HF Sourcing: FFTs on Sourcing Data

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Thursday, June 12, 2014

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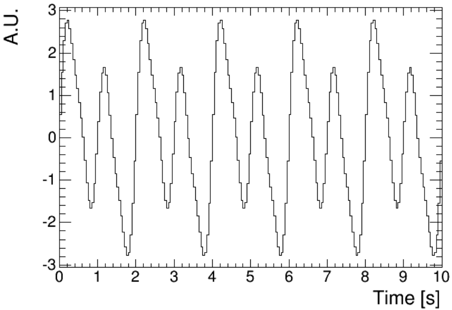
Fourier transforms reminder

- Fourier transform (FT) definition
  - $F(u) = \int_{-\infty}^{+\infty} f(t) e^{-2\pi i u t} dt$
- FTs have real and imaginary components
  - Real: $\mathcal{R}(F)$
  - Imaginary: $\mathcal{I}(F)$
- FTs have magnitude and phase in complex space:
  - Magnitude: $|F| = |\mathcal{R}(F)^2 + \mathcal{I}(F)^2|^{1/2}$
  - Phase: $\phi(F) = \tan^{-1} \frac{\mathcal{R}(\mathcal{F})}{\mathcal{I}(\mathcal{F})}$

Method

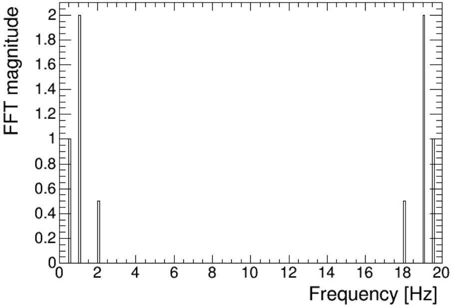
- Two very simple steps
  1. Use sine functions to test ROOT FFT software
  2. Use ROOT FFT software to analyze sourcing data
- All of this code is on git:
  1. Link to code for testing FFTs
  2. Link to code for running FFTs on sourcing data

FFT test on sine functions



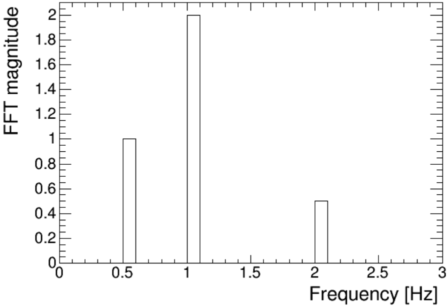
- Fill a histogram using linear combo of sine functions:
  - $f(t) = \sum_{i=0}^{3} A_i \cdot \sin(2\pi \cdot f_i \cdot t)$
  - $A_i = \{1.0, 2.0, 0.5\}$ [A.U.]
  - $f_i = \{0.5, 1.0, 2.0\}$ [Hz]

Look at magnitude of FFT



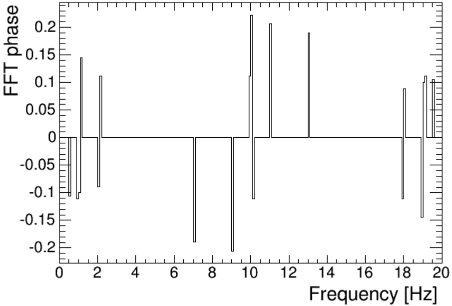
- Recall original linear combo of sine functions:
  - $f(t) = \sum_{i=0}^{3} A_i \cdot \sin(2\pi \cdot f_i \cdot t)$
  - $A_i = \{1.0, 2.0, 0.5\}$ [A.U.]
  - $f_i = \{0.5, 1.0, 2.0\}$ [Hz]

Look at magnitude of FFT (left side of function)



- Magnitude (even function) returns A_i and f_i
  - $f(t) = \sum_{i=0}^{3} A_i \cdot \sin(2\pi \cdot f_i \cdot t)$
  - $A_i = \{1.0, 2.0, 0.5\}$ [A.U.]
  - $f_i = \{0.5, 1.0, 2.0\}$ [Hz]

Look at phase of FFT



- Phase information not useful for our purposes...
  - $f(t) = \sum_{i=0}^{3} A_i \cdot \sin(2\pi \cdot f_i \cdot t)$
  - $A_i = \{1.0, 2.0, 0.5\}$ [A.U.]
  - $f_i = \{0.5, 1.0, 2.0\}$ [Hz]

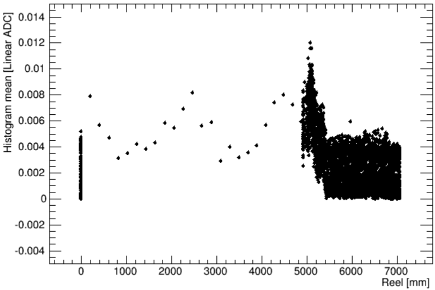
Conclusion of test:

- Can use ROOT FFT software
- ROOT FFT software can reconstruct parameters of sines
    - FT magnitude contains useful information for analysis
    - FT phase not useful for this analysis (?)
    - Can use FT phase to reconstruct original function (inverse FFT)
- Ready to try sourcing data

Look at sourcing data

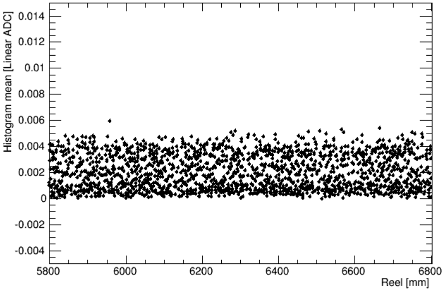
- histogram name:
  "`HFP13_ETA38_PHI25_T10_SRCTUBE_`
  `Ieta38_Iphi25_Depth2`
  `Run 221509reelPosition`"
- *x*-axis: Reel [mm]
- *y*-axis: Histogram mean [linear ADC]

Look at sourcing data: full range of reel vals



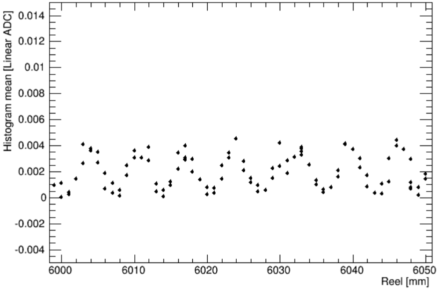
- Next: focus on reel ϵ $[5800, 6800]$ [mm], where amplitude is stable

Look at sourcing data: zoomed reel vals (TGraph)



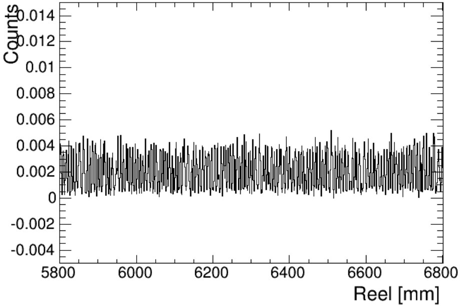
- This looks stable. We can do our FFT on this data.
- Next: zoom in even further ($[6000, 6050]$) to see what frequency we suspect naively

Look at sourcing data: zoomed reel vals (TGraph)



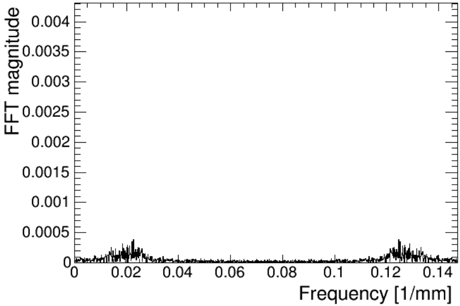
- 7 troughs in 50mm:
  - $T = 50\ [\mathrm{mm}]/7 = 7.14\ [\mathrm{mm}]$
  - $f = 1/T = 0.14\ [1/\mathrm{mm}]$
- Only a naive guess for the frequency!

Look at sourcing data: zoomed reel vals (TH1F)



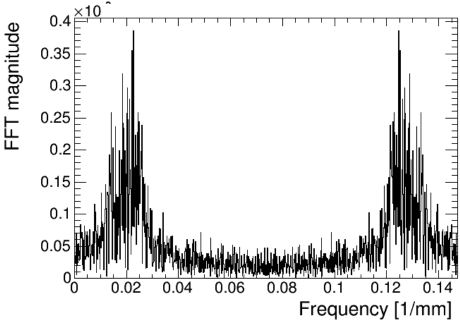
- Now make a histogram from the TGraph (result above)
  - If multiple points in TGraph have the same x-value, use their mean y-value on y-axis for histogram
- Next: do FFT on this histogram

Look at sourcing data: FFT magnitude



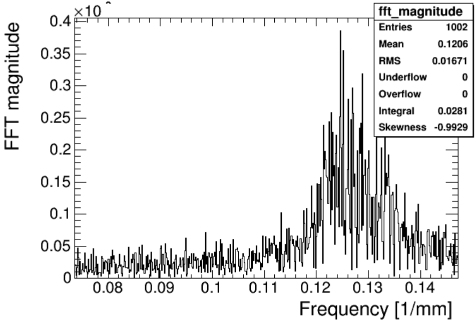
- Magnitude at zero is very large, because *y*-values of the original histogram are not centered at zero
- Next: remove bin at Frequency = 0

Look at sourcing data: FFT magnitude, no first bin



- Now we can see the structure of the FFT magnitude
- Next: consider only the upper "half" of the magnitude's range

Look at sourcing data: FFT magnitude, upper half



- FFT magnitude peaks between “reel frequency” (in [1/mm]) of 0.12 and 0.13
- Roughly matches our naive guess (0.14)

Conclusion

- We can use ROOT software to do FFTs
  - Tests done on sine waves in time / frequency space
  - Prelim. results on data in reel / "reel frequency" space
- Prelim. results show peak in "reel frequency"
  - Around 0.12 - 0.13 [1/mm]
- Would be nice to repeat the study on sourcing data in time (OrN)
  - Need plots for this