THE EFFECT OF VARYING INTERCONNECT CABLE LENGTHS

ON CASCADED CAVITY FILTERS

By Jeff DePolo, WN3A

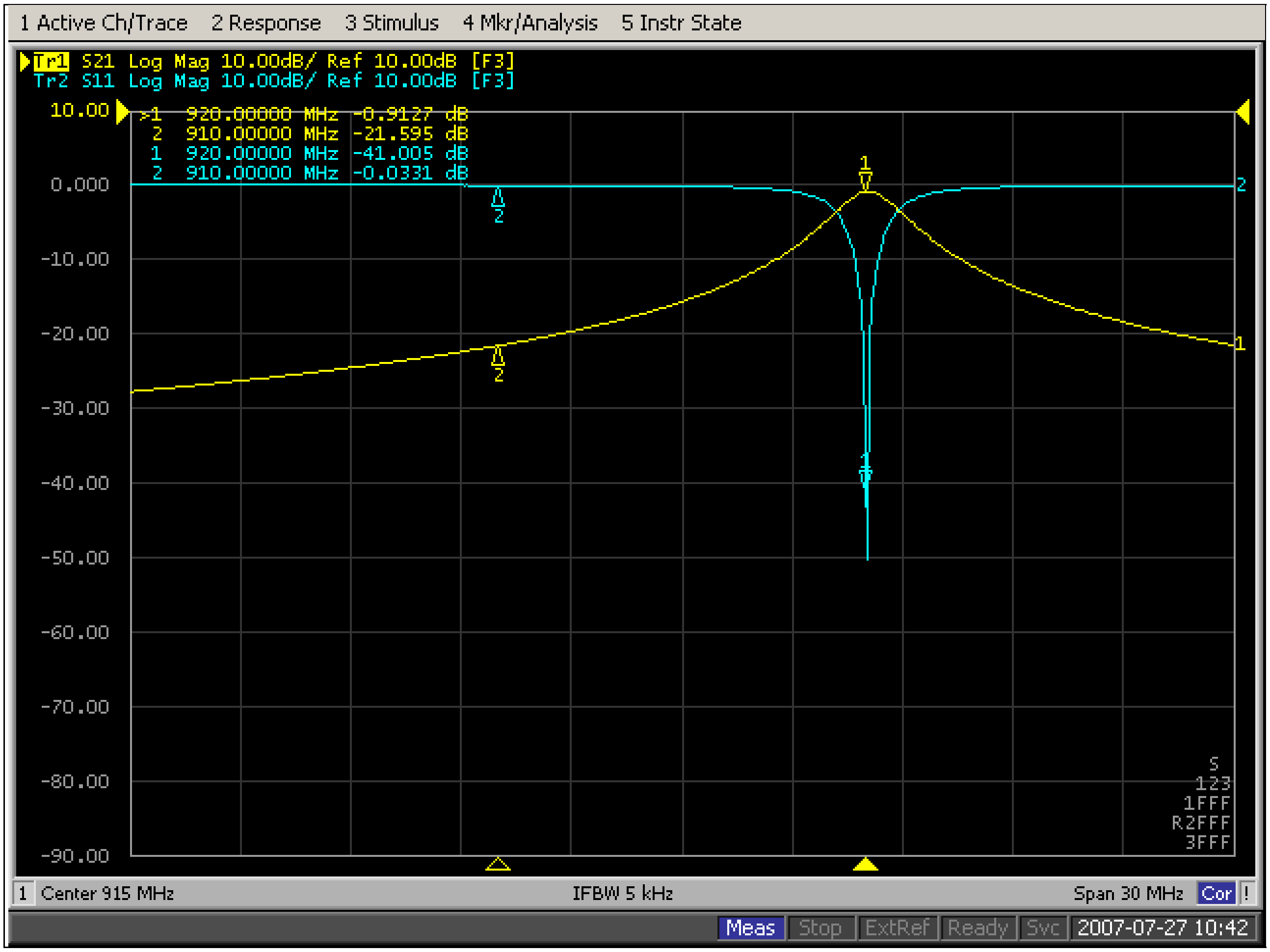
The purpose of this experiment is to determine what affect varying the cable length between two cavity filters, one pass-only and one pass/reject, has on the response of the filters when connected in cascade.

The bandpass filter used is a Wacom 4" diameter cavity with adjustable coupling loops. The loops were set for approximately 0.9 dB insertion loss, and the filter tuned for maximum return loss at the pass frequency of 920.000 MHz.

The pass/reject filter used, also a Wacom 4" diameter cavity, does not have adjustable coupling loops. It was tuned to pass 920.000 MHz, and reject 910.000 MHz.

Measurements were made with an Agilent E5070B ENA-series 3-port vector network analyzer calibrated with an Agilent 85032F precision calibration kit and precision test cables from Huber+Suhner. All cable losses and inherent mismatches were calibrated out; that is, the S11 (reflection) and S21 (transmission) measurements shown in the plots are solely those of the devices under test.

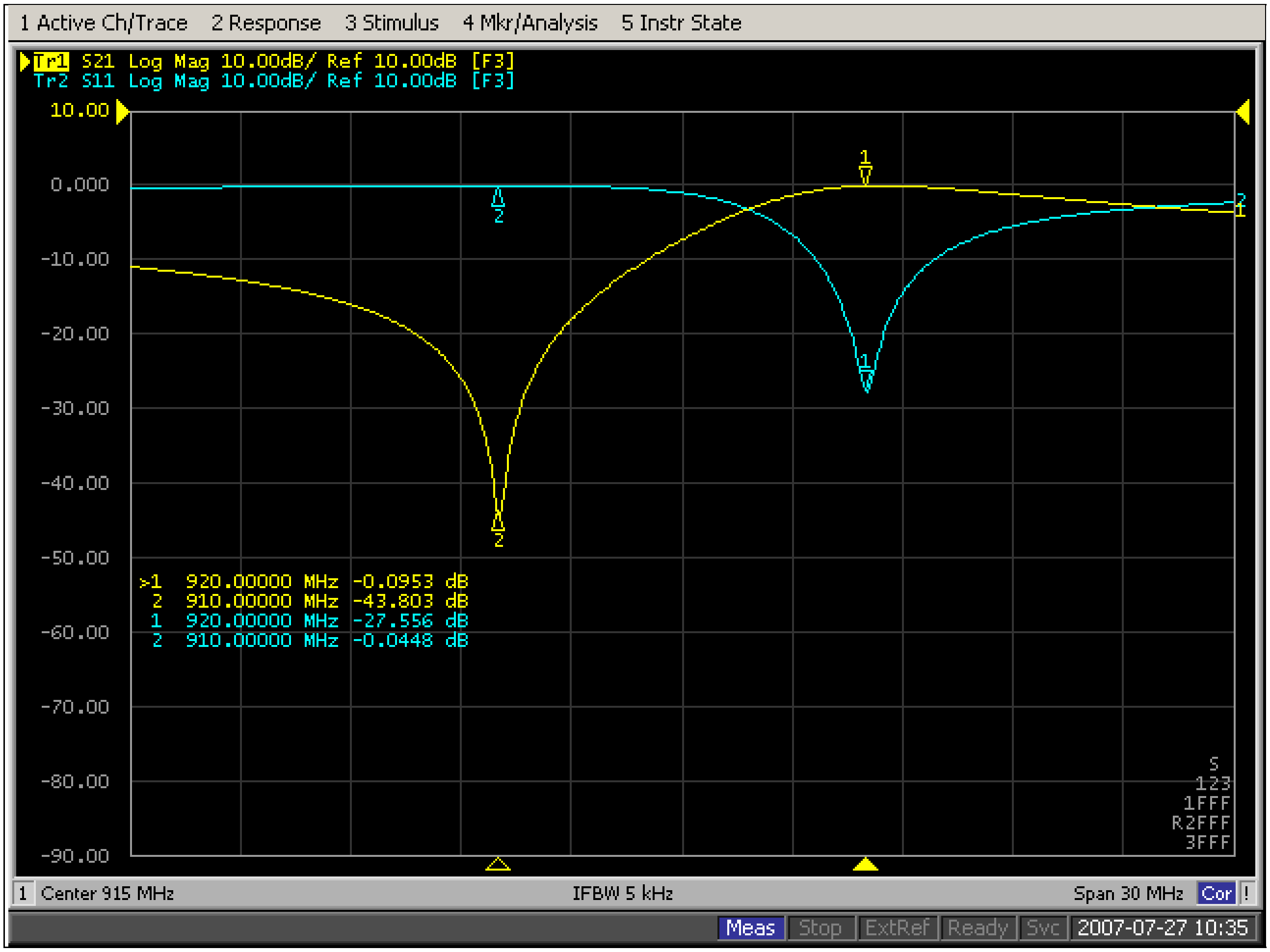
BANDPASS CAVITY ALONE



Bandpass filter response:

- 21.6 dB rejection at 910 MHz
- 0.9 dB insertion loss

PASS/REJECT CAVITY ALONE

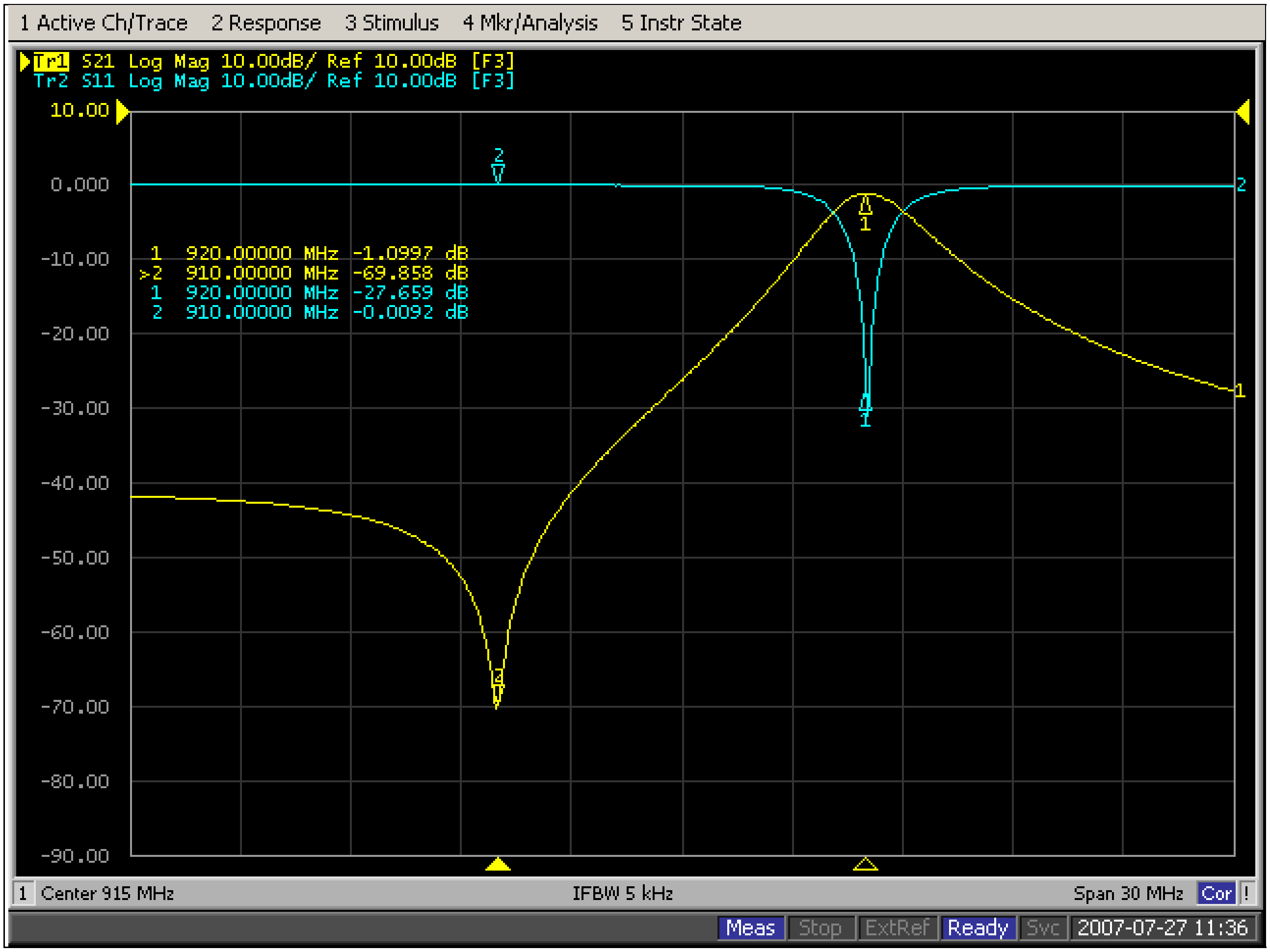


Pass/reject filter response:

- 43.8 dB rejection at 910 MHz
- 0.1 dB insertion loss

FILTERS IN CASCADE WITH FACTORY CABLE

The two filters were then connected in cascade using the factory-supplied cable: RG142B/U with type N male connectors on each end, 8.75 inches tip-to-tip. From an electrical standpoint, at 920 MHz, 8.75 inches of RG142B/U cable (69.5% velocity factor) is equal to 0.98λ. The length of the connectors and loop assembly factor into the actual electrical length between filter sections, therefore this 0.98λ cable length is only noted only as a baseline reference from which additional cable lengths will be added later to ascertain their effect.



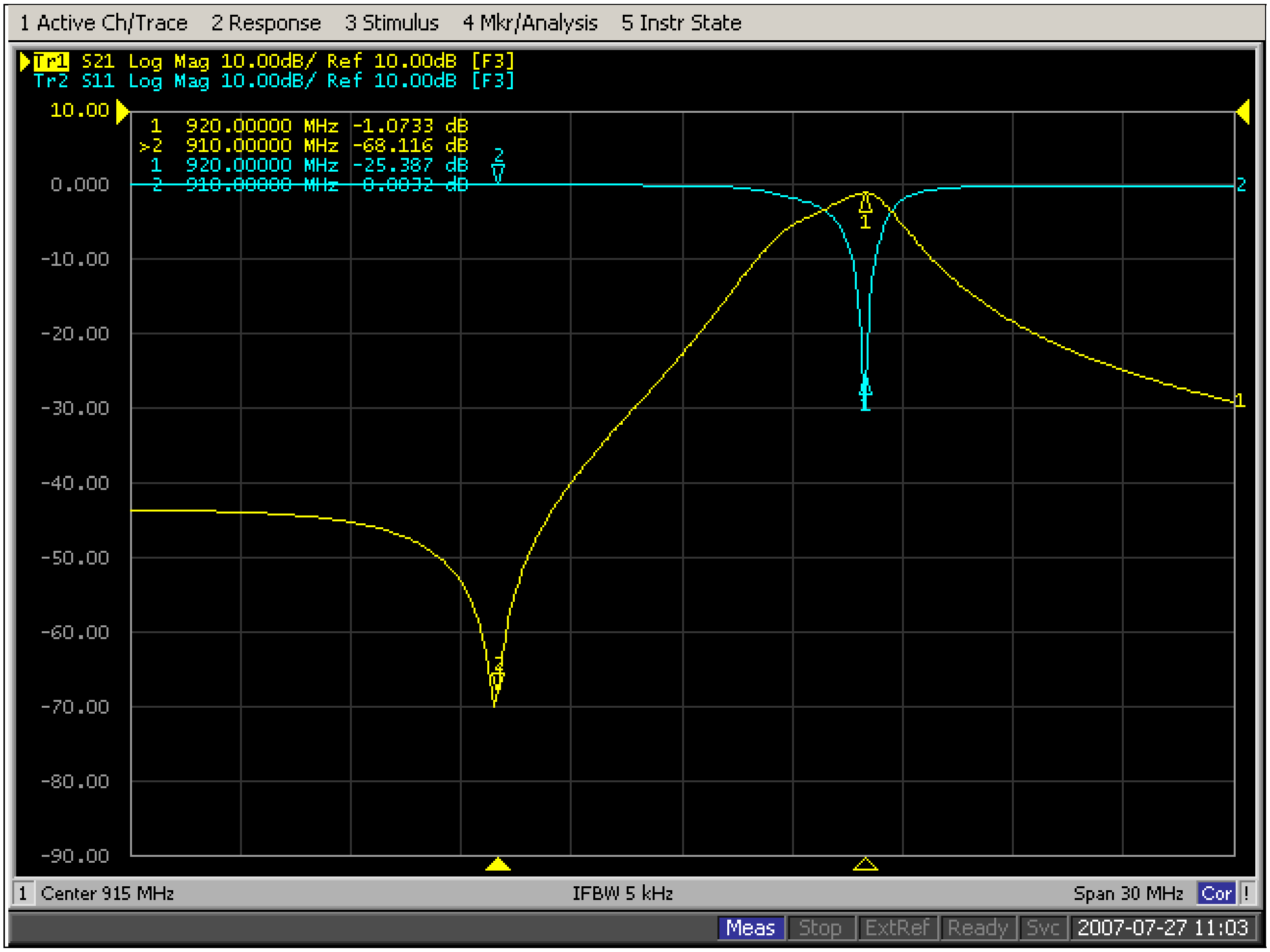
Both filters in cascade:

- 69.9 dB rejection at 910 MHz
- 1.1 dB insertion loss

The filters individually had 21.6 and 43.8 dB of rejection at 910 MHz respectively, or theoretically 65.4 dB of rejection when in cascade. The additional rejection of 4.5 dB (69.9 measured, 65.4 predicted) is due to the optimization of the interconnect cable length between filter sections. The insertion loss of 1.1 dB is equal to the sum of the losses of the individual components: 0.9 dB for the bandpass filter, 0.1 dB for the pass/reject filter, and the balance due to cable/connector losses . Return loss and passband insertion loss hold true with filters in cascade when both were tuned for maximum return loss individually.

FILTERS IN CASCADE WITH FACTORY CABLE PLUS ONE ELBOW ADAPTER

A high-quality Andrew type N male-to-female 90 degree “elbow” adapter was then added between the two cavities, effectively increasing the length of the cable by 53 degrees (0.148 wavelength) as measured on the network analyzer.



Both filters in cascade with factory cable plus <u>one</u> elbow adapter:

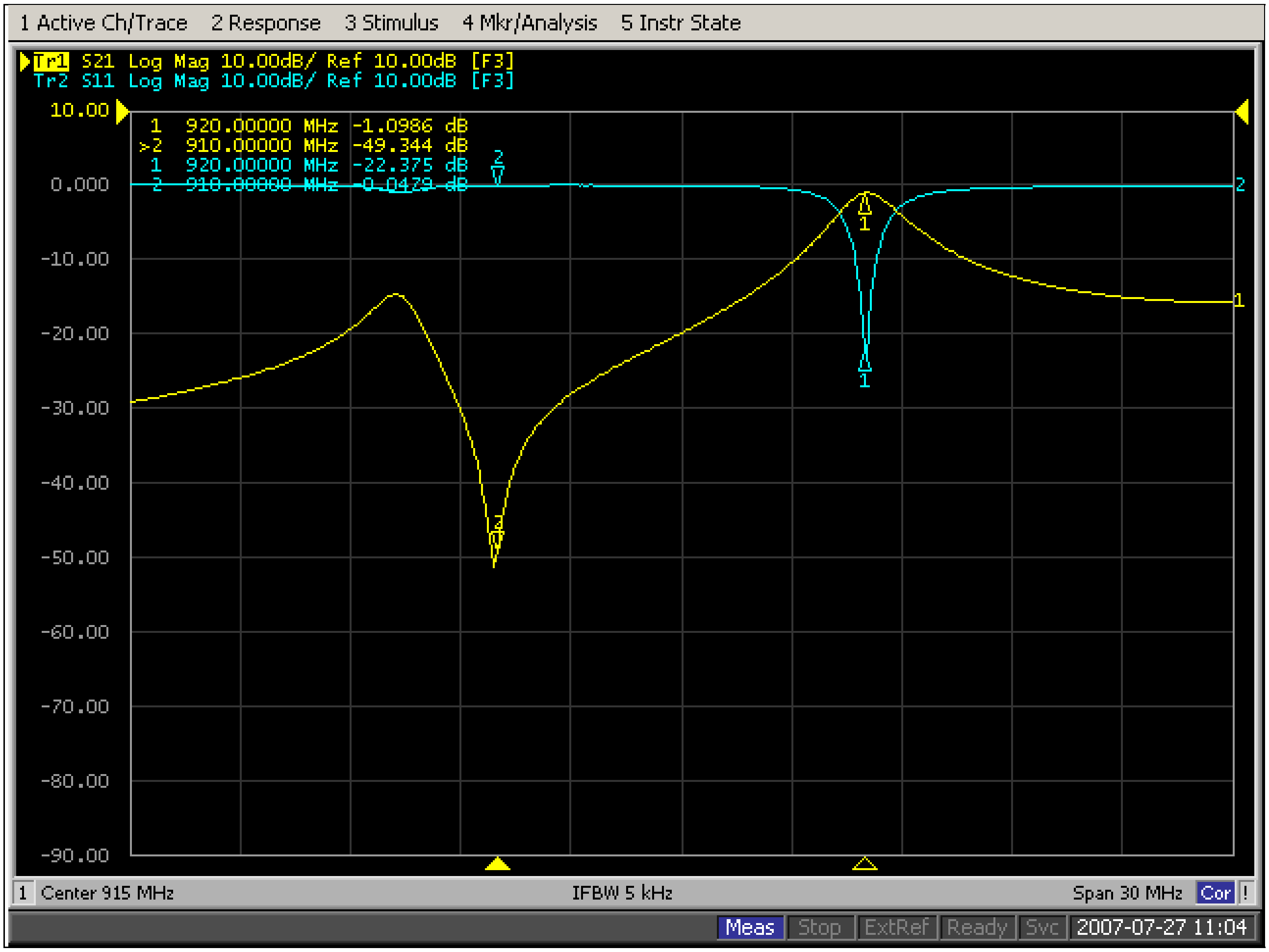
- 68.1 dB rejection at 910 MHz
- 1.1 dB insertion loss

Note that by adding the additional cable length in the form of an elbow adapter (approximately 0.15 λ) that the notch has shifted slightly, with a corresponding decrease in rejection at 910 MHz.

Also note that the return loss degraded slightly via the addition of the elbow adapter. Although the adapter used is a high-quality Andrew “cubic” style elbow, it does degrade the match slightly.

FILTERS IN CASCADE WITH FACTORY CABLE PLUS TWO ELBOW ADAPTERS

A second Andrew "elbow" adapter was then added, effectively increasing the length of the cable by another 1.5 inch.



Both filters in cascade with factory cable plus <u>two</u> elbow adapters:

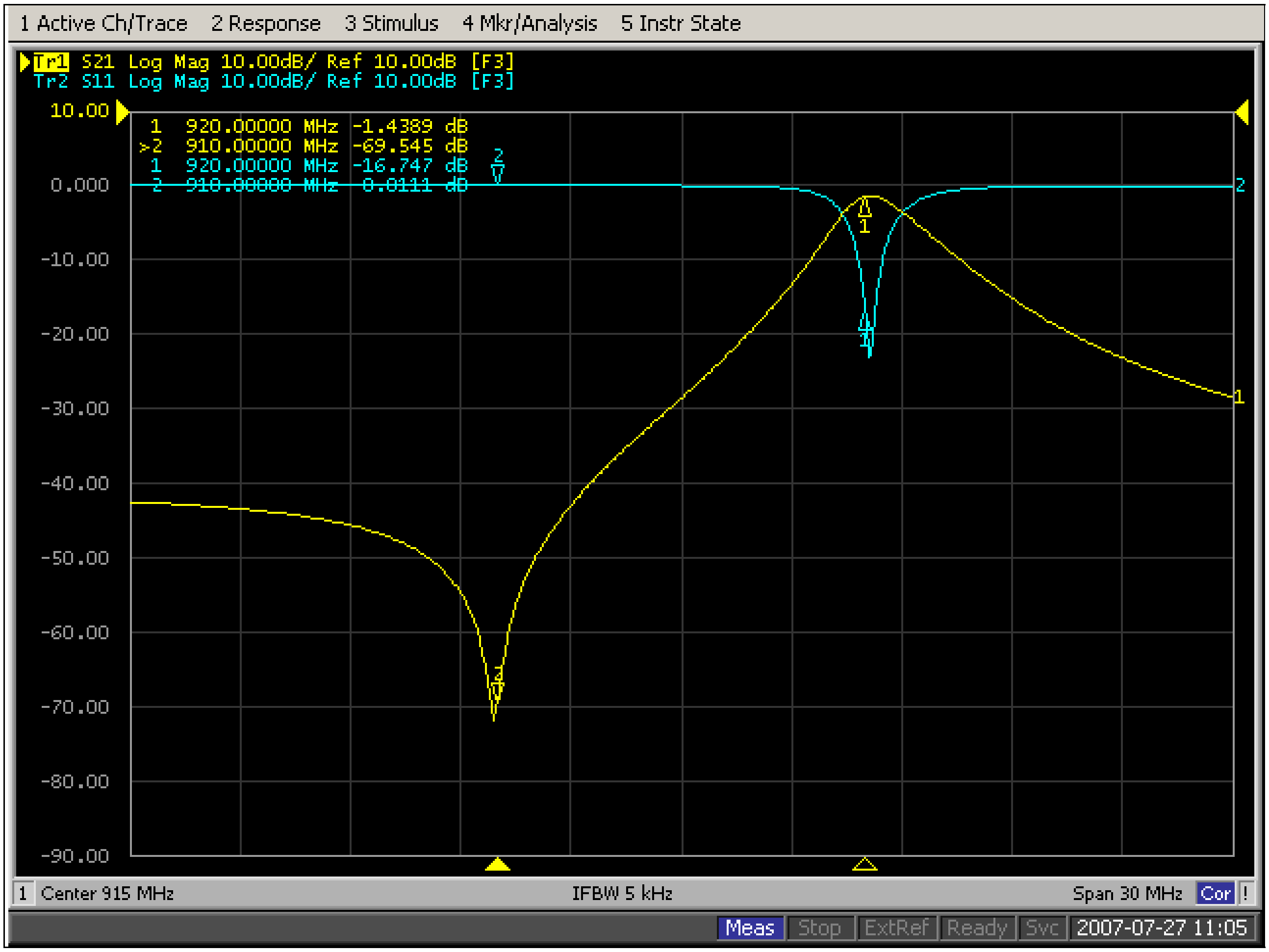
- 49.3 dB rejection at 910 MHz
- 1.1 dB insertion loss

By adding two elbow adapters, the effective electrical length of the cable was increased by approximately 1/4 wavelength (0.15λ x 2 = 0.3 λ). The notch has degraded greatly, from 69.9 dB best-case to 49.3 dB, or a reduction of 20.6 dB. A new quasi-pass "spike" has also appeared below the notch at approximately 907.5 MHz.

Note that the return loss at the pass frequency continues to degrade incrementally as more elbow adapters are added.

FILTERS IN CASCADE WITH FACTORY CABLE PLUS THREE ELBOW ADAPTERS

A third “elbow” adapter was then added, effectively increasing the length of the cable by another 1.5 inch.



Both filters in cascade with factory cable plus <u>three</u> elbow adapters:

- 69.5 dB rejection at 910 MHz
- 1.4 dB insertion loss

By adding a third elbow adapters, performance improved and was comparable the case of one elbow adapter, though still slightly less than that obtained with the original cable length.

The third elbow adapter inserted was not the Andrew “cubic” type, but rather a miter-type adapter manufactured by Amphenol. The addition of this adapter has reduced the return loss significantly, and in doing so, shifted the return loss maxima higher in frequency than the desired 920 MHz frequency. Likewise, the insertion loss has also increased by 0.3 dB, and it can be seen that the minimum insertion loss point has shifted higher in frequency.

So what have we learned:

- Interconnect cable lengths between cascaded filters of this type primarily affects the response outside of the passband (i.e. the "reject" frequency or range of frequencies).

- Little change in pass performance in terms of insertion loss and return loss is realized when intra-cavity cable lengths are changed if the cavities are properly tuned for maximum return loss (i.e. impedance as close to 50+*j*0 as possible) initially.

- Elbow adapters can be problematic, particularly at higher frequencies. The cubic-style adapters perform better than their miter-type counterparts. Use elbows only when absolutely necessary.

- Unless you have access to a network analyzer, stick with the interconnect cable lengths specified by the manufacturer. If you end up with the wrong cable length, which is typically odd-quarter-wavelength-multiples different than the optimum length, the performance of the cascaded filters will suffer significantly.

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