



Altair HyperWorks 2024 新版本发布会

AI 赋能技术创新，开启仿真新篇章

2024年8月28日 | 北京



ALTAIR FEKO – 新界面的升级体验及求解器性能的最新突破

焦金龙 / Altair 技术经理 / Aug 28, 2024

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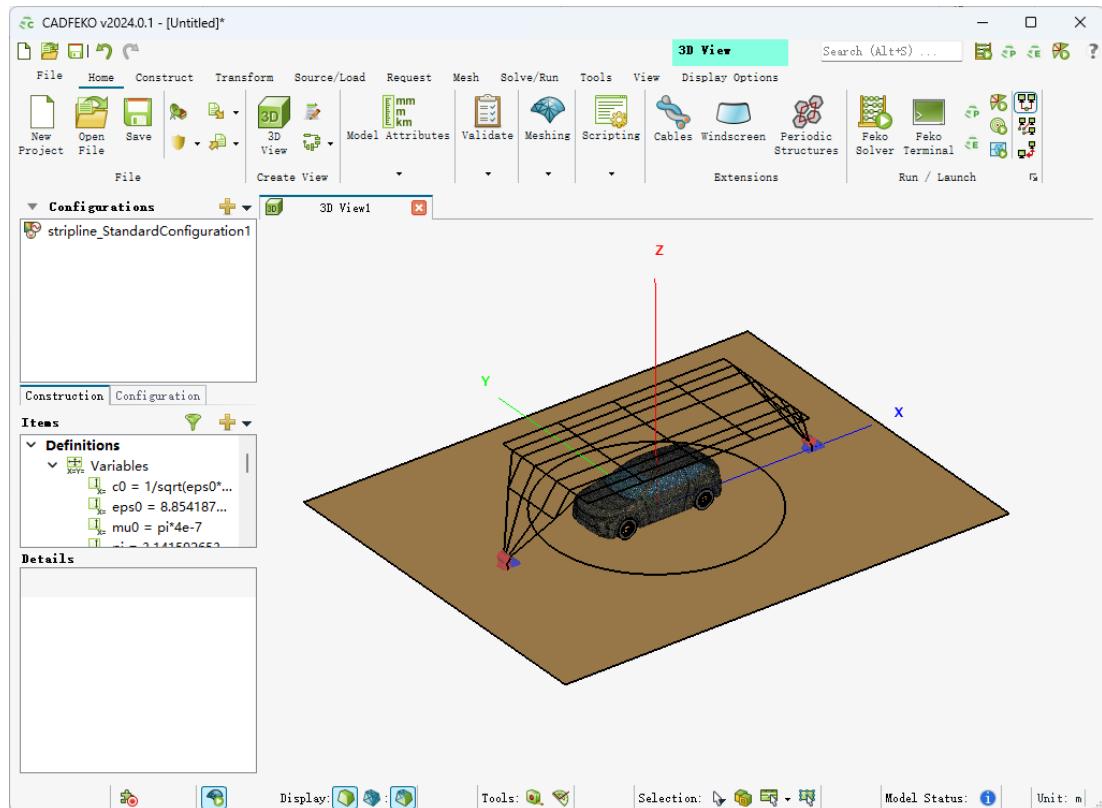
1 CADFEKO全新界面

2 求解器新功能

3 典型算例

4 小结

CADFEKO 新界面



模型加密



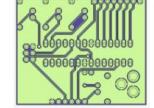
易用的切平面



自动划分网格



PCB导入接口



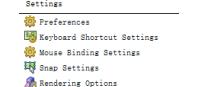
支持模型筛选



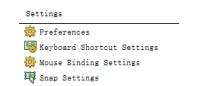
模型边界限制移除



支持自定义快捷键



模型任意隐藏/显示



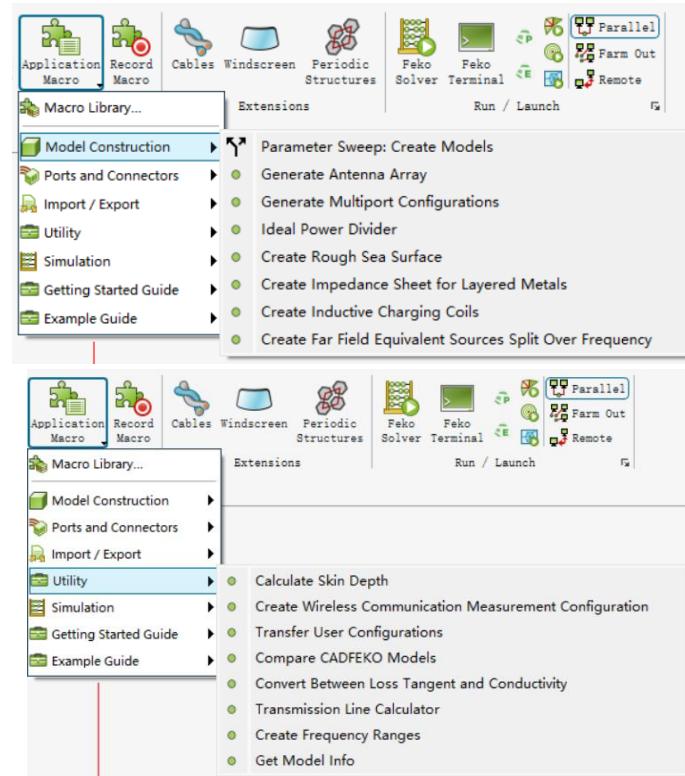
应用程序宏类库(Application Macro Library)扩展

CADFEKO应用程序宏

新增类库宏可协助完成以下计算任务

- 建模：扫参、天线阵列、多端口配置、粗糙海平面、充电线圈等
- 导入/导出：数据处理等
- 实用工具 (Utilities)：不同版本求解配置转换、CADFEKO模型对比、损耗角正切与电导率转换等
- RCS 分析：RCS任务发送到PBS作业调度HPC平台

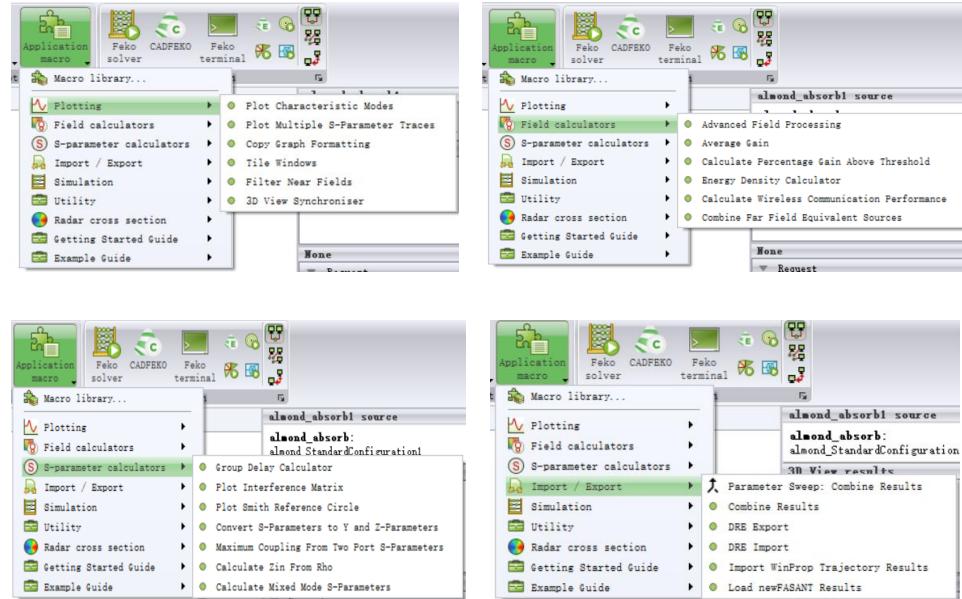
某些应用程序宏在CADFEKO 和 POSTFEKO中是相关的



应用程序宏类库(Application Macro Library)扩展

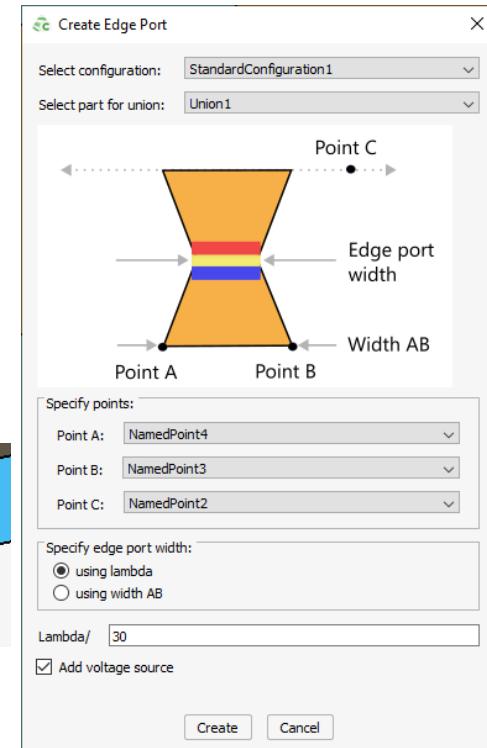
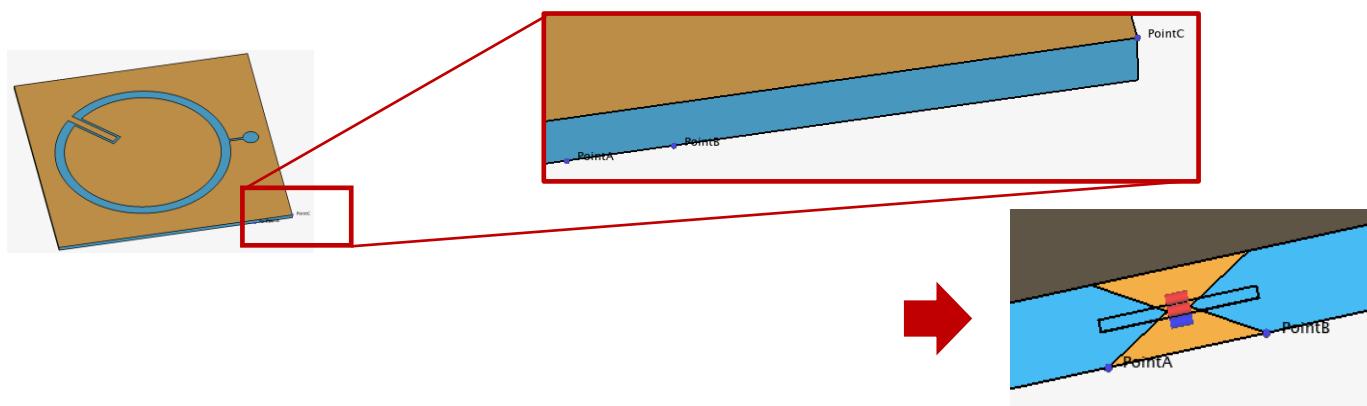
POSTFEKO 应用程序宏

- 新增应用程序宏*可协助完成以下后处理任务:
 - 数据绘图:** CMA特征模绘图、多条S参数曲线绘图、复制带格式的2D曲线、平铺窗口、近场数据筛选、3D视图同步等
 - 场计算:** 场数据高级处理功能、平均增益、高于指定阈值的增益占比、能量密度计算器等
 - S-参数计算:** 群延迟计算、干扰矩阵绘图、Smith参考圆绘图、S散射矩阵->Y/Z矩阵转换、两端口S散射矩阵->最大耦合、反射系数Rho->输入阻抗Zin计算器以及混合模式S参数计算器等
 - 导入/导出:** 扫参结果数据汇总、DRE导出/导入、导入WinProp计算得到的飞行路径上的结果等



有限大基板创建Edge Port的脚本实现

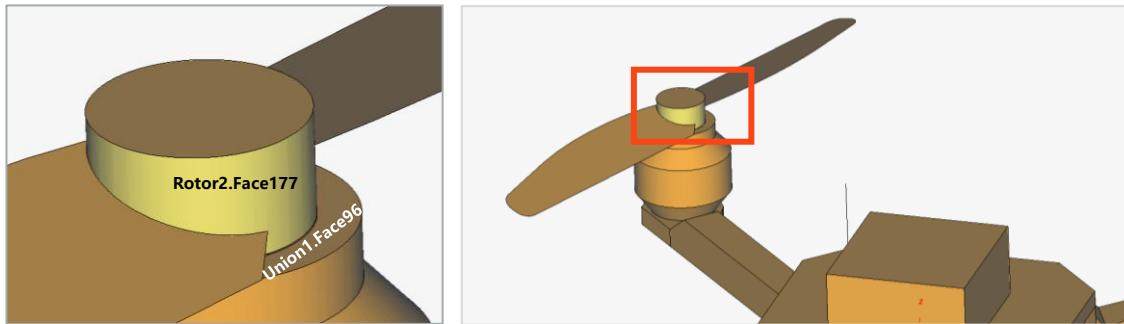
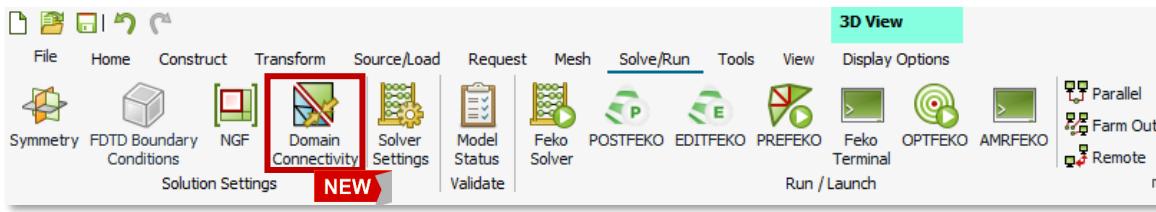
CADFEKO > Home Tab > Application Macro > Model Construction > Create Edge Port for Finite Substrate



模型&网格连接-预处理

前处理菜单: CADFEKO > Solve/Run > Solution Settings > Domain Connectivity

- 新增 **Domain Connectivity** 工具，该工具允许在网格交界处一定容差范围内，将指定的网格视为“连接”，即使这些网格原本不共节点
- 适用于天线布局、雷达隐身等应用方向



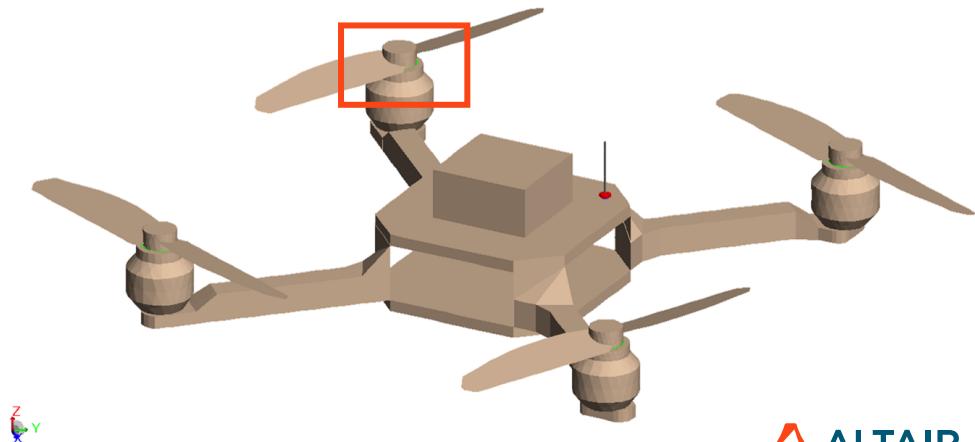
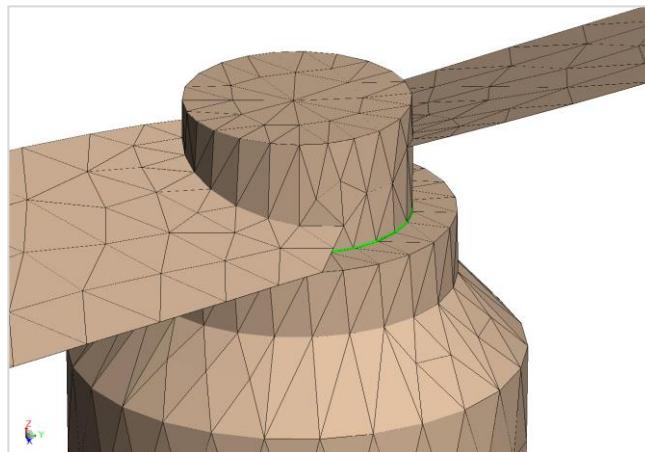
7



模型&网格连接-预处理

后处理菜单：POSTFEKO > 3D View Contextual tab > Mesh > Tools > Domain Connectivity

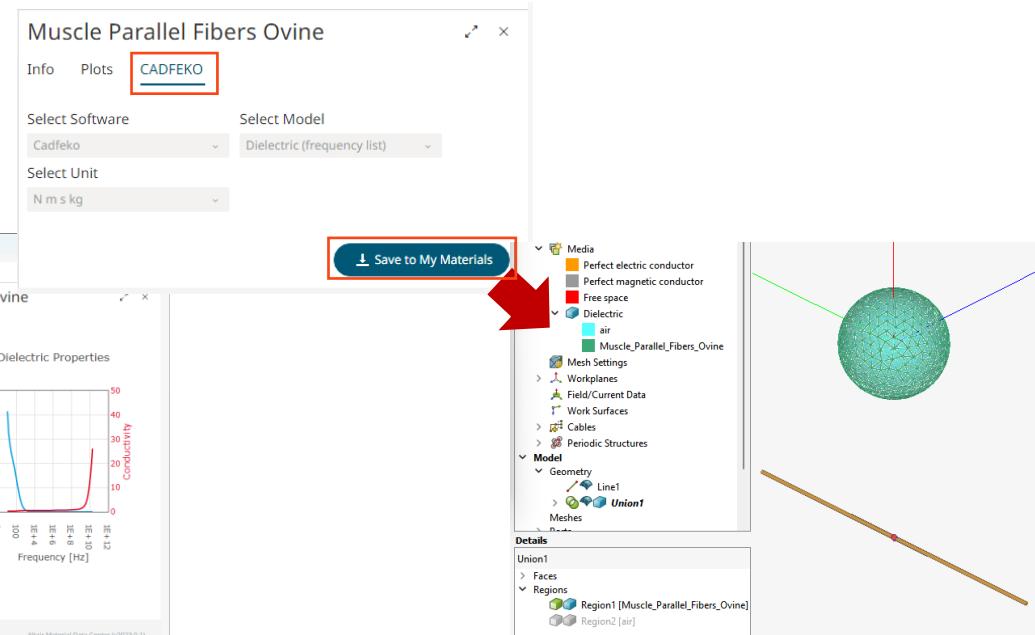
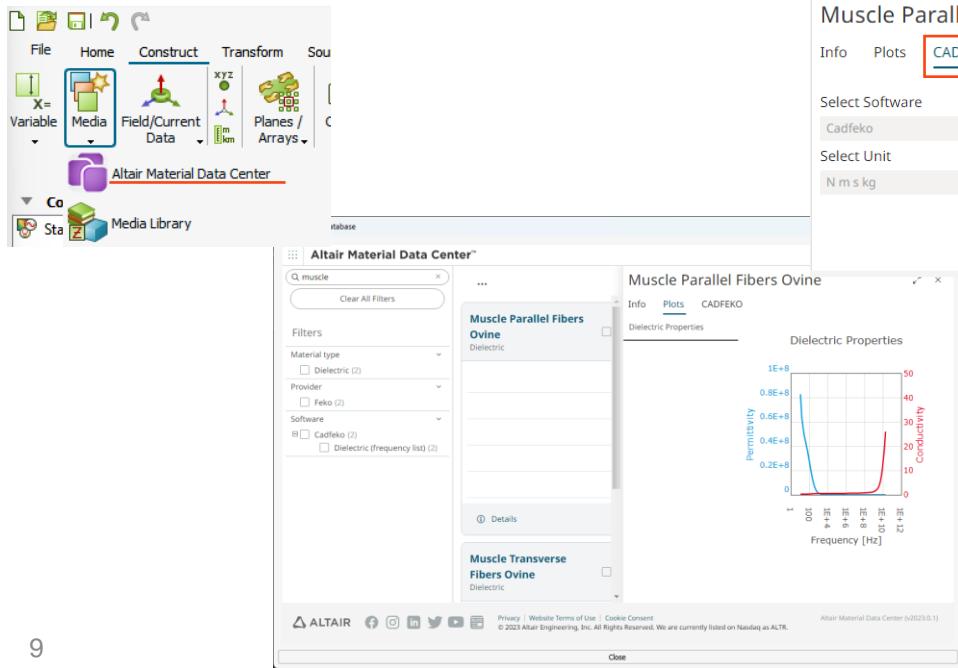
- 在3D视图中添加 **Domain Connectivity** 工具按钮，用于显示/隐藏模型预连接效果



Feko支持线上材料库AMDC

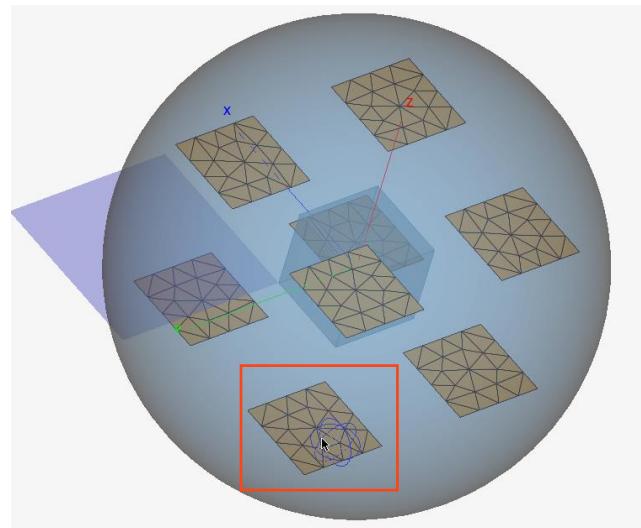
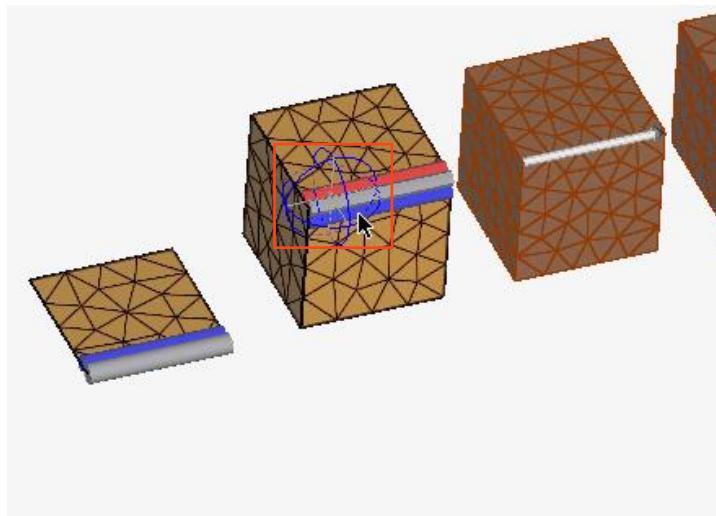
CADFEKO > Construct > Define > Media > Altair Material Data Center.

打开Altair材料中心(AMDC) , 登录 Altair One , 读取需要的材料。



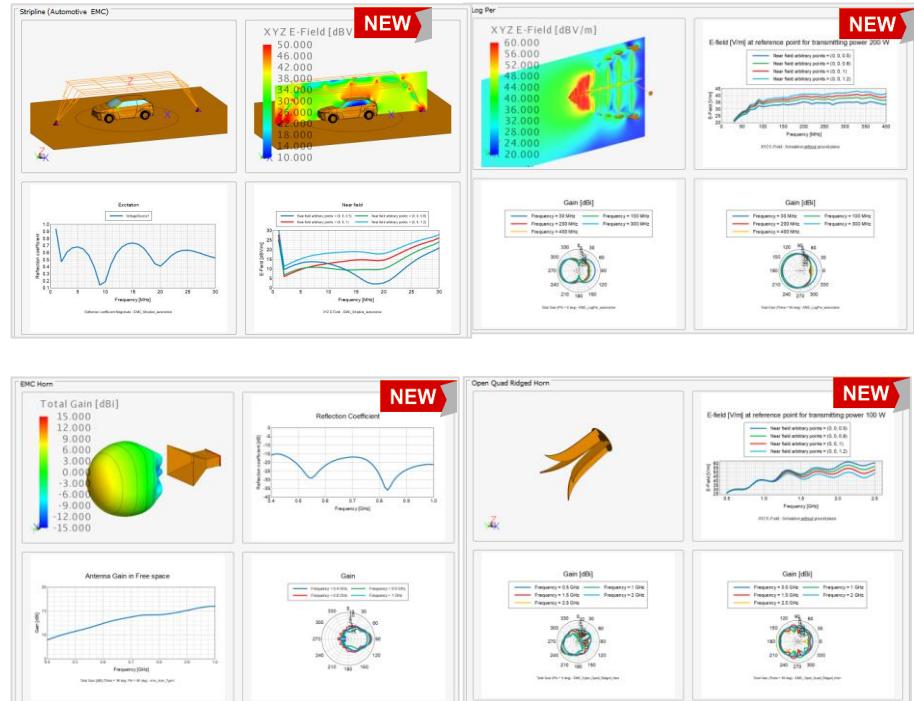
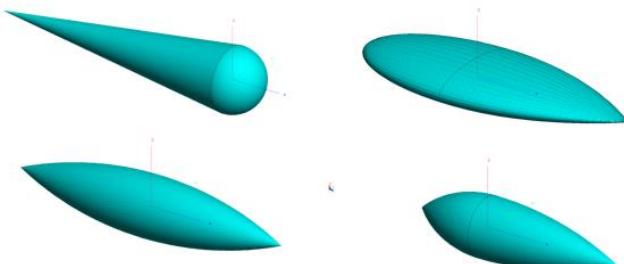
3D旋转模型性能改进

- 改进了光标位于端口上方时的旋转中心。
- 允许在几何体/网格上选择旋转中心。



新增模型库

- EMC 带状天线: 0.5 MHz – 30 MHz
- EMC 对数周期天线: 30MHz – 400MHz
- EMC 双锥对数周期天线: 100MHz – 1GHz
- EMC 喇叭天线 : 400 MHz – 1 GHz
- EMC 四脊喇叭: 0.5 – 2.5GHz
- RCS标准模型

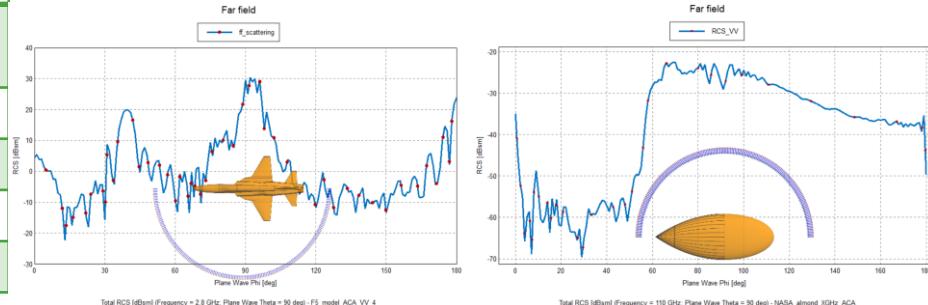
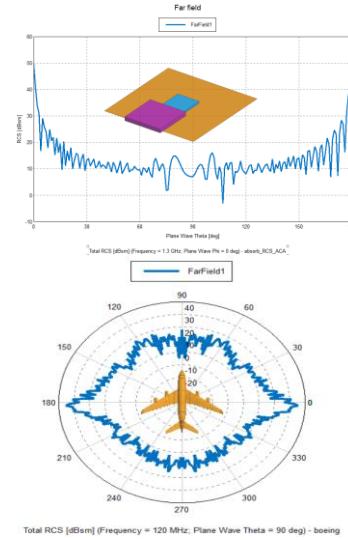


求解器新功能

ACA并行求解加速

- 最新版本的ACA性能
 - ✓ 吸波结构单站RCS，2023版本相比2020版本，加速11.1倍
 - ✓ 金属飞机模型，2023版本相比2020版本加速5.8倍
 - ✓ 杏仁核，直接求解>120万网格模型，稳定求解大规模模型

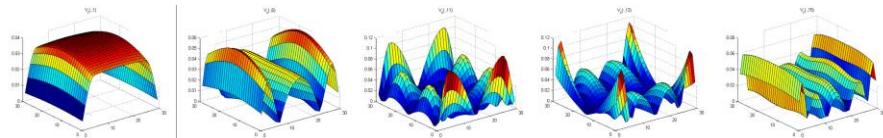
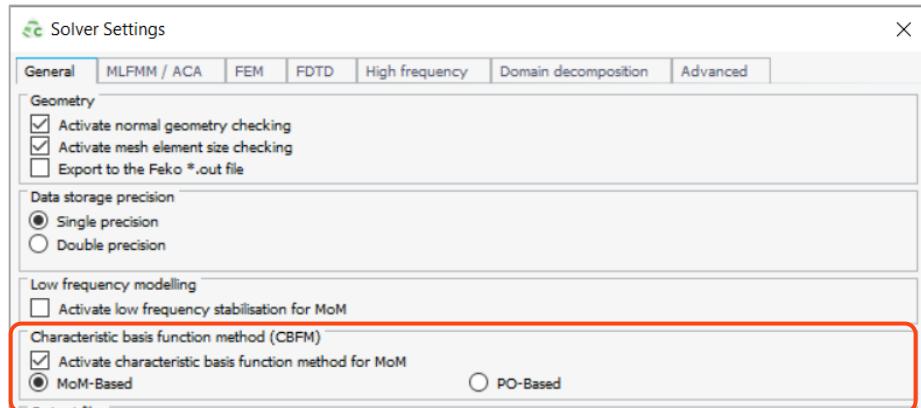
模型	网格数量	仿真时间(小时)
吸波结构	金属 68,980 介质 35,652	0.391
飞机模型	金属 101,536	0.33
杏仁核	金属 1,248,768	27.52
F5飞机模型	金属 1,266,370	30.37
F5飞机模型	金属 1,573,355	54.92



特征基函数法 (CBFM)

CADFEKO > Solve/Run > Solution Settings > CBFM

- CBFM是对传统MoM或MLFMM的改进，利用宏基函数减少了未知数的数量。
- 使用CBFM时，矩阵的计算需要更多时间，但求解时间会加快。
- 因此，CBFM 对于单静态RCS等有许多右侧激励的问题最为有效。

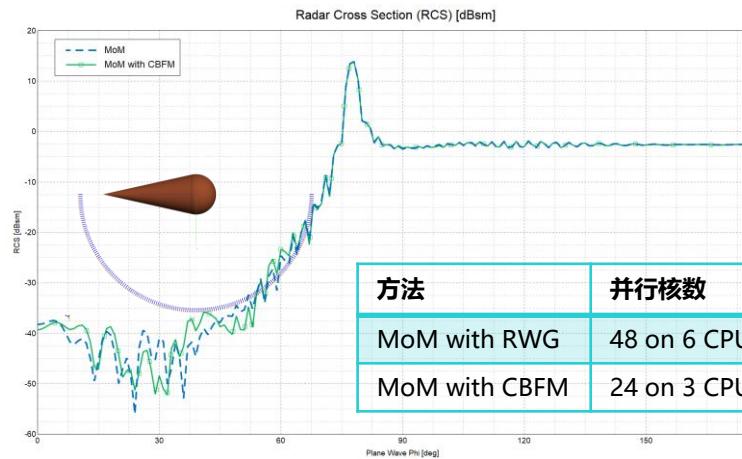


支持特征基函数 (CBFM)

- CBFM 可用于**介质体**的 RCS 仿真。
- 显著减少对 MoM 的内存要求

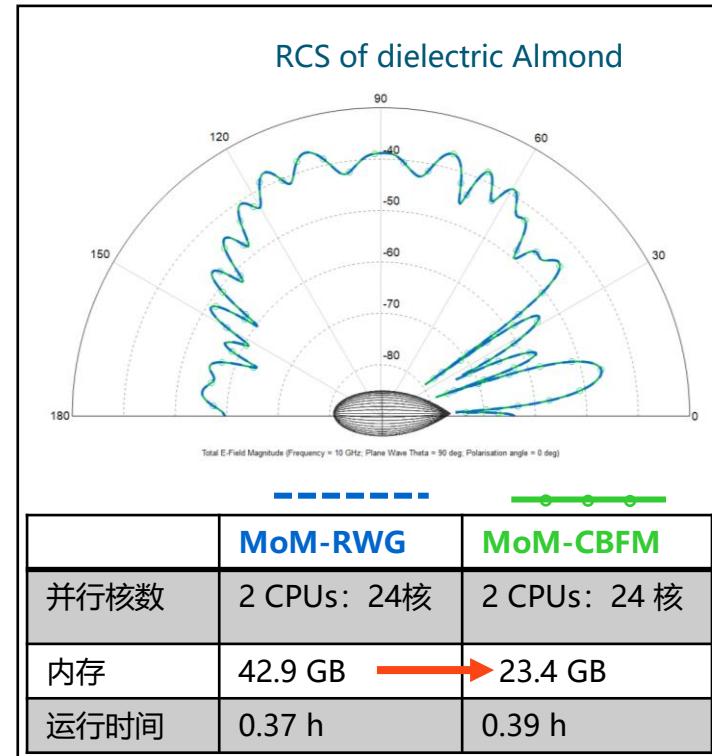
算例：

- Almond 介质模型仿真 10 GHz单站RCS
- 介质球锥模型



CBFM直接求解器：计算低散射单站RCS

**CBFM+MLFMM: 收敛性优于
RWG-MLFMM**

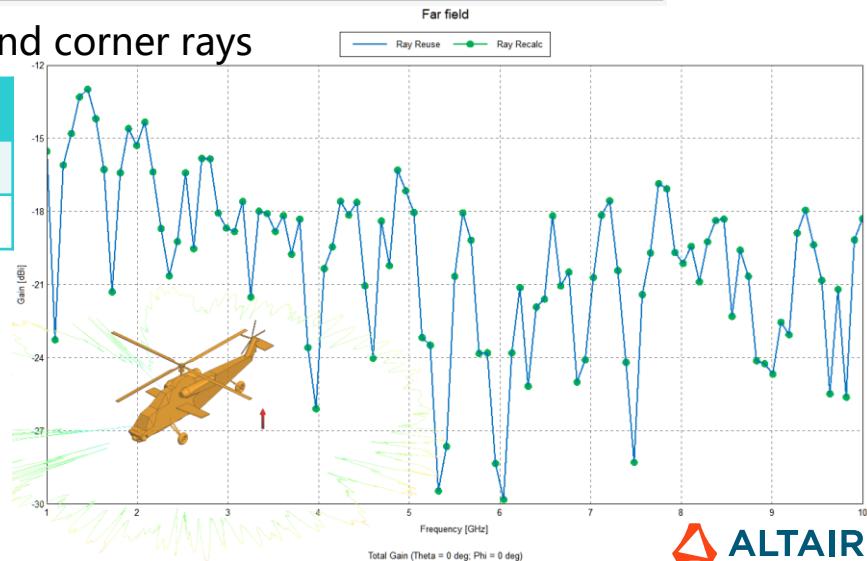
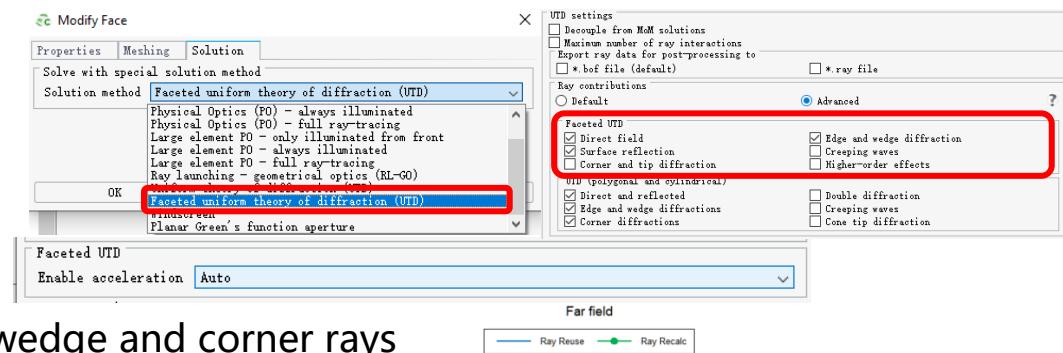
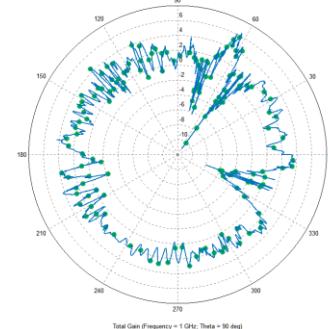


Faceted UTD支持快速扫频

- 通过在频段复用射线，实现更快的扫频
- 21603 request points
- 101频点
- 6549 UTD 三角形
- 2 ray interactions, direct, reflected, wedge and corner rays

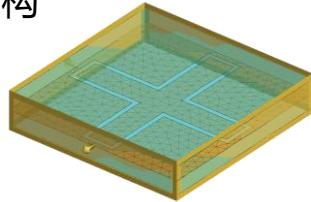
重新计算		复用
运行时间 64核并行	160432s (44.4h)	1745s (0.43h)
内存	28.048 GB	28.069 GB

- 不支持:
 - 球面波接收天线
 - 矩量法网格

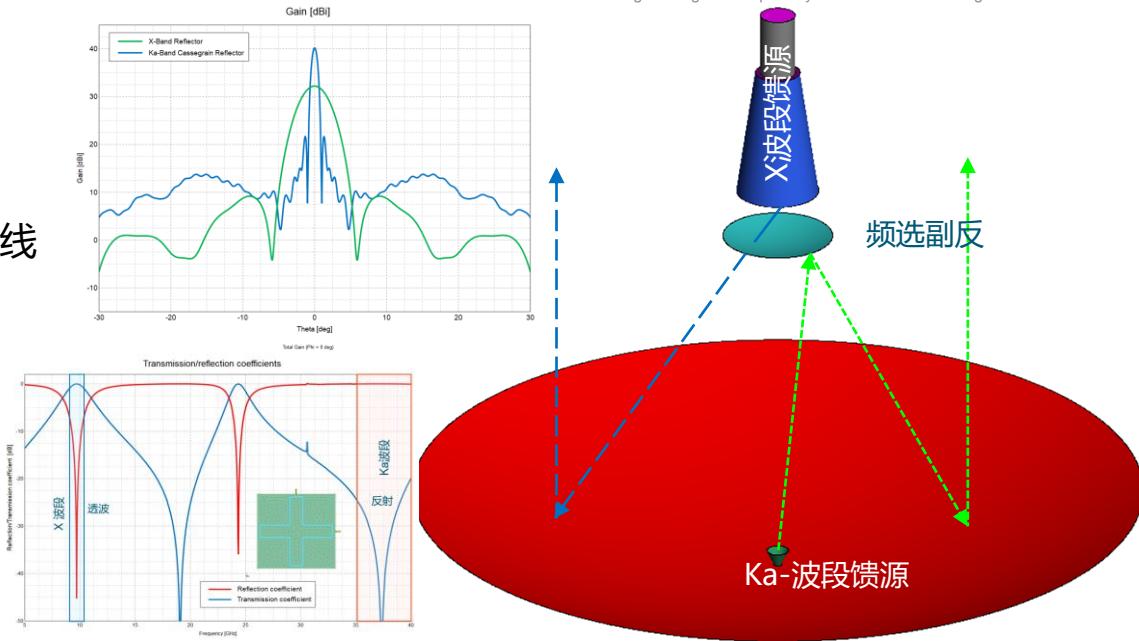


MLFMM+特征面技术

- 双馈源反射面天线
 - ✓ Ka波段 (35.75 GHz) 卡塞格伦天线
 - ✓ X波段 (9.55 GHz) 反射面天线
- 副反内置FSS结构
 - ✓ Ka波段反射
 - ✓ X波段透波



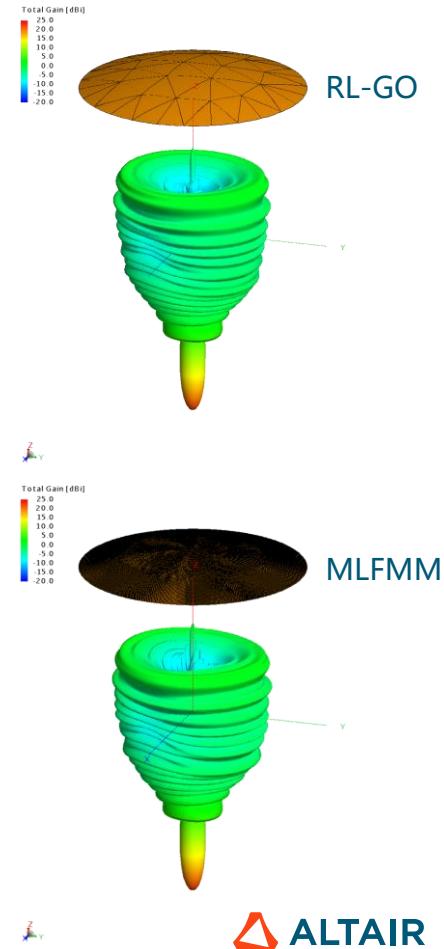
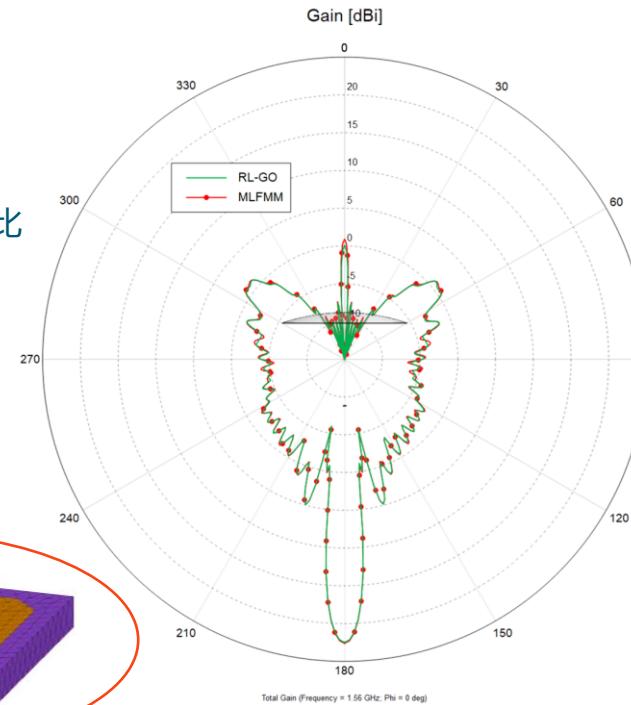
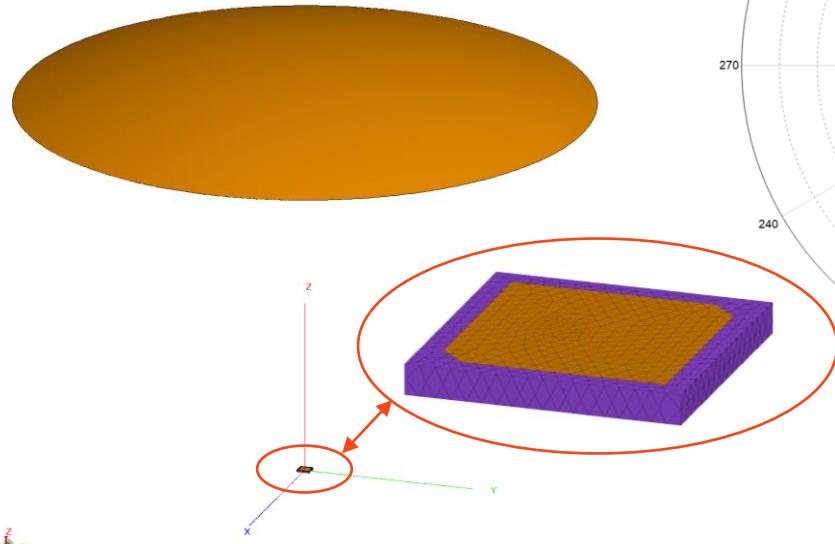
稳定的MLFMM可以用于带FSS结构的反射面天线



模型	未知量	并行核数	峰值内存(GB)	运行时间(秒)
Ka 波段, 副反为理想金属面(PEC)	2,144,896	24核 (2 CPUs)	72.5	953 秒
Ka 波段, 副反为内置FSS结构 (采用特征面技术)	2,189,807	24核 (2 CPUs)	130.7	2387 秒
X 波段, 无副反	153,113	24核 (2 CPUs)	10.4	37 秒
X 波段,副反为内置FSS结构 (采用特征面技术)	159,385	24核 (2 CPUs)	10.8	103 秒

RL-GO与矩量法混合求解

- 支持部分矩量法介质模型
- 面等效求解介质区域
- 算例: 微带与反射面
 - MLFMM方法与MOM+ RLGO对比

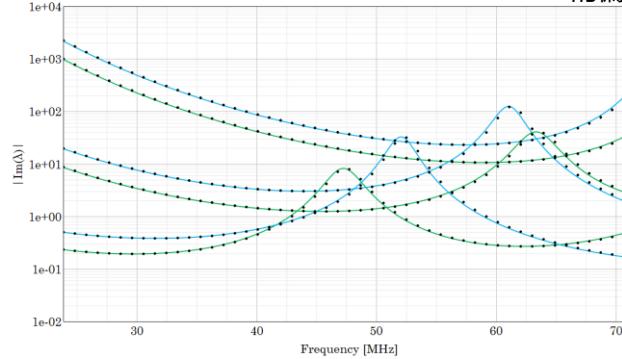
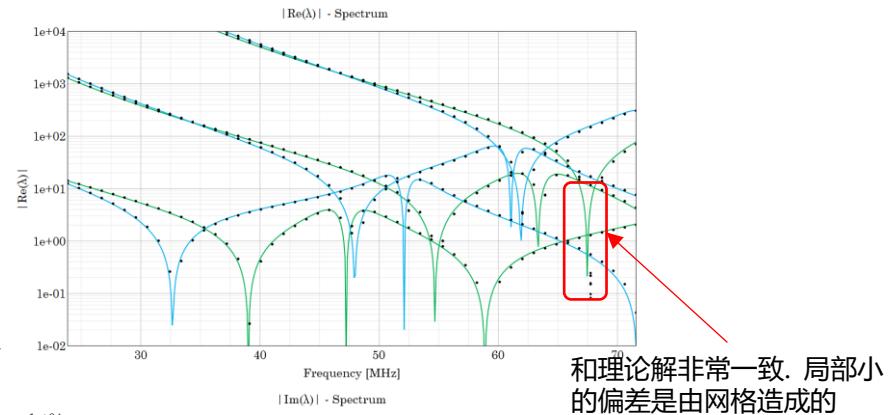
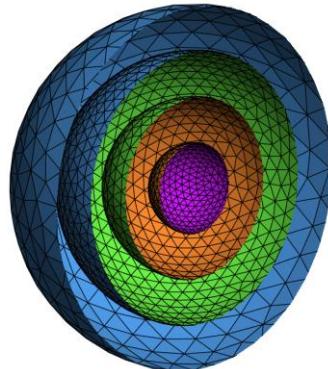


特征模分析(CMA)-功能改进

- 支持有耗(lossy)介质

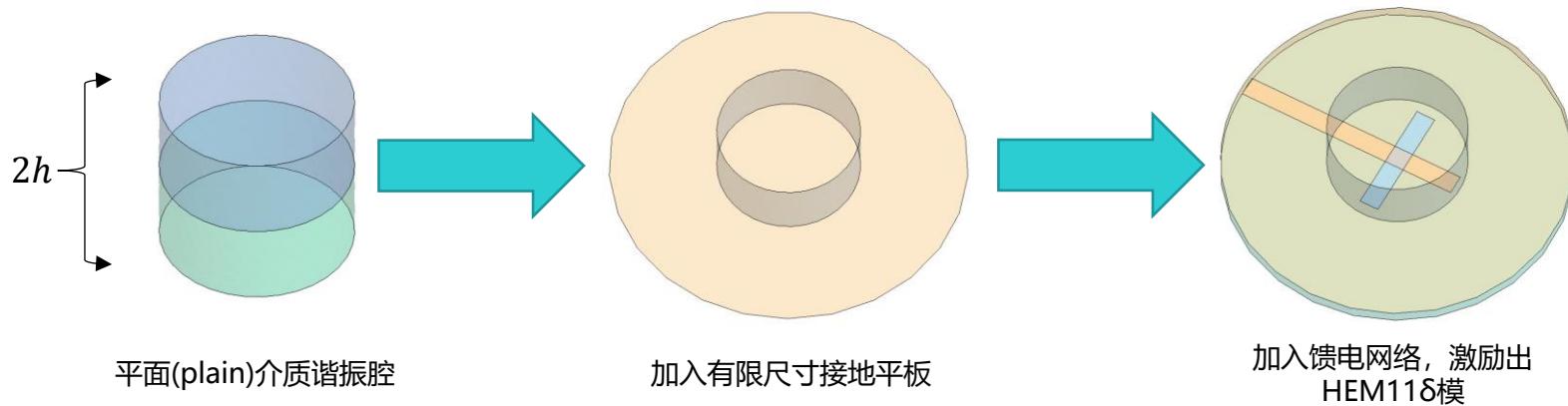
- 验证算例:

- 四层介质球本征模分析:
- 最外层 1: $\epsilon_r = 7, \mu_r = 4, \tan\delta_\epsilon = 0.01, \tan\delta_\mu = 0.01, r = 1.00m$
- 中间层-外1: $\epsilon_r = 6, \mu_r = 3, \tan\delta_\epsilon = 0.02, \tan\delta_\mu = 0.02, r = 0.75m$
- 中间层-内 1: $\epsilon_r = 3, \mu_r = 9, \tan\delta_\epsilon = 0.03, \tan\delta_\mu = 0.05, r = 0.50m$
- 最内层 1: $\epsilon_r = 5, \mu_r = 2, \tan\delta_\epsilon = 0.04, \tan\delta_\mu = 0.03, r = 0.25m$



特征模分析(CMA)-功能改进

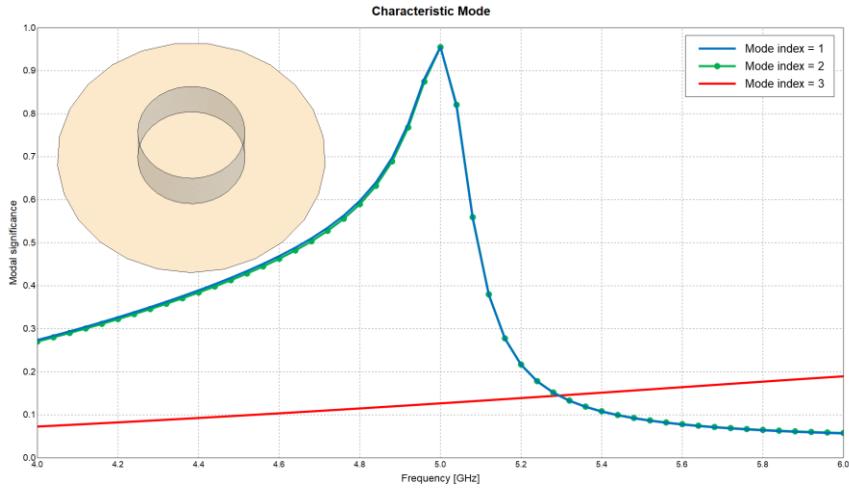
- **设计算例:** 基于CMA分析孔径耦合馈电的柱形DRA天线, 谐振频率5GHz, 工作模式HEM11δ:
- $\epsilon_r = 42, \tan\delta_\epsilon = 0.0015, r = 3.8mm, h = 4.2mm$
- 孔径、馈线、短截线(Stub)和介质基板的几何参数都可以进行调整, 以实现所需的性能特性。**介质谐振腔和基板均采用有耗介质。**



特征模分析(CMA)-功能改进

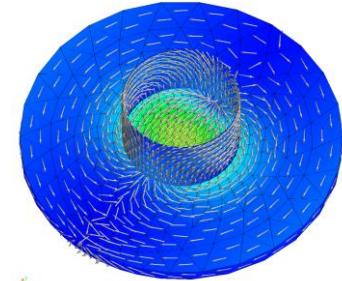
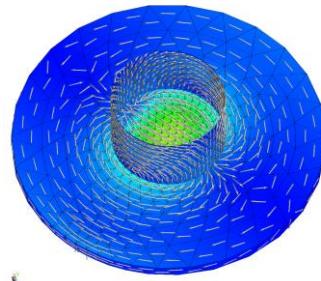
设计算例: 介质谐振天线 (DRA)

- 计算4 – 6 GHz范围内模式重要性系数 MS_n
- 由于结构的对称性, 模式1和模式2的电流分布
在方位方向相差90度
- 使用谐振模式的电流分布来决定DRA天线激励
的合适位置
- 添加激励, 重新运行CMA分析, 确认是否存在
相关谐振模式



模式1电流密度(5 GHz)

模式2电流密度(5 GHz)

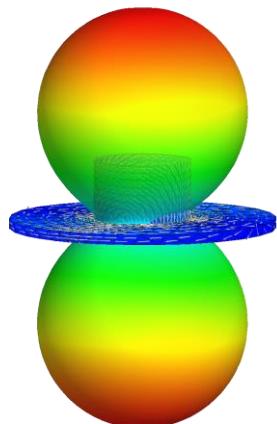


特征模分析(CMA)-功能改进

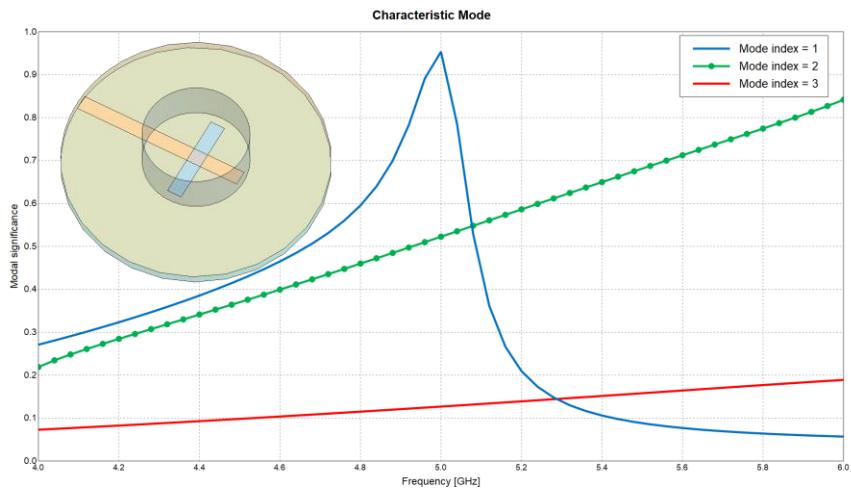
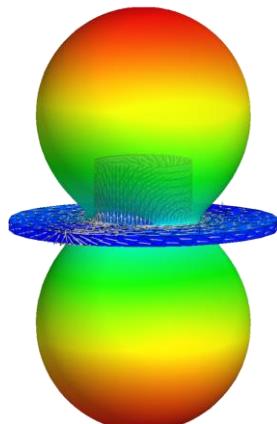
设计算例: 介质谐振天线 (DRA)

- 选择Slot位置添加激励, 模式1可以激发出来
- 对应的谐振模式2 消失
- 5GHz工作模式1的辐射场型:

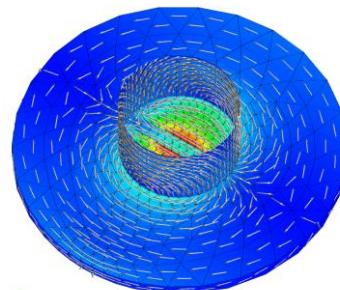
开槽处不加激励时



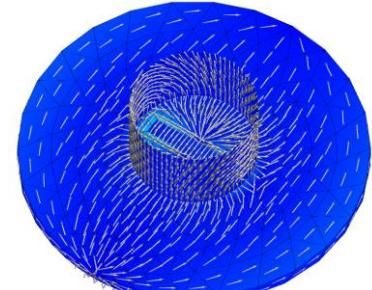
开槽处添加激励



模式 1 电流密度(5 GHz)

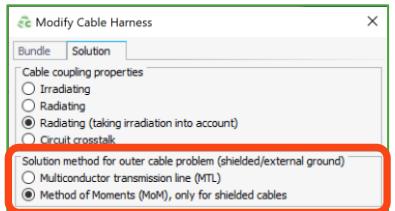
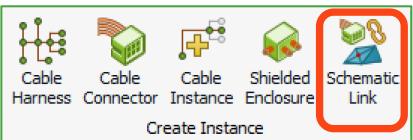


模式 2 电流密度(5 GHz)

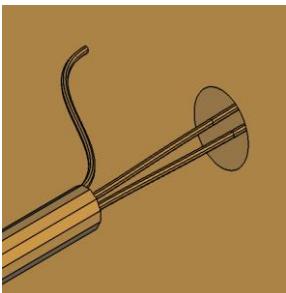


线束原理图 – 将屏蔽电缆信号连接到 3D 模型

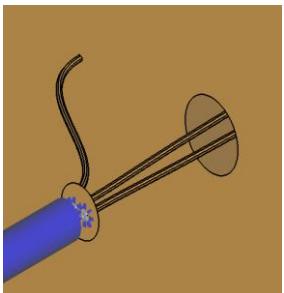
- 混合MOM/MTL支持一下模型：
 - 屏蔽层带猪尾效应
 - 电缆信号连接，例如线缆连接到PCB



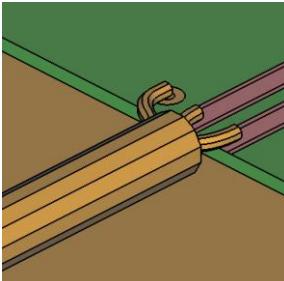
屏蔽双线 – 屏蔽层通过猪尾连接到外壳、芯线连接在
外壳内部的电线



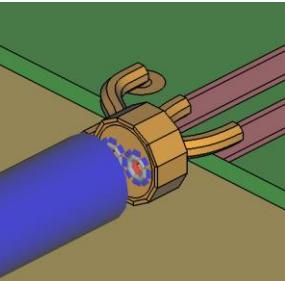
物理模型



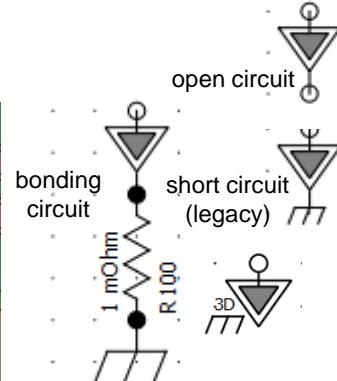
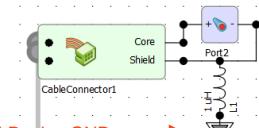
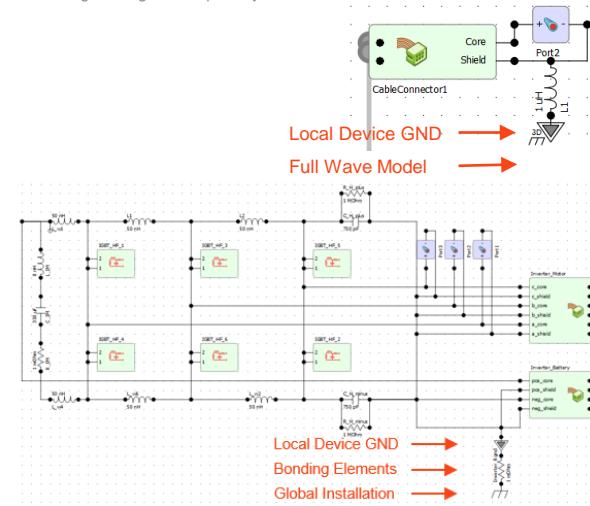
MoM/MTL 模型



物理模型

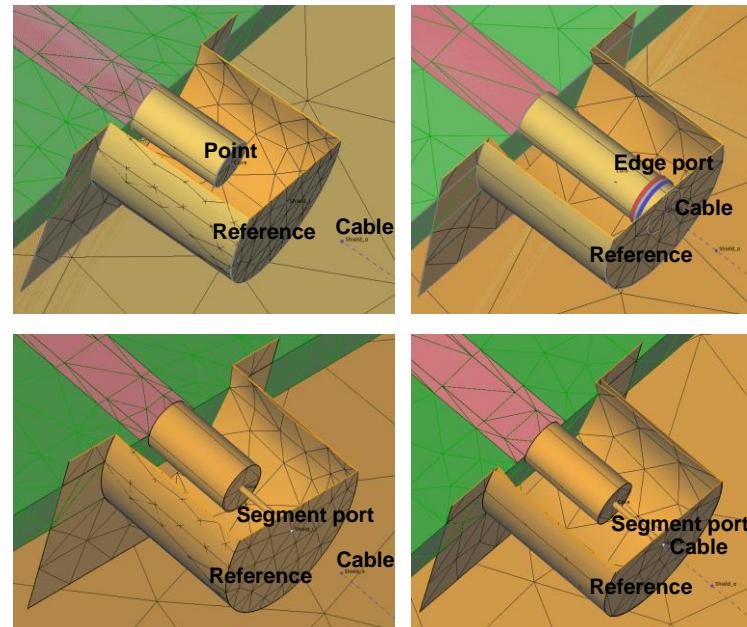
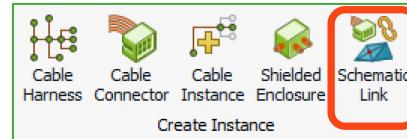


MoM/MTL 模型



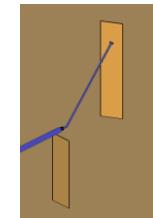
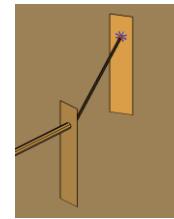
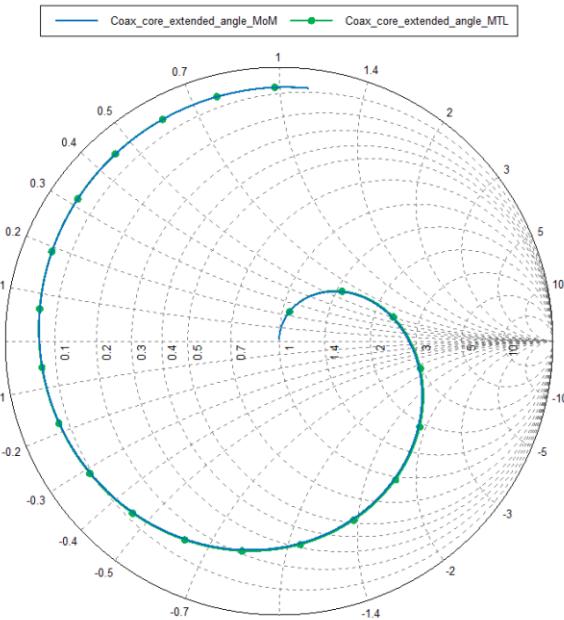
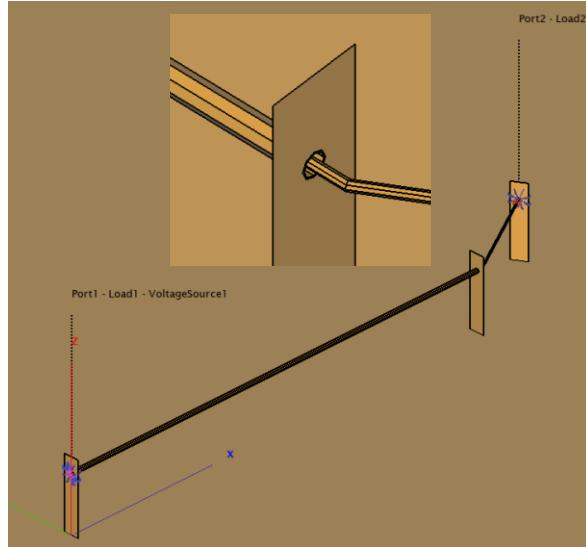
线束原理图 – 将屏蔽电缆信号连接到 3D模型

- 通过以下组合实现与 3D 几何体的电缆信号连接：
 - 单芯线束
 - 网格顶点
 - 几何端口:
 - 棱边
 - 线段
 - 顶点



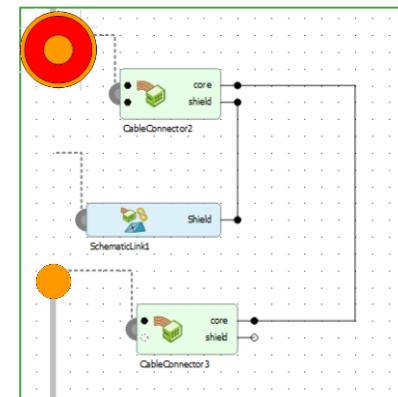
线束原理图 - 点和电缆连接

- 案例1、同轴线与芯线



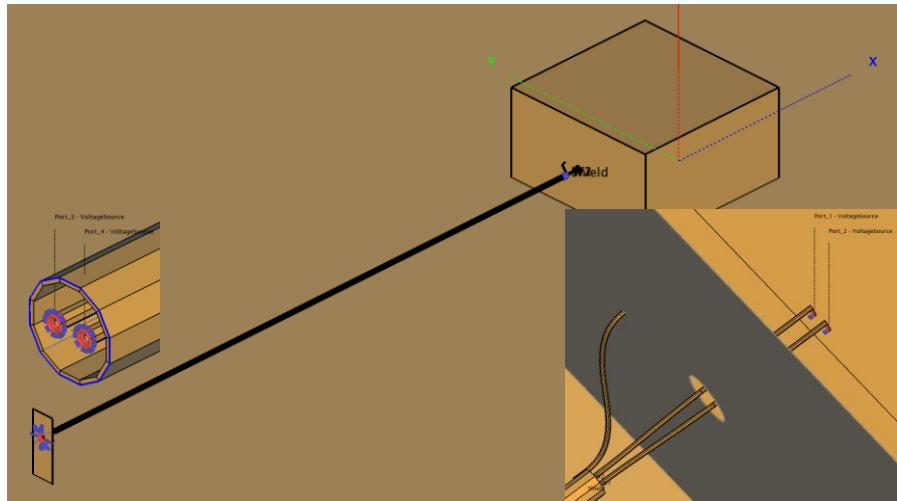
物理模型

MoM/MTL模型



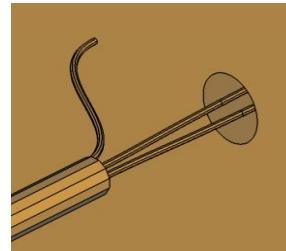
线束原理图 - 端口连接

- 案例2、屏蔽双线，带猪尾连接到外壳

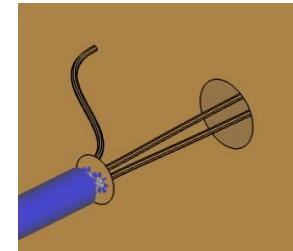


Calculate 75 Ohm S-parameters between all four ports and near-fields associated with each port active - 100MHz to 1GHz

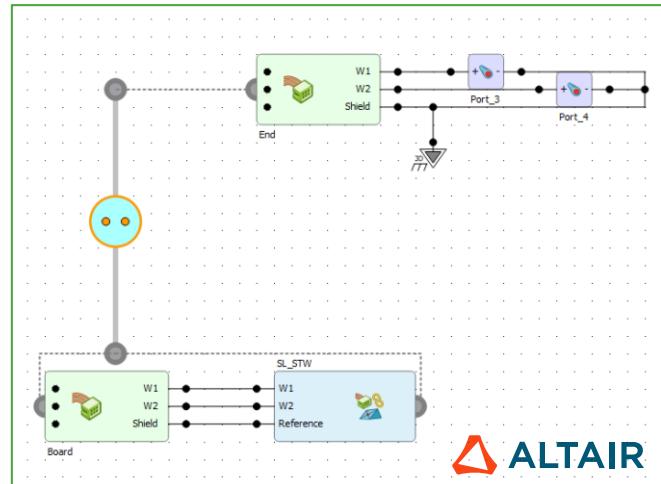
屏蔽双线 – 屏蔽层通过猪尾连接到外壳、芯线连接在
外壳内部的电线



物理模型

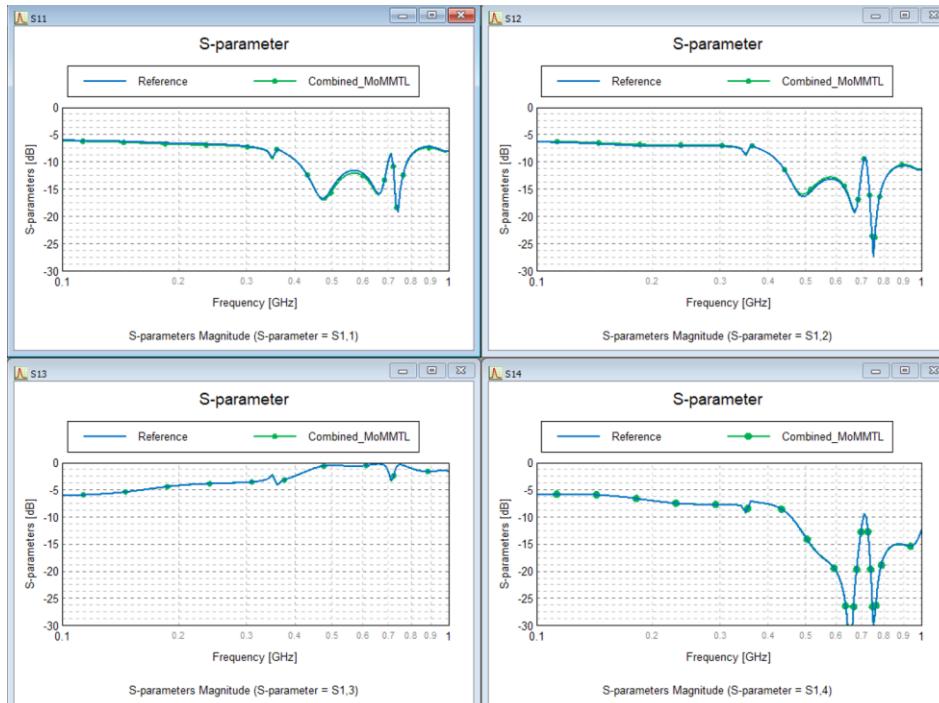


MoM/MTL模型

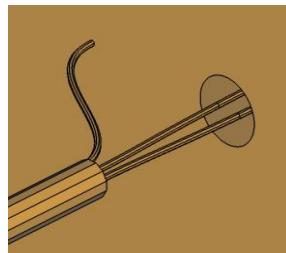


线束原理图 - 端口连接

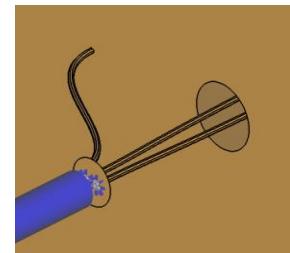
- 案例2: S参数对比



屏蔽双线 – 屏蔽层通过猪尾连接到外壳、芯线连接在
外壳内部的电线



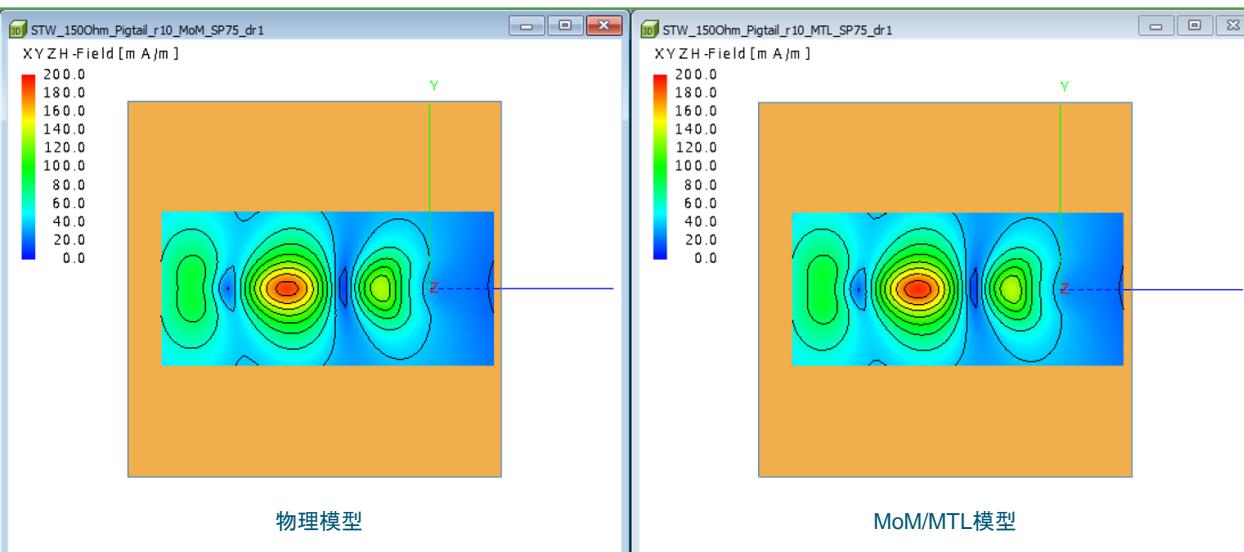
物理模型



MoM/MTL模型

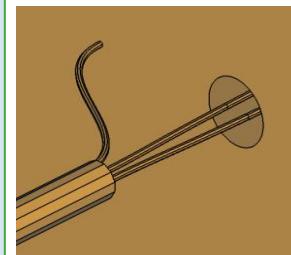
线束原理图 - 端口连接

- 案例2：场强对比

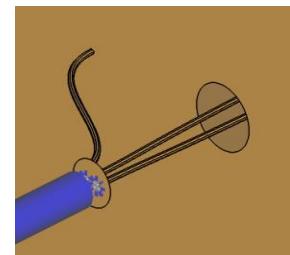


工作频率0.7GHz， H场高于地平面 75 毫米：端口 4 发射功率 0.5W

屏蔽双线 - 屏蔽层通过猪尾连接到外壳、芯线连接在
外壳内部的电线



物理模型

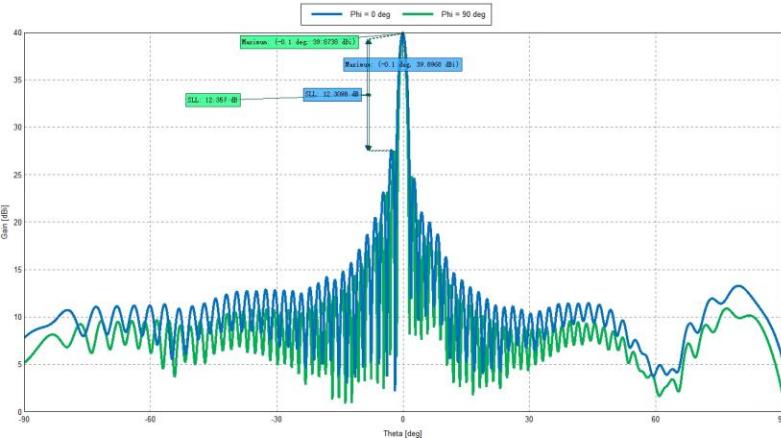
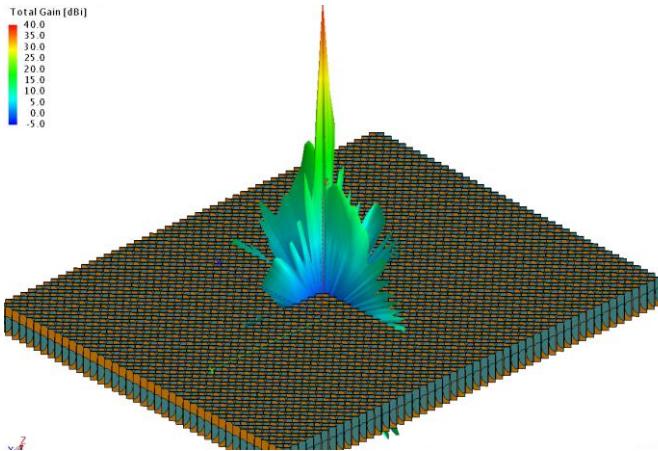


MoM/MTL混合模型

典型算例

Vivaldi天线阵列

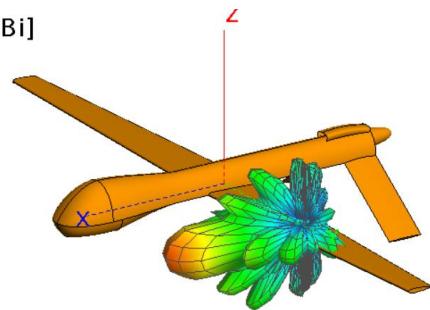
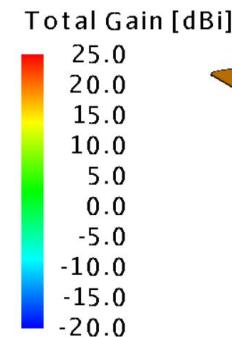
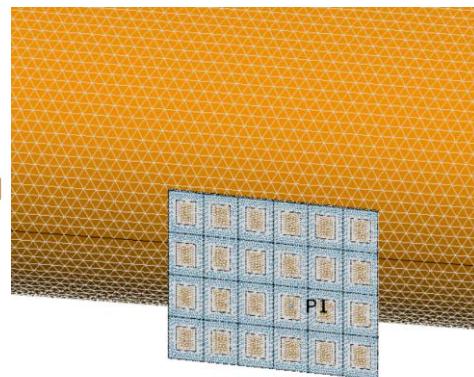
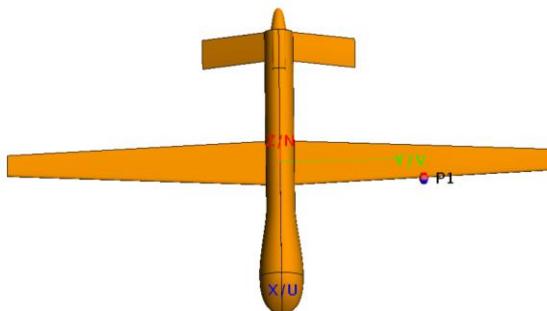
- 单元数量：50*40 单元；，金属网格：2 056 382，介质网格：2 608 748 未知量：12,995,390
- 求解器：MLFMM精确求解
- 幅度加权：均匀阵列
- 仿真时间：14.33h，40 核并行



无人机天线阵布局

- 无人机载体翼展: 14.84m
- 仿真频率: 20GHz, 模型电尺寸989倍波长
- 天线阵列: 24元微带阵列
- 求解器: 多层快速多极子

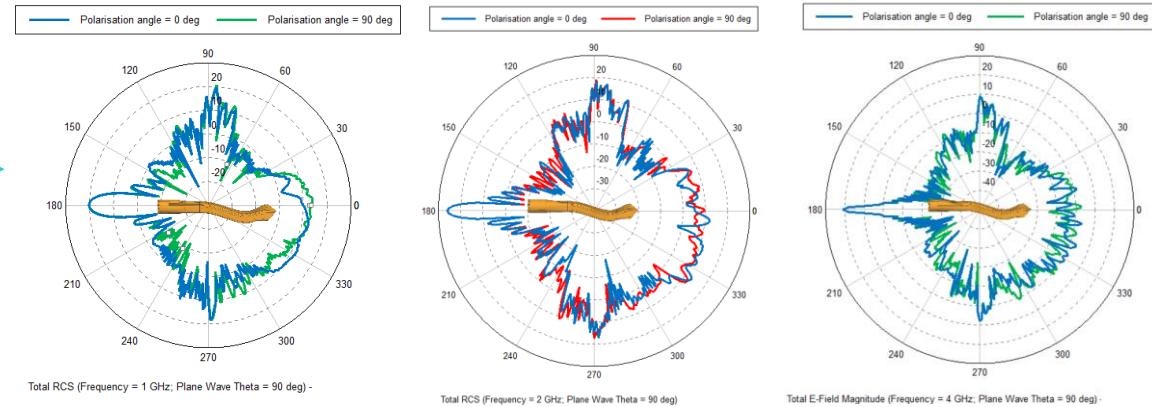
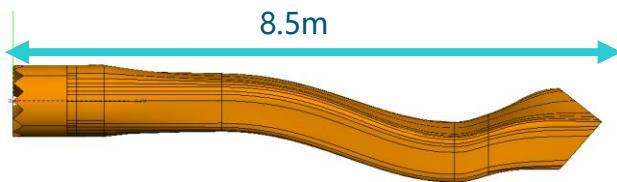
网格数量	仿真时间[H] (56核)
13 785 294	7.736



ACA求解进气道RCS

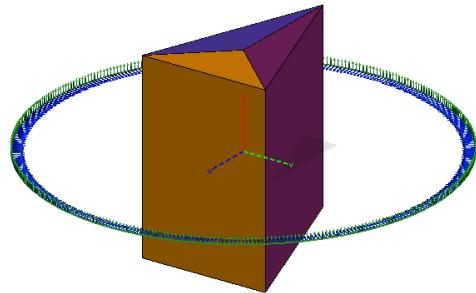
- 进气道模型模型尺寸8.5m
- 典型的腔体结构，收敛速度慢
- 入射角度: Theta=90°, Phi=0~360, 步进1°
- 水平与垂直极化

频率GHz	电尺寸 (倍波长)	网格数量	时间(16核) [小时]
1	28	33,492	0.072
2	56	132,210	0.581
4	112	528,209	8.161

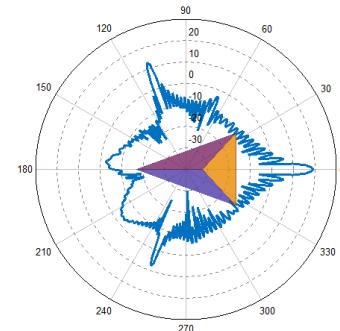


金属与吸波结构

- 三棱柱金属与吸波结构，高度0.37m
 - ✓ 材料1：介电常数4，损耗角正切：0.075
 - ✓ 材料2：介电常数1.4，损耗角正切：0.5
- 求解器：直接求解的ACA

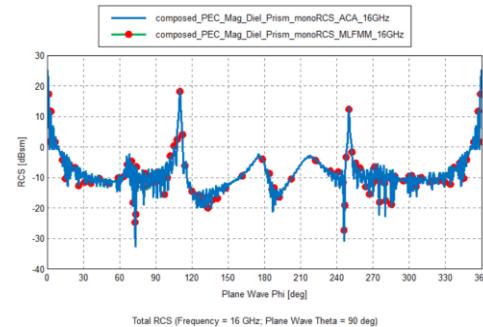


吸波结构模型



8GHz单站RCS仿真结果

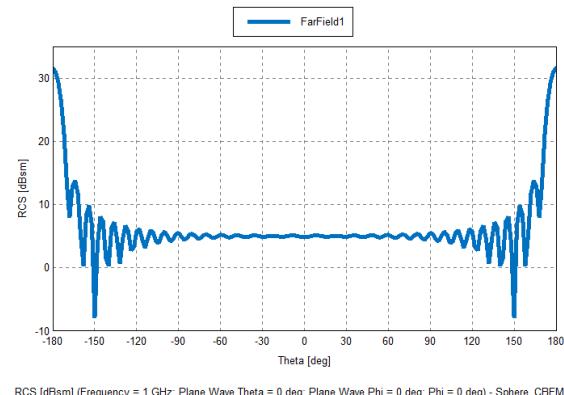
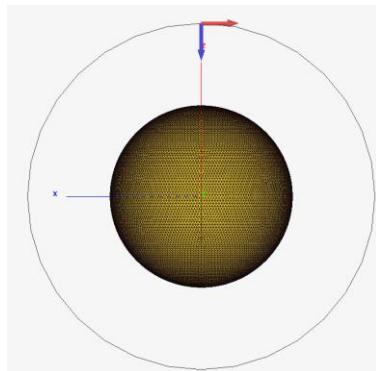
频率[GHz]	电尺寸	网格数量	时间(16核)[小时]
8	10	金属: 41, 826 介质: 70, 194	3.155
12	15	金属: 94, 732 介质: 158, 296	22.673
16	20	金属: 168, 408 介质: 281, 396	18.295 (28核)
24	30	金属: 263, 138 介质: 440, 346	43.846 (30核)



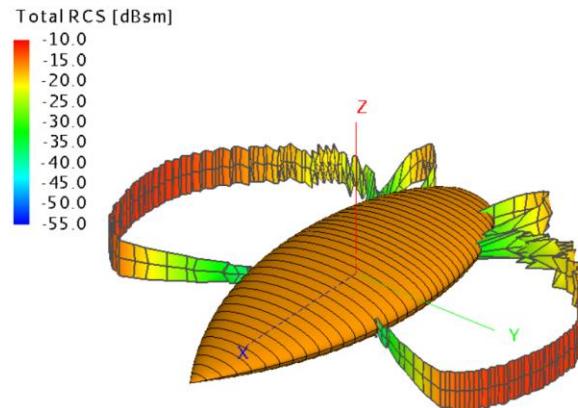
16GHz单站RCS仿真结果

特征基函数(CBFM)

- 球体半径: 1m
- 网格尺寸: $\lambda/10$
- 双站RCS仿真
- 求解器: CBFM-直接求解
- 支持介质**

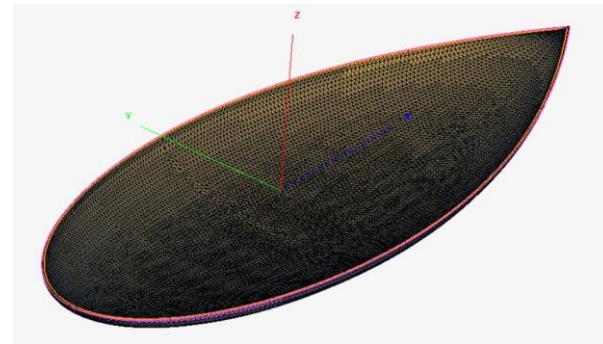
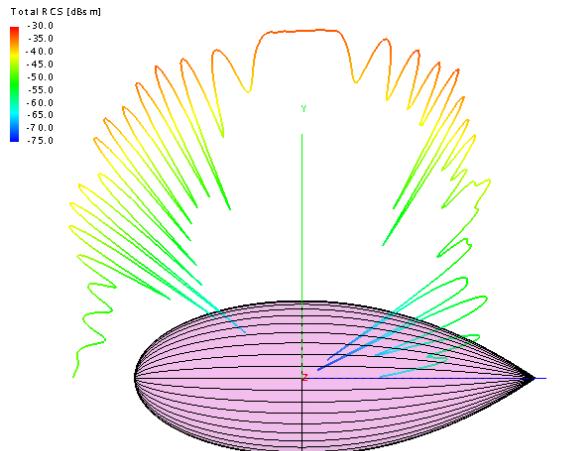


频率 (GHz)	电尺寸	网格数量	仿真时间 (H)	并行数
3 (球体)	20.1	251 772	2.635	20
4 (球体)	26.8	447 840	8.662	20
5 (球体)	33.5	699 960	21.974	20
6 (球体)	40.2	1 227 018	40.311	40
7 (球体)	46.9	1 665 328	74.764	56
20(杏仁体)	66.7	773 376	12.060	40

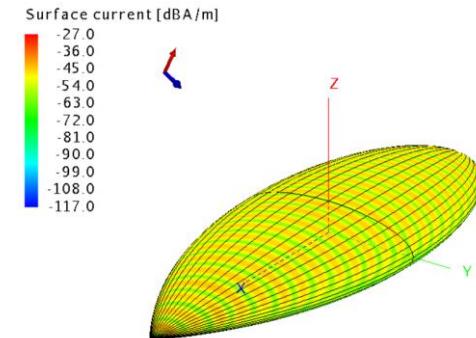


特征基函数支持介质求解

- 杏仁体+吸波涂层 实际建模RCS仿真
- 求解器：CBFM+MLFMM



频率[GHz]	网格规模	并行数量	仿真时间
60 (50倍)	介质: 58 788	28	1.087
80 (67倍)	介质: 131 736	28	5.233
120	介质: 234 912	28	14.733h
150	金属: 207 656 介质: 210 572	28	41.10h



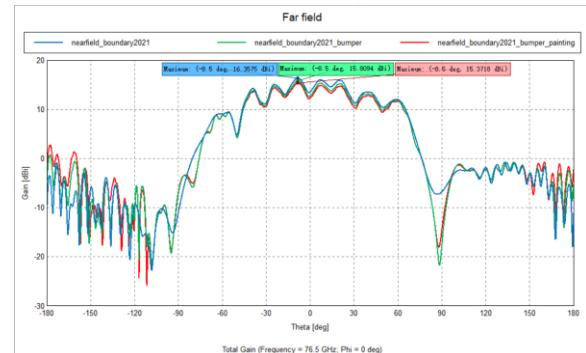
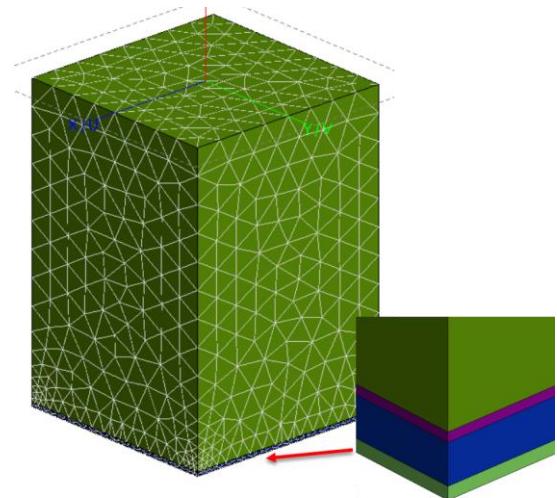
ACC雷达保杠一体化仿真

- 保杠尺寸约: 250mm*130mm
- 天线取近场包络约: 52mm*68mm
- 分别计算仅有保杠基底材料 (模型1) 和考虑涂层 (模型2) 的情况
- 收发共6通道计算资源统计:

	网格数量	工况数	并行数	内存[GB]	计算时间 [小时]
模型1	643 696	6	24	115	4.213
模型2	1 581 124	6	56	486	3.520

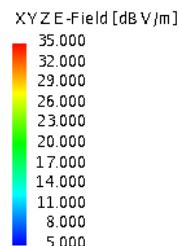
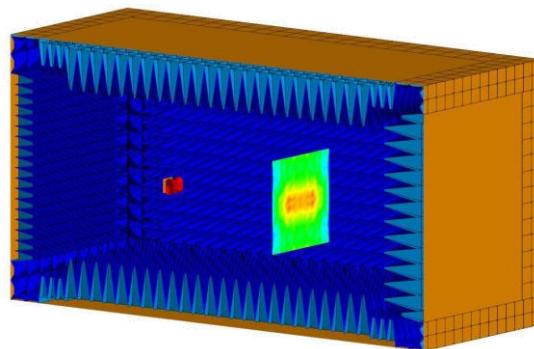
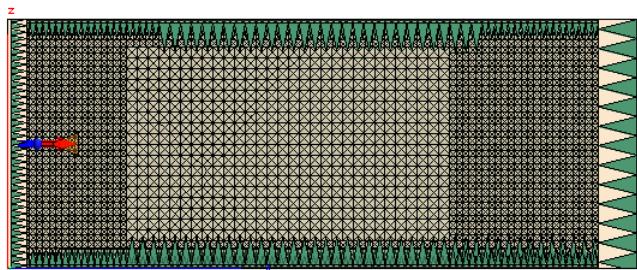
Intel(R) Xeon(R) Gold 6348 CPU @ 2.60GHz; 2 physical CPUs with a total of 56 processors

Intel(R) Xeon(R) Gold 6136 CPU @ 3.00GHz; 2 physical CPUs with a total of 24 processors



微波暗室仿真

- 暗室尺寸: 10mX3mX4m
- 仿真频率: 2GHz, 电尺寸66.7倍
- 求解器: MLFMM



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半波EMC暗室设计仿真 – 球面模式等效场 + RL-GO

模型说明	网格数量	并行数量	仿真时间[小时]
暗室+喇叭天线	金属: 1 668 110 介质: 5 753 476 总数: 7 421 586	40	4.059

```

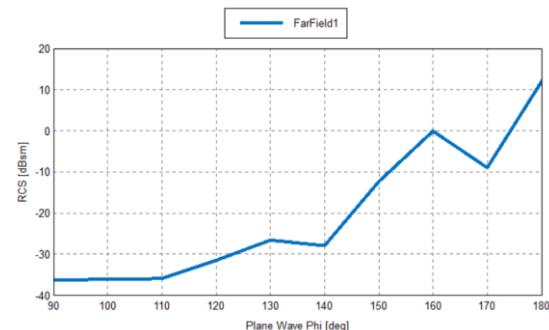
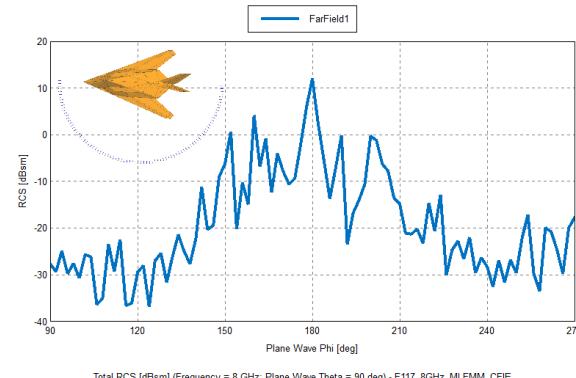
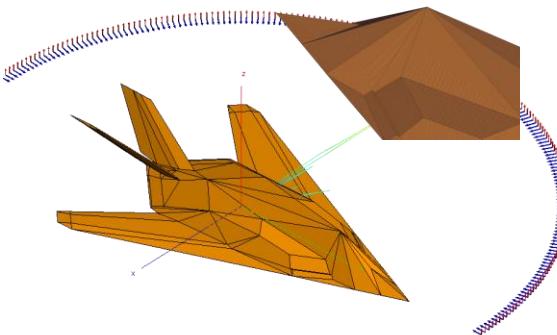
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15 of 250 2.55274799E-01
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17 of 250 2.69844207E-01
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21 of 250 6.07447960E-01
22 of 250 2.25763784E-01
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24 of 250 2.89030688E-01
25 of 250 8.47020990E-02
26 of 250 4.51267819E-02
27 of 250 4.11177043E-02
28 of 250 4.14438706E-02
29 of 250 2.41322464E-02
30 of 250 2.11265675E-02
31 of 250 1.50412540E-02
32 of 250 1.51926101E-02
33 of 250 1.19984779E-02
34 of 250 9.44682734E-03
35 of 250 2.05604683E-02
36 of 250 6.78744917E-03
Determination of the impedances and powers
0% ----- 100%
Calculate the far field
(Power integration over full far field sphere)
Precomputation of far field tables for the MLFMM
0% ----- 100%

```

多层快速多极子仿真单站RCS

- 飞机尺寸: 20.35米
- 入射角度: Theta=90, Phi=90~270°
- 仿真频率:
 - ✓ 2GHz (135波长), 4GHz (270波长), 步进1°
 - ✓ 8GHz (540波长), 步进2°
 - ✓ 15GHz (1017波长), 24个入射角度; 22GHz, 10个角度

频率	求解方法	网格数量	仿真时间(小时)
2GHz	MLFMM	895,234	2.569
4GHz	MLFMM	3,584,468	12.967
8GHz	MLFMM	14,336,888	22.544
15GHz	MLFMM	57,248,788	45.527
22GHz	MLFMM	90,701,504	96.997



THANK YOU

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