

## Frequency Selective Surface

There is a growing demand for new materials to enhance device performances at low cost. For several years, many periodicals there have been published (built from large number of uniform cells) which show that such engineering issues can be resolved. A typical problem would be to place an antenna in front of ground plane. In order to allow propagating waves, incident to the ground plane, to reflect and to continue its propagation with the same phase as wave radiated from the antenna, the ground plane should be a quarter of a wavelength away from the antenna. In many such cases this would increase the size of the system, making the approach impractical. The next few cases will demonstrate how some typical problems can be solved by using WIPL-D software. Such simulation models are easy to build using built-in objects and manipulations.

### Dipole Radiation Modification over FSS

This EM simulation demonstrates how to place dipole antenna very close to FSS and get a very good radiation pattern. Model is presented in Figure 1. The dimensions are: distance between cells 2.54 mm, gap between cells 0.15 mm, via radius 0.12 mm, substrate height 1.55 mm and permittivity 2.2. Frequency is 13 GHz.

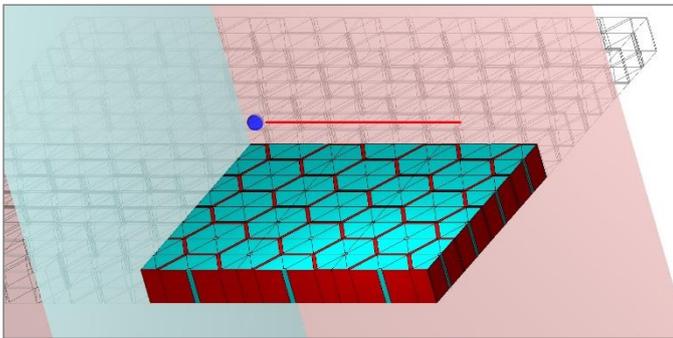


Figure 1. Dipole antenna above FSS (2 symmetry planes applied)

In order to demonstrate the influence of positioning the dipole above FSS, we run 4 different scenarios and compare radiation pattern: dipole in free space, dipole above infinite PEC plane, dipole above finite PEC plane of same size as FSS surface and finally dipole above FSS (radiation patterns are presented in Figs 2-3). Efficient use of symmetry makes the model of dipole above FSS to require only 7,700 unknown coefficients. The simulation typically lasts less than a minute on standard desktop or laptop.

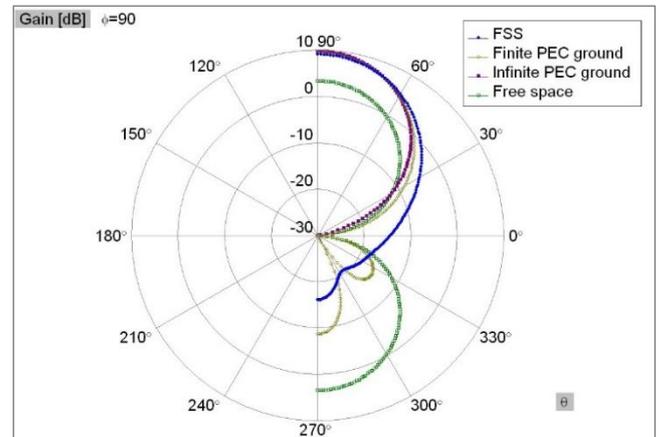


Figure 2. Dipole pattern in four cases for Phi 90 degrees

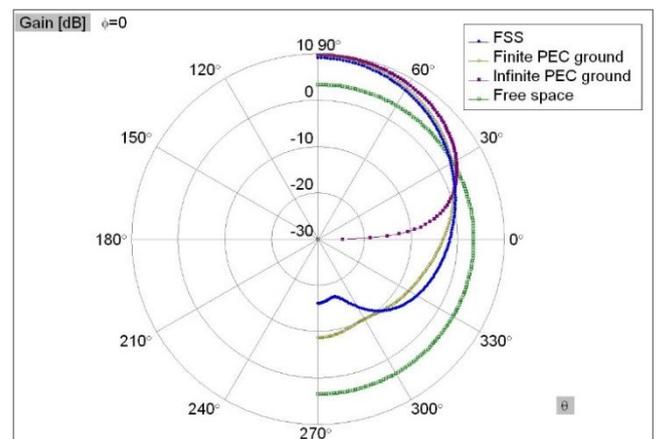


Figure 3. Dipole pattern in four cases for Phi 0 degrees

### Coupling between Dipoles over FSS

The next EM simulation illustrates how coupling between antennas can be enhanced at selected frequencies by positioning them above FSS. The pattern is similar (Figure 4). The dimensions are: distance between cells 2.4 mm, gap between cells 0.15 mm, post edge 0.36 mm, substrate height 1.6 mm and permittivity 2.2. Frequency range is between 9 and 13 GHz. Dipoles are electrically short (1 mm half length). Symmetry is applied to reduce number of unknown coefficients.

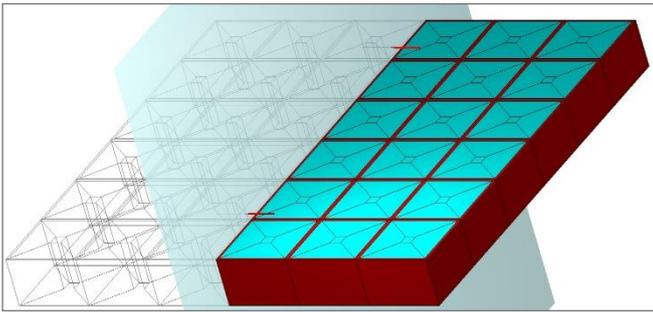


Figure 4. Dipoles above FSS

We again run 4 different scenarios and compare coupling between antennas: dipole in free space, dipole above infinite PEC plane, dipole above finite PEC plane of same size as FSS surface and finally dipole above FSS (Figure 5).

WIPL-D is inherently able to calculate very low values of antenna coupling, well below -100 dB. Model requires only 4,000 unknown coefficients and simulation time is well below one minute per frequency on standard desktop or laptop.

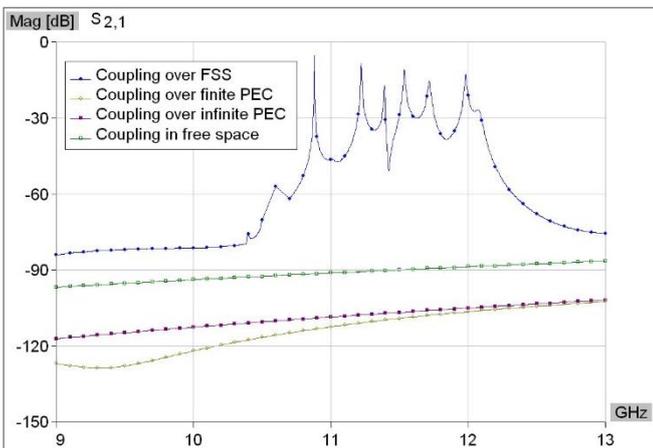


Figure 5. Coupling between dipoles for four scenarios

### RCS from FSS on Dielectric Slab

FSS are often used in radar technologies and this simulation demonstrates efficient use of WIPL-D to calculate RCS from FSS printed on dielectric slab. Size of FSS is 7x7 cells. The dimensions are: length of crosses 50 mm, width of crosses 2.5 mm, distance between cells 75 mm, dielectric slab thickness 12.5 mm and permittivity 3.78. Frequency is 3 GHz. Symmetry is applied to reduce number of unknown coefficients.

Entire simulation requires 25,000 unknown coefficients and simulation time is under a minute on standard desktop PC equipped with inexpensive GPU card.

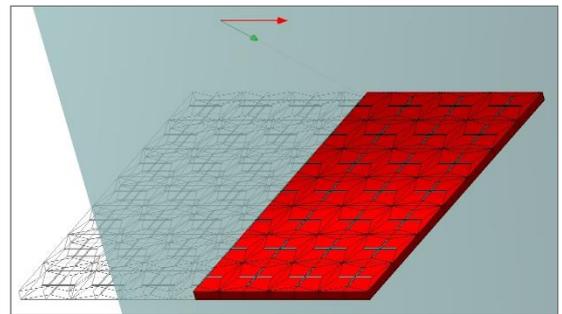
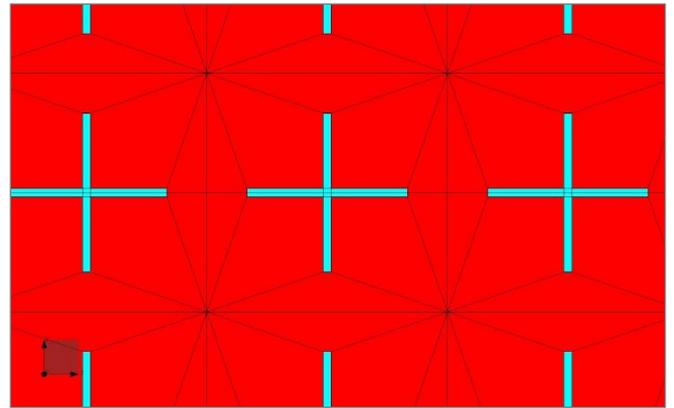


Figure 6. FSS structure and magnified unit cell

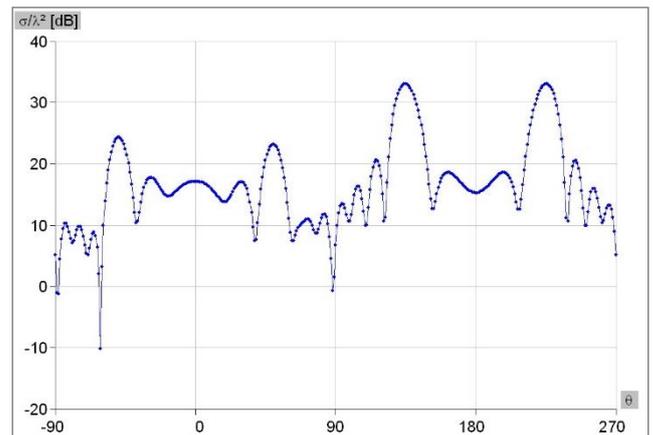


Figure 7. RCS from FSS

## Energy Transfer through FSS

FSS can be used to allow transfer between antennas at selected frequencies and block the transfer at others. This can be achieved via FSS obtained by copying circular resonators. The dimensions are: spacing between cells 12.56 mm, ring radii 3.07, 3.75, 4.735, 5.765 mm, dielectric thickness 0.564 mm and permittivity 3.45. Operating frequency is set between 6 and 12 GHz.

The pattern can be used in two inverted configurations as illustrated in the following figure.

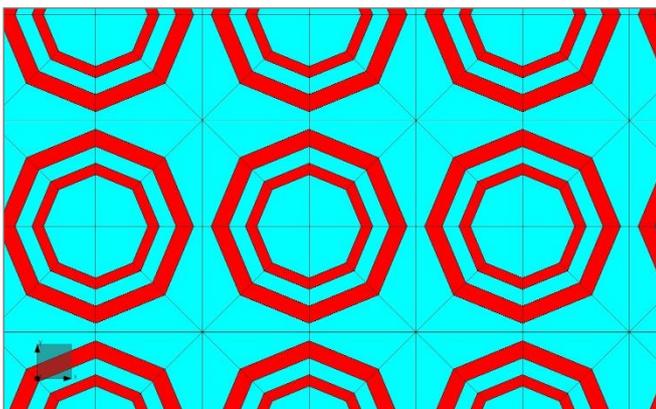
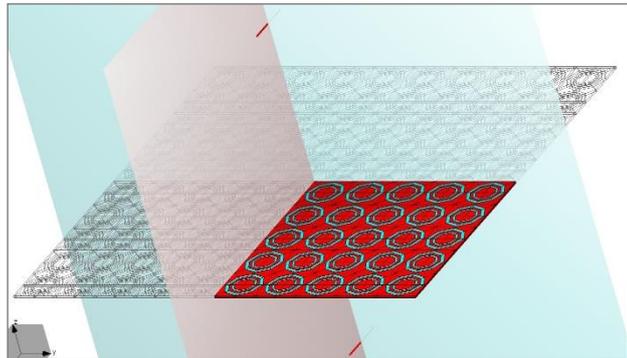
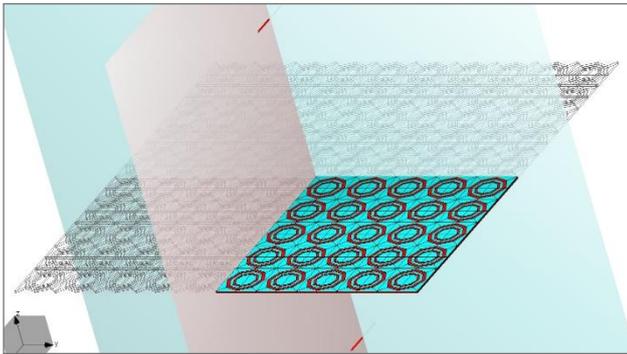


Figure 8. Two inverted FSS configuration with cell detail

EM simulation time is under a minute on standard desktop PC equipped with inexpensive GPU card (24,000 unknown coefficients).

Coupling between half wavelength dipoles is calculated through two inverted configurations and in free space. Each dipole operating frequency is 9 GHz (Figure 9). The result indicates that

FSS can allow full transfer of energy at selected frequencies while inverted configuration allows additional 30 dB isolation at same frequency, thus allowing this structure to function and band pass or band stop device.

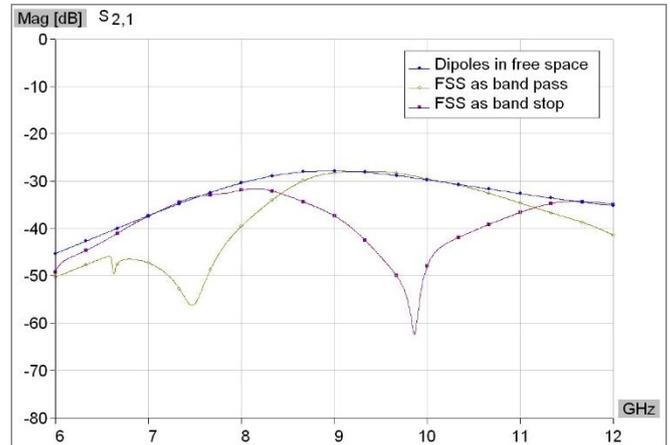


Figure 9. Coupling between dipole antennas for 3 scenarios

## Rectangular Horn Covered with FSS Metallic Radome

FSS are effectively used in radars applications as radomes for on board antennas. Very often such radomes have a very complicated shape and FSS is applied to that shape. The following example demonstrates how such a complex application can be modeled in WIPL-D software.

The model is created in WIPL-D Pro CAD, a tool that allows modeling of complex geometries with automated mesh. It consists over an ellipsoidal radome to which surface FSS is applied.

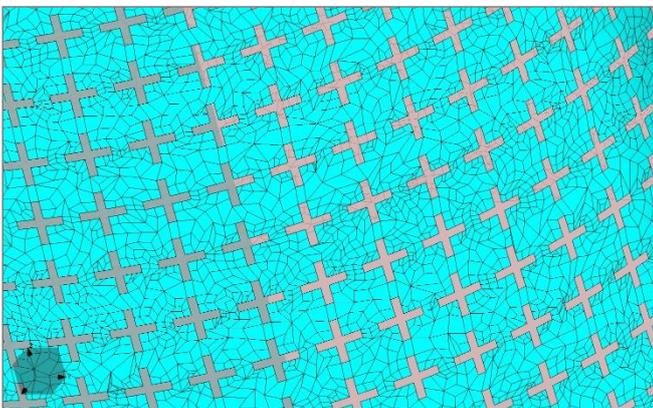
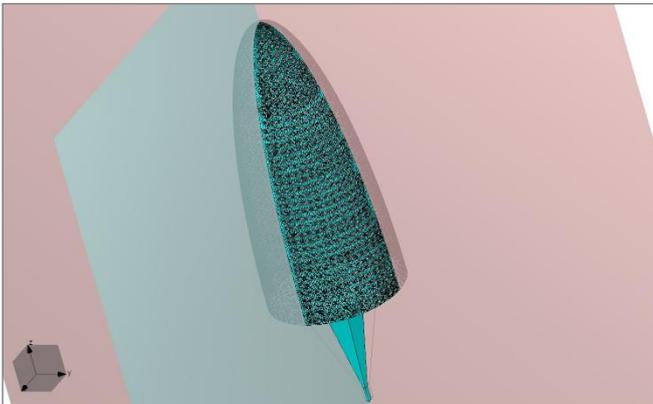


Figure 10. FSS metallic radome

Usually such a metallic radome is covered with a layer of foam of permittivity close to 1, but we will keep the model as pure metallic due to simplicity. The operating frequency is 9.375 GHz. Unit cell dimensions are: crosses are 15 mm long and 2.8 mm narrow, distance between cells is around 21 mm. Model applies two symmetry planes.

Simulation is EM challenging. It requires 40,000 unknowns and under 30 minutes on standard desktop PC equipped with inexpensive GPU card. The results indicate pattern distortion due to the presence of metallic layer in front of the antenna.

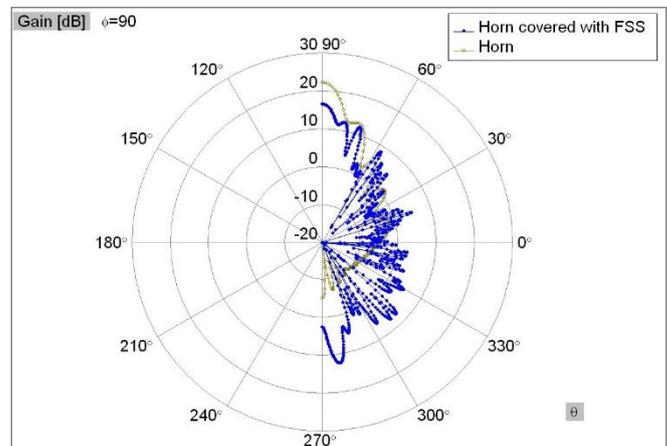
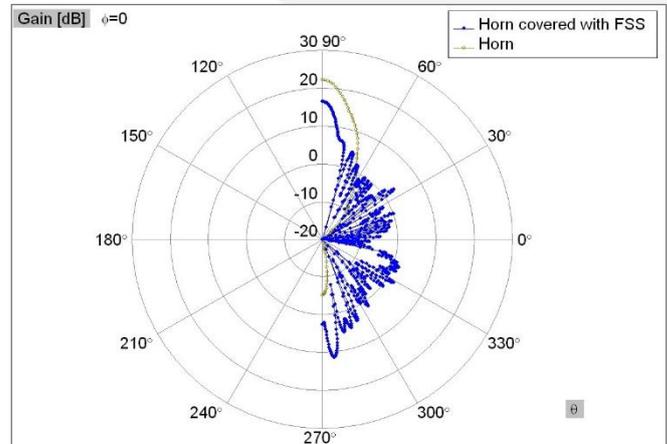


Figure 11. Pattern distortion due to presence of metallic FSS over rectangular antenna