

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]]

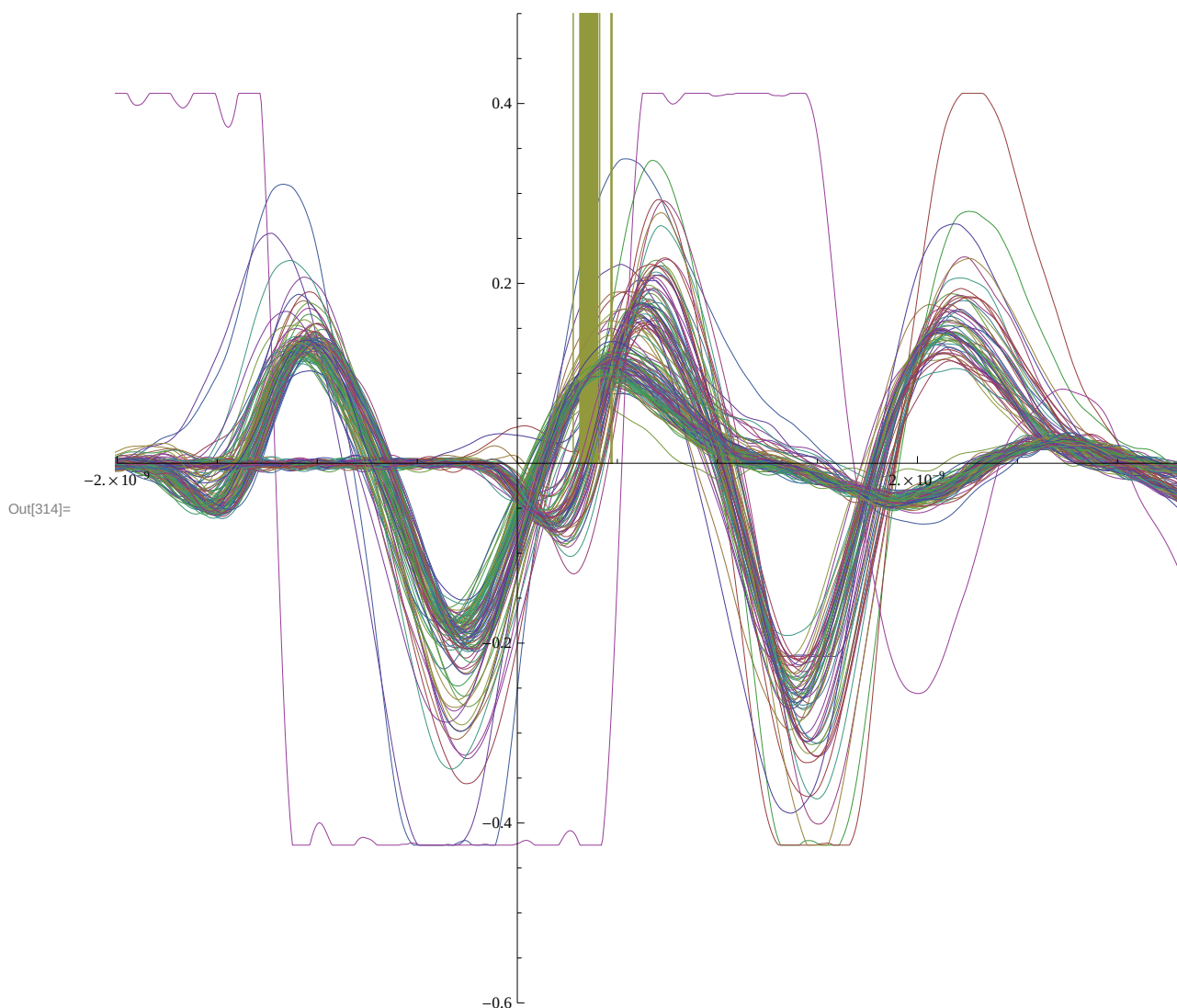
Out[313]= -0.000421501
```

Front and Back are the 2 APDs which face each other. Front is closest to the CO⁶⁰ source.

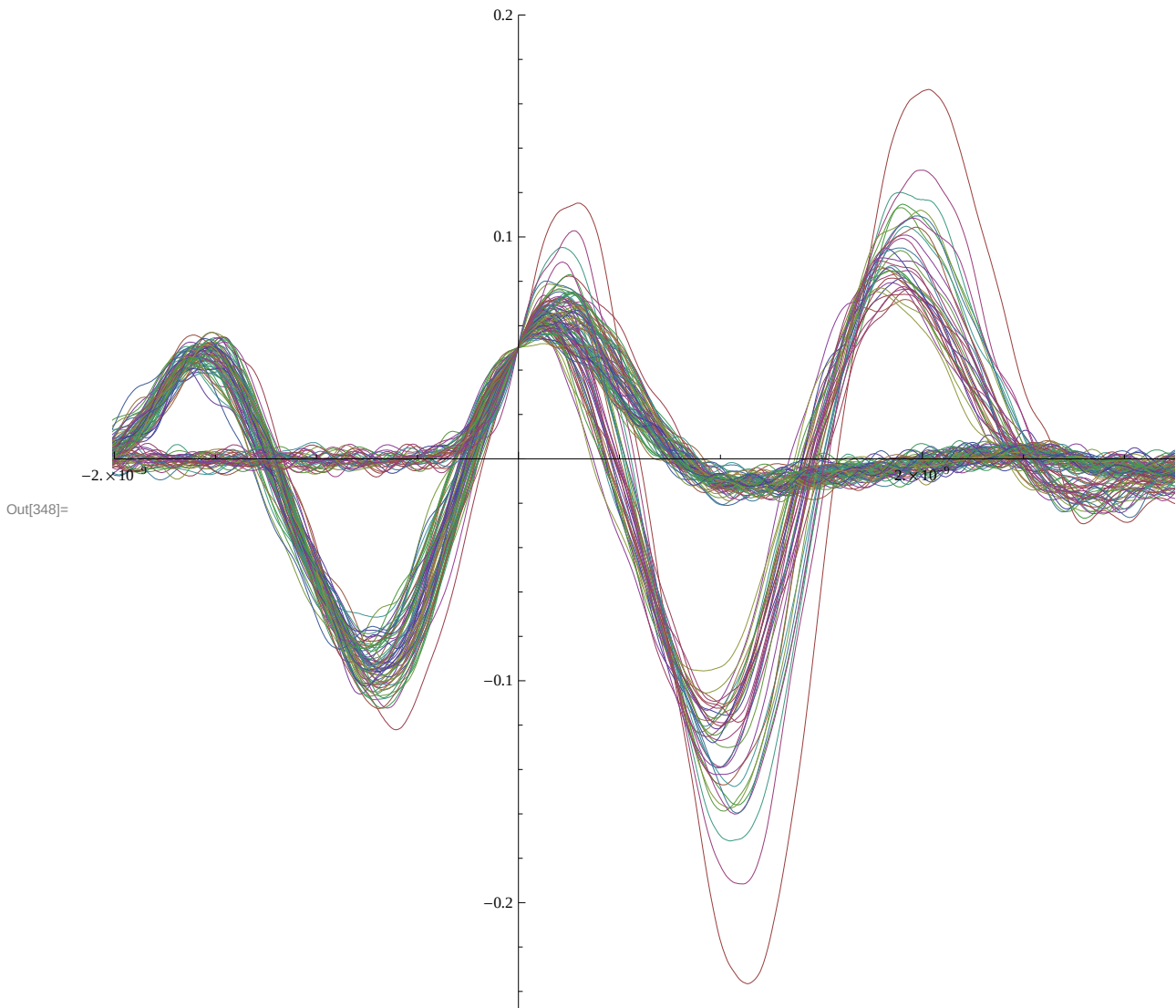
The first 49 nanoseconds are used to extract the baseline correction which is typically ~1 mV.

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]
```



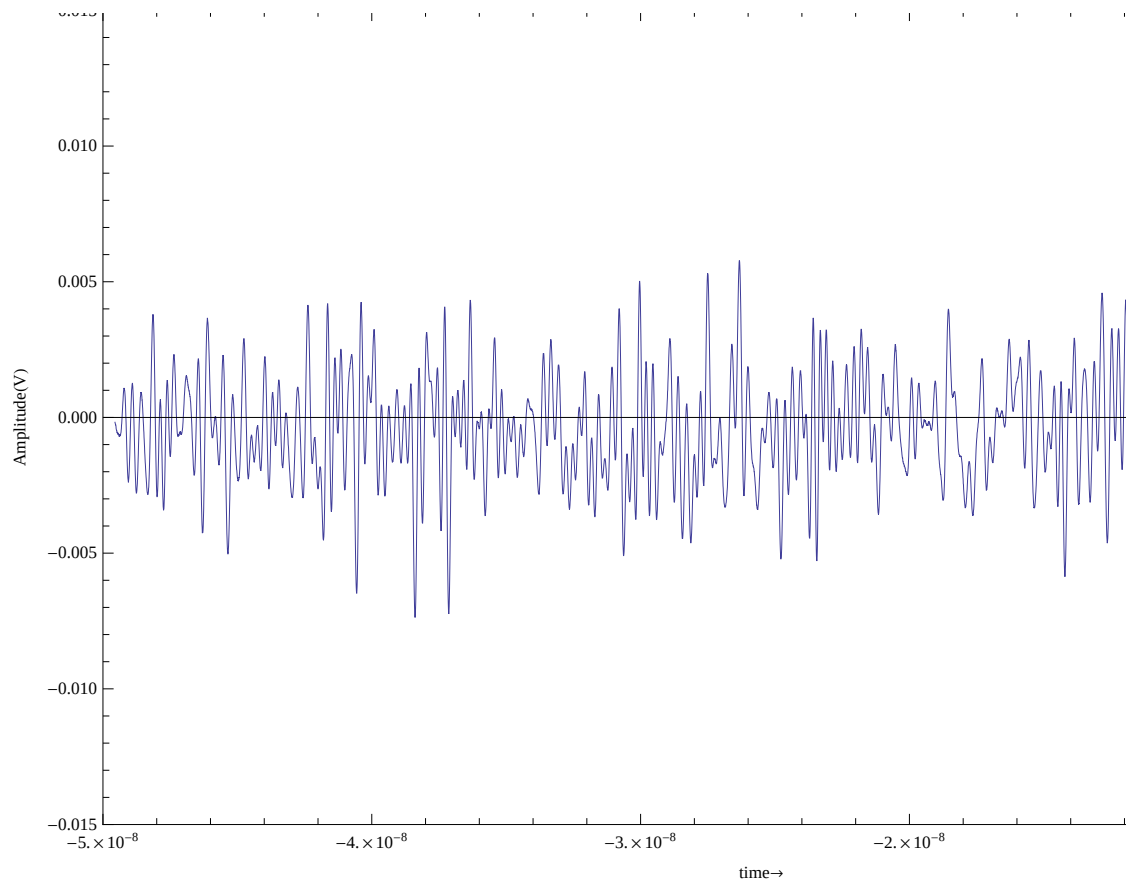
```
In[348]:= ListPlot[Table[Transpose[{Transpose[Import[Namelist[[i]], "Data"]][[1]],
  Transpose[Import[Namelist[[i]], "Data"]][[3]]}], {i, 1, 100}],
  PlotRange → {{-0.000000002, .000000006}, {- .25, .2}}, Joined → True]
```



```
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}}]]]
```

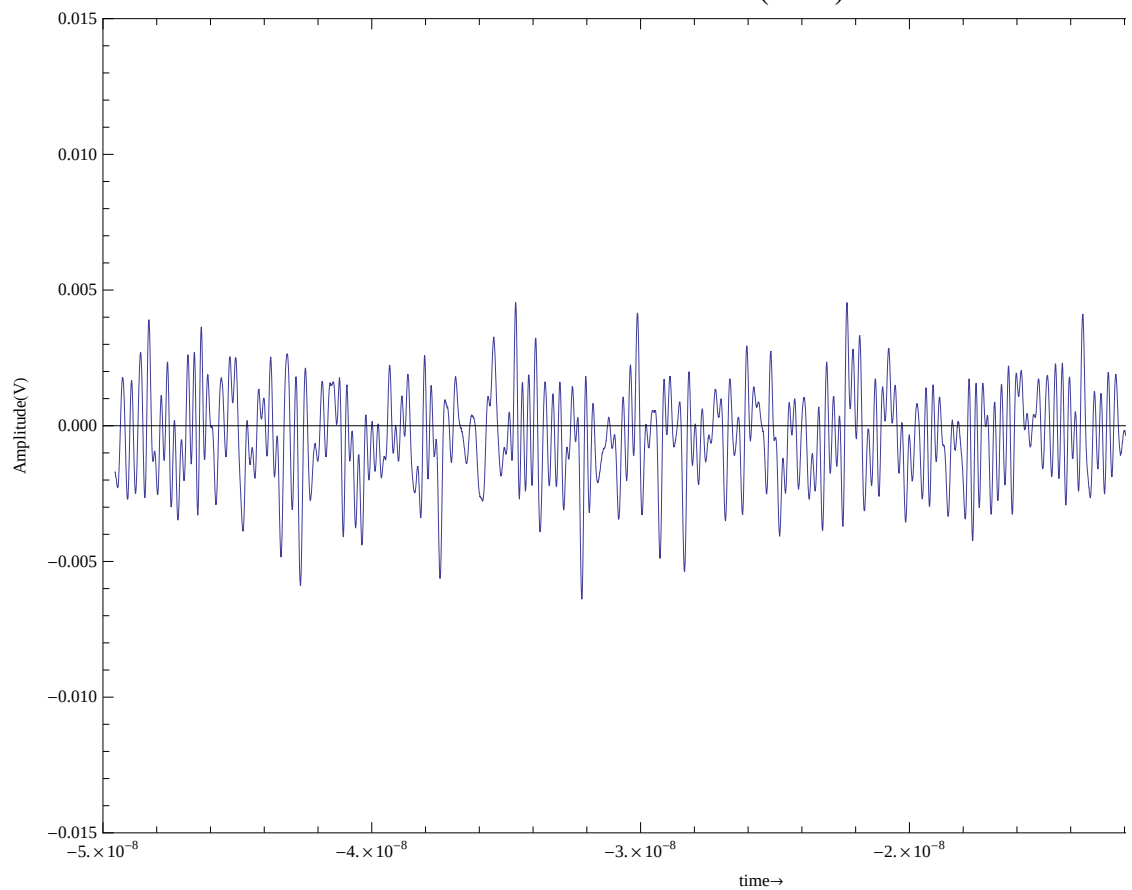
Out[321]= -0.000401331





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
```

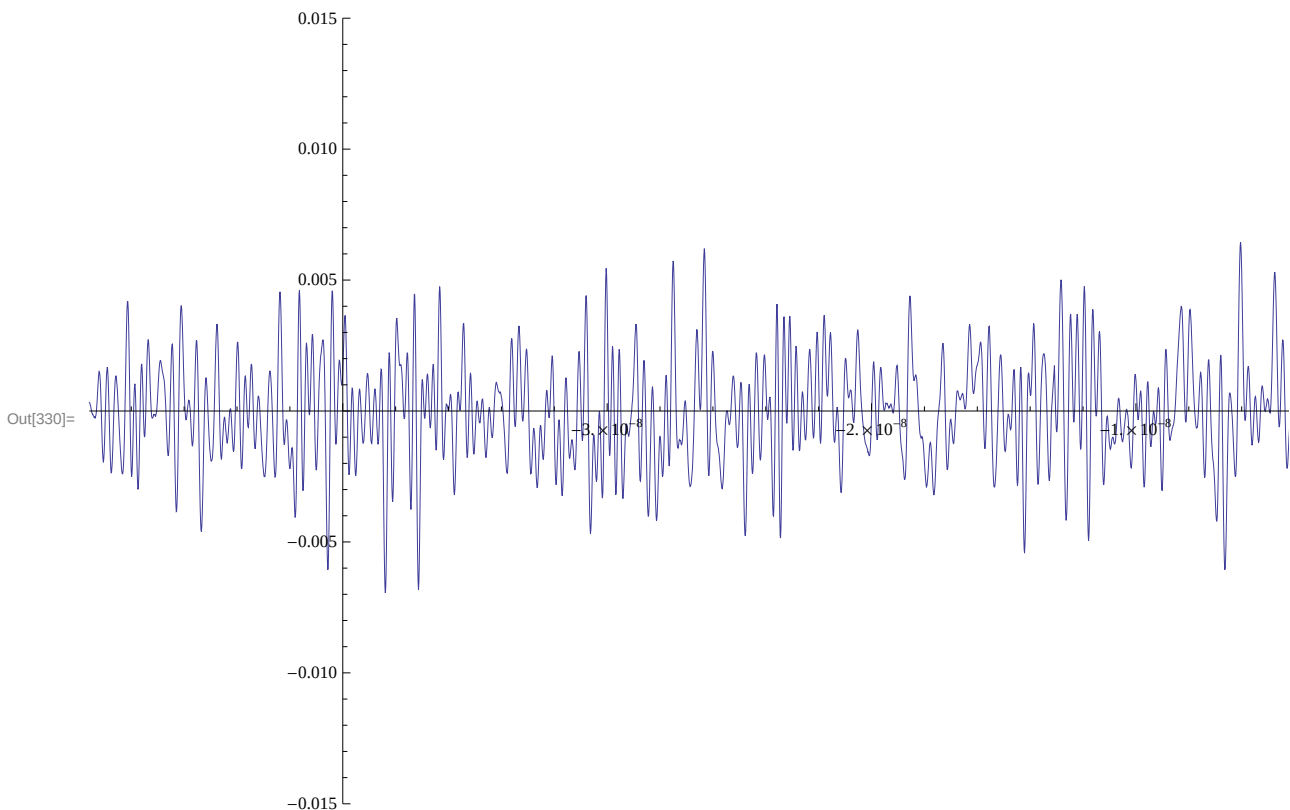
```
Out[327]= 8.06452 × 1010
```

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}}, <>]
```

```
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```



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

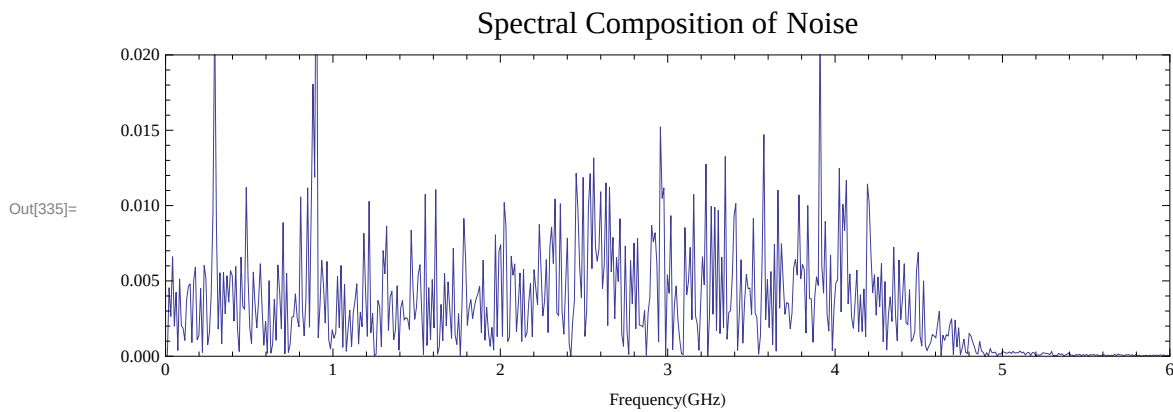
In[333]:= freq = Range[df, fftrange, df] / 1000000000.;

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'

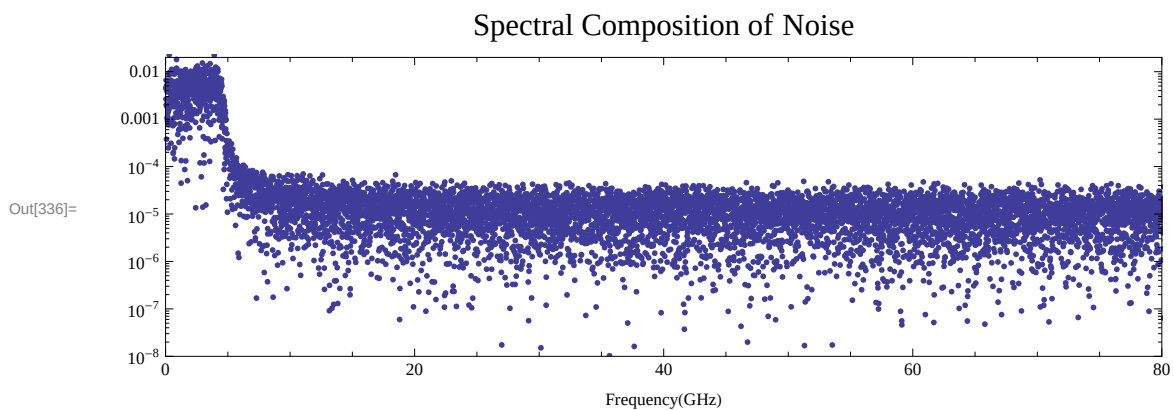
interpolation.

```
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}}]
```

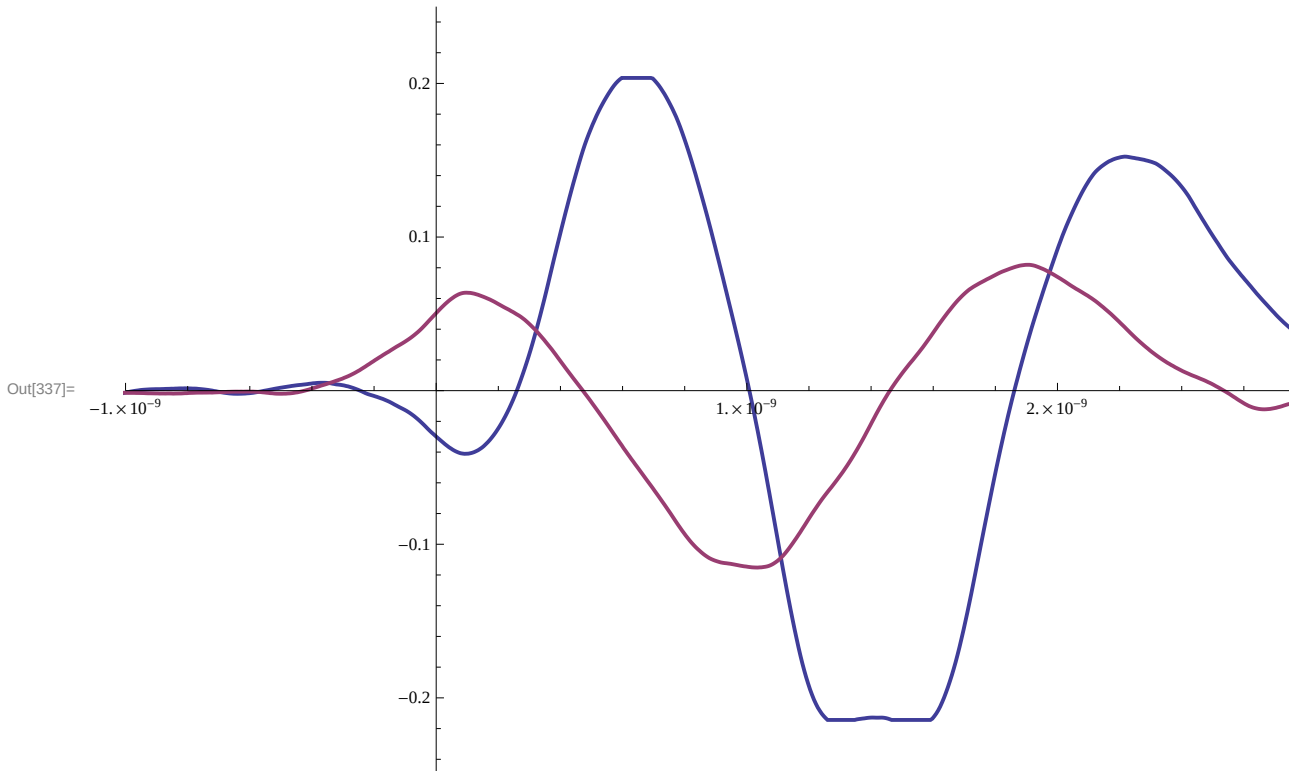


This has zero frequency in element 1. The 7693- th element corresponds to 1/2 the sampling frequency. After that aliasing takes over and the frequency heads back to zero.

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

Out[342]= {833}

```
In[343]:= 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];
  Dimensions[front2]
  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}]
```

Set::write : Tag Times in 0{833} is Protected. >>

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General::stop : Further output of Set::write will be suppressed during this calculation. >>

```
In[344]:= Zeroesb = x /. FindRoot[Wb[#][x], {x, 1.5 × 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. >>

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

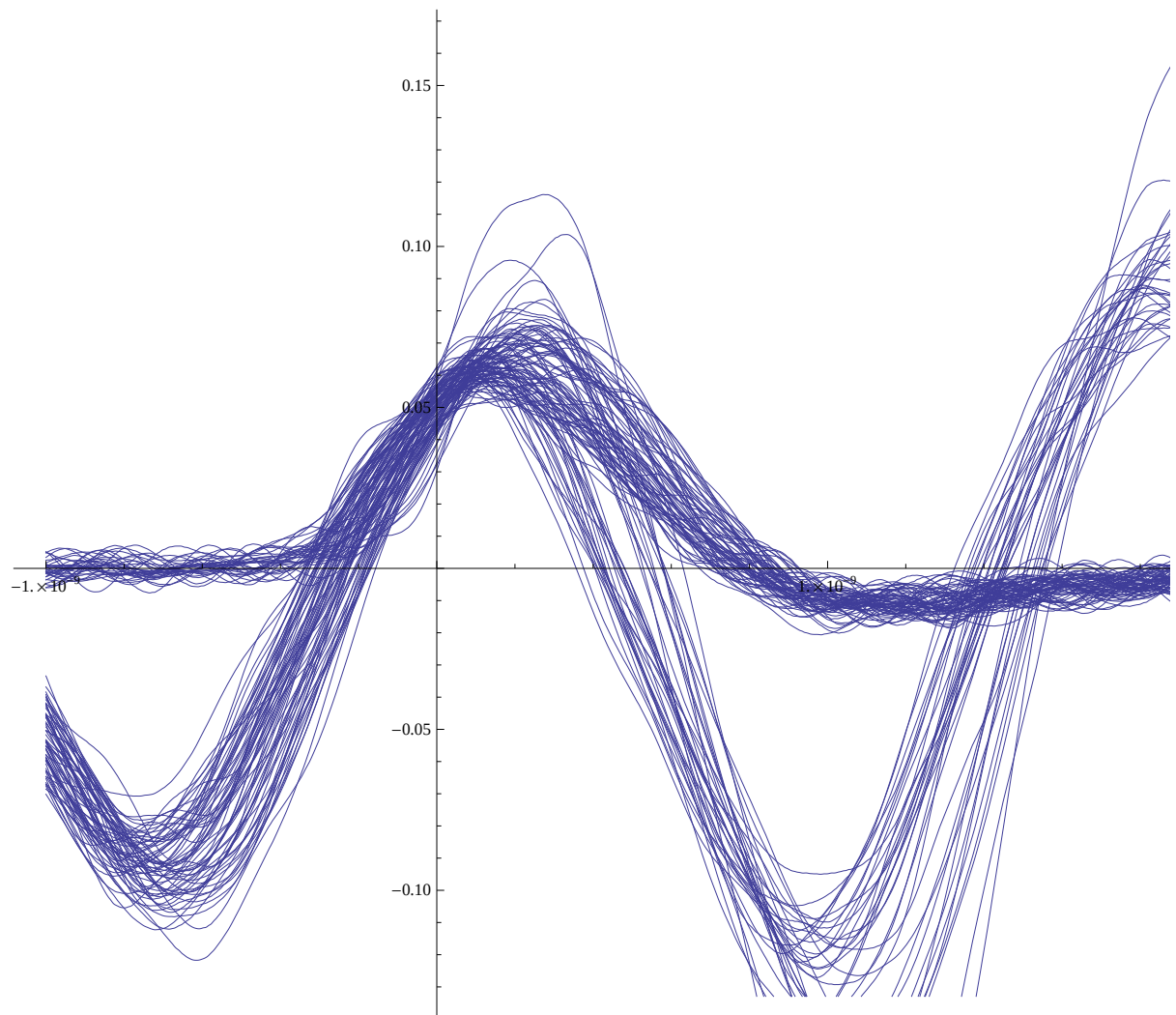
```
Zeroesf = x /. FindRoot[Wf[#][x], {x, 0.5 × 10-9}] & /@Range[20];
```

```
In[345]:= Print[Zeroesb]
```

```
{1.46078 × 10-9, 1.54817 × 10-9, 2.10616 × 10-9, 1.99682 × 10-9, 2.15407 × 10-9, 1.51983 × 10-9,
2.12157 × 10-9, 2.08321 × 10-9, 1.68169 × 10-9, 3.71854 × 10-9, 2.72426 × 10-9,
1.44425 × 10-9, 2.25535 × 10-9, 2.0987 × 10-9, 2.13261 × 10-9, 1.94282 × 10-9, 8.57411 × 10-10,
7.71207 × 10-10, 2.12484 × 10-9, 2.02241 × 10-9, 2.46739 × 10-9, 2.17915 × 10-9,
3.36154 × 10-9, 1.37058 × 10-9, 1.54138 × 10-9, 3.49517 × 10-9, 1.32467 × 10-9, 2.12151 × 10-9,
1.53243 × 10-9, 1.35085 × 10-9, 1.69487 × 10-9, 1.43264 × 10-9, 7.93765 × 10-10,
1.48943 × 10-9, 3.73216 × 10-9, 1.44678 × 10-9, 1.61033 × 10-9, 7.97889 × 10-10,
1.87608 × 10-9, 1.52661 × 10-9, 1.451 × 10-9, 2.16616 × 10-9, 6.97268 × 10-10, 2.01903 × 10-9,
1.3954 × 10-9, 1.42744 × 10-9, 1.8442 × 10-9, 2.05504 × 10-9, 1.55599 × 10-9, 1.93023 × 10-9,
2.08755 × 10-9, 3.1481 × 10-9, 2.11509 × 10-9, 1.43217 × 10-9, 7.29484 × 10-10, 1.41593 × 10-9,
1.58794 × 10-9, 2.32083 × 10-9, 2.53398 × 10-9, 1.88925 × 10-9, 2.78847 × 10-9,
2.72409 × 10-9, 1.68042 × 10-9, 1.92675 × 10-9, 2.03993 × 10-9, 1.81664 × 10-9,
2.03216 × 10-9, 1.79462 × 10-9, 1.37615 × 10-9, 1.45795 × 10-9, 1.38314 × 10-9,
2.31213 × 10-9, 1.89607 × 10-9, 1.39454 × 10-9, 2.7515 × 10-9, 2.1502 × 10-9, 2.27703 × 10-9,
2.16042 × 10-9, 3.6669 × 10-9, 1.36174 × 10-9, 1.45475 × 10-9, 1.39558 × 10-9, 8.5176 × 10-10,
2.39449 × 10-9, 1.50513 × 10-9, 2.06559 × 10-9, 1.4119 × 10-9, 1.51344 × 10-9, 1.94812 × 10-9,
1.52754 × 10-9, 1.44649 × 10-9, 2.913 × 10-9, 1.97884 × 10-9, 1.78808 × 10-9, 1.55046 × 10-9,
3.31739 × 10-9, 1.48271 × 10-9, 1.56064 × 10-9, 1.50418 × 10-9, 1.42679 × 10-9}
```

```
In[346]:= Plot[Table[Wb[[i]][x], {i, 1, 100}], {x, -1 × 10-9, .3 × 10-8}]
```

Out[346]=



In[347]:=