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
Current State of Long-Range WPT

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

Microwave Beaming
Ubiquitous WPT requires greater range than provided by near-field technologies.
Current State of Long-Range WPT

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

Microwave Beaming

Precise Alignment

Obstructions
Ubiquitous WPT requires greater range than provided by near-field technologies.
1. **Time Forward Step**

   Target requests power, source records sona

![Diagram](Enclosed cavity with reflecting walls)
1. Time Forward Step

Target requests power, source records sona

Gaussian Pulse (50 ns)

Target Device

Power Source

“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

(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

“Reconstruction” pulse

“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

“Reconstruction” pulse
Good for rectification

(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

+35
0 (mm)
-35
Spatial Profiling of Reconstruction

Target: 0

Constant Velocity 0.2 mm/s
Spatial Profiling of Reconstruction

Target: 0

Constant Velocity 0.2 mm/s
Spatial Profiling of Reconstruction

Target: 0

Constant Velocity 0.2 mm/s
Spatial Profiling of Reconstruction

Target: 0

Constant Velocity 0.2 mm/s
Spatial Profiling of Reconstruction

\[ V(x) = a \cdot \left| \text{sinc} \left( \frac{x + c}{b} \right) \right| + d \]
Spatial Profiling of Reconstruction

\[ V(x) = a \cdot \left| \text{sinc} \left( \frac{x + c}{b} \right) \right| + d \]
Spatial Profiling of Reconstruction

\[ V(x) = a \cdot \left| \text{sinc} \left( \frac{x + c}{b} \right) \right| + d \]
Spatial Profiling of Reconstruction

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

“Dead” time
Targeting a Moving Receiver

“Refresh” the sona before it gets stale

Peak-To-Peak Voltage (V) vs. Time (s)

“Dead” time

V(t)
Targeting a Moving Receiver

“Refresh” the sona before it gets stale

Experimental Results

Peak-To-Peak Voltage (V) vs. Time (s)
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.
Time Reversal is a promising new basis for long-range WPT. It 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