Time Reversed Electromagnetic Wave Propagation as a Novel Method of Wireless Power Transfer

Frank Cangialosi, Tyler Grover, Patrick Healey,
Tim Furman, Andrew Simon, Steven M. Anlage

CNAM
Center for Nanophysics and Advanced Materials

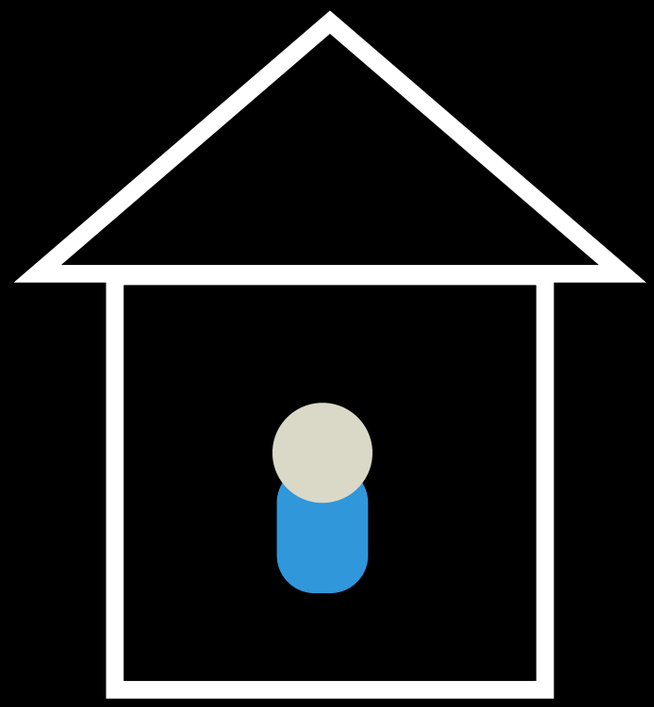
UNIVERSITY OF MARYLAND 18 56

GEMSTONE
UNIVERSITY OF MARYLAND

Current State of Long-Range WPT

Ubiquitous WPT requires greater range
than provided by near-field technologies

Microwave Beaming



Current State of Long-Range WPT

Ubiquitous WPT requires greater range
than provided by near-field technologies

Microwave Beaming

Precise Alignment

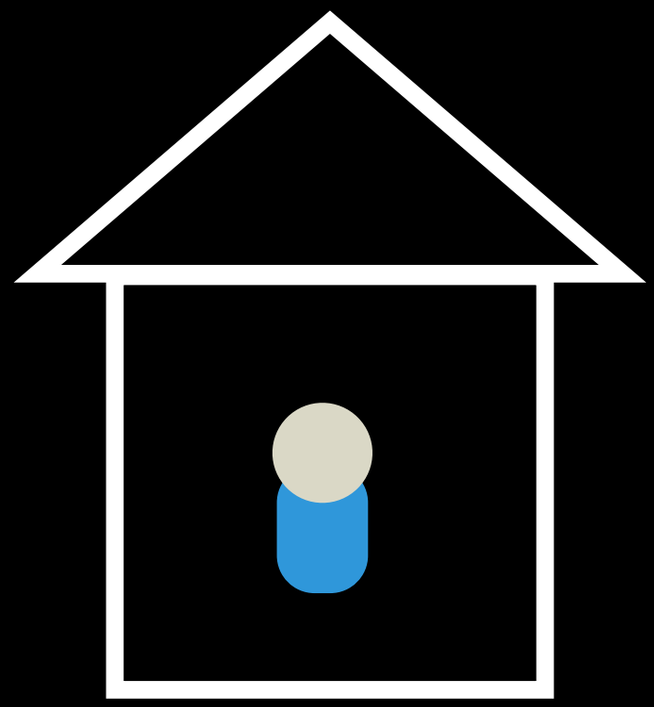
Obstructions

Current State of Long-Range WPT

Ubiquitous WPT requires greater range than provided by near-field technologies

Microwave Beaming

Precise Alignment



Obstructions

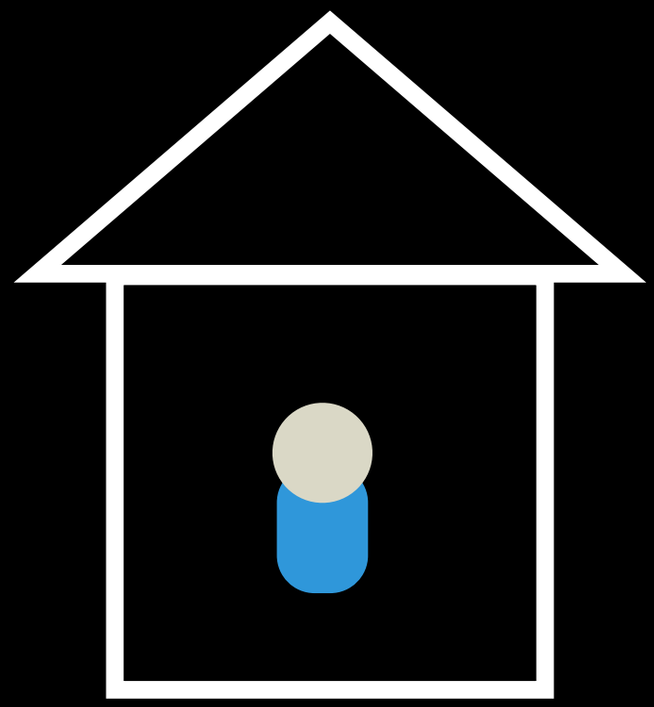
Current State of Long-Range WPT

Ubiquitous WPT requires greater range
than provided by near-field technologies

Microwave Beaming

Precise Alignment

Safety Hazard



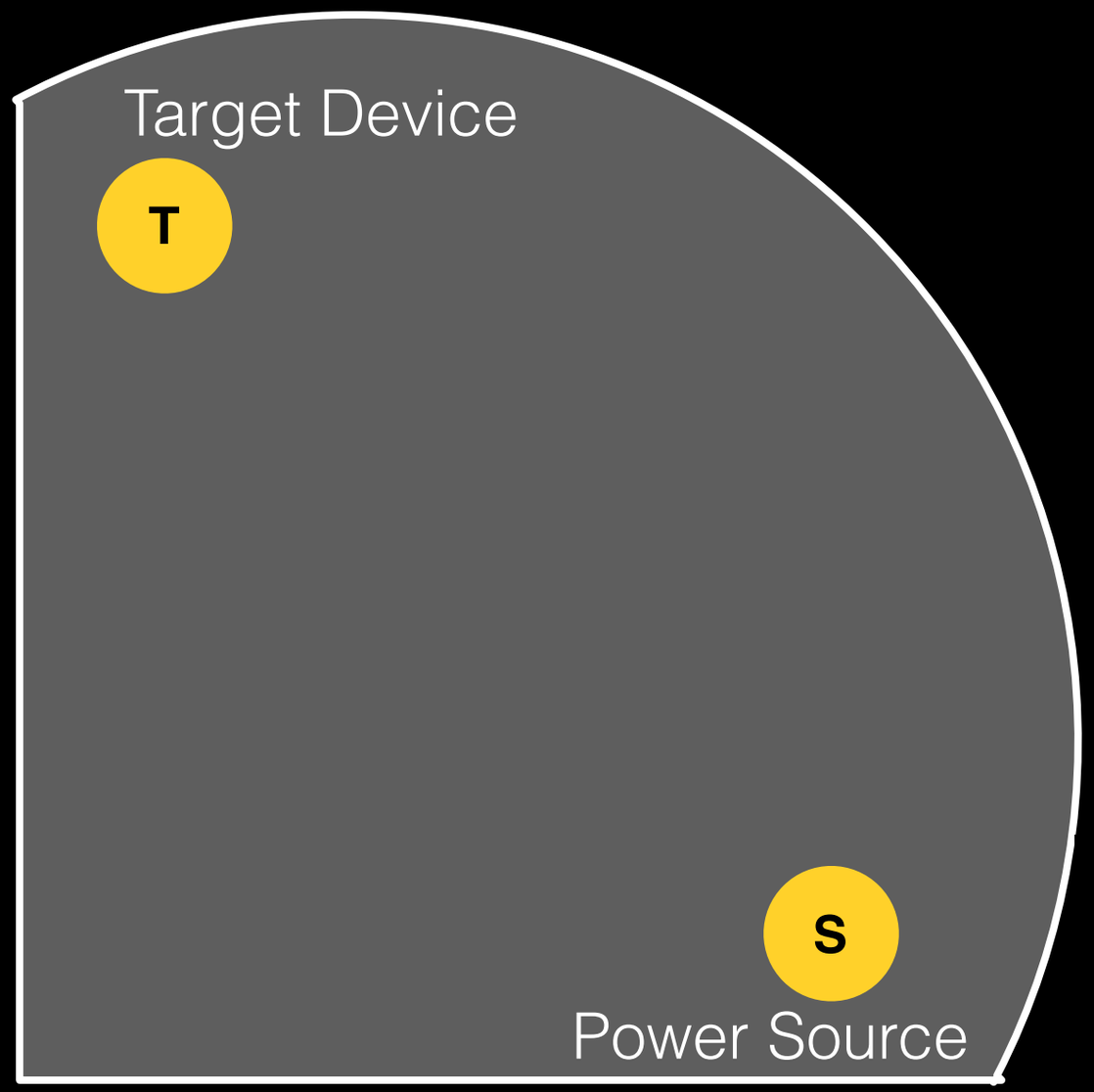
Obstructions

Time Reversal

A signal-focusing technique

1. Time Forward Step

Target requests power,
source records sona



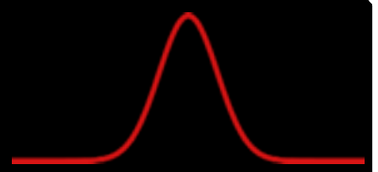
(Enclosed cavity with reflecting walls)

Time Reversal

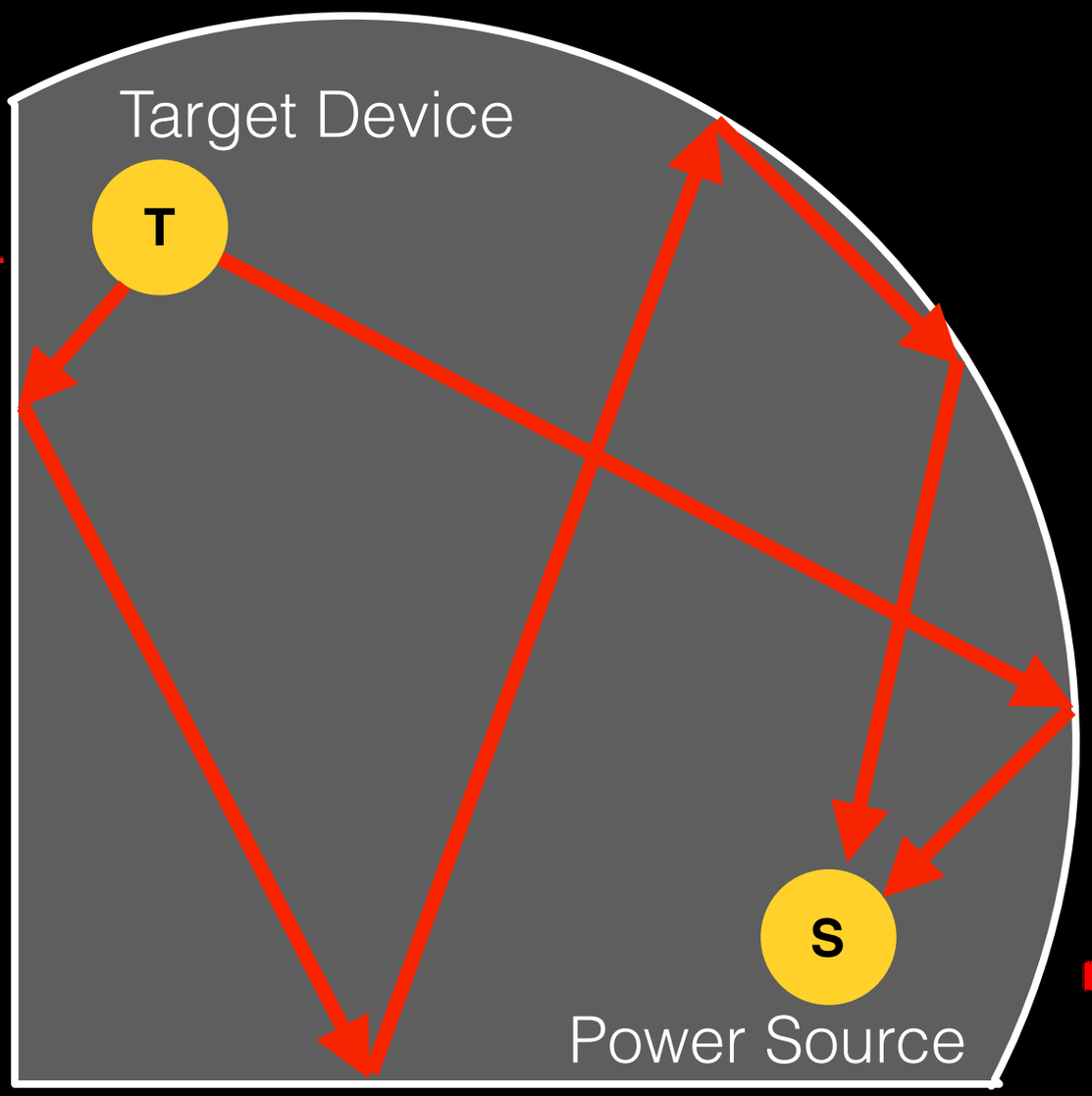
A signal-focusing technique

1. Time Forward Step

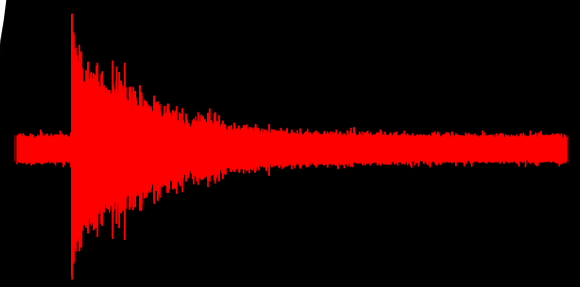
Target requests power,
source records sona



Gaussian
Pulse
(50 ns)



“Sona"



(Enclosed cavity with reflecting walls)

Time Reversal

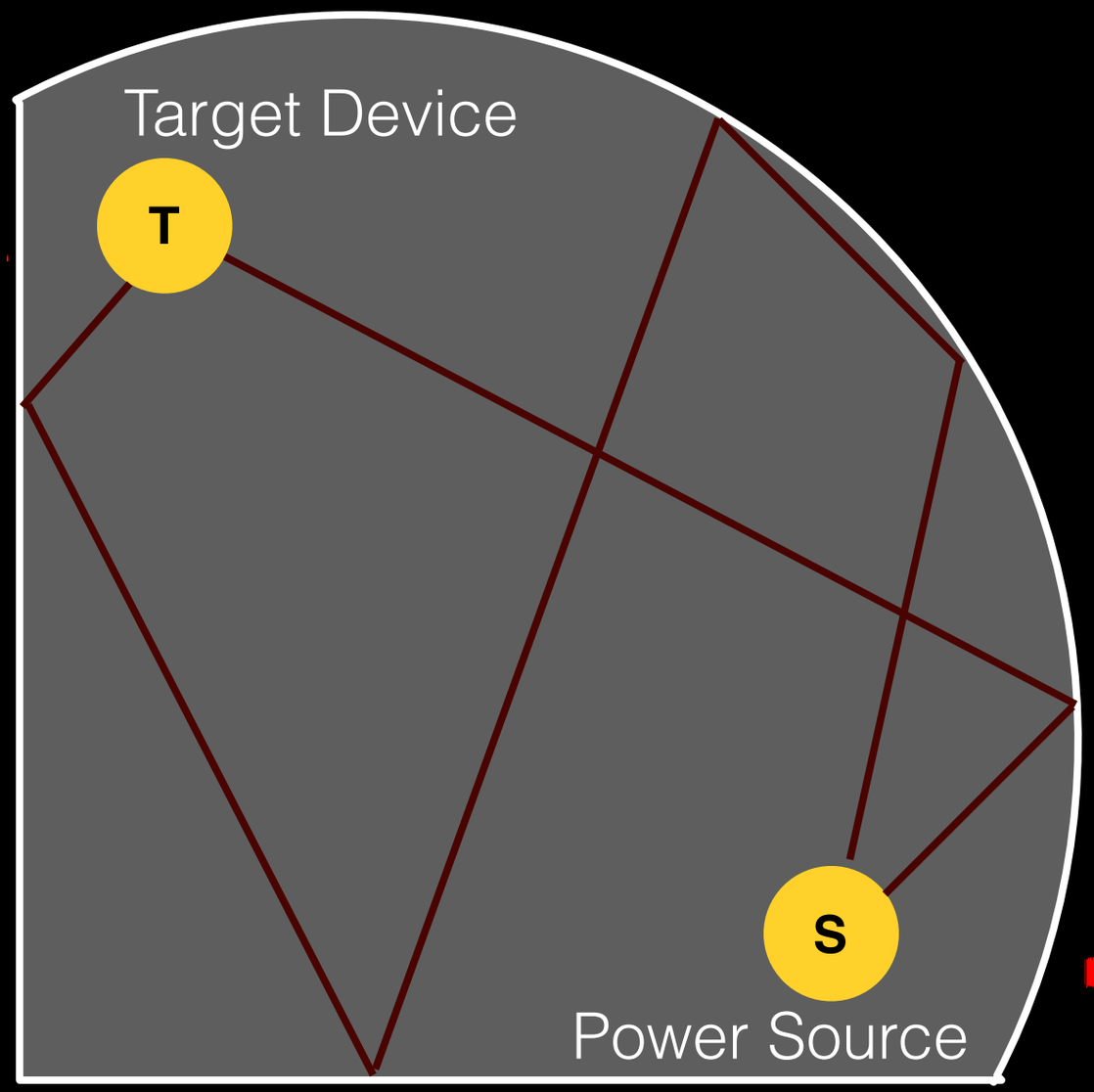
A signal-focusing technique

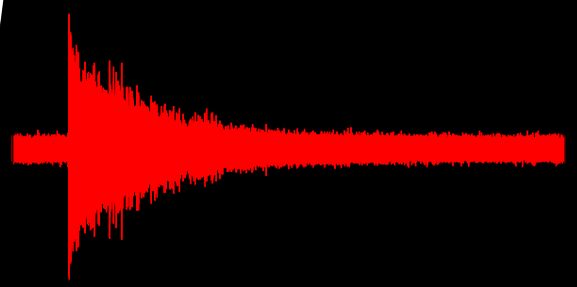
1. Time Forward Step

Target requests power,
source records sona

2. Time Reverse Step

Source reverses and broadcasts,
sona reconstructs on target





(Enclosed cavity with reflecting walls)

Time Reversal

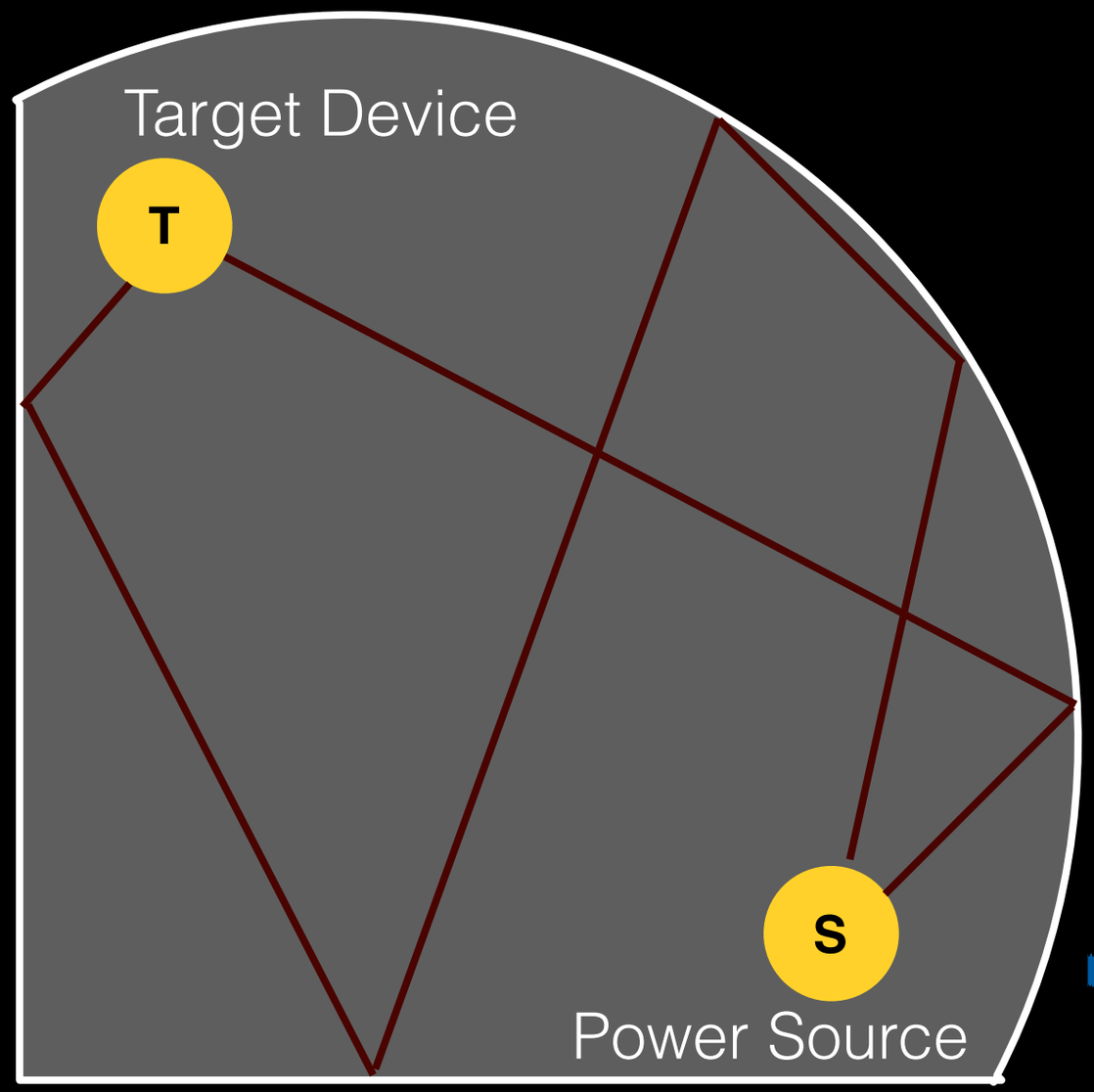
A signal-focusing technique

1. Time Forward Step

Target requests power,
source records sona

2. Time Reverse Step

Source reverses and broadcasts,
sona reconstructs on target



“Sona"

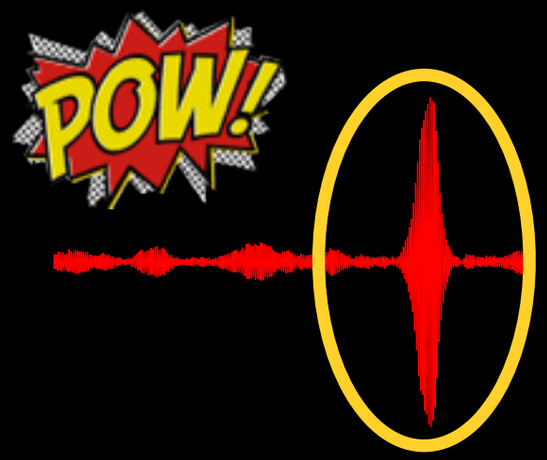
(Enclosed cavity with reflecting walls)

Time Reversal

A signal-focusing technique

1. Time Forward Step

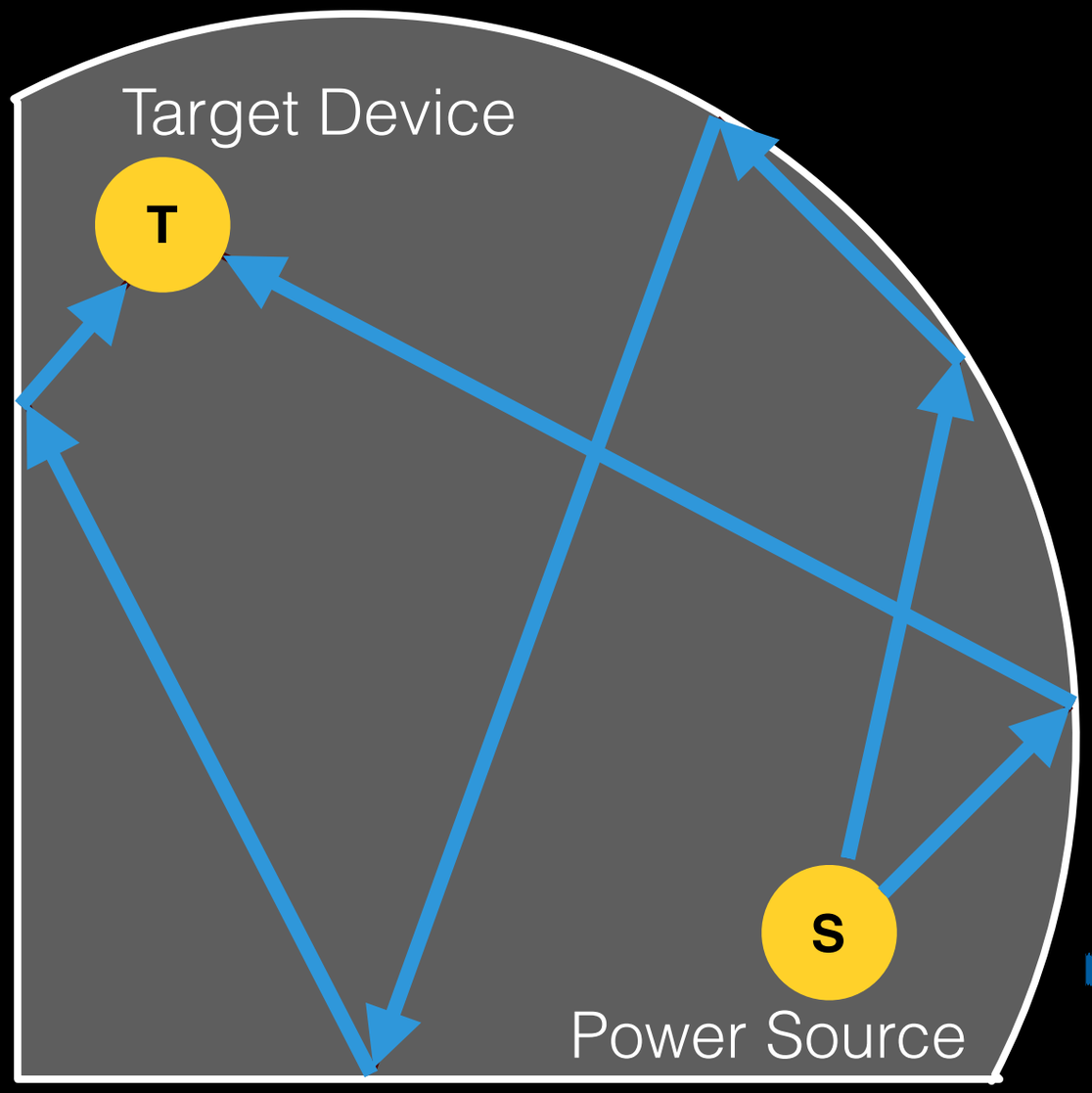
Target requests power,
source records sona



“Reconstruction”
pulse

2. Time Reverse Step

Source reverses and broadcasts,
sona reconstructs on target



“Sona"

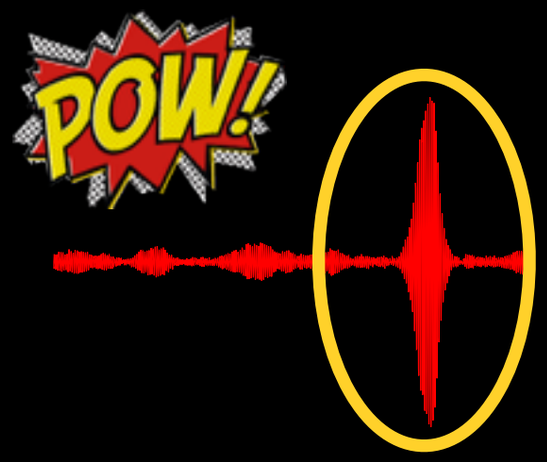
(Enclosed cavity with reflecting walls)

Time Reversal

A signal-focusing technique

1. Time Forward Step

Target requests power,
source records sona

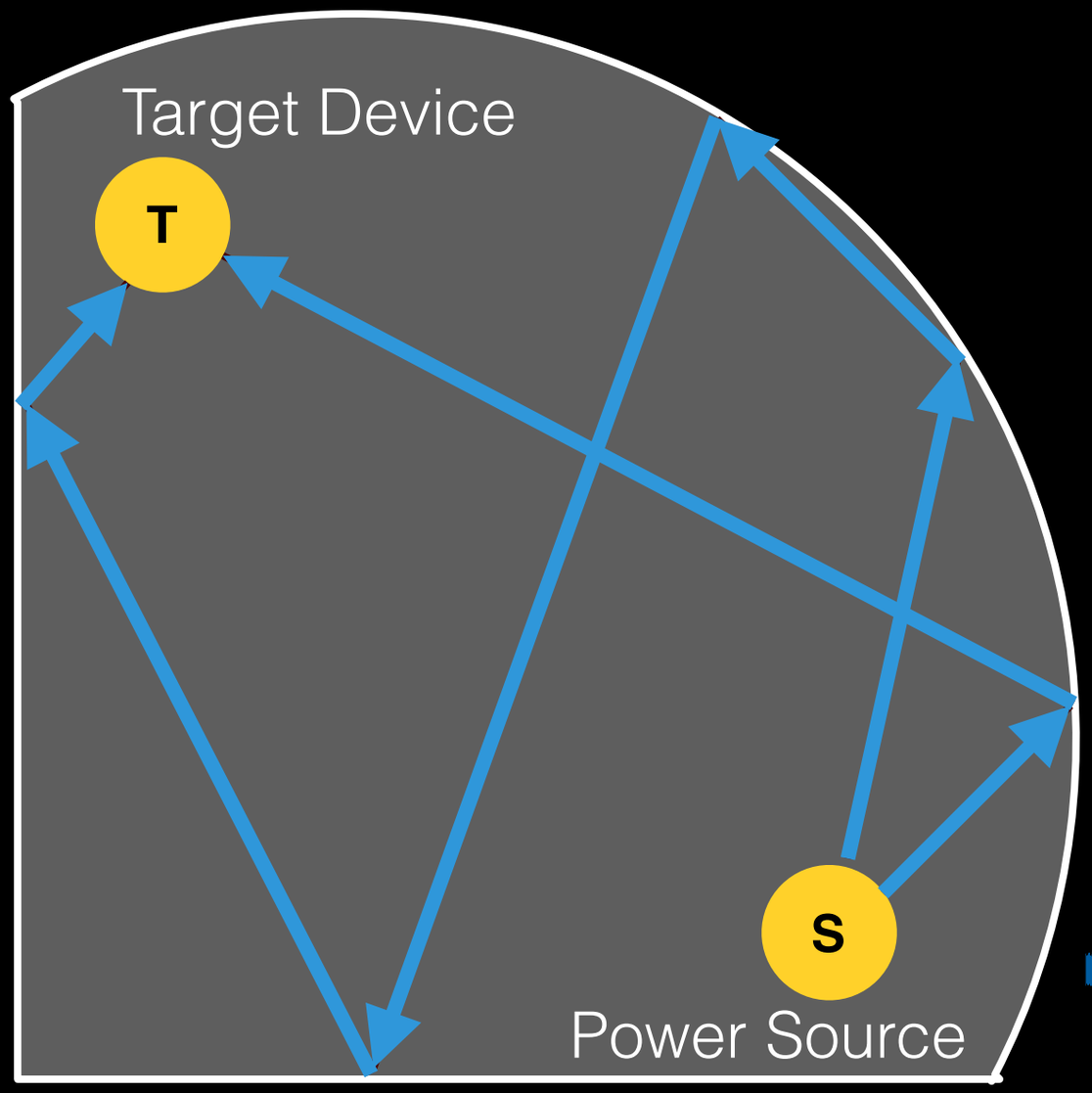


“Reconstruction”
pulse

Good for rectification

2. Time Reverse Step

Source reverses and broadcasts,
sona reconstructs on target



“Sona"

(Enclosed cavity with reflecting walls)

Time Reversal for WPT

Requires…

1. Spatial reciprocity of the wave equation
2. Reflective surfaces
3. Ray-chaotic environment

Provides…

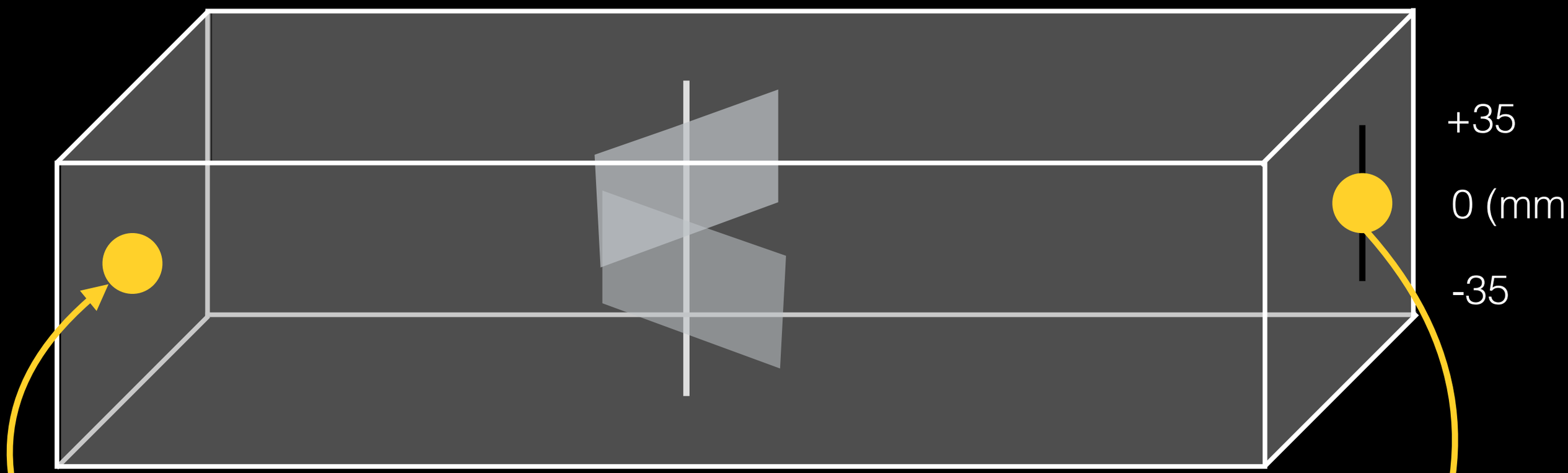
1. Range (not limited to free space drop-off)
2. Resilience to obstructions
3. Power concentrated at any given location

Experimental Setup

Power Source
(5Ghz, 3dBm)

Scattering panels
ensure **ray chaos**

Device
(on MikroMove)



Wave Generation (TX)

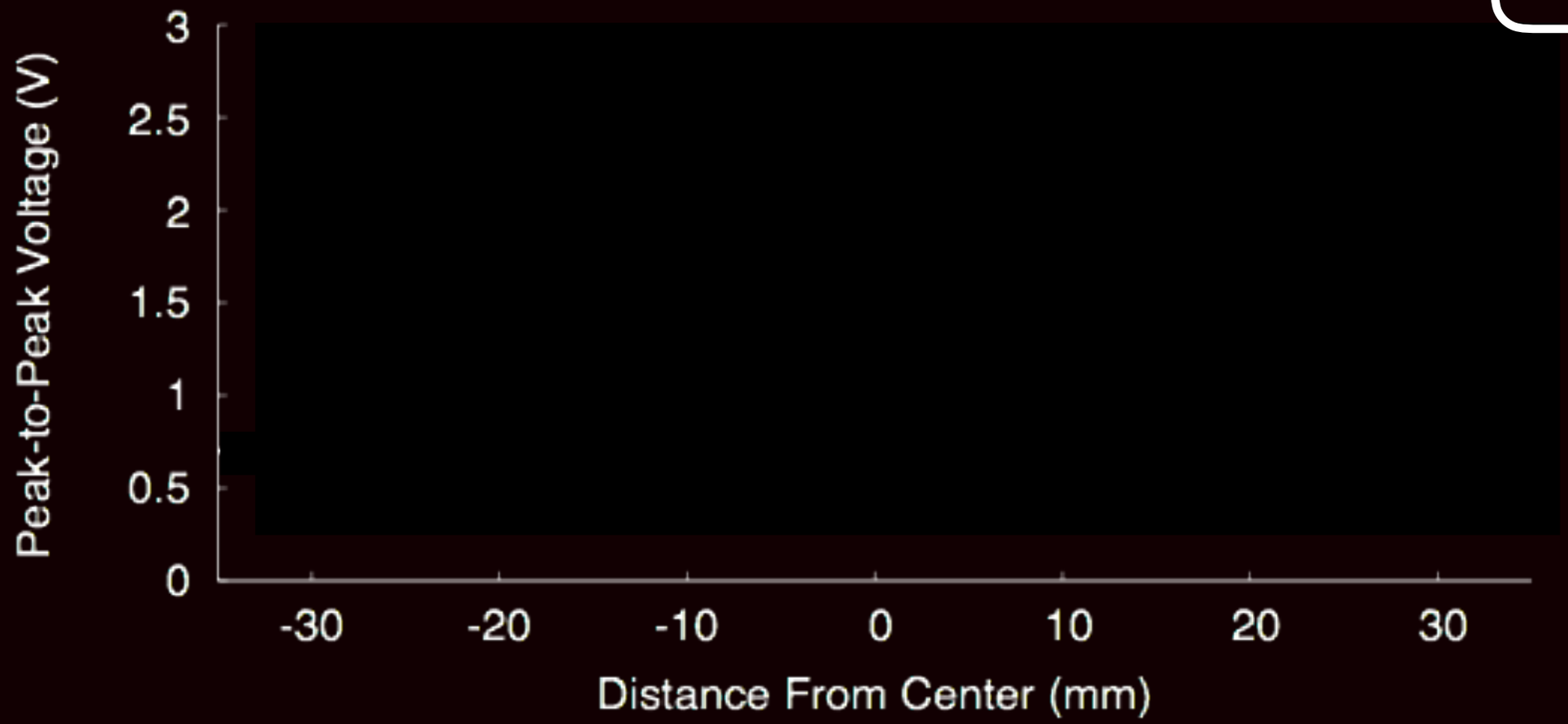
PSG ← **AWG**

Wave Analysis (RX)

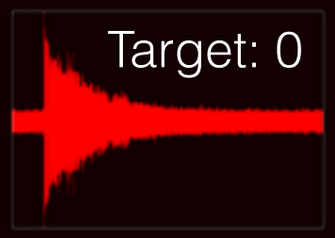
MATLAB ← **Oscilloscope**

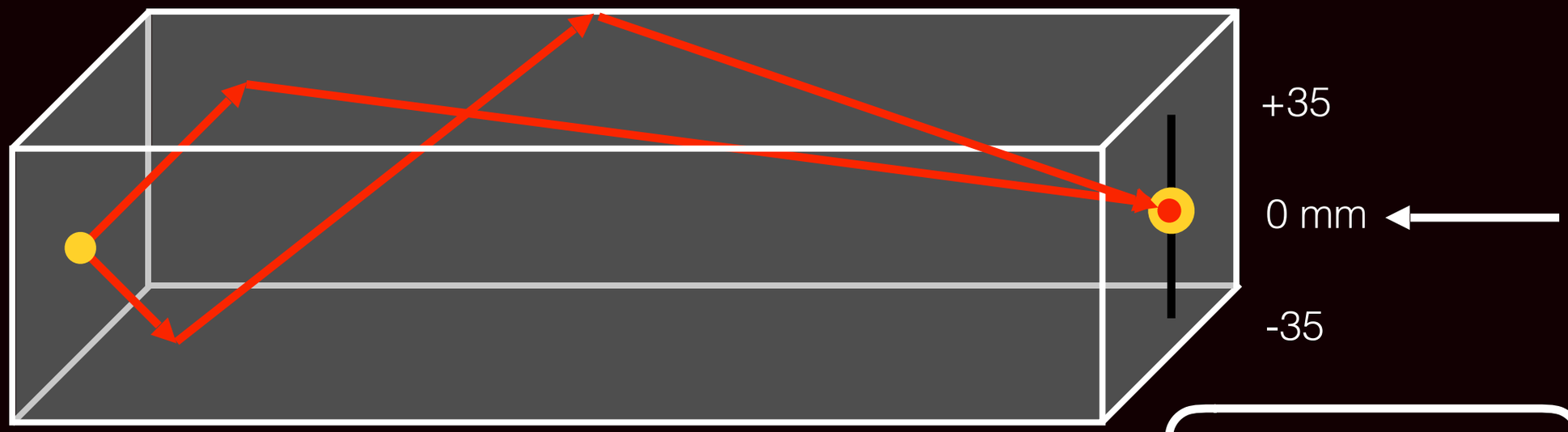
Spatial Profiling of Reconstruction

Constant Velocity
0.2 mm/s

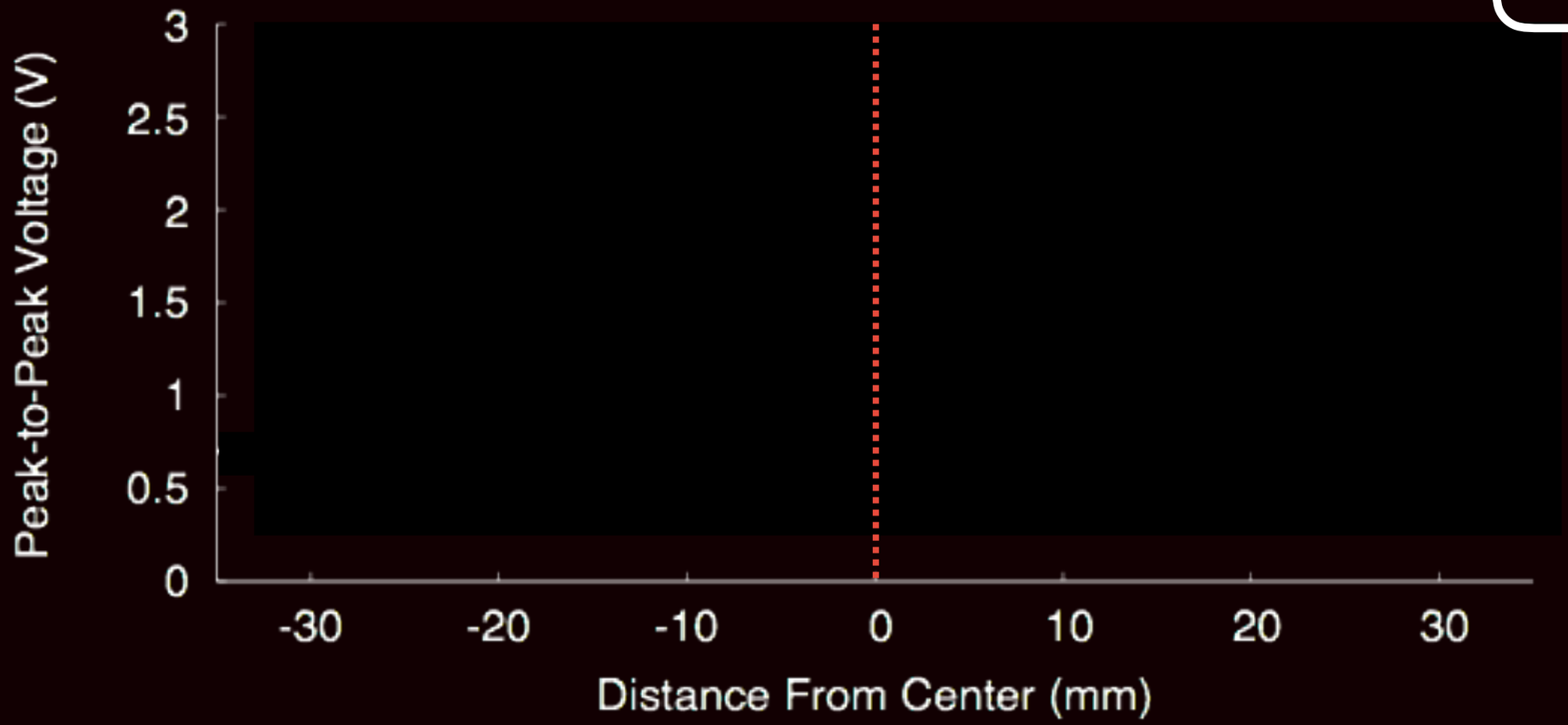


Spatial Profiling of Reconstruction

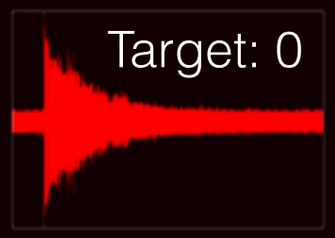


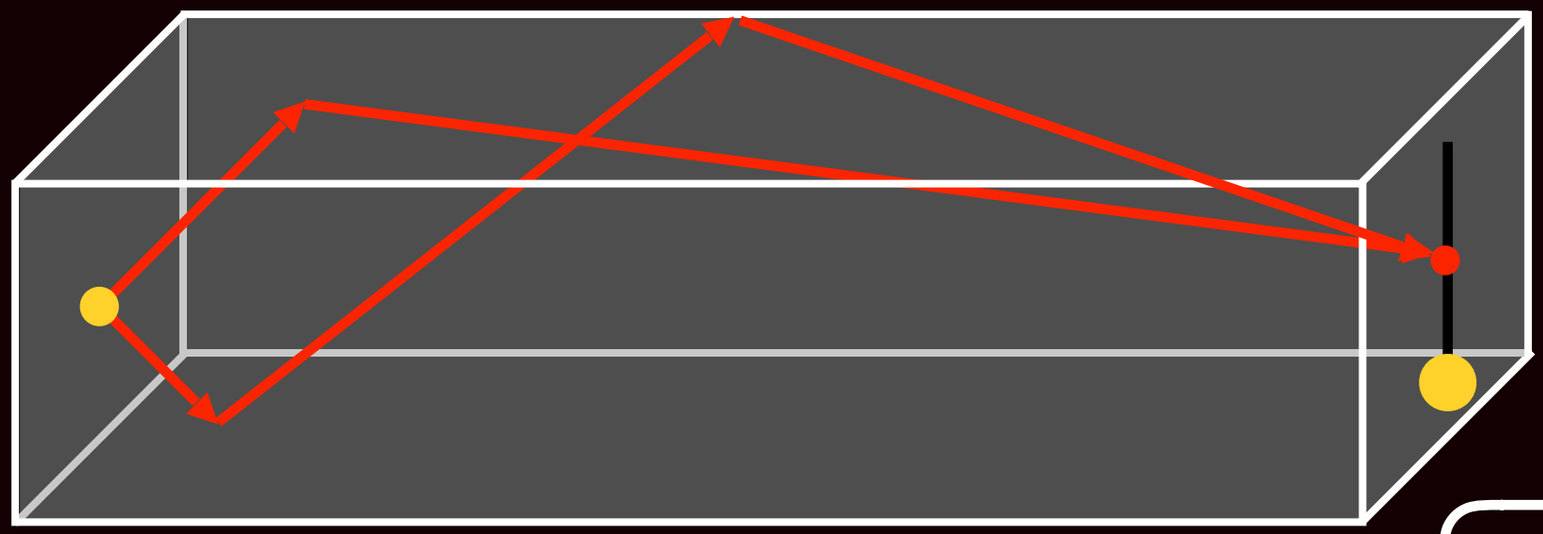


Constant Velocity
0.2 mm/s

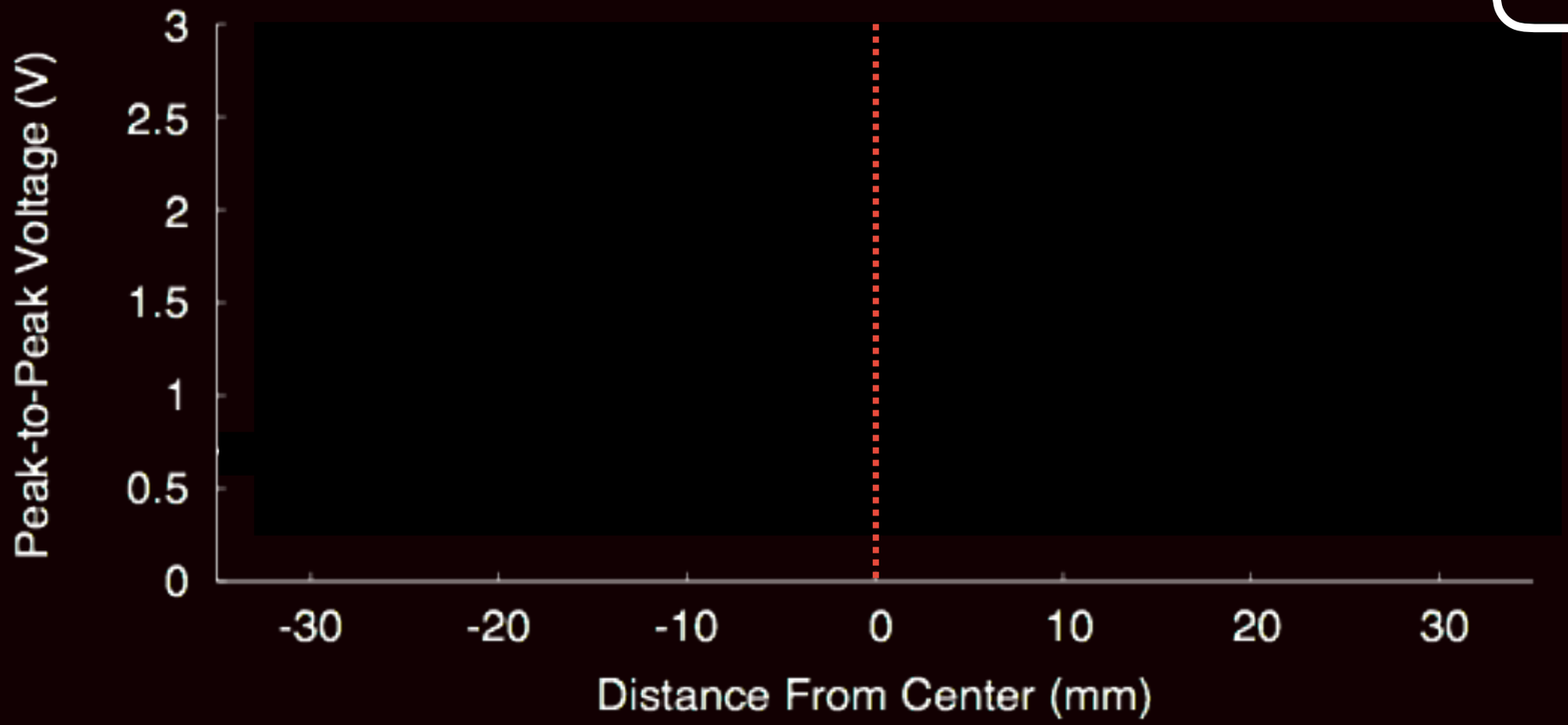


Spatial Profiling of Reconstruction

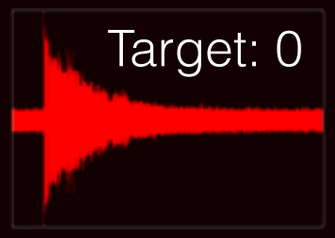


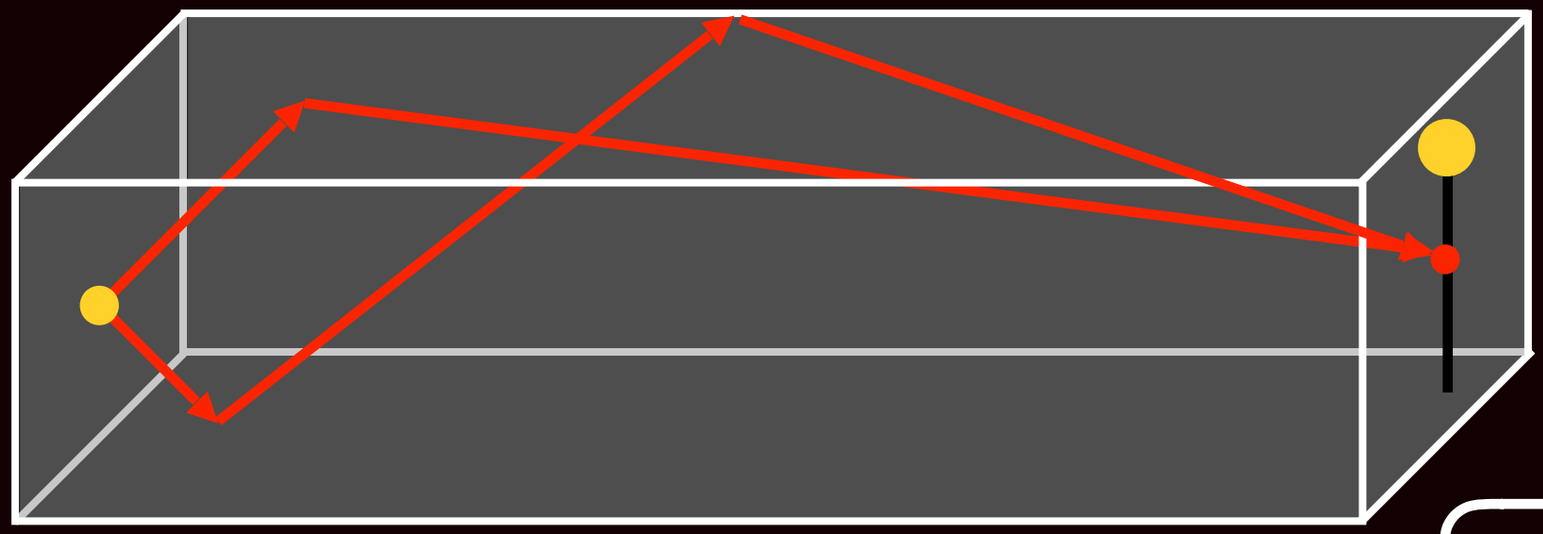


Constant Velocity
0.2 mm/s

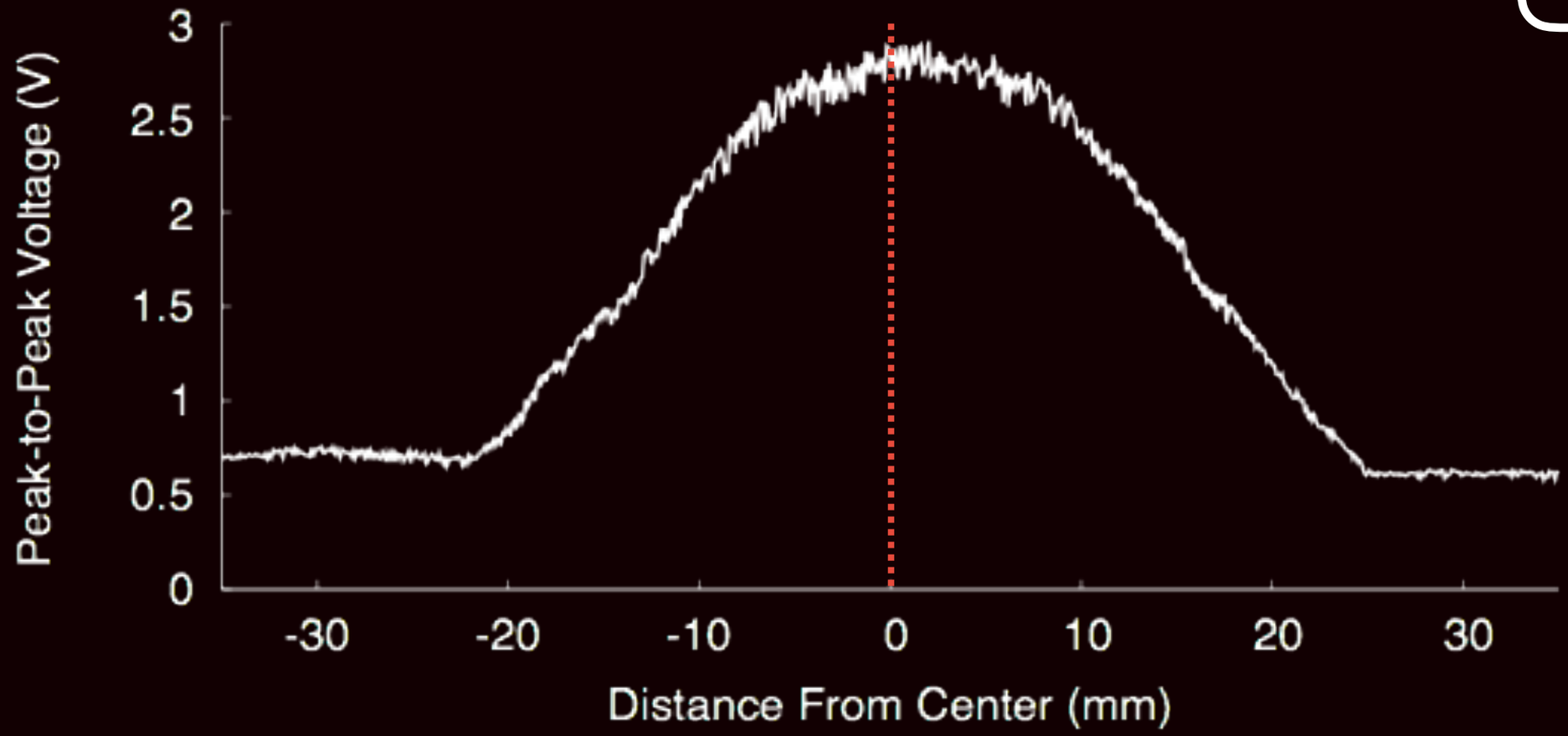


Spatial Profiling of Reconstruction



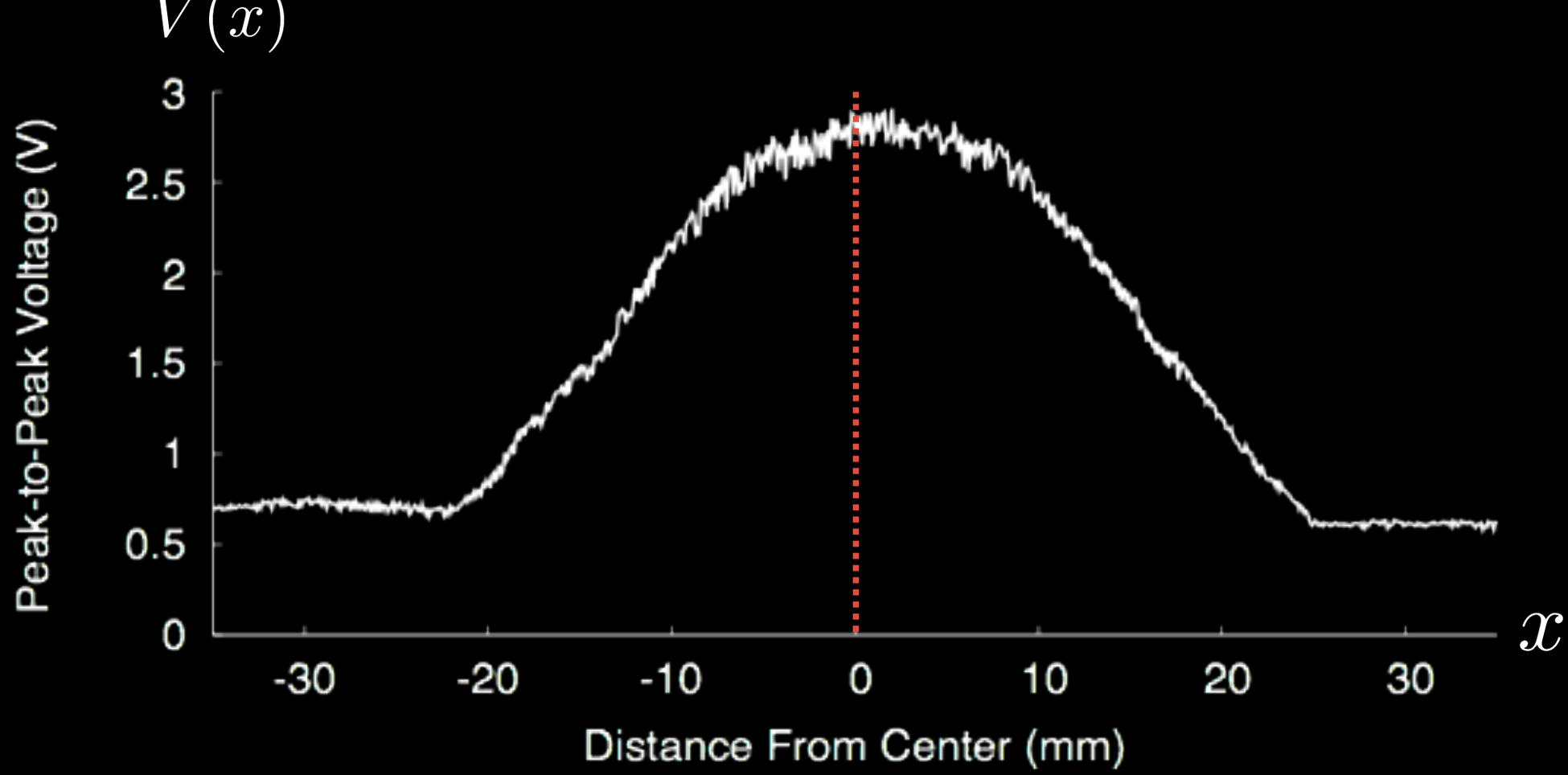


Constant Velocity
0.2 mm/s



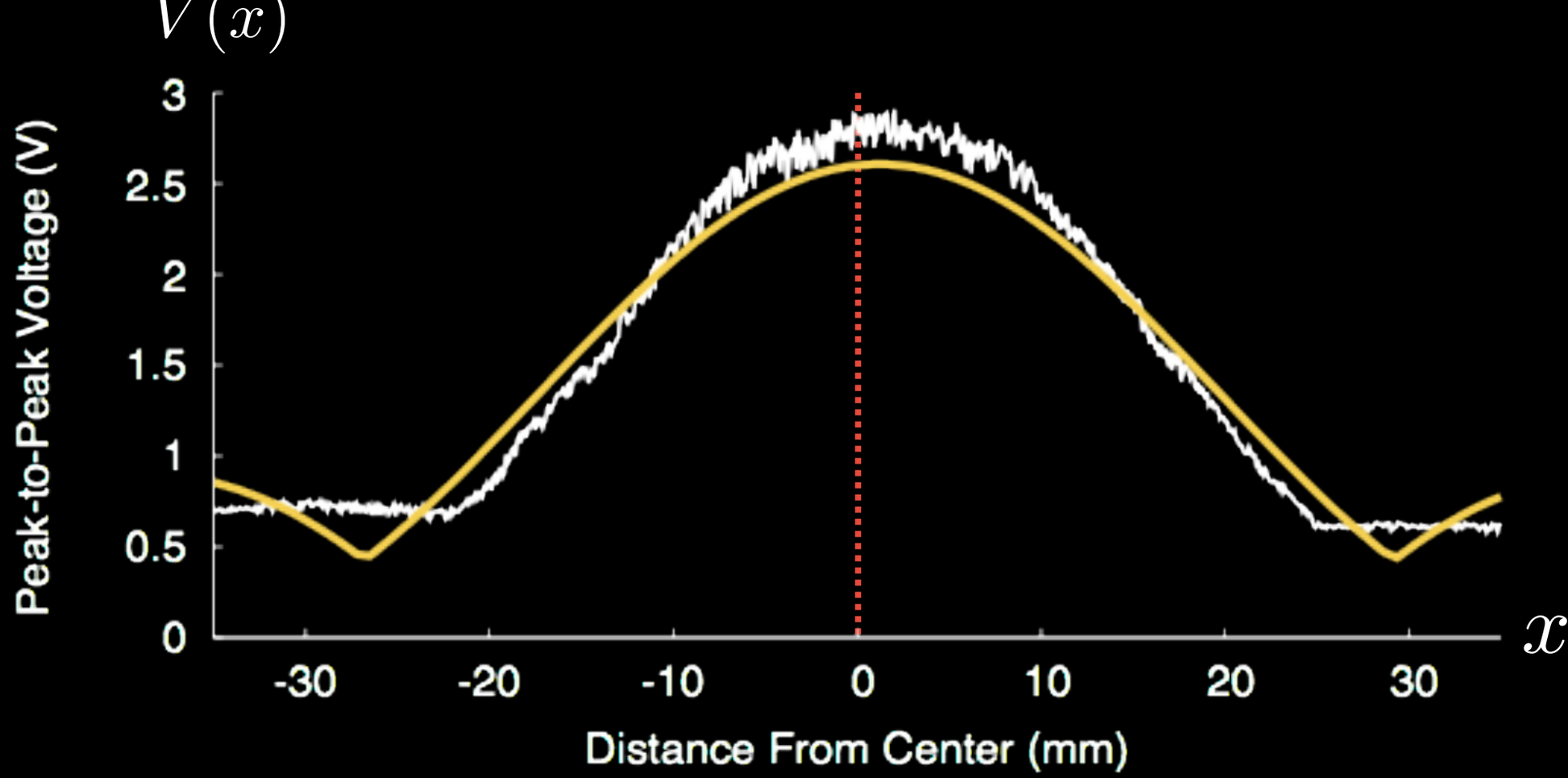
Spatial Profiling of Reconstruction

$$V(x) = a \cdot \left| sinc\left(\frac{x+c}{b}\right) \right| + d$$



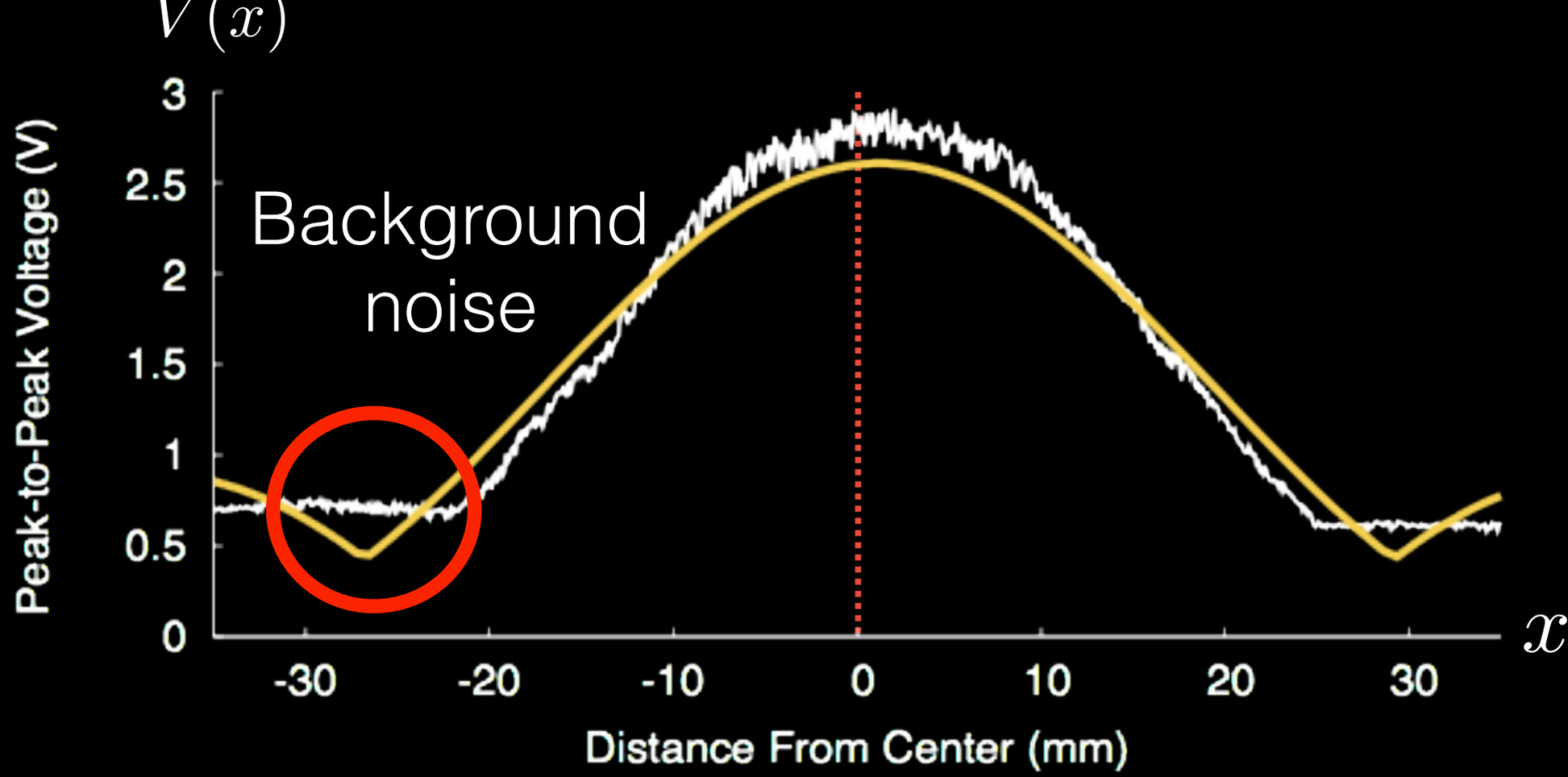
Spatial Profiling of Reconstruction

$$V(x) = a \cdot \left| sinc\left(\frac{x+c}{b}\right) \right| + d$$



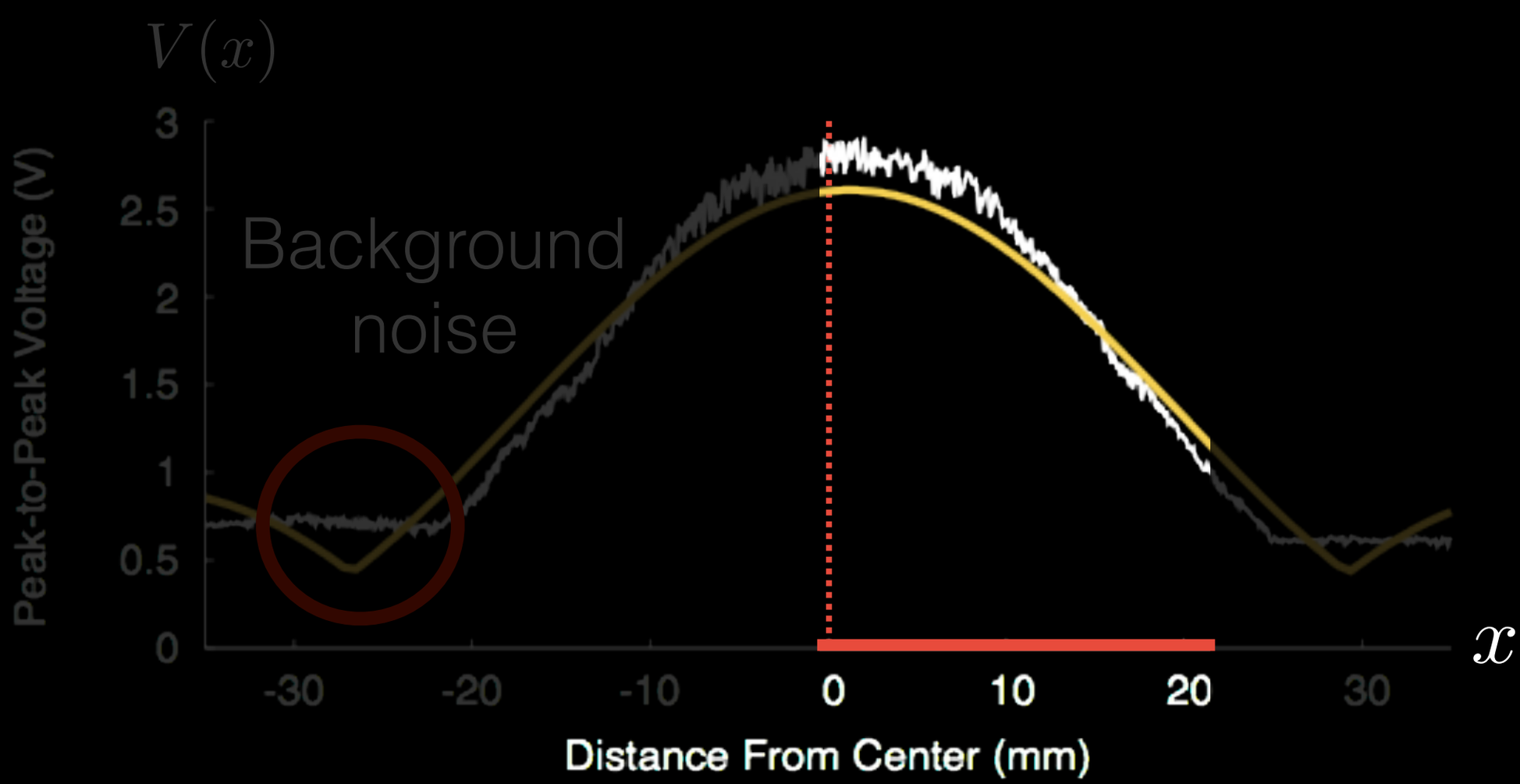
Spatial Profiling of Reconstruction

$$V(x) = a \cdot \left| sinc\left(\frac{x+c}{b}\right) \right| + d$$



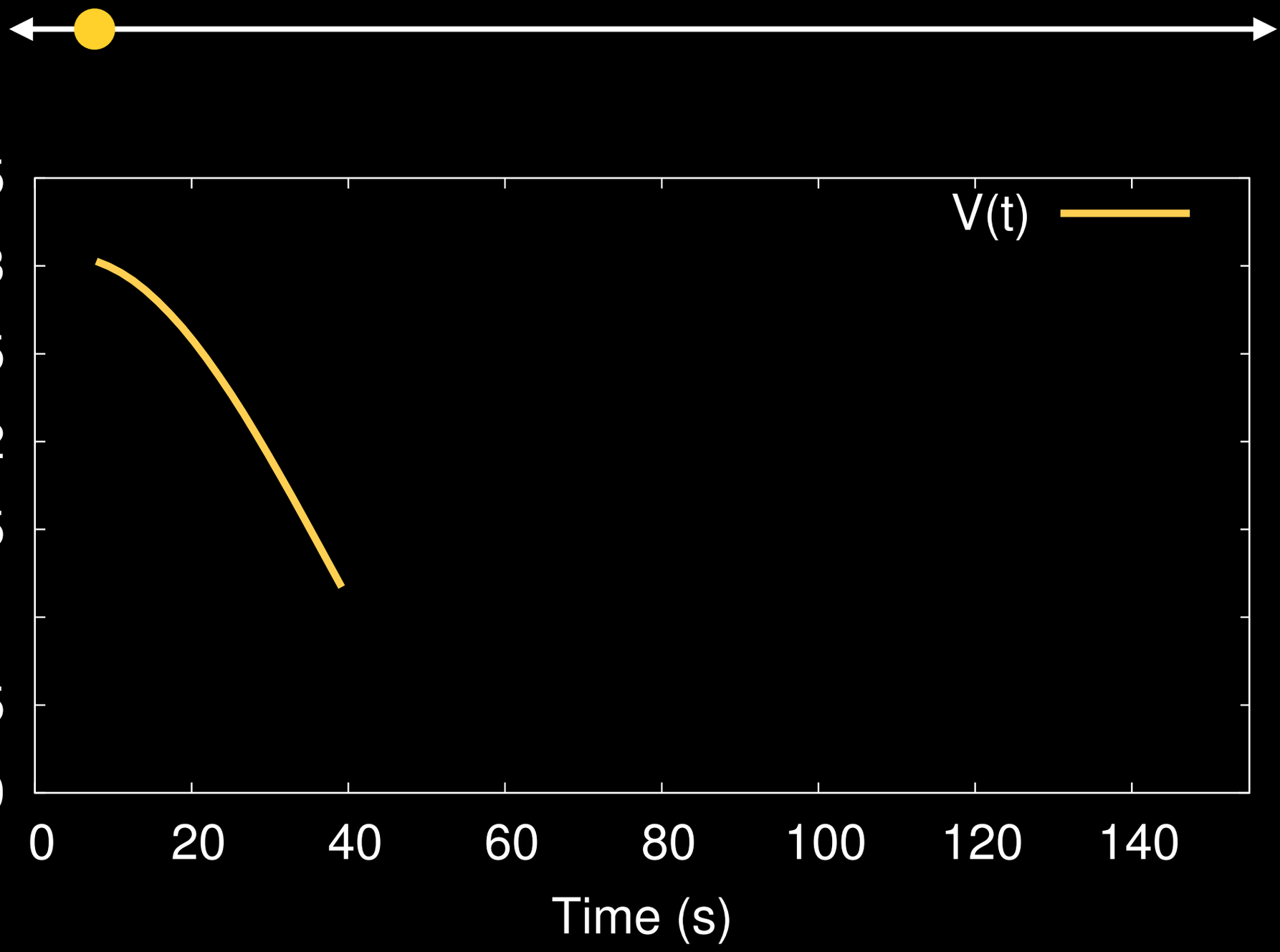
Spatial Profiling of Reconstruction

$$V(x) = a \cdot \left| sinc\left(\frac{x+c}{b}\right) \right| + d$$



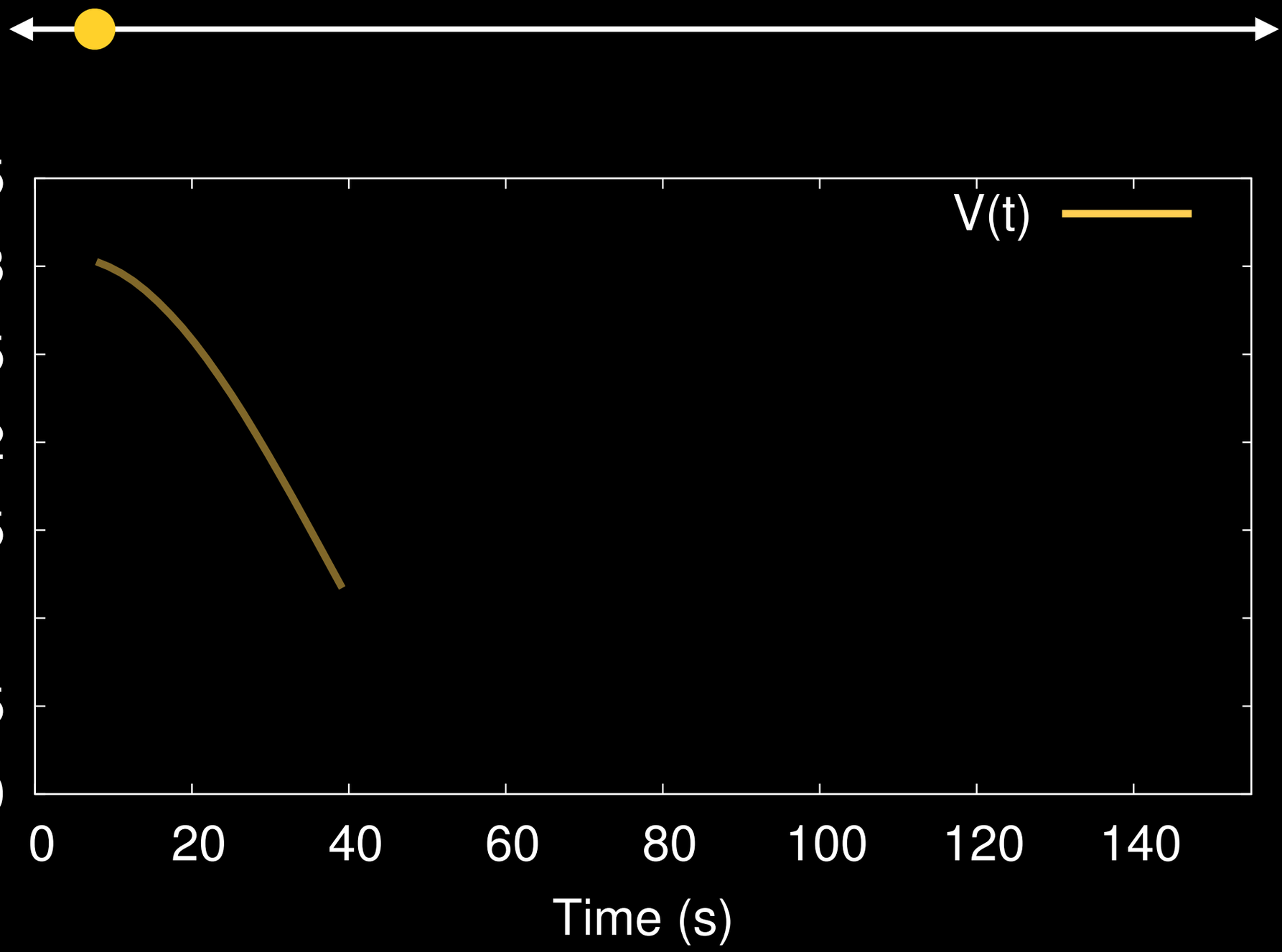
Targeting a Moving Receiver

"**Refresh**" the sona before it gets stale



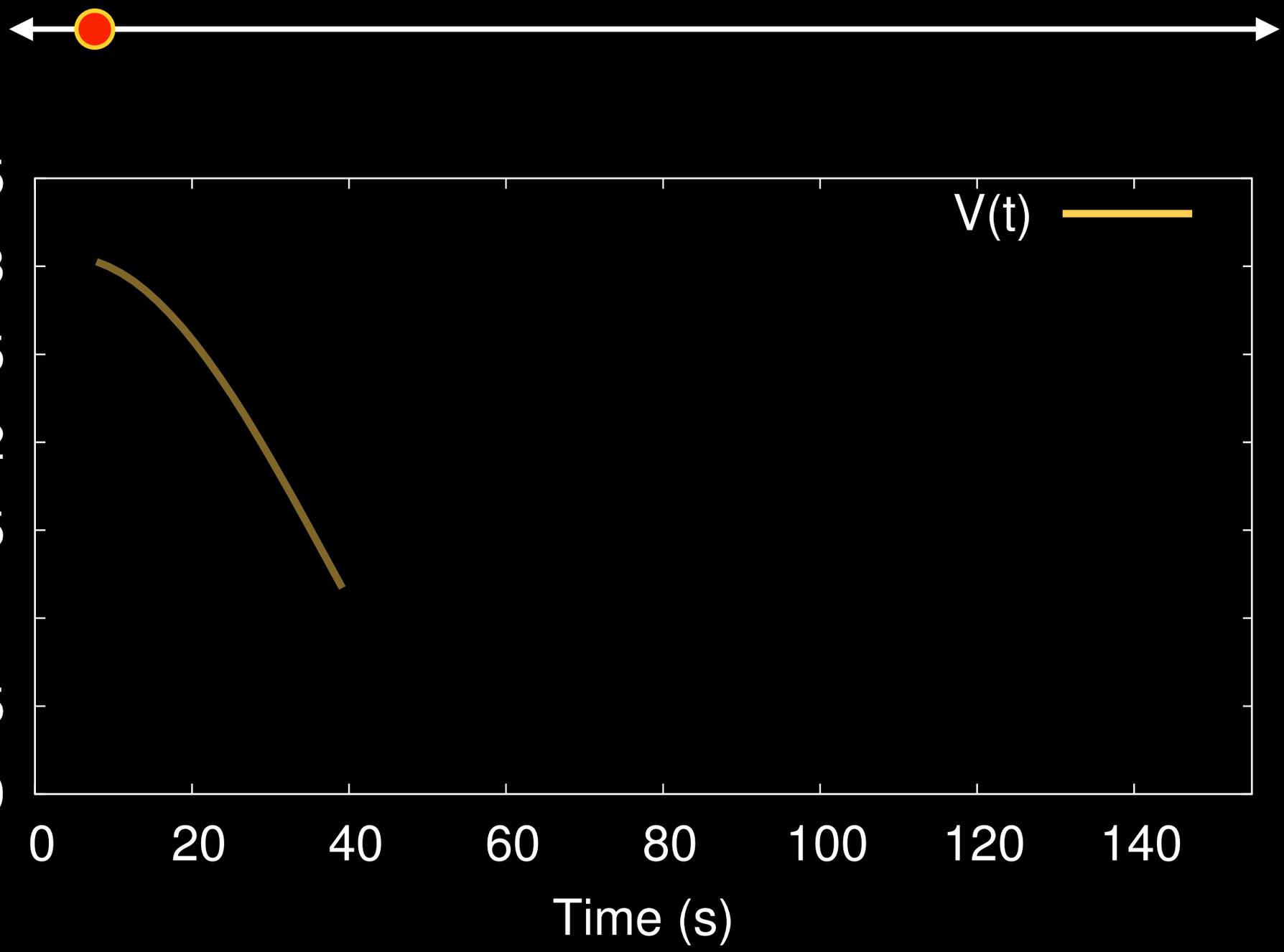
Targeting a Moving Receiver

"**Refresh**" the sona before it gets stale



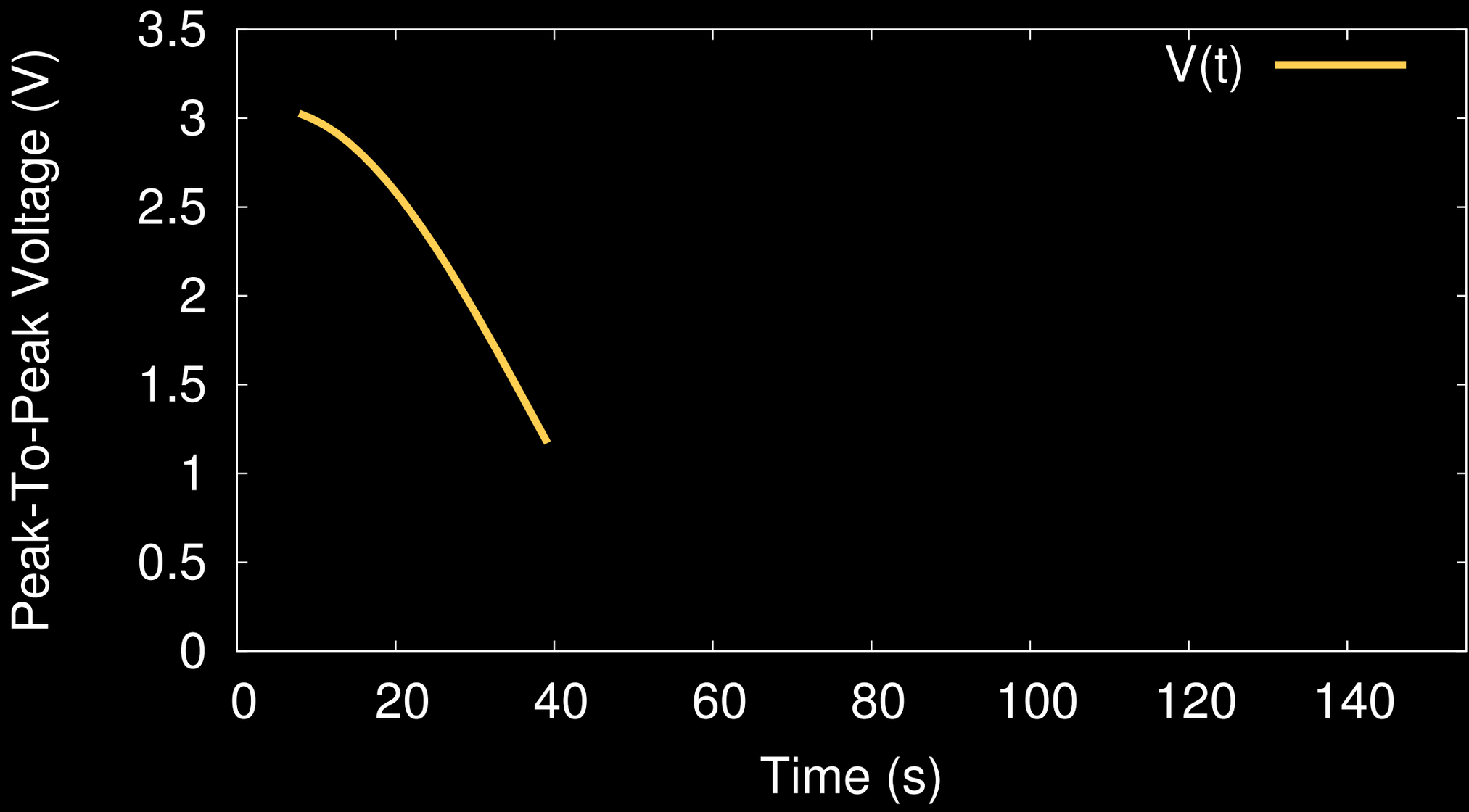
Targeting a Moving Receiver

"**Refresh**" the sona before it gets stale



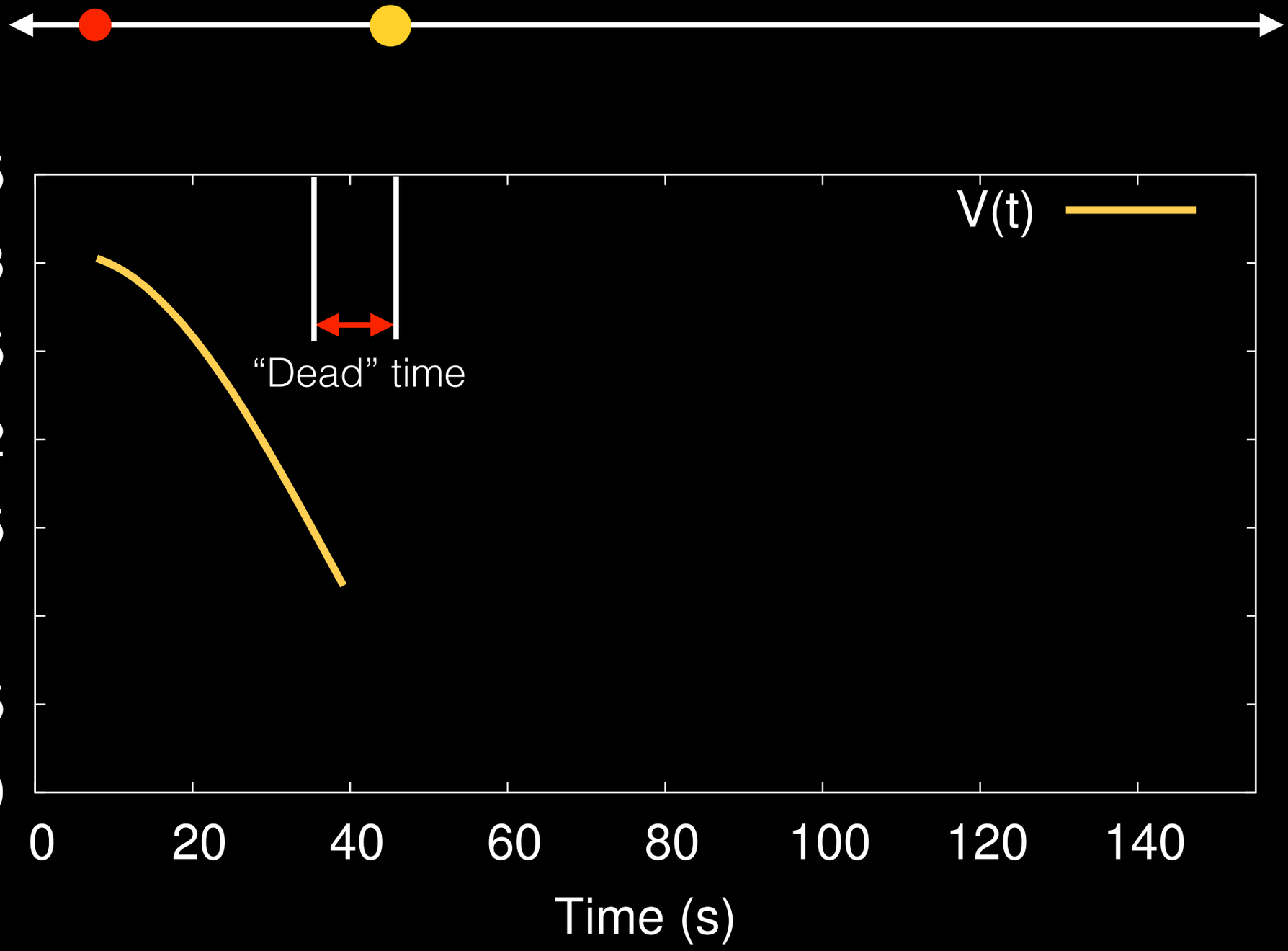
Targeting a Moving Receiver

"**Refresh**" the sona before it gets stale



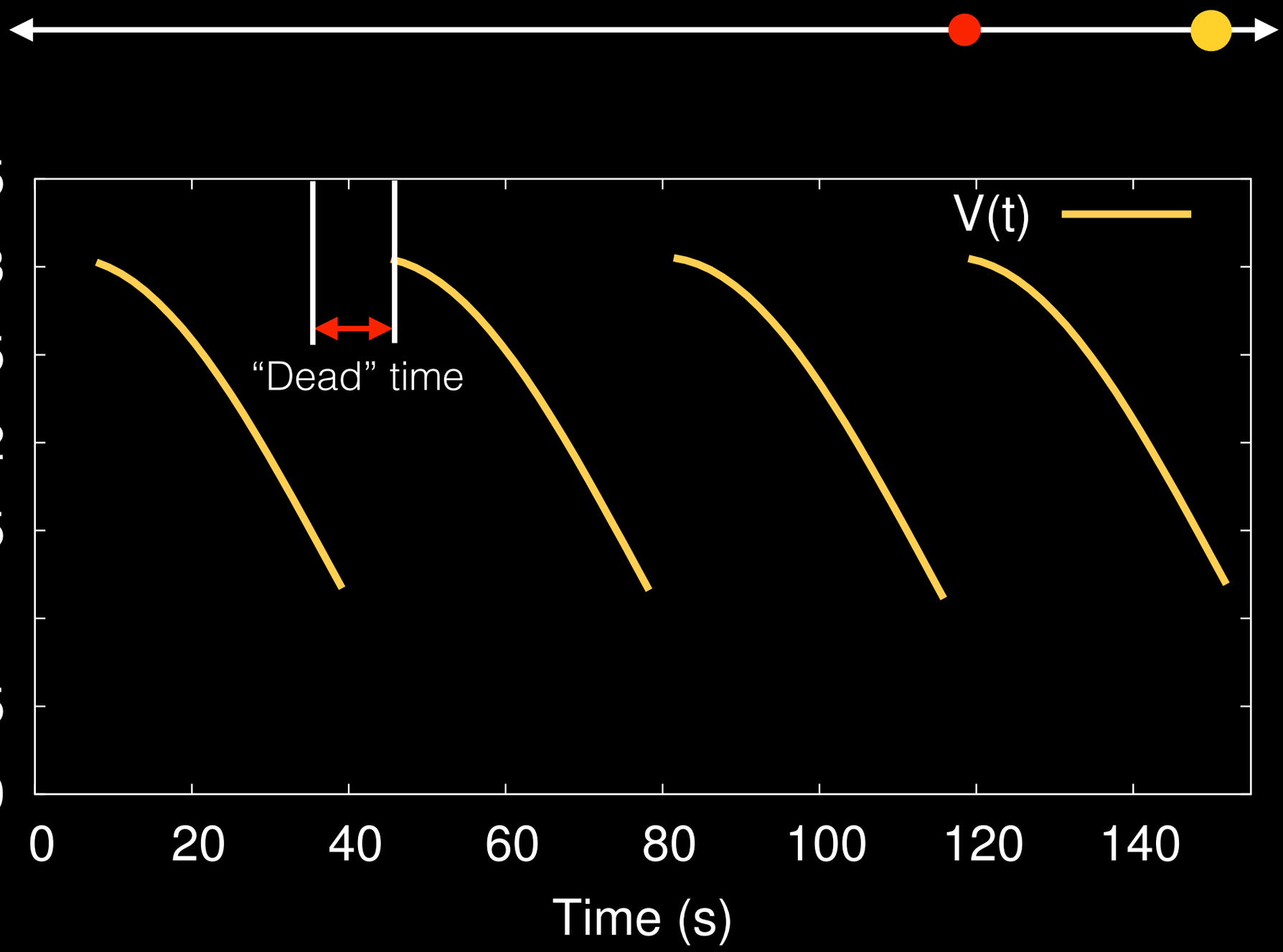
Targeting a Moving Receiver

"**Refresh**" the sona before it gets stale



Targeting a Moving Receiver

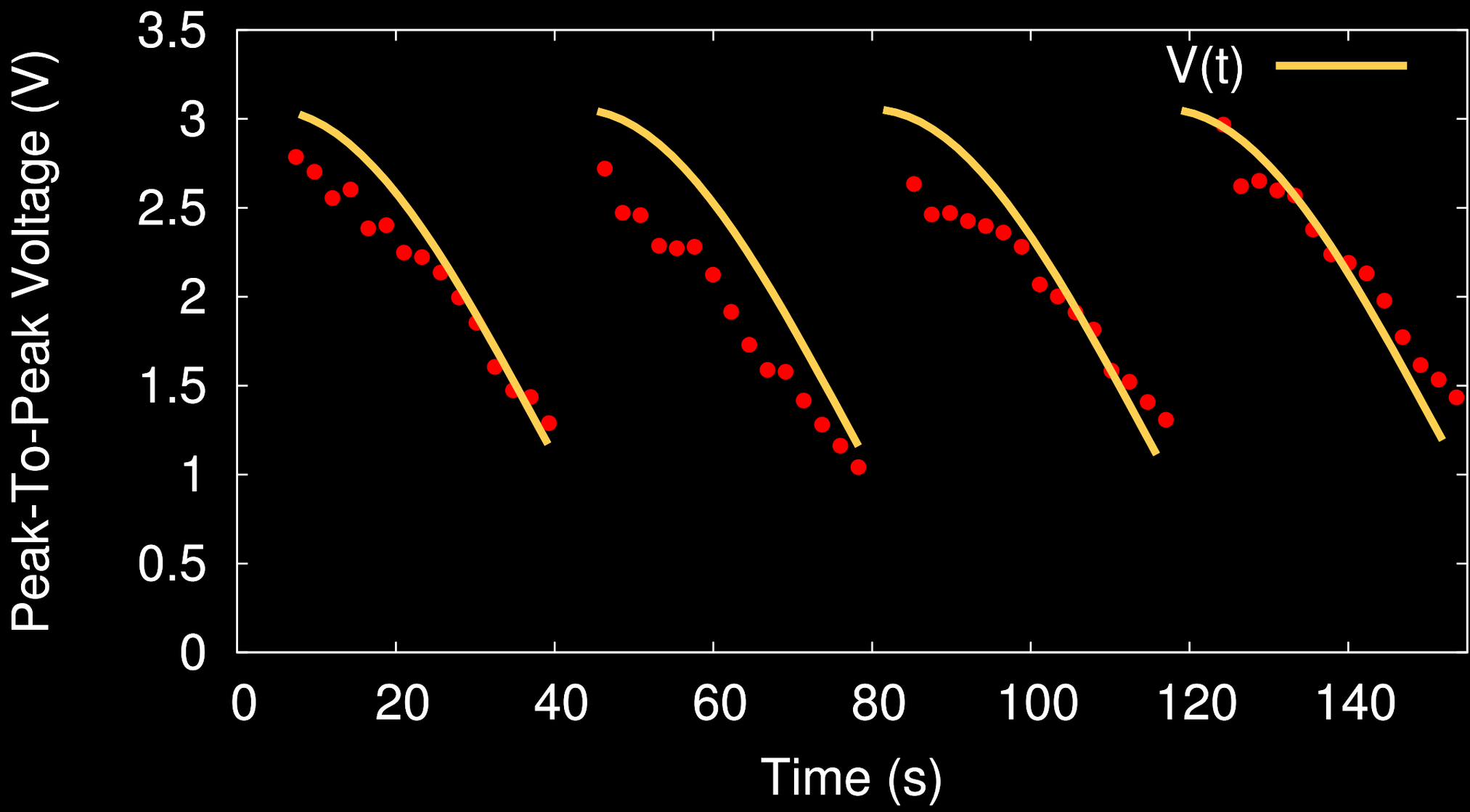
"**Refresh**" the sona before it gets stale



Targeting a Moving Receiver

"**Refresh**" the sona before it gets stale

Experimental Results



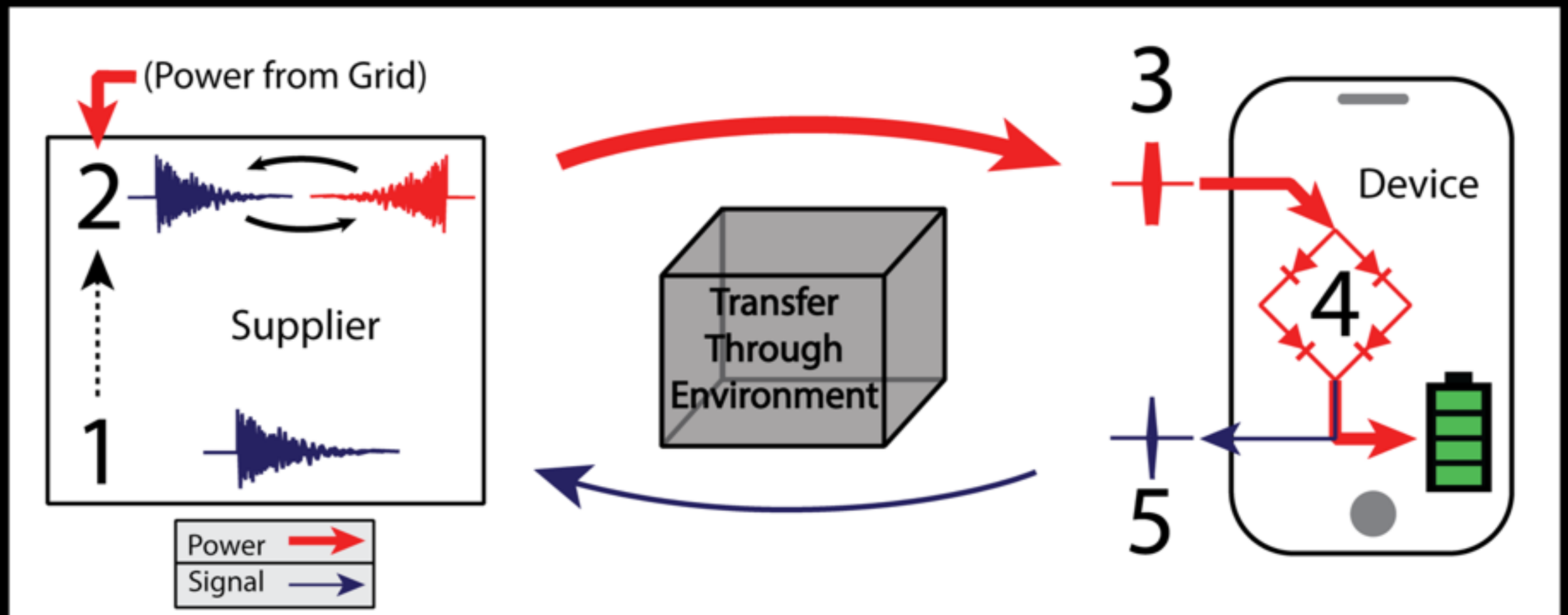
Potential WPT System

Initialization Supplier searches for participating devices (which may or may not have charge)

Steady State Small fraction of power reflected by device, allowing supplier to find new location

Talk Session 5
Friday,17:45

(Selective Collapse of Nonlinear Time Reversed Electromagnetic Waves)



Limitations And Future Work

Transfer efficiency

- Use multiple channels

Environmental losses

- Investigate and mitigate

Dead time

- Use dedicated hardware
- TX and calculate new sona simultaneously

These limitations are dependent on our lab equipment, they are not fundamental limitations of the technique

Summary

Time Reversal is a promising new basis for long-range WPT
can transmit energy to receivers in motion
does not require the receiver to be powered

Poster Session 2
Friday, 14:40

(Time Reversed Wave Propagation as a Novel Method of WPT)

Talk Session 5
Friday, 17:45

(Selective Collapse of Nonlinear Time Reversed Electromagnetic Waves)

frank@cs.umd.edu

anlage@umd.edu