



## 2th European Doctoral School on Metamaterials

### Modelling and Application of Metamaterials, Metasurfaces and High Impedance Surfaces

Siena, Italy, November 21-25, 2005

#### Program:

#### *Monday 21*

Hour	Topic	Lecturer
8:00 - 9:00	Geometries of radiators for enhanced broadside (boresight) radiation: high/low permittivity/permeability metamaterial slabs, low/high refraction index metamaterial slabs, Fabry-Perot cavities (FPC) with partial reflective surfaces (PRS) and EBG superstrates. Background for enhanced radiation at broadside.	F. Capolino
9:00 - 10:00	Transmission-line analysis of planar radiators; excitation of directive structures; conditions for maximum broadside power density.	P. Burghignoli
10:00 -10:15	<b>Coffee break</b>	
10:15 - 11:00	Excitation and waves excited in planar metamaterial and FPC structures: space wave, surface waves, leaky waves; enhanced directivity and leaky waves. Radiation bandwidth of directive radiators. Simple engineering formulas.	P. Burghignoli
11:00 - 12:00	Case study. Enhanced radiation by using a grounded low-permittivity metamaterial slab (grounded plasma slab)	G. Lovat
12:00 - 13:30	<b>Lunch</b>	
13:30 - 14:30	Study of combinations of high/low permittivity-permeability metamaterial slabs	G. Lovat
14:30 - 15:30	Comparison between PRS-based and metamaterial-based radiators with enhanced directivity: enhancement, bandwidth, feeds, etc.	F. Capolino
15:30 - 15:45	<b>Coffee break</b>	
15:45 - 16:30	Assignments and self-study: solutions of simple problems. Assignments for the next day. Study of important published papers.	M. Albani, P. Burghignoli, F. Capolino, G. Lovat
16:30 - 17:30	Design of an enhanced-directivity radiator, feed and structure. A dual polarization sparse array antenna with high directivity. Impedance bandwidth.	M. Albani

#### *Tuesday 22*

Hour	Topic	Lecturer
8:00 - 10:00	Assignments and self-study:	M. Albani,

	Study of important published papers. Student presentations	P. Burghignoli, F. Capolino, G. Lovat
10:00 - 10:15	Coffee break	
10:15 - 12:00	Design, fabrication and measurement of Metasurfaces for highly directive antennas	A. Feresidis
12:00 - 13:30	Lunch	
13:30 - 14:30	Theory of basic HIS, part 1. Introduction – what are high-impedance surfaces? Concept of impedance boundary conditions (IBC). Plane-wave surface impedance $Z_s$ for 2D periodic arrays. Grid (sheet) impedance $Z_g$ . Averaged boundary conditions for wire grids. General relations for $Z_s$ , $Z_g$ , and reflection coefficient. Transmission-line approach for $Z_s$ , restrictions. Basic properties of $Z_s$ and $Z_g$ . A concept of basic HIS. Drawbacks of the surface impedance concept. Simple and two-level mushroom structures (MS).	C. Simovski
14:30 - 15:30	Theory of basic HIS, part 2. Quasistatic model of MS. Dynamic model of MS: wire grid theory, approximate Babinet principle, grid impedance of the patch array, wire medium (WM) theory, input impedance of the metal-backed layer of WM, analytical calculation of $Z_s$ .	C. Simovski
15:30 - 15:45	Coffee break	
15:45 - 17:30	Assignments and self-study: To calculate $Z_s$ of MS with hexagonal patches (normal incidence). To calculate $Z_s$ for two-level mushroom structures using the combination of the quasistatic model (to find $Z_g$ ) and transmission-line approach to find $Z_s$ (normal incidence). To compare with purely quasistatic model. To study a journal paper about the influence of the ground plane to $Z_g$ of the patch array.	S. Tretyakov, C. Simovski

### Wednesday 23

Hour	Topic	Lecturer
8:00 - 10:00	Theory of basic HIS, part 3. Surface impedance of MS for arbitrary incidence. Comparison with simulations and experiments. Problem of the angular stability of the resonance. HIS based on self-resonant grids (SRG): Anderson's theory of SRG, $Z_s$ of HIS based on SRG. Angular stabilization of the resonance. Microstrip model of Itoh's HIS (UC PBG surface over the ground plane). Dynamic model of Itoh's HIS. Summary of formulas for $Z_g$ and $Z_s$ for basic HIS.	C. Simovski, S. Tretyakov
10:00 - 10:15	Coffee break	
10:15 - 12:00	Plenary discussion – presentation of self-study results	C. Simovski, S. Tretyakov
12:00 - 13:30	Lunch	
13:30 - 14:30	Exotic HIS: HIS of C-particles (Diaz), HIS of Pi-particles (Simovski), HIS of L-loaded wires (Belov, Simovski, Tretyakov), HIS of helices (Sievenpiper)	C. Simovski
14:30 - 15:30	FSS theory, analysis and design. FSS for HIS. measurement and testing, guidance with modeling, Method of Moments for studying HIS. Examples.	G. Goussetis
15:30 - 15:45	Coffee break	



15:45 -16:30	Measurement and testing, guidance with modeling, Method of Moments for studying HIS. Examples.	G. Goussetis
16:30 -17:30	Assignments and self-study: Hands-on exercises, demonstration.	G. Goussetis

### Thursday 24

Hour	Topic	Lecturer
08:00 - 10:00	The pole-zero matching method for the dispersion analysis of thin HIS. 1-Basic physics and simplified analysis models: FSS properties; Equivalent circuit analysis: Homogenization of the boundary conditions based on Floquet wave expansion. 2- Rigorous integral equation analysis; Spectral domain MoM analysis; Rigorous dispersion equation; Multipole network and accessible mode; “reduced” dispersion equation;	S. Maci
10:00 - 10:15	Coffee break	
10:15 - 11:00	The pole-zero matching method for the dispersion analysis of thin HIS. 3. Pole-zero matching method- Properties of the FSS admittance matrix eigenvalues; Foster’s properties; Pole-Zero and Pole-Residue Representations.	S. Maci
11:00 - 12:00	Assignments.	A. Cucini, S. Maci
12:00 - 13:30	Lunch	
13:30 - 15:30	Design of HIS, fabrication, measurements. Miniaturization issues. Examples of cell-phone antennas integrated with HIS. Example of patch antennas and microstrip line resonators with HIS. Assignments.	A. Feresidis
15:30 - 15:45	Coffee break	
15:45 -16:30	Assignments and self-study: To calculate Zs of MS for oblique incidence. To calculate Zs for two-level mushroom structures using the known Zg for normal incidence and known angular dependence of Zg for MS. Oblique incidence. To compare with purely quasistatic model. To study a journal paper about influence of Zs to far- and near-field patterns and a journal paper about HIS with self-resonant grids.	C. Simovski, S. Tretyakov
16:30 - 17:30	Some applications of HIS. Magnetic-wall regime (constructive interference) and EBG regime (suppression of surface waves). Problem of HIS with angle-independent resonance for complex angles. Shaping antenna pattern using HIS in the regime of resonant and moderate impedances. HIS as an artificial magnetic layer. Suppressing cross-talk and leaky waves in microstrips and coplanar lines. All-angle thin absorbing layers.	S. Tretyakov

### Friday 25

Hour	Topic	Lecturer
8:00 - 10:00	HIS as EBG. Surface waves on mushroom structures, theory, simulations, experiment.	C. Simovski, S. Tretyakov



	Primitive model and self-consistent model. Restrictions of IBC for surface waves. Bulk waves inside the structure: Transmission-Line and effective medium models. Backward waves and resonator mode. Role of vias. Surface waves on SRG	
10:00 - 10:15	Coffee break	
10:15 - 12:00	Plenary discussion – presentation of self-study results	C. Simovski
12:00 - 13:30	Lunch	
13:30 - 15:30	Artificially hard and soft surfaces realized by using printed dipoles and slots; hard and soft waveguides; compact resonators; quasi TEM waveguide; leaky wave antennas; array element decoupling.	A. Cucini
15:30 - 15:45	Coffee break	
15:45 - 17:30	Assignments and self-study	A. Cucini, S. Maci