Field Propagation Through Cavity Regions in a Parallel Plate Waveguide

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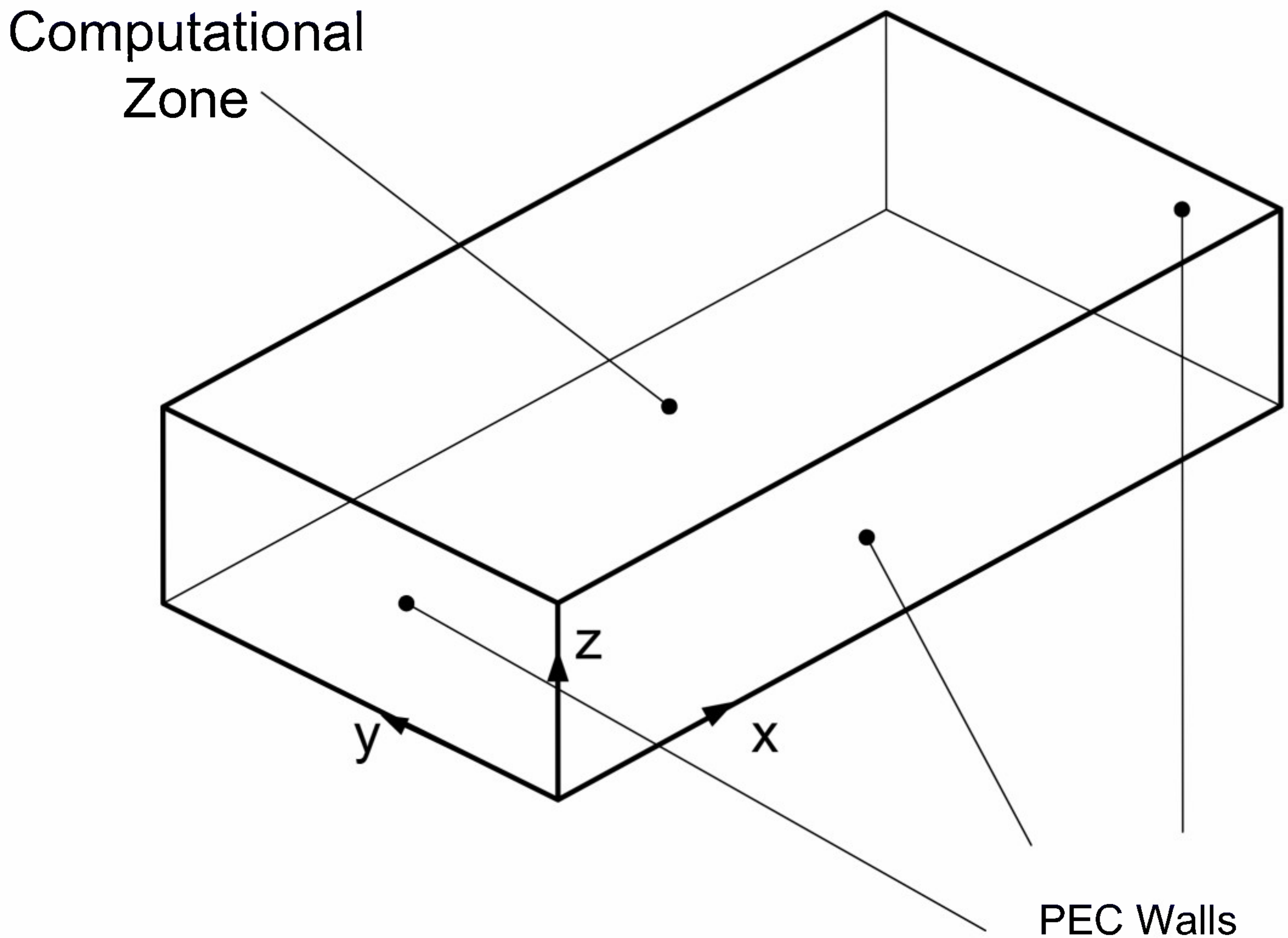
Goal of this work

- To develop an understanding of electromagnetic coupling mechanisms in systems and structures
- To develop the tools to predict the properties of a transient signal as it makes its way from the exterior of a structure or of a substructure, through a transmission path, to the terminals of a deeply embedded digital system
- To catalog the properties of transient signals that might be expected to reach digital systems – as guidance to other MURI investigators who assess the reaction of a digital system to a transient stimulus

Propagation in a Parallel Plate Waveguide

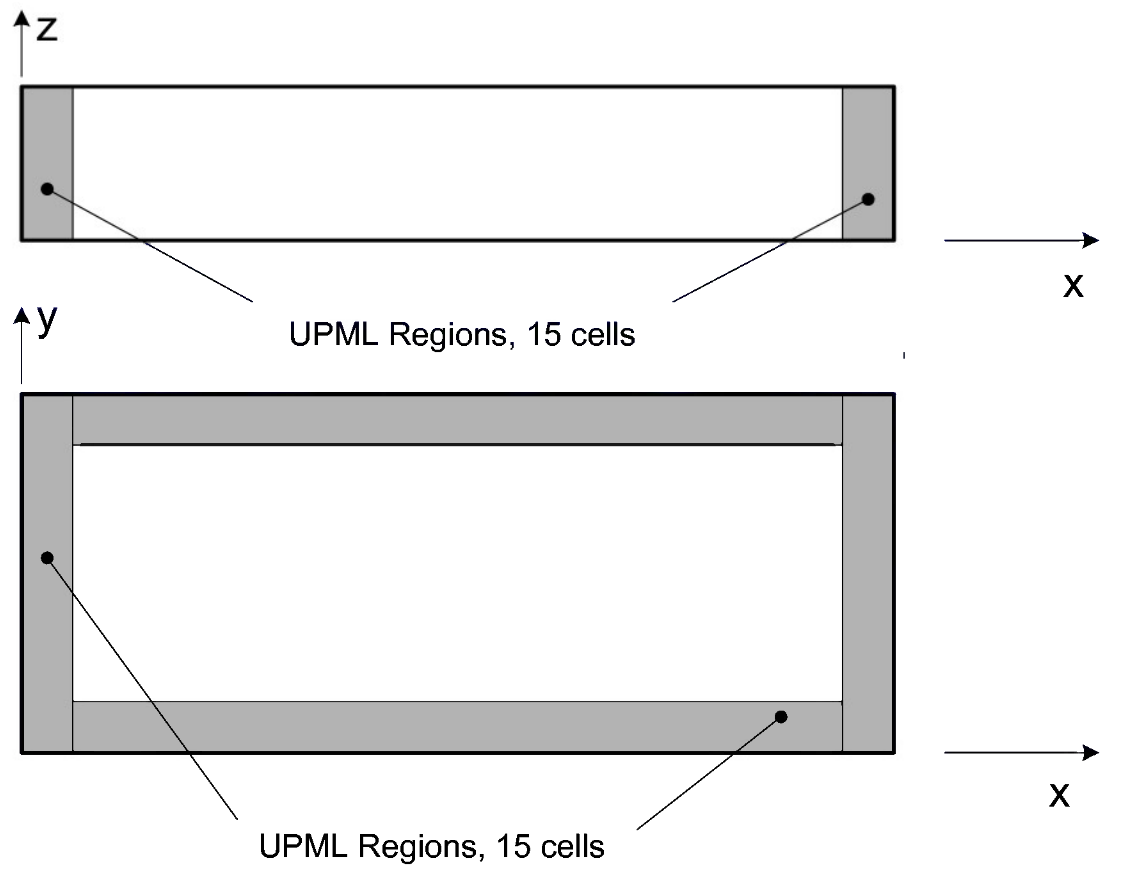
- Addressed in time domain with FDTD
- 3D computational zone is PEC box
- Uniaxial Perfectly Match Layers (UPML) line four walls of the interior of box to effectively create a Parallel Plate Waveguide (or a rectangular WG)
- UPML layers are 15 cells thick, resulting in very low reflection at the box walls
- Conducting walls with slots are placed inside the free space region to form various cavities
- Gaussian Pulse Excitation

The FDTD Computational Zone



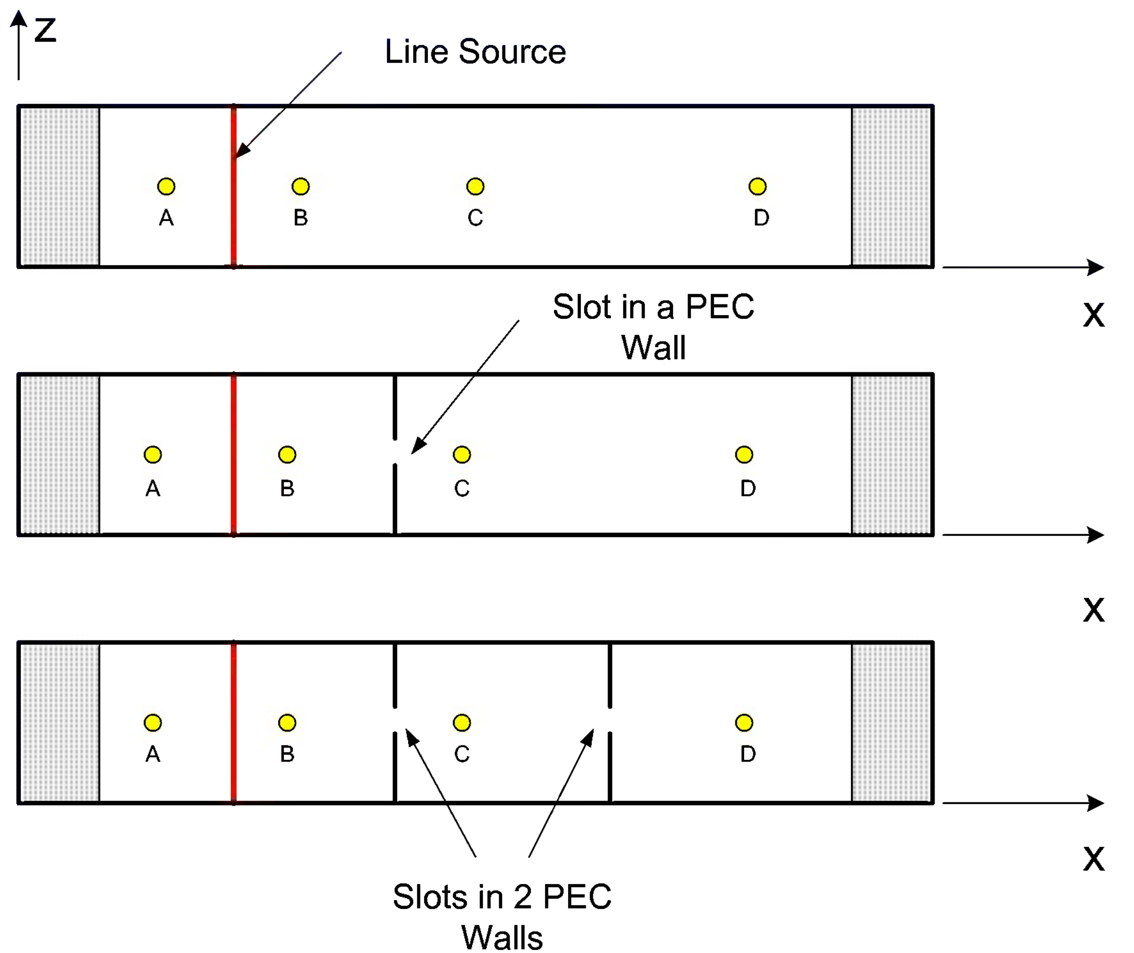
Interior Region

- UPML regions can be selectively turned off, to allow modeling a cavity, a rectangular waveguide, or a parallel plate waveguide
- The UPML acts as a very good absorber of EM waves
- The UPML works well for all angles and is very wideband, as we will see
- 15-cell UPML is used to ensure very good absorption



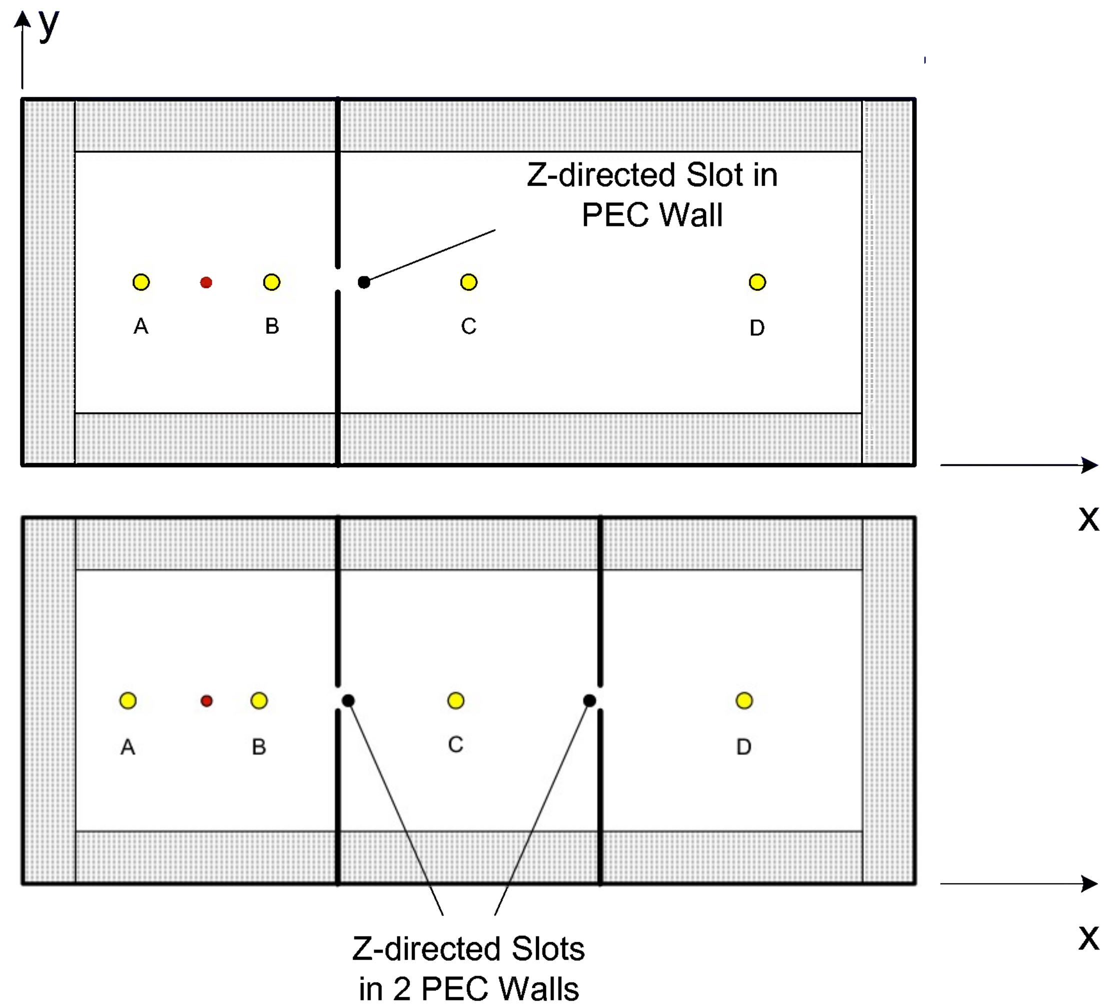
Structures – Y-directed Slots

- Here we see the source and the locations of possible field observation points
- By inserting metal walls with slots, we form cavity regions inside the PEC box
- This illustration shows y-directed slots in metal walls that form cavities



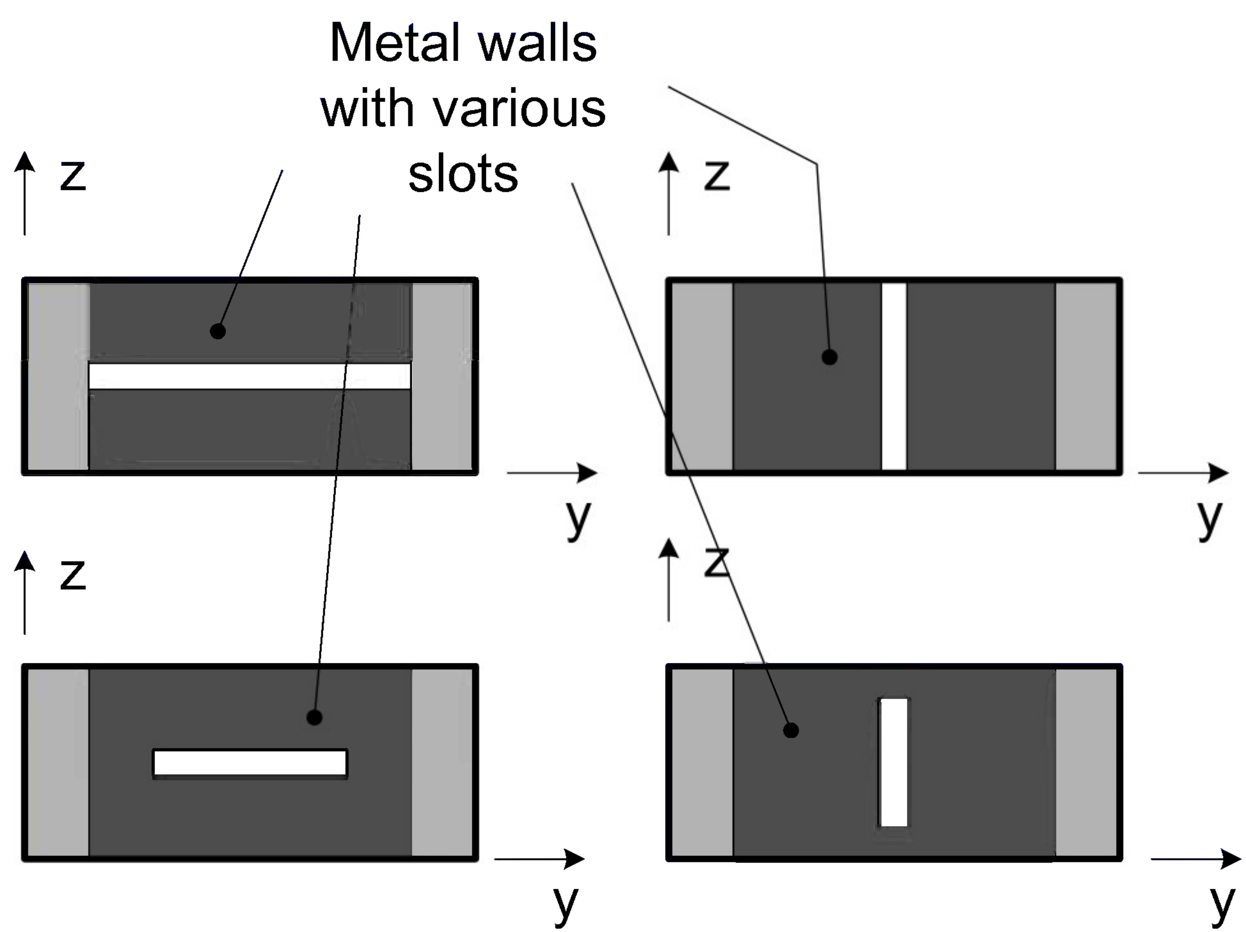
Structures – Z-directed Slots in Walls

- We can also model z-directed slots in metal walls
- The field observation points can be moved within the regions



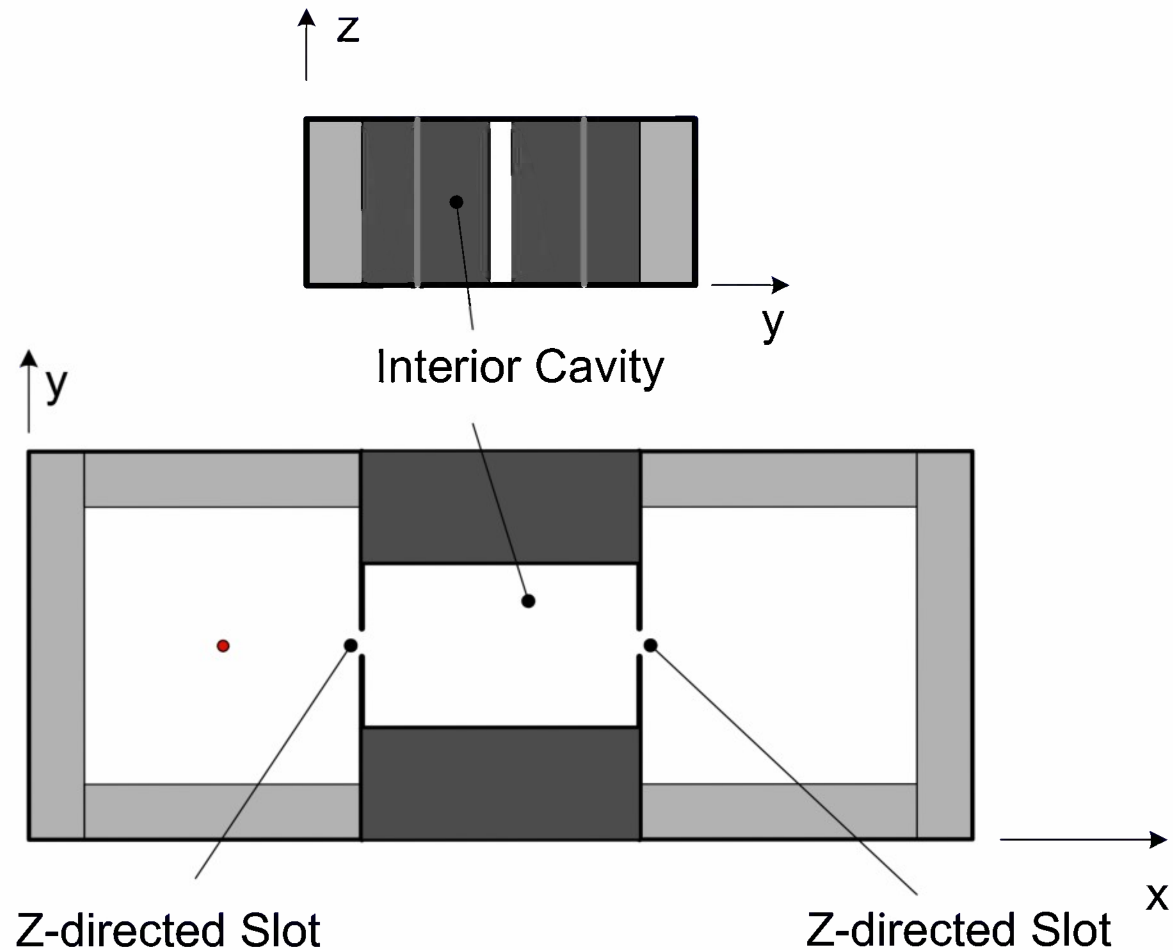
Structures – Combinations of Slots

- We can position multiple walls with various kinds of slots
- Slots can extend from wall to wall and into the PML region
- Slots that extend into the PML region model infinitely long slots
- The slots are NOT necessarily narrow

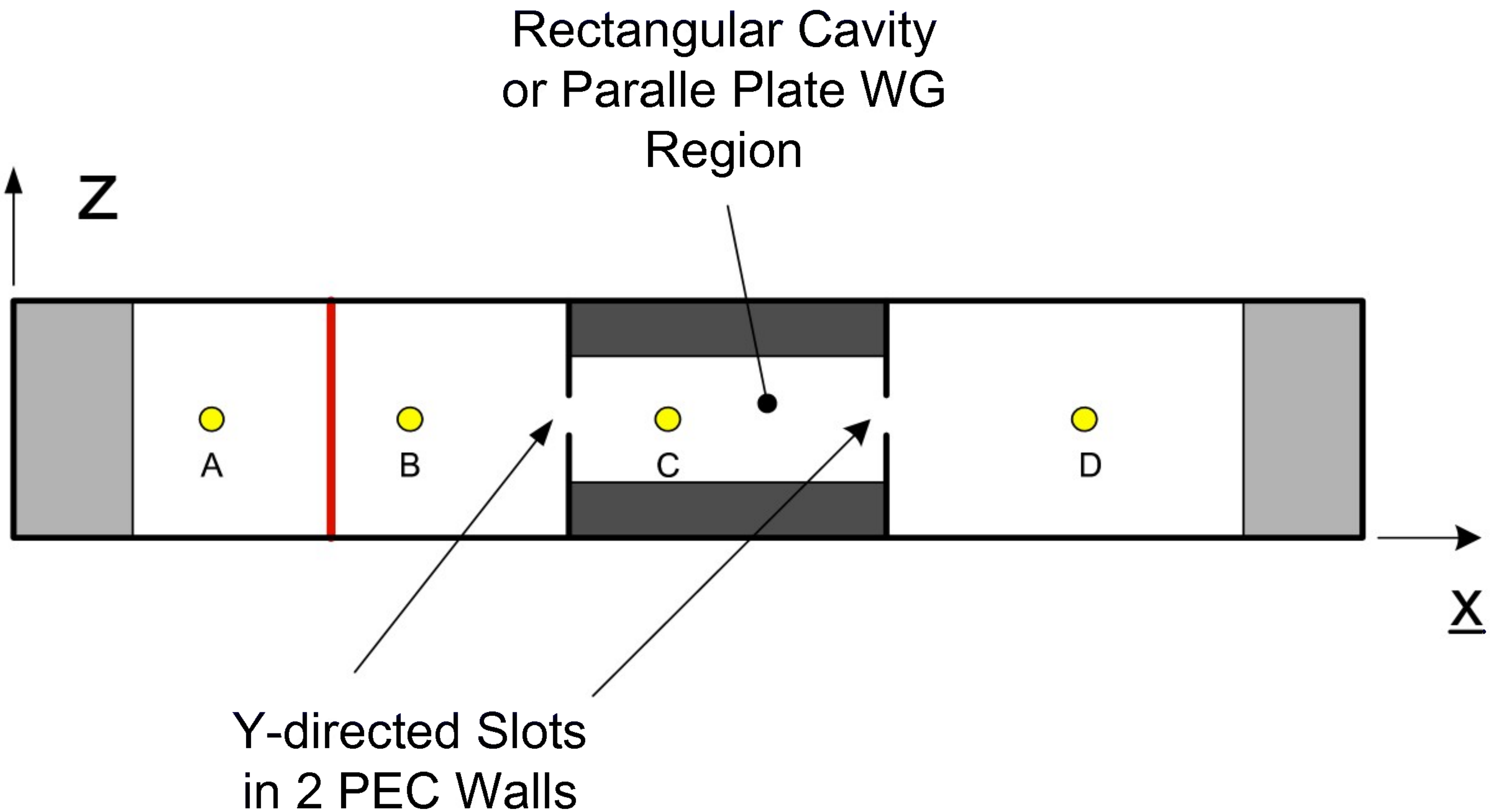


Structures – Z-directed Slots & Cavities

- An interior rectangular cavity is formed between two walls that contain slots
- Note that either type of slot can be used on either wall



Structures – Y-directed Slots & Cavities

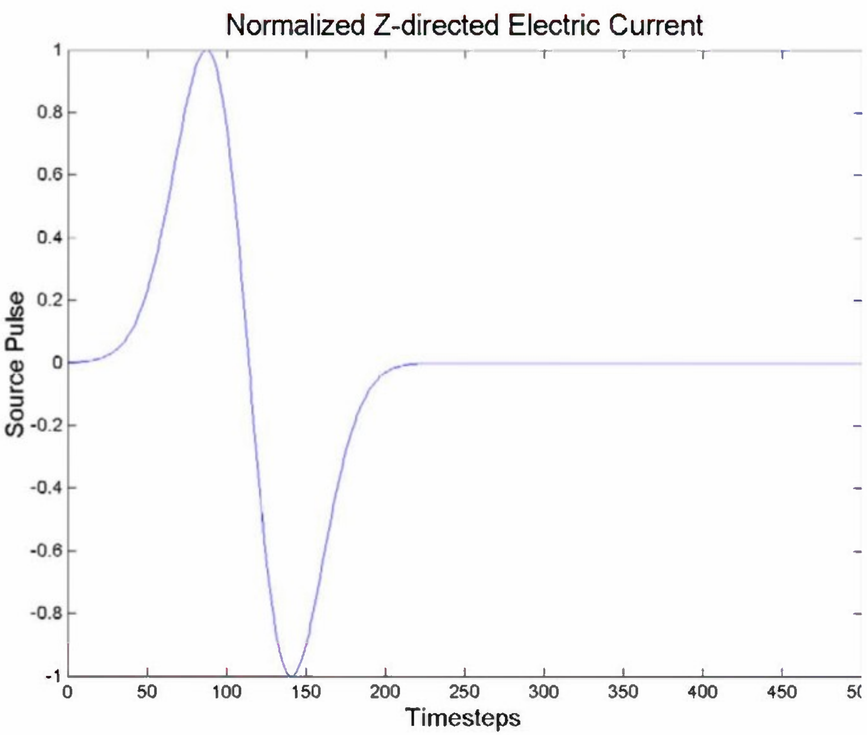


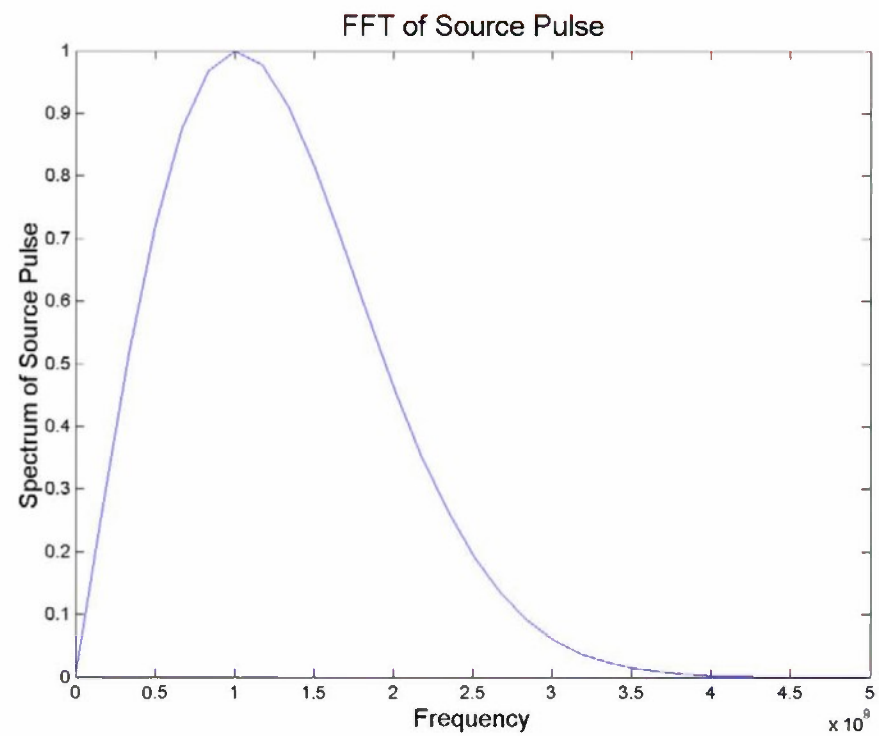
FDTD Details

- Source: $J_z = -J_0(t-t_0)\exp\left(-[(t-t_0)/\tau]^2\right)$
- τ=0.2216ns, t_0=3 τ
- 3D Box Size: 35 cm by 16.1 cm by 7 cm
- Mesh (unless otherwise stated): 120 by 70 by 20
- Mesh Cell Size: 0.0035 m
- UPML: 15 cells
- Source: l_s=30 cells

Effects of RF Pulses on Circuits and Systems – Pieces

Source Pulse





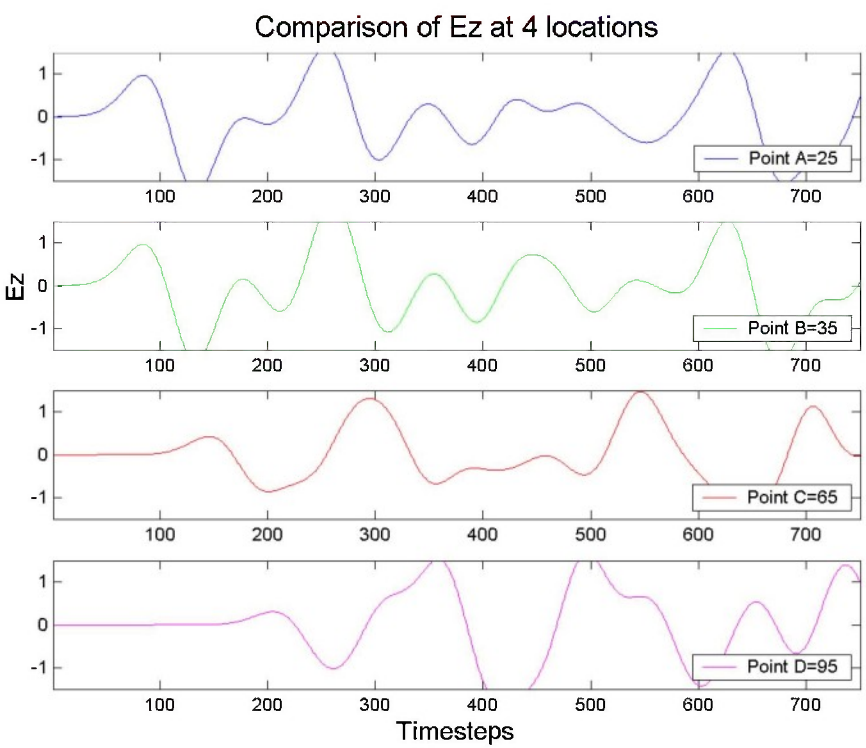
Effects of RF Pulses on Circuits and Systems – Pieces

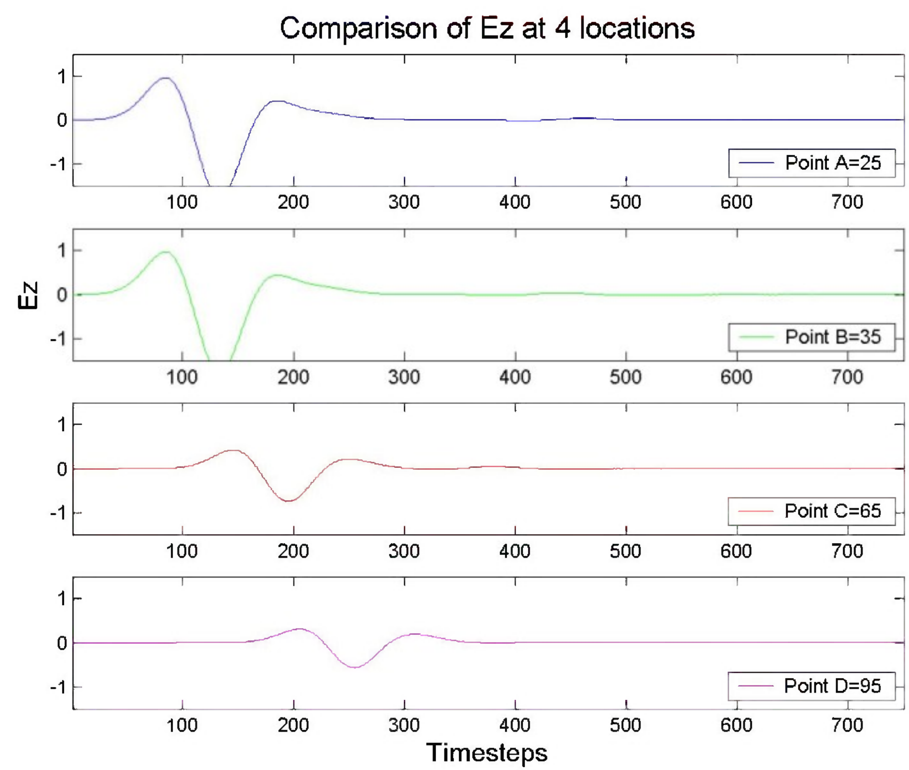
Baseline Comparison

No UPML
No slots

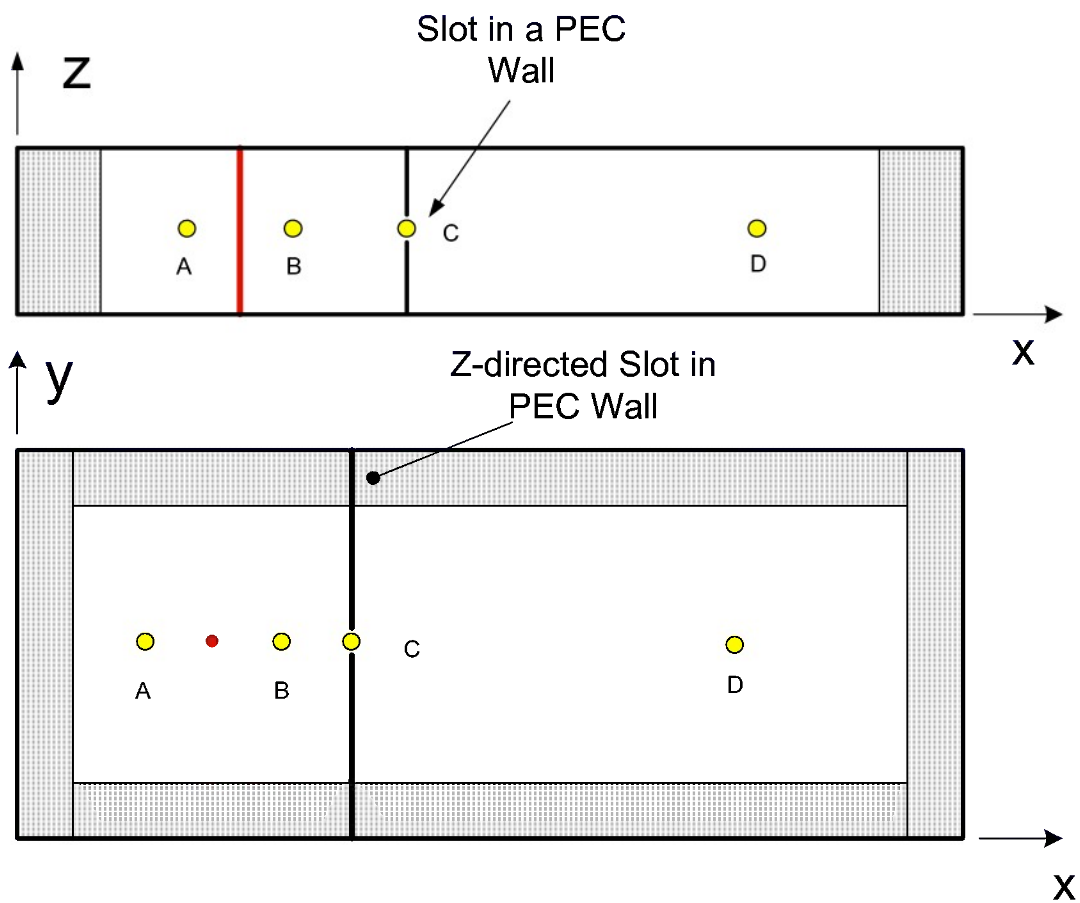
Observation along center axis of rectangular cavity

UPML
No slots





Propagation Through a Slotted Wall

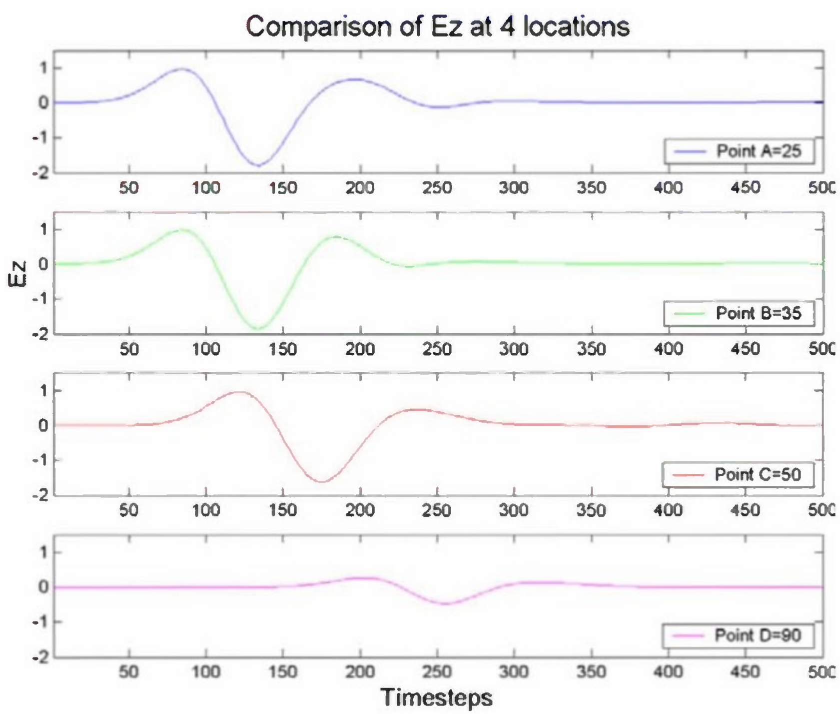


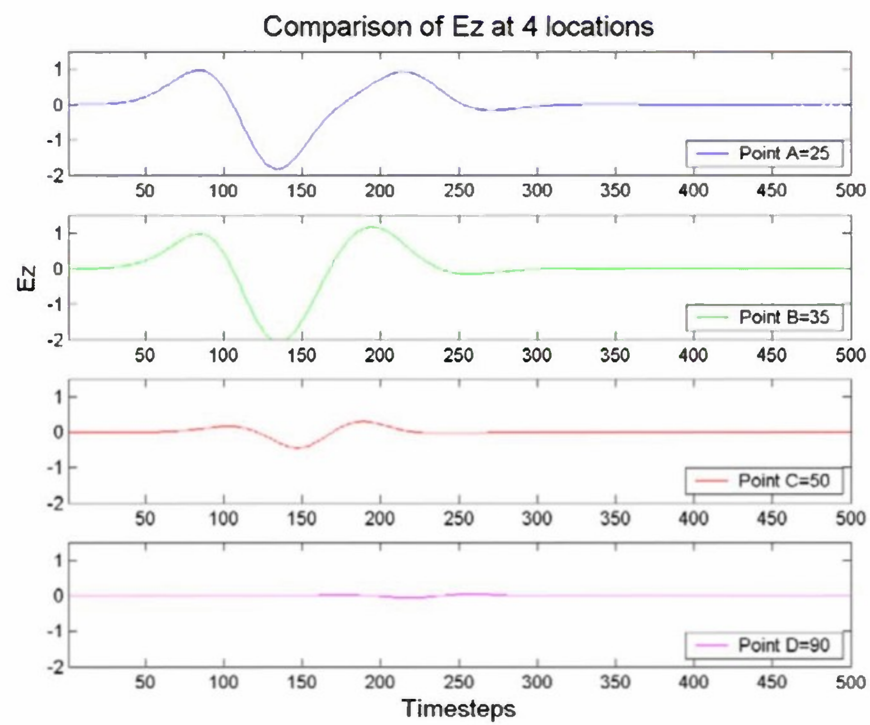
Propagation Through a Slotted Wall

z z

Slot 8 cells wide, i_s=30, i_w=50

y y





Propagation Through a Slotted Wall

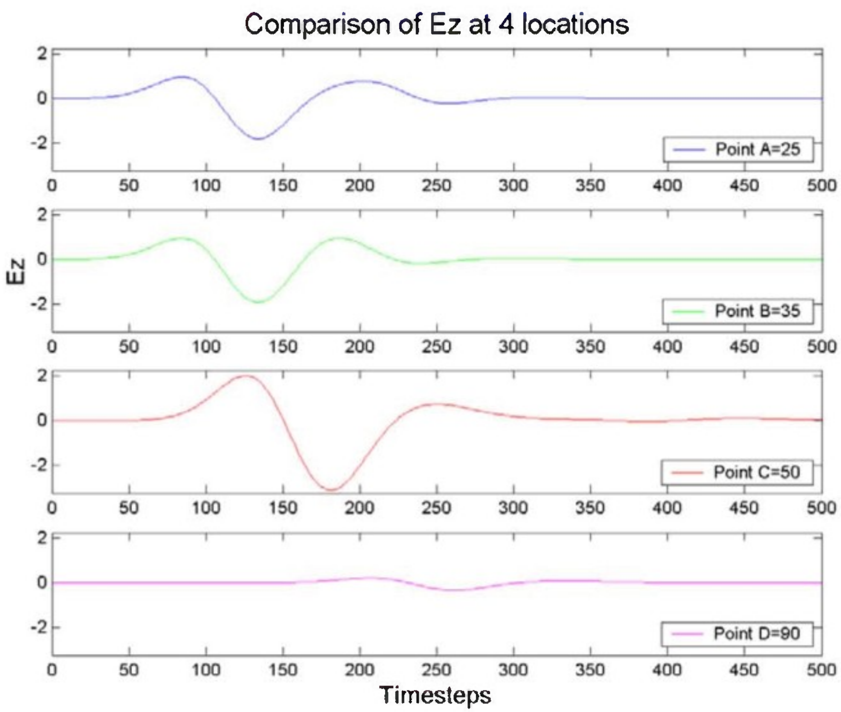
z

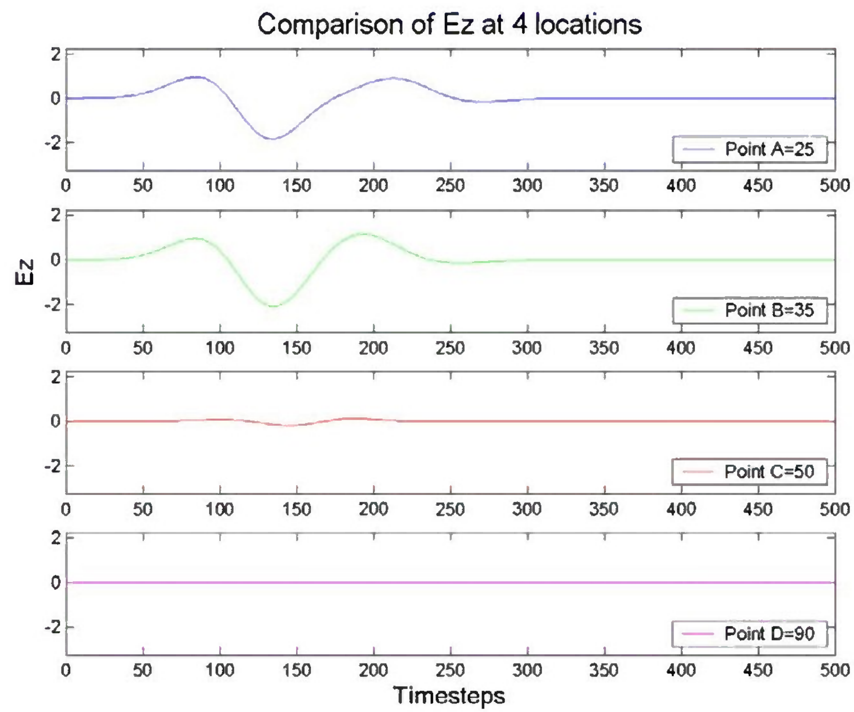
z

Slot 2 cells wide, i_s=30, i_w=50

y

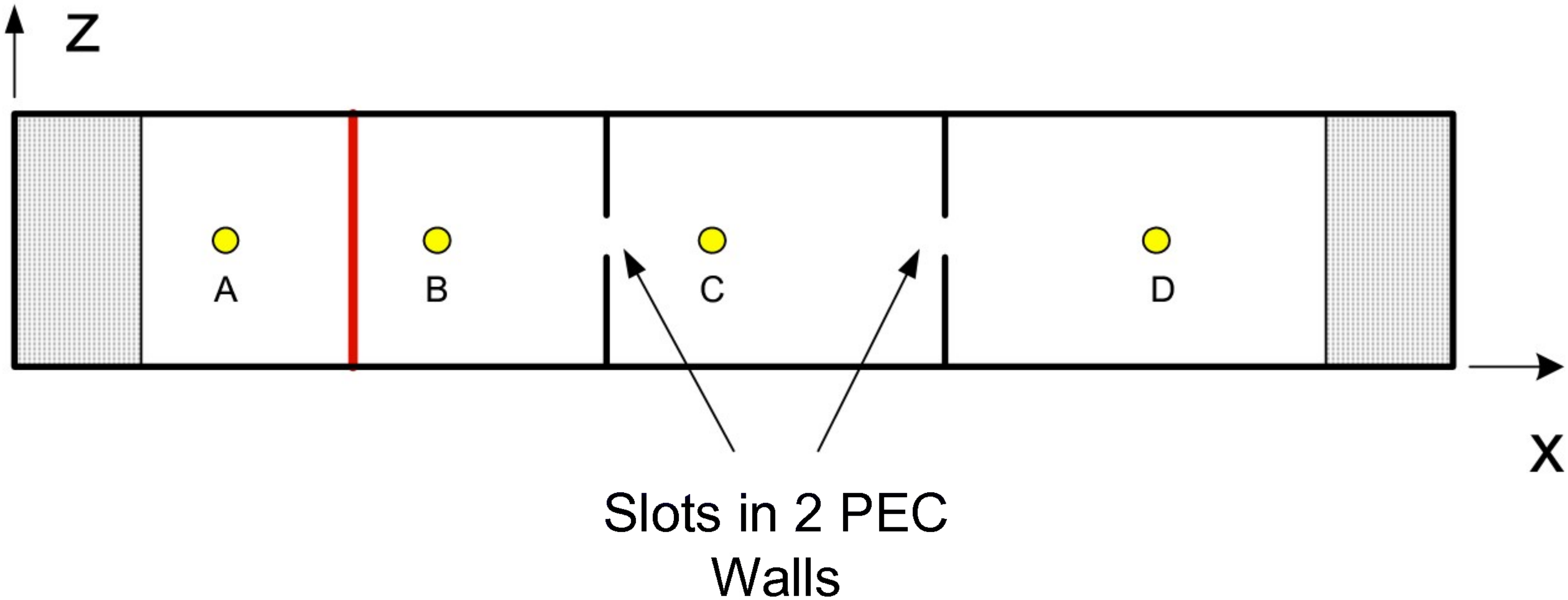
y





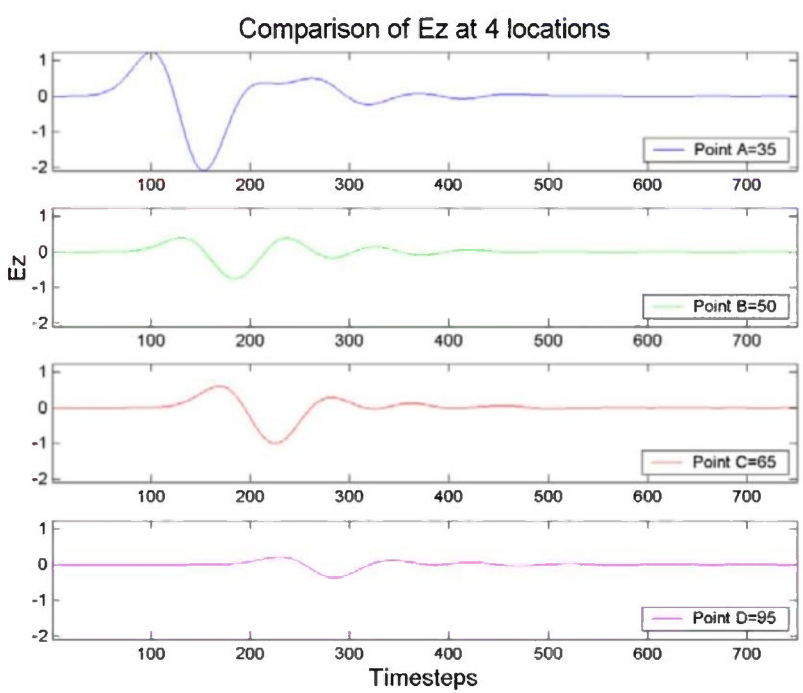
Propagation Through 2 Slotted Walls

2 Slots 8 cells wide, i_s=25

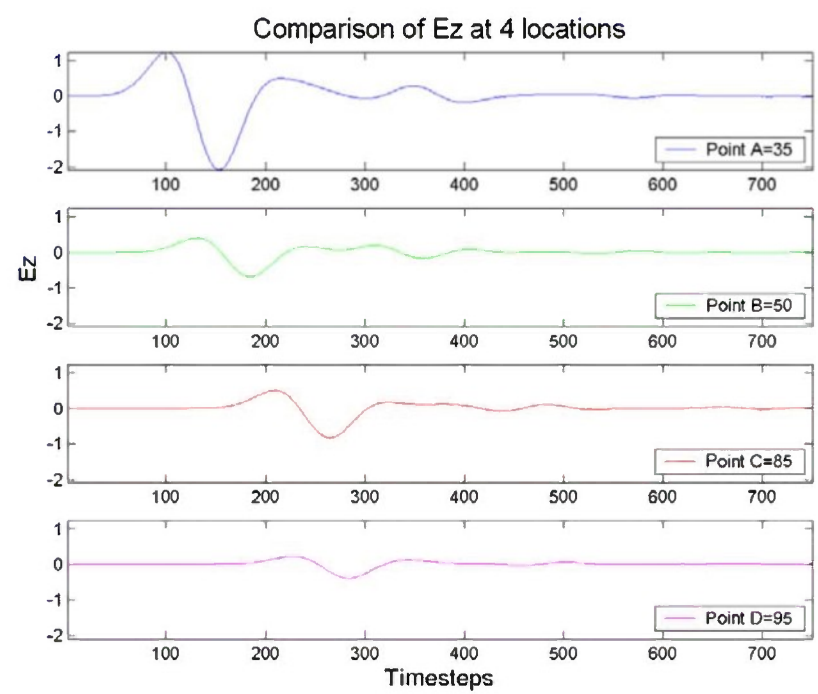


Propagation Through 2 Slotted Walls

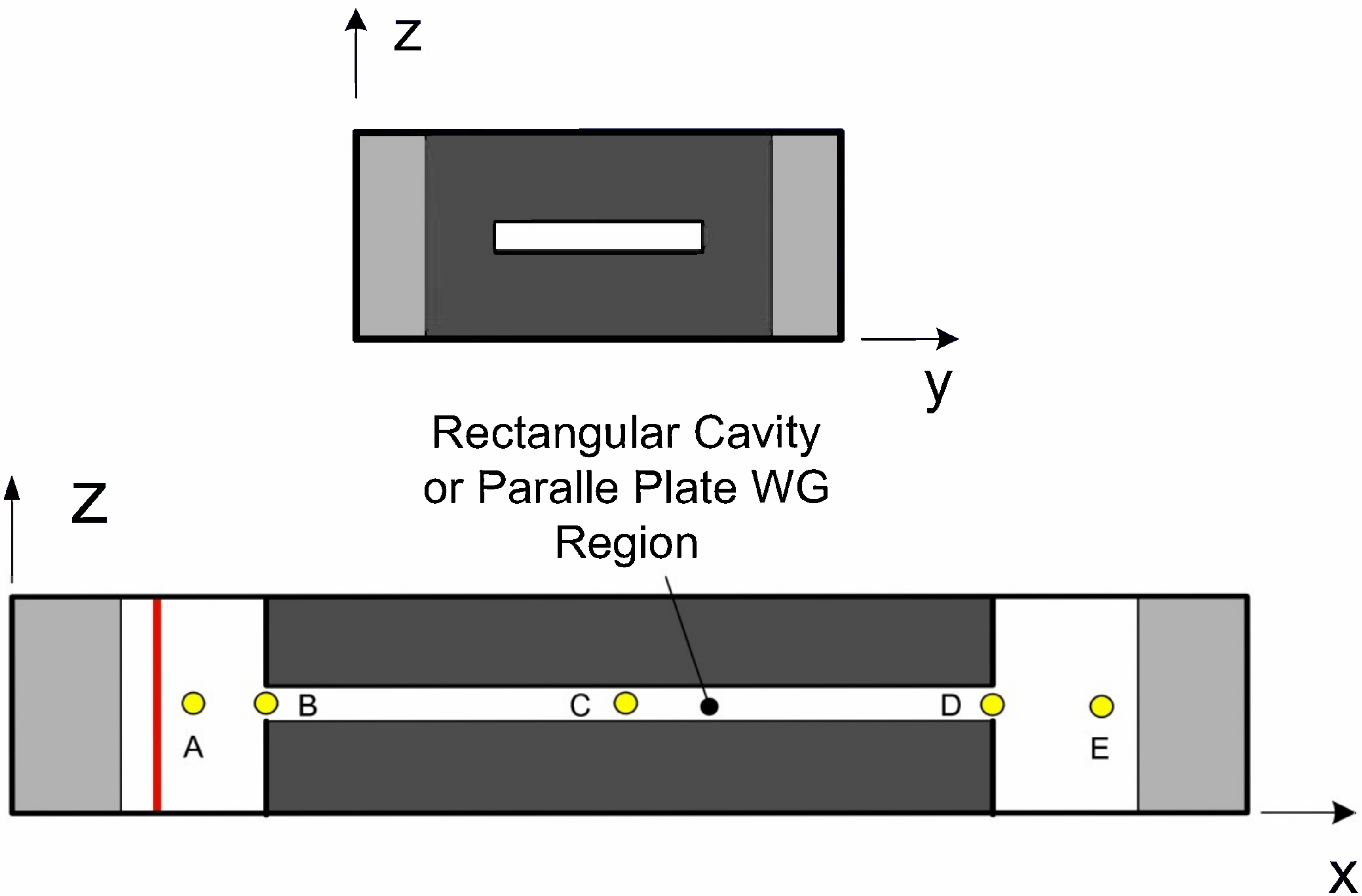
$i_{w1}=35, i_{w2}=65$



$i_{w1}=35, i_{w2}=85$



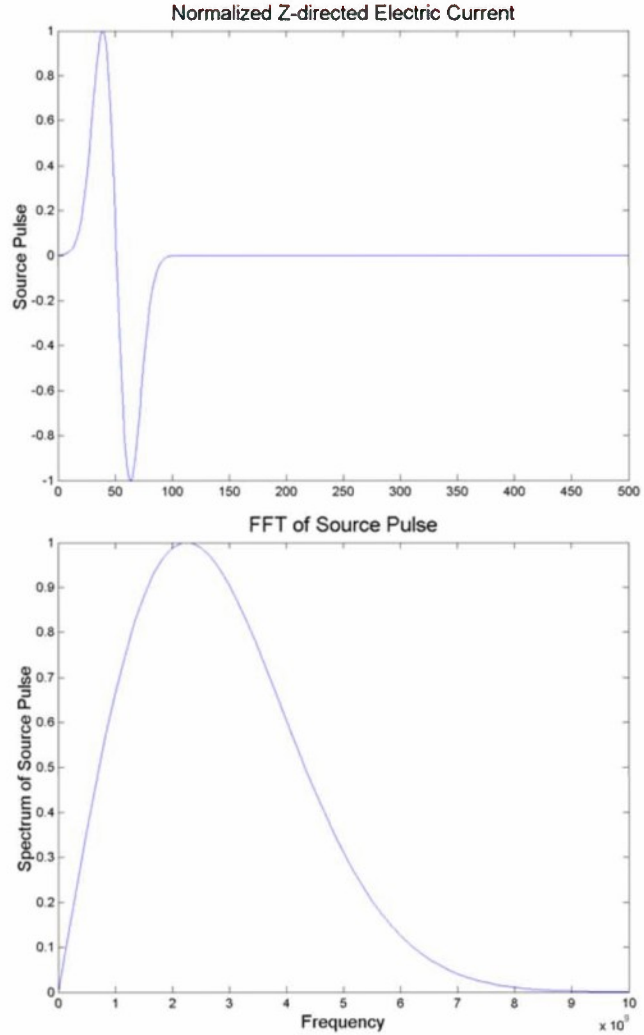
Penetration Through Deep Cavity



Effects of RF Pulses on Circuits and Systems – Pieces

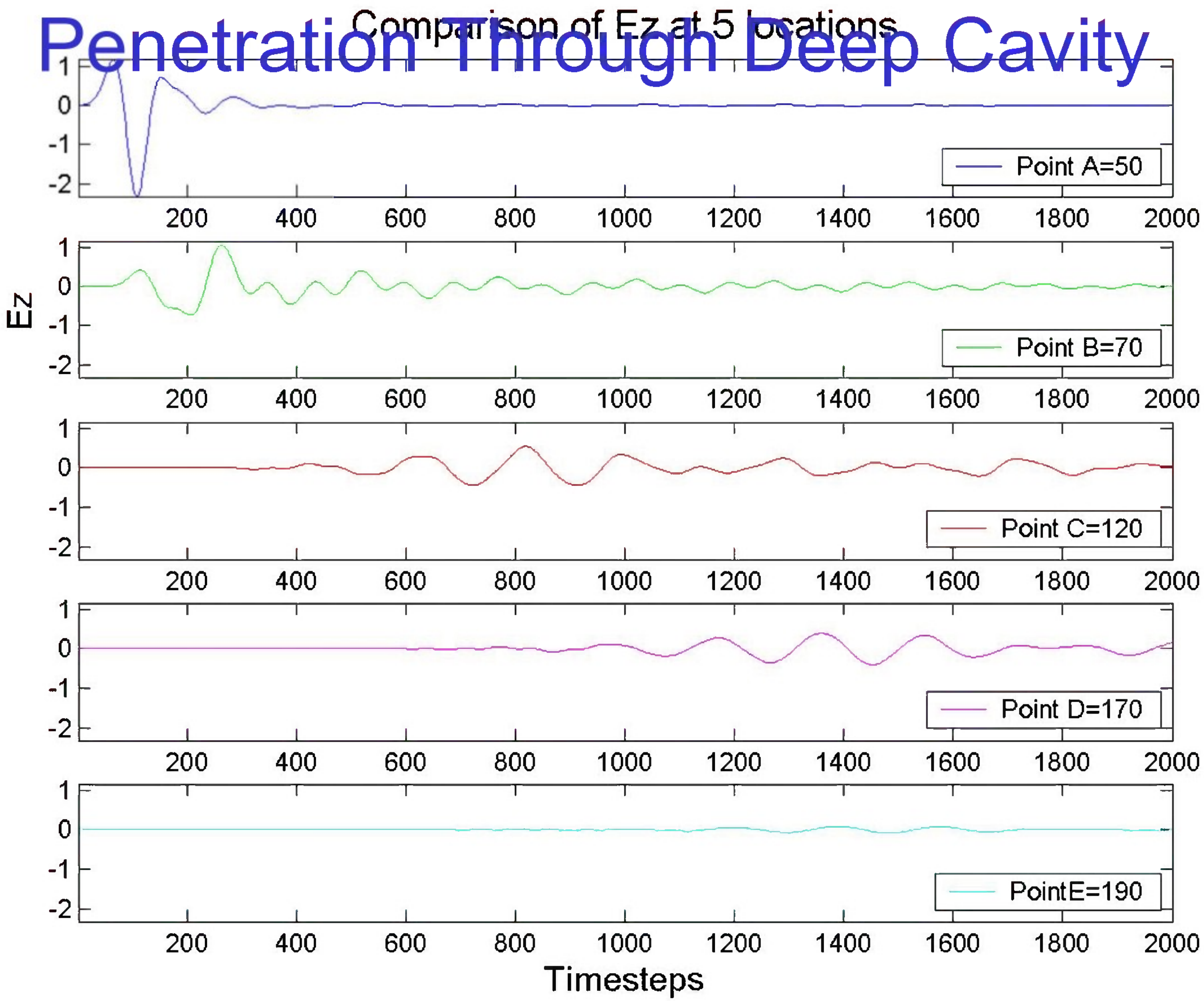
Deep Cavity

- τ=0.1ns, t_0=3 τ
- Length: 17.5cm
- Width: 10.5 cm (30 cells)
- Height: 1.4 cm (4 cells)
- TE_{10} cutoff: 1.43 GHz

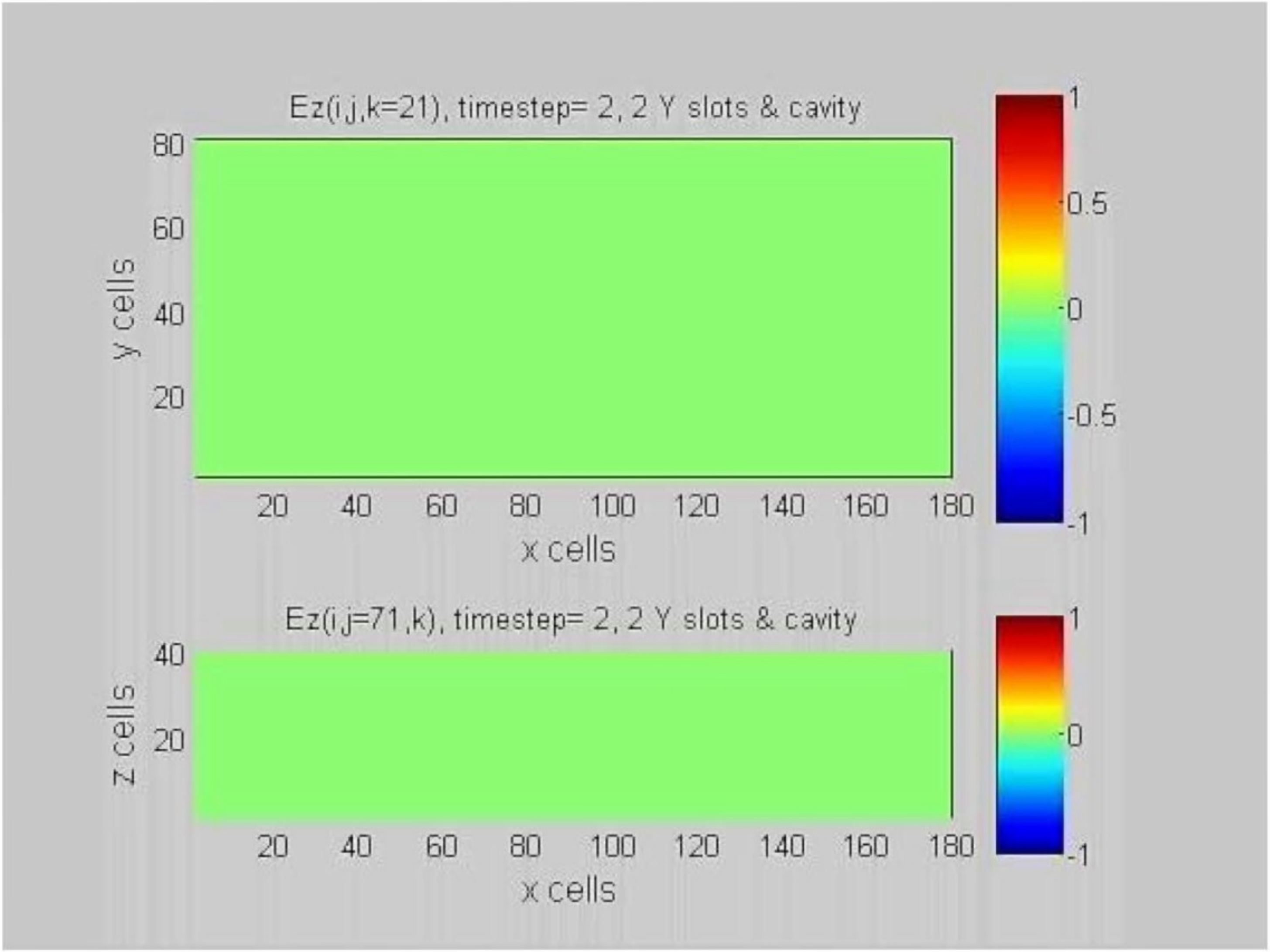


Effects of RF Pulses on Circuits and Systems – Pieces

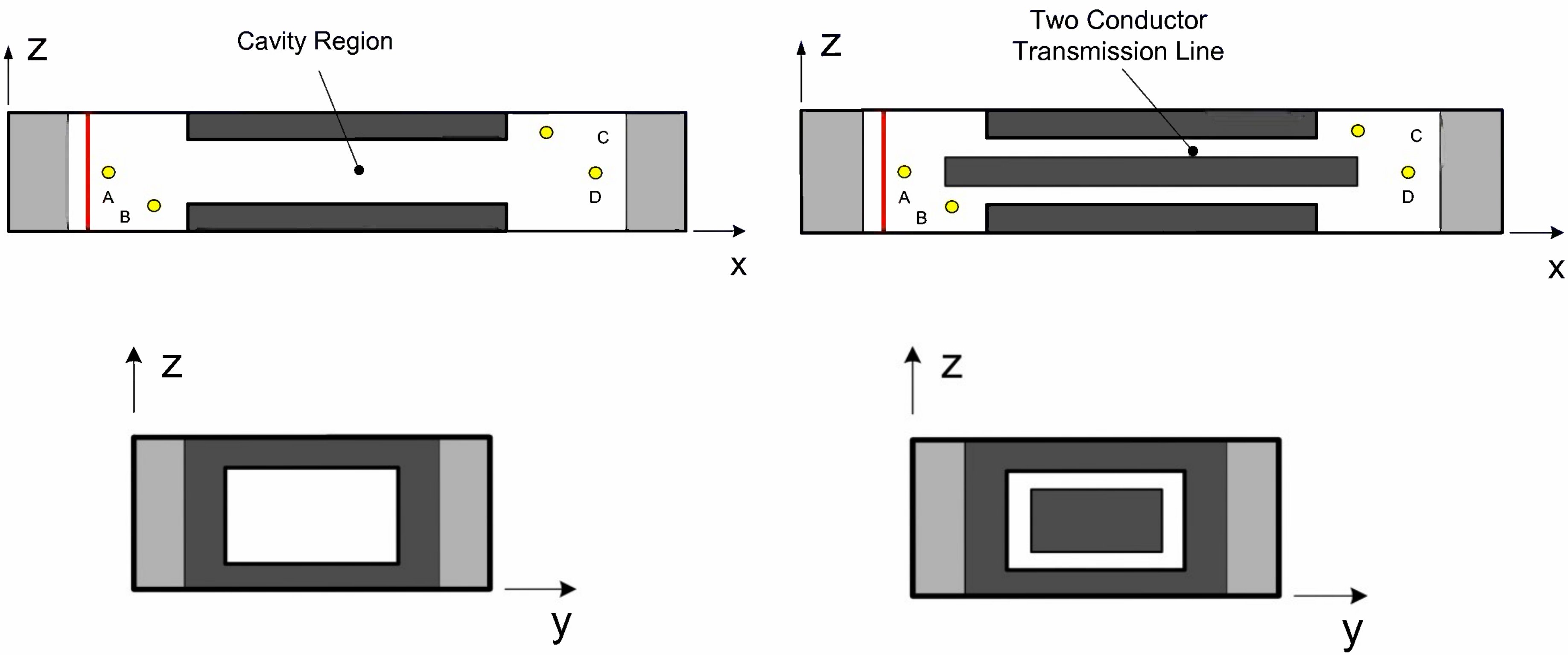
Penetration Through Deep Cavity



Penetration Through Deep Cavity



Comparison of Propagation Through Cavity and Transmission Line



Cavity Details

- Cavity: 12 by 12 cells (4.2 cm by 4.2 cm)
- Rod: 8 by 8 cells (2.8 cm by 2.8 cm)
- Rod extends for 4 cells into PPWG regions
- Cavity Depth: 50 cells (17.5 cm)
- ♦=0.2219 ns (centered at 1 GHz)
- TE_{10} cutoff of Rect. WG = 3.5 GHz

Effects of RF Pulses on Circuits and Systems – Pieces

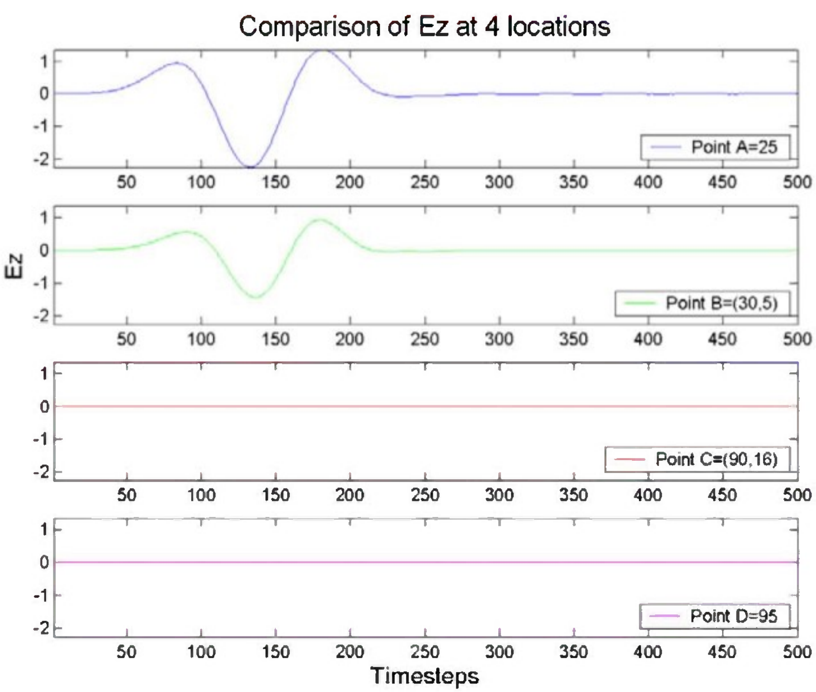
Results w/o & w/ Rod

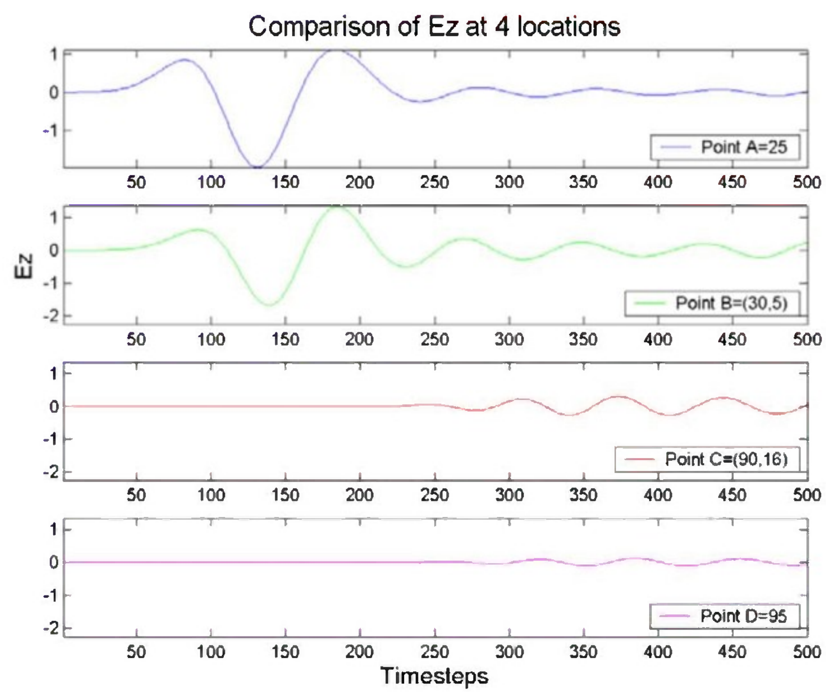
z

z

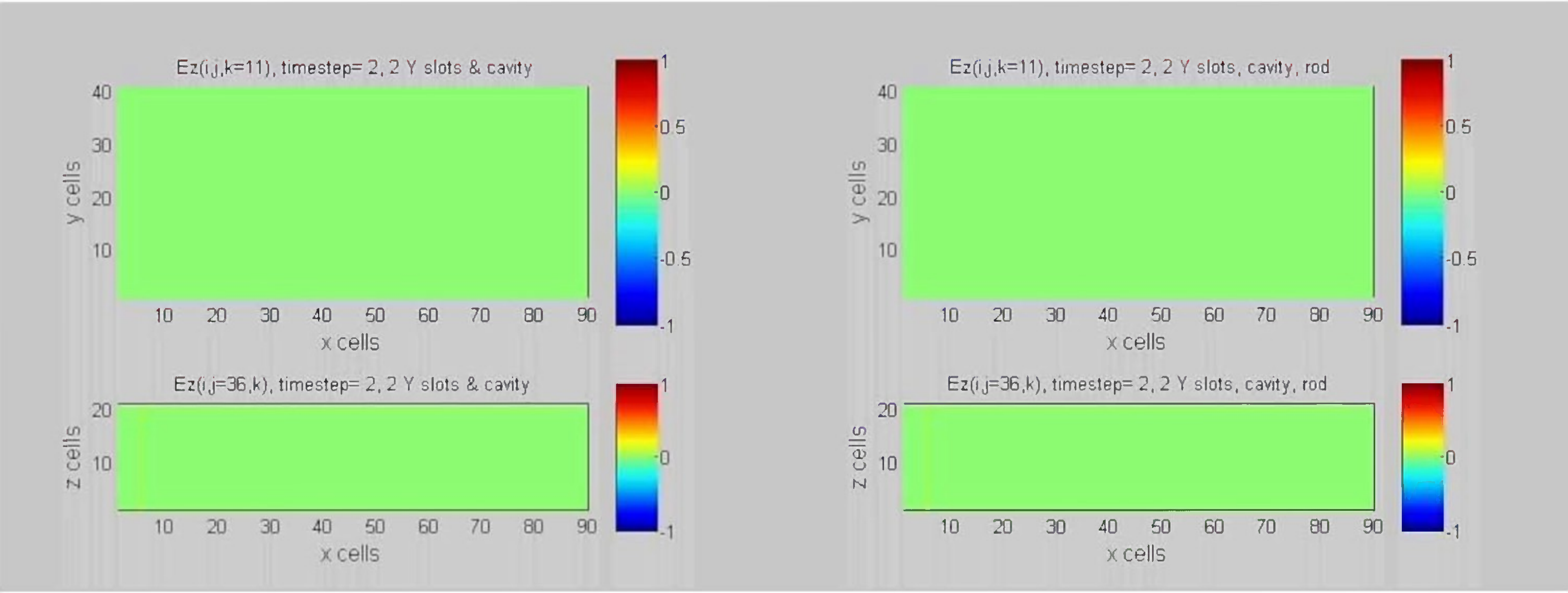
y

y





Movie Results



Future Work

- Validation
- Different excitations: pulse trains
- More structures; features
- Open-region propagation into enclosures (removal of PPWG)
- Cataloging of responses to various excitations