USER GUIDE

Analysis of Frequency Selective Surfaces

DEMO VERSION D1.0

Maurizio Bozzi and Luca Perregrini

University of Pavia – Dept. of Electronics
Via Ferrata, 1 – 27100 Pavia (ITALY)
e–mail: m.bozzi@ele.unipv.it, l.perregrini@ele.unipv.it
web page: http:\\microwave.unipv.it

July 15, 2002

Contents

M. Bozzi and L. Perregrini — University of Pavia (Italy)

Chapter 1

Introduction

The code `fss_unipv.exe` (Demo Version D1.0—July 2002) performs the analysis of inductive frequency selective surfaces (FSSs). In particular, it permits to determine the frequency response of a thick metal screen perforated periodically with arbitrarily shaped apertures, and illuminated by a uniform plane wave (Fig. 1.1).

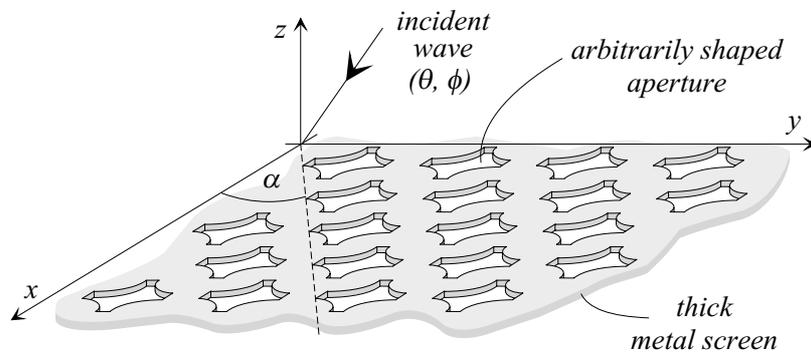This version of the code can be downloaded and distributed for free. It is available at the web site: `http:\\microwave.unipv.it`.

Figure 1.1: A frequency selective surface with arbitrarily shaped apertures.

This code implements the MoM/BI–RME method. The analysis is based on the Method of Moments (MoM) in conjunction with entire domain basis functions. The fields in free–space are written as combinations of Floquet modes, and the fields inside the holes perforating the metal screen are combinations of the modes of the waveguide of cross-section coincident with the aperture. The aperture modes are numerically determined by the Boundary Integral–Resonant Mode Expansion (BI–RME) method.

M. Bozzi and L. Perregrini — University of Pavia (Italy)

A full description of the MoM/BI–RME method, its theoretical basis, and its application can be found in

> M. Bozzi, L. Perregrini, J. Weinzierl, and C. Winnewisser, "Efficient Analysis of Quasi–Optical Filters by a Hybrid MoM/BI–RME Method," *IEEE Transactions on Antennas and Propagation*, Vol. AP–49, No. 7, pp. 1054–1064, July 2001.

The Demo Version D1.0 has the following limitations: (*i*) a single metal screen can be considered; (*ii*) each unit cell of the periodic array may comprise only one aperture; (*iii*) the structure is illuminated by a uniform plane wave incident from the normal direction ($\theta = 0$, $\phi = 0$).

Chapter 2

Getting Started

2.1 Installation of the Code

This code runs on a PC equipped with Windows 95, 98, 2000, or NT operating system.

The Demo Version D1.0 is distributed as a compressed (Win–Zipped) file, named `fss_install_D10.zip`. It can be downloaded from the web site:

`http:\\microwave.unipv.it`

By un–zipping the `fss_install.zip` file, the user is asked for an installation directory, for instance:

`C:\programs\`

Under the selected directory, the following three directories are automatically created:

`C:\programs\fss_unipv\bin\`

which contains the executable file `fss_unipv.exe`;

`C:\programs\fss_unipv\doc\`

which contains the user guide `userguide.pdf`, in Acrobat format, and a template of the input file `filename.fss`;

```
C:\programs\fss_unipv\examples\
```

which contains some examples, stored in subfolders.

2.2   Running of the Code in DOS Mode

The code can be run either in a DOS shell, or in Windows mode. To run the code in DOS mode, the following steps are required:

- Add the bin directory to the PATH (*e.g.*, `C:\programs\fss_unipv\bin\`), modifying the `autoexec.bat` file

- Open a MS–DOS shell

- Move to the directory containing the input file `filename.fss`

- Run the code by the command: `fss_unipv filename`

2.3   Running of the Code in Windows Mode

To run the code in Windows mode, the following steps are required:

- When installing the code, click on an input file `filename.fss` with the right button of the mouse and choose: `Open with`; select `browse` and choose the application `fss_unipv.exe`.

  All the files with extension `.fss` will be associated to the executable file `fss_unipv.exe` from now on.

- The following analyses will start by double–clicking an `.fss` input file.

Chapter 3

Input and Output Files

3.1   Input file

The input data are given through an ASCII file:

`filename.fss`

The `filename.fss` file contains information concerning the periodicity of the structure, the goemetry of the aperture, the thickness of the metal screen, the angle of incidence and the frequency range of analysis (Figs. 3.1 and 3.2).

The data must be written in the prescribed order, following the template provided in `filename.fss` file.

There are two header lines, which are not decoded by the program. They can be used for comments (*e.g.*, for the title of the project).

Moreover, there are 8 numbered lines, describing the meaning of the input data. Such numbered lines, on the one hand, are decoded by the program, and, on the other hand, help the user in checking the inserted data.

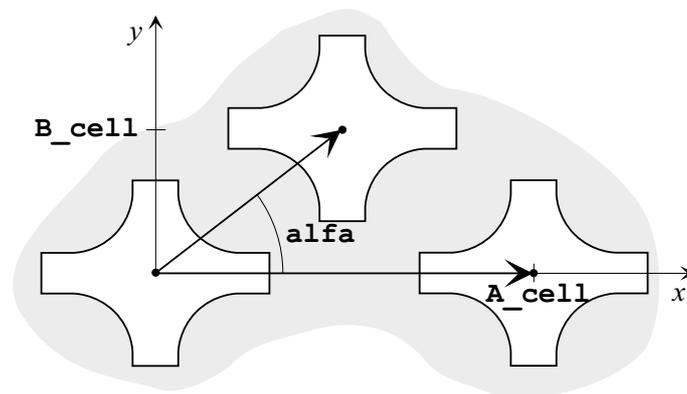No empty line is allowed in this file.

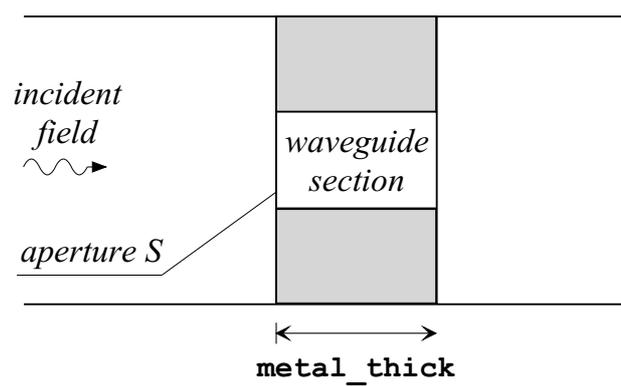Figure 3.1: Periodicity of the structure.

Figure 3.2: Side view of the Frequency Selective Surface.

The structure of the `filename.fss` file is the following:

```
FSS Code - University of Pavia
--------------------------------------
1) dimensions of the unit cell (A,B) [mm]
A_cell    B_cell
2) lattice angle (alfa) [deg]
alfa
3) metal thickness [mm]
metal_thick
4) geometry of the apertures [mm]
x₁ y₁ x₂ y₂
  ...
x₁ y₁ x₂ y₂ x₃ y₃
  ...
5) angles of incidence theta, phi [deg]
theta    phi
6) frequency range (f_min, f_max, f_step) [GHz]
freq₁    freq₂    Δfreq
7) max frequency waveguide modes [GHz]
max_freq_aperture_modes
8) max frequency Floquet modes [GHz]
max_freq_Floquet_modes
```

The meaning of the symbols is the following:

    A_cell B_cell

are the dimensions of the unit cell. These dimensions are given in mm.

    alfa

is the skew angle of the lattice expressed in degrees.

    metal_thick

is the thickness of the metal screen, given in mm.

The geometry of the aperture in block 4) is described through segments and arcs. A segment is described through the coordinates of the two extreme points P_1 and P_2 (see Fig. 3.3)

    x$_1$ y$_1$ x$_2$ y$_2$

whereas an arc is described through the coordinates of the two extreme points P_1 and P_2, and the coordinates of an intermediate point P_3.

    x$_1$ y$_1$ x$_2$ y$_2$ x$_3$ y$_3$

The segments and arcs do not need to be in any partucular order, but the line describing the boundary of the aperture must be closed.
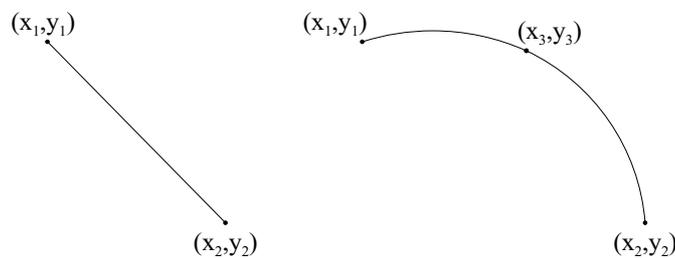

Figure 3.3: Definition of segments and arcs.

```
theta    phi
```

represent the angle of incidence of the uniform plane wave. All angles are given in degrees. In the Demo Version of the code, these angles must be zero (normal incidence). If different angles are set in the input file, the program gives and error message and stops.

```
freq₁ freq₂ Δfreq
```

freq_1 and freq_2 represent the limits of the loop in frequency, and Δfreq is the frequency step. All frequencies are given in GHz. If the analysis at a single frequency is needed (no frequency loop required), freq_1 and freq_2 must be set identical, and Δfreq must be different from 0. Note that $\text{freq}_1 = 0$ is meaningless and is not allowed.

```
max_freq_aperture_modes
```

is the maximum cutoff frequency of the waveguide modes used in the representation of the aperture fields. The frequency is given in GHz.

```
max_freq_Floquet_modes
```

is the maximum cutoff frequency of the Floquet modes used in the representation of the fields in free–space. The frequency is given in GHz.

Note that the choice of `max_freq_aperture_modes` and `max_freq_Floquet_modes` determines the convergence of the method. Therefore, these two values can be used as accuracy parameters.

3.2   Output file

The code generates an output file in ASCII format:

    filename.out

The `filename.out` file contains an header, and the simulation results in a format suitable for plotting by Software packages like Excel of Gnuplot.

As an header, the description of the version of the code and some information from the `filename.fss` input file are reported:

```
            ANALYSIS OF FREQUENCY SELECTIVE SURFACES
            ----------------------------------------
                    Demo Version - July 2002
                    by M. Bozzi & L. Perregrini
                    University of Pavia (Italy)
                              ****
   A = A_cell mm
   B = B_cell mm
   Skew angle = alfa deg
   Metal thickness = metal_thickness mm
   Number of basis functions = #_basis_functions
   Number of Floquet modes = #_Floquet_modes
```

where `A_cell`, `B_cell`, `alfa`, and `metal_thickness` are described in the previous section, and `#_basis_functions` and `#_Floquet_modes` are the number of aperture modes and of Floquet modes used in the analysis, respectively.

Afterwards, there is a line with 9 keywords describing the type of output data:

```
   freq[GHz] magTy[dB] phTy[deg] magTx[dB] phTx[deg]
             magRy[dB] phRy[deg] magRx[dB] phRx[deg]
```

followed by other lines containing the corresponding data calculated by the code.

The meaning of these keywords is the following:

    freq

is the frequency of analysis expressed in GHz.

    magTy

is the magnitude of the transmission coefficient of the plane wave polarized along the y–axis. It is expressed in dB.

    phTy

is the phase of the transmission coefficient of the plane wave polarized along the y–axis. It is expressed in deg.

    magTx

is the magnitude of the transmission coefficient of the plane wave polarized along the x–axis. It is expressed in dB.

    phTx

is the phase of the transmission coefficient of the plane wave polarized along the x–axis. It is expressed in deg.

    magRy

is the magnitude of the reflection coefficient of the plane wave polarized along the y–axis. It is expressed in dB.

    phRy

is the phase of the reflection coefficient of the plane wave polarized along the y–axis. It is expressed in deg.

    magRx

is the magnitude of the reflection coefficient of the plane wave polarized along the x–axis. It is expressed in dB.

> phRx

is the phase of the reflection coefficient of the plane wave polarized along the x–axis. It is expressed in *deg*.

Note that the phase of the transmission coefficients is defined as the difference of phase measured in transmission with and without the frequency selective surface.

References

M. Bozzi and L. Perregrini, "Efficient analysis of thin conductive screens perforated periodically with arbitrarily shaped apertures," *Electronics Letters*, Vol. 35, No. 13, pp. 1085–1087, 24 June 1999.

M. Bozzi, L. Perregrini, J. Weinzierl, and C. Winnewisser, "Design, Fabrication and Measurement of Frequency Selective Surfaces," *Optical Engineering*, Vol. 39, No. 8, pp. 2263–2269, Aug. 2000.

M. Bozzi, L. Perregrini, J. Weinzierl, and C. Winnewisser, "Efficient Analysis of Quasi–Optical Filters by a Hybrid MoM/BI–RME Method," *IEEE Transactions on Antennas and Propagation*, Vol. AP–49, No. 7, pp. 1054–1064, July 2001.

M. Bozzi and L. Perregrini, "Efficient Analysis of FSSs with Arbitrarily Shaped Patches by the MoM/BI–RME Method," *2001 IEEE APS International Symposium*, pp. 390–393, Boston, Massachusetts, USA, July 8–13, 2001.

M. Bozzi, F. Bruni, and L. Perregrini, "Analysis of Multi-Grid and Stepped-Waveguide FSS by the Segmentation Technique and the MoM/BI–RME Method," *2002 IEEE AP-S International Symposium*, San Antonio, Texas, USA, June 16–21, 2002.

P. Besso, M. Bozzi, L. Perregrini, L. Salghetti Drioli, and W. Nickerson, "Deep Space Antenna for Rosetta Mission: Design and Testing of the S/X–Band Dichroic Mirror," *IEEE Transactions on Antennas and Propagation*, Vol. AP–50, No. 12, Dec. 2002 (to appear).