THEORY AND TESTING OF DUPLEXERS

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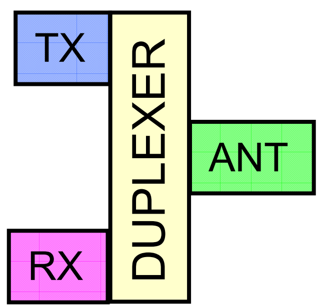
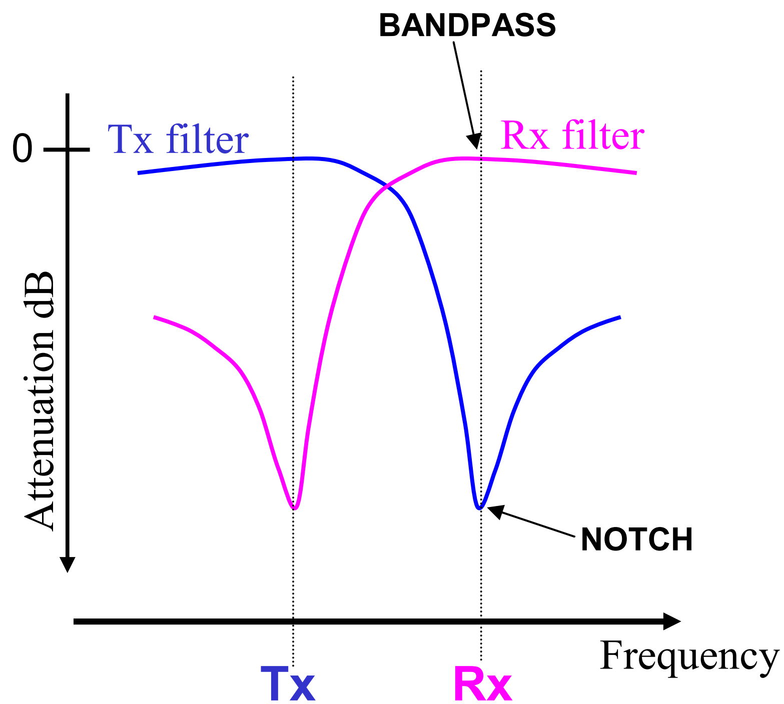
- ❑ INTRO
- ❑ WHY USE DUPLEXERS ?
- ❑ BASIC TYPES OF DUPLEXERS
- ❑ SIMPLE LC MODELS FOR EACH TYPE
- ❑ ADJUSTMENT AND VERIFICATION
- ❑ PUTTING IT ALL TOGETHER - EXAMPLES
- ❑ PITFALLS
- ❑ REFERENCES

WHY USE DUPLEXERS ?

DUPLEXERS…

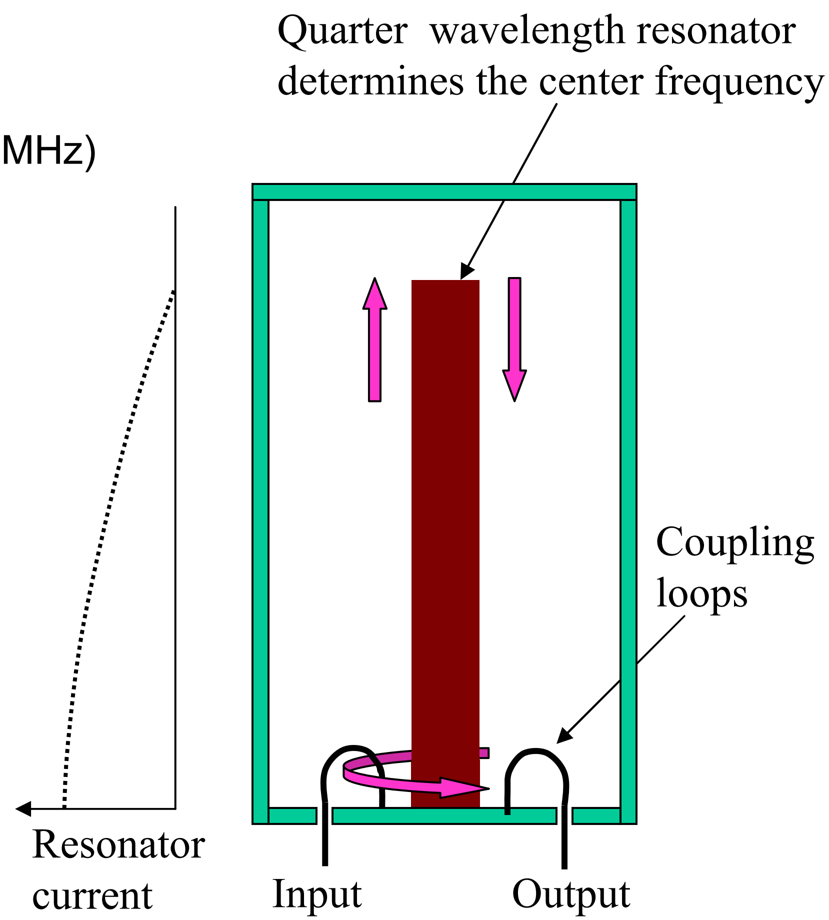
- Allow simultaneous transmit and receive on the same antenna
- The Rx filter attenuates the TX signal ~ 75 dB or more (approx 30 million times) and vice-versa
- The Tx filter attenuates the TX broadband noise being fed into the Rx by a similar amount
- Three port devices:





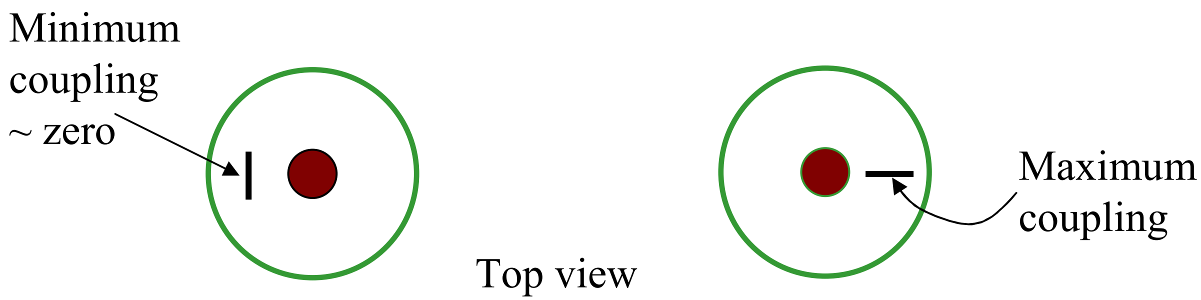
CAVITIES IN GENERAL

- Use a very low loss transmission line to improve selectivity (high Q) (~0.08 dB loss / 100 ft for a 6 in. cavity @ 150 MHz)
- The resonator acts as a quarter wave antenna inside a closed box, with max. current at the base
- In – out loops magnetically couple energy to the resonator
- Capacitive coupling may also used but not discussed here



LOOP COUPLING TO THE RESONATOR

- ❑ Loop orientation affects coupling:



- ❑ Loop size: increasing the loop size increases coupling and its inductance as well

- ❑ Loop proximity from the resonator: placing the loop closer will increase coupling.

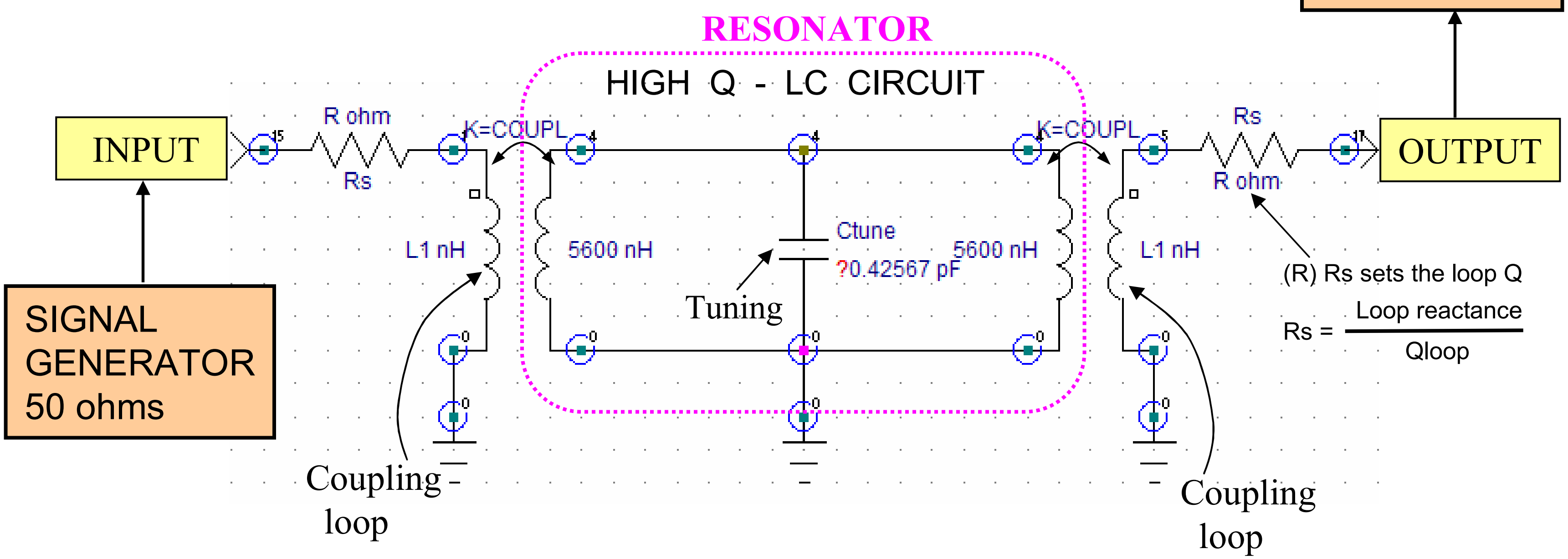
- ❑ Loop coupling affects the insertion loss and selectivity in the bandpass region and the notch frequency in notch-bandpass designs.

BASIC TYPES OF DUPLEXERS

	TX – RX FREQ SEPARATION
❑ LO – HI PASS FILTERS	WIDE
❑ BANDPASS CAVITIES	MEDIUM
❑ NOTCH – BANDPASS CAVITIES	NARROW
❑ NOTCH CAVITIES	NARROW

BANDPASS CAVITIES

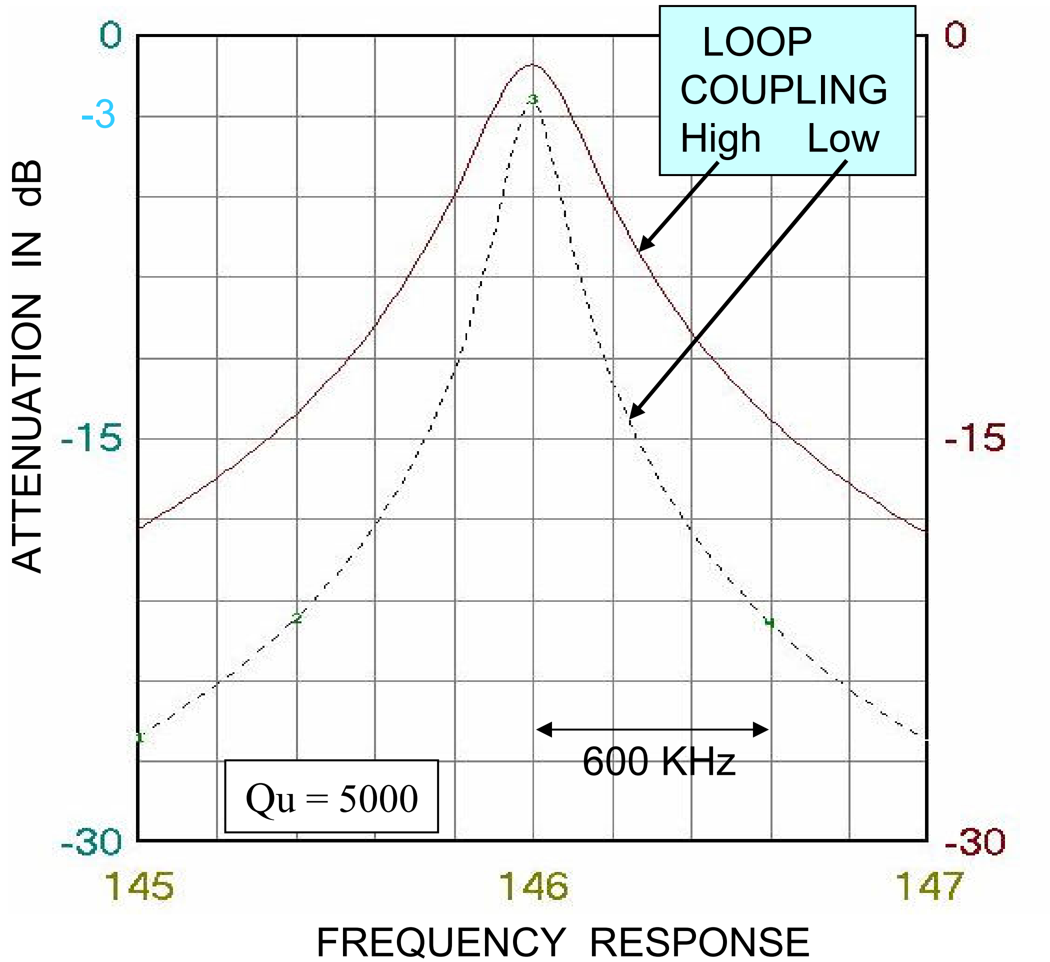
EQUIVALENT CIRCUIT



- ❑ THE QUARTER WAVELENGTH RESONATOR IS MODELED WITH A HIGH Q - LC CIRCUIT (2 x 5600 nH inductors and a capacitor)
- ❑ TYPICAL RESONATOR Qu VALUES: **2000** for 4 in. Cavity, **> 5000** for a 6 in. cavity

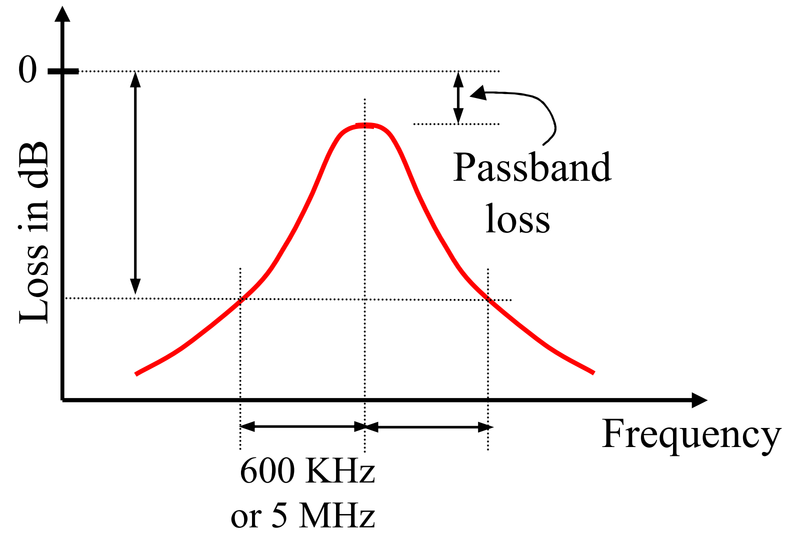
BANDPASS RESONATOR RESPONSE CURVES

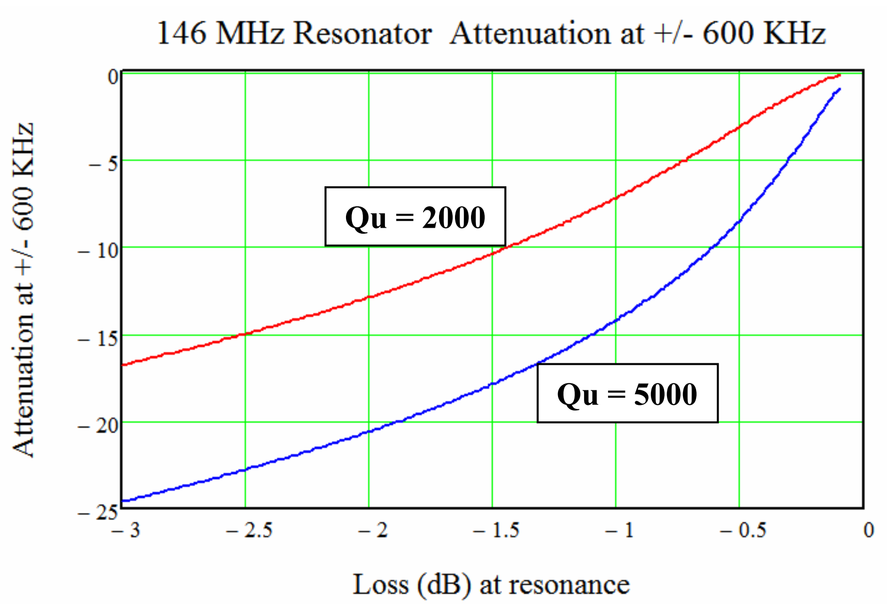
- CHANGING THE COUPLING TRADES BANDPASS LOSS FOR SELECTIVITY
- THE Qc OF THE COUPLING LOOPS DOES NOT AFFECT THE RESPONSE IF: Qc > 100

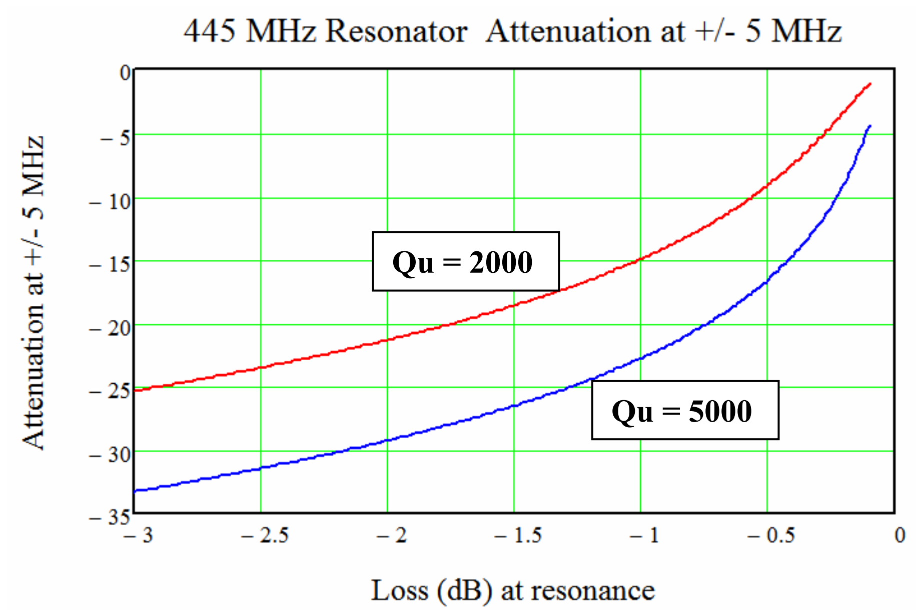


RESONATOR Qu , PASSBAND LOSSES AND SELECTIVITY

- Qu IS THE QUALITY FACTOR OF THE RESONATOR (unloaded Q)
- Qu INFLUENCES THE PASSBAND LOSSES AND THE ATTENUATION AWAY FROM THE PASSBAND
- ONE MAY TRADE PASSBAND LOSS FOR SELECTIVITY AND VICE-VERSA

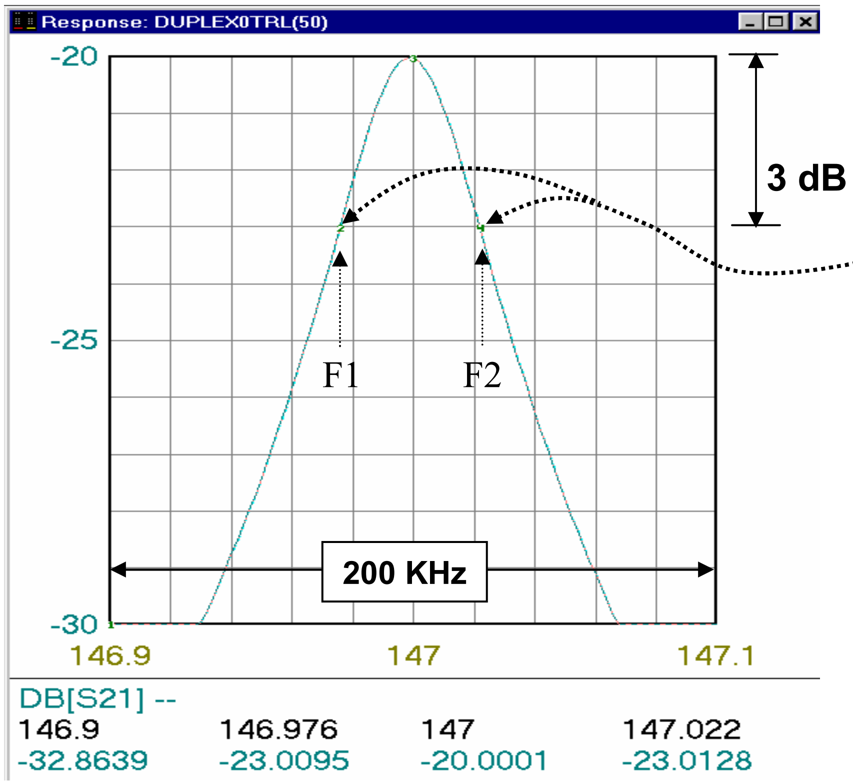






MEASURING THE Qu FACTOR (Unloaded Q of the cavity)

See also: http://ve2azx.net/technical/Q-FactorCalc.xls



- Adjust the coupling loops to obtain <u>~ 20 dB loss in the passband</u>
- Mesure and note the frequencies F1 and F2 (in MHz) that give 3 dB attenuation w/r to the peak:
- Calculate the quality facteur **Qu:**

$$\mathbf{Qu} = \frac{0.55*(F1 + F2)}{(F2 - F1)}$$

(Use F2 > F1)

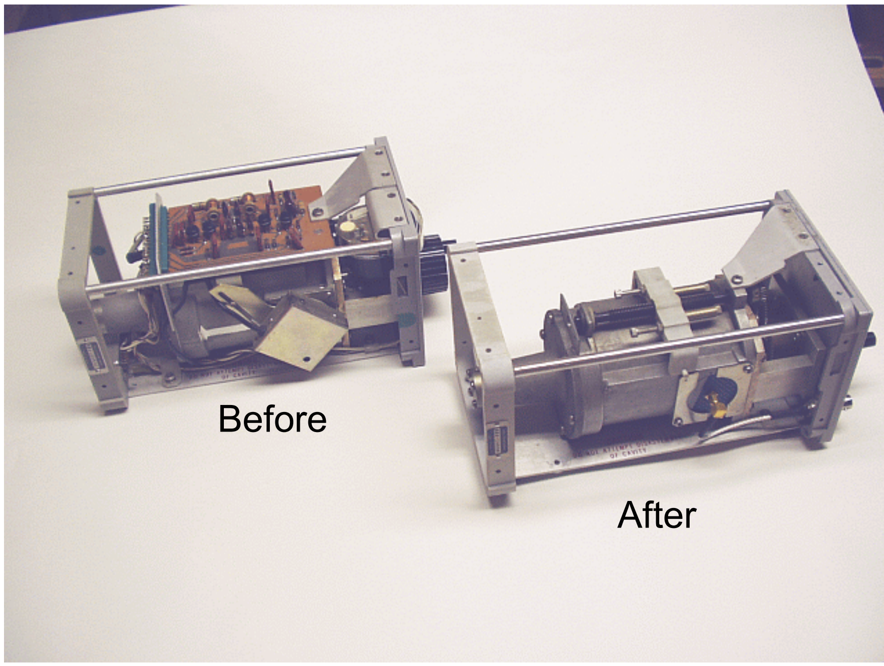
A 6 in. VHF cavity should yield Qu > 4000, typically 5000

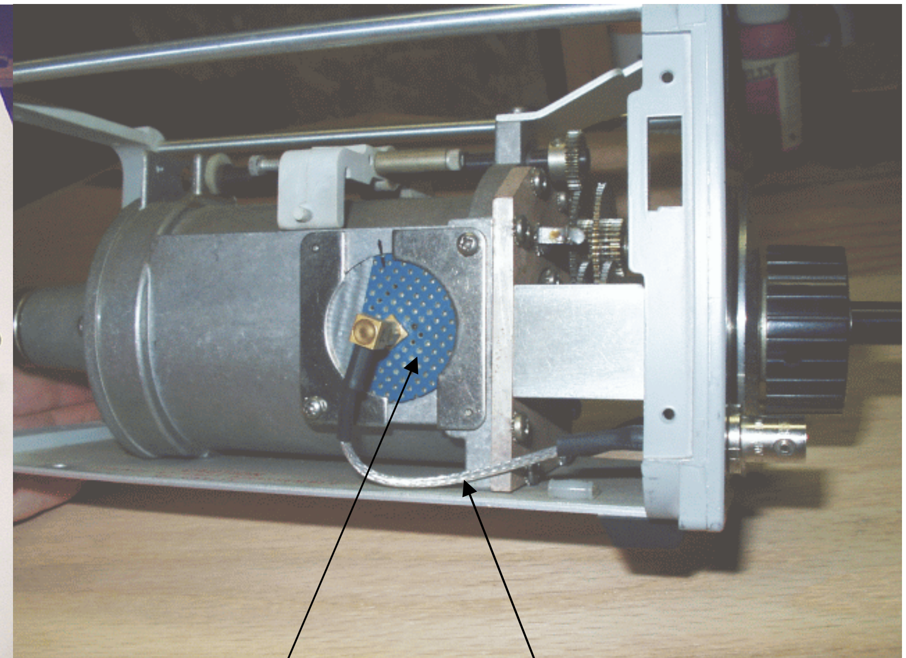
Measured values on a 6 in. cavity (notch): Q = 4650 (Davicom Technologies Inc model BR-15107)
On a 6 in. bandpass cavity: Q = 5675 (Sinclair FP20107*3)

A MINIATURE BANDPASS CAVITY FROM HP

- ❑ This is model HP 5253 Plug-in Frequency Converter
- ❑ Easily modified to form a bandpass cavity
- ❑ Covers 50 - 500 MHz frequency range

A MINIATURE BANDPASS CAVITY FROM HP



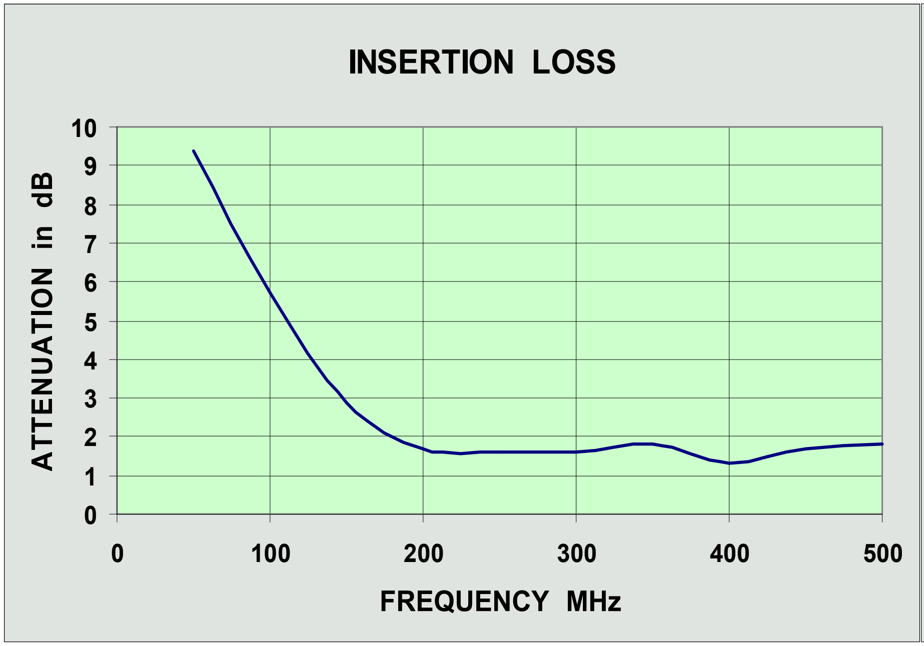


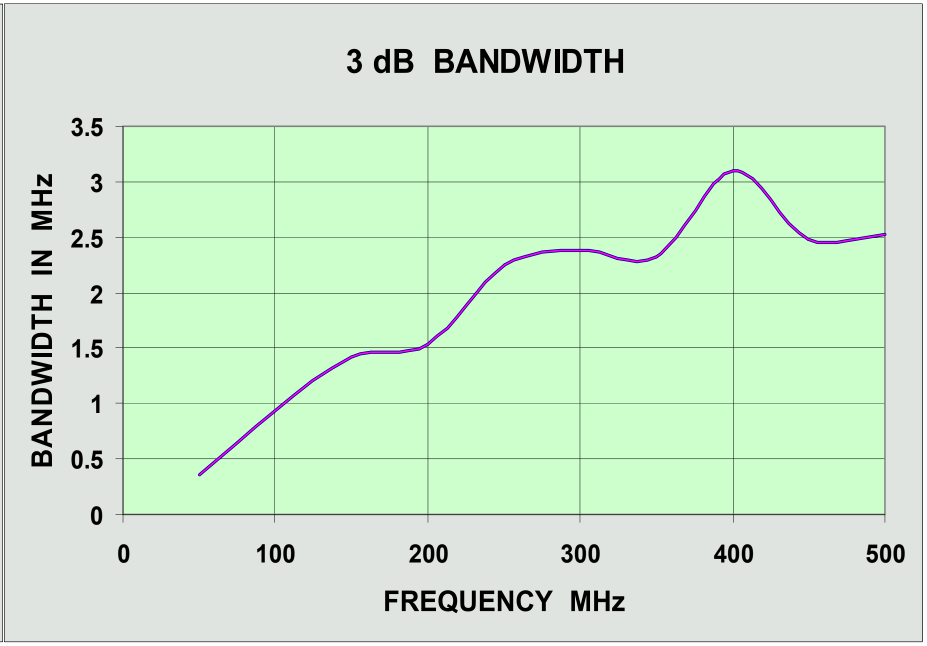
Adding the loop and cable
(both sides)

A MINIATURE BANDPASS CAVITY FROM HP

Details of the coupling loop

Note: loops are oriented at right angle of each other to minimize direct loop to loop coupling

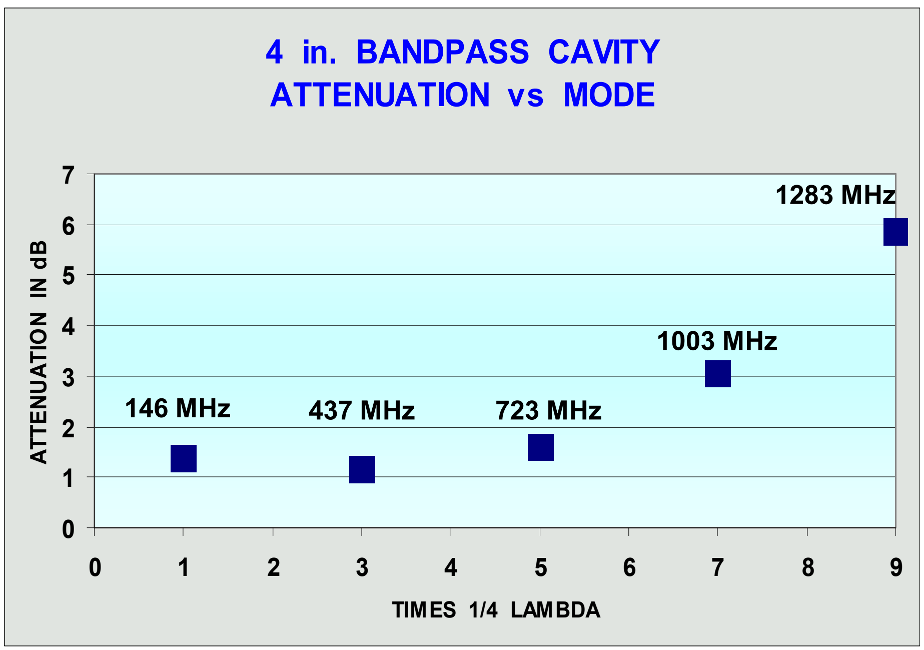


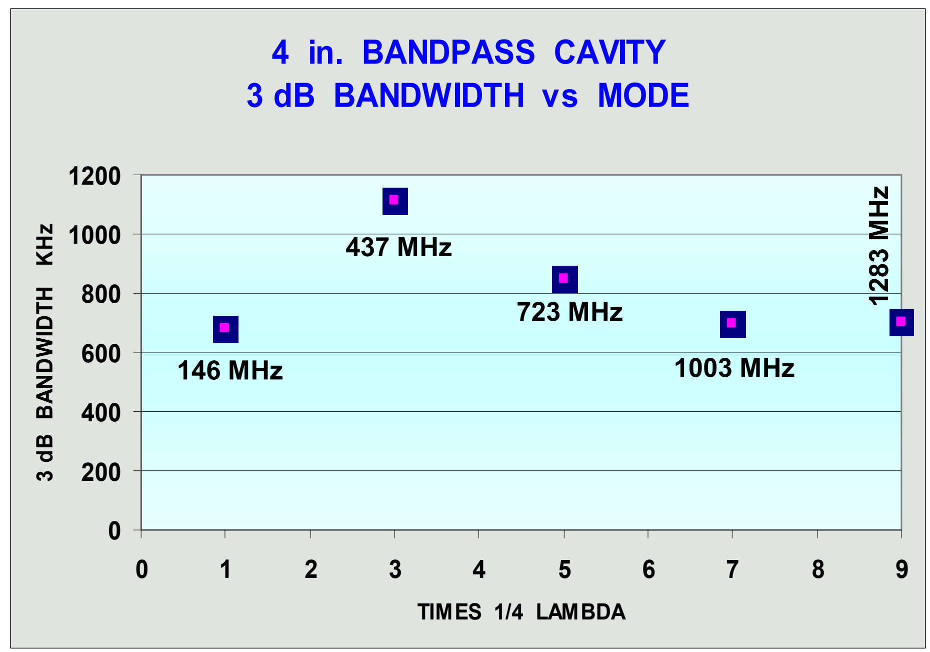


BANDPASS CAVITIES - OVERTONE OPERATION

- ❑ CAVITIES WILL OPERATE AT ODD MULTIPLES OF THEIR FUNDAMENTAL FREQUENCY

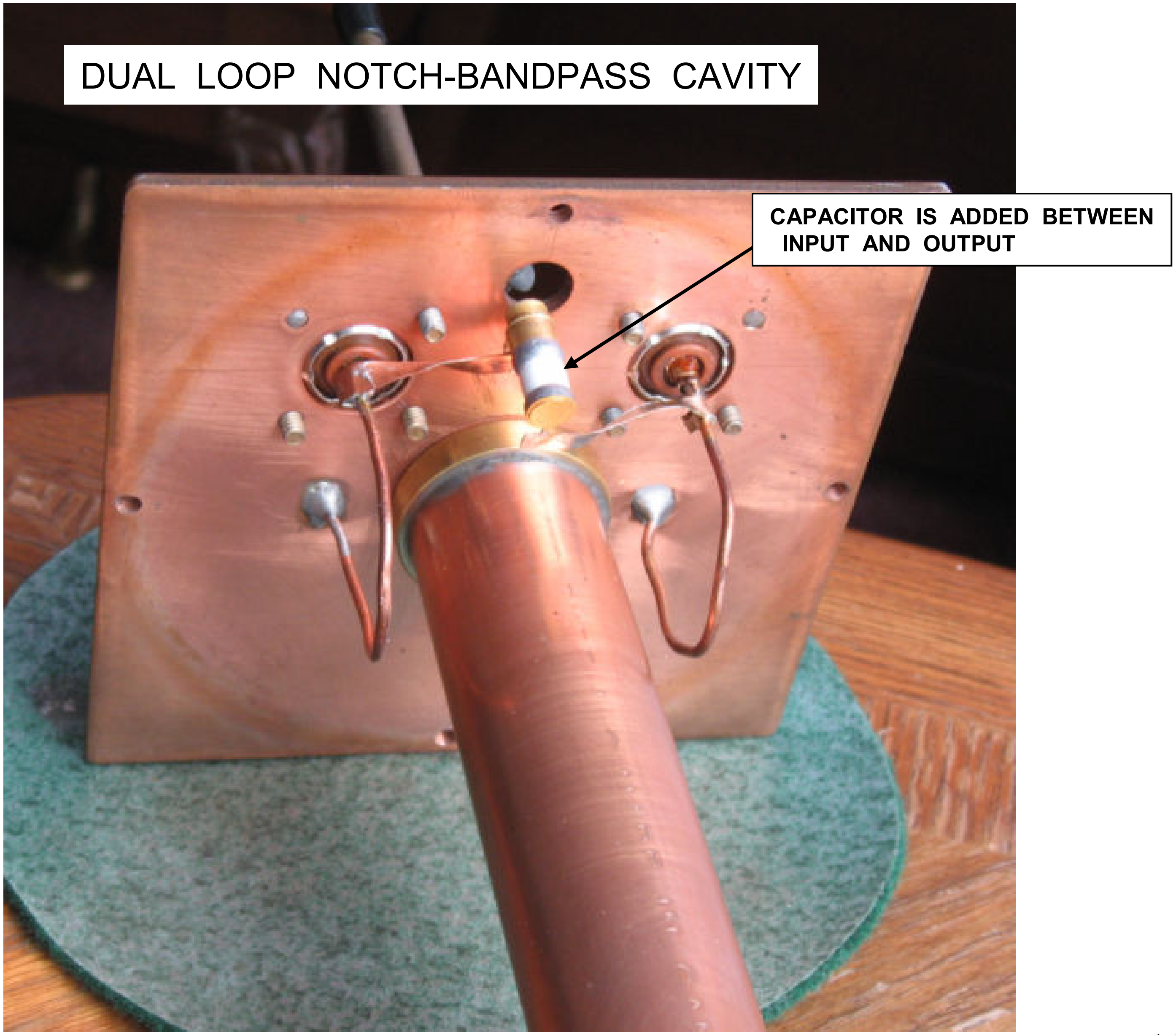
- ❑ OPERATION AT 3X and 5X THE FUNDAMENTAL FREQUENCY PROVIDES LOW LOSSES AND A HIGHER Qu FACTOR
  (Qu IS MULTIPLIED BY 1.7 AT 3X THE FUNDAMENTAL)





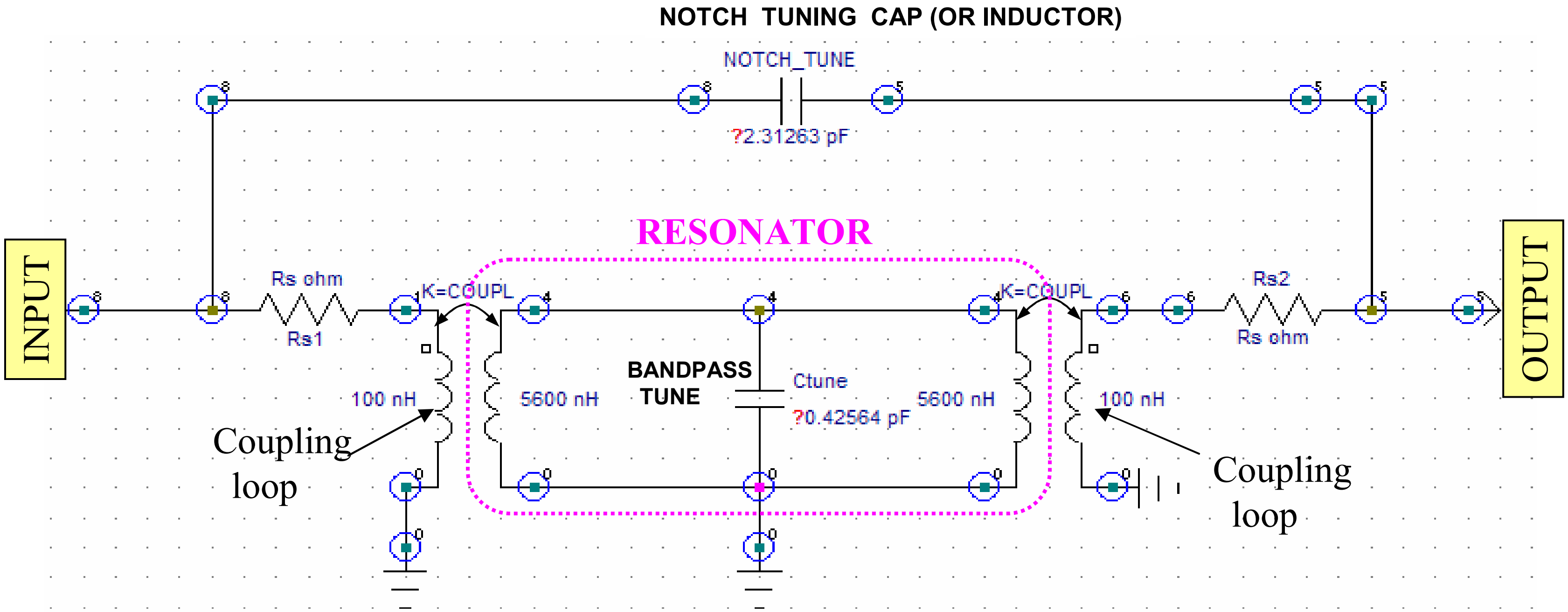
NOTCH – BANDPASS CAVITIES

- ❑ LO PASS – HI PASS FILTERS
- ❑ BANDPASS CAVITIES
- ❑ NOTCH – BANDPASS CAVITIES
  - ❑ DUAL LOOP NOTCH-BANDPASS CAVITIES
  - ❑ SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS
  - ❑ SINGLE LOOP PARALLEL RESONANT NOTCH-BANDPASS (Q circuit)


DUAL LOOP NOTCH-BANDPASS CAVITY
CAPACITOR IS ADDED BETWEEN
INPUT AND OUTPUT

DUAL LOOP NOTCH-BANDPASS (modified bandpass)

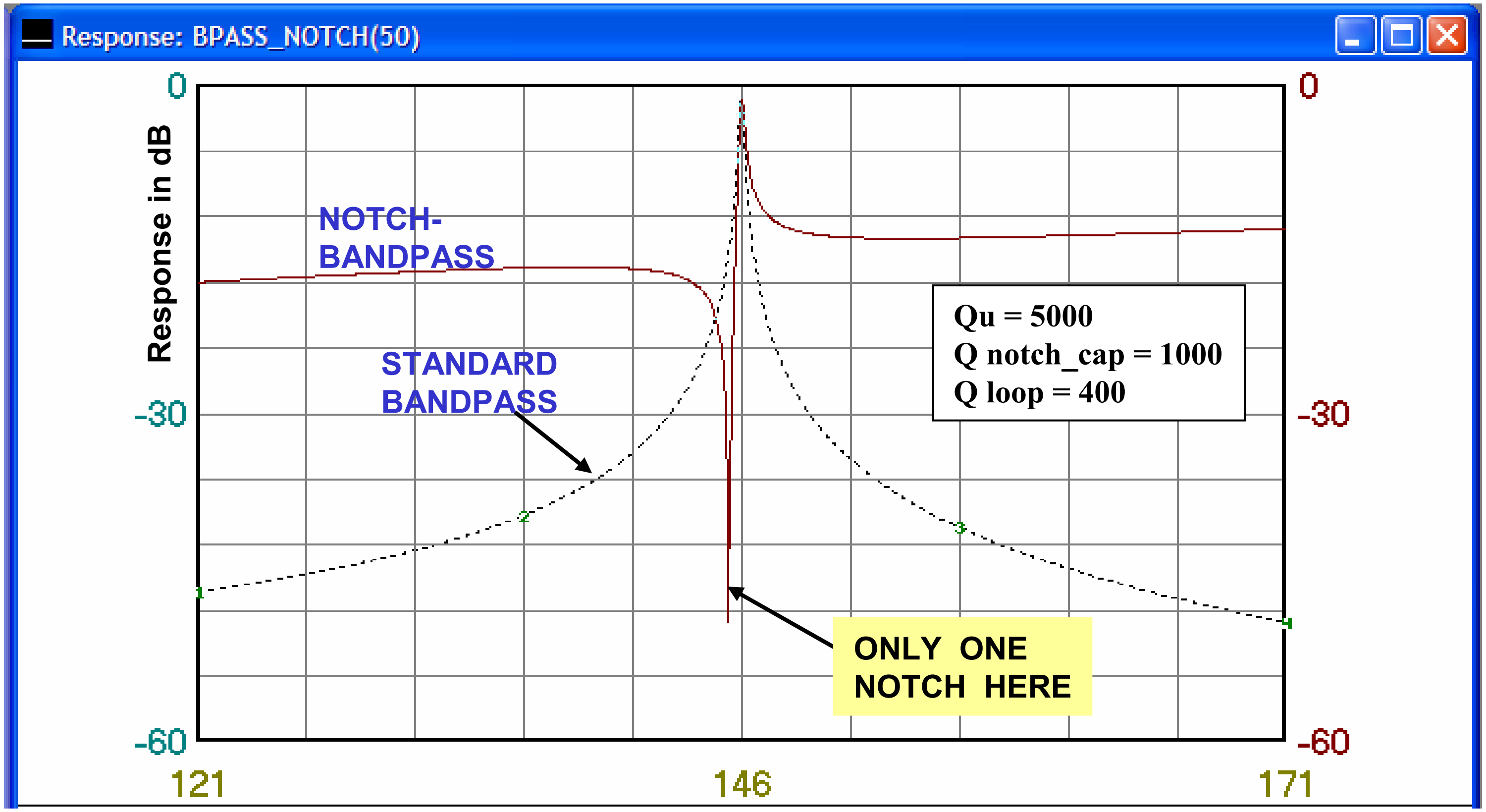
- **A LOW VALUE CAPACITOR IS ADDED BETWEEN INPUT AND OUTPUT**
- **GENERATES A TRANSMISSION NOTCH BELOW THE BANDPASS**
- **AN INDUCTOR WILL SET THE NOTCH ABOVE THE BANDPASS**
- **NOTCH TUNING INTERACTS SOMEWHAT WITH CENTER FREQUENCY**
- **THE CAPACITOR MAY BE REPLACED BY A SERIES L-C THAT CAN GIVE L OR C BEHAVIOUR**



EQUIVALENT CIRCUIT

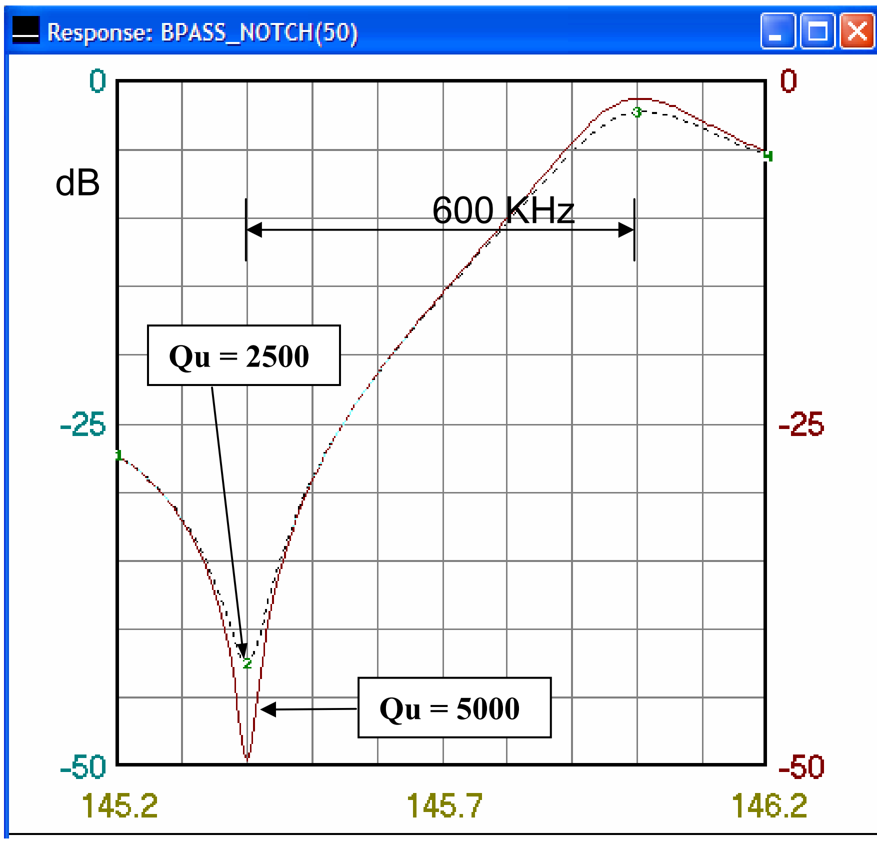
DUAL LOOP NOTCH-BANDPASS (modified bandpass)

- **SERIES CAPACITOR BETWEEN INPUT AND OUTPUT (~ 2.3 pF) GIVES THE DESIRED NOTCH-BANDPASS CHARACTERISTIC – ALLOWS NOTCH TUNING**
- **SERIES CAPACITOR TUNING SENSITIVITY: ~ 16 % PER 100 KHz (146 MHz) (REDUCING C MOVES THE NOTCH UP IN FREQUENCY)**
- **BANDPASS LOSS ~ UNCHANGED – COMPARED TO STANDARD BANDPASS**

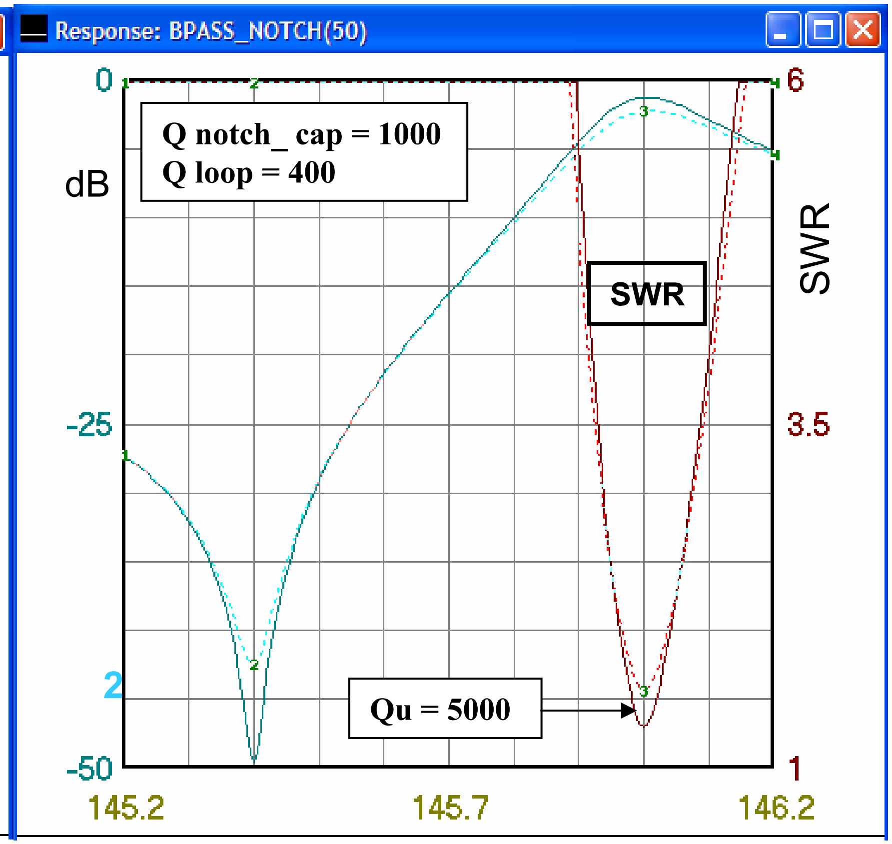


DUAL LOOP NOTCH-BANDPASS (modified bandpass)

- REDUCING Qu FROM 5000 TO 2500 REDUCES THE NOTCH BY ~ 5 dB AND ADDS ~ 1 dB LOSS IN THE BANDPASS
- THE BANDPASS CENTER HAS LOWEST SWR - ALWAYS



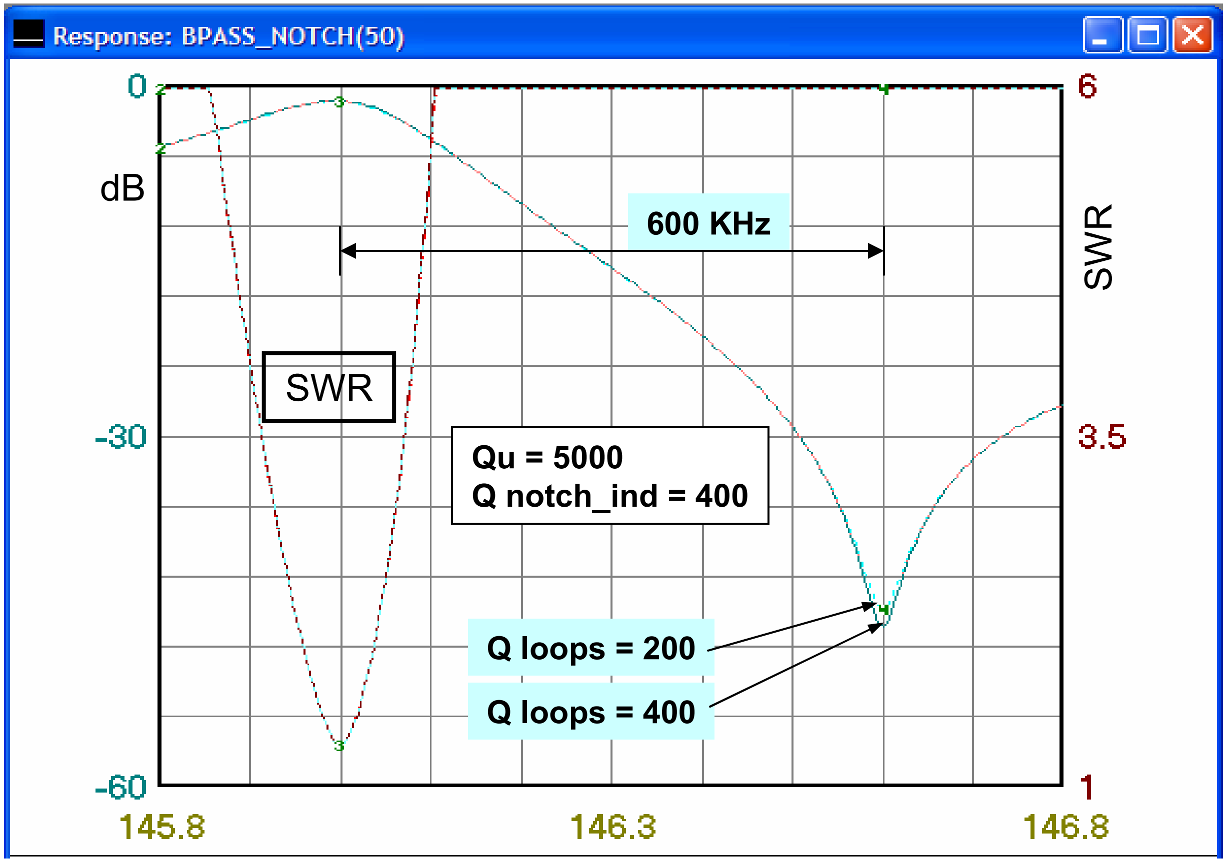
EFFECT OF CAVITY Q (Qu)



THE SWR CURVE DEFINES THE EXACT BANDPASS FREQUENCY

DUAL LOOP NOTCH-BANDPASS (modified bandpass)

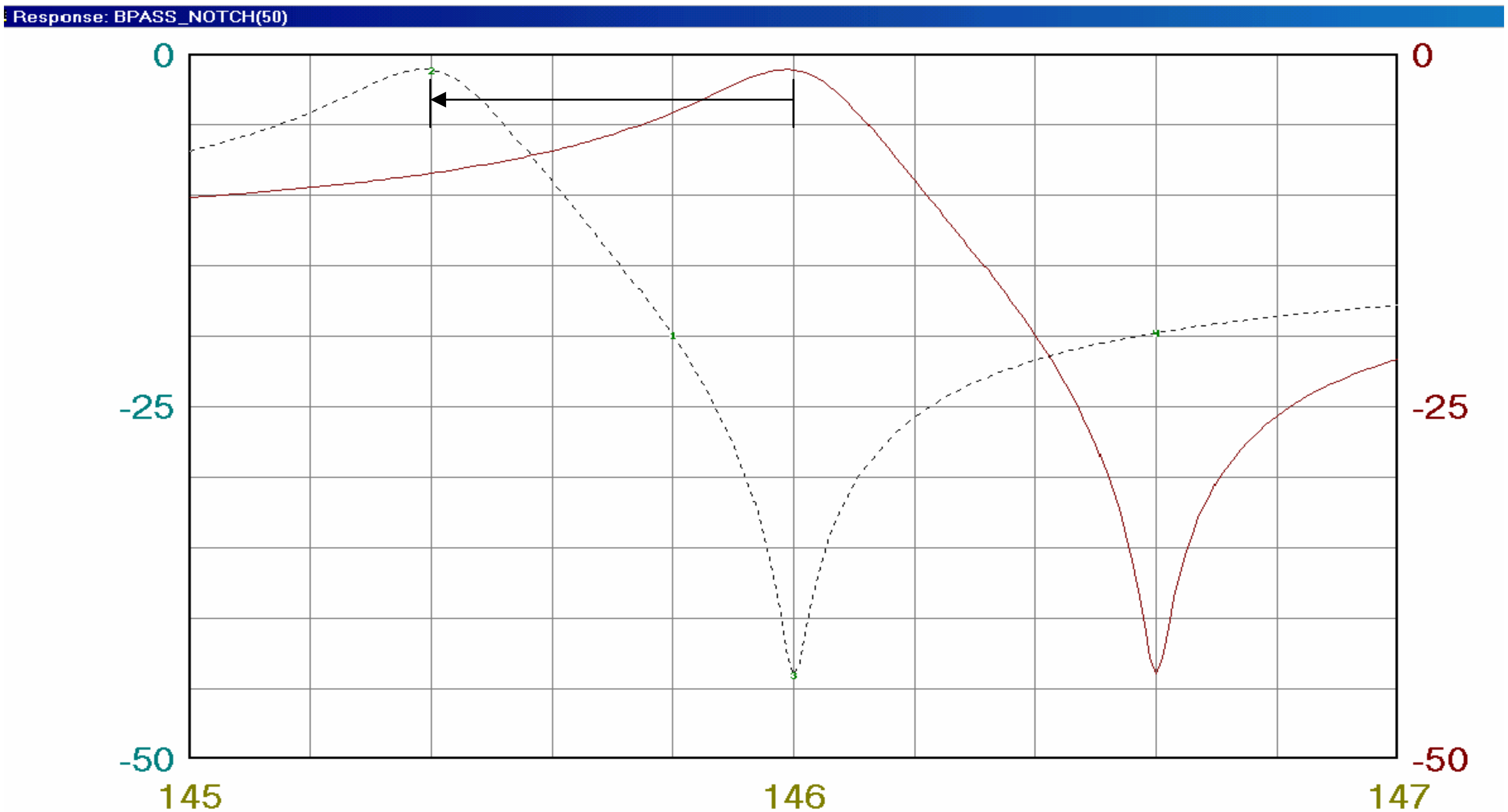
- **SETTING THE NOTCH ABOVE THE BANDPASS REQUIRES REPLACING THE SERIES CAP BY A SERIES INDUCTOR (~ 500 nH at 146 MHz)**
- **REDUCING THE Q FACTOR OF THE LOOPS FROM 400 TO 200 DEGRADES THE NOTCH DEPTH BY ~ 1.5 dB**



SETTING THE NOTCH ABOVE THE BANDPASS

DUAL LOOP NOTCH-BANDPASS (modified bandpass)

- ❑ **INCREASING THE RESONATOR LENGTH MOVES THE BANDPASS FREQUENCY DOWN**
- ❑ **SHIFTING THE BANDPASS FREQUENCY DOWN ALSO SHIFTS THE NOTCH FREQUENCY BY THE SAME AMOUNT**

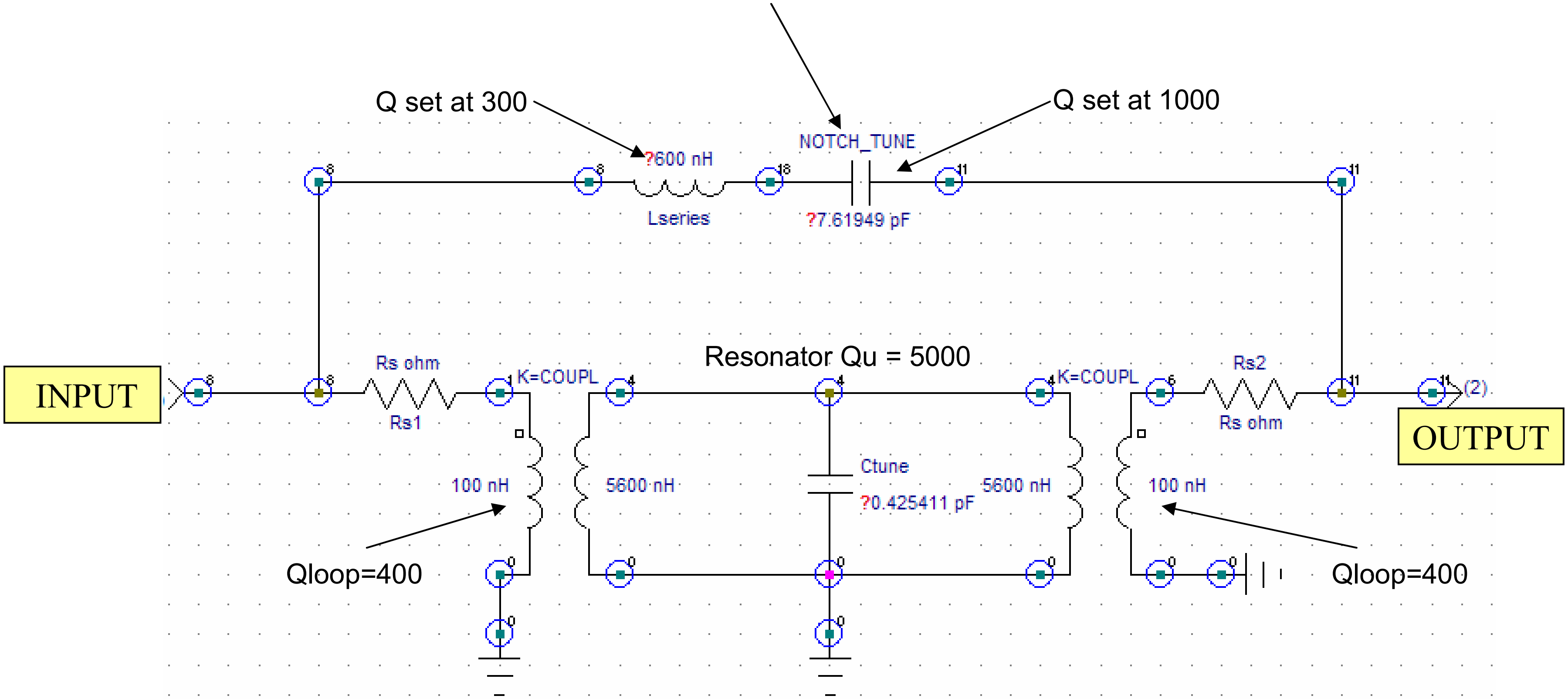


MOVING THE BANDPASS FREQUENCY DOWN MOVES THE NOTCH BY THE SAME AMOUNT

DUAL LOOP NOTCH-BANDPASS (modified bandpass)

SERIES L-C BETWEEN INPUT AND OUTPUT

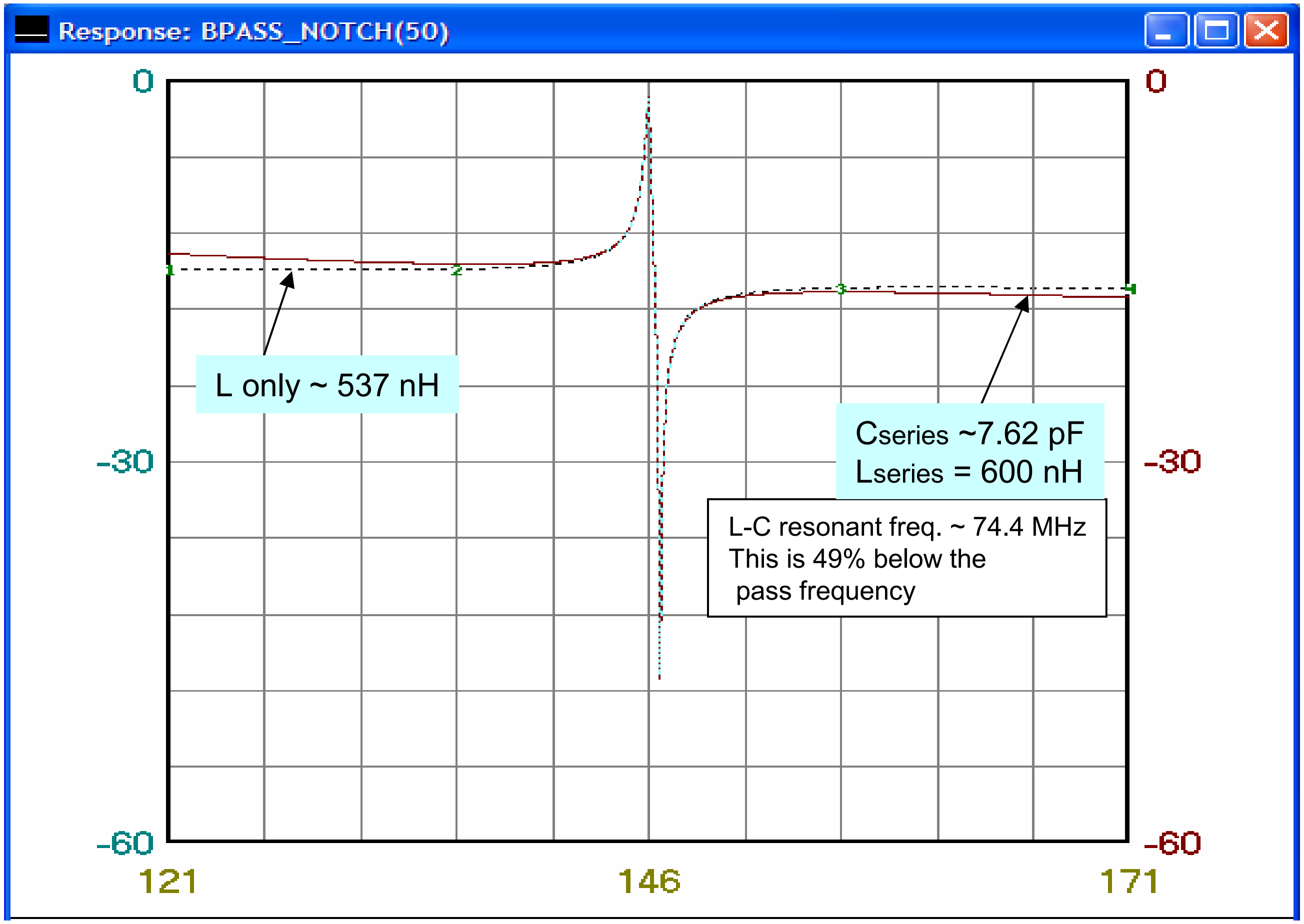
- ALLOWS SETTING THE NOTCH ABOVE AND BELOW THE BANDPASS FREQUENCY BY ADJUSTING THE C ELEMENT ONLY (Cseries)



DUAL LOOP NOTCH-BANDPASS (modified bandpass)

SERIES L-C BETWEEN INPUT AND OUTPUT

NOTCH ON HIGH SIDE

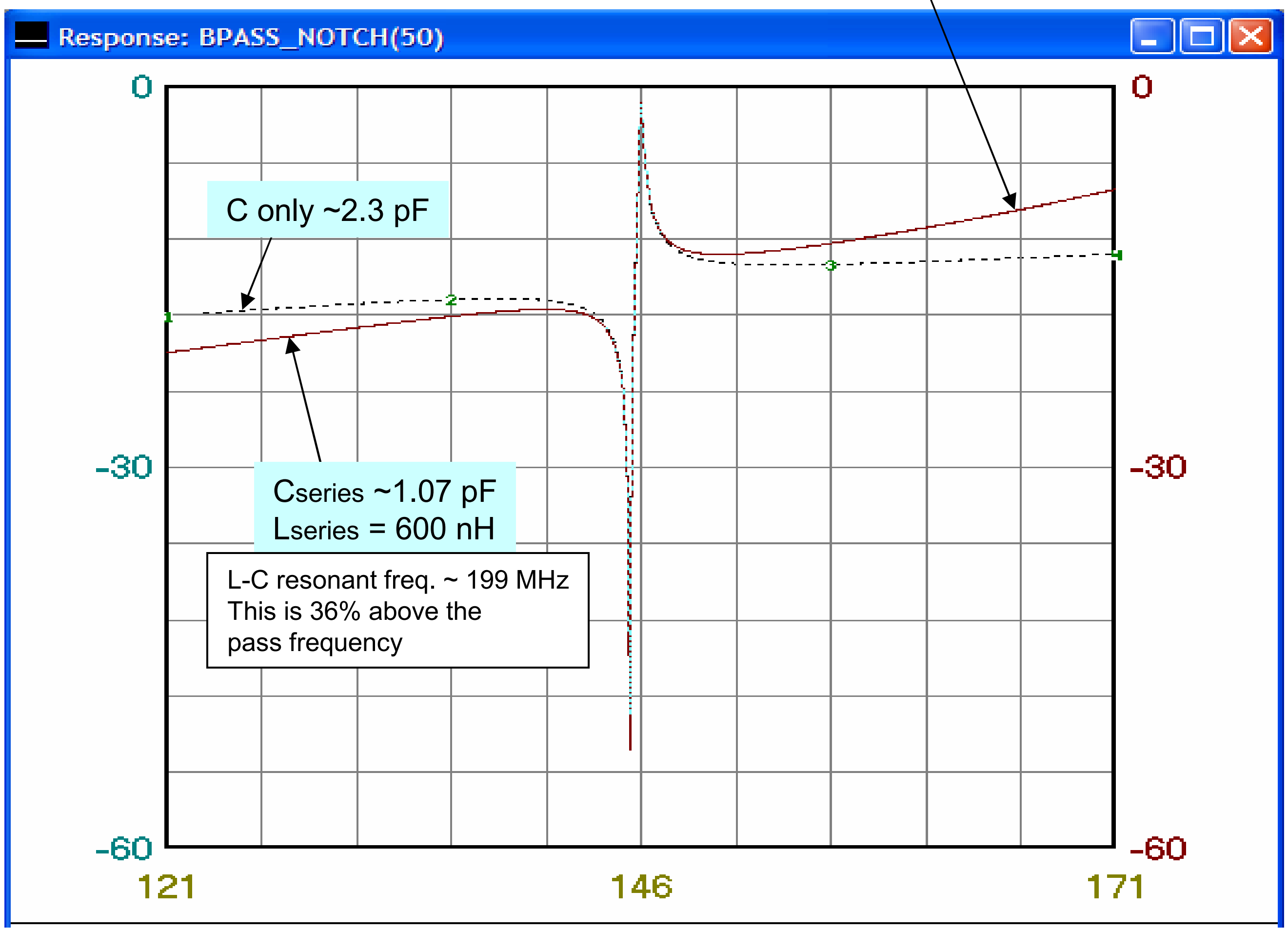


DUAL LOOP NOTCH-BANDPASS (modified bandpass)

SERIES L-C BETWEEN INPUT AND OUTPUT

NOTCH ON LOW SIDE

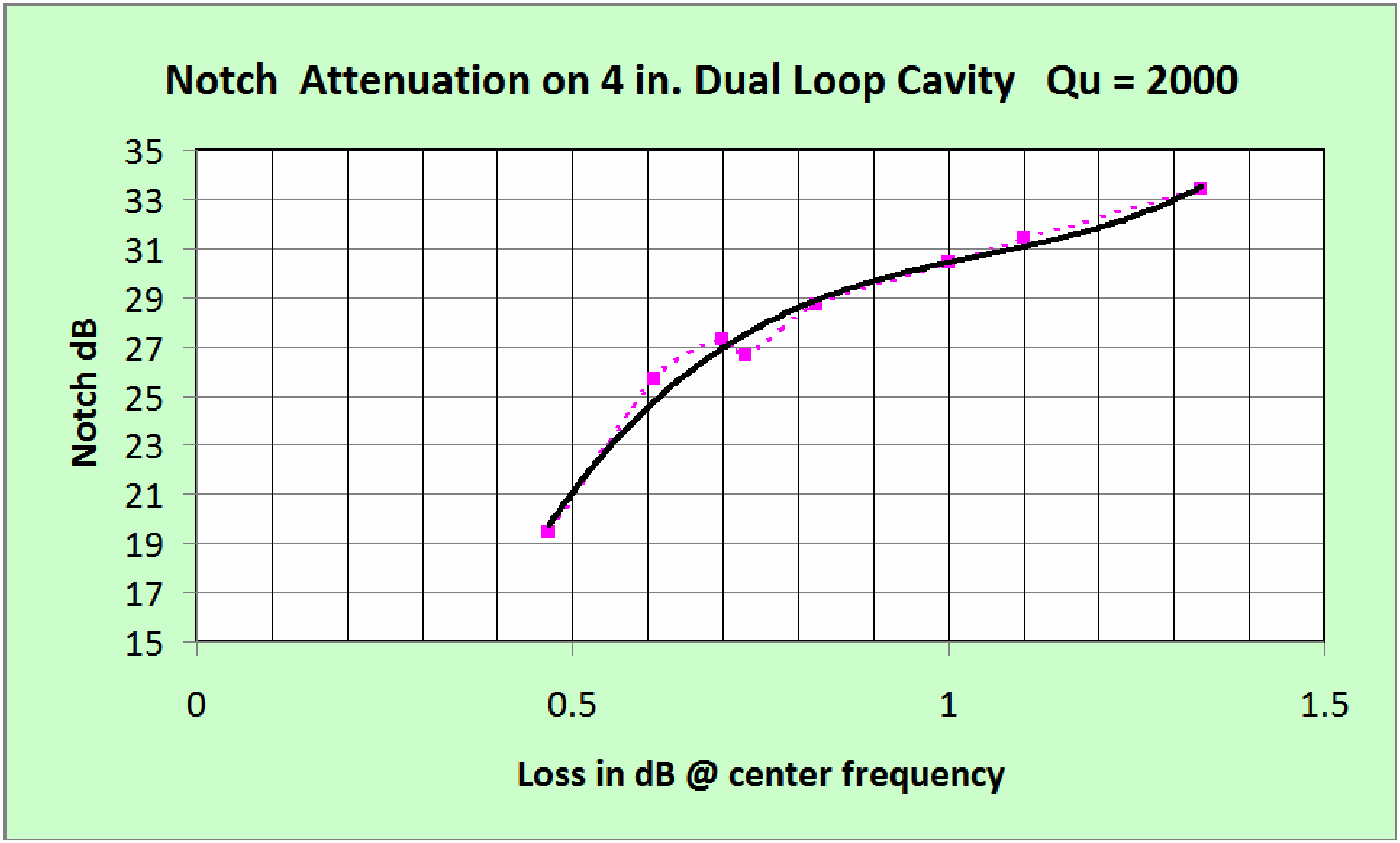
Note the degradation of the attenuation above the pass frequency



DUAL LOOP NOTCH-BANDPASS (modified bandpass)

SERIES L-C BETWEEN INPUT AND OUTPUT

See page 50 for more comparisons



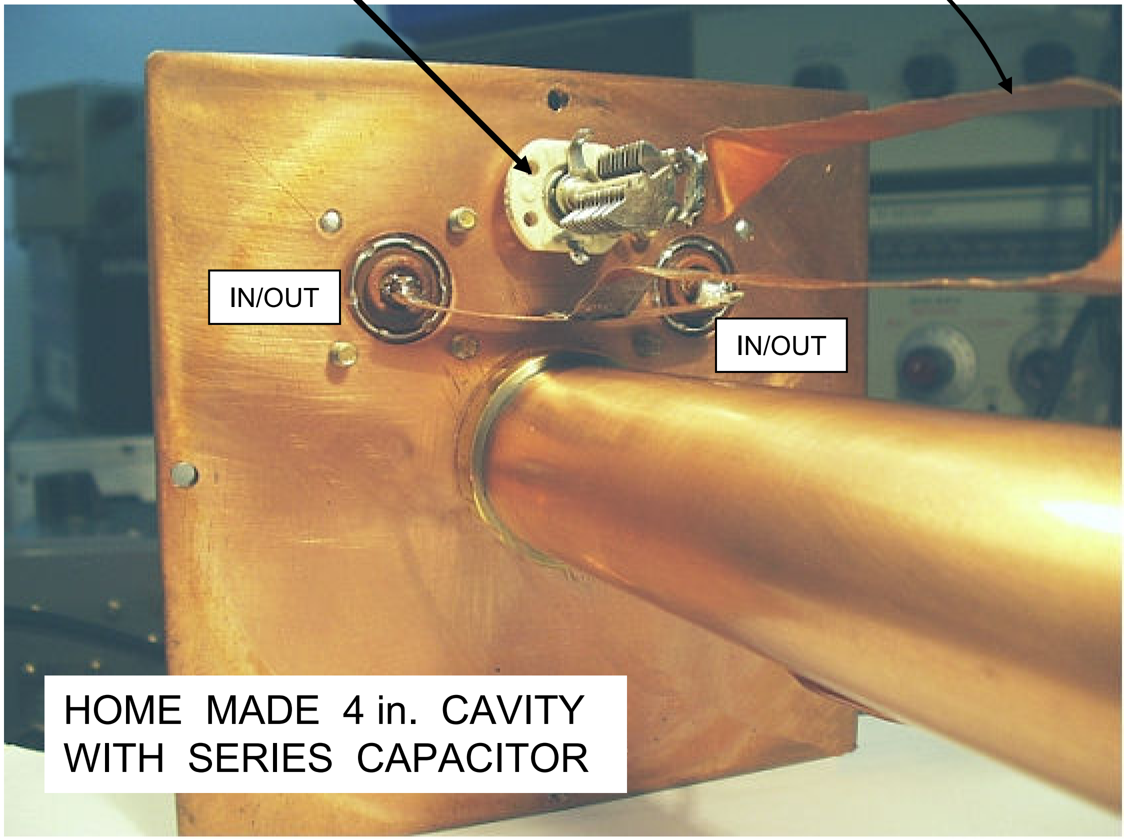
NOTCH – BANDPASS
SERIES RESONANT LOOP CAVITIES

- ❑ DUAL LOOP NOTCH-BANDPASS CAVITIES
- ❑ SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS
- ❑ SINGLE LOOP PARALLEL RESONANT NOTCH-BANDPASS (Q circuit)

SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

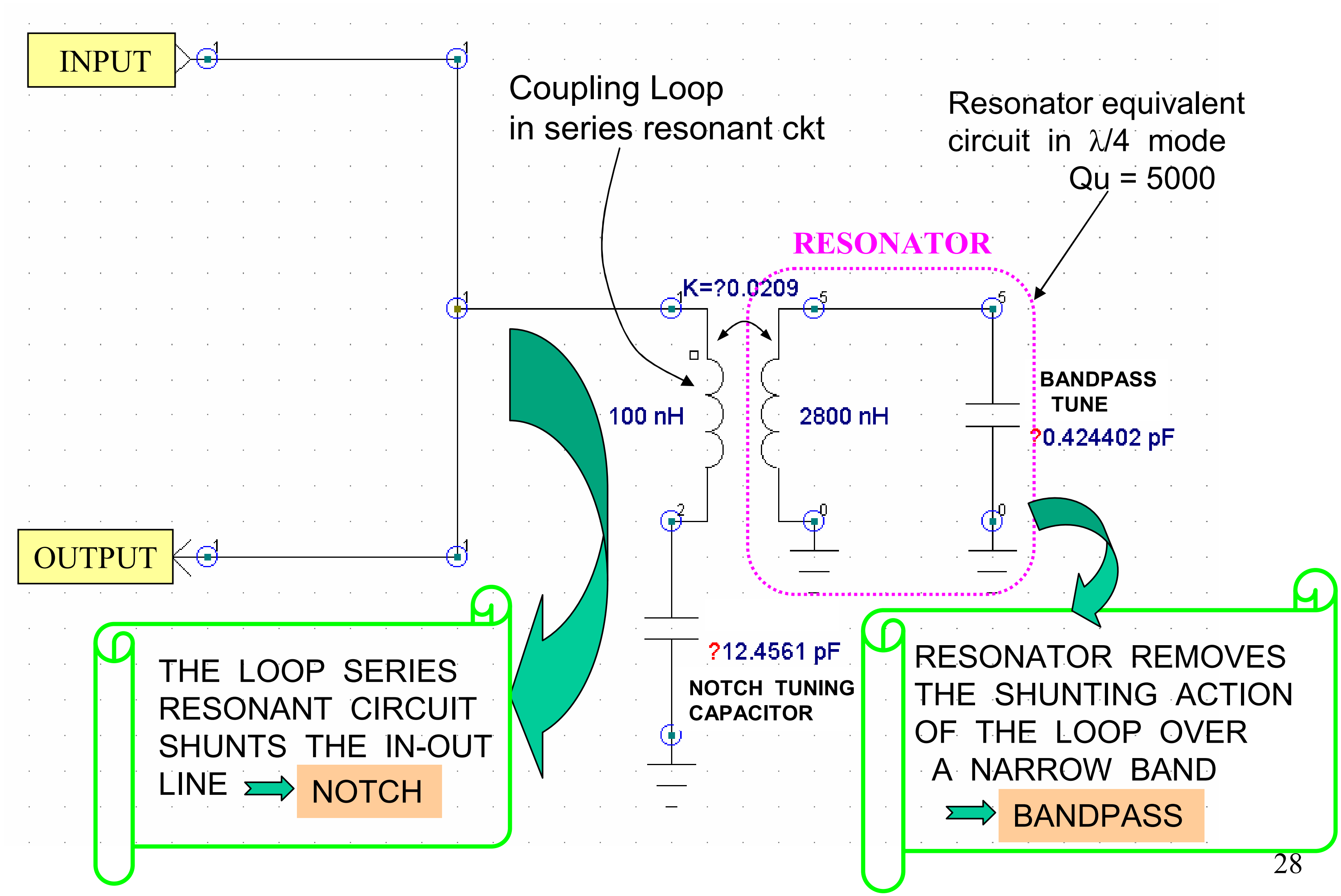
- ONLY ONE LOOP IS USED
- A SERIES CAPACITOR ADJUSTS THE NOTCH FREQUENCY ABOVE AND BELOW THE BANDPASS

A SINGLE CONNECTOR WITH AN EXTERNAL TEE WILL WORK AS WELL



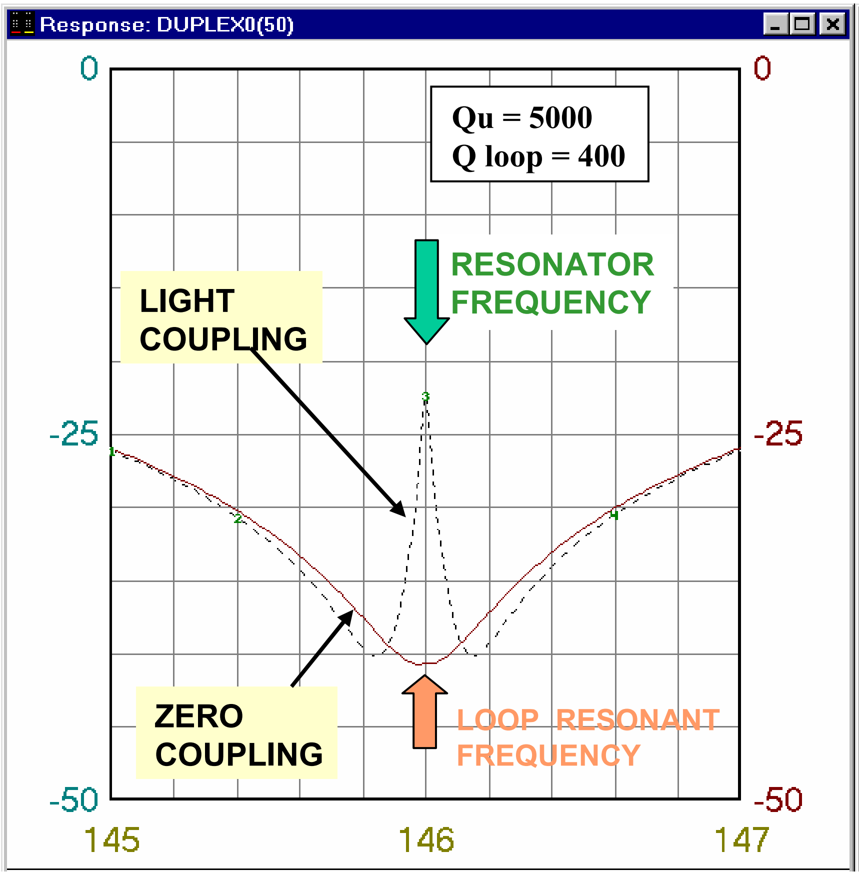
SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

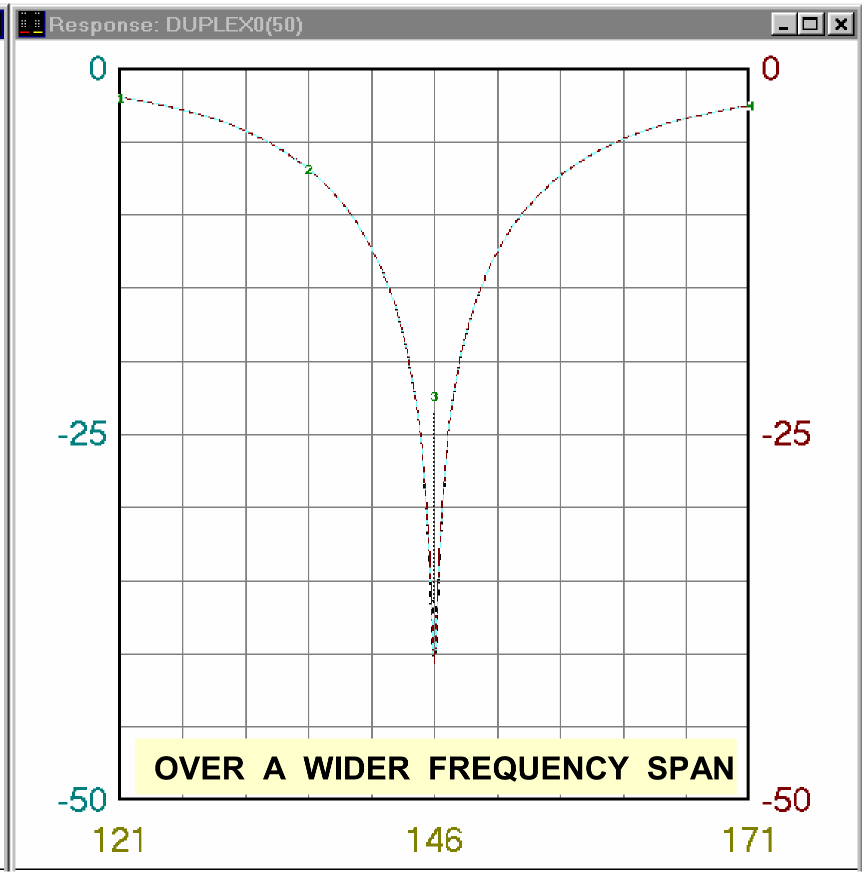
GIVES NOTCH – BANDPASS RESPONSE



SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

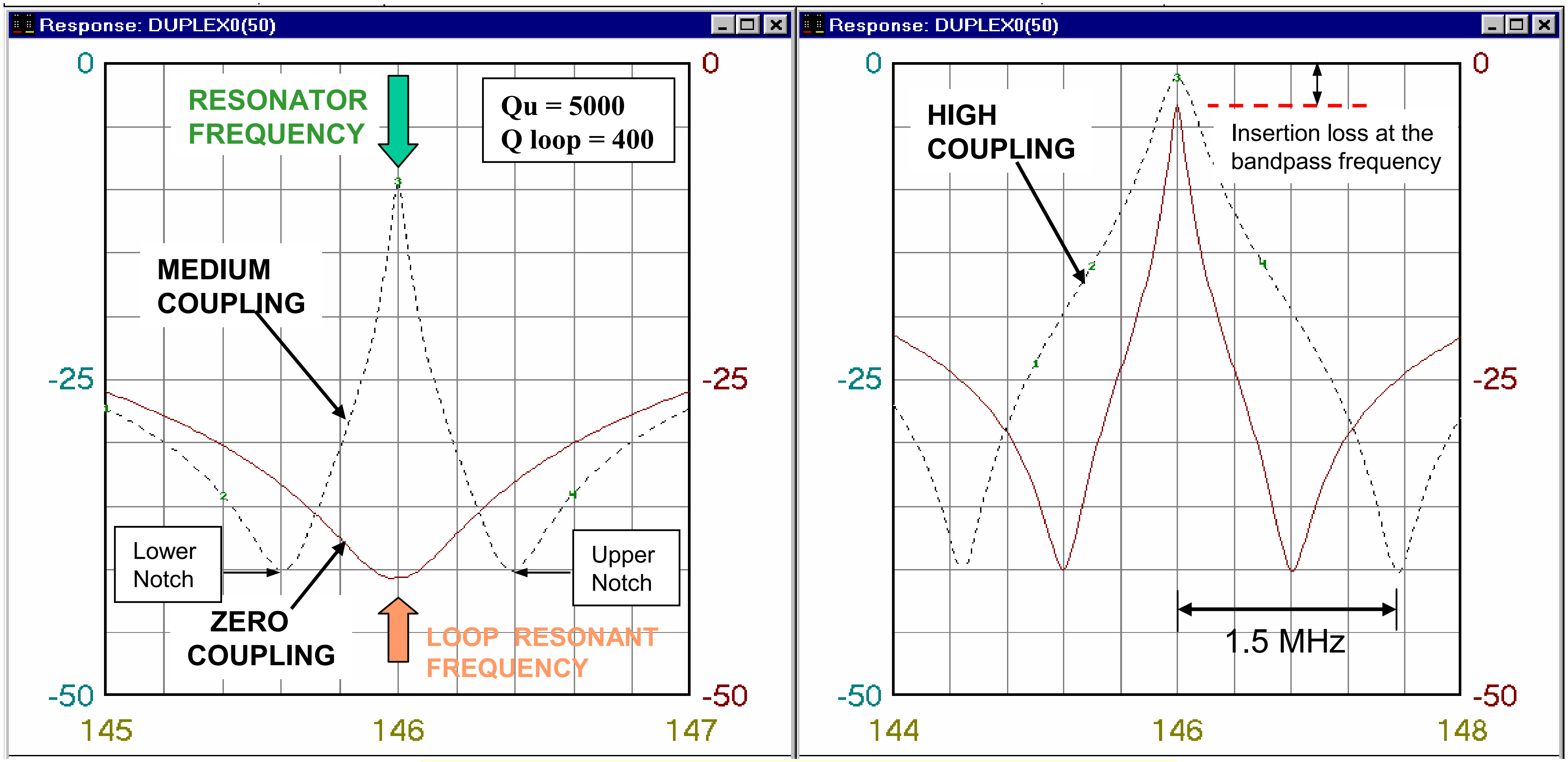
- ❑ **THE COUPLING LOOP IS INITIALLY UNCOUPLED FROM THE RESONATOR** (Removed from the cavity)
- ❑ **SERIES CIRCUIT GIVES MAXIMUM ATTENUATION AT SERIES RESONANCE** (Coupling is zero)
- ❑ **NOTCH DEPTH IS A FUNCTION OF THE Q OF THE LOOP** (Orange curve)
- ❑ **THE RESONATOR IS TUNED AT THE SAME FREQUENCY** (With the loop inside the cavity and light coupling)





SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

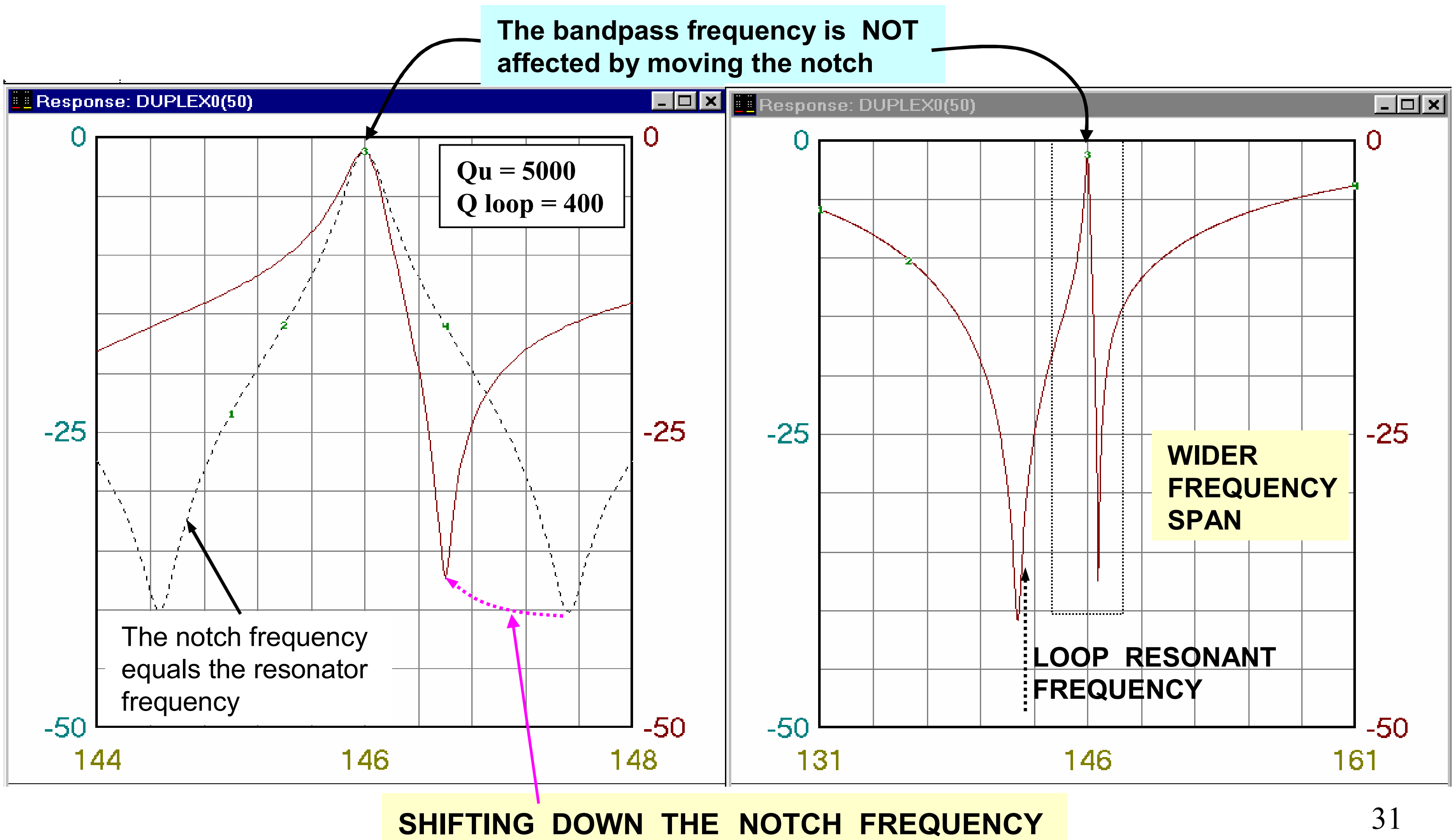
- ❑ **INCREASING THE COUPLING SPREADS THE TWO NOTCHES APART AND…**
- ❑ **DECREASES THE INSERTION LOSS AT THE BANDPASS FREQUENCY**
- ❑ **FOR 1 dB LOSS THE NOTCHES ARE AT +/- 1.5 MHz – NEED TO SHIFT THE DESIRED NOTCH**



EFFECT OF CHANGING THE LOOP COUPLING

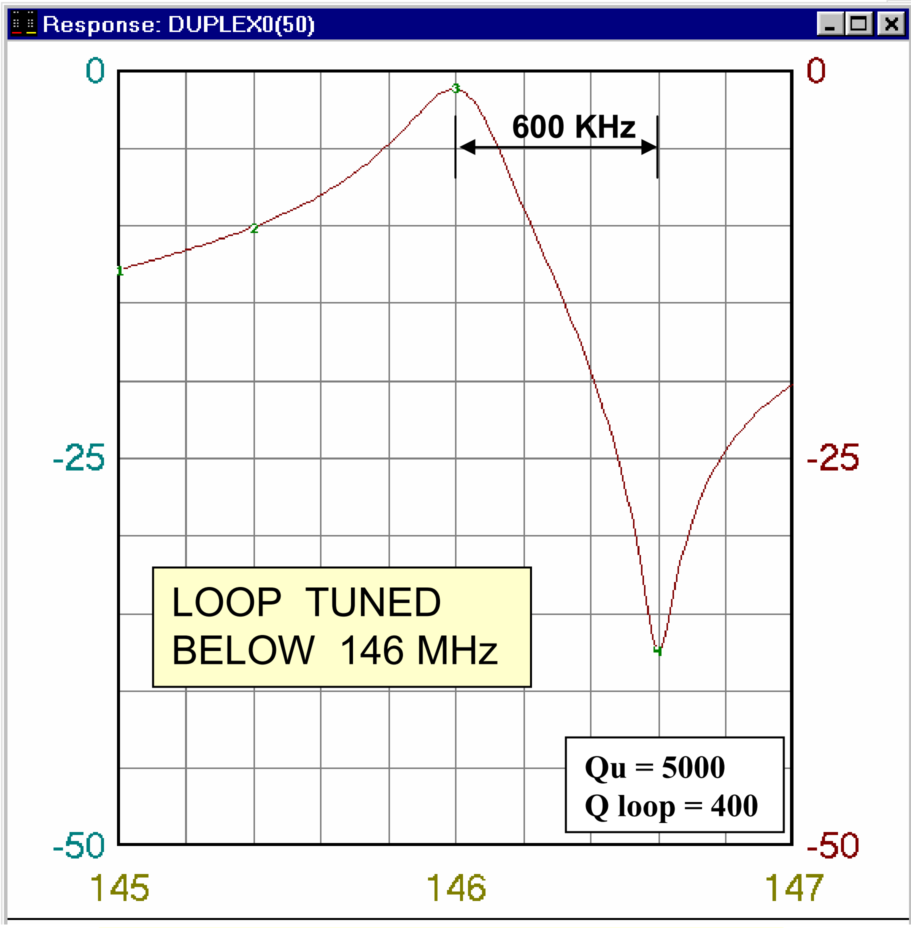
SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

- **THE UPPER NOTCH FREQUENCY IS SHIFTED DOWN BY LOWERING THE LOOP RESONANT FREQUENCY (SOLID BROWN CURVE)**
- **THE DEPTH OF THE UPPER NOTCH SUFFERS**

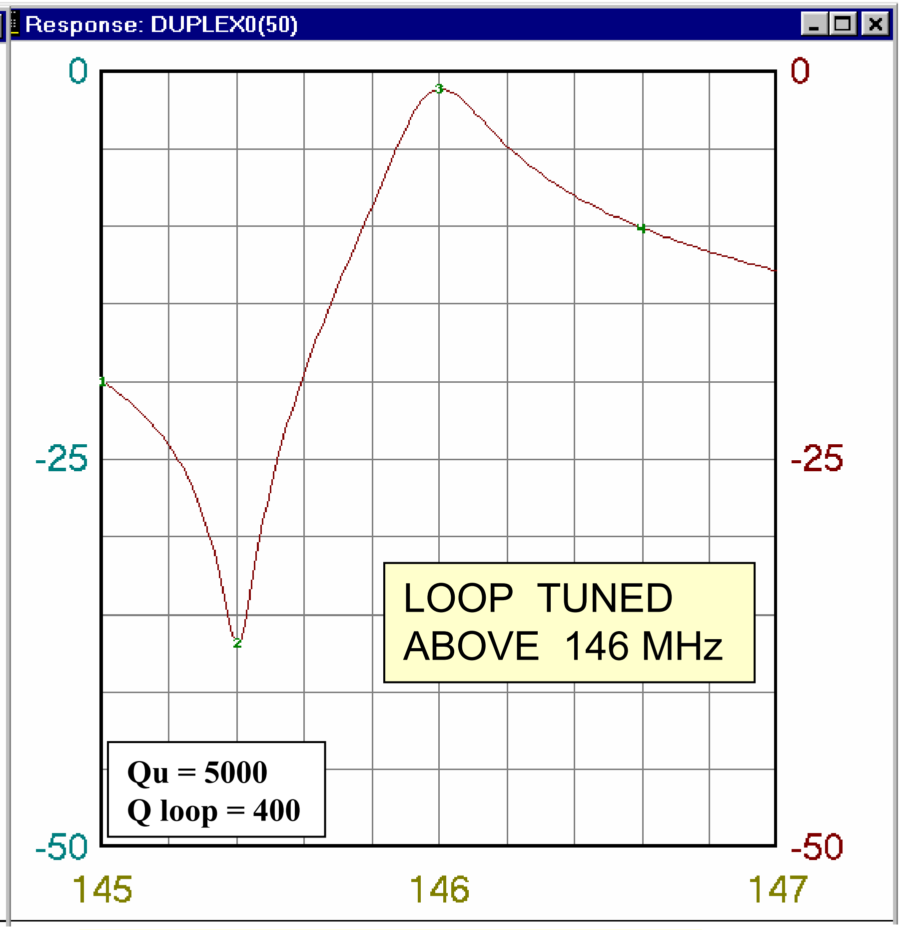


SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

- **TUNING THE LOOP BELOW AND ABOVE THE BANDPASS FREQUENCY WILL SET THE NOTCH +/- 600 KHz**



NOTCH FREQUENCY SHIFTED DOWN

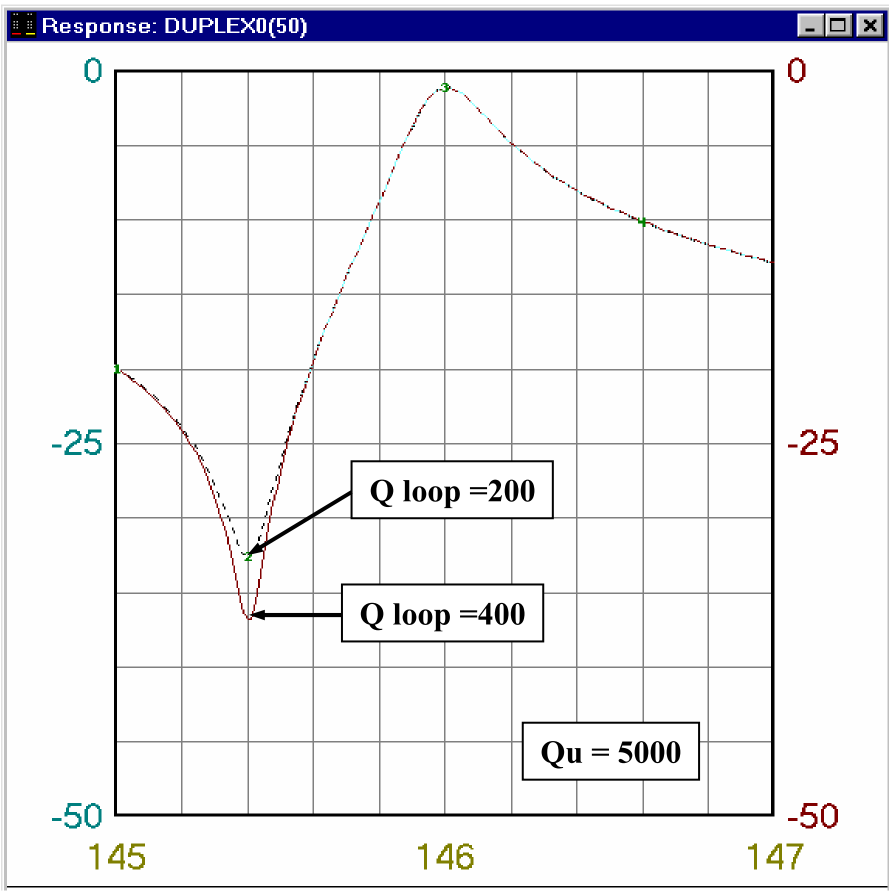


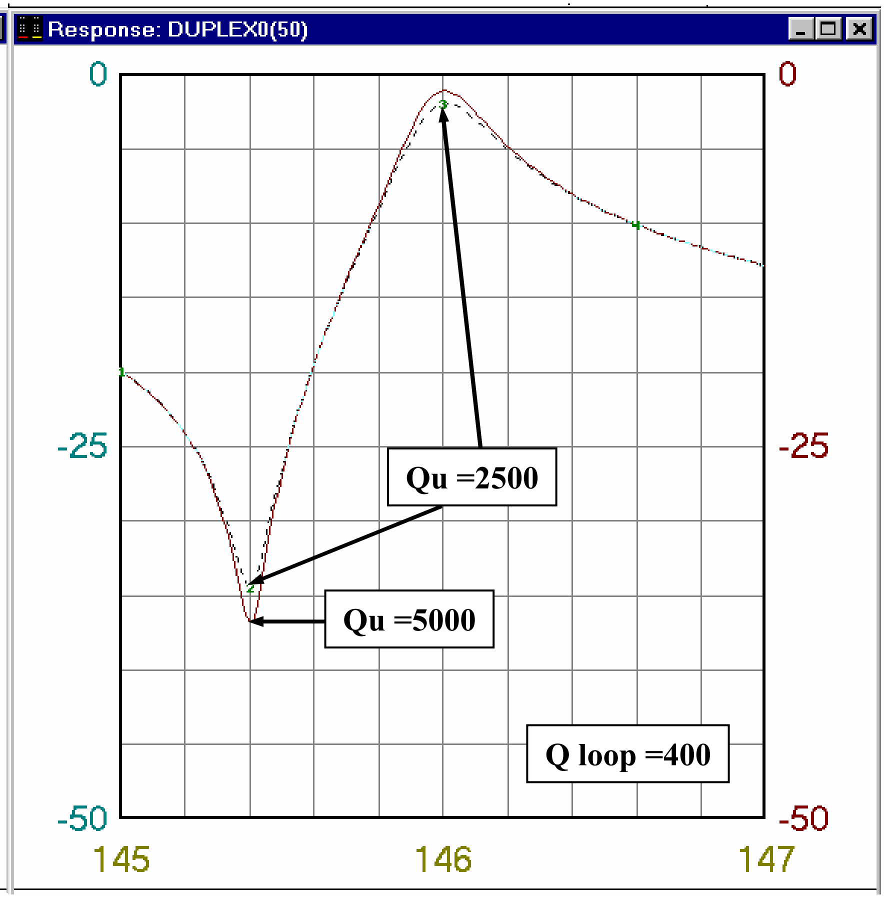
NOTCH FREQUENCY SHIFTED UP

SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

- **THE Q OF THE LOOP SETS THE NOTCH DEPTH**

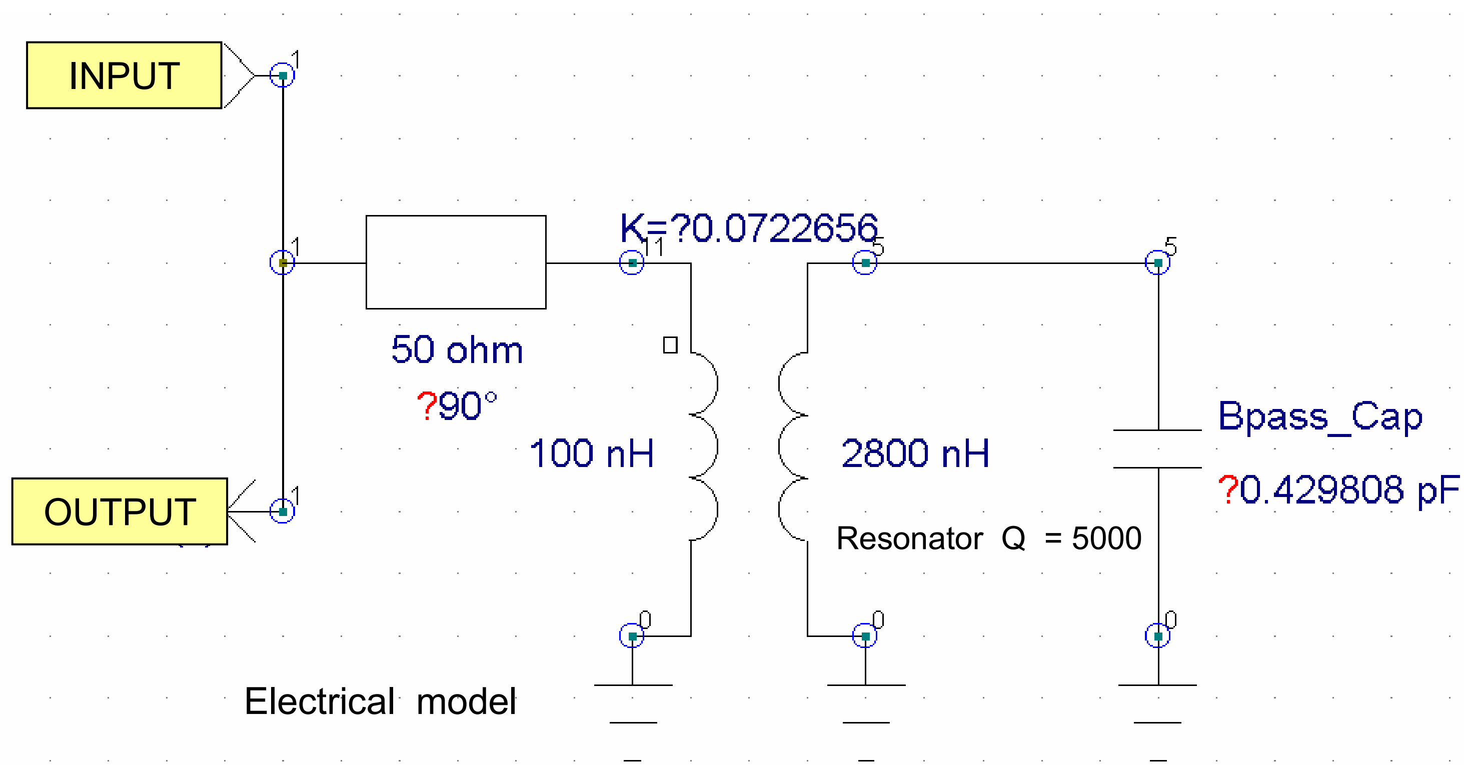
- **THE Q OF THE CAVITY (Qu) AFFECTS BOTH THE BANDPASS LOSS AND THE NOTCH DEPTH**





SINGLE LOOP SERIES NON-RESONANT NOTCH-BANDPASS

- **UNTUNED COUPLING LOOP IN SERIES WITH A TRANSMISSION LINE**
- **PROVIDES NOTCH-BANDPASS OPERATION**
- **THE LINE LENGTH AND THE LOOP COUPLING ARE ADJUSTED TO OBTAIN THE DESIRED NOTCH BANDPASS RESPONSE.**
- **GIVES 2 NOTCHES AS IN THE RESONANT NOTCH BANDPASS**



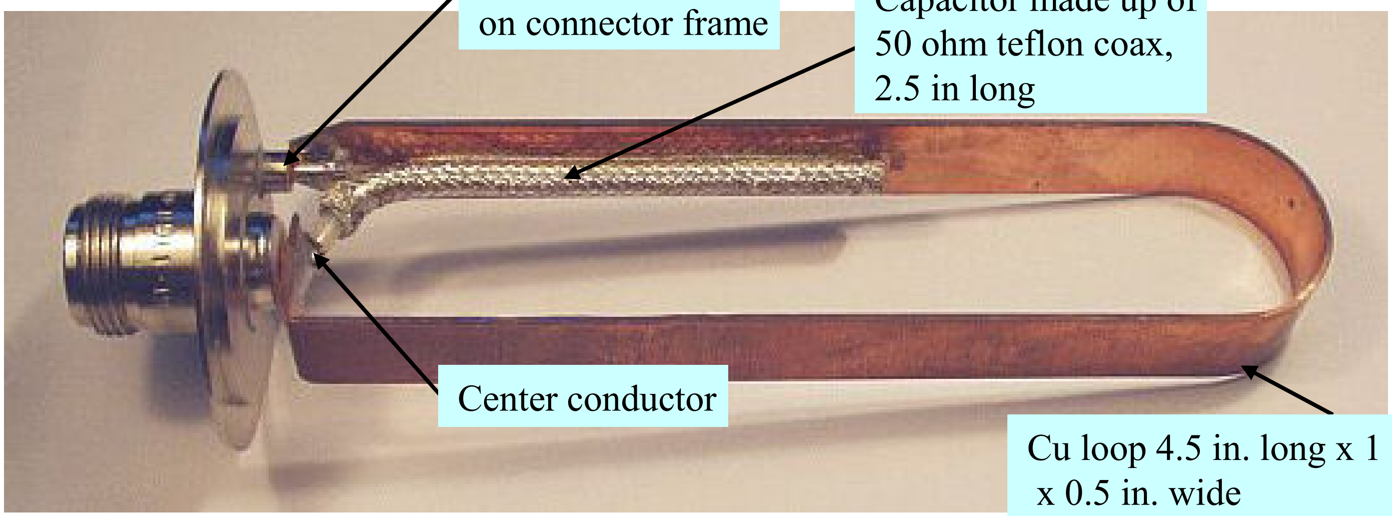
Thanks to: Pedro M.J. Wyns (ON7WP-AA9HX)

NOTCH – BANDPASS MODE
PARALLEL RESONANT LOOP CAVITIES

- ❑ DUAL LOOP NOTCH-BANDPASS CAVITIES
- ❑ SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS
- ❑ SINGLE LOOP PARALLEL RESONANT NOTCH-BANDPASS (Q circuit)

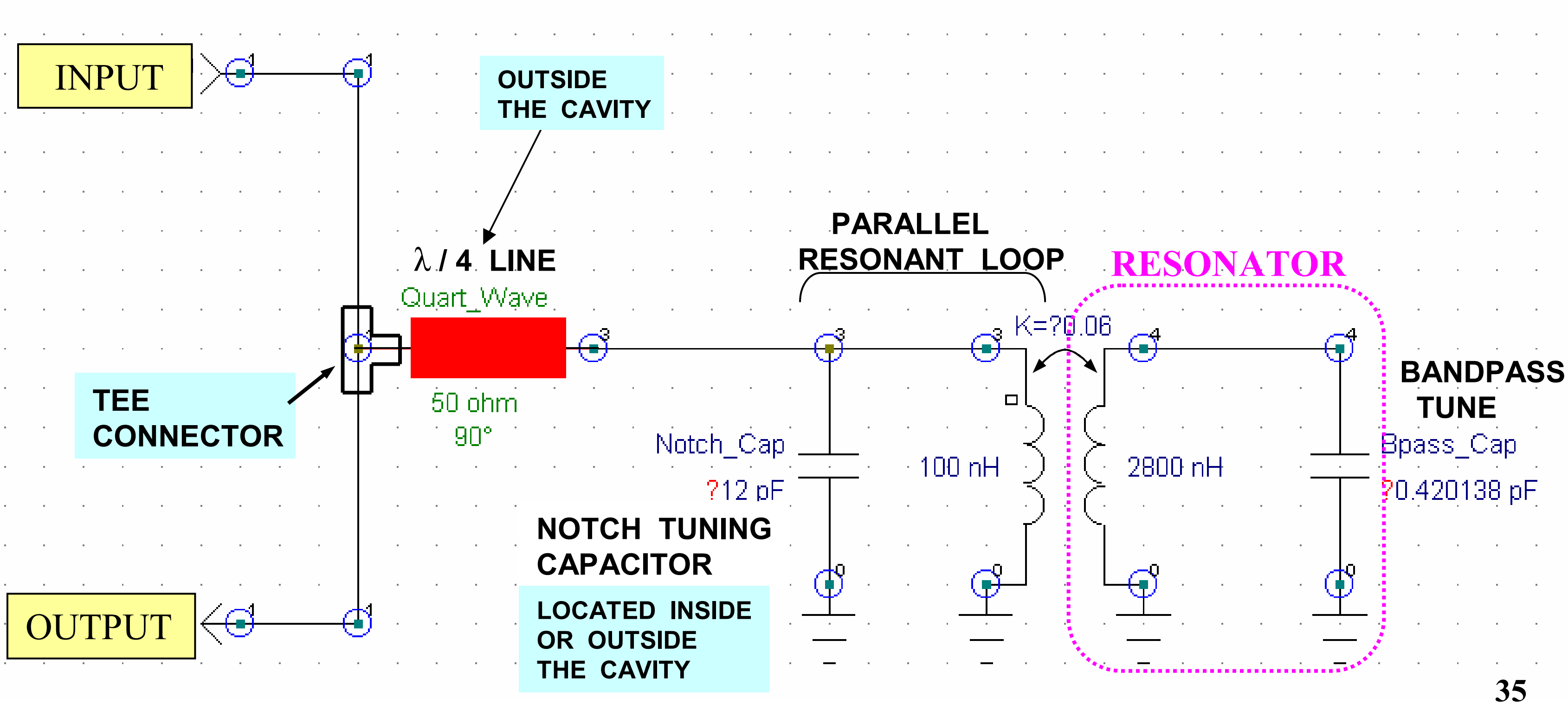
PARALLEL RESONANT LOOP (Q circuit)

- EXAMPLE OF A PARALLEL RESONANT LOOP
- HERE THE CAPACITOR IS MADE WITH A SHORT LENGTH OF COAX



PARALLEL RESONANT LOOP (Q circuit)

- A QUARTER WAVELENGTH LINE TRANSFORMS THE LOOP PARALLEL CIRCUIT INTO A SERIES CIRCUIT – EFFECTIVELY
- OPERATION IS SIMILAR TO THE SERIES RESONANT LOOP
- TWO NOTCHES ARE ALWAYS PRESENT WITH THIS CONFIGURATION

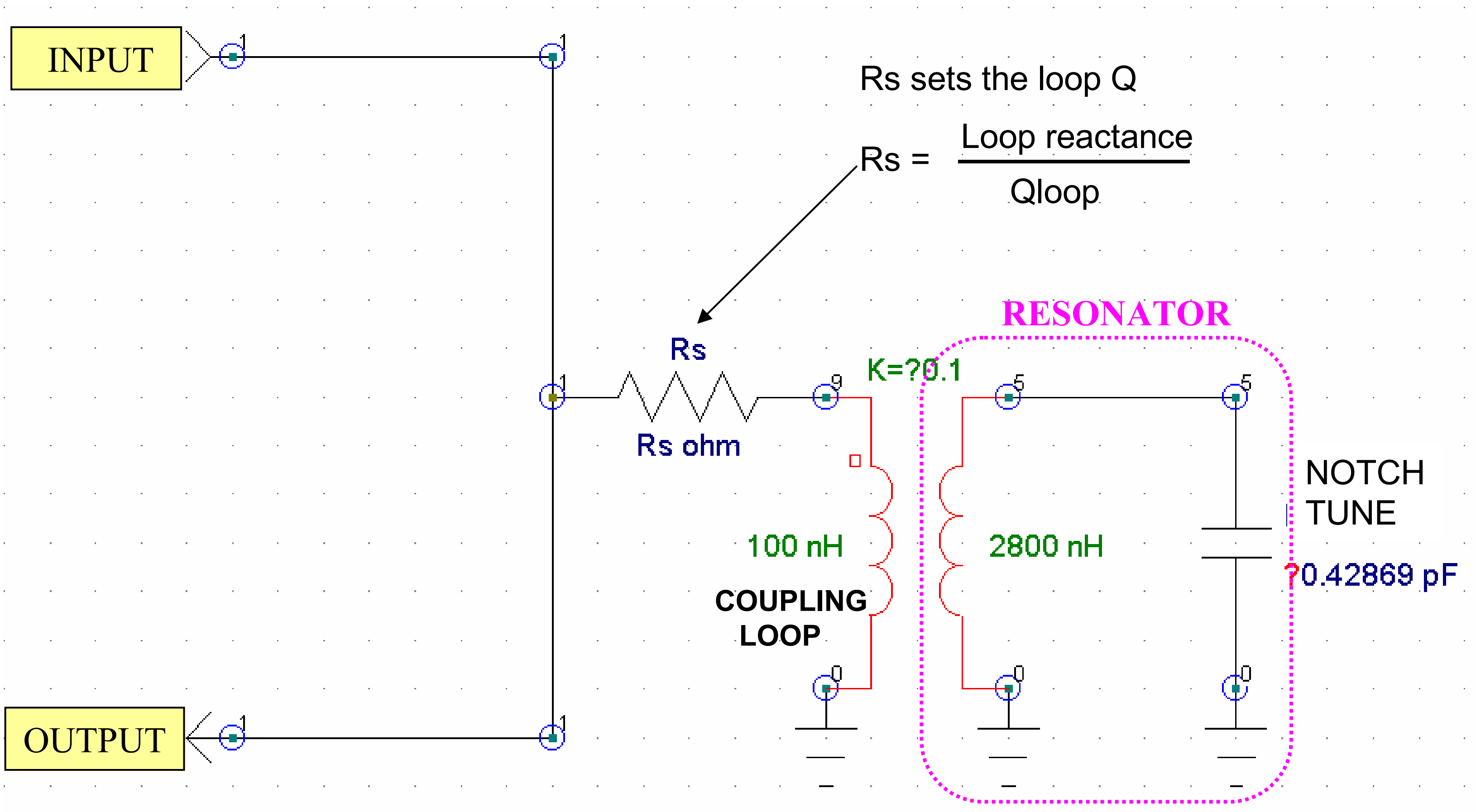


NOTCH CAVITIES

- ❑ CAVITY NOTCHERS
- ❑ HELIAX NOTCHERS

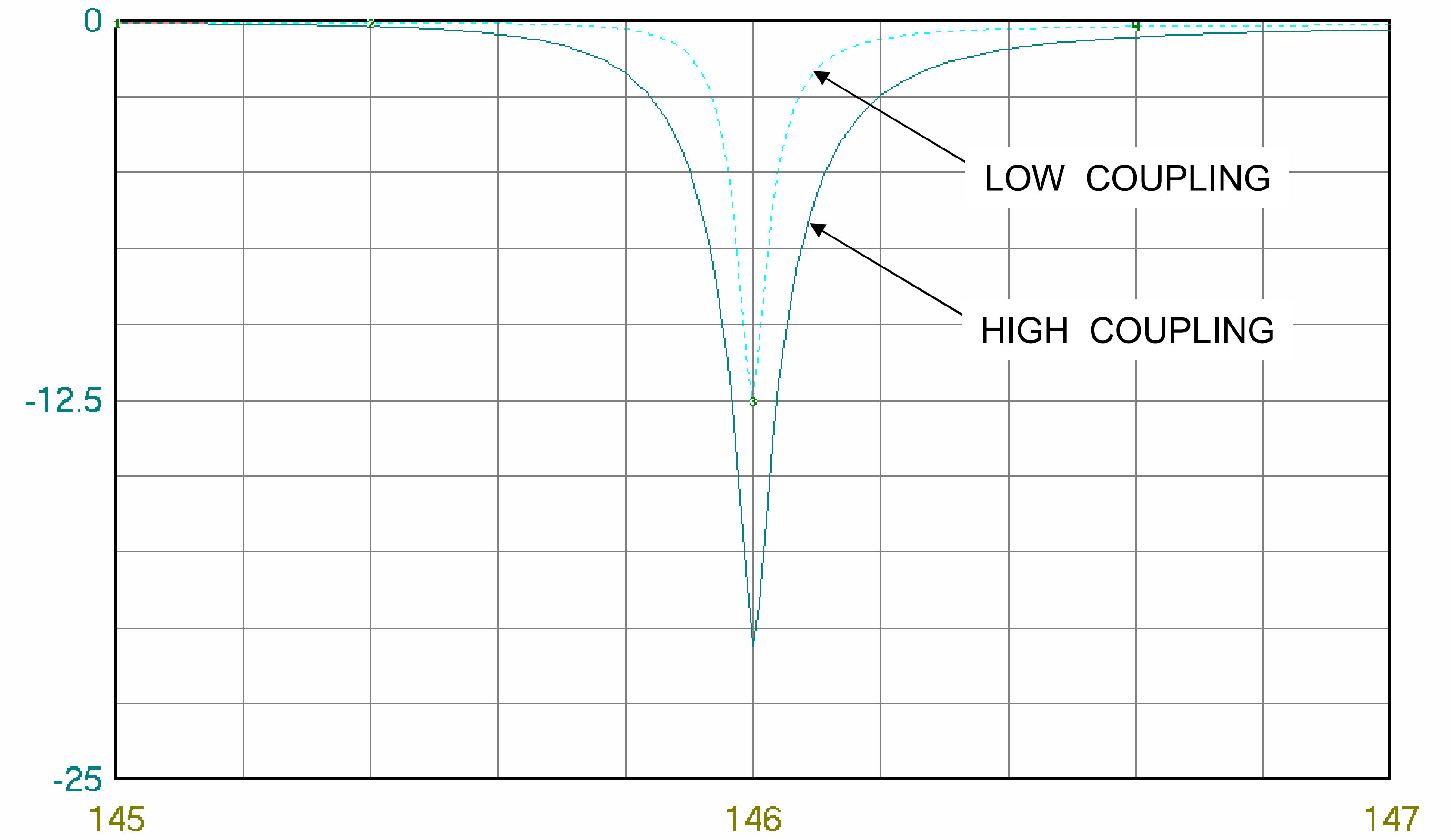
CAVITY NOTCHER for 146 MHz

EQUIVALENT CIRCUIT



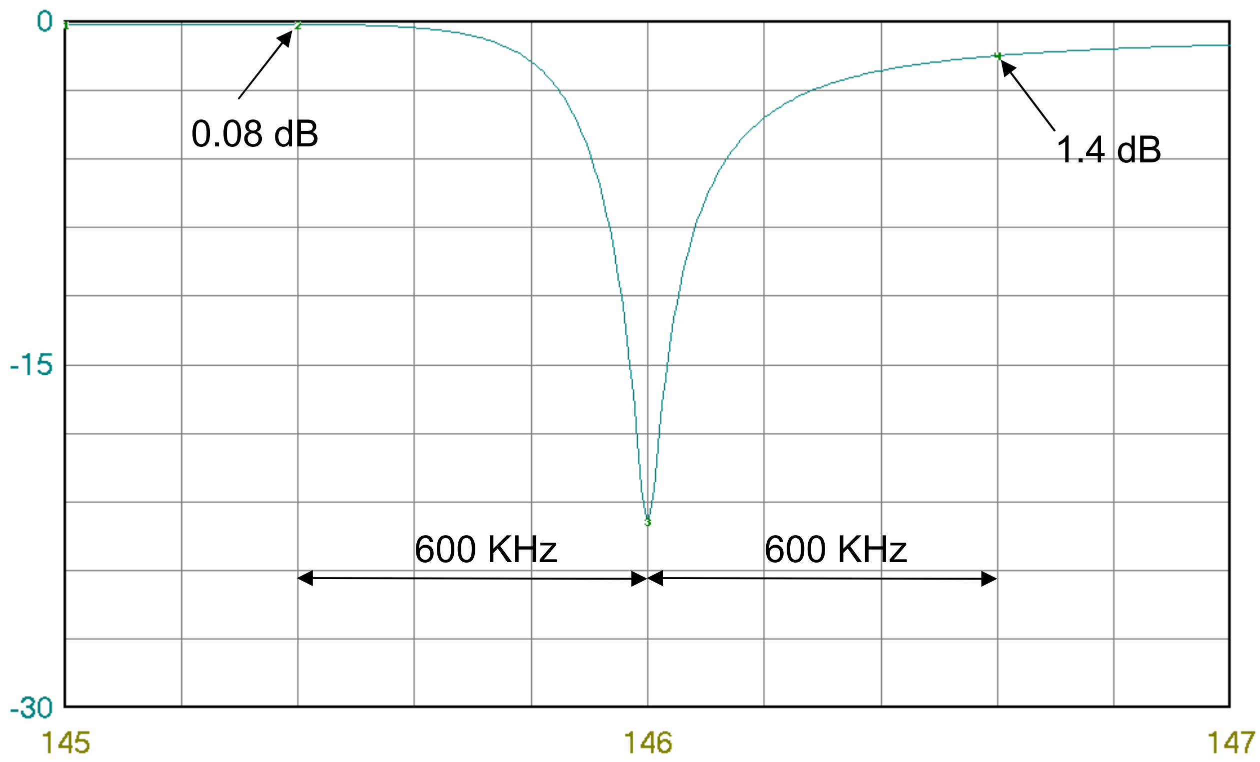
CAVITY NOTCHER FREQUENCY RESPONSE

- ❑ VARYING THE LOOP COUPLING AFFECTS THE NOTCH DEPTH AND
- ❑ DETUNES THE NOTCH FREQUENCY SOMEWHAT



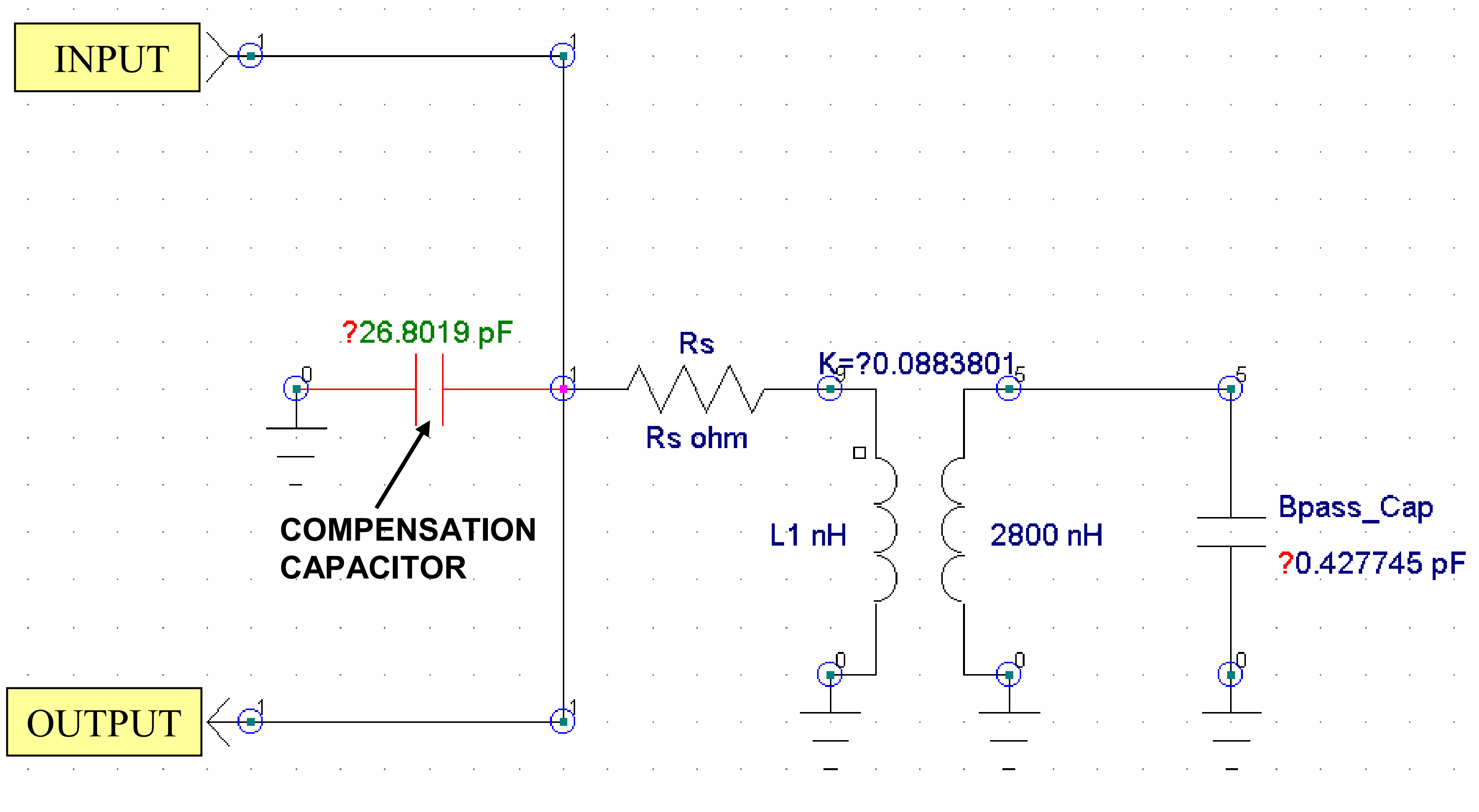
CAVITY NOTCHER FREQUENCY RESPONSE

- RESPONSE NOT SYMETRICAL AT +/- 600 KHz
- HIGH SIDE HAS A LOT MORE ATTENUATION AT + 600KHz



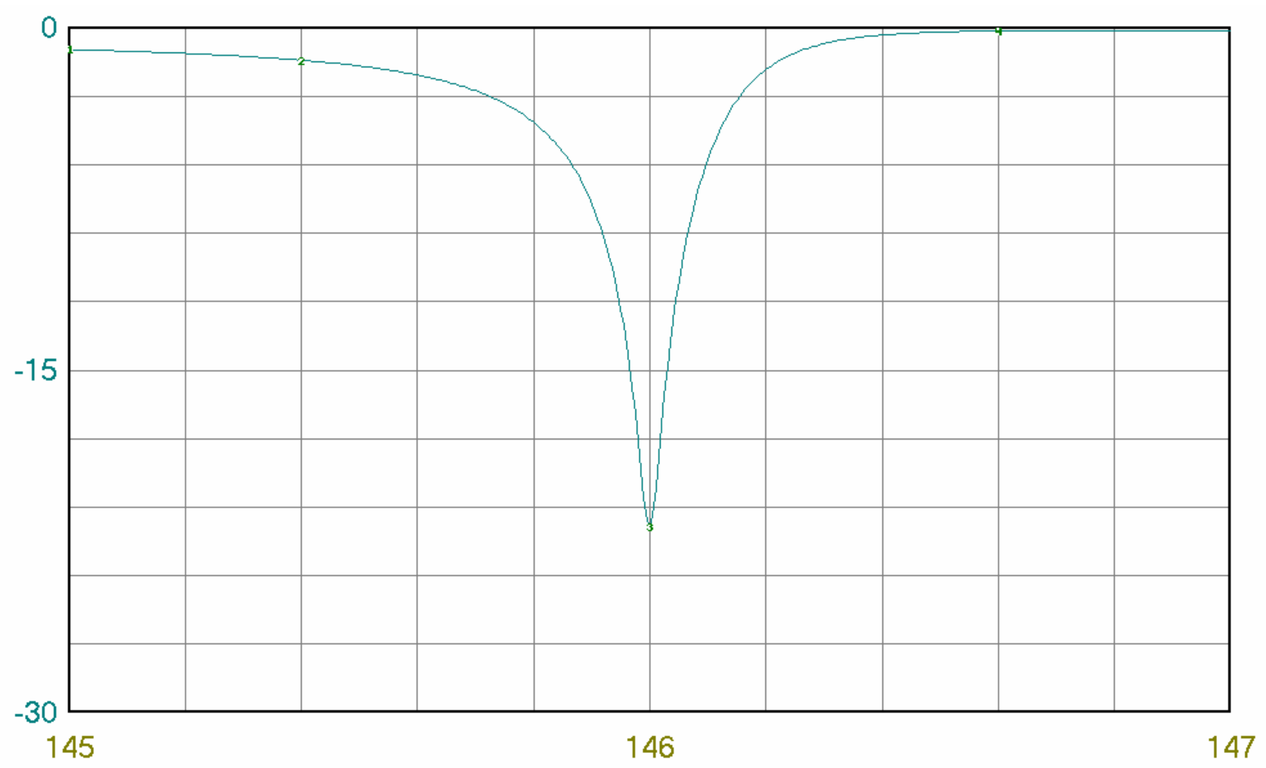
CAVITY NOTCHER WITH COMPENSATION CAPACITOR

- ADDING A COMPENSATION CAPACITOR DECREASES THE LOSSES ON THE UPPER SIDE
- THE COMPENSATION CAPACITOR HAS AN OPTIMUM VALUE FOR A GIVEN SPLIT
- ITS Q FACTOR IS NOT CRITICAL - AN OPEN COAX STUB MAY BE USED



CAVITY NOTCHER WITH COMPENSATION CAPACITOR

- ❑ CONSIDERABLY REDUCED HIGH SIDE INSERTION LOSS
- ❑ LOW SIDE NOW HAS THE HIGH INSERTION LOSS



CAVITY NOTCHERS - GENERAL

- OBTAINING THE DEEPEST NOTCH REQUIRES:

  INCREASING THE LOOP COUPLING

  DECREASING THE LOOP INDUCTANCE

- THESE TWO REQUIREMENTS ARE CONTRADICTORY SINCE
  A LOW INDUCTANCE LOOP WILL HAVE LESS COUPLING AND VICE VERSA

- IT MAY BE DIFFICULT TO GET 30 dB REJECTION ON A 6 in. CAVITY

- THE LOW SIDE MAY HAVE TO BE COMPENSATED WITH AN INDUCTOR
  TO ACHIEVE MINIMUM LOSSES (OR A SHORTED STUB)

- THE Q FACTOR OF THE LOOPS IS NOT CRITICAL, AS LONG AS $Q > 100$ OR SO

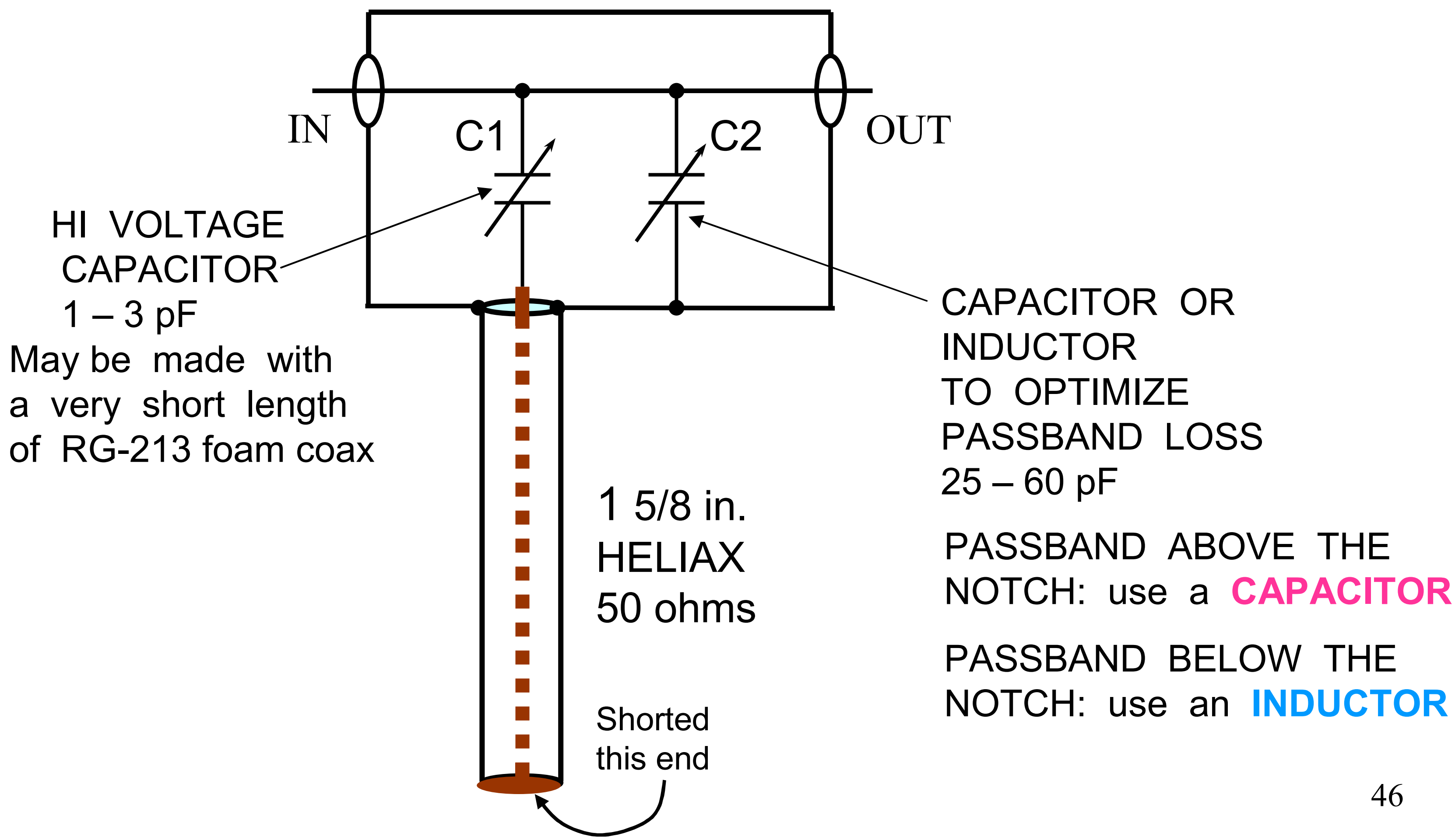
- THE NOTCH - BANDPASS MODE MAKES A MORE EFFICIENT USE OF THE CAVITY.
  NOTCH DEPTHS BETTER THAN 35 dB ARE EASILY OBTAINED WITH A 6 in. CAVITY

NOTCH CAVITIES

- ❑ CAVITY NOTCHERS
- ❑ HELIAX NOTCHERS

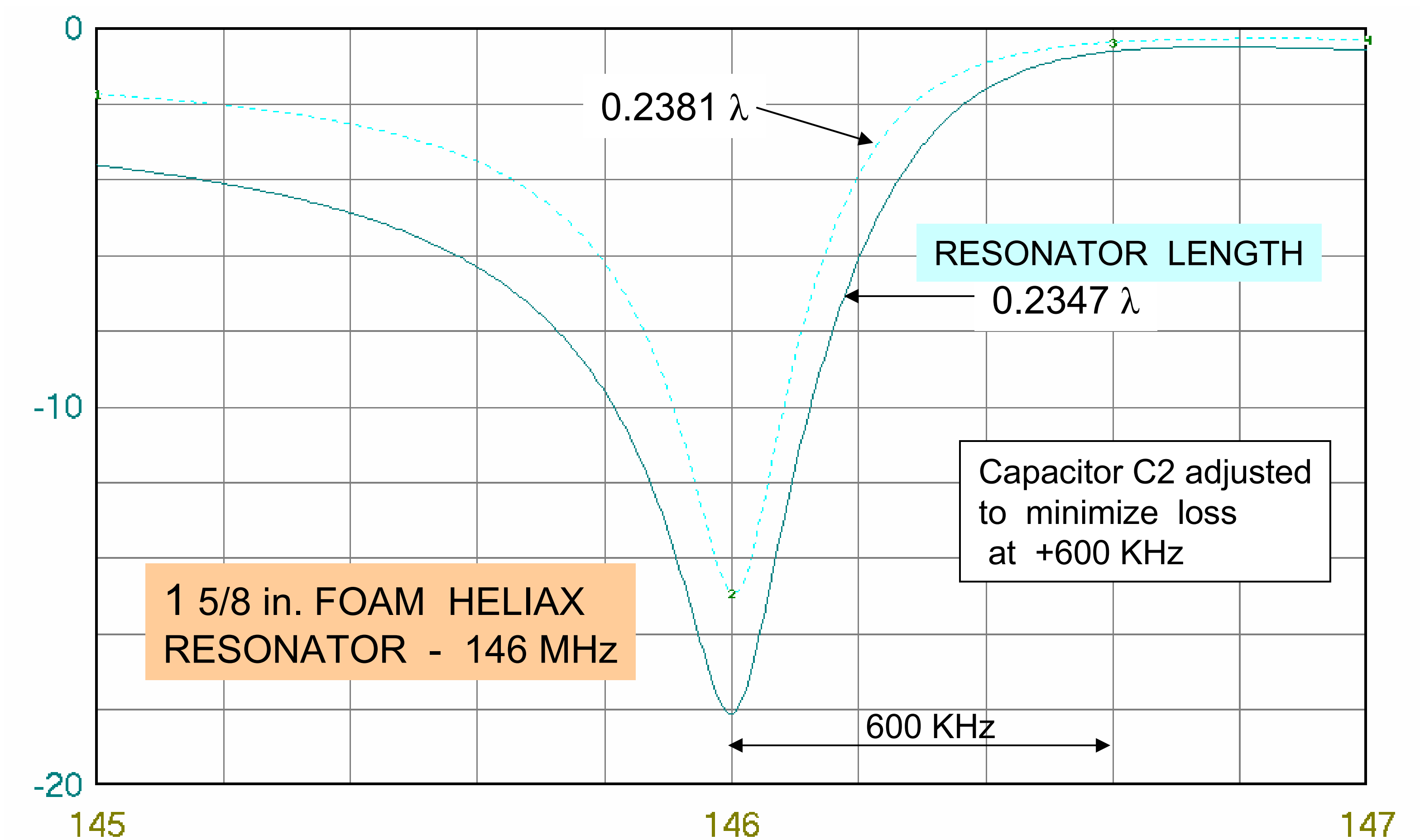
HELIAX NOTCHER for 146 MHz

- USES AN INDUCTIVE SHORTED STUB   See ref. 3 and 4
- THE STUB EXHIBITS SERIES RESONANCE AT THE NOTCH FREQUENCY



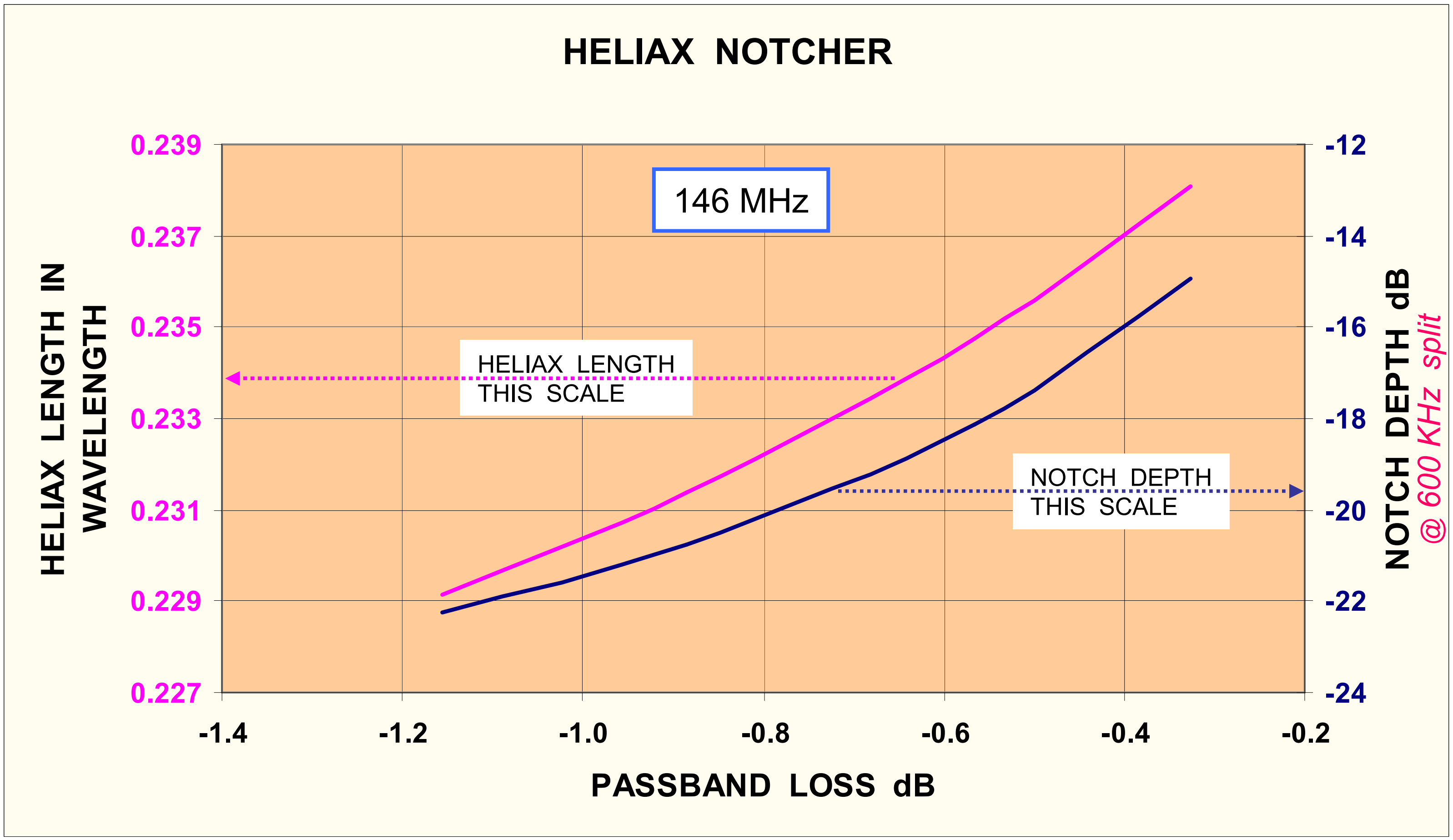
HELIAX NOTCHER - FREQUENCY RESPONSE

1 5/8 in. FOAM HELIAX Vf=0.87 50 ohms 0.156 dB/100 ft @ 50 MHz
Series cap = 50 ohm foam coax Vf=0.87 2.2 dB/100 ft @ 150 MHz



ATTENUATION AND LENGTH DATA FOR THE HELIAX NOTCHER

1 5/8 in. FOAM HELIAX Vf=0.87 50 ohms 0.156 dB/100 ft @ 50 MHz
Series cap = 50 ohm foam coax Vf=0.87 2.2 dB/100 ft @ 150 MHz

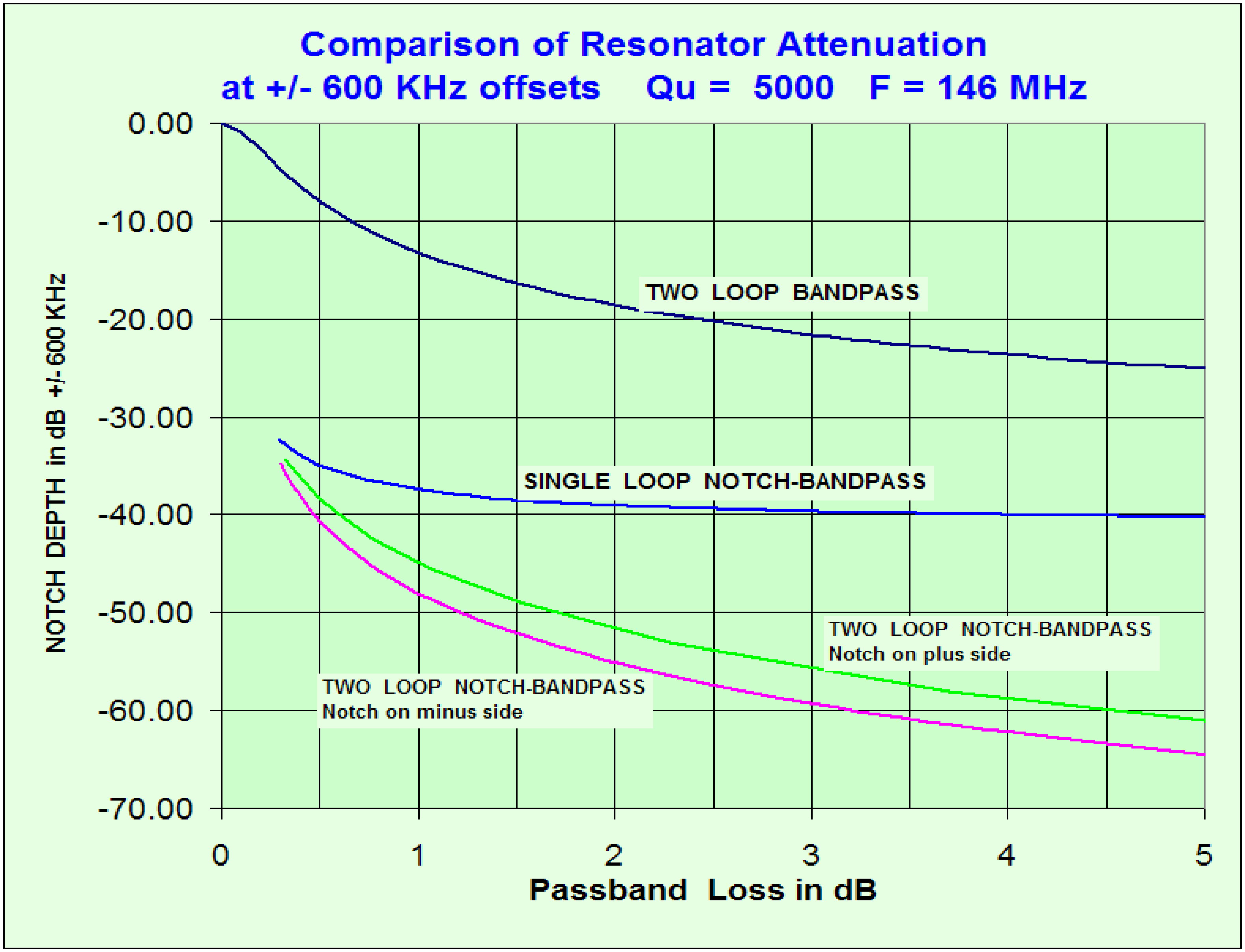


NOTE: Use with a $\lambda/4$ connecting line. The line adds ~ 5 dB to the notch depth

COMPARISONS

CAVITY TYPE	PLUS	MINUS
BANDPASS	• EASIEST TO ADJUST • INCREASING REJECTION OF OUTSIDE SIGNALS	• POOR REJECTION CLOSE TO BANDPASS (12-18 dB @ 600 KHz on 2m)
DUAL LOOP NOTCH-BANDPASS	• BEST NOTCH DEPTH ~ 45 dB typical 6" cavity • ONLY ONE NOTCH • NOTCH TUNE SENSITIVITY IS LOW: 16% / 100KHz	• FLOATING SERIES CAPACITOR • SERIES INDUCTOR DIFFICULT TO ADJUST • SOME REJECTION OUTSIDE BANDPASS • NOTCH FREQ. INTERACTS SOMEWHAT WITH BANDPASS FREQUENCY
SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS	• EASY TO ADJUST VIA SER CAP OR COUPLING • GOOD NOTCH DEPTH ~ 37 dB typical 6" cavity • NOTCH FREQ. INDEPENDANT OF BANDPASS FREQUENCY	• TWO NOTCHES – MISLEADING • NOTCH TUNE SENSITIVITY IS HIGH: -1% / 100KHz • LOOP Q DETERMINES NOTCH DEPTH • LITTLE REJECTION OUTSIDE BANDPASS AND NOTCH
SINGLE LOOP PARALLEL RESONANT NOTCH-BANDPASS (Q circuit)	• SAME AS SERIES RESONANT LOOP	• SAME AS SERIES RESONANT LOOP • QUARTER WAVELENGTH CABLE INTRODUCE ADDITIONAL LOSSES
NOTCH CAVITIES	• ATTENUATE A NARROW BAND OF FREQUENCIES • MAY BE BUILT USING HELIAX CABLE	• NOTCH DEPTH NOT AS GOOD AS IN NOTCH-BANDPASS DESIGNS • USE WITH BANDPASS CAVITIES TO PROVIDE REJECTION FAR FROM TX/RX

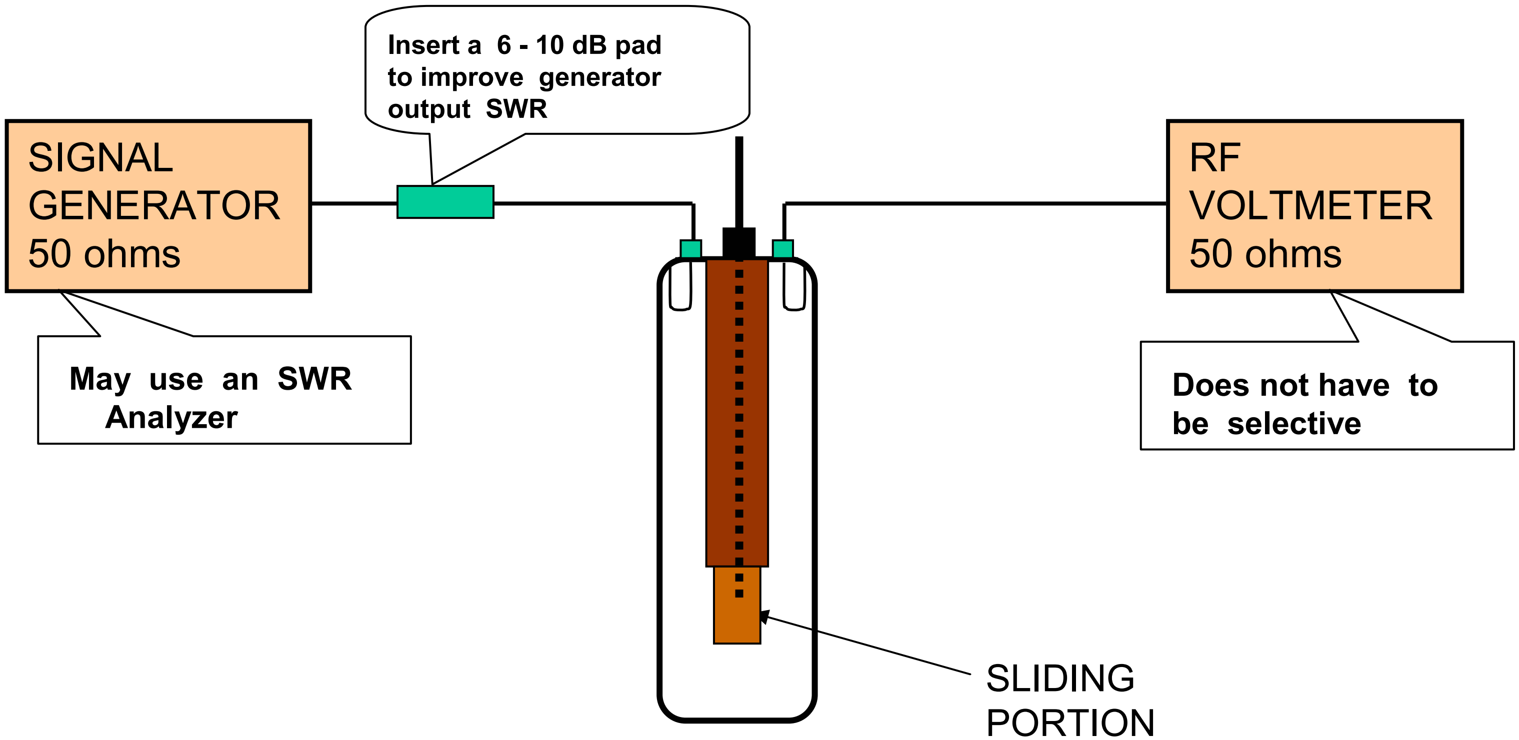
COMPARISONS



TUNING INDIVIDUAL CAVITIES

TUNING BANDPASS CAVITIES

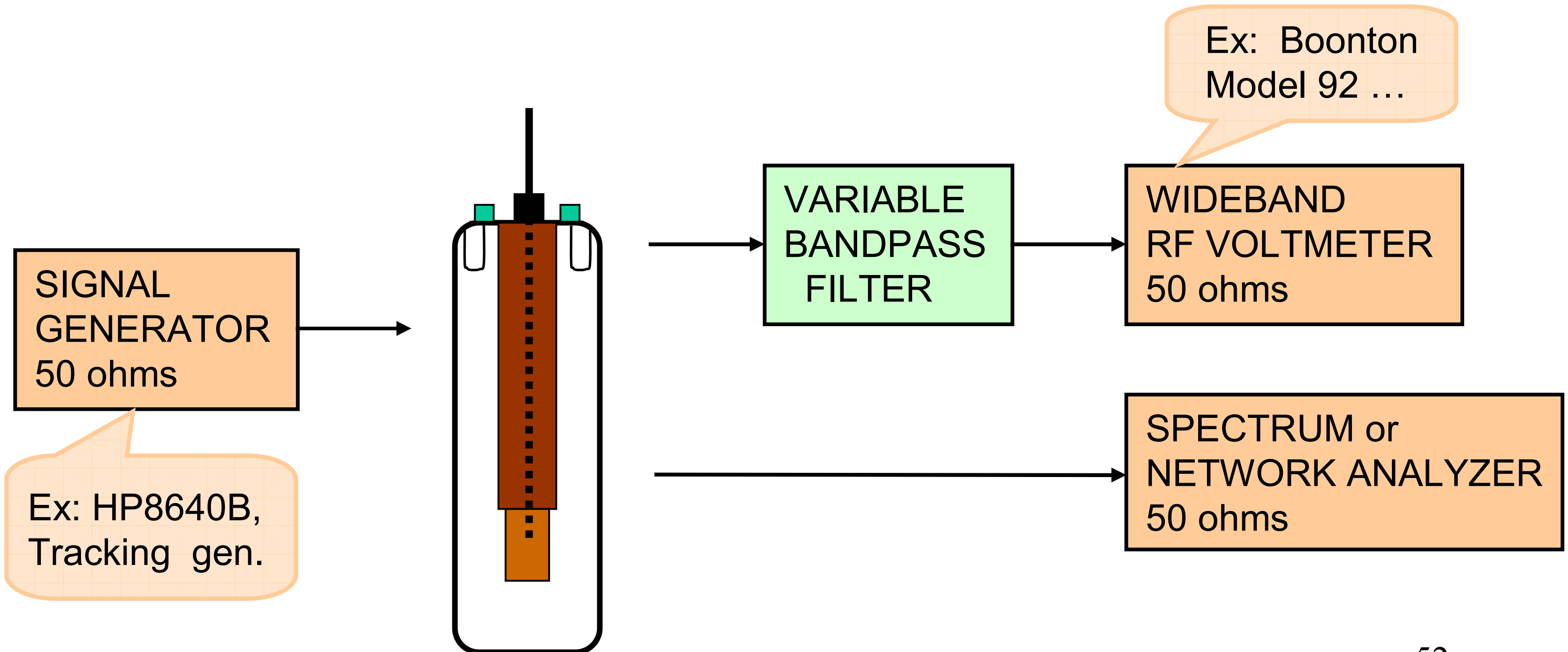
- ❑ ADJUST THE BANDPASS FREQUENCY FOR MAXIMUM SIGNAL
- ❑ CHECK THE INSERTION LOSS. CHANGE THE LOOP COUPLING IF REQ'D



TUNING NOTCH - BANDPASS CAVITIES

ABOUT THE VOLTMETER…

- WIDE BAND VOLTMETERS MAY PICK UP GENERATOR HARMONICS WHEN MEASURING <u>NOTCH DEPTH</u>
- A SELECTIVE VOLTMETER IS REQUIRED



TUNING NOTCH - BANDPASS CAVITIES

DUAL LOOP CAVITIES (MODIFIED BANDPASS TYPES)

- ADJUST THE BANDPASS FREQUENCY FOR MAXIMUM SIGNAL
- CHECK THE PASSBAND ATTENUATION AND ADJUST THE LOOP COUPLING AS REQUIRED (typically 0.3 TO 1.5 dB)
- TO INCREASE THE NOTCH FREQUENCY:

  DECREASE THE NOTCH CAPACITOR OR
  DECREASE THE NOTCH INDUCTOR
- NOTE THAT NOTCH DEPTH GETS WORSE AS THE NOTCH FREQUENCY GETS CLOSER TO THE BANDPASS PREQUENCY
- ADJUST THE BANDPASS FREQUENCY FOR LOWEST SWR
- RECHECK THE INSERTION LOSS AT THE BANDPASS FREQUENCY
- RECHECK THE NOTCH FREQUENCY AND DEPTH

TUNING NOTCH - BANDPASS CAVITIES

SERIES OR PARALLEL LOOP CAVITIES

- ❑ ADJUST THE BANDPASS FREQUENCY FOR MAXIMUM SIGNAL
- ❑ CHECK THE PASSBAND ATTENUATION AND ADJUST THE LOOP COUPLING AS REQUIRED (typically 0.3 TO 1.5 dB)
- ❑ TO INCREASE THE NOTCH FREQUENCY:
  - UPPER NOTCH - ABOVE BANDPASS:
    - DECREASE THE NOTCH CAPACITOR OR INCREASE COUPLING
  - LOWER NOTCH - BELOW BANDPASS:
    - DECREASE THE NOTCH CAPACITOR OR DECREASE COUPLING
- ❑ NOTE THAT NOTCH DEPTH GETS WORSE AS THE NOTCH FREQUENCY GETS CLOSER TO THE BANDPASS PREQUENCY
- ❑ ADJUST THE BANDPASS FREQUENCY FOR LOWEST SWR
- ❑ RECHECK THE INSERTION LOSS AT THE BANDPASS FREQUENCY
- ❑ RECHECK THE NOTCH FREQUENCY AND DEPTH

NOTCH - BANDPASS CAVITIES

LOOP RESONANCE VERIFICATIONS - SERIES OR PARALLEL LOOPS

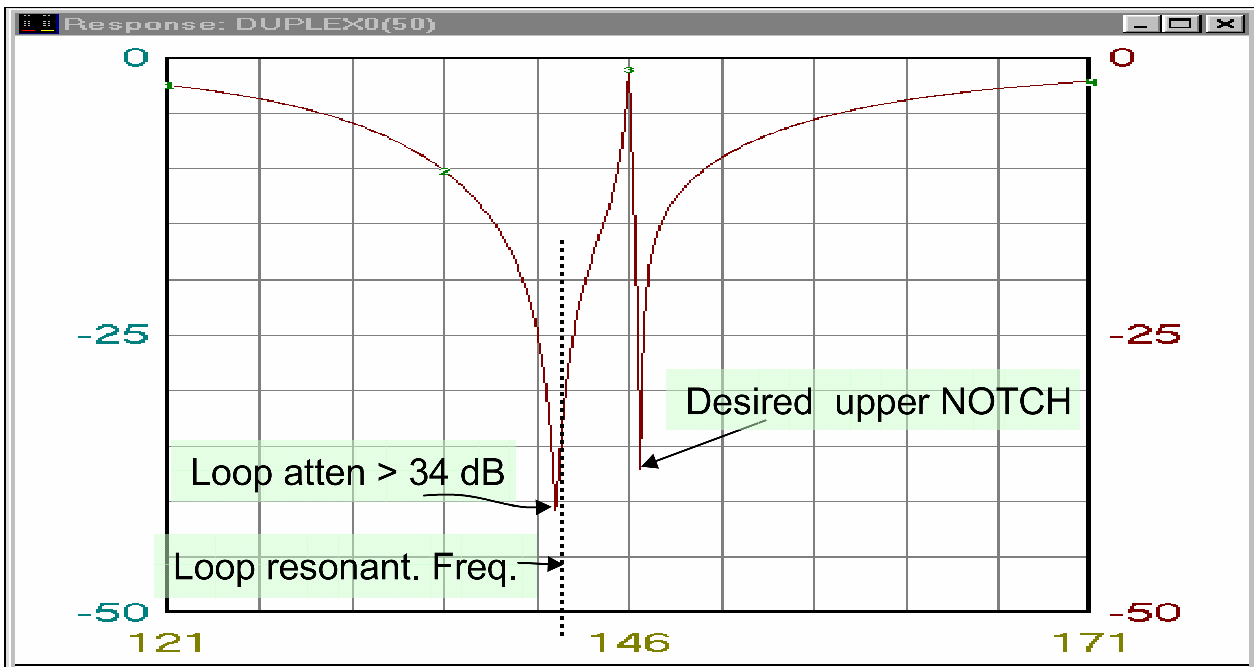
BEST DONE WITH THE LOOP REMOVED FROM THE CAVITY

UPPER NOTCH - ABOVE BANDPASS: (see the graph below)
THE LOOP SHOULD RESONATE FROM ~ 130 to 140 MHz

LOWER NOTCH - BELOW BANDPASS:
THE LOOP SHOULD RESONATE FROM ~ 150 to 160 MHz

SHOULD GIVE AT LEAST 34 dB ATTENUATION (IN A 6 in. CAVITY)

AS SHOWN HERE:
THE LOOP RESONANT
FREQ. AND ATTEN.
MAY ALSO BE OBTAINED
FROM THE CAVITY
RESPONSE



NOTCH - BANDPASS CAVITIES
SINGLE LOOP SERIES RESONANT TYPE

Qu FACTOR VERIFICATION

- ADJUST THE RESONATOR

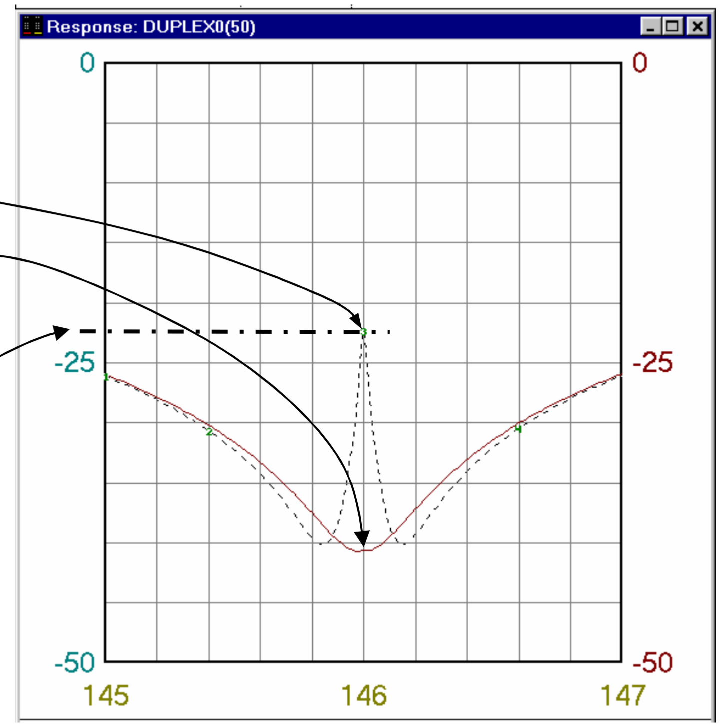
- AND THE COUPLING LOOP (outside the cavity)

  TO RESONATE AT THE SAME FREQUENCY

- ADJUST THE COUPLING FOR
  ~ 20 dB ATTENUATION

- MEASURE THE -3 dB FREQUENCIES AT THE PEAK AND CALCULATE Qu AS PREVIOUSLY DESCRIBED

- THE EXPECTED Qu IS > 5000 FOR A 6 in. CAVITY

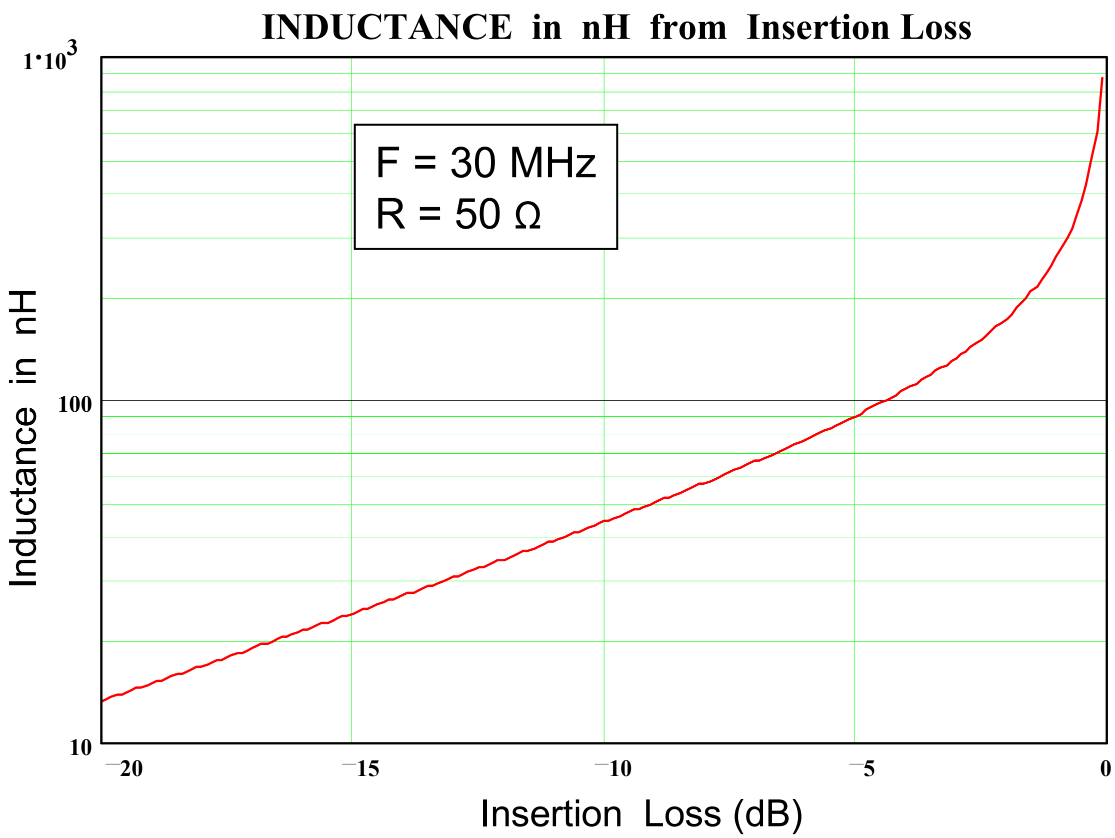


Qu FACTOR VERIFICATION

MEASURING LOOP INDUCTANCE

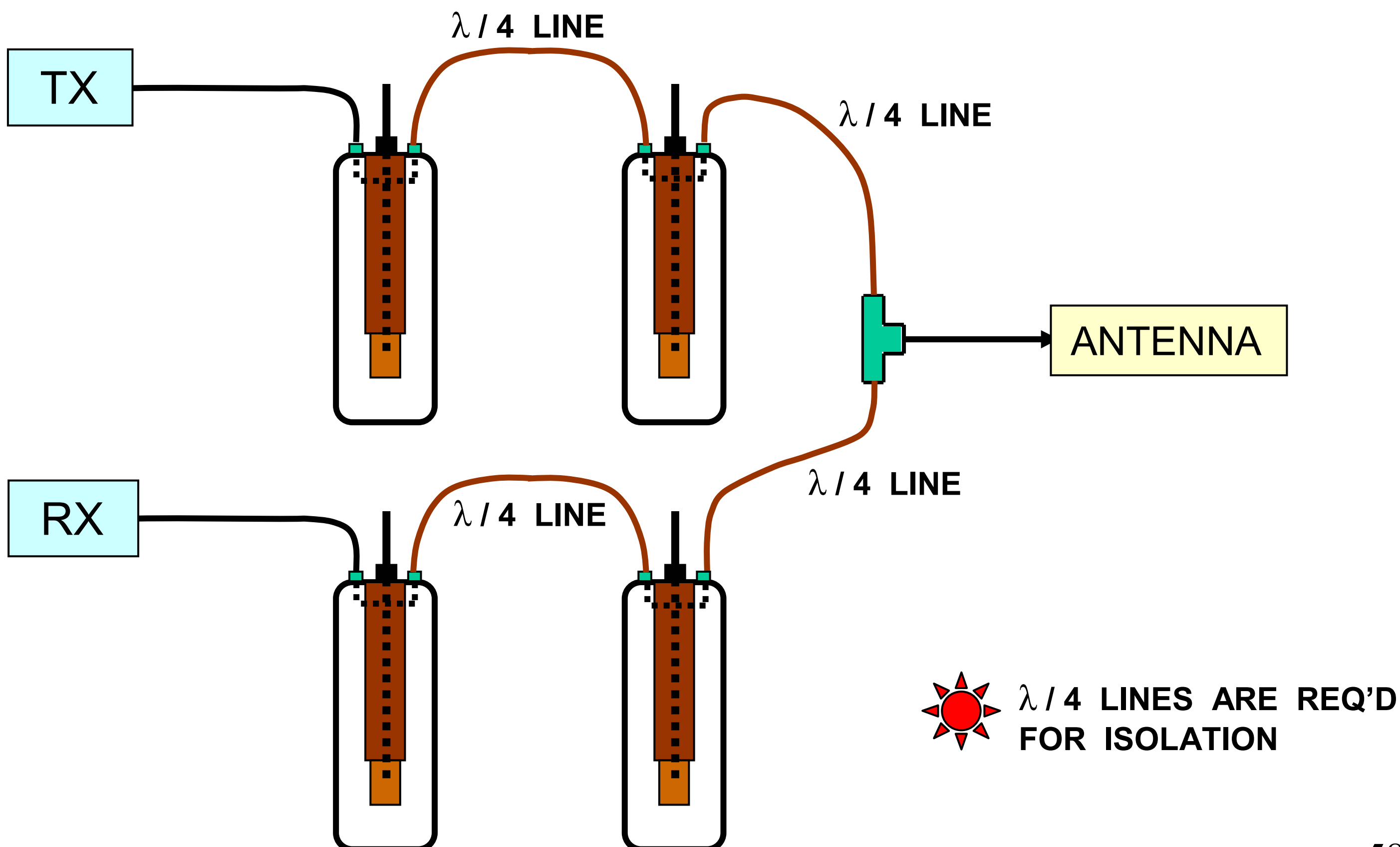
MEASURE THE ATTENUATION IN dB CAUSED BY INSERTING THE LOOP IN A SHUNT CIRCUIT (no series cap.) WITH A GENERATOR / DETECTOR IMPEDANCE = R (ohms) at a FREQUENCY: F in MHz AND COMPUTE THE INDUCTANCE L in nH:

$$L = \frac{79.58 \cdot R \cdot 10^{\frac{dB}{20}}}{F \cdot \sqrt{1 - \left[10^{\left(\frac{dB}{20}\right)}\right]^2}} \quad \text{in nH}$$



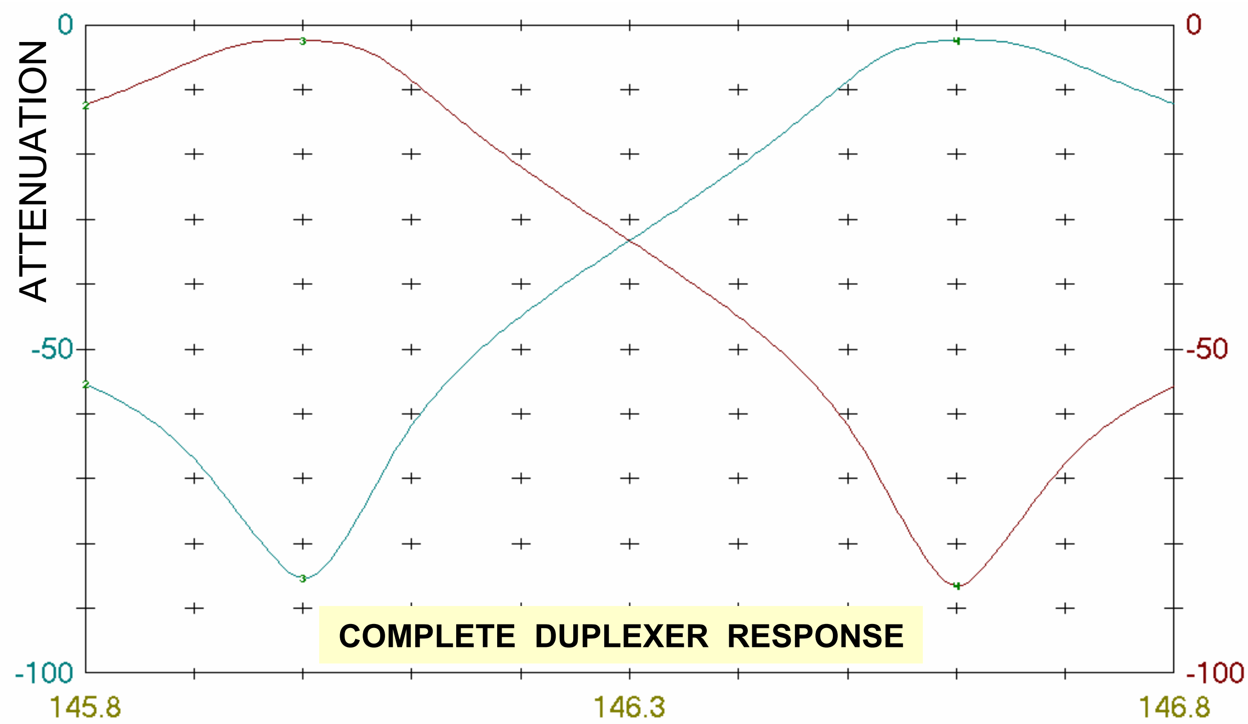
PUTTING IT ALL TOGETHER

DUPLEXER BUILT WITH FOUR 6 in. <u>SERIAL LOOP CAVITIES</u>



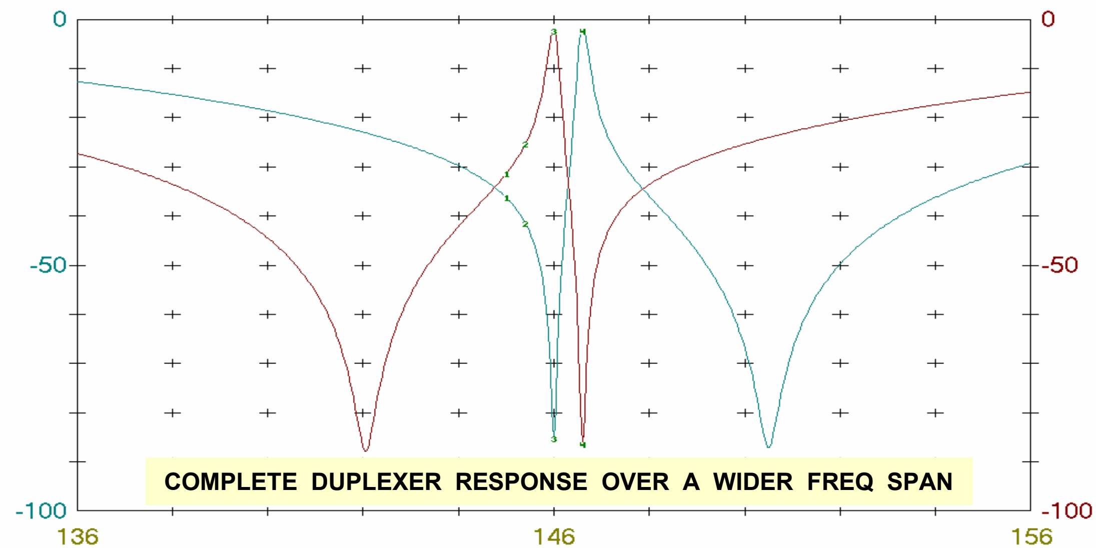
EXAMPLE OF DUPLEXER BUILT WITH FOUR 6 in. SERIAL LOOP CAVITIES

- BANDPASS INSERTION LOSS: ~ 2.2 Db (1 dB PER CAVITY + $\lambda/4$ LINE LOSSES)
- NOTCH DEPTH: ~ 85 dB
- NOTCH DEPTH = ~ SUM OF NOTCH DEPTH OF EACH CAVITY + 5.5 dB ***PER*** $\lambda/4$ LINE
  Example: NOTCH DEPTH = 37 dB + 37 dB + 5.5 x 2 cables = 85 dB



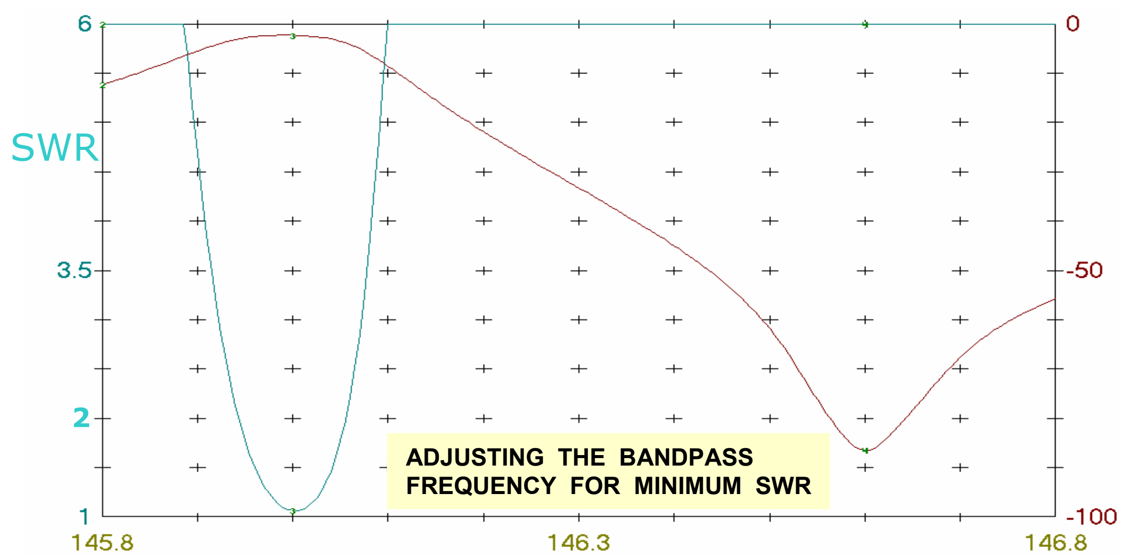
EXAMPLE OF DUPLEXER BUILT WITH FOUR 6 in. SERIAL LOOP CAVITIES

- THIS TYPE OF DUPLEXER PROVIDES LITTLE REJECTION OF OUT OF BAND SIGNALS



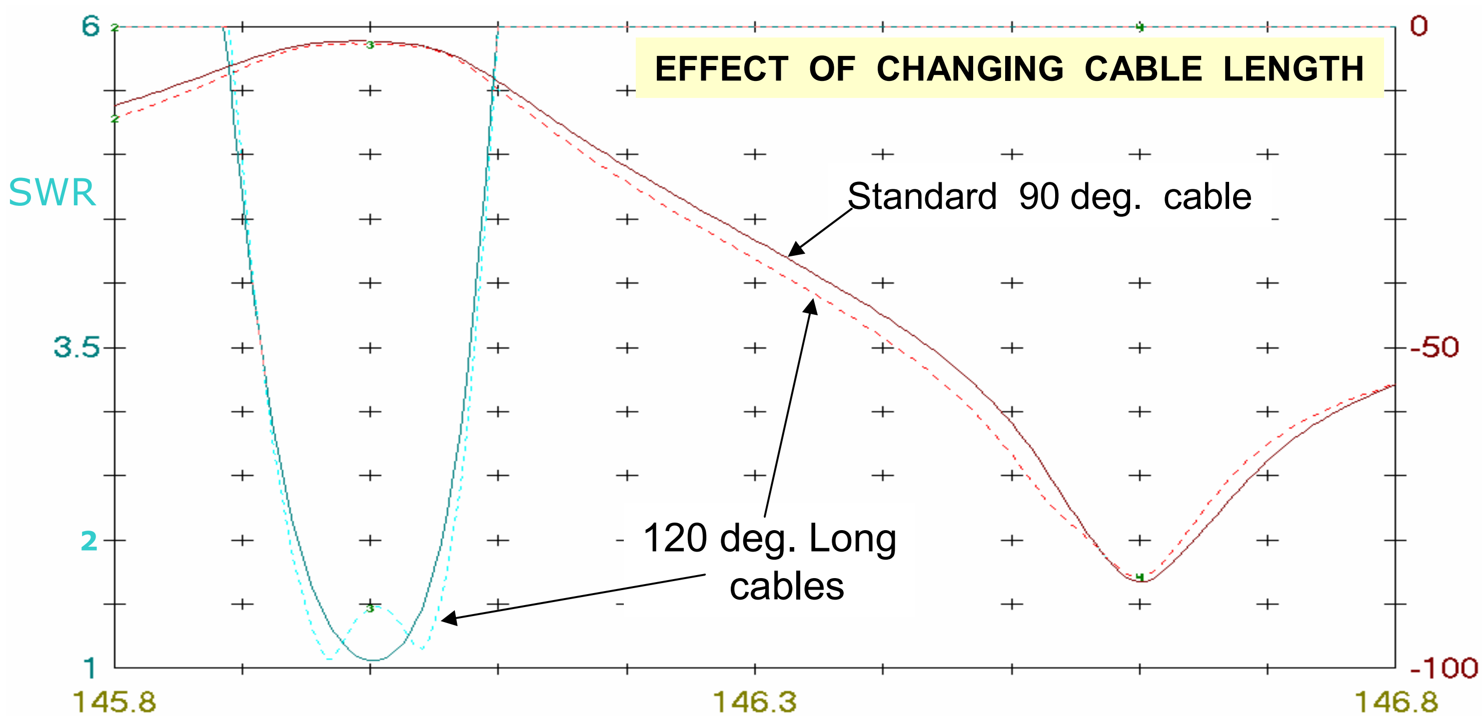
- ADJUSTING THE BANDPASS FREQUENCY FOR MINIMUM SWR IS BEST

- MAY REQUIRE ABILITY TO READ LOW SWR VALUES



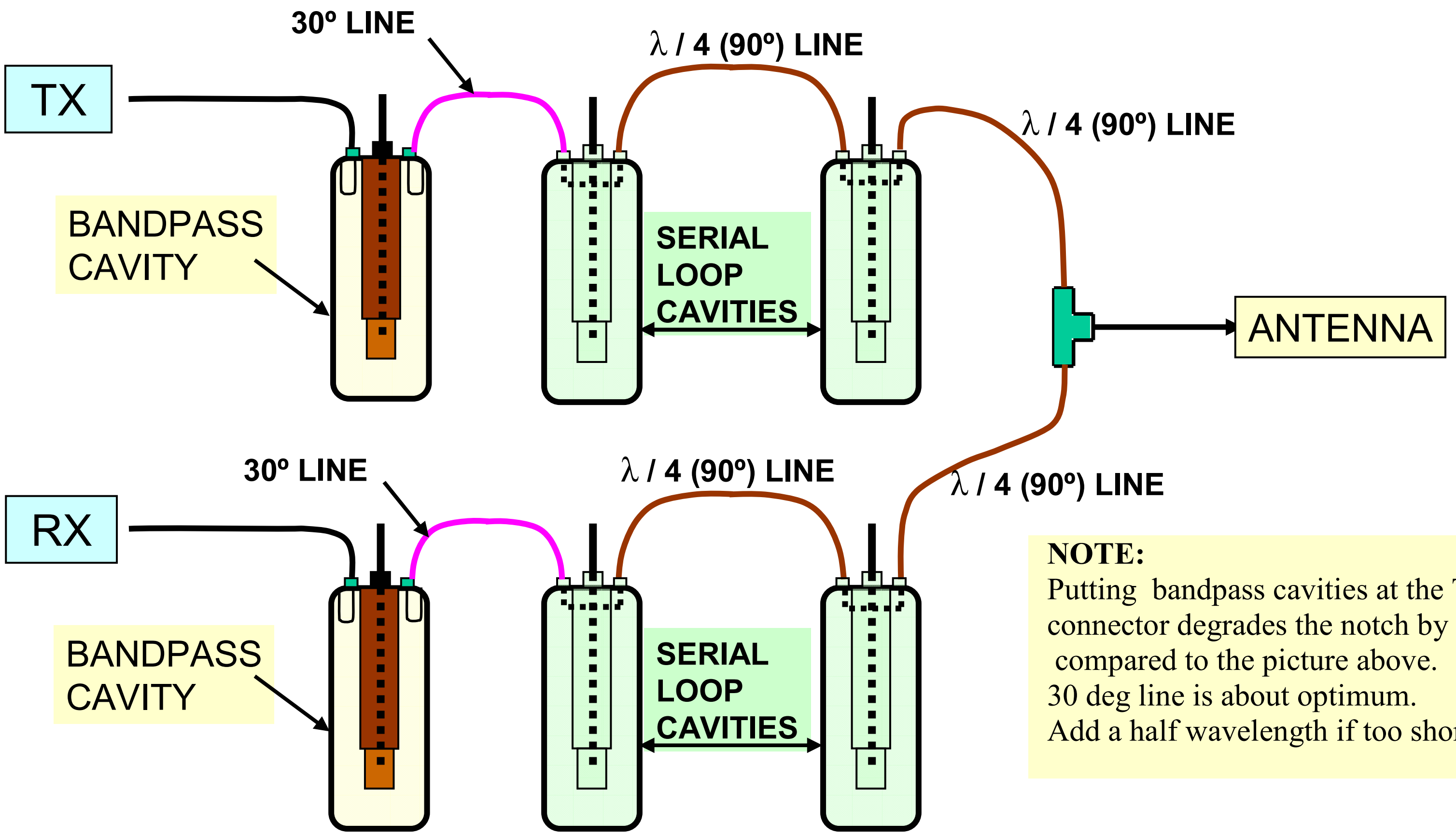
EXAMPLE OF DUPLEXER BUILT WITH FOUR 6 in. SERIAL LOOP CAVITIES

- THE λ/4 CABLES AT THE TEE JUNCTION HAVE BEEN INCREASED IN LENGTH 33%
- SLIGHT CHANGE IN RESPONSE
- SWR CURVE HAS RIPPLES NOW. THIS MAY BE USED TO CHECK FOR PROPER CABLE LENGTHS



EXAMPLE OF DUPLEXER BUILT WITH
(2) BANDPASS + (4) SERIAL LOOP NOTCH BANDPASS CAVITIES

- **BANDPASS CAVITIES SHOULD BE PLACED AHEAD OF SERIAL LOOP CAVITIES**
- **THE 30º LINE AFTER THE BANDPASS CAVITIES ADDS ~ 5dB NOTCH DEPTH**
  (Two Loop Notch Bandpass cavities require different cable lengths)
- **IMPROVES REJECTION AWAY FROM THE NOTCH – BANDPASS FREQUENCIES**

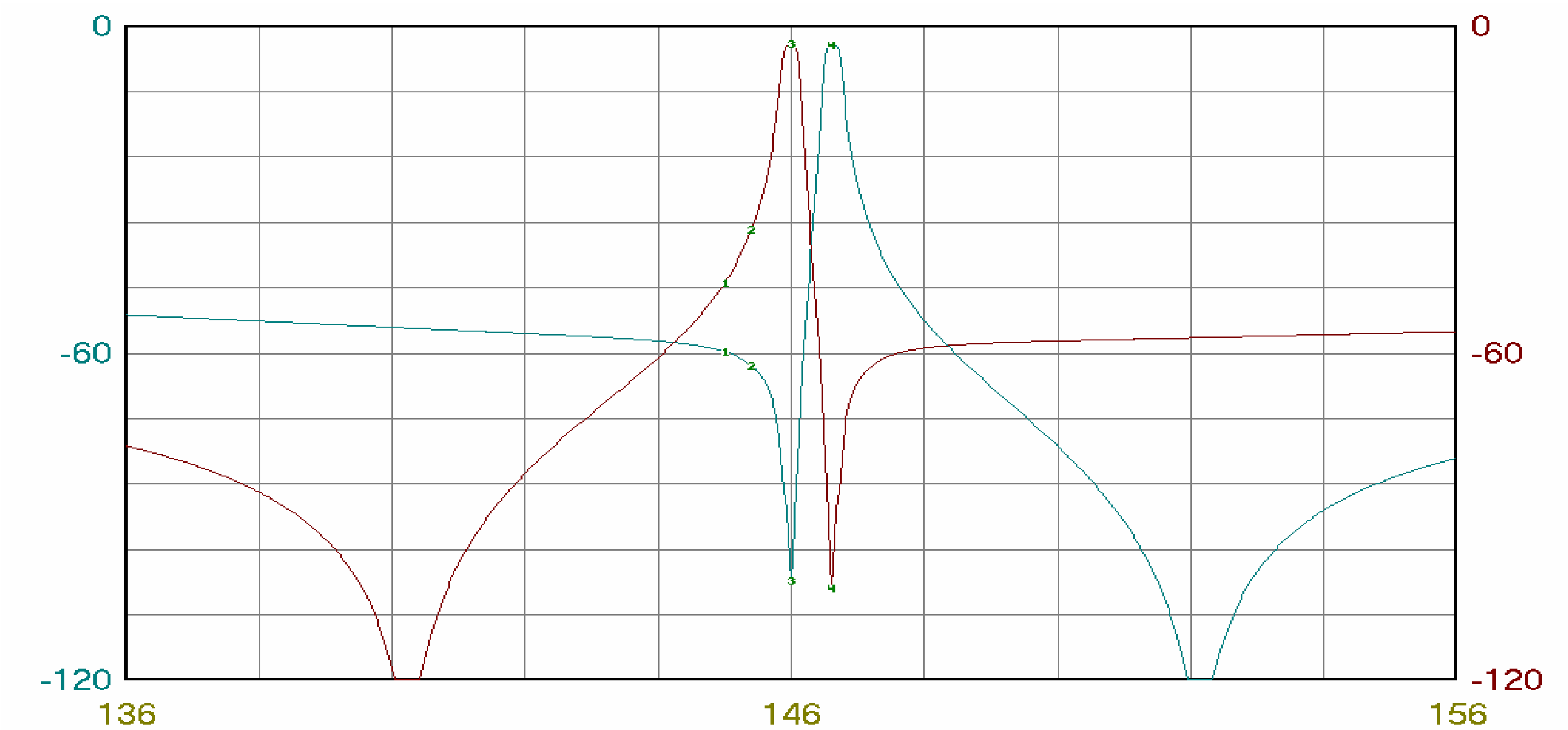


NOTE:
Putting bandpass cavities at the Tee connector degrades the notch by 4 to 10 dB, compared to the picture above.
30 deg line is about optimum.
Add a half wavelength if too short.

EXAMPLE OF DUPLEXER BUILT WITH TWO BANDPASS + FOUR SERIAL LOOP CAVITIES

FEATURES:

- 3 dB BANDPASS LOSS (~ 1dB per cavity)
- ~102 dB NOTCH
- EXCELLENT REJECTION OF OUT OF BAND SIGNALS



COMPLETE DUPLEXER RESPONSE OVER A 20 MHz FREQ SPAN

Calculating the Cable Lengths

$$L := deg \cdot 32.785 \cdot \frac{Vf}{f}$$

Where:
L = length in inches. This is the <u>overall length</u> from
- The connector base to connector base
- From connector base to the center of the Tee (if used)

Deg = electrical degrees as req'd from previous slides
If the calculated length is too short add 180 degrees
or an integer multiple.
Vf = Coax velocity factor
f = mid frequency in MHz
= average frequency of the bandpass and notch frequencies.

Example:

With Vf = 0.67 f = 220 MHz deg = 28.5
Gives:
L = 2.845 inch … which is probably too short !

We can add any integer multiple of a half wavelength (180 deg.) to the cable
We recalculate using deg = 28.5 + 180 = 208.5
Gives L = 20.82 in. … much better !

PITFALLS

- AVOID LOW QUALITY CONNECTORS SPECIALLY TEES.

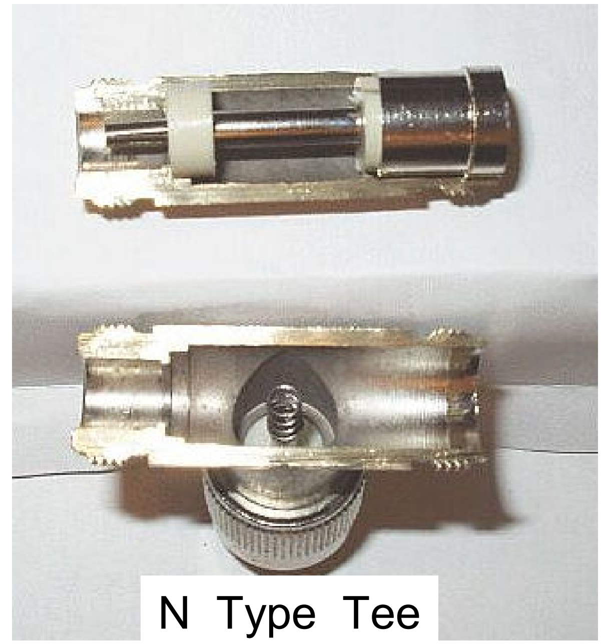
  The picture on the right shows an N type connector that uses a steel spring for making contact with the thru line. The added inductance was calculated from return loss measurement at 100 MHz (9.5 dB) and 1 GHz (5 dB) with both female ends terminated (50 ohms) This gave ~ 7 nH inductance. Therefore a 100 nH loop will have its inductance increased by 7%, thus lowering its resonant frequency 3.5% or ~ 5 MHz at 146 MHz **!**

- USE SILVER PLATED CONNECTORS

- UNPLATED COPPER CAVITIES MAY BE POLISHED AND CLEANED WITH "BRASSO" (liquid copper / brass cleaner) LEAVES A PROTECTIVE FILM

- SLIDING CONTACTS MAY BE LUBRICATED WITH SILICONE CLEANER OR VASELINE

- TERMINATE THE "UNUSED" PORT WHEN TESTING FOR LOSS OR SWR

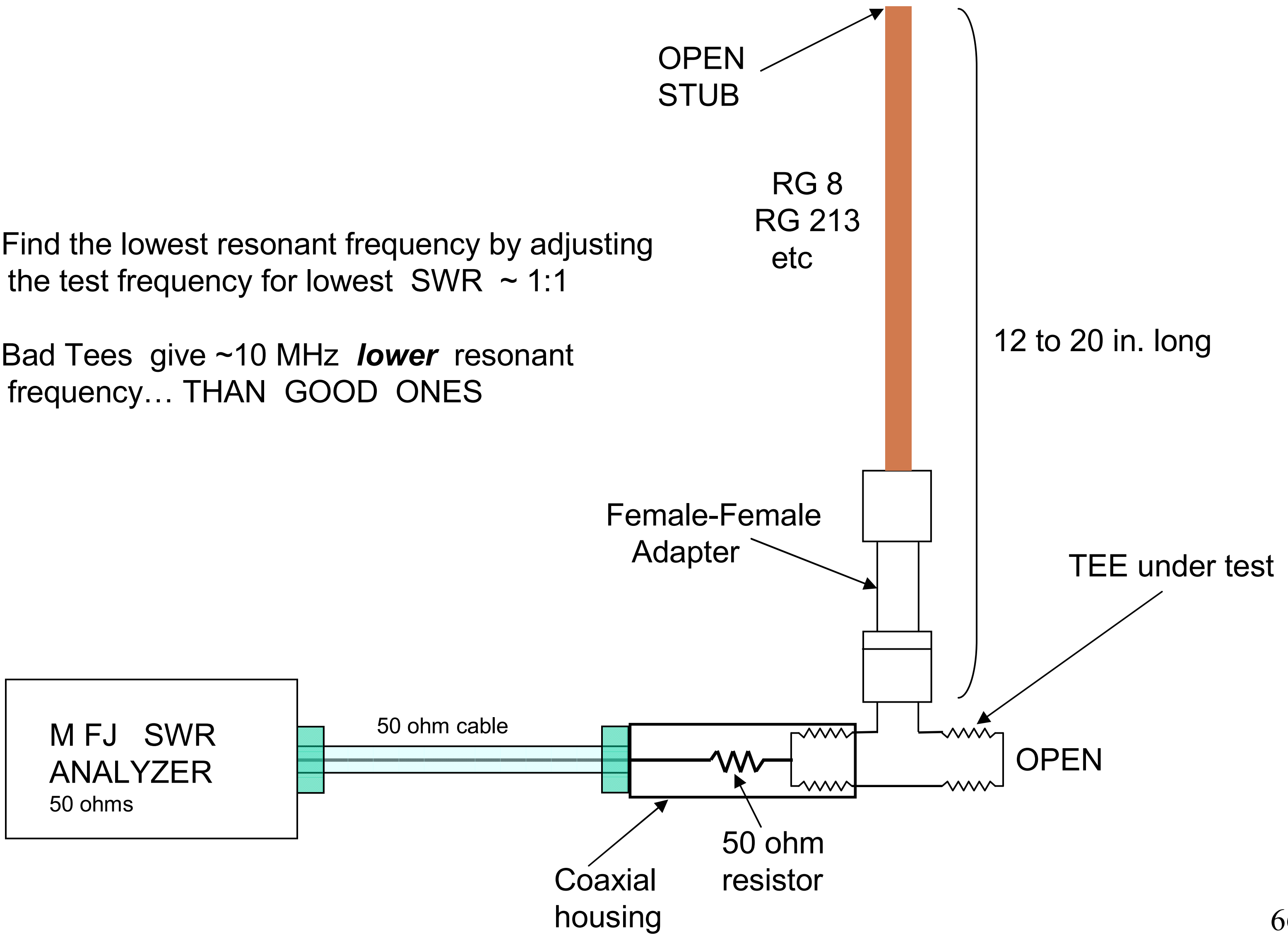


CENTER CONNECTOR USES A SPRING FOR CONTACT !

TEE CONNECTOR TEST SET-UP

- Find the lowest resonant frequency by adjusting the test frequency for lowest SWR ~ 1:1

- Bad Tees give ~10 MHz ***lower*** resonant frequency… THAN GOOD ONES

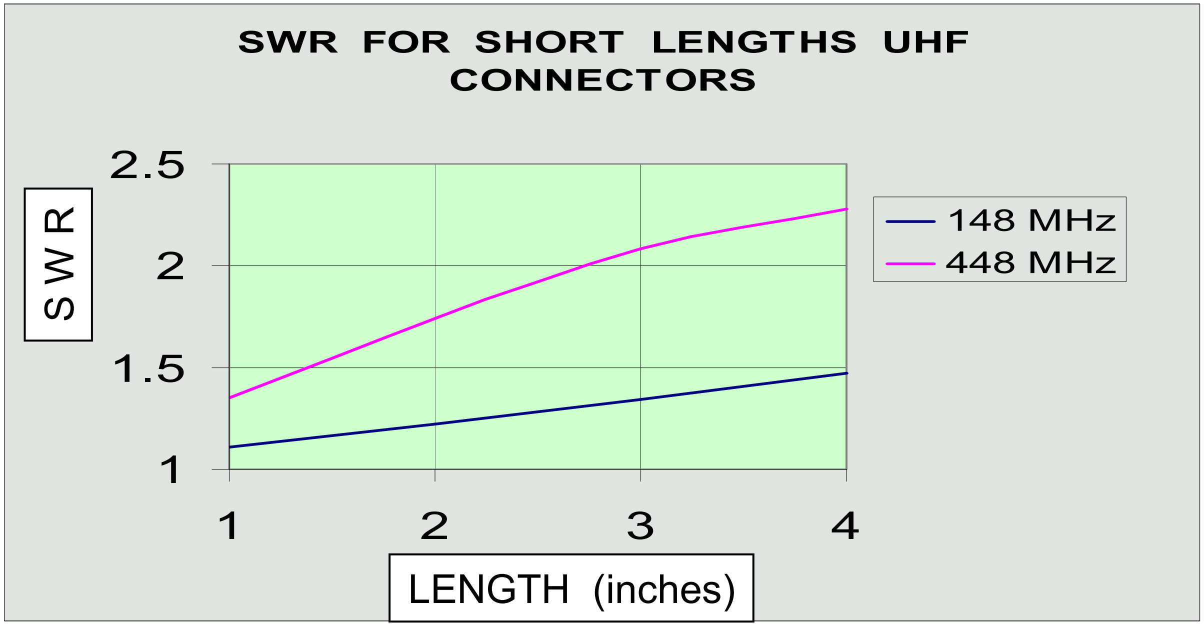


PITFALLS

- TEMPERATURE SENSITIVITY:
  UNCOMPENSATED Cu RESONATORS WILL SHOW
  A TEMPERATURE COEFFICIENT OF ~ -1.3 KHz / degC (146 MHz)

- DOUBLE SHIELD CABLES AND N TYPE CONNECTORS PREFERED

- AVOID – IF POSSIBLE - UHF ADAPTERS
  THEIR IMPEDANCE IS BELOW 50 OHMS: ~33 OHMS
  THEY WILL LIKELY INCREASE THE SWR See: http://www.qsl.net/vk3jeg/pl259tst.html



CONCLUSION

- THIS PRESENTATION COVERS THE MOST IMPORTANT DUPLEXER ELEMENTS:
  BANDPASS + 4 TYPES OF NOTCH – BANDPASS + NOTCH DESIGNS

- SIMULATION SOFTWARE WITH REAL TIME TUNING CAPABILITIES ALLOWS « BREADBOARDING » DUPLEXERS

- LEARN TUNING, CHECK FOR SENSITIVITY TO COMPONENT VARIATIONS SUCH AS Q FACTOR, CABLE LENGTHS ETC.

REFERENCES

- Repeater Builder Website: http://www.repeater-builder.com/rbtip/
- LINEAR SIMULATION SOFTWARE:
  SuperStar from Eagleware - now Agilent (used here)
  Designer SV for Windows from Ansoft (free) http://www.ansoft.com/downloads.cfm
  LT Spice / Switcher CAD (free) http://www.linear.com/company/software.jsp
- Duplexer Theory and Testing by Dave Metz WA0UAQ (.pdf format)
- KI7DX 6 Meter Repeater http://www.wa7x.com/ki7dx_rpt.html
- 6 Meter Heliax Duplexers http://www.dallas.net/~jvpoll/dup6m/dup6m.html
- Duplexers: theory and tune up http://www.seits.org/duplexer/duplexer.htm
- Upgrading Boonton Models 92/42 RF Voltmeters Jacques Audet
  Communications Quarterly Spring 97
- THANKS to Jean-Nicol VE2BPD for the photos and the bad tee
- THANKS to Bob G3VVT for reporting the reversed notch location in double loop cavities.