Questions

Any questions to exercises and homeworks from last time?

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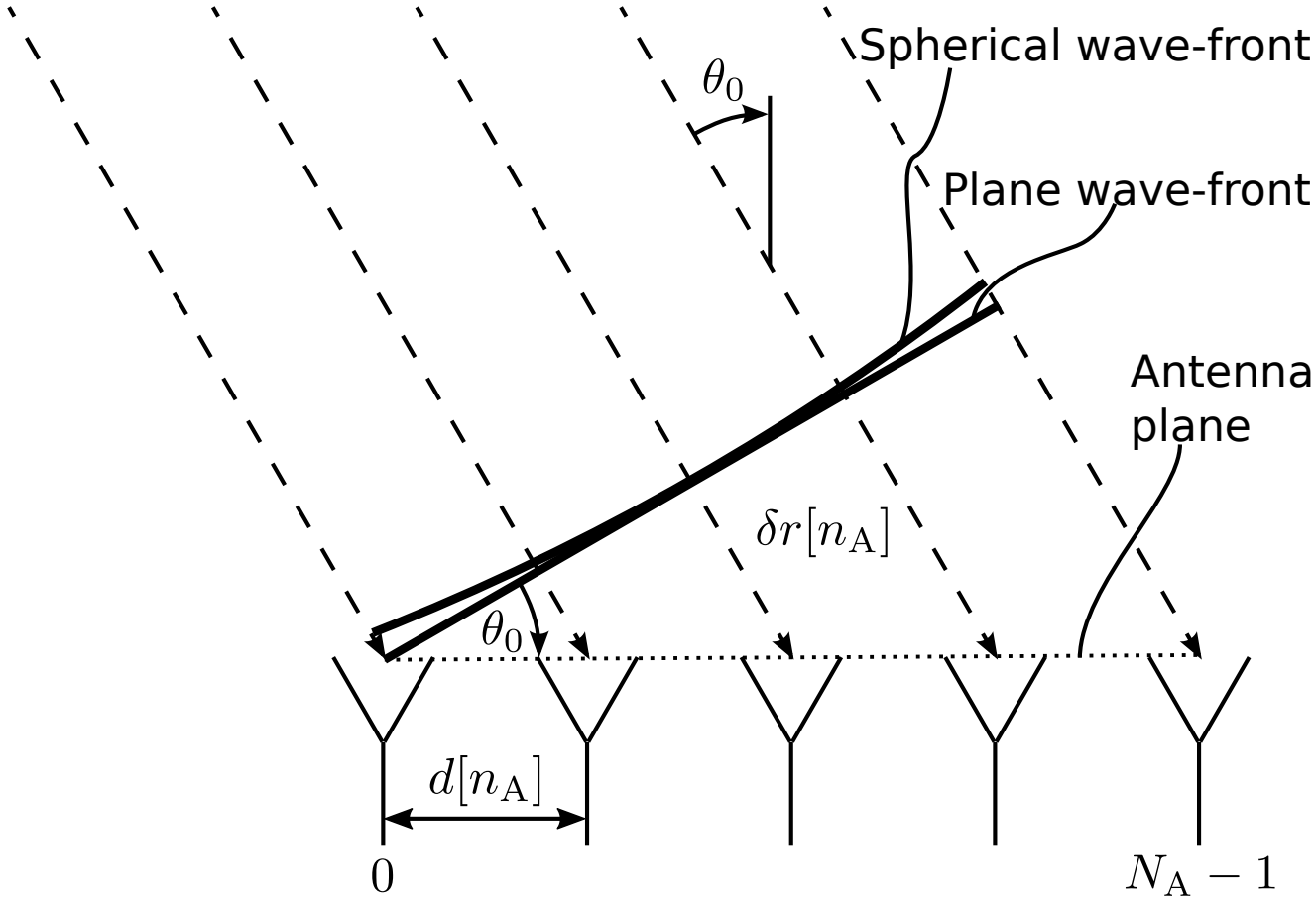
Linear Receive Array



Single Chirp, Multiple Antennas

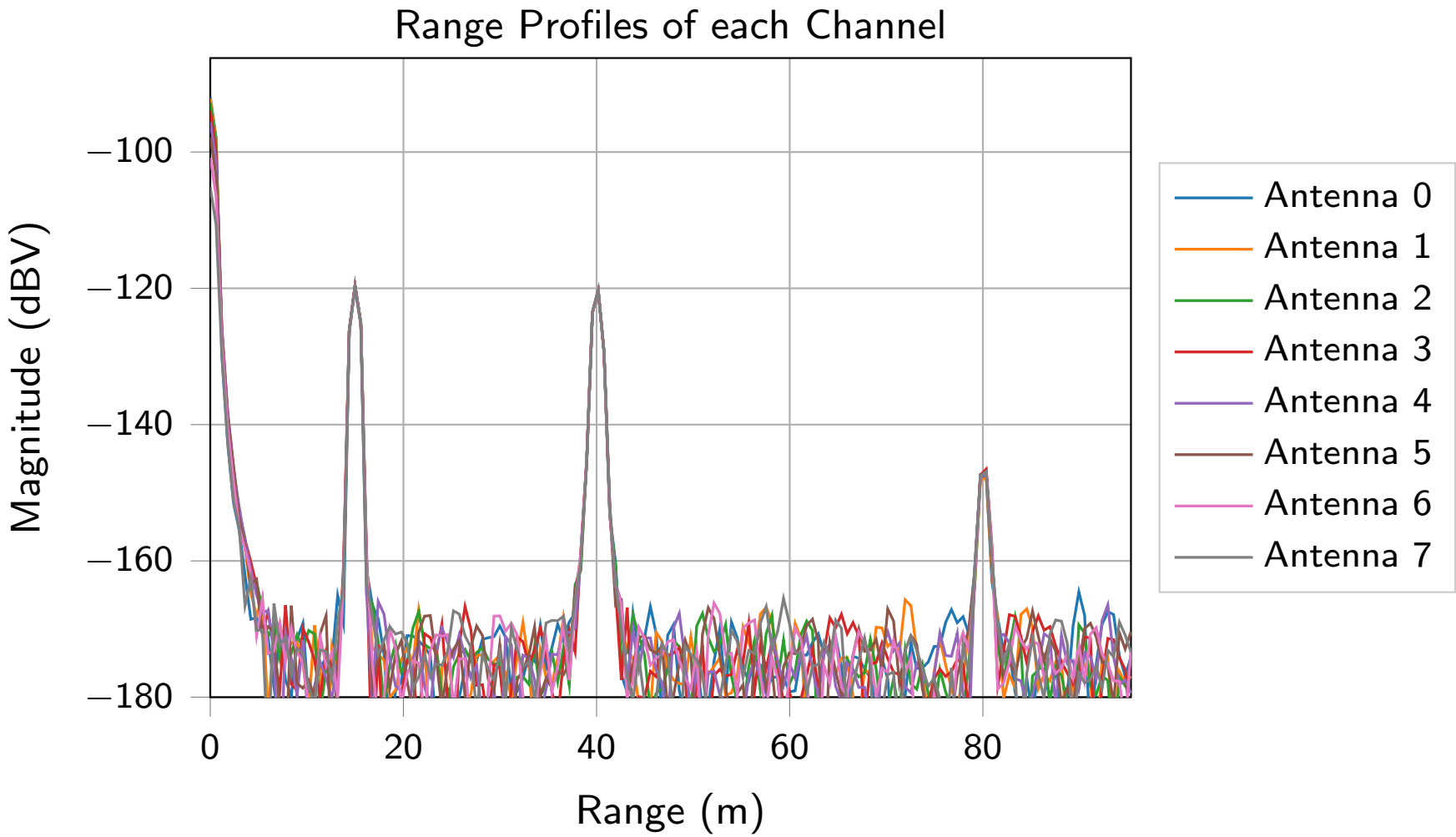
- Simplified signal model for a single chirp and a uniform linear array (ULA) with a spacing of $d = \lambda/2$

$$s_{\mathrm{IF}}[n, n_{\mathrm{A}}] \approx \sum_{m=0}^{M-1} A_m \cos\left(2\pi\phi_m[n, n_{\mathrm{A}}]\right) + w[n, n_{\mathrm{A}}]$$

$$\phi_m[n, n_{\mathrm{A}}] = \frac{2f_c r_{0,m}}{c_0} + \underbrace{T_{\mathrm{S}}\frac{2kr_{0,m}}{c_0}}_{\psi_N} n + \underbrace{\frac{1}{2}\sin\left(\theta_{0,m}\right)}_{\psi_{\mathrm{A}},u} n_{\mathrm{A}}$$

System Parameters		*Environment*	
f_c	carrier frequency	$r_{0,m}$	ranges of targets
B	bandwidth	$\theta_{0,m}$	directions in rad of target
T	chirp duration	$A_{0,m}$	magnitude of targets
$k = B/T$	ramp slope	$w[n, n_{\mathrm{A}}]$	additive noise
T_{S}	sampling interval		

Range Profiles



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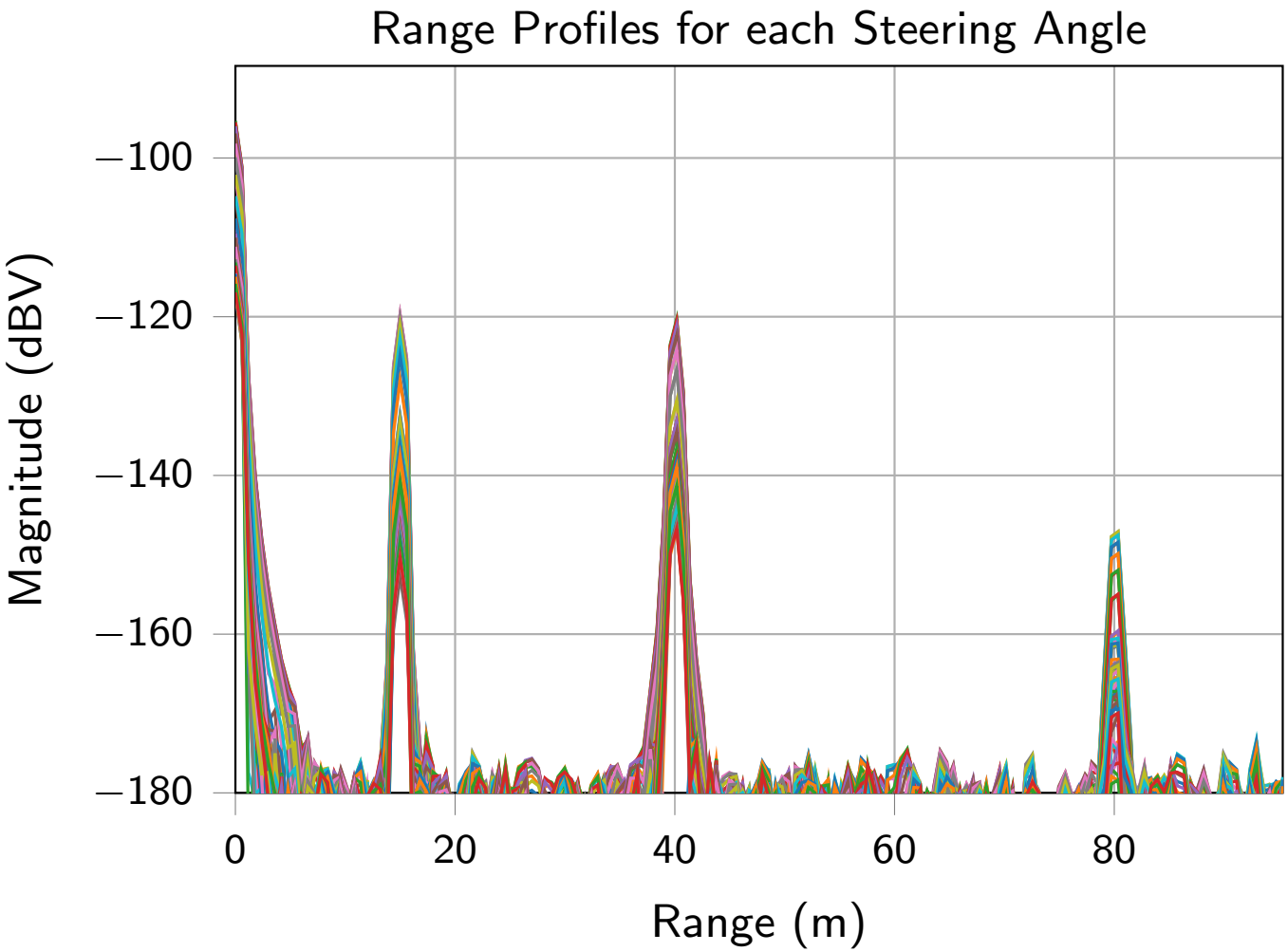


Exercise: FMCW: Single Chirp with ULA

- Consider a single chirp with the following Parameters (you can reuse parts from exercise "FMCW: Single Chirp"):

```
fs=1e6; B=250e6; fc=24.125e9; T=1e-3; F_dB=12; T0=270; R=50
NA=8          # number of channels
```

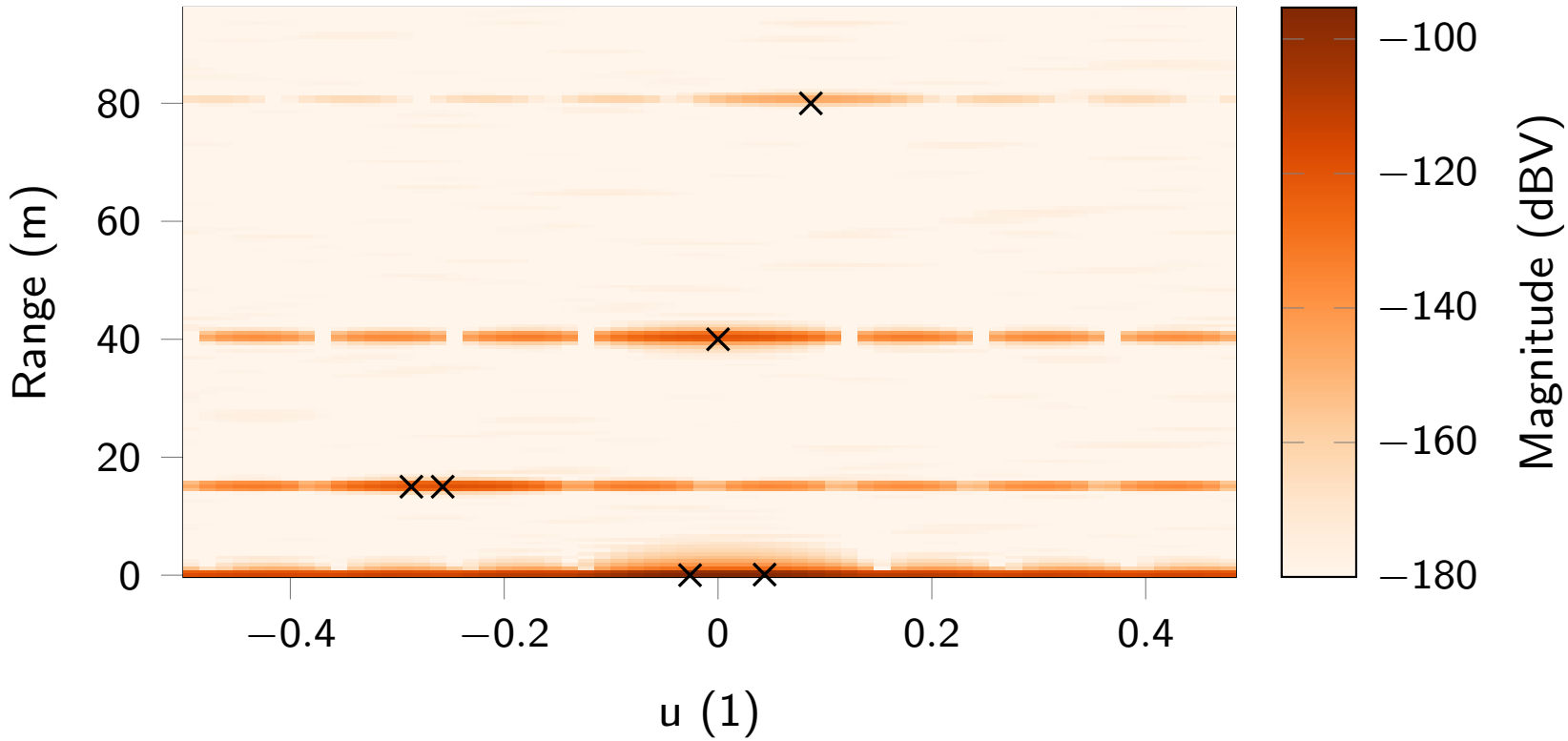
- Two close (spurious) targets and four wanted targets:

```
A0_arr=np.array([20, 18, 0.1, 2, 2, 0.1])*1e-6  # magnitude
r0_arr=np.array([0.001, 0.1, 15, 15, 40, 80])   # ranges
theta0_arr=np.array([-3, 5, -35, -31, 0, 10])   # angles (degree)
```

- Calculate the IF signal for all channels of a $\lambda/2$-spaced ULA.
- Use the 2D-FFT to estimate the spectrum
  - For hints on the 2D-FFT, see FMCW slides.
  - Use a hanning window in range-dimension and a rectangular window in direction of arrival dimension.

Exercise: FMCW: Single Chirp with ULA - FFT Spectrum

- Plot the result of the 2D-FFT for spectrum estimation
  - Set the lower plot limit to $-180\,\mathrm{dBV}$.
  - Mark the true locations.



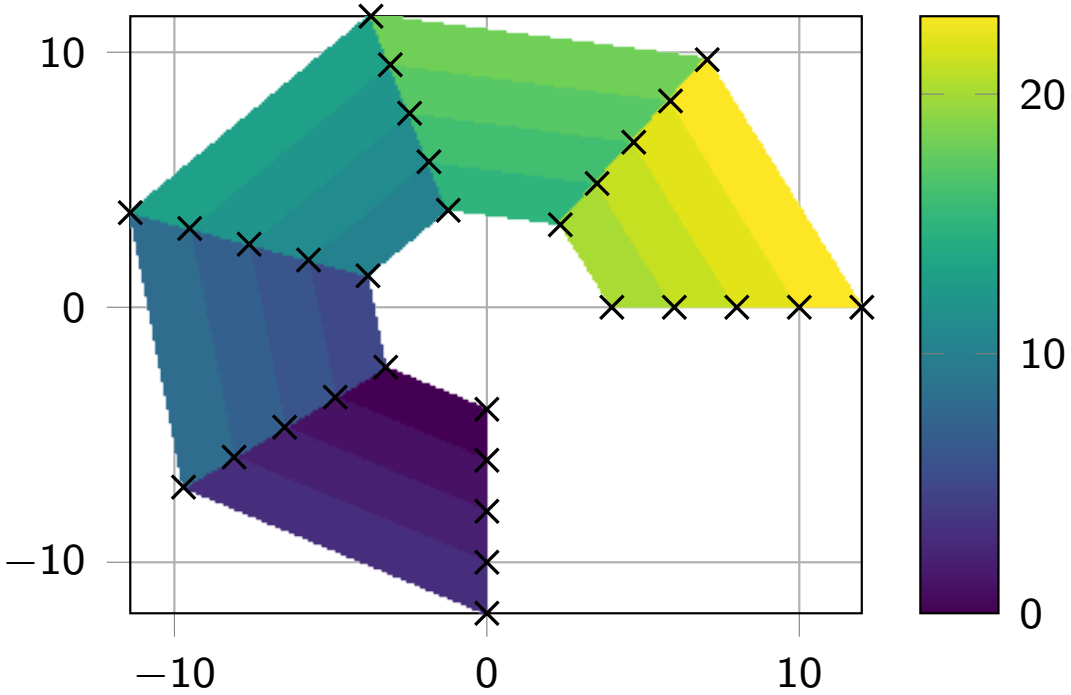
Pcolormesh Plots

```
import matplotlib.pyplot as plt
import numpy as np
from matplotlib2tikz import save as tikz_save

data=np.reshape(np.arange(6*5),(6,5)) # dummy data

# map to a circular ring sector
theta=np.linspace(-np.pi, np.pi/2, data.shape[0])
theta=theta[:,np.newaxis]              # make theta a column vector
r=np.linspace(4, 12, data.shape[1])
X=r*np.sin(theta); Y=r*np.cos(theta) # list x colum vector produces a matrix
# plot
c=plt.pcolormesh(X, Y, data)           # plot it
plt.colorbar()                         # add colorbar
plt.plot(X, Y, 'kx')                   # combination with other plots possible
plt.grid()                             # common plot formatting stuff works too
# export
tikz_save('test_pcolormesh.tikz',
          tex_relative_path_to_data='python',
          override_externals=True)
plt.savefig('test_pcolormesh.png', dpi=150)
```

Relation between Coordinates and Data Array

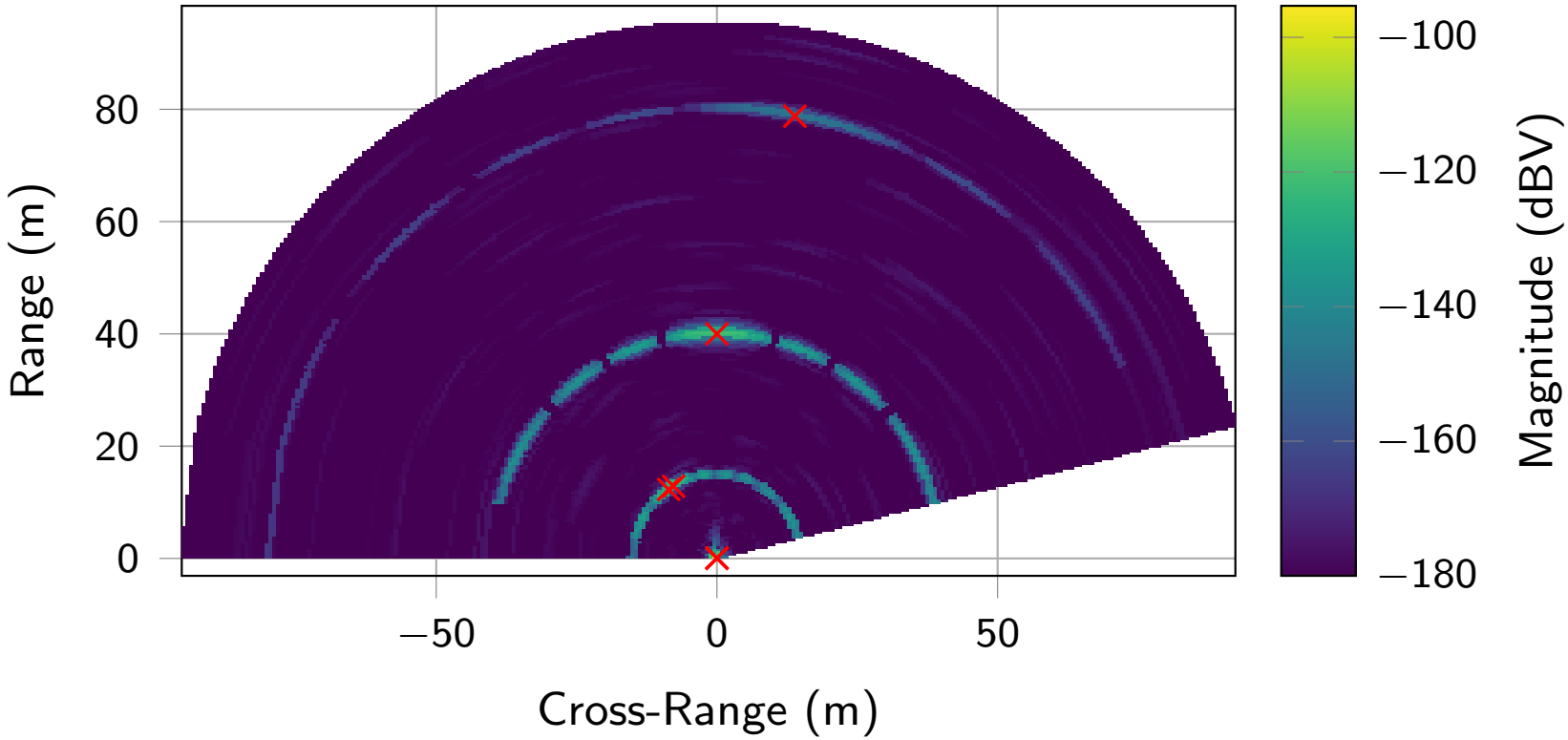


- Data was 6x5, but plot segments are 5x4!
- X and Y must be one element larger in both dimensions.

https://matplotlib.org/api/_as_gen/matplotlib.pyplot.pcolormesh.html

Homework: FMCW: Single Chirp with ULA - DBF

- Use `pcolormesh` to map the spectrum to range/cross-range coordinates, i.e. Cartesian coordinates.
- Mark the true locations.



Pseudo Spectrum Estimation Methods

- Note the high sidelobes in DoA dimension, compared to range dimension. Windows with high sidelobe suppression have broad main lobes. A nuttall mainlobe of ± 4 bins would cover all eight channel.
- Zero-padding can increase accuracy but not resolution. Zero-padding in 2D (3D for many ramps) needs lots of memory.
- Use different spectrum estimation methods.
- Spectrum module: `https://github.com/cokelaer/spectrum`
  - Spectrum is in channel conda-forge! Don't use `--add`, but `--append` to get channels right.
- Other methods gain advantage by considering model parameters, but are not that robust and fast as the FFT.
- Use FFT to locate ranges (or range/Doppler) bins above threshold and do different spectrum estimation methods only for those bin.

Super-Resolution and the Music Algorithm

- Super-resolution algorithms: Better resolution than DFT by utilizing more signal parameters/assumptions, like number of sinusoids, or sparsity.
  - resolution gets better
  - sensitivity towards model assumption (noise color, number of sinusoids) gets worse
  - computational demand gets worse
- Music:
  - Assumption: P complex exponentials in AWGN.
  - Uses, eigenvector decomposition of the covariance matrix and separates noise based and signal based eigenvectors.
  - P-strongest one can be bogus if only less than P complex exponentials are present.
  - Music does not preserve power!

Conda Channels I

- `conda` can use packets from different sources for installing and upgrading modules.
- If no dedicated source is given upon installation, packets are located in the channels, i.e. packet repositories.
- Documentation

  https://conda.io/docs/user-guide/tasks/manage-channels.html
- Only channel `defaults` is tested by Anaconda from compatibility among all packets.
- Most prominent channel: `conda-forge`, which contains far more packets than `defaults`, but might provide broken modules.
- Show list of active channels (from an Anacond Prompt):

  ```
  conda config --show channels
  ```
- Highest priority channel is on top of list.

Conda Channels II

- If `defaults` channel was not the first entry in the channel list, auto-selected packets (during upgrade or from dependencies) might be pulled from undesired channels.
- To manipulate the channel list, to following commands are provided:

```
conda config --add channels channel_name
conda config --append channels channel_name
conda config --prepend channels channel_name
conda config --remove channels channel_name
```

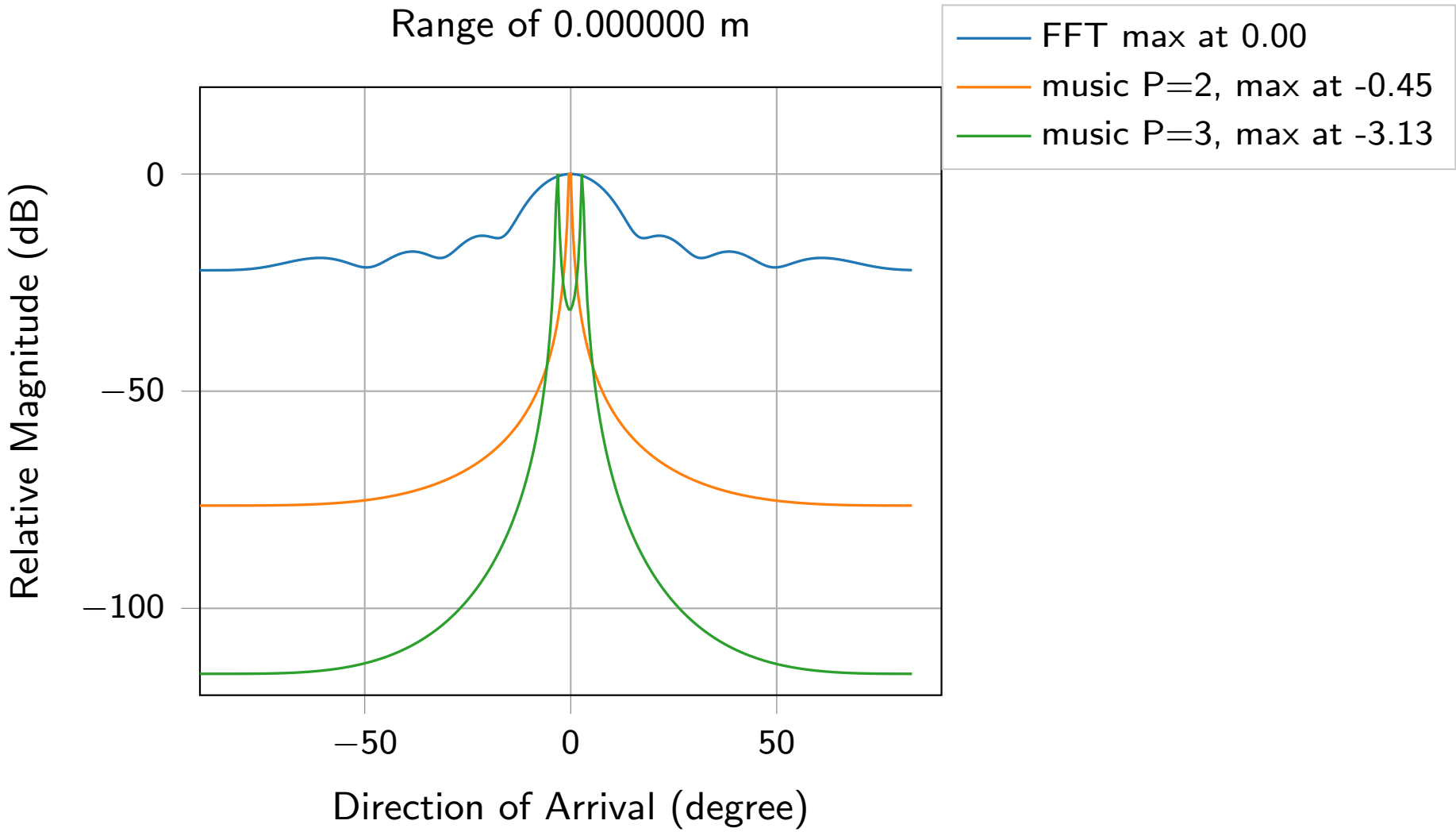
Homework: Pseudo Spectrum

- Take the IF signal from exercise "FMCW: Single Chirp with ULA"
- Use a threshold of $T_{\mathrm{dB}} = -160\,\mathrm{dBV}$ to find those range indices (in the 2D-spectrum), where at least one DoA bin exceeds the threshold.
  - Take a look at `numpy`'s functions `any`, `where`, and `flatnonzero`, which can help to avoid (slow) for-loops.
- For found ranges, plot the angular FFT spectrum and the music spectrum for `P=2` and `P=3` and `ZA_fine=256`

```
import spectrum as sp
res=sp.music(data, P, NFFT=ZA_fine) # data is in time domain!
res[0]                              # contains spectral data
```

- Note: as the mainlobe in range has a width of many FFT bins, multiple detection per targets are made.

Music Pseudo Spectra vs. FFT Spectrum



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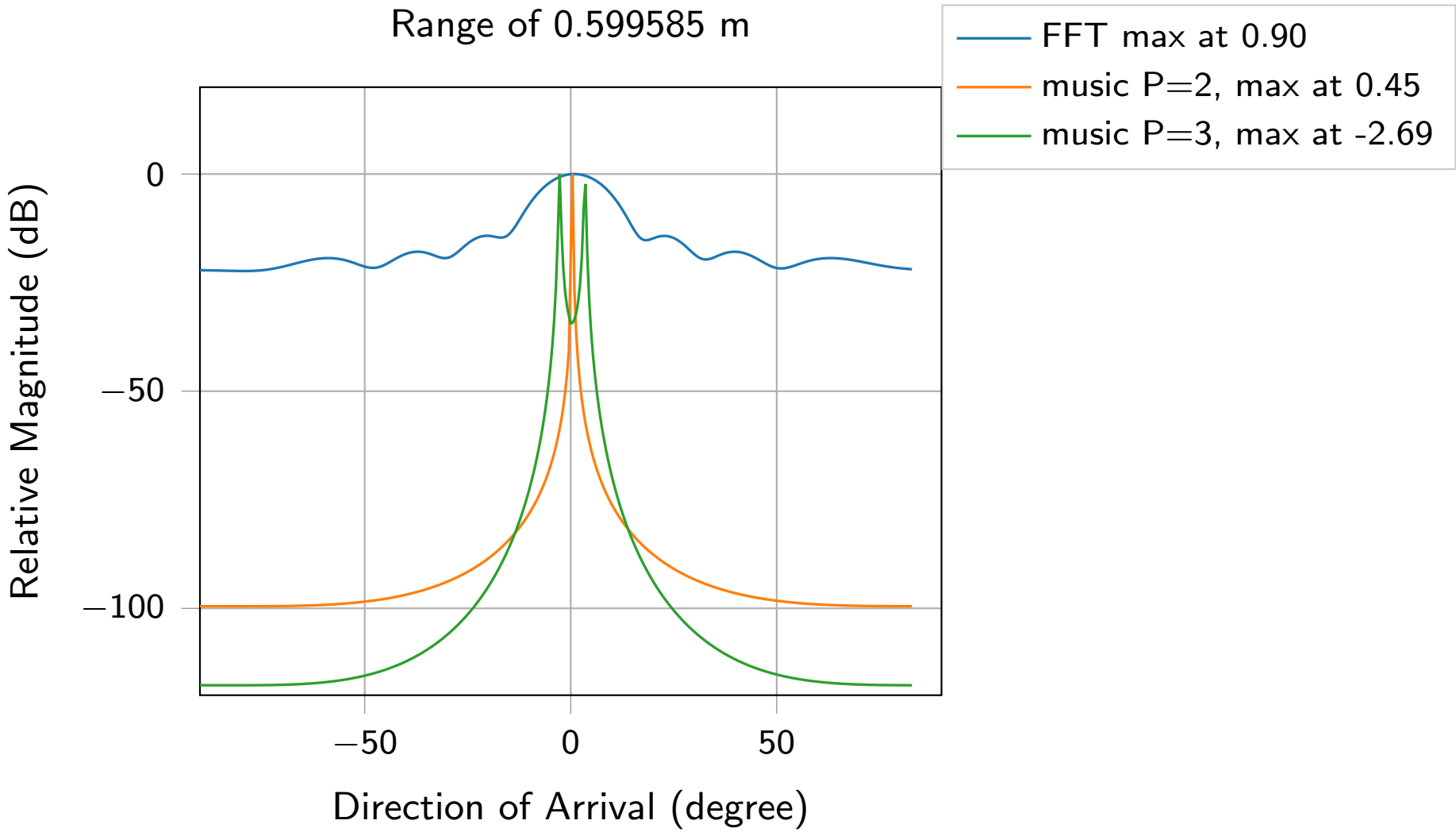

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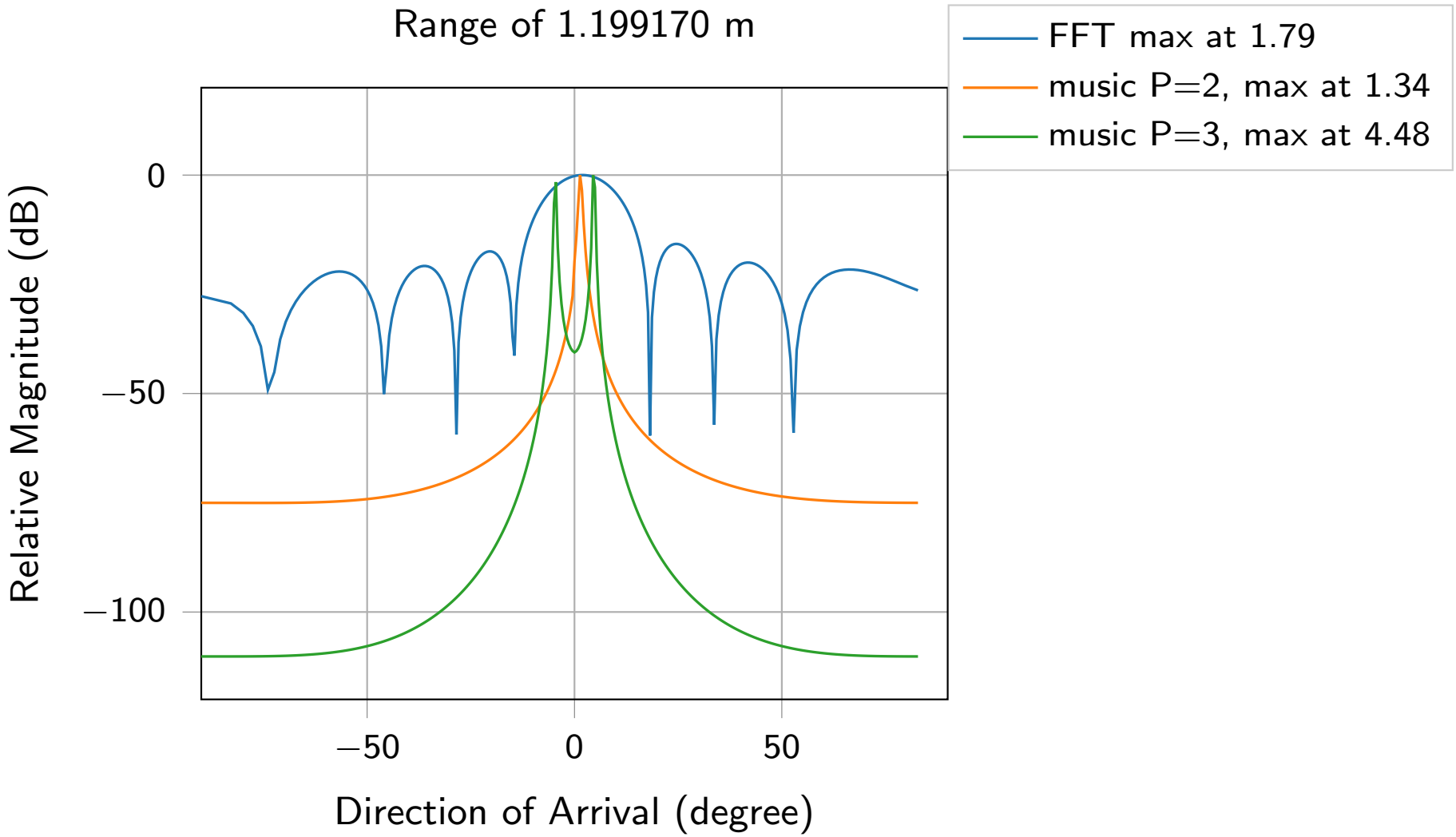

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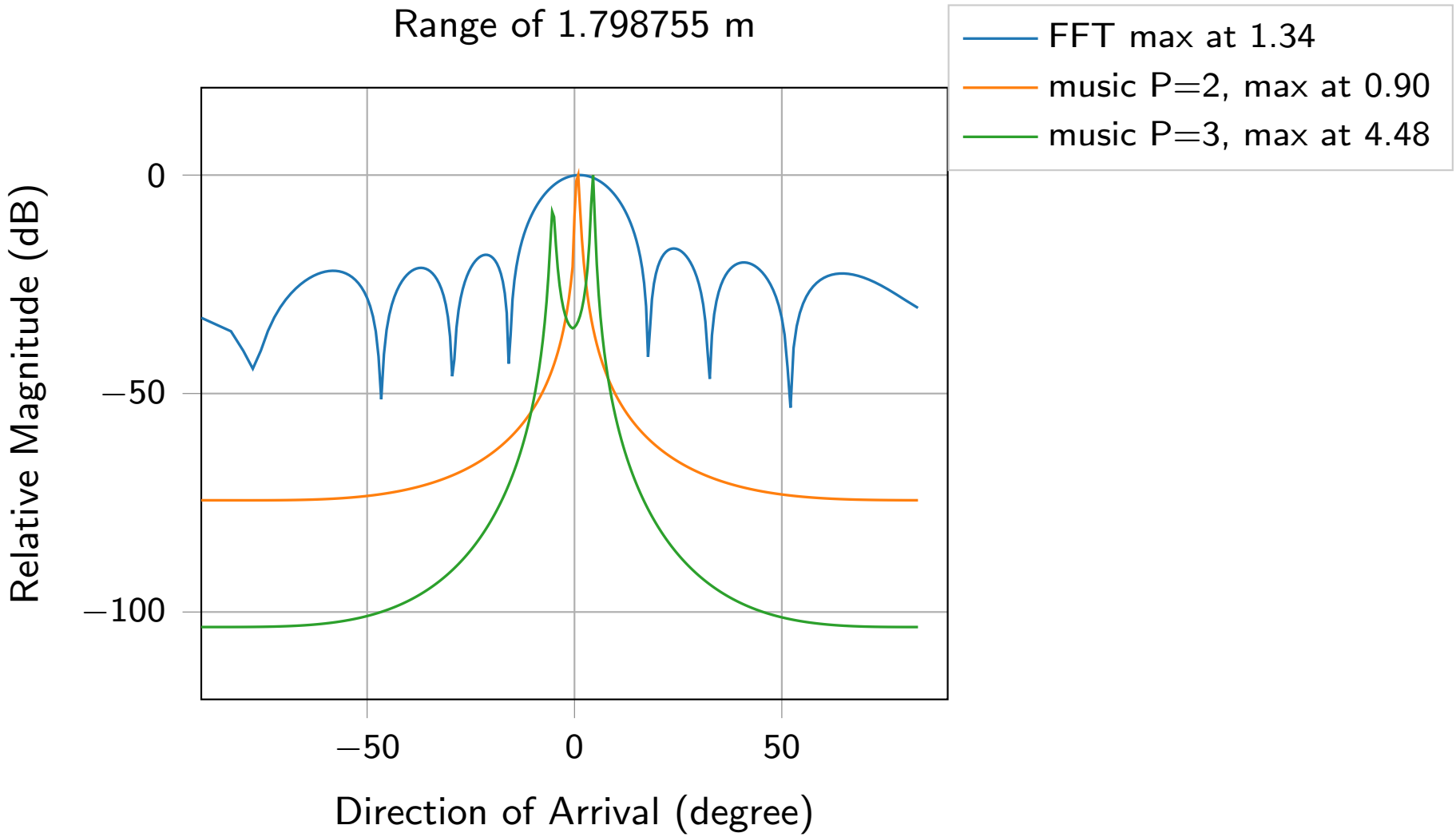

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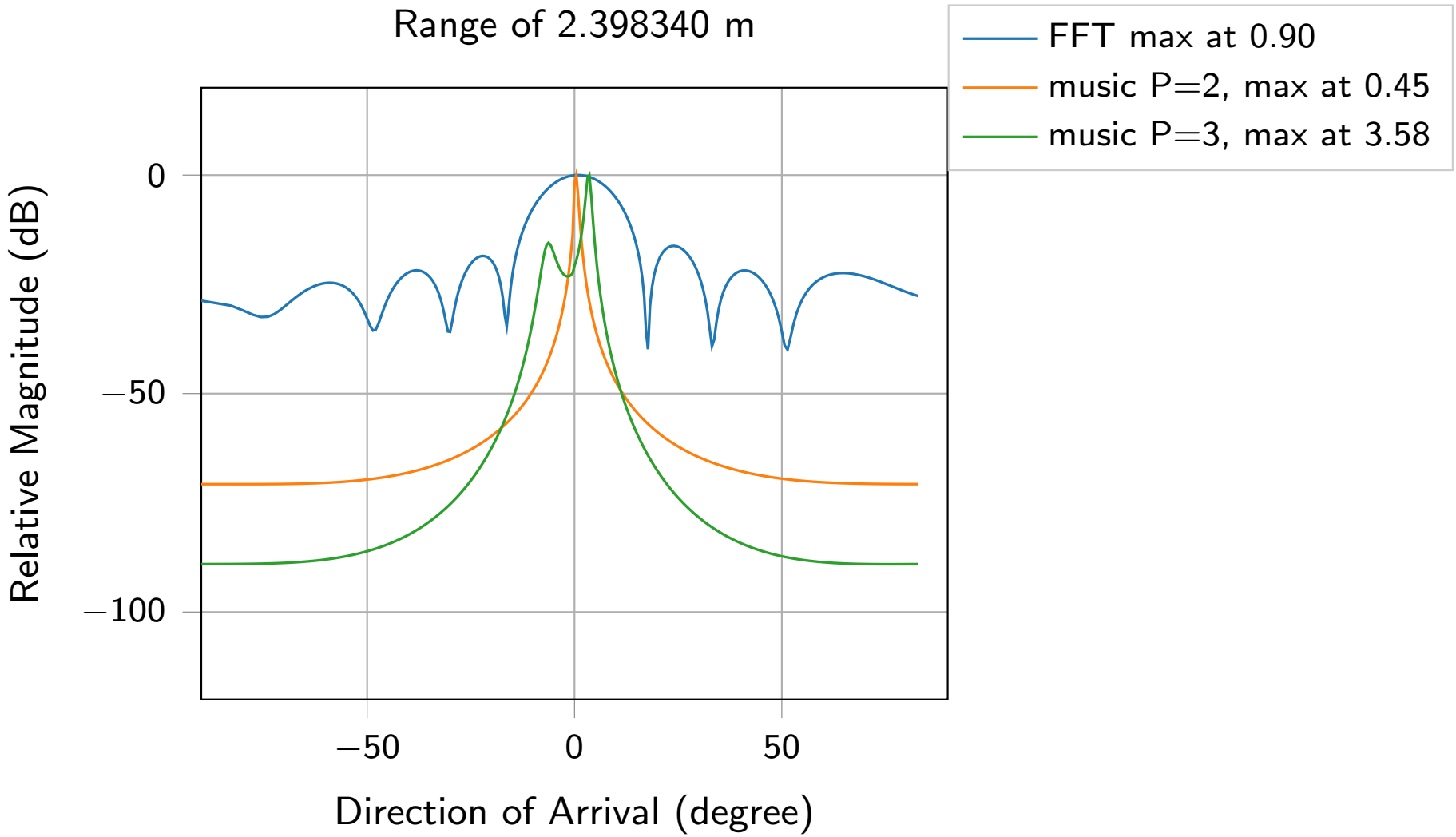

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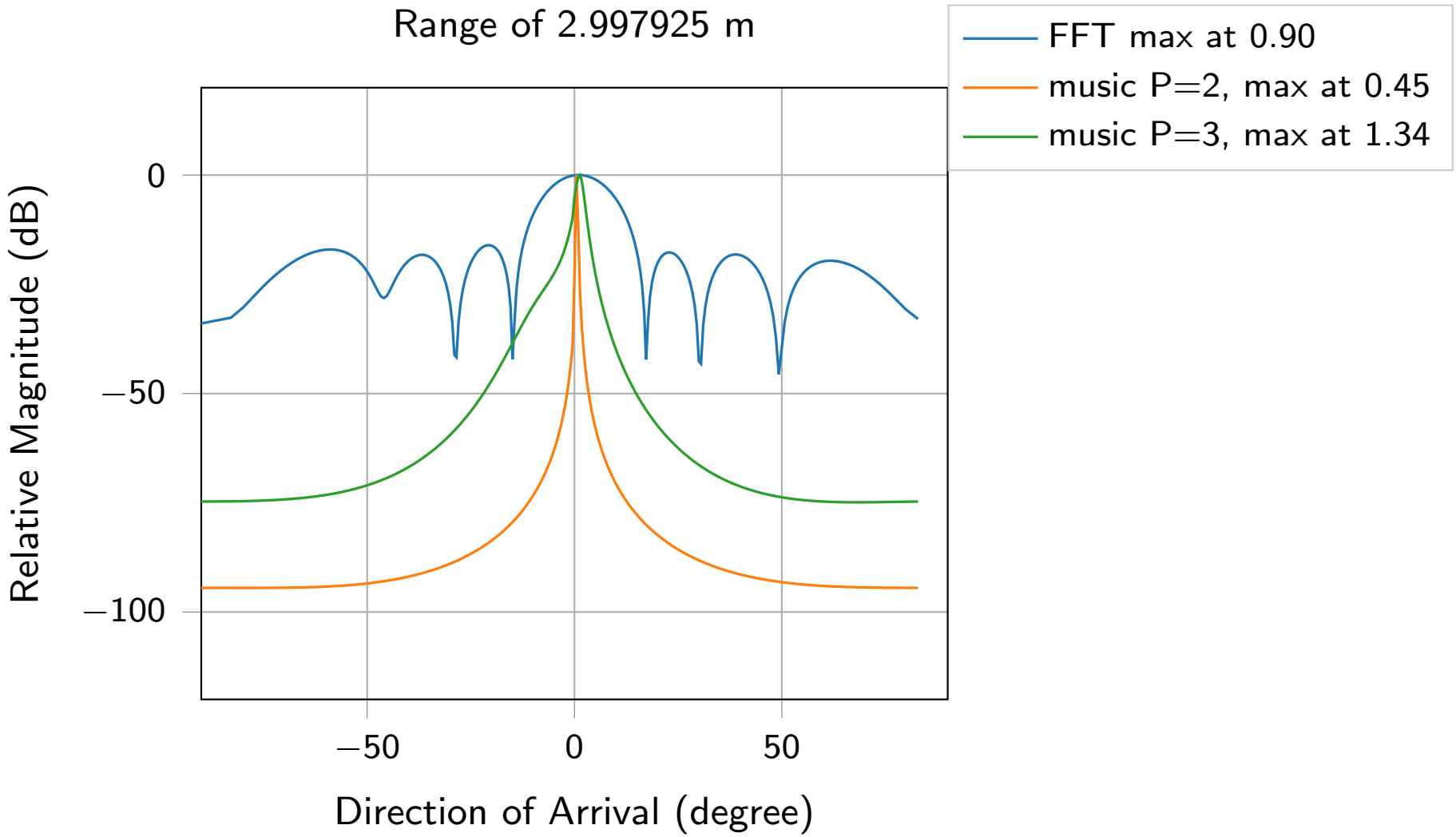

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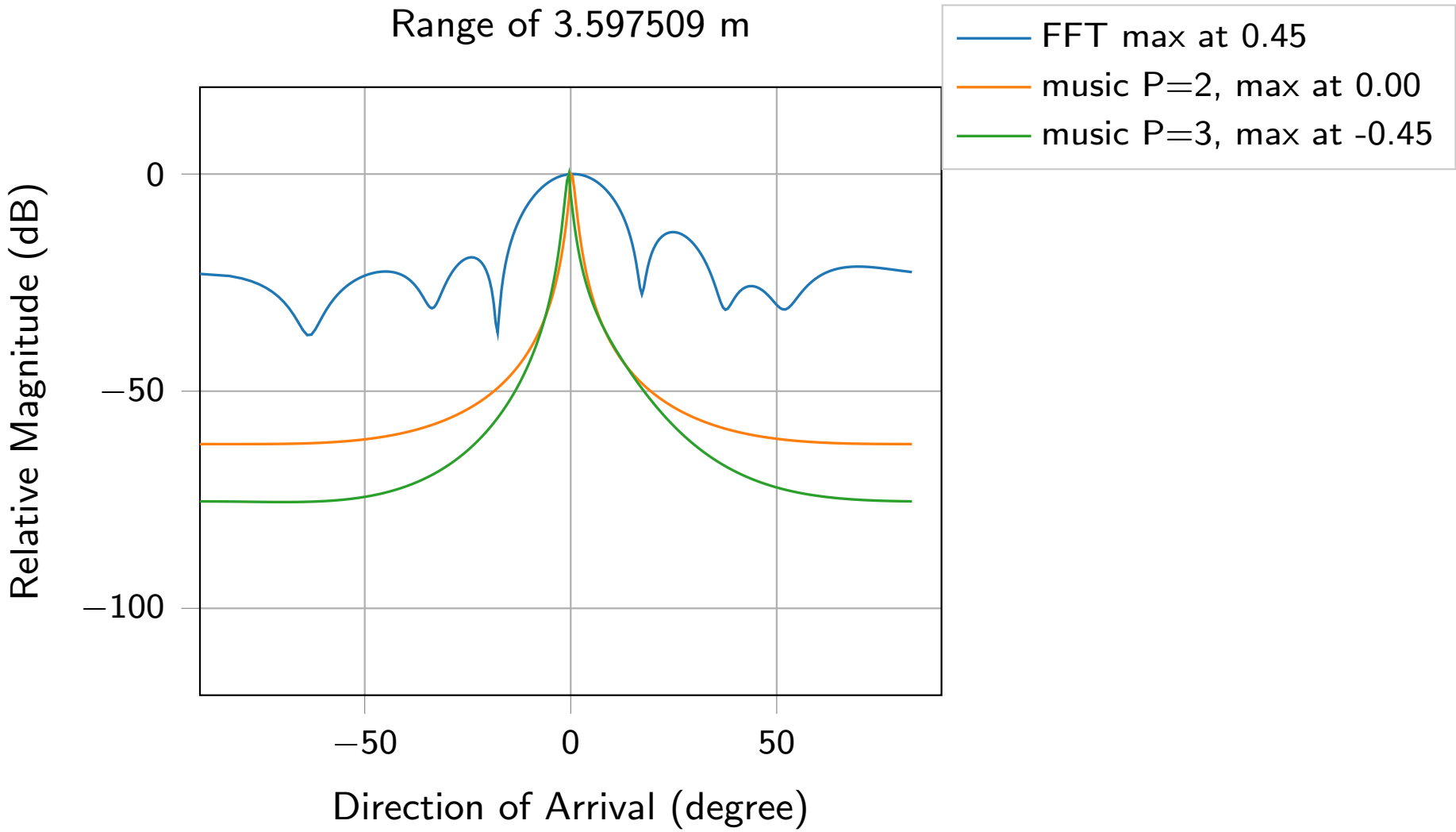

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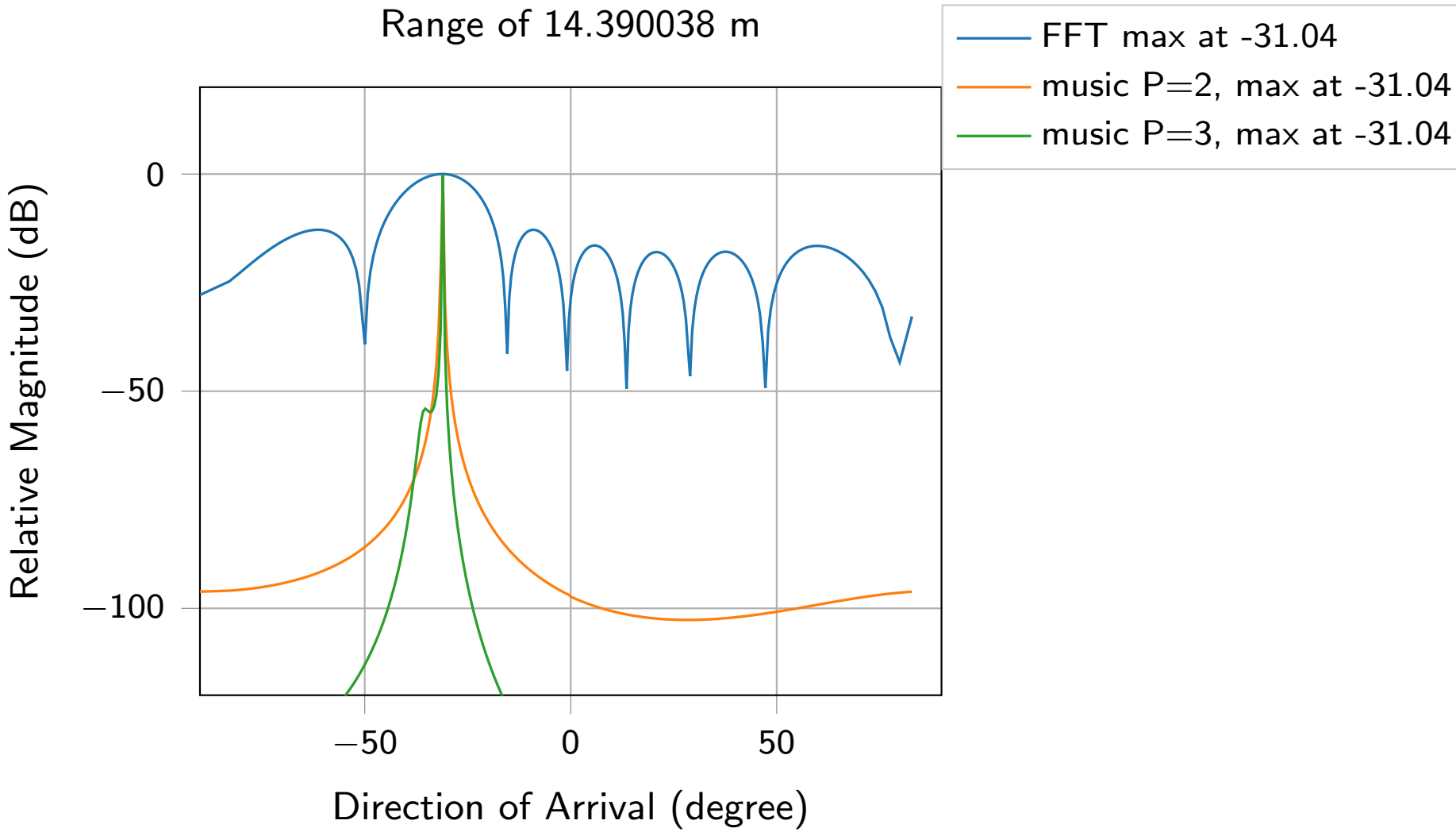

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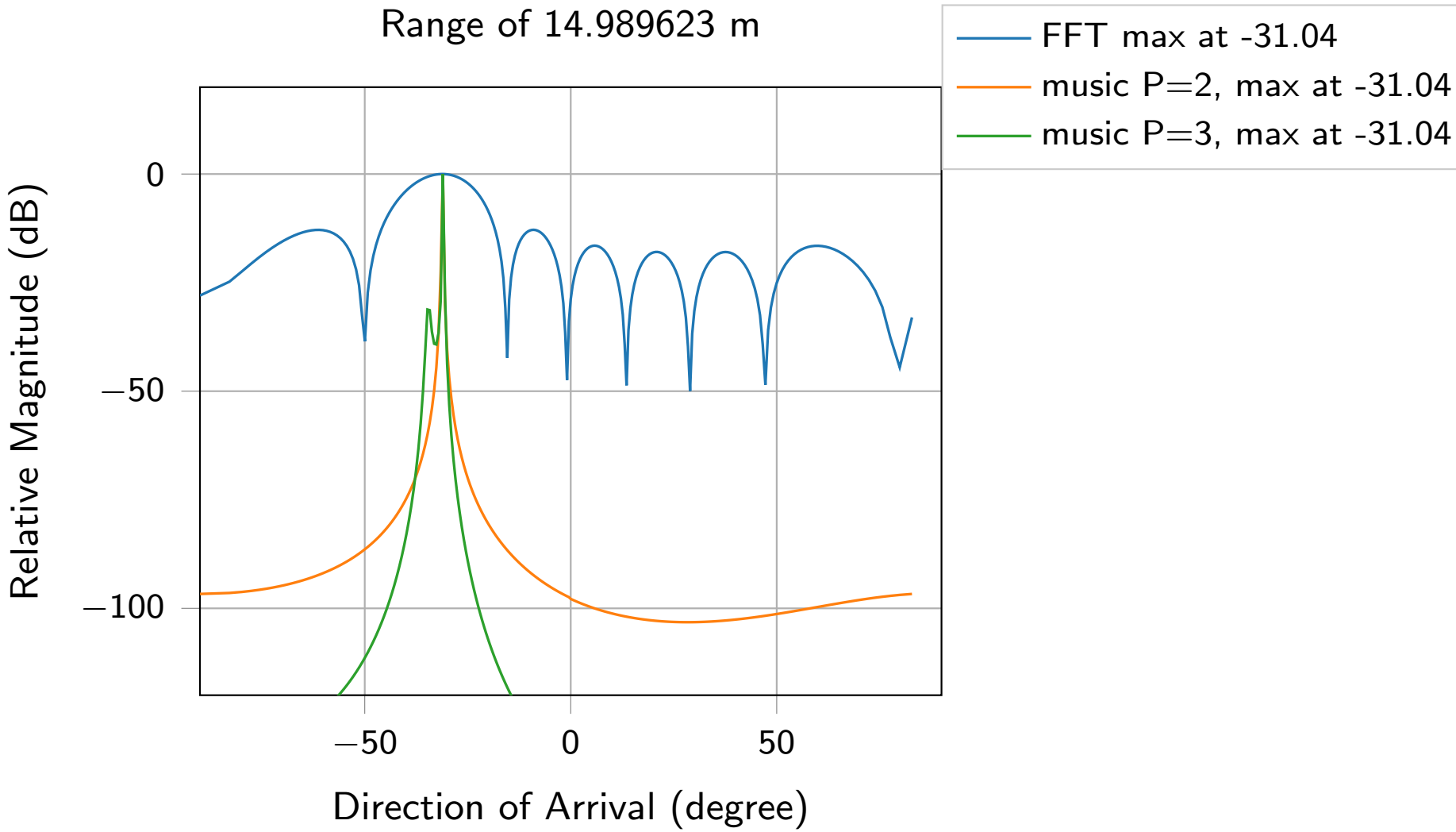

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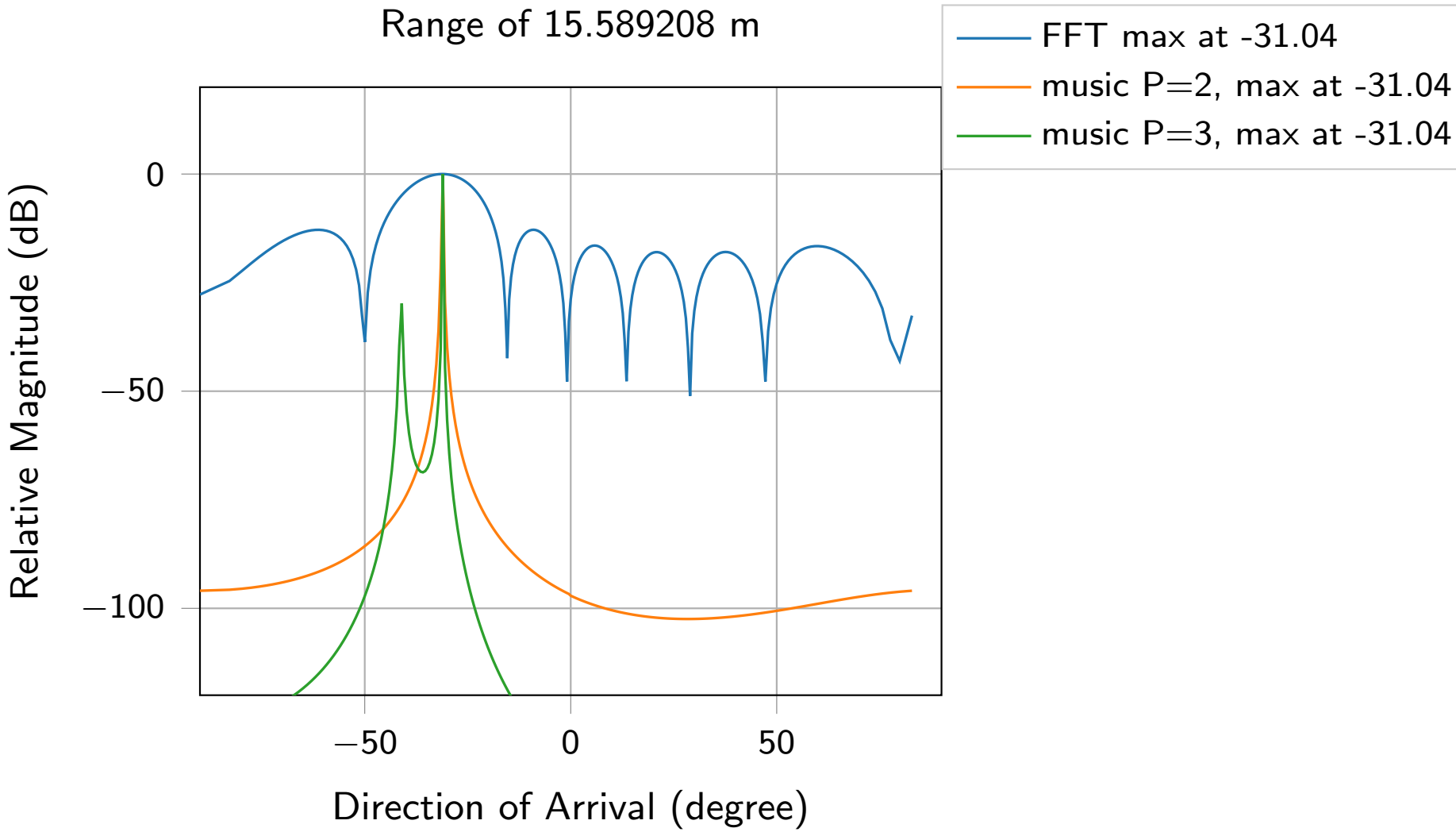

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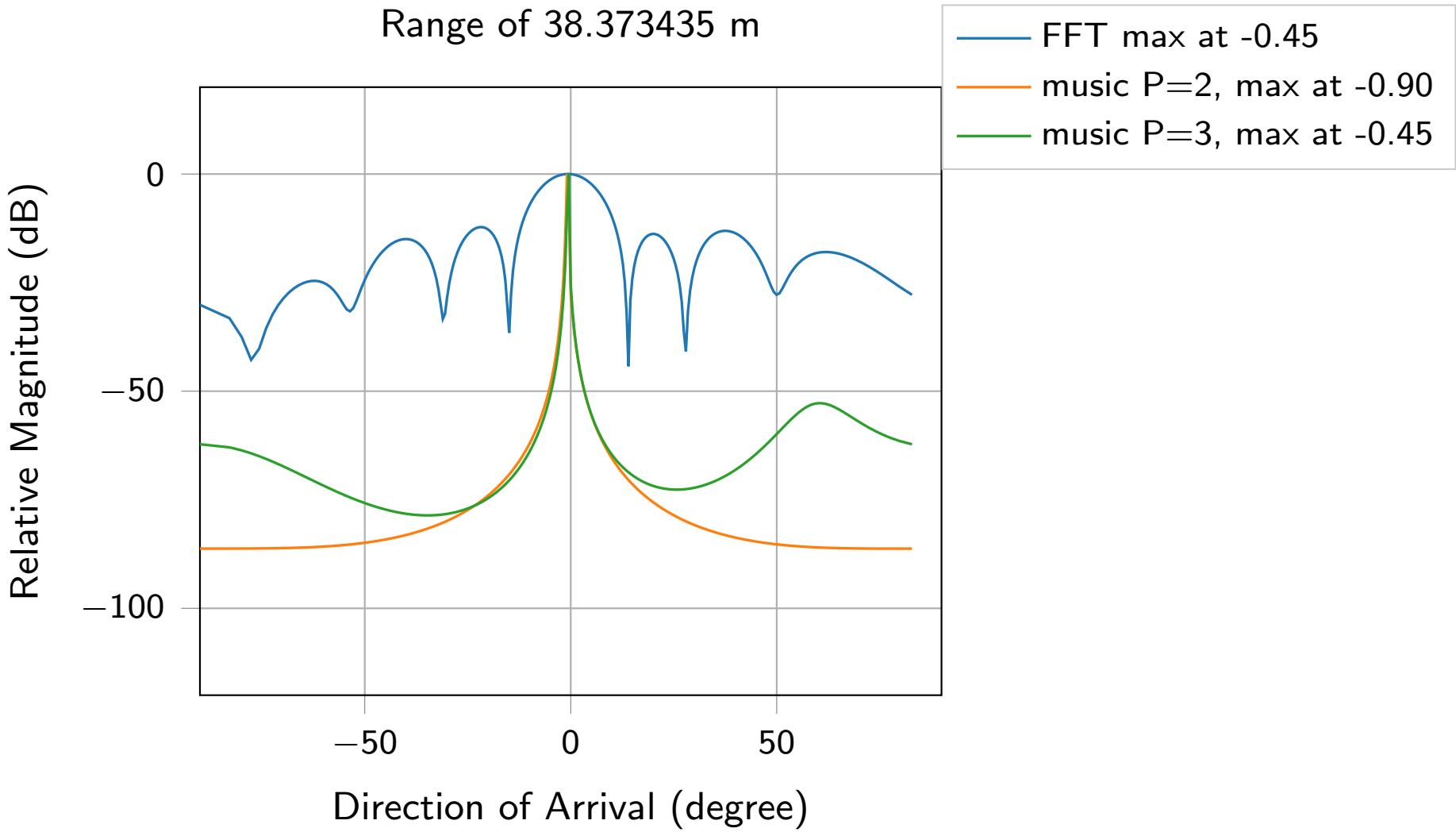

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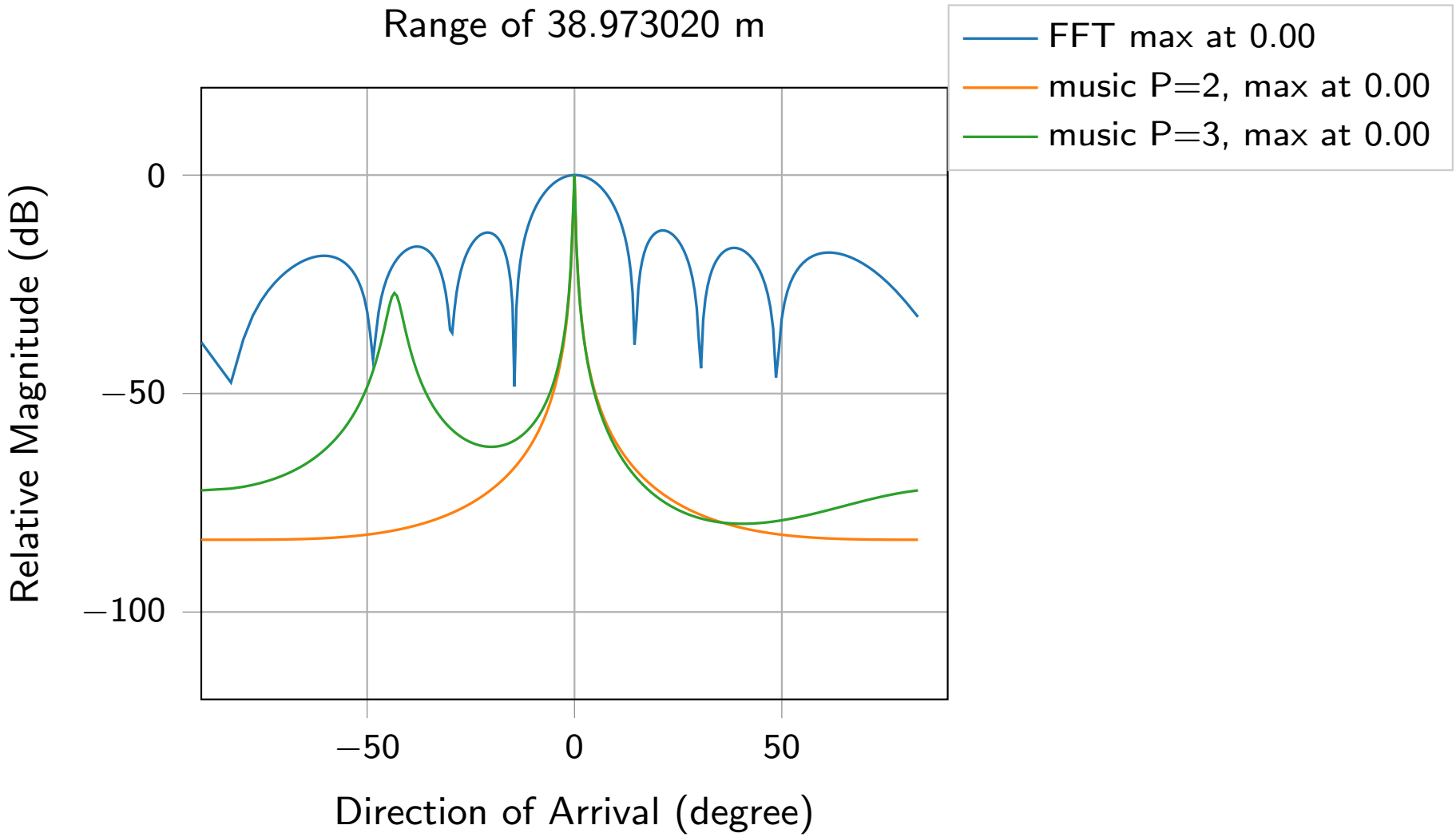

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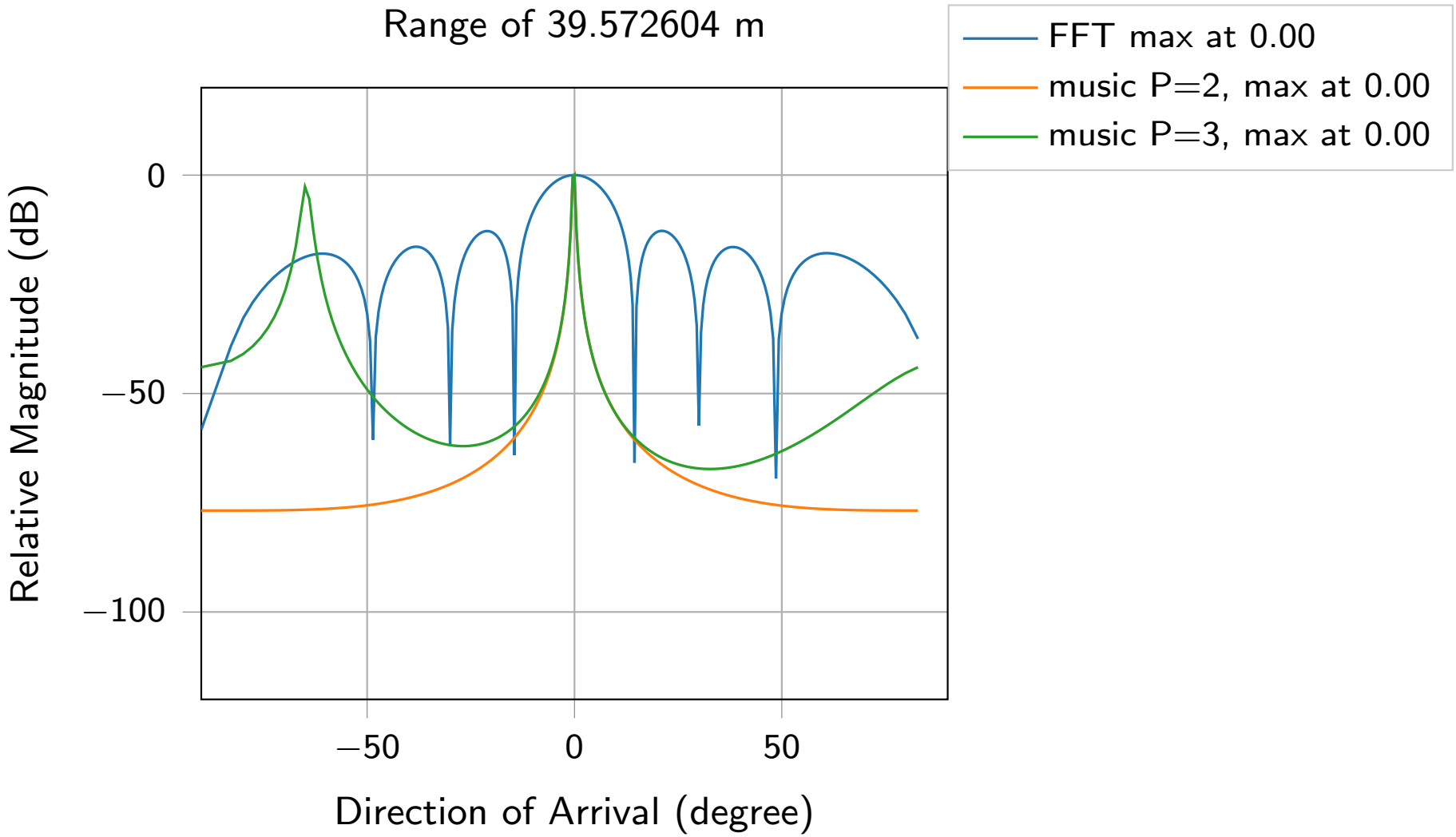

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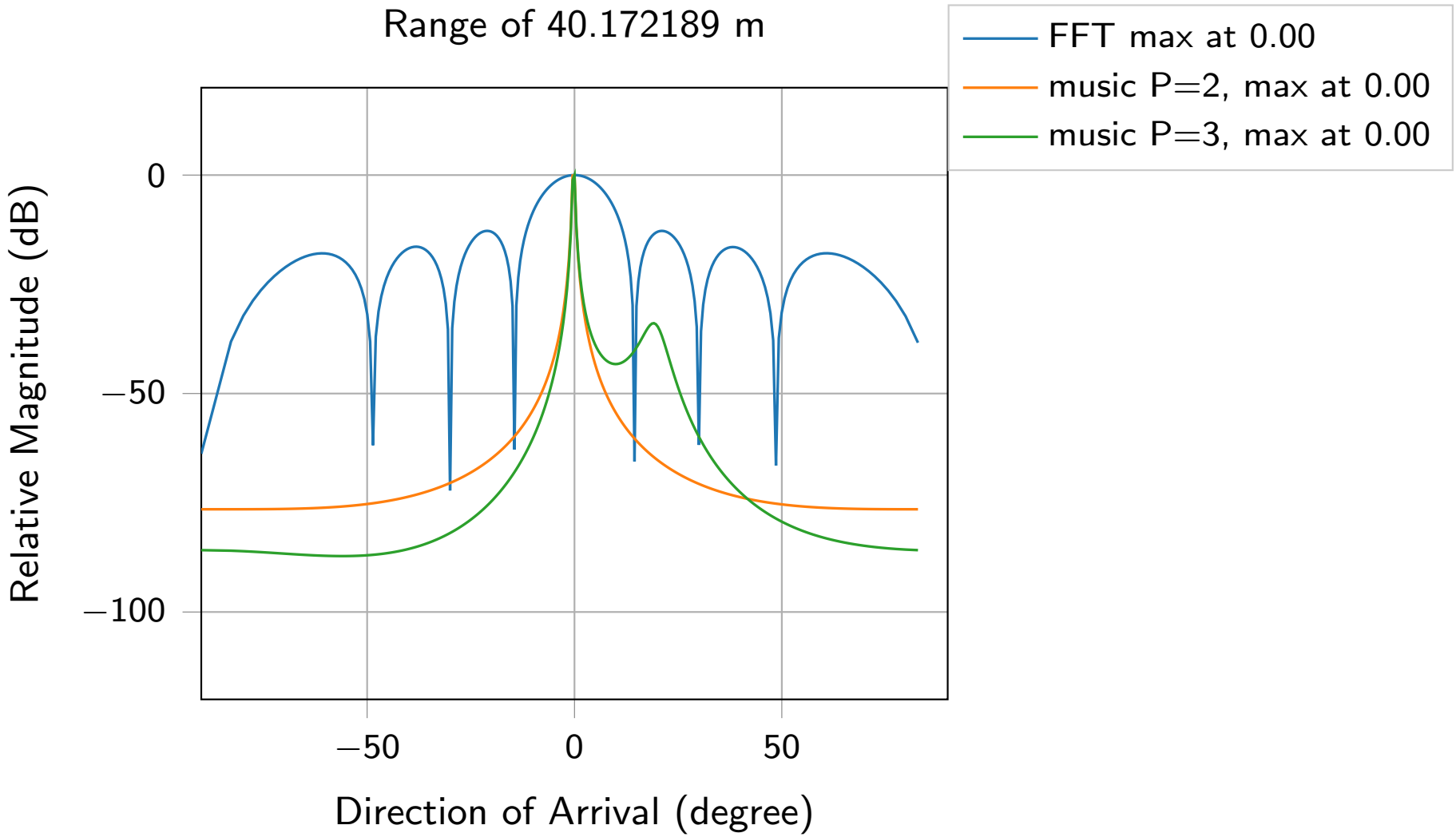

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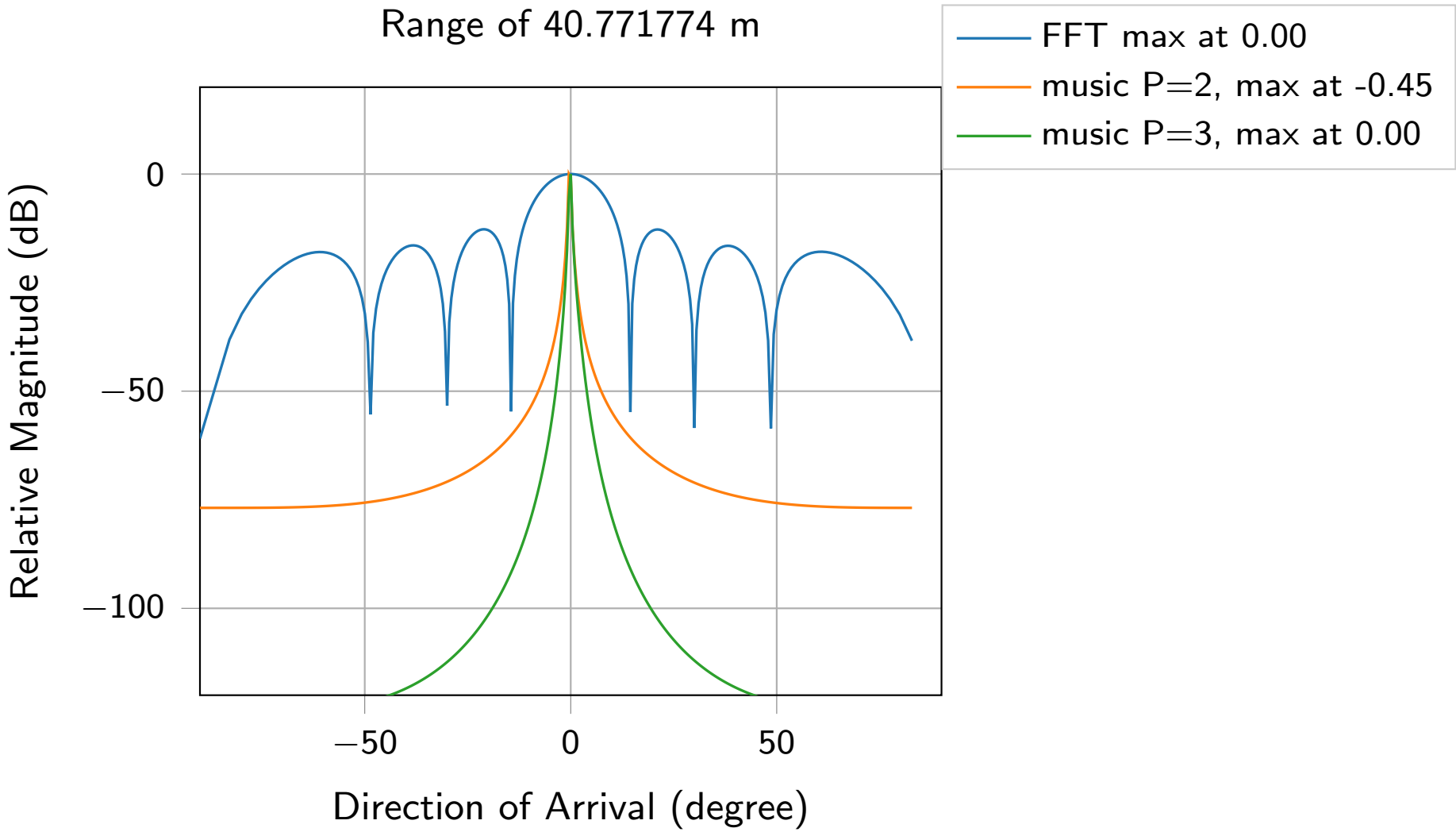

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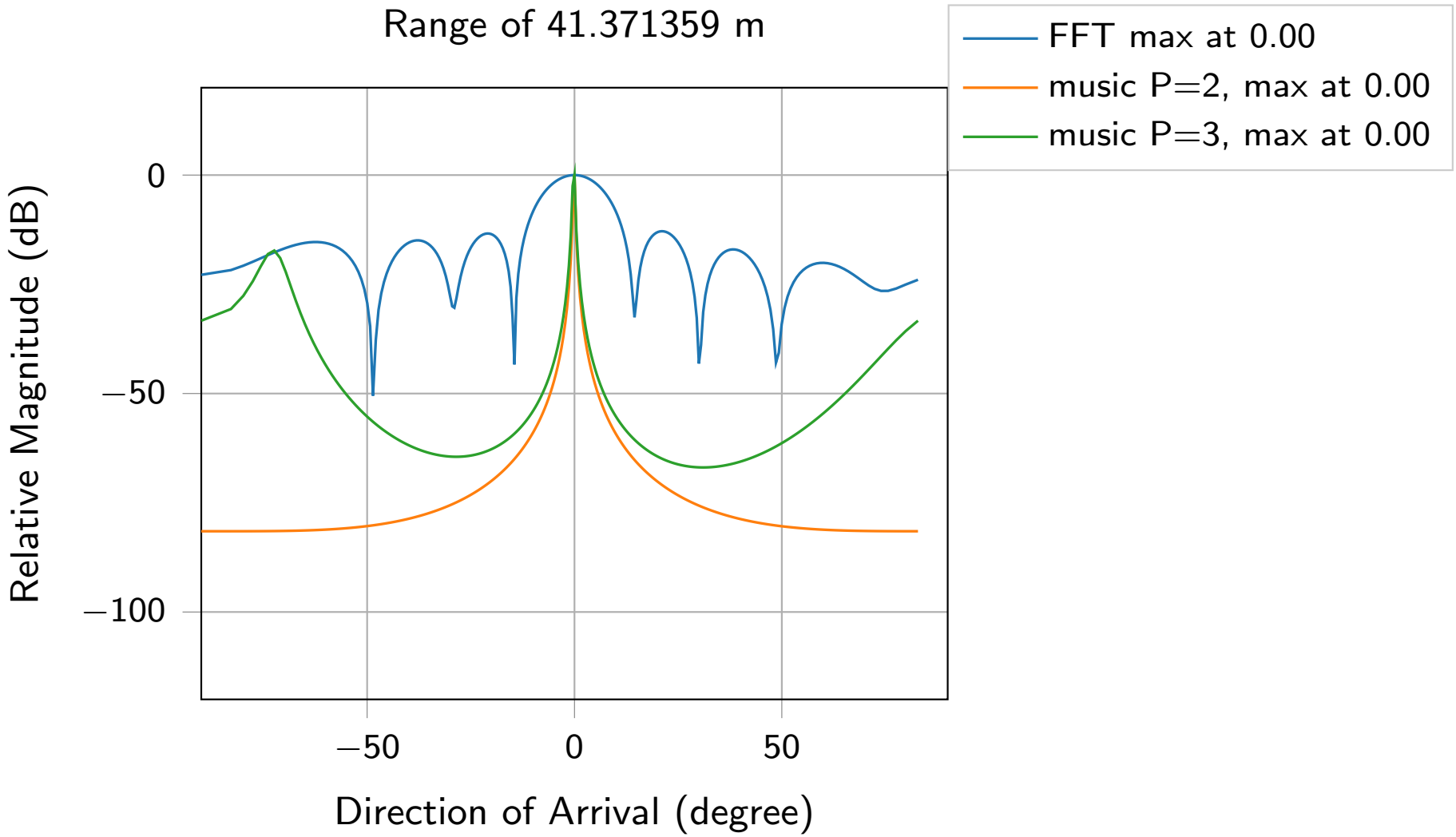

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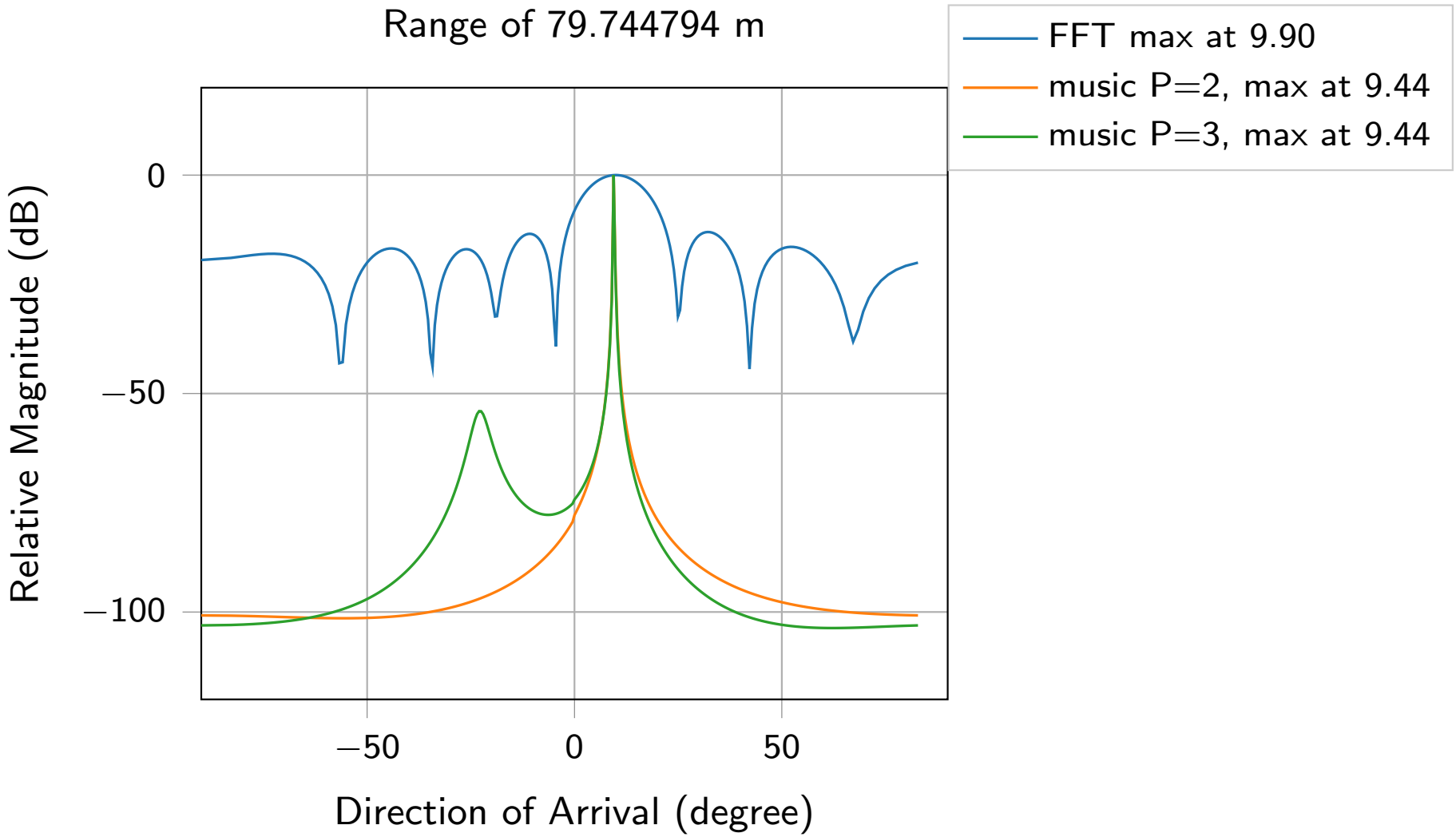

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