**Active shaping of an electromagnetic field - EMC applications**

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**Objectives**

To control an electromagnetic field (or voltage) in different environments (transmission lines (TL), free space).

1. Control an electromagnetic field in a TL network
   - Software correction of a defective network
   - Detection and localization of defects
2. Control an electromagnetic field in free space environment

**Introduction**

The idea of identifying a source that produces a specified electromagnetic field at a given point in space has received a considerable attention over the past 20 years or so. It has been popularized by the time reversal (TR) method, first applied in acoustic and has since spread in various other domains, including electromagnetic compatibility (EMC).

The advantage of such method is its simplicity. However, its major drawback comes from the fact that it becomes less reliable when imposing complex conditions on the time duration, the target field or when dealing with multiple points in space. Consequently, the need for novel techniques dedicated to accurately tackle such problems is necessary.

**Methods**

- The methods to control an EM field are:
  - Time Reversal (TR)
  - Linear Combination of Configuration Fields (LCCF)

<table>
<thead>
<tr>
<th>TR</th>
<th>LCCF</th>
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</thead>
<tbody>
<tr>
<td>Inaccurate due to numerical errors</td>
<td>Compensates numerical errors</td>
</tr>
<tr>
<td>Tackle only lossless problems</td>
<td>Tackle problems with arbitrary losses</td>
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<tr>
<td>Less reliable with a complex EM field</td>
<td>Reliable with a complex EM field</td>
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<tr>
<td>Requires perfect Huygens surface</td>
<td>Perfect Huygens surface is not required</td>
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**Mathematical Section: LCCF theory**

- The LCCF steps are:
  1. Construct the LCCF transfer matrix \( A \): Inject an impulsion and record at a specified point.
  2. Construct the vector \( b \): Inject a signal \( \delta \) and record at the same point considered in the 1\(^{st}\) step.
  3. Solve the linear system: \( As = -b + F \)

   ![Figure: The configuration of the TL network used](image)

   - To find \( s \) the signal to be injected after \( \delta \), in order to obtain the target field \( F \).
   - Nullifying at several points requires the following system to be solved:
     \[
     \begin{pmatrix}
     A_1 & b_1 \\
     A_M & b_M
     \end{pmatrix} s = \begin{pmatrix}
     F_1 \\
     F_M
     \end{pmatrix} \Leftrightarrow \sum s = -\delta + \mathcal{F} \tag{1}
     \]

   - The system (1) is not square and has to be solved in the least square sense.

   - (1) requires to be regularized (Tikhonov), it takes the form:
     \[
     \sum\left(\mathcal{F}'\mathcal{F} + \epsilon I\right) s = \mathcal{F}'\left(-\delta + \mathcal{F}\right), \epsilon > 0
     \]

- By the LCCF method, we can compute the new voltage source to be injected in order to obtain the voltages of the healthy network.

**Conclusion**

- To summarize, using the LCCF technique we can:
  - Detect defects (hard or soft).
  - Bring a software correction to defective complex TL networks.
- Future work:
  - Locate the defects in TL networks
  - Control an electromagnetic field in 3D
  - Control an electromagnetic field in the frequency domain
  - Experimental Tests

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**Results: Null Voltage (\( F = 0 \)) / Defect Detection**

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<thead>
<tr>
<th>Branch nb</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
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<td>5</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
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**Results: Software Defect Correction**

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