NSLSII STORAGE RING AND BOOSTER PILOT TONE COMBINER LAB TESTING RESULTS

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Abstract

NSLSII is a third generation light source and one of our requirements is sub-micron resolution of the beam position. To achieve this we chose to use a Pilot Tone Calibration approach. Because our Booster requires an isolated grounded system, this required a slightly different design. This paper will discuss the differences observed during lab testing of the two designs.

INTRODUCTION

Because of the strict resolution requirements for position at NSLSII a Pilot Tone Calibration design was implemented. Using a common signal on all channels we could calibrate our electronics however, because our booster electronics have to be isolated from ground a slightly different design had to evolve. The design comprised of a floating ground circuit board and metal enclosure. Both designs although very similar have differences which were observed during testing. The design comprised of all passive devices and the PC board was modified to allow for the floating ground requirements for our booster. These measurements were done in the lab only using a Vector Network Analyzer (VNA). Because this design was to be used as a calibration device care was taken to make all the channels as identical as possible. Channel to Channel isolation was a major concern and because of enhancements we observed on the SR version we improved the design even further with the Booster version.

INSTRUMENT SETUP

Our initial setup is illustrated below in Fig. 1, we would use the two ports of the VNA to perform all “S” parameters and group delay. The Agilent E5071C is a 2 port device so the channel to channel measurements can be done by only moving one of the ports. We would measure S21 and S11 as well as group delay. This “S” parameter matrix would allow examination of channel to channel isolation and through measurements (S21). From the S11 measurement results we were able to determine how good the input and output impedance match was. From these measurements we were able to categorize a device and compare it to other units. The repeatability also proved to be very good. We initially looked at the units out of the enclosure to observe differences. These results are not included in this paper; however, the out of box experiment did show a reduced performance. Final tests results were also performed not only in the box but also with the cover on the unit. Because the unit had a calibration channel, we could also measure how well the isolation was from any given channel to the calibration channel. When performing measurements all unused inputs and outputs were terminated using SMA 50ohm terminations.

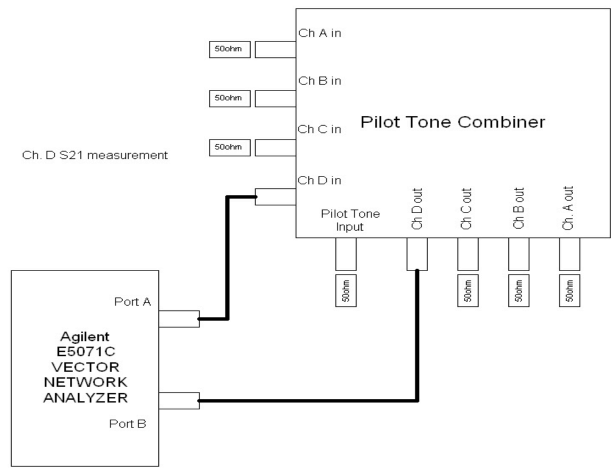

Figure 1: VNA setup – the pilot tone module connected for an S21 measurement of channel “D”.

SR PILOT TONE COMBINER

Our Storage Ring (SR) requirements didn’t require an isolated ground so this made the design more straightforward. During initial testing of our first articles, we noticed that the channel to channel isolation wasn’t as good as we would have liked, because of this stitching vias were added along the microstrip. This did improve the coupling slightly so we decided to increase the isolation even further, we moved to a Stripline design using PCB layers for isolation. With this modification we were able to increase some channel to channel isolation by as much as 20dB. Fig. 2 shows the unit under test. The device was designed to have a PC board installed in a solid Aluminum enclosure, and the bottom side of the PC board was a solid ground. The board was connected to the metal enclosure with 6 mounting holes. During testing we noticed that with additional mounting holes to the metal enclosure we picked up an additional 3dB of isolation due to a better ground connection. One last modification to add mounting holes between every channel and several in the middle of the board was implemented and the storage ring design was finished. Based on the results we saw the production order was placed and we are currently awaiting the aluminum assemblies. The results of our testing can be seen in Figs 3 and 4. The PTC units can now also be used as a health check for our BPM electronics, by injecting into the Pilot tone port the same signal would be coupled on to every channel thus verifying the electronics are working correctly.

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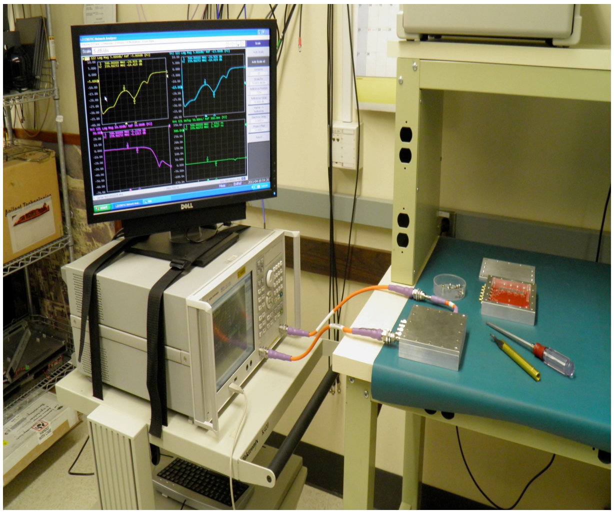

Figure 2: SR PTC under test.

Port Assignments

	Input Port	Output Port
CHA	1	6
CHB	2	7
CHC	3	8
CHD	4	9
Pilot Tone	5	

S Matrix Measurement (@500MHz)

CHA		CHB		CHC		CHD	
|Sij|	Measured (dB)	|Sij|	Measured (dB)	|Sij|	Measured (dB)	|Sij|	Measured (dB)
S11	-17.859	S22	-17.458	S33	-17.015	S44	-16.774
S66	-21.640	S77	-19.841	S88	-18.672	S99	-19.693
S61	-1.754	S72	-1.746	S83	-2.287	S94	-2.381
S65	-30.628	S75	-30.542	S85	-31.426	S95	-30.256
S51	-42.535	S52	-41.114	S53	-42.450	S54	-40.811
S71	-57.701	S62	-57.023	S63	-68.370	S64	-69.789
S81	-68.942	S82	-59.138	S73	-59.713	S74	-66.559
S91	-70.966	S92	-67.333	S93	-69.050	S84	-67.699

S21 Group Delay Measurement

Measurement	Group delay (ns)	Min (ns)	Max (ns)	Pk-Pk (ns)	AVE (ns)	STDEV (ns)
S61	3.056	3.0466	3.0573	0.0107	3.05	0.01
S72	3.047					
S83	3.057					
S94	3.048					

Figure 3: Final design PTC S-parameter measurements.

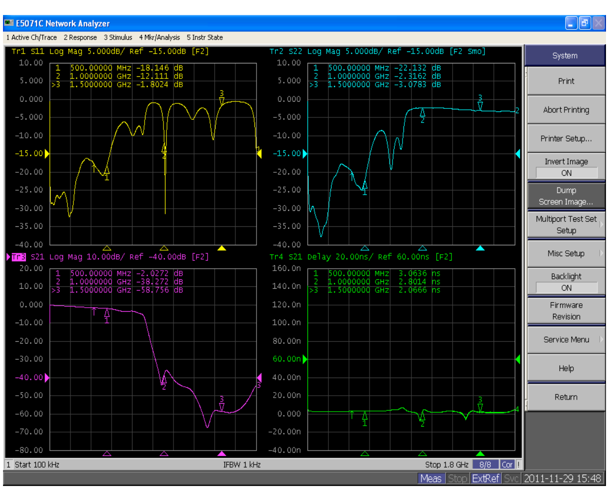

Figure 4: Final design PTC S-parameter plots.

BOOSTER PILOT TONE COMBINER

The vendor that was responsible with constructing our Booster required that we have no physical connections between our electronics and the booster ring girder. This involved several challenges. Our design was already AC coupled so we were isolated on the transmission line however, the physical connection from the girder to the box and the box through our connectors presented another problem. We were able isolate the box from the girder by using isolation washers; from there the board was modified to isolate the physical connecter ground from the board ground. We accomplished this by creating "islands" around all the connectors and AC coupling those islands to the board with capacitors. The total capacitance had to be calculated so that it still would be acceptable with our design. Simulating showed that a parallel combination of 800pf. Caps worked very well. Because the board was so similar to the SR version we even further improved the channel to channel isolation by decoupling the channels by separating the striplines by eliminating most of the source of the coupling. The signals paralleled each other for some length, making a perfect coupler. By minimizing any parallel lines by bending the traces away from each other help significantly. This modification can be seen in Fig. 7. The prototype board was built and our first prototype performed very well. The only issue was a resonance that showed up at 7 Mhz. This was a result of the isolated ground causing a resonant circuit. To damp this resonance we chose to just add a High Pass Filter in series with our Low Pass filter. A quick lab experiment proved that this would work very well. A second rev of the prototype (first article) was fabricated and it greatly outperformed even the SR version. We observed some channel to channel isolation as low as -80dB. Because of the isolation washers, a different enclosure was also developed.

Pilot Tone Combiner Module (PTCM) Datasheet

DATE: 6-Apr-2012
PTCM SERNO: 02

Port Assignments

	Input Port	Output Port
CHA	1	6
CHB	2	7
CHC	3	8
CHD	4	9
Pilot Tone	5	

S Matrix Measurement (@500MHz) (Original Data)

CHA		CHB		CHC		CHD	
|Sij|	Measured (dB)	|Sij|	Measured (dB)	|Sij|	Measured (dB)	|Sij|	Measured (dB)
S11	-10.110	S22	-12.222	S33	-11.634	S44	-11.303
S66	-15.840	S77	-19.090	S88	-18.437	S99	-16.977
S61	-3.076	S72	-2.780	S83	-2.854	S94	-2.920
S65	-46.404	S75	-55.555	S85	-53.866	S95	-58.135
S51	-45.869	S52	-44.075	S53	-49.294	S54	-44.264
S71	-70.141	S62	-80.804	S63	-76.451	S64	-82.846
S81	-76.451	S82	-70.556	S73	-72.043	S74	-80.467
S91	-82.846	S92	-80.804	S93	-70.169	S84	-68.724

CHA		CHB		CHC		CHD	
|Sij|	Measured (dB)	|Sij|	Measured (dB)	|Sij|	Measured (dB)	|Sij|	Measured (dB)
S61	-3.076	S72	-2.78	S83	-2.854	S94	-2.92
S65	-46.404	S75	-55.555	S85	-53.866	S95	-58.135

Figure 5: Booster PTC S-parameter measurements.

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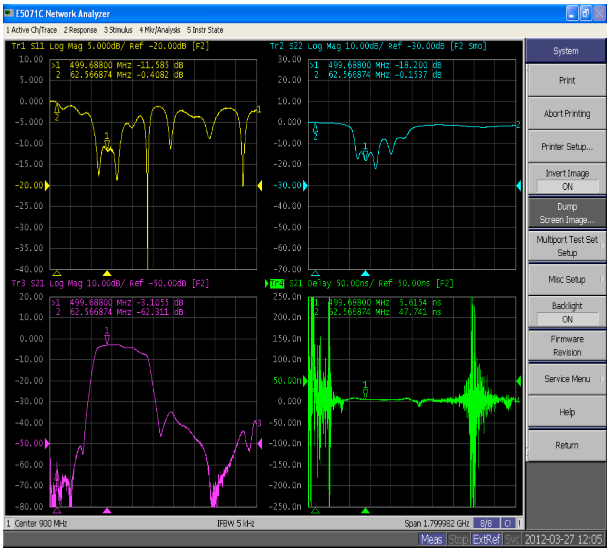

Figure 6: Booster PTC S-parameter plots.

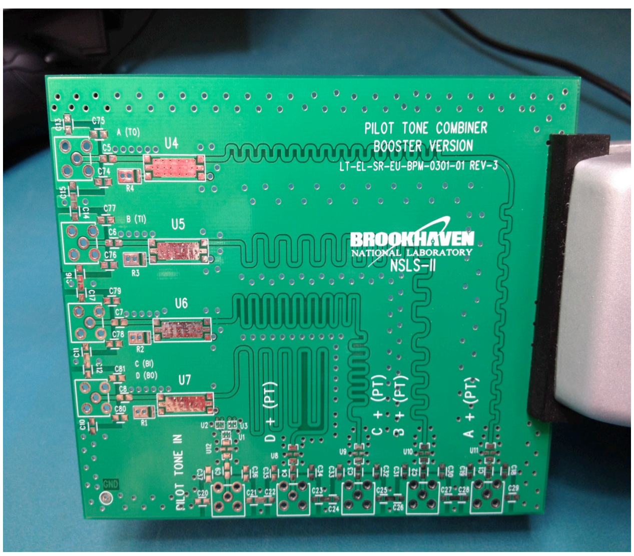

Figure 7: Booster PTC.

CONCLUSION

The Pilot Tone Combiner Board will allow NSLSII to achieve submicron resolution in both our Booster and Storage Ring BPM measurements. Our initial simulations regarding the isolated grounded version compared very well with the actual response we observed. The lessons learned regarding isolation became extremely important. One being, a simple modification of just adding stitching vias along the transmission line, to steer any coupling fields to ground as closes as possible. Also allowing the advantage of a multilayer board with ground layers between channels to further improve our isolation. All these results lead the Booster version to outperform the SR version. Understanding the result of isolating the ground and dealing with the problems that come by doing so. The storage ring version has been already tested on a real machine (ALS 2011) however, with our booster almost a year away we can only continue to examine lab data using synthesized data.

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