# TEST CASE 2: Metal Cube with Metamaterial Coating

**Monostatic and bistatic RCS**

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## 1. *Definition of the Geometry*

The target is an aluminium cube with the side length $L_f$. One face of the cube is coated with a metamaterial absorber (Fig. 1). The absorber is a periodic array of copper Jerusalem crosses with the thickness $d_c$ on top of a dielectric layer (FR4) with the thickness $a_x$. The array of 71 x 71 unit cells covers an area with the side length $L_a$, which results in a margin of the width $w$ around it. Every unit cell is a square with the side length $a_y = a_z$; the crosses are built from copper stripes of the lengths $l_1$ and $l_2$ with the widths $c_1$ and $c_2$ (Fig. 2).

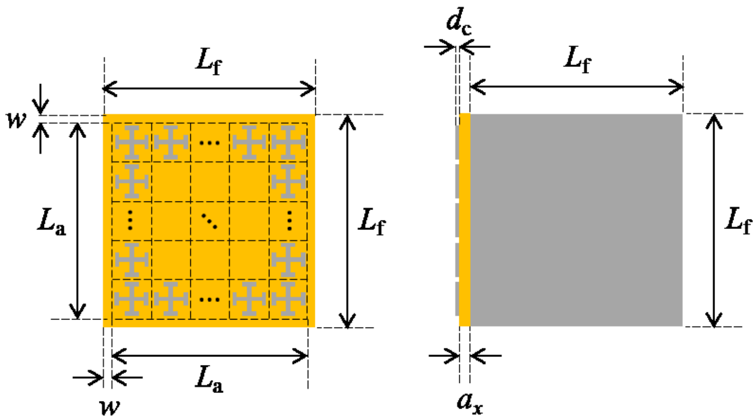


Figure 1. The front view (left) and a side view (right) of a metal cube. The front face is coated with a dielectric layer with a periodic array of metal cross-shaped patches.

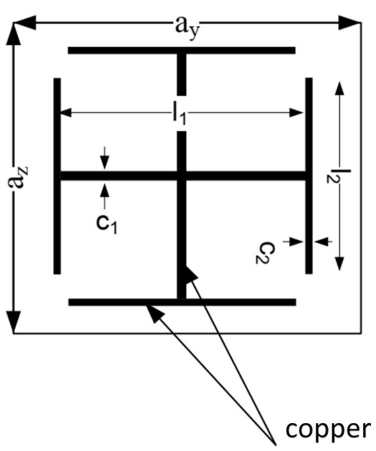


Figure 2: The unit cell of the metamaterial absorber.

The $x$-axis of the coordinate system is perpendicular to the coated face of the cube. The scattering geometry, monostatic and bistatic, is depicted in Fig. 3. In the monostatic case, the transmitting (Tx) and receiving (Rx) antennas are at the same location and move together around the target. In the bistatic case, the transmitter is fixed.

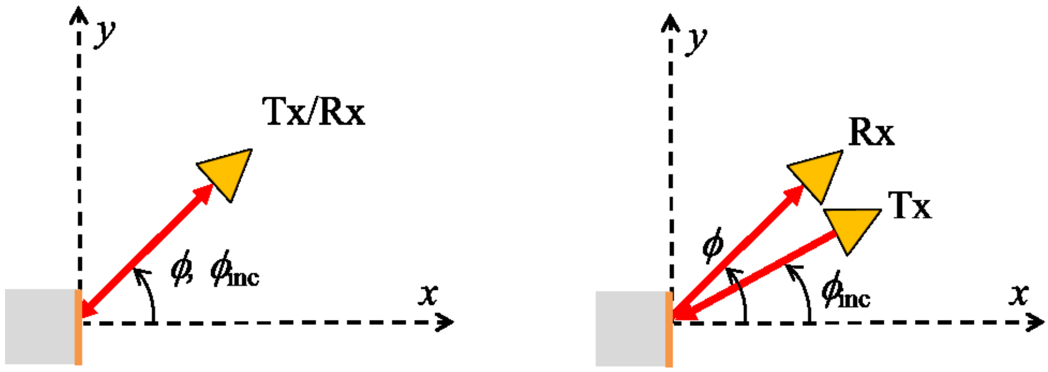


Figure 3. Monostatic (left) and bistatic (right) scattering geometry.

## 2. *Simulation Parameters*

The cube with the side length $L_f$ = 50 mm is assumed to be PEC. The dielectric layer (FR4 Panasonic R1755M) has the thickness $a_x$ = 0.05 mm, the relative permeability $\mu_r$ = 1 and the relative permittivity $\varepsilon_r = 4.4 - \mathrm{j}\,0.088$. The square unit cells with the side lengths $a_y = a_z$ = 0.7 mm are arranged in a 71 x 71 array, which takes up a square area with the side length $L_a$ = 49.7 mm. The array is located in the middle of the coated face with the margin $w$ = 0.15 mm. The strips are made from copper with the thickness $d_c$ = 0.005 mm, the width $c_1 = c_2$ = 0.075 mm and the lengths $l_1$ = 0.45 mm and $l_2$ = 0.3 mm.

Monostatic and bistatic RCS of the cube with and without the coating shall be simulated at 94 GHz. The results for the uncoated cube serve as a reference to evaluate the performance of the absorber. The assumed time dependence is $\exp(\mathrm{j}\omega t)$.

### *2.1. Reflection Coefficient of an Infinite Planar Array*

The reflection coefficient ($S_{11}$) of an infinite planar periodic array built from the unit cells shown in Fig. 2 is to be simulated for the normal incidence on the array in the frequency range from 90 GHz to 98 GHz with the step 0.01 GHz. The wave is incident at 90° to the surface of the array and polarized along a metal strip in the Jerusalem cross, i.e. along the $y$ axis.

### *2.2. Monostatic RCS*

The monostatic RCS is to be simulated in the $xy$ plane ($\theta = 90°$) for the azimuth angle ($\phi$) between 0° and 180° with the step $\Delta\phi$ = 0.2°. Co- and cross-polarization data should be provided for the coated and uncoated cubes.

### *2.3. Bistatic RCS*

The bistatic calculations for the coated and uncoated cubes are to be performed in the $xy$ plane with $\Delta\phi$ = 0.2° in the following cases (for all cases $\theta = \theta_{inc} = 90°$):

i) $\phi_{inc} = 0°$, $y$ –polarized incident wave (H polarization), $\sigma_\phi$ (HH) and $\sigma_\theta$ (VH) for $\phi$ between 0 and 180°

ii) $\phi_{inc} = 0°$, $z$ –polarized incident wave (V polarization), $\sigma_\phi$ (HV) and $\sigma_\theta$ (VV) for $\phi$ between 0 and 180°

iii) $\phi_{inc} = 45°$, incident wave polarized in the $xy$ plane (H polarization), $\sigma_\phi$ (HH) and $\sigma_\theta$ (VH) for $\phi$ between 0 and 360°

iv) $\phi_{inc} = 45°$, $z$ –polarized incident wave (V polarization), $\sigma_\phi$ (HV) and $\sigma_\theta$ (VV) for $\phi$ between 0 and 360°.

3. *Data Formats*

The results will be stored in ASCII files, named as:

- *test_case_2_array_CONTRIBUTOR_NAME.txt*
- *test_case_2_mono_PEC_CONTRIBUTOR_NAME.txt*
- *test_case_2_mono_MTM_CONTRIBUTOR_NAME.txt*
- *test_case_2_bi1_PEC_CONTRIBUTOR_NAME.txt*
- *test_case_2_bi1_MTM_CONTRIBUTOR_NAME.txt*
- *test_case_2_bi2_PEC_CONTRIBUTOR_NAME.txt*
- *test_case_2_bi2_MTM_CONTRIBUTOR_NAME.txt*
- *test_case_2_bi3_PEC_CONTRIBUTOR_NAME.txt*
- *test_case_2_bi3_MTM_CONTRIBUTOR_NAME.txt*
- *test_case_2_bi4_PEC_CONTRIBUTOR_NAME.txt*
- *test_case_2_bi4_MTM_CONTRIBUTOR_NAME.txt*

where “CONTRIBUTOR_NAME” should be replaced by the name of the contributing institution, if necessary followed by a postfix indicating the method used for the simulations, e.g., Contributor1_FDTD, Contributor1_MoM,…

The array file (“*test_case_2_array_...”)* should be written in the format:

F  Re $S_{11}$  Im $S_{11}$  Abs($S_{11}$)

where F is the frequency in GHz, S11 is the S parameter (ratio of the reflected and transmitted signals), Re $S_{11}$ and Im $S_{11}$ denote the real and imaginary parts of the S parameter and Abs($S_{11}$) is the absolute value of the parameter in dB, i.e. 20 lg(Abs ($S_{11}$)).

The monostatic file (“*test_case_2_mono_...”)* should be written in the format:

$\phi$  Abs($\sigma_{VV}$)  Abs($\sigma_{HV}$)  Abs($\sigma_{VH}$)  Abs($\sigma_{HH}$)

where $\phi$ is the angle in degrees, and Abs($\sigma_{VV}$), Abs($\sigma_{HV}$), Abs($\sigma_{VH}$) and Abs($\sigma_{HH}$) denote the monostatic RCS in dBm² (10 lg $|\sigma|$) for the respective polarization cases.

The bistatic files should have either the format

$\phi$  Abs($\sigma_{VV}$)  Abs($\sigma_{HV}$)

when the incident field is $z$ polarized or

$\phi$ Abs($\sigma_{VH}$) Abs($\sigma_{HH}$)

when the incident wave is horizontally polarized. $\phi$ is the azimuth angle in degrees, and Abs($\sigma_{VV}$), Abs($\sigma_{HV}$), Abs($\sigma_{VH}$) and Abs($\sigma_{HH}$) are the bistatic RCS in dBm² for the respective polarization cases.

## 4. *Additional Information*

Each *.txt* file should be accompanied by an *.info* file, stating additional information relevant for the simulation, e.g., short description of the method used, CPU time, memory usage, number of unknowns, characteristics of simulation hardware (number of cores, processor speed),…