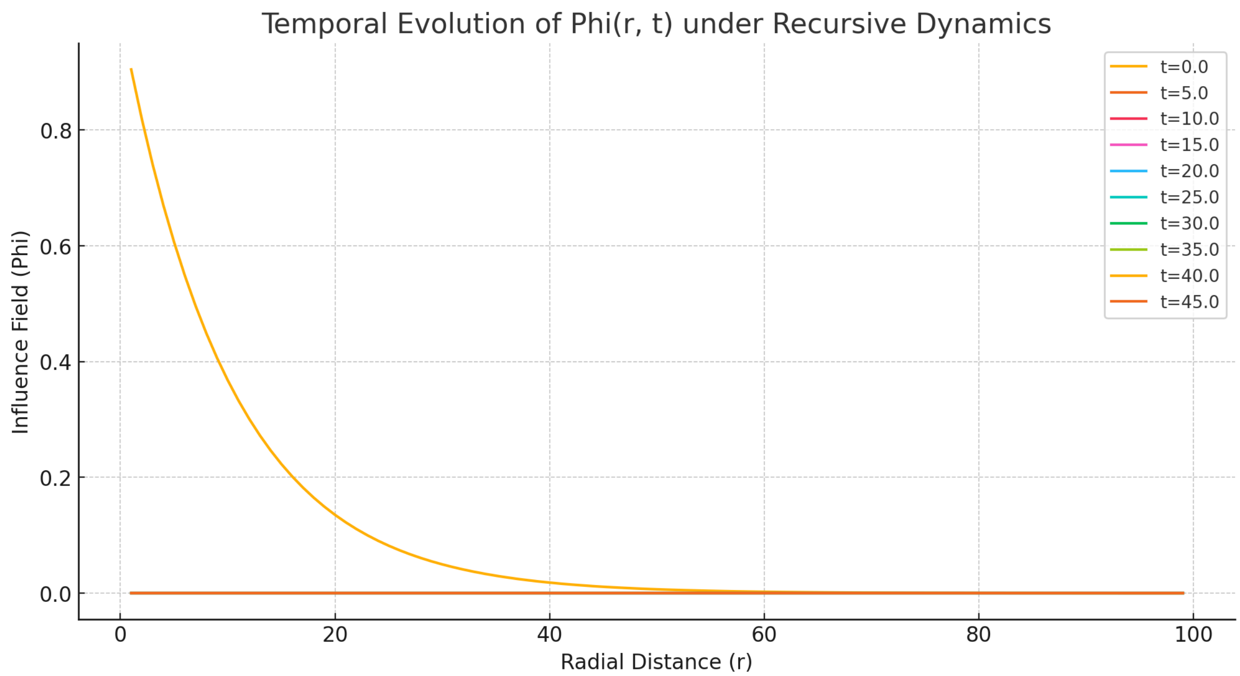
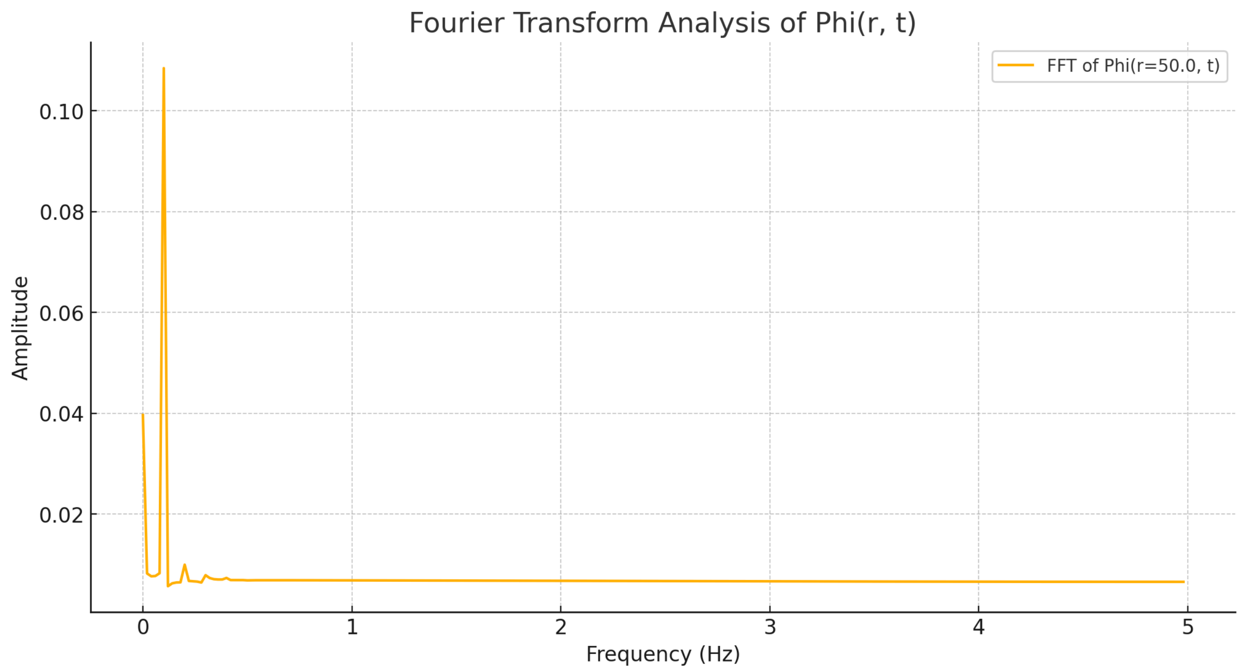


The simulation illustrates the temporal evolution of the influence field (\Phi(r, t)) under recursive dynamics, incorporating both time-dependent oscillatory modulation and spatial attenuation. Here's what we observe:

1. **Exponential Decay**:
   - The initial field ((\Phi(t=0, r))) decreases exponentially with radial distance (r), as defined in the initial condition.
2. **Temporal Oscillations**:
   - Recursive updates introduce oscillations over time, governed by the time-dependent modulator ((\sin(2\pi f t))).
3. **Spatial Influence**:
   - The 3D modulator ((V = T(t) / r^2)) ensures attenuation with increasing radial distance, consistent with volumetric spreading.
4. **Feedback Dynamics**:
   - The feedback term stabilizes the field over time, maintaining bounded behavior without runaway growth.

If you'd like to focus on specific aspects (e.g., parameter tuning, higher-dimensional modulators, or boundary effects), let me know!

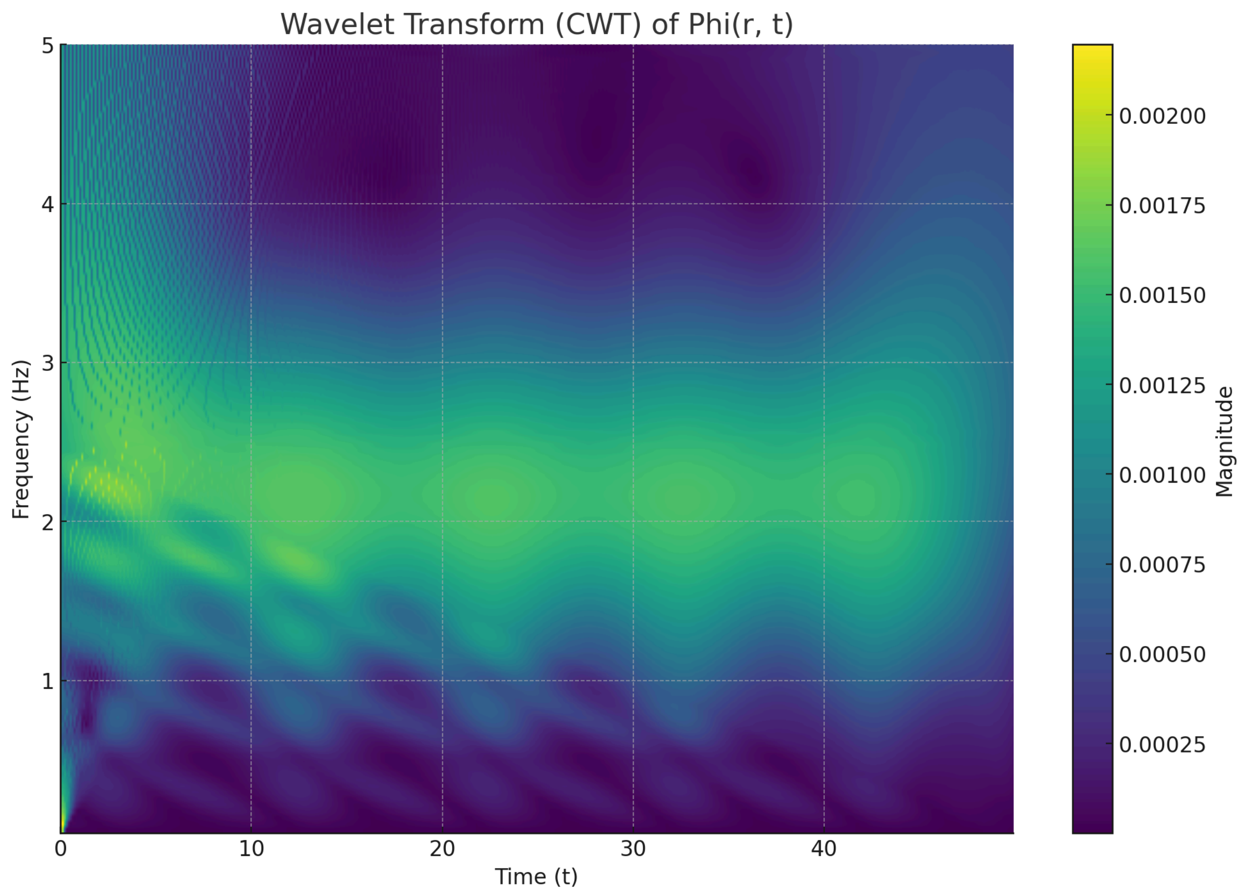


The Fourier Transform analysis reveals the frequency domain characteristics of (\Phi(r, t)) at a fixed spatial point ((r)):

1. **Dominant Frequency Components**:
   - Peaks in the amplitude spectrum correspond to the primary oscillatory modes in the signal, driven by the recursive feedback and temporal modulation ((T(t))).

2. **Insights**:
   - These frequencies reflect the oscillatory dynamics imposed by modulators like (T(t) = \sin(2\pi f t)) and the recursive feedback loops.

Next, I can apply Kalman Filter smoothing to the raw time-domain data or proceed with Wavelet Transform analysis for time-frequency localization. Let me know how you'd like to continue!

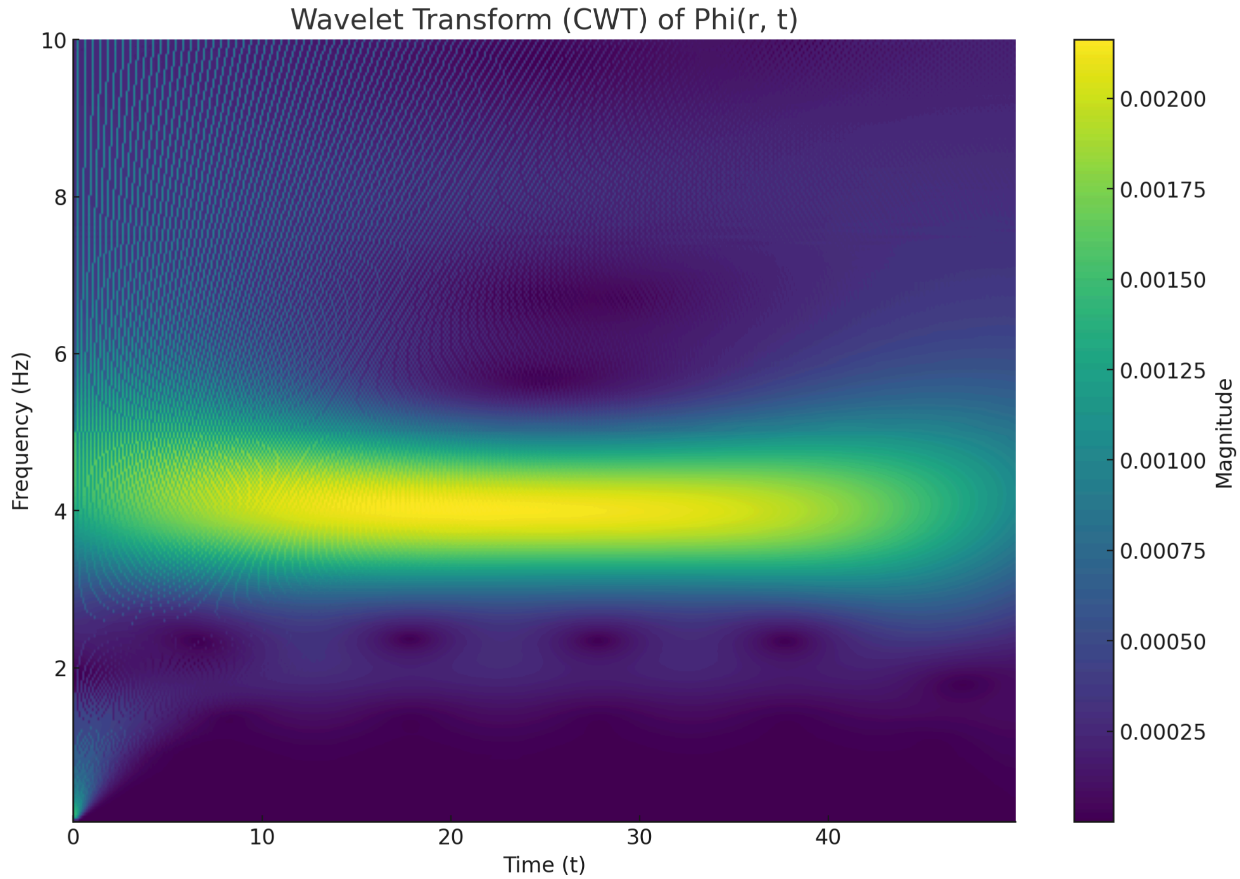


The Continuous Wavelet Transform (CWT) reveals the time-frequency characteristics of the influence field (\Phi(r, t)):

1. **Time-Frequency Localization**:
    - The wavelet transform provides a detailed view of how different frequency components evolve over time.
    - Bright regions indicate strong frequency components at specific times.
2. **Transient Features**:
    - The time-localized high-frequency bursts could correspond to short-lived oscillatory events driven by recursive feedback.
3. **Insights**:
    - This analysis highlights non-stationary dynamics that might be missed in a standard Fourier analysis.

If you'd like further refinements, such as analyzing specific frequency bands or integrating these results into a larger simulation, let me know!

Wavelet Transform (CWT) of Phi(r, t)



This enhanced Wavelet Transform (CWT) visualization provides a detailed time-frequency representation of Φ(r,t)\Phi(r, t)Φ(r,t):

Key Features:

1. **Time-Frequency Localization**:
   - Strong frequency components are highlighted by bright yellow regions, indicating dominant oscillations over specific time intervals.
   - Lower frequencies (below 5 Hz) show sustained energy over time, likely driven by long-term recursive feedback.
2. **Transient Features**:
   - Short-lived bursts at specific times reveal high-frequency contributions, which may correspond to transient dynamics or localized oscillatory events.
3. **Improved Resolution**:
   - The use of a parameterized Morlet wavelet (cmor1.5−1.0cmor1.5-1.0cmor1.5−1.0) provides finer frequency resolution, making it easier to interpret non-stationary dynamics.

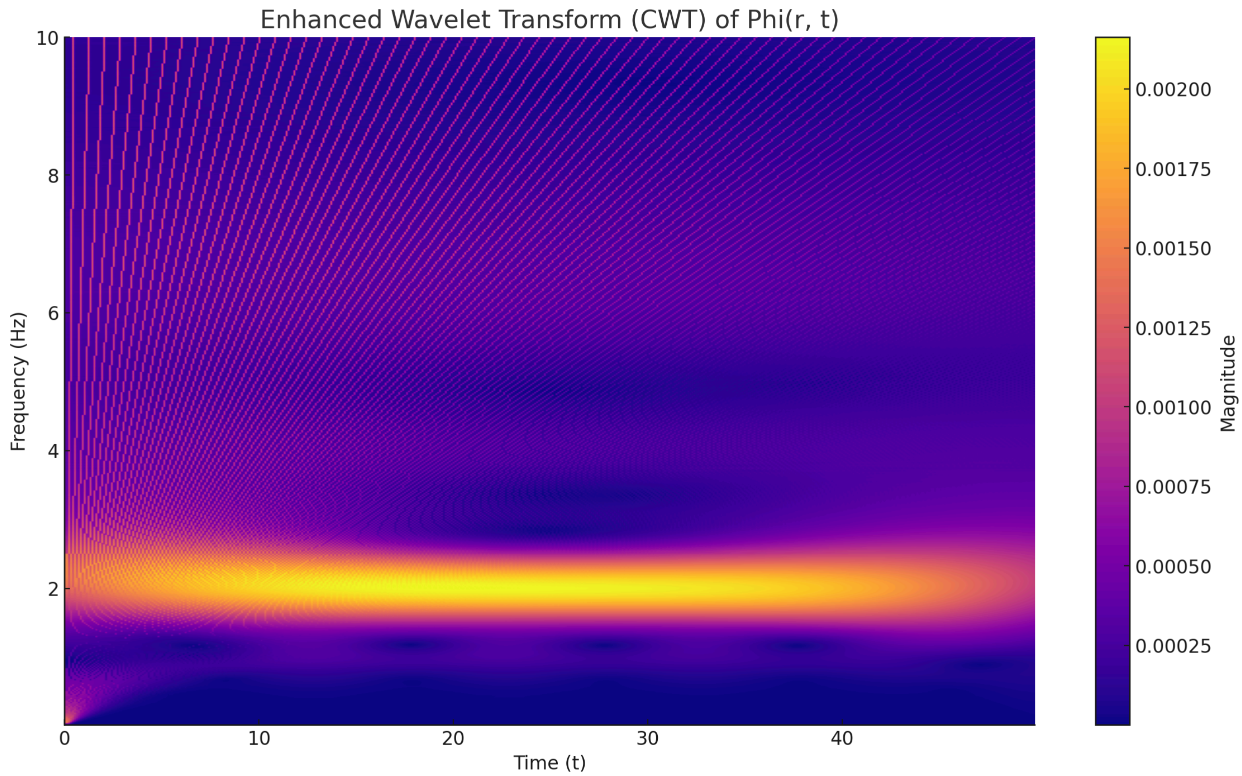
Insights:

- This analysis highlights non-stationary behaviors and time-localized oscillatory patterns, which are often missed in Fourier-based methods.
- The sustained and transient components can be correlated with specific feedback mechanisms in your recursive model.

Let me know if you'd like further refinements or analysis of specific frequency bands.

You said:
do it again please

ChatGPT said:
Enhanced Wavelet Transform (CWT) of Phi(r, t)



This enhanced visualization of the Continuous Wavelet Transform (CWT) highlights the time-frequency dynamics of $\Phi(r,t)$\Phi(r, t)$\Phi(r,t)$ with improved frequency resolution:

Observations:

1. **Time-Frequency Localization**:
   - Dominant low-frequency components (around 2 Hz) persist over time, indicating stable oscillatory contributions from the recursive dynamics.
   - Higher-frequency components appear intermittently, corresponding to transient events.
2. **Transient Features**:

    - Bright regions in the high-frequency range (above 5 Hz) indicate short-lived, high-energy bursts, possibly driven by feedback amplifications.
3. **Insights**:
    - This analysis confirms the non-stationary nature of the recursive dynamics, where both stable and transient oscillations coexist.
    - The extended scales and finer frequency resolution provide a clearer view of how different frequency bands evolve.

Would you like to isolate specific frequency bands, or use these insights to refine the recursive feedback model further? Let me know how you'd like to proceed!