A Long-Duration Balloon Experiment

Payload for Ultrahigh Energy Observations (PUEO)

Last edited: 2025-09-24

Overview of the Experiment

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The Mission

- The impulsive radio signals mentioned earlier could be produced by ultrahigh energy neutrinos (above 10^{17} eV)

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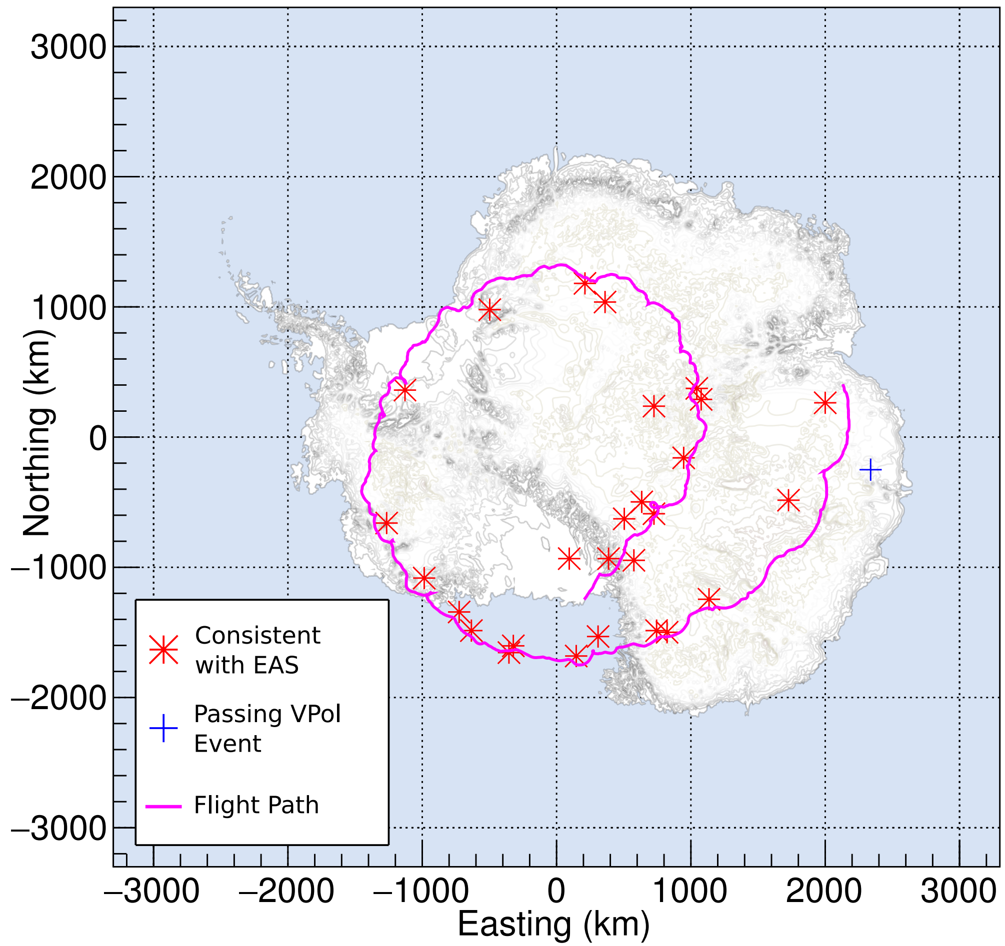

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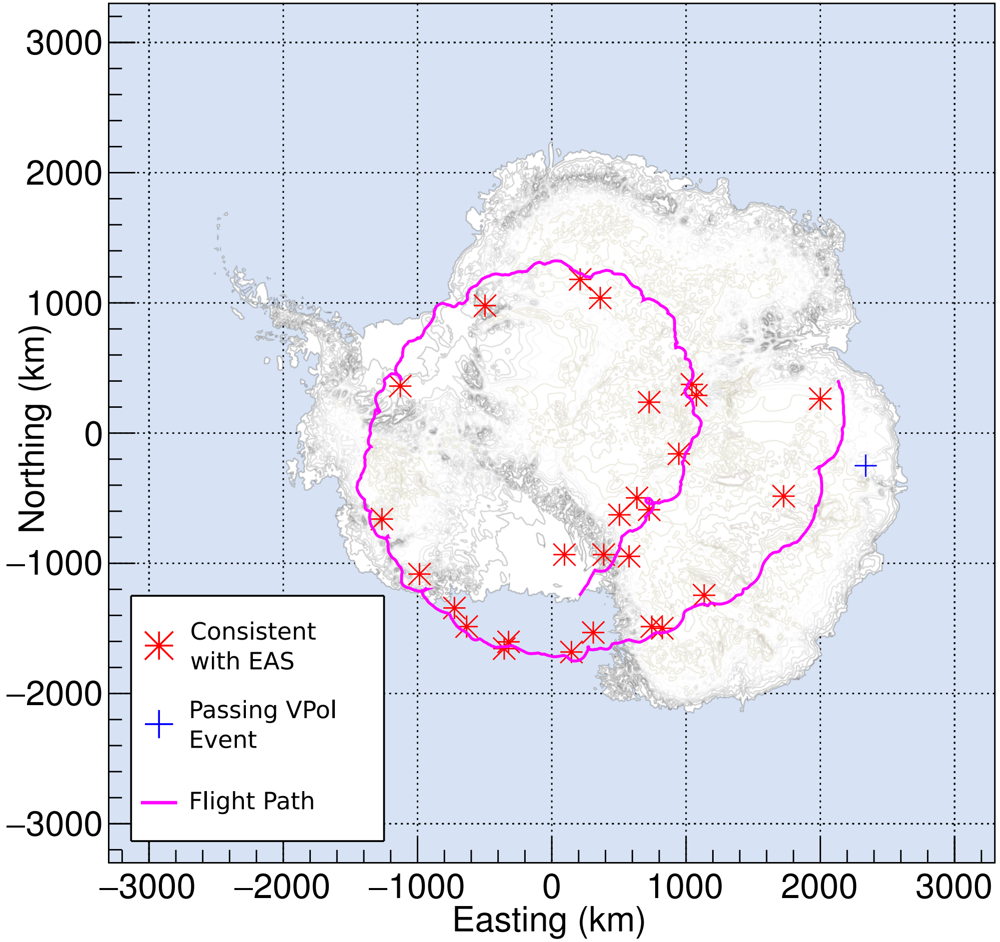

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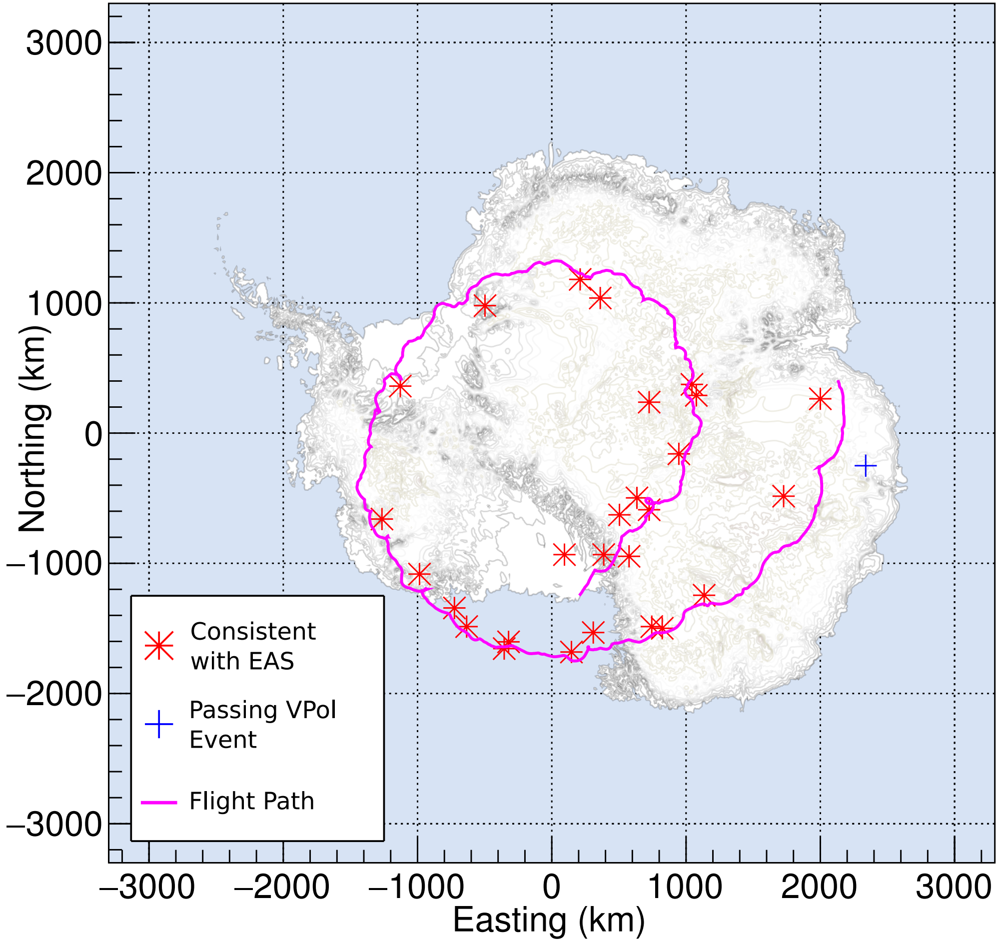

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- A3 at any one time surveyed a ~600-km-radius disk. Assuming ice depth ~1 km, the detection volume is about 1 million km^3.

Why Neutrino?

The Neutrino as a Messenger

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- In other words, we can "see" the world through neutrinos, provided that we can (1) detect them, and (2) figure out their directions.

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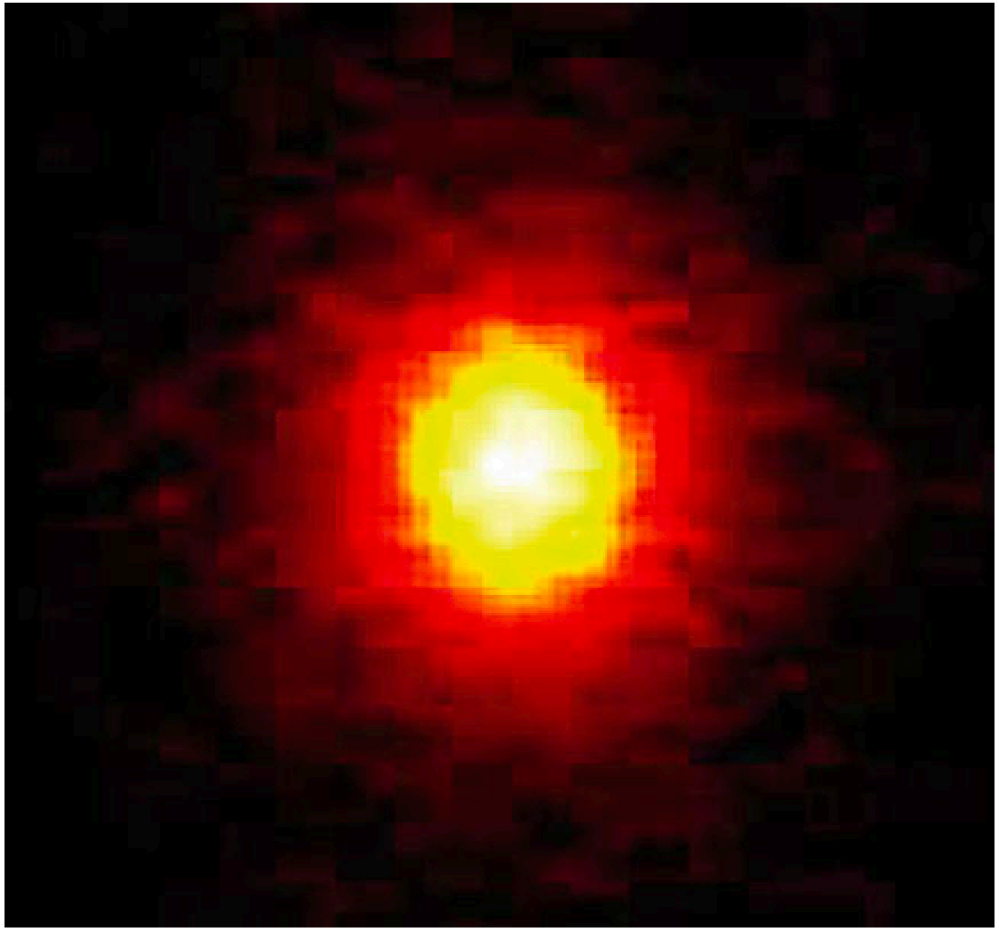

Figure 1: A picture of our sun, taken by the Super-Kamiokande neutrino detector

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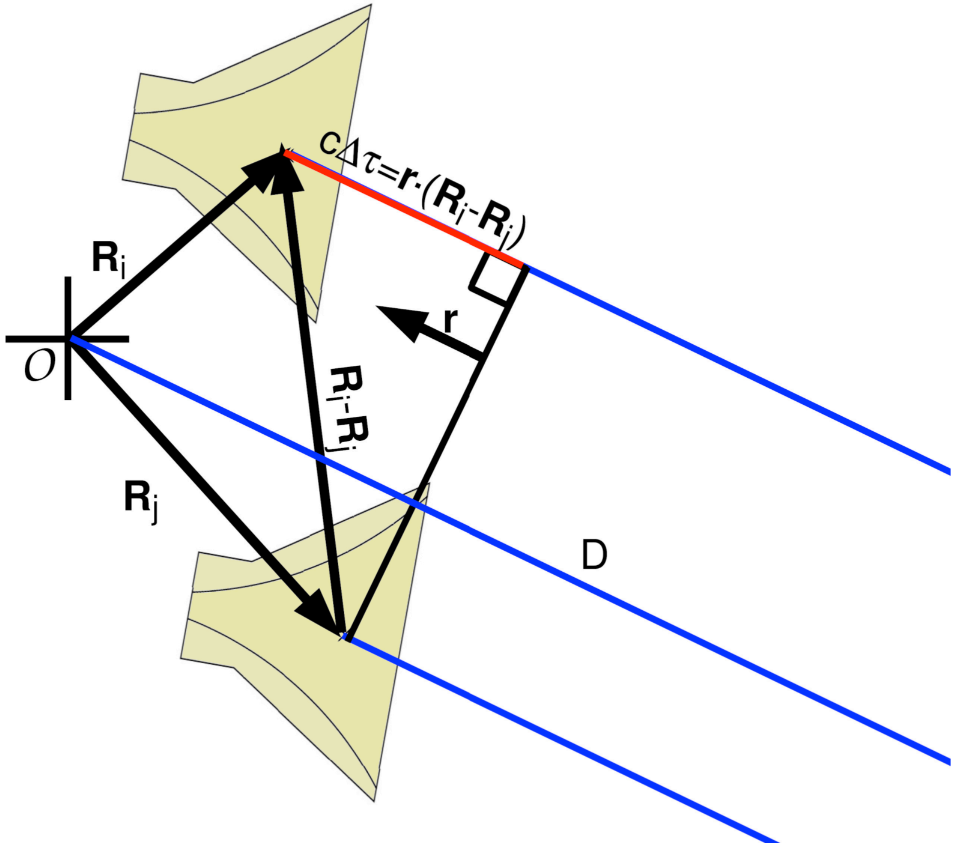
Direction Reconstruction: PUEO

Signal Delay: Some Trig



- Consider two antennas
  - $\boldsymbol{R_i}$ and $\boldsymbol{R_j}$ denote the locations of a generic pair of antennas.
  - $\boldsymbol{R_i} - \boldsymbol{R_j}$ denotes the displacement vector.

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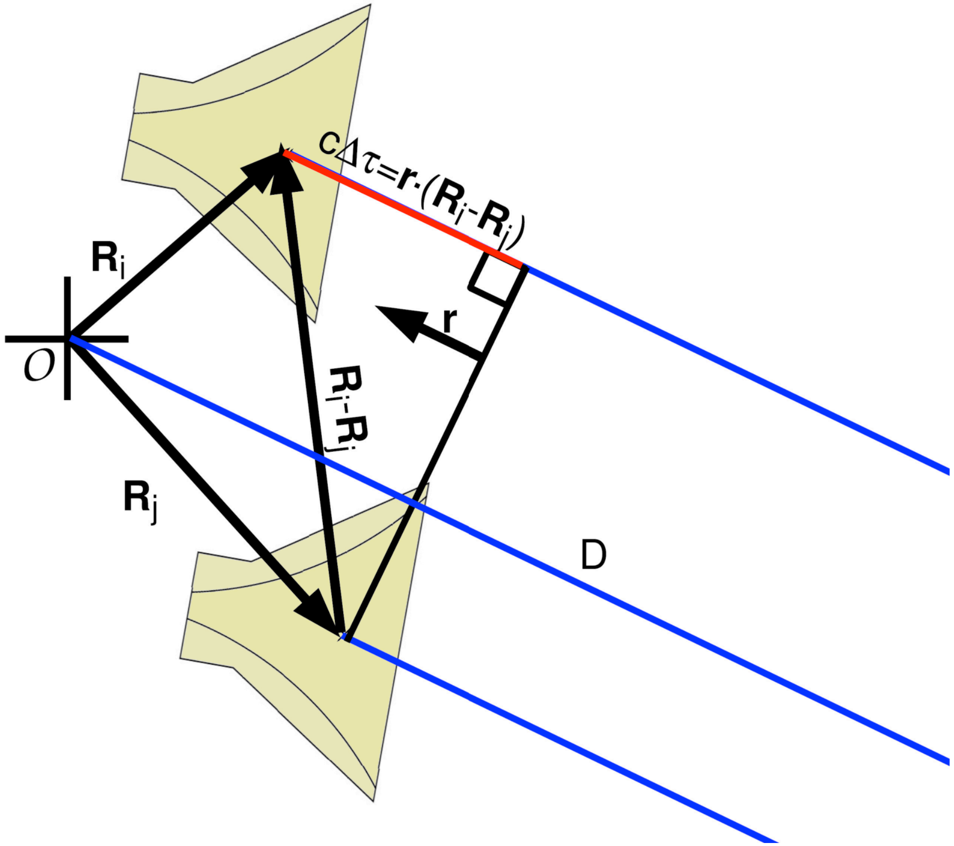

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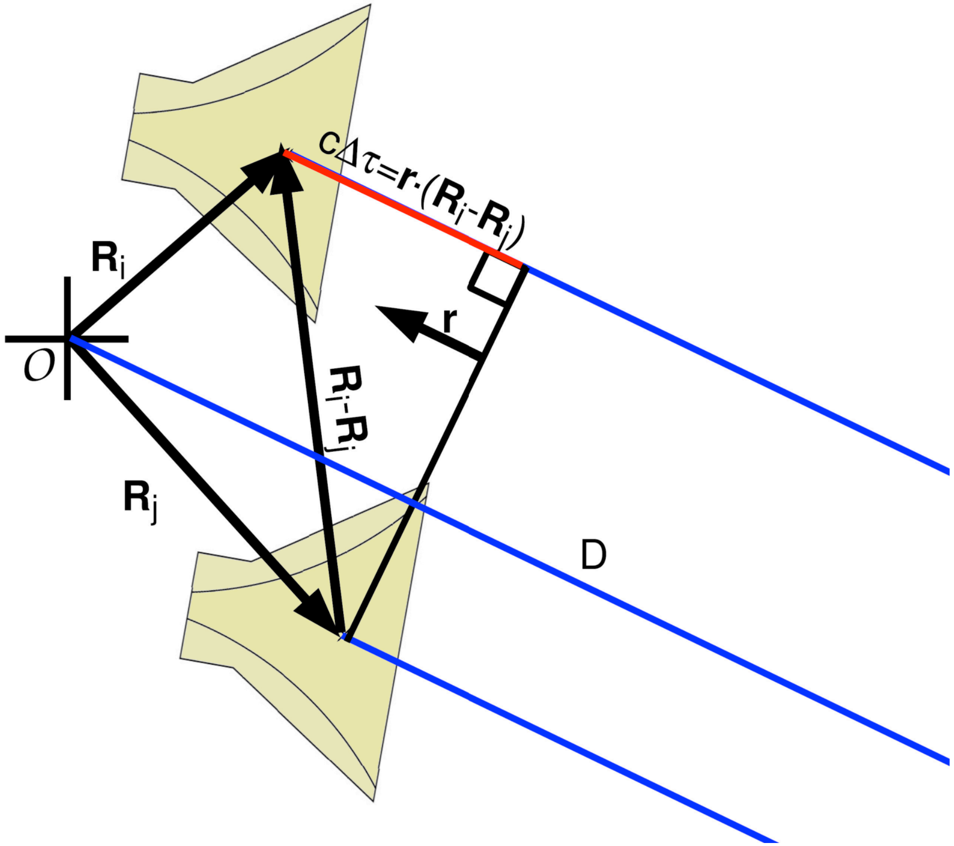

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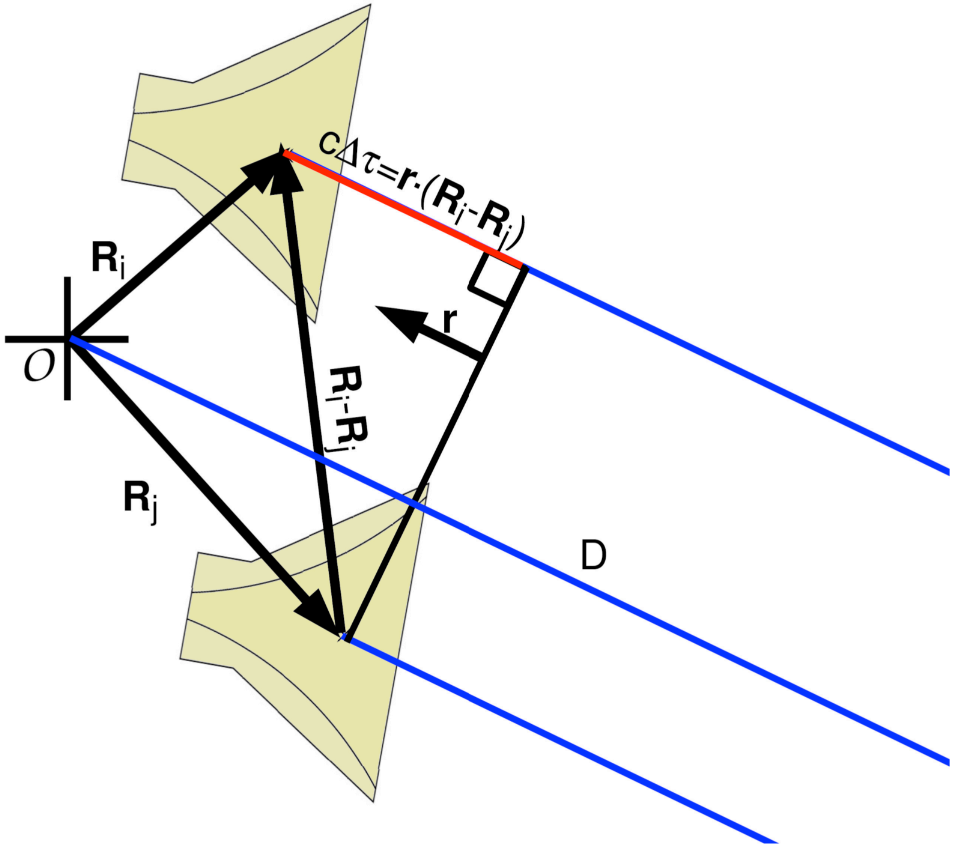

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- Evidently we can compute the extra distance by taking a **dot product**

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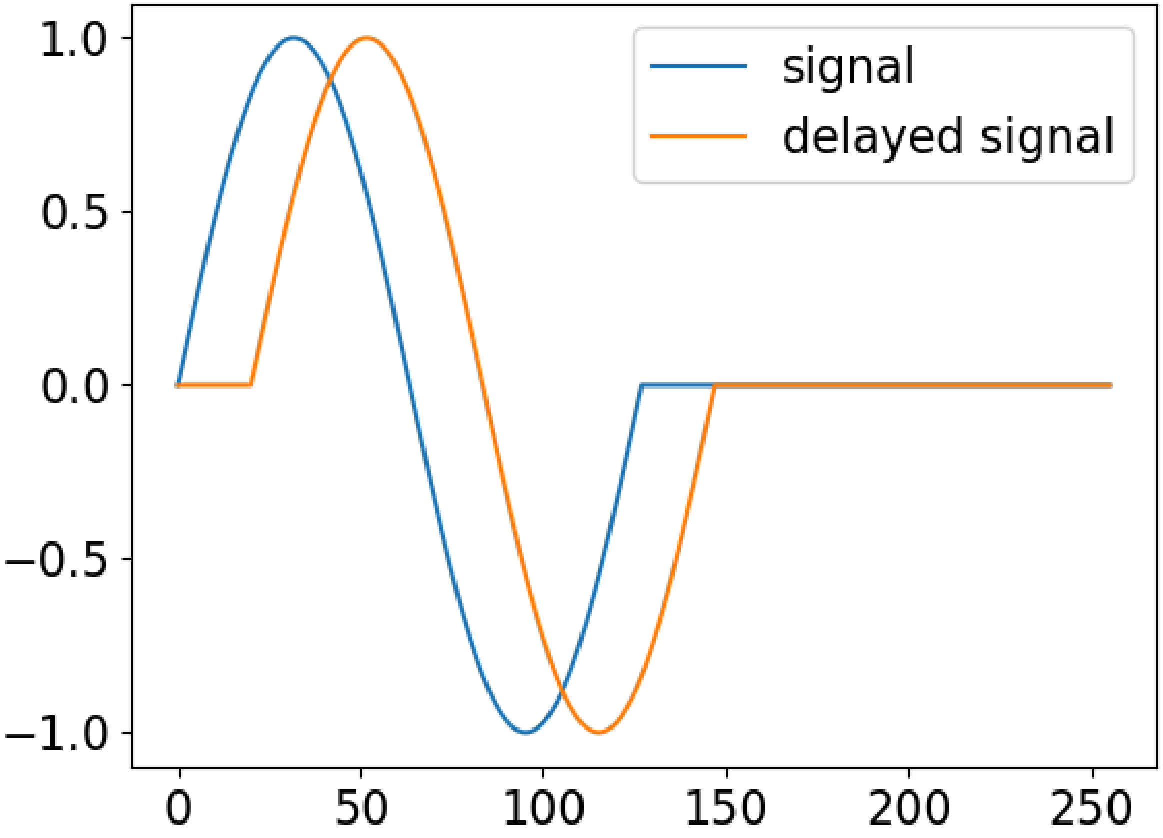

- Now consider what shows up on our computer

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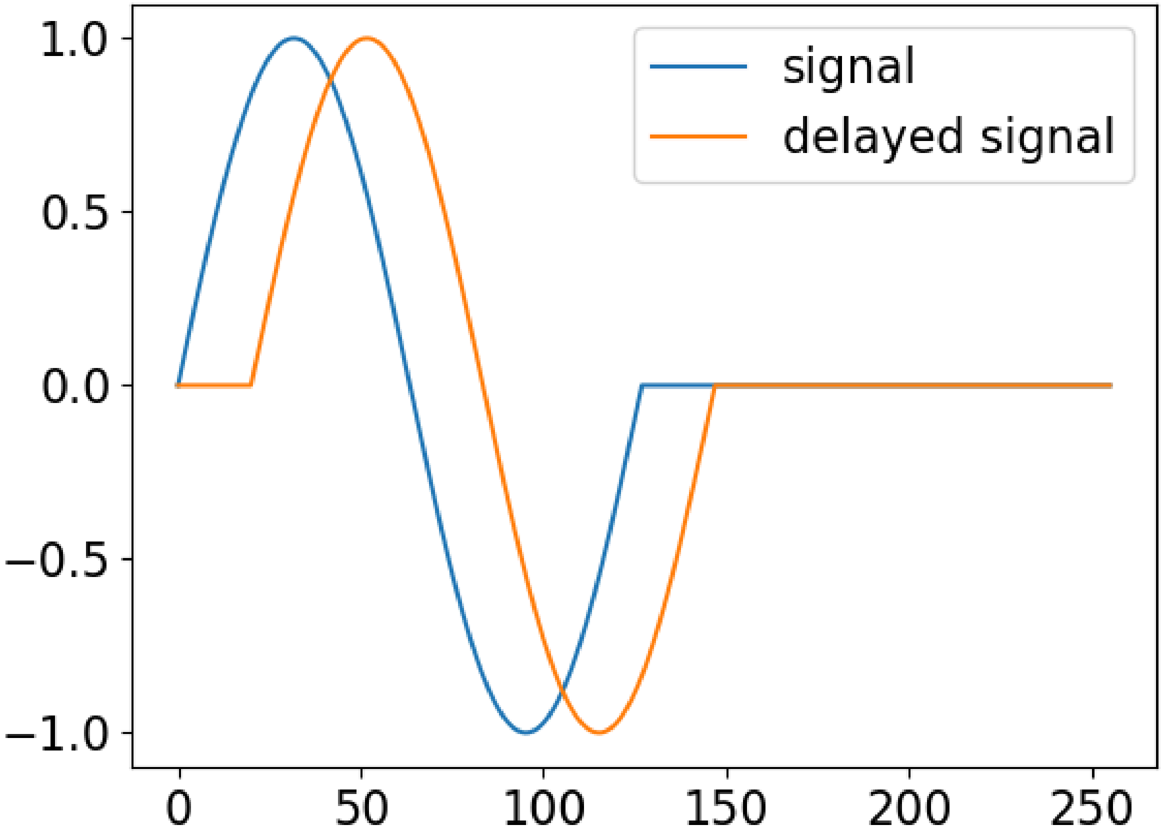

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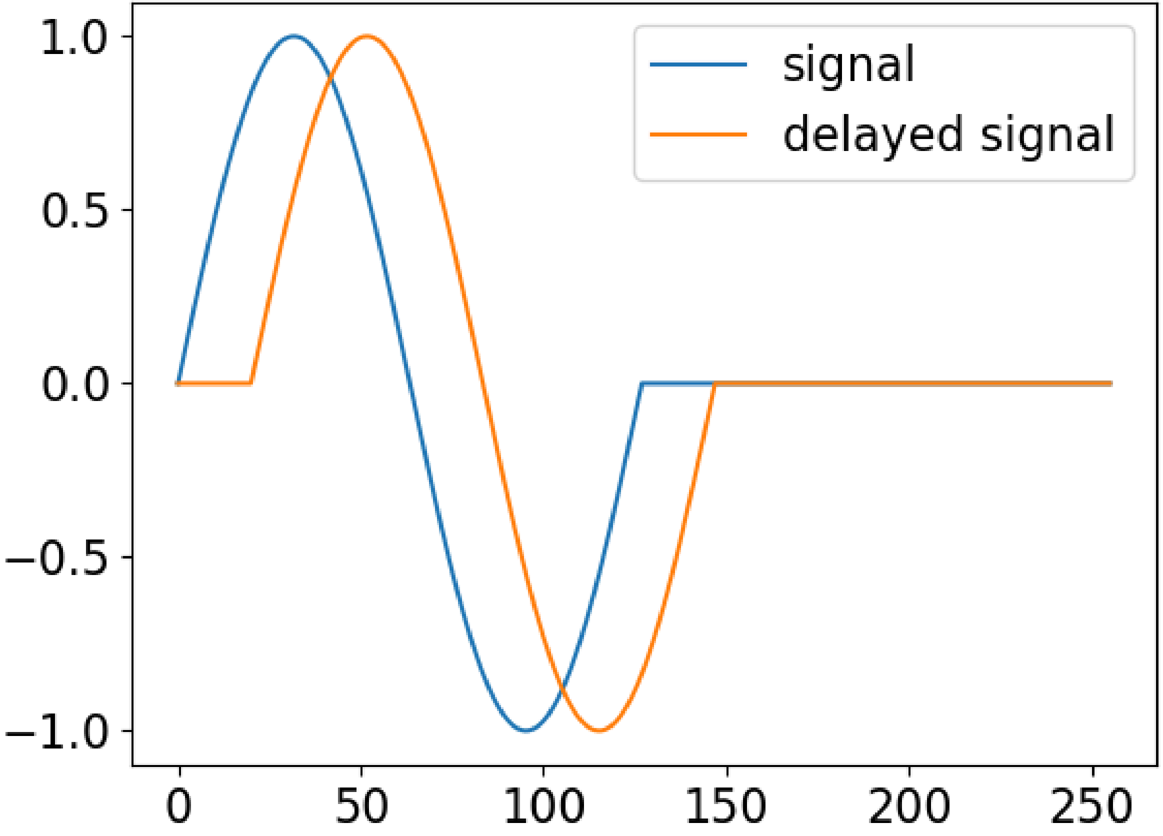

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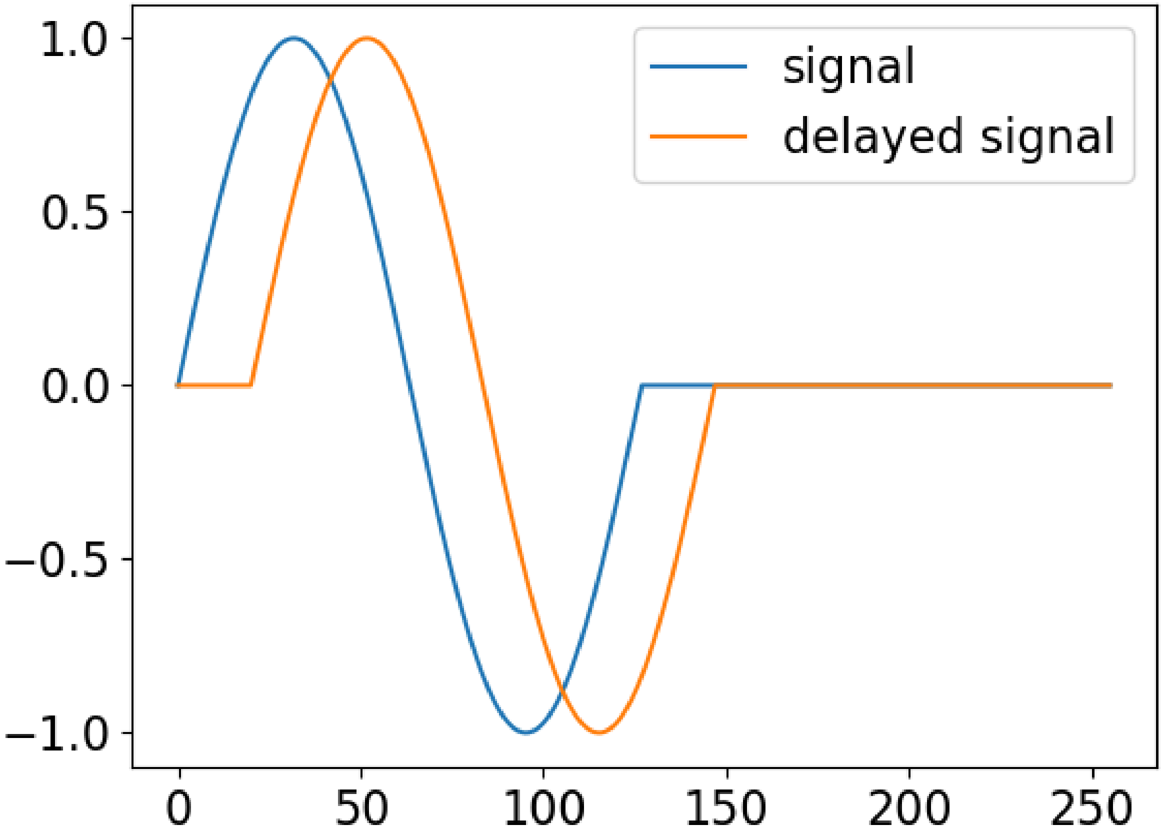

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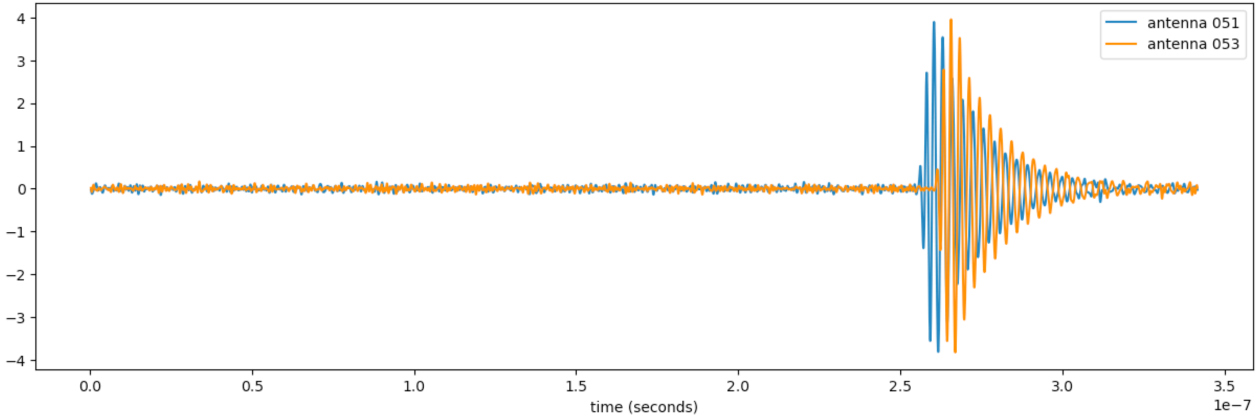
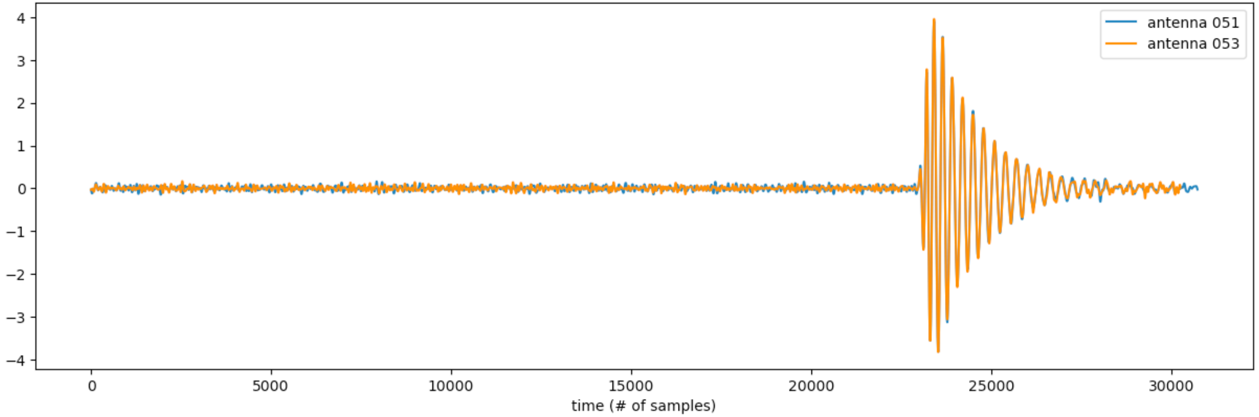


waveform 2 (ant. 053) shifted to the left by 472 samples



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- Eventually, when the two signals are on top of each other, the sum would be the largest.

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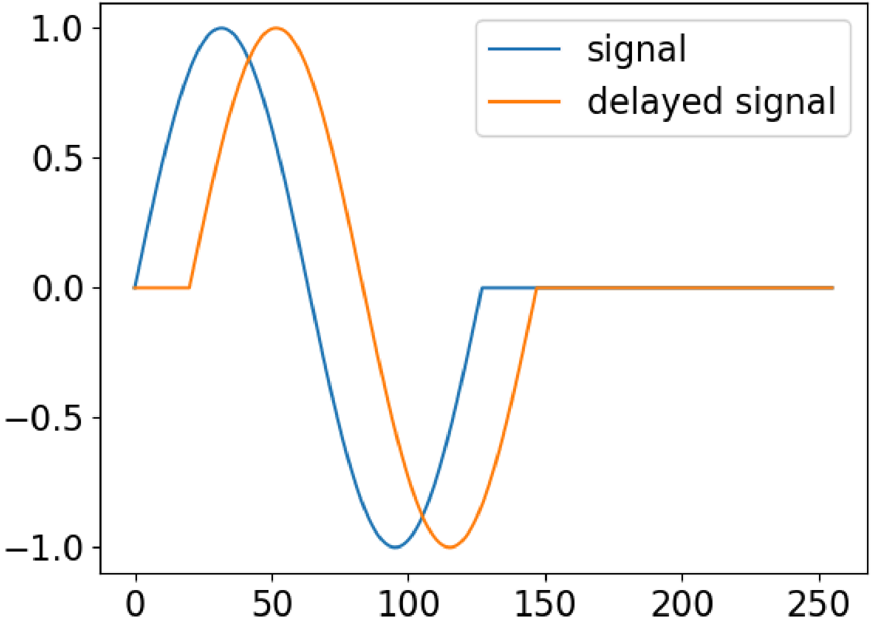

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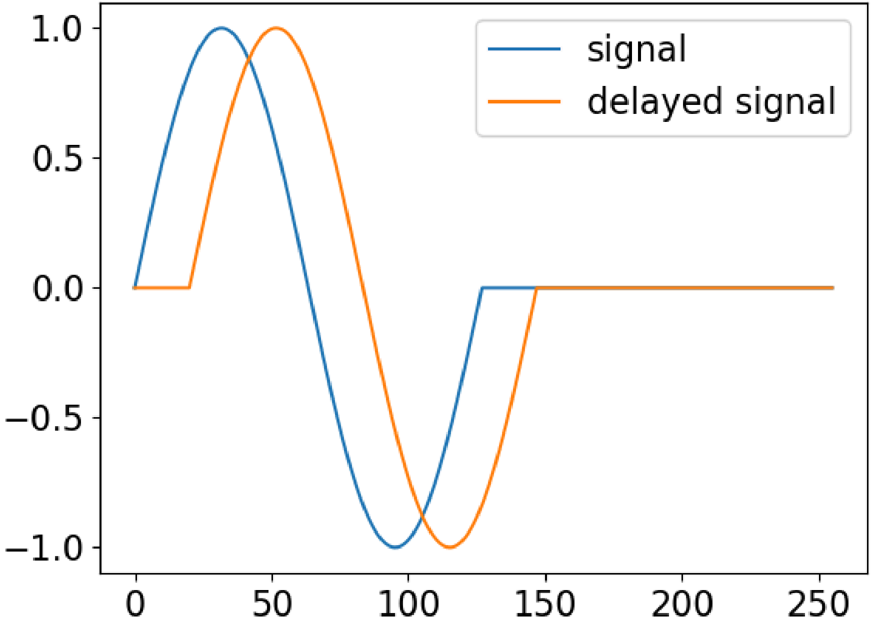

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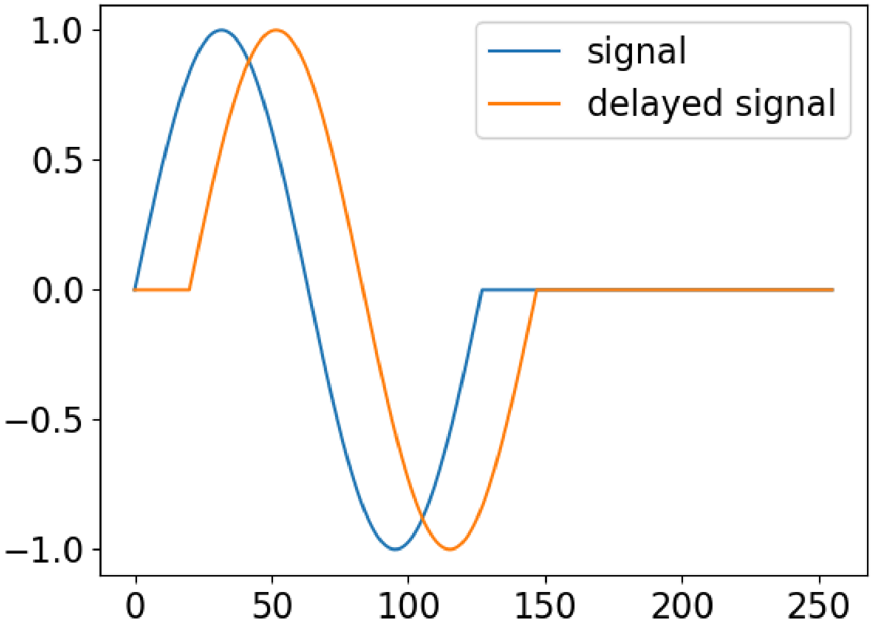

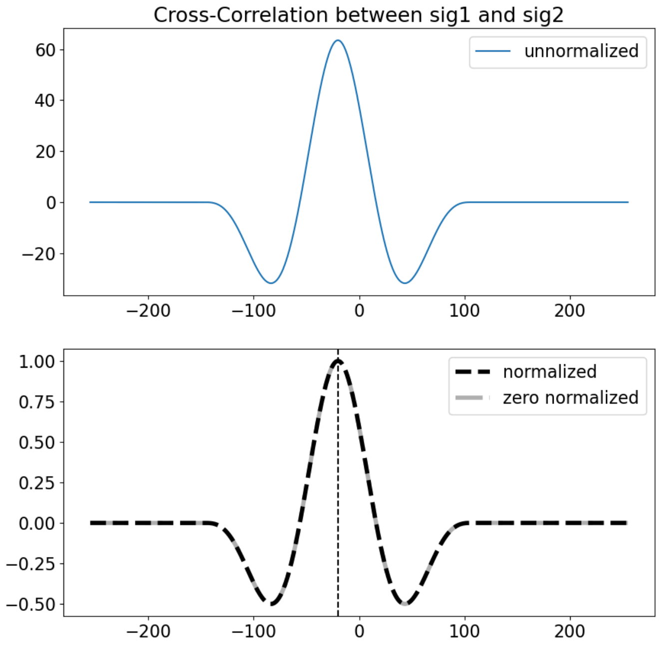

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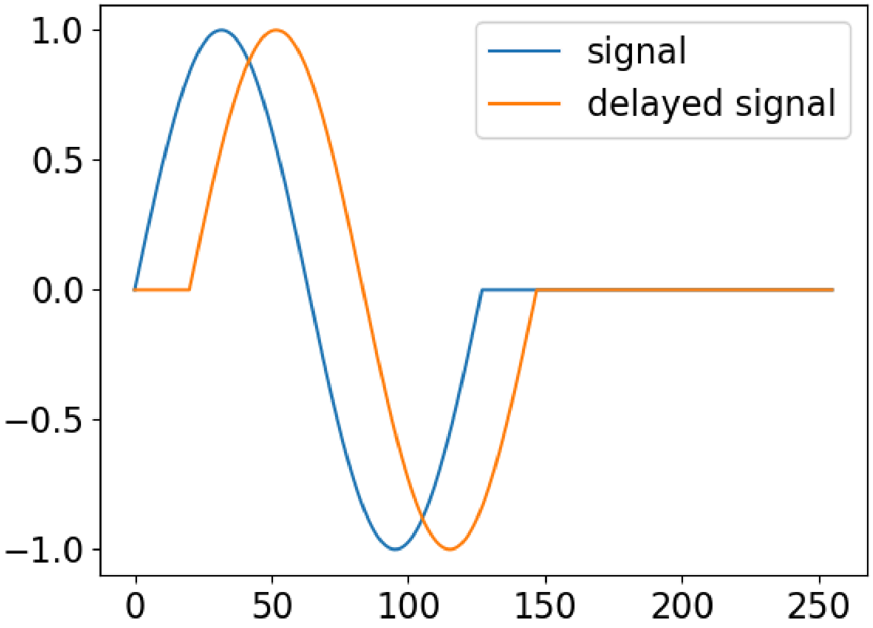

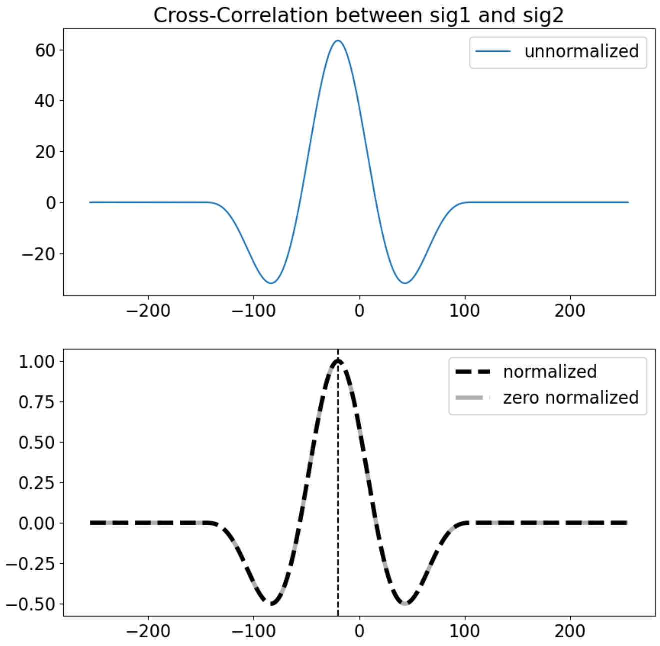

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This means if we shift the delayed signal to the left by 20, the two signals would align.

- Take away: by (blindly) shifting and summing, we will eventually get a peak in correlation scores
- Peak correlation means we have found the correct time delay.

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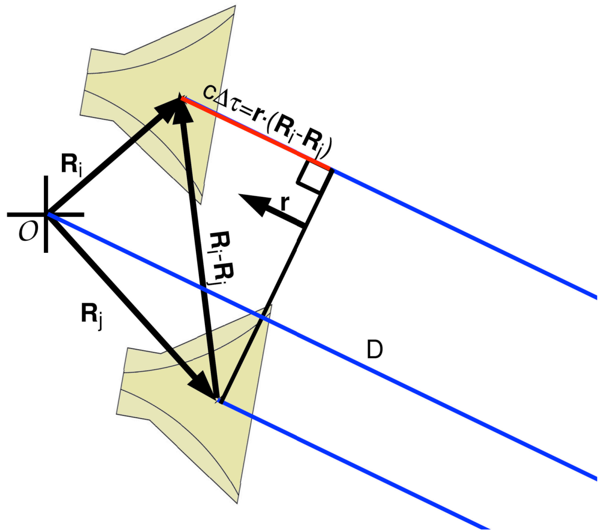

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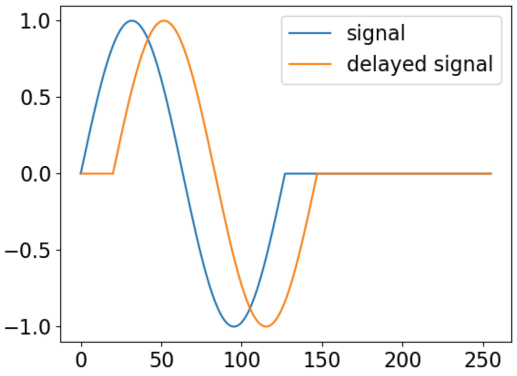

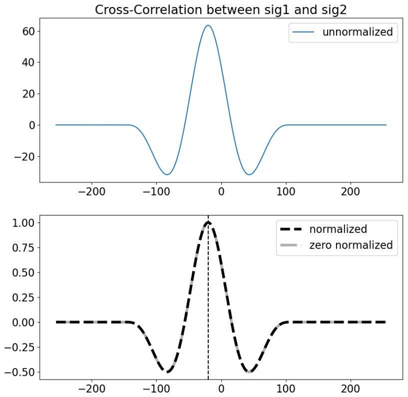

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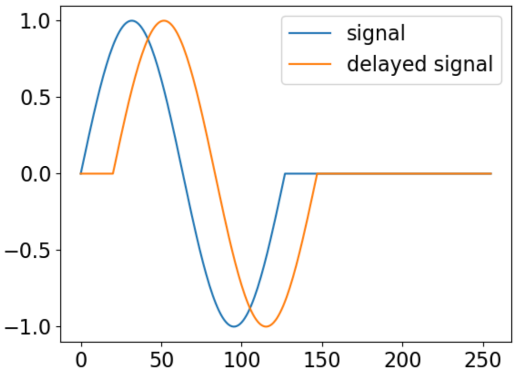

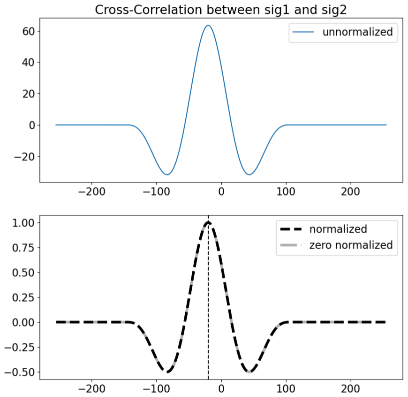

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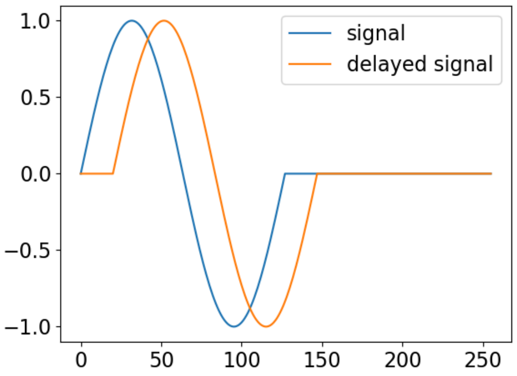
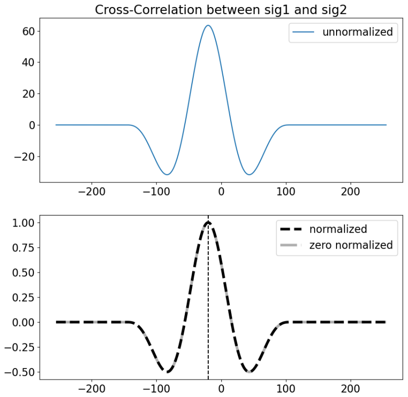




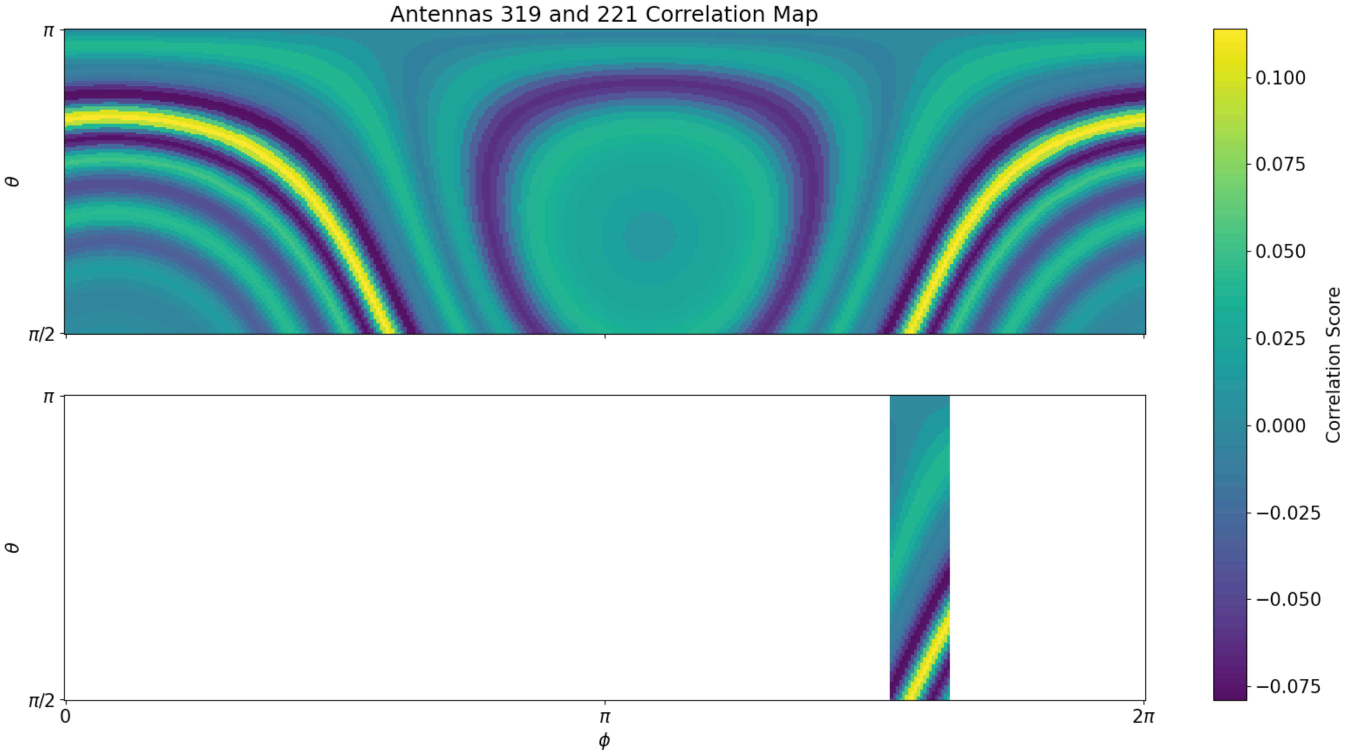
Easy as 1-2-3! (except we do this for $O[1000]$ pairs of antennas, for each pair there are typically $O[10000]$ $\hat{\boldsymbol{r}}_{\text{guess}}$, and oh the signal length is not really 1024 because we "upsample", but those are details.)

Correlation Map

Anyway, the result is what we call a **correlation map** (for a single pair of antennas)

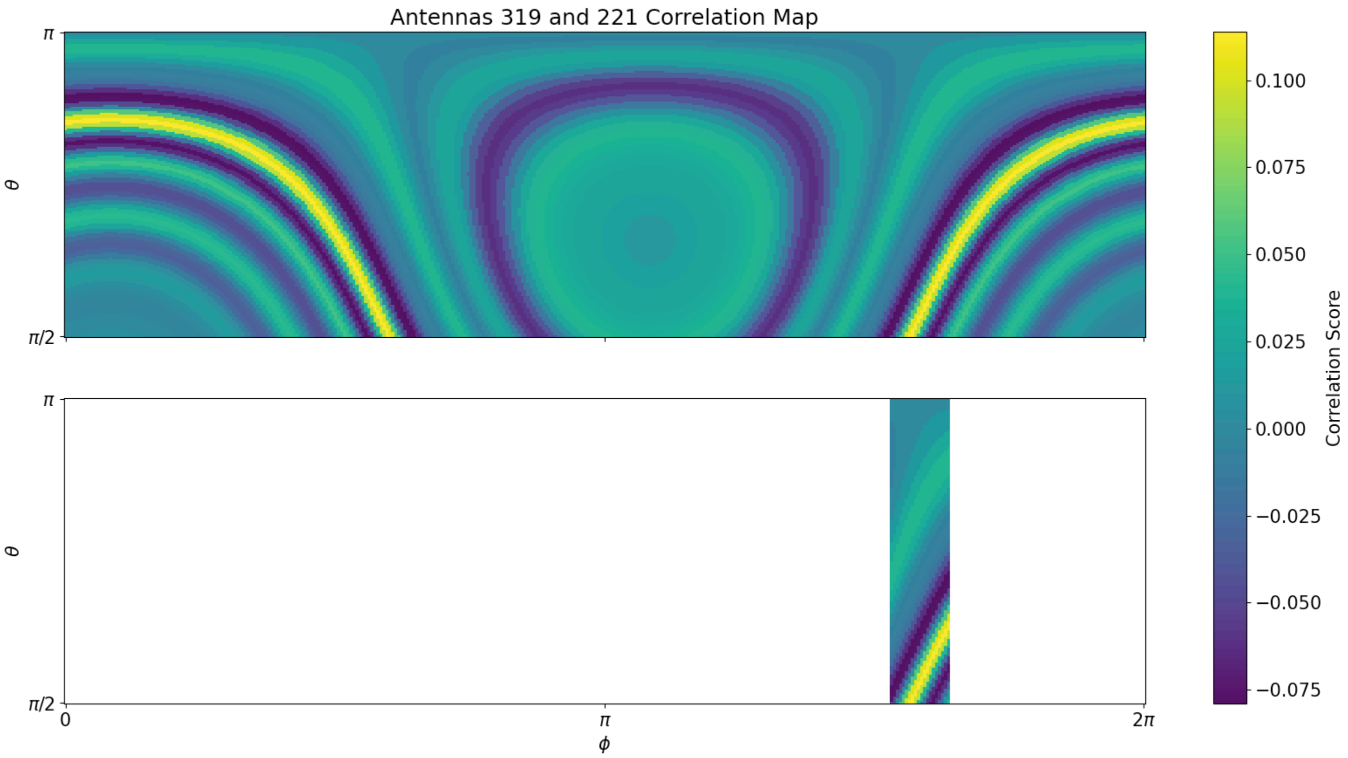
Correlation Map

The $\hat{\boldsymbol{r}}_{\text{guess}}$ mentioned earlier are the tiny direction **bins** in the map below.



Correlation Map

You can see that for some bins the correlation is strong, meaning that the signal *could* be coming from these directions, as far as **this antenna pair** is concerned.



Correlation Map

If we now overlay all pair-wise maps (all $O[1000]$ antenna pairs) on top of each other: