ANSOFT'S HFSS USERS PRESENTATIONS

19th FEBRUARY, 2004

Los Angeles, CA; Crowne Plaza Hotel, LA International Airport

TITLE

ANTENNA AND MICROWAVE COMPONENTS DESIGN
WITH ANSOFT'S HIGH FREQUENCY SIMULATOR
VERSION 9.1

PRESENTED
BY
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Space and Airborne Systems

Electronic Warfare Systems
6380 Hollister Avenue
Goleta, CA 93117-3114

EXAMPLE OF RAYTHEON EW PRODUCTS

Raytheon

Space and Airborne Systems
Electronic Warfare Systems

Integrated EW Systems

ECM pods and integrated systems for current and future airborne/shipboard platforms

ALQ-184 and ALQ-184(V)9 Pods

ALR-69 RWR Upgrade

SLQ-32 ESM/ECM

UCAV/UAV ESM/EA

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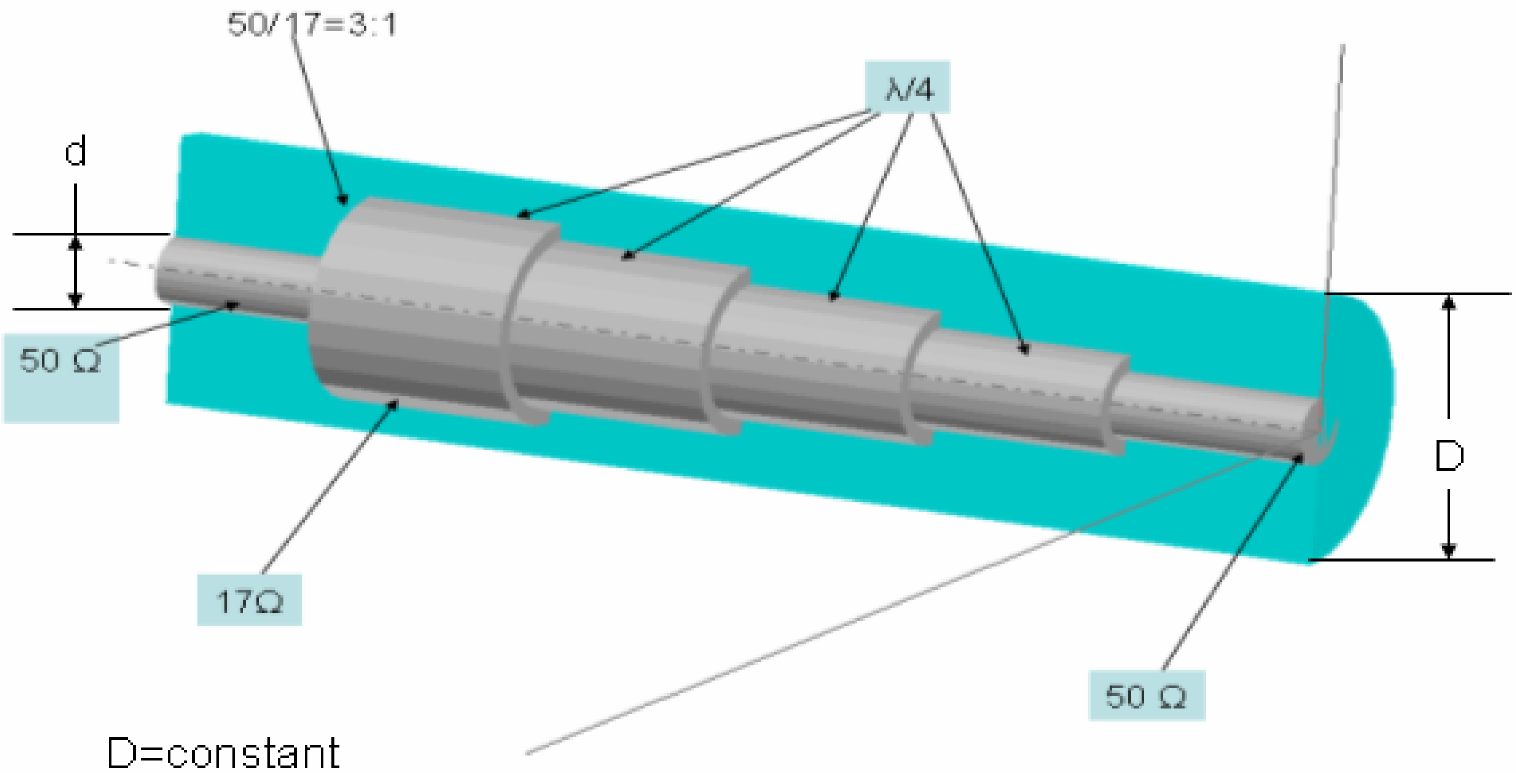
ACKNOWLEDGEMENTS:

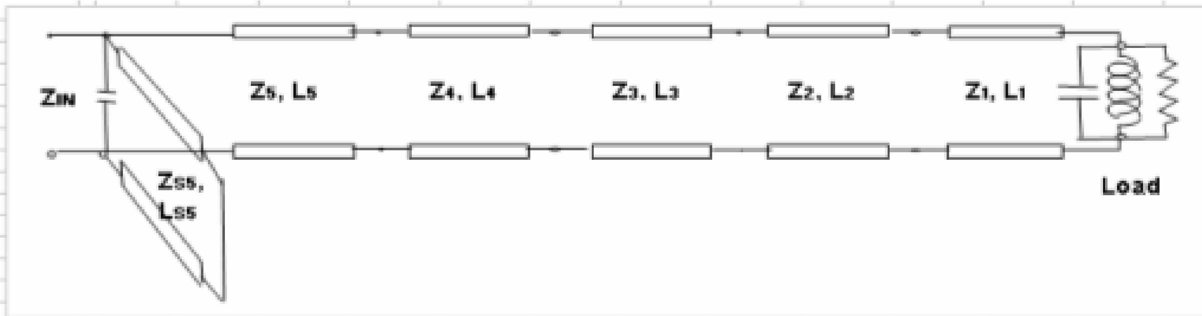
- Special thanks to Tom Debski from Raytheon Corporation, Goleta for providing material presented herein.
- Also, thanks to Dr Martin Vogel from Ansoft Corporation for providing the thermal analysis for one of the problems listed in this presentation

DESIGN OF A COAXIAL TRANSFORMER WITH HFSS WITH EXCEL HELP

REQUIREMENTS: 3:1 VSWR MATCH; D TO REMAIN CONSTANT



EXAMPLE OF IMPEDANCE TRANSFORMER DESIGN WITH EXCEL HELP



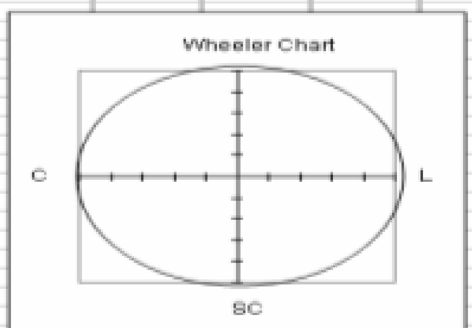
	Input	Stub		Xfmr 5	Xfmr 4	Xfmr 3	Xfmr 2	Xfmr 1		Load
Z	50	0	Z	46.4	38.4	28.85	21.7	17.93	R (ohms)	50
cap (pF)	0	0	Length	0.59	0.59	0.59	0.59	0.59	cap (pF)	0
									ind (nH)	0

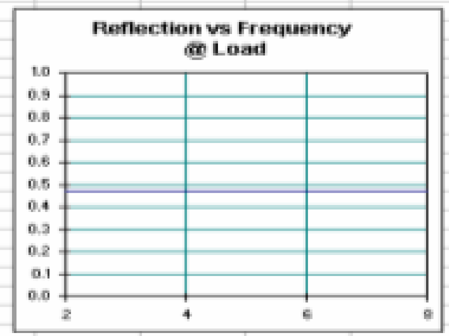
5-Stage 50 to 16.7 with 50 load

resload (ohms)	50		
loadcut (GHz)	0	0.02	G
capload (pF)	0	0.000	Bc
indload (nH)	0	0.000	Bl
admittance	2E-002	0.000	B
zee1 (ohms)	17.93	17.93	
cutoff 1 (GHz)	0		
		mag	phase
reflec @ load	0.4721036	0.472	0.0

misc constants		CDE
deg per rad	57.29578	
complex one	1	
complex neg	-1	

Enter new input data in shaded boxes,
then use [F9] to start calculation

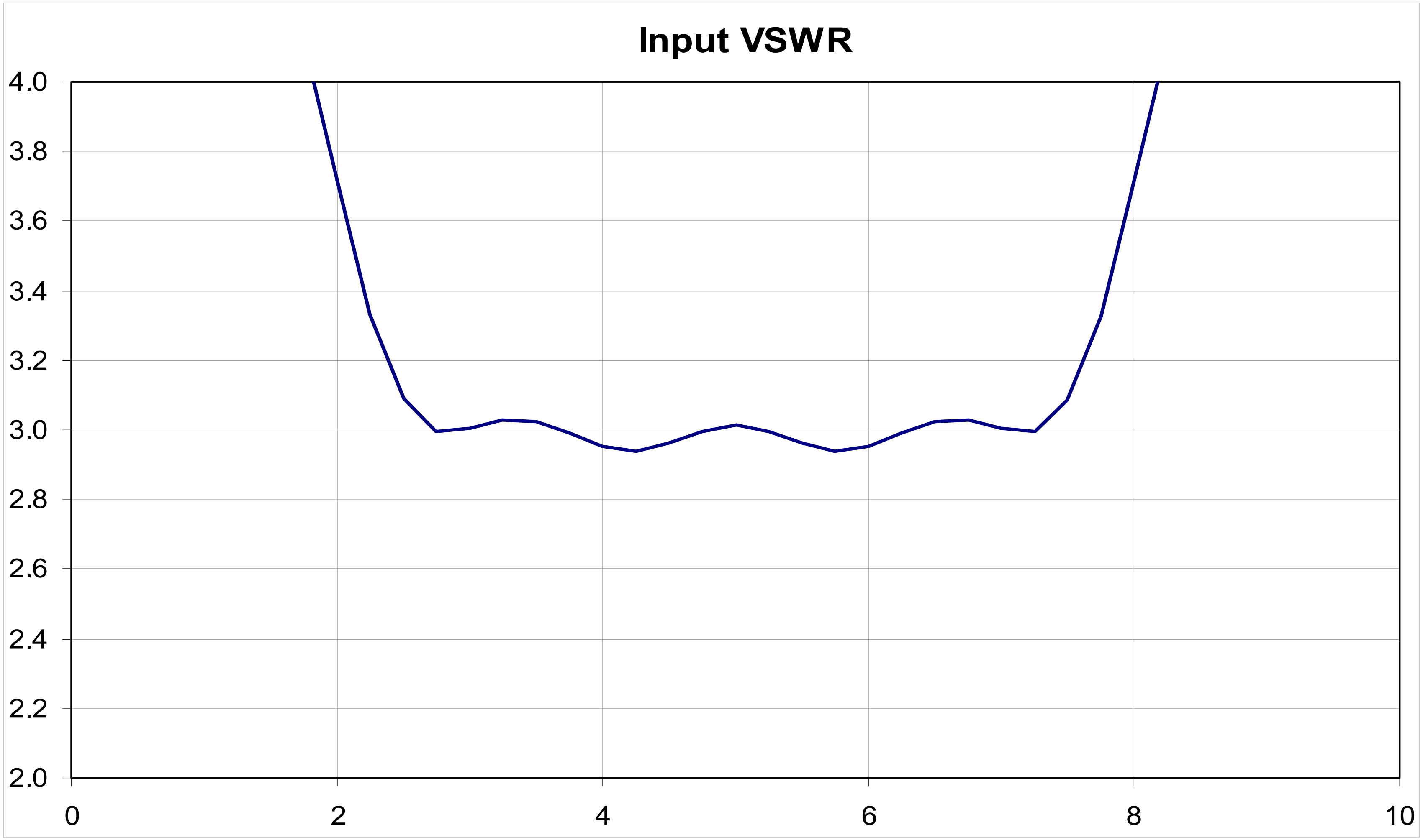




freq (GHz)	R load	x sin	x cos	R 2/1	R 3/2	R 4/3	R 5/4	R in	x sin	x cos
1	0.472	0.000	0.472	0.414	0.420	0.514	0.579	0.598	0.379	-0.462
1.5	0.472	0.000	0.472	0.434	0.504	0.602	0.634	0.629	0.617	0.121
1.75	0.472	0.000	0.472	0.446	0.535	0.618	0.626	0.609	0.426	0.436
2	0.472	0.000	0.472	0.458	0.558	0.619	0.600	0.575	0.058	0.573
2.25	0.472	0.000	0.472	0.470	0.573	0.606	0.560	0.538	-0.326	0.428
2.5	0.472	0.000	0.472	0.481	0.581	0.580	0.515	0.511	-0.508	0.054
2.75	0.472	0.000	0.472	0.492	0.582	0.544	0.481	0.500	-0.372	-0.333

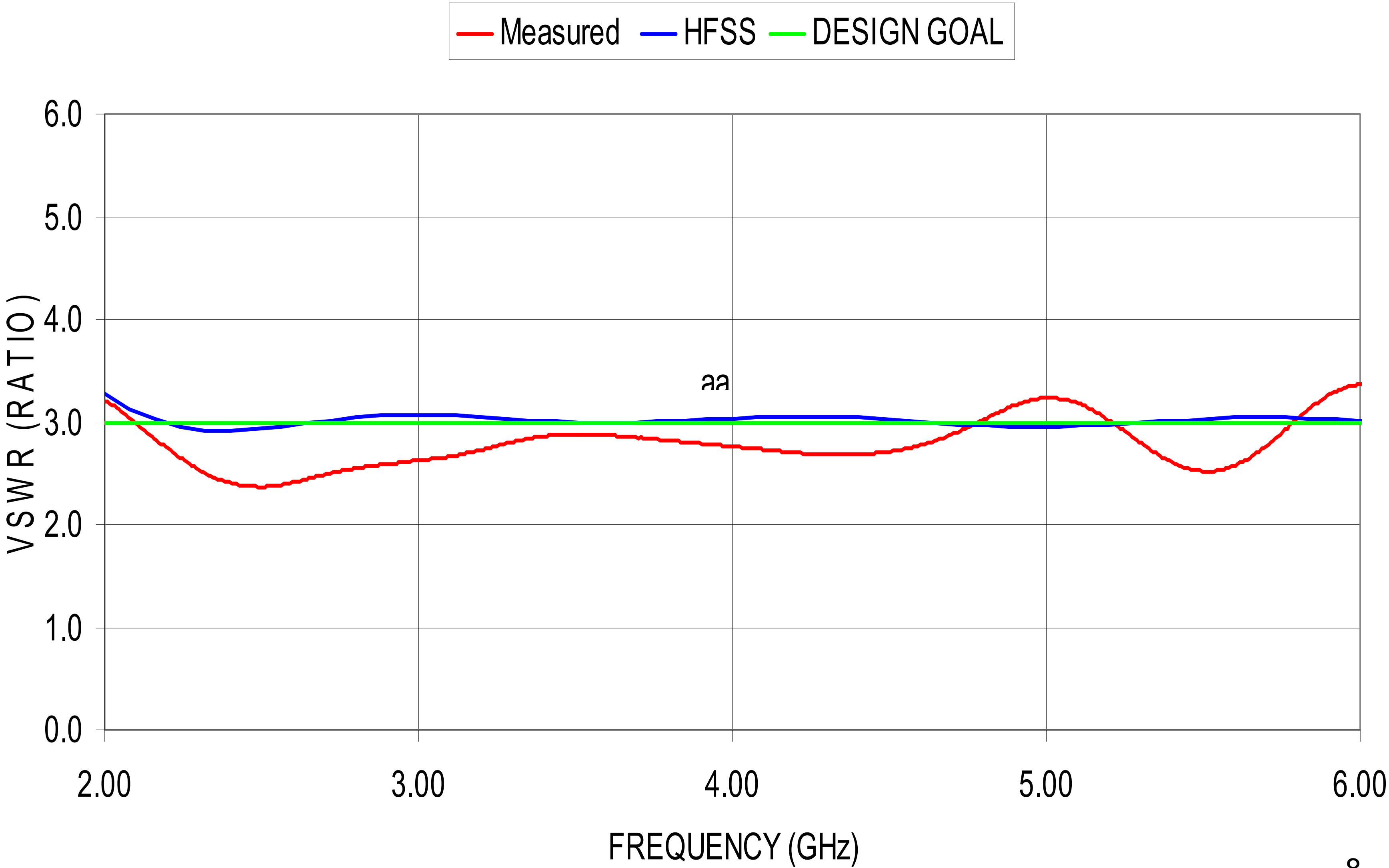
$$Z_0(ohms) = \left(138/\sqrt{\varepsilon_r}\right) \times \left(\log_{10} D/d\right)$$

THEORETICAL RESULTS PREDICTION WITH FORMULAS DEVELOPED WITH EXCEL

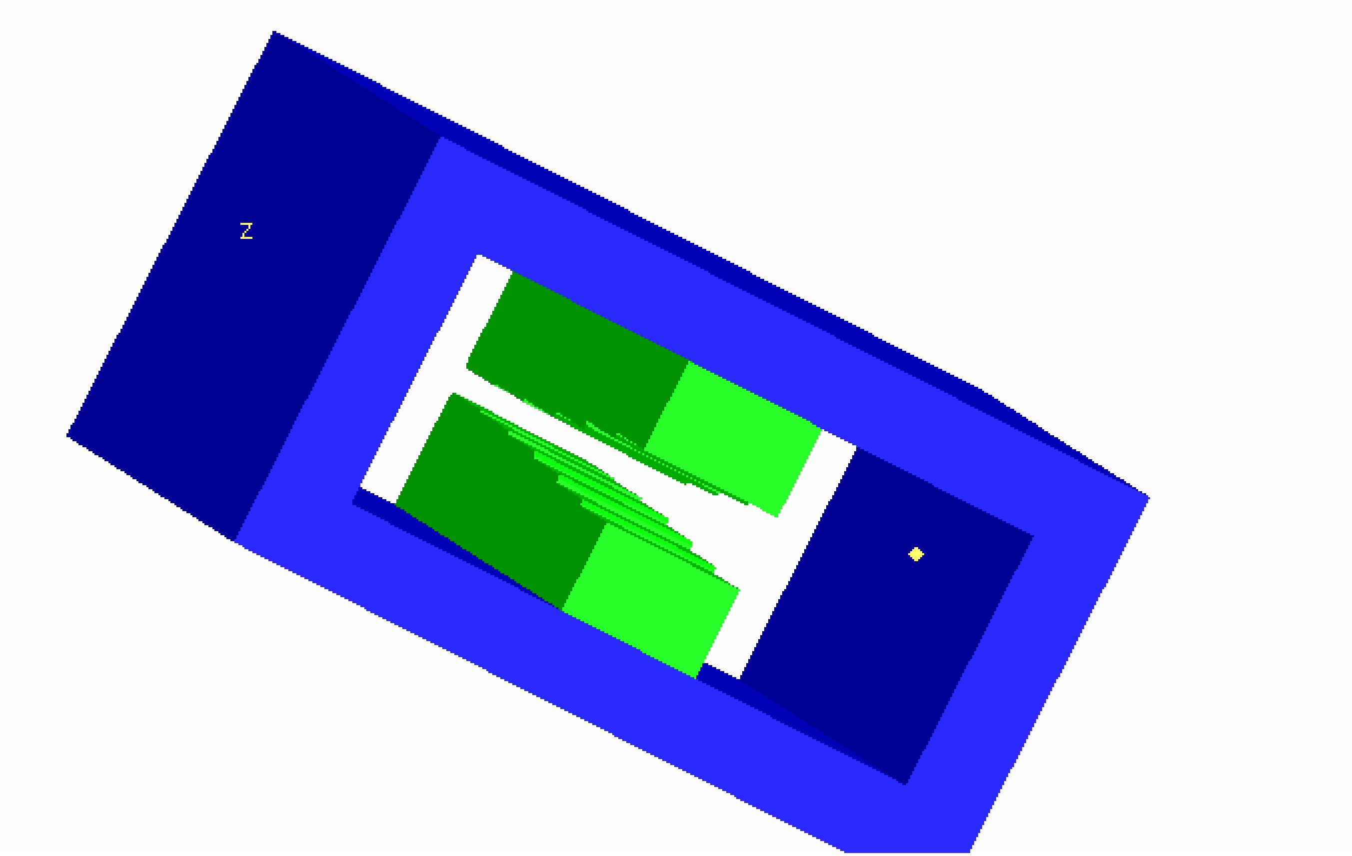


FREQUENCY (GHz)

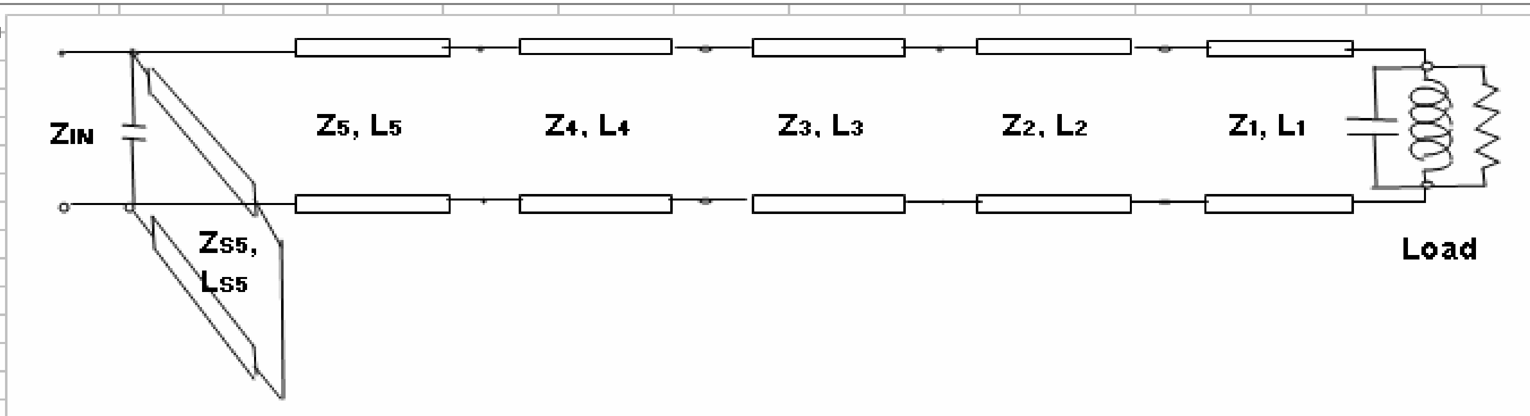
MEASURED DATA Vs. THEORETICAL DATA (HFSS) OF A COAXIAL 3:1 MATCH LOAD



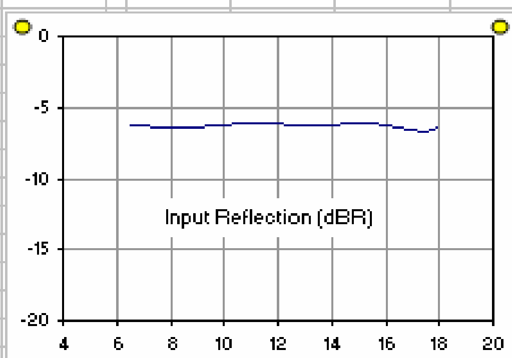
DESIGN OF WRD 650 IMPEDANCE TRANSFORMER WITH HFSS AND EXCEL HELP (REQUIREMENTS 3:1 VSWR MATCH)

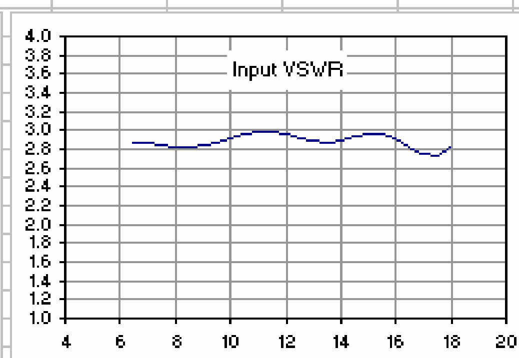


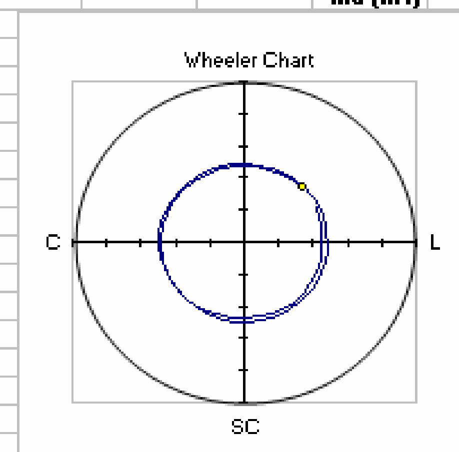
DESIGN WITH EXCEL WRD 650



	Input	Stub		Xfmr 5	Xfmr 4	Xfmr 3	Xfmr 2	Xfmr 1		Load
Z	220	0	Z	203.5	170	127	94.77	79.37	R (ohms)	220
ap (pF)	0	0	Length	0.253	0.248	0.238	0.233	0.231	cap (pF)	0
									ind (nH)	0



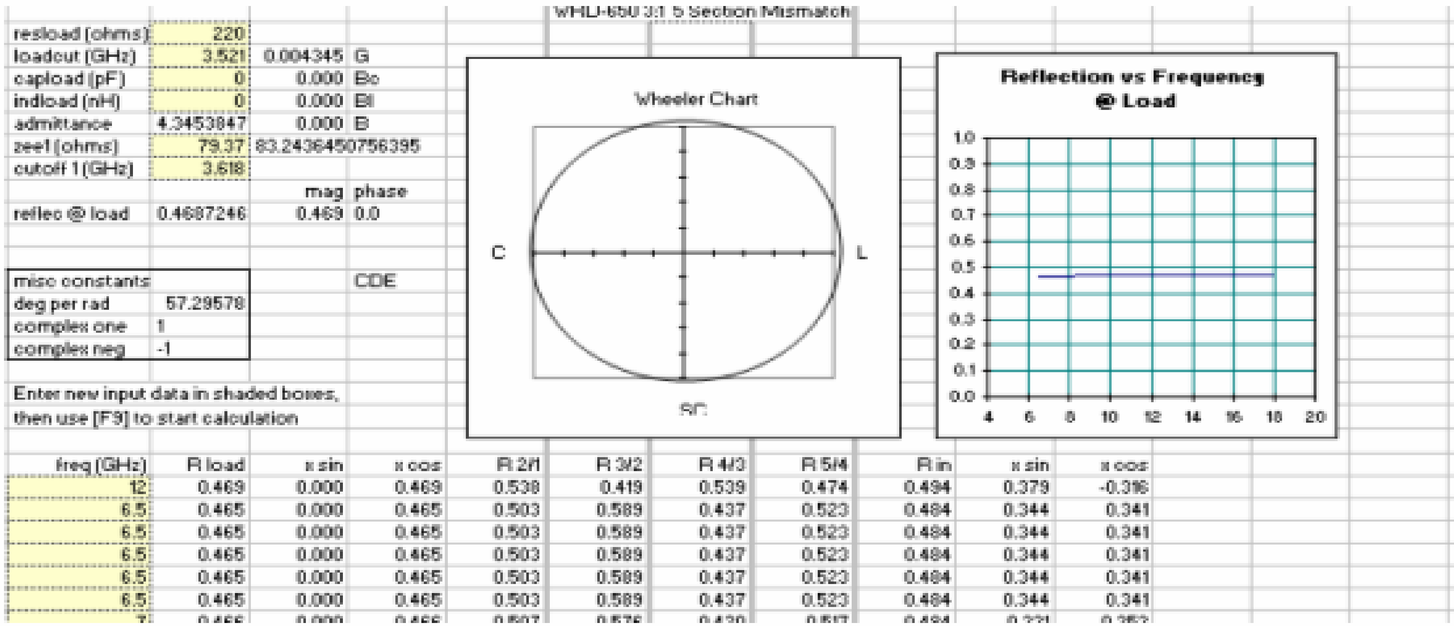




WRD-650 3:1 5 Section Mismatch comment: 3:1 transfmr

lengths are in air

ITERATIONS OF WR 650 DESIGN WITH EXCEL



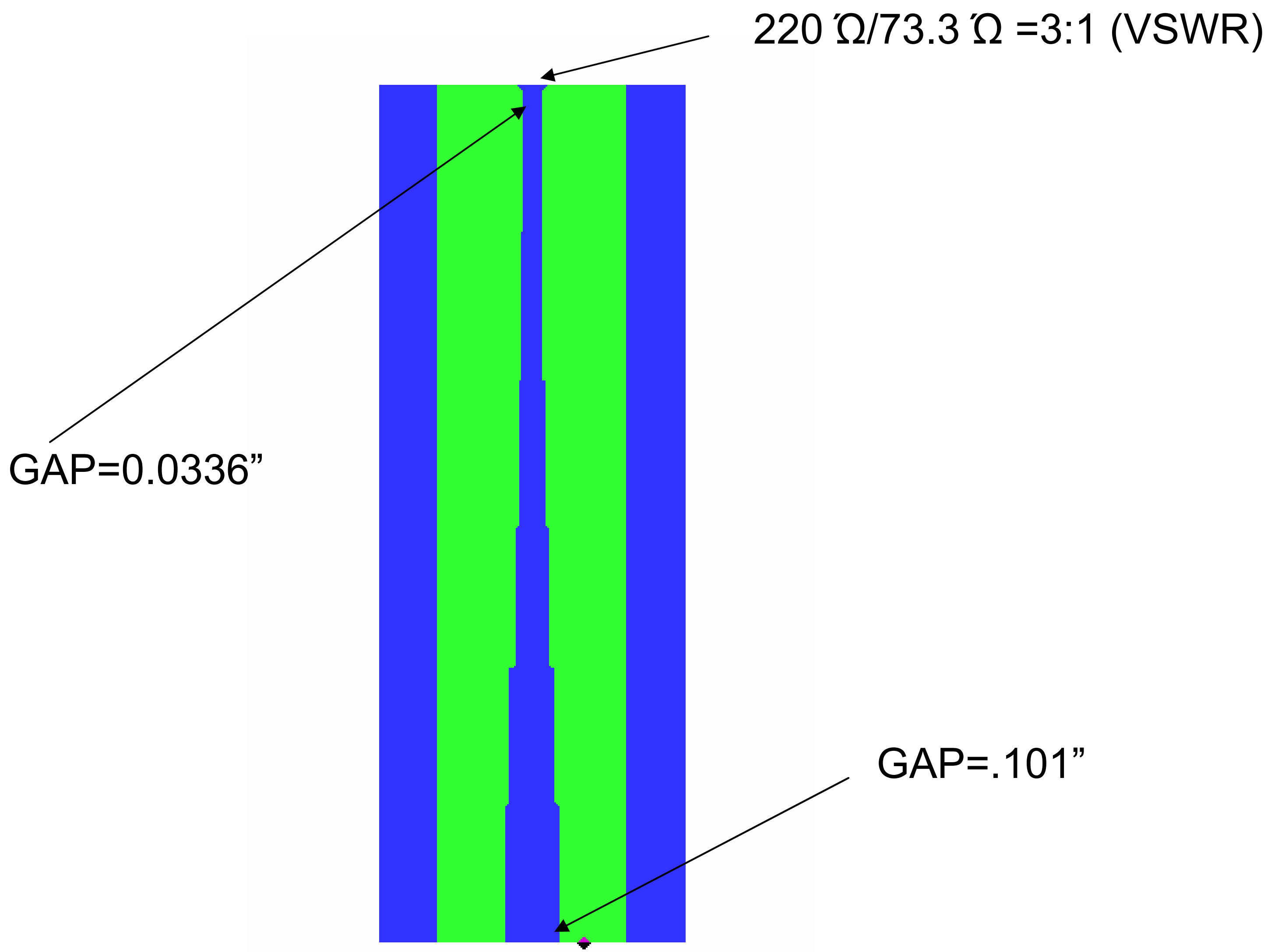
resload (ohms)	220		
loadcut (GHz)	3.521	0.004345	G
capload (pF)	0	0.000	Bc
indload (nH)	0	0.000	Bl
admittance	4.3453847	0.000	B
zee1 (ohms)	79.37	83.2436450756395	
cutoff 1 (GHz)	3.618		
		mag	phase
reflec @ load	0.4687246	0.469	0.0

misc constants		CDE
deg per rad	57.29578	
complex one	1	
complex neg	-1	

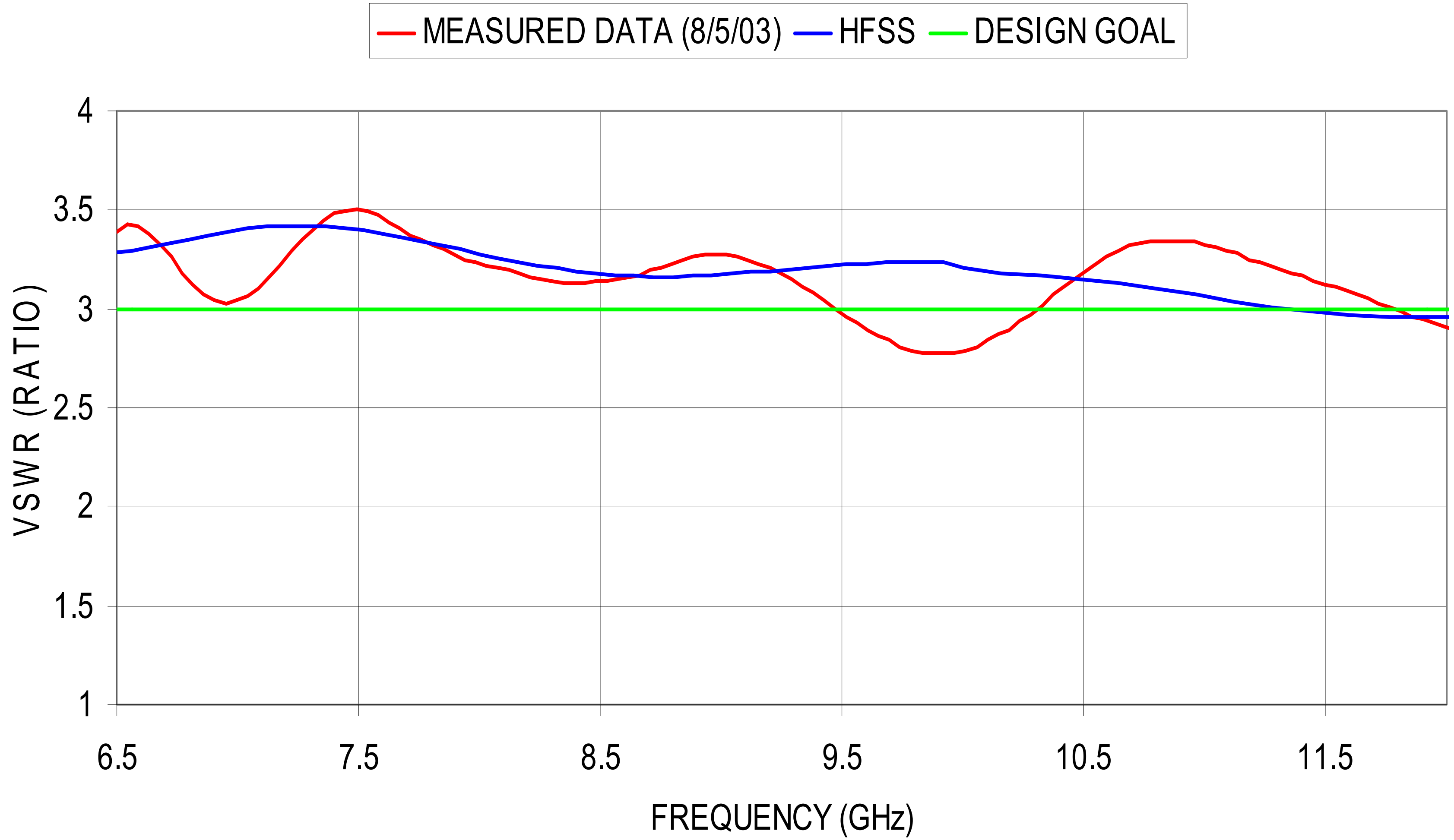
Enter new input data in shaded boxes,
then use [F9] to start calculation

freq (GHz)	R load	x sin	x cos	R 2/1	R 3/2	R 4/3	R 5/4	R in	x sin	x cos
12	0.469	0.000	0.469	0.538	0.419	0.539	0.474	0.494	0.379	-0.316
6.5	0.465	0.000	0.465	0.503	0.589	0.437	0.523	0.484	0.344	0.341
6.5	0.465	0.000	0.465	0.503	0.589	0.437	0.523	0.484	0.344	0.341
6.5	0.465	0.000	0.465	0.503	0.589	0.437	0.523	0.484	0.344	0.341
6.5	0.465	0.000	0.465	0.503	0.589	0.437	0.523	0.484	0.344	0.341
6.5	0.465	0.000	0.465	0.503	0.589	0.437	0.523	0.484	0.344	0.341
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

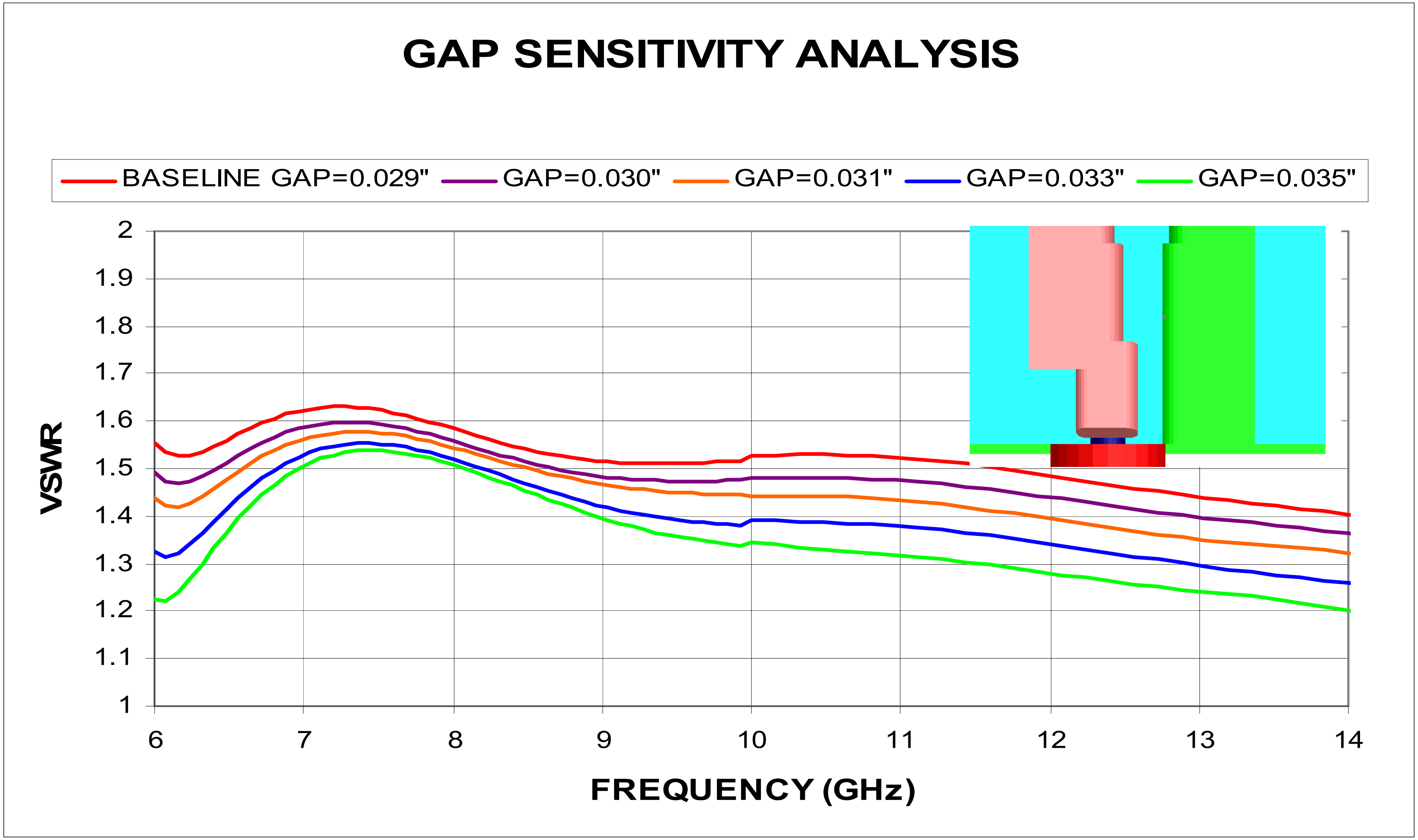
Z	Gap	Fc	L/4
73.33	0.0336	3.505	N/A
79.375	0.0364	3.618	0.256
94.776119	0.0434	3.887	0.259
127	0.0583	4.404	0.265
170.18	0.078	4.972	0.275
203.2	0.0932	5.32	0.282
220	0.101	5.468	N/A
0.2331	used L/4 x 0.9		


220 Ώ/73.3 Ώ =3:1 (VSWR)
GAP=0.0336”
GAP=.101”

MEASURED DATA Vs. THEORETICAL DATA (HFSS) OF A 3:1 MATCH WR 650

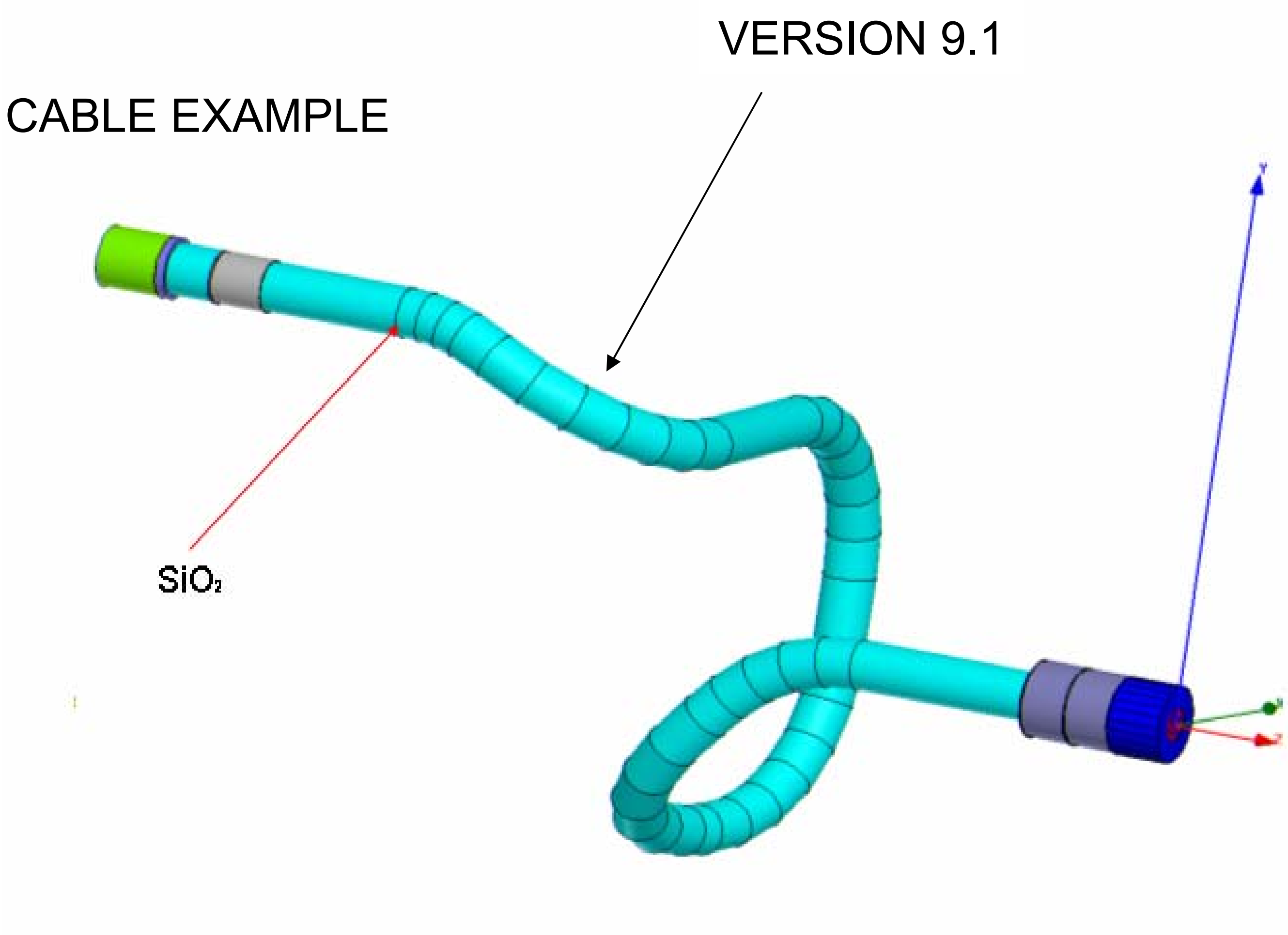


EXAMPLE OF A DUAL RIDGE WAVEGUIDE GAP ANALYSIS

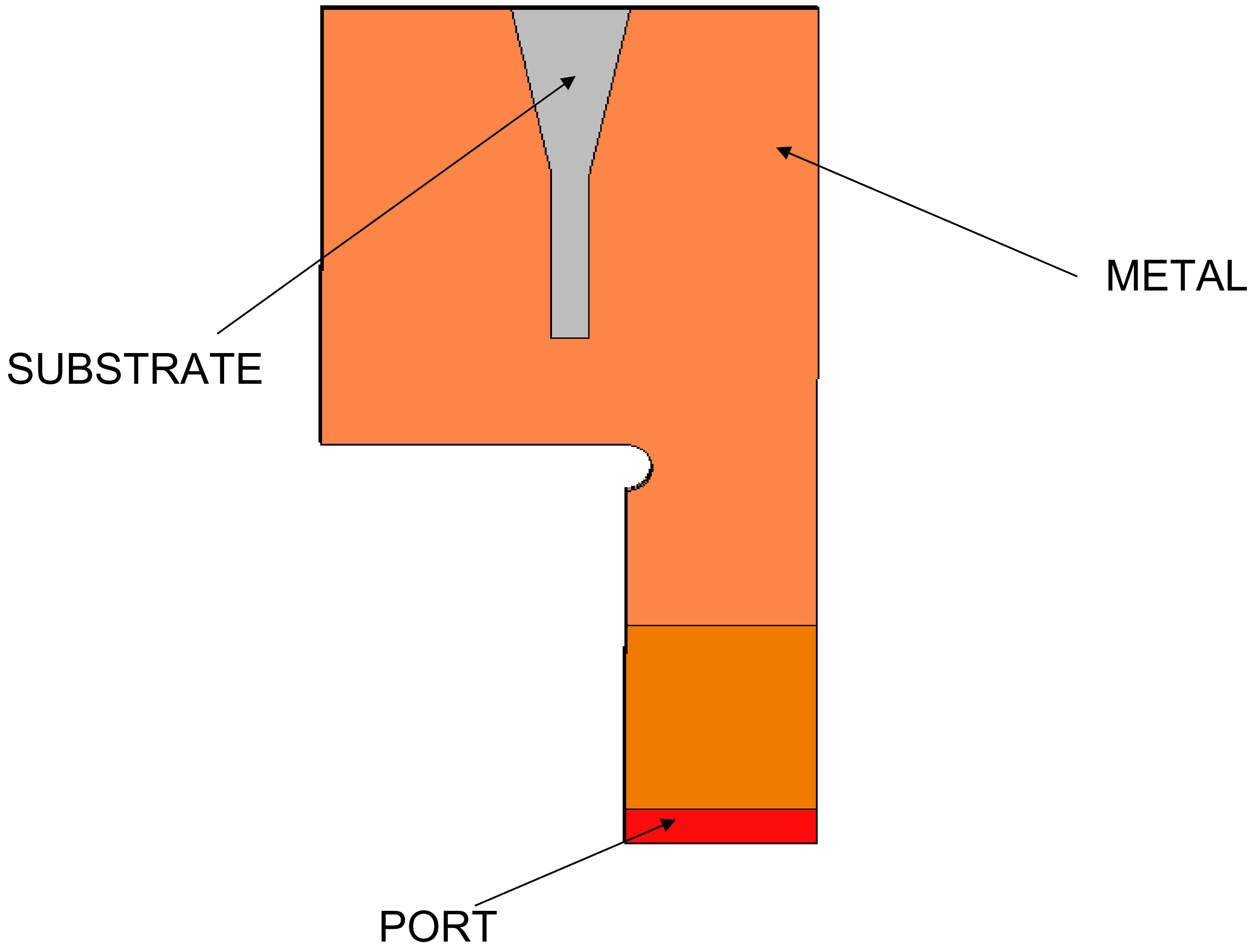


SWEEPING WITH HFSS VERSION 9.1 Vs 8.

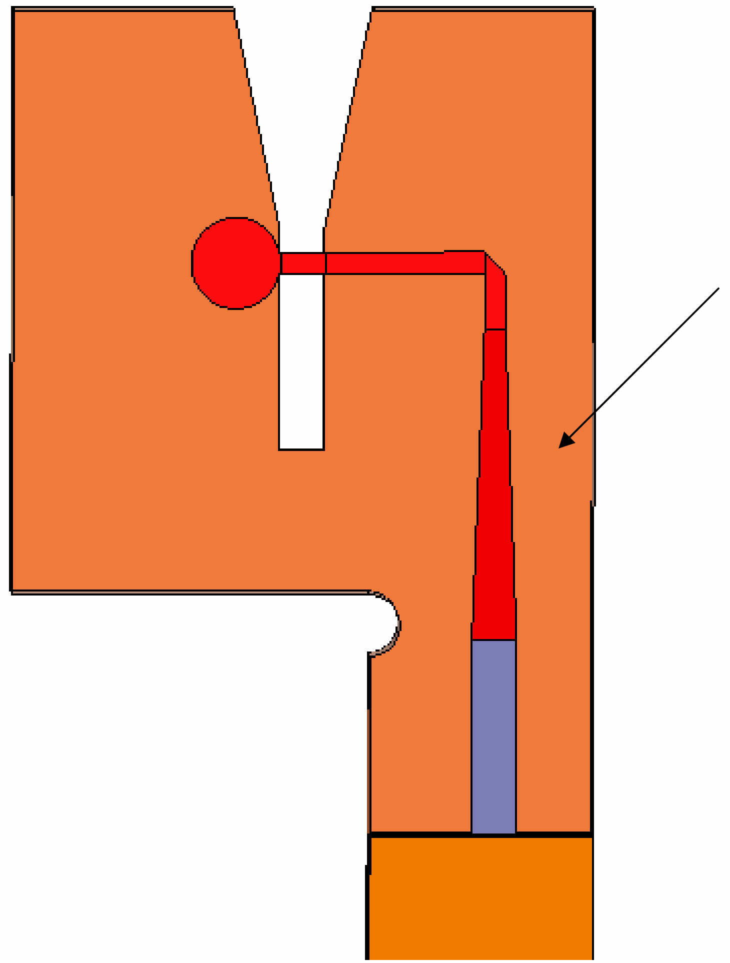
IN VERSION 8 THE GEOMETRY SHOWN COULD ONLY SWEEP
4 SEGMENTS OVER A COMPLICATED PATH.



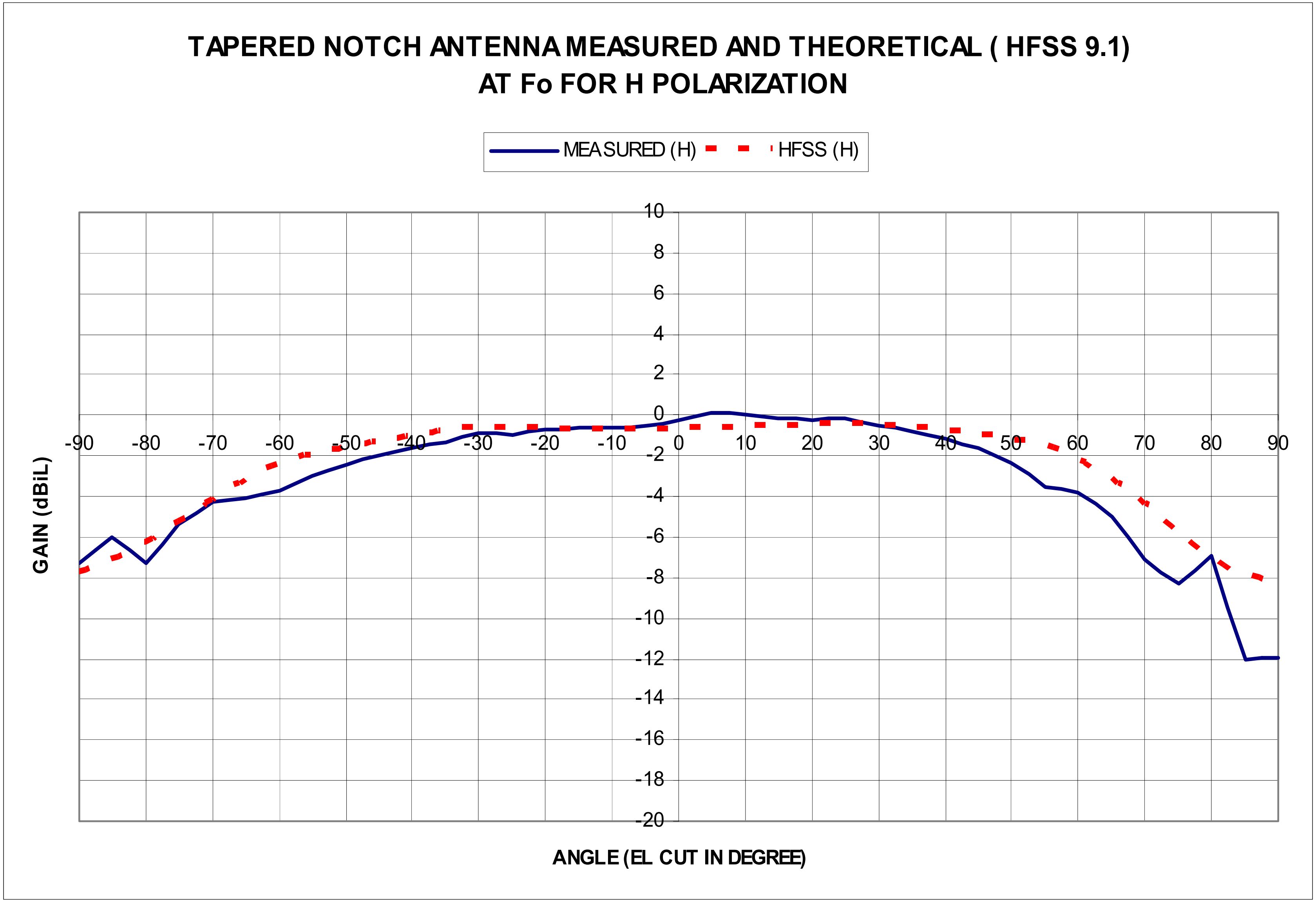
A TYPICAL TAPERED NOTCH ANTENNA MODEL WITH HFSS VER. 9.1

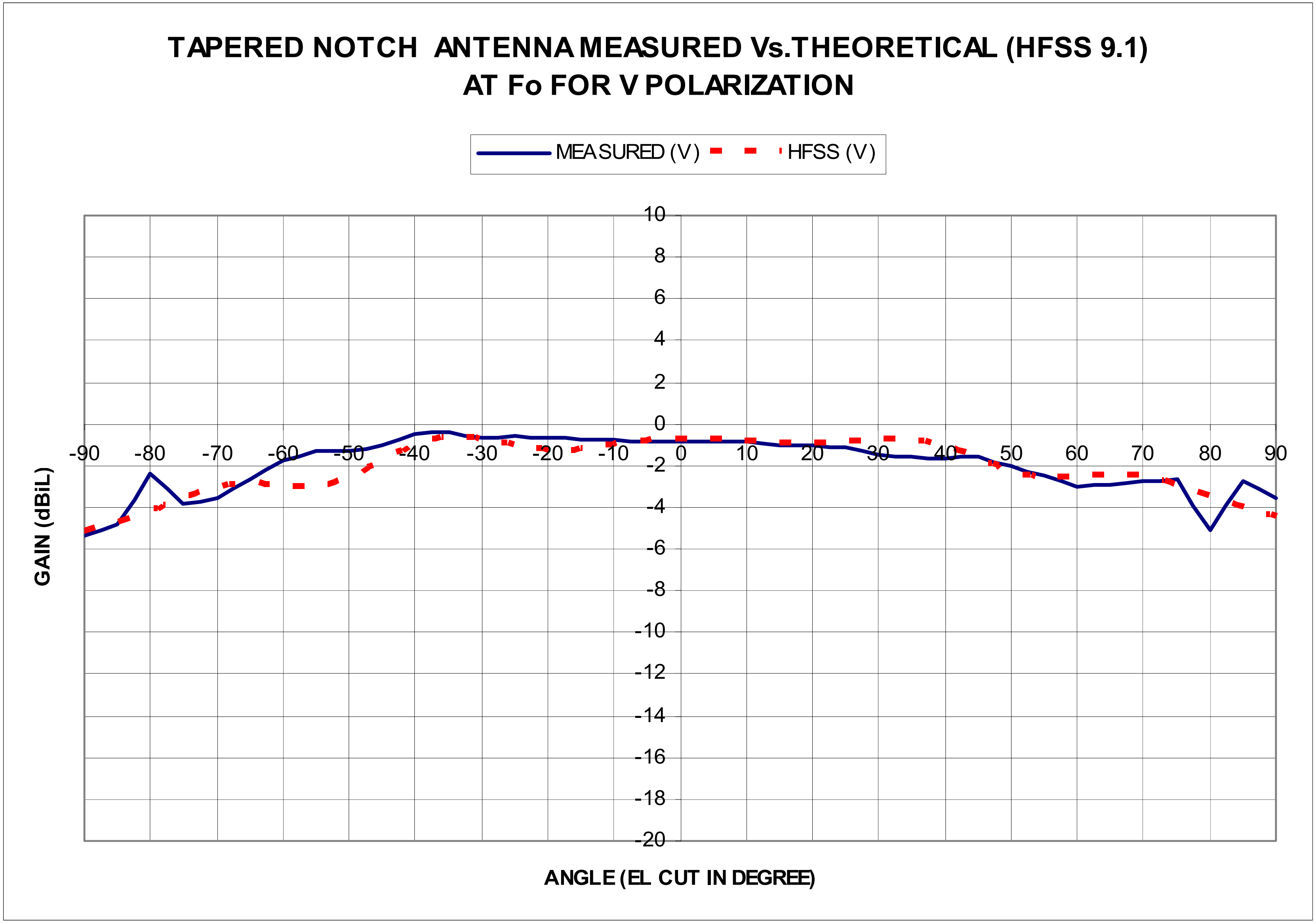


A TYPICAL TAPERED NOTCH ANTENNA MODEL WITH HFSS VER. 9.1

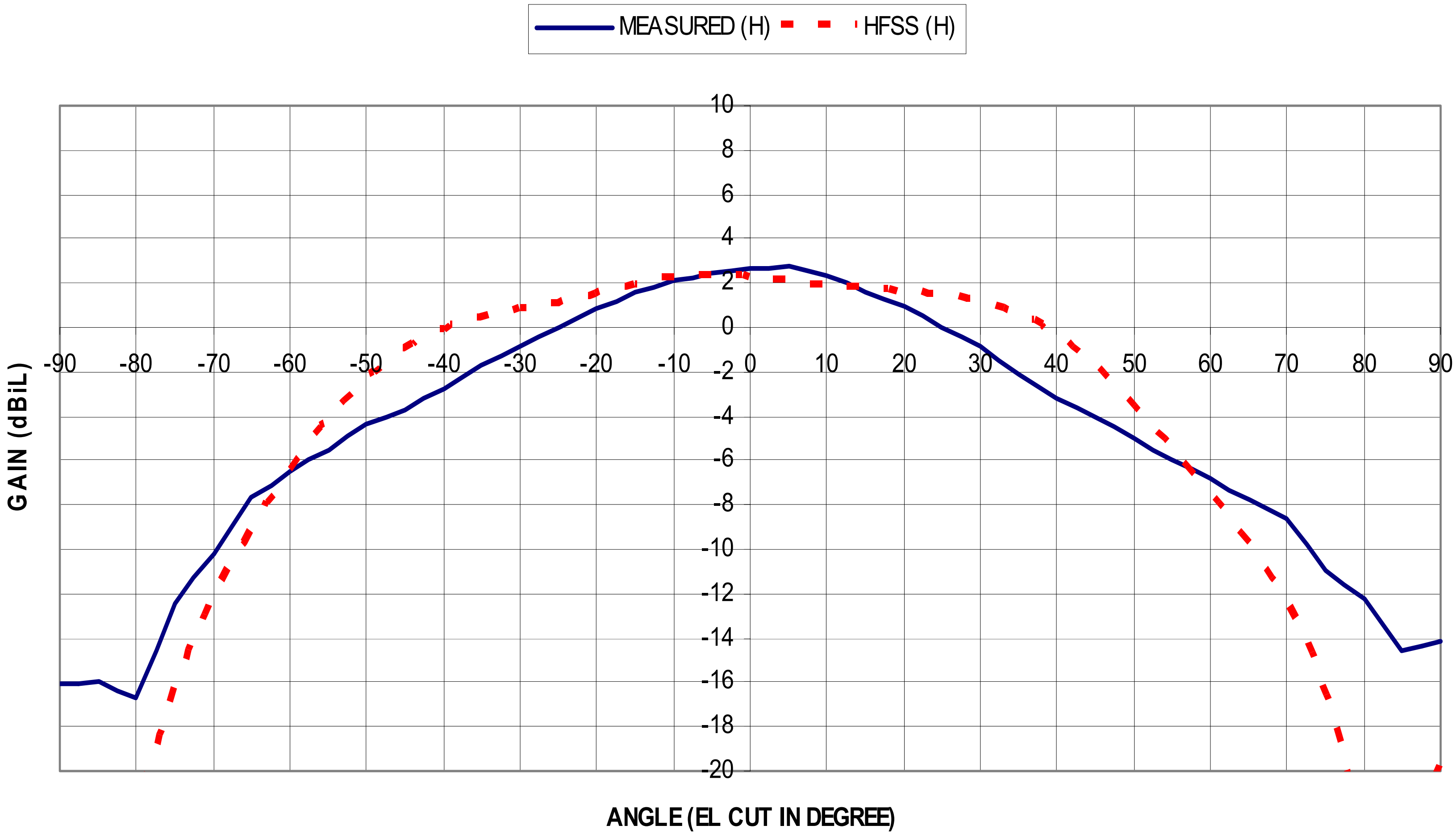


A STRIP LINE FEEDS THE ANTENNA TAPERED SECTION

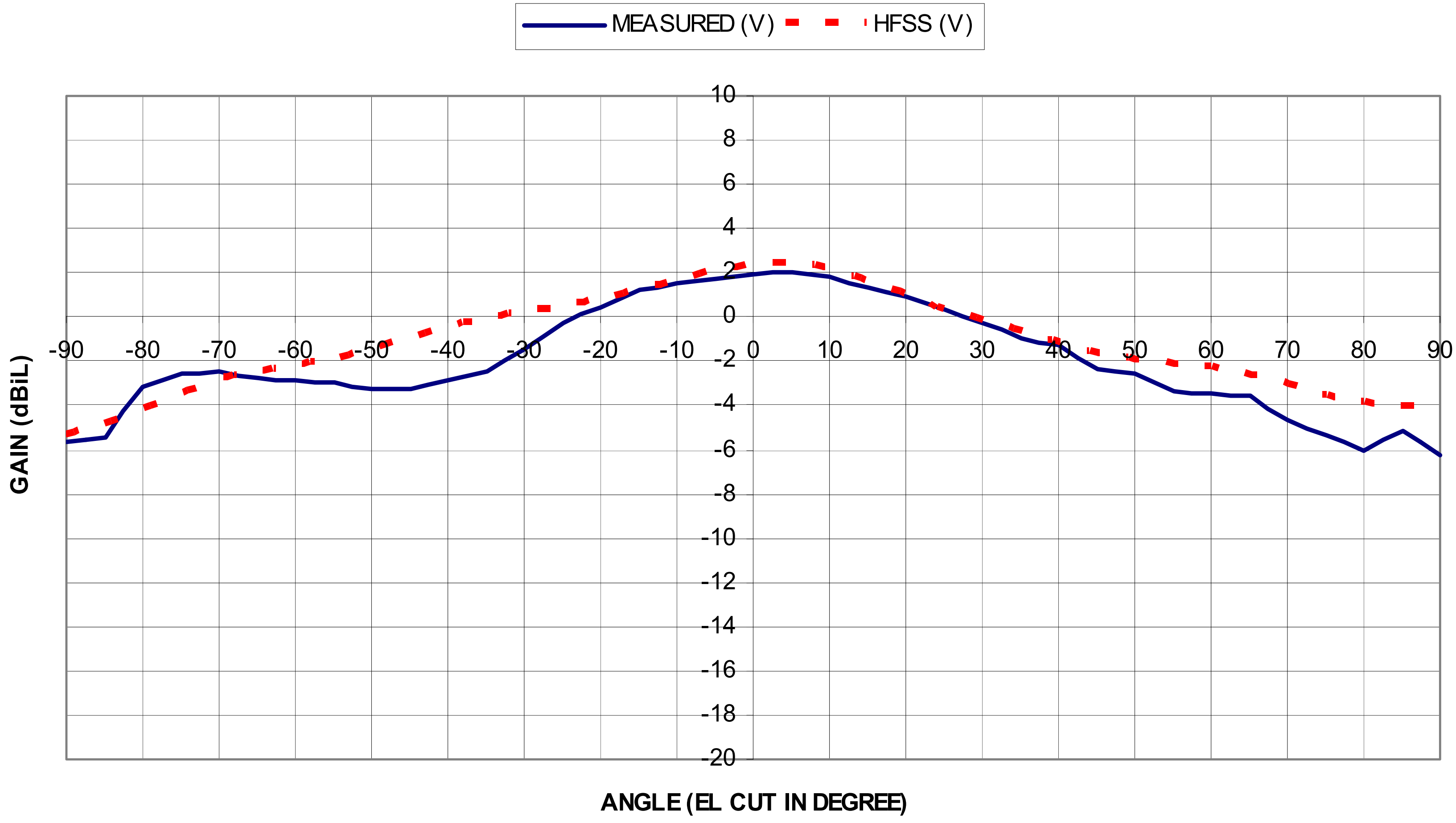

TAPERED NOTCH ANTENNA MEASURED AND THEORETICAL (HFSS 9.1)
AT Fo FOR H POLARIZATION
MEASURED (H)
HFSS (H)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
GAIN (dBiL)
ANGLE (EL CUT IN DEGREE)


TAPERED NOTCH ANTENNA MEASURED Vs.THEORETICAL (HFSS 9.1)
AT Fo FOR V POLARIZATION
MEASURED (V)
HFSS (V)
GAIN (dBiL)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
ANGLE (EL CUT IN DEGREE)

TAPERED NOTCH ANTENNA MEASURED Vs THEORETICAL (HFSS 9.1) AT 1.33 Fo FOR H POLARIZATION

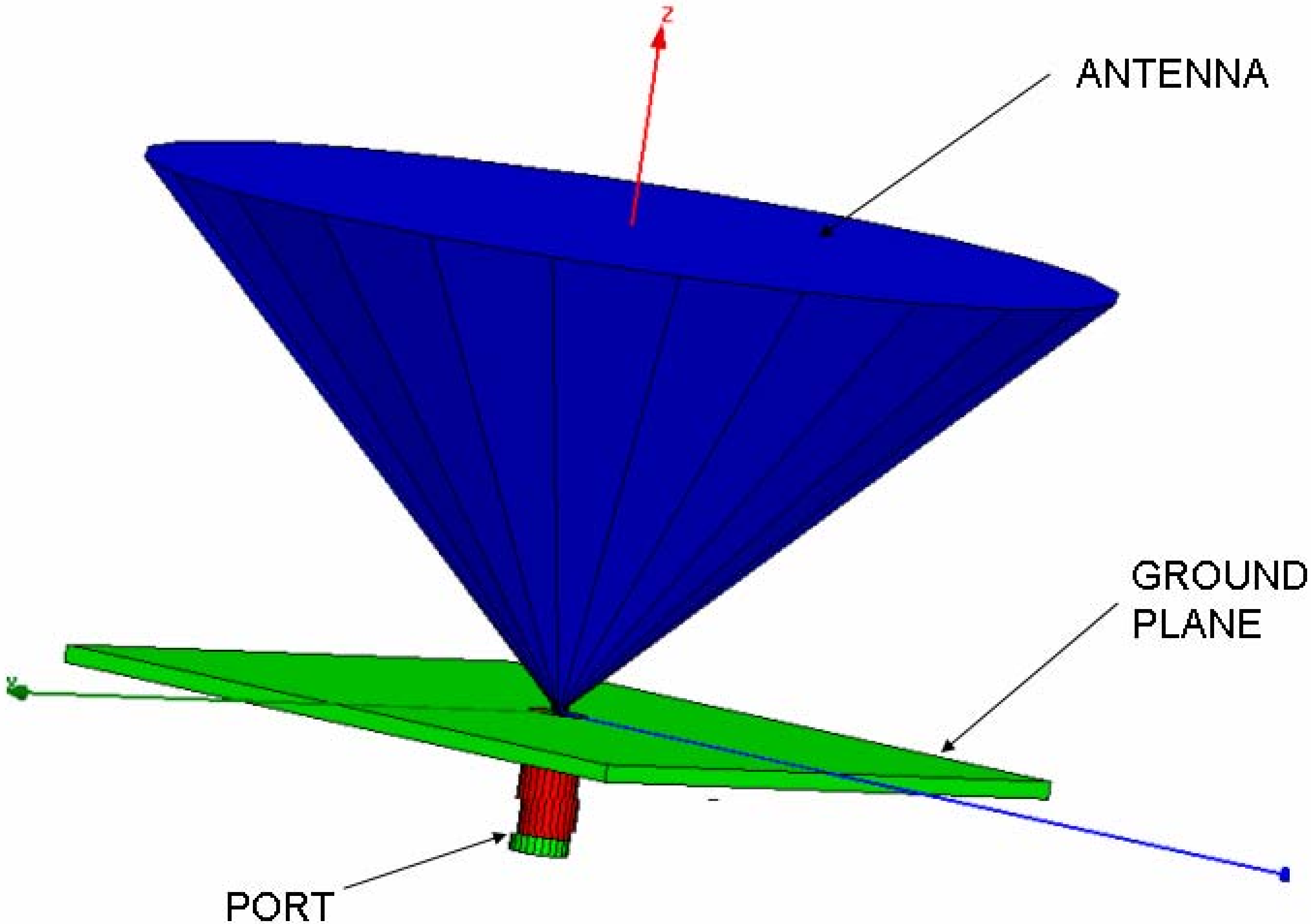


TAPERED NOTCH MEASURED Vs THEORETICAL (HFSS 9.1) AT 1.33 Fo FOR V POLARIZATION

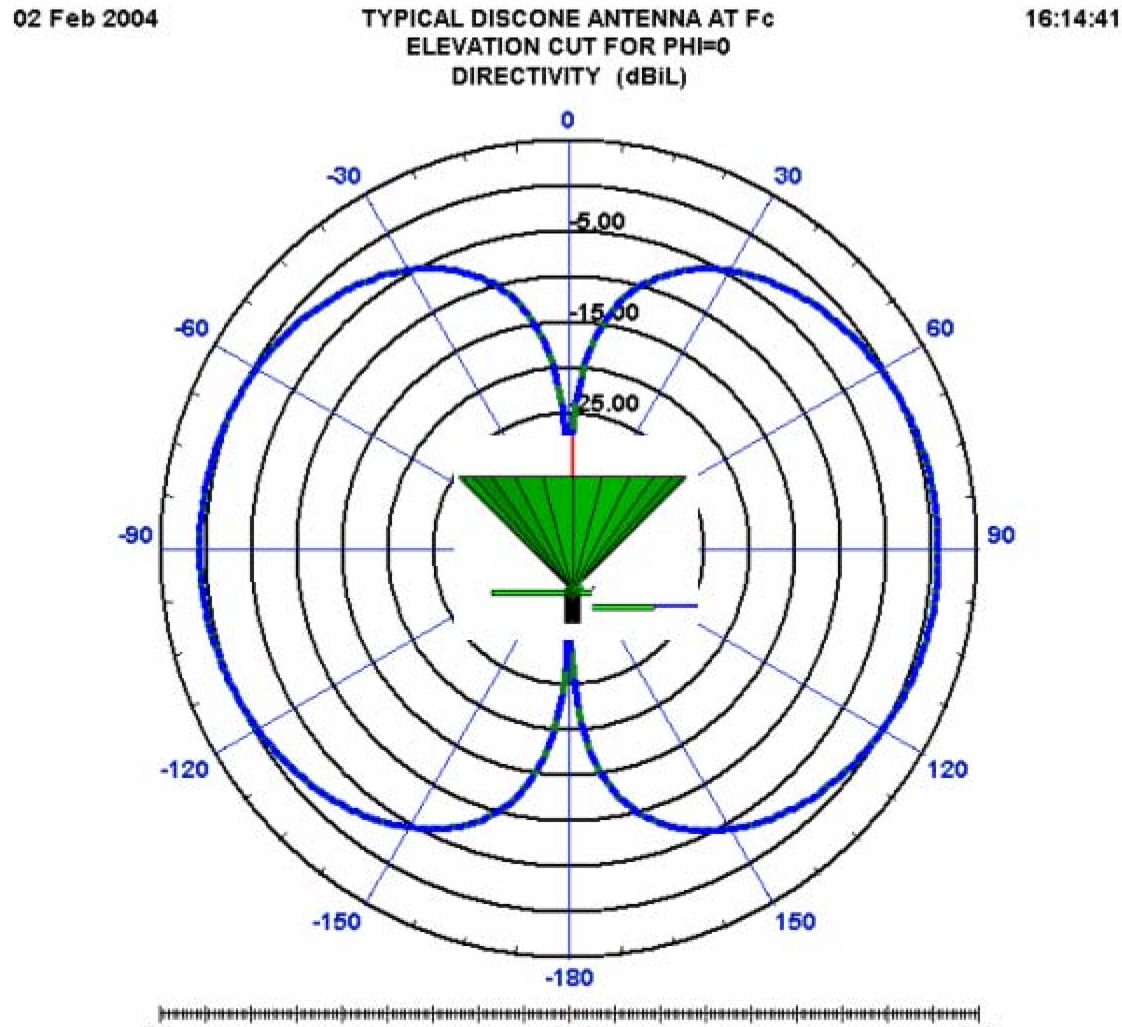


HFSS 9.1

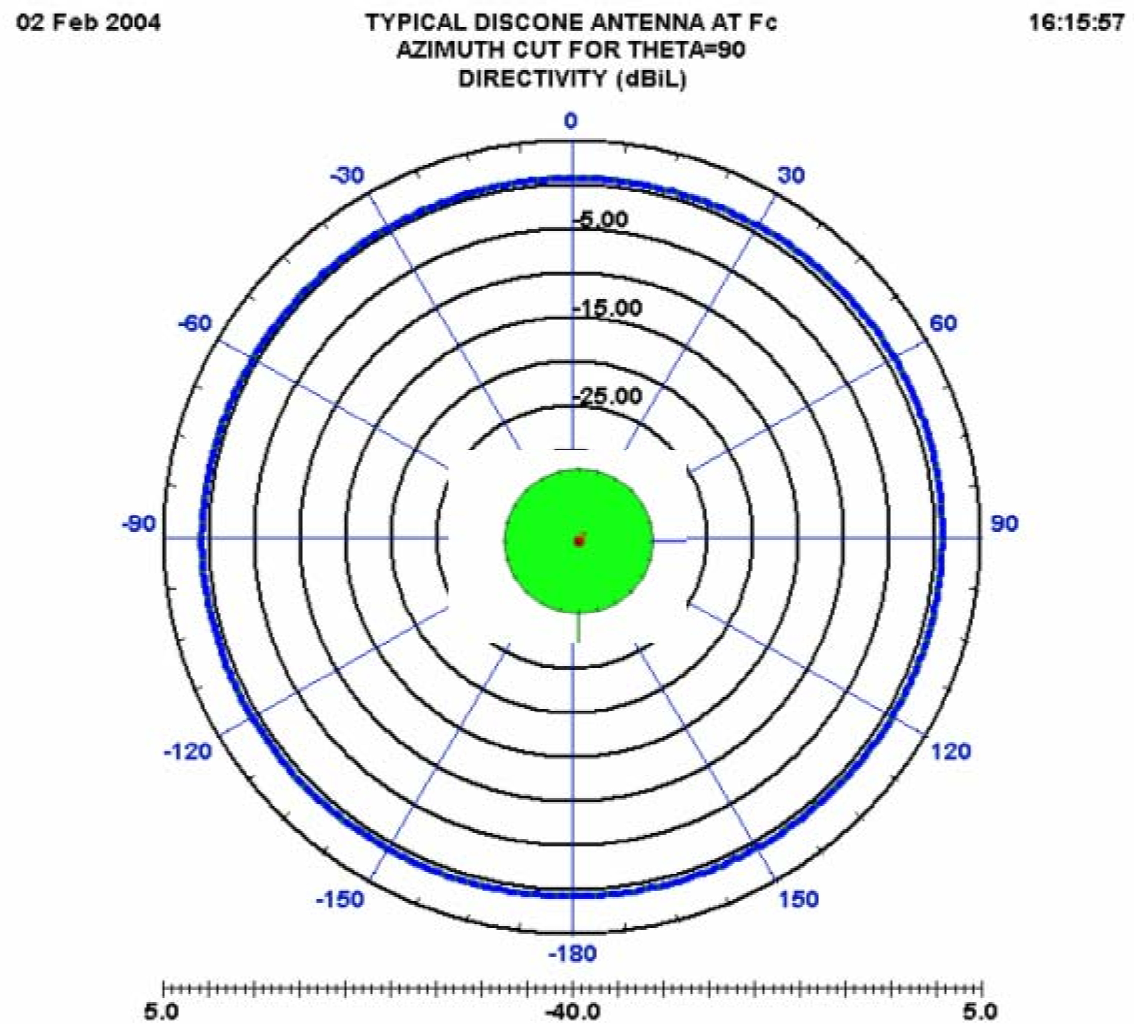
TYPICAL DISCONE ANTENNA



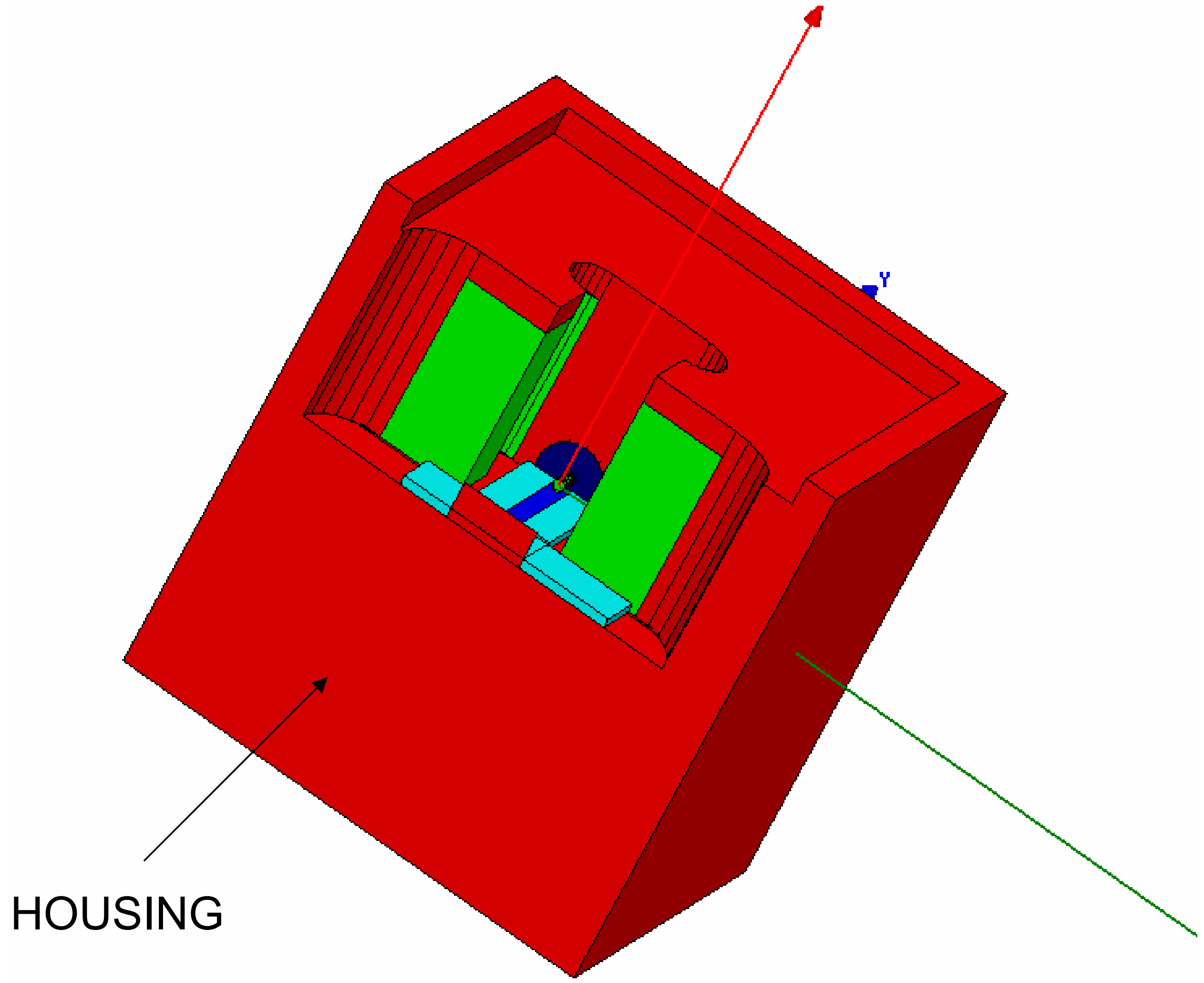
HFSS 9.1


02 Feb 2004
TYPICAL DISCONE ANTENNA AT Fc
ELEVATION CUT FOR PHI=0
DIRECTIVITY (dBiL)
16:14:41
0
30
60
90
120
150
-180
-150
-120
-90
-60
-30
-5.00
-15.00
-25.00

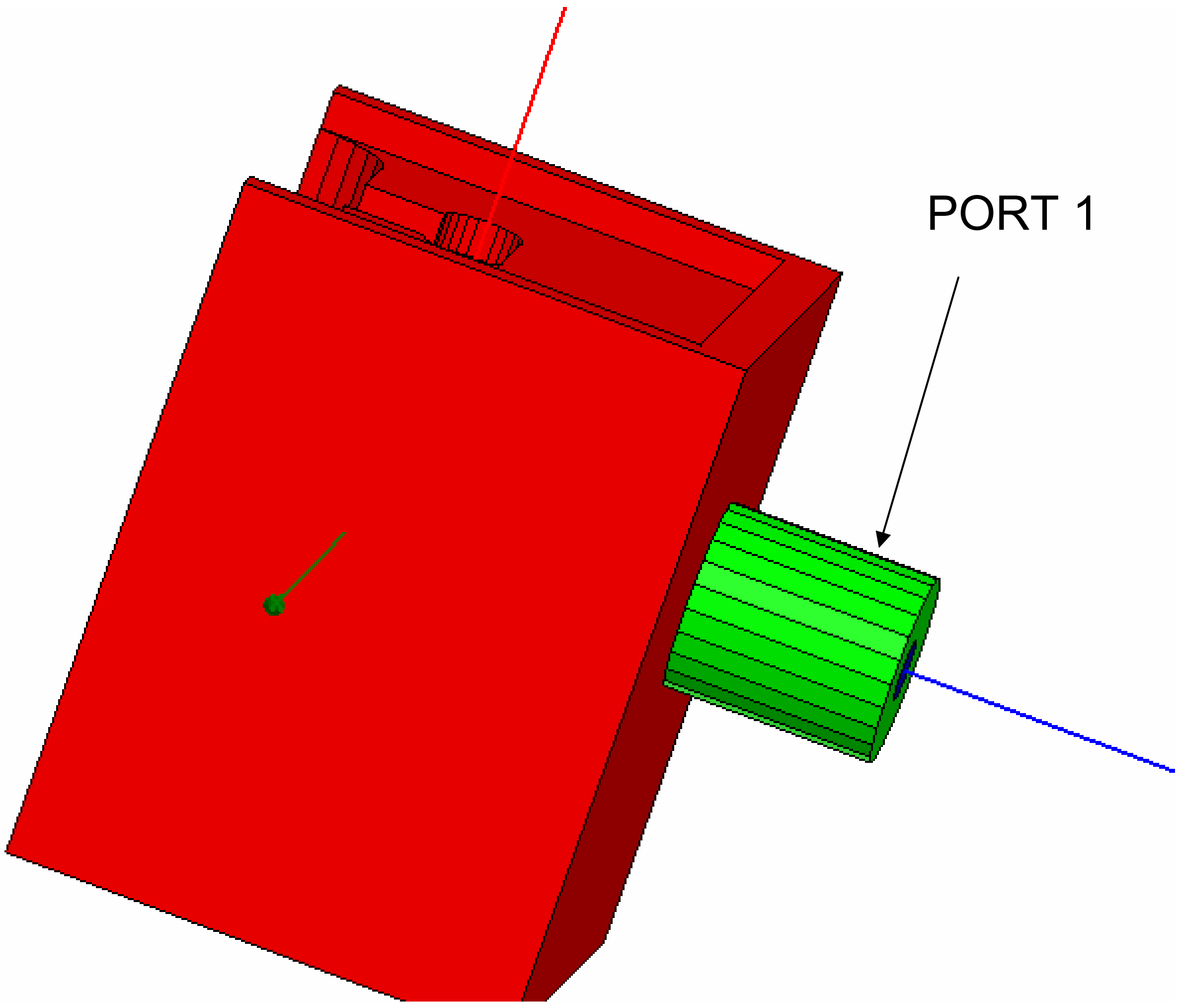
HFSS 9.1


02 Feb 2004
TYPICAL DISCONE ANTENNA AT Fc
AZIMUTH CUT FOR THETA=90
DIRECTIVITY (dBiL)
16:15:57
0
30
60
90
120
150
-180
-150
-120
-90
-60
-30
-5.00
-15.00
-25.00
5.0
-40.0
5.0

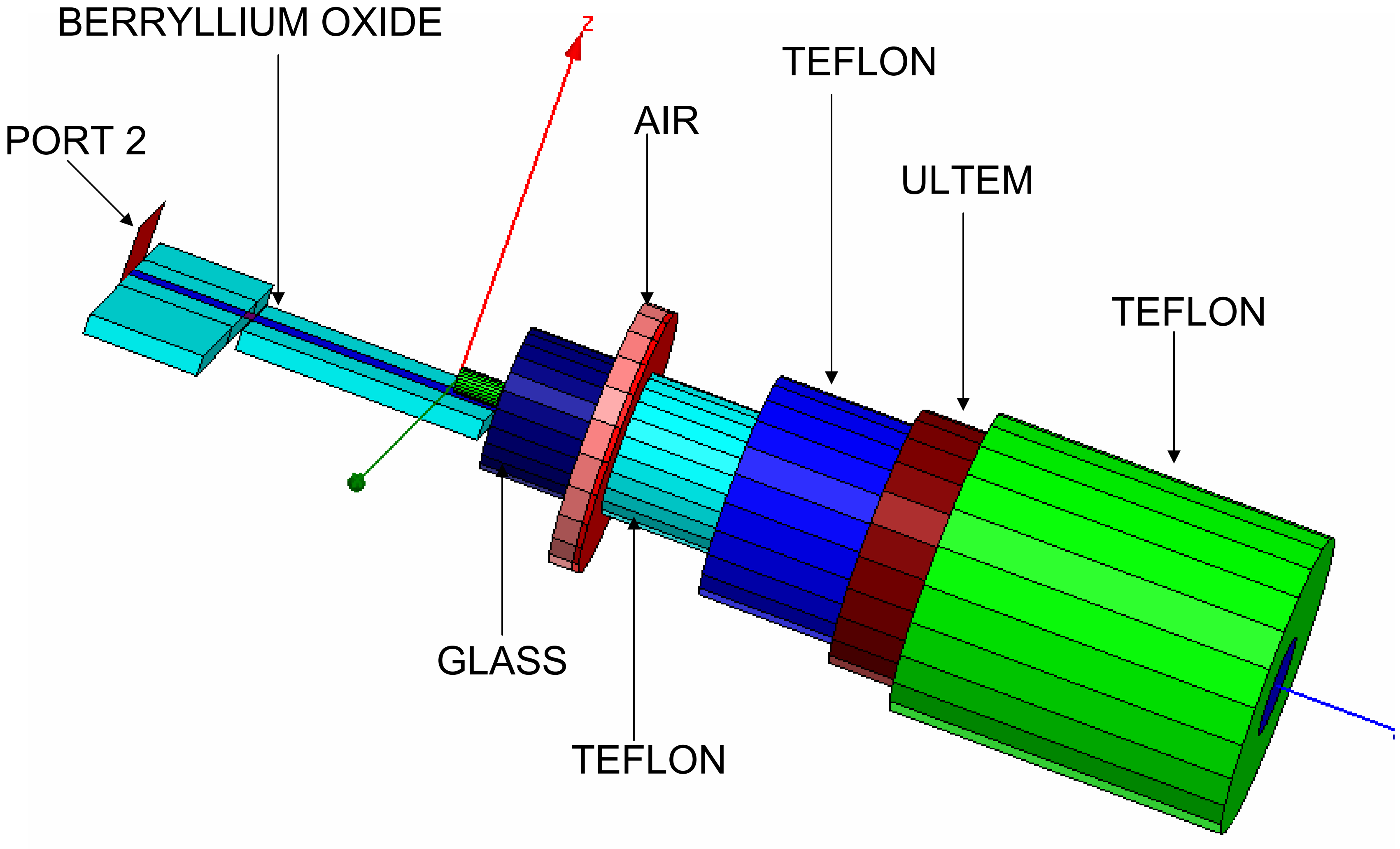
COAX TO MICROSTRIP TRANSITION



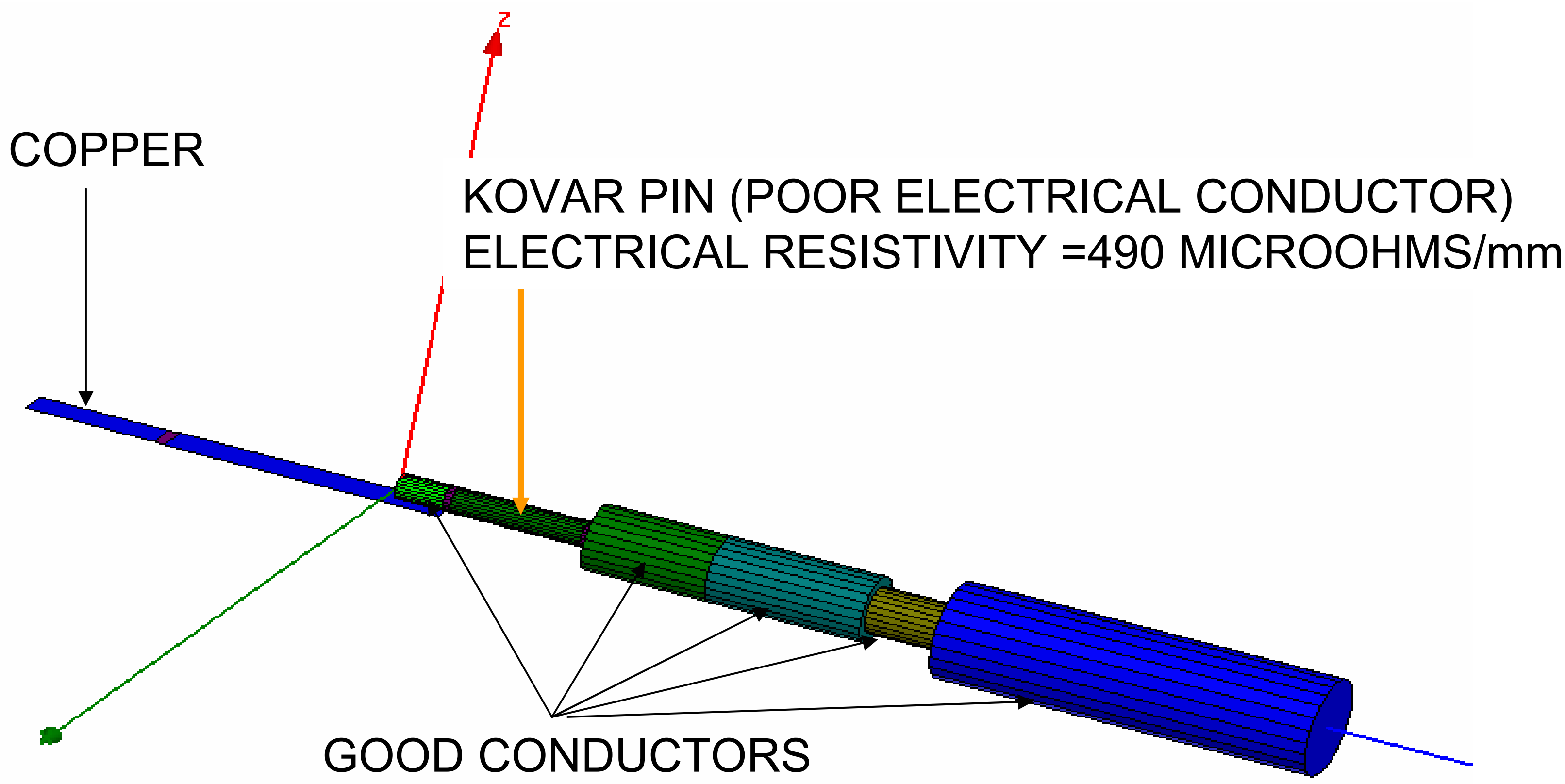
COAX TO MICROSTRIP TRANSITION



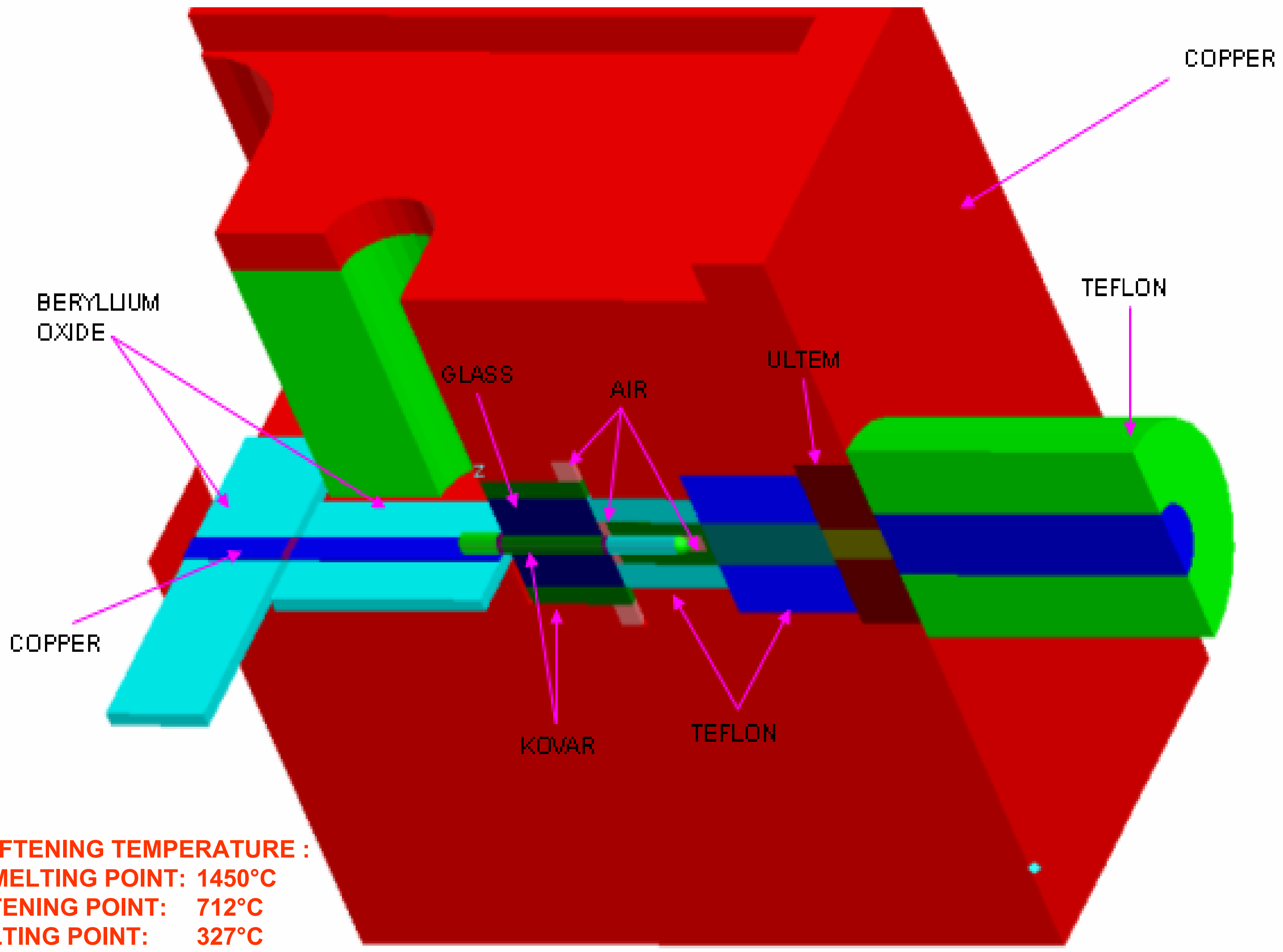
COAX TO MICROSTRIP TRANSITION (DIELECTRICS)



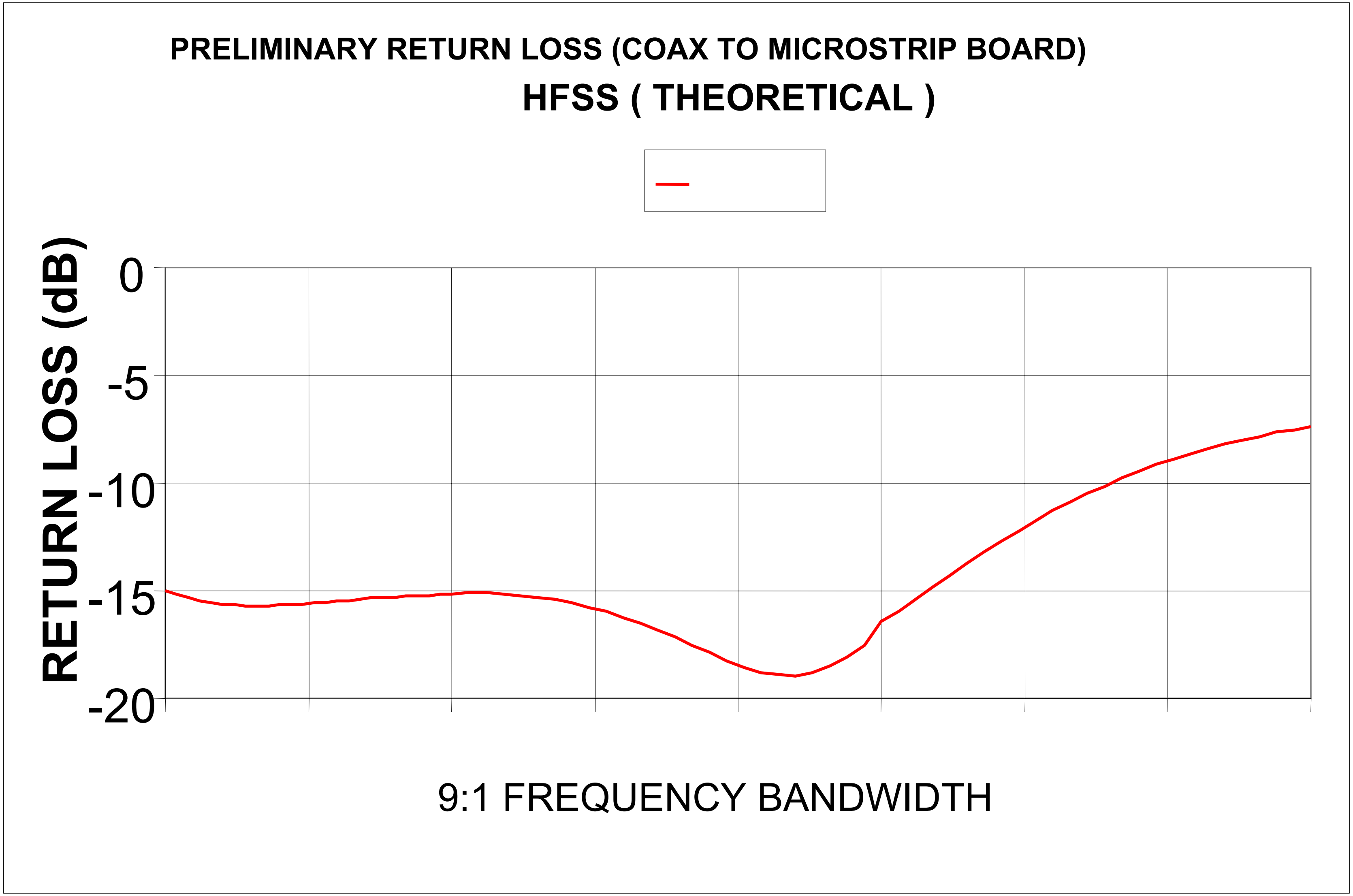
COAX TO MICROSTRIP TRANSITION



COAX TO MICROSTRIP TRANSITION (CUT VIEW OF COMPONENTS)



MELTING/SOFTENING TEMPERATURE :
KOVAR PIN MELTING POINT: 1450°C
GLASS SOFTENING POINT: 712°C
TEFLON MELTING POINT: 327°C


PRELIMINARY RETURN LOSS (COAX TO MICROSTRIP BOARD)
HFSS (THEORETICAL)
RETURN LOSS (dB)
0
-5
-10
-15
-20
9:1 FREQUENCY BANDWIDTH

COAX TO MICROSTRIP TRANSITION

KOVAR / GLASS SEAL:

- KOVAR AND GLASS FORM A HERMETICALLY SEAL.
- KOVAR AND GLASS HAVE SIMILAR THERMAL EXPANSION COEFFICIENTS.
- FOR LOW RF POWER APPLICATION THE COMBINATION OF KOVAR AND GLASS PERFORM SATISFACTORY.
- THE MAIN FAILURE MECHANISM CONSISTS OF THERMAL BREAKDOWN.
- IT APPEARS THAT THE GLASS CAN'T REMOVE SUFFICIENT HEAT FROM THE KOVAR PIN RESULTING IN AN OVERHEATING EVENT.
- THE HEAT IS MOSTLY GENERATED BY THE KOVAR PIN AND TEFLON DIELECTRICS.

COAX TO MICROSTRIP TRANSITION

HIGH RF POWER APPLICATION:

- OVERHEATING IS THE PRIMARY FACTOR FOR LIMITING POWER HANDLING IN RF CABLES AND CONNECTORS.
- THERE EXIST SEVERAL FACTORS TO CONSIDER WHEN DESIGNING FOR HIGH POWER APPLICATIONS . SOME OF THESE ARE:

1) DIAMETER OF PIN
2) PIN MATERIAL
3) OPERATING TEMPERATURE

- THE ABOVE LISTED FACTORS LIMITS THE MAXIMUM CURRENT (A/m) A CABLE AND/OR CONNECTOR CAN HANDLE

COAX TO MICROSTRIP TRANSITION

COMMENTARY:

1) AS CURRENT (H FIELD A/m) FLOWS ALONG THE CENTER CONDUCTOR, RESISTANCE HEAT IS GENERATED.

2) VOLTAGE BREAKDOWN IS ALSO A CONCERN (E FIELD V/m).

3) THERE EXIST ALSO OTHER FACTORS THAT MERIT ATTENTION. FOR EXAMPLE, COAXIAL TRANSMISSION PRINCIPAL MODE IS TEM; BUT, TE11 COULD BE EXCITED RESULTING IN POSSIBLE RESONANCE.

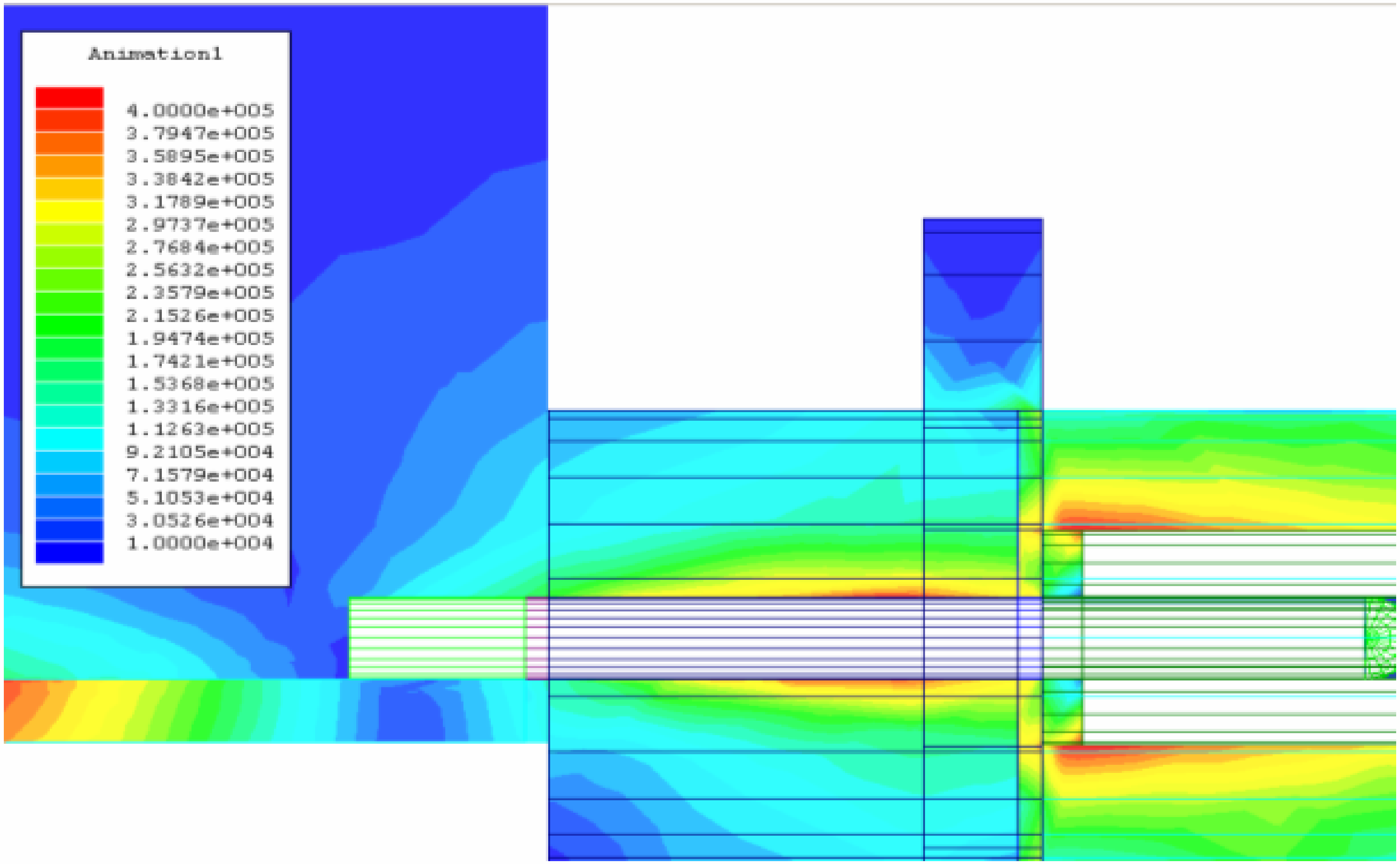
4) HFSS CAN PROVIDE INSIGHT TO HEAT FAILURE MECHANISM

COAX TO MICROSTRIP TRANSITION

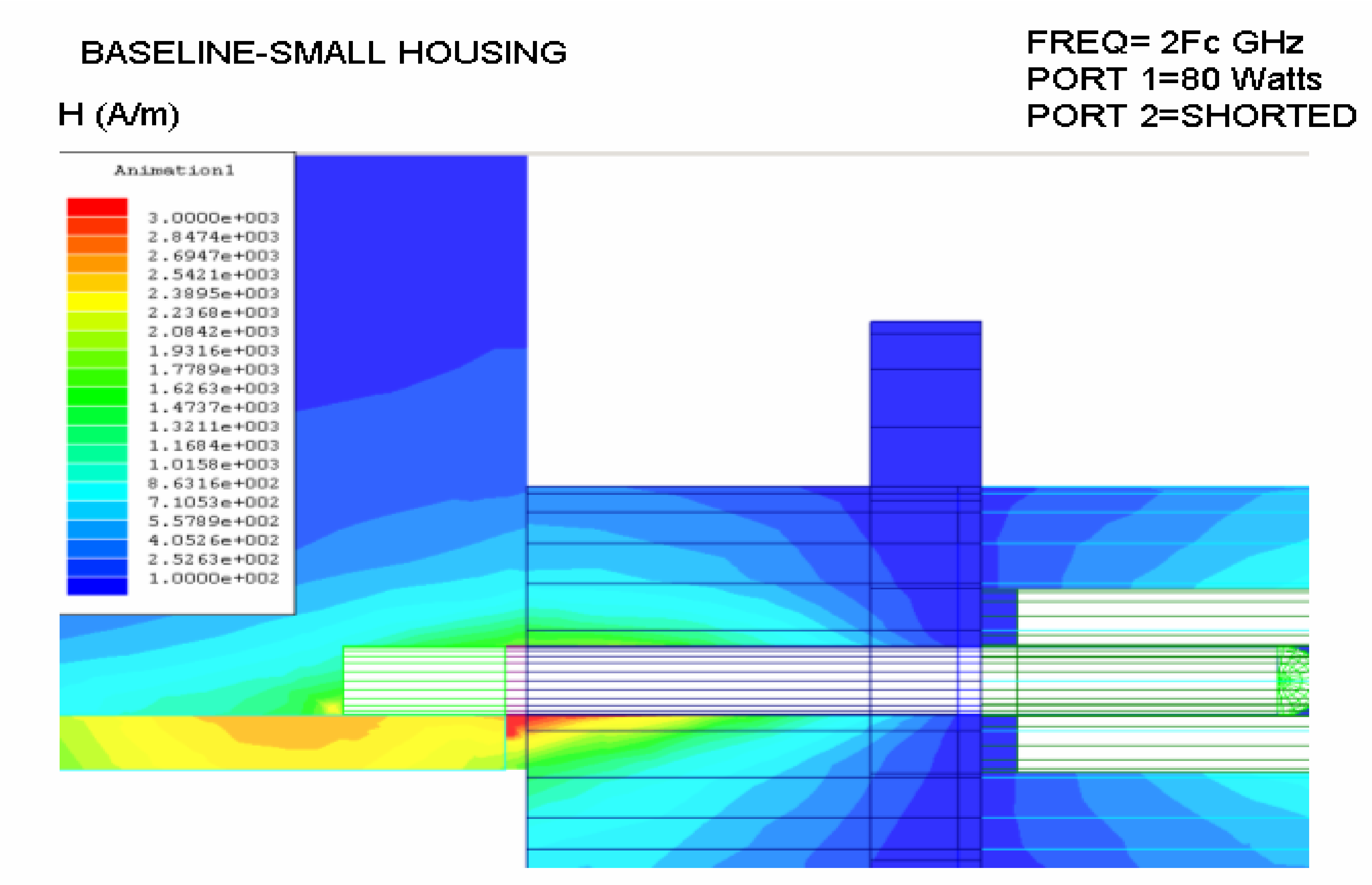
BASELINE-SMALL HOUSING

E (V/m)

FREQ=2Fc GHz
PORT 1=80 Watts
PORT 2=SHORTED



COAX TO MICROSTRIP TRANSITION



COAX TO MICROSTRIP TRANSITION

HFSS AND EPHYSICS

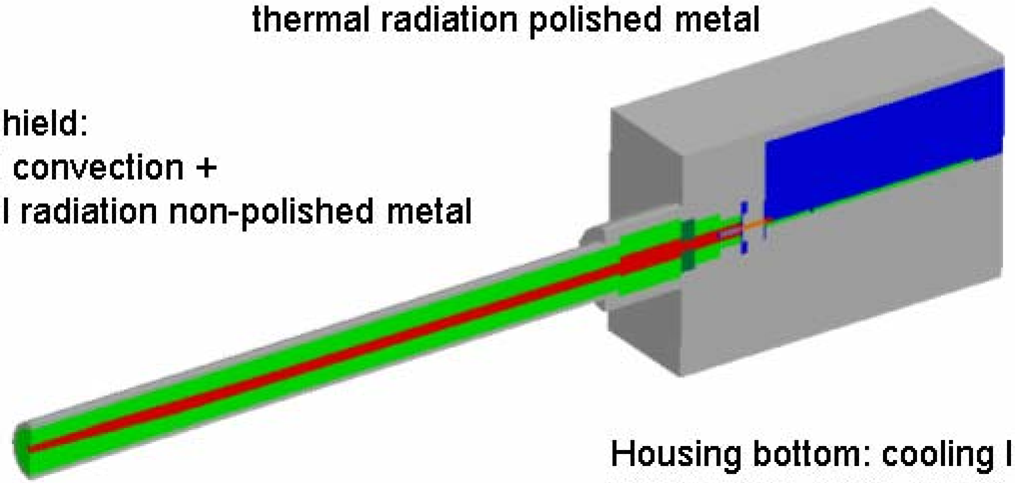
THE NEW OPTIONAL MODULE PROVIDE ADDITIONAL CAPABILITY THAT WAS NOT AVAILABLE BEFORE.

YOU CAN NOW TRANSPORT MODEL FROM HFSS TO EPHYSICS.

THIS MINIMIZES THE ERRORS THAT EXISTED WHEN TRANSFERRING HFSS INFORMATION TO A MECHANICAL THERMAL SOLVER. SPECIFICALLY POWER MAPPING OF THE EM MODEL TO THE MECHANICAL THERMAL SOLVER WAS IN MANY INSTANCES INCORRECT DUE TO HUMAN TRANSCRIBING ERROR.

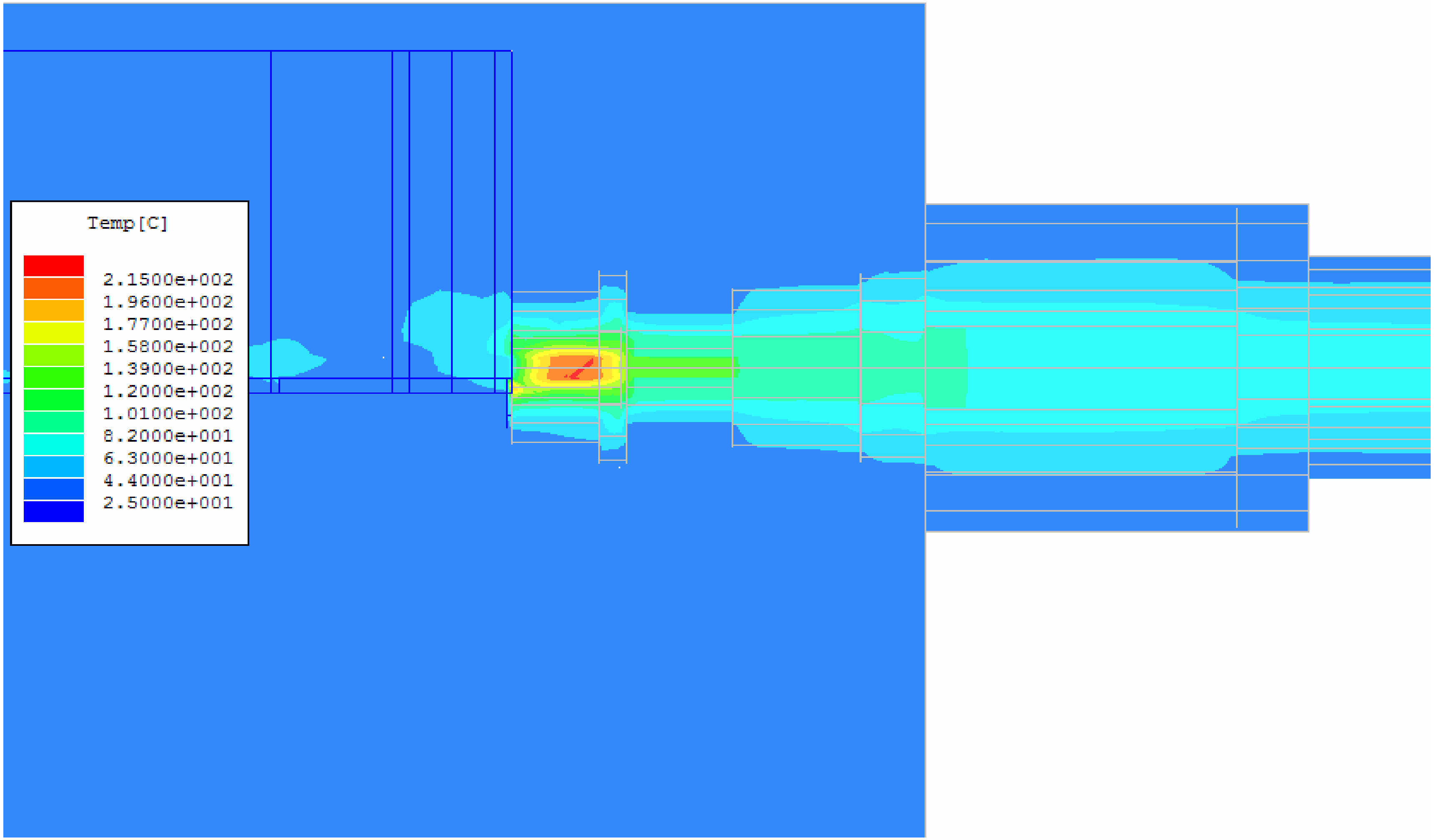
THE FOLLOWING THERMAL ANALYSIS SLIDES WERE PROVIDED BY Dr. MARTIN VOGEL FROM ANSOFT CORPORATION

Thermal boundary conditions



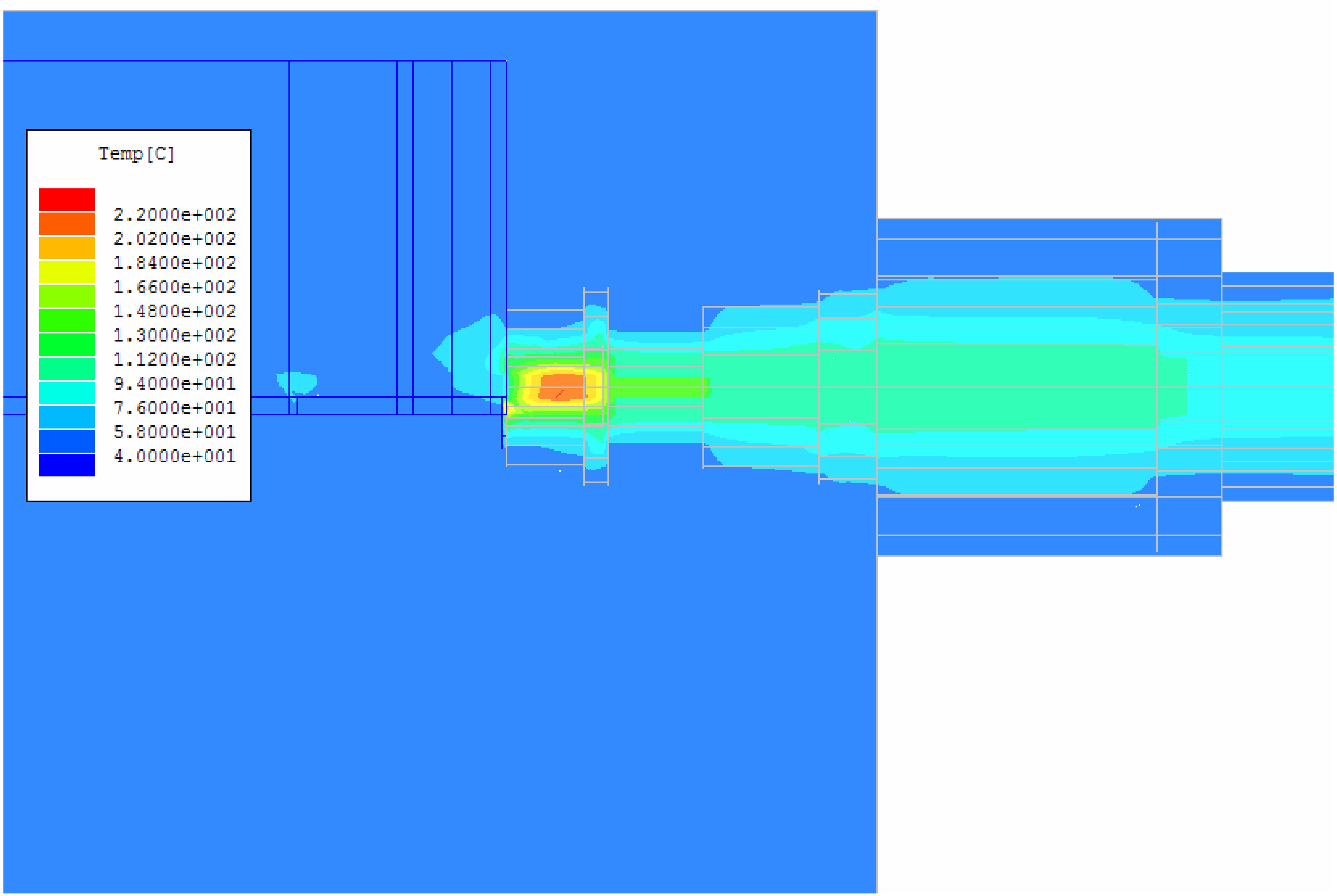
15 seconds

Maximum temp exceeds 200 ^{o}C already.



30 seconds

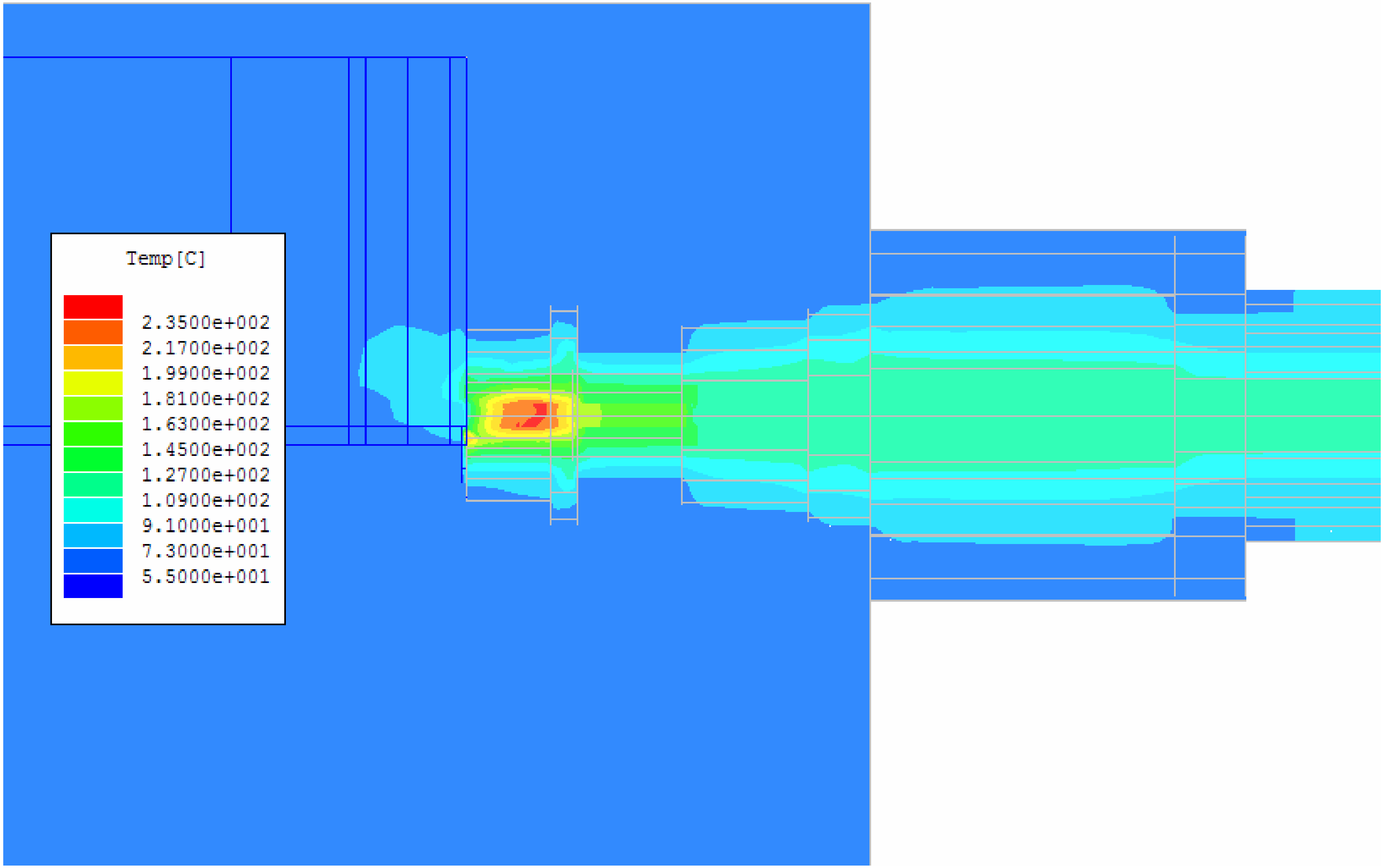
Temp rises in rest of structure.



Raytheon

60 seconds

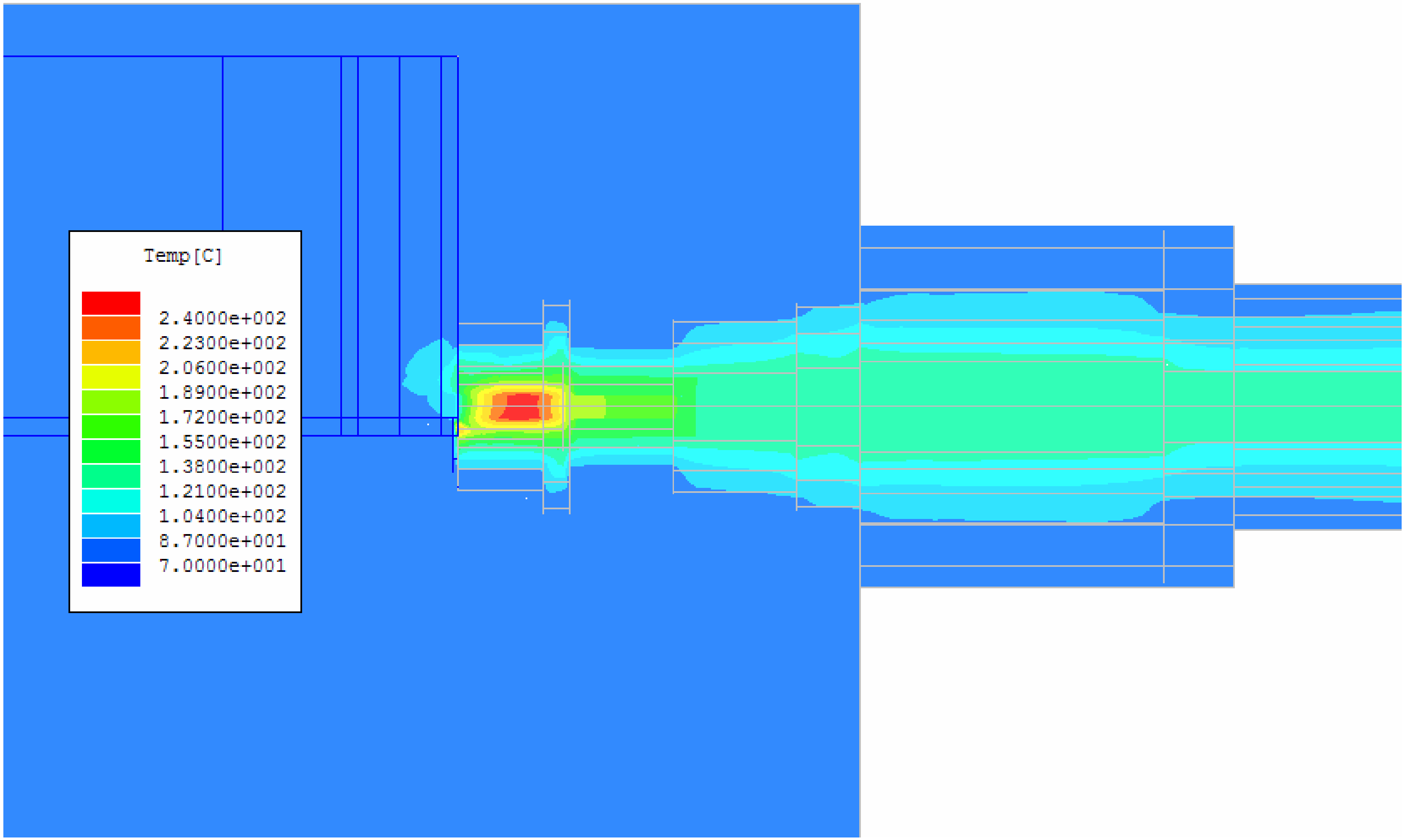
Space & Airborne Systems
Electronic Warfare Systems



Raytheon

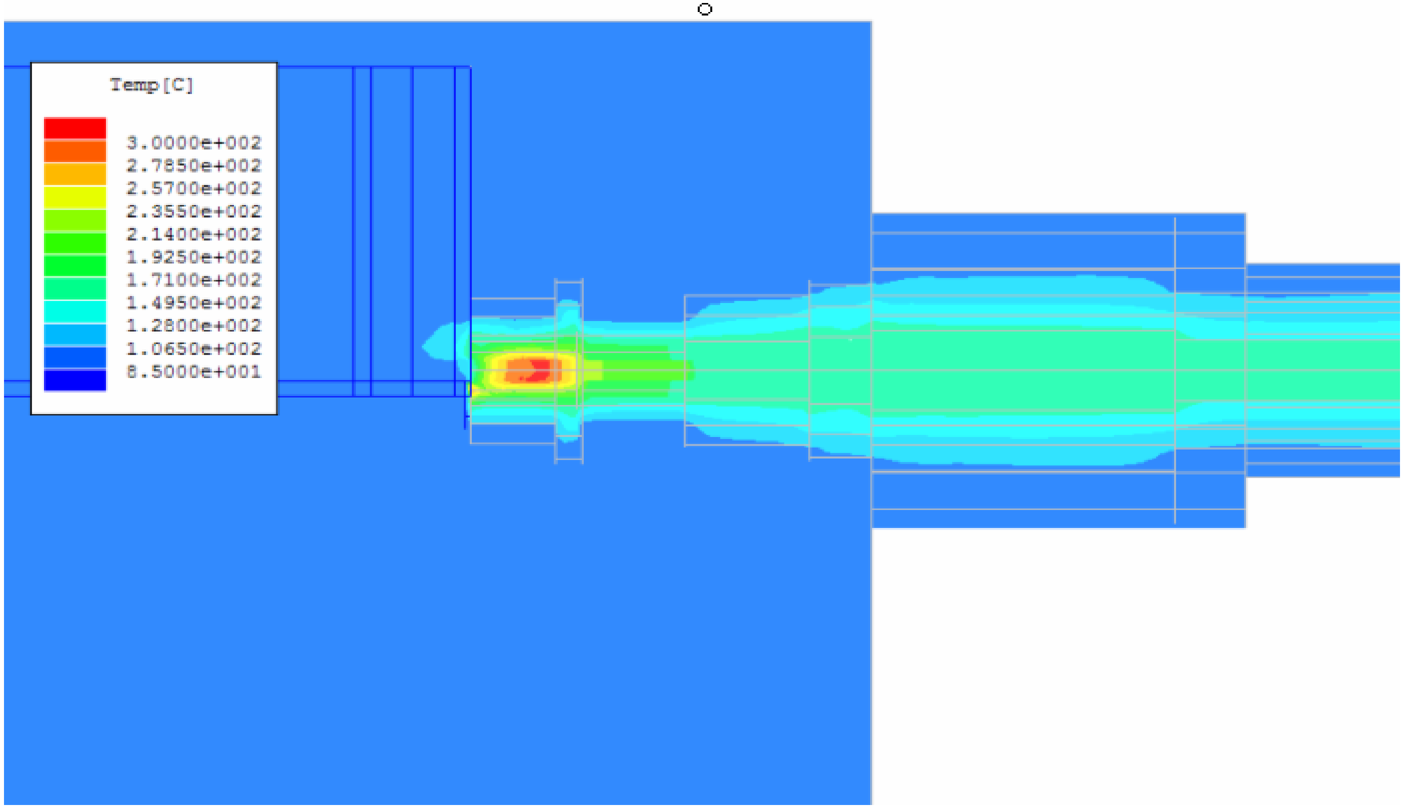
90 seconds

Space & Airborne Systems
Electronic Warfare Systems



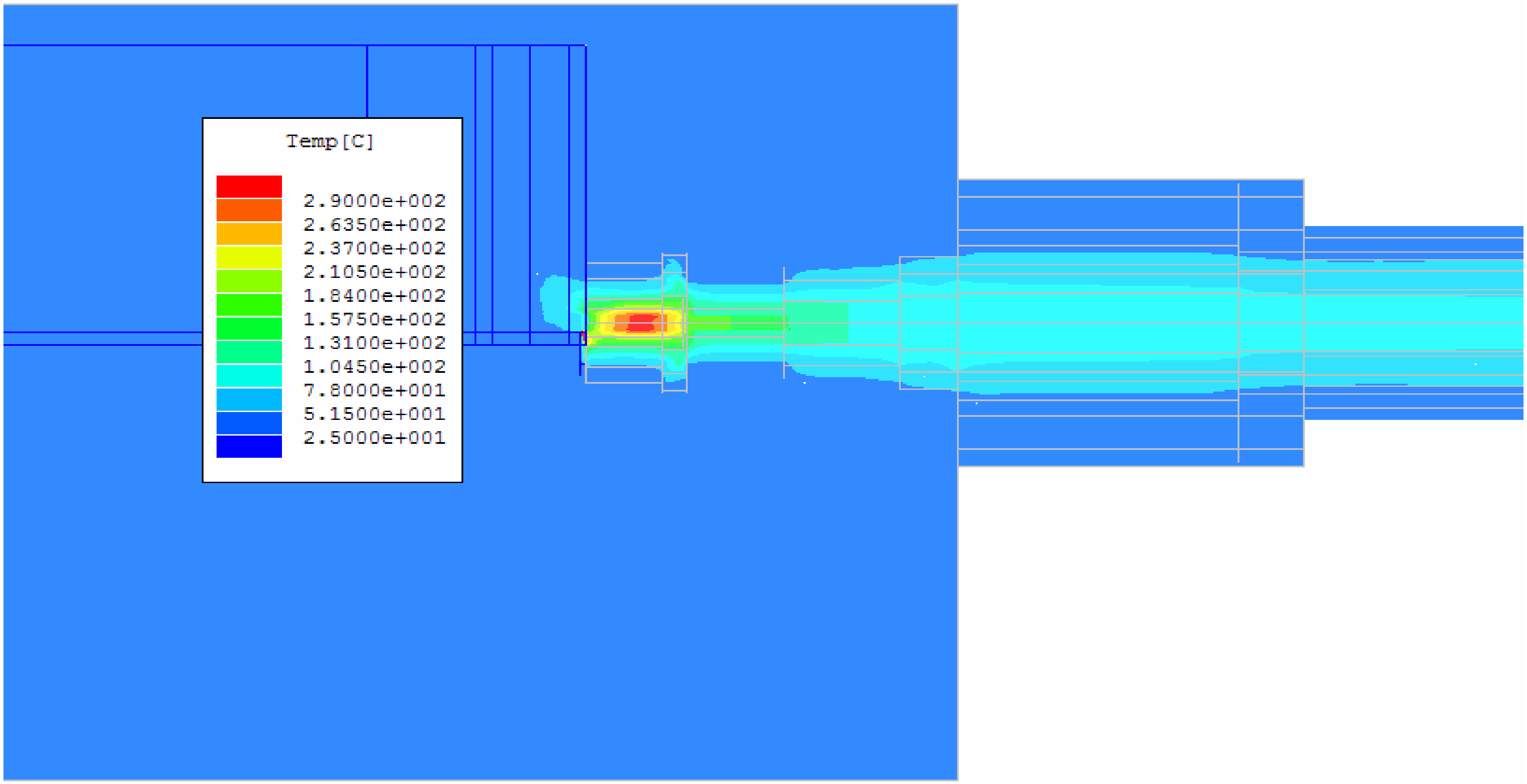
INCREASING POWER BY 20 WATT

100 W input
Eventually 300 ºC reached, up from 255ºC

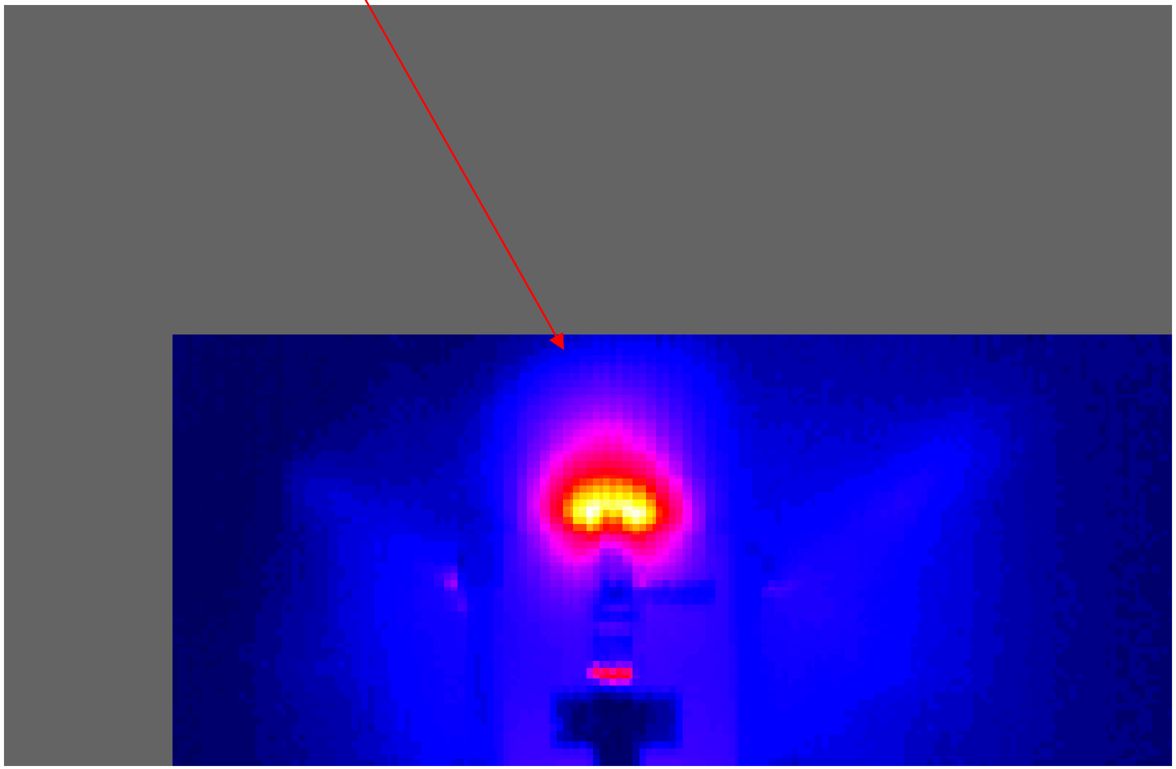


SENSITIVITY ANALYSIS
REDUCTION IN KOVAR PIN DIAMETER BY 8.5%

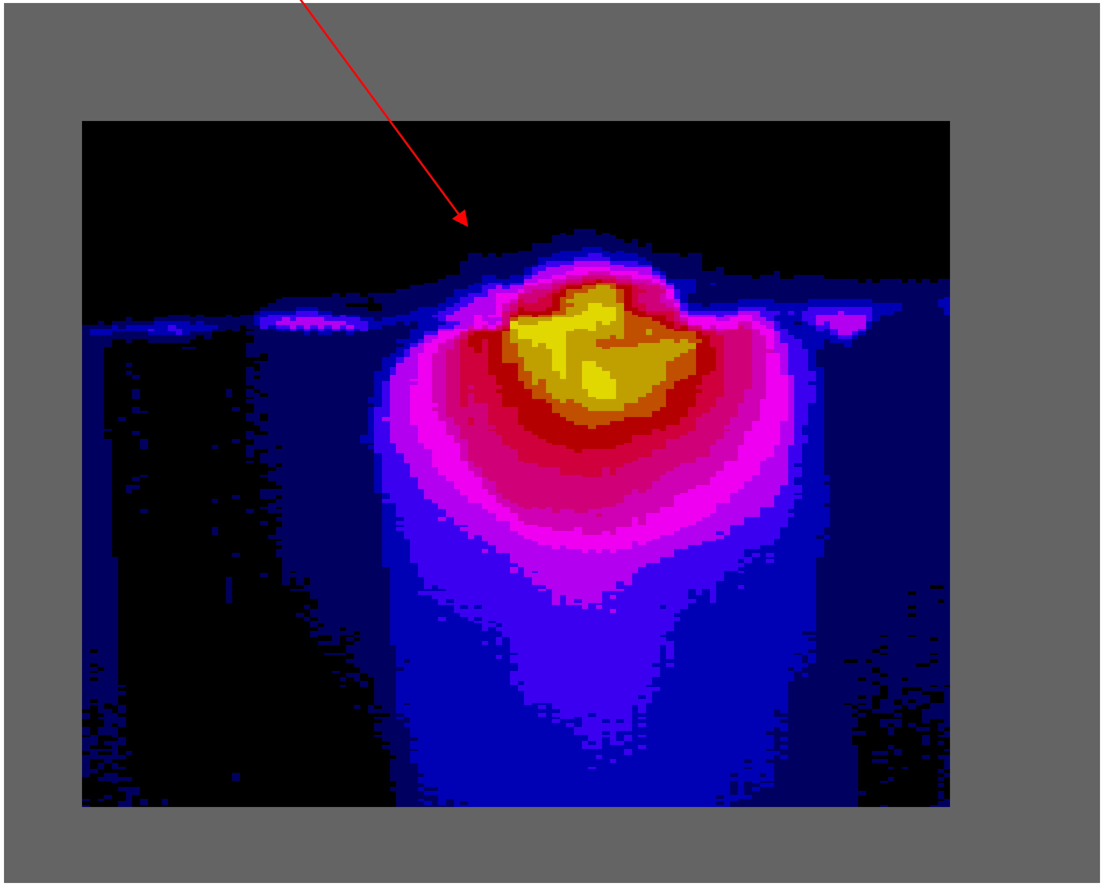
In only 15 s, 290 ^{o}C is reached.



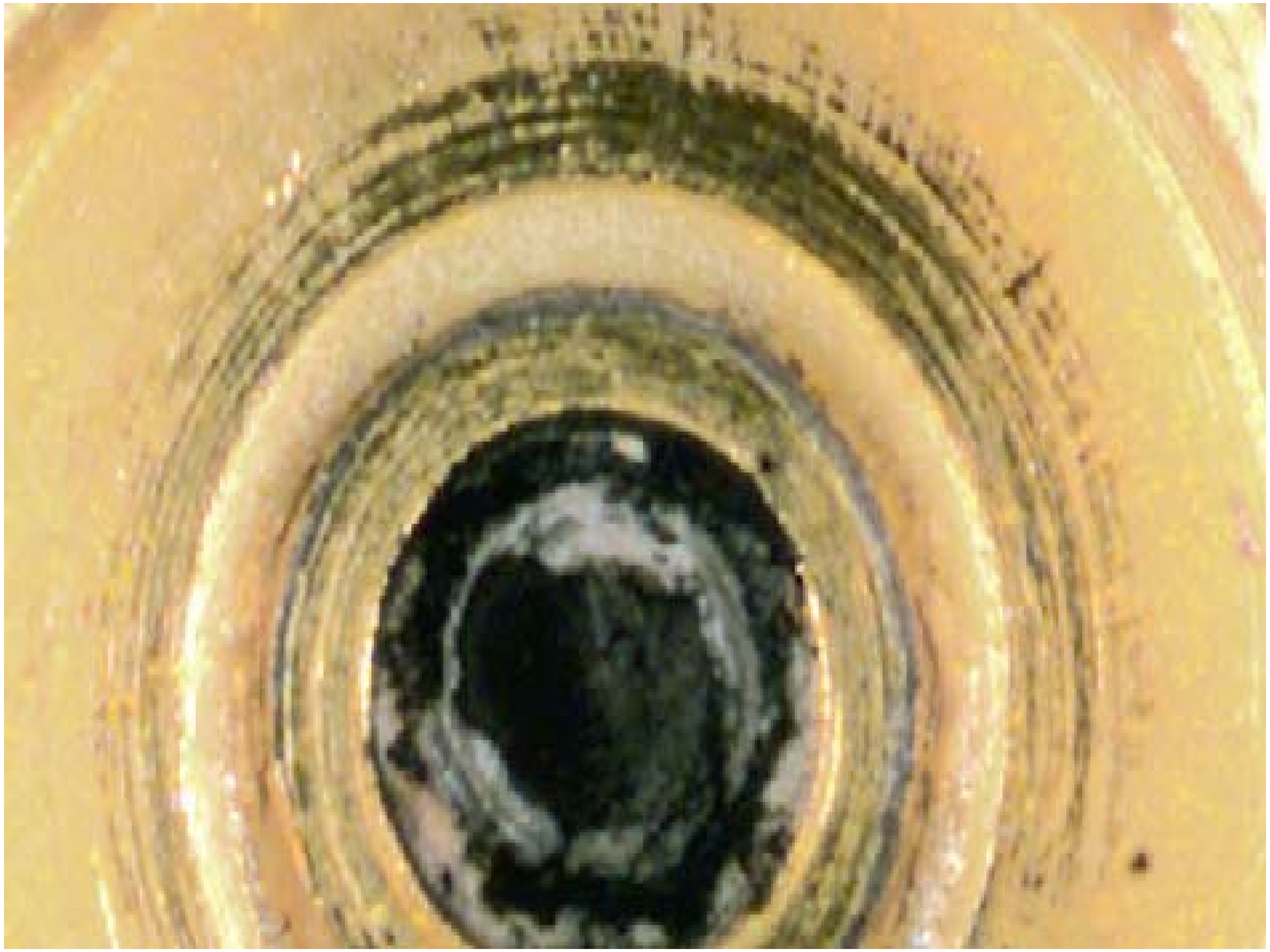
INFRARED THERMAL IMAGE (KOVAR/GLASS/TEFLON)



INFRARED THERMAL IMAGE
(KOVAR/GLASS/TEFLON)



COAX TO MICROSTRIP TRANSITION

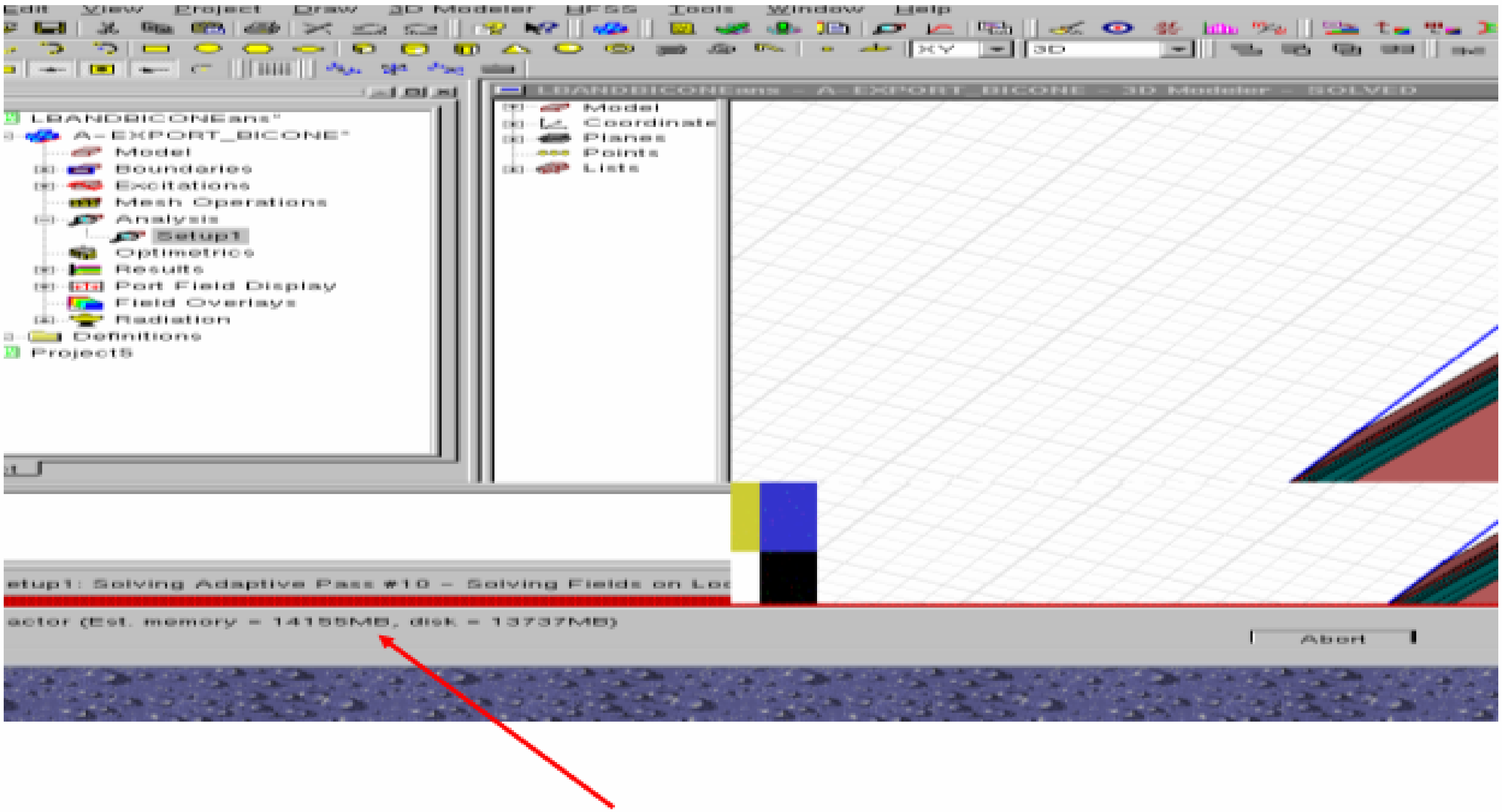


COAX TO MICROSTRIP TRANSITION

LARGE SIZE PROBLEM MODELING

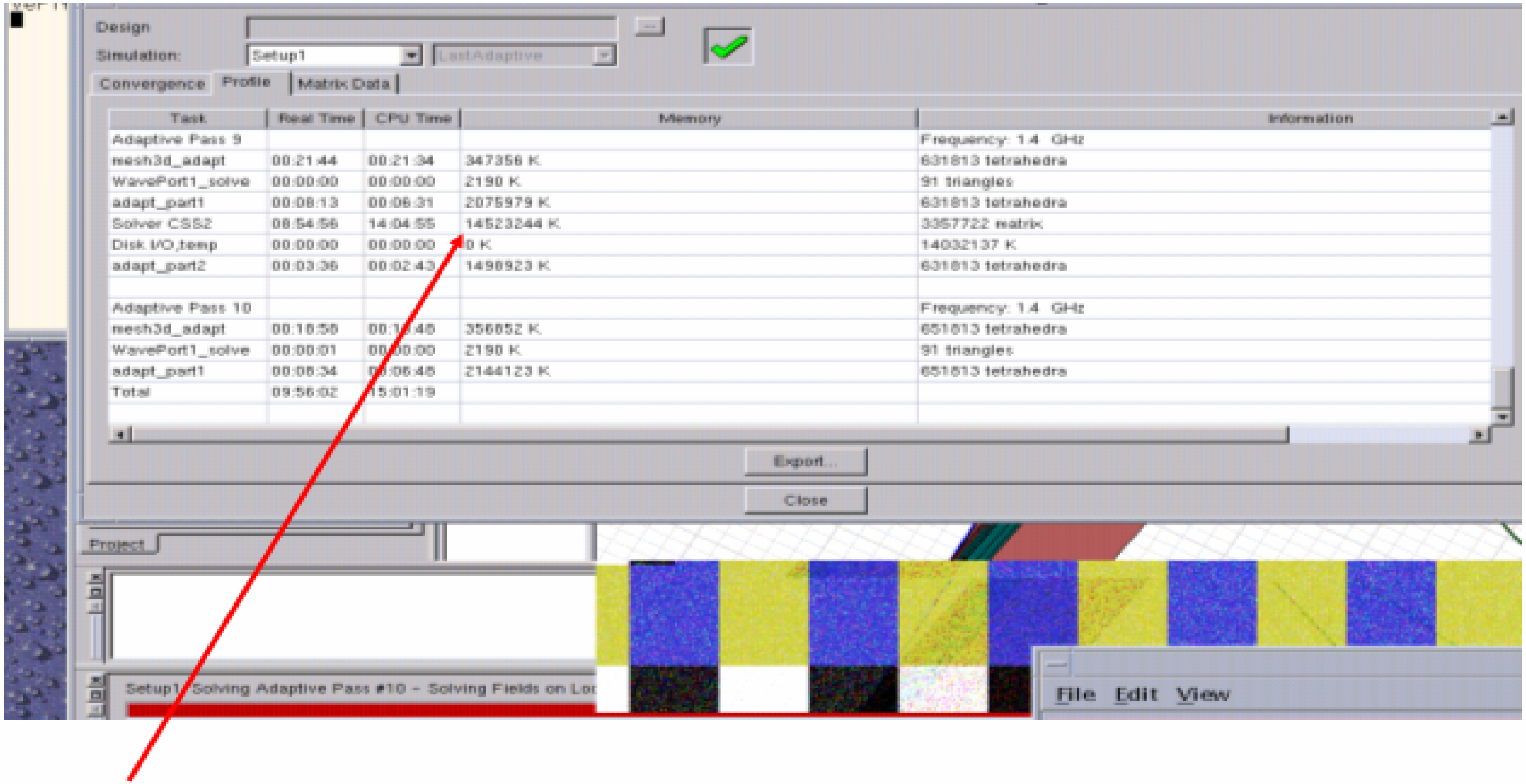
HFSS 9.1 (64 BIT SOFTWARE)
SUN MICROSYSTEM
UNIX OPERATING SYSTEM (SOLARIS VERSION 8)
COMMON DESKTOP ENVIRONMENT (CDE)
Sun Blade 2000 (DUAL PROCESSORS (SPARK III) AT 1.2 GHz EACH)
WITH 16 GB RAM MEMORY

SOLVING LARGE SIZE PROBLEMS



HFSS INDICATES 14.1 GB ESTIMATED SIZE

SOLVING LARGE SIZE PROBLEMS



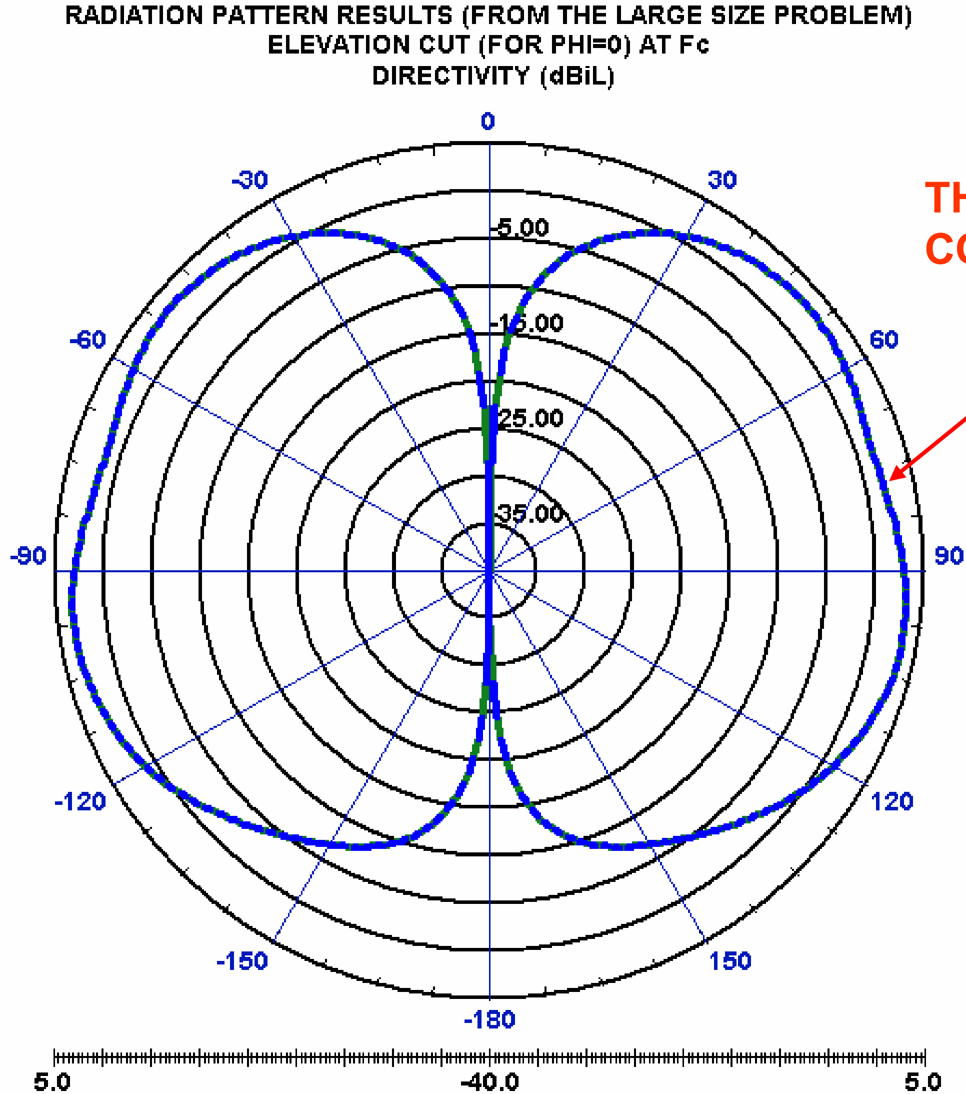
PROFILE AT PASS 9 INDICATES 14.5 GB SIZE REACHED

SOLVING LARGE SIZE PROBLEMS

Task	Real Time	CPU Time	
Solver CSS2	06:54:40	11:35:55	12584
Disk I/O,temp	00:00:00	00:00:00	0 K
adapt_part2	00:03:15	00:02:30	13973
Adaptive Pass 8			
mesh3d_adapt	00:20:19	00:20:04	33819
WavePort1_solve	00:00:01	00:00:00	2190
adapt_part1	00:07:51	00:06:16	19996
Solver CSS2	07:20:42	12:07:30	13379
Disk I/O,temp	00:00:00	00:00:00	0 K
adapt_part2	00:03:30	00:02:38	14478
Total	37:58:21	58:28:37	

AT PASS 8= 37 HRS 58 HRS

SOLVING LARGE SIZE PROBLEM



THIS RESULTS SHOW CORRECT SOLUTION

SUGGESTIONS:

- CONSTRUCT COMPLETE MODEL WITH HFSS VER. 9.1 (P.C.)
- SAVE MODEL IN HFSS 9.1 (UNIX) PROJECT DIRECTORY.
- SOLVE PROBLEM IN UNIX.
- OPEN SOLVED MODEL IN HFSS 9.1 P.C.
  FOR POST PROCESSING