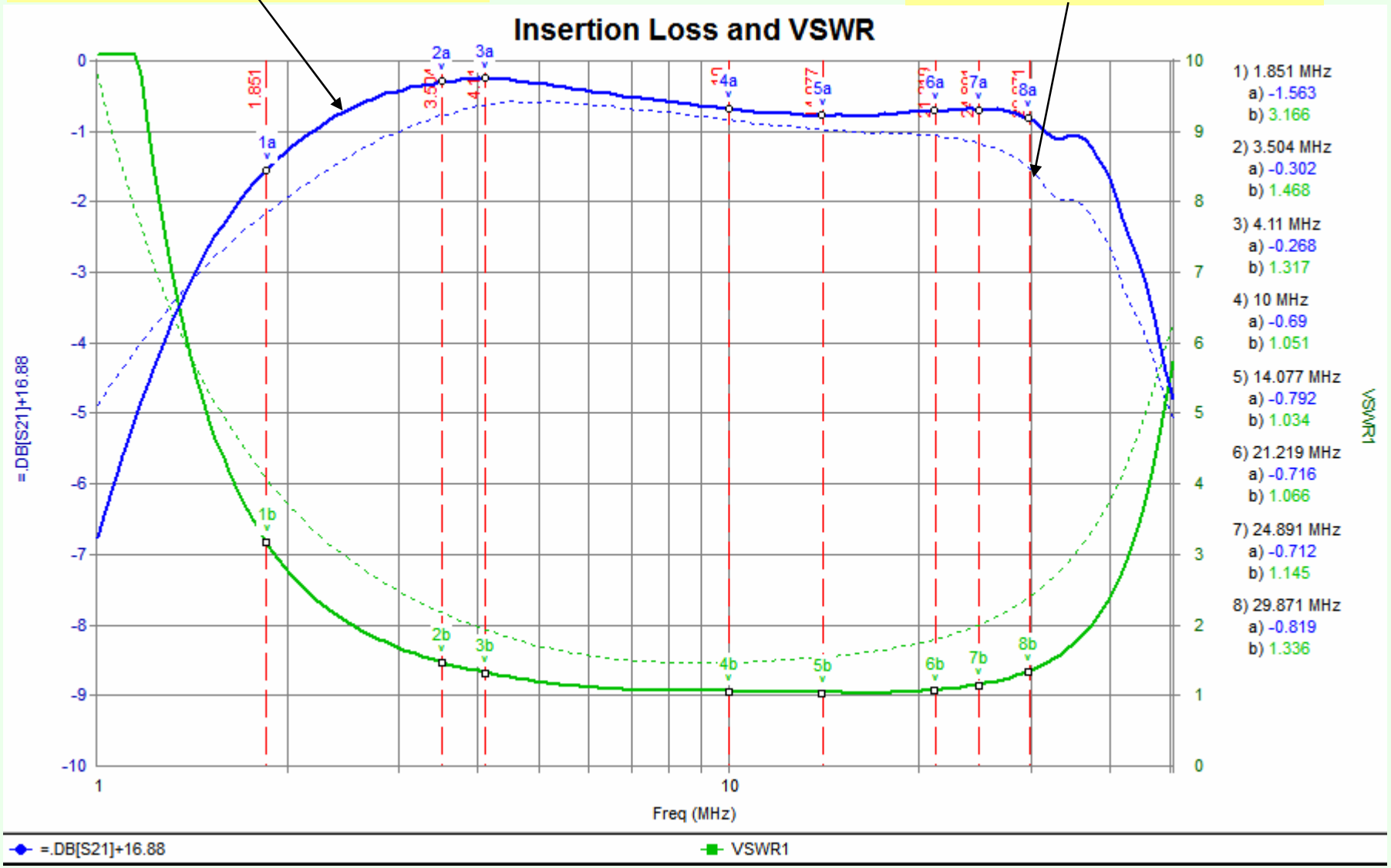
Ref.: http://ve2azx.net/technical/ChokeCurrentBalun.pdf

49 to 1 Transformer 140 mil wide Cu strip on 2T primary / 14T Secondary

Two FT240-52 Cores Isolated Secondary Tight Winding

Added 72 pF Cap across input and 2500 pF in series with the input

No input cap across input and No series cap at input



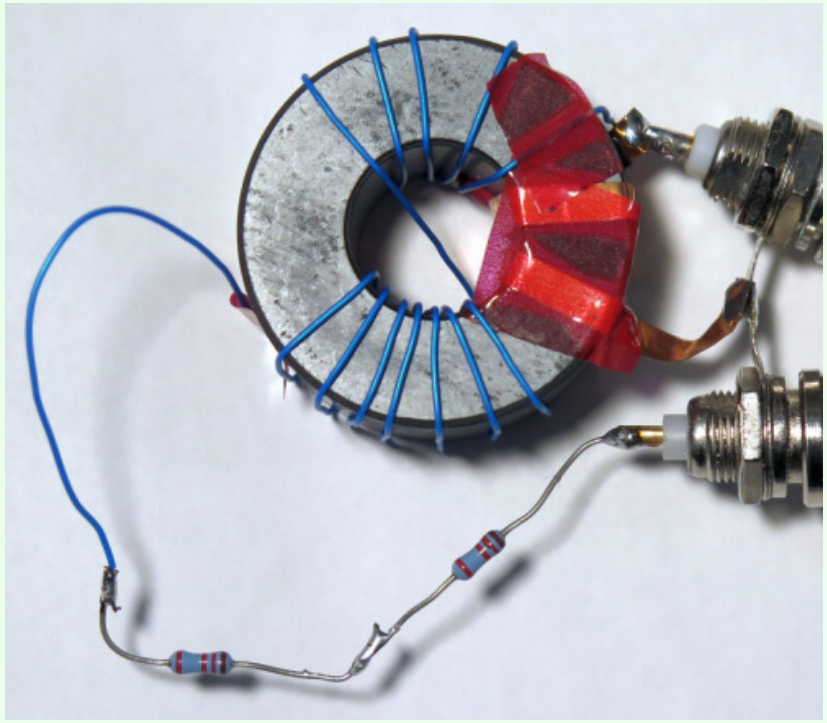
Ref.: FT240-52-2cores-26wireVer2-NoCap-WdgsTighter-FloatingOutput.wsp

49 to 1 Transformer 140 mil wide Cu strip on 2T primary / 12T Secondary
Two FT240-52 Cores Isolated Secondary Tight Winding

This unit gave similar results as the 1:7 ratio version

49 to 1 Auto Transformer 140 mil wide Cu strip on 2T primary / 12T secondary
<u>One</u> Fair-Rite #2643251002 43 type Core

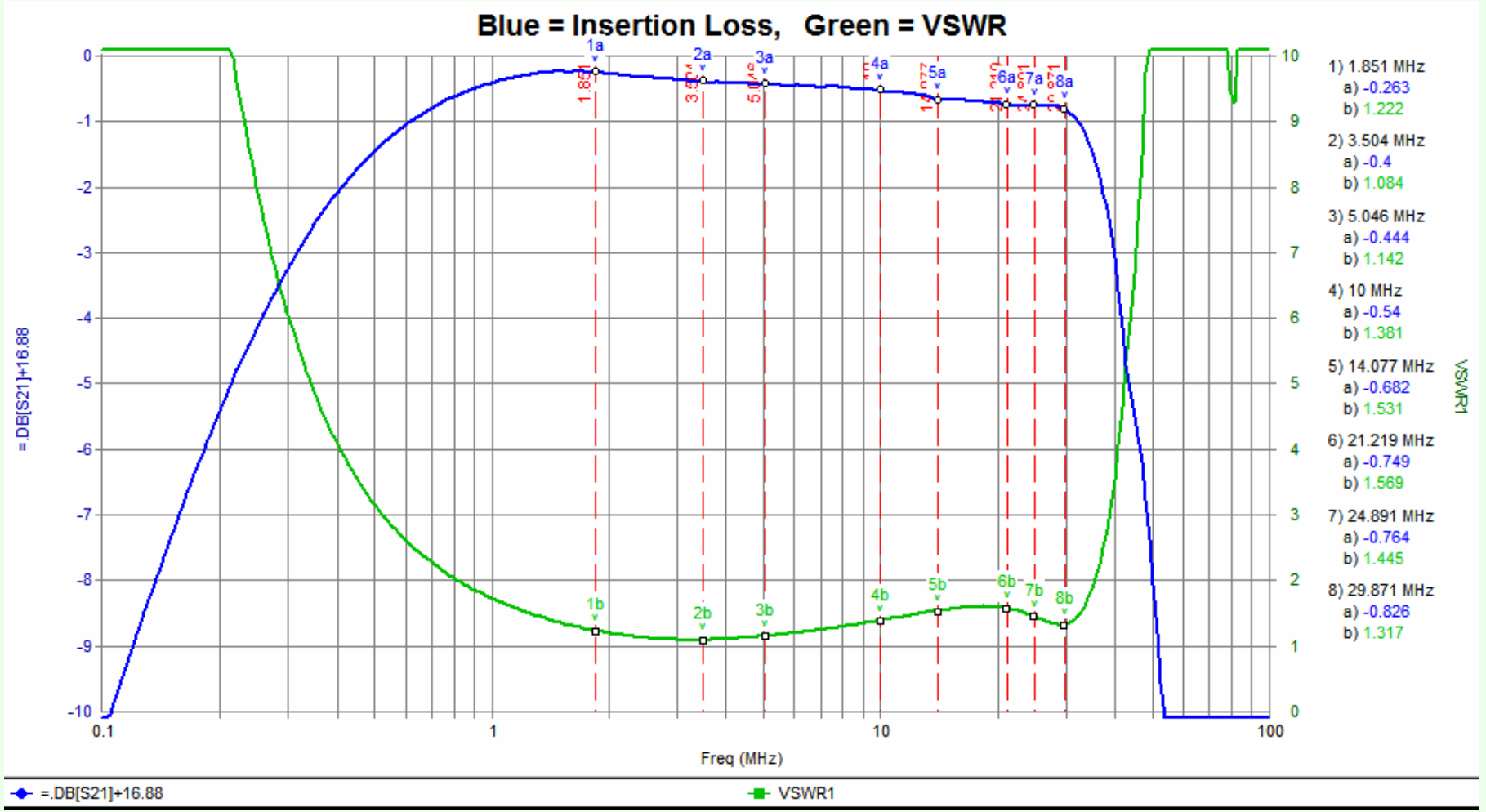
SPLIT SECONDARY



M =	**75.23**	Mutual inductance	F3 dB Low MHz=	0.62
K =	**0.984**	Coupling Coeff.	F3dB High MHz=	28.30
	0.209	Primary leakage Inductance	F3dB High MHz=	38.14
	7.417	Secondary leakage Inductan.	F3dB High MHz=	52.58

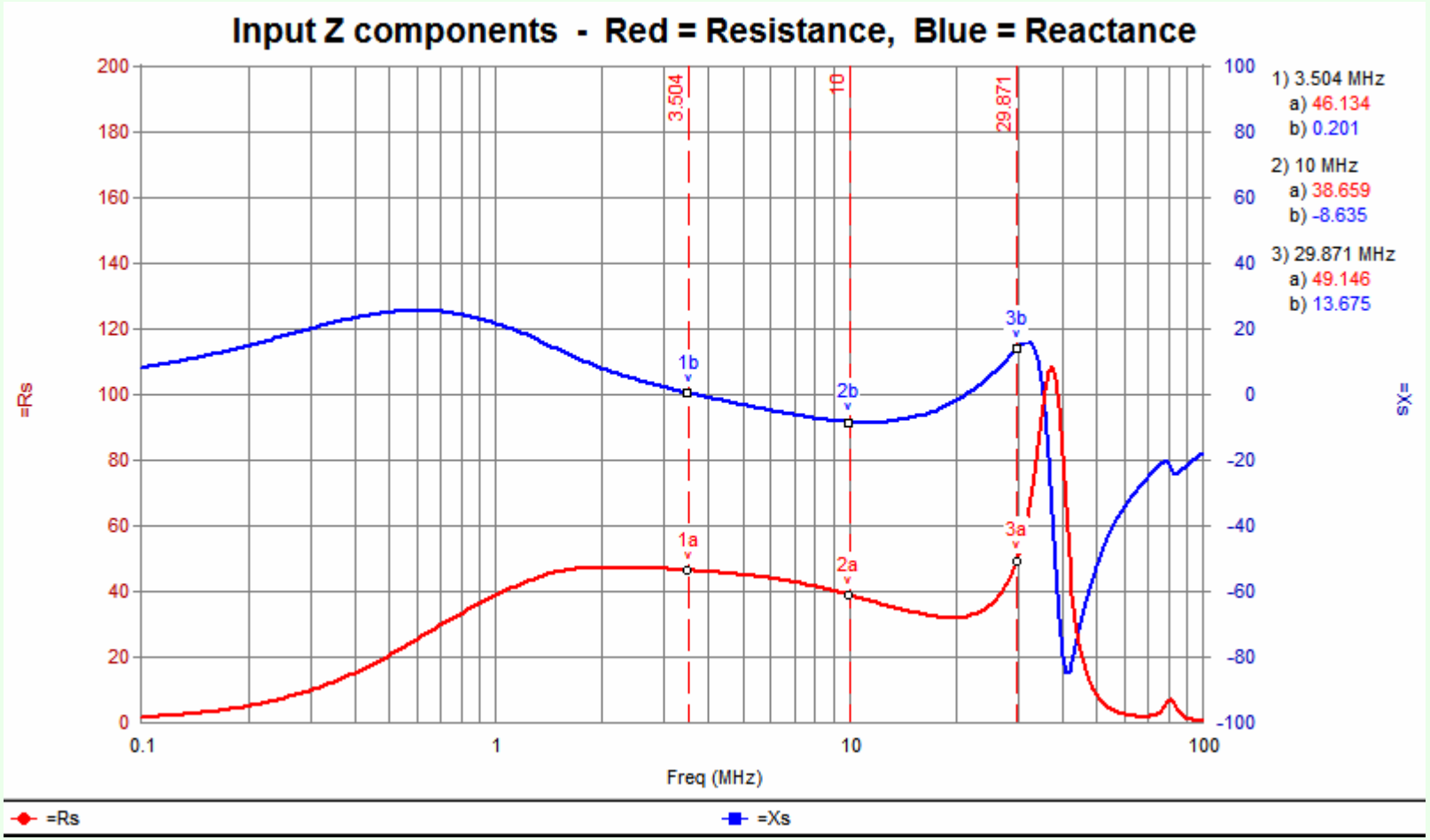
49 to 1 Auto Transformer 140 mil wide Cu strip on 2T primary / 12T secondary
<u>One</u> Fair-Rite #2643251002 43 type Core

Added 100 pF Cap across input



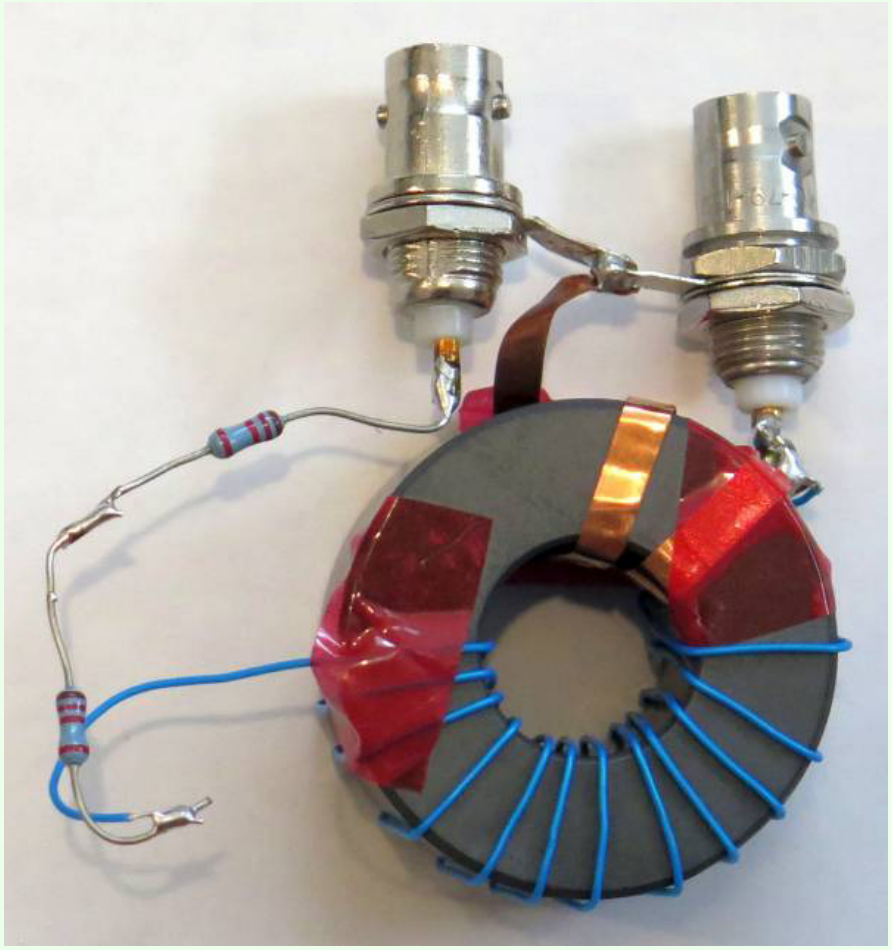
49 to 1 Auto Transformer 140 mil wide Cu strip on 2T primary / 12T secondary
<u>One</u> Fair-Rite #2643251002 43 type Core

Added 100 pF Cap across input



49 to 1 Auto Transformer 140 mil wide Cu strip on 2T primary / 12T secondary
<u>One</u> Fair-Rite #2643251002 43 type Core

CONTINUOUS SECONDARY

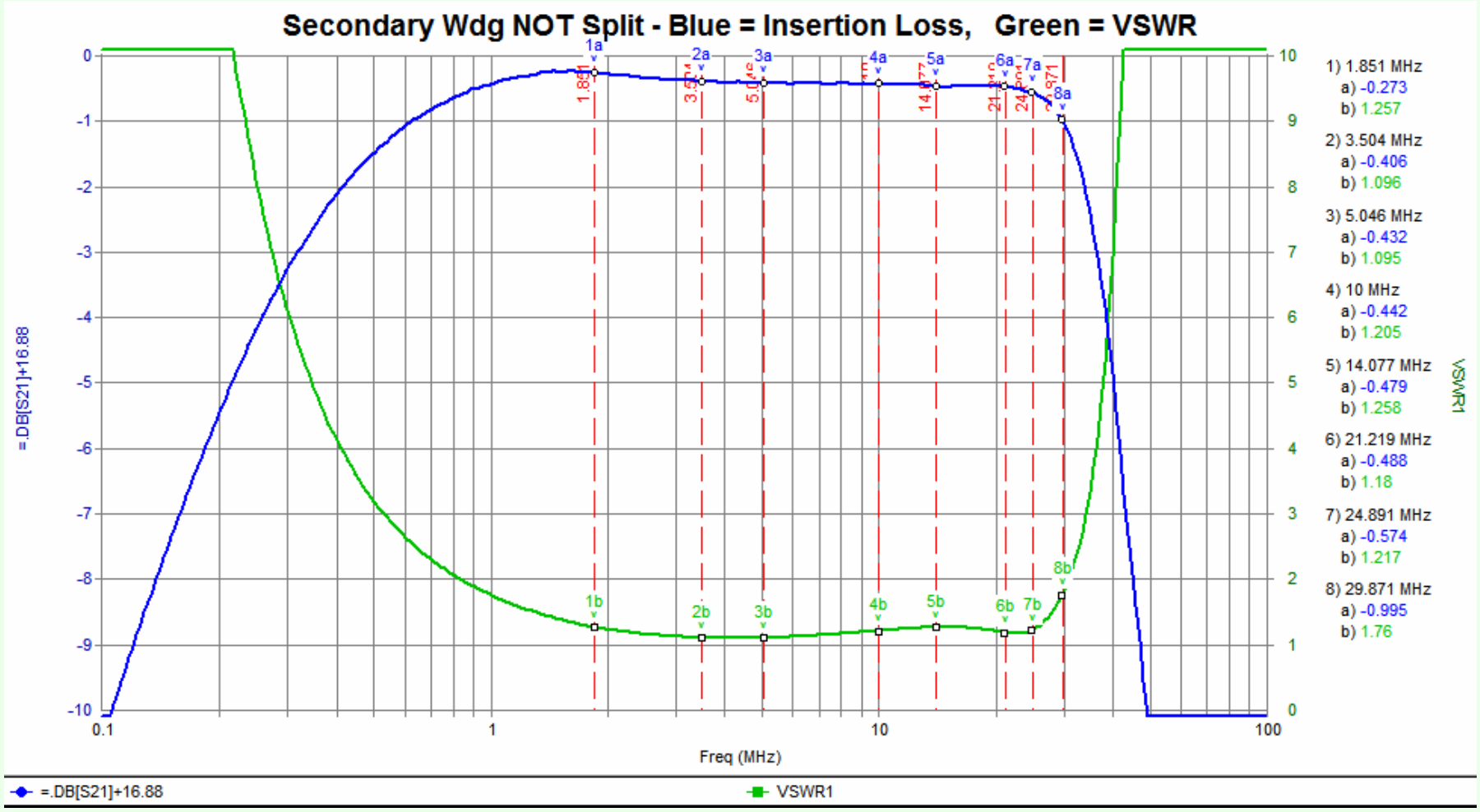


M =	**74.28**	Mutual inductance	F3 dB Low MHz=	0.63
K =	**0.980**	Coupling Coeff.	F3dB High MHz=	22.75
	0.259	Primary leakage Inductance	F3dB High MHz=	30.68
	9.239	Secondary leakage Inductan.	F3dB High MHz=	42.21

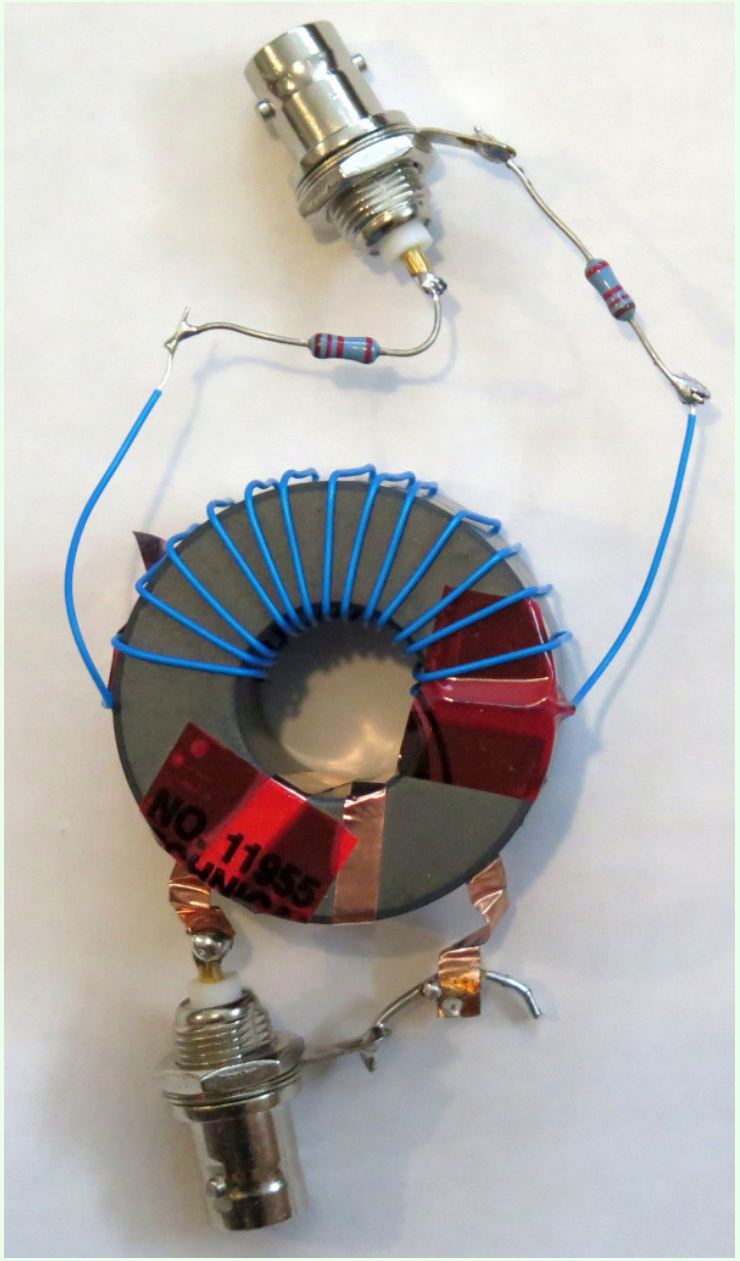
49 to 1 Auto Transformer 140 mil wide Cu strip on 2T primary / 12T secondary
<u>One</u> Fair-Rite #2643251002 43 type Core

Added 100 pF Cap across input

CONTINUOUS SECONDARY

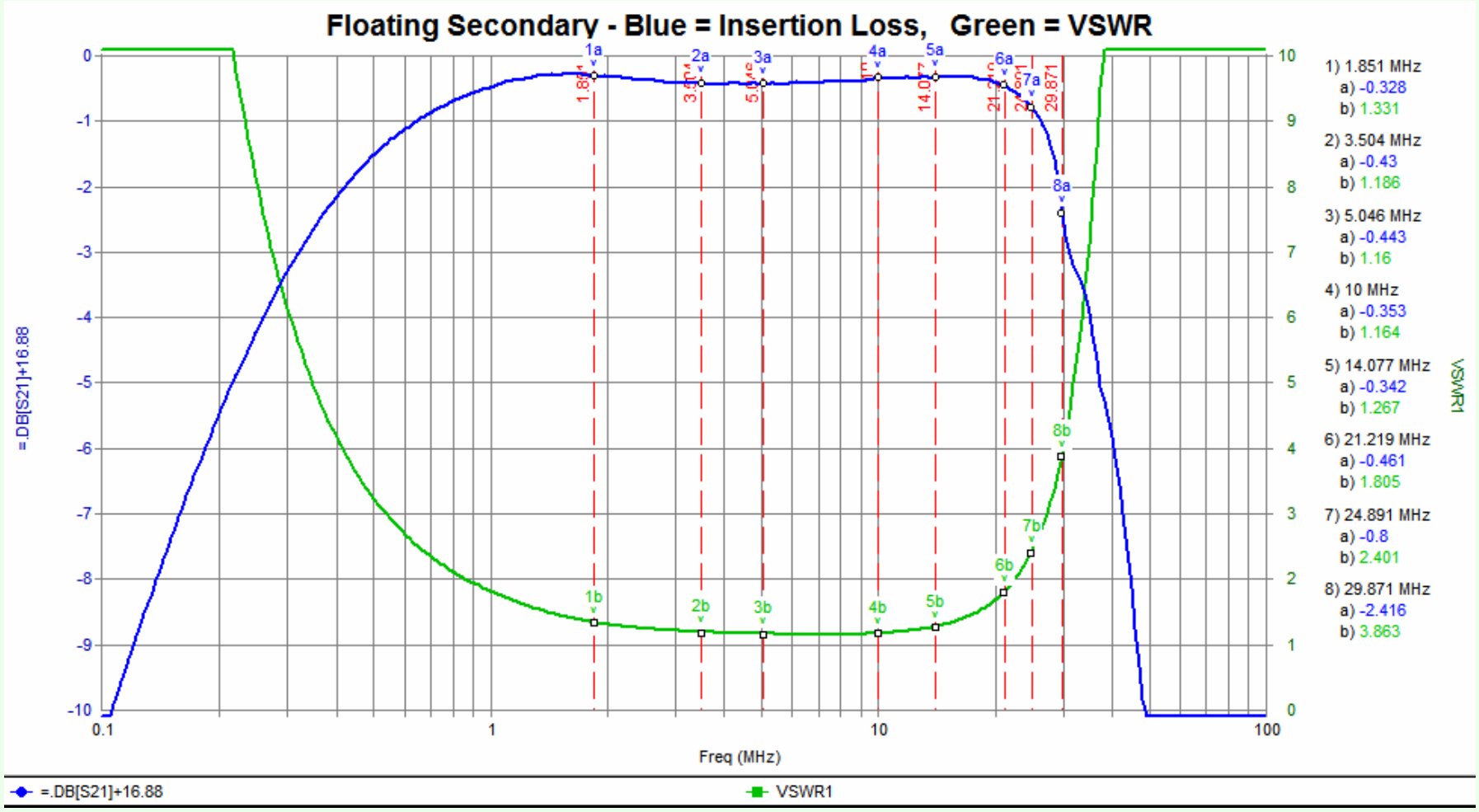


49 to 1 Transformer Floating Output
140 mil wide Cu strip on 2T primary / 14T secondary
<u>One</u> Fair-Rite #2643251002 43 type Core



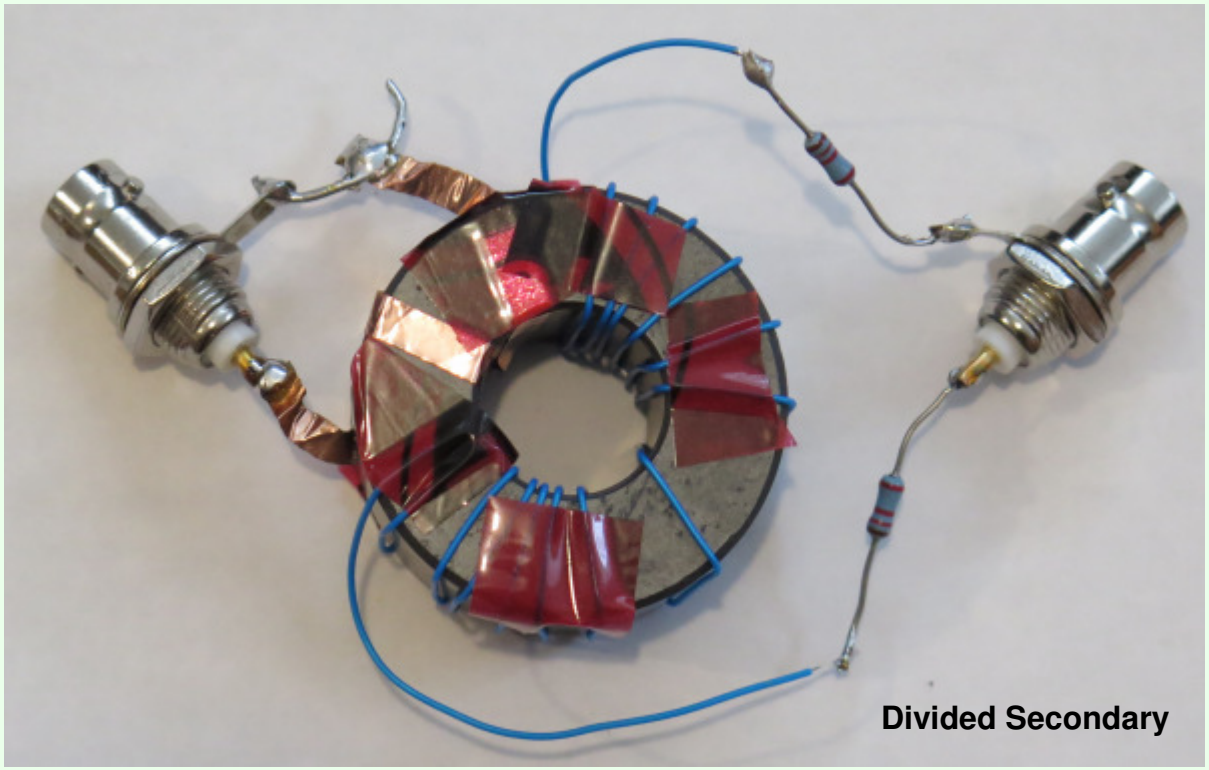
49 to 1 Transformer Floating Output
140 mil wide Cu strip on 2T primary / 14T secondary
<u>One</u> Fair-Rite #2643251002 43 type Core

Added 100 pF Cap across input



49 to 1 Transformer Floating Output - Divided Secondary
140 mil wide Cu strip on 2T primary / 14T secondary
<u>One</u> Fair-Rite #2643251002 43 type Core

Added 100 pF Cap across input

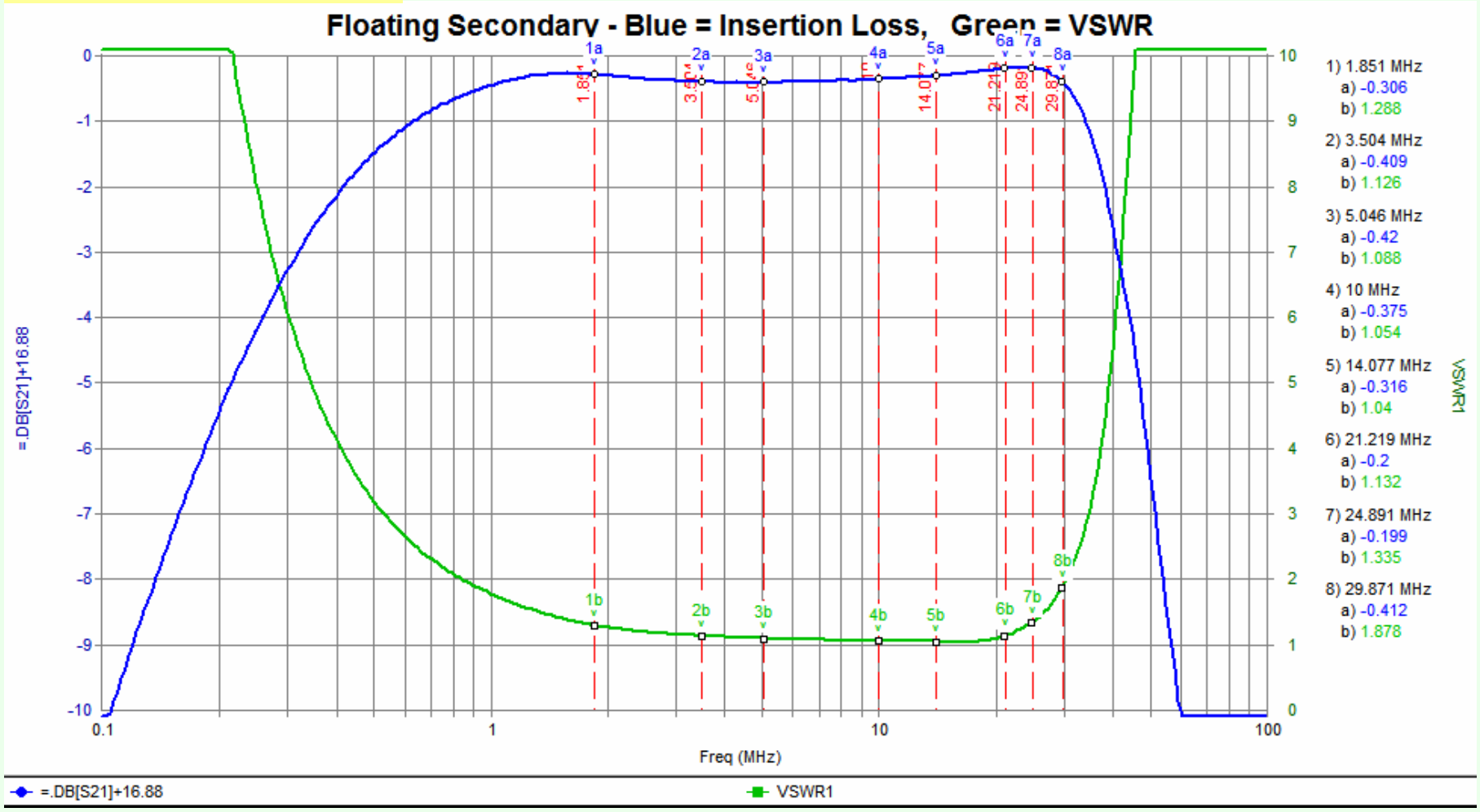


Divided Secondary

M =	**87.30**	Mutual inductance	F3 dB Low MHz=	0.63
K =	**0.987**	Coupling Coeff.	F3dB High MHz=	32.03
	0.161	Primary leakage Inductance	F3dB High MHz=	49.45
	7.784	Secondary leakage Inductan.	F3dB High MHz=	50.09

49 to 1 Transformer Floating Output - Divided Secondary
140 mil wide Cu strip on 2T primary / 14T secondary
<u>One</u> Fair-Rite #2643251002 43 type Core

Added 100 pF Cap across input

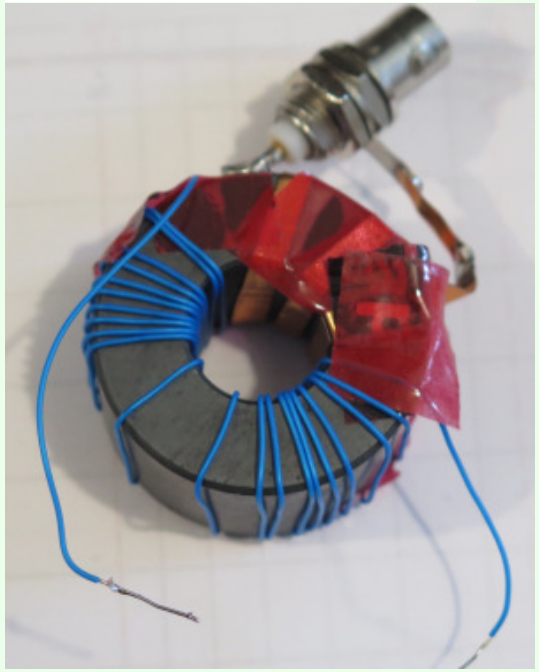


49 to 1 Transformer Floating Output - Divided Secondary
140 mil wide Cu strip on 3T primary / 21T secondary
<u>One</u> Fair-Rite #2643251002 43 type Core

Added 100 pF Cap across input

Since the maximum power is proportional to the number of turns squared,
Why not use a 3 to 21 turns ratio ?
Going from 2T to 3T on the primary should increase the maximum power by:
$(3/2)^2 = 2.25$ times
Ref: Inductors M and K Calculations.xls / Core Max Power

Fair-Rite core #2643251002
1.54 x 0.66 x .875 in.
43 material μ = 800



Note that the coupling coefficient is close to 1.

M =	**200.15**	Mutual inductance	F3 dB Low MHz=	0.28
K =	**0.993**	Coupling Coeff.	F3dB High MHz=	25.66
	0.201	Primary leakage Inductance	F3dB High MHz=	39.69
	9.738	Secondary leakage Inductan.	F3dB High MHz=	40.04

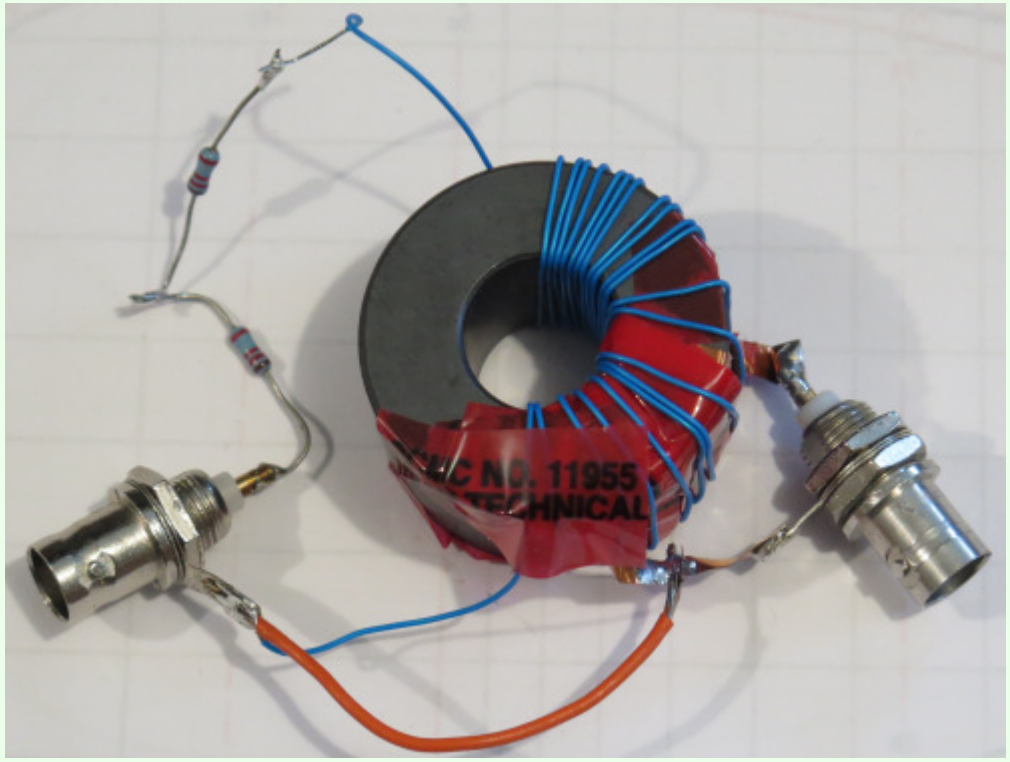
49 to 1 Transformer Floating Output - Divided Secondary
140 mil wide Cu strip on 3T primary / 21T secondary
<u>One</u> Fair-Rite #2643251002 43 type Core

Added 53 pF Cap across input

Too much losses above 10 MHz,
even if coupling coeff. is close to unity.
BUT Low frequency performance
extends far below 1 MHz

Ref.: UNUN 49to1-26wire-21a3Tours-SplitSecondary-1core 2643251002.wsp

49 to 1 Transformer Floating Output - <u>Secondary wound over Primary</u>
140 mil wide Cu strip on <u>3T primary / 21T secondary</u>
<u>Prim and Sec interconnected. Tape added over the primary.</u>
<u>One</u> Fair-Rite #2643251002 43 type Core



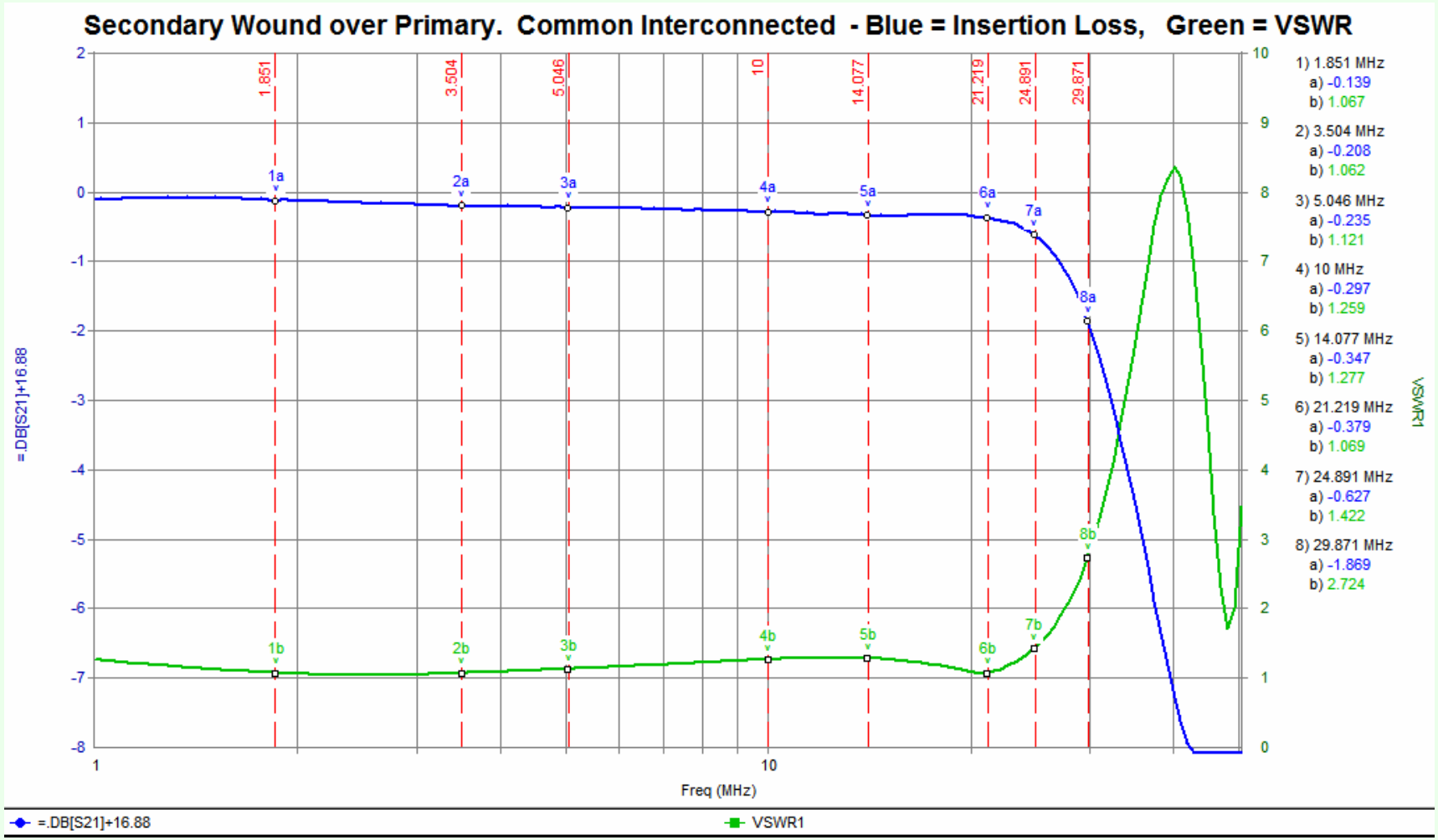
With Sec. wound over the Prim.,
the coupling factor is very close to 1

M =	**202.30**	Mutual inductance	F3 dB Low MHz=	0.28
K =	**1.003**	Coupling Coeff.	F3dB High MHz=	56.93
	-0.090	Primary leakage Inductance	F3dB High MHz=	-88.14
	-4.393	Secondary leakage Inductan.	F3dB High MHz=	-88.76

49 to 1 Transformer Floating Output - Secondary wound over Primary
140 mil wide Cu strip on 3T primary / 21T secondary
Prim and Sec interconnected. Tape added over the primary.
One Fair-Rite #2643251002 43 type Core

Added 100 pF Cap across input

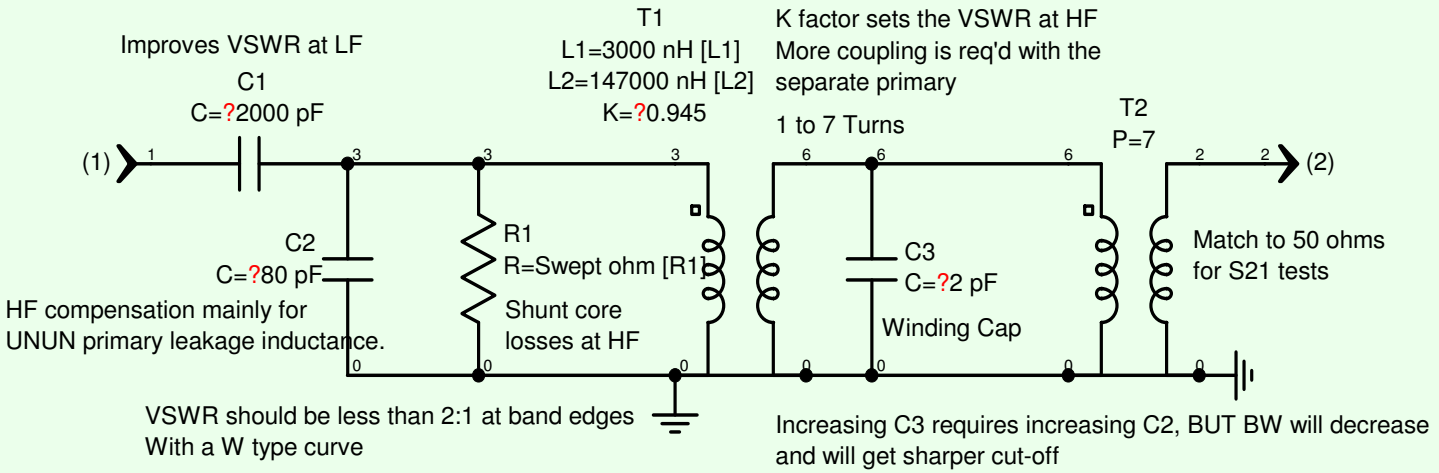
-With Sec. wound over the Prim., the coupling factor is very close to 1
- Response OK up to 25 MHz.
- Low freq. performance has shifted towards low frequencies Only 0.14 dB loss at 1.8 MHz



Ref.: UNUN 49to1-26wire-21a3Tours-Prim and Sec shorted-1core 2643251002.wsp

Modelling the 49 to 1 UNUN

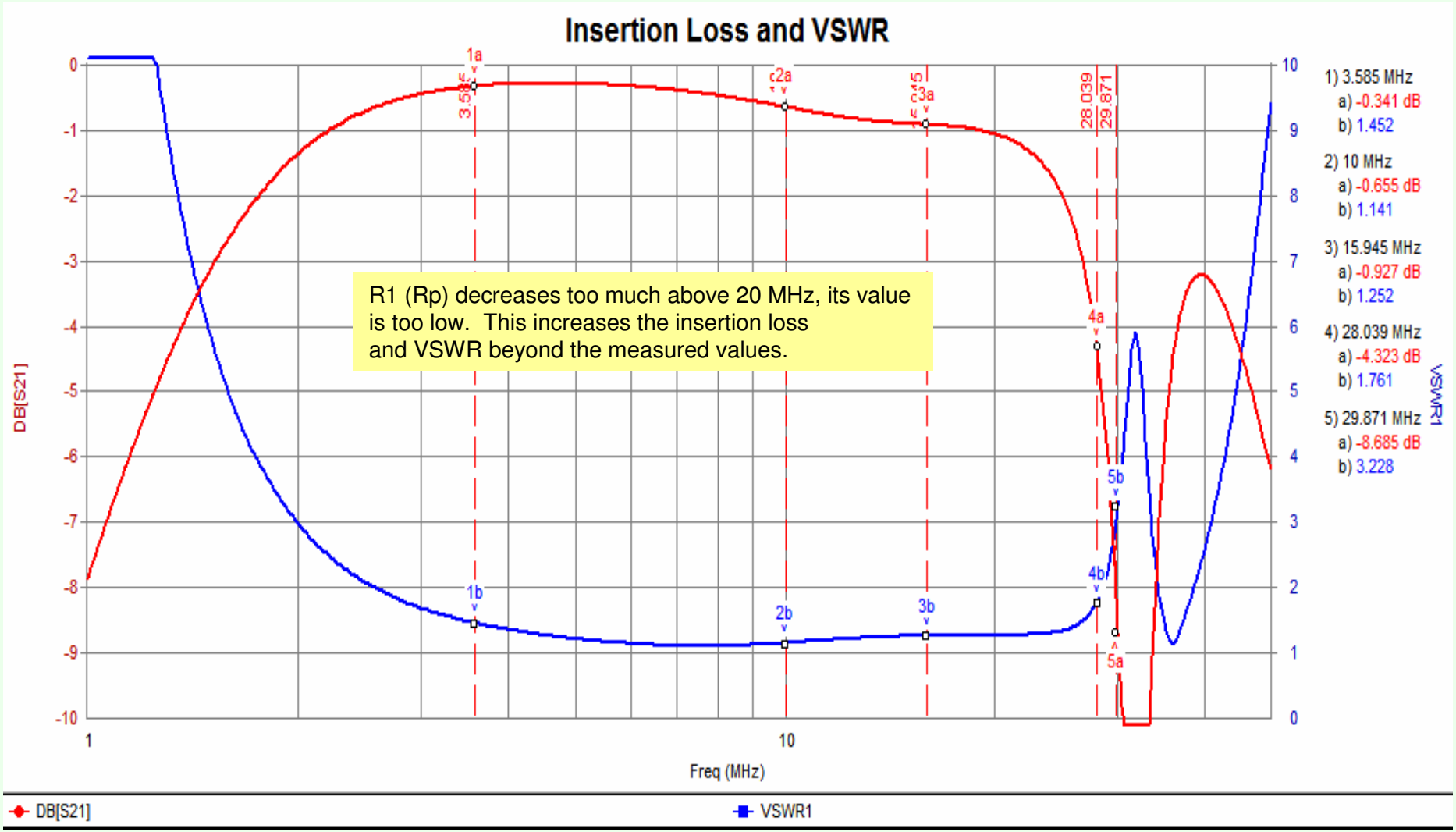
separate primary/secondary model



R1 vs FREQ modelled from:
FT240-52-2cores-2T-CuStrip-Ver2-PrimaryOnly-Sec26wireOpen.wsp
and: FT240-52-2cores-2T-CuStrip-Ver2-PrimaryOnly-Sec26wireOpen.xls
R1 decreases at higher freq causing increased losses

Ref: Transformer_sim3_FT240-52-R1_modelled.wsp

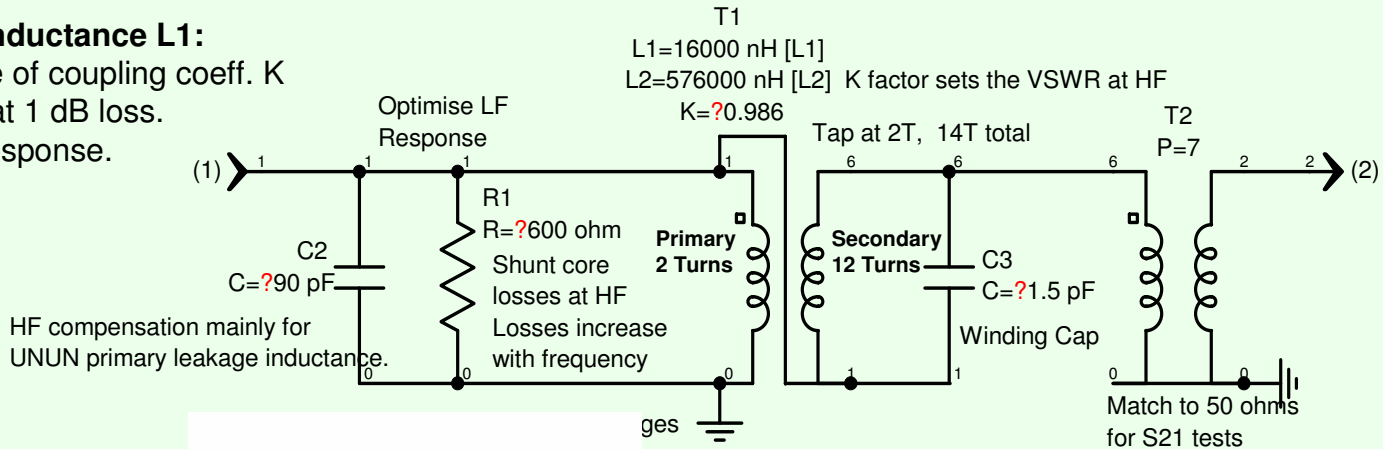
Using the measured R1 (parallel Rp) with open secondary in the previous model

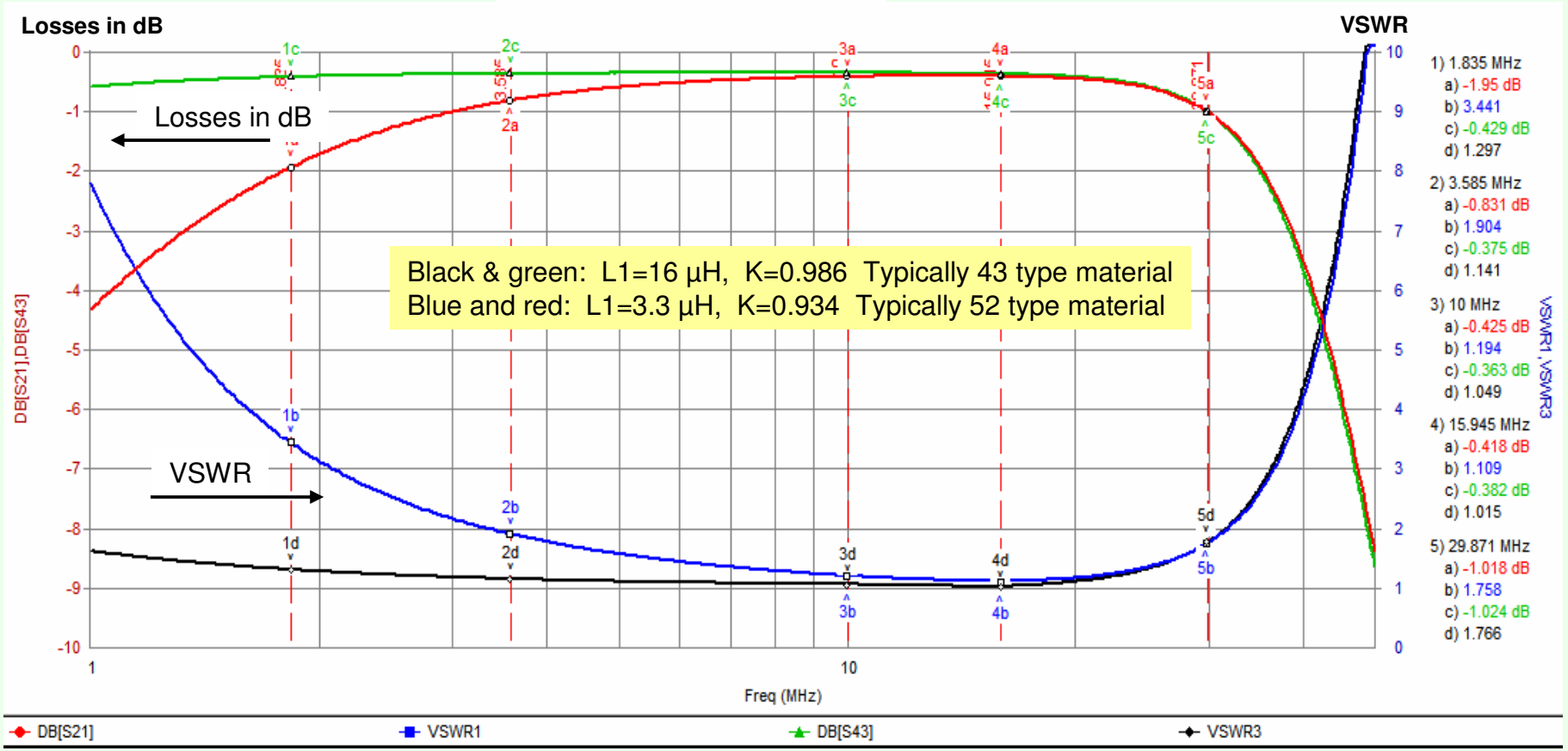


Ref: Transformer_sim3_FT240-52-R1_modelled.wsp

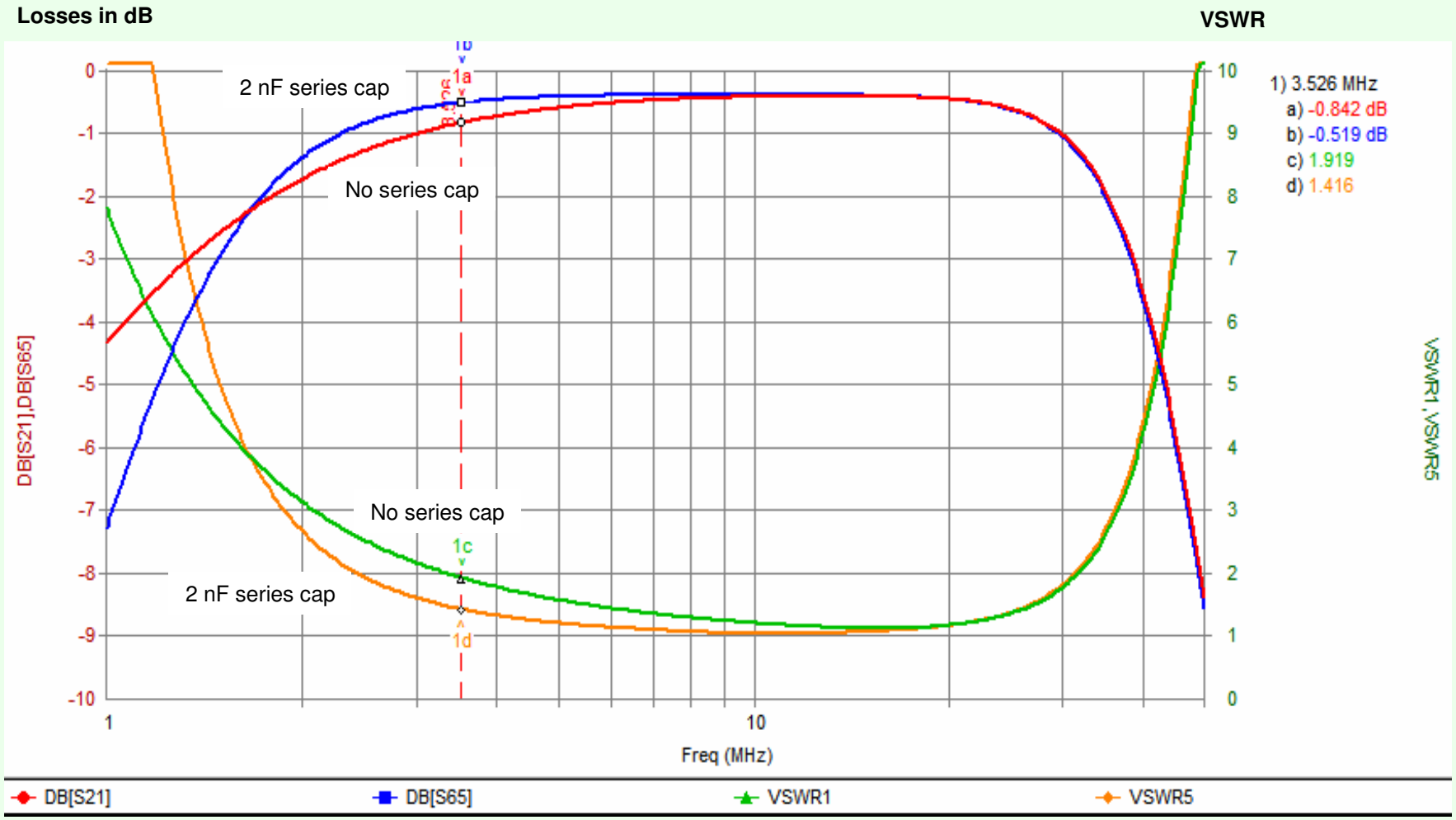
Simulations of Tapped Inductor/Transformer

Increasing primary inductance L1:
- Requires an increase of coupling coeff. K to keep HF response at 1 dB loss.
- Improves low freq. response.





Simulations of Tapped Inductor
Series Capacitor improves Losses and VSWR at low frequencies



Adding a shunt Inductor before the Series Capacitor Further improves Losses and VSWR at low frequencies

(pink and brown) Allows coverage of 160m band.