Report On Some Tests Of Fiber Phase (Delay) Variation Induced By Bending

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April 27, 2010

1 Introduction

The object of the tests reported herein was to obtain a quick-look at about how much the delay in a test sample of fiber changes with bending, twisting, and temperature changes. All this was done pretty casually to the numerical results are only semi-quantitative.

2 Test Setup

The fiber under test was a 2-meter "patch cord" of single mode fiber with FC/APC terminations at either end, operated at 1550 nm. This was part number S37A7AS2FISC, sold by Fiber Instrument Sales, Inc.

The transmitter and receiver were made by Photonic Systems, Inc, under the combined model # PSI-1601.

The link was evaluated with an Agilent N5230A VNA, which was calibrated from 300 kHz to 13 GHz with an N4431 "ECAL" module. Port 2 of the VNA was then connected to the RF input of the fiber link transmitter, and Port 3 of the VNA received signals from the fiber link receiver. The test power applied to the fiber link transmitter RF port was 0 dBm. With these connections, S32 gives the complex transmission through the link.

The transmitter and receiver modules, each about the size of a paperback book, were stacked atop one another. Before manipulation the fiber's path or shape could be loosely described as a hairpin loop about 1 meter long with the sides spaced about 3 to 4 inches apart.

3 Test Procedure (such as it is)

Initial measurements of the transmission through the link were taken with the hairpin lying straight out and screen shots were stored, showing:

'magnitude.png': Transmission magnitude at 5 dB/div.

'phase.png': Transmission phase at 10 deg/div (17.7 ns of electrical delay bucked out).

'group_delay.png': Transmission delay at 100 ps/div (17.7 ns of electrical delay bucked out). Note: the very narrow glitches seen at 1.2, 2.3, 3.2 divisions in (and at other locations) appear to be VNA artifacts. I'm quite confident they are not real.

Next the data was saved as a reference and the analyzer was set to display the phase of the complex ratio of current data to reference data, at a scale factor of 1 deg/div. At the right end of the sweep (13 GHz), 1 deg variation corresponds to a delay variation of 0.214 ps. See screen shots 'delta_phase_fresh.png', 'delta_phase_coiled.png', and 'delta_phase_twisted.png'.

The fiber was then subjected to a variety of manipulations such as twisting of the hairpin (two to three turns), coiling it up (radius of roughly 3 inches), and combinations of the two. These motions tended to tilt the anaylzer display in varying amounts, corresponding to delay variations of roughly 1 to 1.5 ps peak to peak. The screen shots show only one point in time as I manipulated the fiber, not the total extent of effects.

But not all of this could be ascribed purely to the mechanical motions, because I noticed that a residual effect could be seen upon straightening out the hairpin, and that this residuum would in time mostly recover. I conclude that this effect was thermal, arising from handling the fiber with my warm hands. Further tests showed that a delay variation of very roughly 2 ps could be caused by gently warming most of the length (4 to 5 feet) of the fiber to roughly 100F. 'delta-warm.png' shows one such example, captured as quickly as I could following removal of the heat, but not nearly soon enough to catch the peak effect.

4 Comments and Conclusions

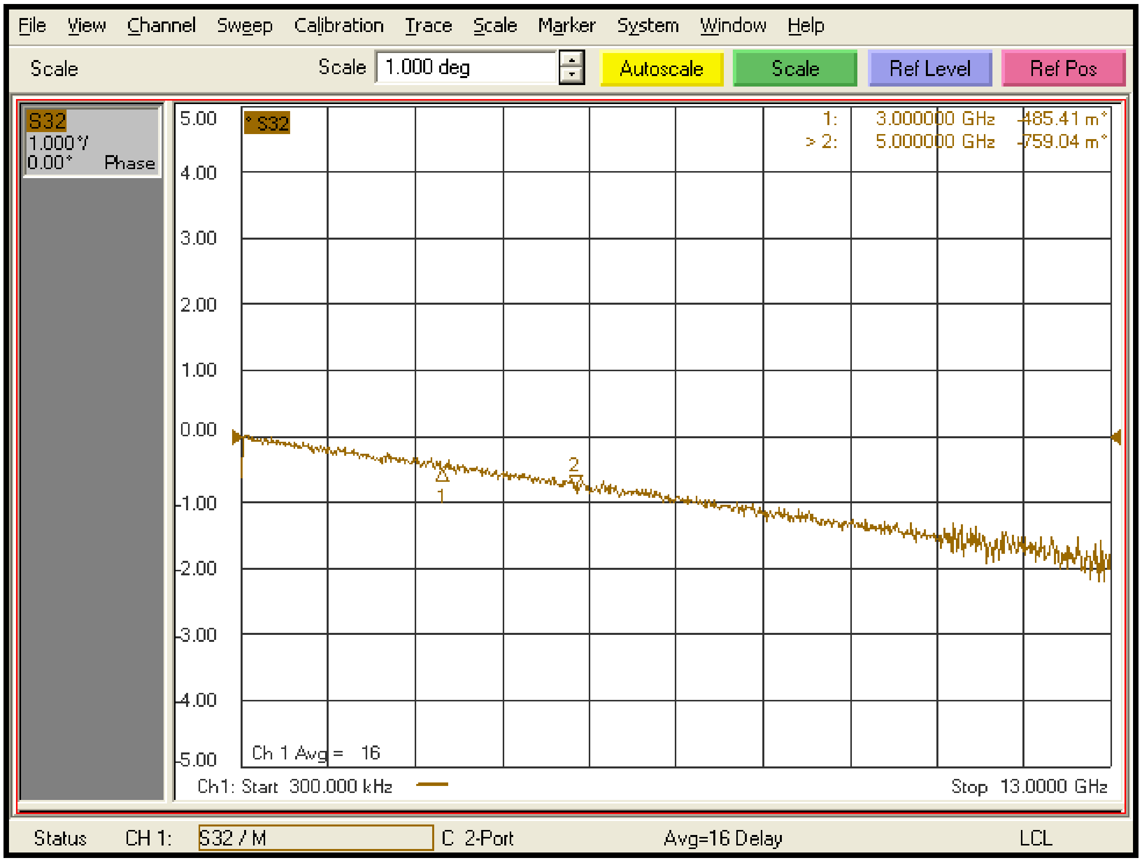
Temperature appears likely to be the real enemy of stability, not flexing and/or twisting per se. But we need to allow for this because as the antenna tracks objects in the sky, the temperature inside the feed cone in particular will change as the sunlight and shadow geometry changes with pointing angle. This is in addition to the normal air temperature changes as the day wears on. So there is certainly no doubt that it will be necessary to monitor delay changes in the fiber and report them to the proper "authorities".

The initial measurements of the overall transmission through the fiber are rather disturbing to me. In particular the delay can be seen to have wild and steep variations (hundreds of ps over a few hundred MHz). I guess the question is: will the phase calibrator system be adequate to account for this so that good correlations can be obtained?

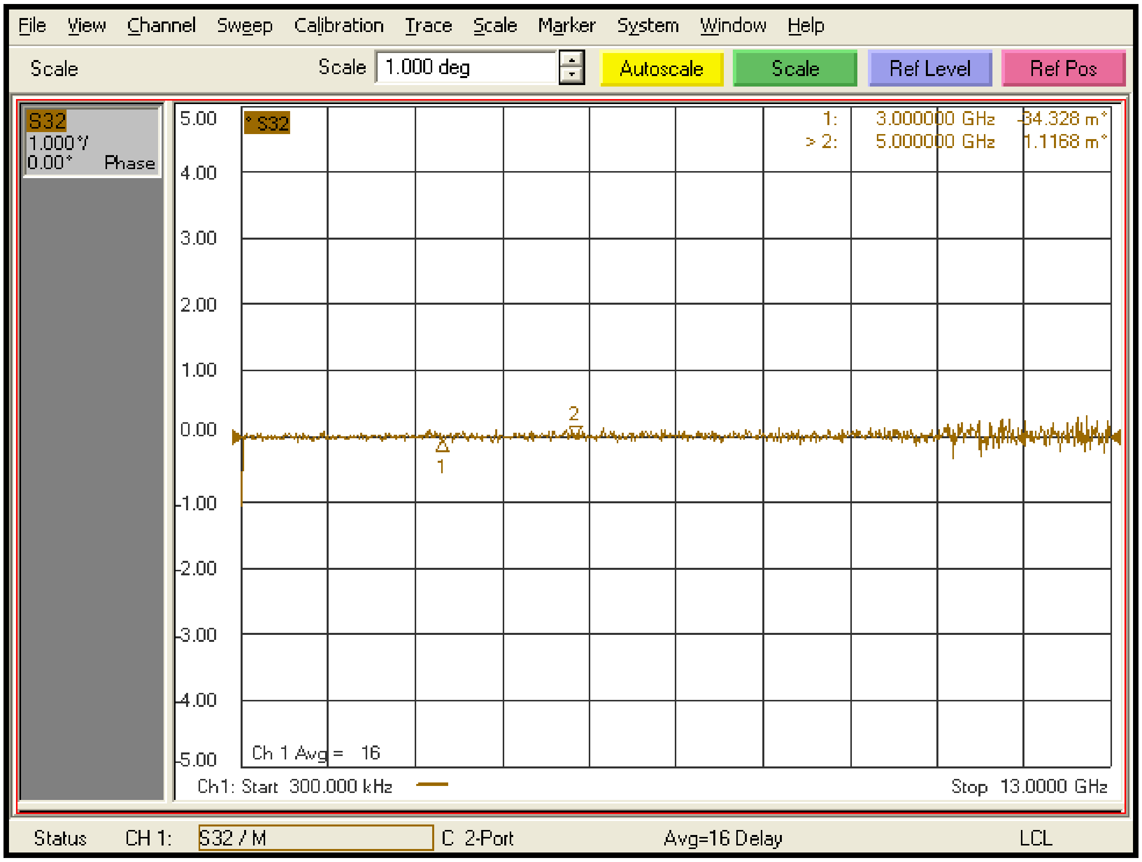
I tried adding in a second length of fiber with an FC/APC "barrel" and found that the form of both the amplitude and delay variations over frequency remained virtually unchanged. So I have to think that this problem is originating in the fiber link transmitter and receiver combination, not in the fiber itself or in reflections at the fiber terminations.

5 Plots

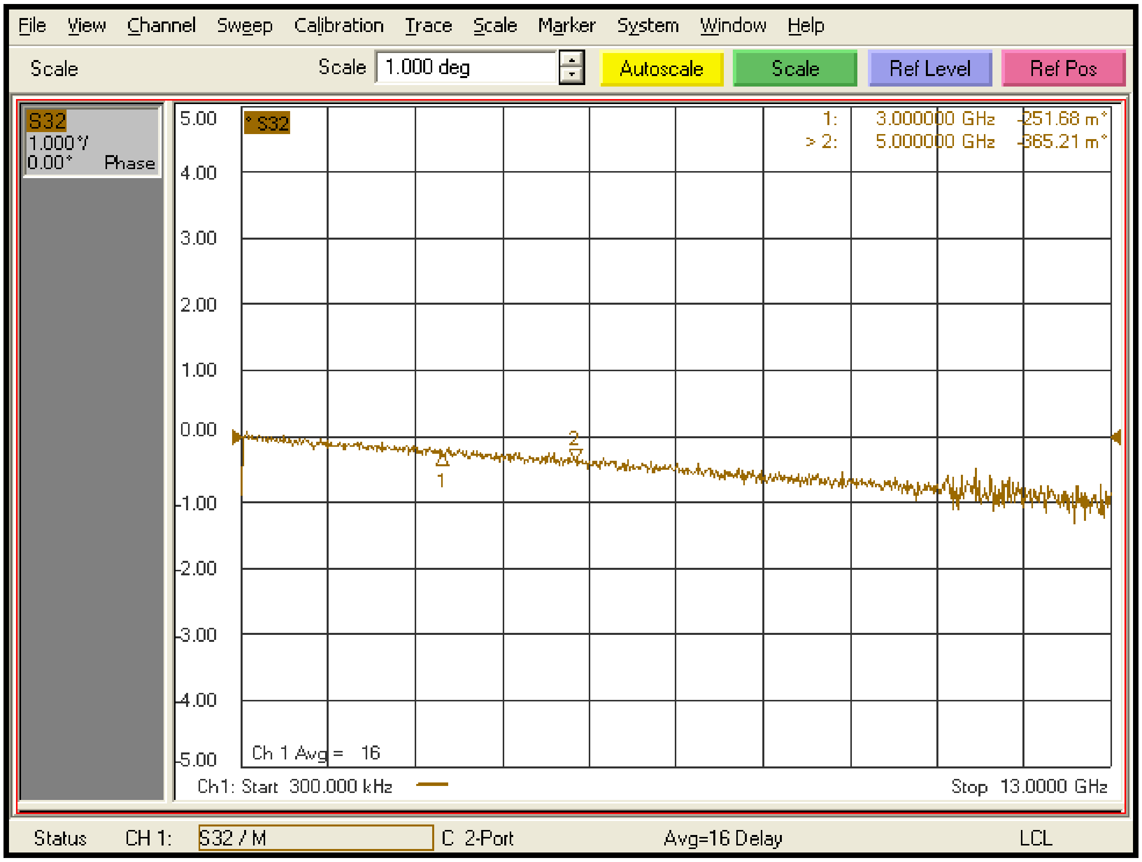
5.1 Delta Phase Coiled



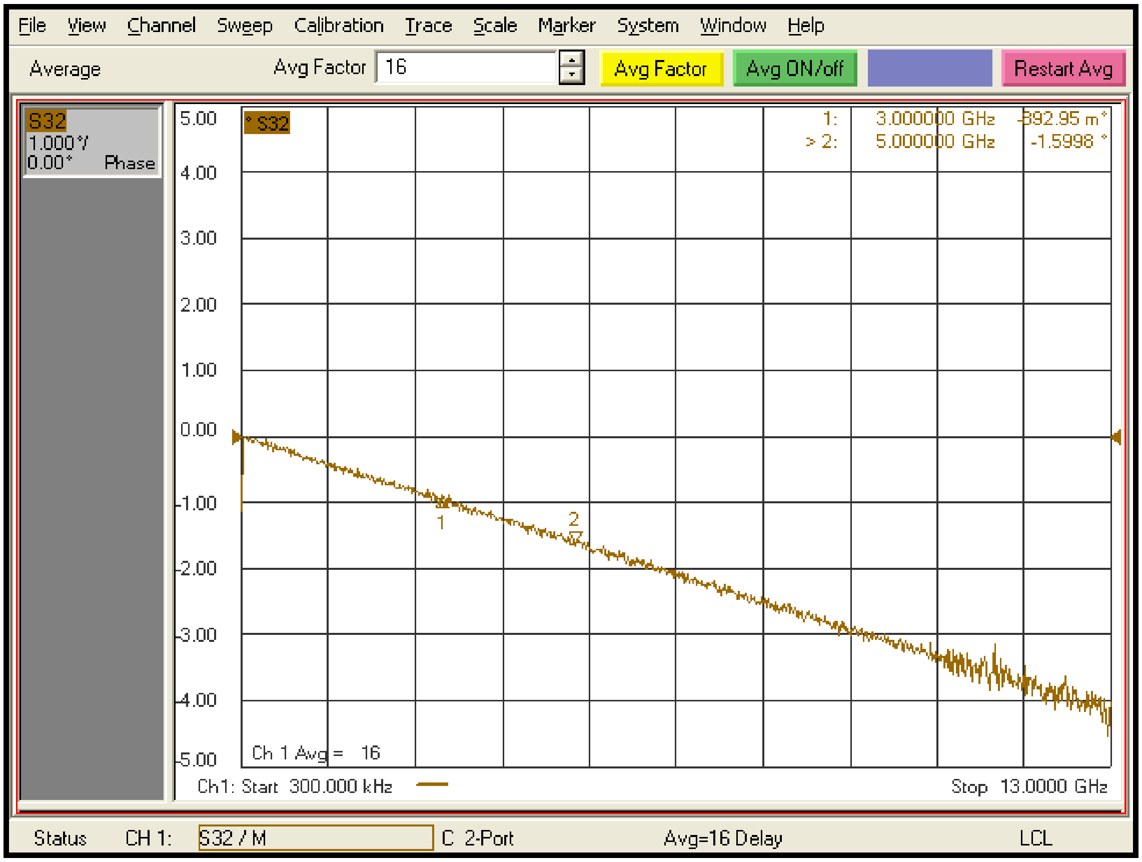
5.2 Delta Phase Fresh



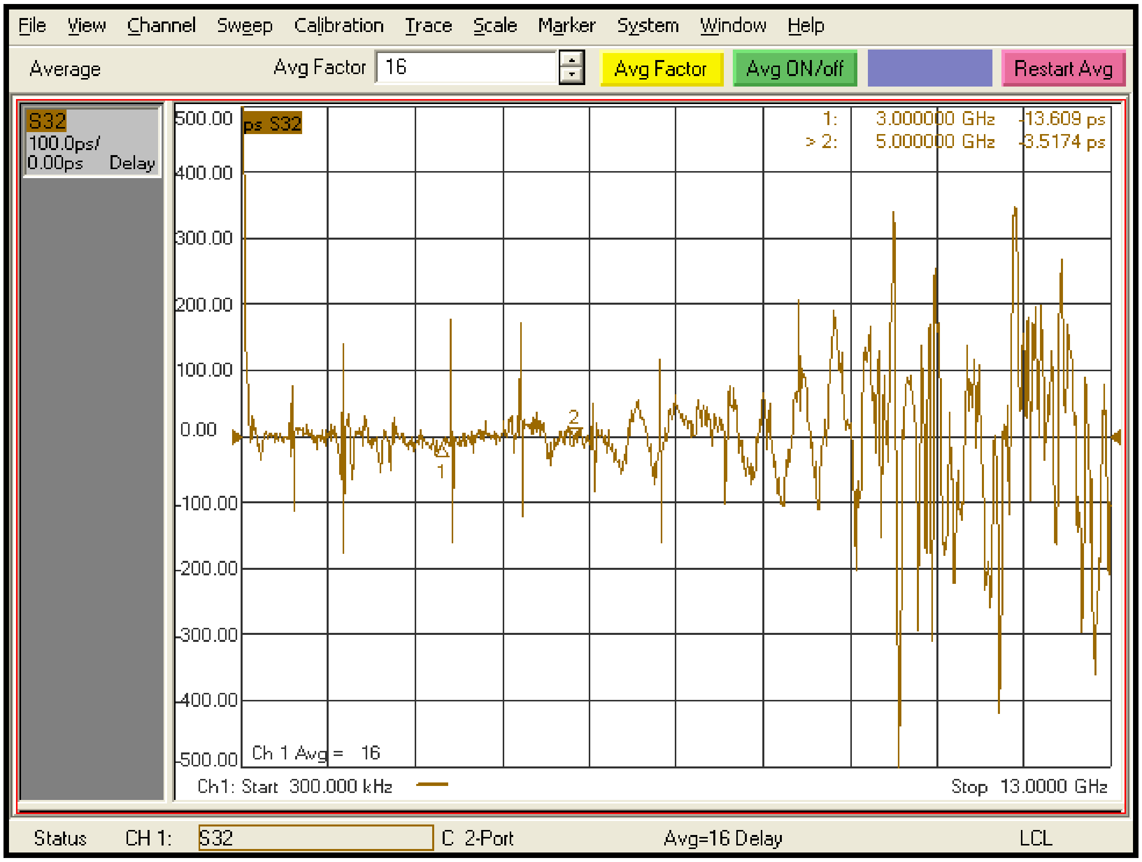
5.3 Delta Phase Twisted



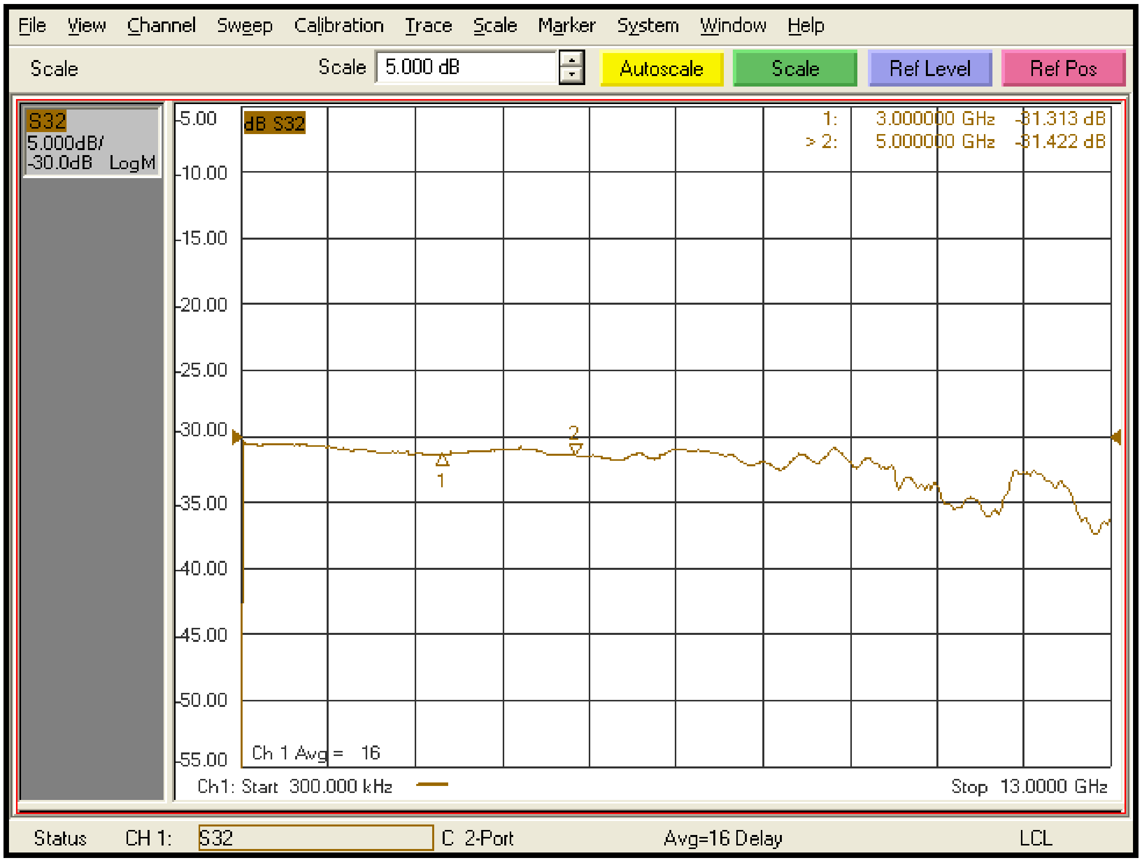
5.4 Delta Warm



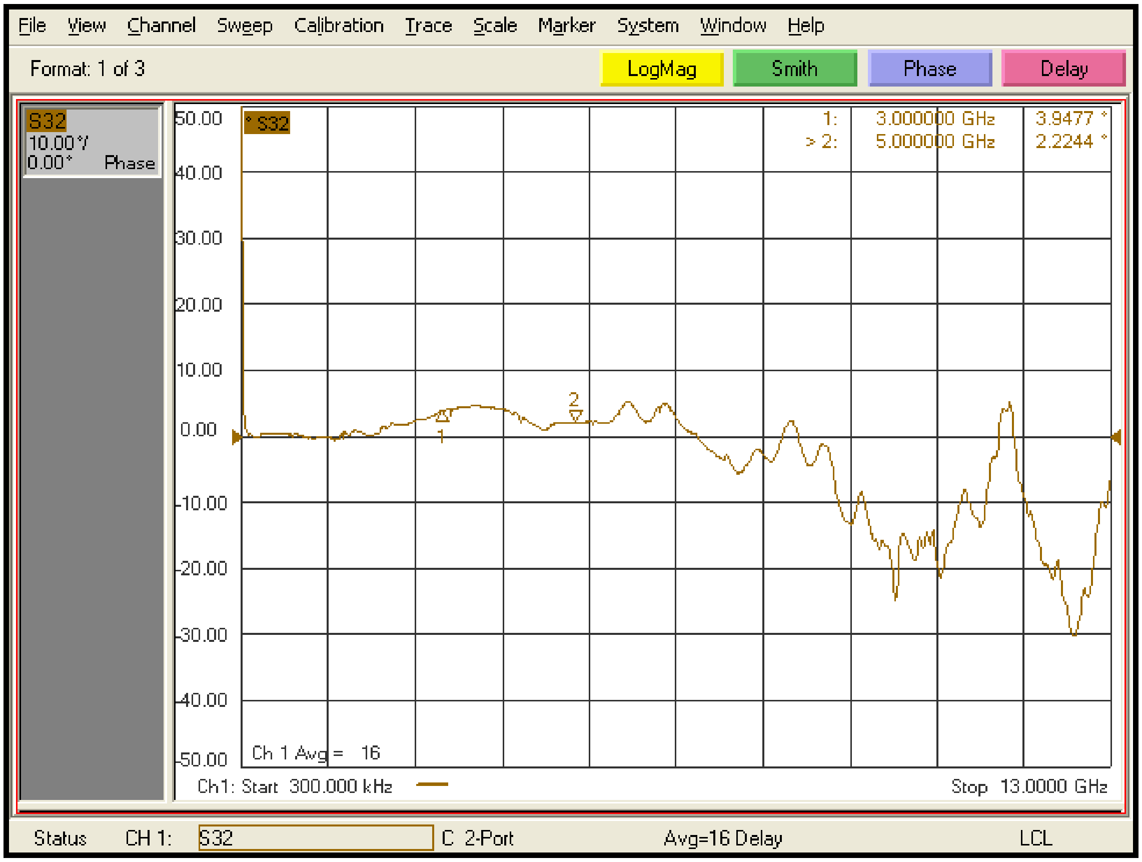
5.5 Group Delay



5.6 Magnitude



5.7 Phase


File View Channel Sweep Calibration Trace Scale Marker System Window Help
Format: 1 of 3
LogMag
Smith
Phase
Delay
S32
10.00°/
0.00°
Phase
* S32
1: 3.000000 GHz 3.9477 °
> 2: 5.000000 GHz 2.2244 °
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
Ch 1 Avg = 16
Ch1: Start 300.000 kHz
Stop 13.0000 GHz
Status
CH 1:
S32
C 2-Port
Avg=16 Delay
LCL