import numpy as np

import matplotlib.pyplot as plt

from scipy.integrate import trapezoid

# --- Parameters ---

grid\_size = 120

timesteps = 180

dt = 0.12

width = 6

r = np.linspace(0, grid\_size, grid\_size)

dr = r[1] - r[0]

# --- Barrier Profile ---

V = np.zeros\_like(r)

V[(r > 50) & (r < 56)] = 0.08

V[(r > 62) & (r < 72)] = 0.04

# --- Breathing Seed Function ---

def breathing\_seed(center, freq, base\_phase, t):

phase = base\_phase + 0.5 \* np.sin(freq \* t)

return np.exp(-((r - center)\*\*2)/(2 \* width\*\*2)) \* np.exp(1j \* phase)

# --- Evolution Function (Fixed Phase, Varying Frequency) ---

def evolve\_frequency(seed\_freq, seed\_center=67, seed\_base\_phase=np.pi, x0=95, k0=-1.2):

ψ = np.exp(-((r - x0)\*\*2) / (2 \* width\*\*2)) \* np.exp(1j \* k0 \* r)

for t in range(timesteps):

ψ\_internal = breathing\_seed(seed\_center, seed\_freq, seed\_base\_phase, t)

lap\_int = np.zeros\_like(ψ, dtype=complex)

lap\_int[1:-1] = (ψ\_internal[2:] - 2 \* ψ\_internal[1:-1] + ψ\_internal[:-2]) / dr\*\*2

lap\_ψ = np.zeros\_like(ψ, dtype=complex)

lap\_ψ[1:-1] = (ψ[2:] - 2 \* ψ[1:-1] + ψ[:-2]) / dr\*\*2

ψ += dt \* (0.65 \* lap\_ψ - 0.5 \* V \* ψ + 0.65 \* lap\_int)

norm = np.sqrt(trapezoid(np.abs(ψ)\*\*2, r))

if norm != 0:

ψ /= norm

final = np.abs(ψ)\*\*2

T = trapezoid(final[r > 85], r[r > 85])

return T

# --- Frequency Sweep ---

freq\_list = np.linspace(0.01, 0.15, 50)

transmissions = []

for freq in freq\_list:

T = evolve\_frequency(seed\_freq=freq)

transmissions.append(T)

# --- Plot Frequency Response ---

plt.figure(figsize=(10, 6))

plt.plot(freq\_list, transmissions, color='teal', linewidth=2)

plt.xlabel("Breathing Frequency of Seed (rad/step)")

plt.ylabel("Transmission Probability")

plt.title("MBT Dispatch Frequency Resonance Curve")

plt.grid(True)

plt.tight\_layout()

plt.show()