EDISOn: the Electromagnetic Design of flexIble SensOrs research program

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1. Sensors

Epidermal (on-skin) **sensors** that conform to the body and adhere well to the skin, such sensors may be printed and may use different sensing mechanisms, including electromagnetic waves for dielectric property assessment. To enable external sensor readouts for health and wellness monitoring, an antenna that can be placed directly on curved skin (which could be stretched or shrunk) and yet can radiate into the air with good efficiency needs be designed. Similar problems are found for biodegradable and low-energy sensor technologies that are desired for ecofriendly electronics used in low-cost remote sensing of environmental conditions, with potential applications in agriculture, the food industry, transportation, logistics, and weather monitoring.

2. Skin sensor

http://news.berkeley.edu/2016/01/27/wearable-sweat-sensors/

3. Numerical Simulations

Practically any prototyping of an electronic device involves **computer simulations**. To develop sensors that use electromagnetic waves to probe the material sample, detect radiation, or transmit the results of measurements using a wireless link, the shape of the sensor, a receiving/transmitting antenna (or an array of radiators/detectors) must be carefully designed. Each design is unique, as it depends on the properties of the constitutive parameters, the operation frequency, the environment in which the sensor is to be used, and the curvature of the surface in the case of flexible, stretchable, or bent substrates. These factors make the design process particularly challenging, as the final form of the device can only be determined via a large number of computer simulations that involve solving Maxwell's equations in presence of curved surfaces and inhomogeneous, often lossy and dispersive media, resulting in signal attenuation and the potential degradation of wireless transmission. Fast yet accurate software packages capable of performing such tasks in the most efficient way are thus needed to develop the sensors.

4. Finite Element Method - Model Order Reduction

The N-dimensional Finite Element discretization of a Helmholtz equation for a dielectric-loaded, lossy structure Ω results in the following second-order input–output system of equations:

$$(\Gamma + sG + s^2C)E(s) = sBI, \quad U = B^T E(s), \tag{1}$$

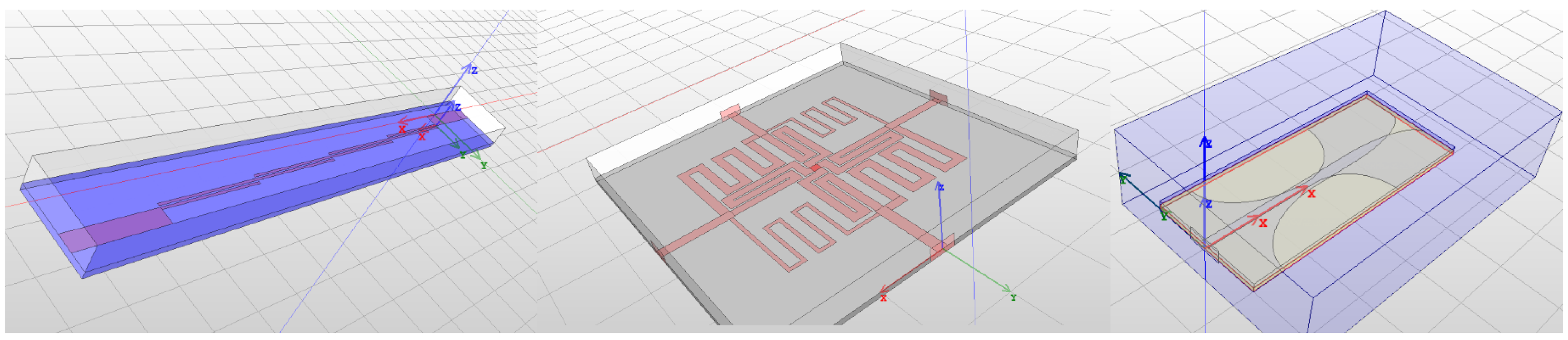
where $\Gamma, G, C \in \mathbb{C}^{N\times N}$ are system matrices, $s = j\omega/c$, I, and U are the vectors of amplitude of the normalized currents and voltages, respectively, $B \in \mathbb{C}^{N\times M}$ denotes a normalized port selection matrix, $E(s) \in \mathbb{C}^{N\times M}$ is a matrix of unknown FE coefficients, and M is the total number of excitation modes.

In order to efficiently simulate and design a flexible sensors by means of Finite Element Method, a wideband-frequency Model-Order Reduction approach has been developed in EDISOn project. The reduced-order model, which approximates the properties of the FEM system has the following form:

$$(\Gamma_r + sG_r + s^2C_r)E_r(s) = sB_rI, \quad \hat{U} = B_r^T E_r(s), \tag{2}$$

where $\Gamma_r = Q^T\Gamma Q$, $G_r = Q^TGQ$, $C_r = Q^TCQ$, $B_r = Q^TB$ are reduced system matrices, $Q \in \mathbb{C}^{N\times q}$ is the orthonormal projection matrix, and q denotes the reduced order, where $q \ll N$.

5. Structures

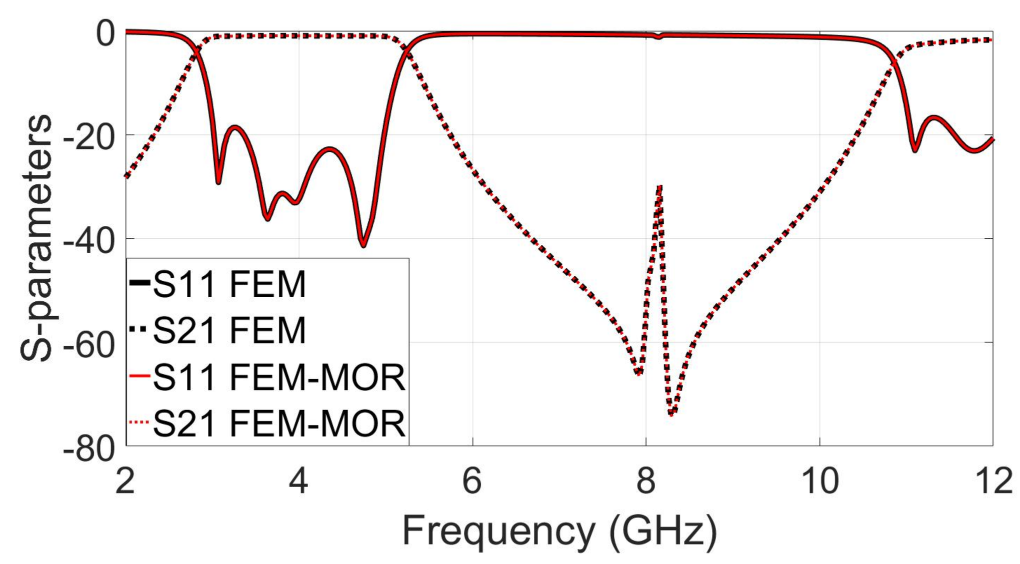


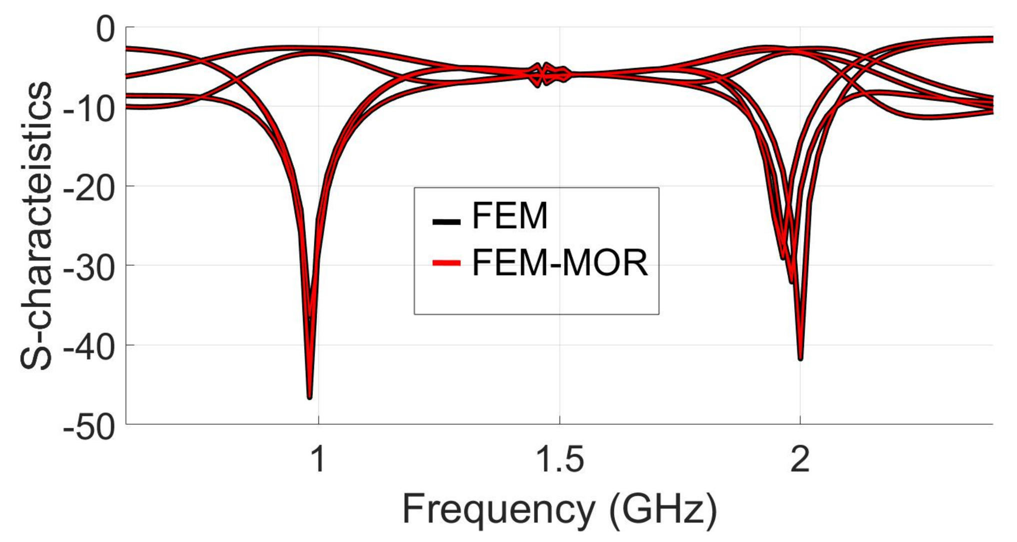
a) Filter b) Coupler c) Vivaldi antenna

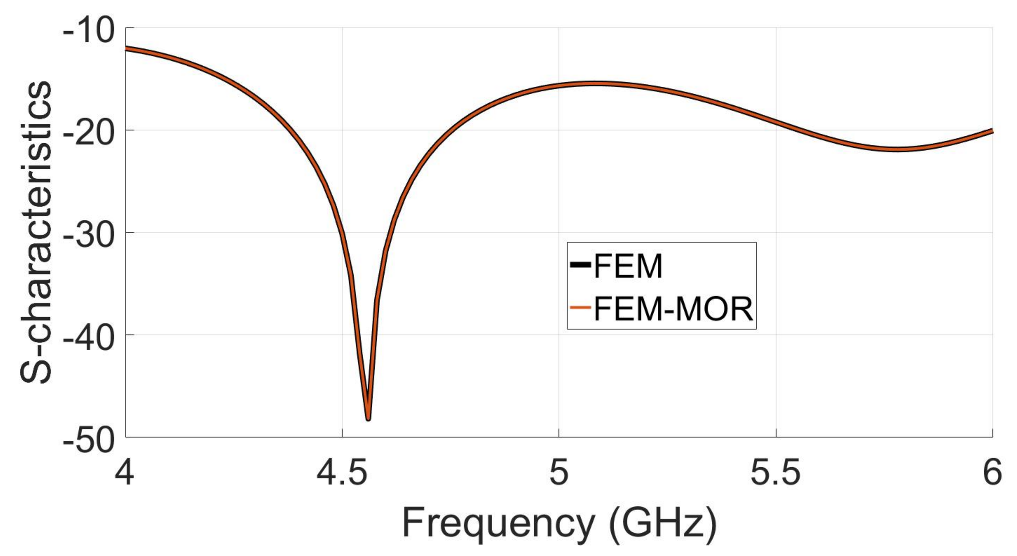
6. The speedup of computations

	Transmission Line Filter	Coupler	Vivaldi Antenna
Number of Frequency points	300	100	101
Frequency bandwidth	2-12 GHz	0.6-2.4 GHz	4-6 GHz
Number of expanding points	4	1	3
Number of vectors in Q	54	36	21
Speedup	19.8	10.8	26
Reduction time	83.3 s	23.4 s	108.94 s

7. Characteristics







8. EDISOn

https://edison.wicomm.pl/
http://eminvent.com/

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