High Gain Antenna Pointing on the Mars Exploration Rovers

Tony Vanelli
Khaled Ali

IEEE SMC’05 October 2005
IEEE SMC'05
High Gain Antenna Pointing on MER
A Overview of Flops on Mars Pathfinder

IEEE SMC’05
High Gain Antenna Pointing on MER
Mars Exploration Rover

Camera Assembly

LGA

G1

Gimbal Assembly

HGA

G2

Rx
IEEE SMC’05
High Gain Antenna Pointing on MER
Limits on Azimuth motion as seen from above the rover deck

High Gain Antenna Pointing on MER
Inadmissible Region “B”

Cannot point in this region

$W_B$
Admissibility Map from Motion Limits

IEEE SMC’05
High Gain Antenna Pointing on MER
Basic Spherical Circle - Notation

Circle $C$ with axle $\omega$ and half-angle $\alpha$
Earth Trajectory as seen from Rover POV

IEEE SMC’05
High Gain Antenna Pointing on MER
Basic Occlusion Definition

Occlusion circle $C$ with test point $q$.

$$(q - c) \cdot \omega \geq 0 \Rightarrow q \text{ is inside } C.$$
$$(q - c) \cdot \omega < 0 \Rightarrow q \text{ is outside } C.$$
Paden-Kahan Solution #2 - illustrated

IEEE SMC'05
High Gain Antenna Pointing on MER
IEEE SMC'05
High Gain Antenna Pointing on MER
Wedge Occlusion

IEEE SMC’05
High Gain Antenna Pointing on MER
Constructing the PMA Meld Occlusions

IEEE SMC'05
High Gain Antenna Pointing on MER
IEEE SMC'05
High Gain Antenna Pointing on MER
At the beginning of a communication session, the HGA pointing algorithm computes the incursion times for each of the occlusions and then computes the overall incursion time for each branch using

\[
  t_A = \min(t_T, t_D, t_{HA}, t_{PA}), \quad t_B = \min(t_T, t_D, t_{HB}, t_{PB}).
\]

The algorithm selects whichever branch provides the longest possible time until incursion, and begins tracking the Earth using that branch.
Figure 6: The hardstops create two wedges (indicated as red and green shadows on the sphere between lines $t_1$ and $t_2$). The earth trajectory as a function of time is shown starting at position $v_0$ at time $t_0$, entering wedge $W_B$ at $v_1$ and exiting at $v_2$. For this example, the earth sets before entering the wedge $W_A$. 
If the current branch does become occluded during the course of the track, then the algorithm takes one of the following actions, depending on which occlusion is encountered.

- **Terrain or Deck Occlusion:** The communication session is immediately terminated.

- **Hardstop Occlusion:** The algorithm performs a flop to the alternate branch.

- **Pancam Occlusion:** Rather than flop, for operational reasons the algorithm continues to track but alerts the communications manager to send only real-time health and status data. When the Pancam Occlusion is cleared, the HGA algorithm informs the communications manager that it may resume its normal transmission behavior.
The Complete Occlusion Set

IEEE SMC’05
High Gain Antenna Pointing on MER
Acknowledgements

This work was prepared at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.
References


Backup - Example

Mars Exploration Rover

IEEE SMC'05
High Gain Antenna Pointing on MER
IEEE SMC'05
High Gain Antenna Pointing on MER
High Gain Antenna Pointing on MER

IEEE SMC’05

Crude mapping of PMA RFI
Sun, Earth plotting, with future trajectory
(Note earth obscured by PMA)
HGA hardstop limits for each HGA pointing solution ("branch")
HGA boresight and gimbal angles
Attitude knowledge

Times in all the useful timebases