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FETS Fast Chopper: Meander Line Design Progress

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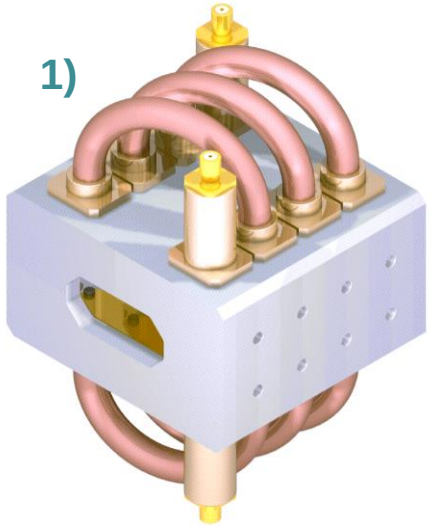
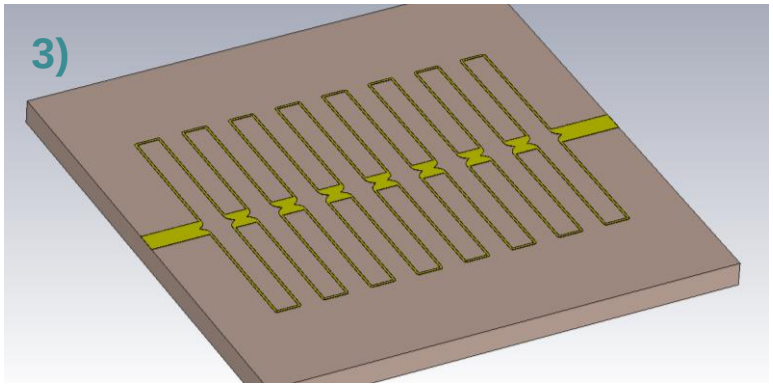
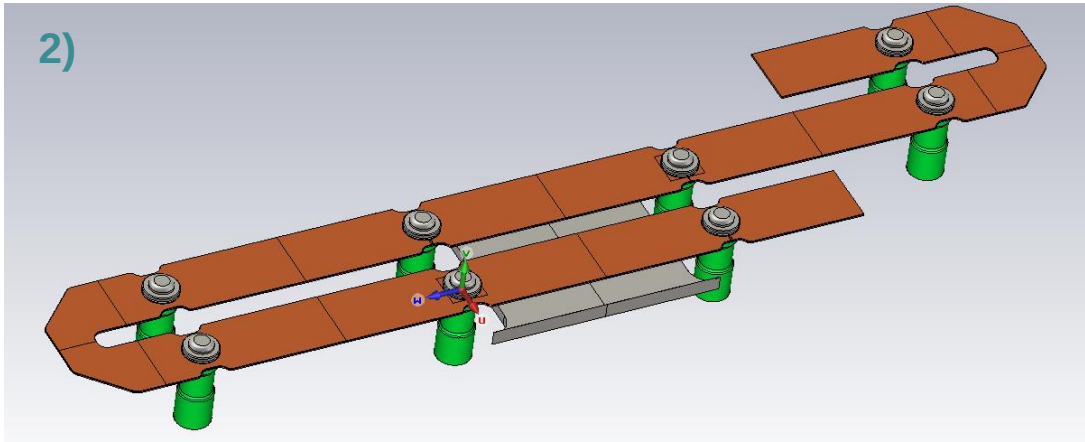
Starting Point – 3 Options For Design

- Three options for the fast chopper design:
  1) Helical (Right)
  2) Planar Stripline (Bottom Right)
  3) **Meander line on ceramic substrate (Bottom Left)**
- Option 3) was chosen due to time/ease of manufacture







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Starting Point

- There is no currently available CST model or documentation of MCG's existing meander line design.
- However there **is** documentation available that describes the (similar in concept) CERN LINAC-4 fast chopper.
  - The documentation gives an overview of the design process and goals, but not a full set of dimensions.
- There is also a CST model available of one of MCG's old planar-stripline style designs, which can be run to generate a set of target results.
- Therefore as a starting point, a meander line similar to the CERN design was modelled in CST, then optimised.
  - This design works on the same concept of a central 50Ω line, which is split into two 100 Ω lines.
  - The line is made from a thin strip of copper, printed onto a ceramic substrate with an earthed base.

Design Process

- CST Microwave Studio has been used to create an initial design, parameterised it and then begun optimisation.
- This has been carried this out with the following list of characteristics taken into account (listed in order of optimisation priority):
  1) Port Impedances
     - 50 Ω required at each end of the line
  2) S-Parameters for reflection and transmission of signal
     - S(1,1) target is <-30dB between 0-1000 MHz with minimised fluctuations
  3) Signal integrity after transmission (aka the reduction of “ringing” effects on the edges of the travelling pulse)
  4) Coverage factor
     - Not yet studied (target 75-80%+)
  5) Delay time for the signal travelling through the structure
     - Has been roughly set
  6) Current density in the conducting material
     - Not yet studied

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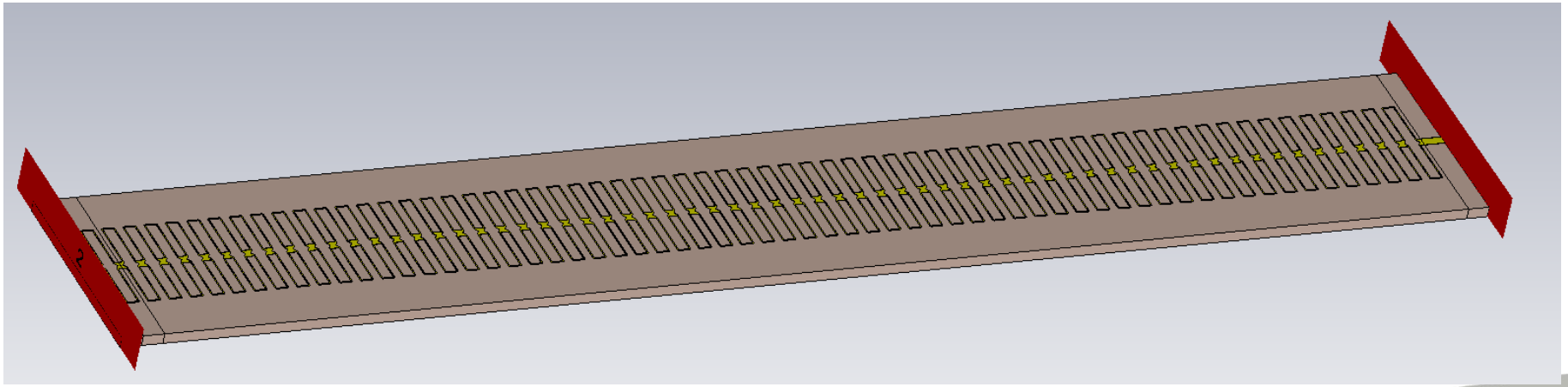
- Port impedance:
  - 49.88 Ω port impedance
  - Total Length = 37.2 cm
  - Effective velocity = 0.085 c
  - The full line consists of 60 repeating cells, each of identical structure
  - Much of the optimisation has been performed initially on an 8 cell structure to save time



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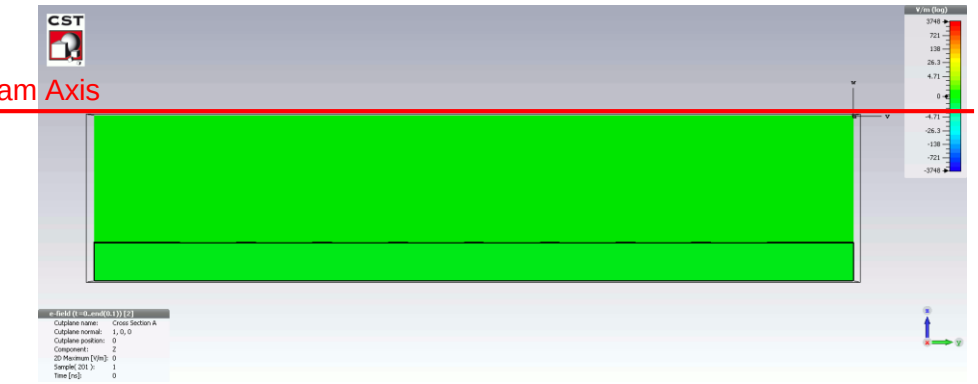
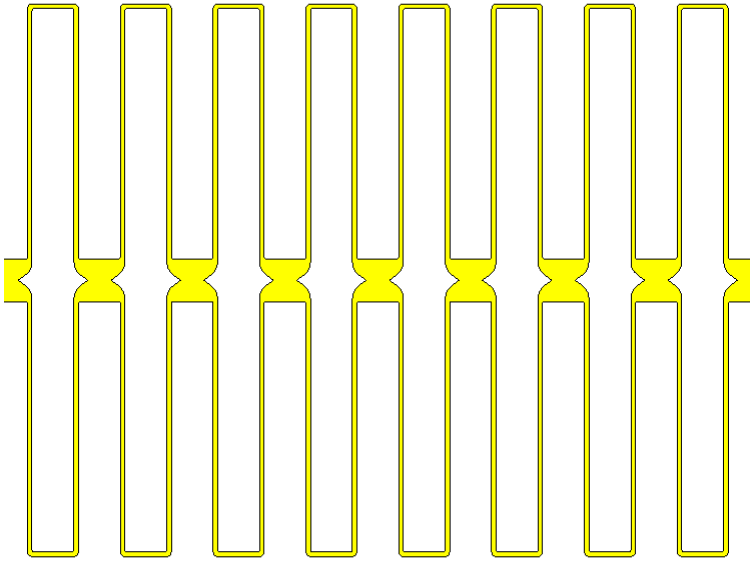
6 April - The Current Design

- Port impedance:
  - 49.86 Ω port impedance
  - Total Length = 37.2 cm
  - Group delay time = 14.471 ns*
  - Effective velocity = 0.085 c*

*The velocity will be fine tuned once the total required length is known



A cross section down the centre of the line showing the Vertical E-Field component as the kicking pulse travels



A section of the repeating meander line structure

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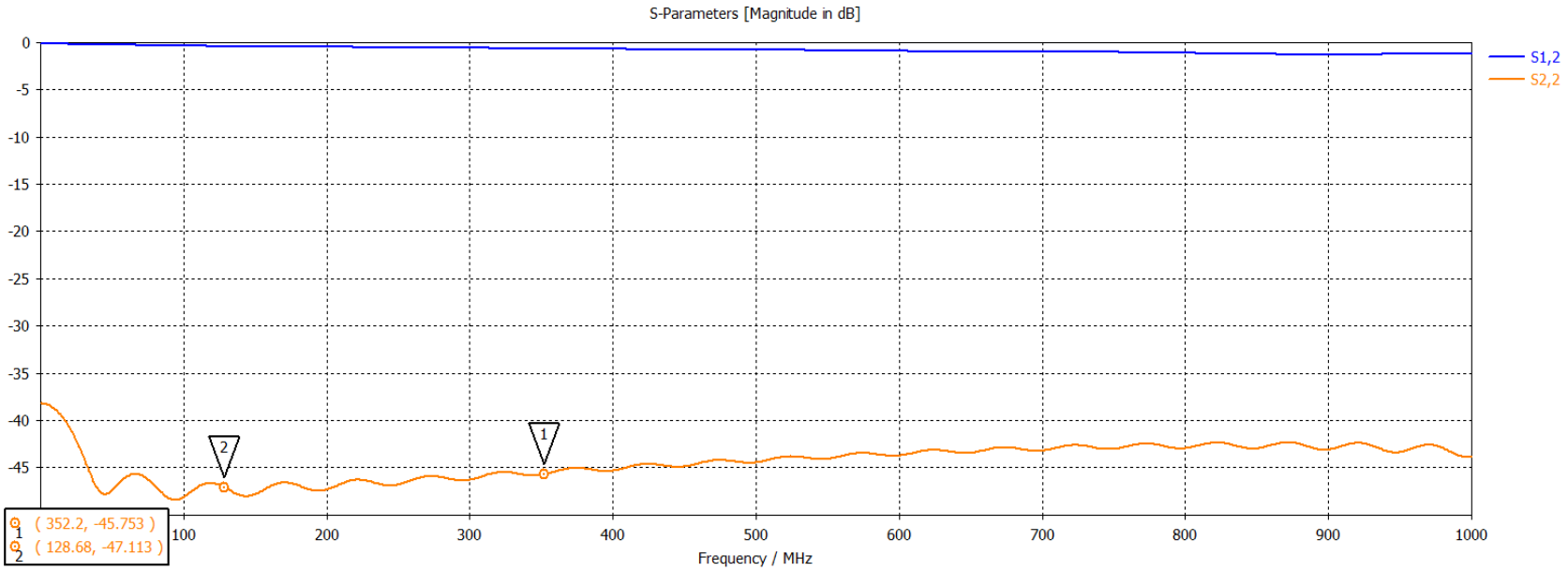
- S Parameters:
  - Port 2 is used as the source of the kicking pulse in the simulation, so S(2,2) represents reflected power in the meander line
  - The design aim is to minimise this with a target of < -30dB between 0-1 GHz, while also reducing the amount of variation with frequency
  - Achievement of this *should* result in most of the other desired properties of the line being roughly correct as well and just requiring fine tuning.



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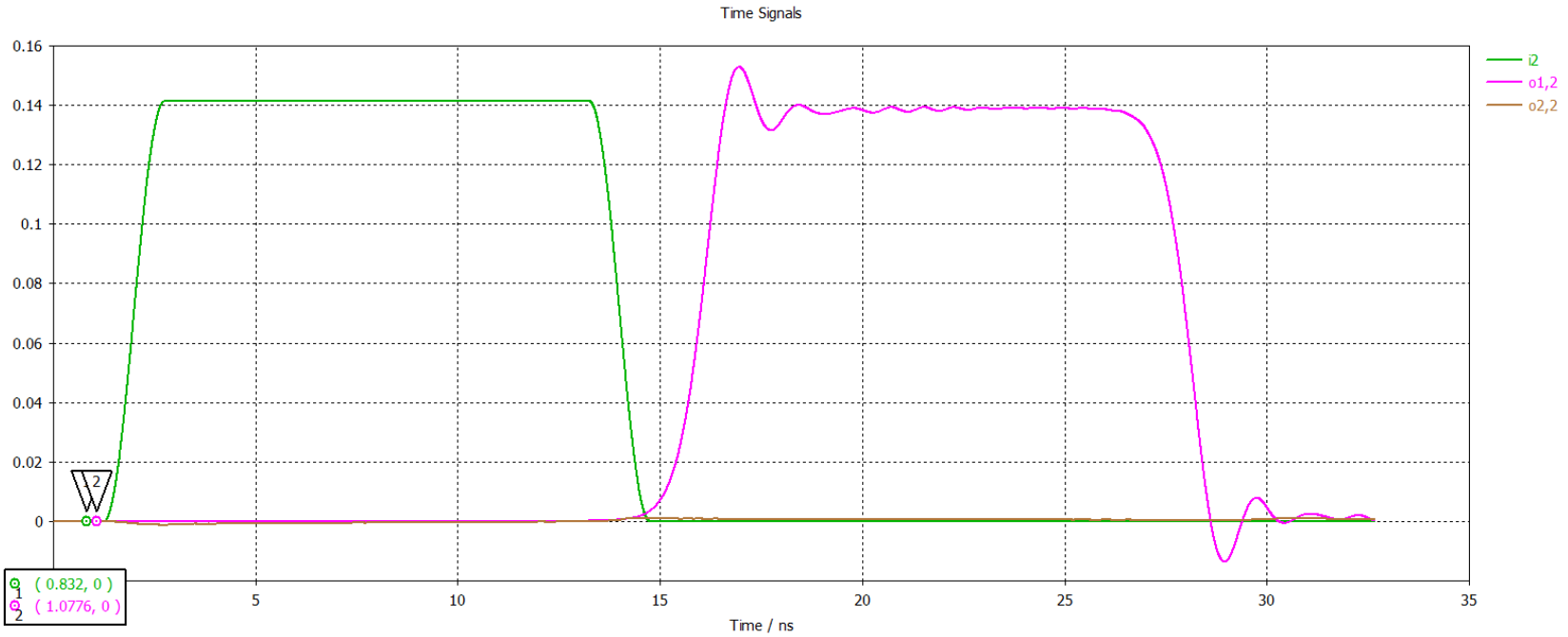
- Signal Distortion:
  - The signals shown here are the kick pulse before (green) and after (purple) transmission through the line
  - The “ringing” effects at the start and end of the transmitted pulse have been reduced as the design has been optimised



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What's next?

- Further simulation work to optimise:
  - Coverage factor of the kicking signal
  - Effective velocity of the fast chopping signal
  - Current density in the meander line track
- Finalising the design will also require changes to the transverse width of the ceramic substrate, and the overall length of the structure.
  - If dimensions of the vessel that the chopper will sit in are available, they would be helpful, along with the required longitudinal length of the chopper.
- Creating a prototype of the meander line to verify simulation accuracy.
  - Dependant on funds/time
  - It is possible to get a smaller version of this meander line manufactured. Copernica have been recommended if a ceramic base is needed, though a fibreglass base would be cheaper.
  - The prototype could be measured with our VNA to check that the simulation is producing reliable results.

Any Questions?

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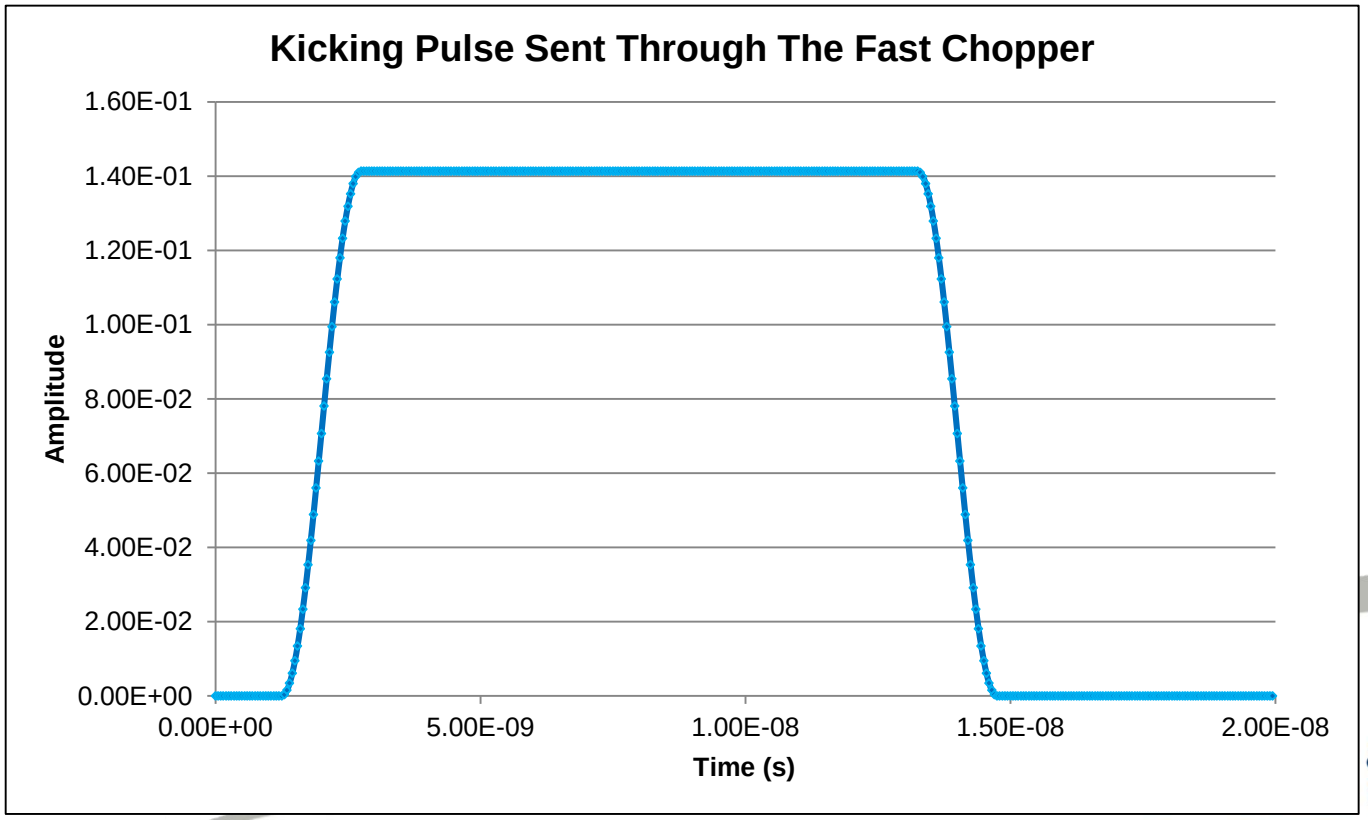
Additional Slides (1/3)

- Beam In Chopper Details:
  - Energy = 3.0 Mev → Velocity = 2.3903 x $10^7 ms^{-1}$ (current design aim ~24 mm per ns)
  - Pulse Repitition Frequency = 1.3 MHz
  - Chopping Signal Transition Time = 2 ns (Time taken for the pulse below to rise/fall from 10%-90% strength
  - Chopper Beam Width = 18 mm
  - Coverage Factor Target ~80%



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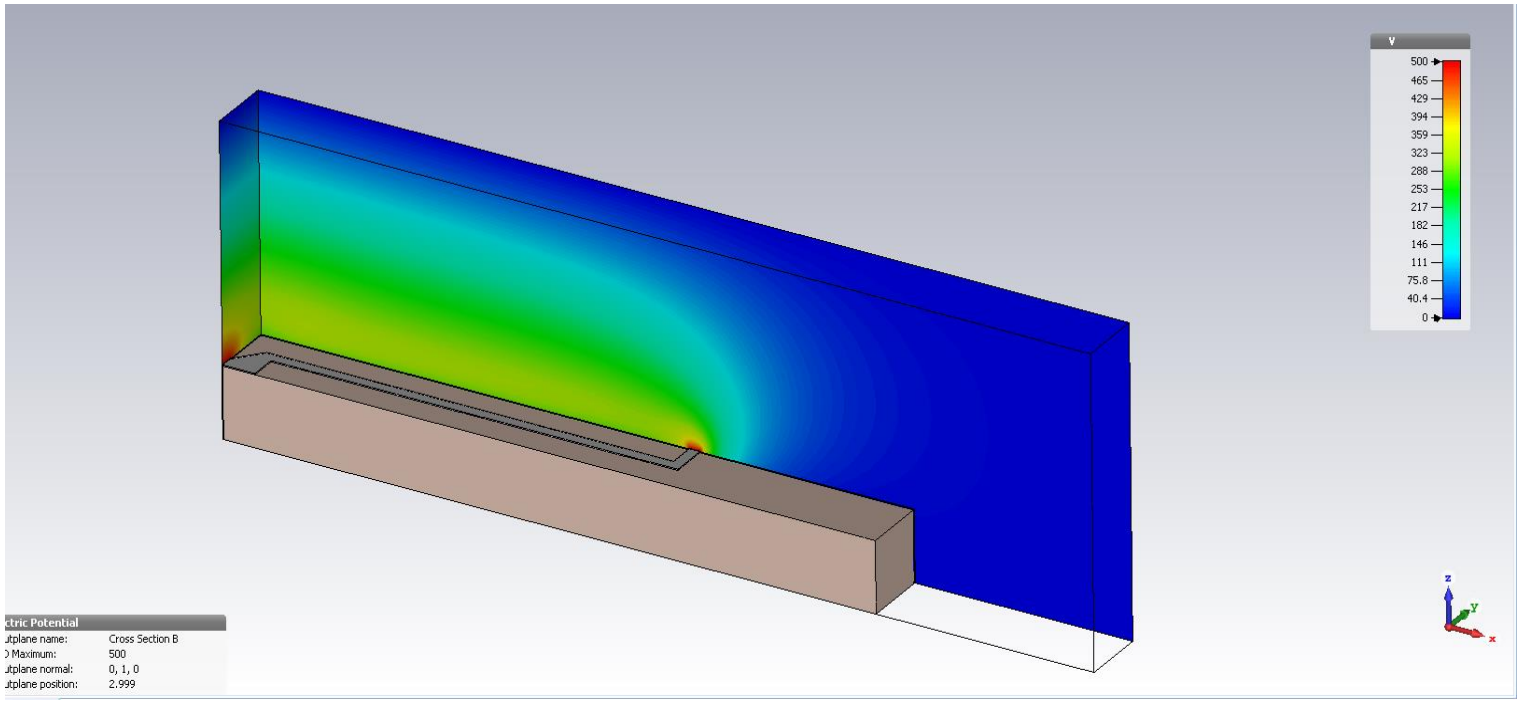
Additional Slides (2/3)

- Potential Plot for ¼ repeatable cell (500V on meander line)



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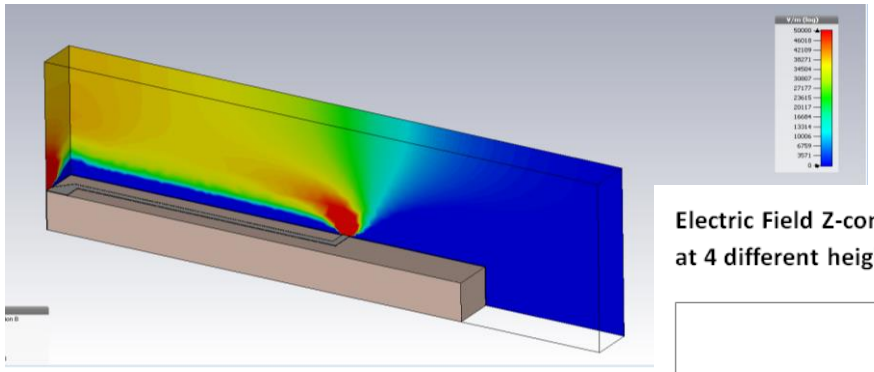
Additional Slides (3/3)

- Static Simulation, Electric Field vertical kicking component (Ez), plotted for ¼ repeatable cell (500V meander line)



Electric Field Z-component vs Horizontal Displacement (0 is at the beam centre). This is plotted at 4 different heights above the meander line