

Analysis of CO $^{60}\beta$ -source data. Data set consists of 1805 time stamped waveforms recorded at 145 GSa/s.

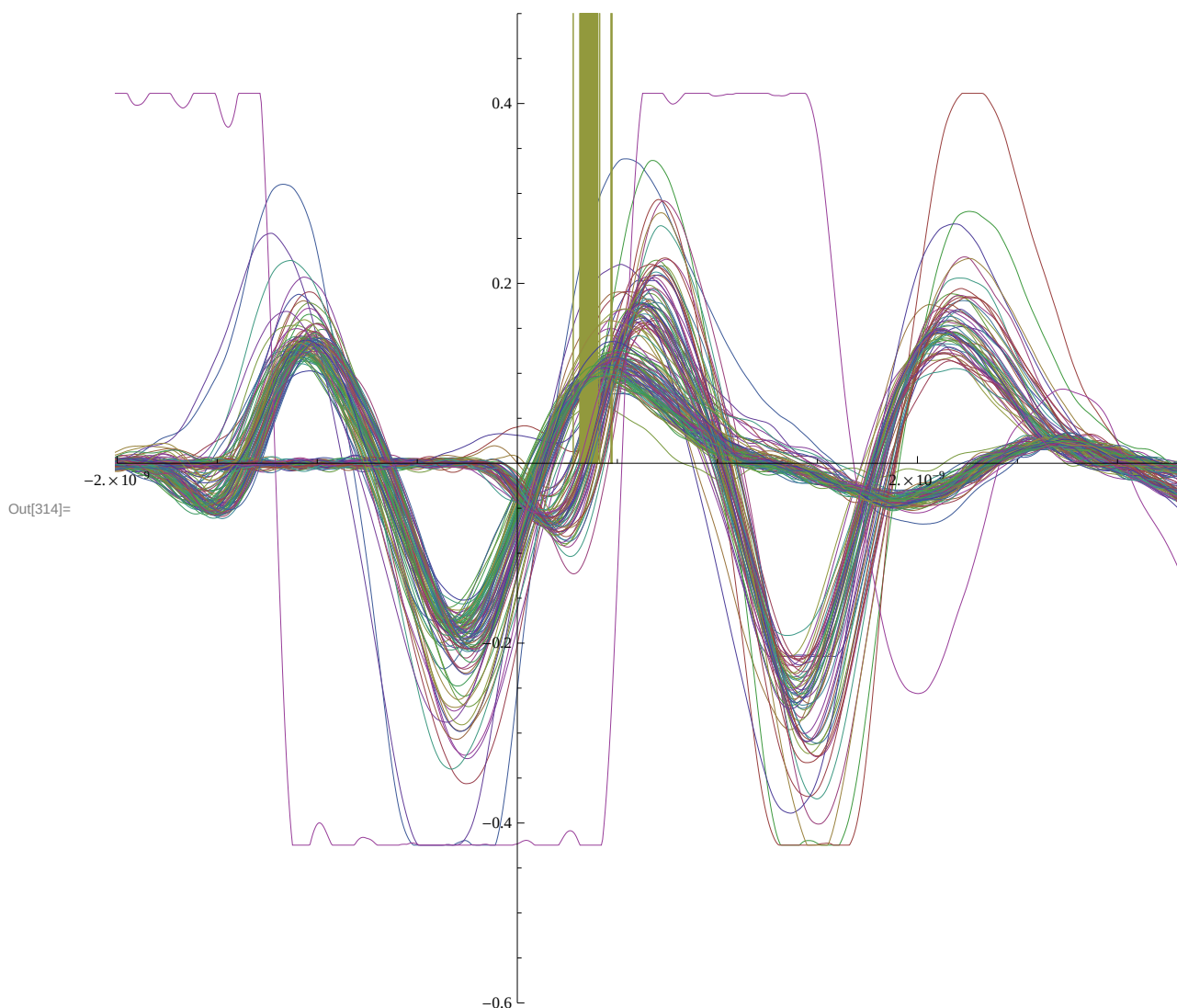
```
In[304]:= SetDirectory["~white/Desktop/4mm^2"];  
          Drop[FileNames[], 1] // Length;  
          ntrace = %  
  
Out[306]= 1805  
  
In[307]:= Namelist = Drop[FileNames[], 1];  
          itrace = 1;  
          time = Transpose[Import[Namelist[[itrace]], "Data"]][[1]];  
          Dimensions[time];  
          half = % / 2  
  
Out[311]= {7993}  
  
In[312]:= front = Transpose[Import[Namelist[[itrace]], "Data"]][[2]];  
          offset = Mean[Take[front, 7693]]  
  
Out[313]= -0.000421501
```

Front and Back are the 2 APDs which face each other. Front is closest to the CO^{60} source.

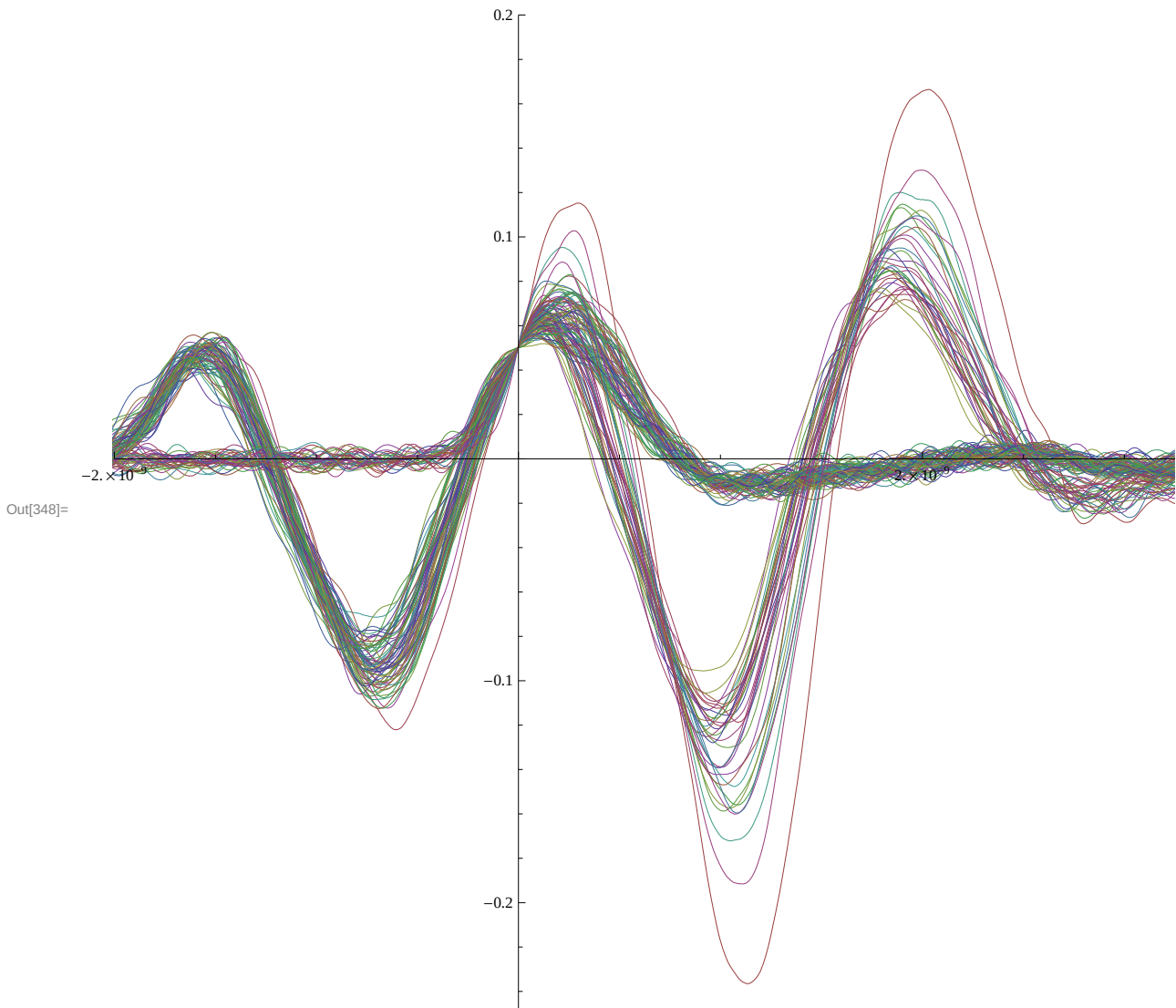
The first 49 nanoseconds are used to extract the baseline correction which is typically ~ 1 mV.

Inspect some waveforms

```
In[314]:= ListPlot[Table[Transpose[{Transpose[Import[Namelist[[i]], "Data"]][[1]],
  Transpose[Import[Namelist[[i]], "Data"]][[2]]}], {i, 1, 150}],
  PlotRange → {{-0.000000002, .000000006}, {- .6, .5}}, Joined → True]
```



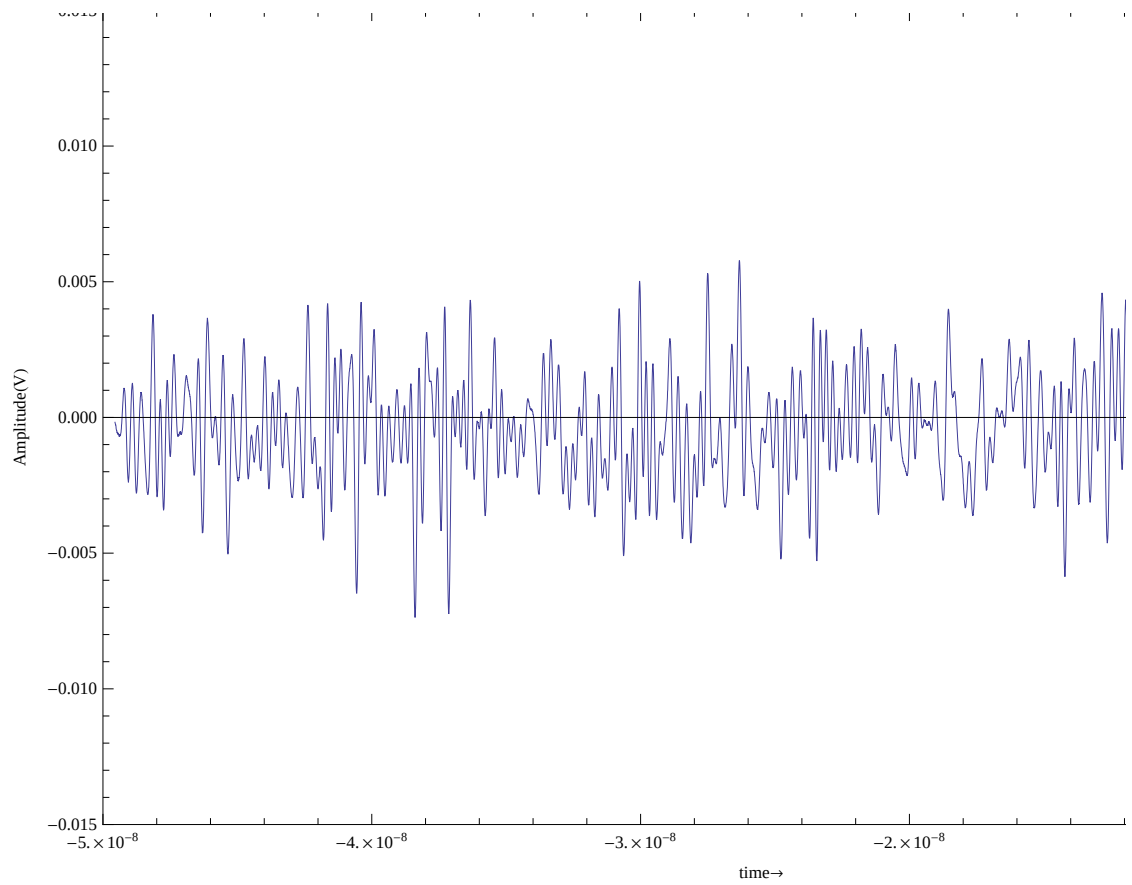
```
In[348]:= ListPlot[Table[Transpose[{Transpose[Import[Namelist[[i]], "Data"]][[1]],
  Transpose[Import[Namelist[[i]], "Data"]][[3]]}], {i, 1, 100}],
  PlotRange → {{-0.000000002, .000000006}, {- .25, .2}}, Joined → True]
```



```
In[316]:= offfront = ConstantArray[offset, 15986];
front1 = Take[front - offfront, 7693];
time1 = Take[time, 7693];
time2 = Drop[time1, -7460];
back = Transpose[Import[Namelist[[itrace]], "Data"]][[3]];
offset = Mean[Take[back, 7693]]
offback = ConstantArray[offset, 15986];
back1 = Take[back - offback, 7693];
GraphicsColumn[{ListPlot[Transpose[{time, front}], Joined → True, Frame → True,
  FrameLabel → {"Amplitude(V)", }, {"time→", "Noise(front)"}},
  PlotRange → {{-0.000000005, -0.000000001}, {- .015, .015}}],
  ListPlot[Transpose[{time, back}], Joined → True, Frame → True,
  FrameLabel → {"Amplitude(V)", }, {"time→", "Noise(back)"}},
  PlotRange → {{-0.000000005, -0.000000001}, {- .015, .015}}]]]
```

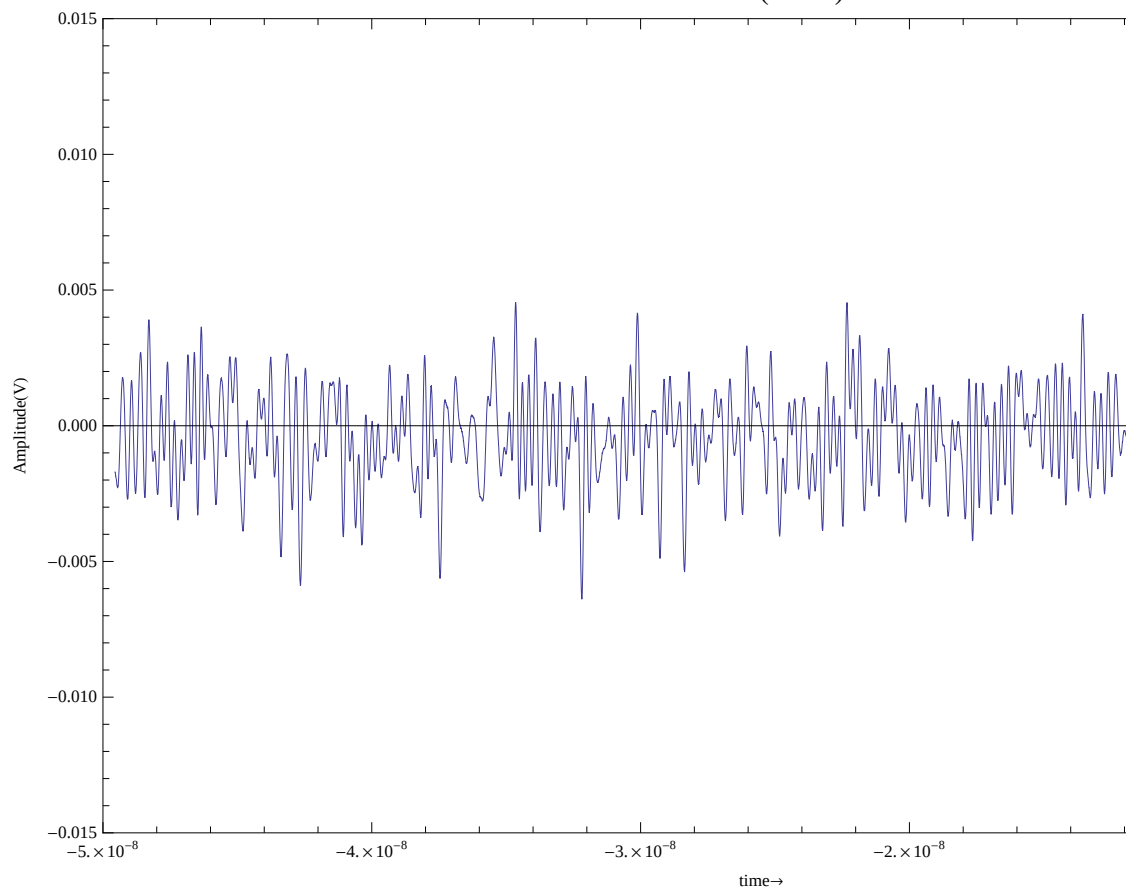
Out[321]= -0.000401331





Out[324]=

Noise(back)




```
In[325]:= dt = time[[2]] - time[[1]] // EngineeringForm
f = 1 / (time[[2]] - time[[1]]);
fftrange = f / 2
```

```
Out[325]//EngineeringForm=
6.2 × 10-12
```

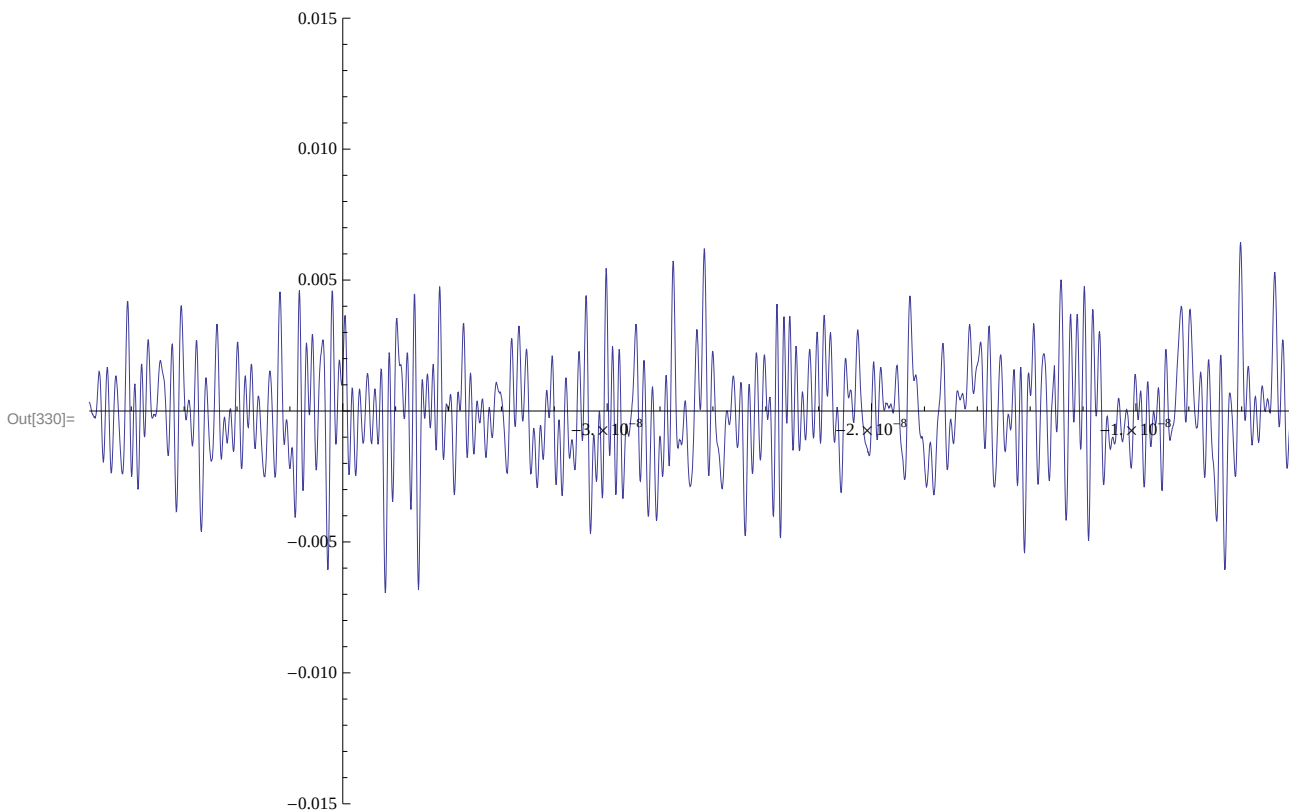
```
Out[327]= 8.06452 × 1010
```

Noise Waveform as a function for later use

```
In[328]:= Ff = Interpolation[Transpose[{time1, front1}], Method → "Spline"]
Fb = Interpolation[Transpose[{time1, back1}], Method → "Spline"]
Plot[Ff[x], {x, -4.9586 × 10-8, -1.5117 × 10-9},
PlotRange → {{-4.9586 × 10-8, -1.5117 × 10-9}, {- .015, .015}}]
```

```
Out[328]= InterpolatingFunction[{{-4.95526 × 10-8, -1.4776 × 10-9}}, <>]
```

```
Out[329]= InterpolatingFunction[{{-4.95526 × 10-8, -1.4776 × 10-9}}, <>]
```



```
In[331]:= fftout1 = Abs[FourierDCT[front1]];
df = fftrange / 7693;

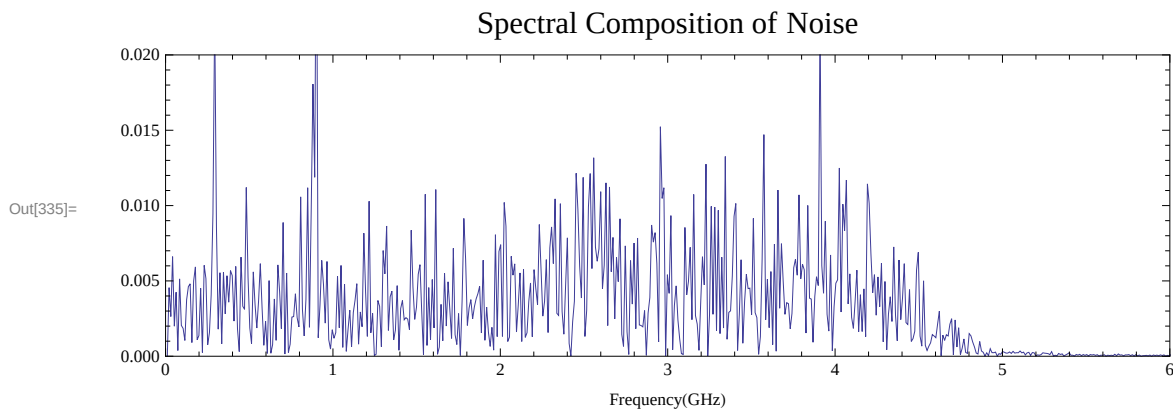
In[333]:= freq = Range[df, fftrange, df] / 1000000000.;

In[334]:= fftnew = Transpose[{freq, fftout1}];
```

For this scope the Sampling frequency is much higher than the actual bandwidth. Therefore in the plots below there is a white noise distribution out to a few GHz. Above this (the scope bandwidth) there is an apparent reduction in noise. But in this region data are really reflecting the fact that high sampling frequency is really a figment of 'on-chip'

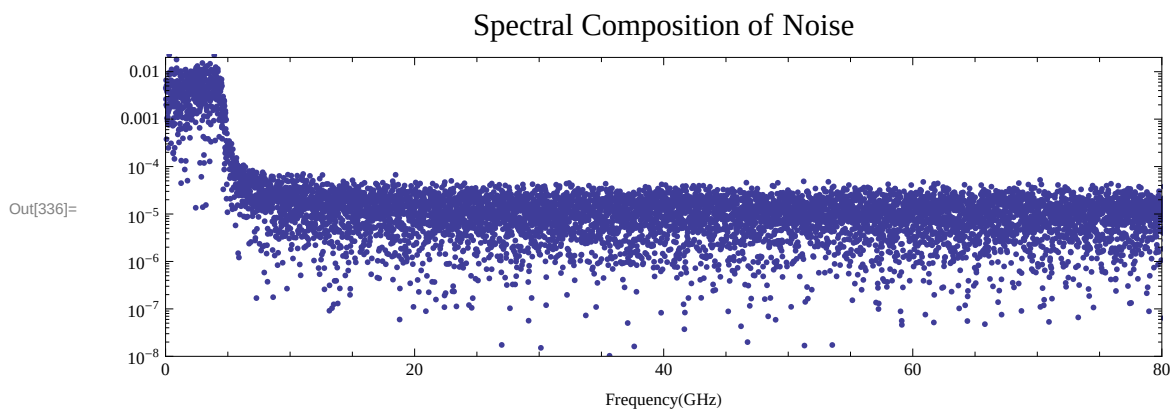
interpolation.

```
In[335]:= ListPlot[fftnew, Joined → True, AspectRatio → 0.3, ImageSize → Large, Frame → True,
  FrameLabel → {{}, {"Frequency (GHz)", "Spectral Composition of Noise"}},
  PlotRange → {{0, 6}, {0, .02}}]
```

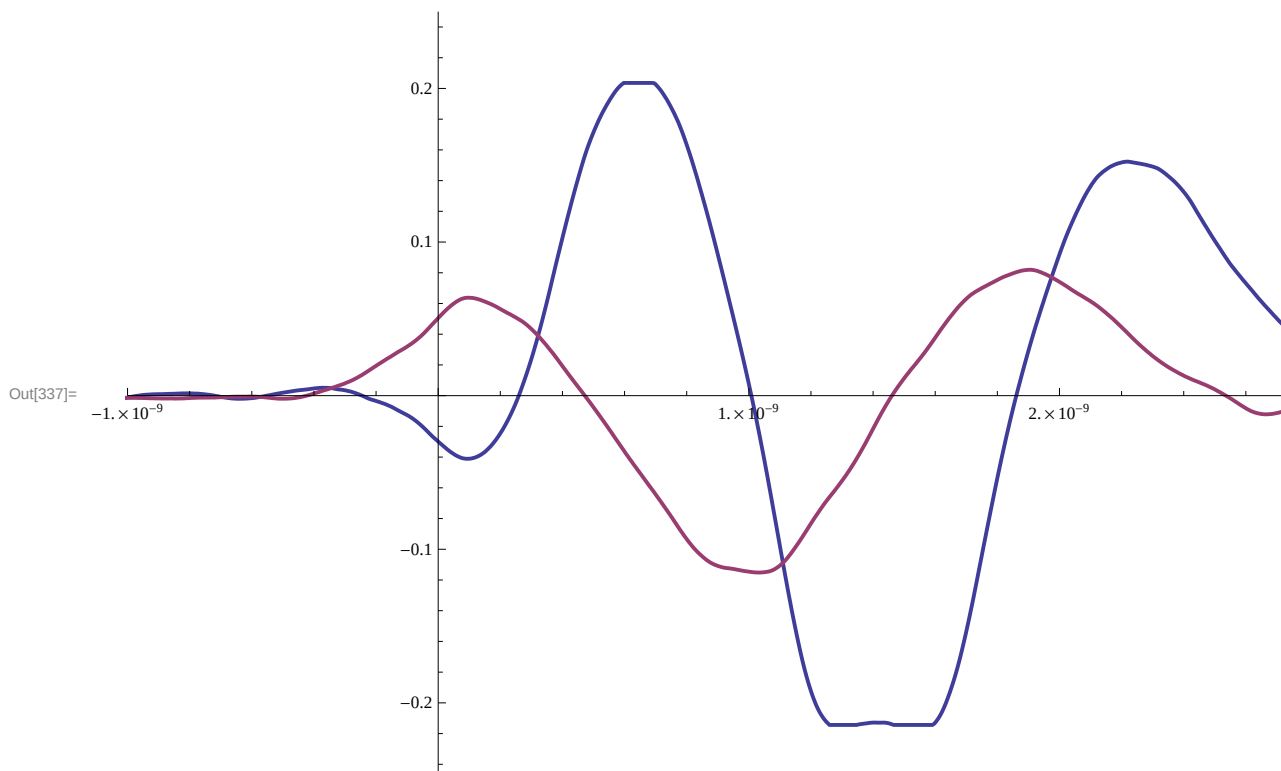


This has zero frequency in element 1. The 7693- th element corresponds to 1/2 the sampling frequency. After that aliasing takes over and the frequency heads back to zero.

```
In[336]:= ListLogPlot[fftnew, AspectRatio → 0.3, Frame → True,
  FrameLabel → {{}, {"Frequency (GHz)", "Spectral Composition of Noise"}},
  ImageSize → Large, PlotRange → {{0, 80}, {10-8, .02}}]
```



```
In[337]:= ListPlot[{Transpose[{time, front - offfront}], Transpose[{time, back - offback}]},
  Joined → True, PlotStyle → Thick, PlotRange → {{-10-9, .3 × 10-8}, {- .25, .25}}]
```



```
In[352]:= Wf = ConstantArray[0, 1000];
Wb = ConstantArray[0, 1000];
time = Transpose[Import[Namelist[[1]], "Data"]][[1]];
time2 = Drop[Drop[time, 7693], -7460];
Dimensions[time2]
```

Out[356]= {833}

```
In[357]:= Do[
  Clear[front, front2, back, back2];
  front = Transpose[Import[Namelist[[itrace]], "Data"]][[2]];
  front2 =
    Drop[Drop[front - ConstantArray[Mean[Take[front, 7693]], 15986], 7693], -7460];
  Wf[[itrace]] = Interpolation[Transpose[{time2, front2}], Method → "Spline"];
  back = Transpose[Import[Namelist[[itrace]], "Data"]][[3]];
  back2 = Drop[Drop[back - ConstantArray[Mean[Take[back, 7693]], 15986], 7693], -7460];
  Wb[[itrace]] = Interpolation[Transpose[{time2, back2}], Method → "Spline"];
  , {itrace, 100}]
```

```
In[363]:= Zeroesb = x /. FindRoot[Wb[[#]][x], {x, -0.2 × 10-9}] & /@ Range[100];
```

FindRoot::lstol :

The line search decreased the step size to within tolerance specified by AccuracyGoal and PrecisionGoal but was unable to find a sufficient decrease in the merit function. You may need more than MachinePrecision digits of working precision to meet these tolerances. >>

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The line search decreased the step size to within tolerance specified by AccuracyGoal and PrecisionGoal but was unable to find a sufficient decrease in the merit function. You may need more than MachinePrecision digits of working precision to meet these tolerances. >>

FindRoot::lstol :

The line search decreased the step size to within tolerance specified by AccuracyGoal and PrecisionGoal but was unable to find a sufficient decrease in the merit function. You may need more than MachinePrecision digits of working precision to meet these tolerances. >>

General::stop : Further output of FindRoot::lstol will be suppressed during this calculation. >>

```
In[364]:= Zeroesf = x /. FindRoot[Wf[[#]][x], {x, 0.1 × 10-9}] & /@Range[100];
```

```
In[365]:= Print[Zeroesf]
```

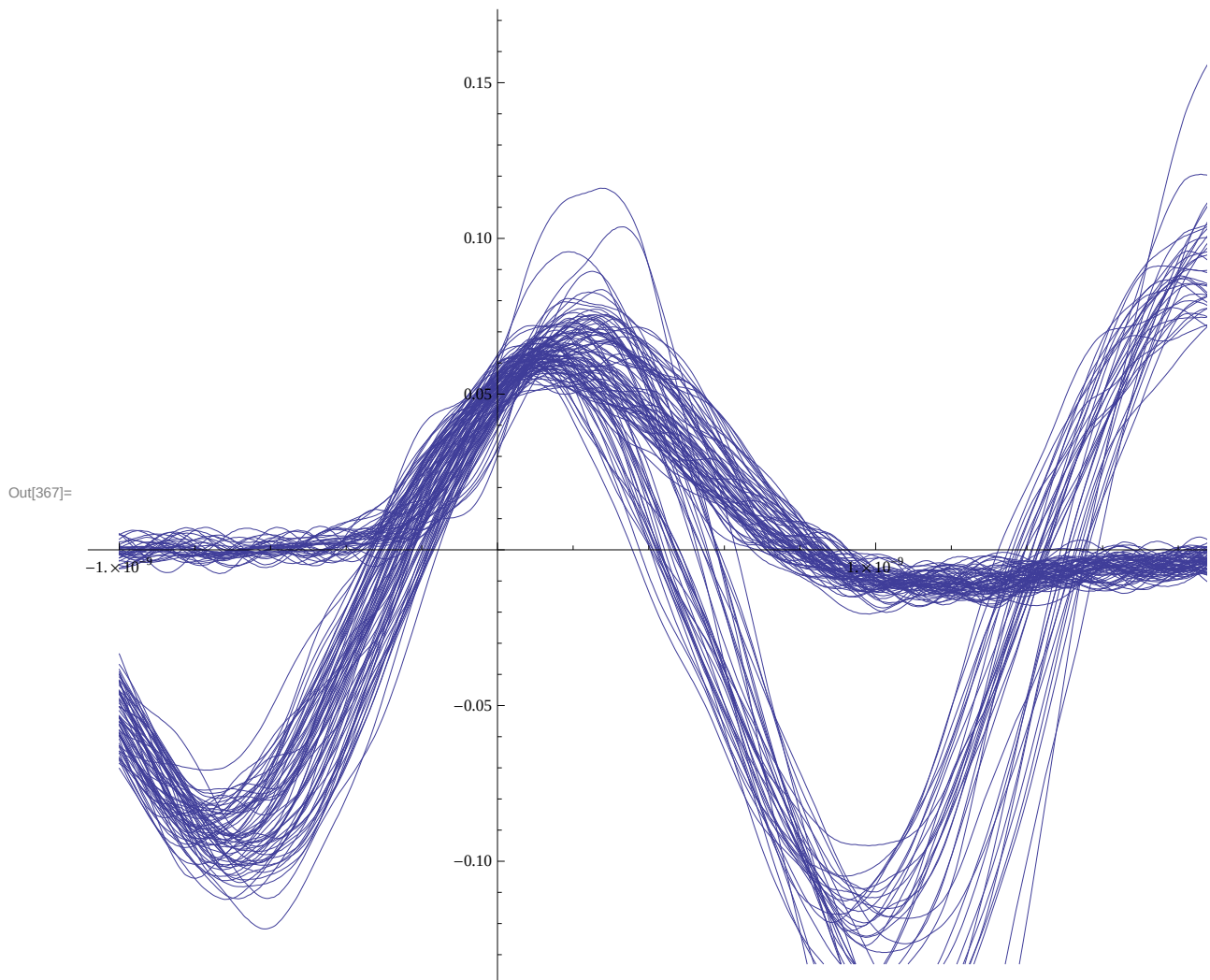
```
{2.59585 × 10-10, -8.3846 × 10-11, 1.44583 × 10-10, 1.68224 × 10-10, 1.49622 × 10-10,
1.0606 × 10-10, 2.26036 × 10-10, 9.58298 × 10-12, 5.12614 × 10-11, 2.6785 × 10-10,
5.98113 × 10-11, -2.27201 × 10-10, 2.402 × 10-11, 1.58444 × 10-10, 1.74181 × 10-10,
1.09305 × 10-11, 1.70579 × 10-10, 8.69782 × 10-11, 1.48309 × 10-10, 1.03022 × 10-10,
3.85697 × 10-11, 1.89211 × 10-10, 1.38779 × 10-10, -3.02762 × 10-11, -4.00967 × 10-11,
8.02981 × 10-11, 9.16954 × 10-10, 1.54525 × 10-10, -8.31451 × 10-11, -7.07058 × 10-10,
9.57899 × 10-11, -1.94793 × 10-10, 1.80718 × 10-10, -1.99055 × 10-10, 1.01285 × 10-10,
-5.74593 × 10-10, 8.14686 × 10-11, 3.88412 × 10-11, 1.55094 × 10-10, -2.03717 × 10-10,
-1.74657 × 10-10, 1.99297 × 10-10, 6.37107 × 10-11, 3.16786 × 10-11, -3.16199 × 10-10,
-3.6474 × 10-10, 1.72595 × 10-10, 1.31668 × 10-10, -1.17385 × 10-9, 1.01593 × 10-10,
9.66481 × 10-11, 1.71961 × 10-10, 8.45867 × 10-11, -1.3019 × 10-10, 7.97938 × 10-11,
-2.16076 × 10-10, -1.4841 × 10-11, 8.72567 × 10-11, 3.92861 × 10-11, 7.54441 × 10-11,
2.17522 × 10-10, 9.00102 × 10-11, 5.95548 × 10-11, 6.02125 × 10-11, 9.25816 × 10-11,
8.51858 × 10-11, 2.0678 × 10-10, 5.53916 × 10-11, -1.46742 × 10-9, -5.28527 × 10-10,
2.71371 × 10-10, 1.84875 × 10-10, 1.22152 × 10-10, -3.3169 × 10-10, 1.12927 × 10-10,
1.32485 × 10-10, 1.16522 × 10-10, 9.49781 × 10-11, 2.09947 × 10-10, 2.92104 × 10-9,
-2.20112 × 10-10, 1.76926 × 10-9, 1.16492 × 10-10, 1.66921 × 10-10, -7.91695 × 10-11,
1.0803 × 10-10, 2.98662 × 10-9, -8.46161 × 10-11, 8.20152 × 10-11, 1.40354 × 10-10,
-1.32782 × 10-10, 9.63853 × 10-11, 1.28799 × 10-10, 1.20473 × 10-10, -8.16324 × 10-11,
1.28716 × 10-10, 1.26664 × 10-10, -1.09761 × 10-11, -6.11505 × 10-11, -1.77683 × 10-10}
```

```
Zeroesf = x /. FindRoot[Wf[[#]][x], {x, 0.5 × 10-9}] & /@Range[20];
```

```
In[366]:= Print[Zeroesb]
```

```
{-4.2324 × 10-10, -4.74167 × 10-10, -2.23405 × 10-10, -1.84708 × 10-10, -1.96312 × 10-10,
-2.41483 × 10-10, -1.68271 × 10-10, -3.37007 × 10-10, -3.24358 × 10-10, -1.80524 × 10-10,
-3.05526 × 10-10, -4.71934 × 10-10, -3.39042 × 10-10, -2.23991 × 10-10, -1.79434 × 10-10,
-3.42106 × 10-10, -1.80207 × 10-10, -2.75272 × 10-10, -1.87628 × 10-10, -2.47399 × 10-10,
-2.98797 × 10-10, -1.70254 × 10-10, -2.29586 × 10-10, -1.31833 × 10-9, -5.21944 × 10-10,
-2.72012 × 10-10, -7.64261 × 10-10, -2.25818 × 10-10, -5.68035 × 10-10, -7.21873 × 10-10,
-2.83679 × 10-10, -3.91768 × 10-10, -2.35809 × 10-10, -6.86959 × 10-10, -2.57923 × 10-10,
-6.5409 × 10-10, -2.77957 × 10-10, -3.26463 × 10-10, -2.84368 × 10-10, -5.11066 × 10-10,
-1.01028 × 10-9, -1.97242 × 10-10, -2.87685 × 10-10, -3.30901 × 10-10, -4.43566 × 10-10,
-5.51093 × 10-10, -2.11907 × 10-10, -2.35156 × 10-10, -5.43624 × 10-10, -2.63068 × 10-10,
-3.11293 × 10-10, -2.04085 × 10-10, -2.6191 × 10-10, -6.89623 × 10-10, -3.32515 × 10-10,
-5.29222 × 10-10, -2.63368 × 10-10, -2.41476 × 10-10, -3.13683 × 10-10, -2.89627 × 10-10,
-1.56691 × 10-10, -2.18778 × 10-10, -3.1044 × 10-10, -3.04848 × 10-10, -2.56372 × 10-10,
-3.06293 × 10-10, -1.84054 × 10-10, -2.82799 × 10-10, -1.00322 × 10-9, -5.30515 × 10-10,
-9.06845 × 10-10, -1.9256 × 10-10, -2.67788 × 10-10, -1.0314 × 10-9, -2.40271 × 10-10,
-2.07214 × 10-10, -2.3281 × 10-10, -3.0821 × 10-10, -1.72822 × 10-10, -5.1299 × 10-10,
-1.03708 × 10-9, -8.96169 × 10-10, -2.35826 × 10-10, -1.74459 × 10-10, -4.26385 × 10-10,
-2.85789 × 10-10, -3.57787 × 10-10, -5.98519 × 10-10, -2.92748 × 10-10, -2.05883 × 10-10,
-4.68696 × 10-10, -2.70234 × 10-10, -2.37542 × 10-10, -2.33955 × 10-10, -7.98033 × 10-10,
-2.53963 × 10-10, -2.23723 × 10-10, -2.39234 × 10-10, -3.15292 × 10-10, -1.34985 × 10-9}
```

In[367]:= **Plot**[**Table**[**Wb**[**[i]**][**x**], {**i**, **1**, **100**}], {**x**, -1×10^{-9} , $.3 \times 10^{-8}$ }



In[406]:= **Difference** = **Table**[(**Zeroesf**[**[i]**] - **Zeroesb**[**[i]**]), {**i**, **1**, **100**});
Histogram[**Difference**, { 0.3×10^{-9} , 0.42×10^{-9} , 0.015×10^{-9} }]

