

# **BANDPASS CAVITY RESONATORS**

**S Parameters Measurements and Modelling  
Using Bandpass Cavities for Impedance Matching**

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## INTRODUCTION

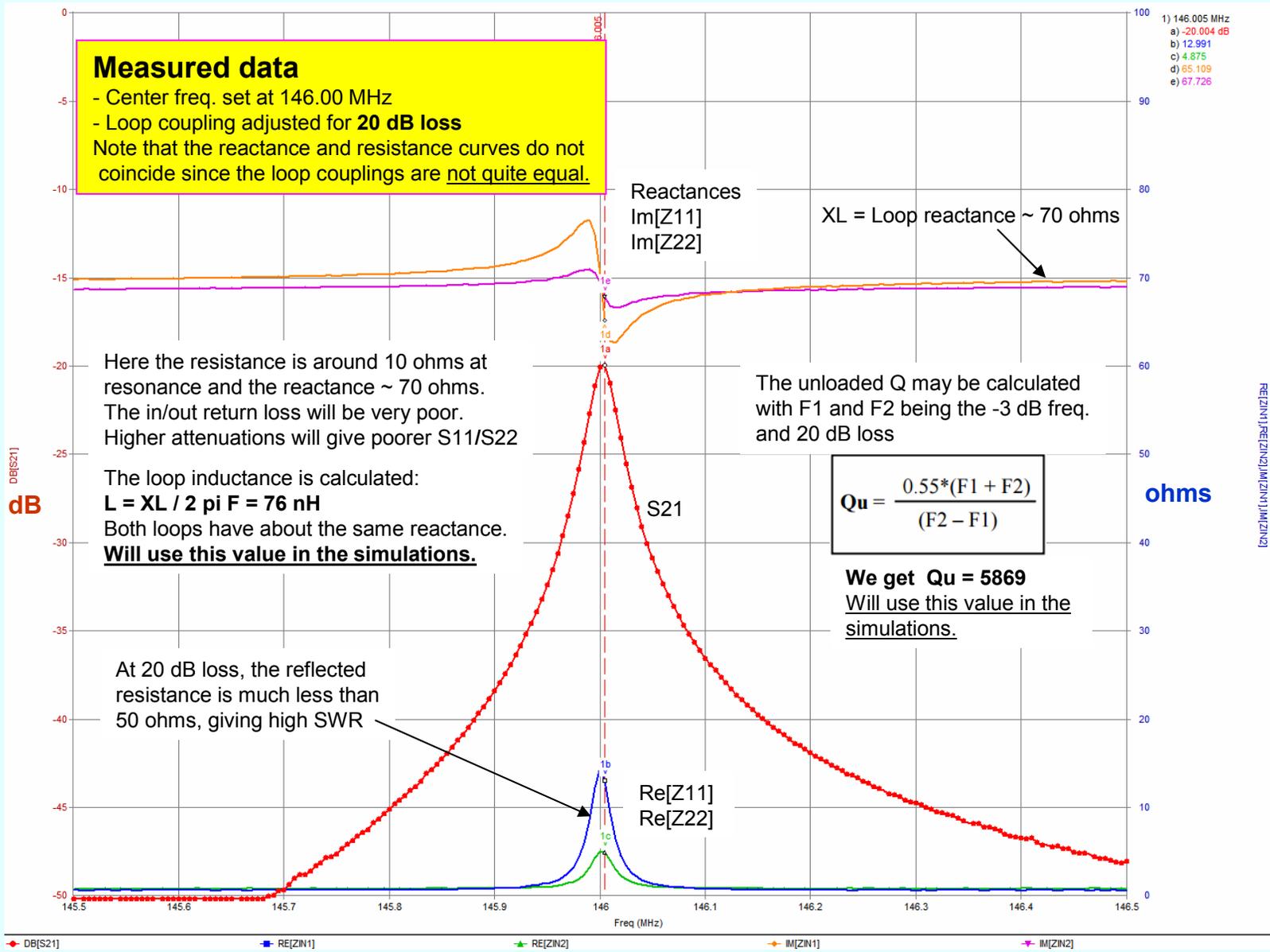
This investigation on the bandpass cavities came after a conversation with Luc Laplante VE2ULU.

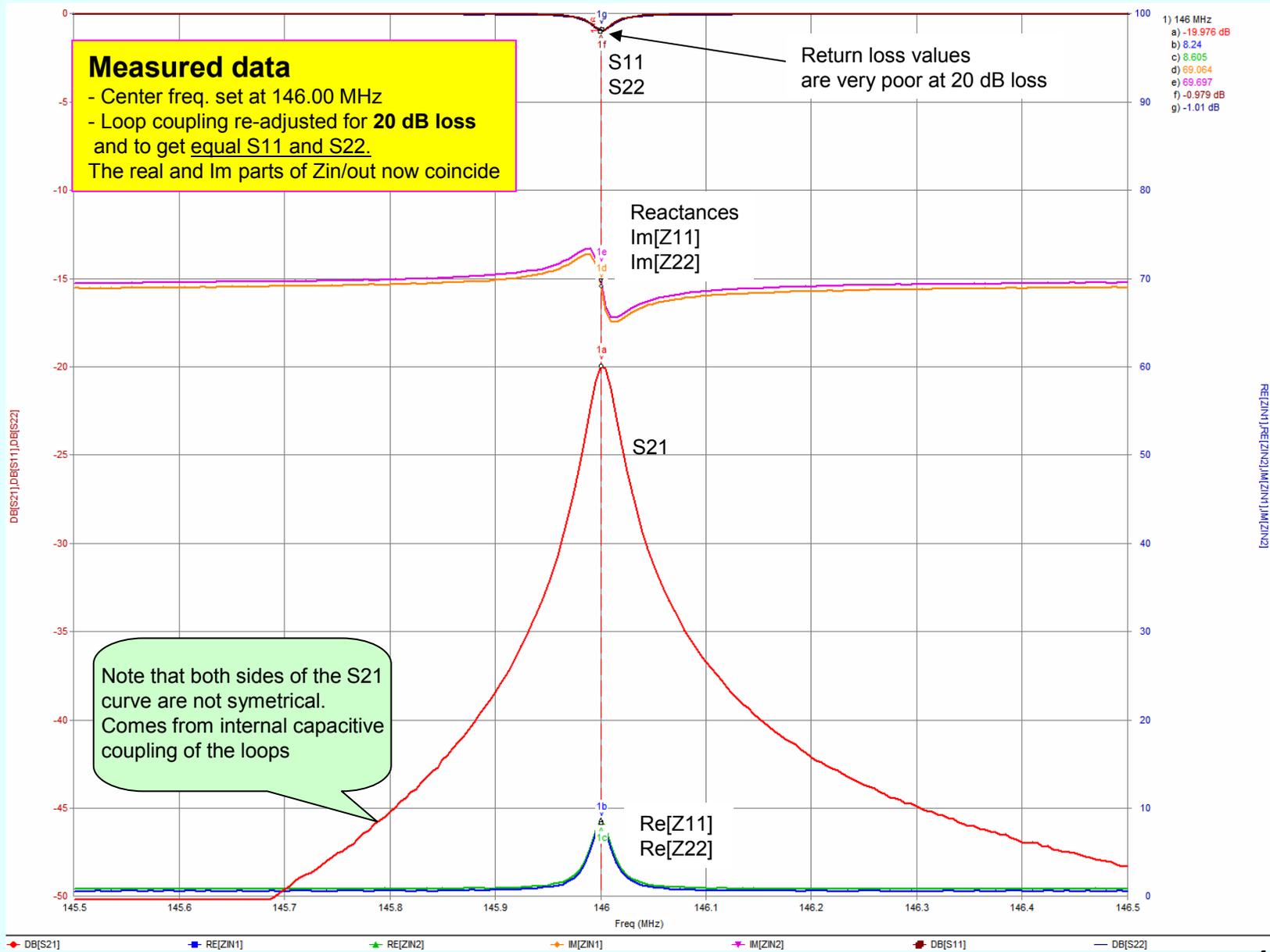
Luc has used bandpass cavities for impedance matching by adjusting the loop couplings.

I was interested to see if this capability would show up in the simulations of the cavity resonators.

This technique also improves RX sensitivity mostly for receivers operating above the 2 meter band, where atmospheric noise levels are lower. It also allows matching 75 ohm heliax antenna cable to the duplexer.

S parameter measurements as well as simulations were done on a bandpass cavity to better understand what is going on.





## Circuit used for simulation

Uses mutually coupled inductors with coupling coeff.  $K$ , adjusted for desired loss at the resonant freq..

L1 inductors (lossless) are the coupling coils that control attenuation at resonance.

L2 inductors (lossless) sets the resonant freq. at 146 MHz.

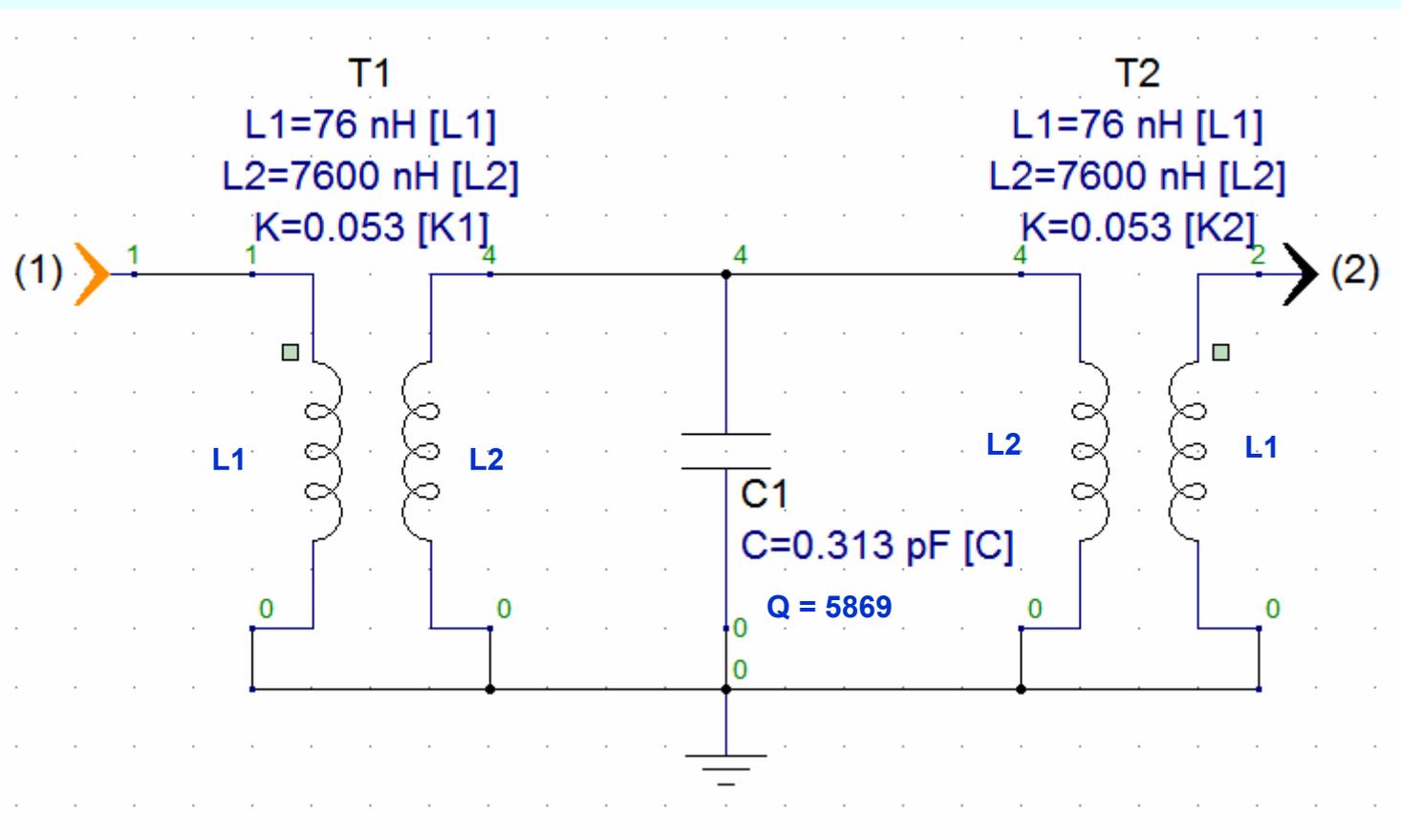
L2 is 100 X L1 but **ANY** ratio will give the same results !

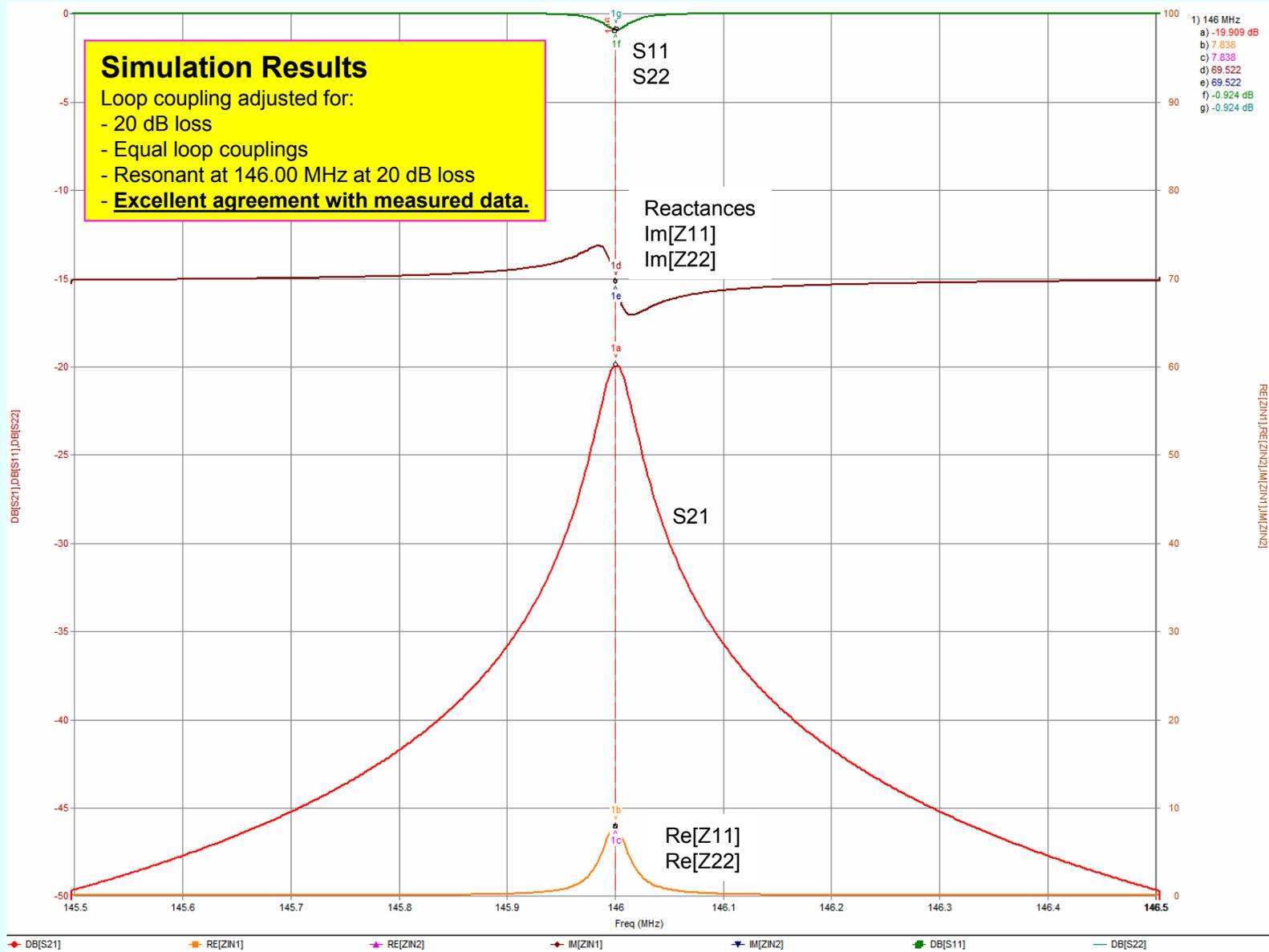
C1 is set to resonate at 146 MHz, and sets the Q factor of the cavity.

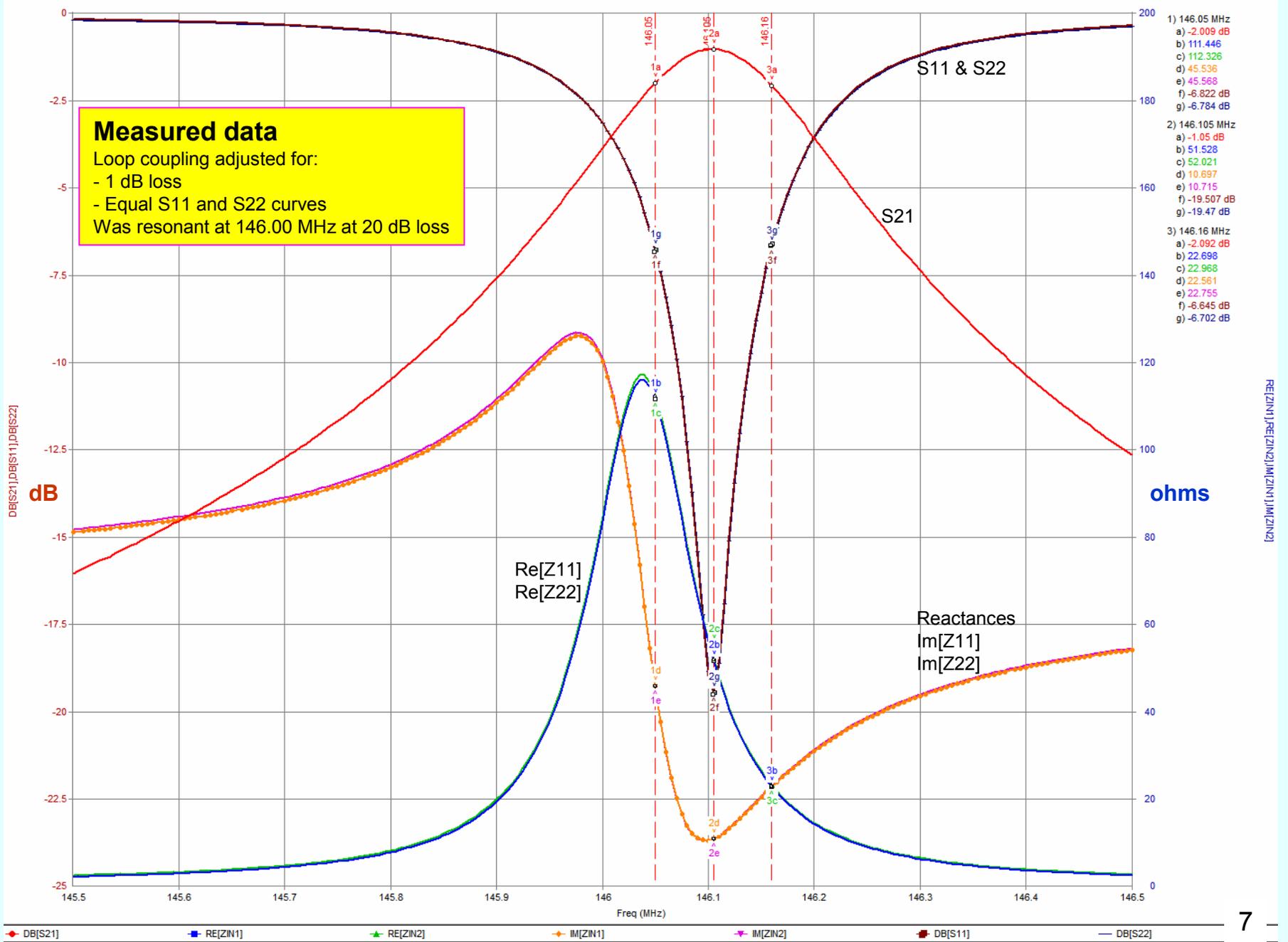
- Gives equal S11 and S22 curves

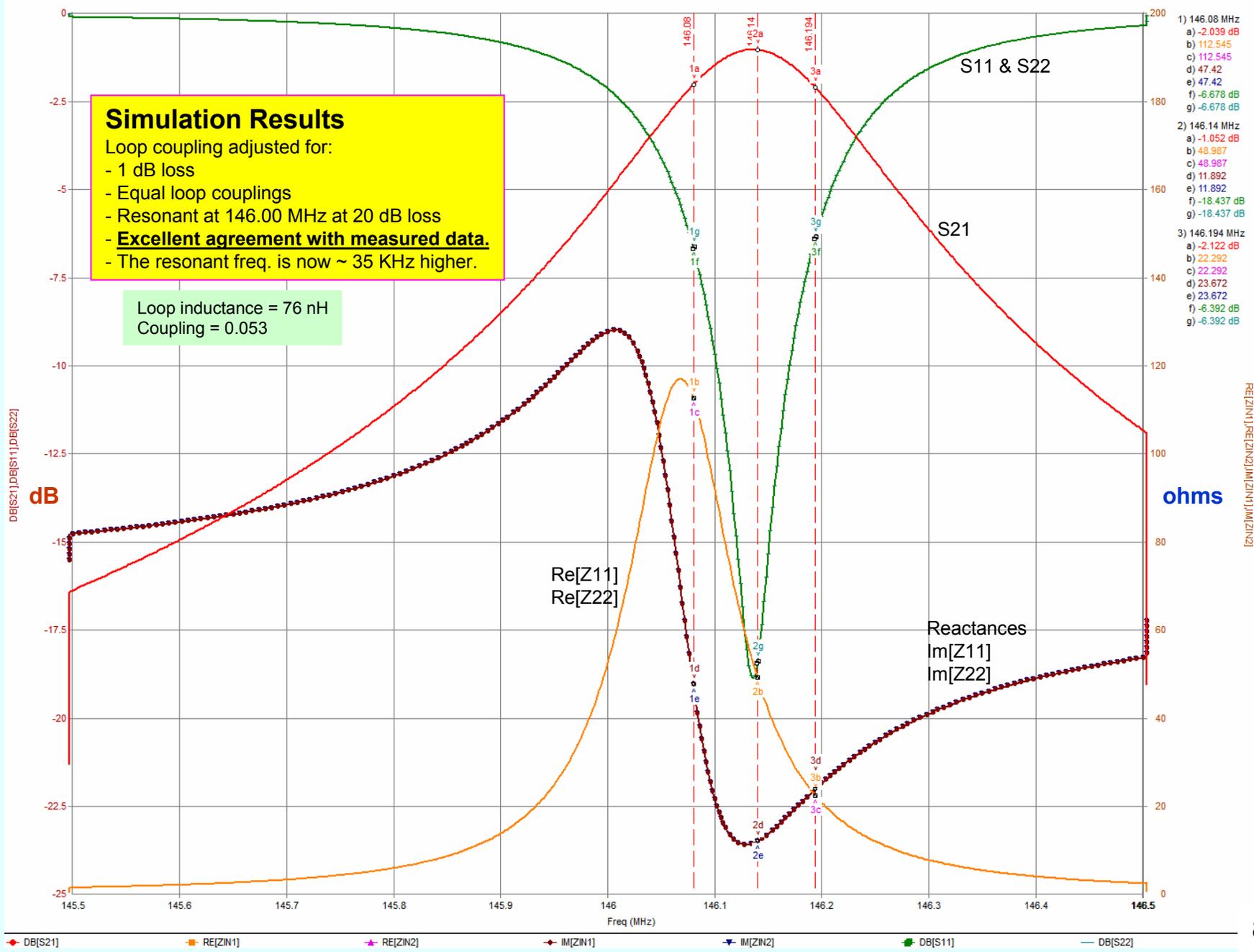
- Resonant at 146.00 MHz at 20 dB loss

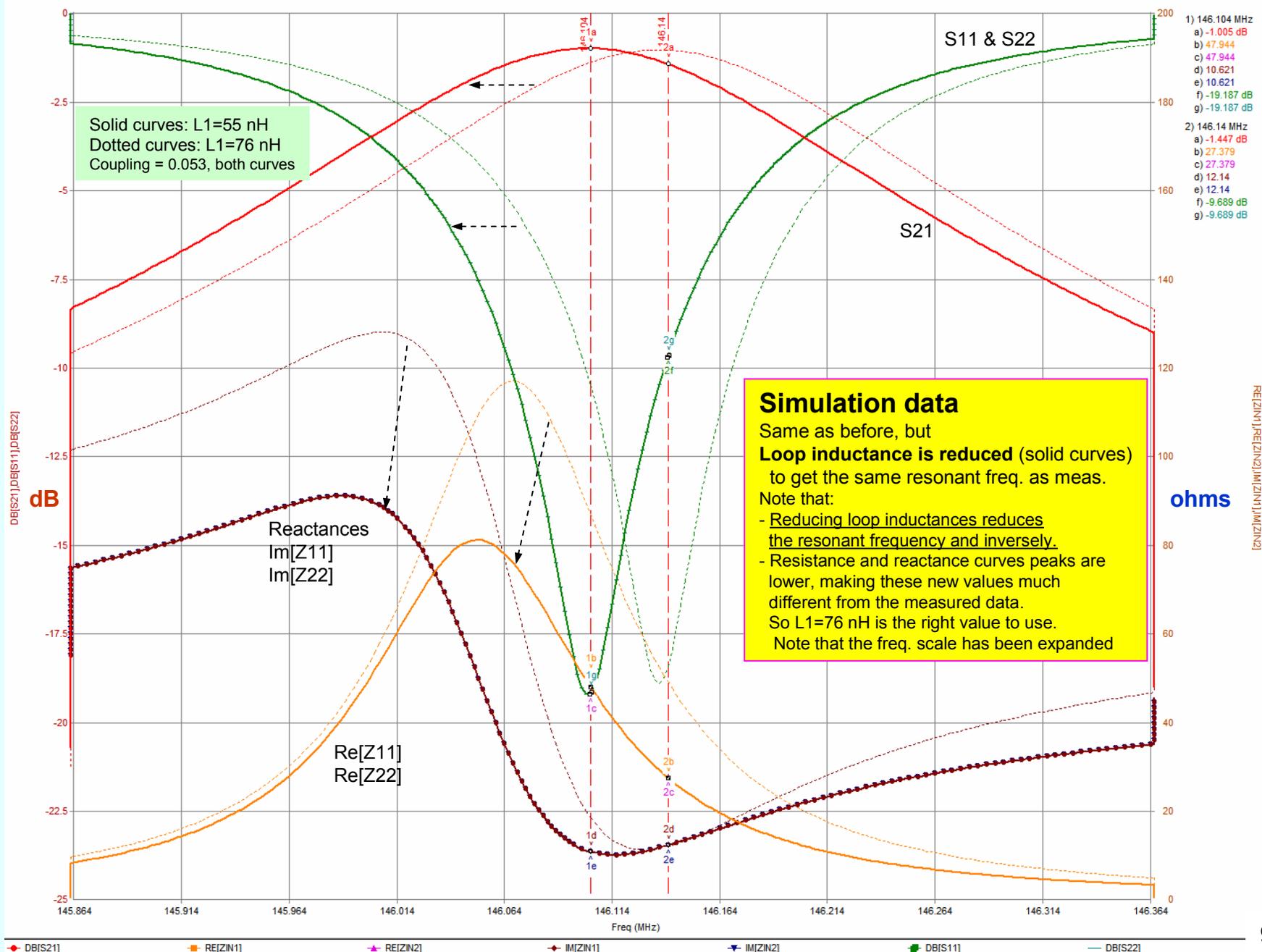
- A small value capacitor (not shown), connected between in – out, will simulate the loop to loop coupling.







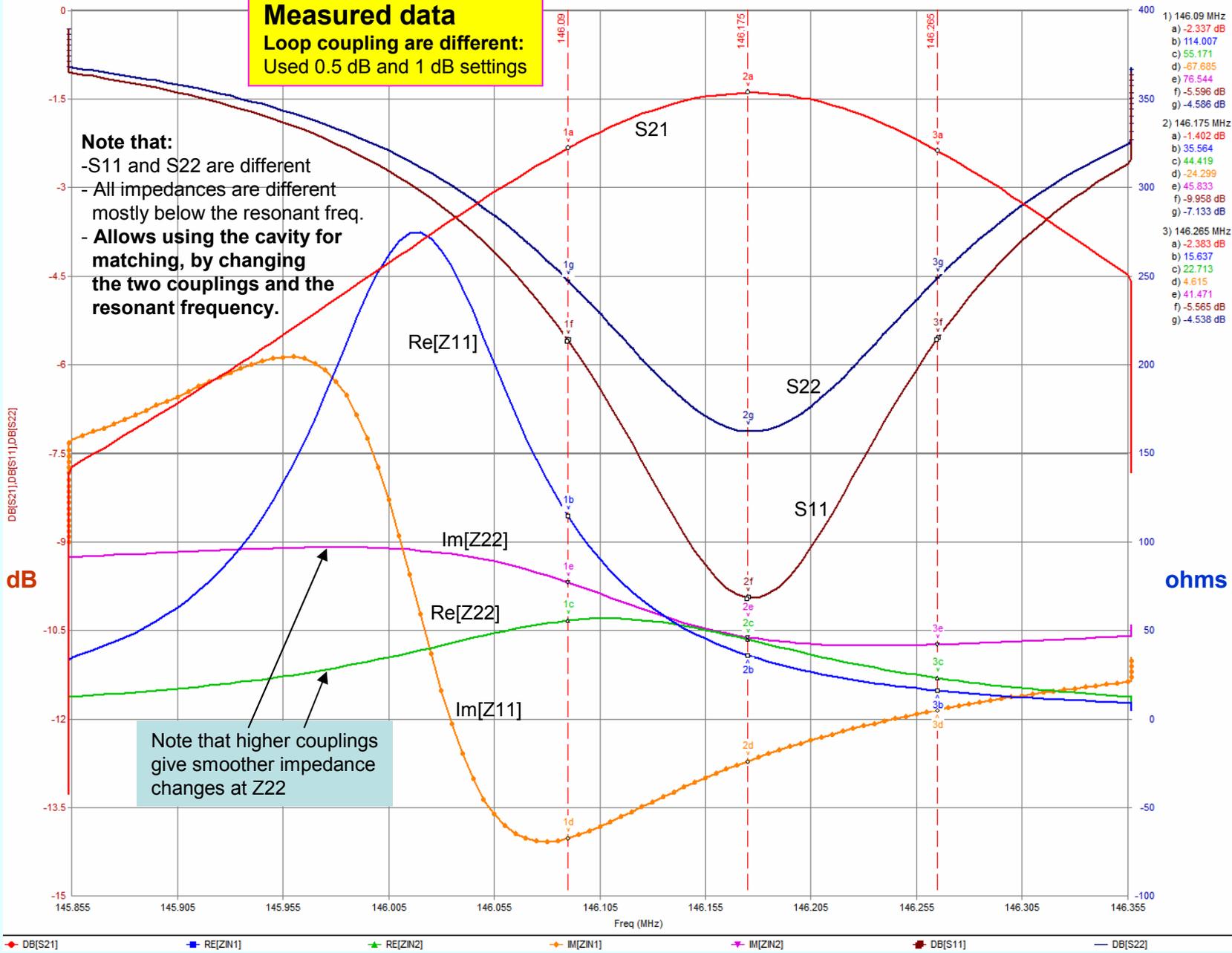




**Measured data**  
**Loop coupling are different:**  
 Used 0.5 dB and 1 dB settings

**Note that:**  
 -S11 and S22 are different  
 - All impedances are different mostly below the resonant freq.  
 - **Allows using the cavity for matching, by changing the two couplings and the resonant frequency.**

Note that higher couplings give smoother impedance changes at Z22

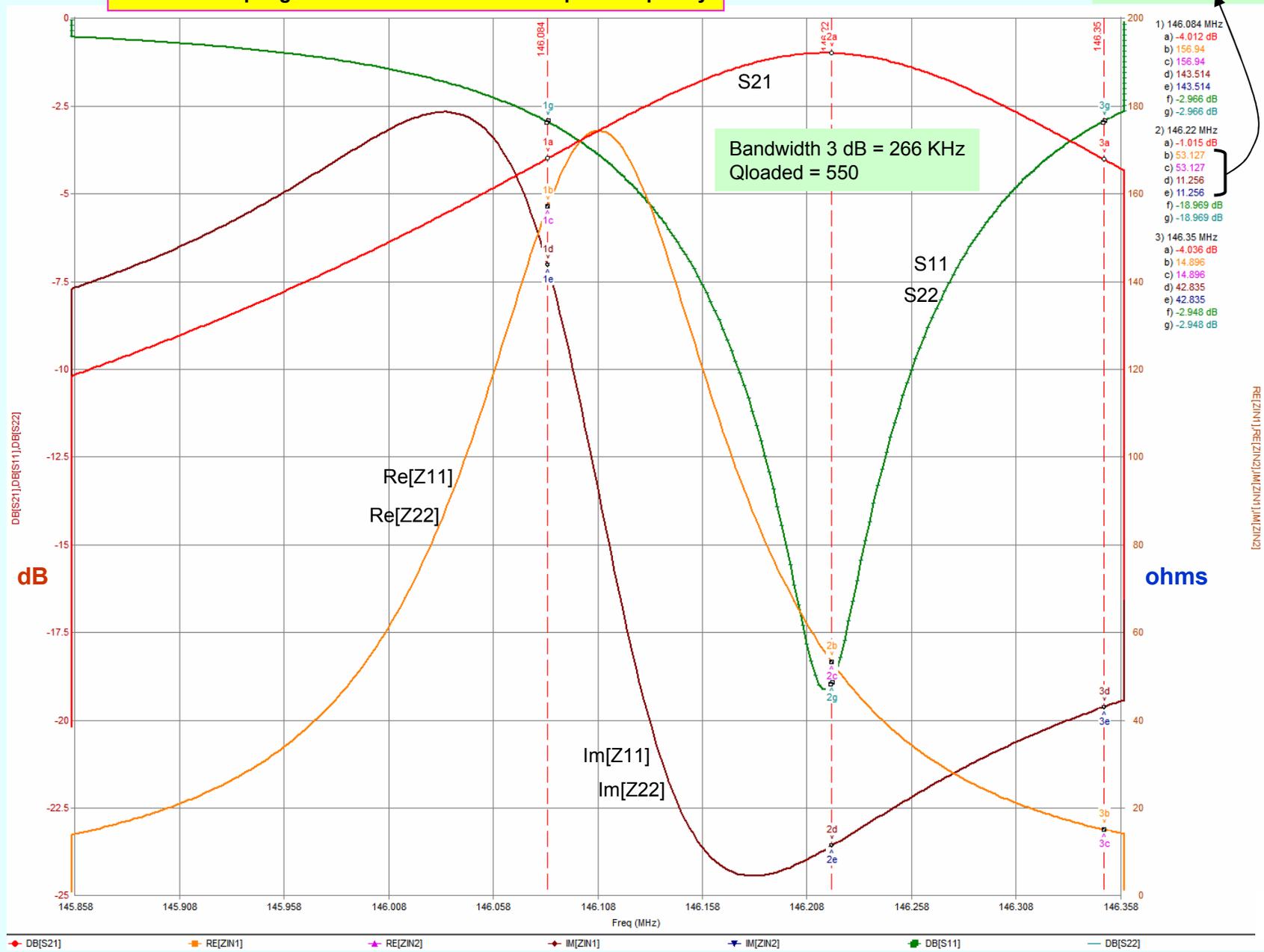


RE[ZIN1] RE[ZIN2] IM[ZIN1] IM[ZIN2]

ohms

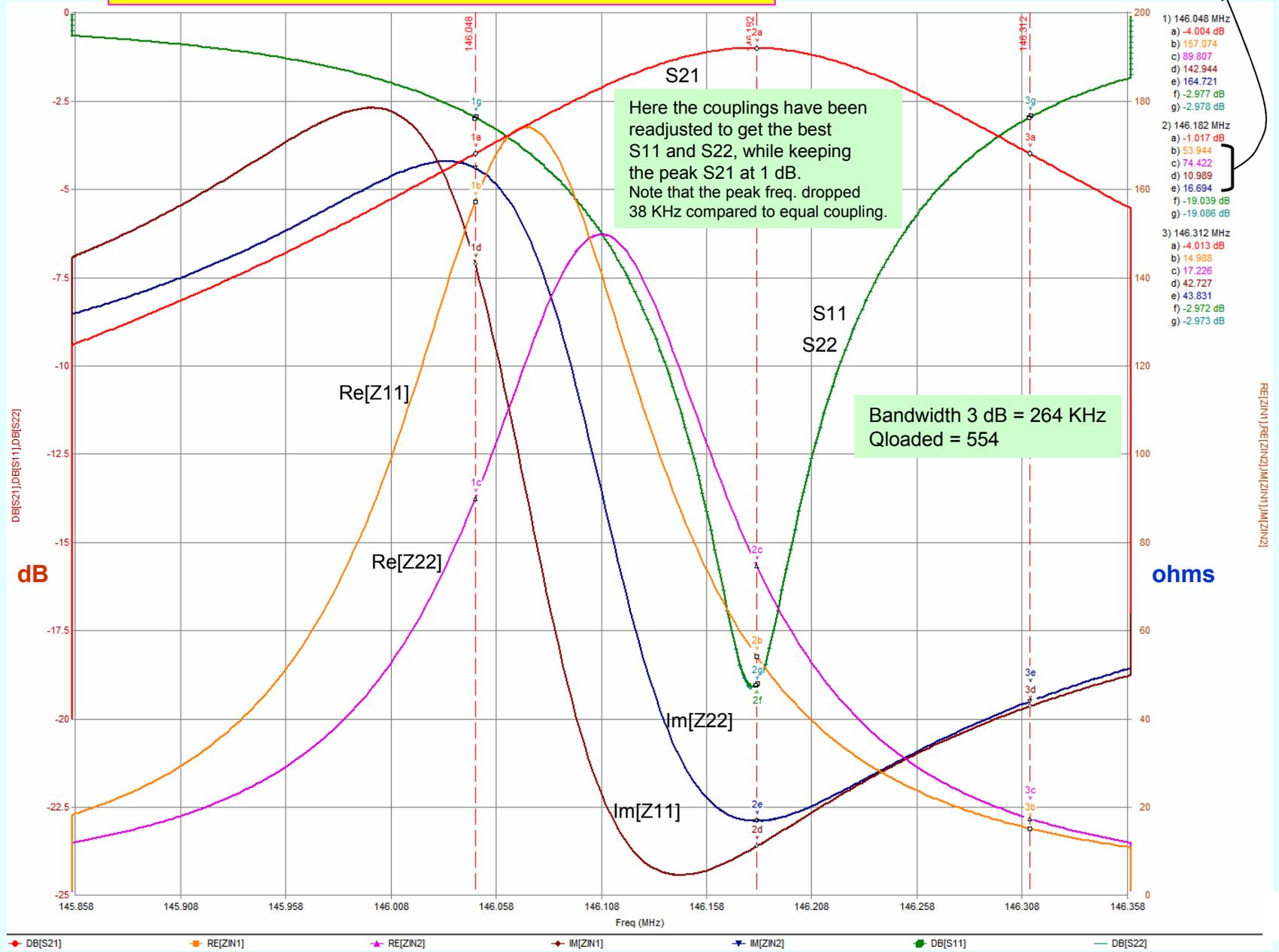
**Simulation data**  
 Identical couplings to match 50Ω to 50Ω at the peak frequency

$Z_{in} = 53.127 + j 11.256$   
 $Z_{out} = 53.127 + j 11.256$



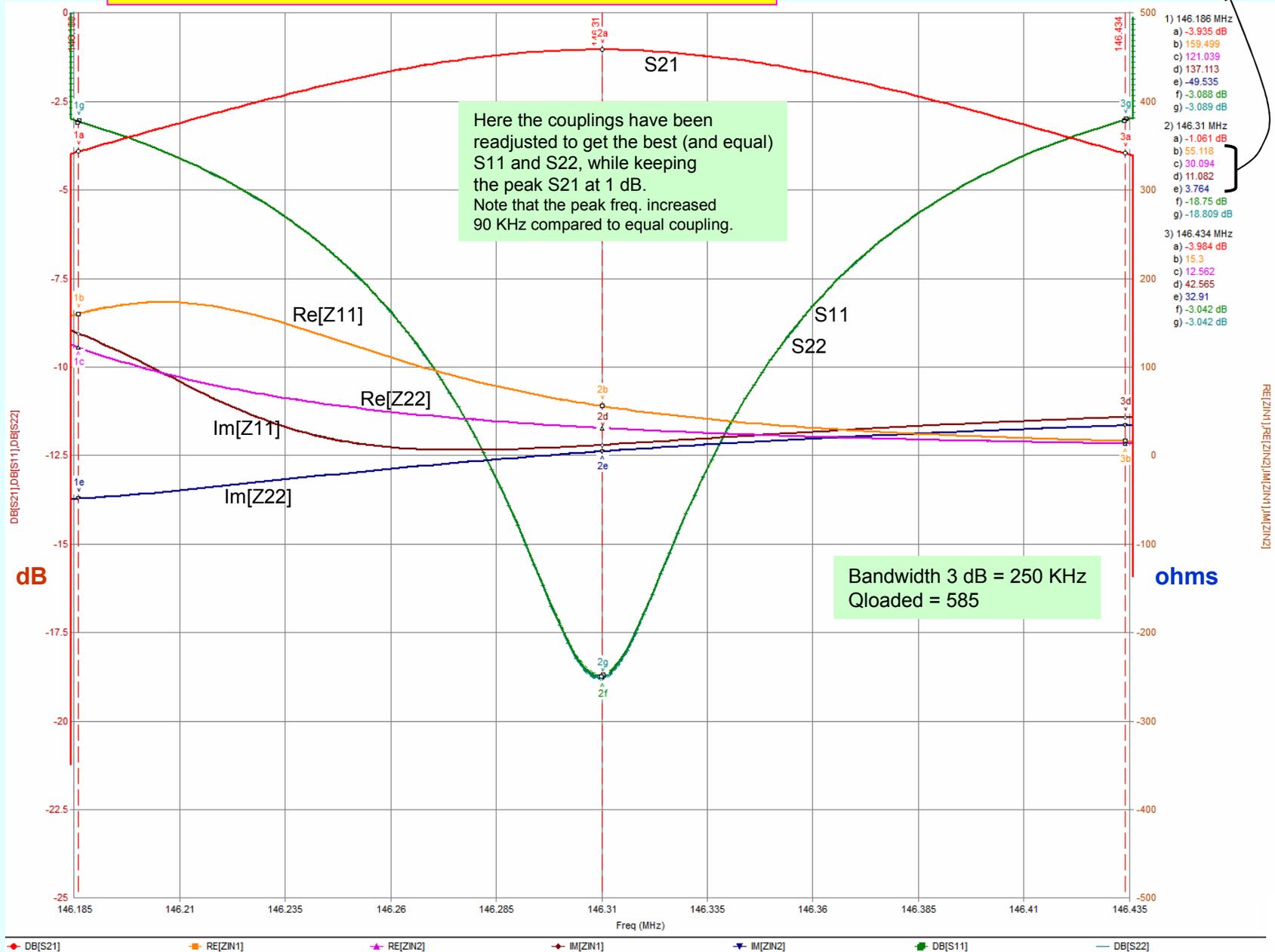
**Simulation data**  
**Changing the couplings to match 50Ω to 75Ω at the peak frequency**

$Z_{in} = 53.944 + j 10.989$   
 $Z_{out} = 74.422 + j 16.694$



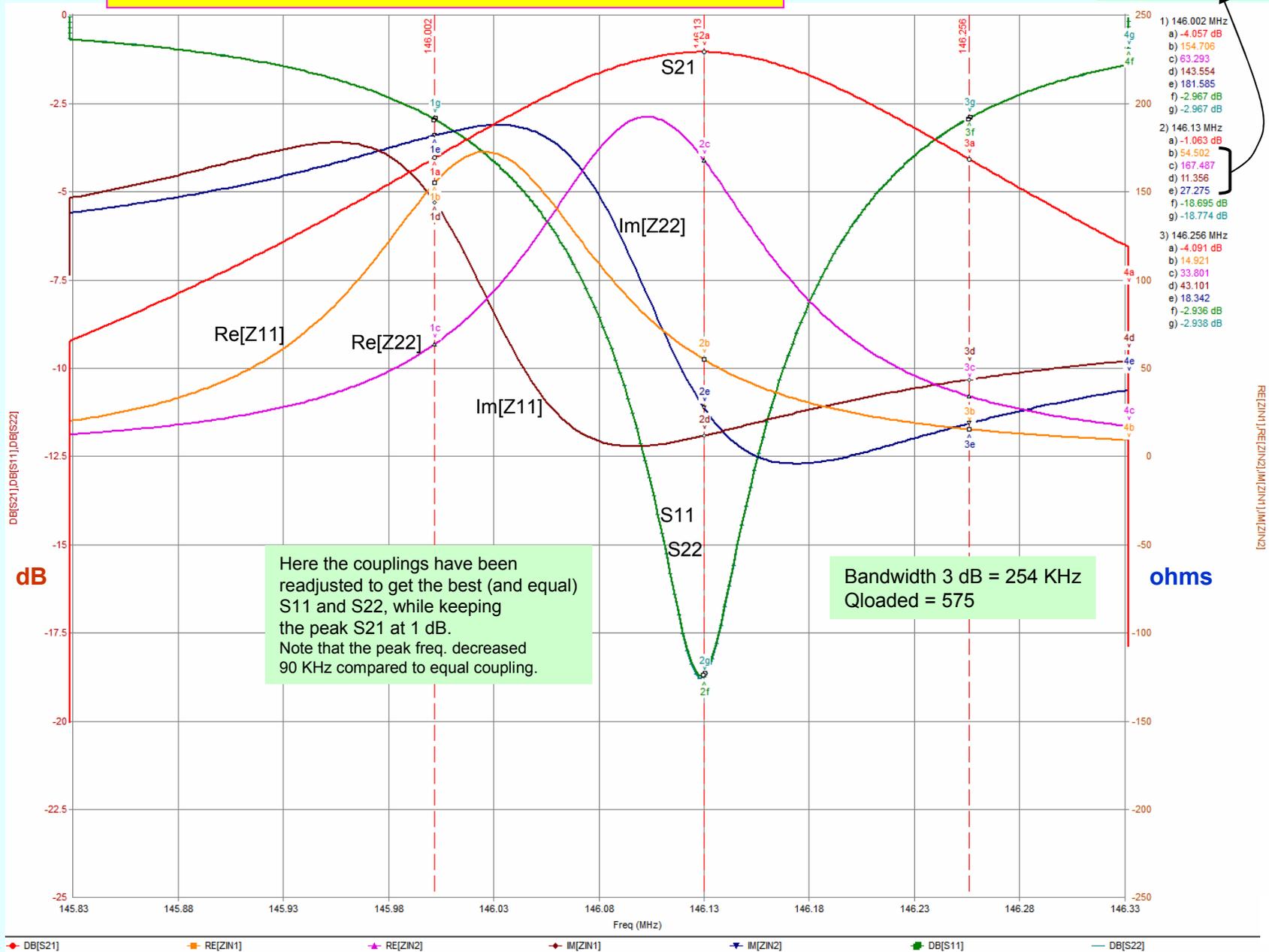
**Simulation data**  
 Changing the couplings to match 50Ω to 25Ω at the peak frequency

$Z_{in} = 55.118 + j 11.082$   
 $Z_{out} = 30.094 + j 3.764$



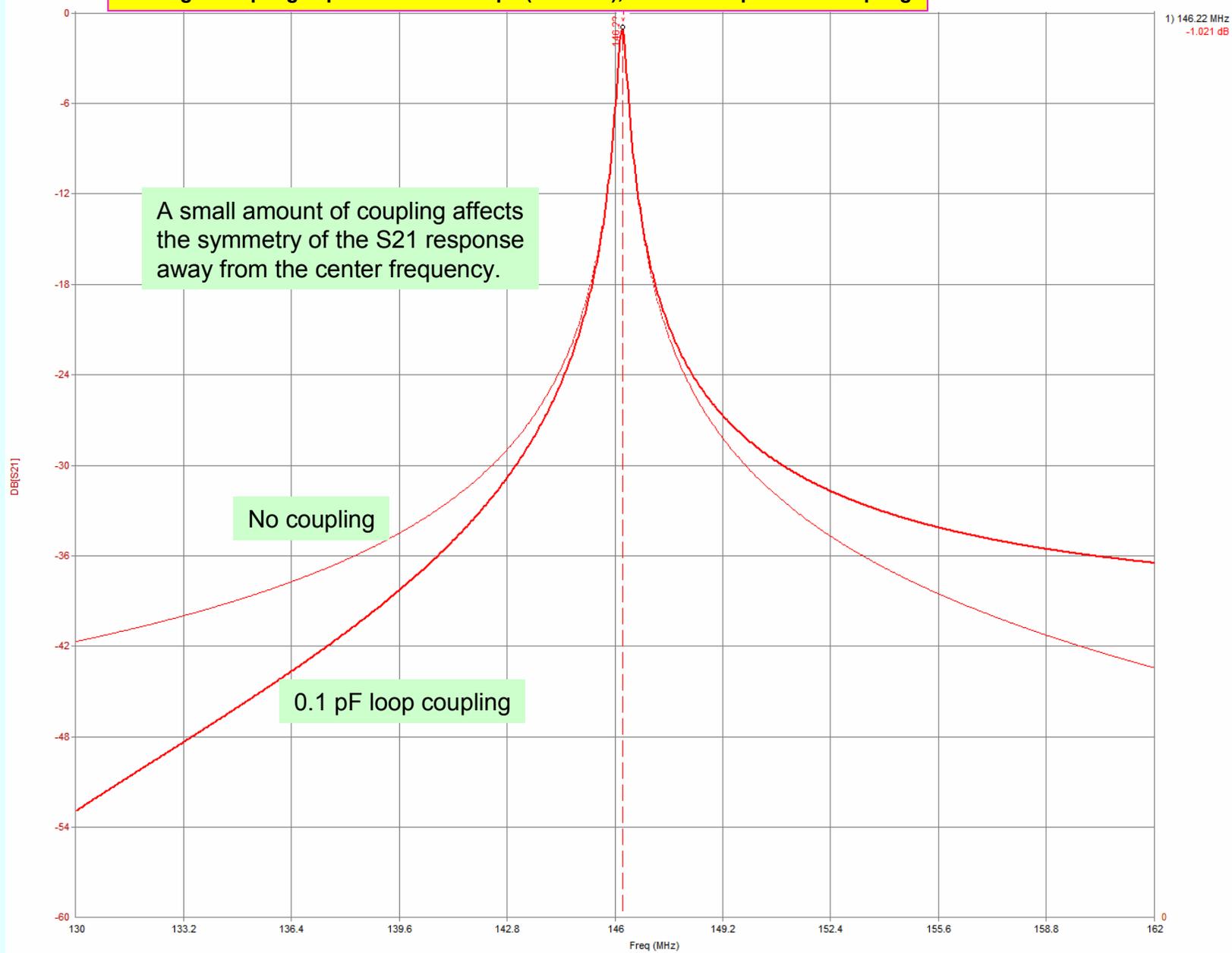
**Simulation data**  
**Changing the couplings to match 50Ω to 200Ω at the peak frequency**

$Z_{in} = 54.502 + j 11.356$   
 $Z_{out} = 167.487 + j 27.275$

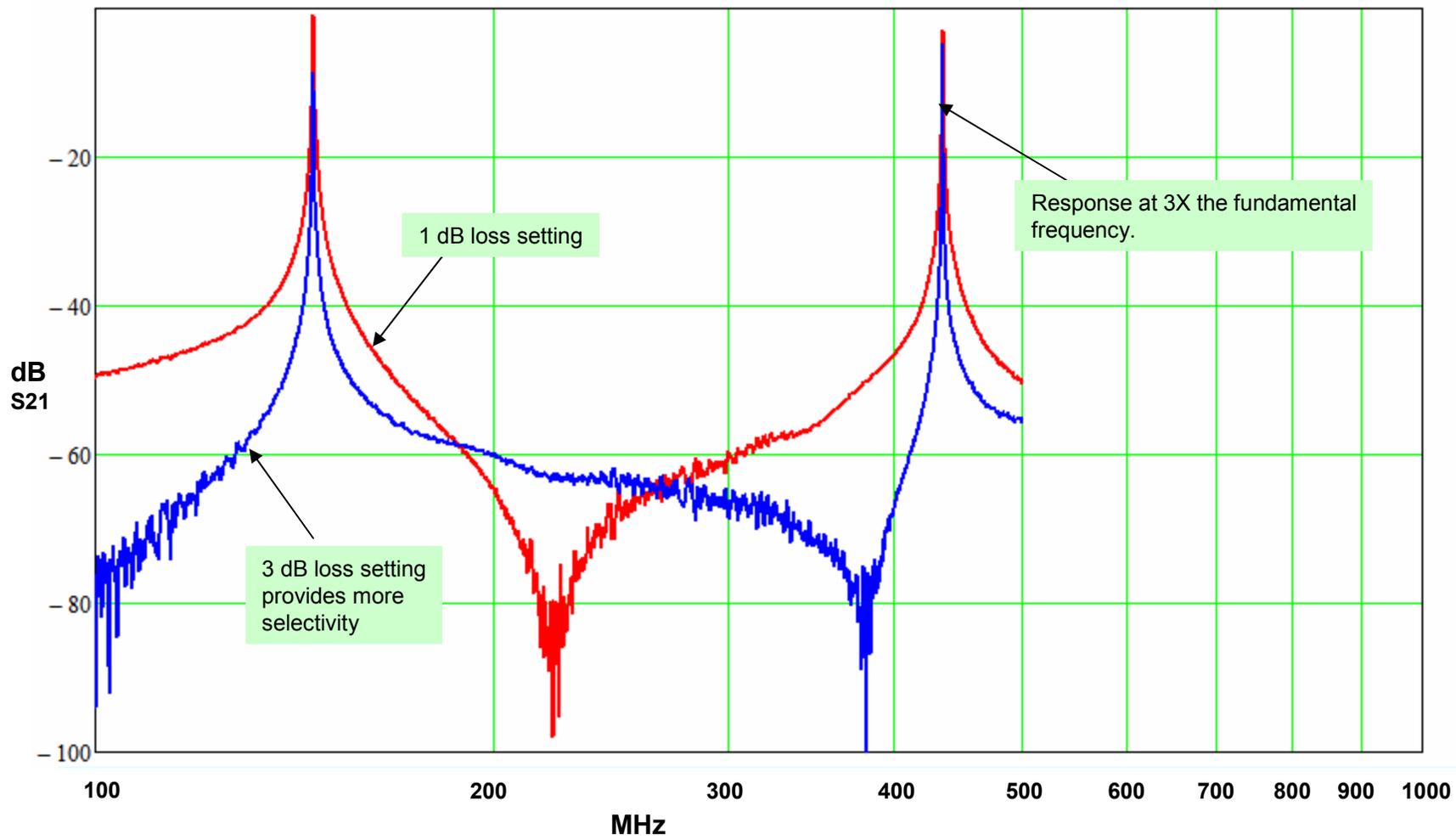


## Simulation data

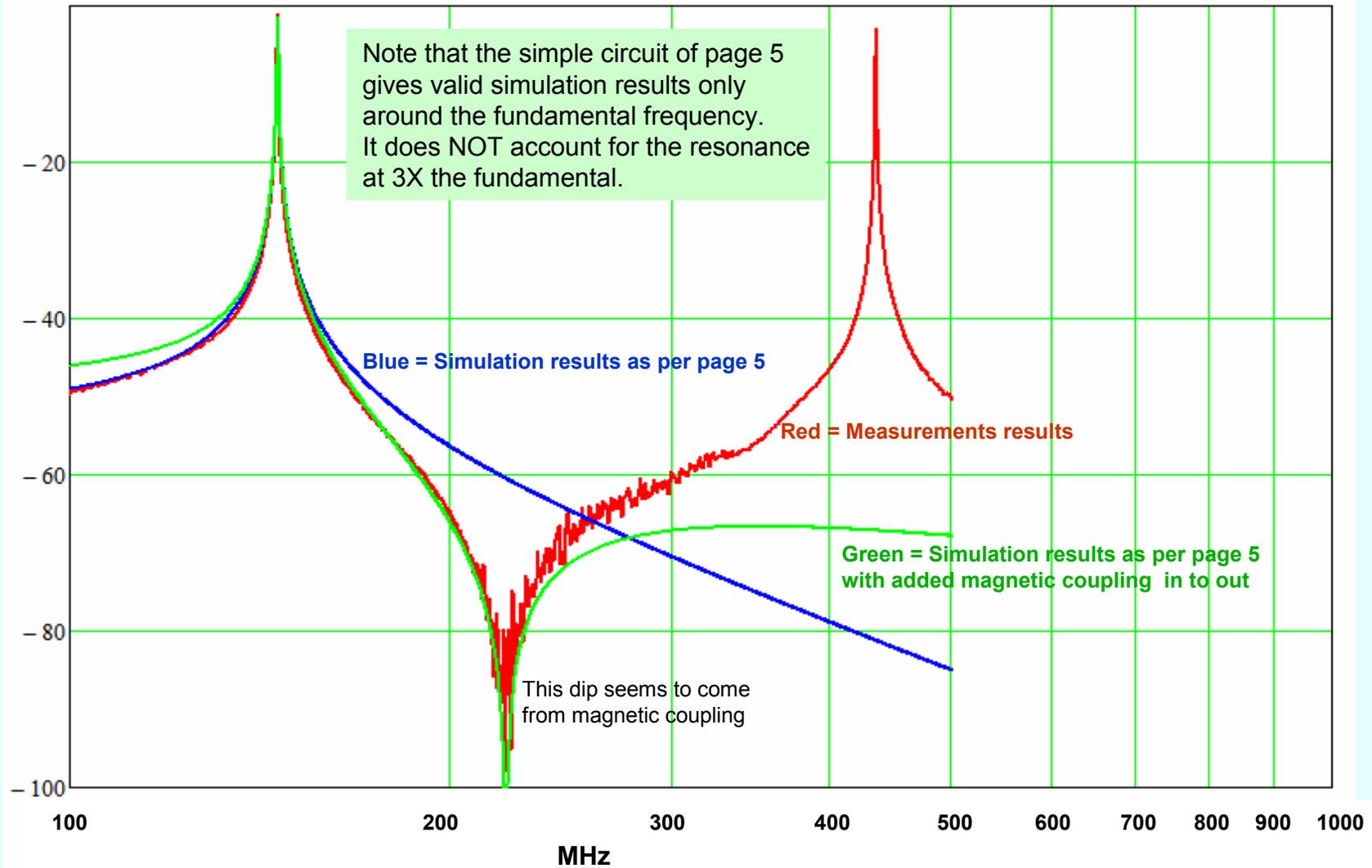
Adding a coupling cap between the loops (in to out), to simulate parasitic coupling



**MEASURED WIDEBAND RESPONSE Red = 1 dB loss Blue = 3 dB loss**



## Comparison between Measured and Simulated Response Data for 1 dB coupling



# SUMMARY

## Simulations of the bandpass cavity.

An L-C circuit with dual coupling loops is a good model to use around the resonant frequency, in the region where the S21 response is above - 50 dB.

The L-C resonant tank circuit may have any L/C values, as long as it resonates at the desired frequency.

The loop coupling is adjusted to obtain the desired insertion loss. The resonant C sets the Q factor.

A similar circuit may be used for Notch-Bandpass cavities, as done in: <http://ve2azx.net/technical/ve2azx-duplexerinfo.pdf>

The unequal attenuation on both sides of the passband peak comes from capacitive stray coupling between the two loops.

It may be simulated with a small value capacitor connected between input and output. Measure the attenuation at +/- 10% above and below the center frequency and record the S21. In the simulator place a negative capacitor across the in – out.

Adjust its value until the attenuations are the same at +/- 10% above and below the center frequency.

This is the + value of the capacitor to use in the model.

## Increasing the loop coupling...

Decreases the insertion loss at the resonant frequency.

The resonant frequency also moves upward somewhat.

The impedance matching is improved at the same time. (On a cavity with equal loop couplings)

The return loss and rate of change of the impedances decreases.

A symmetrical cavity has equal return loss at both in/out ports. This is obtained by adjusting the in/out couplings.

The bandpass cavity may be used for impedance matching, by setting different couplings and by changing the resonant frequency slightly to set the peak response (and best return loss) at the desired frequency.

## Loop inductance...

Increasing loop inductance moves the resonant frequency upwards slightly.

The rate of change of the impedances increases.

The return loss is improved.

Is easily measured by adjusting for a very low coupling (like 20 dB loss) and measuring the complex S11 or S22.

Another method is detailed on page 56 of my document: <http://ve2azx.net/technical/ve2azx-duplexerinfo.pdf>

Is not critical. It should provide a reactance in the 50 to 100 ohms region at the operating frequency.

## Using different loop couplings...

Allows using the bandpass cavity for impedance matching, thus increasing the RX sensitivity.

Allows matching the antenna to the preamp input impedance and/or the preamp to the RX.

Allows matching 75 ohm heliax antenna cable to the duplexer.

The center of the bandpass frequency changes when loop couplings are adjusted and with changing load impedances.

Readjusting may be necessary. Adjust for best return loss at the 50 ohm port.

The bandwidth and return loss are not affected, as long as the insertion loss S21 is kept constant at the peak frequency.