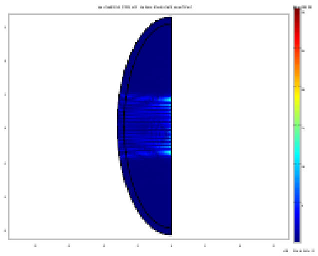
COMSOL Model Report



1. Table of Contents

2. Model Properties

Property	Value
Model name	
Author	
Company	
Department	
Reference	
URL	
Saved date	Jan 11, 2011 10:43:53 AM
Creation date	Jan 11, 2011 10:11:54 AM
COMSOL version	COMSOL 3.5.0.603

File name: C:\Users\TXGONG\Desktop\WGM 2Dsymmetry.mph

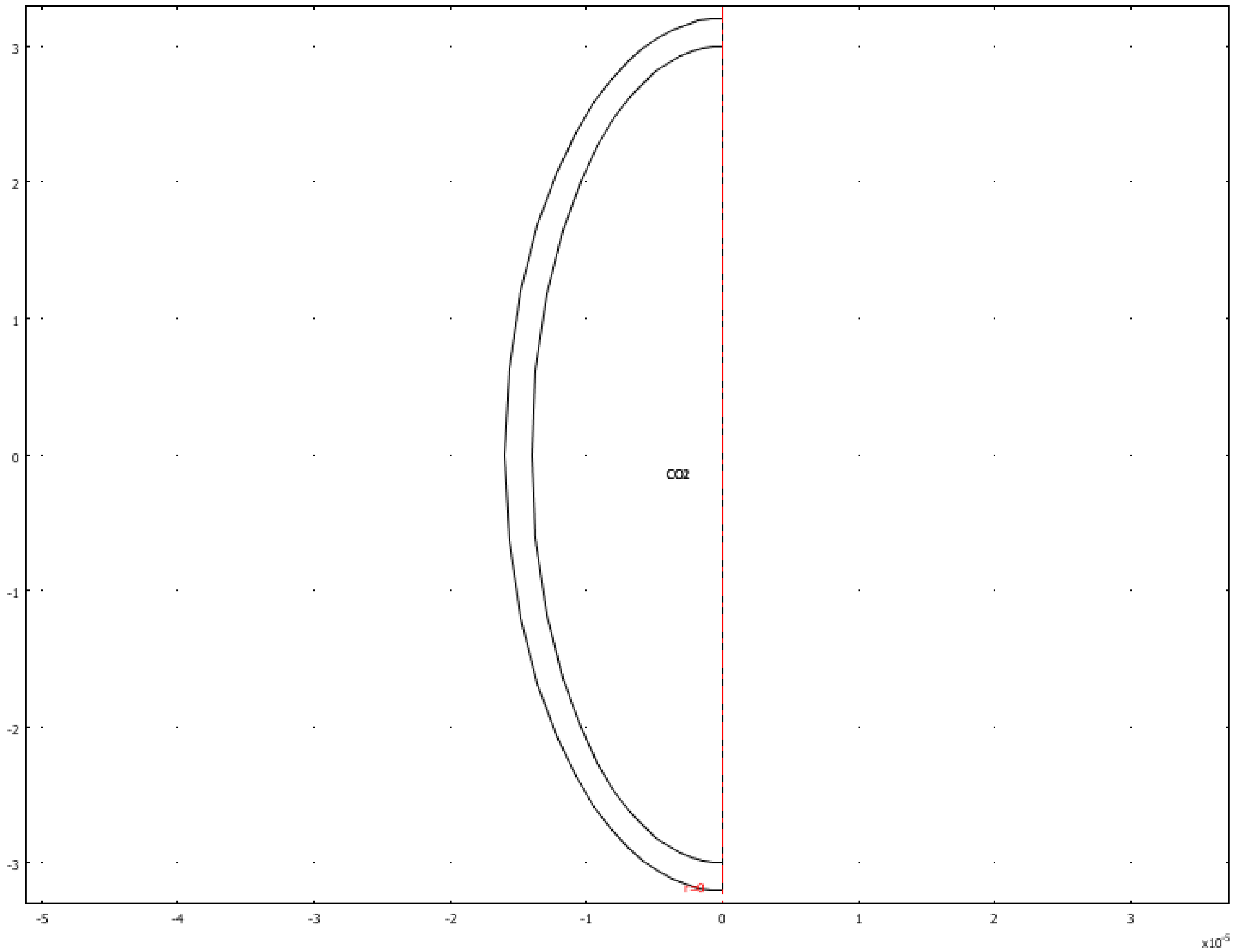
Application modes and modules used in this model:

- Geom1 (Axial symmetry (2D))
  - Hybrid-Mode Waves (RF Module)

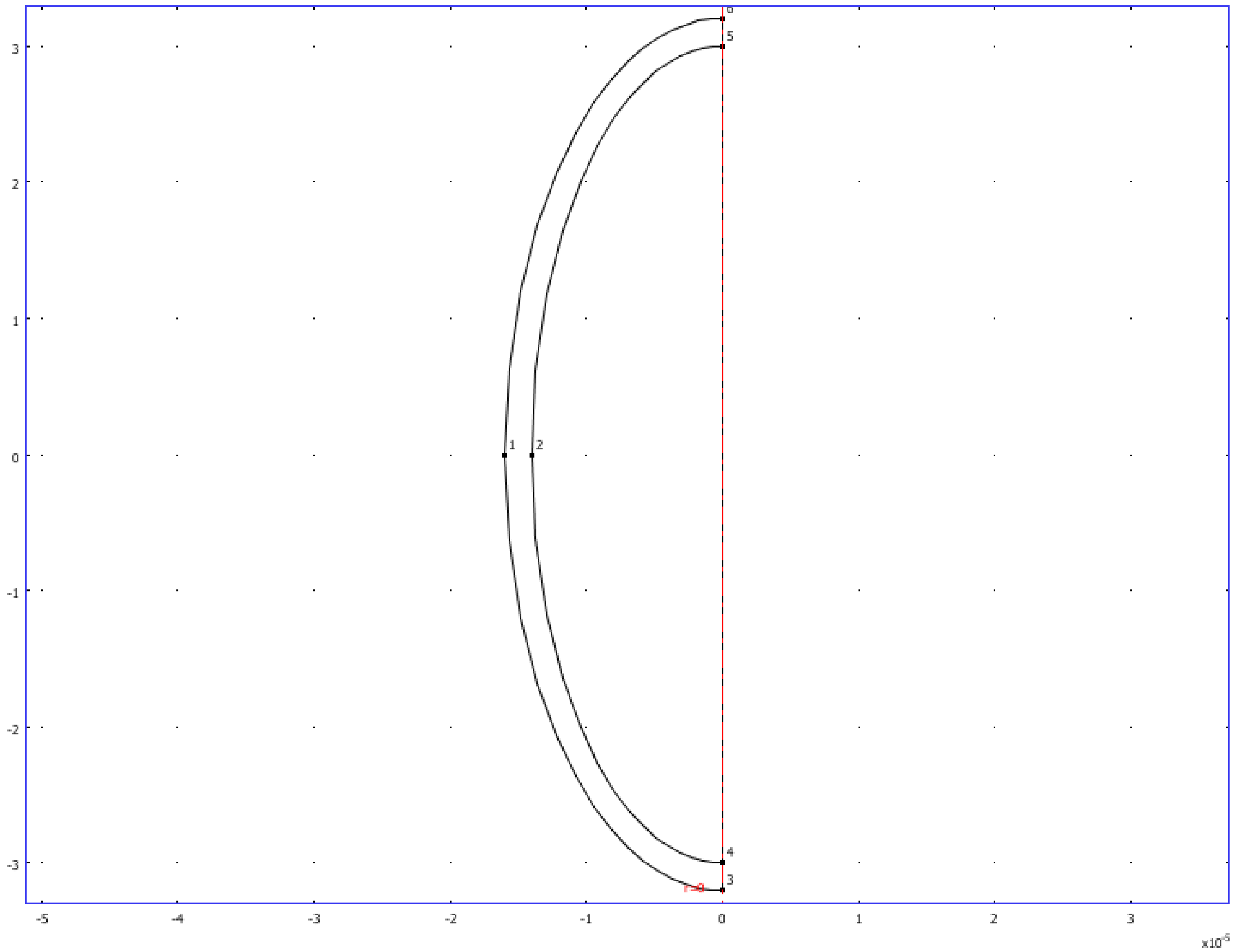
3. Geometry

Number of geometries: 1

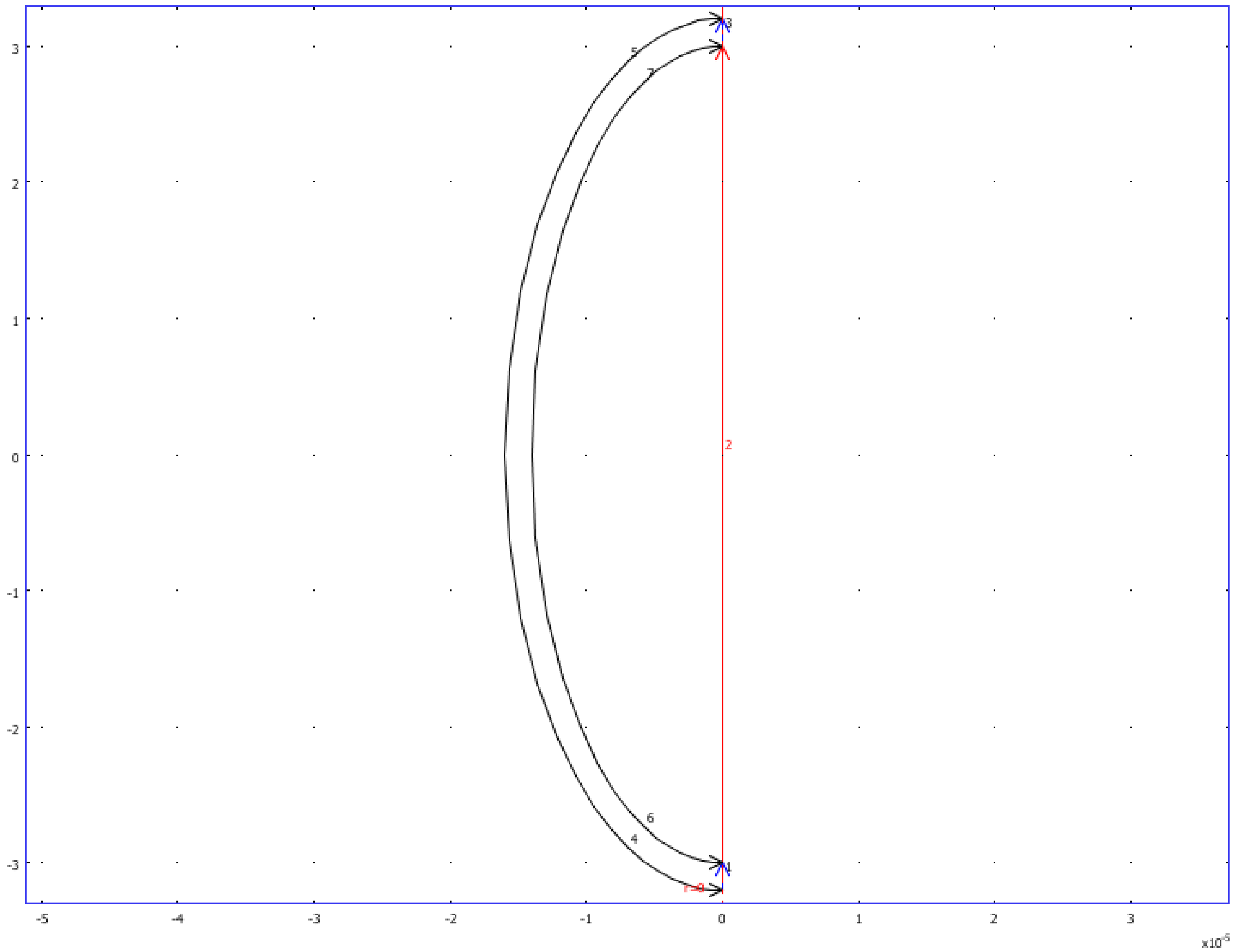
3.1. Geom1



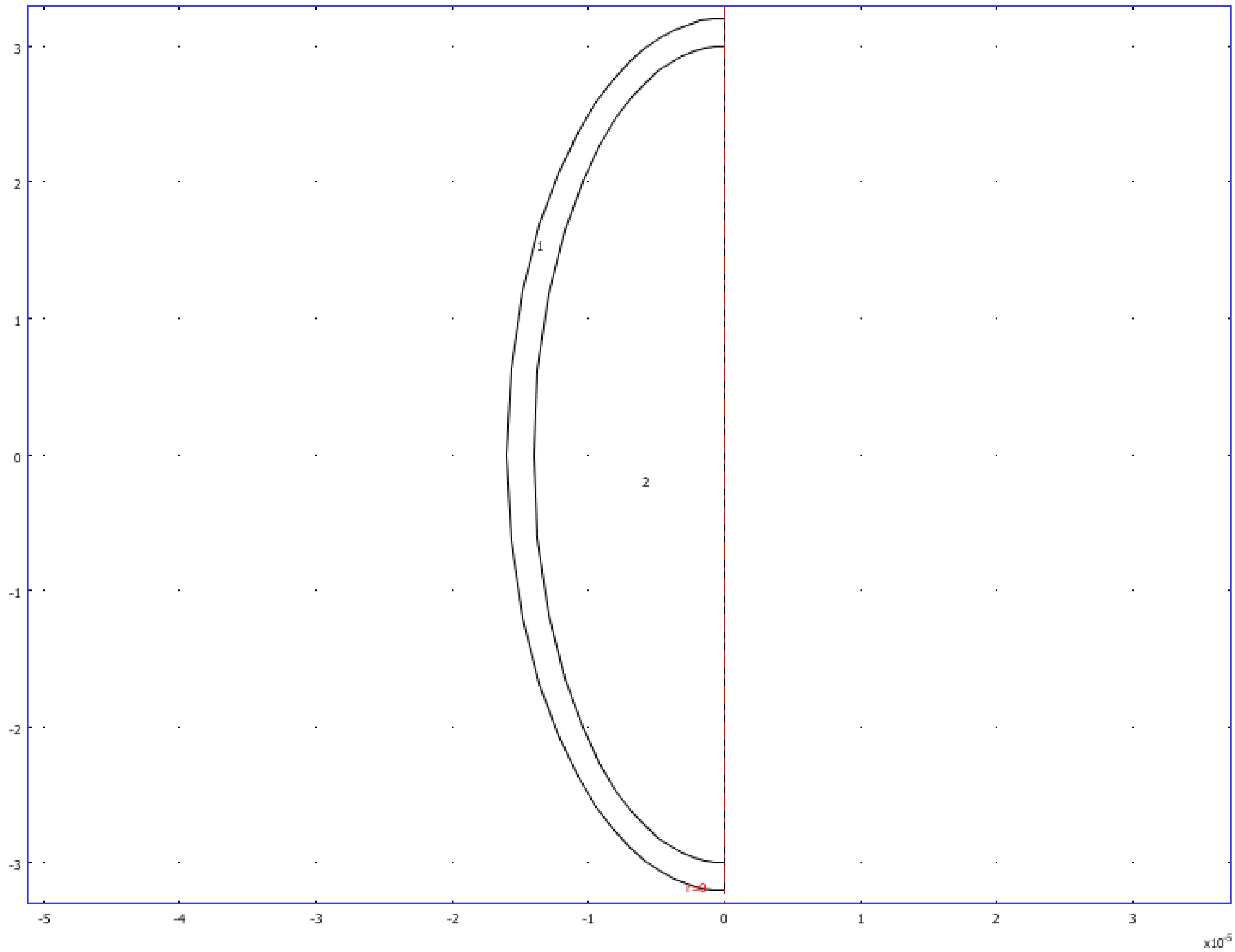
3.1.1. Point mode



3.1.2. Boundary mode



3.1.3. Subdomain mode



4. Geom1

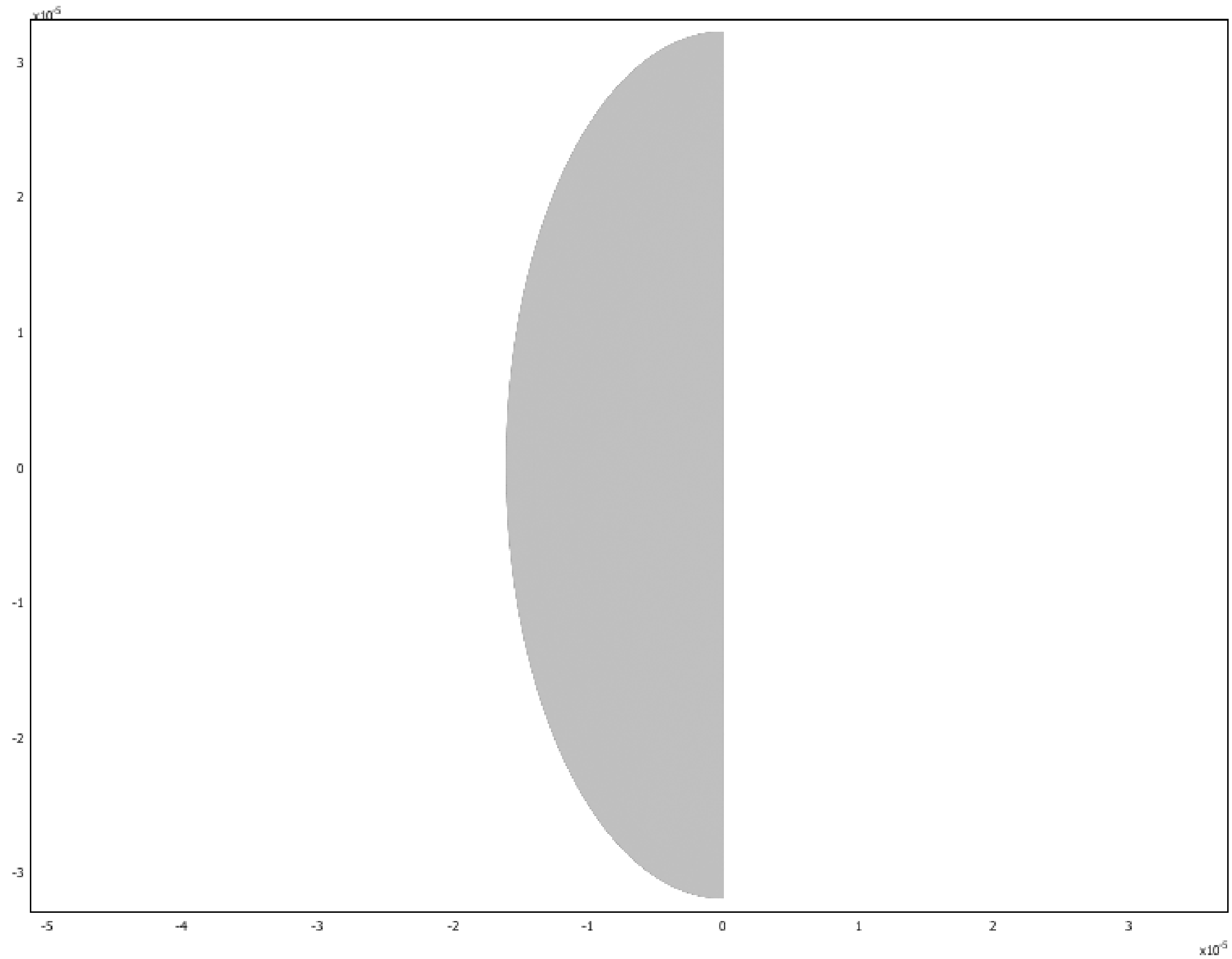
Space dimensions: Axial symmetry (2D)

Independent variables: r, phi, z

4.1. Mesh

4.1.1. Mesh Statistics

Number of degrees of freedom	953346
Number of mesh points	119553
Number of elements	237568
Triangular	237568
Quadrilateral	0
Number of boundary elements	2432
Number of vertex elements	6
Minimum element quality	0.726
Element area ratio	0.096



4.2. Application Mode: Hybrid-Mode Waves (rfweh)

Application mode type: Hybrid-Mode Waves (RF Module)

Application mode name: rfweh

4.2.1. Scalar Variables

Name	Variable	Value	Unit	Description
epsilon0	epsilon0_rfweh	8.854187817e-12	F/m	Permittivity of vacuum
mu0	mu0_rfweh	4*pi*1e-7	H/m	Permeability of vacuum

4.2.2. Application Mode Properties

Property	Value
Default element type	Lagrange - Quadratic
Analysis type	Eigenfrequency
Field type	Hybrid-mode waves
Specify wave using	Frequency
Specify eigenvalues using	Eigenfrequency
Divergence condition	Off
Frame	Frame (ref)

Weak constraints	Off
Vector element constraint	Off
Constraint type	Ideal

4.2.3. Variables

Dependent variables: Ephi, Hphi, Ar, Aphi, Az, scEphi, scHphi, psi

Shape functions: shlag(2,'Ephi'), shlag(2,'Hphi')

Interior boundaries not active

4.2.4. Boundary Settings

Boundary		1-3	4-5
Type		Axial symmetry	Perfect electric conductor

4.2.5. Subdomain Settings

Subdomain		1	2
Refractive index (n)	1	**{1.44,0,0;0,1.44,0;0,0,1.44}**	**{1.6,0,0;0,1.6,0;0,0,1.6}**
matparams		**n**	**n**
Absorbing in # direction (coordOn)		**{1;0}**	{0;0}

5. Solver Settings

Solve using a script: off

Analysis type	Eigenfrequency
Auto select solver	On
Solver	Eigenfrequency
Solution form	Automatic
Symmetric	auto
Adaptive mesh refinement	Off
Optimization/Sensitivity	Off
Plot while solving	Off

5.1. Direct (UMFPACK)

Solver type: Linear system solver

Parameter	Value
Pivot threshold	0.1
Memory allocation factor	0.7

5.2. Eigenfrequency

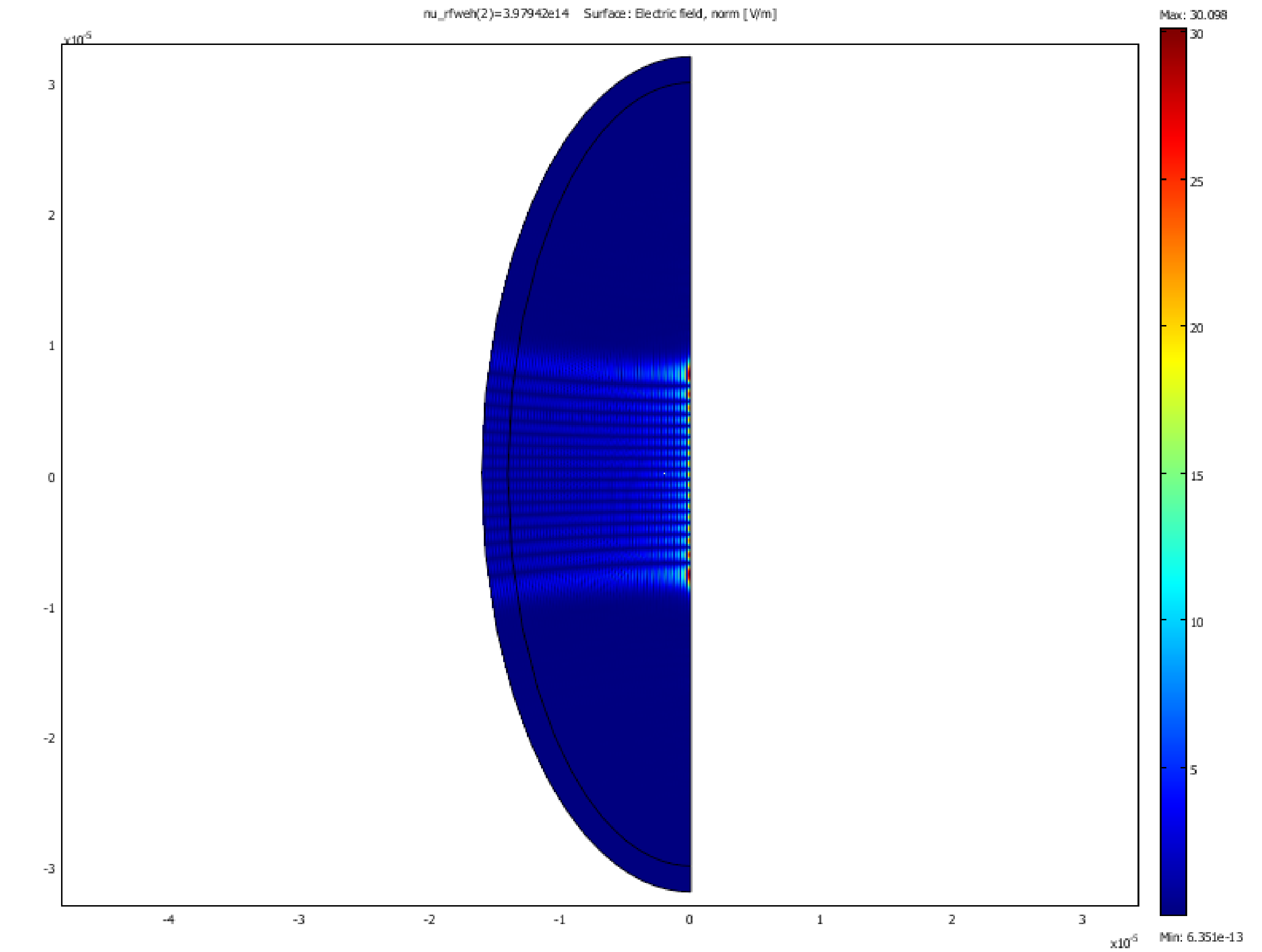
Parameter	Value
Desired number of eigenvalues	15
Search for eigenvalues around	3.98e14
Eigenvalue tolerance	0.0

Maximum number of eigenvalue iterations	300
Dimension of Krylov space	0

5.3. Advanced

Parameter	Value
Constraint handling method	Elimination
Null-space function	Automatic
Automatic assembly block size	On
Assembly block size	1000
Use Hermitian transpose of constraint matrix and in symmetry detection	Off
Use complex functions with real input	On
Stop if error due to undefined operation	On
Store solution on file	Off
Type of scaling	Automatic
Manual scaling	
Row equilibration	On
Manual control of reassembly	Off
Load constant	On
Constraint constant	On
Mass constant	On
Damping (mass) constant	On
Jacobian constant	On
Constraint Jacobian constant	On

6. Postprocessing



6.1. Eigenfrequency

3.979286981133166E14
3.979419826775022E14
3.979573529726887E14
3.979611734637679E14
3.9797830984859594E14
3.979797915907824E14
3.979835959958815E14
3.979858933102335E14
3.979990830242607E14
3.980047240616253E14
3.9801895857199925E14
3.9803402976554225E14
3.9804022000357956E14
3.980577649115981E14
3.980626755111642E14

7. Variables

7.1. Boundary

Name	Description	Unit	Expression
dVolbnd_rfweh	Area integration contribution	m	Sr_rfweh
Jsphi_rfweh	Surface current density, phi component	A/m	-unr * (Hz_rfweh_down-Hz_rfweh_up)+unz * (Hr_rfweh_down-Hr_rfweh_up)
Qsav_rfweh	Surface resistive heating, time average	W/m^2	0.5 * real(Jsphi_rfweh * conj(Ephi))
nPoav_rfweh	Power outflow, time average	W/m^2	nr_rfweh * Porav_rfweh+nz_rfweh * Pozav_rfweh
Z_TE_rfweh	Wave impedance, TE waves	ohm	omega_rfweh * mu_rfweh/betaport_rfweh
Z_TM_rfweh	Wave impedance, TM waves	ohm	betaport_rfweh/(omega_rfweh * epsilon_rfweh)
Z_TEM_rfweh	Wave impedance, TEM waves	ohm	sqrt(mu_rfweh/epsilon_rfweh)
Pin_port_rfweh	Port power level for the inport	W	Pport_rfweh
wport_rfweh	Width of port	m	
hport_rfweh	Height of port	m	
ahr_rfweh	Voltage reference direction, r component	1	
ahz_rfweh	Voltage reference direction, z component	1	

7.2. Subdomain

Name	Description	Unit	Expression
SRcoord_rfweh	PML radial coordinate		
Sr_rfweh	PML r coordinate	m	r
S0r_guess_rfweh	Inner r coordinate default guess	m	0
Sdr_guess_rfweh	Width in r direction default guess	m	0
rCylr_rfweh	PML r cylindrical vector, r component	m	
Sz_rfweh	PML z coordinate	m	z
S0z_guess_rfweh	Inner z coordinate default guess	m	0
Sdz_guess_rfweh	Width in z direction default guess	m	0
rCylz_rfweh	PML r cylindrical vector, z component	m	
detJ_rfweh	PML transformation matrix determinant	1	1
Jrr_rfweh	PML transformation matrix, element rr	1	1
invJrr_rfweh	PML inverse transformation matrix, element rr	1	1
Jrz_rfweh	PML transformation matrix, element rz	1	0
invJrz_rfweh	PML inverse transformation matrix, element rz	1	0
Jzr_rfweh	PML transformation matrix, element zr	1	0
invJzr_rfweh	PML inverse transformation matrix, element zr	1	0

Jzz_rfweh	PML transformation matrix, element zz	1	1
invJzz_rfweh	PML inverse transformation matrix, element zz	1	1
k_rfweh	Wave number	1/m	k0_rfweh * sqrt(mur_rfweh * (epsilonr_rfweh+sigma_rfweh/(jomega_rfweh * epsilon0_rfweh)))
dVol_rfweh	Volume integration contribution	m	Sr_rfweh * detJ_rfweh
c_rfweh	Phase velocity	m/s	c0_rfweh/sqrt(epsilonr_rfweh * mur_rfweh)
Z_wave_rfweh	Wave impedance	ohm	c_rfweh * mu0_rfweh * mur_rfweh
delta_rfweh	Skin depth	m	1/real(sqrt(j * omega_rfweh * mu0_rfweh * mur_rfweh * (sigma_rfweh+j * omega_rfweh * epsilon0_rfweh * epsilonr_rfweh)))
curlHr_rfweh	Curl of magnetic field, r component	A/m^2	-Hphiz
curlHz_rfweh	Curl of magnetic field, z component	A/m^2	if(abs(r)<0.001 * h,Hphir,Hphi/Sr_rfweh)+Hphir
depHphi_rfweh	Magnetic field test variable, phi component	A/m	Hphi
curlEr_rfweh	Curl of electric field, r component	V/m^2	-Ephiz
curlEz_rfweh	Curl of electric field, z component	V/m^2	if(abs(r)<0.001 * h,Ephir,Ephi/Sr_rfweh)+Ephir
depEphi_rfweh	Electric field test variable, phi component	V/m	Ephi
Qmav_rfweh	Magnetic hysteresis losses	W/m^3	real(0.5 * j * omega_rfweh * (Br_rfweh * conj(Hr_rfweh) +Bphi_rfweh * conj(Hphi)+Bz_rfweh * conj(Hz_rfweh)))
epsilon_rfweh	Permittivity	F/m	epsilon0_rfweh * epsilonr_rfweh
epsilonrr_rfweh	Permittivity, rr component	F/m	epsilon0_rfweh * epsilonrrr_rfweh
epsilonrphi_rfweh	Permittivity, rphi component	F/m	epsilon0_rfweh * epsilonrrphi_rfweh
epsilonrz_rfweh	Permittivity, rz component	F/m	epsilon0_rfweh * epsilonrrz_rfweh
epsilonphir_rfweh	Permittivity, phir component	F/m	epsilon0_rfweh * epsilonrphir_rfweh
epsilonphiphi_rfweh	Permittivity, phiphi component	F/m	epsilon0_rfweh * epsilonrphiphi_rfweh
epsilonphiz_rfweh	Permittivity, phiz component	F/m	epsilon0_rfweh * epsilonrphiz_rfweh
epsilonzr_rfweh	Permittivity, zr component	F/m	epsilon0_rfweh * epsilonrzr_rfweh
epsilonzphi_rfweh	Permittivity, zphi component	F/m	epsilon0_rfweh * epsilonrzphi_rfweh
epsilonzz_rfweh	Permittivity, zz component	F/m	epsilon0_rfweh * epsilonrzz_rfweh
mu_rfweh	Permeability	H/m	mu0_rfweh * mur_rfweh
murr_rfweh	Permeability, rr component	H/m	mu0_rfweh * murrr_rfweh
murphi_rfweh	Permeability, rphi component	H/m	mu0_rfweh * murrphi_rfweh

murz_rfweh	Permeability, rz component	H/m	mu0_rfweh * murrz_rfweh
muphir_rfweh	Permeability, phir component	H/m	mu0_rfweh * murphir_rfweh
muphiphi_rfweh	Permeability, phiphi component	H/m	mu0_rfweh * murphiphi_rfweh
muphiz_rfweh	Permeability, phiz component	H/m	mu0_rfweh * murphiz_rfweh
muzr_rfweh	Permeability, zr component	H/m	mu0_rfweh * murzr_rfweh
muzphi_rfweh	Permeability, zphi component	H/m	mu0_rfweh * murzphi_rfweh
muzz_rfweh	Permeability, zz component	H/m	mu0_rfweh * murzz_rfweh
Dr_rfweh	Electric displacement, r component	C/m^2	epsilonrr_rfweh * Er_rfweh+epsilonrz_rfweh * Ez_rfweh
Jdr_rfweh	Displacement current density, r component	A/m^2	jomega_rfweh * Dr_rfweh
Jir_rfweh	Induced current density, r component	A/m^2	sigmarr_rfweh * Er_rfweh+sigmarz_rfweh * Ez_rfweh
jwHr_rfweh	Magnetic field, r component, times jω	A/(m*s)	jwBr_rfweh/mu0_rfweh
Hr_rfweh	Magnetic field, r component	A/m	jwHr_rfweh/jomega_rfweh
Er_rfweh	Electric field, r component	V/m	jwEr_rfweh/jomega_rfweh
jwEr_rfweh	Electric field, r component, times jω	m*kg/(s^4*A)	curlHr_rfweh/(n_rfweh^2 * epsilon0_rfweh)
Dz_rfweh	Electric displacement, z component	C/m^2	epsilonzr_rfweh * Er_rfweh+epsilonzz_rfweh * Ez_rfweh
Jdz_rfweh	Displacement current density, z component	A/m^2	jomega_rfweh * Dz_rfweh
Jiz_rfweh	Induced current density, z component	A/m^2	sigmazr_rfweh * Er_rfweh+sigmazz_rfweh * Ez_rfweh
jwHz_rfweh	Magnetic field, z component, times jω	A/(m*s)	jwBz_rfweh/mu0_rfweh
Hz_rfweh	Magnetic field, z component	A/m	jwHz_rfweh/jomega_rfweh
Ez_rfweh	Electric field, z component	V/m	jwEz_rfweh/jomega_rfweh
jwEz_rfweh	Electric field, z component, times jω	m*kg/(s^4*A)	curlHz_rfweh/(n_rfweh^2 * epsilon0_rfweh)
Dphi_rfweh	Electric displacement, phi component	C/m^2	epsilonphiphi_rfweh * Ephi
Jdphi_rfweh	Displacement current density, phi component	A/m^2	jomega_rfweh * Dphi_rfweh
Jiphi_rfweh	Induced current density, phi component	A/m^2	sigmaphiphi_rfweh * Ephi
jwBr_rfweh	Magnetic flux density, r component	V/m^2	-curlEr_rfweh
jwBz_rfweh	Magnetic flux density, z component	V/m^2	-curlEz_rfweh
Br_rfweh	Magnetic flux density, r component	T	jwBr_rfweh/jomega_rfweh
Bz_rfweh	Magnetic flux density,	T	jwBz_rfweh/jomega_rfweh

	z component		
Bphi_rfweh	Magnetic flux density, phi component	T	muphiphi_rfweh * Hphi
normB_rfweh	Magnetic flux density, norm	T	sqrt(abs(Br_rfweh)^2+abs(Bz_rfweh)^2+abs (Bphi_rfweh)^2)
normH_rfweh	Magnetic field, norm	A/m	sqrt(abs(Hr_rfweh)^2+abs(Hz_rfweh)^2+abs(Hphi)^2)
normE_rfweh	Electric field, norm	V/m	sqrt(abs(Er_rfweh)^2+abs(Ez_rfweh)^2+abs(Ephi)^2)
normD_rfweh	Electric displacement, norm	C/m^2	sqrt(abs(Dr_rfweh)^2+abs(Dz_rfweh)^2+abs (Dphi_rfweh)^2)
normPoav_rfweh	Power flow, time average, norm	W/m^2	sqrt(abs(Porav_rfweh)^2+abs(Pozav_rfweh)^2+abs (Pophiav_rfweh)^2)
Wmav_rfweh	Magnetic energy density, time average	J/m^3	0.25 * real(Hr_rfweh * conj(Br_rfweh)+Hz_rfweh * conj (Bz_rfweh)+Hphi * conj(Bphi_rfweh))
Weav_rfweh	Electric energy density, time average	J/m^3	0.25 * real(Er_rfweh * conj(Dr_rfweh)+Ez_rfweh * conj (Dz_rfweh)+Ephi * conj(Dphi_rfweh))
Wav_rfweh	Total energy density, time average	J/m^3	Wmav_rfweh+Weav_rfweh
Qav_rfweh	Resistive heating, time average	W/m^3	0.5 * real(j * real(omega_rfweh) * (-Er_rfweh * conj (Dr_rfweh)-Ez_rfweh * conj(Dz_rfweh)-Ephi * conj (Dphi_rfweh)))
Porav_rfweh	Power flow, time average, r component	W/m^2	0.5 * real(Ephi * conj(Hz_rfweh)-Ez_rfweh * conj(Hphi))
Pozav_rfweh	Power flow, time average, z component	W/m^2	0.5 * real(-Ephi * conj(Hr_rfweh)+Er_rfweh * conj(Hphi))
Pophiav_rfweh	Power flow, time average, phi component	W/m^2	0.5 * real(-Er_rfweh * conj(Hz_rfweh)+Ez_rfweh * conj (Hr_rfweh))