ATA Beamforming Utility

Software development requirements document

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Quick Primer: Primary/Incoherent Beam

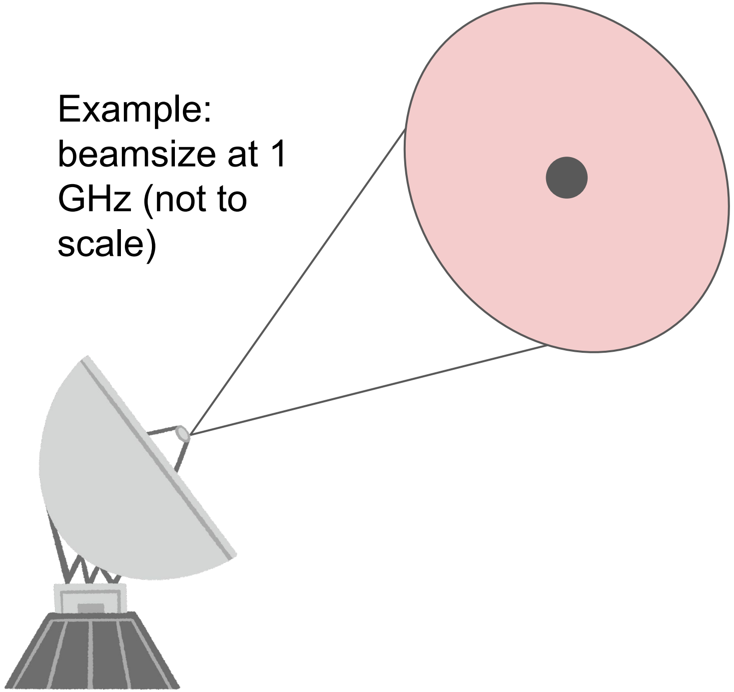
- “Primary beam”, “incoherent beam”, or “field-of-view” are all terms to describe **how large a patch of the sky a dish is sensitive to** around its central pointing location
- The equation for the *diameter* of the incoherent beamsize at the ATA is:

$$\theta_{\mathrm{PrimaryBeam}} \sim \left(\frac{3.5}{f_{GHz}}\right)^{\circ}$$

Beam diameter in degrees

Observing Frequency in GHz

Example: beamsize at 1 GHz (not to scale)



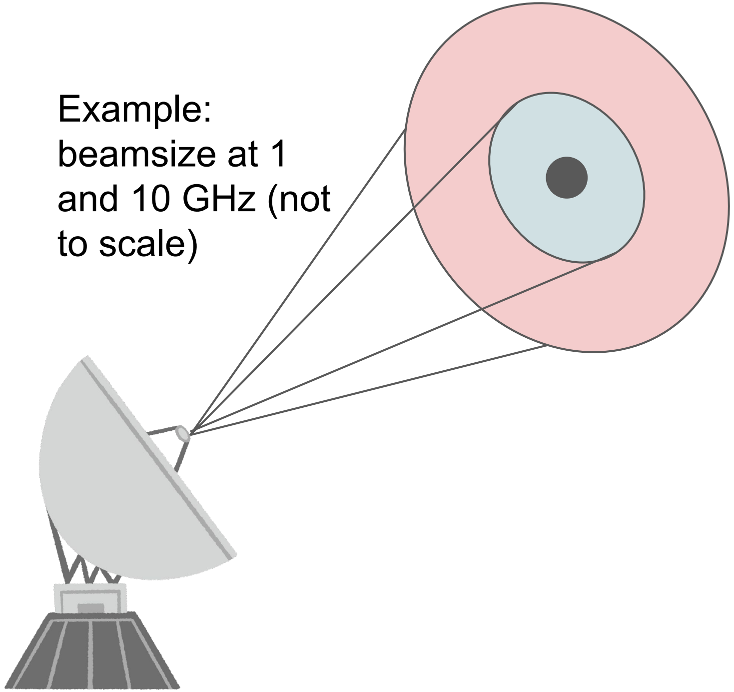
[that equation is derived from the Rayleigh criterion equation]

The primary beam is smaller at higher frequencies

$$\theta_{\text{PrimaryBeam}} \sim (\frac{3.5}{f_{GHz}})^{\circ}$$

- This equation means that the **primary beam gets smaller as the frequency gets higher**

Example: beamsize at 1 and 10 GHz (not to scale)



We can “zoom in” on multiple spots on the sky at once with beamforming

- This is super necessary for good science with the ATA because we can observe N different things at once!

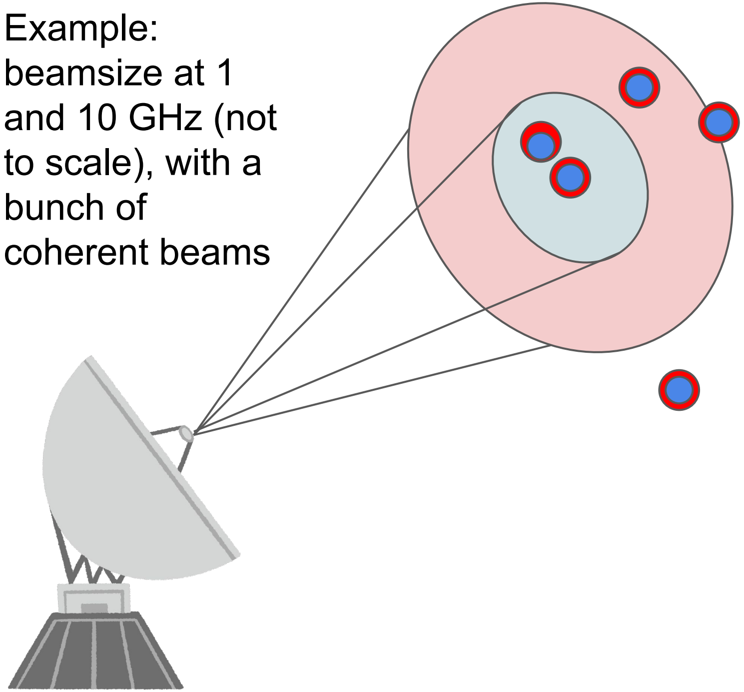
- The equation for the width of a “synthesized” / ”coherent” / ”beamformed” beam is

$$\theta_{\text{SynthBeam}} \sim \left(\frac{3.5 * 1.2}{f_{GHz}}\right)'$$

Beam diameter in arcminutes

Observing Frequency in GHz

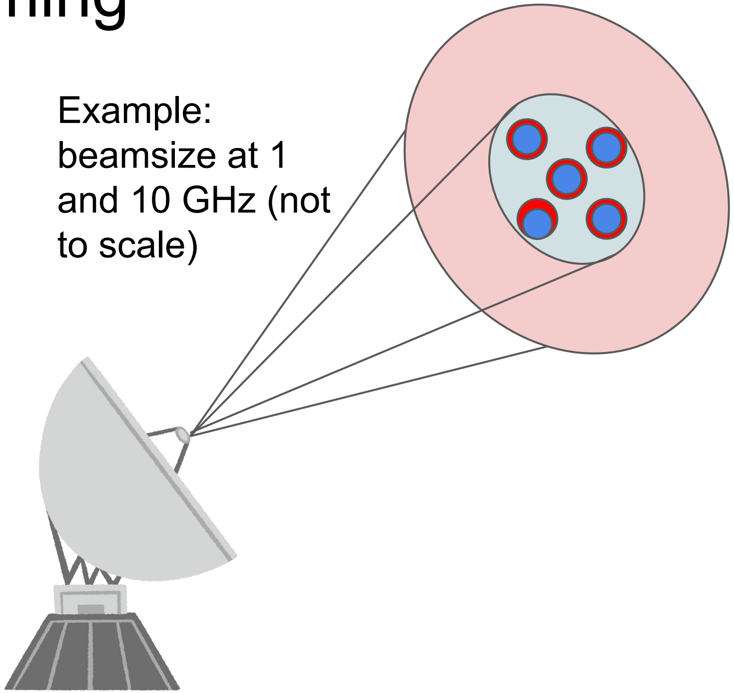
Example: beamsize at 1 and 10 GHz (not to scale), with a bunch of coherent beams



Science Objective: Help science observers pick valid off-source locations when beamforming

- Eventually, we want a piece of code with inputs:
    - **Frequency 1** (4.5) [GHz, can go from ~1-11 GHz]
    - **Frequency 2** (8.0) [GHz]
    - **RA** (12.345) [decimal hours, goes from 0-24]
    - **Dec** (45.345) [decimal degrees, goes from -90 to +90]
    - **N** [number of desired beams]
- Which will produce **N beams that are as far apart as possible while still being inside both primary beams**

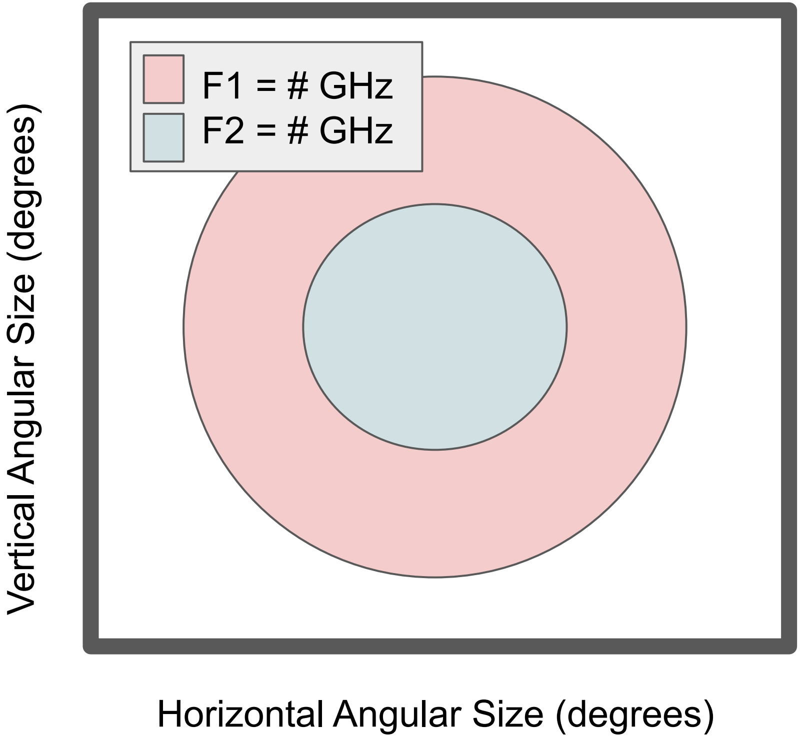
Example: beamsize at 1 and 10 GHz (not to scale)



Break the problem into pieces!

- **First step:** Write a Python function that uses the Primary Beam diameter equation (on slide 2)
  - Inputs: Center frequency1 and frequency2 [in GHz]
  - Outputs: Creates a plot that shows the two primary beams at different center frequencies on the same plot, to scale
    - They will be circles! (for now)
    - Add a legend (plt.legend) to say which is which

- **Next step:** same plot, but use the edge frequencies (low freq - 672/2 MHz, high freq + 672/2 MHz) to make the most extreme comparison



Logistics!

- I made a folder in the HCRO Github for this project!
    - https://github.com/SETIatHCRO/Front-Page/tree/master/Beamforming-Utility-Scripts
- Create a fork of the project, and when you're happy with your progress, create a pull request for it (and let me know)
    - Document as you go (comments in the scripts, instructions on how to run them in the README?)
- Then, I'll add unit tests and make sure everything works as expected

Python Specifications

- Use Python 3 (not 2)
- Use numpy, matplotlib, and **astropy**, if you use other packages, just let me know
- Astropy is kinda critical here because **it handles units and coordinates for you**
    - **How to use units in Astropy:** Units and Quantities (astropy.units)
    - **How to use coordinates in Astropy** (not necessary at the start but we'll have to add it later): Astronomical Coordinate Systems (astropy.coordinates) — Astropy v5.2.3.dev0+g32d49b960.d20230411