SIO DPG Phase Shift Issue

10/19/2012 Don Forsyth sent a plot on DPG phase shift (from OBSIP meeting) and a plot showing the frequency averaged phase shift for all 6 SIO instruments that had both working seismometers and DPGs. One of the SIO instruments was way off. The phase shifts were estimated from average of cross-correlations of Rayleigh wave forms from several events. There was also one DPG with a large phase shift.

10/19/2012 John Collins said that the problem probably lies with the DPG response rather than the seismometer response because seismometer responses are better known.

10/19/2012 Don confirms that it is the DPG response by looking at ambient noise analysis on the seismometer and the other seismometers

10/22/2012 Spahr Webb asks if the response was measured at seafloor temperature. There is a significant increase in the viscosity of oil with decreasing temperature and compressibility decreases with increasing pressure. DPGs are designed to have a leak time constant of 100-120s.

10/22/2012 Don asks if changing time constants could be responsible for small phase shifts or the larger DPG phase shift.

10/23/2012 Time constant of 60s, minus time constant of 250s. time constant of 1500s minus time constant of 90s. Not sure if this could fix the problem.

Cascadia YR1 SIO DPG instrument response files

**SAME PROBLEM IN 2009/2010 South Shatsky Fracture Zone Experiment
** Don Forsyth**

6/28/2013 Spahr Webb compared the pressure spectra between the WHOI (DPG), SIO (DPG), and LDEO (APG) instruments. The SIO DPG spectra vary greatly from the LDEO and WHOI instruments responses. The phase relationship between the vertical acceleration and the pressure gauge should be close to zero. Problem thought to be the response file for the instrument. **Suggested solution by Spahr Webb:** The gain and phase responses are way off. It appears that you have an extra pole and the wrong gain. Removing the pole at -2.12770E-01 fixes the spectral shape and gets the phase close, although the long period phase response is still slightly off, probably because of the temperature effect lengthening the capillary leak time constant.

7/2/2013 Don Forsyth, while working on deriving transfer functions between DPG to verticals, noticed that the WHOI DPG response functions described by poles and zeroes archived at IRIS to remove the response, we get zero phase shifts between pressure and displacement (also corrected for response). When we correct the SIO records in the same way, we get a large, frequency dependent phase shift in the transfer function approaching pi/2 at zero frequency. However, if we make NO correction to the SIO DPGs, we get zero phase shift again between pressure and vertical displacement. **Suggested solution:** the SIO DPG data is already corrected for response and the poles and zeros should NOT be applied

7/3/2013 Spahr notes that Don's solution and his own are consistent

SIO DPG Transfer Function

10/26/2012 Doug Toomey contacts OMO after contacting SIO about Gabi Laske's report and receiving no response. Normally the DPG and vertical seismometers provide comparable data, particularly in the 10s to 30s band. Report by Gabi show no usable data on the DPGs. In the 20 to 60s band the DPG data does not look vertical.

2/13/2013 Anne Sheehan asks for citation for the constants in the SIO DPG transfer function. There is a paper in publication that should discuss the DPG instrument response and the variability of the DPG transfer functions.

Forwarded conversation

Subject: **DPG phase shift plots**

From: **Forsyth, Donald** <donald_forsyth@brown.edu>
Date: Fri, Oct 19, 2012 at 4:16 PM
To: Spahr Webb <scw@ldeo.columbia.edu>, Collins John <jcollins@whoi.edu>

Hi guys,

I don't know how this will help exactly, but attached are the plot on DPG phase shift I showed at the OBSIP meeting (just 4 OBSs shown) and a plot showing the frequency averaged phase shift for all 6 SIO instruments that had both working seismometers and DPGs. The LDEO DPGs didn't work properly. In the second plot, the standard errors of the phase shifts are also shown - smaller than the symbol size. So, 5 of the 6 had similar, small phase shifts, but statistically not identical, and then one was way off. (The numbering in the second plot is arbitrary and does not correspond to the OBS #s in the first plot.) These were the shifts necessary after correcting for instrument response of both vertical and DPG (but using only poles and zeros).

These phase shifts were estimated from average of cross-correlations of Rayleigh waves from several events with high SNR (at least on the vertical) in period range from about 16 to 40 s. There is no indication of significant frequency dependence of the phase shift, so the time shifts vary with frequency. We also got almost identical phase shifts from ambient noise cross-correlations in the 3 to 15 s period range. Looks frequency independent. There were significant differences in the amplitude responses, as expected for DPGs, but the amplitude response for DPG #1 with the strange, large phase shift was very similar to DPG #4 which had the normal, small phase shift.

Let me know if you want any other info.

Don

--
Donald Forsyth
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401-863-1699

From: **John A. Collins** <jcollins@whoi.edu>
Date: Fri, Oct 19, 2012 at 6:01 PM
To: "Forsyth, Donald" <Donald_Forsyth@brown.edu>
Cc: "John A. Collins" <jcollins@whoi.edu>, Spahr Webb
<scw@ldeo.columbia.edu>

Don

It seems reasonable to assume the problem is with the DPG response rather than the seismometer response, as the latter is much better known. We can also predict the frequency response
of the DPG preamp board if we know the R and C values.

If one sets aside the DPG with the 0.5 rad phase shift, then perhaps the mean shift of the remaining units (less than 0.1 rad) and the difference in phase shifts might be explained by differences in the
time constant. We have measured time constants that range from 30 seconds to 120 seconds. The attached plot shows the predicted phase response for a range of time constants.

Perhaps the preamp. board on the unit with the 0.5 radian shift has a wrong resistor.

>
> <DPGphaseShiftsPlot.jpg><FreqAveragedPhaseShifts.jpg>

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John A. Collins
Dept. of Geology and Geophysics, MS 24
Woods Hole Oceanographic Institution
360 Woods Hole Road
Woods Hole, MA 02543

e-mail: jcollins@whoi.edu
voice: 508-289-2733
fax: 508-457-2150
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From: **Forsyth, Donald** <donald_forsyth@brown.edu>
Date: Fri, Oct 19, 2012 at 7:19 PM
To: "John A. Collins" <jcollins@whoi.edu>
Cc: Spahr Webb <scw@ldeo.columbia.edu>

It is definitely the DPG response - we can confirm by ambient noise analysis that there is no time shift between that seismometer and the other seismometers.

It does look like the other phase shifts could be due to different time constants, since the differences in the curves you show in this frequency band are nearly frequency independent and small. Do the different time constants arise due to the same variability that causes the differences in amplitude response?

Thanks for your insight John.

Don

> <DPGphaseShiftsPlot.jpg><FreqAveragedPhaseShifts.jpg>

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From: **Spahr Webb** <scw@ldeo.columbia.edu>
Date: Mon, Oct 22, 2012 at 4:49 PM
To: "John A. Collins" <jcollins@whoi.edu>
Cc: "Forsyth, Donald" <Donald_Forsyth@brown.edu>

On Oct 19, 2012, at 6:01 PM, John A. Collins wrote:

> Don
> It seems reasonable to assume the problem is with the DPG response rather than the seismometer response, as the latter is much better known. We can also predict the frequency response of the DPG preamp board if we know the R and C values.
>
> If one sets aside the DPG with the 0.5 rad phase shift, then perhaps the mean shift of the remaining units (less than 0.1 rad) and the difference in phase shifts might be explained by differences in the time constant. We have measured time constants that range from 30 seconds to 120 seconds. The attached plot shows the predicted phase response for a range of time constants.
>
> Perhaps the preamp. board on the unit with the 0.5 radian shift has a wrong resistor.

John, Don:

Were these DPG responses measured at seafloor temperatures? There is a significant increase in the viscosity of the oil with decreasing temperature (Cox et al., 1984) and the compressibility decreases with increasing pressure. The second factor may counteract the first some, and the compliance of the valves may also matter. The viscosity almost doubles from 20C to 2C. Thus time constants measured at room temperature may need to be nearly doubled for seafloor temps. The DPG was designed to have a leak time constant near 100-120s at room temperature, which suggest a cold time constant of over 200s. If the time constant is very long to start with, than the changes with depth and temperature don't matter very much for seismology. I generally assume that when you see much shorter time constants in lab tests that you have a small bubble of air in the needle, so you can move a lot of fluid into the needle with a small change in pressure. This makes the time constant look short. You can also get very long time constants (infinite) when the leak is plugged. We were finding gunk in the needles that was plugging the leak off. (It looked like the cutting oil had not been cleaned out of the threads before the gauges had been assembled at SIO).

Spahr Webb

On Oct 19, 2012, at 4:16 PM, Forsyth, Donald wrote:

Hi guys,

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Let me know if you want any other info.

Don

--

Donald Forsyth

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<DPG_Phase_Question.pdf>

<DPGphaseShiftsPlot.jpg><FreqAveragedPhaseShifts.jpg>

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From: **Forsyth, Donald** <donald_forsyth@brown.edu>
Date: Mon, Oct 22, 2012 at 4:59 PM
To: Spahr Webb <scw@ldeo.columbia.edu>
Cc: "John A. Collins" <jcollins@whoi.edu>

So, Spahr, do you think changing time constants could be responsible for the small phase shifts between most of the DPGs? If not, do you have any other suggestions? How about the huge phase shift for DPG #1?

Don

Were these DPG responses measured at seafloor temperatures? There is a significant increase in the viscosity of the oil with decreasing temperature (Cox et al., 1984) and the compressibility decreases with increasing pressure. The second factor may counteract the first some, and the compliance of the valves may also matter. The viscosity almost doubles from 20C to 2C. Thus time constants measured at room temperature may need to be nearly doubled for seafloor temps. The DPG was designed to have a leak time constant near 100-120s at room temperature, which suggest a cold time constant of over 200s. If the time constant is very long to start with, than the changes with depth and temperature don't matter very much for seismology. I generally assume that when you see much shorter time constants in lab tests that you have a small bubble of air in the needle, so you can move a lot of fluid into the needle with a small change in pressure. This makes the time constant look short. You can also get very long time constants (infinite) when the leak is plugged. We were finding gunk in the needles that was plugging the leak off. (It looked like the cutting oil had not been cleaned out of the threads before the gauges had been assembled at SIO).

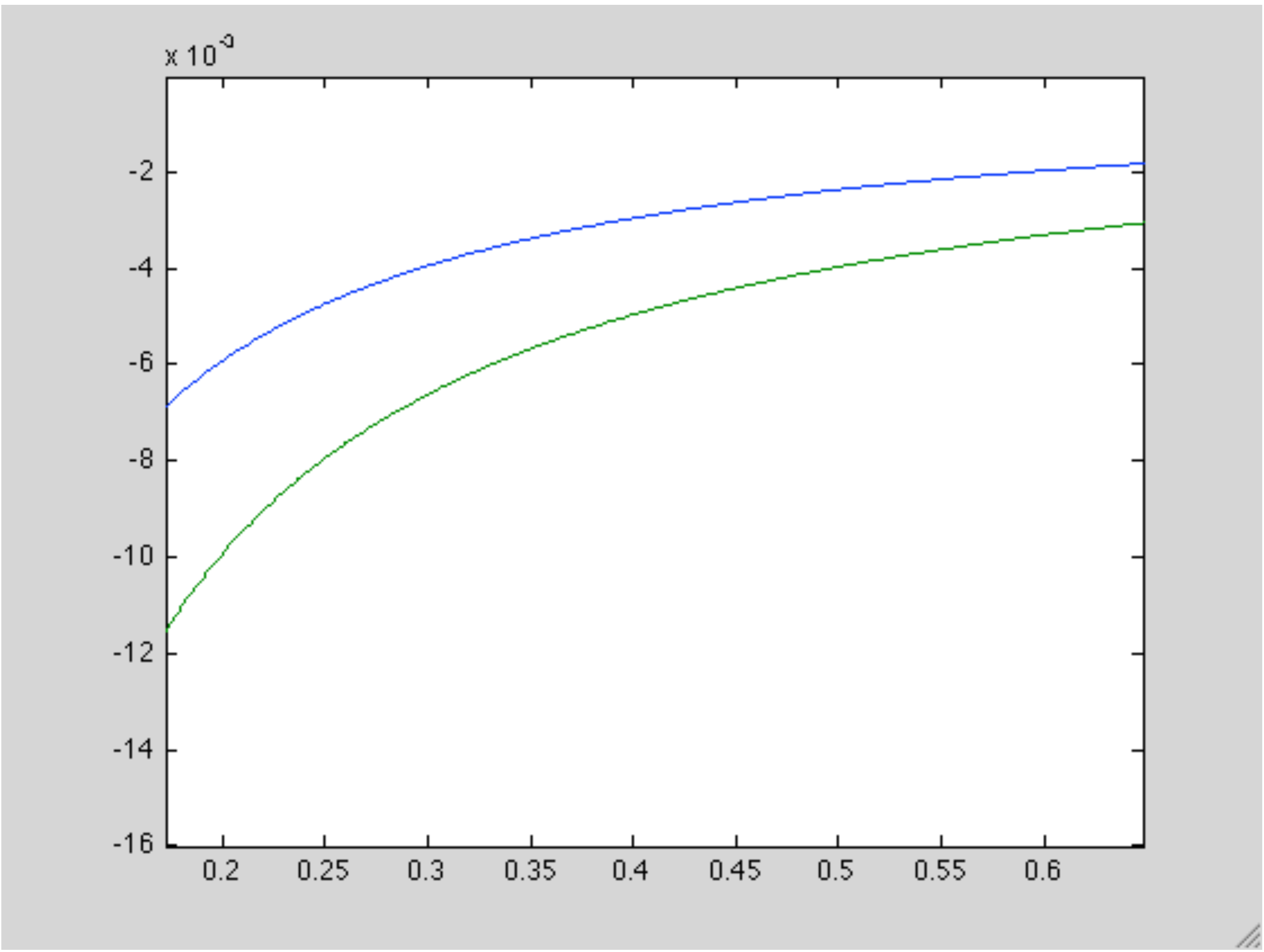
From: **Spahr Webb** <scw@ldeo.columbia.edu>
Date: Tue, Oct 23, 2012 at 12:02 PM
To: "Forsyth, Donald" <Donald_Forsyth@brown.edu>

On Oct 22, 2012, at 4:59 PM, Forsyth, Donald wrote:

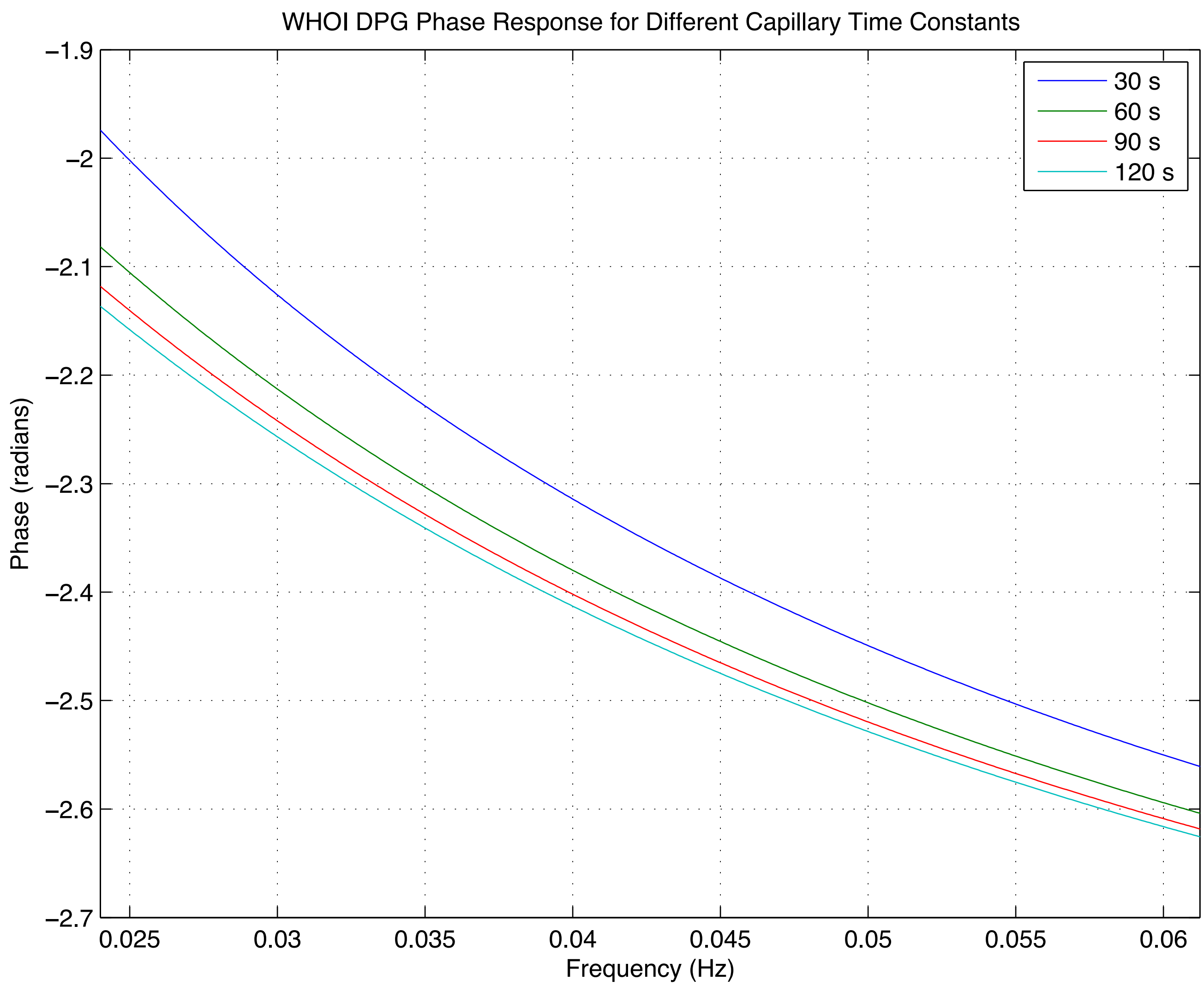
> So, Spahr, do you think changing time constants could be responsible for the small phase shifts between most of the DPGs? If not, do you have any other suggestions? How about the huge phase shift for DPG #1?
>
> Don
>

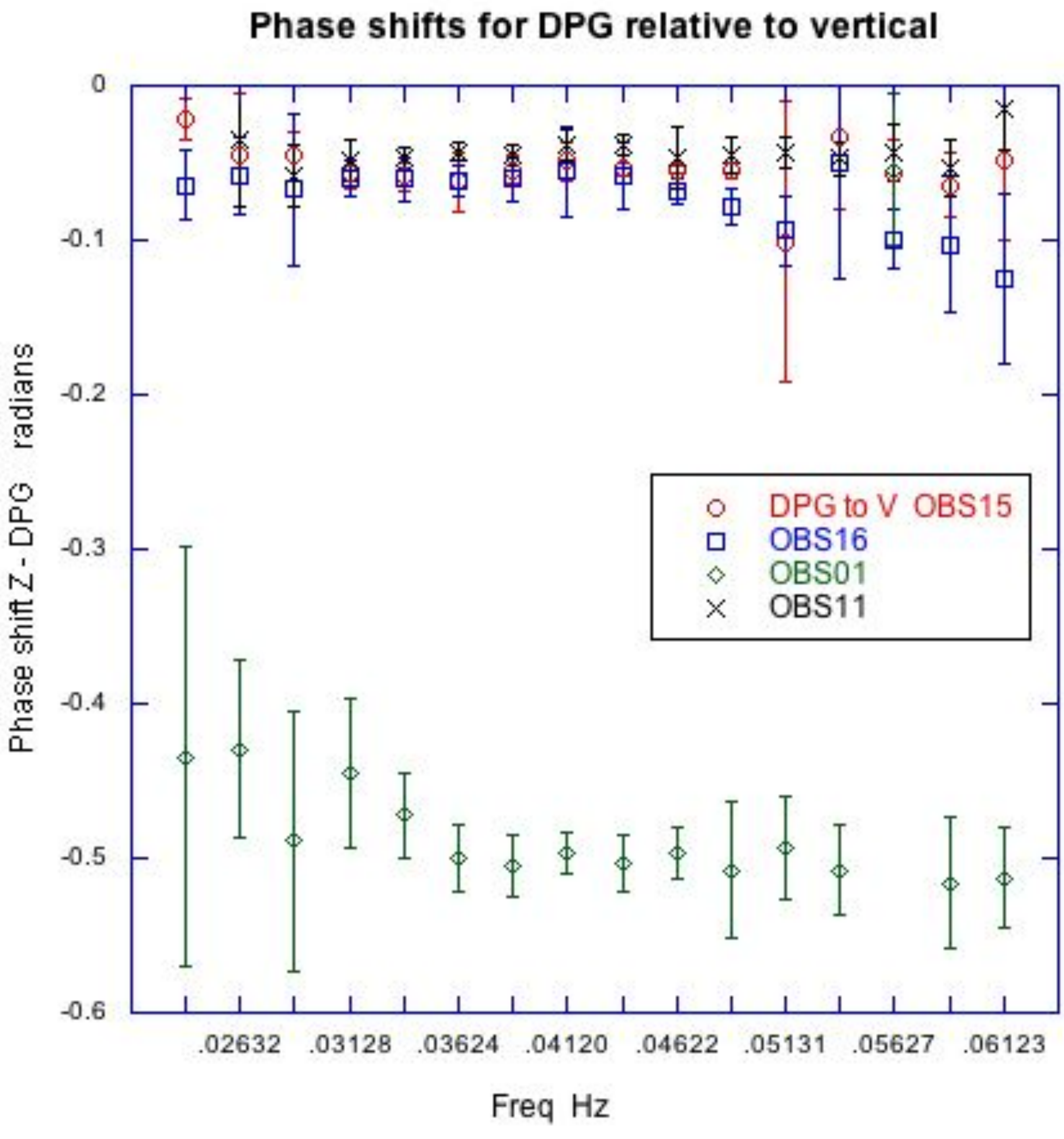
Do you have the response file for the SIO DPGs? (the dataless header). What time constant are they using for the DPG leaks? Its possible that it is just a difference in leak constants if they are using a very short leak constant in the current response file. DPG01 is hard too explain with a screwed up leak constant since you would see a significant frequency dependence to the phase if the leak were very short.

Spahr



x 10^-3
-2
-4
-6
-8
-10
-12
-14
-16
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6


WHOI DPG Phase Response for Different Capillary Time Constants
−1.9
−2
−2.1
−2.2
−2.3
−2.4
−2.5
−2.6
−2.7
Phase (radians)
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
Frequency (Hz)
30 s
60 s
90 s
120 s


Phase shifts for DPG relative to vertical
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Phase shift Z - DPG radians
DPG to V OBS15
OBS16
OBS01
OBS11
.02632
.03128
.03624
.04120
.04622
.05131
.05627
.06123
Freq Hz

These are the sorts of differences in response between short and long leak constants for phase in radians versus frequency. (time constant of 60s, minus time constant of 250s. time constant of 1500s minus time constant of 90s). I have not figured out if the sign of the phase correction is correct though to fix your problem.

--
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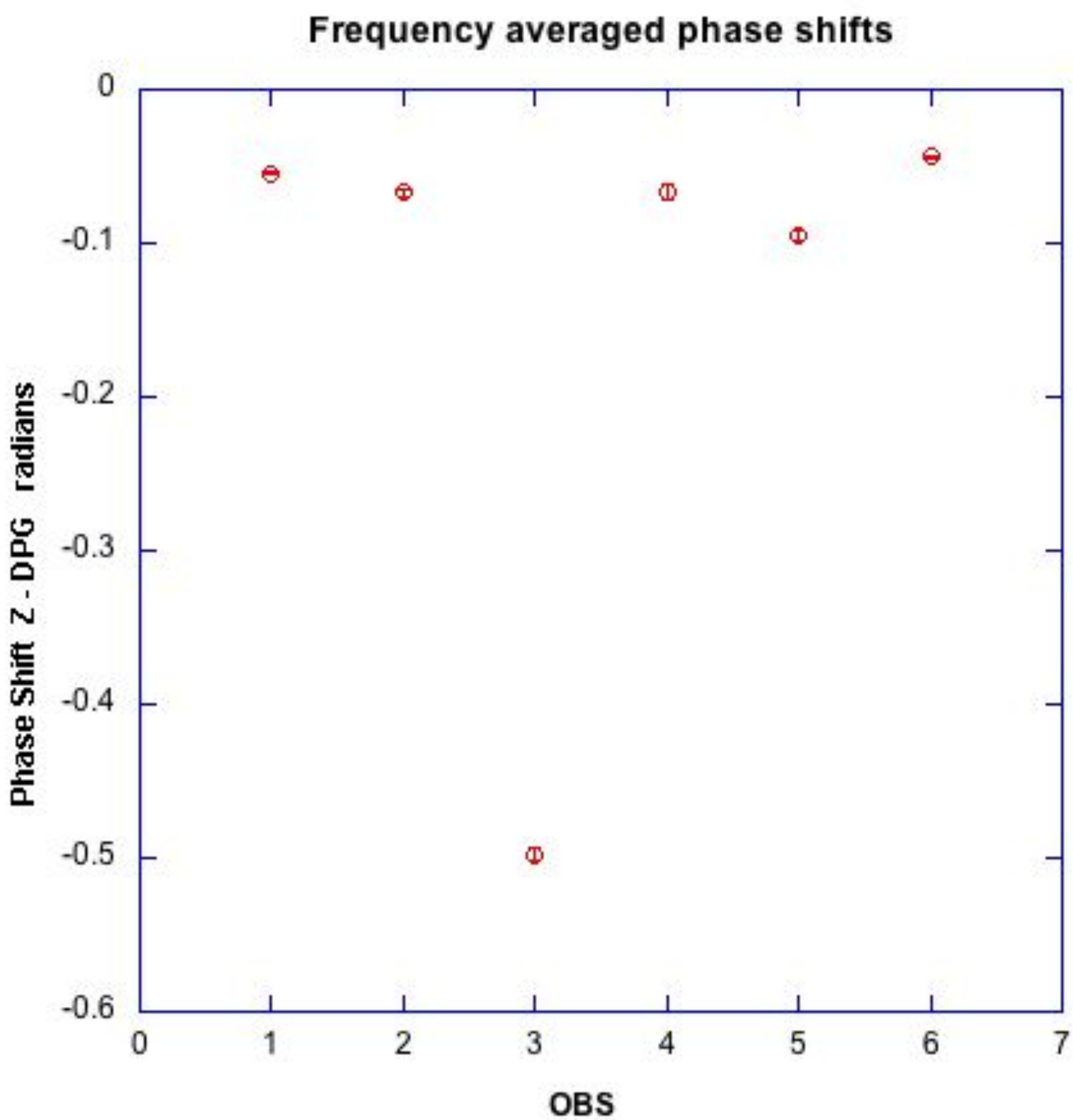
Frequency averaged phase shifts
Phase Shift Z - DPG radians
OBS
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0
1
2
3
4
5
6
7