CERTIFIED
ELITE CHANNEL
PARTNER

Sub-THz device design and analysis by multi-physics simulation

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CYBERNET SYSTEMS TAIWAN Co. Ltd

2022 R2
Engineering What's Ahead.

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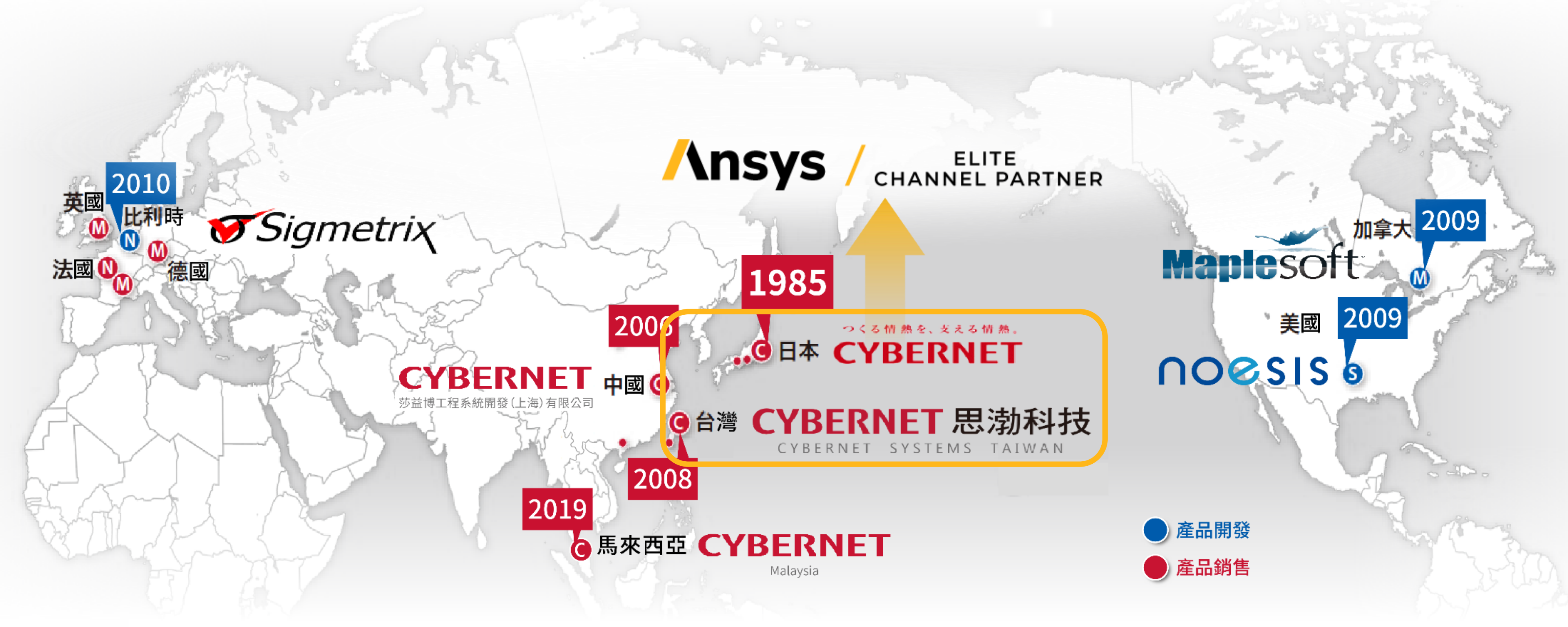

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頂尖產品方案

Ansys 多領域 CAE 模擬

Ansys / CERTIFIED ELITE CHANNEL PARTNER /

結構分析　計算流體力學
電子散熱　高頻電磁場模擬
光學設計　低頻電磁場模擬

測試與測量

ADLINK
Mechanical Simulation
OPAL-RT
gather tech
WOODWARD

數位轉型

ptc
paloalto NETWORKS
FORESCOUT
Symantec. A Division of Broadcom
tenable

集團產品

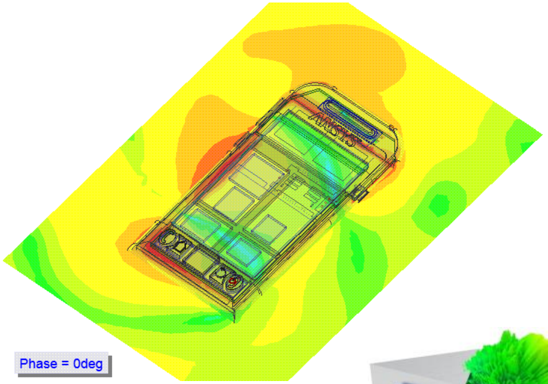
Maplesoft
noesis
Sigmetrix

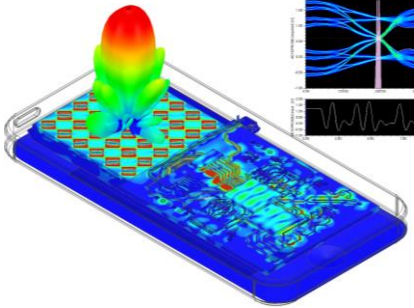
專業技術服務

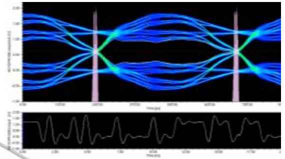
- 代理世界首屈一指之解決方案
- 現場安裝與技術支援
- 與原廠同步之專業技術
- 專業教育訓練課程
- 定時舉辦技術交流研討會

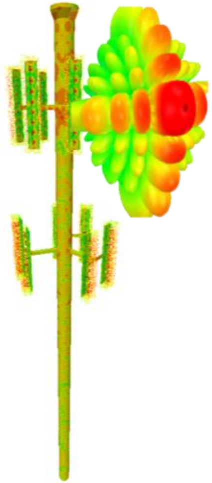
Agenda

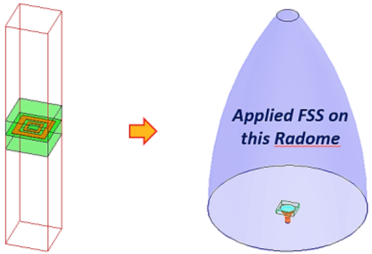
- **Introduction**
  - Background: 5G
  - Why Ansys?
- **Sub-THz Simulation**
  - Antenna Design
  - Array Synthesis and Script
  - Installed Performance
  - Sub-THz Case
- **Multi-Physics**
  - Thermal Simulation

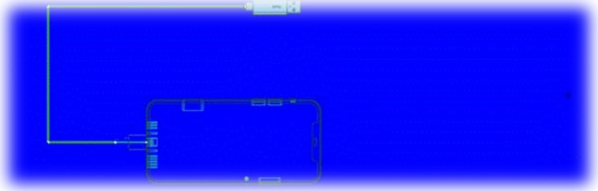












Introduction

Ansys 2022 R2
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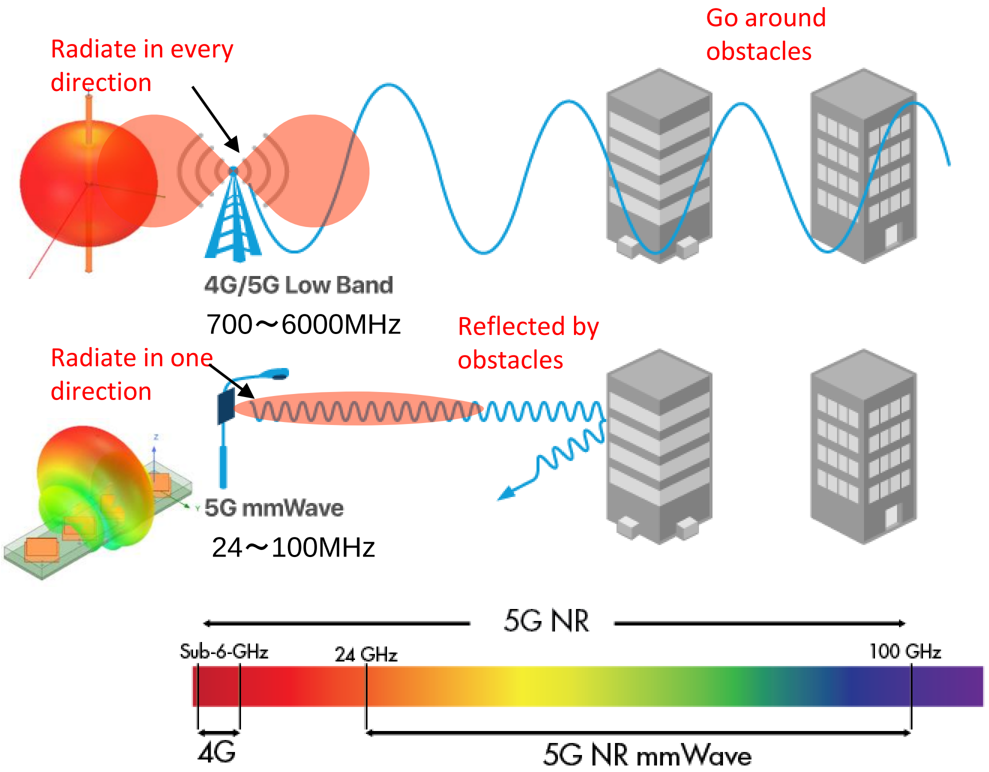
Background: 5G

- True 5G mobile network needs to exploit Millimeter Wave Bands
- 5G mm-Wave Antenna is required on both Base Station and user devices

5G mm-Wave Communication



5G mm Wave pros and cons

Pros	Cons
･Wide bandwidth→ultra high capacity (multi-Gbps) ･Less interference due to pencil beam	･Big loss due to propagation, environment ･Low penetration, mostly reflected by obstacles (building, car)→need Line of Sight (LoS) link

Antenna design tips

･Mm-Wave antenna must be highly directional to combat the propagation loss at mm-wave bands
･Higher power by the RF module
･Multiple antenna modules should be installed to extend coverage

5G mm Wave requirements

･High gain, high power ☞ RF exposure must be considered
･Multiple antenna ☞ link budget & coverage must be considered

Simulation Solutions for 5G Systems

/ HIGH BIT RATE SYSTEMS

- PRE LAYOUT DESIGN
- POWER INTEGRITY & RELIABILITY
- SIGNAL INTEGRITY ANALYSIS
- RFI, EMI/EMC, ESD
- THERMAL INTEGRITY & DESIGN RELIABILITY
- OPTICAL INTEGRITY

/ END USER EQUIPMENT

- MULTI BAND & MM WAVE ANTENNA DESIGN
- ANTENNA SYSTEMS PLACEMENT & INTEGRATION
- 5G STATISTICAL ANALYSIS
- EXTERNAL EFFECTS & HUMAN BODY INTERACTION
- ELECTROTHERMAL & RELIABILITY MANAGEMENT
- SYSTEM INTEGRATION

/ EDGE PROCESSORS

- POWER BUDGETING
- IP/CUSTOM VALIDATION
- PACKAGE AWARE SOC VALIDATION
- CHIP AWARE PACKAGE-SYSTEM VALIDATION

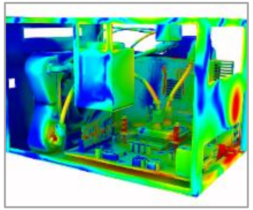
/ MICRO-INFRASTRUCTURE & ELECTRICALLY LARGE COMMUNICATION ENVIRONMENT

- BASE STATION ANTENNA ARRAY DESIGN
- MICROCELL ARRAY INSTALLATION & INTEGRATION
- MODELING SIMULATION ENVIRONMENT
- CONNECTIVITY & RFI ANALYSIS
- MULTIPHYSICS & ELECTROTHERMAL MODELING
- CHANNEL MODELING & COMMUNICATION ANALYSIS

AEDT products

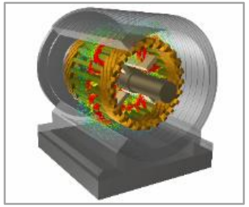
Ansys Electronics solutions help you solve the most critical aspects of your product designs through simulation. If you work with antennas, RF, microwave, PCB, package, IC design or even an electromechanical device, we provide you with industry gold standard simulators. Ansys helps you solve any electromagnetic, temperature, SI, PI, EMC, parasitics, cabling, filter and vibration challenges in your designs. We build on this with complete product simulation, allowing you to achieve first pass success designing an airplane, car, cellphone, laptop, inverter, wireless charger, or any other system.

HFSS



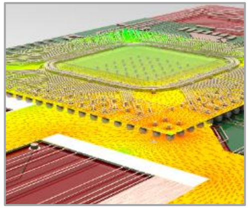
Simulates 3D electromagnetic fields to design high-frequency, high-speed electronic components. Its FEM, IE, asymptotic and hybrid solvers address RF, microwave, IC, PCB and EMI problems.

Maxwell



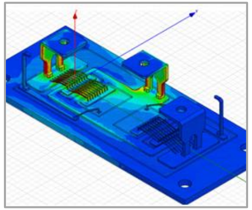
Solves static, frequency-domain and time-varying electric fields. Maxwell is an EM field low-frequency solver for electric machines, transformers, actuators and other electromechanical devices.

SIwave



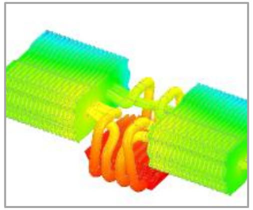
Solves power delivery systems and high-speed channels in electronic devices. A specialized tool for power integrity, signal integrity and EMI analysis of IC packages and PCBs.

Q3D Extractor



Calculates the parasitic parameter of frequency-dependent resistance, inductance, capacitance, and conductance (RLCG) for electronic products. Simulate and design electronic packaging and power electronic devices.

Icepak



Predicts airflow, temperature and heat transfer in IC packages, PCBs, electronic assemblies/enclosures, power electronics. Icepak is a CFD solver for electronics thermal management.

Sub-THz Simulation

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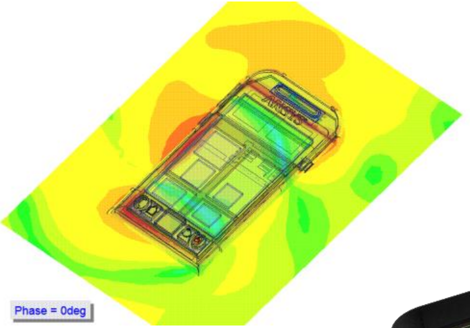
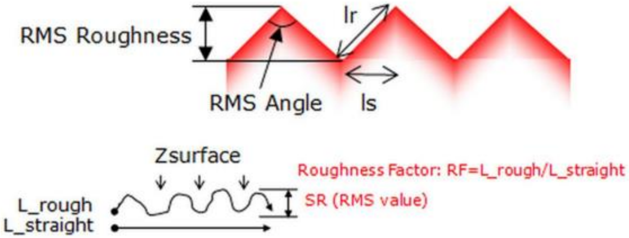
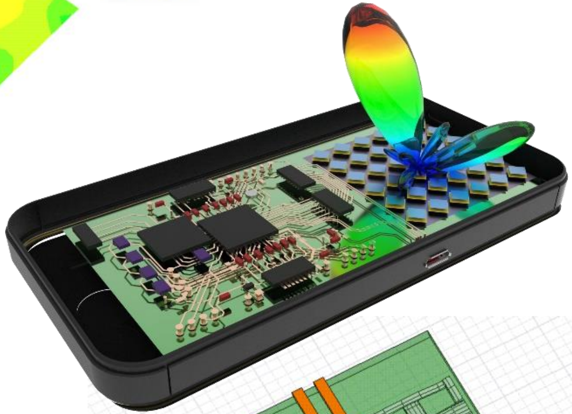
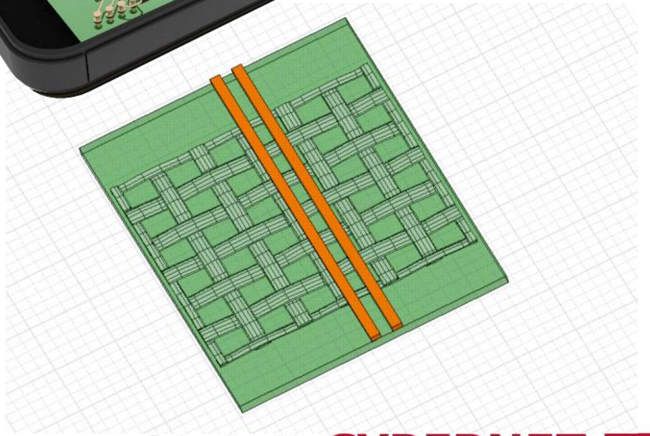
Simulation Challenge

- **Challenge**
  - Surface Roughness
  - High Frequency Dk/Df
- **Simulation Key Factor**
  - HFSS Roughness Setup
  - High Frequency Dk/Df
  - HFSS Mesh Fusion
  - 3D Component Array
  - PyAEDT and Python Script
  - Installed Antenna Performance



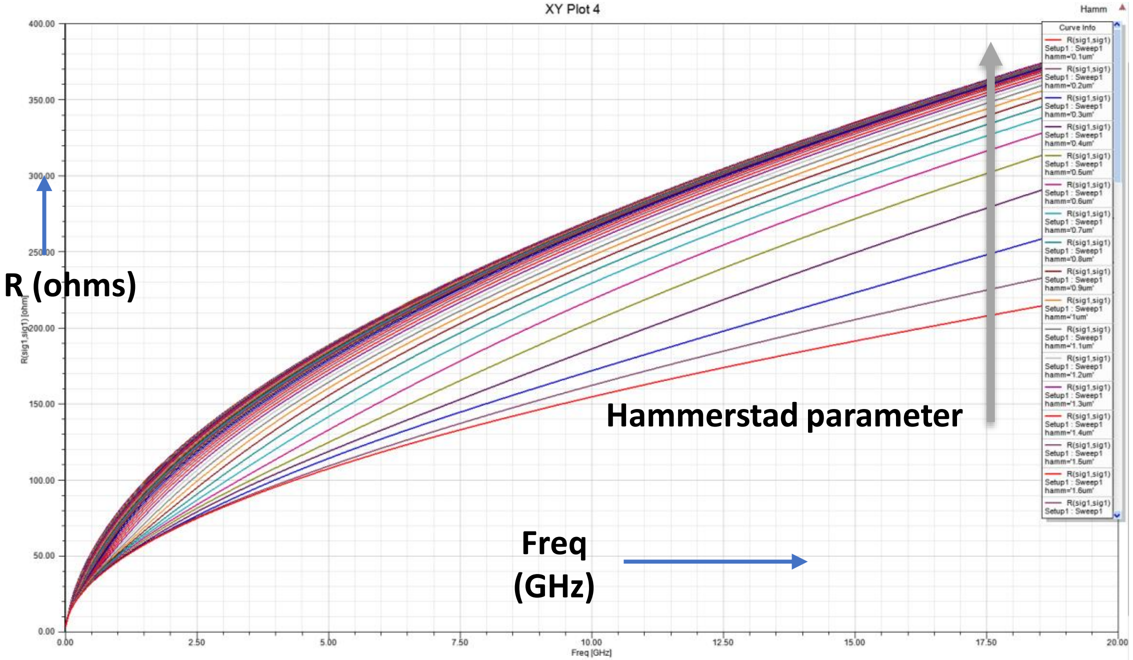






Hammerstad-Jensen Model

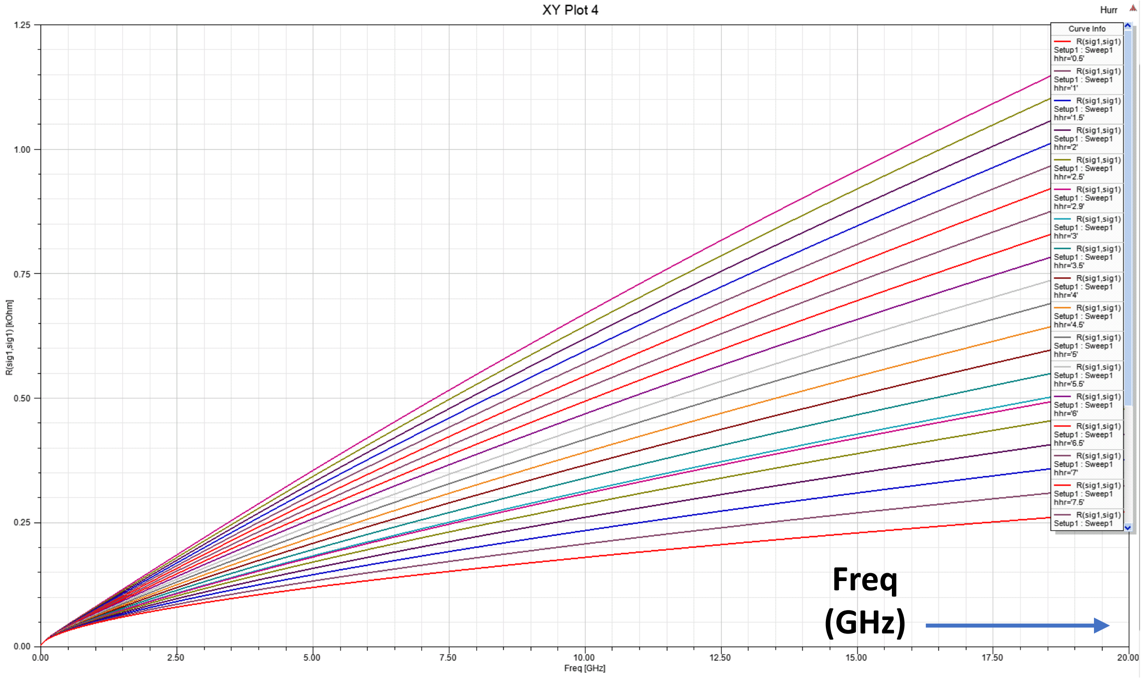
- *Surface Roughness parameter (rms) varied from 0.1um to 5um*
- R_{signal} *vs Freq*



Huray Model

- *Surface Roughness parameters*
  - *Nodule Radius fixed at 0.5um*
  - *Hall-Huray ratio varied from 0.1 to 5*
- R_{signal} *vs Freq*

R (ohms)



Freq (GHz)

Hall-Huray ratio

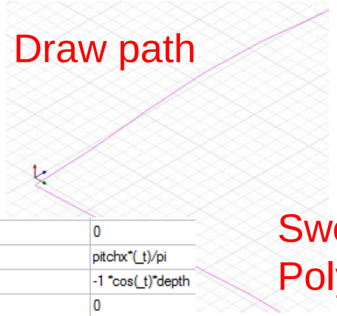
Creating Glass models

Fill

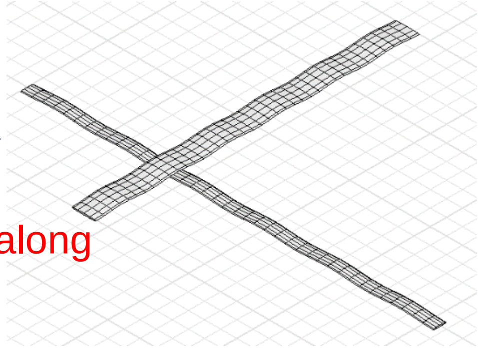
Warp

Draw Yarn
Cross-sections

Draw path

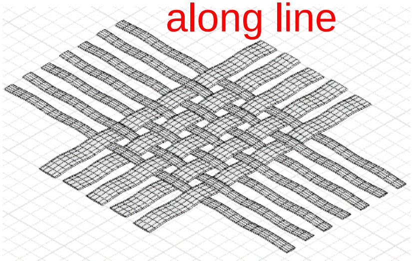


X(_t)	0
Y(_t)	pitchx*(_t)/pi
Z(_t)	-1 *cos(_t)*depth
Start _t	0
End _t	bends*2*pi
Number of Points	points



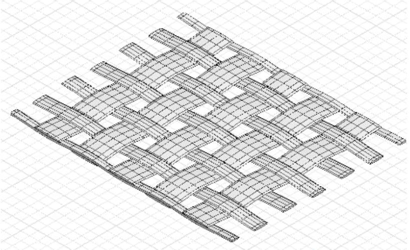
Sweep along
Polyline

Duplicate
along line



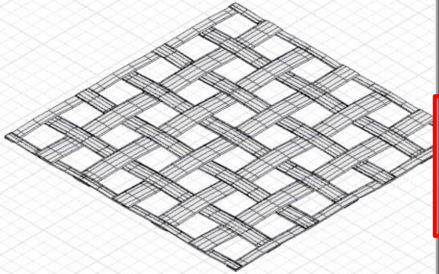
Change phase

Clip edges



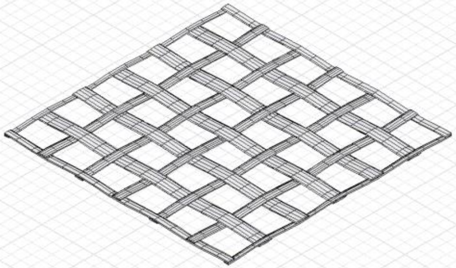
Boolean subtract

Parameterization



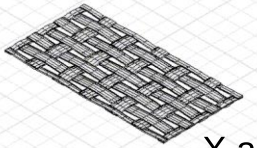
Fill and Warp Height

Name	Value
pitch	35.8
depth	X_height+0.1mil
bends	6
points	40
X_height	0.5
X_width	4
Y_height	0.5
Y_width	7.5
dx	5
dy	2
dz	0.6
dist	2.5
TLwidth	4
TLheight	2.2
dxair	25
dyair	2



Fill and Warp Width

All Dimensions of cloth are parameterized



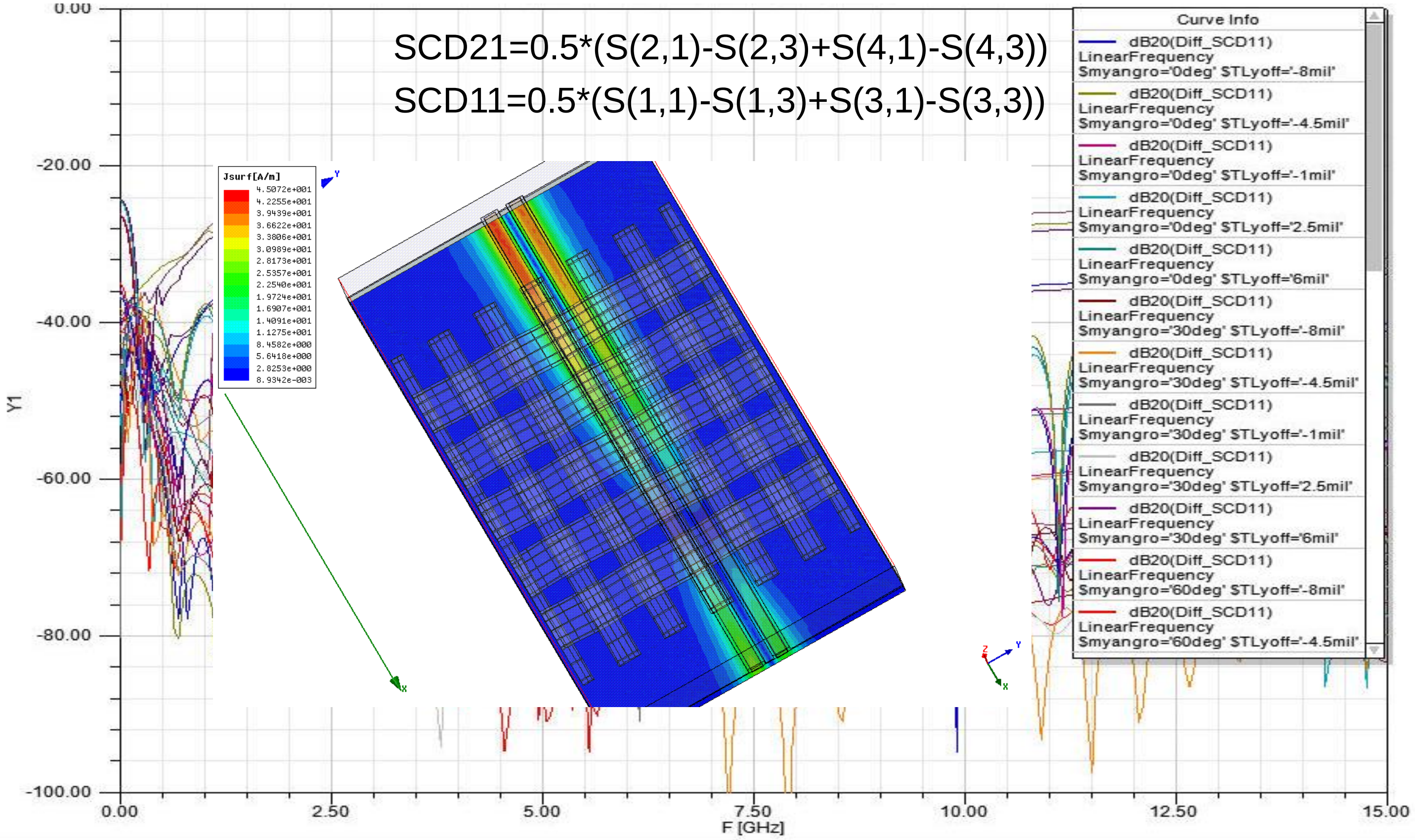
X and Y Pitch

Parameters are adjusted to model any type of glass cloth

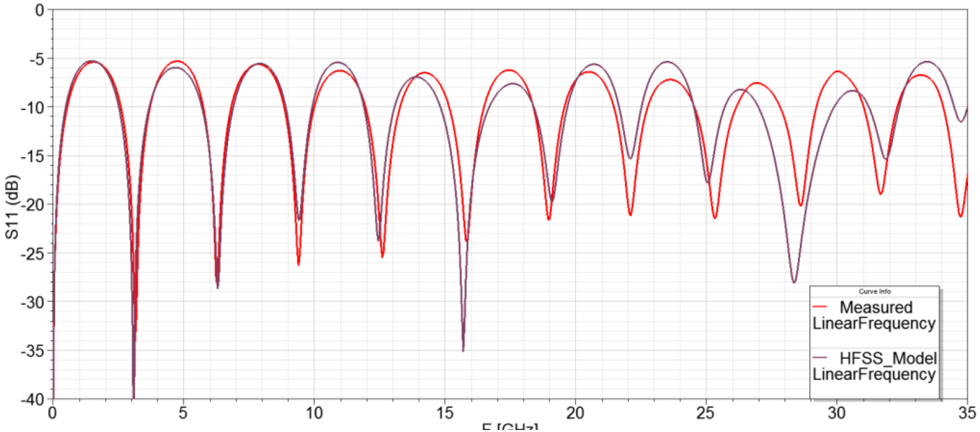
106 Common Mode Conversion

SCD21=0.5*(S(2,1)-S(2,3)+S(4,1)-S(4,3))

SCD11=0.5*(S(1,1)-S(1,3)+S(3,1)-S(3,3))

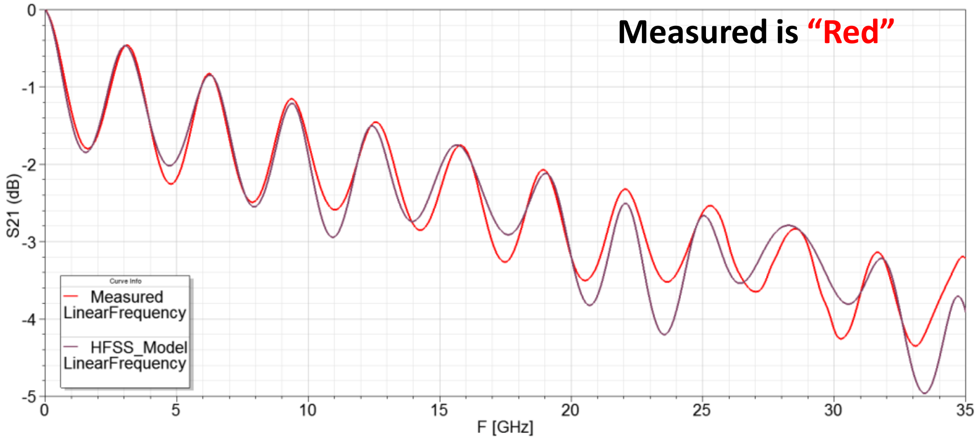


HFSS Simulation With Extracted Parameters

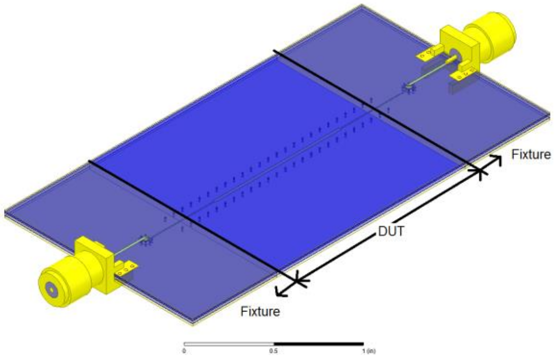


S_{11}

Measured is "Red"



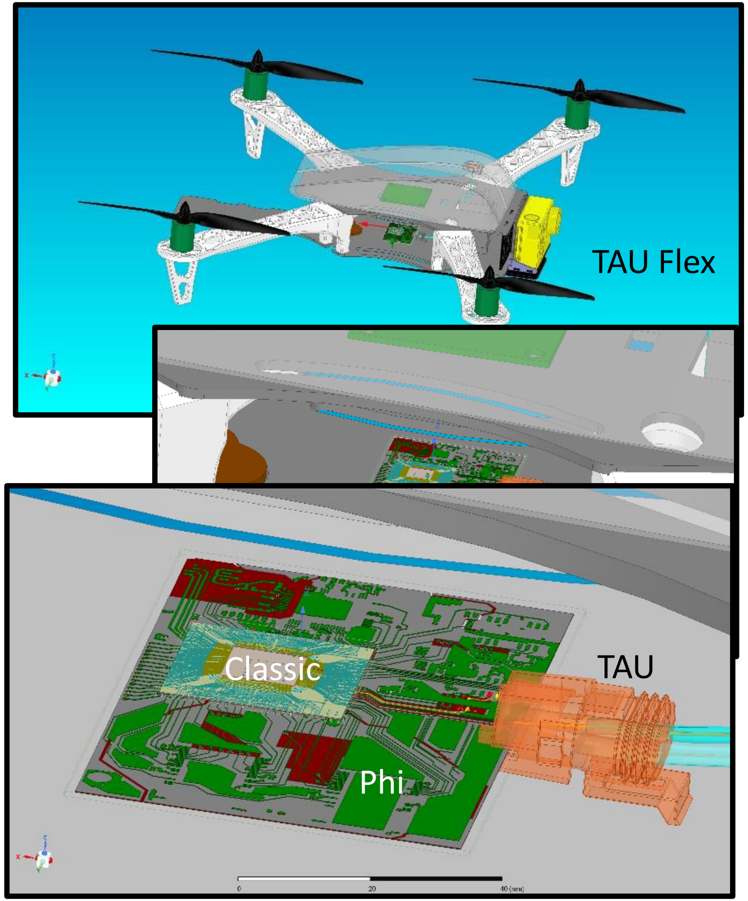
S_{21}



HFSS Mesh Fusion: No Limits

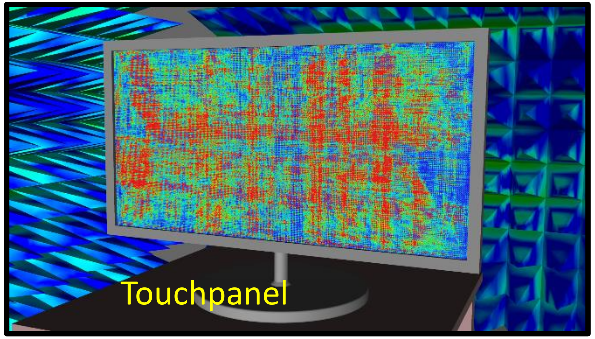
- New Beta Feature in HFSS 2021 R1
  - Fusion of powerful meshing and solving technologies
- Mesh Fusion Features:
  - Independent mesh regions
    - Optimal mesh algorithm and scale for each region
    - Concurrent (i.e., parallel) region by region meshing
      - Faster initial mesh generation
  - Improved reliability for multi-scale assembly designs
    - e.g., Antenna on platform, package on PCB, IC on package

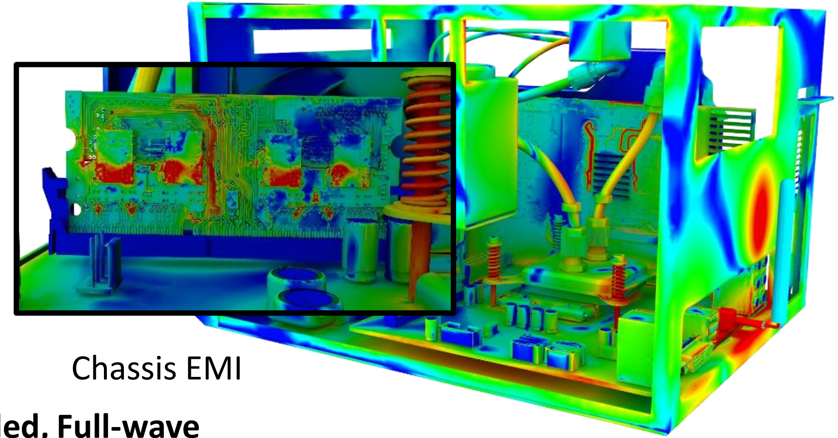
- A Major Breakthrough in FEM Solver Technology
  - Uncompromised and accurate: Fully coupled fields across region interfaces!
  - Solver delivers the true HFSS *Gold-standard Accuracy*



HFSS Mesh Fusion: No Limits

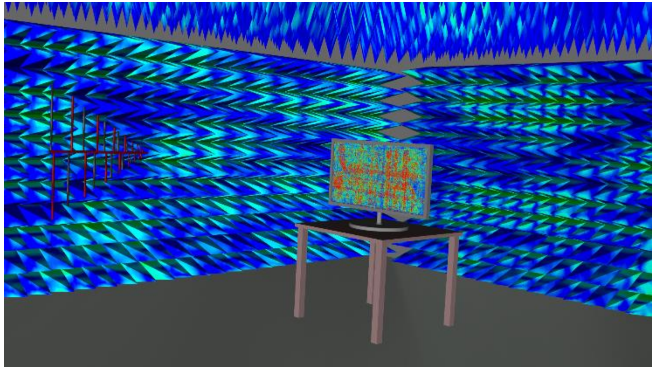
- Simulate Complete Electromagnetic Systems

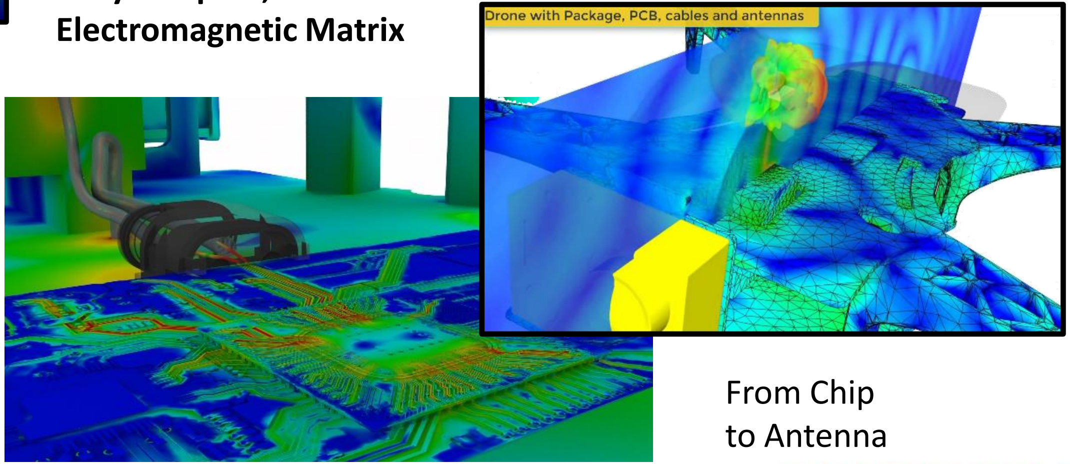




Chassis EMI

Fully-Coupled, Full-wave Electromagnetic Matrix

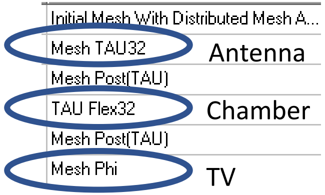




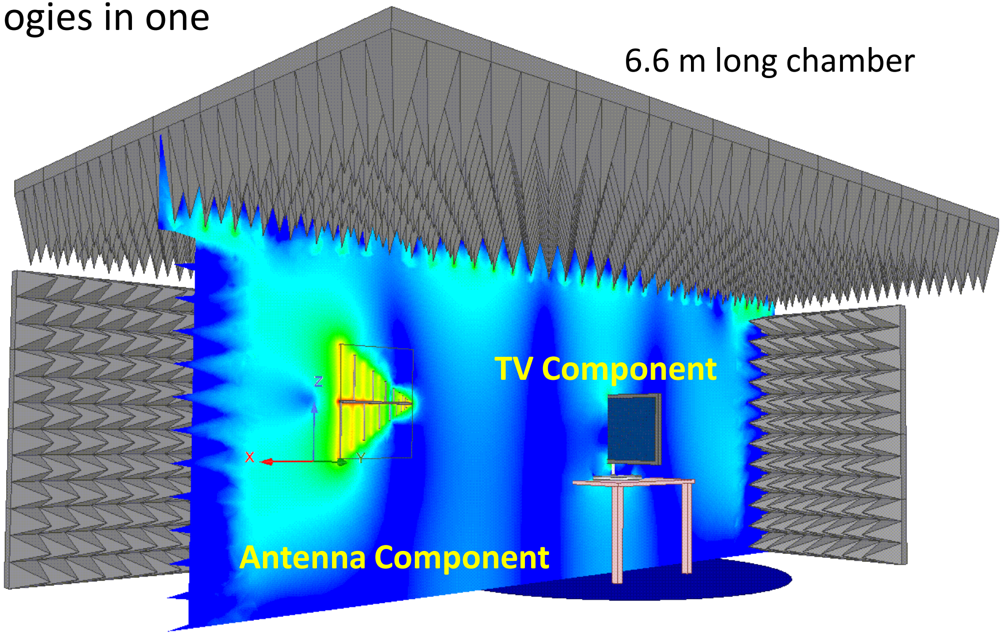
From Chip to Antenna

Mesh Fusion: Large complex "EM Systems"

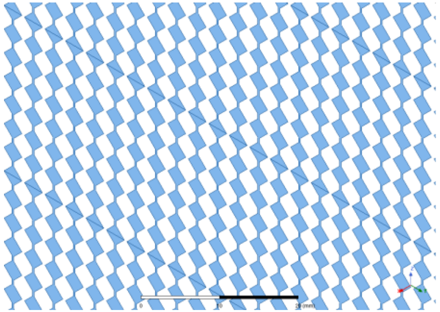
- Television touchscreen in EMI chamber
  um to meters
- Three mesh technologies in one

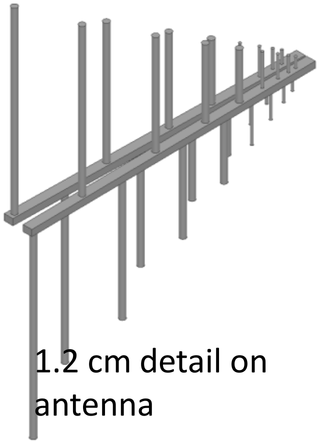


6.6 m long chamber



300 um detail in touchpanel

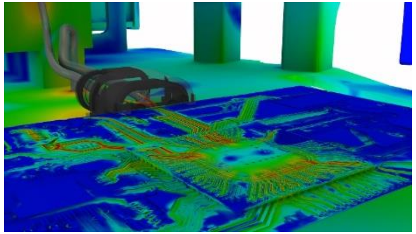


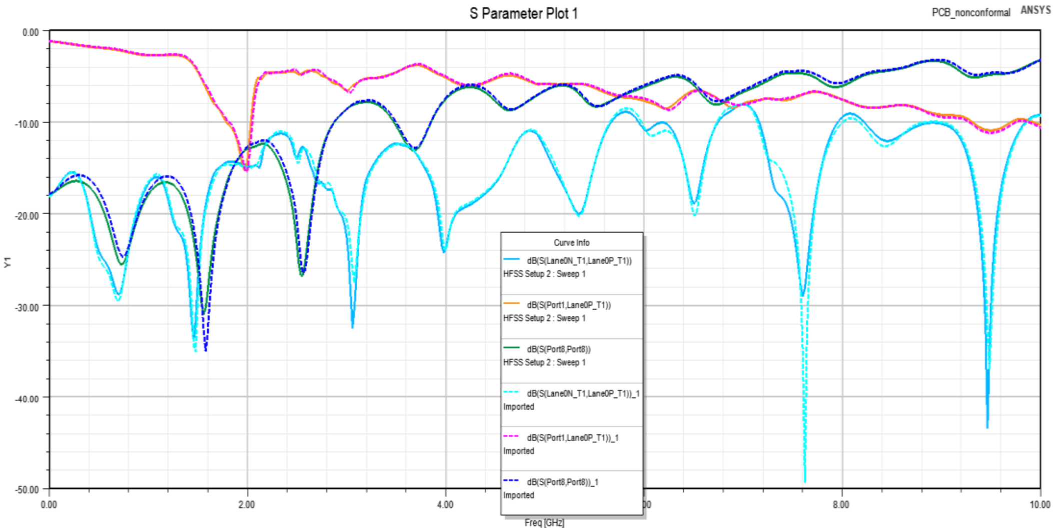


1.2 cm detail on antenna

Mesh Fusion Example: Speed up with Complex Designs

HFSS 3D Layout: Highly complex PCB with bondwire package and edge mount connector





Global Mesh

Pass Number	Solved Elements	Max Mag. Delta S
1	2280999	1
2	2868991	0.72621
3	3258708	0.15402
4	3709952	0.046616
5	4628243	0.010713

Mesh Fusion

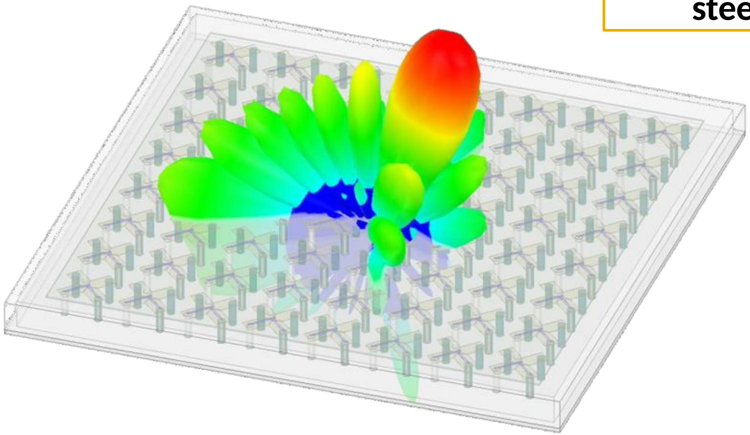
Pass Number	Solved Elements	Max Mag. Delta S
1	1833394	1
2	2292081	0.89003
3	2514092	0.051521
4	2775913	0.015268

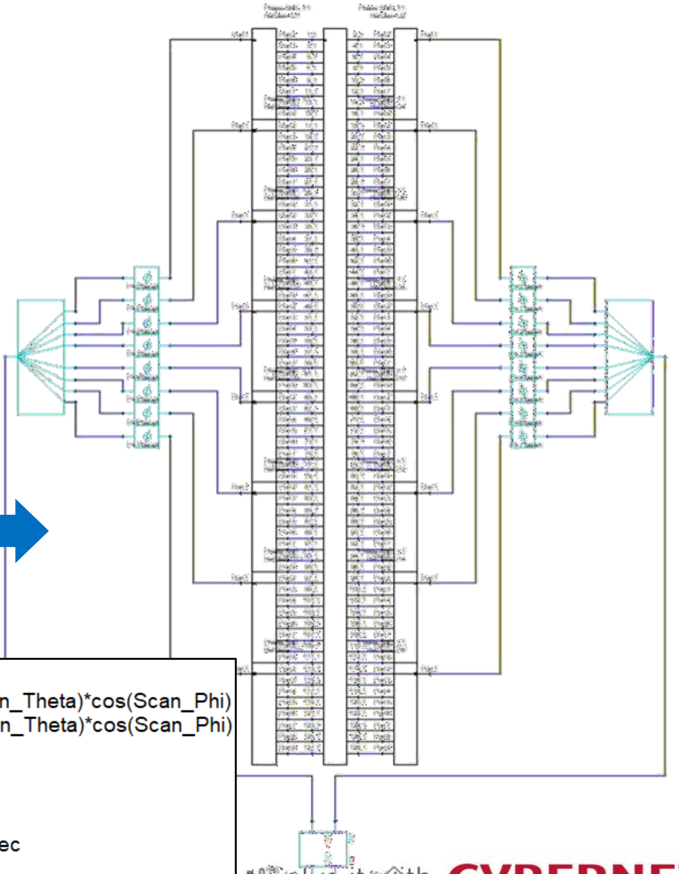
Auto 16 cores	Initial Meshing (2.8X)		# of Passes	Adaptive Meshing (1.5X)		# of Freqs	Interpolating Sweep (3.9X)		Total (3.7X)
	Time	Mem (GB)		Time	Mem (GB)		Time	Mem (GB)	Time
Global Mesh	02:28:49	33.2	5	02:19:22	224	136	72:35:33	447 (2 in II)	77:23:44
Mesh Fusion	00:53:28	8.45	4	01:32:42	89	136	18:33:16	225 (8 in II)	20:59:26

Phased Array Synthesis: Explicit Array

- Explicit modeling of array is necessary for multiphysics analysis
- Dynamic link to beamforming network in Circuit
- Push excitation from Circuit steers the beam in HFSS

Dynamic link/Push Excitation steers beam in HFSS

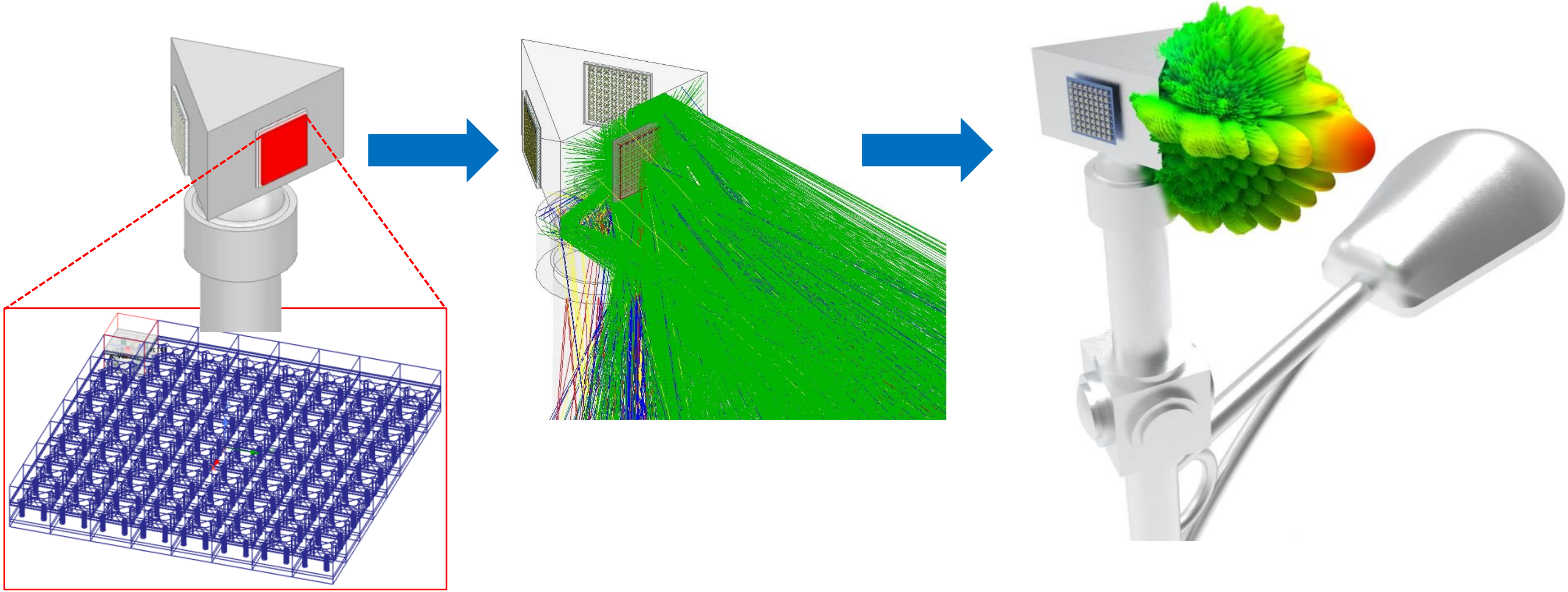




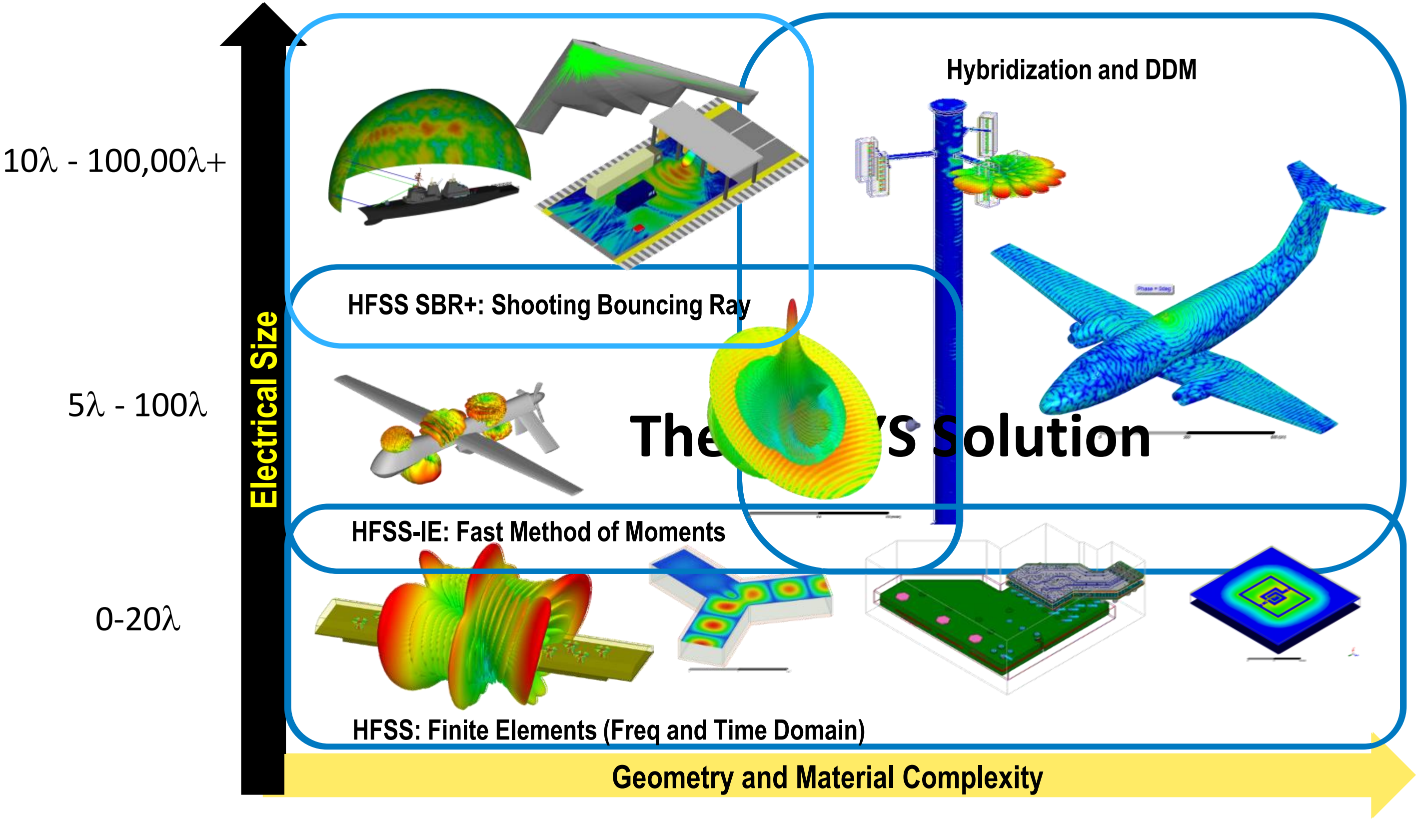
Design Properties
betaY = k_c*dist*sin(Scan_Theta)*cos(Scan_Phi)
betaX = k_c*dist*sin(Scan_Theta)*cos(Scan_Phi)
Scan_Phi = 45deg
Scan_Theta = 30deg
dist = 7mm
k_c = 2*pi*f_c/c
c = 300000000m_per_sec
f_c = 28GHz
Pin = 40

Installed Antenna Performance on a uCell

- FA-DDM simulation of phased array can be mapped onto uCell design in SBR+ as a near-field source
- SBR+ calculates the installed antenna pattern on the uCell

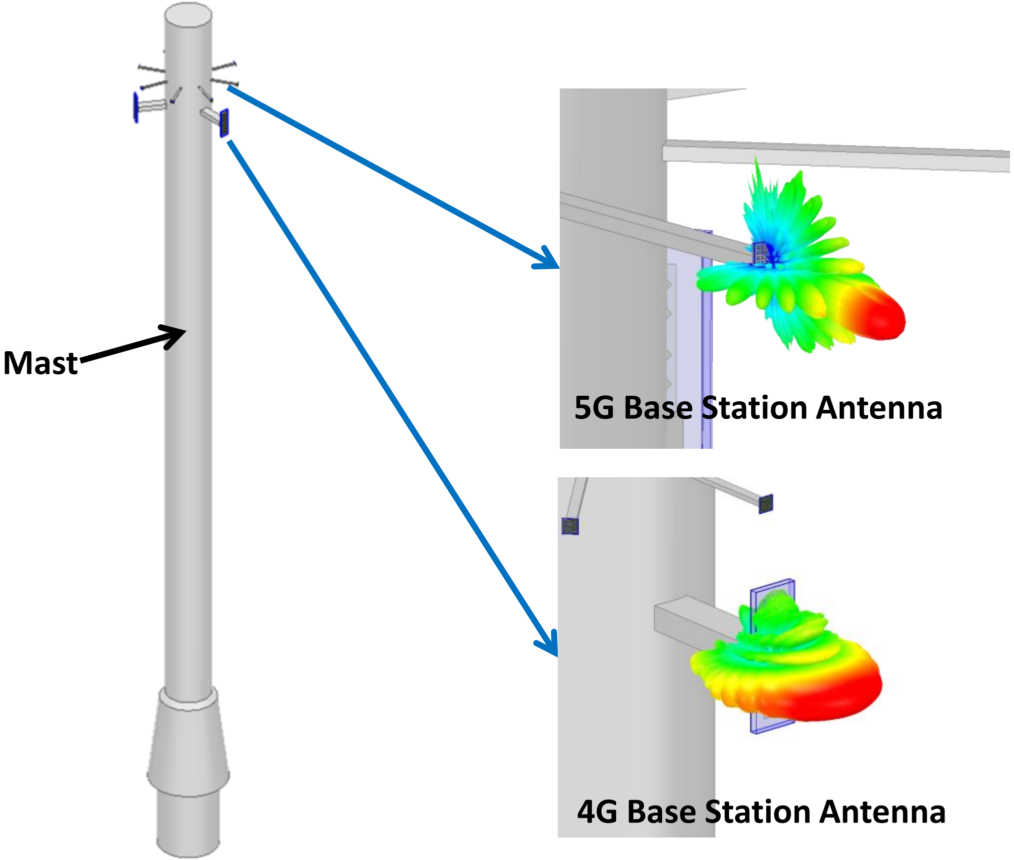


Ansys high frequency (HF) electromagnetic (EM) solvers



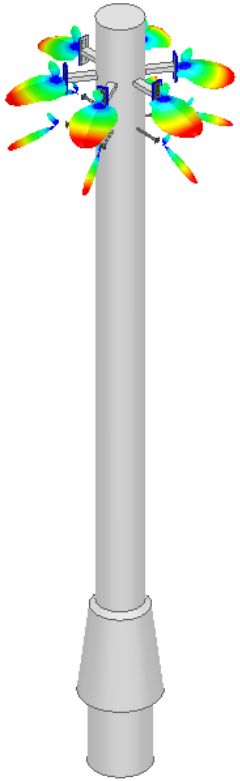
- AUTOMATIC hybridization of techniques
- AUTOMATIC meshing and mesh convergence

Installed Antenna Performance (SBR+)

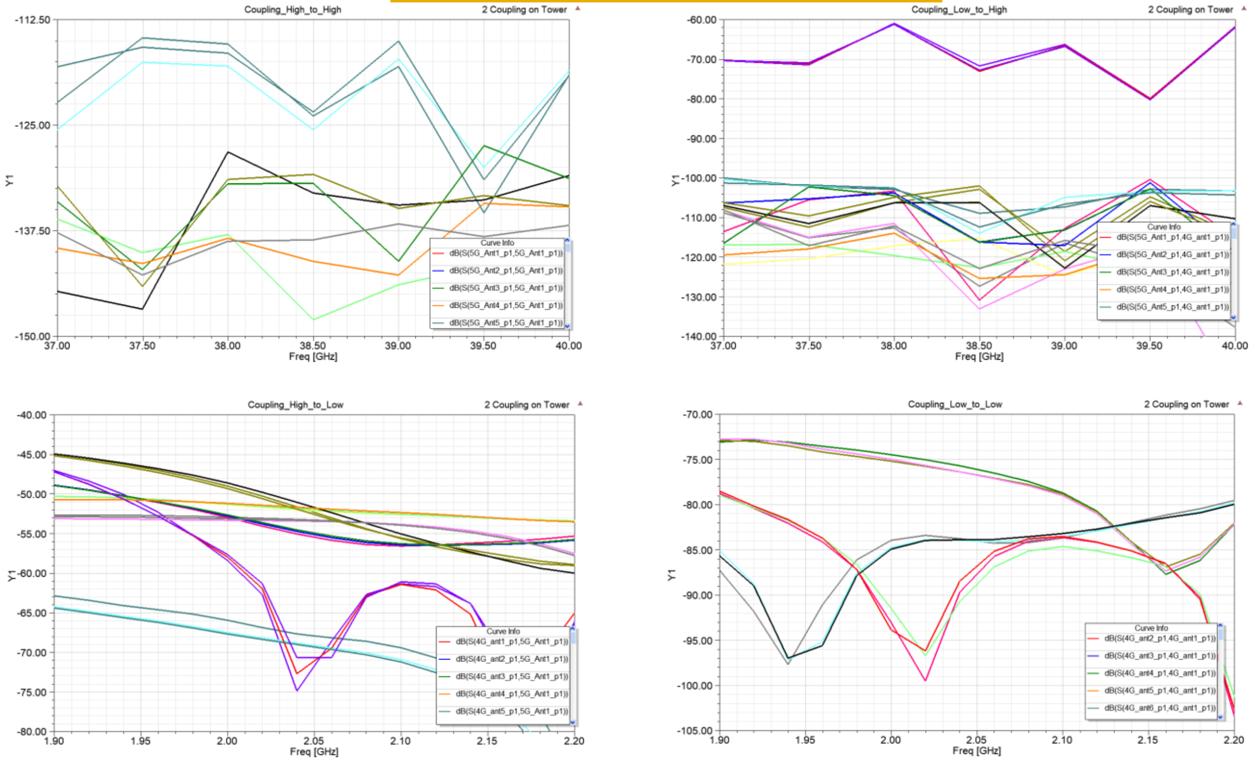


HFSS SBR+ simulation to calculate antenna pattern installed on a communication tower

Installed Antenna Performance



Coupling between 12 BS antennas



Design and characterization of CMOS millimeter-wave transformers

Publisher: IEEE

Cite This

PDF

DOI: 10.1109/IMOC.2009.5427555

Bernardo Leite ; Eric Kerhervé ; Jean-Baptiste Bégueret ; Didier Belot

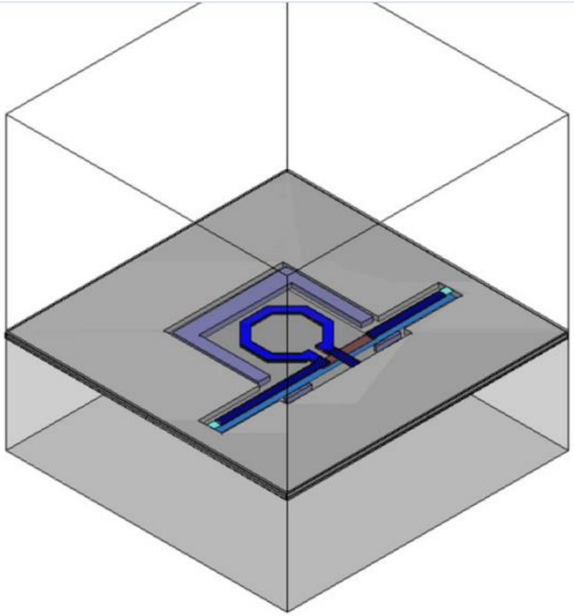


Figure 2. HFSS model of the transformer and interconnects.

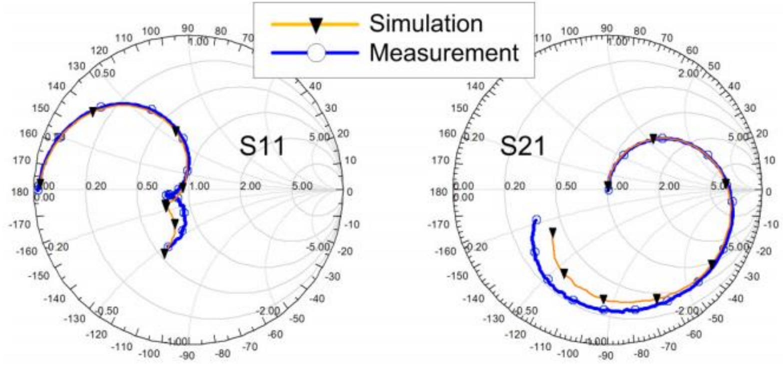


Figure 3. Mesured and simulated S parameters of the transformer.

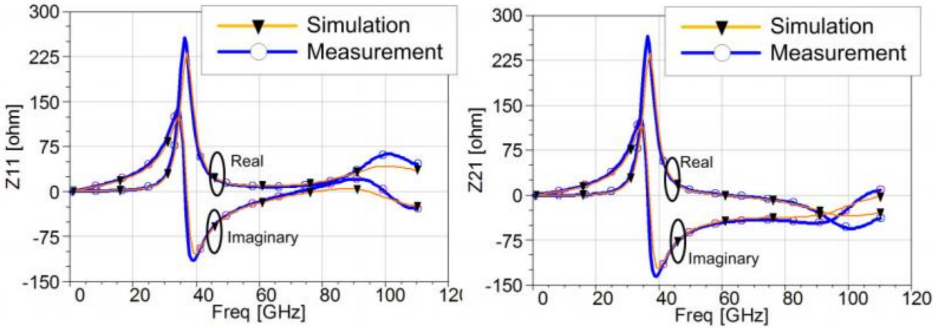


Figure 4. Mesured and simulated Z parameters of the transformer

IEEE Microwave and Wireless Components Letters (Volume: 28 , Issue: 11, Nov. 2018)

Broadband Transition of Substrate-Integrated Waveguide-to-Air-Filled Rectangular Waveguide

Publisher: IEEE

Cite This

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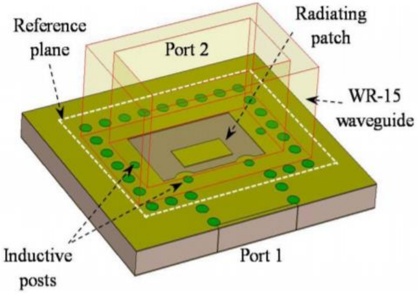
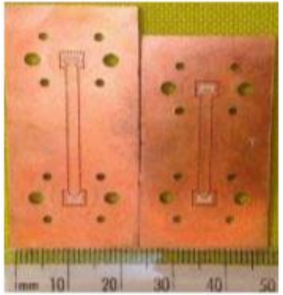
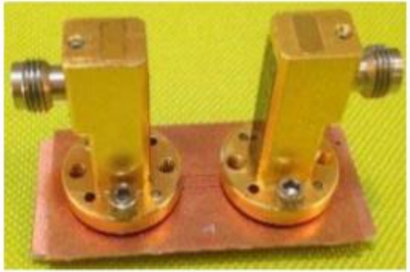
DOI: 10.1109/LMWC.2018.2871330

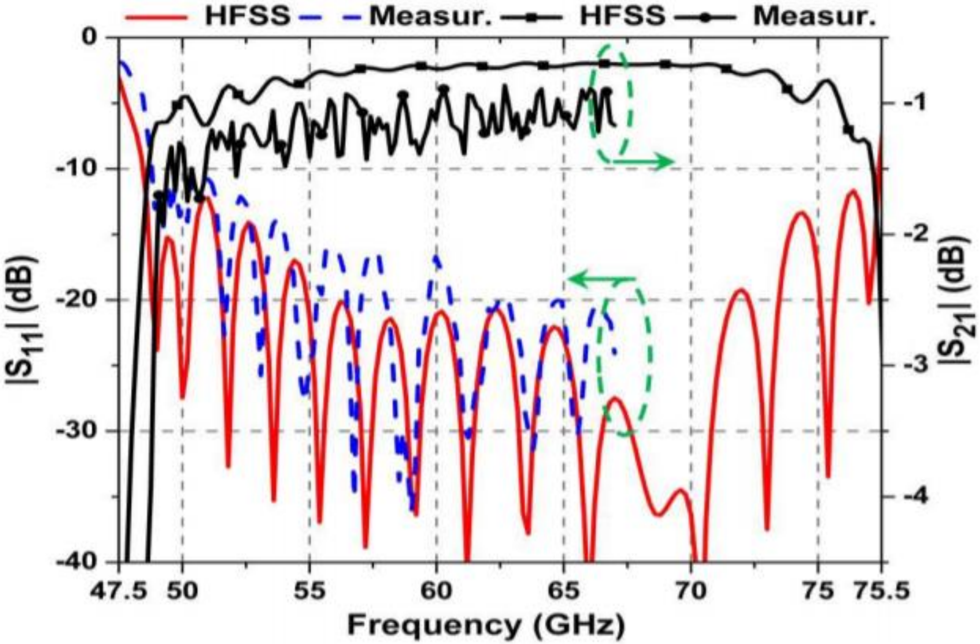
Issa Mohamed ; Abdelrazik Sebak All Authors



Perspective view of the proposed SIW-to-WG transition.







IEEE Microwave and Wireless Components Letters (Volume: 17 , Issue: 3, March 2007)

A 90-GHz Waveguide Variable Phase Shifter

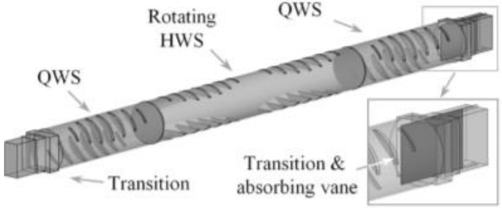
Publisher: IEEE

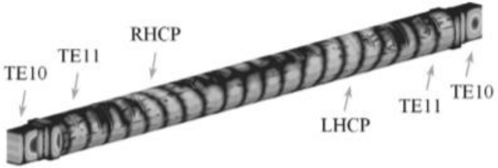
Cite This

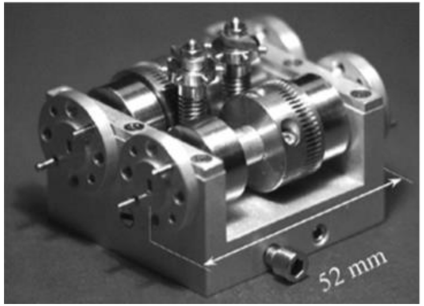
PDF

DOI: 10.1109/LMWC.2006.890476

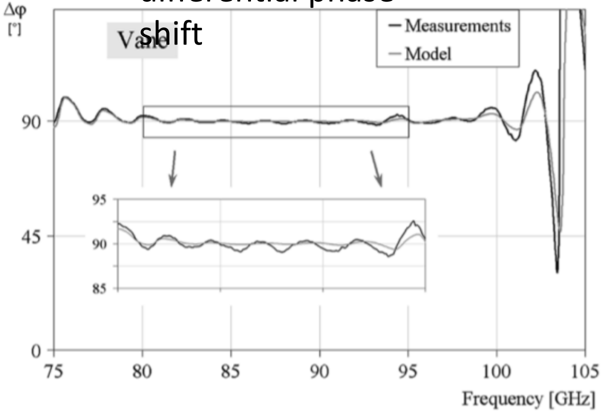
Giampaolo Pisano ; Giorgio Savini ; Luca Pietranera ; Kate Isaak ; Bradley Johnson ; Massimo Gervasi ; Lucio Piccirillo

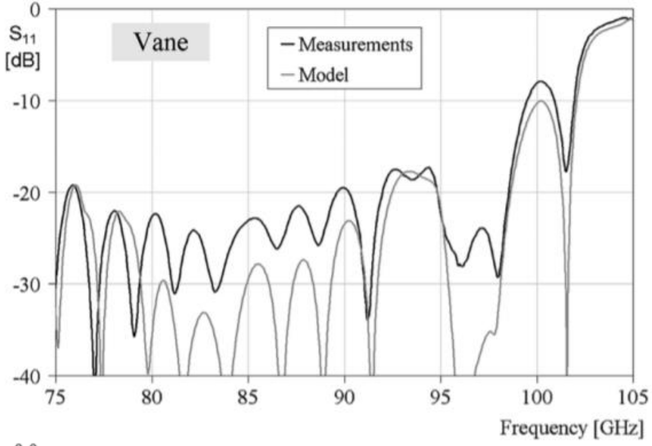


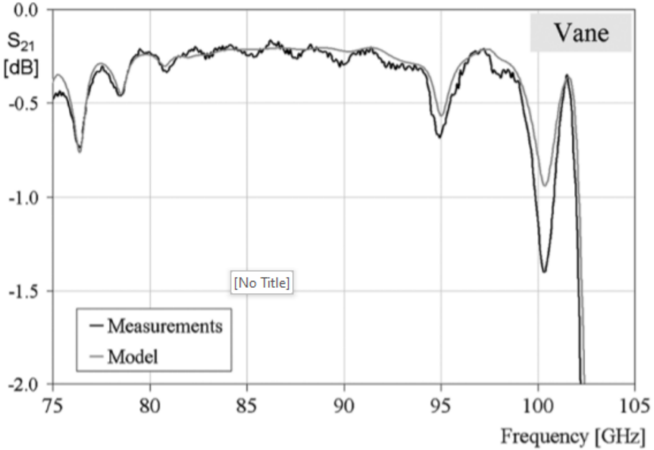




differential phase shift







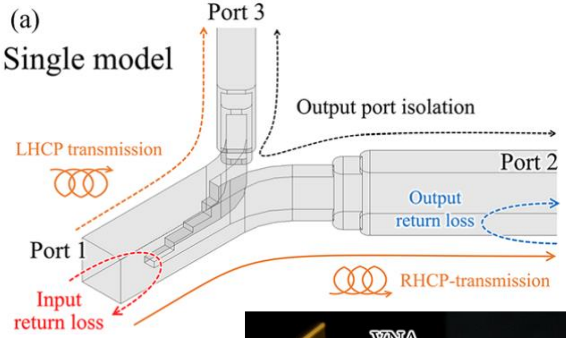
Open Access | Published: 29 October 2020

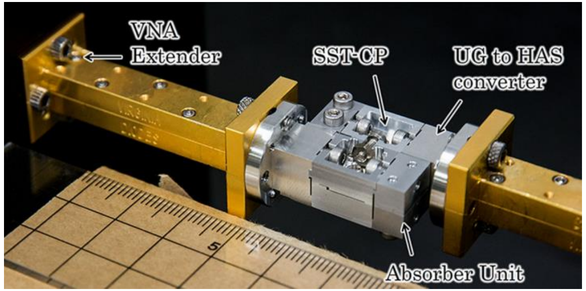
Novel 500-GHz Band Waveguide Stepped Septum-Type Circular Polarizer with a New High-Accuracy and Very Small Waveguide Flange

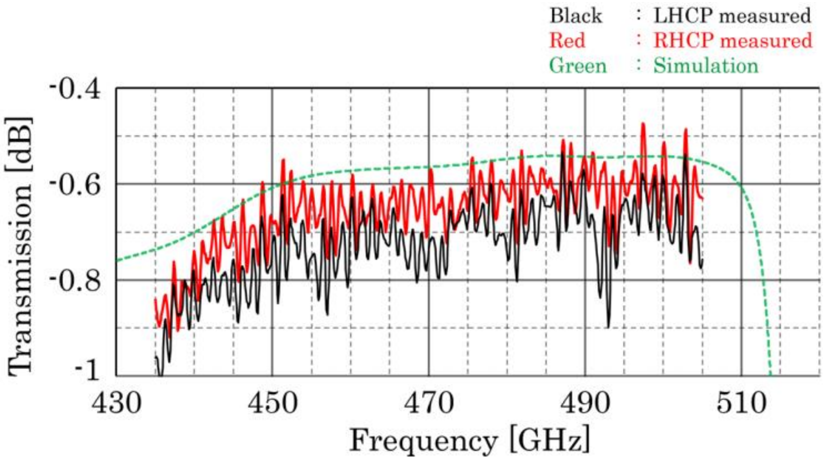
https://doi.org/10.1007/s10762-020-00752-9

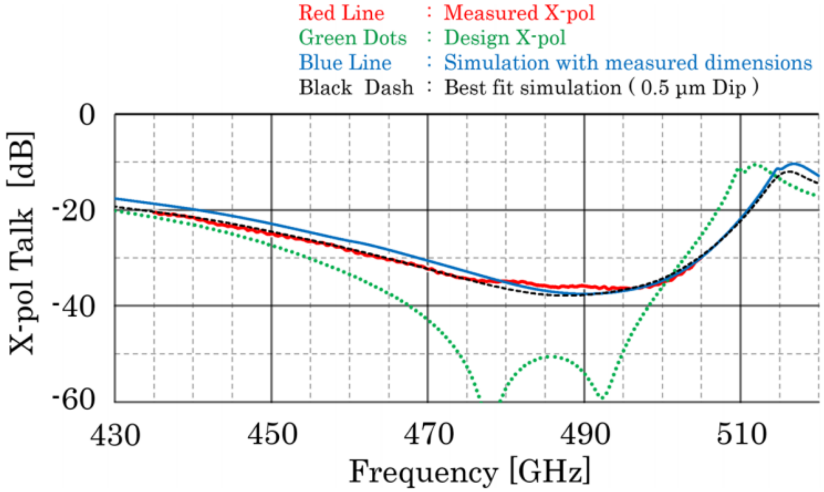
Yutaka Hasegawa, Hiroyuki Maezawa & Hideo Ogawa

Journal of Infrared, Millimeter, and Terahertz Waves 42, 1–16(2021) | Cite this article







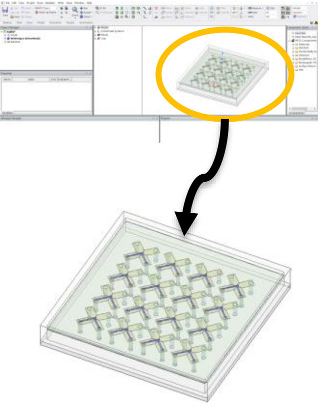


Multi-Physics Simulation

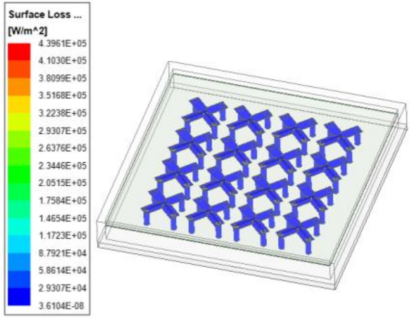
Ansys
2022 R2
Engineering What's Ahead.

HFSS & Icepak Co-Simulation Flow In AEDT

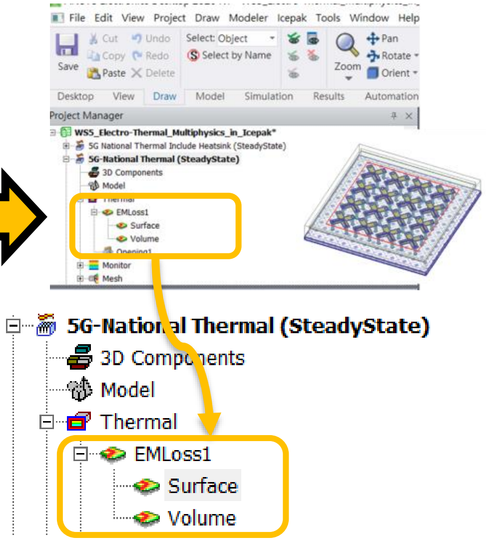
Create 3D model → **Calculate EM Loss in HFSS** → **Import EM loss to Icepak** → **Icepak Result**



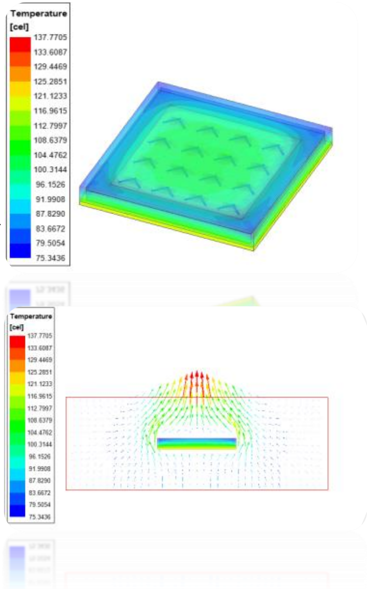
Create Model
(SpaceClaim or HFSS)



Calculate EM Loss
(HFSS)

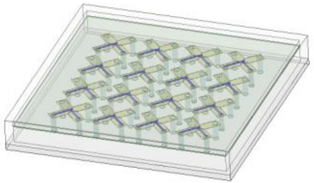


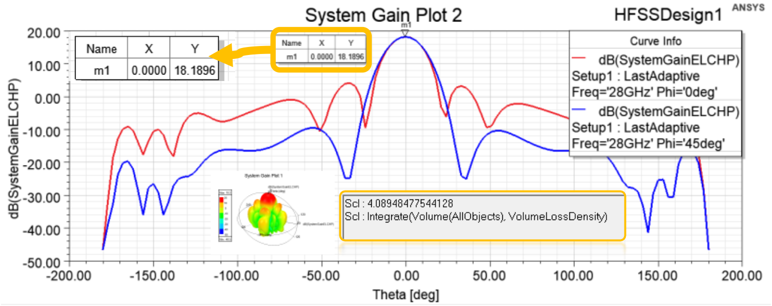
Import EM Loss
(Icepak)

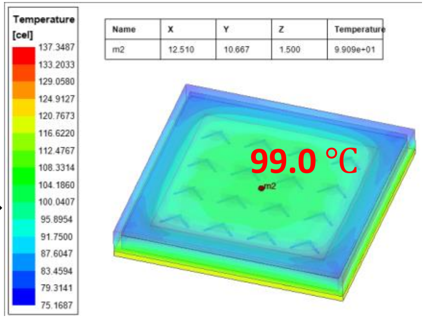


Calculate Temperature
(Icepak)

HFSS & Icepak Co-Simulation Flow In AEDT







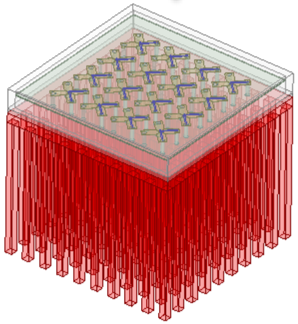
Model 1

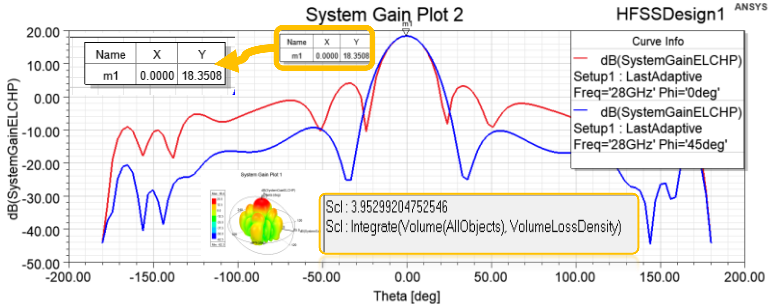
Add Cooling design

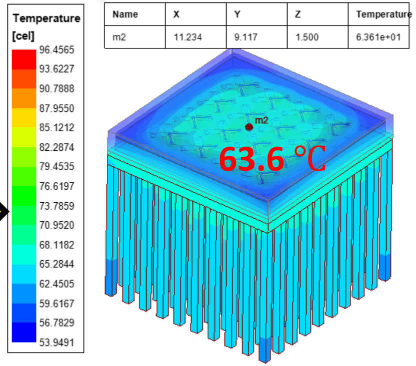
Gain value 18.18 dB improve to 18.35 dB

EM Loss 4.08 W improve to 3.95W

Temperature from 99 ℃ improve to 63.6 ℃

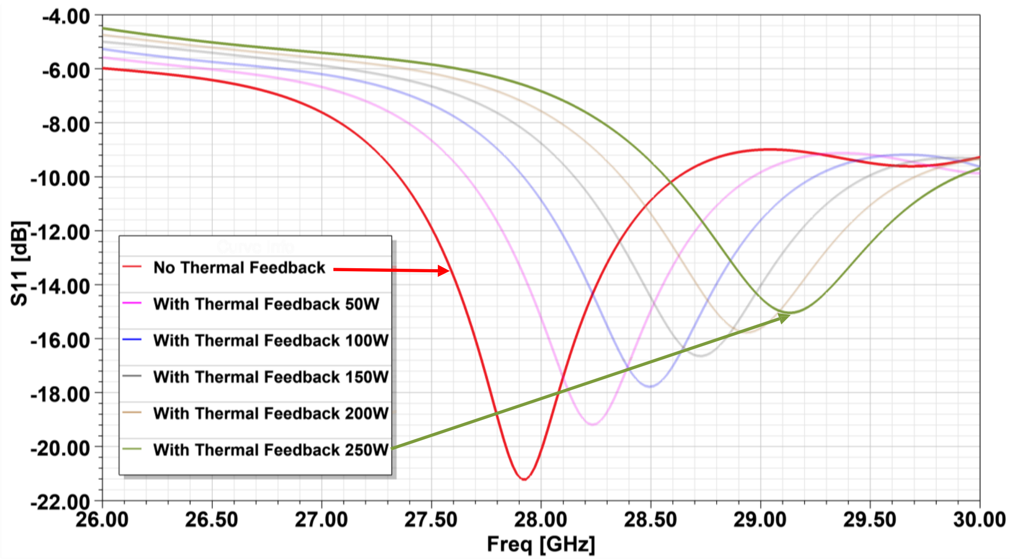


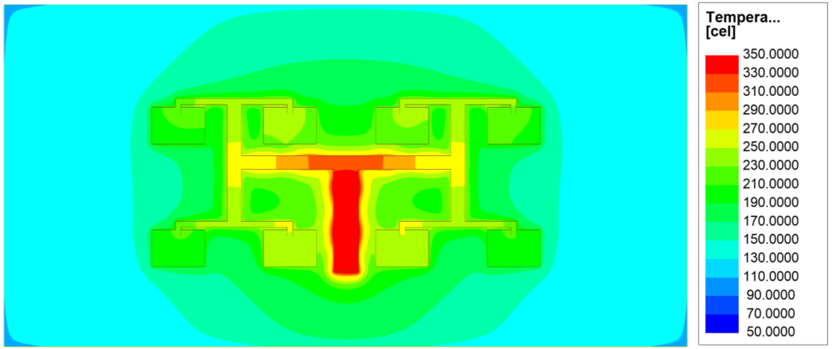


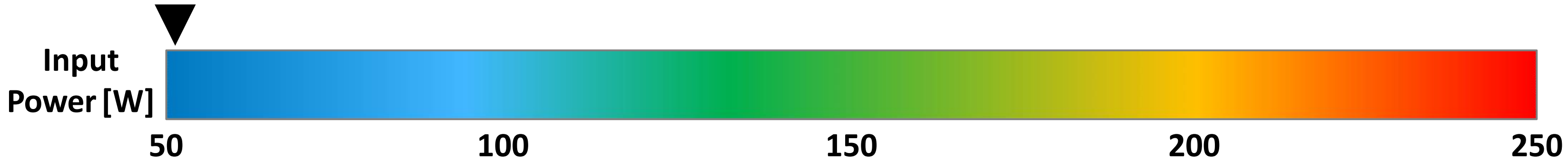


Model 2

Return Loss and Temperature Field vs. Input Power

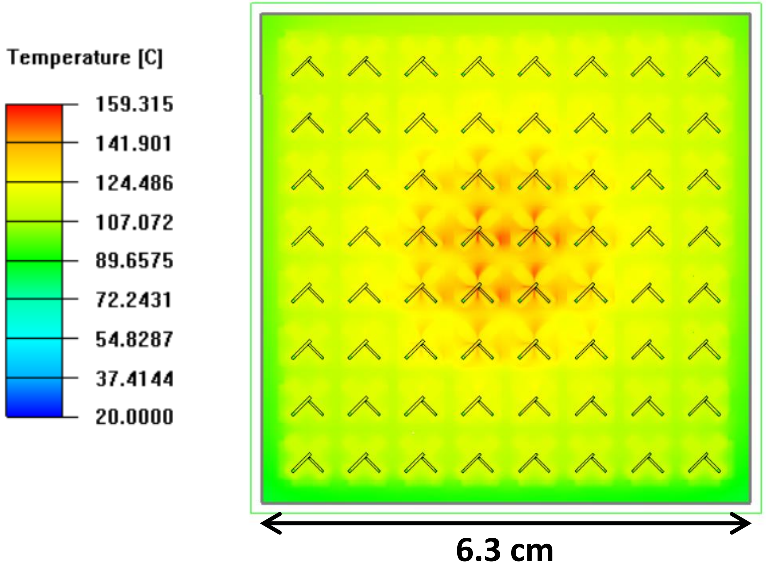






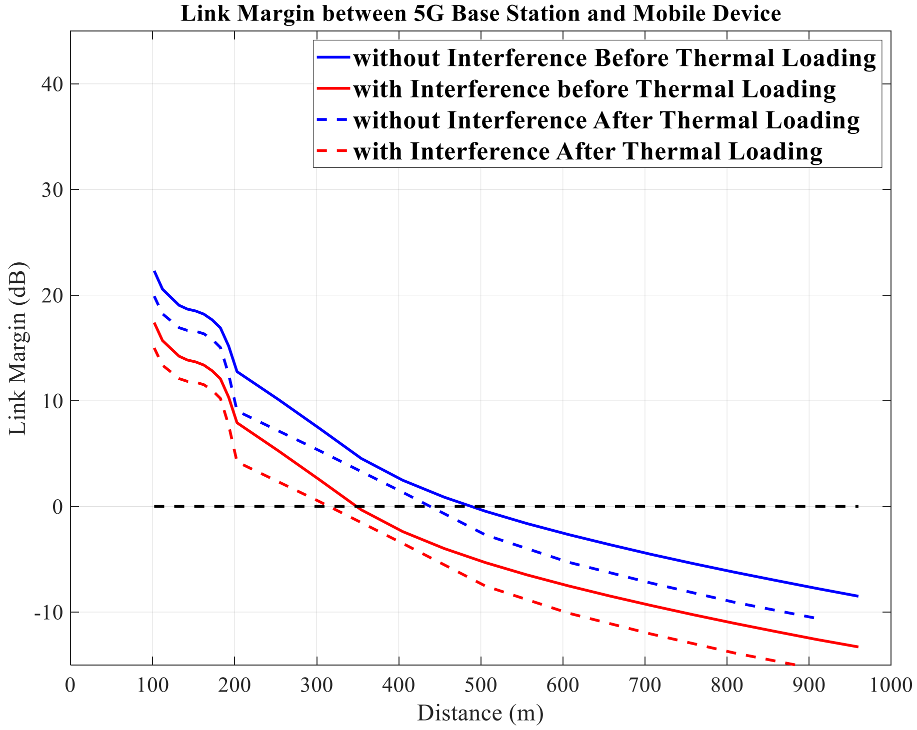
Electro-Thermal Simulation of 5G Base Station Antenna

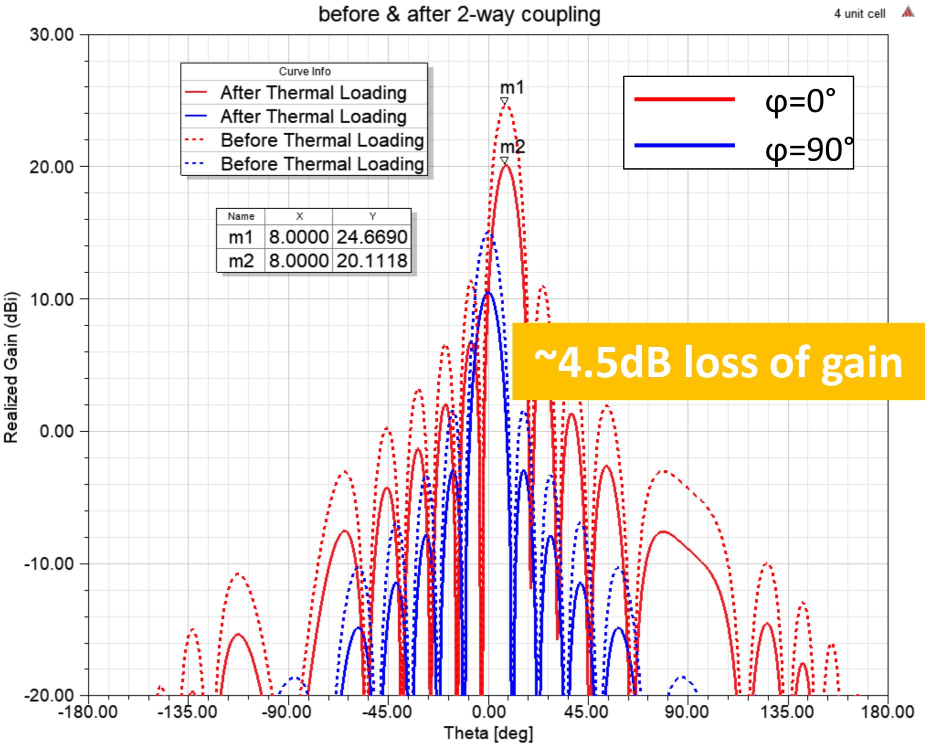
- Temperature of 8x8 dipole array for mmW 5G base station is simulated in Icepak (classic)
- 40W input, ~4W RF loss
  - Input power per unit cell: 0.625W
- Maximum temperature is 159°C ← may exceed the decomposition temperature



ID	Material	EM Loss Type	Maximum Temperature
Dipole	Copper	Surface	146.83 °C
Coax_Inner	Copper	Surface	135.14 °C
Coax_Outer	Copper	Surface	134.535 °C
uStrip_Line	Copper	Surface	146.634 °C
uStrip_Via	Copper	Surface	137.723 °C
Reflector	Aluminum	Surface	129.51 °C
Coax_Middle	Teflon	Volume	140.263 °C
Radome	Teflon	Volume	126.911 °C
Subst	FR4	Volume	159.315 °C

Array Performance After Thermal Loading (2-way Coupling)



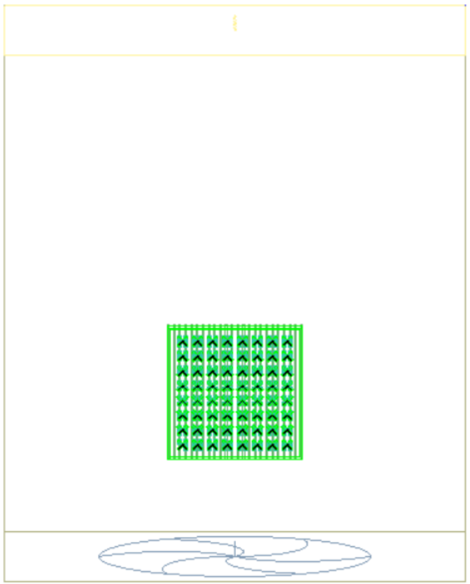


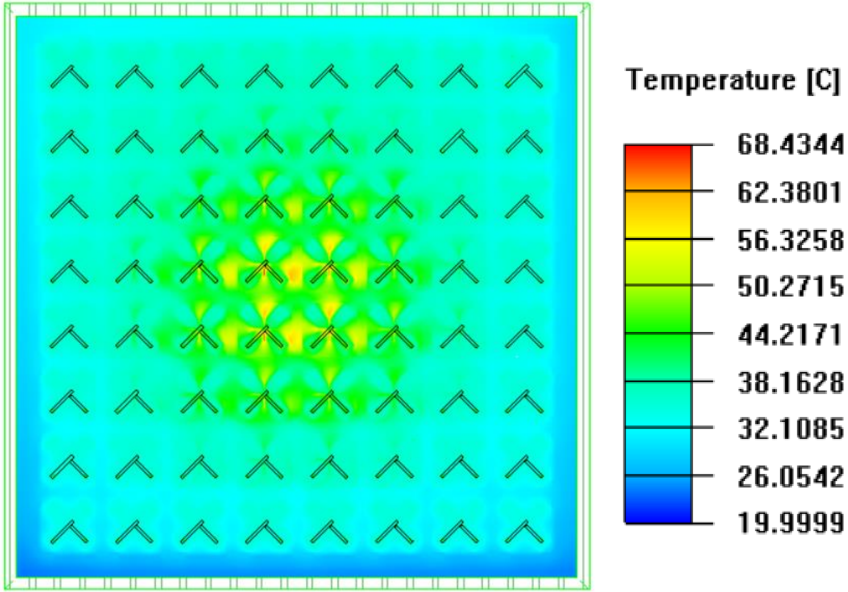
Name	X	Y
m1	8.0000	24.6690
m2	8.0000	20.1118

~4.5dB loss of gain

Thermal Management in Icepak

- To reduce overall temperature, a 50mm fan is added on the bottom
- Temperature is decreased to 68°C
- Thermal issue is much mitigated





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