Modeling Flexible/Curved PCBs using RBF mesh morphing

Marco E. Biancolini[1], Sandeep Medikonda[2], Kelly Morgan[2], Stefano Porziani[3]

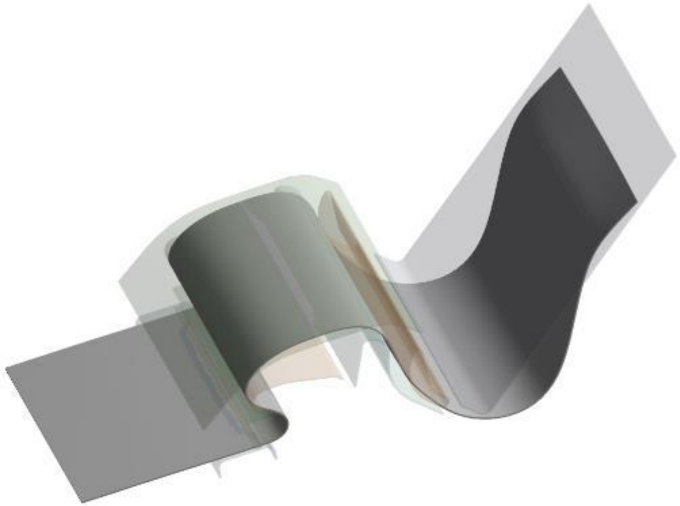
[1]University of Rome "Tor Vergata"

[2]ANSYS Inc.

[3]RBF Morph srl

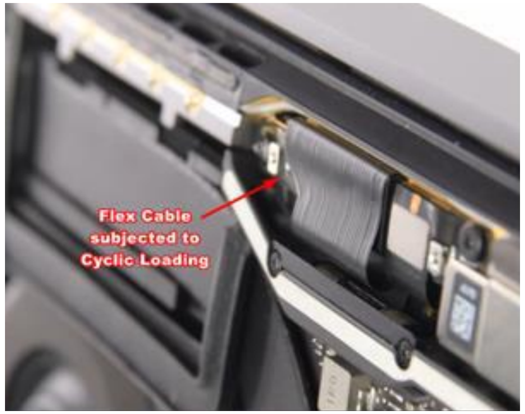
Outline

- Introduction
- Challenge and Goals
- RBF mesh morphing
- Mesh morphing workflow
- Applications and Results
    - Analysis of FCB Cable
    - Analysis of a Rigid Flex PCB
- Conclusions



Introduction

- **What are FCBs?**
  - Flexible Circuit Boards are distinctly patterned circuitry and component arrangement highlighted by malleable base material. They enable the circuitry to be designed to fit the electronic device or product as opposed to building the device to conform the circuit board.
- **Why FCB over traditional PCB?**
  - **Saves Space:** FCBs require only about 10% of the space and weight of an ordinary circuit board assembly, offering great installation and packaging freedom.
  - **Max. Reliability:** FCBs require fewer interconnects, which in turn requires fewer contact crimps, connectors and solder joints.
  - **Enhanced Capabilities:** FCBs are compatible with virtually any type of connector or component and works well with options such as ZIP connectors. They also perform very well in extreme temperatures and offer superior resistance to radiation and chemical.

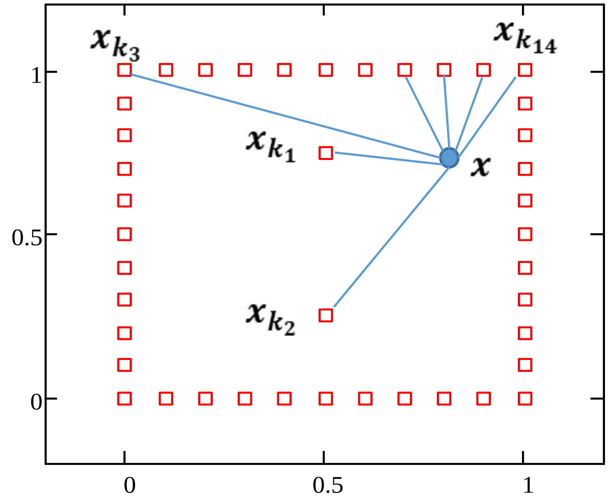


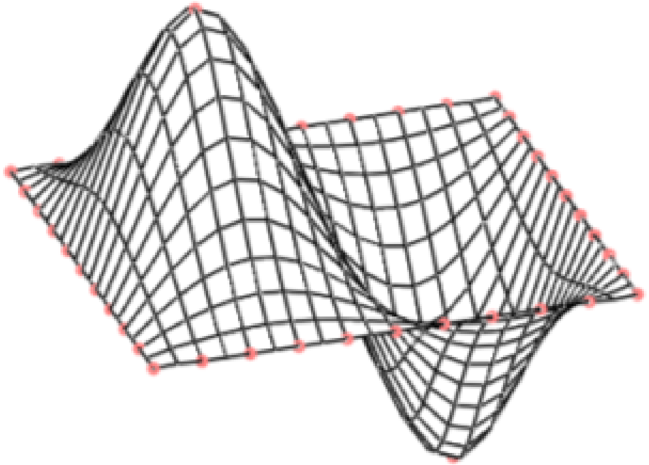
Challenges and Goals

- The detailed design happens **on the flat shape** and
  - the boards are built with layered materials
  - traces have a complex configuration
  - complexity of modelling ranges from **shell structures with traces mapped** up to **solid models** with traces full represented
- Numerical modeling of such structures requires a full nonlinear analysis to **deform the structure onto the installation shape** (hours of simulation on HPC)
- There is a **need for a clear and simple methodology** to adapt the FEA mesh onto the curved shape while preserving the trace mapping and trace modeling typically used while working with Electronic-CAD files.
- In this study we explore the potential of **advanced mesh morphing** based on **Radial Basis Functions**.

Radial Basis Functions (RBF) mesh morphing

- RBF are a mathematical tool capable to **interpolate** in a generic point in the space a function **known** in a discrete set of points (**source points**).
- The three components of a displacement field are interpolated to control and morph a solid mesh (**RBF** mesh **Morphing**)

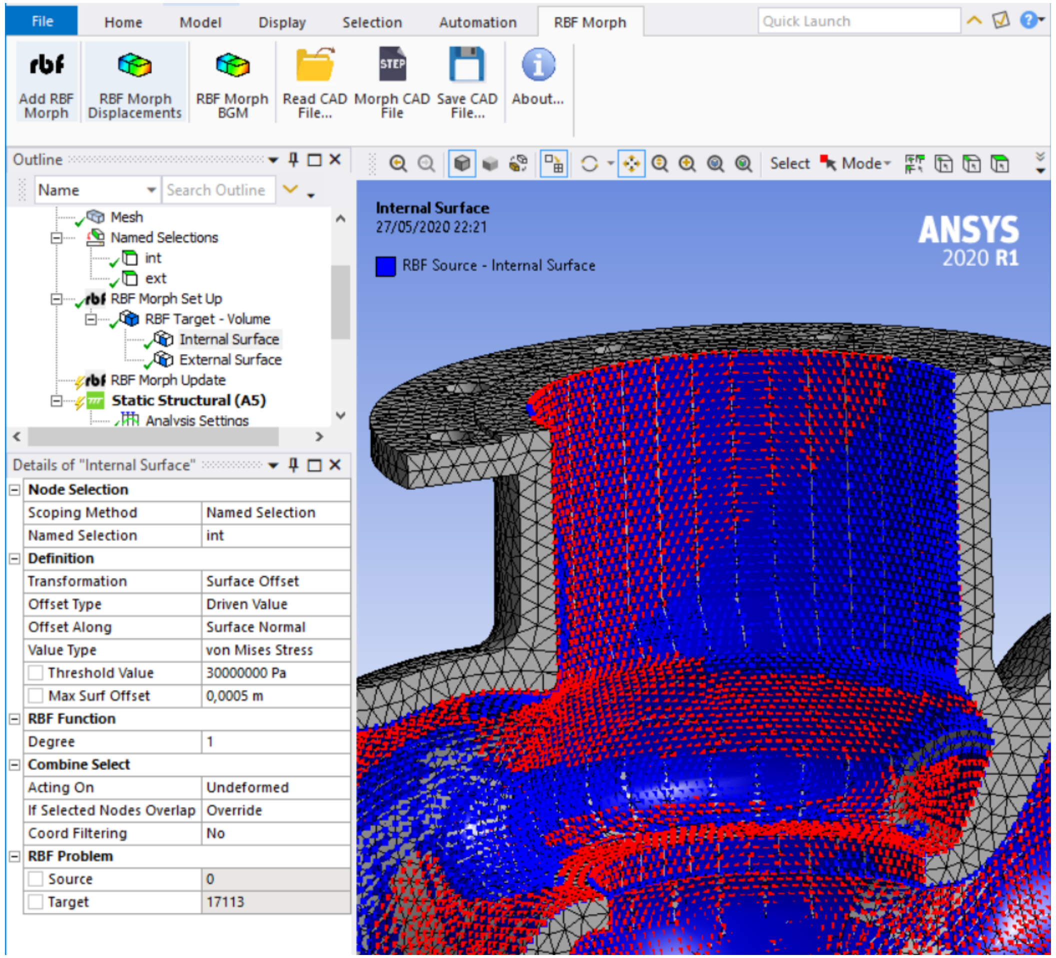




$$
\begin{cases}
s_x(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^x \varphi\left(\boldsymbol{x} - \boldsymbol{x}_{k_i}\right) + \beta_1^x + \beta_2^x x + \beta_3^x y + \beta_4^x z \\
s_y(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^y \varphi\left(\boldsymbol{x} - \boldsymbol{x}_{k_i}\right) + \beta_1^y + \beta_2^y x + \beta_3^y y + \beta_4^y z \\
s_z(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^z \varphi\left(\boldsymbol{x} - \boldsymbol{x}_{k_i}\right) + \beta_1^z + \beta_2^z x + \beta_3^z y + \beta_4^z z
\end{cases}
$$

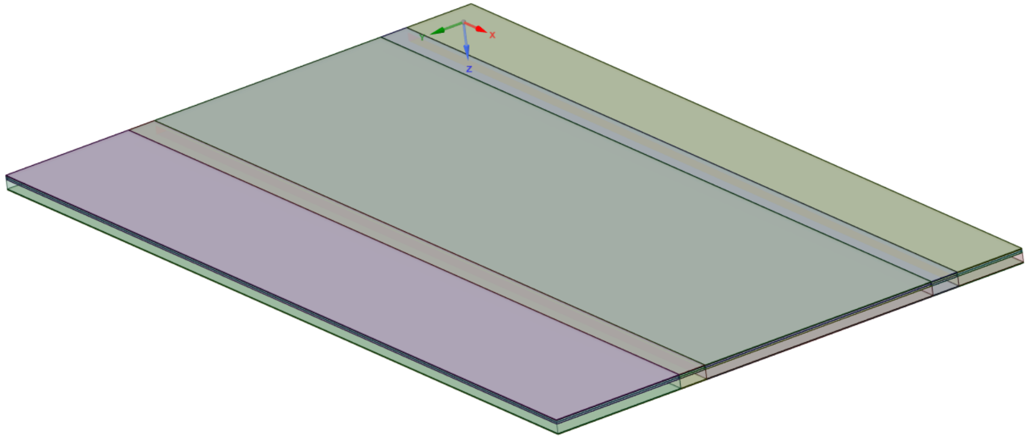
RBF Morph software for ANSYS Mechanical

- ACT Extension **fully integrated** with ANSYS Mechanical
- Powered by a **fast, parallel RBF solver** that tackles any sized problem
- Enables **CAD based mesh morphing** (underlying geometry or auxiliary one)
- Features manufacturing constraints



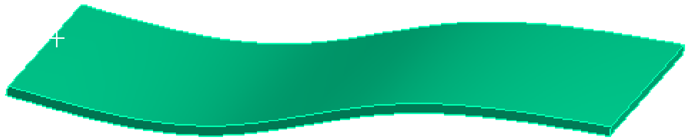
Mesh morphing workflow

PCB tested: Galileo Board (11 Layers)

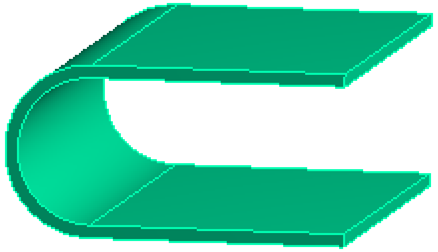


Target Geometries:

- Wavy Structure



- Wrap Structure

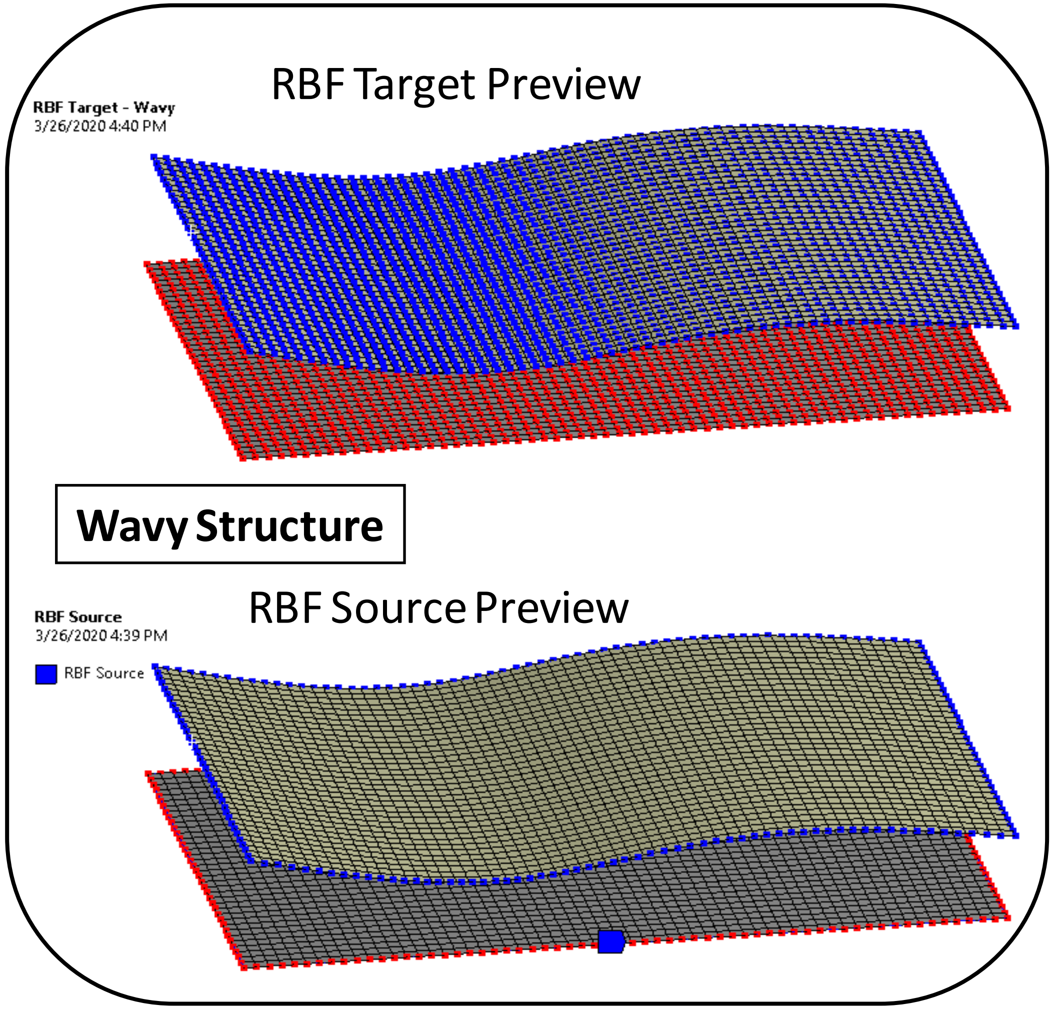


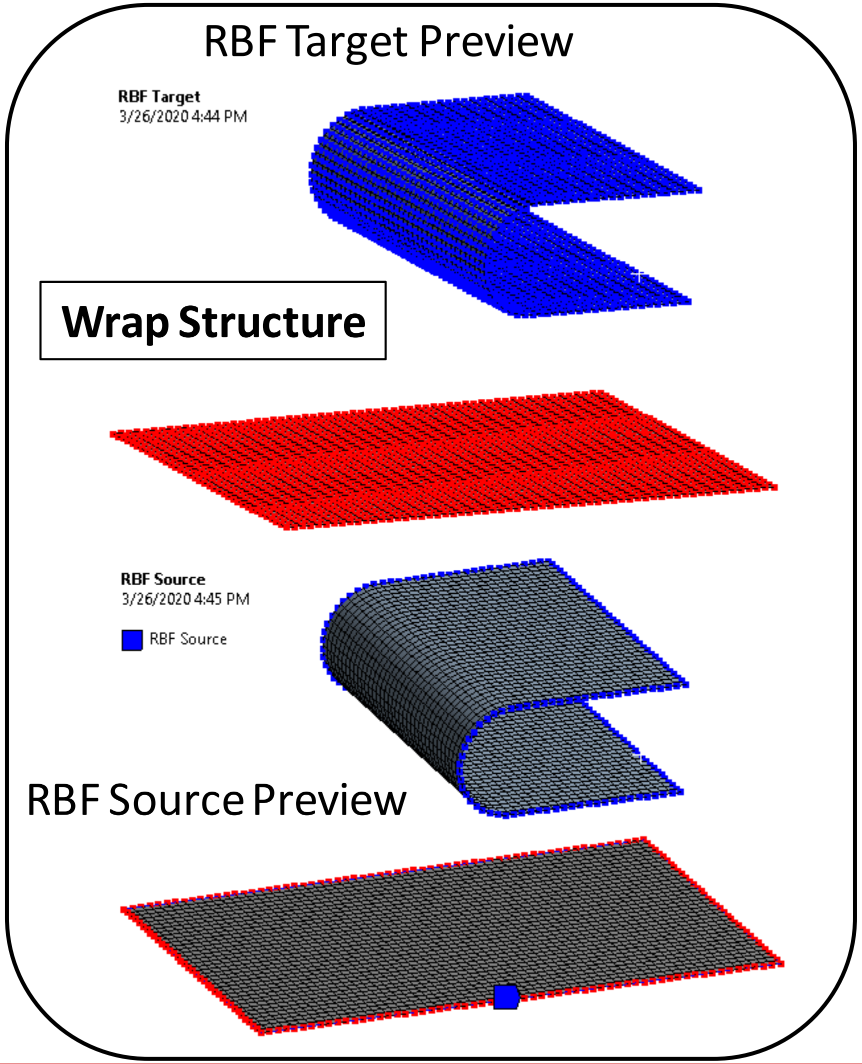
Objective

For both Target Geometries, wrapping should be possible for:

- Shell Trace Mapping
- Solid Trace Mapping
- Solid Trace Modeling

Shell Trace Mapping



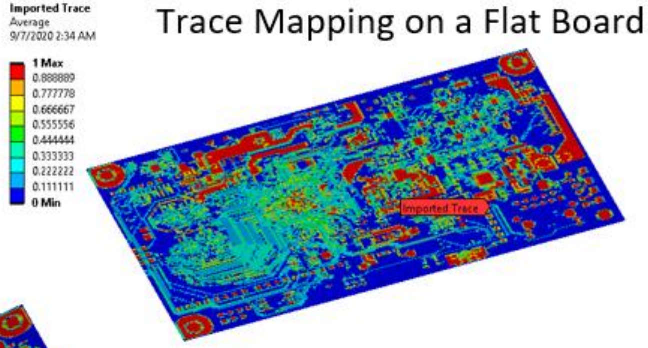


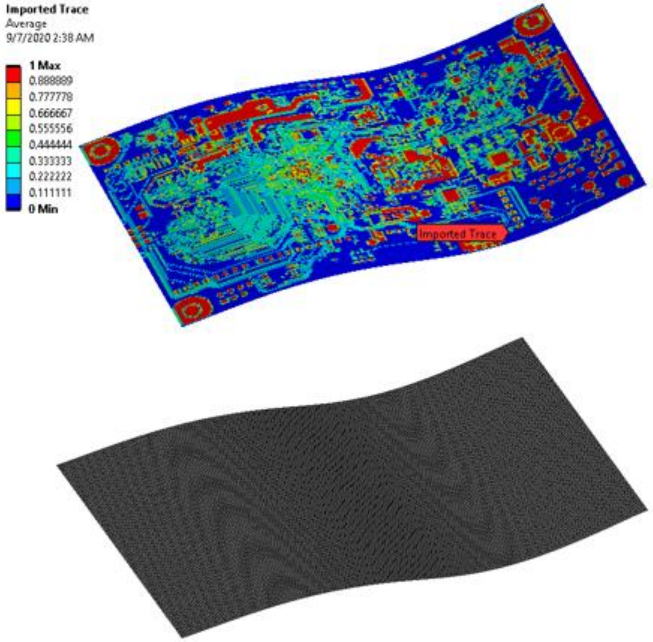
<u>Mesh morphing approach</u>:

- Boundary curves are connected to do a first morphing step
- The projection onto the target surface happens in the second and final morphing step

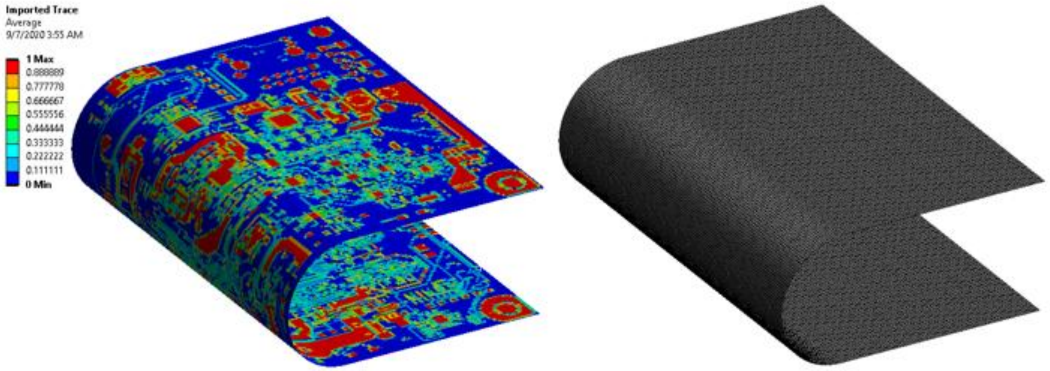
Shell Trace Mapping - Results

Trace Mapping on a Flat Board





Trace Mapping and Morphed Mesh on the Wavy structure

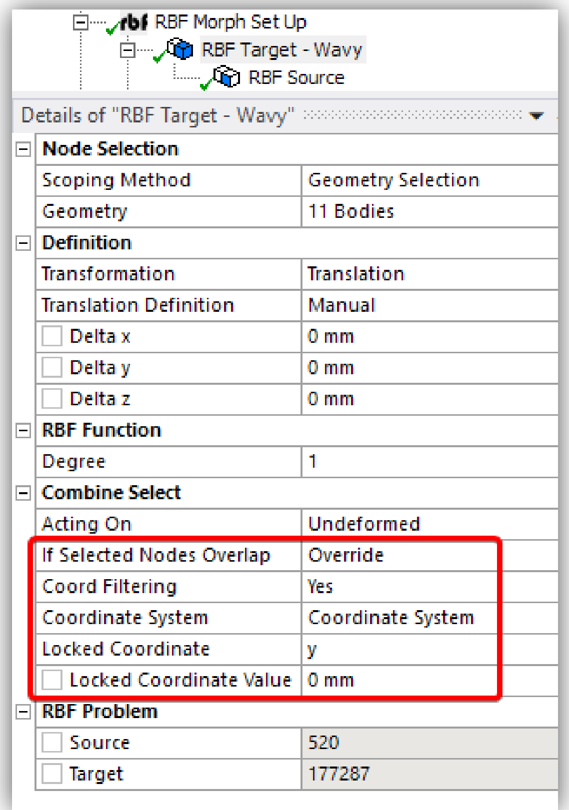


Trace Mapping and Morphed Mesh on the Wrap structure

Solid Trace Mapping

<u>Mesh morphing approach</u>:

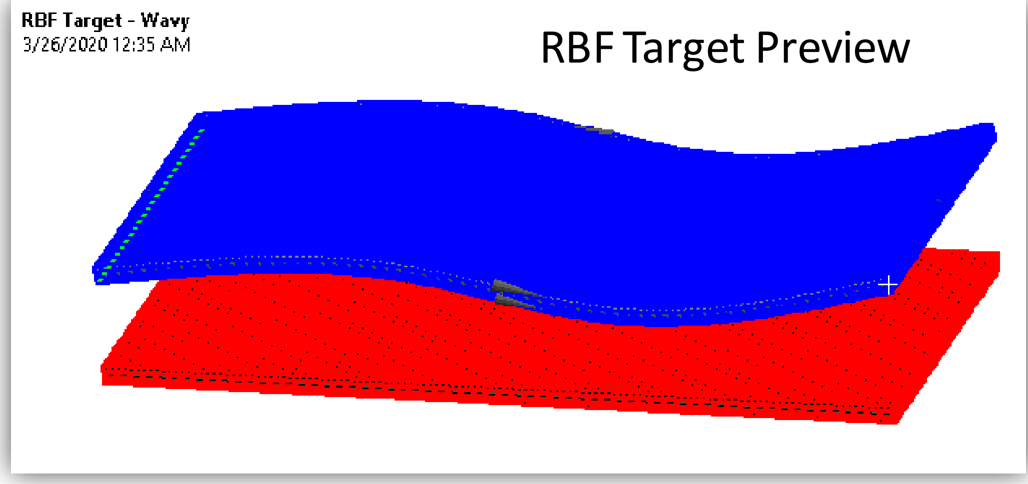
- An auxiliary Surface/Solid is defined to drive 2d morphing
- Curves are connected
- The 2d morphing action is propagated on the complete solid mesh by turning on Coordinate Filtering

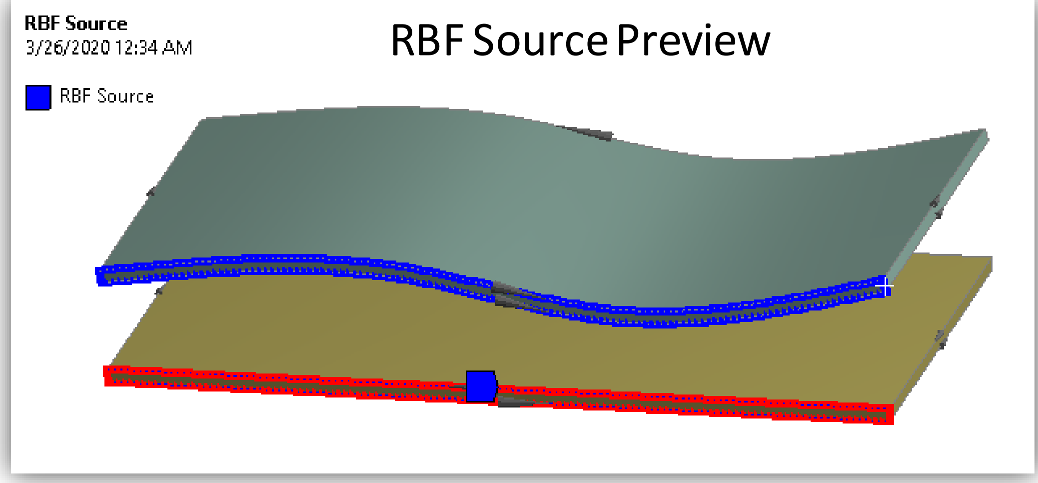


RBF Morph Set Up
RBF Target - Wavy
RBF Source

Details of "RBF Target - Wavy"

Node Selection	
Scoping Method	Geometry Selection
Geometry	11 Bodies
Definition	
Transformation	Translation
Translation Definition	Manual
Delta x	0 mm
Delta y	0 mm
Delta z	0 mm
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	Yes
Coordinate System	Coordinate System
Locked Coordinate	y
Locked Coordinate Value	0 mm
RBF Problem	
Source	520
Target	177287

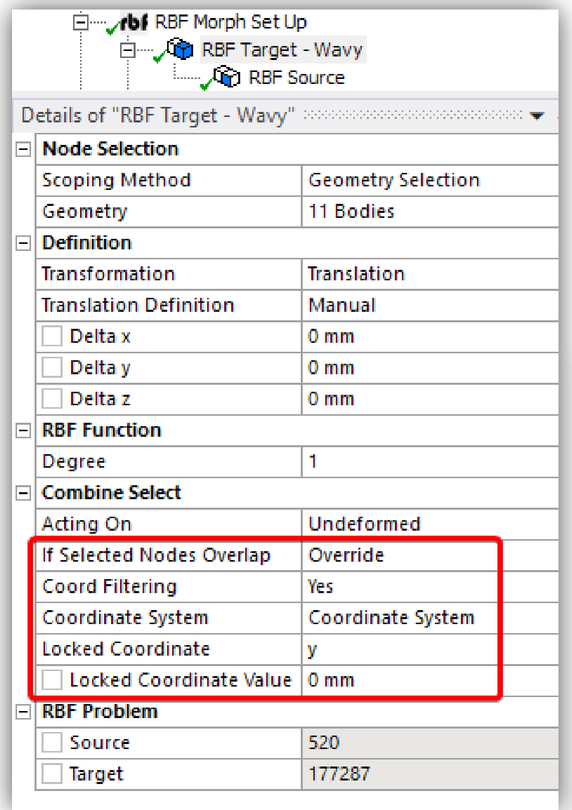




Solid Trace Mapping

<u>Mesh morphing approach</u>:

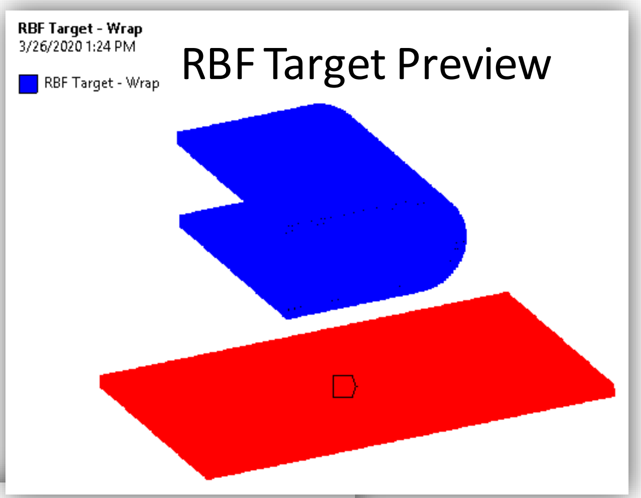
- An auxiliary Surface/Solid is defined to drive 2d morphing
- Curves are connected
- The 2d morphing action is propagated on the complete solid mesh by turning on Coordinate Filtering

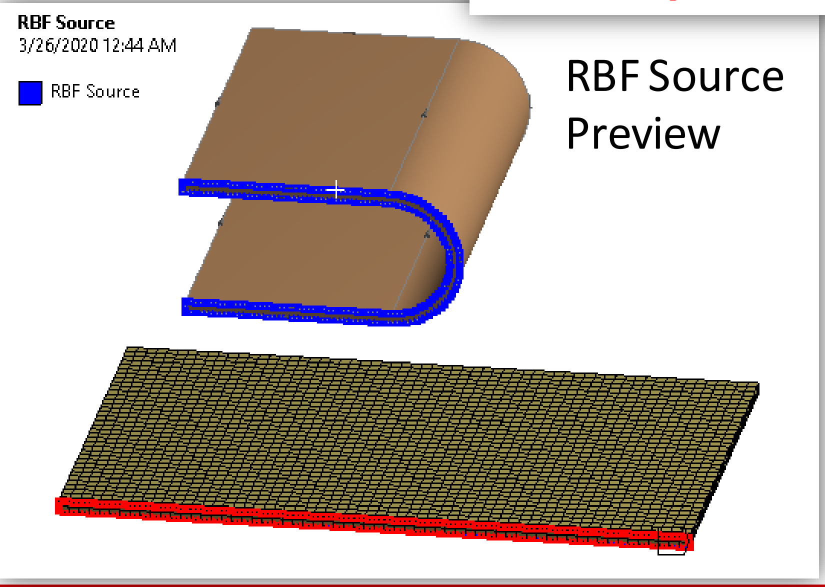


RBF Morph Set Up
RBF Target - Wavy
RBF Source

Details of "RBF Target - Wavy"

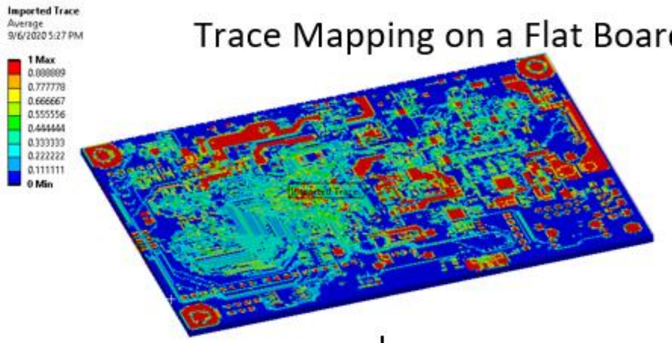
Node Selection	
Scoping Method	Geometry Selection
Geometry	11 Bodies
Definition	
Transformation	Translation
Translation Definition	Manual
Delta x	0 mm
Delta y	0 mm
Delta z	0 mm
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	Yes
Coordinate System	Coordinate System
Locked Coordinate	y
Locked Coordinate Value	0 mm
RBF Problem	
Source	520
Target	177287

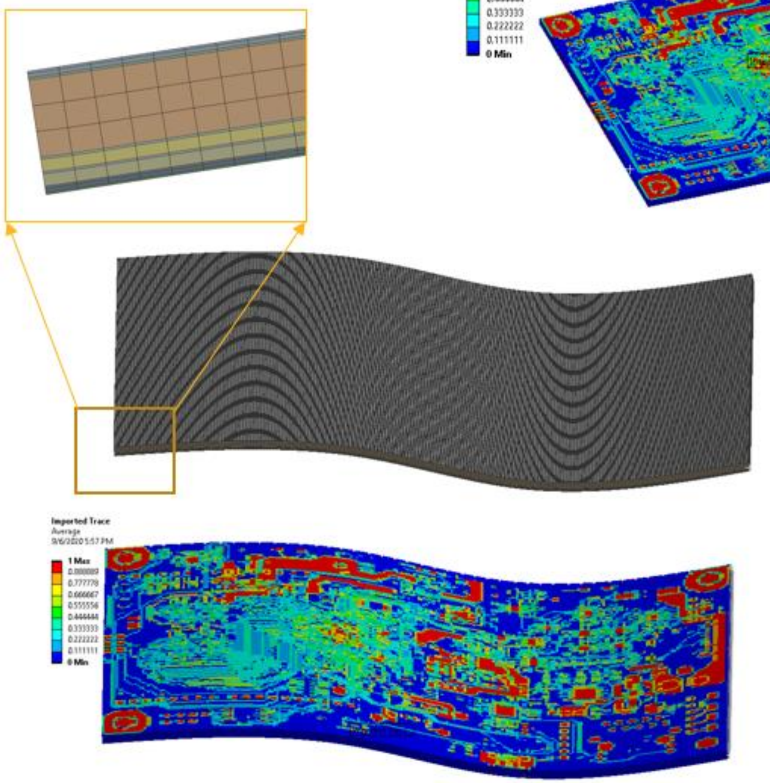




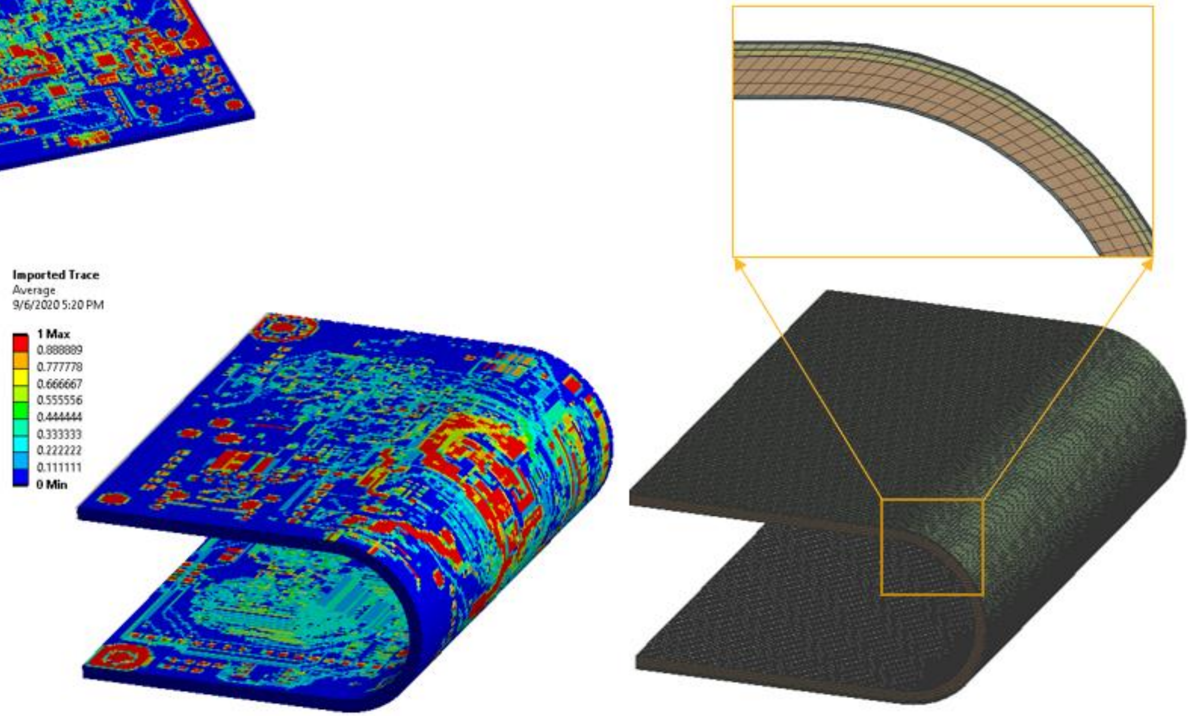
Solid Trace Mapping - Results

Trace Mapping on a Flat Board



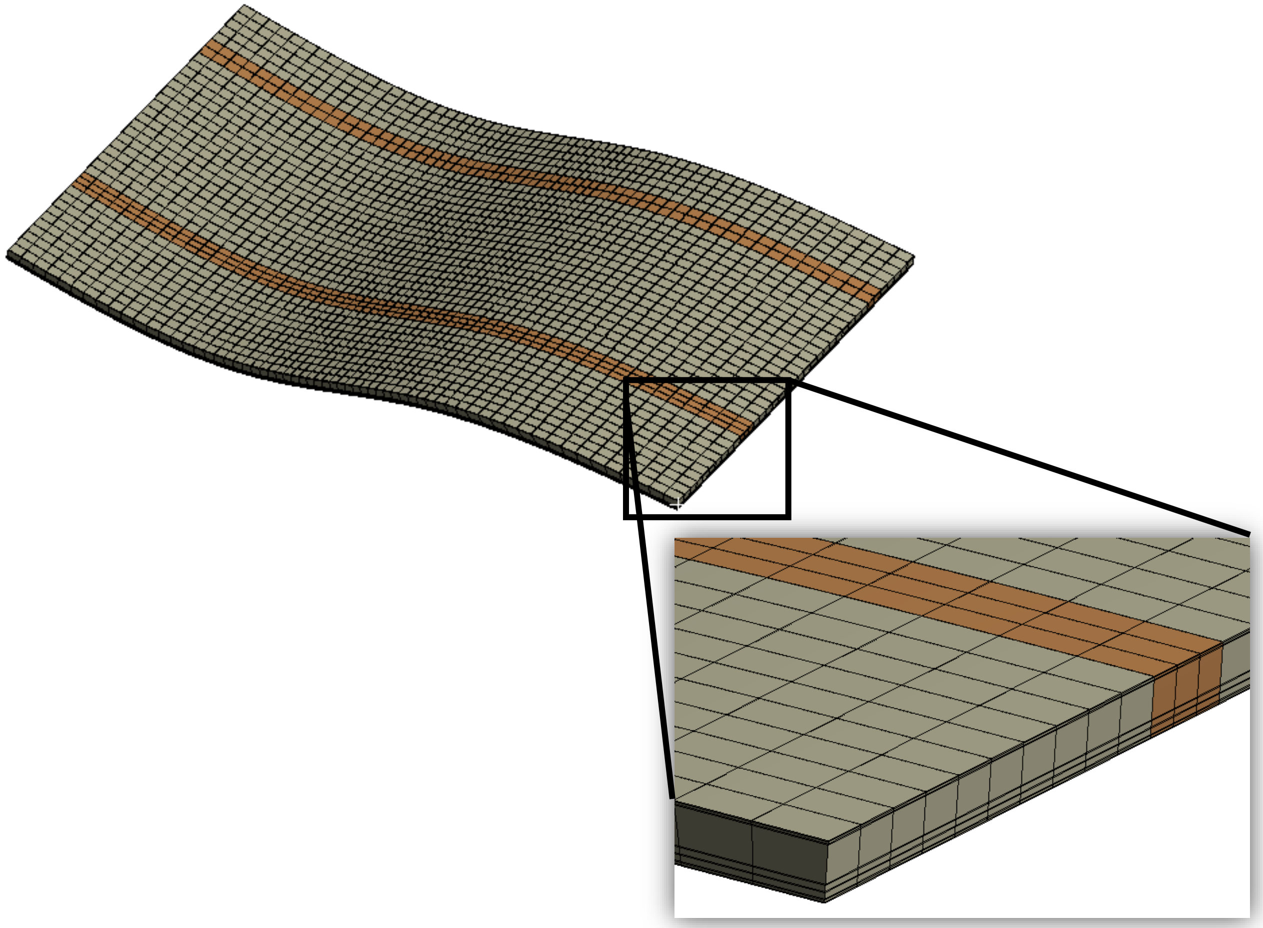


Trace Mapping & Morphed Mesh on the Wavy Structure

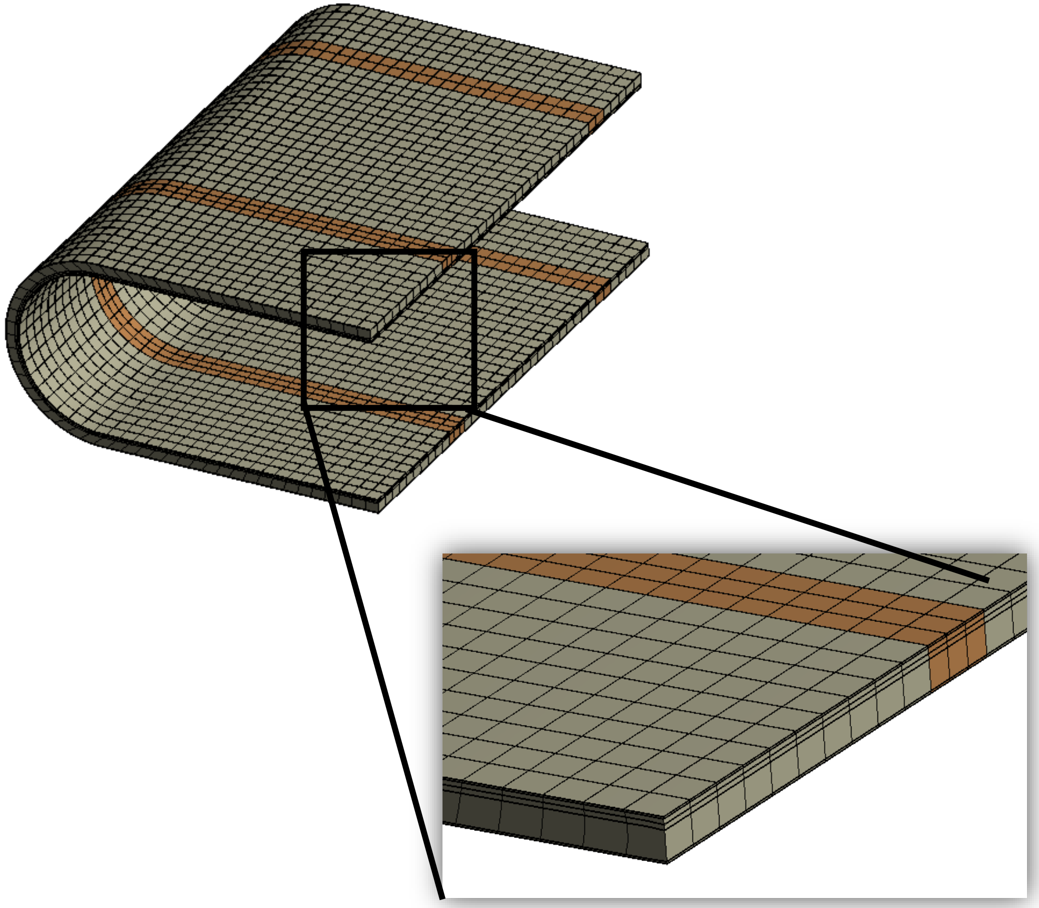


Trace Mapping & Morphed Mesh on the Wrap Structure

Solid Trace Modeling - Results



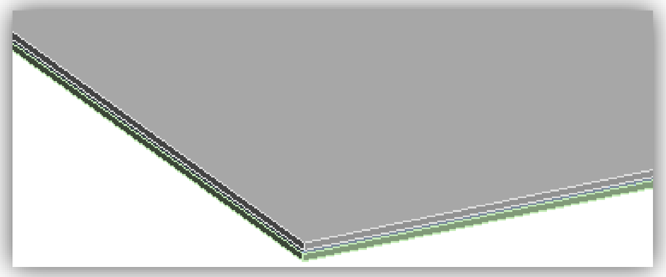
Trace Modeling on the Wavy Structure

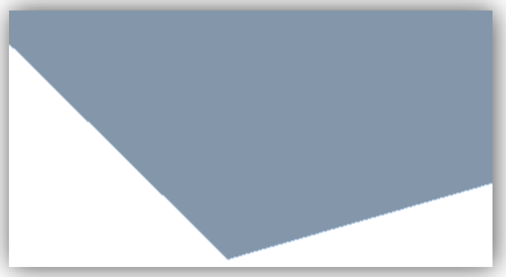


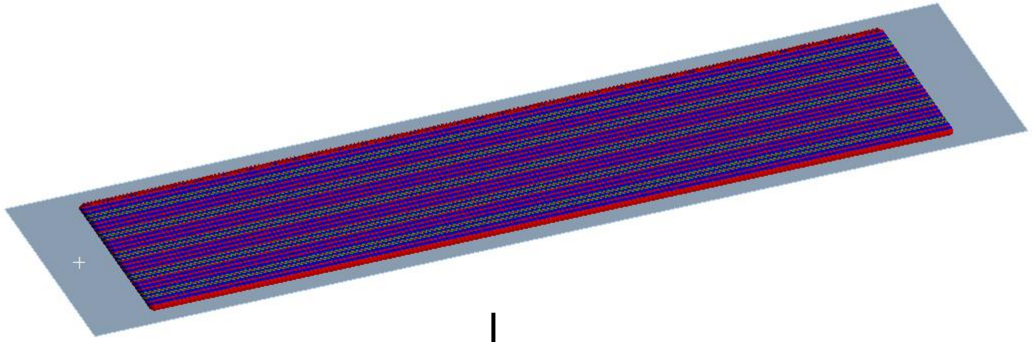
Trace Modelled PCB on the Wrap Structure

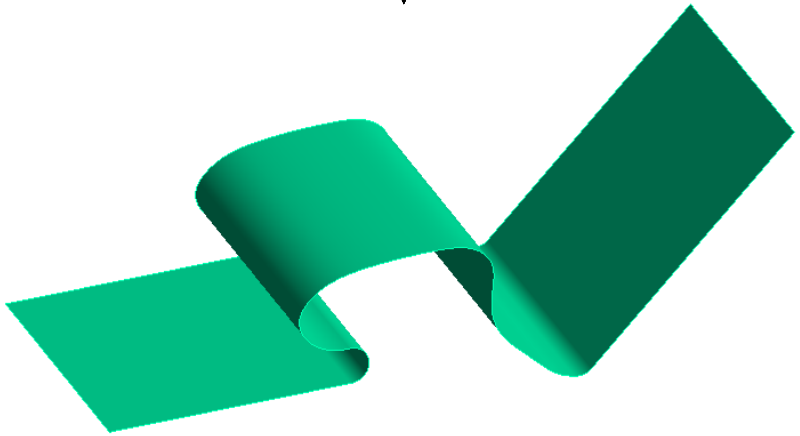
Analysis of FCB Cable

PCB tested: Flex PCB (Solid or Shell)









Target Geometries: Installed Shape in the consumer electronics product

Objective

For the target geometry, wrapping should be possible for:

- Solid Trace Mapping
- Shell Trace Mapping

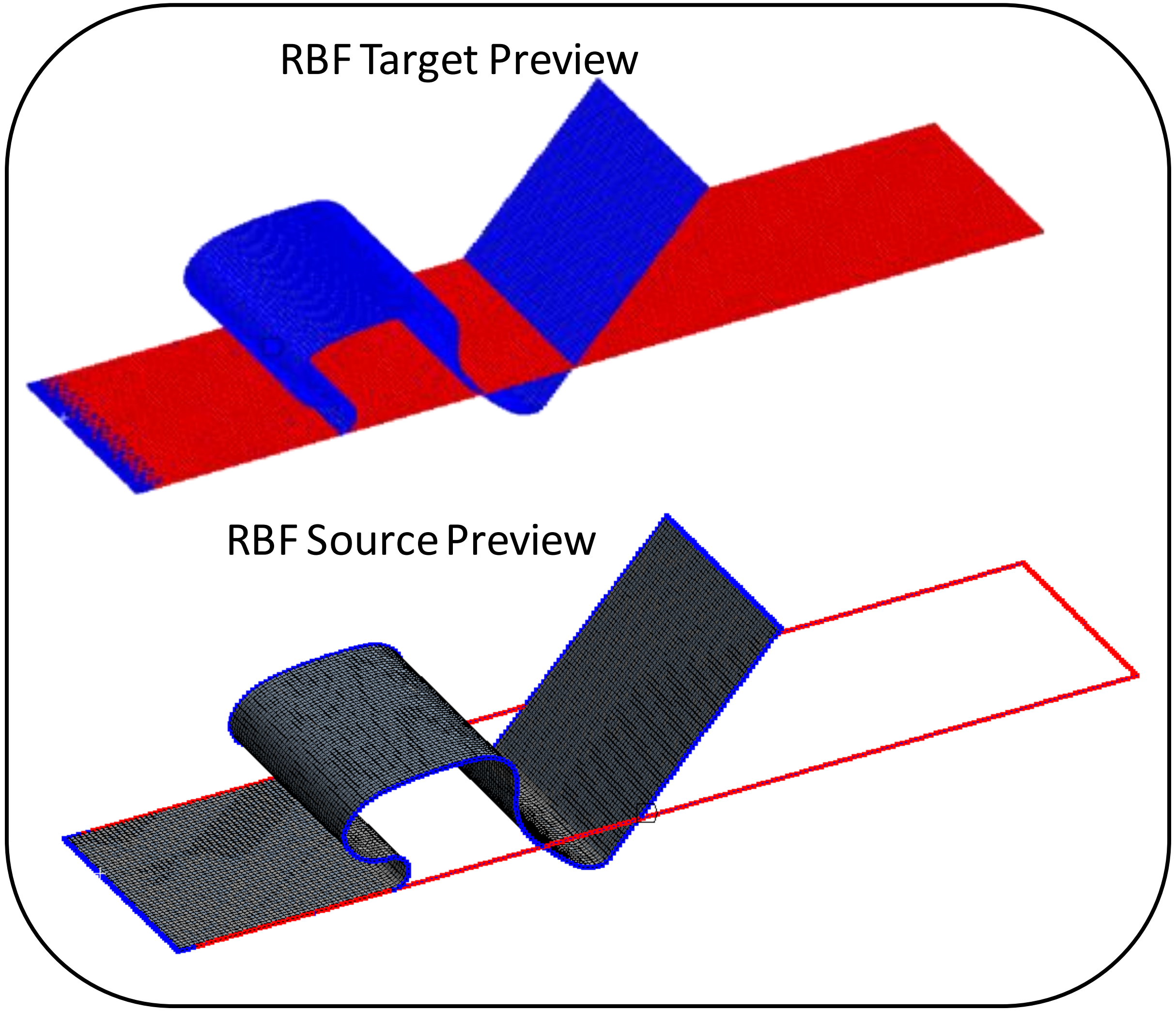
Shell Trace Mapping Logic

<u>Mesh morphing approach</u>:

- Boundary curves are connected to do a first morphing step
- The projection onto the target surface happens in the second and final morphing step

Details of "RBF Source"

Node Selection	
Scoping Method	Geometry Selection
Geometry	4 Edges
General	
Transformation	Curve Targeting
Percentage	1
Invert	No
Method	Segment-wise
Geometry Selection	
Scoping Method	Geometry Selection
Geometry	4 Edges
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	No
RBF Problem	
Source	0
Target	504



Solid Trace Mapping Logic

<u>Mesh morphing approach</u>:

- An auxiliary Surface/Solid is defined to drive 2d morphing
- Curves are connected
- The 2d morphing action is propagated on the complete solid mesh by turning on Coordinate Filtering

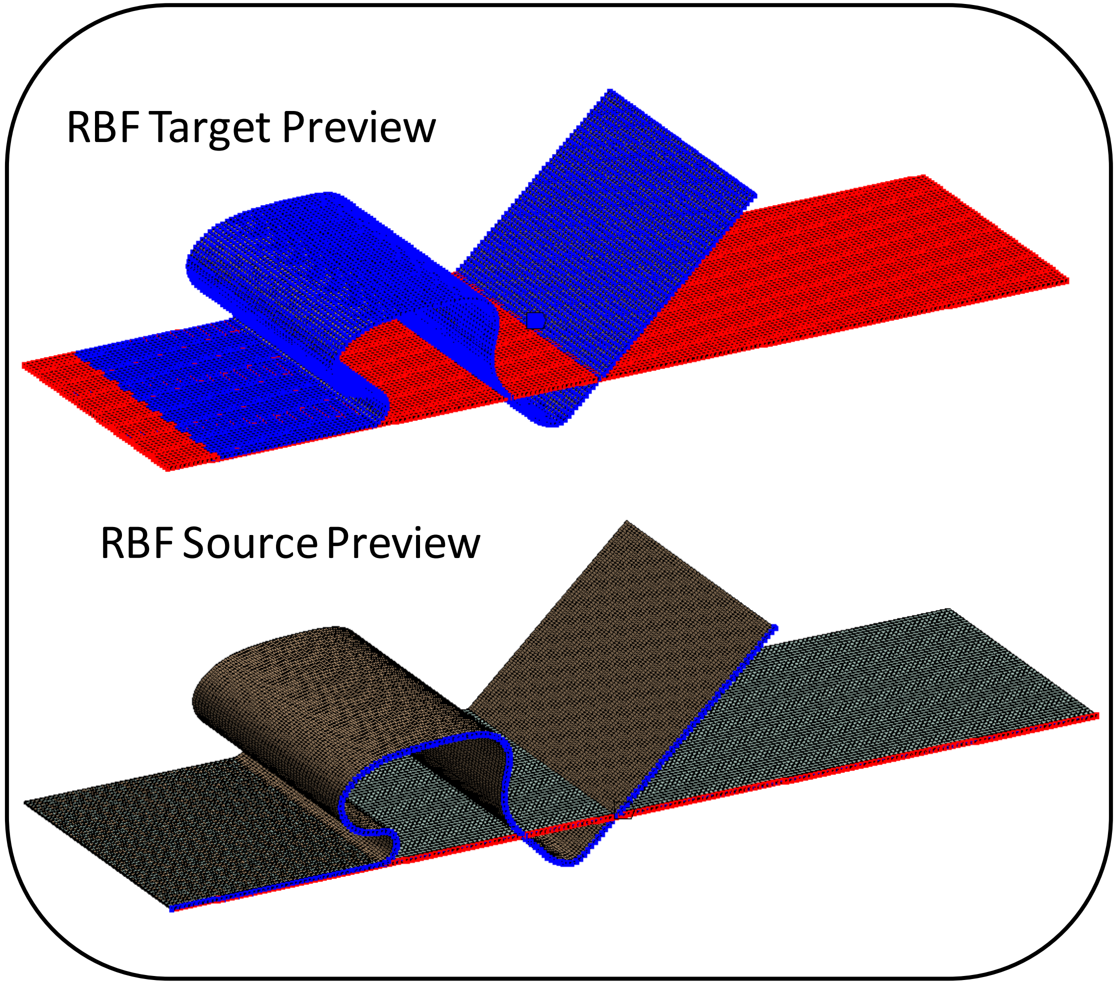
RBF Morph Set Up
RBF Target
RBF Source

Details of "RBF Target"

Node Selection	
Scoping Method	Geometry Selection
Geometry	3 Bodies
General	
Transformation	Translation
Translation Definition	Manual
Delta x	0 in
Delta y	0 in
Delta z	0 in
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	Yes
Coordinate System	Global Coordinate System
Locked Coordinate	x
Locked Coordinate Value	0 in
RBF Problem	
Source	408
Target	61506

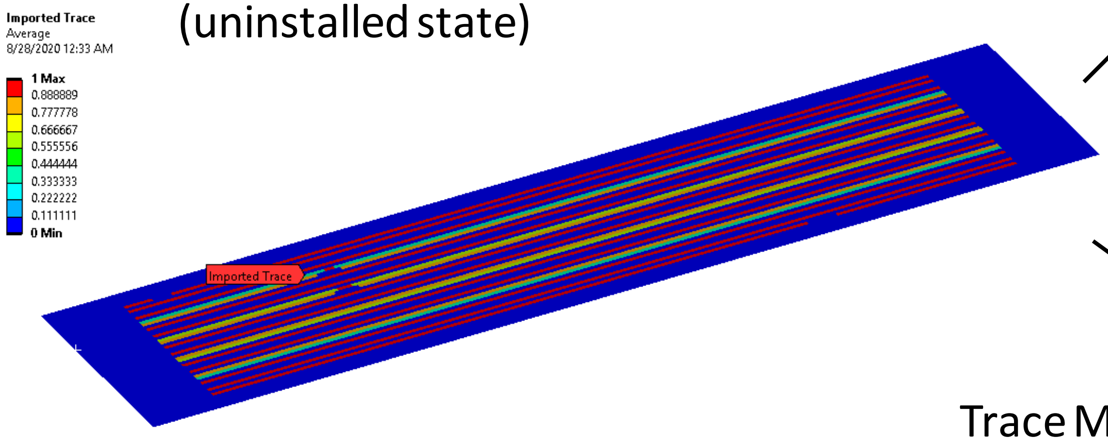
Details of "RBF Source"

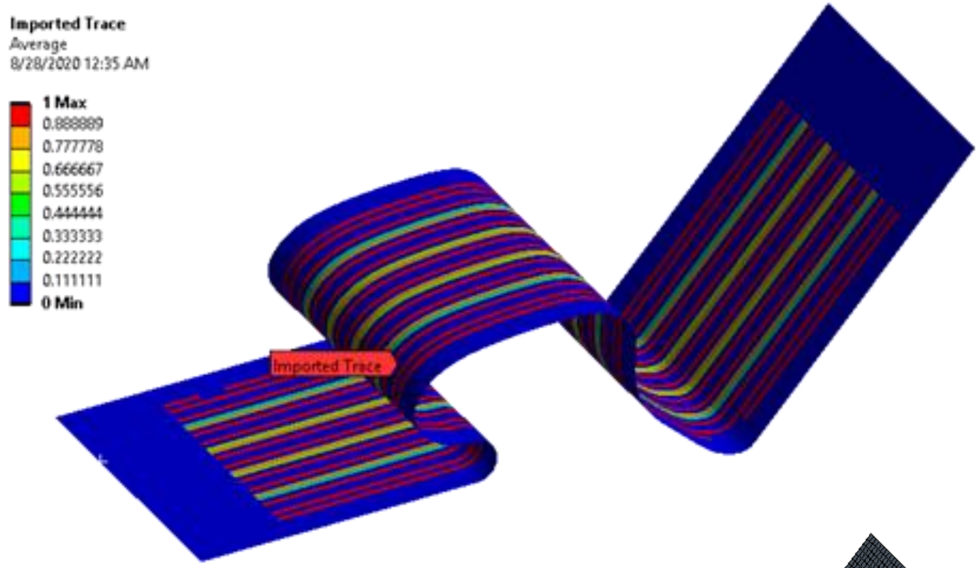
Node Selection	
Scoping Method	Geometry Selection
Geometry	4 Edges
General	
Transformation	Curve Targeting
Percentage	1
Invert	No
Method	Segment-wise
Geometry Selection	
Scoping Method	Geometry Selection
Geometry	4 Edges
RBF Function	
Degree	1



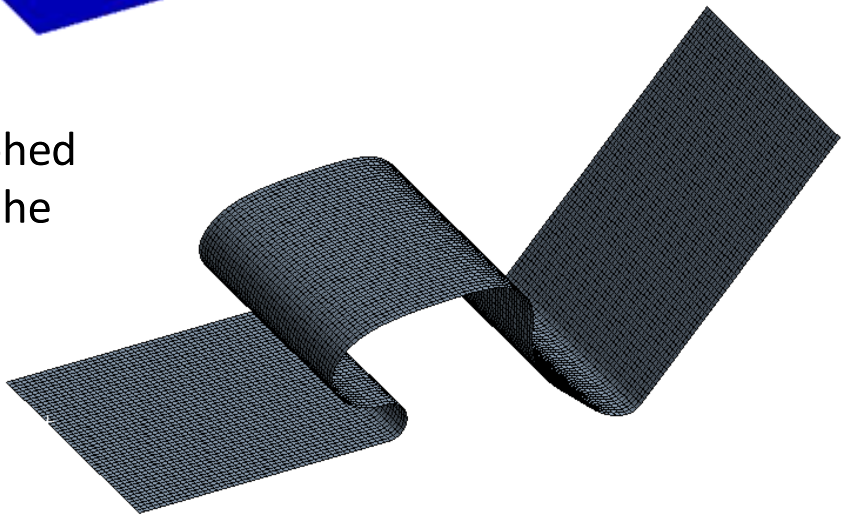
Shell Trace Mapping - Results

Trace Mapping on a flat Board
(uninstalled state)

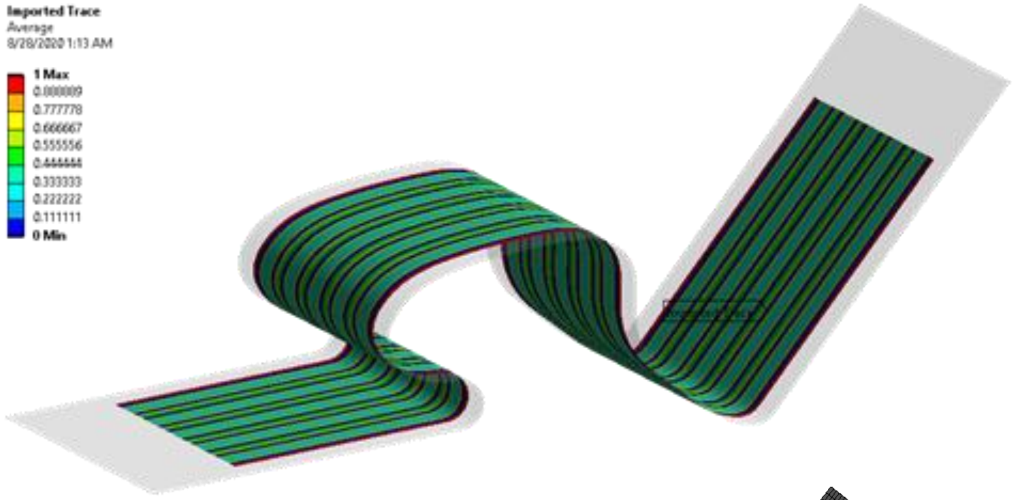




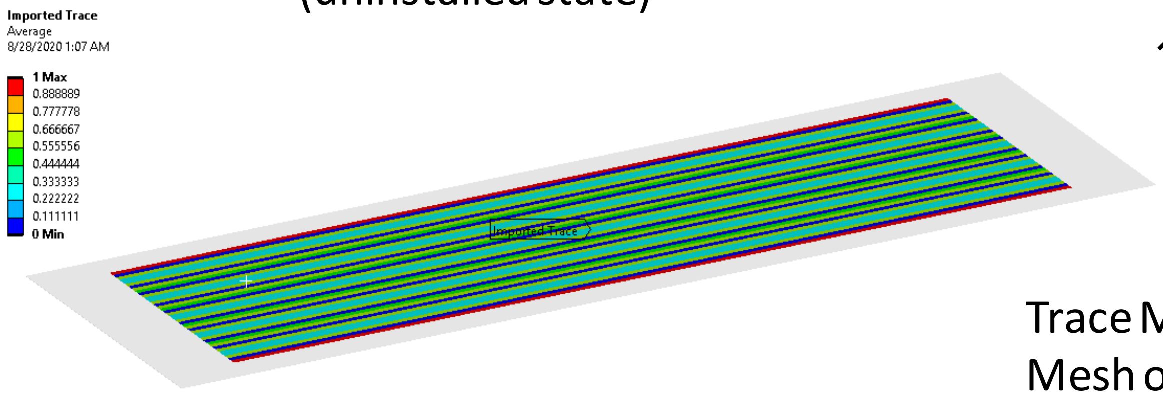
Trace Mapping and Morphed Mesh of the flex PCB on the installed structure



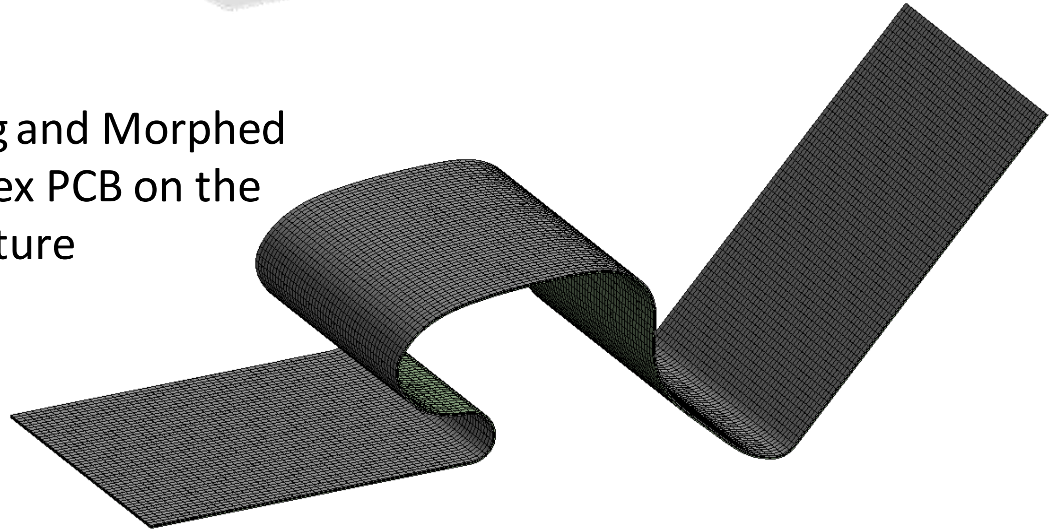
Solid Trace Mapping - Results



Trace Mapping on a flat Board (uninstalled state)



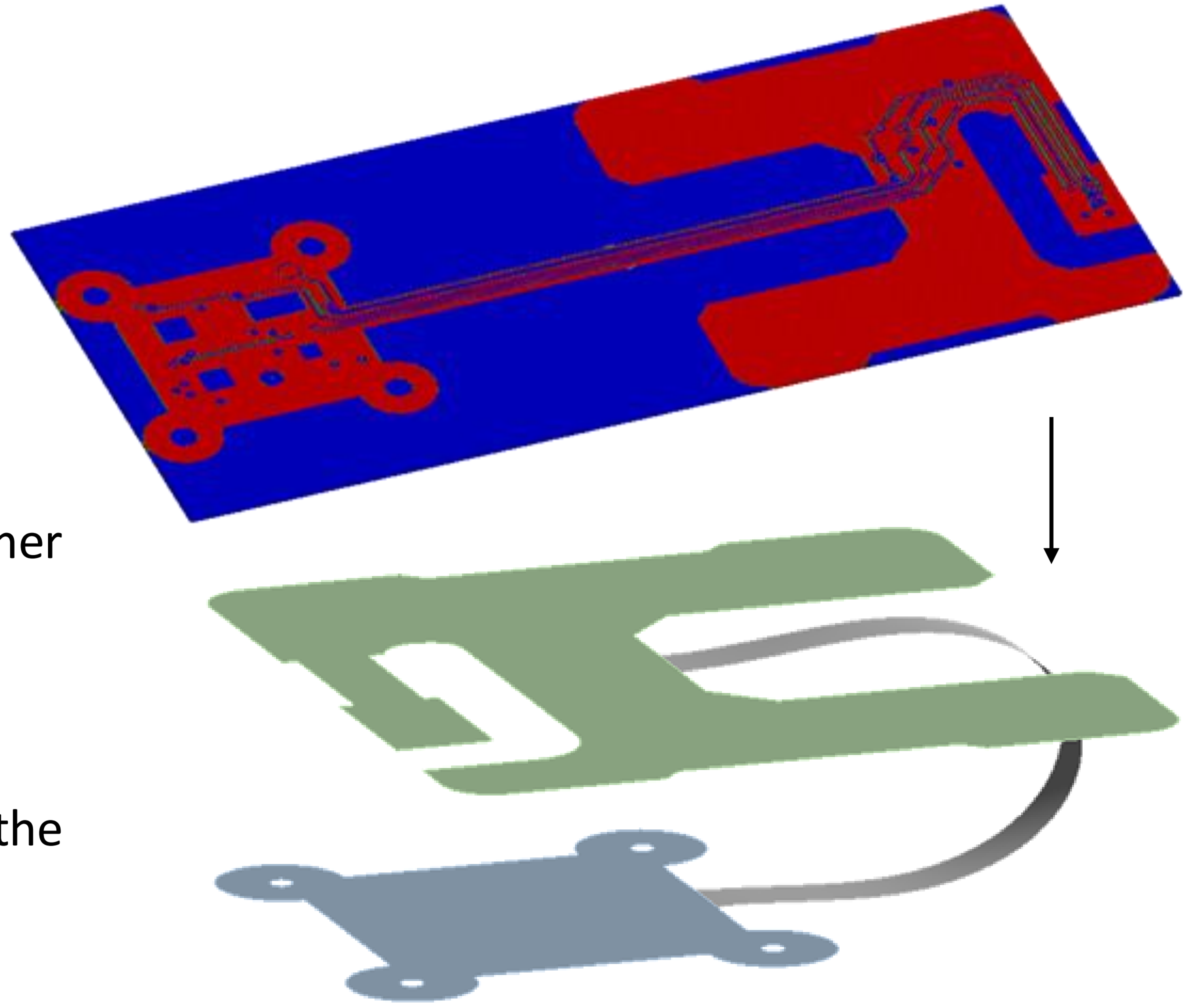
Trace Mapping and Morphed Mesh of the flex PCB on the installed structure



<u>Note:</u> For the Solid case, an averaging scheme was used for material representation which showcases the capability of the Trace Mapping technology

Analysis of a Rigid Flex PCB

PCB tested: Rigid-Flex PCB (Shell)



Target Geometries: Installed Shape in the consumer electronics product

Objective

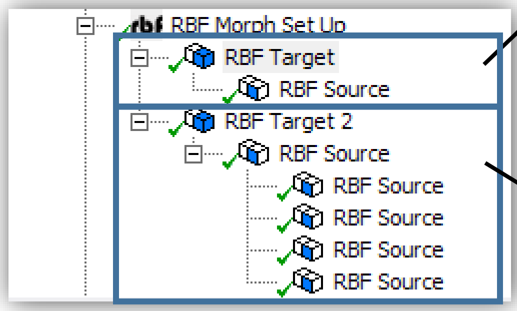
For the target geometry (a 180-degree bend) of the structure should be possible for:

- Shell Trace Mapping

Shell Trace Mapping Logic

Morph Approach for Flex PCB:

- A more complicated (full 3D) Morph strategy is employed here as we are dealing with multiple bodies.

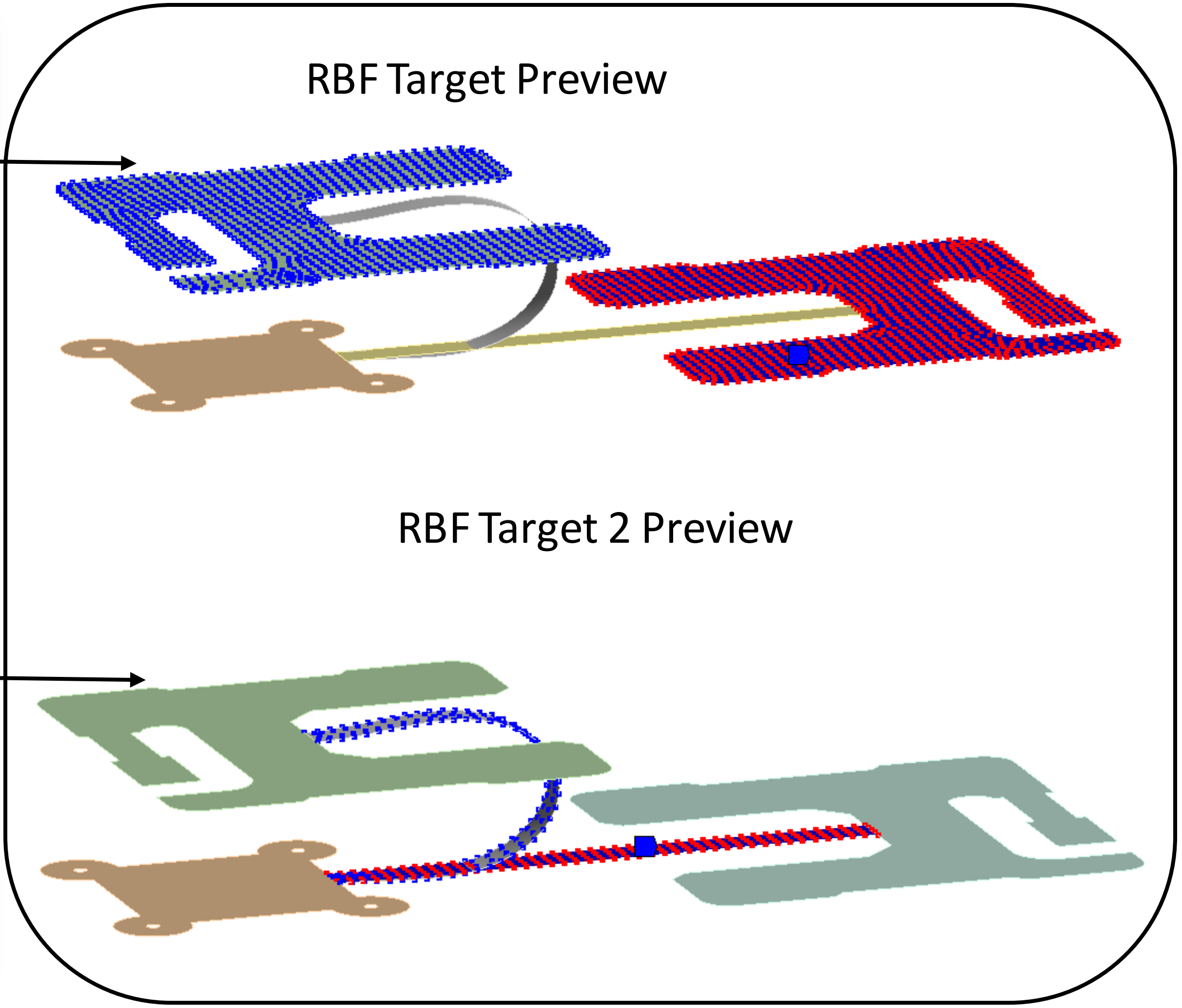


Details of "RBF Target"

Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Body
General	
Transformation	Rotation
Rotation System Definition	By Coordinate System
Angle	180 °
Coordinate System	Coordinate System
Axis Used	y
RBF Function	
Degree	1
Combine Select	
Acting On	Deformed
If Selected Nodes Overlap	Override
Coord Filtering	No

Details of "RBF Target 2"

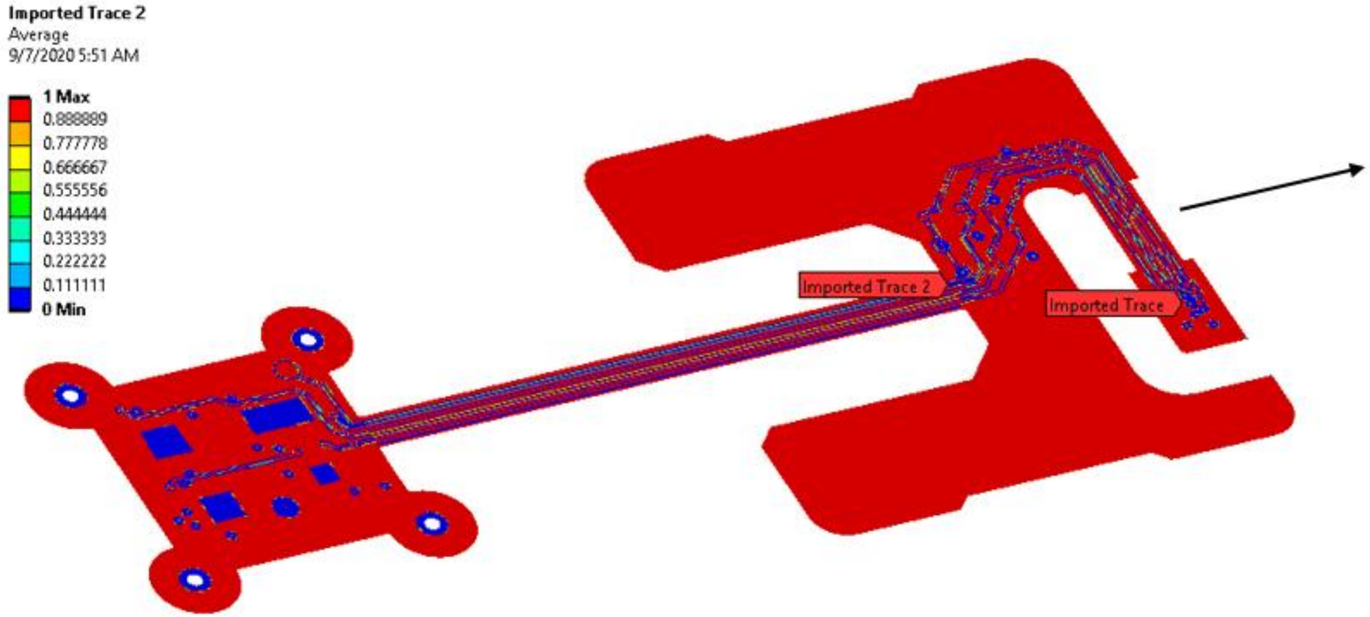
Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Body
General	
Transformation	Translation
Translation Definition	Manual
Delta x	0 in
Delta y	0 in
Delta z	0 in
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	No



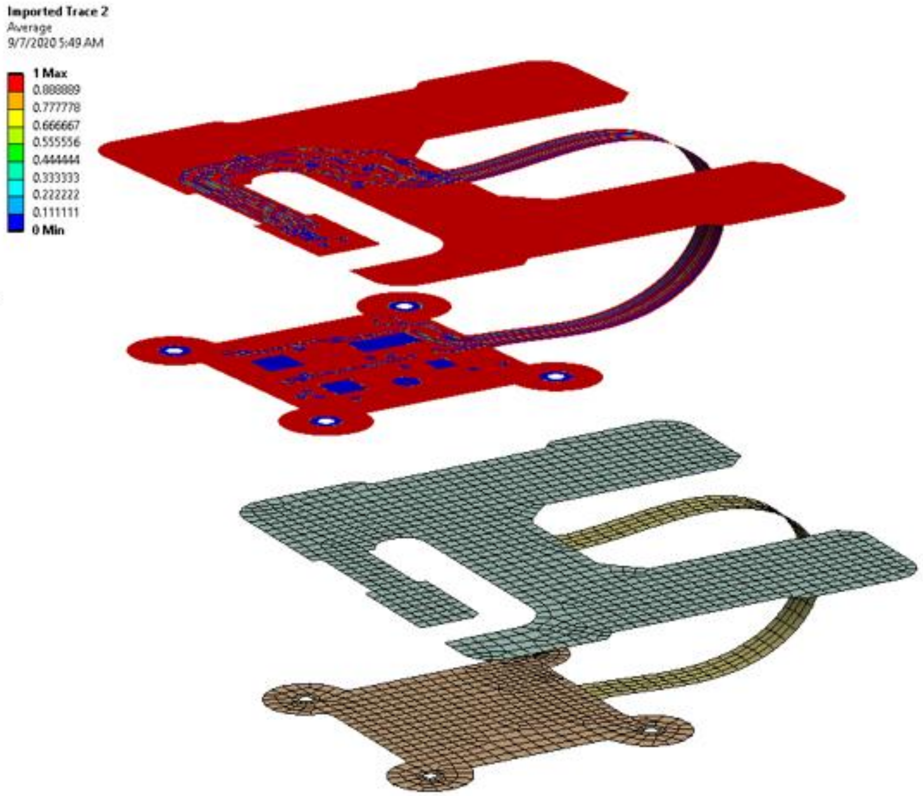
Note: The morphing is performed directly on the faces of the bodies with guides in the case of the flex (i.e., Sources along the edges)

Shell Trace Mapping - Results

Trace Mapping on a flat PCB (uninstalled state)



Trace Mapping and Morphed Mesh of the Rigid-Flex PCB on the installed structure



Conclusions

- An advanced mesh morphing workflow based on radial basis function mesh morphing has been defined for curved PCB modelling
- Two strategies are considered
  - Full solid to solid connection
  - Use of auxiliary 2d geometry to guide single curvature morphing
- For all the geometries investigated the proposed approach gives good results both for the deformed shape and both for the traces representation
- This first study opens to further investigations
  - Generic double curvature deformation
  - Simplified computation of strain and stress by differentiating the RBF field
  - Use of deformed configurations to guide/restart full FEA structural assessment

Thank You For Your Kind Attention!