Aperture Feed Simulations for the 21m CRT

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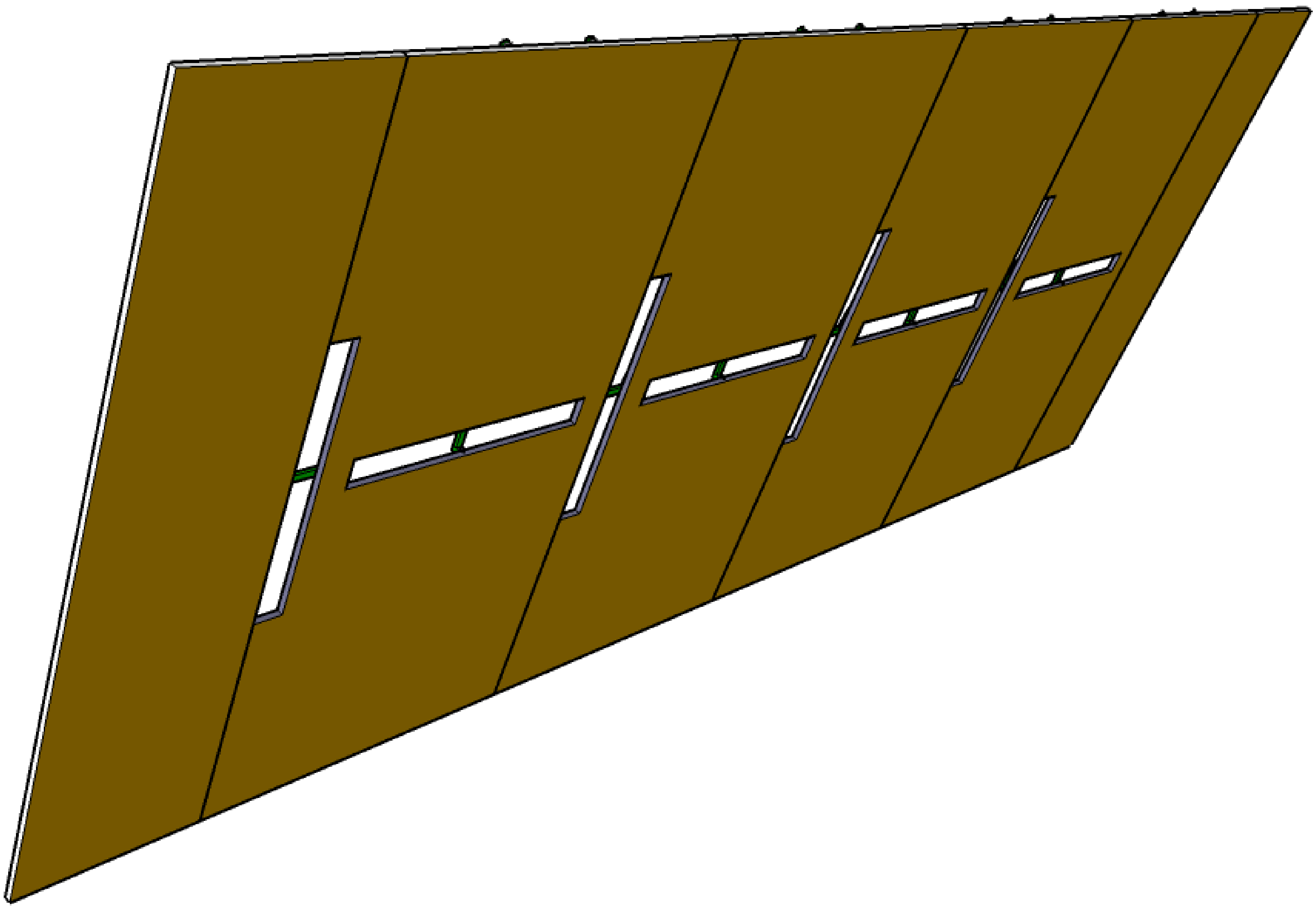
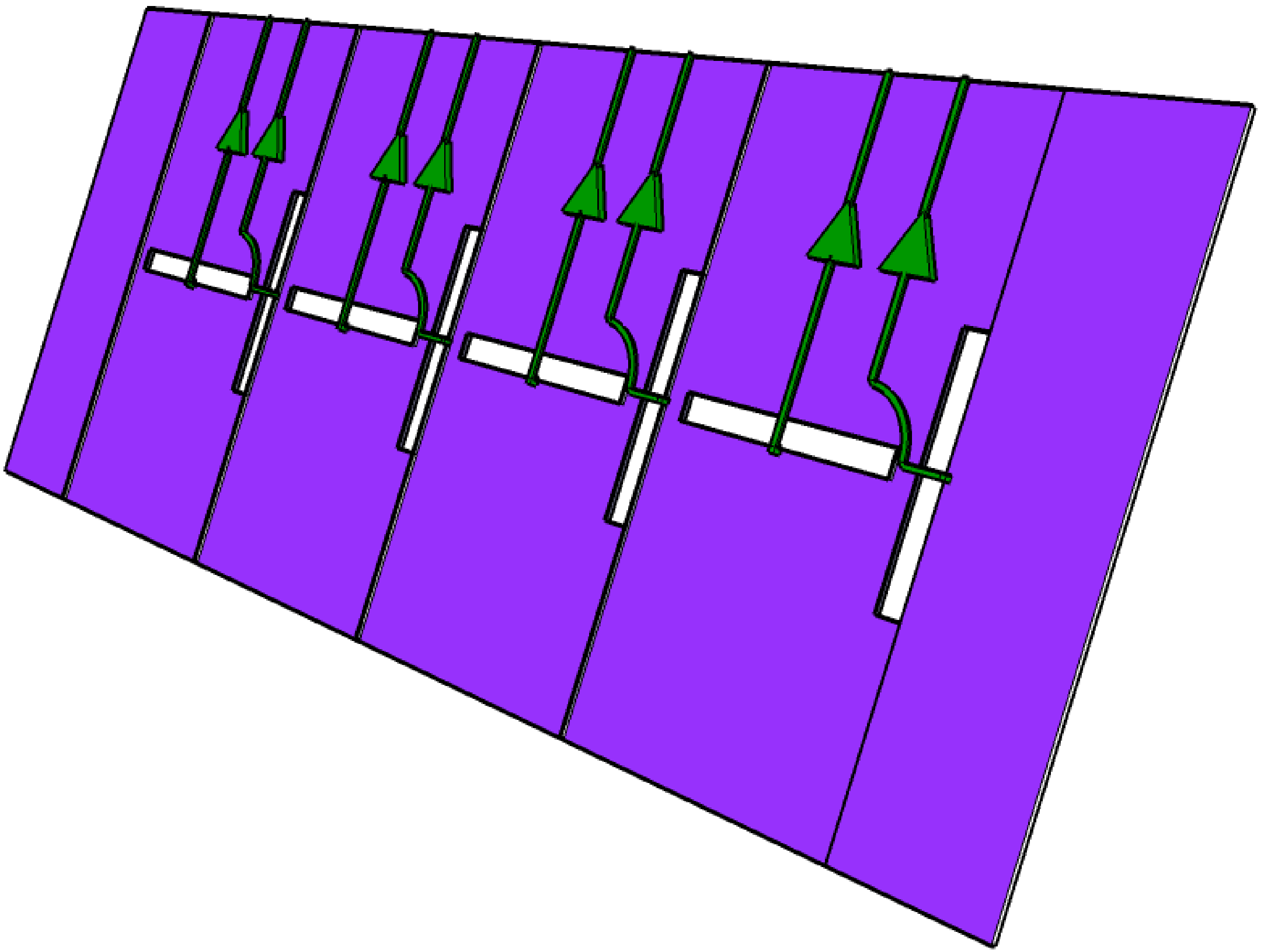
Aperture Feed Concept



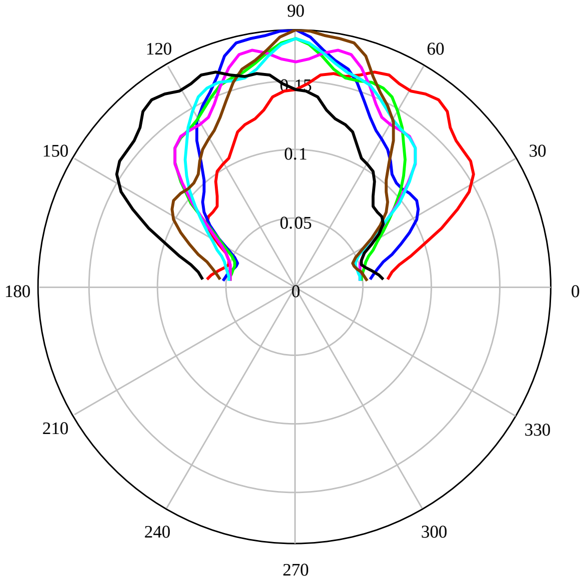
Aperture Feed Concept

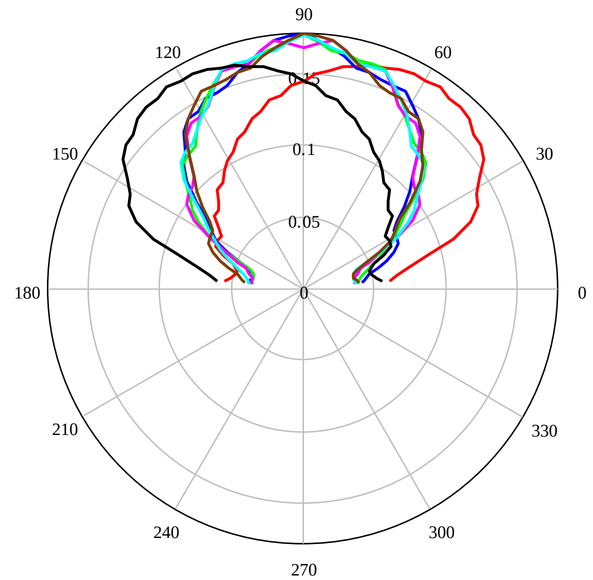


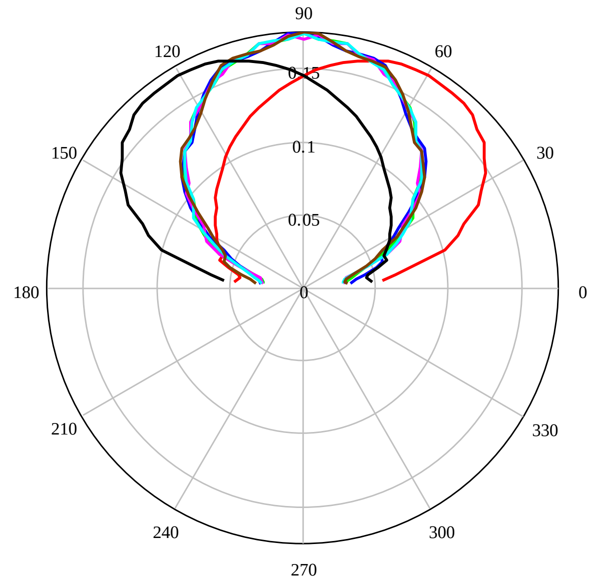
Aperture Feed Concept

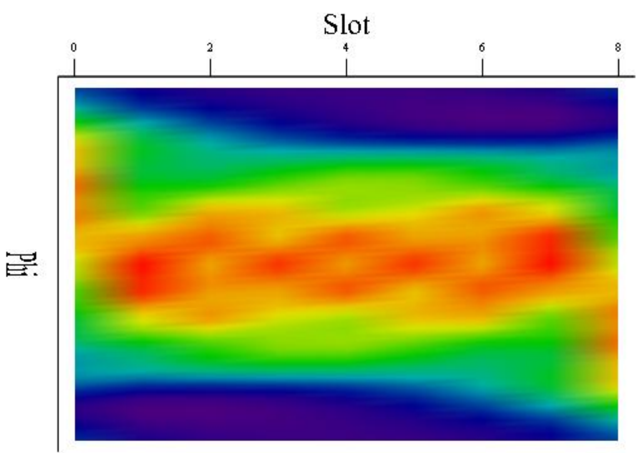
- Aperture Feed is alternative concept at this point.
- Folded wire dipoles or patch antennas are probably the most likely choice for the 21cm CRT at this point
- However, because the ground plane is an integral part of the aperture feed, aperture feeds might:
  - Be less expensive – PC board fabrication
  - Have better noise – amplifiers are mounted very close to the antenna for better noise match control and signal loss
  - Easier to design large arrays . The simple geometry is more straight forward to analyze effects such as antenna to antenna coupling

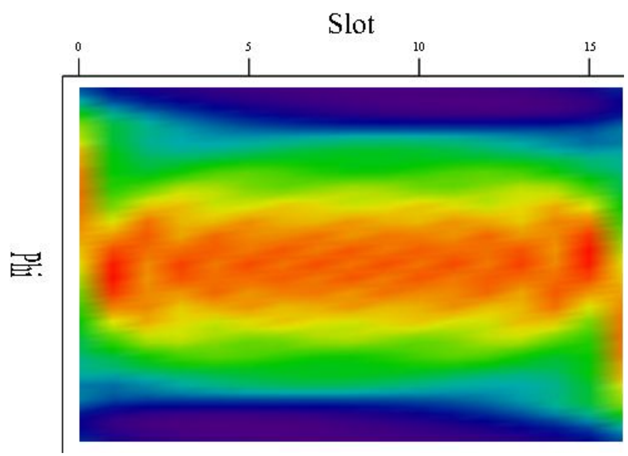
Slot Array Analysis

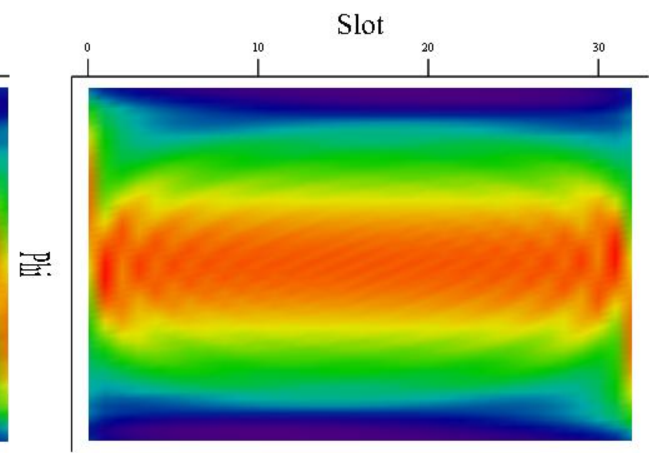












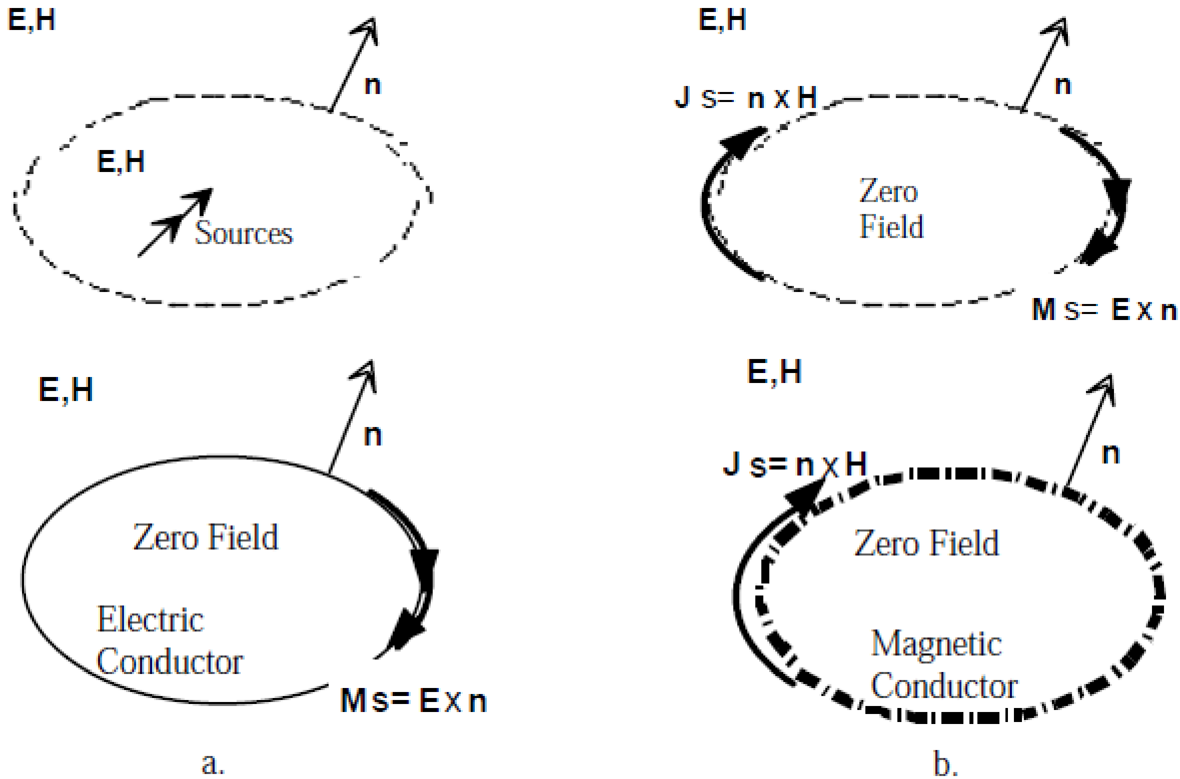
Aperture Feed Analysis

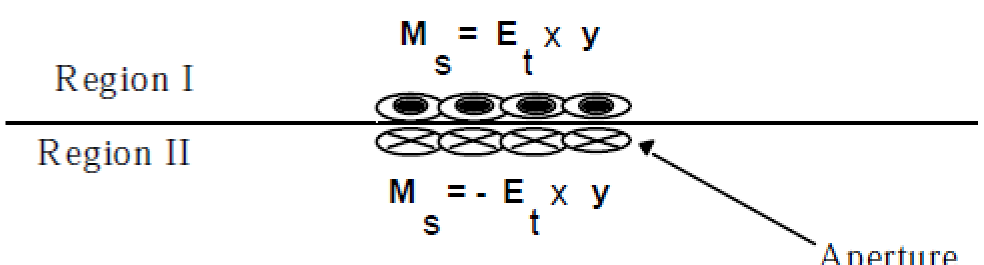
- At this point, I have only analyzed simple slots.
- It has been pointed out to me that other aperture shapes could provide better performance in gain and bandwidth.
- Also the addition of a double ground plane for shielding need to be incorporated.
- I have developed a software tool to analyze complex aperture shapes.

Moment Methods

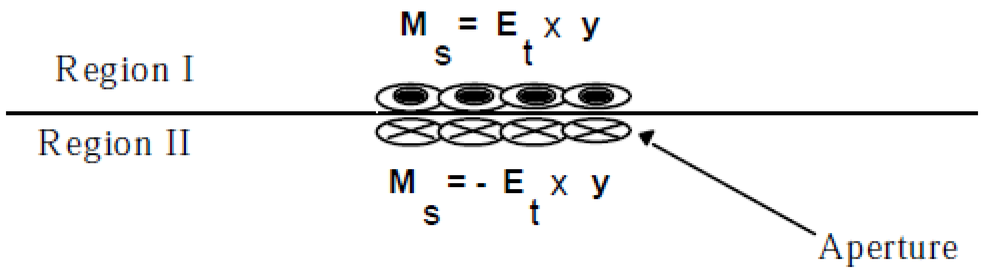
- Moment methods is integral equation approach to solving Maxwell's equations.
- Moment methods is much better suited to analyzing apertures than standard finite element programs.
  - Thin ground planes with apertures require very large finite element meshes
  - Radiation boundary conditions are handled naturally in moment methods.
- Moment methods is the standard technique for analyzing wire antennas (NEC & Mini-Nec)

Equivalence Principle





Moment Methods



$$\vec{H}_t^{(1)} = \vec{H}_t^{(inc)}{}_1 + \vec{H}_t^{(1)}\left(\vec{E}_t \times \hat{y}\right)$$

$$\vec{H}_t^{(2)} = \vec{H}_t^{(inc)}{}_2 + \vec{H}_t^{(2)}\left(-\vec{E}_t \times \hat{y}\right)$$

$$\vec{H}_t^{(1)} = \vec{H}_t^{(2)}$$

$$\vec{H}_t^{(inc)}{}_2 - \vec{H}_t^{(inc)}{}_1 = \vec{H}_t^{(1)}\left(\vec{E}_t \times \hat{y}\right) + \vec{H}_t^{(2)}\left(\vec{E}_t \times \hat{y}\right)$$

$$\vec{E}_t = \hat{x}\sum_n E_{x_n}\theta_n(x,z) + \hat{z}\sum_n E_{z_n}\psi_n(x,z)$$

Moment Method Matrix

$$\langle \phi_m | H_v^{(k)} | \theta_n \rangle = \iint_{x,z} \left(\phi_m(x,z) H_v^{(k)} (\hat{z}\theta_n(x,z)) \right) dxdz$$

$$\langle \phi_m | H_v^{(k)} | \psi_n \rangle = \iint_{x,z} \left(\phi_m(x,z) H_v^{(k)} (\hat{x}\psi_n(x,z)) \right) dxdz$$

$$\left\langle \phi_m \middle| H_v^{(inc)}{}_i \right\rangle = \iint_{x,z} \left(\phi_m(x,z) H_v^{(inc)}{}_i(x,z) \right) dxdz$$

$$\left\langle \phi_m \middle| H_x^{(inc)}{}_1 \right\rangle - \left\langle \phi_m \middle| H_x^{(inc)}{}_2 \right\rangle = \sum_n \left(\sum_k \langle \phi_m | \boldsymbol{H}_x^{(k)} | \psi_n \rangle \right) E_{z_n} - \sum_n \left(\sum_k \langle \phi_m | \boldsymbol{H}_x^{(k)} | \theta_n \rangle \right) E_{x_n}$$

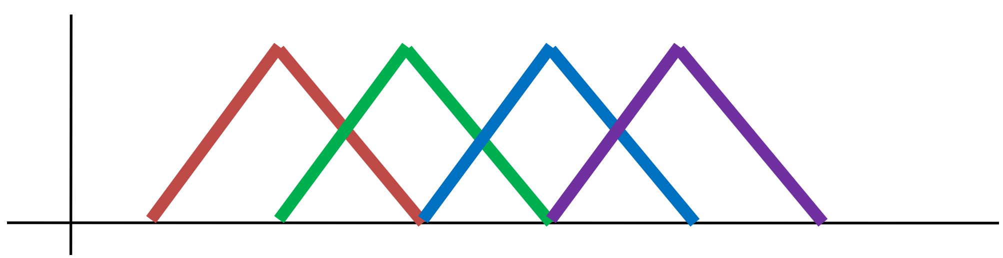
$$\left\langle \phi_m \middle| H_z^{(inc)}{}_1 \right\rangle - \left\langle \phi_m \middle| H_z^{(inc)}{}_2 \right\rangle = \sum_n \left(\sum_k \langle \phi_m | \boldsymbol{H}_z^{(k)} | \psi_n \rangle \right) E_{z_n} - \sum_n \left(\sum_k \langle \phi_m | \boldsymbol{H}_z^{(k)} | \theta_n \rangle \right) E_{x_n}$$

Moment Method Expansion Function

- For smaller matrices, you usually try to use an expansion function that has a shape similar to what the shape of the fields in the aperture are going to look like (Chicken and the egg problem)
- For a aperture generic shape, a generic expansion has to be chosen.

Moment Method Expansion Function

- A 2-D pulse would be the simplest concept.
- However, Maxwell's equations are 2nd order so sharp edges give rise to convergence problems.
- The next best solution would be to use a triangle function.
- The drawback is the triangles have to overlap



The Computer Program

- A moment method computer program for designing 21cm CRT feeds was written in Java.
  - Object Oriented coding is more natural to large array problems
    - Class – Array
      - Class - Antenna
        - » Class - Patch
  - Java is easily transportable to other computers
  - Java is easy to interface to the Web
  - Java has a large amount software available to "borrow" such as graphics

Moment Methods Computer Program

- Because of the capability of generic aperture shapes, the program will require the computation of a large number of matrix elements.
- A computer “farm” of four “cast-off” 2.4 GHz linux computers was put together.
- The program was written to either run by itself (multi-threaded) or communicate with the farm via sockets.

Moment Methods Computer Program

- Because of communicating with the farm and incorporating graphics, a web interface was chosen for controlling the program.
- The program is up, ready, and available for anybody to use.
- The user inputs his feed shape via an XML file.
  - XML is easy for a human to read
  - XML is easy to edit with a simple text editor
  - XML is easy to parse with a computer program

XML Input File

antennaInput.xml

Turn Grammar Constraints Off


```xml
<?xml version="1.0" encoding="UTF-8" standalone="no"?><!--slot antenna in y direction--><!--
--><Simulation>
    <SimulationParameters/>
    <freqPt>
        <thetaPt>
            <phiPt>
                <Array>
                    <Antenna>
                        <Termination resistance="310.0" voltNpts="10">
                            <Start x="-0.0075" y="0.0"/>
                            <Stop x="0.0075" y="0.0"/>
                            <rootArea imag="0.0" magn="0.0" real="0.0"/>
                        </Termination>
                        <Patch conductance="0.0" numGridPts="15">
                            <Center x="0.0" y="-0.06818181818181818"/>
                            <Size x="0.015" y="0.013636363636363636"/>
                            <eXfield imag="0.0" magn="0.0" real="0.0"/>
                            <eYfield imag="0.0" magn="0.0" real="0.0"/>
                        </Patch>
                        <Patch conductance="0.0" numGridPts="15">
                            <Center x="0.0" y="-0.061363636363636356"/>
                            <Size x="0.015" y="0.013636363636363636"/>
                            <eXfield imag="0.0" magn="0.0" real="0.0"/>
                            <eYfield imag="0.0" magn="0.0" real="0.0"/>
```


Design Source

Web Interface

Slot Array Web Interface

Links

- Simulation Setup
- Simulation Status
- Plot File
- Remove Lock
- Create Simple Slot Antenna

Scan Parameters

	Freq (MHz)	Theta (degrees)	Phi (Degrees)
Start	500.0	0.0	0.0
Stop	1500.0	42.971834629200785	42.971834629200785
No. Pts.	3	1	1

Latitude (degrees)	0.0	Reg. 2 GP Space (m)	1.0E9
Dec. Polz.	1.0	Reg. 2 EpsR	1.0
R.A. Polz	0.0	Reg 2. GP Images	0
Antenna X Spacing	0.2	Antenna Y Spacing	0.0
Number of Antenna	1		

Antenna File http://crt21cm3.fnal.gov:8080/SlotAntennaWebInterface/outputFiles/antennaInput.xml

Output File

antennaInput.xml
test.xml
defaultArrayOutput.xml

Run Sockets Number of Segments 2

Simulate

Thu Mar 26 17:03:15 CDT 2009

Web Output Interface

Slot Array Web Interface

Links

[Simulation Setup]
[Simulation Status]
[Plot File]
[Remove Lock]
[Create Simple Slot Antenna]

Scan Parameters

	Freq (MHz)	Theta (degrees)	Phi (Degrees)
Start	750.0	0.0	0.0
Stop	1500.0	42.971834629200785	42.971834629200785
No. Pts.	1	1	1

Latitude (degrees)	0.0	Reg. 2 GP Space (m)	1.0E9
Dec. Polz.	1.0	Reg. 2 EpsR	1.0
R.A. Polz	0.0	Reg 2. GP Images	0
Antenna X Spacing	0.2	Antenna Y Spacing	0.0
Number of Antenna	1		

Output File yslot300.xml

Plot Type

- ○ Freq.
- ○ Theta
- ○ Phi
- ◉ Antenna — ◉ Ex Field / ○ Ey Field

[Plot]

Frequency	750.0
Theta	0.0
Phi	0.0
Antenna	1

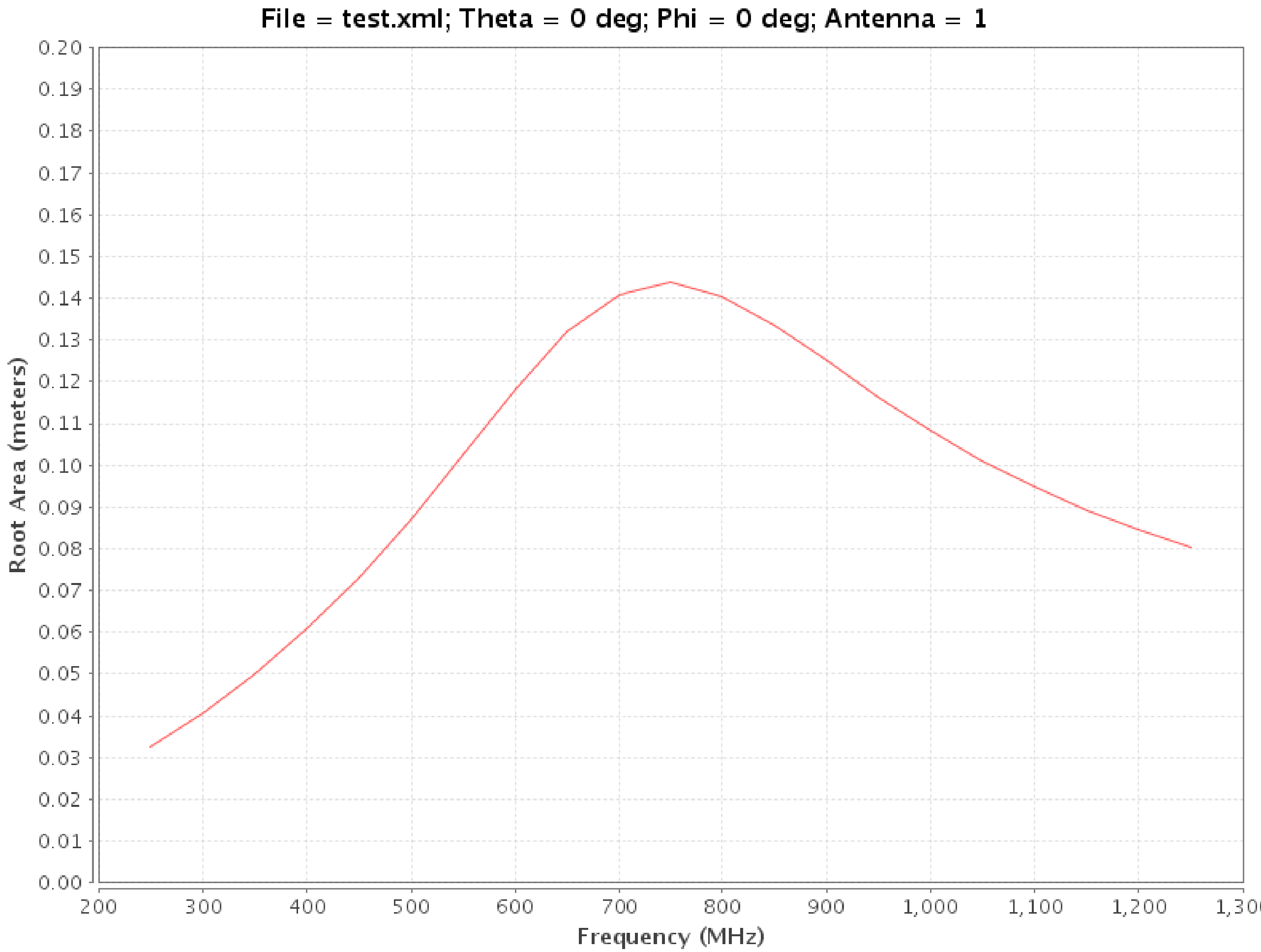
Tue Mar 31 08:23:02 CDT 2009

Frequency Sweep Output

Slot Array Web Interface

Links

Simulation Setup
Simulation Status
Plot File
Remove Lock
Create Simple Slot Antenna



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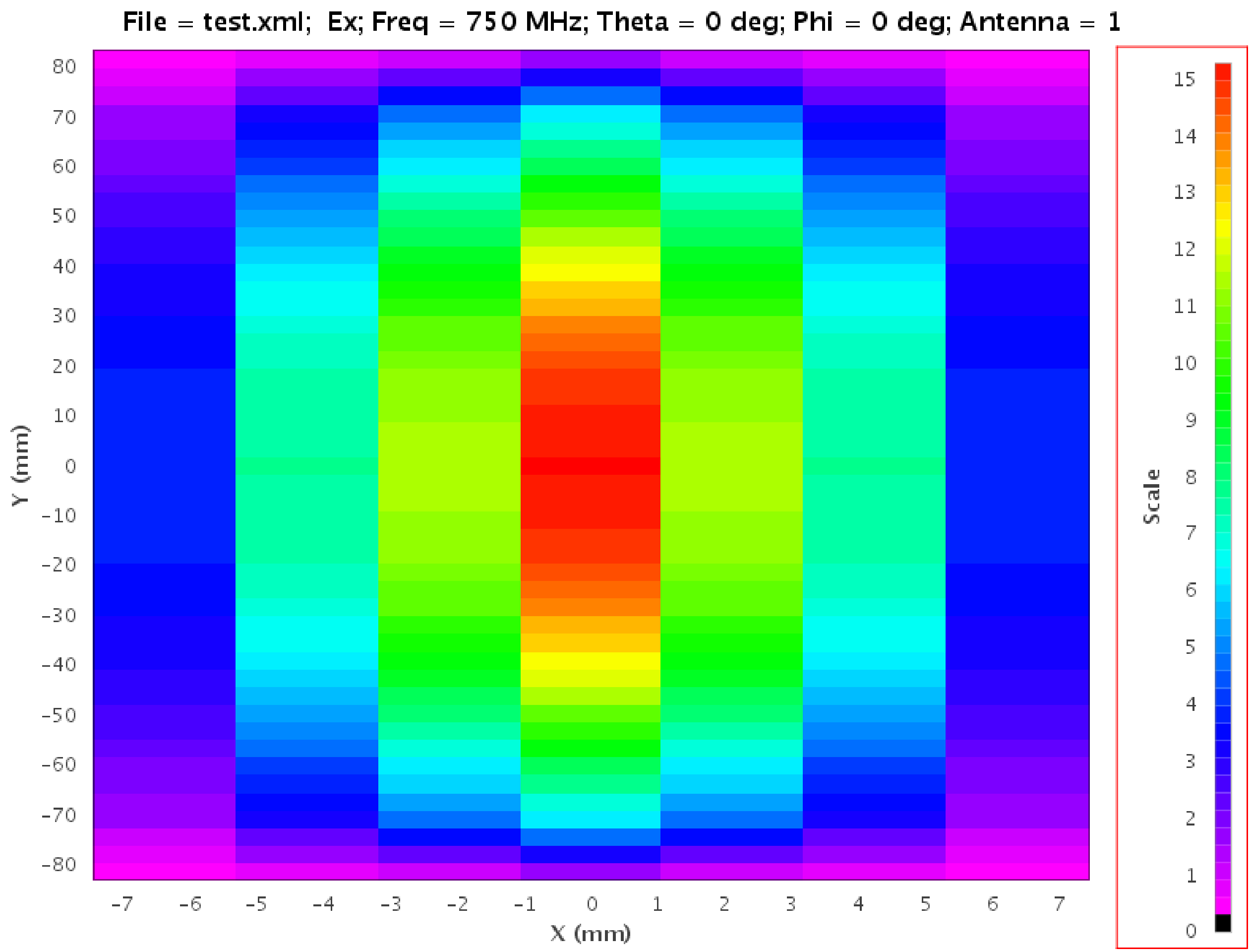
Field Plot

Slot Array Web Interface

Links

Simulation Setup
Simulation Status
Plot File
Remove Lock
Create Simple Slot Antenna



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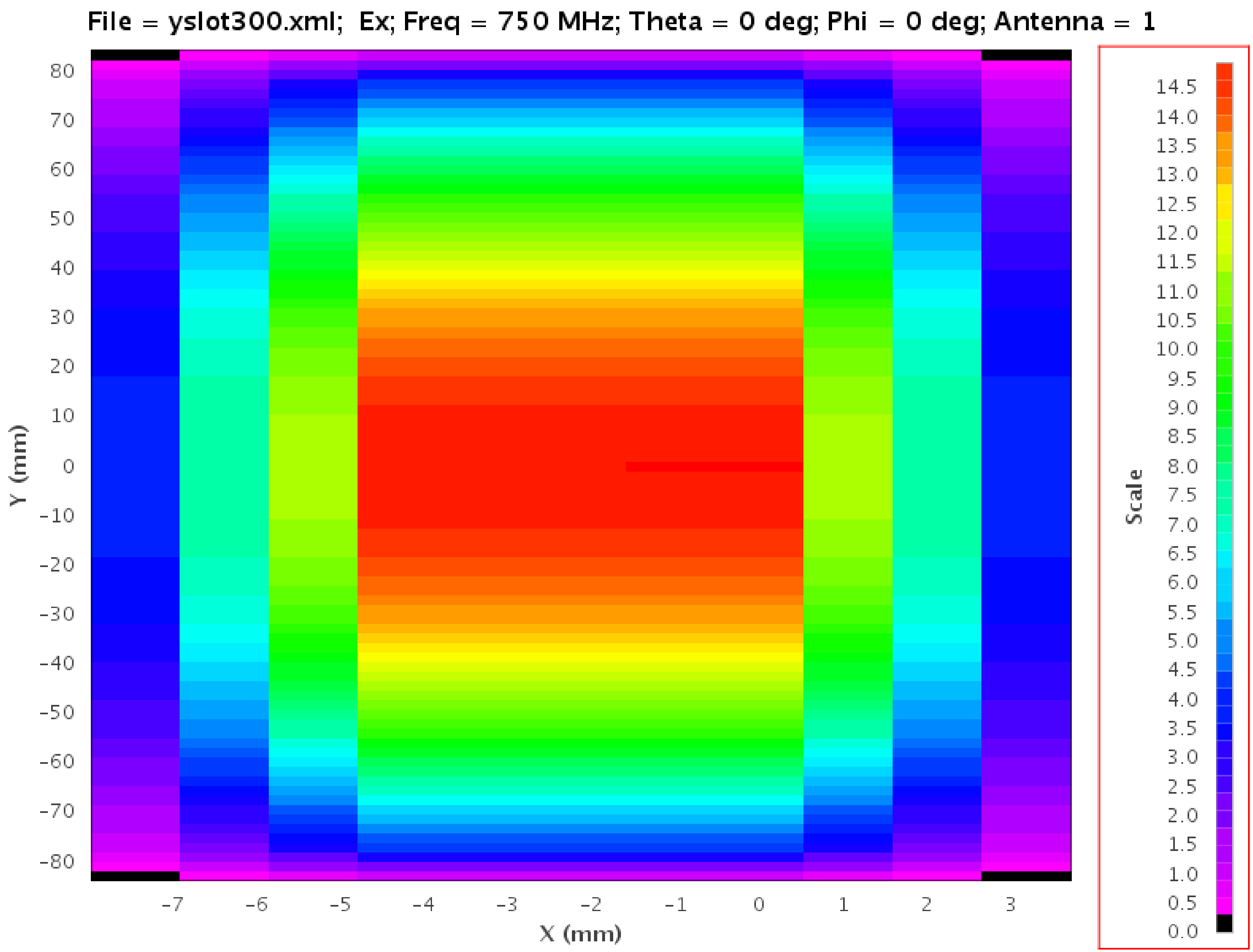
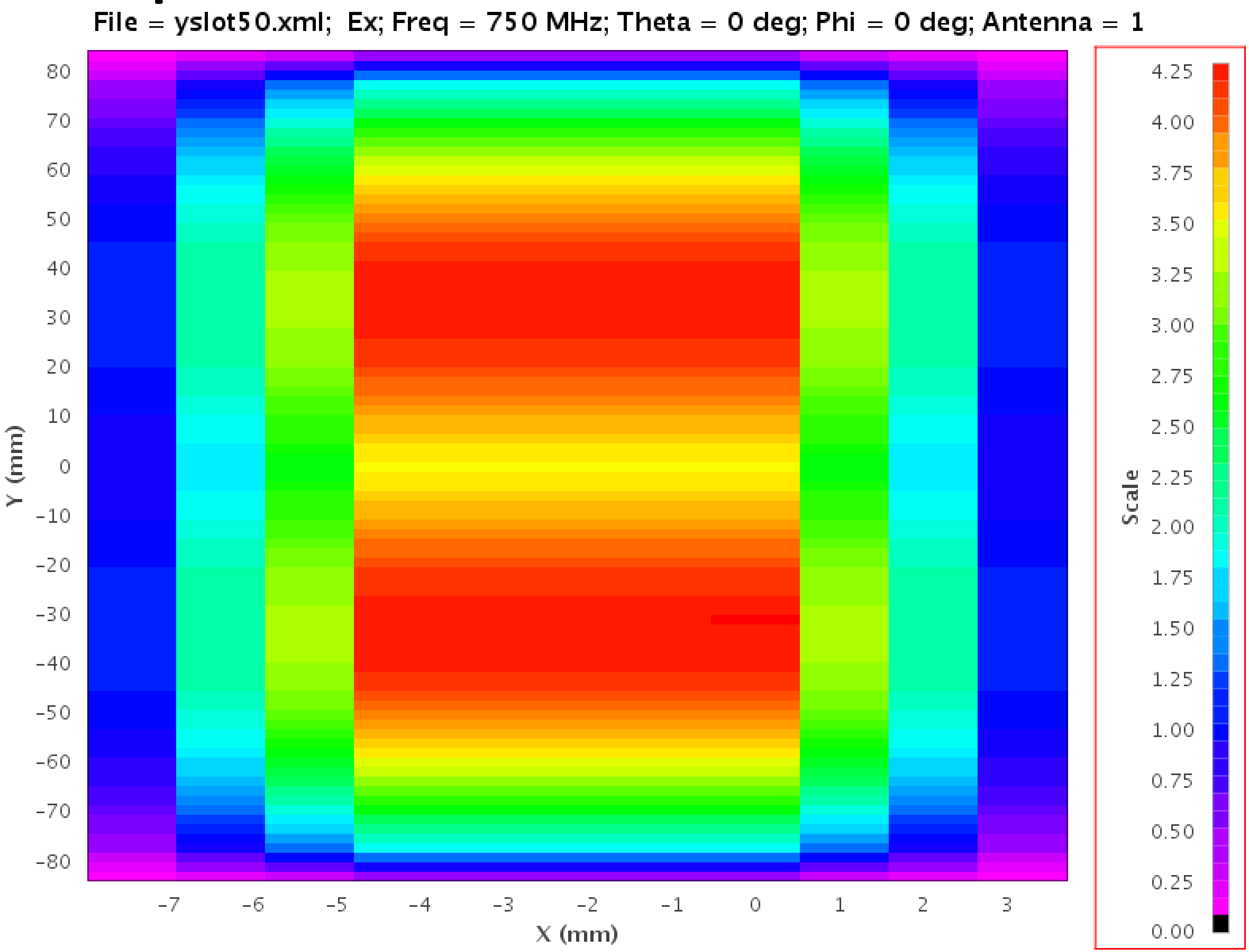
Simple Slot 300 Ohm Termination

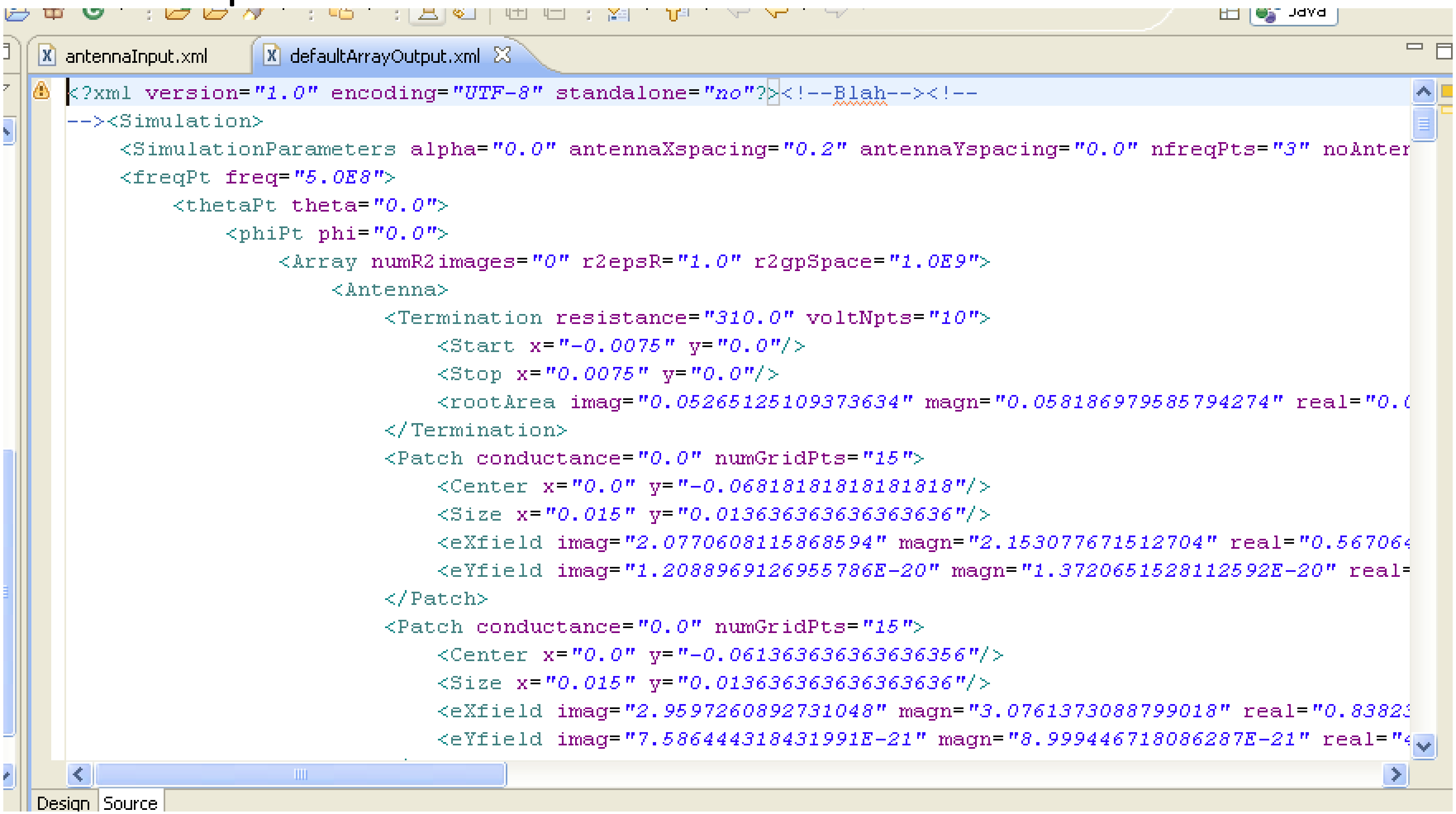


Simple Slot 50 Ohm Termination



Program Output

- Ouput files are also in XML so other programscan easily manipulate the data



What's Next

- Benchmark the program against another calculation method
  - Finite elements?
  - Real measurement?
- Use program to optimize feed geometry
  - Gain
  - Bandwidth
  - Impedance
  - Double ground plane