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

PRESENTED
BY
AMEDEO LARUSSI
EXAMPLE OF RAYTHEON EW PRODUCTS

Integrated EW Systems

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

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

SLQ-32 ESM/ECM

ALR-69 RWR Upgrade

UCAV/UAV ESM/EA
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

\[ Z_0(\text{ohms}) = \left( \frac{138}{\sqrt{\varepsilon_r}} \right) \times (\log_{10} \frac{D}{d}) \]
THEORETICAL RESULTS PREDICTION WITH FORMULAS DEVELOPED WITH EXCEL
MEASURED DATA Vs. THEORETICAL DATA (HFSS) OF A COAXIAL 3:1 MATCH LOAD

FREQUENCY (GHz)

VSWR (RATIO)

Measured  HFSS  DESIGN GOAL

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

<table>
<thead>
<tr>
<th>Input</th>
<th>Stub</th>
<th>Xfmr 5</th>
<th>Xfmr 4</th>
<th>Xfmr 3</th>
<th>Xfmr 2</th>
<th>Xfmr 1</th>
<th>Load</th>
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<tbody>
<tr>
<td>Z</td>
<td>220</td>
<td>0</td>
<td>203.5</td>
<td>170</td>
<td>127</td>
<td>94.77</td>
<td>79.37 R (ohms) 220</td>
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<tr>
<td>ZpF</td>
<td>0</td>
<td>0</td>
<td>0.253</td>
<td>0.248</td>
<td>0.238</td>
<td>0.233</td>
<td>0.231 cap (pF) 0</td>
</tr>
<tr>
<td>Length</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ind (nH) 0</td>
</tr>
</tbody>
</table>

Input Reflection (dBd)

Input VSWR

Wheeler Chart

WRD-650 3:1 5 Section Mismatch
comment: 3:1 transfrm
lengths are in air
ITERATIONS OF WR 650 DESIGN WITH EXCEL

<table>
<thead>
<tr>
<th>Z</th>
<th>Gap</th>
<th>Fc</th>
<th>L/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>73.33</td>
<td>0.0336</td>
<td>3.505</td>
<td>N/A</td>
</tr>
<tr>
<td>79.375</td>
<td>0.0364</td>
<td>3.618</td>
<td>0.256</td>
</tr>
<tr>
<td>94.776119</td>
<td>0.0434</td>
<td>3.887</td>
<td>0.259</td>
</tr>
<tr>
<td>127</td>
<td>0.0583</td>
<td>4.404</td>
<td>0.265</td>
</tr>
<tr>
<td>170.18</td>
<td>0.078</td>
<td>4.972</td>
<td>0.275</td>
</tr>
<tr>
<td>203.2</td>
<td>0.0932</td>
<td>5.32</td>
<td>0.282</td>
</tr>
<tr>
<td>220</td>
<td>0.101</td>
<td>5.468</td>
<td>N/A</td>
</tr>
<tr>
<td>0.2331</td>
<td>used L/4 x 0.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
220 Ω/73.3 Ω = 3:1 (VSWR)

GAP = 0.0336”

GAP = .101”
MEASURED DATA Vs. THEORETICAL DATA (HFSS) OF A 3:1 MATCH WR 650

VSWR (RATIO)

FREQUENCY (GHz)

MEASURED DATA (8/5/03)  HFSS  DESIGN GOAL
EXAMPLE OF A DUAL RIDGE WAVEGUIDE GAP ANALYSIS

GAP SENSITIVITY ANALYSIS

BASELINE GAP=0.029"
GAP=0.030"
GAP=0.031"
GAP=0.033"
GAP=0.035"

VSWR

FREQUENCY (GHz)
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

SUBSTRATE

METAL

PORT
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

ANGLE (EL CUT IN DEGREE)

GAIN (dBiL)

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

ANGLE (EL CUT IN DEGREE) vs. GAIN (dBi)

-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90

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

-90 -80 -70 -60 -50 -40 -30 -20 -10  0  10  20  30  40  50  60  70  80  90
ANGEL (EL. CUT IN DEGREE)

-20 -18 -16 -14 -12 -10 -8 -6 -4 -2  0  2  4  6  8  10
GAIN (dBi L)

MEASURED (H)  HFSS (H)
TAPERED NOTCH MEASURED Vs THEORETICAL (HFSS 9.1) AT 1.33 F₀ FOR V POLARIZATION
TYPICAL DISCONE ANTENNA
COAX TO MICROSTRIP TRANSITION

HOUSING
COAX TO MICROSTRIP TRANSITION

PORT 1
COAX TO MICROSTRIP TRANSITION (DIELECTRICS)

BERRYLLIUM OXIDE

PORT 2

AIR

ULTEM

TEFLON

GLASS

TEFLON

TEFLON
COAX TO MICROSTRIP TRANSITION

COPPER

KOVAR PIN (POOR ELECTRICAL CONDUCTOR)
ELECTRICAL RESISTIVITY = 490 MICROOHMS/mm

GOOD CONDUCTORS
COAX TO MICROSTRIP TRANSITION (CUT VIEW OF COMPONENTS)

MELTING/SOFTENING TEMPERATURE:
- KOVAR PIN MELTING POINT: 1450°C
- GLASS SOFTENING POINT: 712°C
- TEFON MELTING POINT: 327°C
PRELIMINARY RETURN LOSS (COAX TO MICROSTRIP BOARD)
HFSS (THEORETICAL)

RETURN LOSS (dB)

9:1 FREQUENCY BANDWIDTH
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 TEFLOM DIELECTRICS.
HIGH RF POWER APPLICATION:

- OVERHEATING IS THE PRIMARY FACTOR FOR LIMITING POWER HANDLING IN RF CABLES AND CONNECTORS.
- THERE EXISTS 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

BASELINE-SMALL HOUSING

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

H (A/m)
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

Housing sides and top:
natural convection +
thermal radiation polished metal

Coax shield:
natural convection +
thermal radiation non-polished metal

Housing bottom: cooling limits
temperature to 85 deg C

Cut plane of model:
symmetry boundary condition
15 seconds
Maximum temp exceeds 200 °C already.
30 seconds
Temp rises in rest of structure.
60 seconds
90 seconds
INCREASING POWER BY 20 WATT

100 W input
Eventually 300 °C reached, up from 255°C
SENSITIVITY ANALYSIS
REDUCTION IN KOVAR PIN DIAMETER BY 8.5%

In only 15 s, 290 °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

<table>
<thead>
<tr>
<th>Task</th>
<th>Real Time</th>
<th>CPU Time</th>
<th>Memory</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive Pass 9</td>
<td>00:21:44</td>
<td>00:21:34</td>
<td>347356 K</td>
<td>Frequency: 1.4 GHz</td>
</tr>
<tr>
<td>mesh3d_adapt</td>
<td>00:00:00</td>
<td>00:00:00</td>
<td>2190 K</td>
<td>631813 tetrahedra</td>
</tr>
<tr>
<td>WavePort1_solve</td>
<td>00:08:13</td>
<td>00:06:31</td>
<td>2075979 K</td>
<td>91 triangles</td>
</tr>
<tr>
<td>adapt_part1</td>
<td>00:08:13</td>
<td>00:06:31</td>
<td>2075979 K</td>
<td>631813 tetrahedra</td>
</tr>
<tr>
<td>Solver CSS2</td>
<td>09:54:56</td>
<td>14:04:55</td>
<td>14523244 K</td>
<td>3357722 matrix</td>
</tr>
<tr>
<td>Disk I/O_temp</td>
<td>00:00:00</td>
<td>00:00:00</td>
<td>18 K</td>
<td>14032137 K</td>
</tr>
<tr>
<td>adapt_part2</td>
<td>00:03:36</td>
<td>00:02:43</td>
<td>1498923 K</td>
<td>631813 tetrahedra</td>
</tr>
<tr>
<td>Adaptive Pass 10</td>
<td>00:18:59</td>
<td>00:18:46</td>
<td>356852 K</td>
<td>Frequency: 1.4 GHz</td>
</tr>
<tr>
<td>mesh3d_adapt</td>
<td>00:00:00</td>
<td>00:00:00</td>
<td>2190 K</td>
<td>651613 tetrahedra</td>
</tr>
<tr>
<td>WavePort1_solve</td>
<td>00:00:01</td>
<td>00:00:00</td>
<td>2190 K</td>
<td>91 triangles</td>
</tr>
<tr>
<td>adapt_part1</td>
<td>00:08:34</td>
<td>00:06:45</td>
<td>2144123 K</td>
<td>651613 tetrahedra</td>
</tr>
<tr>
<td>Total</td>
<td>09:56:02</td>
<td>15:01:19</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PROFILE AT PASS 9 INDICATES 14.5 GB SIZE REACHED
SOLVING LARGE SIZE PROBLEMS

<table>
<thead>
<tr>
<th>Task</th>
<th>Real Time</th>
<th>CPU Time</th>
</tr>
</thead>
</table>
| Solver CSS2        | 06:54:40  | 11:35:55 | 12584  
| Disk I/O,temp adapt_part2 | 00:00:00  | 00:00:00 | 0K  
| Adaptive Pass 8    | 00:20:19  | 00:20:04 | 33819  
| mesh3d_adapt       | 00:00:01  | 00:00:00 | 21901  
| WavePort1_solve    | 00:07:51  | 00:06:16 | 19996  
| adapt_part1        | 07:20:42  | 12:07:30 | 13379  
| Solver CSS2        | 00:00:00  | 00:00:00 | 0K  
| Disk I/O,temp adapt_part2 | 00:03:30  | 00:02:30 | 14478  
| Total              | 37:58:21  | 58:28:37 |  

AT PASS 8 = 37 HRS  
58 HRS
SOLVING LARGE SIZE PROBLEM

RADIATION PATTERN RESULTS (FROM THE LARGE SIZE PROBLEM)
ELEVATION CUT (FOR PH=0) AT Fc
DIRECTIVITY (dBIL)

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