




N á v r h a o p t i m a l i z a c e r a d o m u

David Kuřátko, Jakub Cejpek

Simulia Days 2025

 PUBLIC

1. Úvod
2. Strukturální simulace
3. Simulace proudění
4. Simulace elektromagnetismu
5. Parametrická optimalizace
6. Závěr

CO V SIMULACI BUDE?

MOTIVACE

- Trendy poslední doby:
 - Multi – oborová analýza (struktura, proudění, EM)
 - Optimalizace
 - Změnové smyčky
- Uvidíte příklad vývoje radomu (krytu radaru)



RADOM A SIMULACE

OD ALBÍKA PO ZLÍNA

- Jaké úkoly radom plní?
 - **Strukturální:** krytí citlivých míst přední části trupu (podmínky proudění, náraz krup a ptáků,...)
 - **Aerodynamické:** snížení odporu, rázové vlny....
 - **Elektro-magnetické:** propustnost signálu

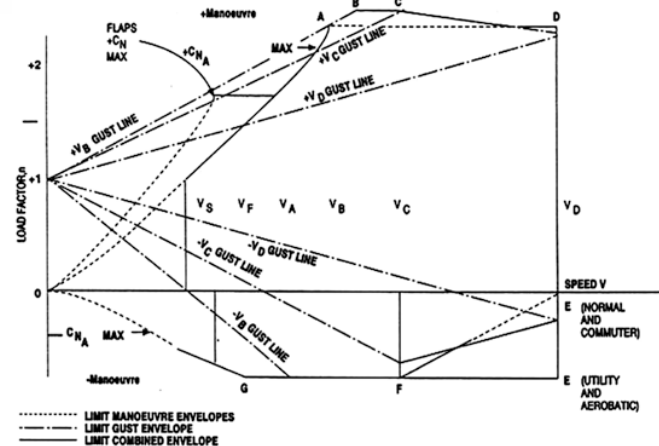


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STRUKTURÁLNÍ SIMULACE

PROBLÉMY, KTERÝM SE NEVYHNETE

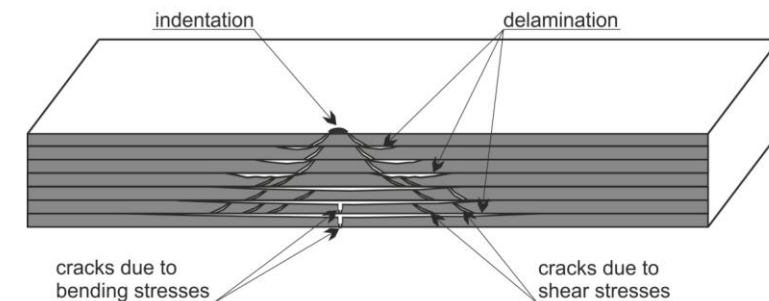
- Specifika kompozitních dílů:
 - Příprava CAD
 - Vrstvení
 - Mesh
 - Properties
 - Poruchová kritéria
- Zátěžné stavy:
 - Manévrové a poryvové
 - Přistávací
 - Havarijní



Flight load cases



CS25.631

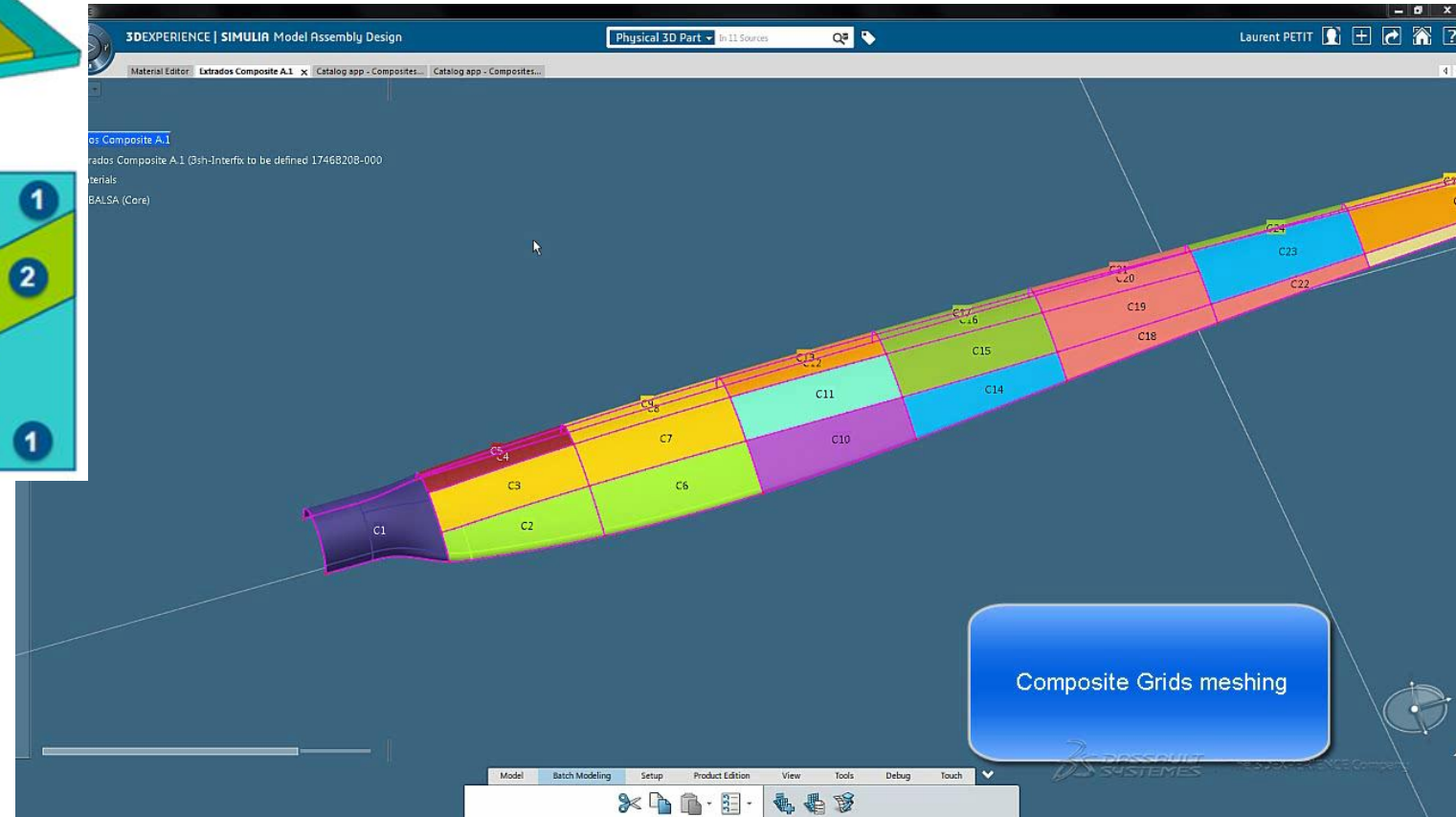
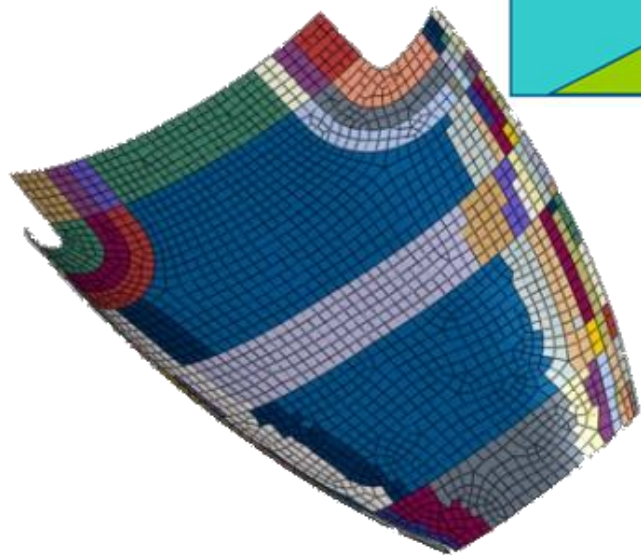
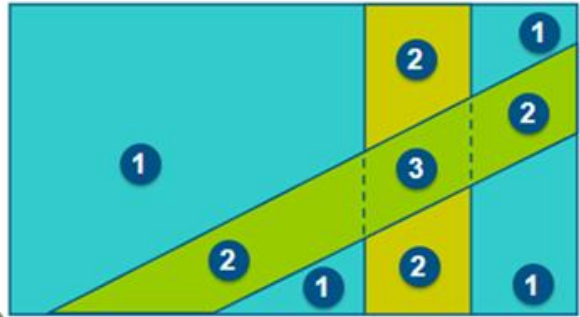
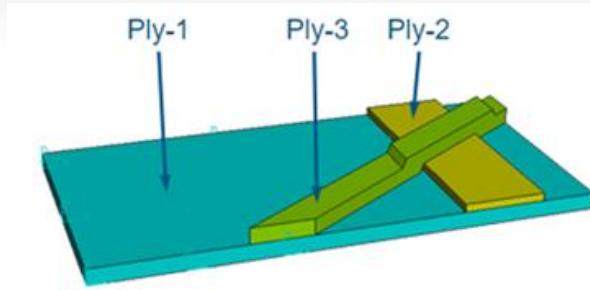


Delamination

STRUKTURÁLNÍ SIMULACE

PŘÍPRAVA MKP MODELU

- Příprava CAD
- Vrstvení
- Mesh
- Properties



STRUKTURÁLNÍ SIMULACE

PŘÍPRAVA MKP MODELU

- Typický tenkostěnný kompozitní díl:
 - Shell S4/S3 elementy
 - Inženýrské hodnoty materiálu v lamině
 - Souřadný systém

*ELASTIC, TYPE=LAMINA

- This is the same as TYPE=ENGINEERING CONSTANTS
- It requires specification of E_1 , E_2 , ν_{12} , G_{12} , G_{13} , G_{23} .

Elastic

Type: Suboptions

☐ Use temperature-dependent data

Number of field variables:

Moduli time scale (for viscoelasticity):

☐ No compression

☐ No tension

Data

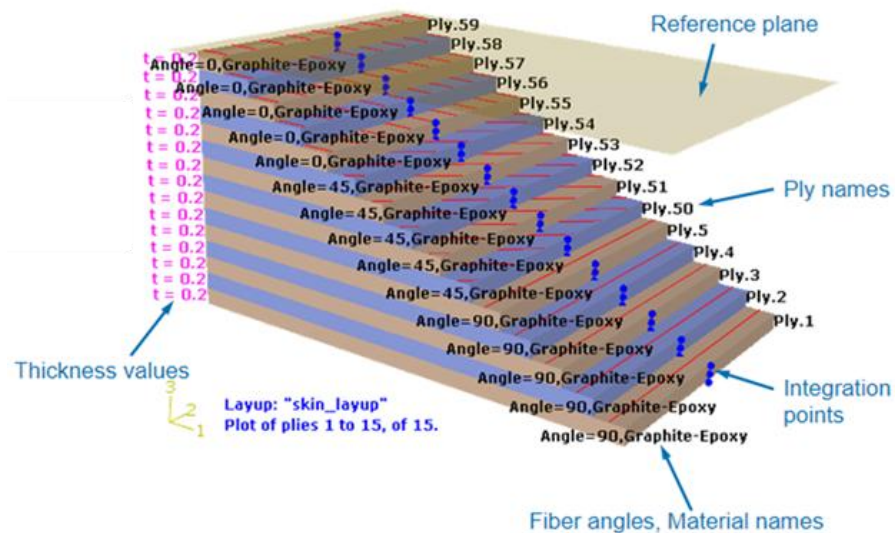
	E1	E2	Nu12	G12	G13	G23
1						

Plane stress assumption

$$\begin{Bmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \gamma_{12} \end{Bmatrix} = \begin{bmatrix} 1/E_1 & -\nu_{21}/E_2 & 0 \\ -\nu_{12}/E_1 & 1/E_2 & 0 \\ 0 & 0 & 1/G_{12} \end{bmatrix} \begin{Bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{12} \end{Bmatrix}$$

Off-plane shear refinement.

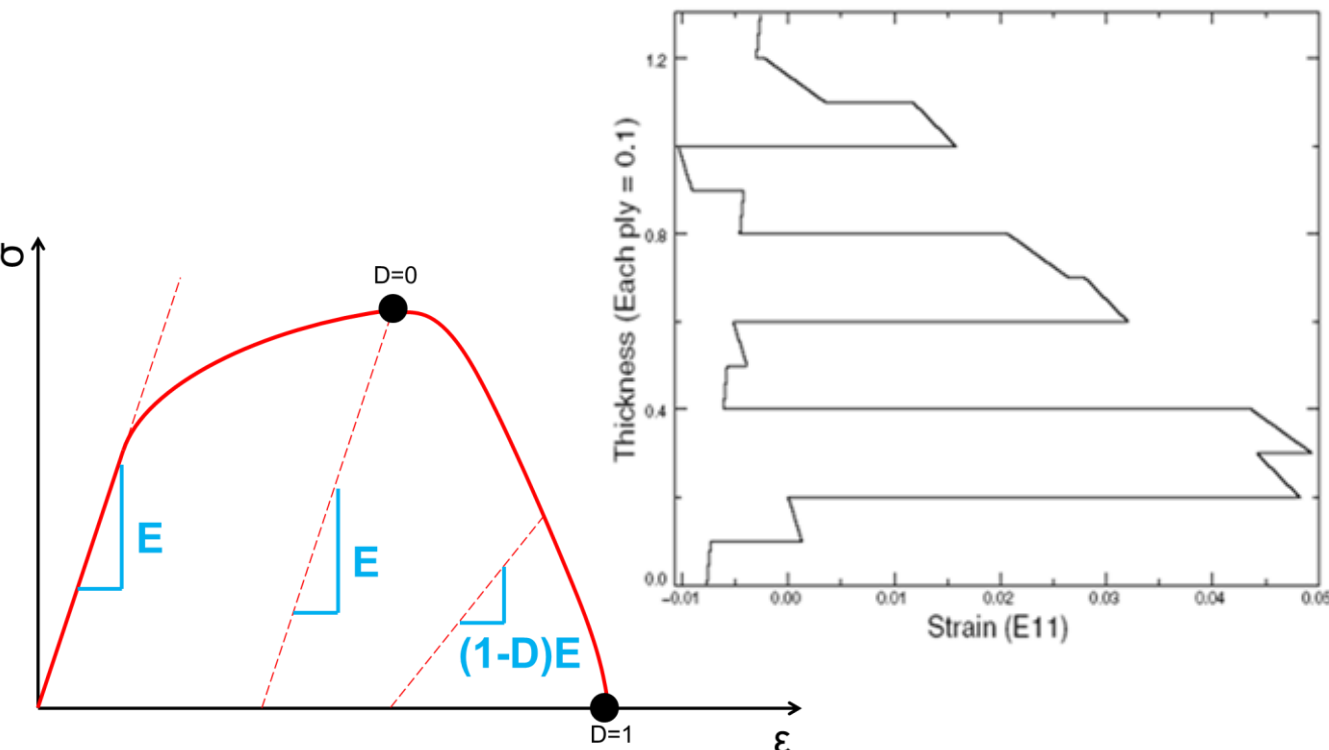
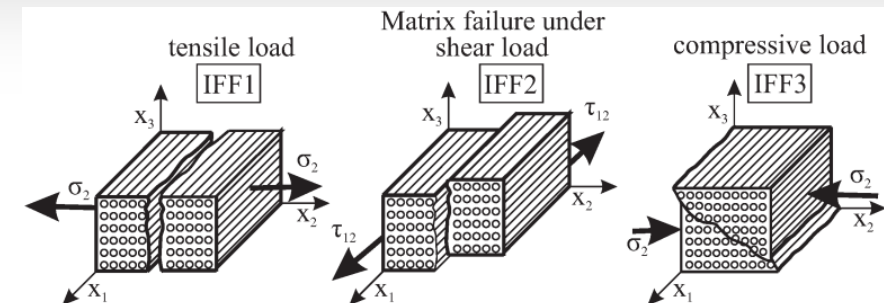
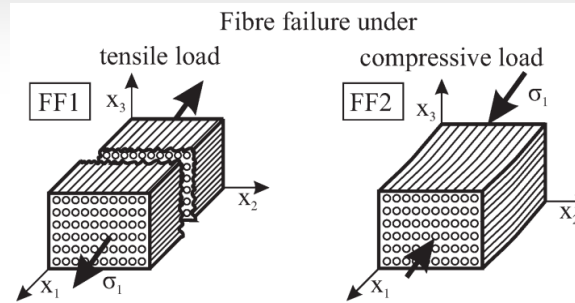
$$\gamma_{13} = 2\varepsilon_{13} = \sigma_{13}/G_{13} \quad \gamma_{23} = 2\varepsilon_{23} = \sigma_{23}/G_{23}$$



STRUKTURÁLNÍ SIMULACE

VYHODNOCENÍ

- Vyhodnocení
 - Každá vrstva
 - Vlákno, matrice
 - Poruchová kritéria



COMPOSITE FAILURE CRITERIA

DEPENDENT

Quadratic failure criteria in composite analysis, based on experimental data, predict failure under various loads. However, they often overlook diverse damage mechanisms and material homogeneity, impacting failure modes. In biaxial tensile stress scenarios, compressive strength can also complicate predictions.

POPULAR FAILURE CRITERIA

Tsai-Wu
Tsai Hill
Azzi-Tsai
Hoffman
Chamis

INDEPENDENT

These criteria identify key failure modes in composites, aiding progressive damage analysis. Non-dependent modes focus on issues like fiber fracture and matrix cracking. Two sub-groups address failure prediction complexities, enhancing the reliability of composite structures.

NON-INTERACTIVE

This category neglects stress and strain interactions within a lamina, leading to errors in multiaxial stress states. Non-interactive criteria illustrate this, compromising failure prediction accuracy.

Maximum stress criteria

Maximum strain criteria

INTERACTIVE

This category considers stress and strain interactions within a lamina, improving failure analysis under multiaxial loading and enhancing predictive reliability.

Hashin

Puck

Hart-Smith

STRUKTURÁLNÍ SIMULACE

BIRDSTRIKE

- Předpisové požadavky CS25.631:
 - $m_{\text{BIRD}} = 1.8\text{kg}$
 - $v_{\text{C}} = 700\text{km/h} \cong 200\text{m/s}$ pro L-39C

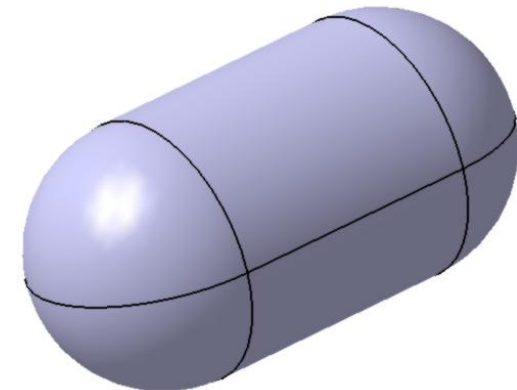
Skutečný pták



Certifikovaný pták



Hydrodynamický FEM pták



STRUKTURÁLNÍ SIMULACE

BIRDSTRIKE

- Dynamic, Explicit
- SPH částice v Abaqusu

***SOLID SECTION**, ELSET=BIRDSET, CONTROLS=EC-1, MATERIAL=BIRD

***SECTION CONTROLS**, NAME=EC-1, ELEMENT CONVERSION=YES, SPH CONVERSION=PER ELEMENT, CONVERSION CRITERION=TIME
1, 1, 1

1, 0

***MATERIAL**, NAME=BIRD

***DENSITY**

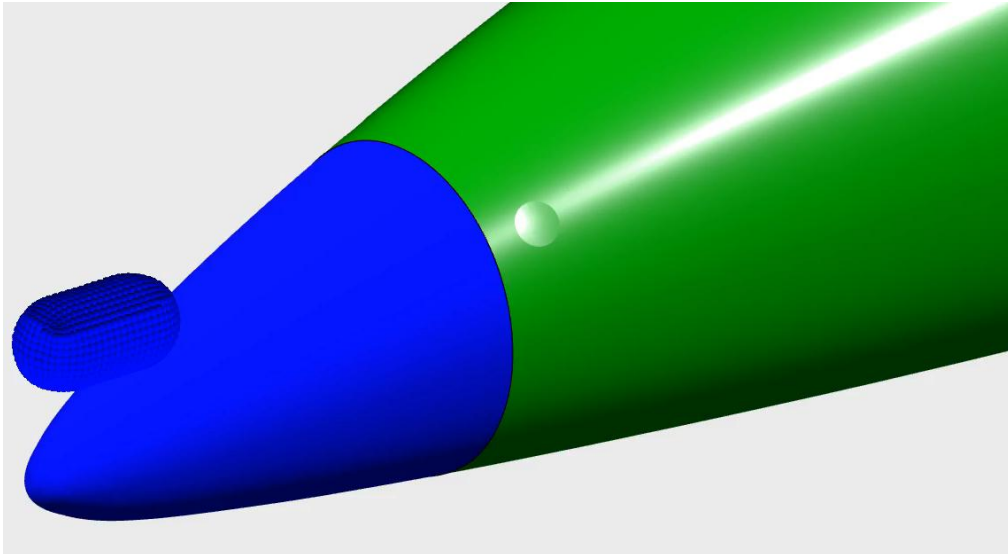
8E-10

***EOS**, TYPE=USUP

1.45E+6, 0, 0

***VISCOSITY**

1E-09

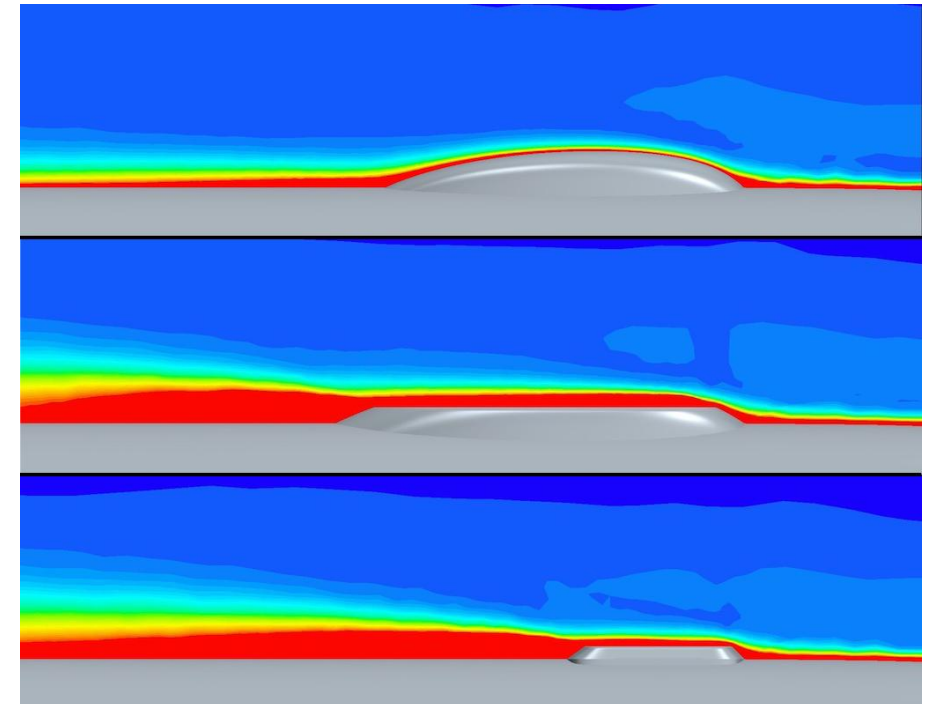


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AERODYNAMICKÁ SIMULACE

MINIMALIZACE ODPORU

- Radom na L39 je dokonalý, ten už měnit nebudeme!
- Ale je spousta retrofit programů....



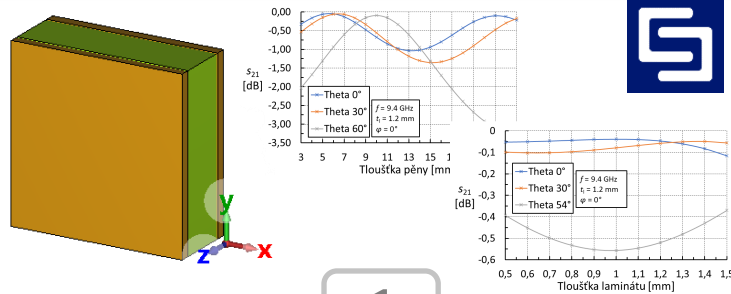
OBSAH

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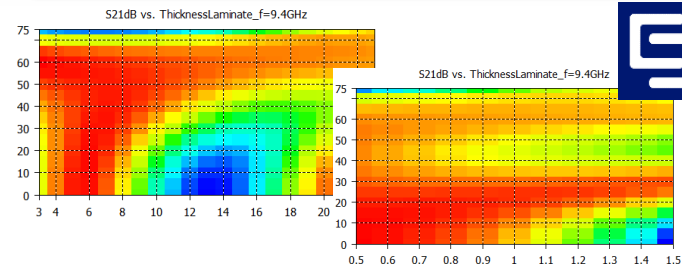
EMAG SIMULACE WORKFLOW

Unit Cell – poměr vrstev



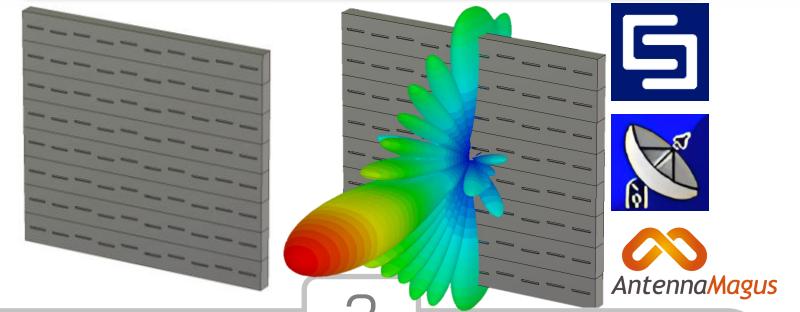
1

Unit Cell – optimalizace s_{21}



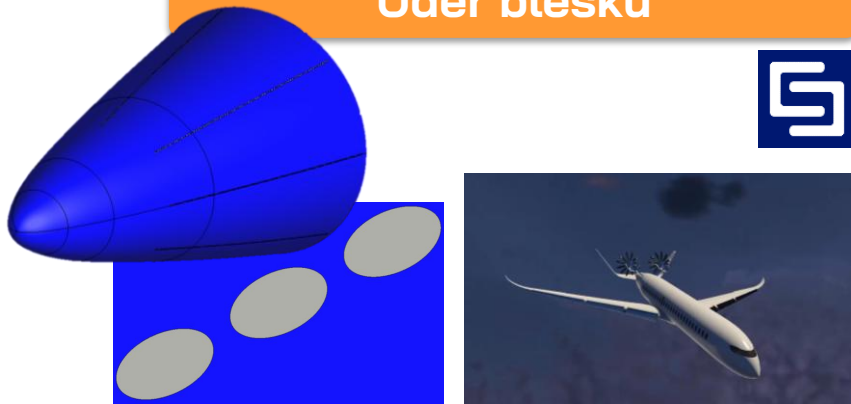
2

Anténní pole

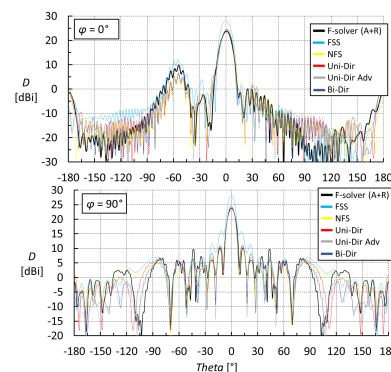


3

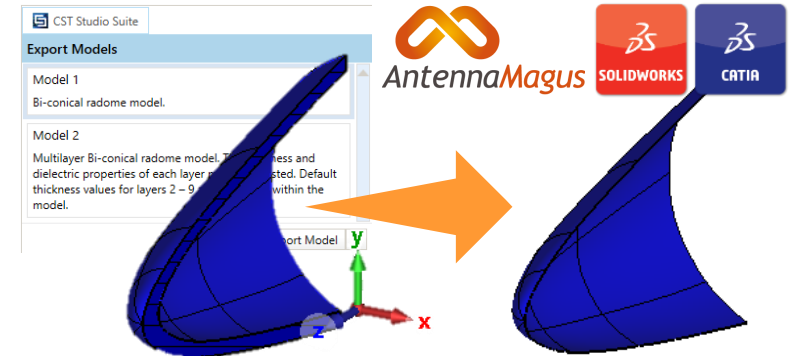
Úder blesku



Celková simulace & BRE



3D model radomu



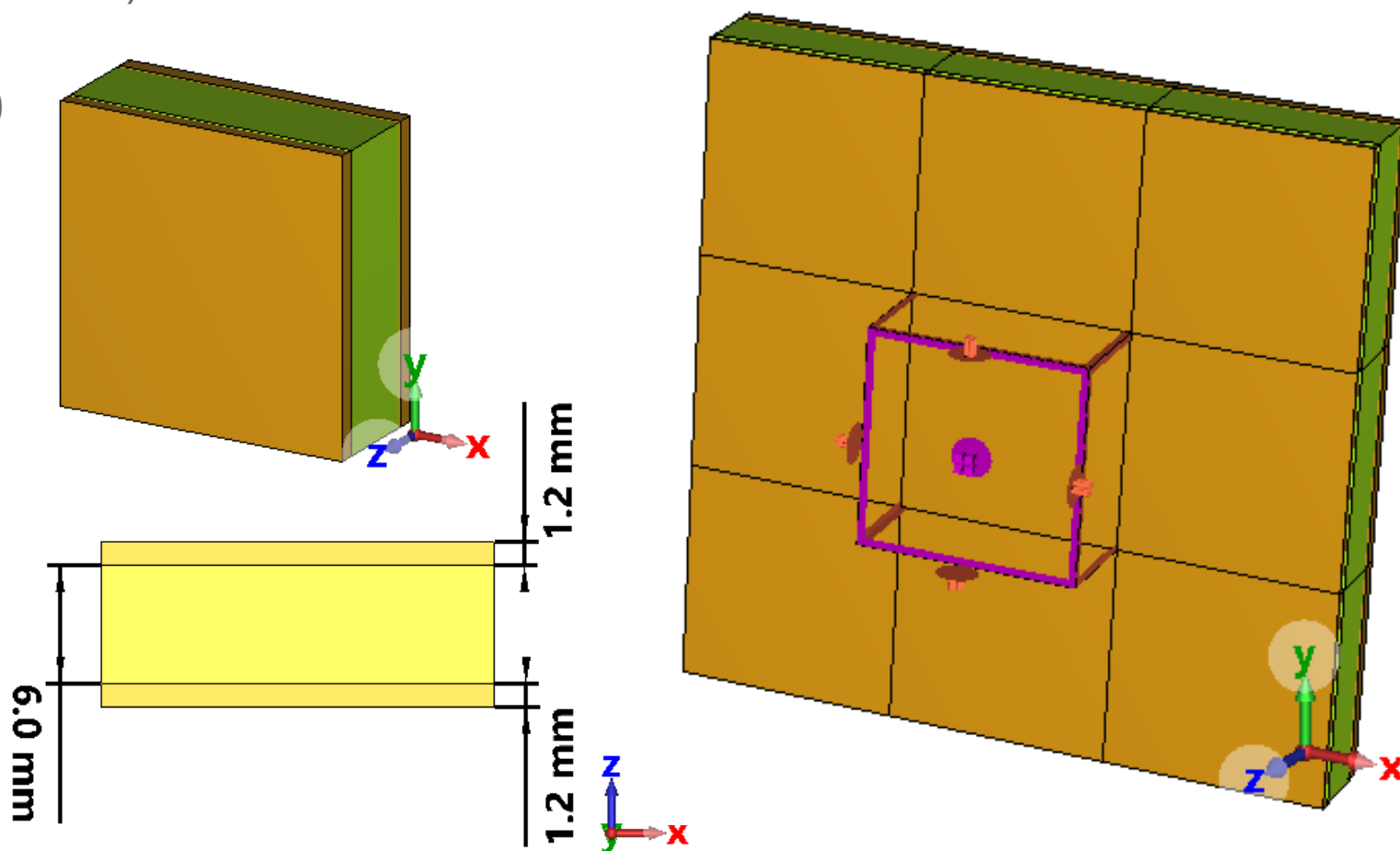


EMAG SIMULACE

UNIT CELL

- Nekonečně rozlehlé pole, které je vybuzené pomocí Floquet portů ve Frekvenčním solveru.
- Sendvičová struktura (laminát, pěna, laminát)
- Simulace přenosu s_{21} pro:
 - Úhel dopadající rovinné vlny (θ, φ)
 - TE a TM polarizace
 - Tloušťka pěny
 - Tloušťka laminátu

Materiál	ϵ_r [-]	$\tan \delta$ [-]
Pěna	1.1	0.004
Laminát	3.23	0.004

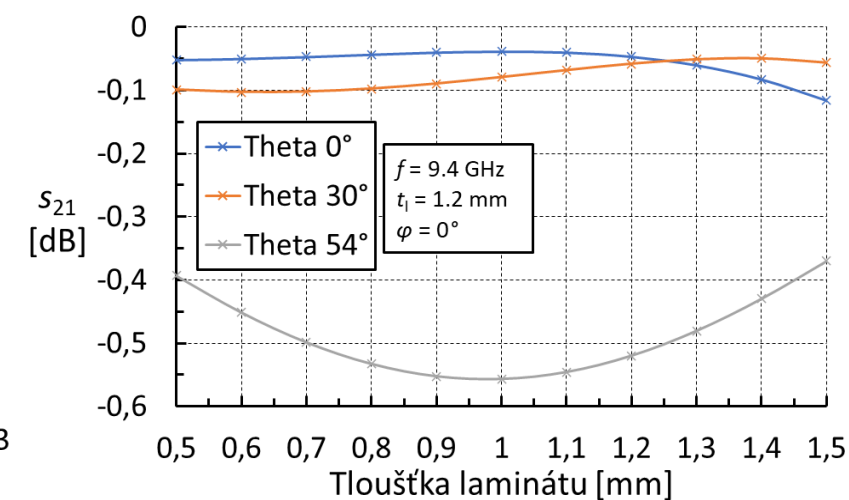
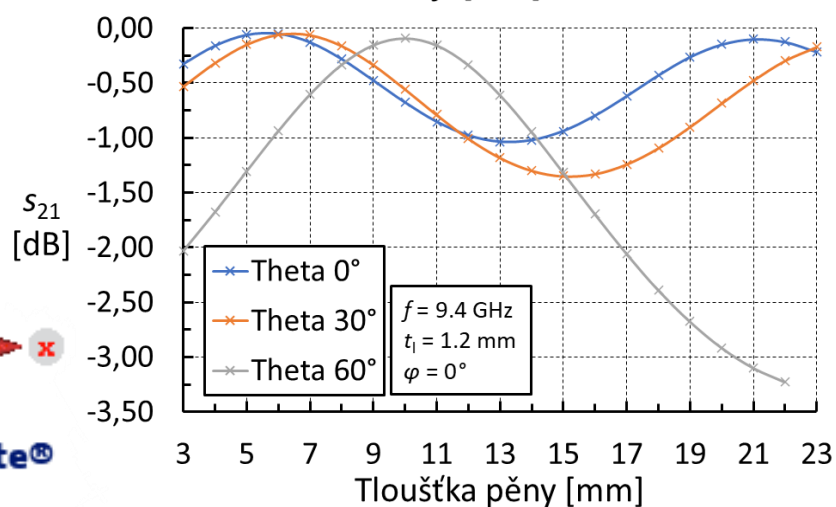
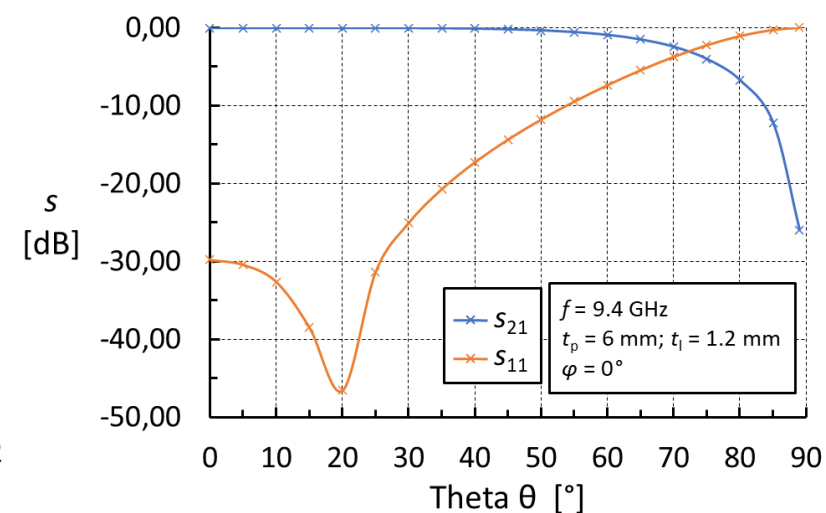
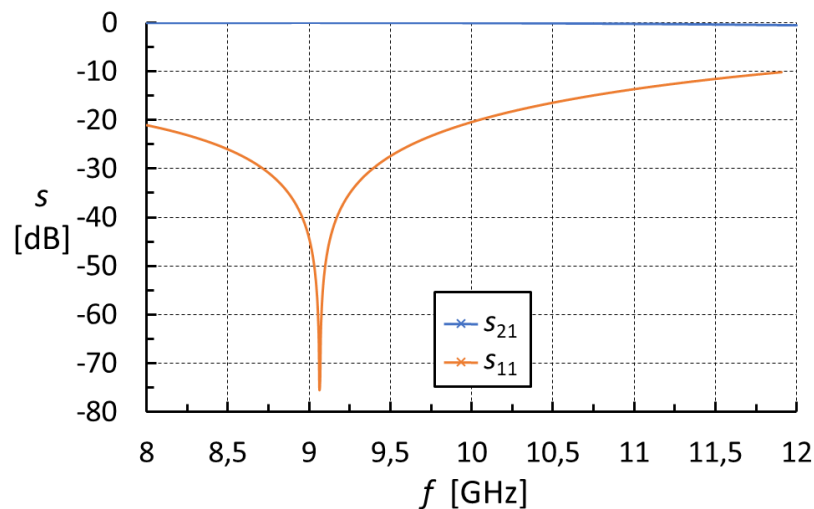
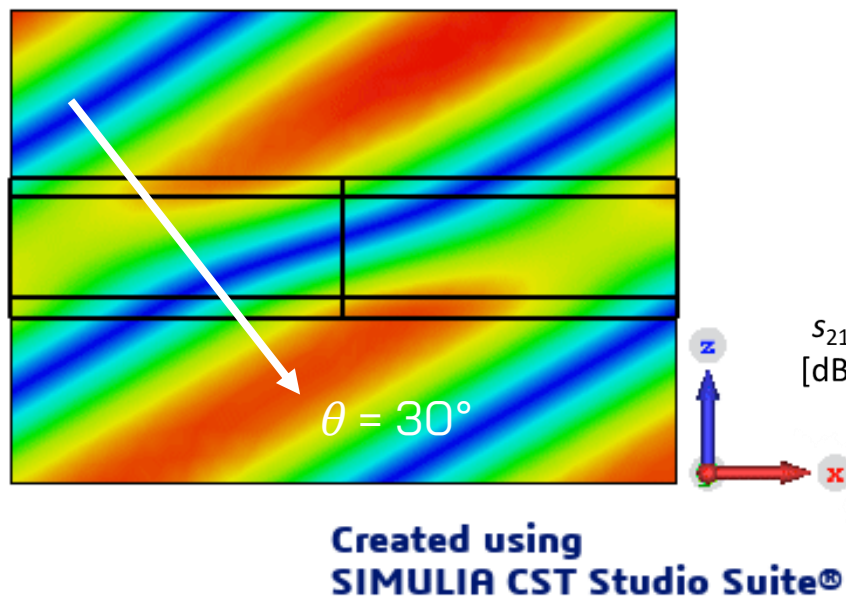




EMAG SIMULACE

UNIT CELL

- S-parametry jsou závislé na:
 - frekvenci,
 - úhlu rovinné vlny,
 - tloušťce pěny a laminátu.





EMAG SIMULACE

UNIT CELL



CONFIDENTIAL

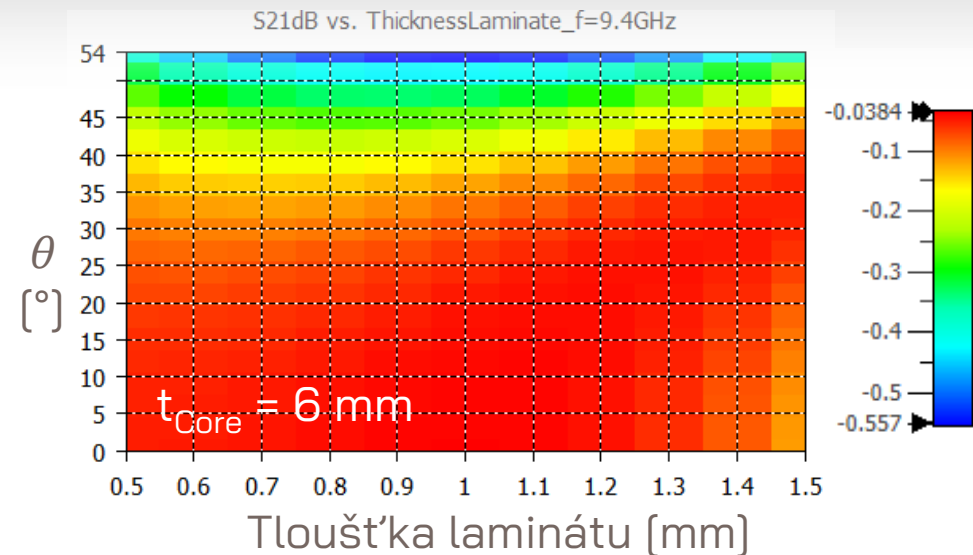
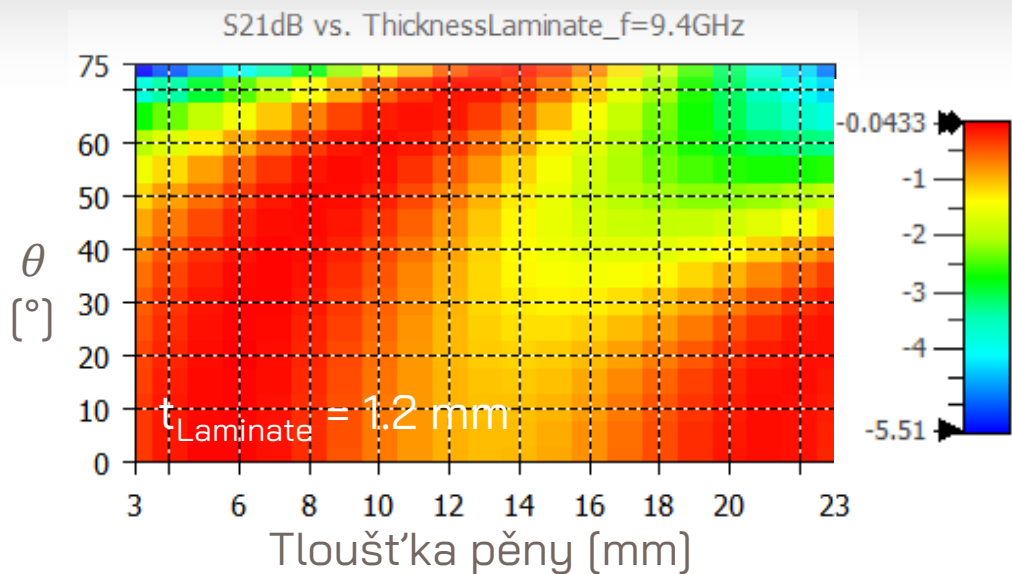
V případě zájmu nás kontaktujte.



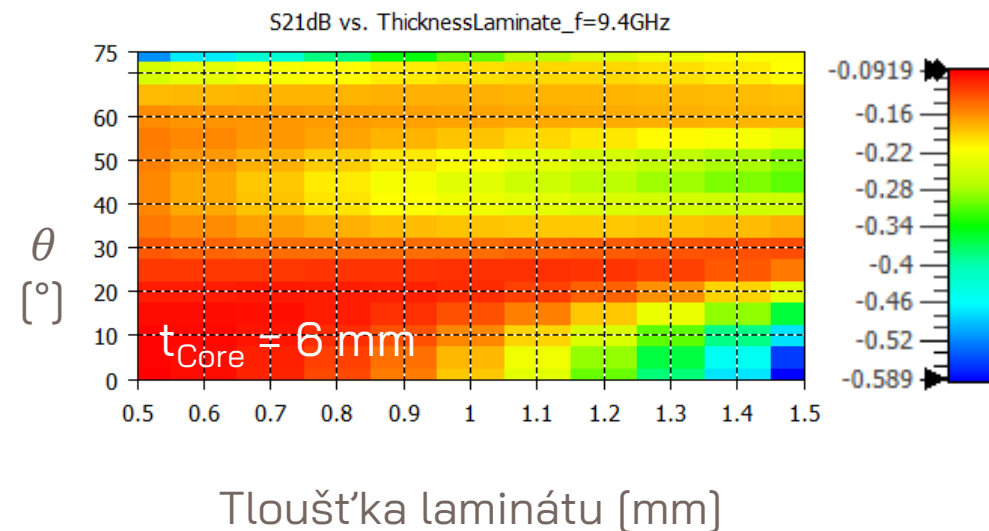
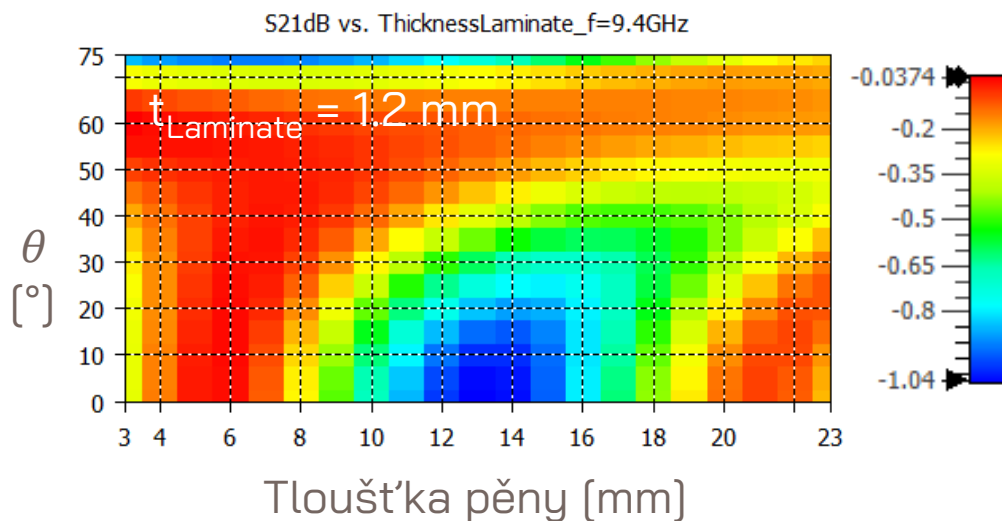
EMAG SIMULACE

UNIT CELL – 2D COLORMAPY

TE polarizace



TM polarizace

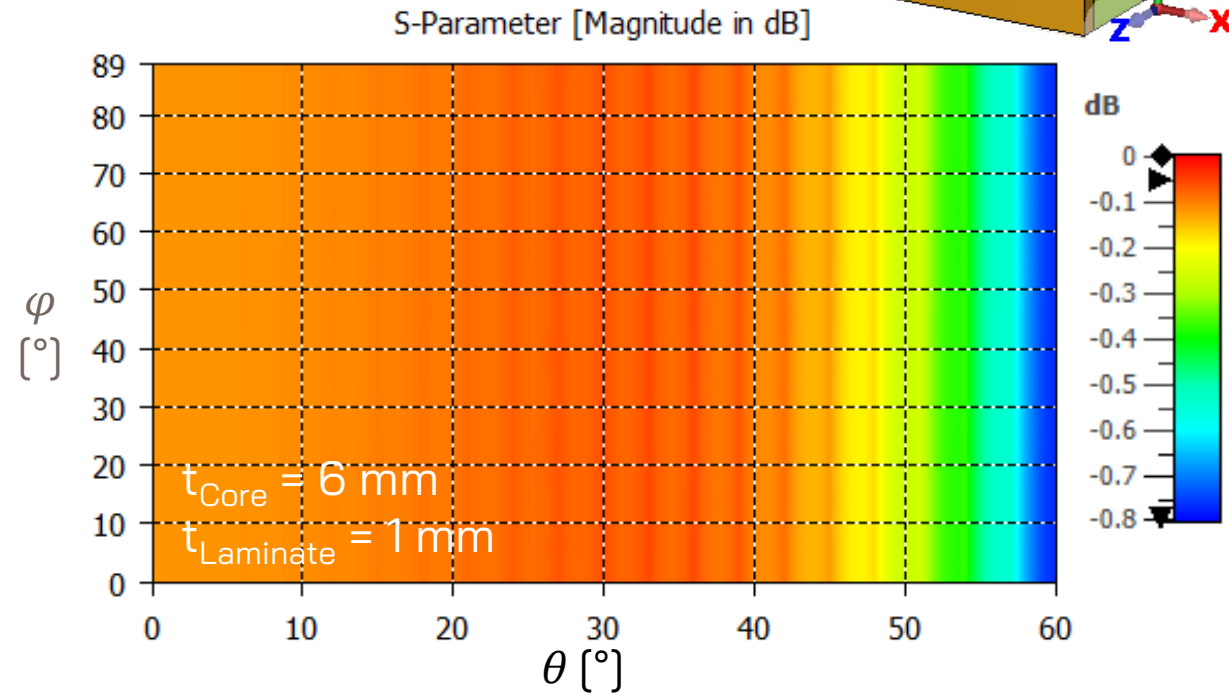
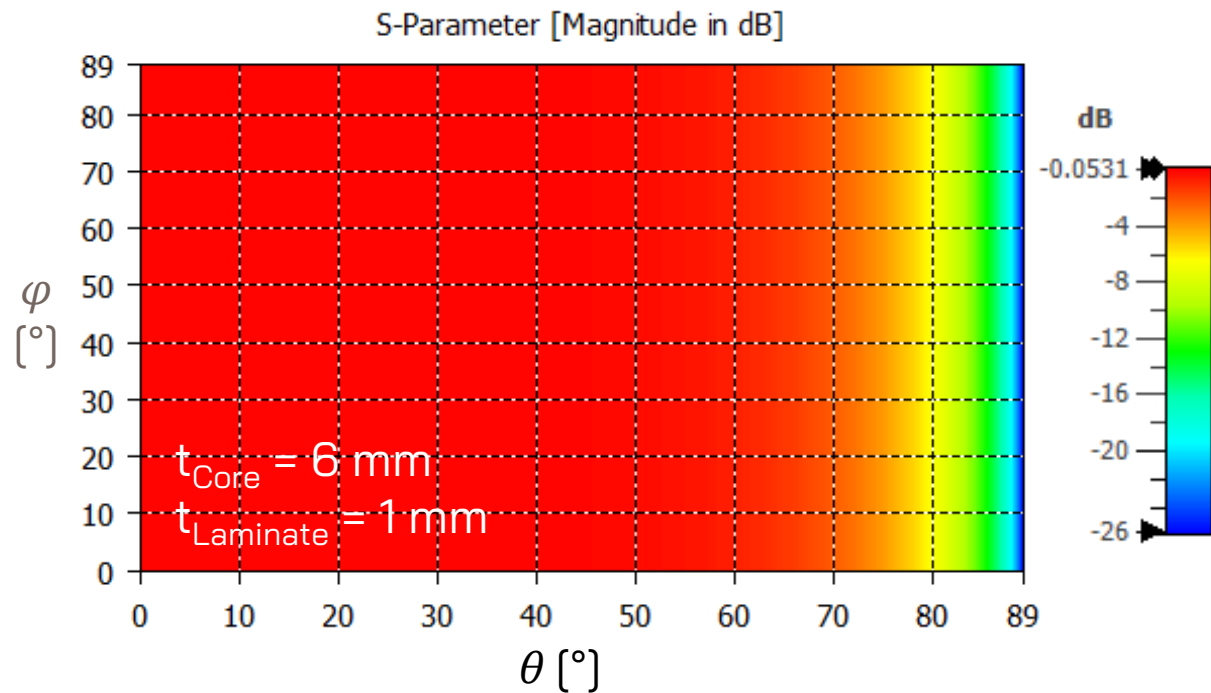
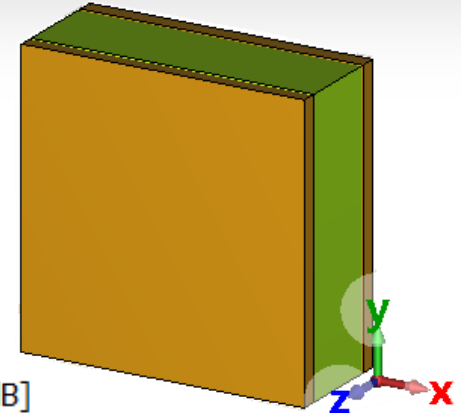




EMAG SIMULACE

UNIT CELL

- Závislost $s_{21} = f(\theta, \varphi)$ pro optimální tloušťky vrstev $t_{\text{Core}} = 6 \text{ mm}$ a $t_{\text{Laminate}} = 1 \text{ mm}$.

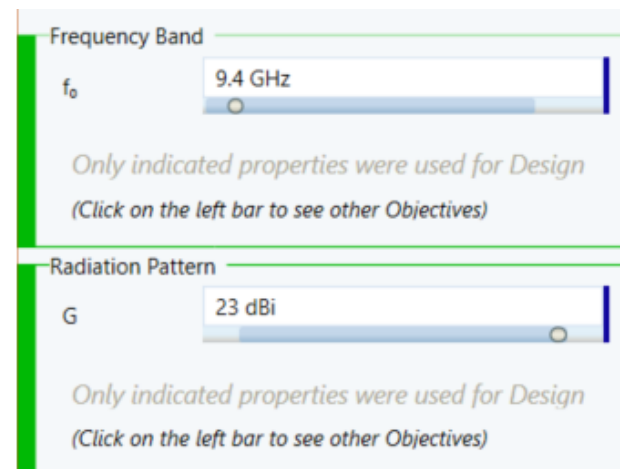
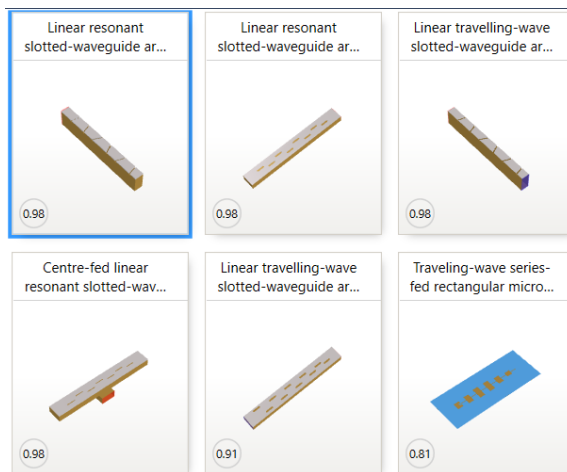
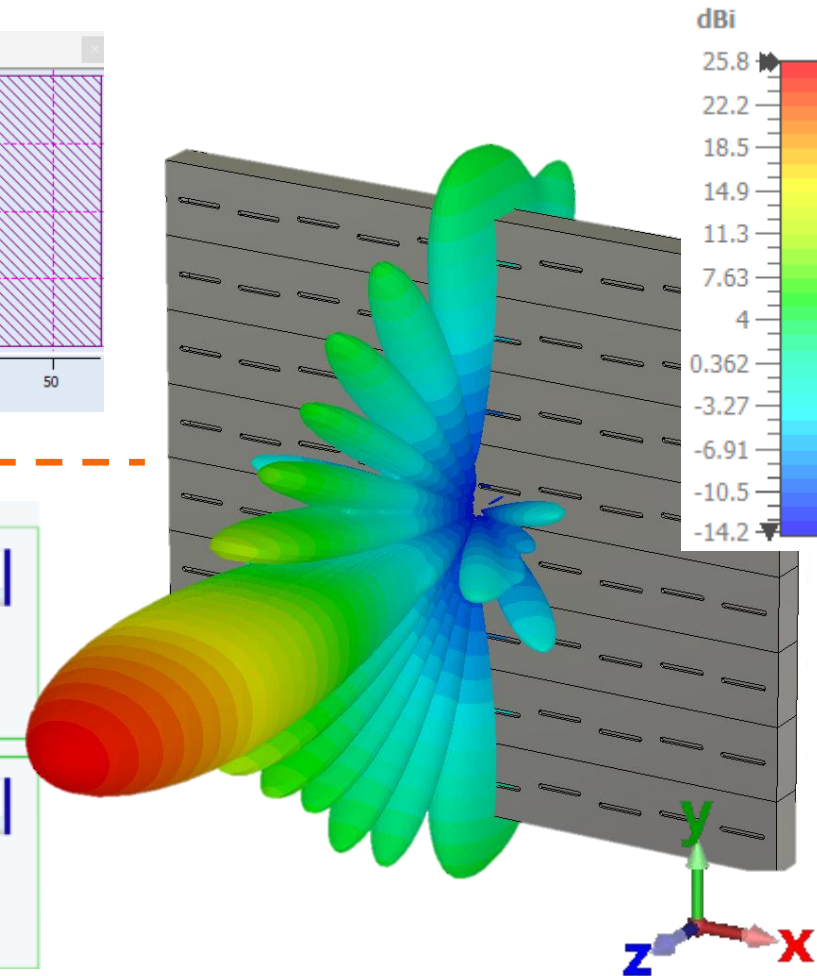
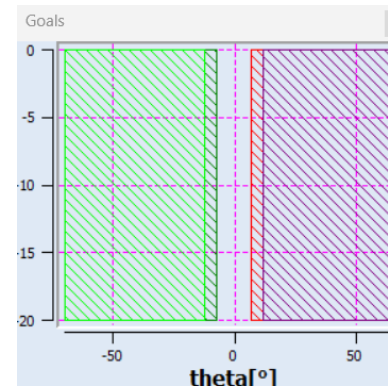
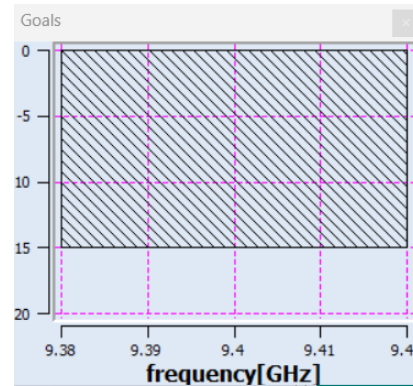
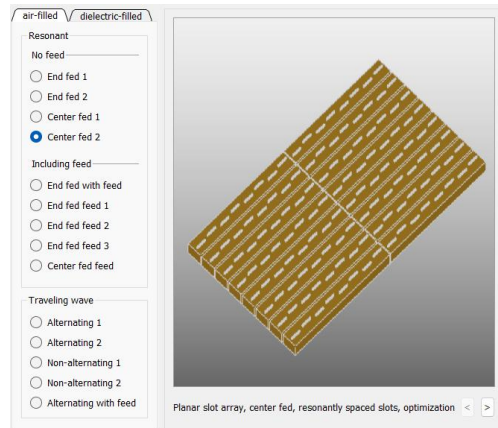


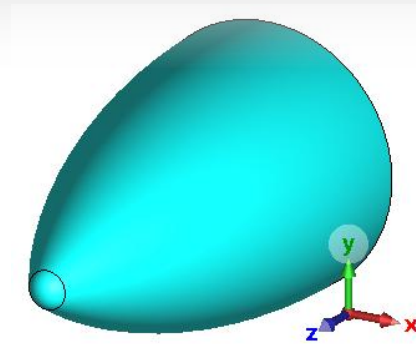
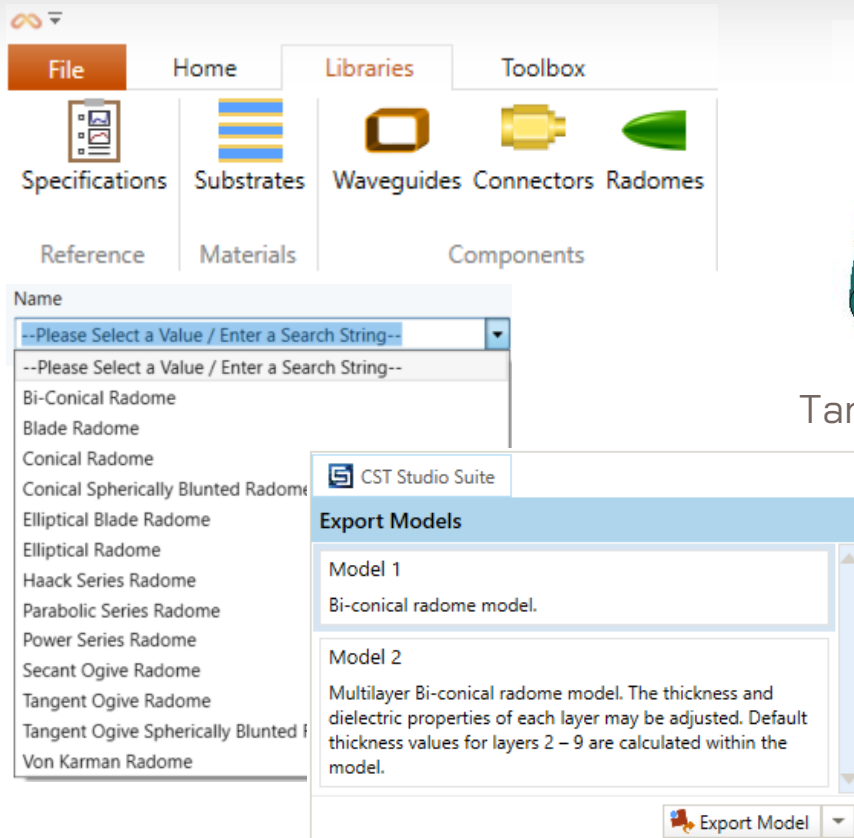


EMAG SIMULACE

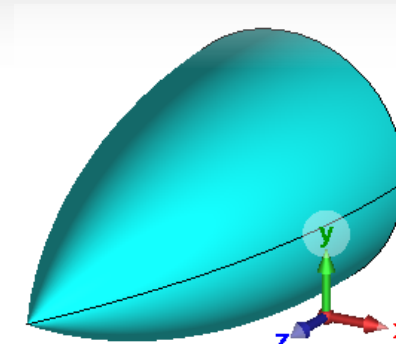
ANTÉNNÍ POLE

- Radom je navržen pro anténní pole na frekvenci 9.4 GHz (X-band).

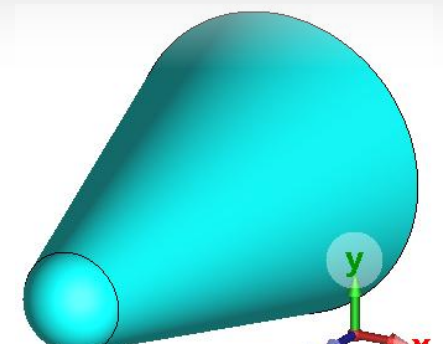




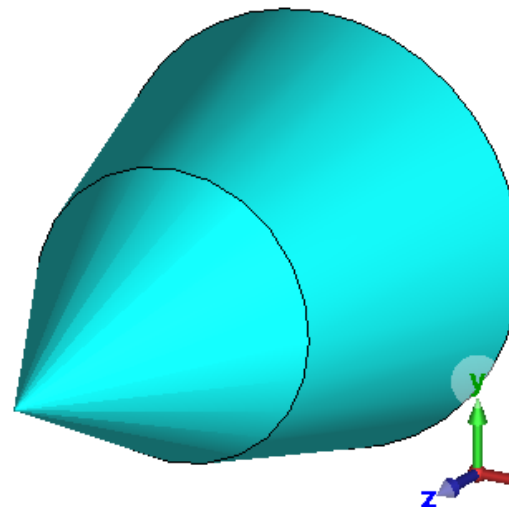
Tangent Ogive Spherically
Blunted Radome



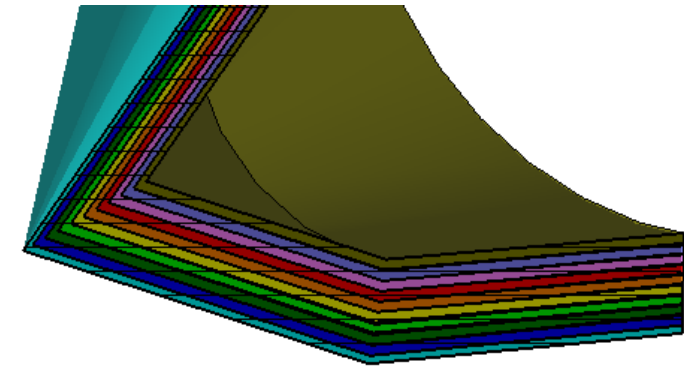
Parabolic Series Radome



Conical Spherically
Blunted Radome



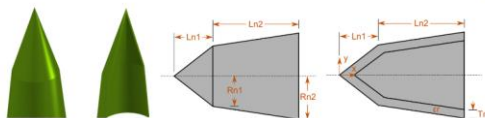
Bi-conical Radome



Physical Description

Each radome profile has an overall length (L_n), a base radius (R_n), a material thickness (T_n), and a material relative permittivity (ϵ_r). In the profile definitions, y is the radius at any point x along the dashed centre line, with x varying from 0 at the radome tip, to overall length, L_n . The radome is formed by rotating this 2-dimensional profile around the dashed centre line.

The Bi-conical radome consists of a cone of length L_{n1} stacked on top of a conical frustum of length L_{n2} . The base radius of the top cone is R_{n1} . The top radius of the conical frustum is R_{n1} whilst the base radius is R_{n2} .

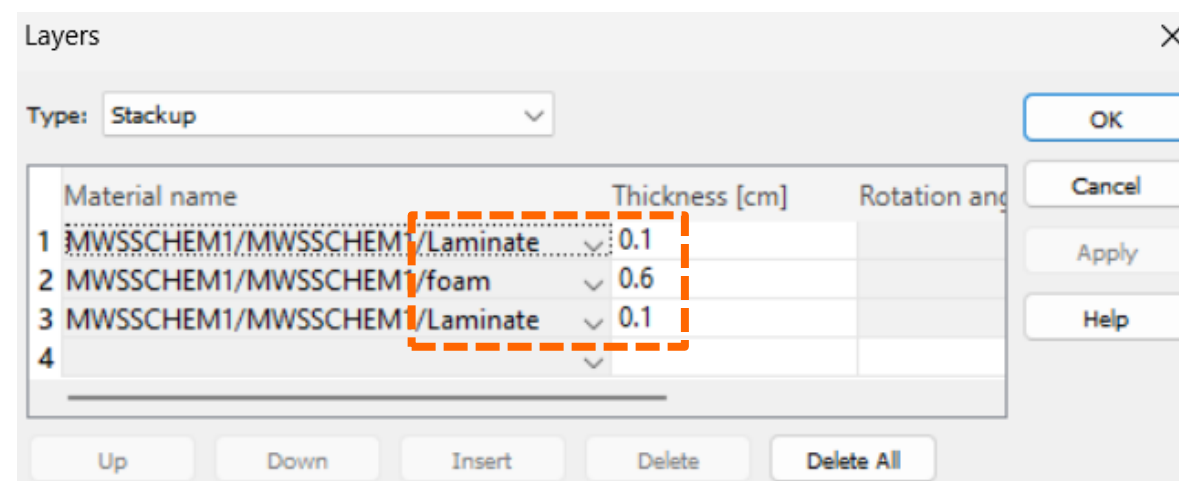
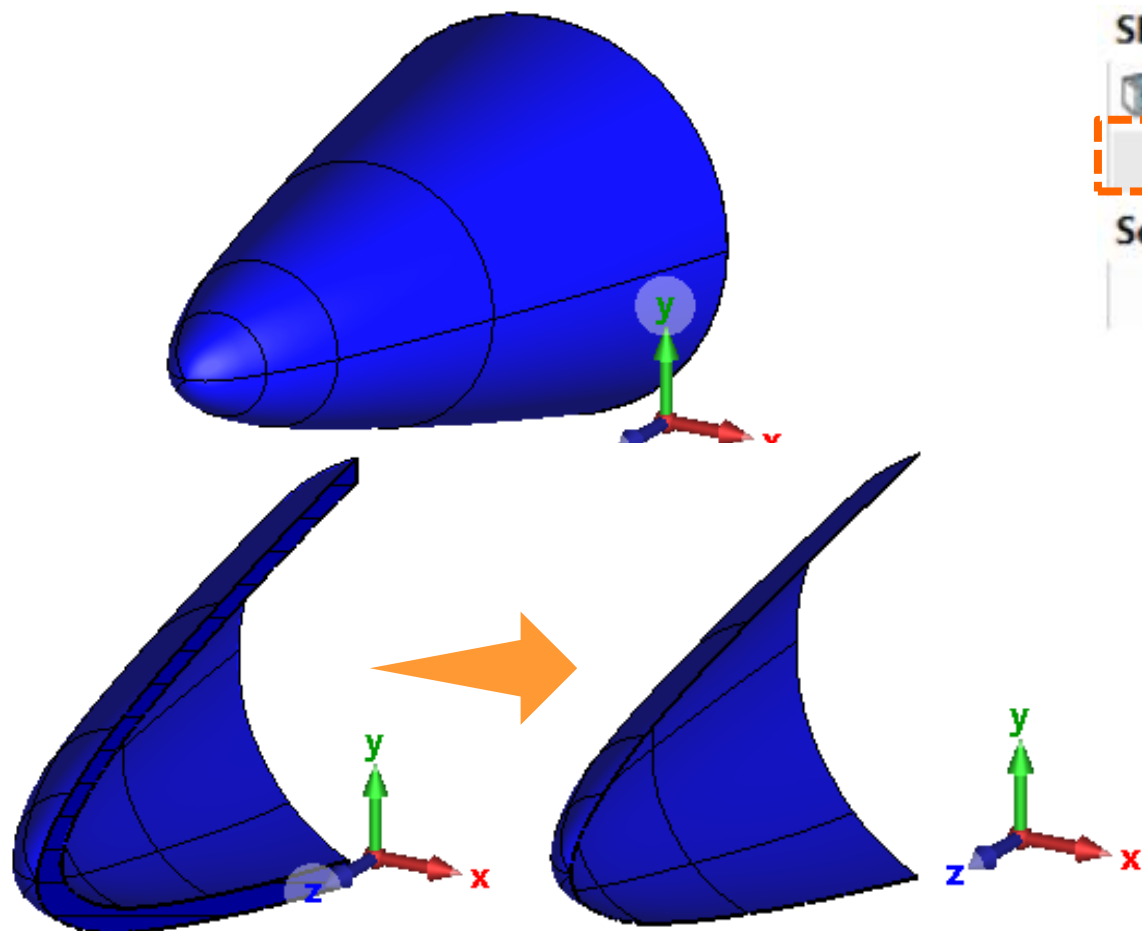




EMAG SIMULACE

3D MODEL RADOMU

- Zjednodušení radomu = Thin Panel





EMAG SIMULACE

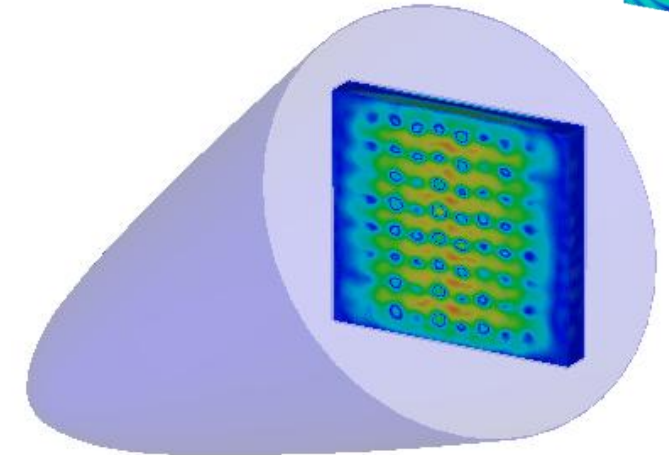
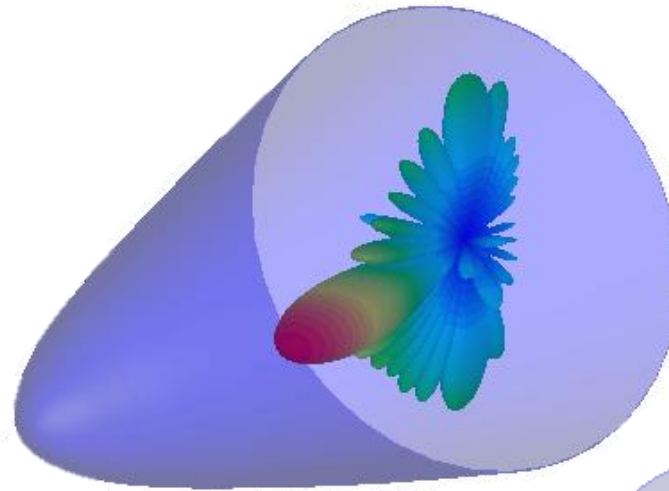
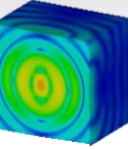
SIMULACE RADOMU A ANTÉNNÍHO POLE

- Nabízí se několik možností:
 - Full 3D (T-/F-solver)
 - FSS nebo NFS (I-/A-solver)
 - Hybrid solver:
 - Uni-directional
 - Uni-directional advanced
 - Bi-directional

Far-field source (FFS)



Near-field source (NFS)



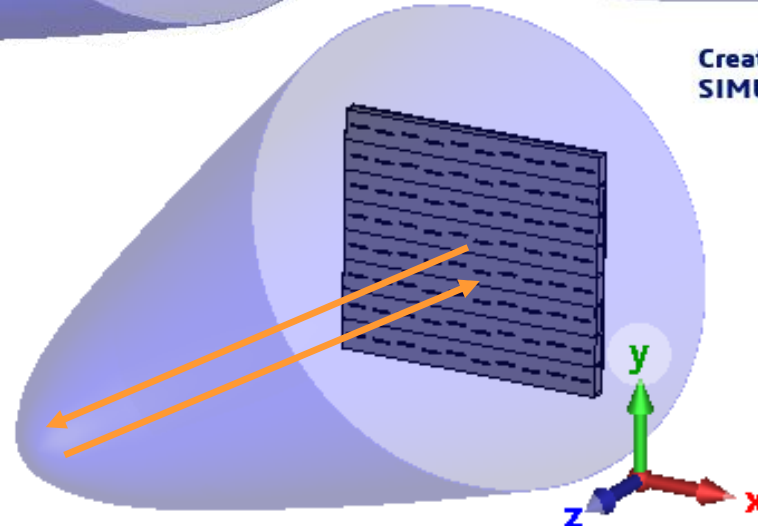
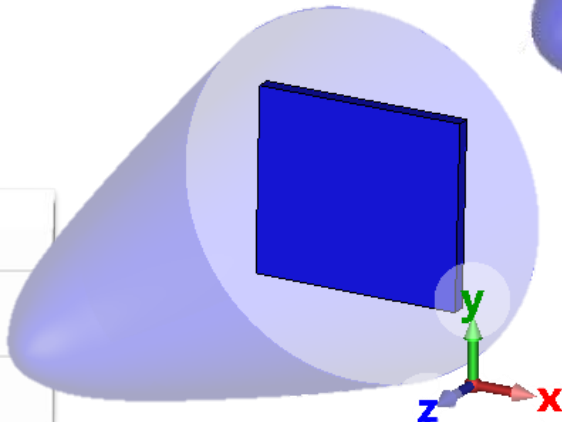
Created using
SIMULIA CST Studio Suite®



Create Simulation Project

- Select Block Representation
- All Blocks as 3D Model
- All Blocks as Schematic Model
- Array Task
- Machine Simulation Sequence
- Hybrid Solver Task
- Biased Ferrite-EM Coupling
- EM-Thermal Coupling

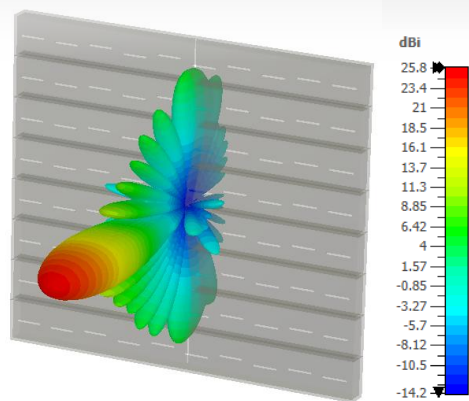
- Uni-/Bi-directional
- Uni-directional (legacy)



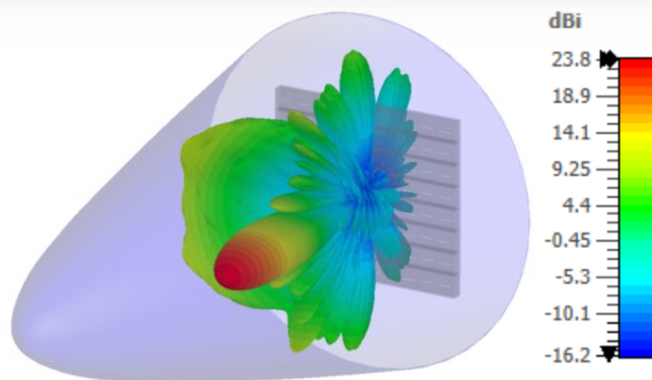


EMAG SIMULACE

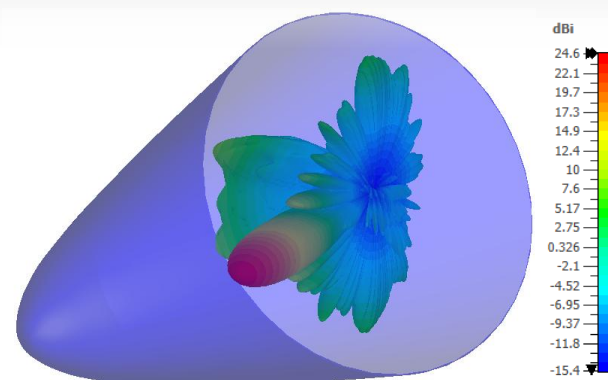
SIMULACE RADOMU A ANTÉNNÍHO POLE



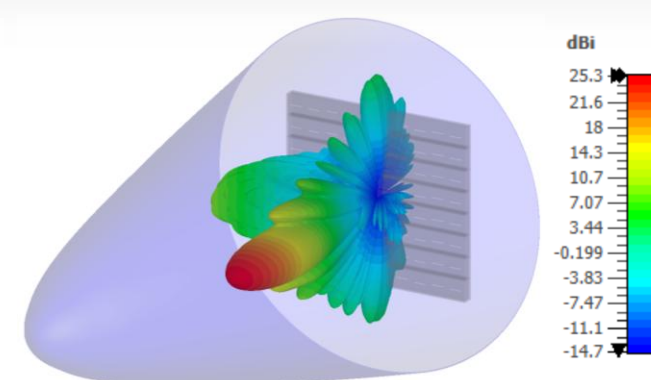
F-solver: Volný prostor



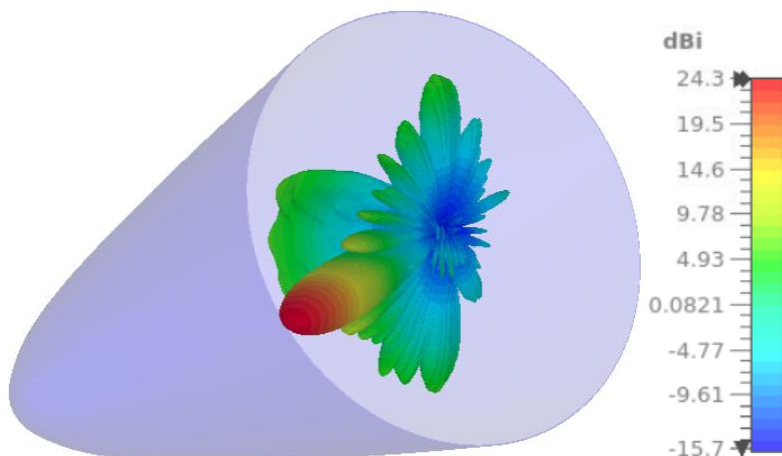
F-solver: radom a anténní pole.



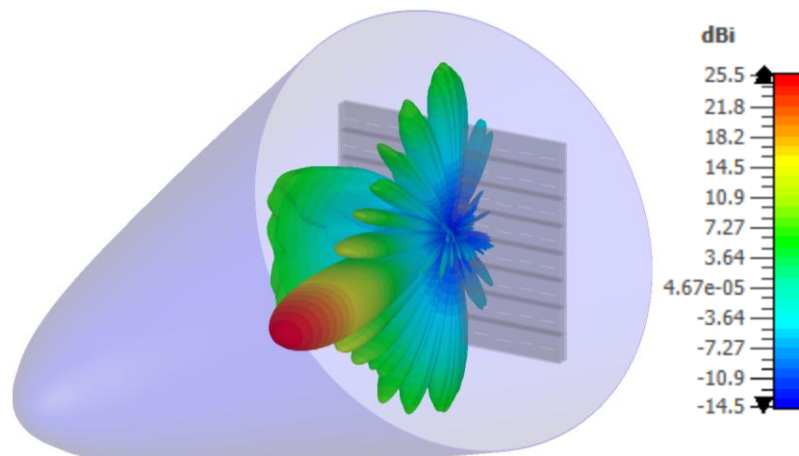
Near-Field Source (NFS)



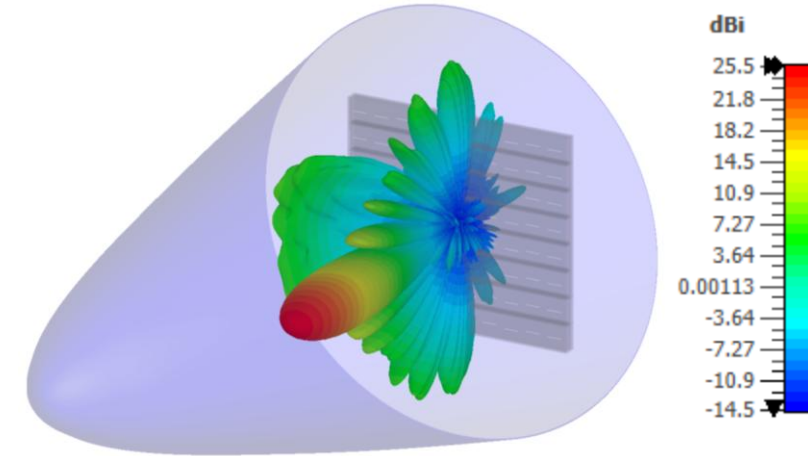
FarField Source (FFS)



HS: Uni-Directional



HS: Uni-Directional Advanced



HS: Bi-Directional

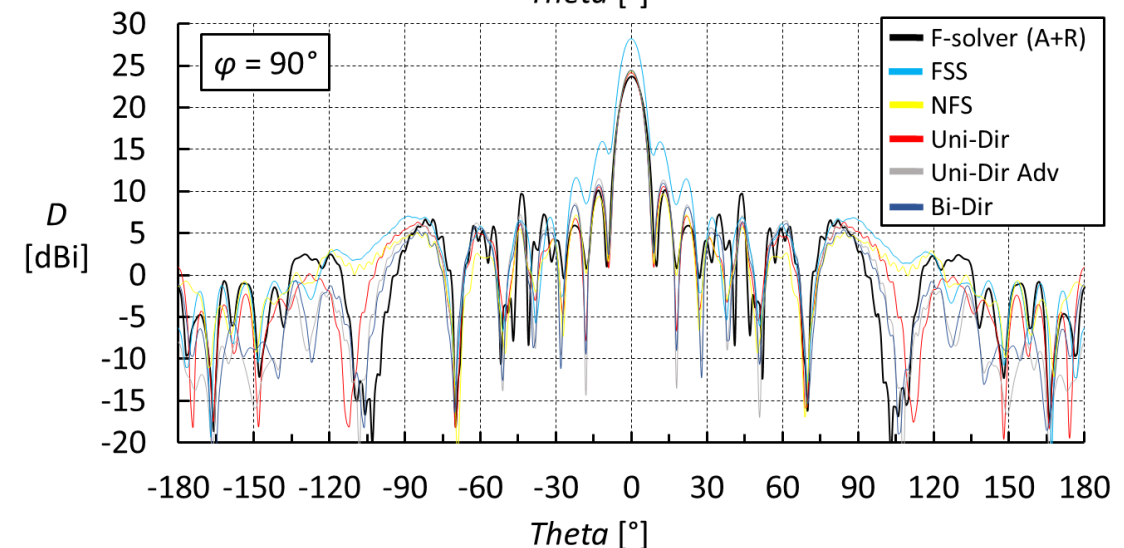
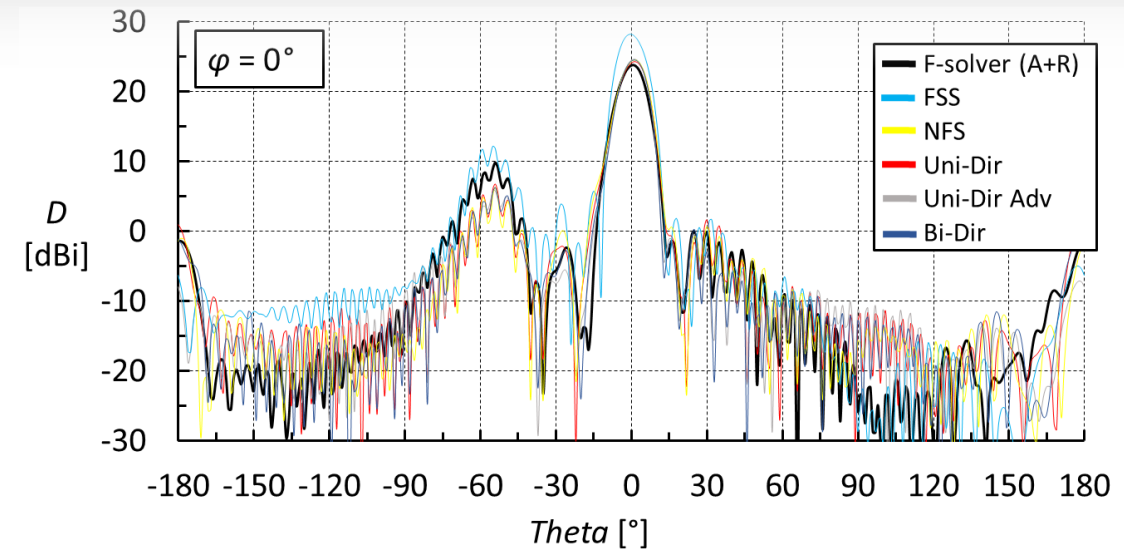


EMAG SIMULACE

SIMULACE RADOMU A ANTÉNNÍHO POLE

- Korelace jednotlivých vyzařovacích diagramů a jejich výpočetní náročnost

Přístup	Výpočetní čas [%]	CORREL ($\theta = 0^\circ$)	CORREL ($\theta = 90^\circ$)
F-solver (A+R)	100 (4h35m)	1	1
F-solver (A)	2.72	-	-
FSS	0.1 (17s)	0.862	0.734
NFS	42.42	0.874	0.737
HS: Uni-Dir	23.63	0.860	0.797
HS: Uni-Dir Adv.	30.99	0.845	0.819
HS: Bi-Dir	77.68	0.860	0.833

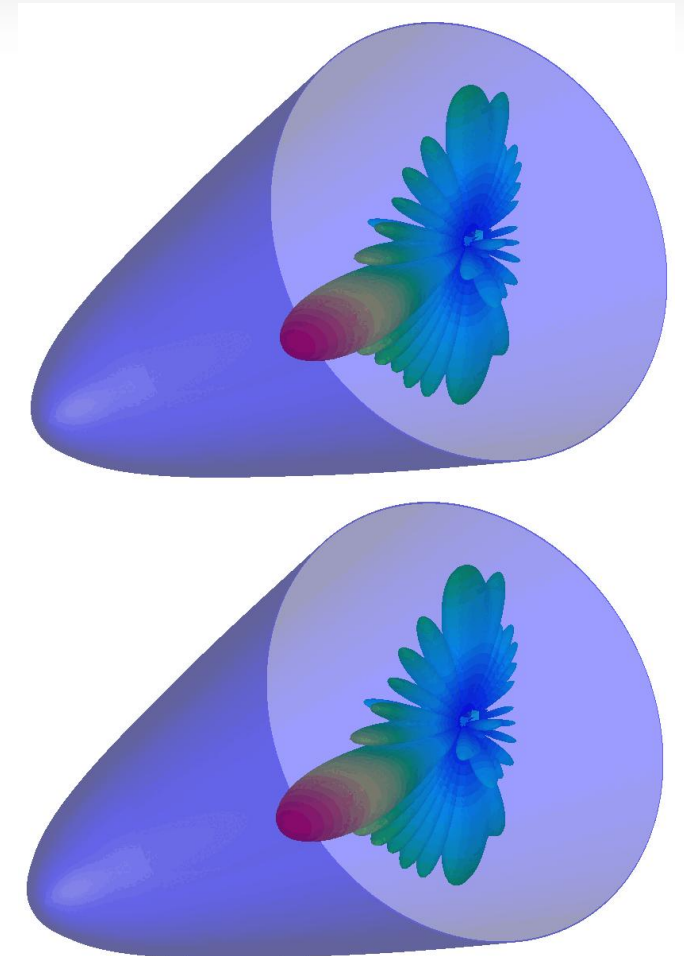
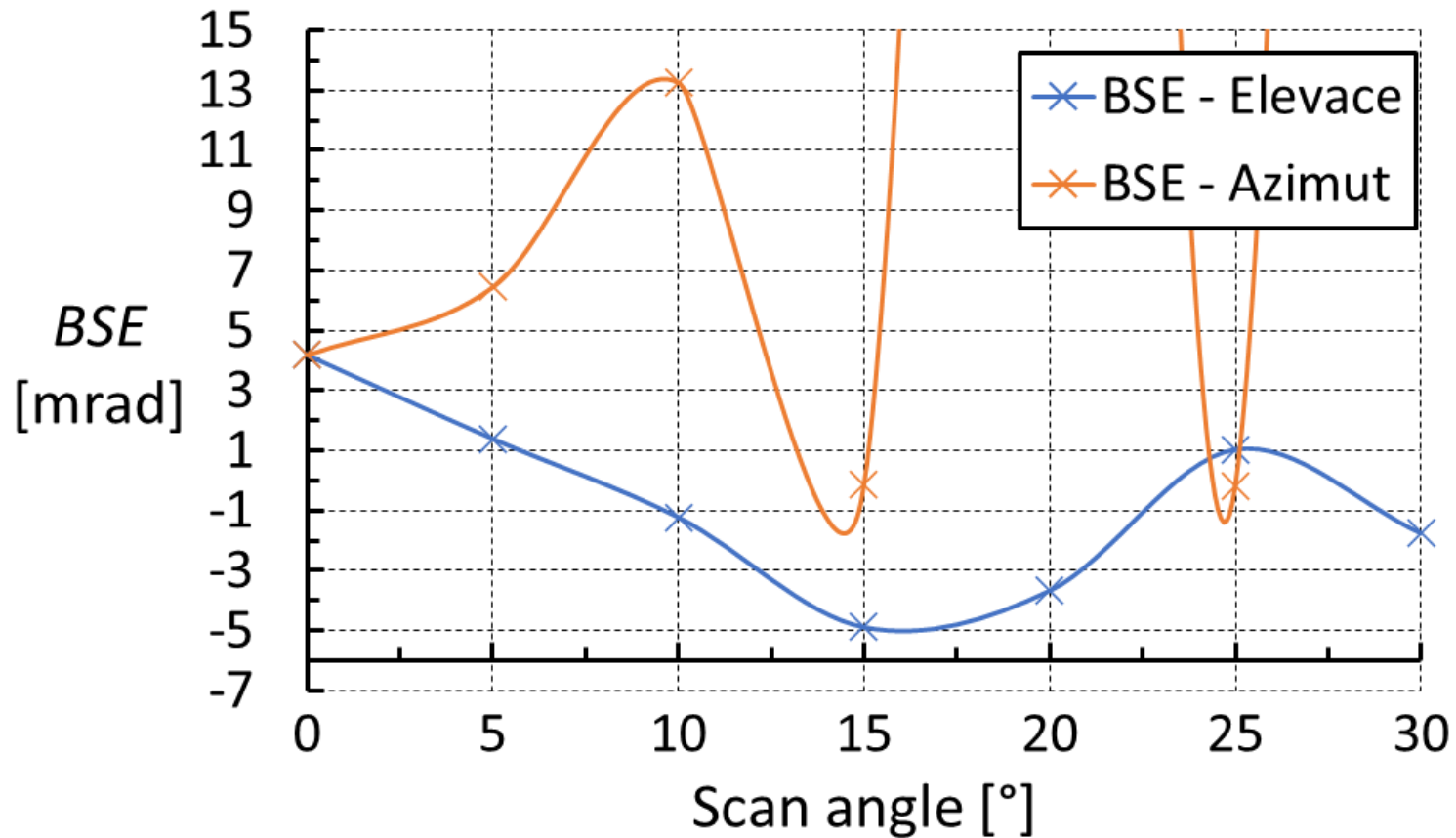




EMAG SIMULACE

SIMULACE RADOMU A ANTÉNNÍHO POLE

- Výpočet Boresight error (BSE)



Azimut & Elevance (Scan angle).



EMAG SIMULACE

ÚDER BLESKU



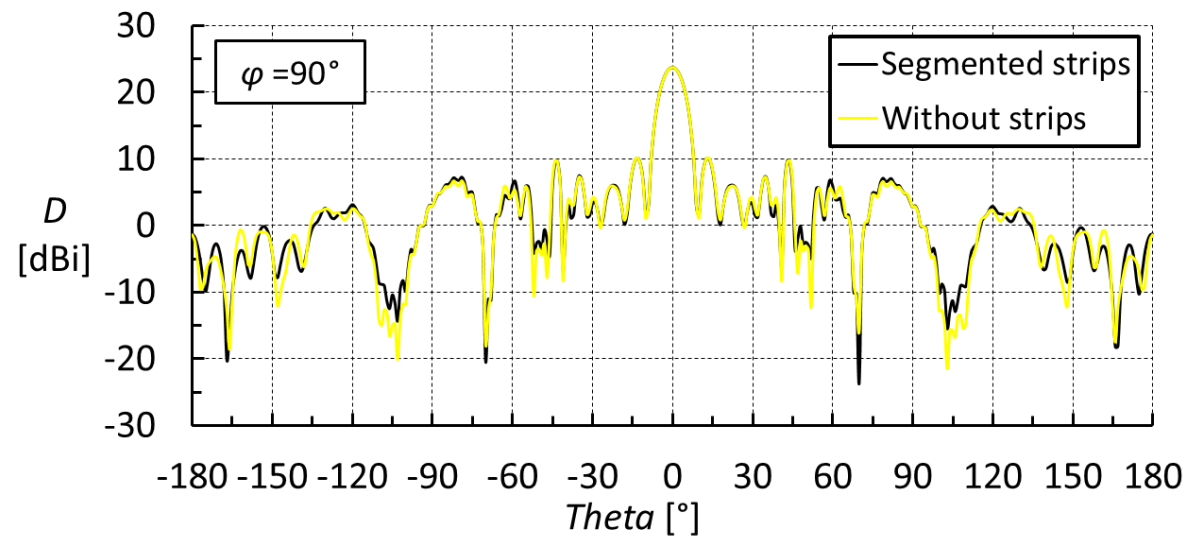
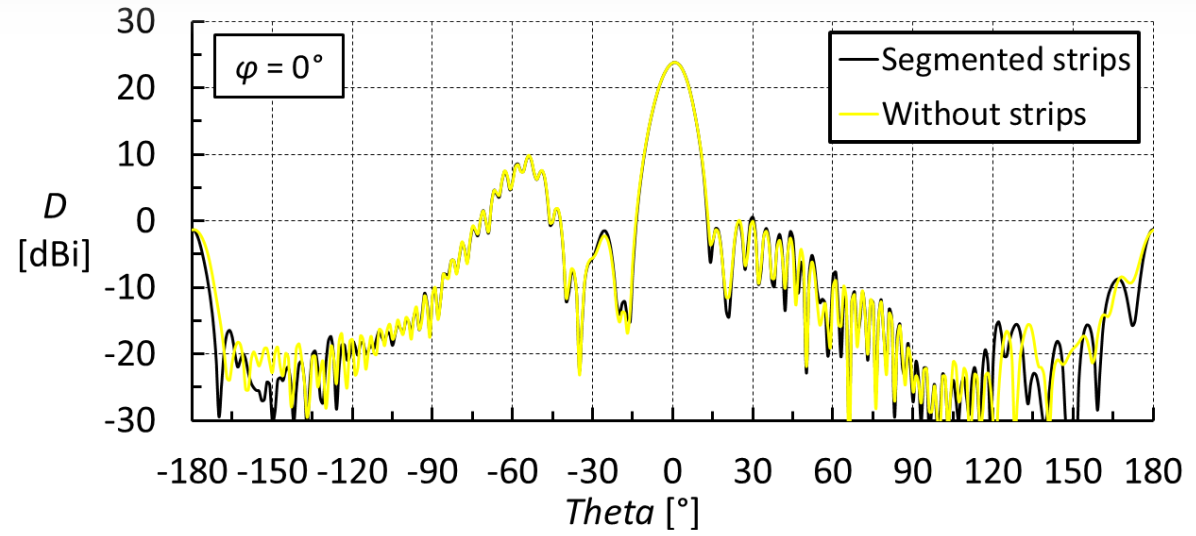
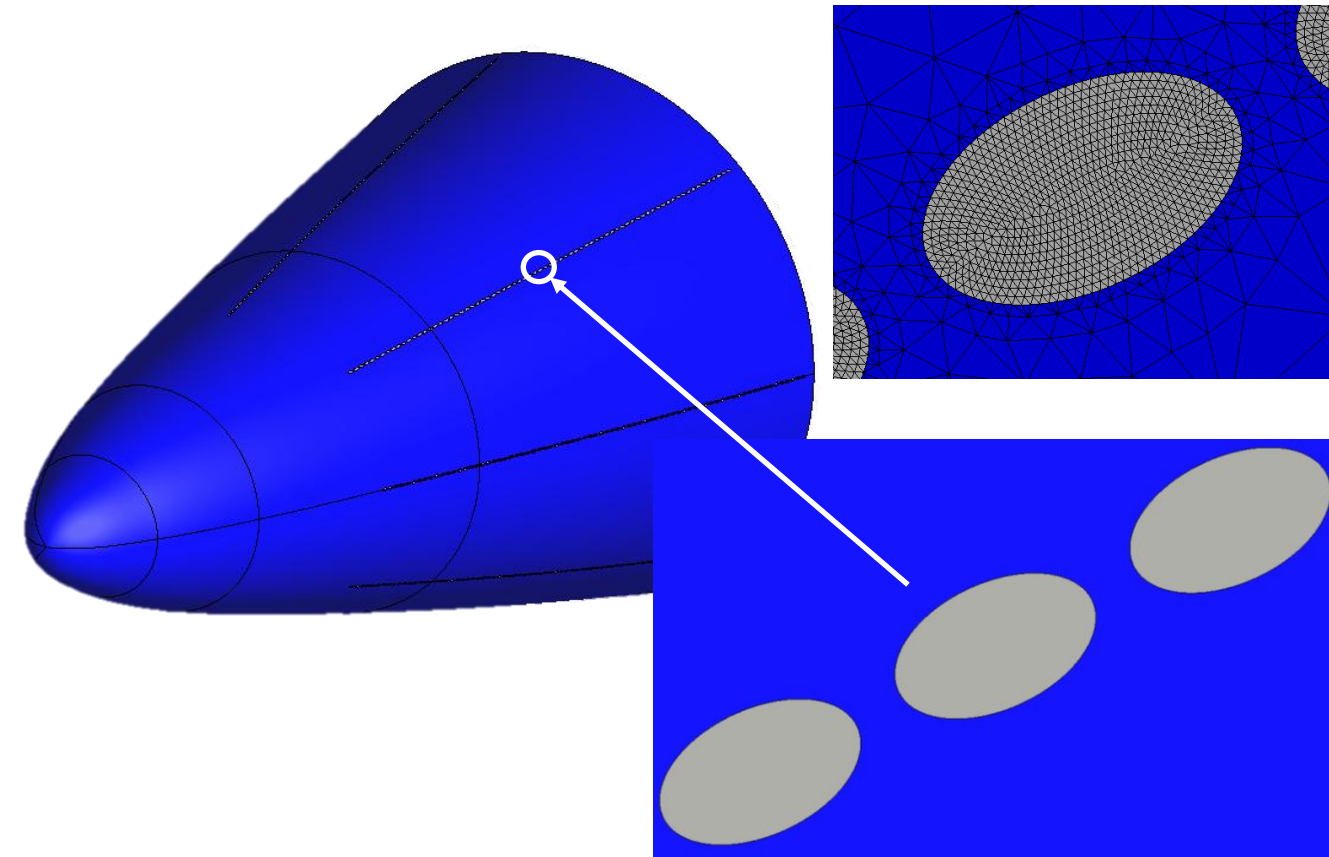
CONFIDENTIAL

V případě zájmu nás kontaktujte.



EMAG SIMULACE ÚDER BLESKU

- Přidání segmentovaných pásků na radom - vytvoření kanálu pro odvod blesku.



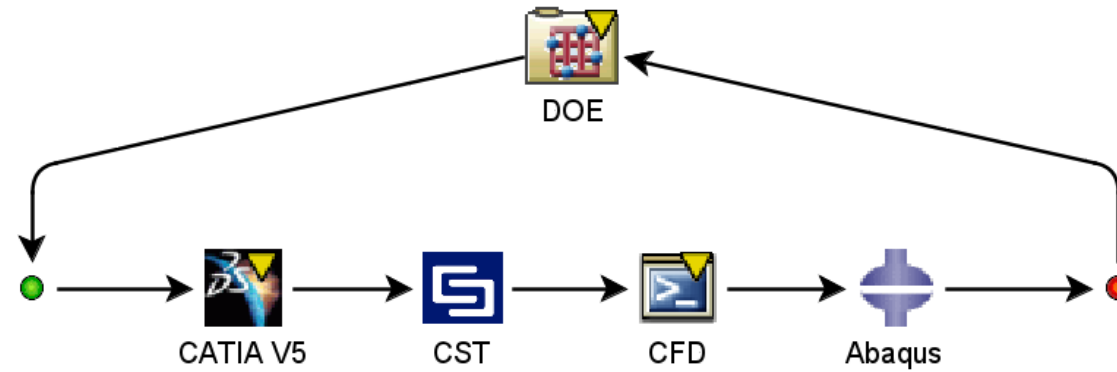
OBSAH

1. Úvod
2. Strukturální simulace
3. Simulace proudění
4. Simulace elektromagnetismu
5. Parametrická optimalizace
6. Závěr

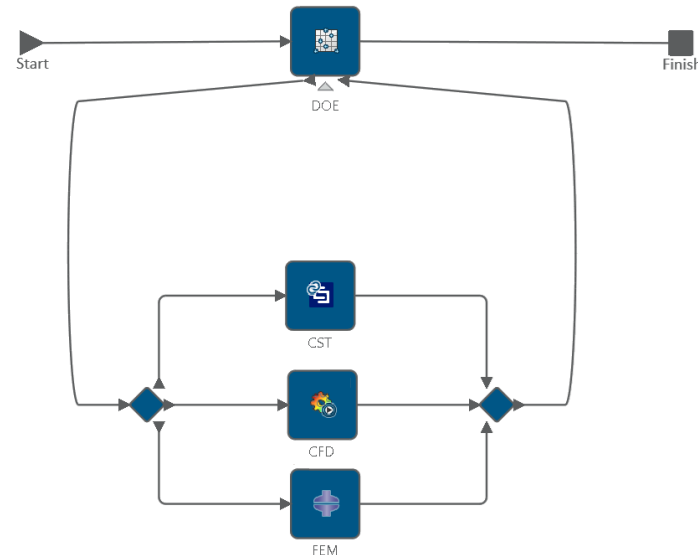
EMAG SIMULACE

SIMULACE RADOMU A ANTÉNNÍHO POLE

- Legacy programs



- Optimalizace na 3DExperience



OBSAH

1. Úvod
2. Strukturální simulace
3. Simulace proudění
4. Simulace elektromagnetismu
5. Parametrická optimalizace
6. Závěr

ZÁVĚR

SIMULACE RADOMU



- Simulia Vám nabízí kompletní simulace radomu:
 - Elektro-magnetické simulace
 - Simulace proudění
 - Strukturální simulace
- 3DExperience nabízí bezprecedentní datové propojení:
 - S plnými CAD daty
 - Pro všechny simulace
 - Vše využitelné pro optimalizační smyčky

Applus IDIADA
Headquarters and Main Technical Centre
L'Albornar – PO Box 20
E-43710 Santa Oliva (Tarragona) Spain
T +34 977 166 000 F +34 977 166 007
e-mail: idiada@idiada.com

www.idiada.com

Applus IDIADA Belgium
T +32 2 757 27 07 (Brussels)
e-mail: idiada_belgium@idiada.com

Applus IDIADA Brazil
T +55 11 4330 9880 (São Paulo)
T +55 31 3591 6832 (Belo Horizonte)
e-mail: idiada_brasil@idiada.com

Applus IDIADA China
T +86 21 6210 0894 (Shanghai)
T +86 21 6210 0894 (Beijing)
T +86 431 8190 9680 (Changchun)
T +86 23 6756 8060 (Chongqing)
T +86 21 6210 0894 (Cixi)
T +86 20 2282 9202 (Guangzhou)
T +86 21 6210 0894 (Ningbo)
T +86 532 66019017 (Qingdao)
T +86 21 6210 0894 (Tianjin)
T +86 21 6210 0894 (Wuhu)
T +86 535 8933658 (Zhaoyuan)
e-mail: idiada_china@idiada.com

Applus IDIADA Czech Republic
T +420 493 654 811 (Hradec Králové)
T +420 778 430 095 (Brno)
T +420 482 424 243 (Liberec)
T +420 326 736 860 (Mladá Boleslav)
e-mail: info@idiada.cz

Applus IDIADA France
T +33 (0) 181 891 943 (Paris)
T +33 (0) 130 370 836 (Paris)
T +33 (0) 141 146 085 (Lyon)
e-mail: idiada_france@idiada.com

Applus IDIADA Germany
T +49 (0) 84188538-30 (Ingolstadt)
T +49 (0) 89309056-0 (Munich)
T +49 (0) 84188538-30 (Stuttgart)
T +49 (0) 5374920606-0 (Wolfsburg)
e-mail: idiada_germany@idiada.com

Applus IDIADA India
T +91 44 2275 2202 (Chennai)
T +91 124 4028 888 (New Delhi)
T +91 20 6605 6800 (Pune)
e-mail: idiada_india@idiada.com

Applus IDIADA Italy
T +39 051 0923530 (Bologna)
T +39 005 10923500 (Erbusco)
T +39 011 2640320 (Turin)
e-mail: idiada_italia@idiada.com

Applus IDIADA Japan
T +81 (0) 42 512 8982 (Tokyo)
T +81 (0) 52 588 5329 (Nagoya)
e-mail: idiada_japan@idiada.com

Applus IDIADA Malaysia
T ++60327281027 (Kuala Lumpur)
T +601 2410 7686 (Penang)
e-mail: idiada_malaysia@idiada.com

Applus IDIADA Mexico
T +52 (222) 644 1374 (Puebla)
e-mail: idiada_mexico@idiada.com

Applus IDIADA Morocco
e-mail: idiada_morocco@idiada.com

Applus IDIADA Poland
T +48 61 6226 905 (Poznan)
e-mail: idiada_polska@idiada.com

Applus IDIADA Slovakia
T +420 778 430 098 (Košice)
e-mail: idiada_slovakia@idiada.com

Applus IDIADA South Korea
T +82 31 478 1821 (Seoul)
e-mail: idiada_korea@idiada.co.kr

Applus IDIADA Spain
T +34 977 166 000 (Santa Oliva)
T +34 928 587 447 (Las Palmas)
T +34 915 095 795 (Madrid)
T +34 950 473 256 (Mojácar)
T +34 868 912 179 (Murcia)
T +34 948 292 921 (Pamplona)
T +34 955 117 111 (Sevilla)
T +34 986 900 300 (Vigo)
e-mail: idiada@idiada.com

Applus IDIADA Sweden
T +46 (0) 31 320 1844 (Gothenburg)
T +46 731 478 202 (Stockholm)
e-mail: idiada_sweden@idiada.com

Applus IDIADA Thailand
T +66 86 7917 071 (Bangkok)
e-mail: idiada_thailand@idiada.com

Applus IDIADA Turkey
T +90 216 250 6050 (Istanbul)
e-mail: idiada_turkey@idiada.com

Applus IDIADA UK
T +44 1223 441 434 (Cambridge)
T +44 2476 328 083 (Nuneaton)
T +44 1926 623 132 (Warwick)
e-mail: idiada_uk@idiada.com

Applus IDIADA UAE
T +971 4 2441313 (Dubai)
e-mail: idiada_uae@idiada.com

Applus IDIADA USA
T +1 248 978 0111 (Detroit)
T +1 760 246 1672 (Los Angeles)
e-mail: idiada_USA@idiada.com

Applus IDIADA Vietnam
T +84 97 724 19 86 (Hanoi)
e-mail: idiada_vietnam@idiada.com

