EXPLAINING THE EM DRIVE WITH THE ELECTROMAG. & GRAVITATIONAL COUPLING THEORY

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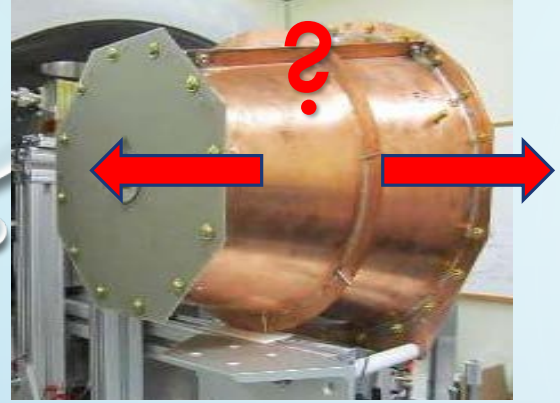


INTRODUCTION

SINCE THE ESTES PARK CONFERENCE – 2016

- **VARIOUS MODELS** EMERGED TO EXPLAIN THE ANOMALOUS THRUST OF THE EM CAVITY (I.E. PHOTON ROCKET, MIHSC MODEL [OR UNRUH RADIATION])
- **MOST OF THEM FAILED** TO TAKE INTO ACCOUNT THE CHANGE OF DIRECTION OF THE THRUST

WHEN INSERTING DIELECTRIC (I.E. HDPE)

- **MACH-LORENTZ THRUSTER** APPLIED TO EM DRIVE WAS FIRST DESCRIBED (E.P.WORKSHOP 2016)), BUT NO ASSUMPTIONS ON HOW THE WOODWARD EFFECT WAS TRIGGERED AND NO ESTIMATION OF THE THRUST
- **BEYOND A WORKING MODEL** : HOW TO CONTROL THE THRUST (INCREASE) ? (CALL IT "FINDING THE GEAR BOX")

MODEL OF THE MACH LORENTZ THRUSTER (1/3)

MLT = WOODWARD EFFECT + LORENTZ FORCES

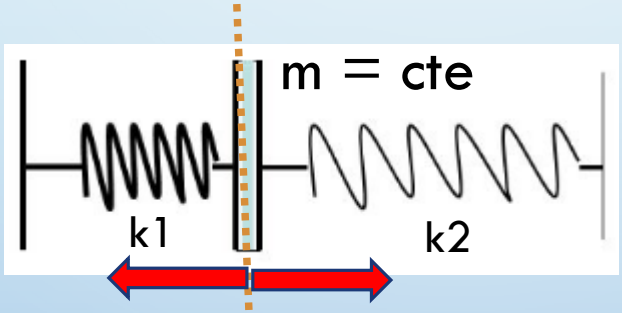
HOW COME?

- **WOODWARD EFFECT** [W.E.]: "DERIVED FROM MACH PRINCIPLE. INERTIA FROM GR THEORY BASED ON INTERACTION OF GRAVITATIONAL FORCES RESULTING FROM MASSIVE BODIES (I.E. PLANETS, BLACK HOLES, …) IN THE UNIVERSE. "
- **ASSUMPTION 1.0**: THE **W.E.** IS A **RELATIVISTIC EFFECT** AND CANNOT BE TRIGGERED BY CLASSICAL MECHANICS (OR MECHANICAL FORCES).
- **ASSUMPTION 2.0:** THE **W.E.** APPLIED TO CLOSED SYSTEMS (I.E. EM CAVITY) OPEN IT DURING MASS VARIATION (SUCH AS ROCKET ENGINE MODEL)

MODEL OF THE MACH LORENTZ THRUSTER (2/3)

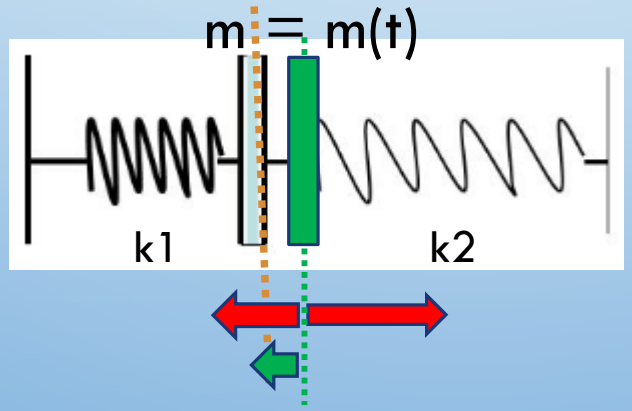
A MECHANICAL ANALOGY TO UNDERSTAND THE W.E: IN THE MACH LORENTZ THRUSTER MODEL

Steady State:



$m.dv/dt = k1.x - k2.x = 0 \quad , k1 = k2$

Perturbed State
Due to Mass variation :



$v.dm/dt + m.dv/dt = k1.x - k2.x + F \quad , k1 \neq k2$

Additional Force to come back to Steady state

MODEL OF THE MACH LORENTZ THRUSTER (3/3)

- ✓ **K1=K2** (STEADY STATE OR SYMMETRICAL SYSTEM): THE SYSTEM NOT VIABLE WITH W.E. . CONSERVATION OF MOMENTUM (I.E. D(M.V)/DT =0) STANDS ALONE!
- ✓ **K1≠K2:** ASYMMETRY IN THE SYSTEM, OR INTERNAL STRESS WHICH RESULTS IN ADDITIONAL FORCE "F" IN ORDER TO HAVE RHS = 0 (AKA CONSERVATION OF MOMENTUM). *"IN PREVIOUS EXAMPLE, **F** PUSHES BACK THE MASS TO ITS ORIGINAL PLACE "*

[ASSUMPTION 3.0]

WE POSTULATE THAT THE ASYMMETRY OF THE SYSTEM IS REQUIRED TO TRIGGER THE W.E. IN THE EM DRIVE CASE

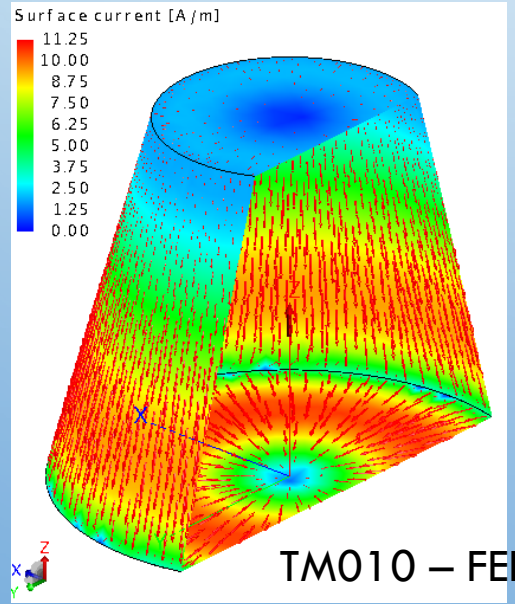
APPLICATION TO EM DRIVE (1/7)

ASYMMETRICAL EM CAVITY = "RELATIVISTIC" CAPACITOR

I. ASYMMETRY?

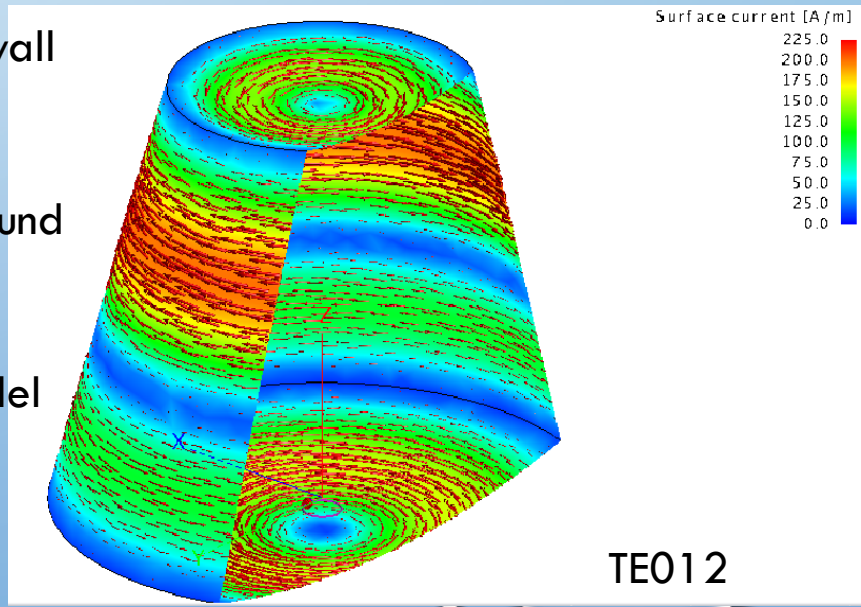
1. ASYMMETRY OF THE EM CAVITY GEOMETRY
2. ASYMMETRY OF THE CHARGE DENSITY INSIDE THE CAVITY = VARIABLE CAPACITANCE

TM mode : capacitor with spherical end plates , Or infinite sum (series) of capacitors



TM010 – FEKO simulations

TE mode : conical wall with homogenous distribution of the charge density around azimuthal angle = infinite sum of capacitors in parallel



TE012

APPLICATION TO EM DRIVE (2/7)

BASED ON ASSUMPTION 3.0 [ASYMMETRY TRIGGERS THE W.E.]

"IN TM (TM010) MODES THE "RELATIVISTIC" CAPACITOR MODELS THE CAVITY AS A SUM OF CAPACITORS IN SERIES WITH VARIOUS CAPACITANCES, WHEREAS THE TE (TE012) MODES IS BEST DESCRIBED AS A SUM OF CAPACITORS IN PARALLEL WITH VARIOUS CAPACITANCES"

WHY "RELATIVISTIC" CAPACITOR AND ITS IMPLICATION?

"RELATIVISTIC" CAPACITOR = VARIATION OF ELECTRIC CHARGE DENSITY ON EM CAVITY'S WALLS = VARIATION OF MASS = WOODWARD EFFECT

APPLICATION TO EM DRIVE (3/7)

II. ELECTROMAGNETIC AND GRAVITATIONAL COUPLING [IN 3 STEPS]

"THE MLT MODEL OF THE EM DRIVE AND ANOMALOUS THRUST CAN BE DESCRIBED SUCH AS AN EMG COUPLING."

- **STEP 1:** CHARGE/DISCHARGE OF THE "RELATIVISTIC" CAPACITOR
- **STEP 2:** THE LORENTZ FORCES ON THE CAVITY'S WALLS
- **STEP 3:** TRIGGERING THE WOODWARD EFFECT AND THE ANOMALOUS THRUST

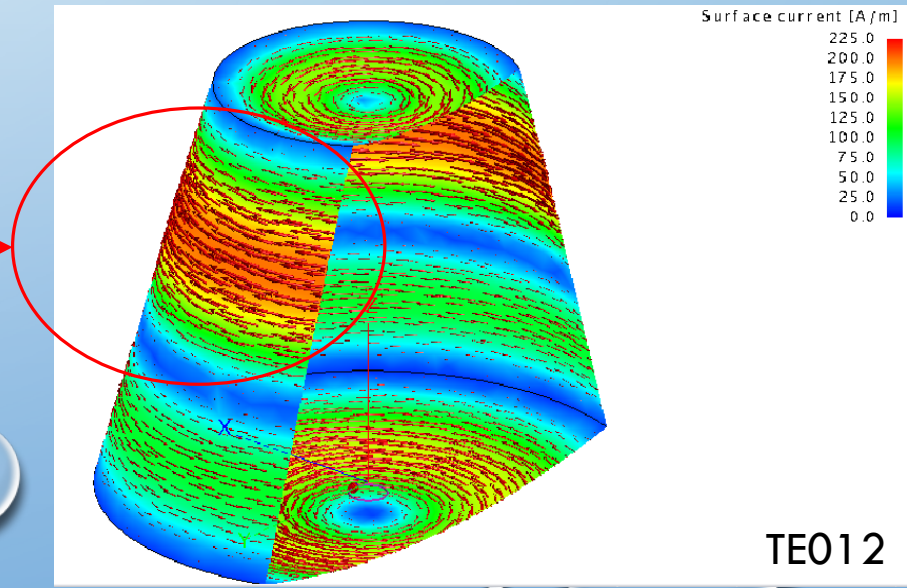
APPLICATION TO EM DRIVE (4/7)

STEP 1: CHARGE/DISCHARGE OF THE "RELATIVISTIC" CAPACITOR

ELECTRICAL CHARGES ARE CREATED ON THE WALL OF THE EM CAVITY VIA EM EXCITATION FROM E,B FIELD INSIDE THE CAVITY [EDDY CURRENTS].

- SIMILAR TO **CHARGE/DISCHARGE OF A CAPACITOR**
- **ASYMMETRY OF THE CHARGE DISTRIBUTION = SUM OF CAPACITORS WITH ≠ CAPACITANCE** (OR ONE VARIABLE CAPACITOR).
- THE PRESENCE OF LARGE EDDY CURRENTS SHOW THE AREAS

WITH HIGH DENSITY ELECTRICAL CHARGES



APPLICATION TO EM DRIVE (5/7)

STEP 2: <u>THE LORENTZ FORCES ON THE CAVITY'S WALLS</u>

IF EM CAVITY WAS AN ACCELERATED MOBILE (Z-AXIS) : APPLICATION OF NEWTON 2ND LAW

$$m\partial_t^2 z = \alpha\partial_t z - Kz + F_{Lo}$$

The Lorenz forces are created from the electrons moving through Electric and Magnetic fields following the Eddy Currents inside cavity's walls.

Dissipative force, Resistivity of copper

Mechanical analogy to capacitor properties of the EM cavity

$\overrightarrow{dFz} = Nq_e\vec{E} + Nq_e\overrightarrow{v_e} \times \vec{B}$ (Lorentz force per electron, N density per surface, (q_e, v_e) charge and velocity

$\overrightarrow{dFzS} = \int \overrightarrow{dFz}\,.\,\overrightarrow{dS} = \int Nq_e\vec{E}\,.\,\overrightarrow{dS} + \overrightarrow{Js} \times \vec{B}$

APPLICATION TO EM DRIVE (6/7)

STEP 3: TRIGGERING THE WOODWARD EFFECT AND THE ANOMALOUS THRUST

THE W.E. - TRANSIENT MASS SOURCE IN TERMS OF REST $\mathcal{E}$

$$\delta\rho_0(t) = \frac{1}{4\pi G}[\frac{1}{\rho_0 c^2}\partial_t^2\mathcal{E} - (\frac{1}{\rho_0 c^2})^2(\partial_t\mathcal{E})^2]$$

THEW.E. - MASS DENSITY VARIATION WITH ASSUMPTION OF EM ENERGY DENSITY

$$\delta\rho(t) = \frac{1}{4\pi G}[\frac{1}{\rho c^2}\partial_t^2 u_{EM} - (\frac{1}{\rho c^2})^2(\partial_t u_{EM})^2]$$

Negligible terms compared with second order variation

ASSUMPTION 4.0 (Montillet's hypothesis = **EM & G. Coupling)**

THE VARIATION IN TIME OF THE REST ENERGY IS MOSTLY DUE TO THE VARIATION OF THE E.M. ENERGY DENSITY WITHIN THE COPPER SKIN DEPTH (CAVITY'S WALLS)

Montillet, Adv. Prop. Workshop, El Segundo meeting, Los Angeles, Nov. 2017

APPLICATION TO EM DRIVE (7/7)

- ESTIMATION OF THE ANOMALOUS THRUST

MECHANICAL ANALOGY $$m\partial_t^2 z + \partial_t z \partial_t m = \alpha \partial_t z - Kz + F_{Lo}$$

Mass variation due to W.E. = open system

USING $Z = Z_0\ e^{-i\omega t}$, WE HAVE: $|Z_0\ | = \frac{1}{\omega^2}.\frac{FL_{0/m}}{\left(\frac{\omega_0^2}{\omega^2}-1\right)-i.\frac{\tau}{\omega}}$, $\mathrm{SUP}(|Z_0\ |) = \frac{1}{\omega^2}.\ FL_0/m$

USING THE APPROXIMATION $|F_{thrust}| \sim \delta m_0.\partial_t^2 Z \sim \delta m_0.FL_0/m$

Approximation of the thrust used in the numerical example!!

NUMERICAL EXAMPLE – TE012 (1/4)

- **SIMULATIONS (DONE BY MR CHRISTIAN ZIEP USING FEKO)**

THE FRUSTUM (BRADY) IS MODELLED IN 3D VIA THE SOFTWARE GRAPHICAL INTERFACE, USING A MESH RESOLUTION OF WAVELENGTH=12, THIS LEADS TO A RESOLUTION OF MORE THAN 5000 TRIANGLES AT THE CONDUCTIVE WALL WHICH BUILDS THE BASIS FOR THE SIMULATIONS . NOTE THAT FEKO SOFTWARE USES A SOLVER TO ESTIMATE THE EM FIELDS BASED ON THE METHODS OF MOMENTS (OR MOM).

DIMENSIONS: **279.4 MM (DIAMETER OF THE LARGE END PLATE), 158.8 MM (DIAMETER OF THE SMALL END PLATE) AND 228.6 MM (HEIGHT OF FRUSTUM).** THE PROPERTIES OF THE **COPPER MATERIAL** (I.E. CONDUCTIVITY, PERMITTIVITY, PERMEABILITY, ...) ARE ALREADY PREDEFINED WITHIN THE SOFTWARE LIBRARY.

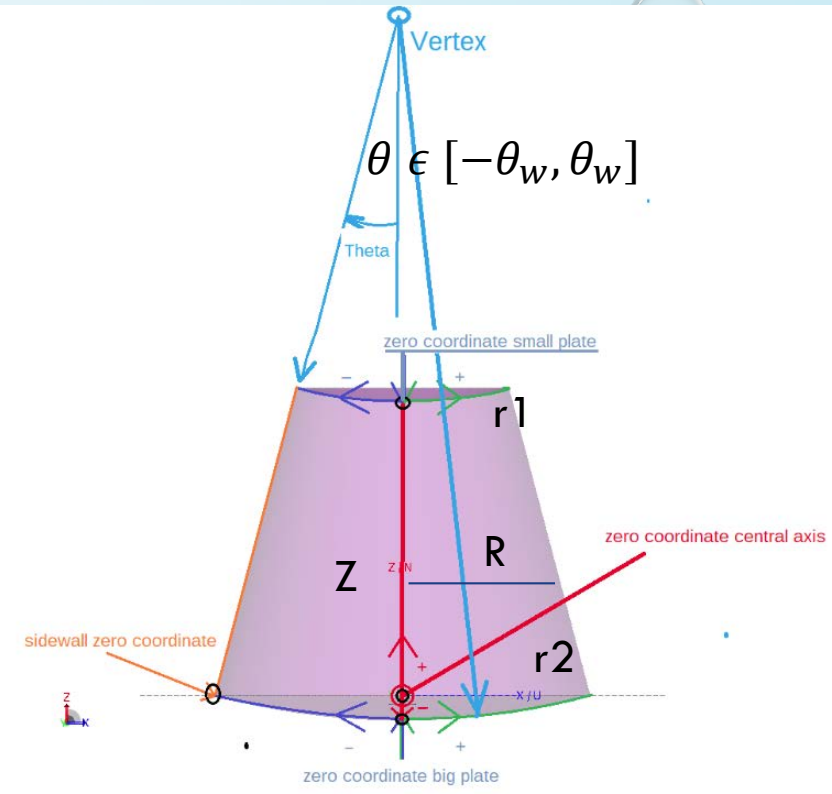
SIMULATIONS ARE DONE **WITH AND WITHOUT DIELECTRIC** FOLLOWING THE **SAME PARAMETERS AS IN NASA REPORT**

NUMERICAL EXAMPLE – TE012 (2/4)

<u>ASSUMPTIONS & APPROXIMATIONS TO GIVE A COARSE ESTIMATE</u>

- **ESTIMATION OF THE LORENTZ** FORCES **USING INTEGRAL OVER THE SURFACE** (I.E. SURFACE CURRENT JS)
- **ESTIMATION OF THE LORENTZ FORCES** WITH $\vec{B}$ FIELD AT SURFACE OF WALL/END
- **ESTIMATION OF AMPLITUDE** OF THE $\vec{B}$ FIELD IN COPPER SKIN LAYER USING **STATIONARY REGIME** ($\vec{\nabla} \times \vec{B} = \mu_0 \overrightarrow{Js}$)
- **EM ENERGY** DENSITY WITHIN SKIN DEPTH VIA **CONSERVATION OF ENERGY LAW** $\partial_t^2 UEM = -\vec{\nabla}.\partial_t\ \vec{S}$, WITH $\vec{S}$ POYNTING VECTOR
- **SURFACE CURRENTS DISPLACEMENT** = DIRECTION OF LORENTZ FORCES AT THE WALL/END

NUMERICAL EXAMPLE TE012 (3/4)



LORENTZ FORCE AT …

- DF(θ, φ) = - Js.B. r^2.SIN(θ) COS(θ)Dθ. Dφ (SPHERICAL ENDS)
- DF(z, φ) = - Js.B.TAN(θw)^2.Z.DZ. Dφ (CONICAL WALLS)

SECOND ORDER VARIATION OF UEM

$\partial_t^2 UEM = \frac{8.\omega}{\gamma}.Js^2.S$, S = SURFACE OF SPHERICAL END PLATES OR CONICAL WALLS

ROUGH ESTIMATION OF THRUST

$F_{Thrust} \sim \delta m_0.FL_0/m \sim \frac{V}{4\pi Gm\text{^}2}\frac{1}{c^2}\partial_t^2 UEM \int_r$ 2.Π. DF(R). DR *(CONICAL WALL)*

$F_{Thrust} \sim \delta m_0.\frac{FL_0}{m} \sim \frac{V}{4\pi Gm^2}\frac{1}{c^2}\partial_t^2 UEM.\pi r^2$ (end plates)

CADFEKO v14.0 - sperical-TE012-001

3D View

Home | Construct | Transform | Cables | Source/Load | Request | Mesh | Solve/Run | Tools | View | Display options

Symmetry | FDTD boundary conditions | NGF | Enable solution | Solver settings — Solution settings

CEM validate | View by solution — Validate

FEKO solver | POSTFEKO | EDITFEKO | Antenna Magus | FEKO terminal — Run/launch

Parallel | Farm out | Remote

Configurations

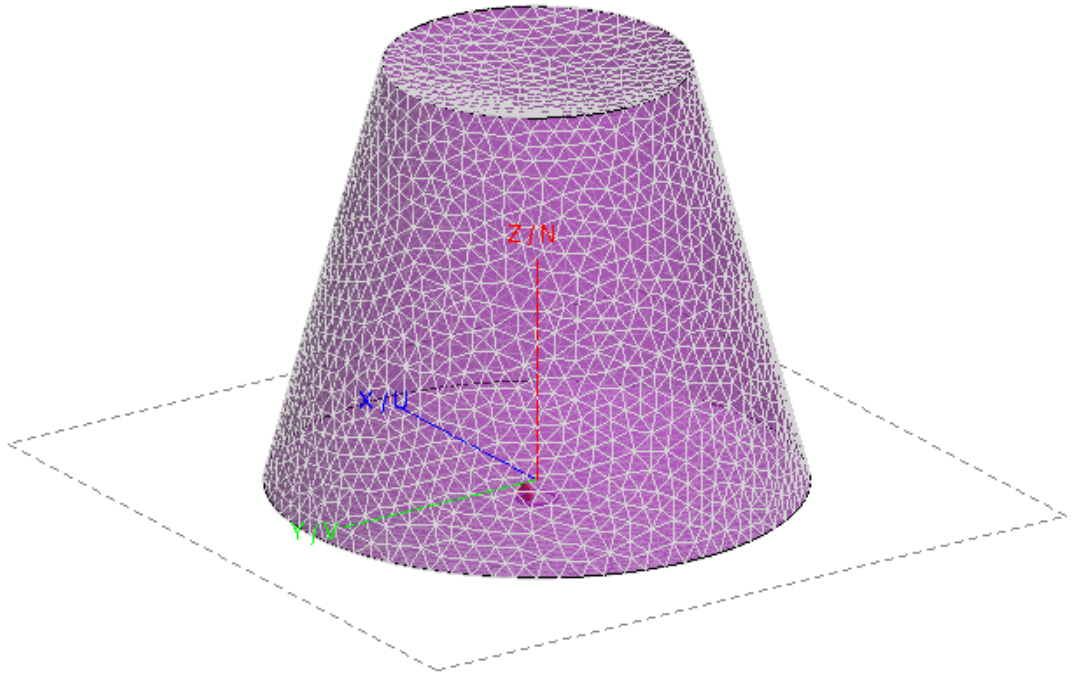
StandardConfiguration1

Construct | Configuration

StandardConfiguration1

- Definitions
  - Variables
    - BIG_D = 27.97
    - Big_depth = (Big_R-Vertex)
    - Big_quasi = (BIG_D^2)/(16*Big_depth)
    - Big_R = sqrt(((BIG_D/2)^2)+(Vertex^2))
    - c0 = 1/sqrt(eps0*mu0)
    - eps0 = 8.85418781761e-12
    - FEED_ANT_D = 2
    - FEED_HEIGHT = -1
    - FEED_RAD = .05
    - FRUST_H = 22.86
    - freq_max = 2.1e9
    - freq_min = 2.2e9
    - lambda_min = c0/freq_max*1000
    - mu0 = pi*4e-7
    - pi = 3.14159265358979323846
    - SMALL_D = 15.88
    - Small_depth = ((SMALL_D/BIG_D)*Big_dep...
    - Small_quasi = (SMALL_D^2)/(16*small_de...
    - Small_R = Big_R*(SMALL_D/BIG_D)
    - Vertex = (BIG_D*FRUST_H)/(BIG_D-SMALL...
    - zf0 = sqrt(mu0/eps0)
  - Media
    - Perfect electric conductor
    - Perfect magnetic conductor
    - Free space
    - Dielectric
    - Metallic
  - Workplanes
- Global

3D view 1

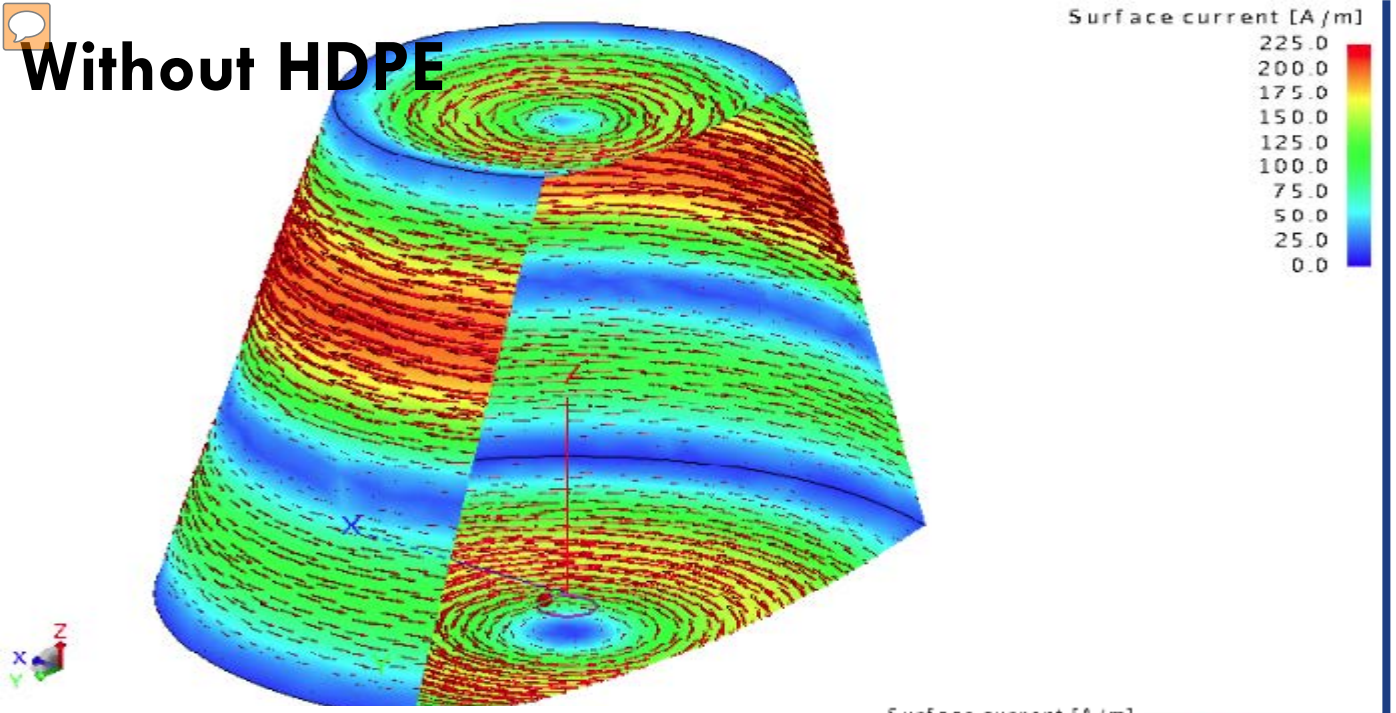


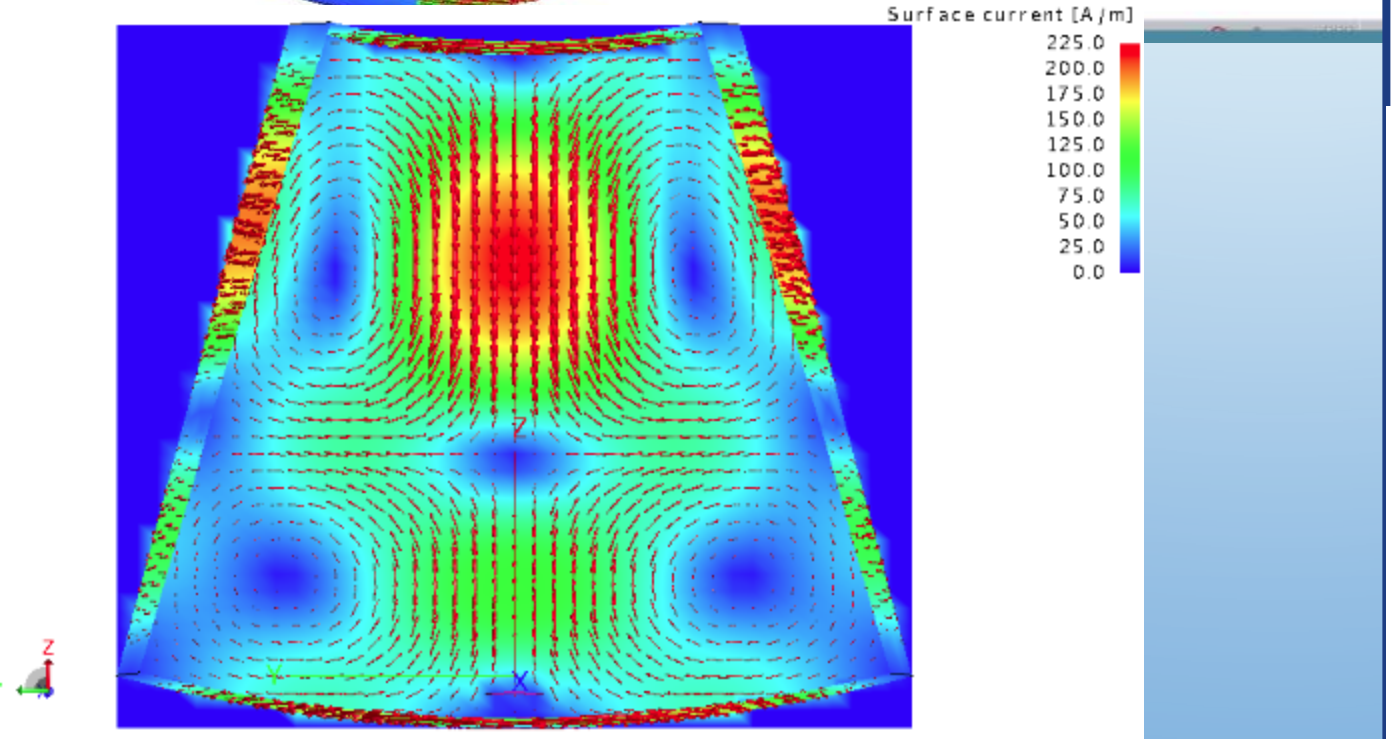
Saving project files...
W:\feko-test\sperical-TE012-001.cfx
W:\feko-test\sperical-TE012-001.cfs
W:\feko-test\sperical-TE012-001.cfm
W:\feko-test\sperical-TE012-001.pre

Display: | Tools: | Selection: | Unit: cm

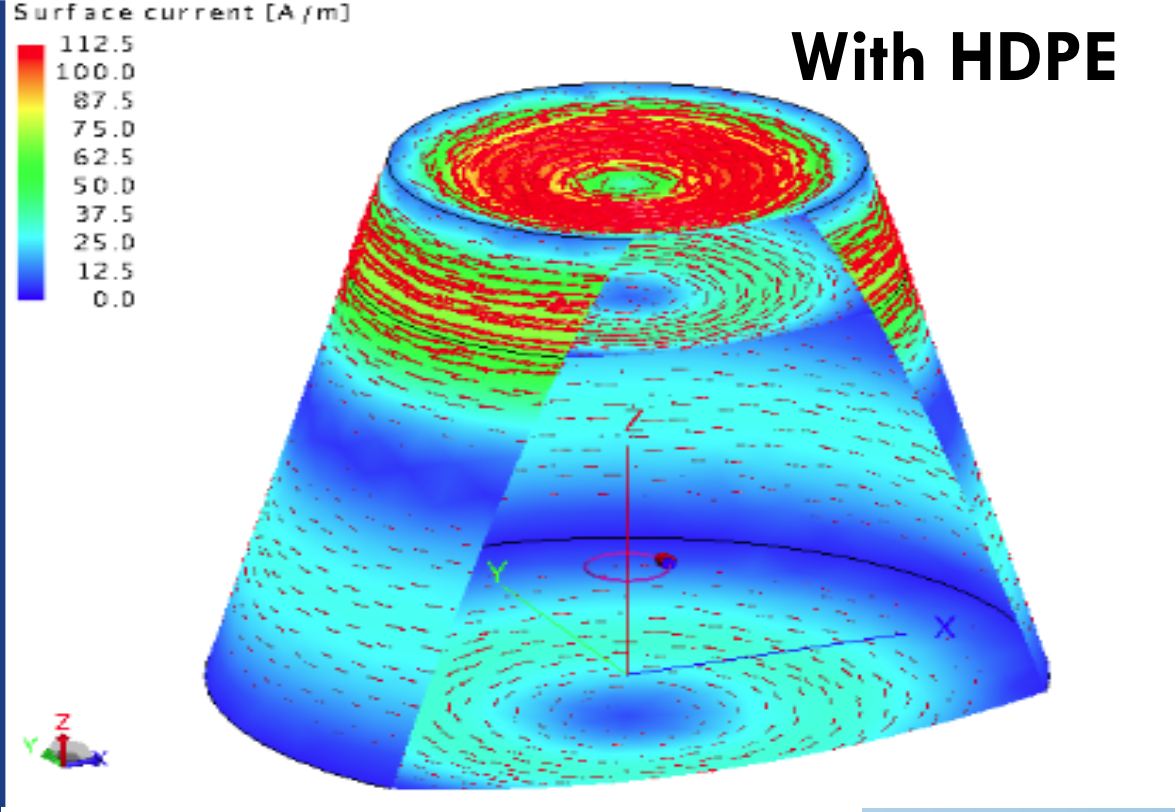
DATA (W:) | Google Übersetzer ... | VeraCrypt | Posteingang - chri... | Verfassen: Re: snip:... | CADFEKO v14.0 - s... | Executing runfeko | 20:28

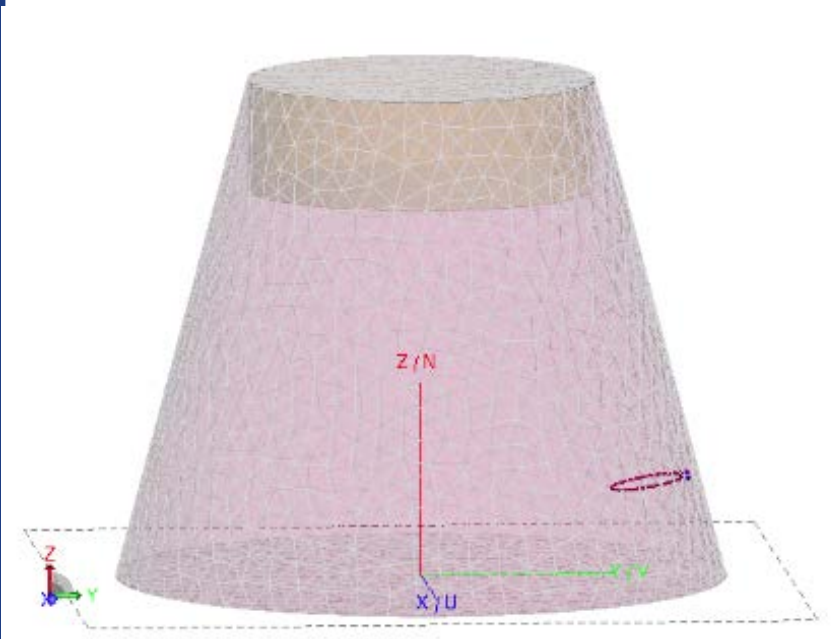
Without HDPE





With HDPE





NUMERICAL EXAMPLE – TE012 (4)

TE012	Without HDPE	With HDPE (@ small end)
Estimated Thrust [microN]	[-70, -10]** (-77*)	[+12, 0.87e-4]** (+34.8*)
Dm (conical wall) [Kg/s^2] (av.)	3e-3 +/- 2.8e-3	2e-4 +/- 2.5e-4
Dm (small end) [Kg/s^2] (av.)	1.6e-6 +/- 1.1e-6	1.1e-6 +/- 8e-7
Dm (large end) [Kg/s^2] (av.)	1.3e-5 +/- 1e-6	6.7e-7 +/- 4.87e-7
Flo (conical wall) (av.) [N/m]	-1.4926e-04 +/- 5.7e-3	8.6e-5 +/- 3.4e-4
Flo (small end) (av.) [N/m]	-1.99e-6 +/- 9.1e-4	-6.04e-20 +/- 6.59e-4
Flo (large end) (av.) [N/m]	4e-20 +/- 1.4e-3	-4e-21 +/- 7.8e-5

** interval for the thrust force based on various assumptions. All other values in following rows are averaged!

* NASA Estimates

In TE012, the spherical ends does not contribute much to the total thrust – only conical wall !!

DISCUSSION (1/3)

LIMITS OF THE MLT MODEL

- ASSUMPTIONS TO BE CHECKED! - ESPECIALLY CONTRIBUTION OF THE EDDY CURRENTS TO THE THRUST – "**ONE CAN LOOK AT THE CONCENTRATION OF THE ELECTRONS INSIDE THE WALLS OF THE EM CAVITY (DUE TO ELECTRIC CURRENTS – EDDY CURRENTS)**" IS IT FEASIBLE ? [NOT SURE FROM VARIOUS SOURCES]
- TRYING TO RECORD A THRUST AT DIFFERENT EIGEN FREQUENCIES TO SEE THE EVOLUTION OF THE ANOMALOUS THRUST WITH SMALLER AMPLITUDE SURFACE CURRENT
- ESTIMATION OF THE THRUST DONE WITH ONE SNAPSHOT (OR AN AVERAGED OVER 1 CYCLE). THUS, NEED A MORE FLEXIBLE APPROACH TO COMPUTE THE THRUST IN "REAL" TIME.

DISCUSSION (2/3)

THE "RELATIVISTIC" CAPACITOR HYPOTHESIS

- INCREASING THE THRUST WITH INCREASING THE SKIN DEPTH ?

PERHAPS, BUT NEED TO TAKE INTO ACCOUNT THE RESISTIVITY /OHMIC LOSSES - QUOTING P. MARCH *"USE SUPERCONDUCTORS TYPE YBCO OR MGB2 TO REPLACE ENTIRELY OR PARTIALLY THE COPPER EM CAVITY"*

- THE THERMAL TRACES OF THE EM CAVITY COULD ALSO SHOW THE OHMIC LOSSES DUE TO THE SKIN DEPTH EFFECT. CAN WE ASSOCIATE THE LARGE OHMIC LOSSES WITH "LARGE" ELECTRIC CHARGES CREATED ON THE WALLS AND SUPPORT OUR "RELATIVISTIC" CAPACITOR?

P. MARCH: *" COAT THE INTERIOR OF THE FRUSTUM WITH A LIQUID CRYSTAL SOLUTION ON A CARBON BLACK BACKING THAT CHANGES COLORS WITH APPLIED LOCALIZED HEATING WHEN RF IS APPLIED TO THE INTERIOR OF THE FRUSTUM"*

DISCUSSION (3/3)

ABOUT THE WOODWARD EFFECT APPLIED TO EM DRIVE

- RESULTS ARE ENCOURAGING WITH THE MLT MODEL. **BUT**, SEVERAL DISCUSSIONS (WITH DR. J. RODAL) HAVE UNDERLINED THAT THE W.E. FORMULA SHOULD BE DIFFERENT FOR THE EM DRIVE (COMPARED WITH THE DERIVATION FOR THE PIEZO STACK). AT THE MOMENT, WE THINK THAT THE EFFECT IS **NOT WELL ESTIMATED** IN THE CASE OF THE EM DRIVE (OVER/UNDERESTIMATED ?).

- $\partial_t^2 \varepsilon \sim \partial_t^2 U_{EM}$ [MONTILLET'S HYPOTHESI]S IS WEAK? NOT ONLY THE EM ENERGY DENSITY IS VARYING WITH TIME – NOTE THAT ELECTROSTRICTIVE EFFECTS ARE NEGLECTED IN THIS HYPOTHESIS – SEE MONTILLET, J. OF MODERN PHYS, DOI:10.4236/JMP.2017.810100

SUMMARY OF THE MLT MODEL

- "RELATIVISTIC" CAPACITOR = ASYMMETRY OF ELECTRIC CHARGES ON CAVITY'S WALLS

➡ **TRIGGER WOODWARD EFFECT** WITH MONTILLET'S HYPOTHESIS $\partial_t^2 \varepsilon \sim \partial_t^2 U_{EM}$ **(EM & G. COUPLING!!)**

- **LORENTZ FORCES** ON EM CAVITY'S WALLS = BALANCING VARIATION OF MASS (ANALOGY WITH MASS AND SPRINGS) ~ STRESS ON CAVITY'S WALLS

- **INCREASING THE THRUST WITH THIS MODEL**

$$\boxed{\frac{F}{P_{in}} = \frac{Q*g}{c}}, Q = w_0 * \frac{Energy\ Stored}{Power\ loss} \approx \boxed{w_0 * \frac{U_{EM}}{Power\ loss}} \approx \boxed{w_0 * \mathrm{R(T)*C(T)}}$$

Rodal's formula — Montillet'H. — Relativistic Capa.

R(T) : Resistivity of the EM cavity
C(T): Capacitance
w_0 = 2*pi* f_0 , f_0 = central frequency

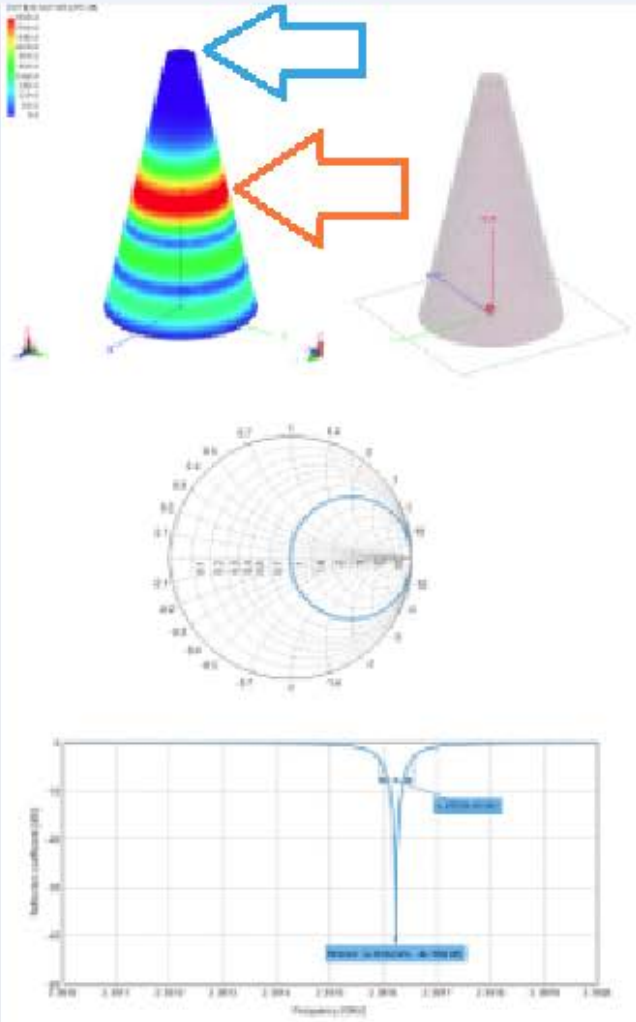
Montillet, Adv. Prop. Workshop, El Segundo meeting, Los Angeles, Nov. 2017

THANKS!!

I WOULD LIKE TO ACKNOWLEDGE THE FOLLOWING PEOPLE FOR THE DISCUSSIONS AND/OR SIMULATIONS NECESSARY FOR ESTABLISHING THIS MODEL.

- DR. JOSÉ RODAL
- PROF. HEIDI FEARN
- MR. PAUL MARCH
- MR. CHRISTIAN ZIEP

THE WORK IS STILL ON GOING!



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SD=50mm
LN=500mm
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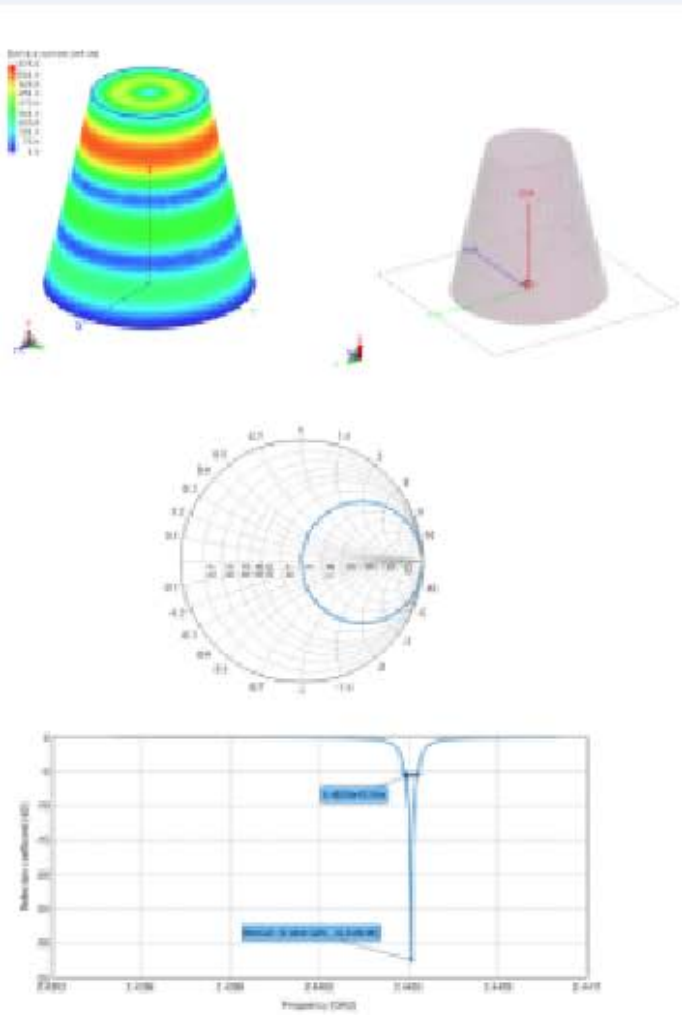

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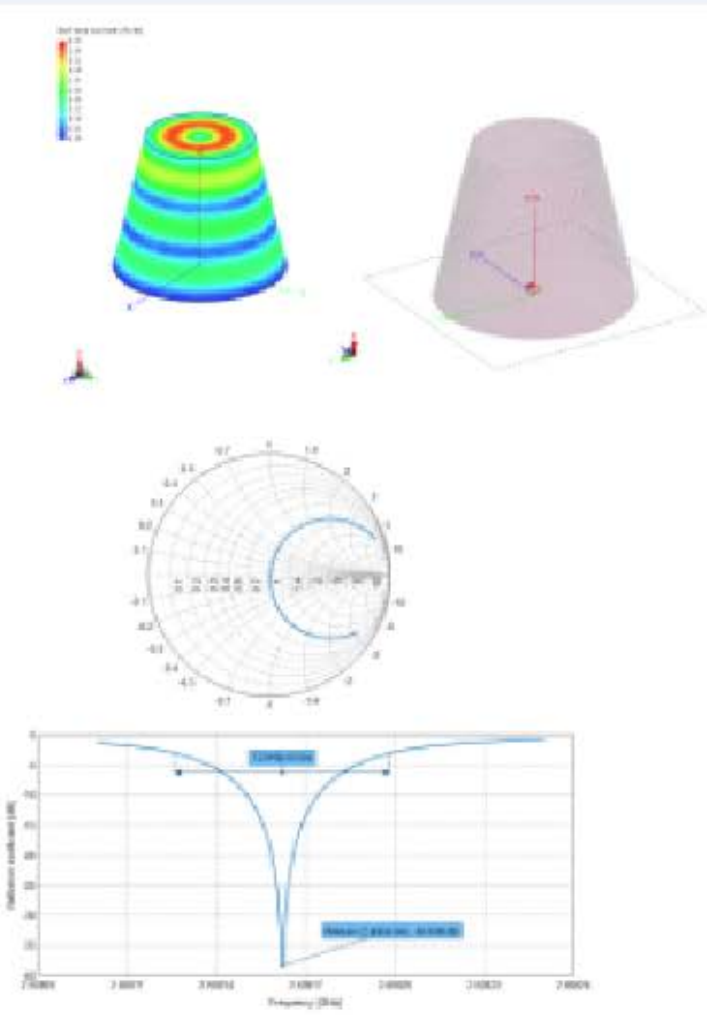

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