A Simple Tool for Design and Analysis of Multiple-Reflector Antennas in a Multi-Disciplinary Environment

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MOTIVATION

- For the foreseeable future, JPL is proposing, designing and building microwave and millimeter wave instruments
- Instruments meet design criteria obtained from science mission goals
  - Beamwidth, sidelobes
  - Pointing
  - Gain
- Design criteria are functions of space environment
  - Fluctuating thermal (deep space and earth orbiting)
  - Mechanical due to thermal load
- Software design tools and environments maturing and becoming integrated

MIRO Instrument (JPL)
wwwmiro.jpl.nasa.gov
Current Design Tools and Process

Disciplines/Tools:

- CAD
  - Pro/Engineer
  - CV
  - IDEAS
- Meshing
  - FEMAP
- Structural
  - NASTRAN
- Thermal
  - TRASYS
  - SINDA
- Antenna/Optics
  - MACOS
  - POPO

Each tool is used by an analyst/designer, who works in one discipline.

When one analyst completes a model, it is passed to the next.

This work focuses on antenna electromagnetic design, and how it is connected to the other disciplines through a common digital geometry.
MODTool (Millimeter-wave Optics Design Tool)

Common Geometry
MODTool Goals

✦ Develop new code only if necessary
  • Try to use/reuse:
    - Commercial applications
    - Previously developed JPL applications
  • Try to develop code so that it can be used for other future projects
    - Use standard packages/tools
    - Always think beyond this project

✦ Ensure users on multiple platforms can easily use tool (client-server)
  • Client written in Tcl/Tk
    - Freely available over the web
    - Available for Unix, PC, Mac
  • Server also written in Tcl/Tk, but on a specific type of machine
    - Uses compiled C code using Unix libraries for user authentication
COMMON GEOMETRY

- Much of the underlying effort was spent in defining a common geometry that can be used by structures, thermal and electromagnetic design
  - Thermal: 100s of mesh points (degrees of freedom)
  - Structures: 1000s of mesh points
  - Electromagnetic: 10,000s of mesh points

- A common analytic description of the antenna surfaces was defined, and any distortions produced from structural/thermal analysis codes were interpolated and added to analytic description
  - Struts, backup structure, spacecraft structures models used in structural/thermal analysis; data stripped for use with electromagnetic analysis
Interface and Functionality

- Designer starts client code on designer’s machine (*The Application Interface*)
  - Designer must enter username and password
  - Designer must select existing or new project on which to work
- Client opens socket to server (*Automatic and Invisible*)
  - Server validates username and password
  - Server creates local work directory
- Designer may then work in one of six modes:
  - Design
  - Prescription
  - Geometric Optics Analysis
  - Physical Optics Analysis
  - Submitting a Mesh
  - Submitting a Load

Interface to thermal and structural design
Design Mode

- Allows designer to create or modify a design
- A design is the description of a set of antenna elements
  - Conic sections:
    - paraboloids, hyperboloids, ellipsoids, flat plates, all cut by an elliptical cutting cylinder
  - Feed location and output coordinate system definitions
- The elements are shown graphically, and the values which control the elements are shown as a table
  - Either the data in the table or the graphical data may be varied
  - The two displays are linked - changes in one are reflected in the other
Design Mode (Cont’d)
Prescription Mode

- Allows the user to create or modify a prescription
- A prescription is an ordered list of a subset of the optical elements from the design
  - Determines which elements should be analyzed and in what order
  - Needed because instruments can have multiple “optical” paths
    - Instrument will be used at multiple frequencies
    - Instrument has multiple modes of operation
- Elements may be modified in location or orientation from the base elements as stored in the design
  - Used for tolerancing analysis
Prescription Mode (Cont’d)

MOD Tool

Current mode is: Prescription

Current design file is: /home/dsk/modtool/miro.des

Current prescription file is: /home/dsk/modtool/miro.sm.pre

Load Prescription File

Save Prescription File

Choose Prescription from Design Data

Frequency: 584.0 GHz

Length Units: mm

Feed File: pm_feed.dat

Distance into feed of Rotation Point: 0.0

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GO Analysis Mode

- Allows the user to perform geometric optics analysis on a design and prescription
- These files are converted to a MACOS input set
  - MACOS provides computationally efficient general ray-trace, differential ray-trace, and scalar-diffraction calculation capabilities
  - Developed at JPL, starting in 1989
  - Commercial and U.S. Government versions are available
- The files must be on the server, which does the conversion, and runs MACOS
  - Only the general ray-tracing capabilities of MACOS are currently supported through MODTool
GO Analysis Mode (Cont’d)
Physical Optics Mode

- Physical Optics (POPO) code
  - Developed at JPL over a long period of time (1971 - present)
  - Versions exist for PCs, workstations, Cray J90, T3D, Beowulf
- Can analyze surfaces from design and prescription mode
- Can also add deformations from load file before analyzing
  - Done using MATLAB to read mesh and load data, and to calculate coefficients for a biquadratic (or other) surface approximating the deformation
  - MATLAB is run on the server, where the design, prescription, mesh and load files are stored
- POPO code is run on supercomputers
  - Using username and password for that machine supplied by user
  - Ensures correct accounting and time-charging
  - Expect is used between the server and the supercomputer
PO Mode (Cont’d)
Mesh and Loads

- Used by structural, thermal and electromagnetic engineers
- Submits a mesh of an instrument from a client to the server
  - Currently, meshes must be FEMAP neutral files
  - One layer is used for the elements that make up each optical element
- Validates that mesh and the “analytic” design are the same geometry
- Used with the load data for physical optics analysis of loaded instruments

Deformations come from structural or thermal loads
  - How the instrument will change from the original design when it is in its operating environment
- The load data must be logically tied to a set of mesh data
- This data is used in the physical optics analysis, with the corresponding mesh data
Current Work

- Adding ZEMAXS 3D optical software as addition to Design input mode
- Interfacing to tool set in JPL TEAM I (Instrument) a concurrent engineering center

Ocean-Salinity Soil-Moisture Integrated Radiometer-Radar Imaging System (OSIRIS) E. Njoku-JPL (Proposal)