Created in COMSOL Multiphysics 6.2

Fast Asymptotic Radar Cross-Section Analysis of a Conductive Sphere

Introduction

This example uses asymptotic techniques to study the radar cross-section (RCS) response of a conductive sphere. The selected physics interface transforms the incident plane-wave field on the boundaries to the far-field using the Stratton–Chu formula. The computed results are compared to the well-known asymptotic RCS value of a conductive sphere in the optical region. The optical region is one of three scattering regions used in radar terminology. The other regions are the Rayleigh and Mie regions. See Table 1 below for a discussion of the characteristic sphere size a for the three scattering regions.

TABLE 1: RADAR TERMINOLOGY SCATTERING REGIONS

REGION	**SIZE OF A SPHERE**
Rayleigh	$r_0 << \lambda_0$
Mie	Between Rayleigh and optical region
Optical	$r_0 >> \lambda_0$, conventionally $2\pi r_0/\lambda_0 > 10$

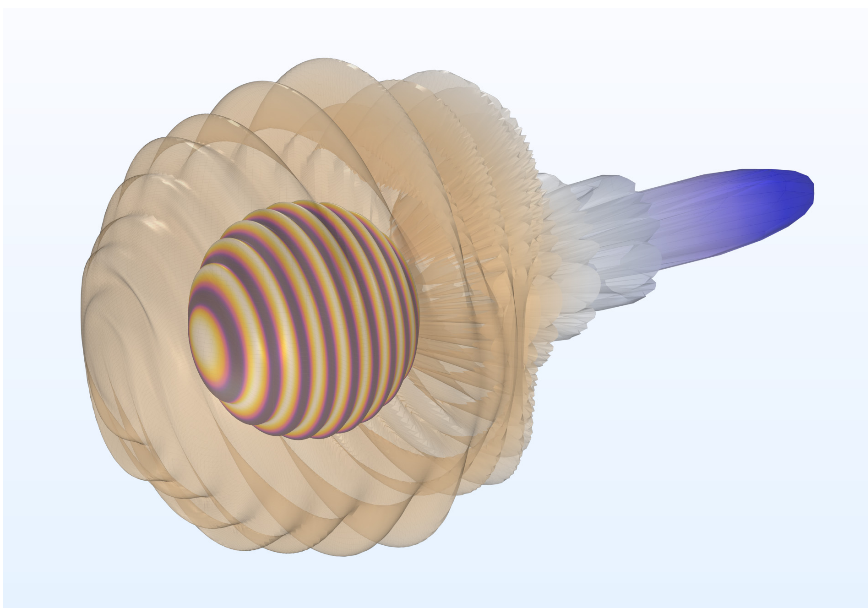


Figure 1: The background field incident on the surface of a PEC sphere is plotted with the 3D RCS pattern that is partially transparent.

Model Definition

The Electromagnetic Waves, Asymptotic Scattering physics interface is useful when approximating the scattered far-field of an object configured only by a perfect electric conductor (PEC) boundary condition. The incident background field is a z-polarized wave propagating along the positive x-axis. Only PEC is available in this physics interface. So, the sphere is set to a PEC by default. The far-field calculation feature transforms the surface background field on the metallic scatterer to the far-field. There is no need to add a surrounding air domain and absorbing boundary condition as in a typical finite element analysis.

Results and Discussion

After computation, two default plots are generated. They are the surface plot of the background field on the sphere (Figure 2) and the 1D plot of the RCS (Figure 3). Figure 2 shows the z-component of the background field projected on the conductive sphere. The field has a sinusoidal spatial variation with a wavelength corresponding to the simulation frequency 30 GHz.

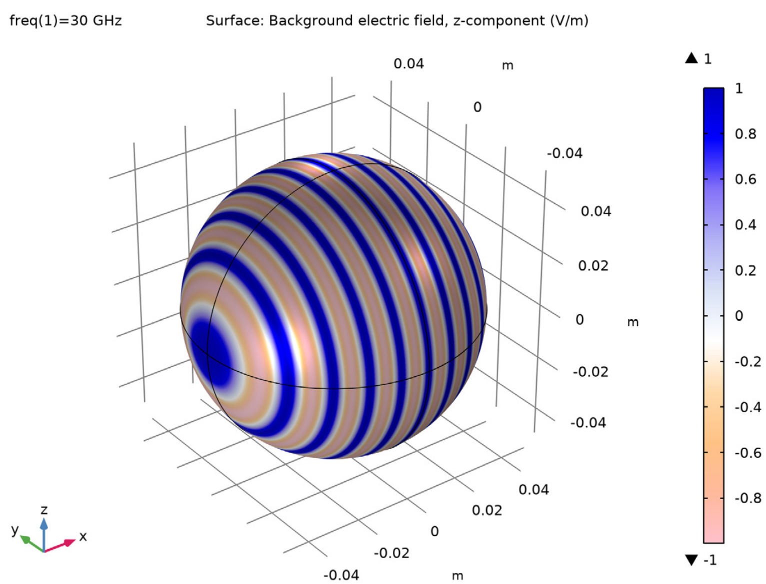


Figure 2: The z-component of the background electric field on the surface of a metallic sphere modeled as perfect electric conductor.

The default RCS plot is modified to show the logarithmic value of the bistatic RCS. When calculating the monostatic RCS, the incident angle of the background field increases corresponding to every RCS observation angle. Here, the bistatic analysis is simpler: the propagation direction of the background field is fixed at one angle while measuring the RCS at each angle of observation. For an electrically large sphere in the optical region, the reference RCS value can be calculated by

$$\sigma = \pi r_0^2$$

where r_0 is the radius of a sphere.

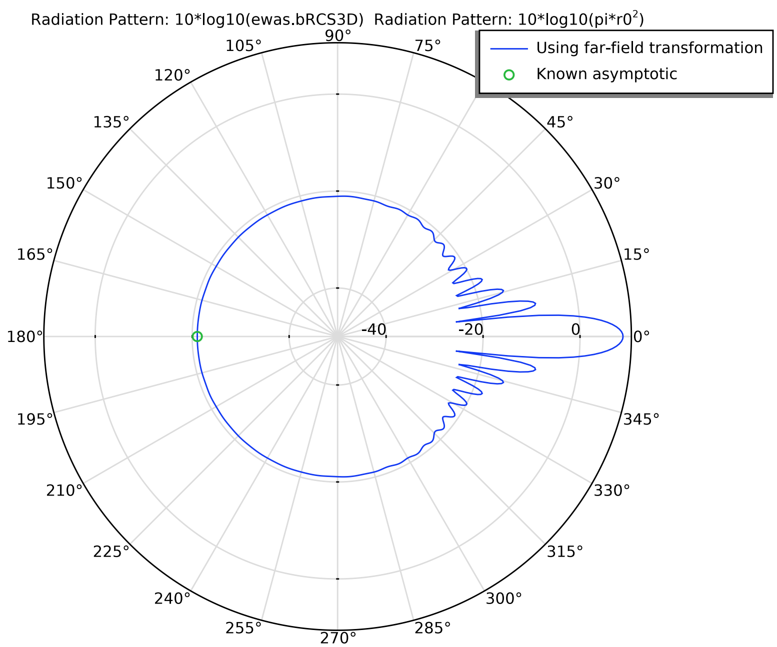


Figure 3: The dB-scaled bistatic RCS plot with the known asymptotic RCS value of the sphere in the optical region.

Notes About the COMSOL Implementation

The Compute action does not perform a real computation. Instead, it is a preprocess for the far-field transformation used in the results plot. At the moment you click one of the generated default plots, the postprocessing of a far-field expression is conducted. Though it is a fast asymptotic method, it still takes time to visualize the 3D far-field response of a finely meshed structure, which is an electrically large scatterer in terms of wavelengths.

The usage of this specific physics interface is limited to a convex-shaped scatterer where multiple reflections are not expected.

Application Library path: `RF_Module/Scattering_and_RCS/rcs_sphere_asymptotic`

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click **Model Wizard**.

MODEL WIZARD

1 In the **Model Wizard** window, click **3D**.

2 In the **Select Physics** tree, select **Radio Frequency>Electromagnetic Waves, Asymptotic Scattering (ewas)**.

3 Click **Add**.

4 Click **Study**.

5 In the **Select Study** tree, select **General Studies>Frequency Domain**.

6 Click **Done**.

GLOBAL DEFINITIONS

Parameters 1

1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.

2 In the **Settings** window for **Parameters**, locate the **Parameters** section.

3 In the table, enter the following settings:

Name	Expression	Value	Description
f0	30[GHz]	3E10 Hz	Frequency
lda0	c_const/f0	0.0099931 m	Wavelength
r0	5*lda0	0.049965 m	Sphere radius

STUDY 1

Step 1: Frequency Domain

Define the study frequency ahead of performing any frequency-dependent operation such as building mesh. The physics-controlled mesh uses the specified frequency value.

1 In the **Model Builder** window, under **Study 1** click **Step 1: Frequency Domain**.

2 In the **Settings** window for **Frequency Domain**, locate the **Study Settings** section.

3 In the **Frequencies** text field, type `f0`.

GEOMETRY 1

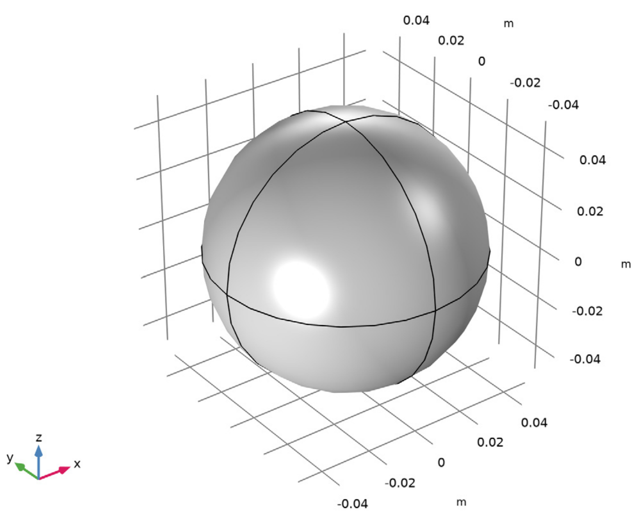
Sphere 1 (sph1)

1 In the **Geometry** toolbar, click **Sphere**.

2 In the **Settings** window for **Sphere**, locate the **Size** section.

3 In the **Radius** text field, type `r0`.

4 Click **Build All Objects**.

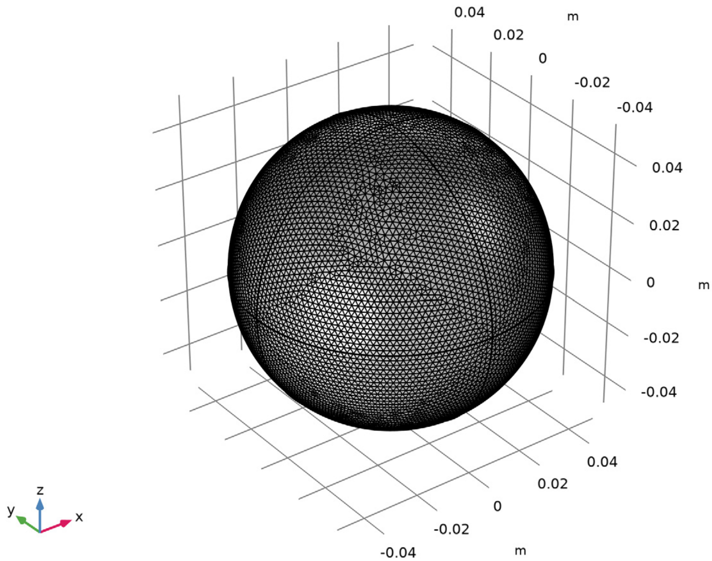


ELECTROMAGNETIC WAVES, ASYMPTOTIC SCATTERING (EWAS)

Use the default settings. The z-polarized plane-wave background field is propagating in the positive x direction in vacuum.

MESH 1

In the **Model Builder** window, under **Component 1 (comp1)** right-click **Mesh 1** and choose **Build All**.

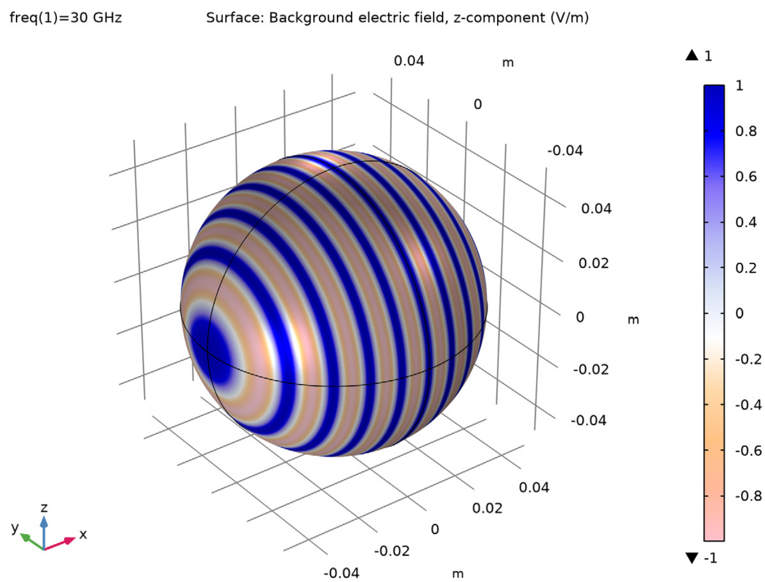


STUDY 1

In the **Home** toolbar, click **Compute**.

RESULTS

Background Electric Field (ewas)



This is the background electric field (z-component) illuminating the sphere.

RCS, xy-plane

1 In the **Model Builder** window, expand the **Results>Radar Cross Section (ewas)** node, then click **Radiation Pattern 1**.

2 In the **Settings** window for **Radiation Pattern**, type `RCS, xy-plane` in the **Label** text field.

3 Locate the **Evaluation** section. Find the **Angles** subsection. In the **Number of angles** text field, type `720`.

4 Click to expand the **Legends** section. Select the **Show legends** check box.

5 From the **Legends** list, choose **Manual**.

6 In the table, enter the following settings:

Legends
`Using far-field transformation`

7 Right-click **RCS, xy-plane** and choose **Duplicate**.

RCS, known asymptotic in the optical region

1. In the **Model Builder** window, under **Results>Radar Cross Section (ewas)** click **RCS, xy-plane 1**.
2. In the **Settings** window for **Radiation Pattern**, type `RCS, known asymptotic in the optical region` in the **Label** text field.
3. Locate the **Expression** section. In the **Expression** text field, type `10*log10(pi*r0^2)`.
4. Locate the **Legends** section. In the table, enter the following settings:

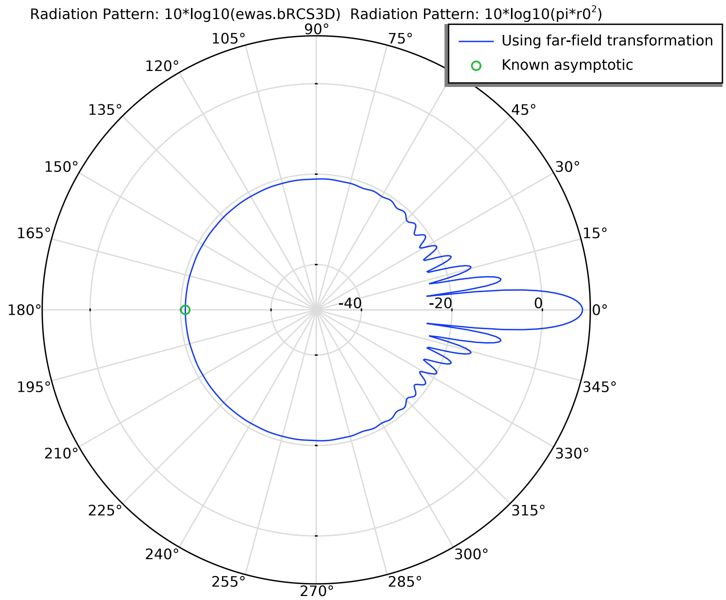
Legends
`Known asymptotic`

5. Click to expand the **Coloring and Style** section. Find the **Line style** subsection. From the **Line** list, choose **None**.
6. Find the **Line markers** subsection. From the **Marker** list, choose **Circle**.
7. In the **Number** text field, type `1`.

Radar Cross Section (ewas)

1. In the **Model Builder** window, click **Radar Cross Section (ewas)**.
2. In the **Settings** window for **Polar Plot Group**, locate the **Axis** section.
3. Select the **Manual axis limits** check box.
4. In the **r minimum** text field, type `-50`.

5 In the **Radar Cross Section (ewas)** toolbar, click **Plot**.



The computed bistatic radar cross-section (RCS) results are compared to the known asymptotic backward scattering RCS value in the optical region.