NPOESS Direct Readout
HRD / LRD RF link Characteristics

Direct Read Out Users Forum

March 2008

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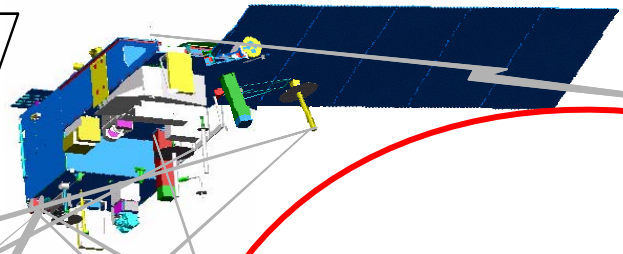
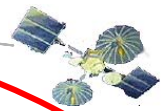
NPOESS RF Overview





TDRS

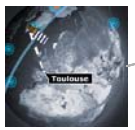
A-DCS Link

Low Data Rate
399.9-400.05 and 401-403 MHz U/L
465.9875 MHz D/L

Command & Telemetry
2106.4/2287.5 MHz
Cmd: 250,500,1 or 2 kbps
Tlm: 1 or 4 kbps

LRD Downlink
Low Rate Data
1707 MHz, 7.76 Mbps

HRD Downlink
High Rate Data
7834 MHz, 40 Mbps



SMD Downlink
High Data Rate
26.7 GHz, 300 Mbps

NGN
Command & Telemetry
2106.4/2287.5 MHz
Cmd:4 kbps or 256 kbps
Tlm LEO&A: 1 or 4 kbps
Tlm Normal: 65 or 524 kbps

Wideband ground communications

SARSAT Link
Low Data Rate
1544.5 MHz D/L. 2.4kbps
406.05 MHz U/L

SafetyNet Receptors

C3S

Svalbard, Norway
Primary T&C

LRD FTS Sites

HRD FTS Sites

Data Rates

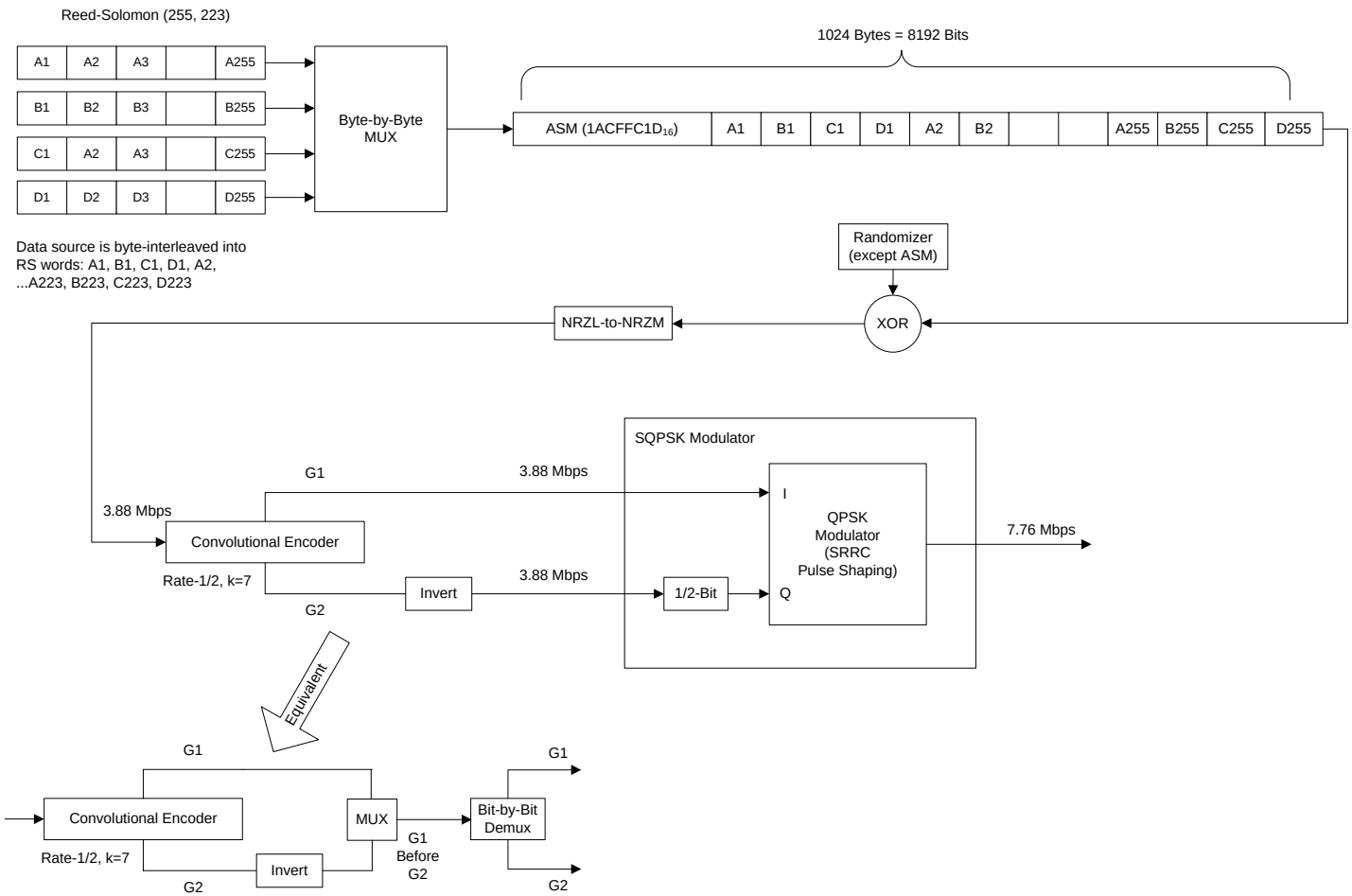
Link	Information Data Rate Prior to CCSDS ASM & FEC Coding (Mbps)	Data Rate After CCSDS ASM & FEC Coding (Mbps)	Signaling Rate with SQPSK Modulation (Mbps)
LRD	3.38	7.76	3.88
HRD	17.42	40.00	20.00

LRD Link Characteristics

Parameter	NPOESS Value
Carrier Frequency	1707 MHz
Maximum Occupied Bandwidth	6 MHz
Information Rate	3.380 Mbps without CCSDS ASM & FEC coding
Coding	(255, 223) Reed Solomon with I=4 Convolutional, R=1/2
Data Format	NRZ-M (Prior to convolutional encoder)
Randomization	$h(x) = x^8 + x^7 + x^5 + x^3 + 1$
Modulation with bit interleaving	SQPSK with square root raised cosine pulse shaping [alpha = 0.5]
Channel Data Rate	7.76 Mbps after coding (i.e., 3.88 Msps)
Polarization	RHCP
Minimum elevation angle	5.0 degrees
Minimum Signal Power at ground	See subsequent slide
Incident Axial Ratio	See subsequent slide
Nominal Ground Aperture Size	1.0 meter
BER after decoding	$\leq 10^{-8}$
Ideal Required Eb/No	2.62 dB
Worst Case Link Availability, using ITU-R P.618-8 orbit-averaging*	99.9%

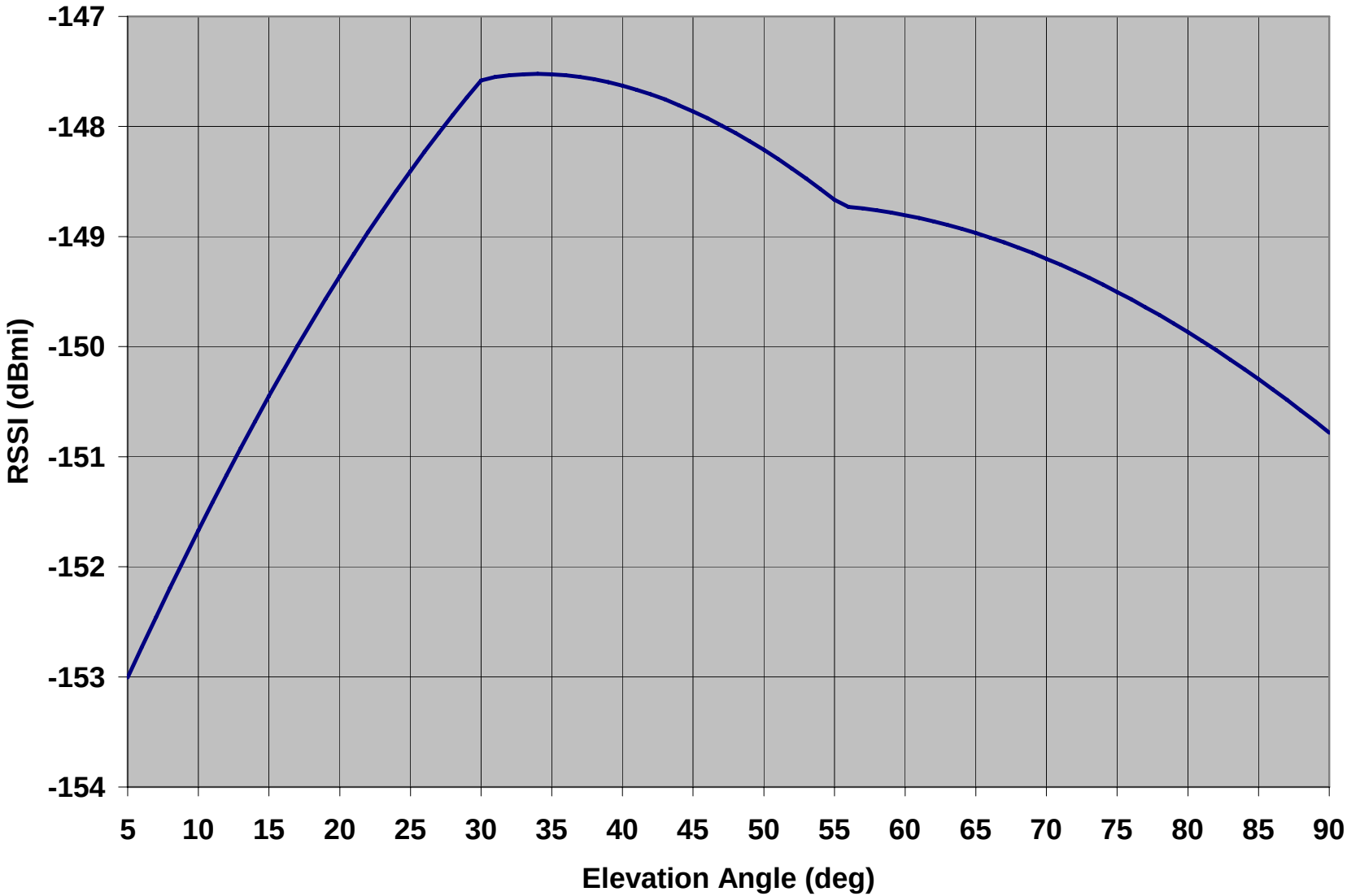
* Orbit-averaged availability shall be verified by analysis at the worst case location (latitude of 4.5 deg, N and a longitude of 78.0 deg, W), excluding ionospheric scintillation, using the method described in paragraphs 2.5 and 8 of ITU-R Recommendation P.618-8 using a reference ground terminal G/T of -1.0 dBi/K, an ideal ground terminal receiver, antenna diameter of 1 m, and ground terminal axial ratio of 2 dB.

LRD CCSDS & Error Correction Encoding



Min LRD Clear Air RSSI vs. Elevation Angle

Spec Antenna Pattern

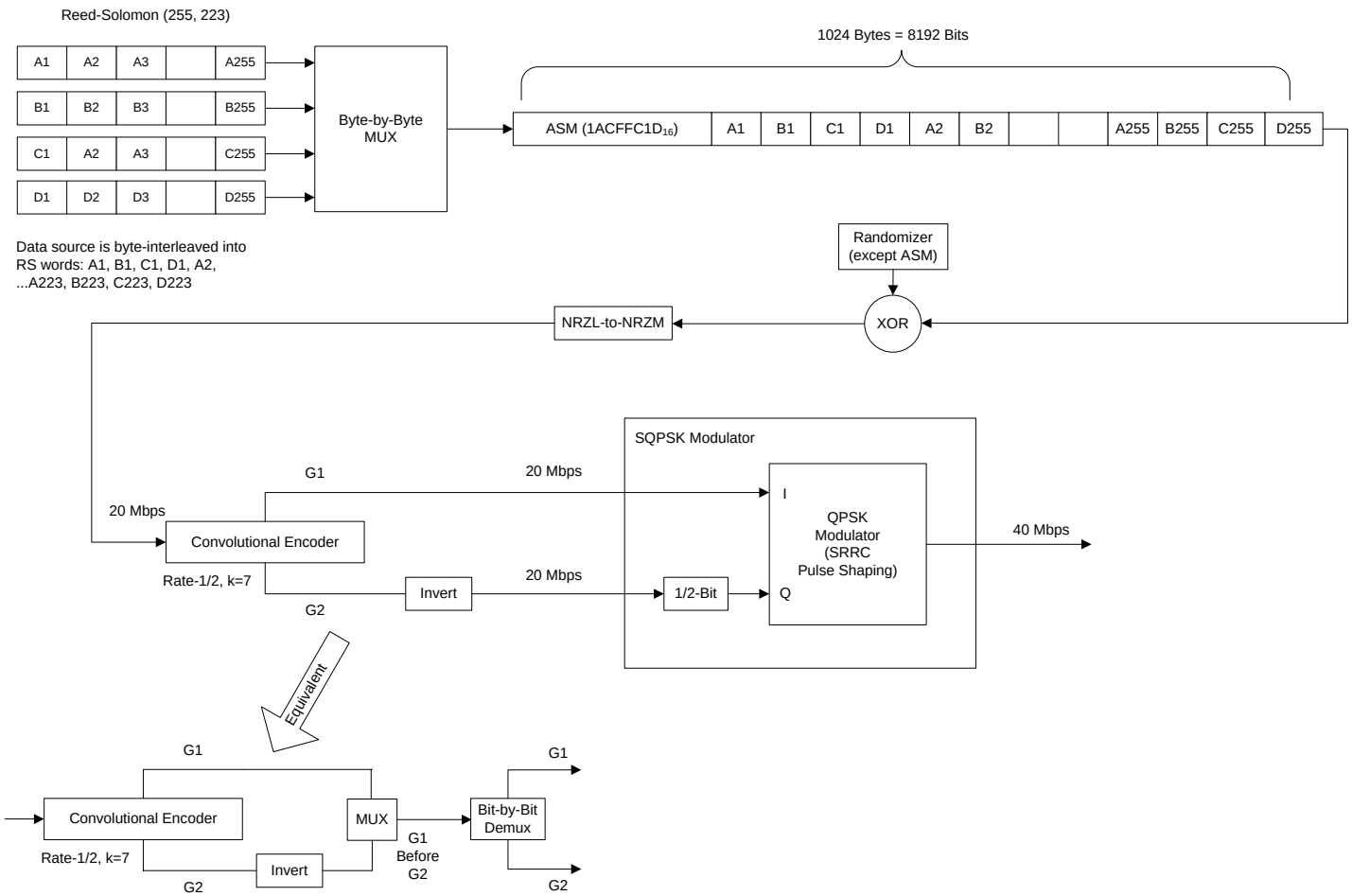


HRD Link Characteristics

Parameter	NPOESS Value
Carrier Frequency	7834 MHz
Maximum Occupied Bandwidth	30.8 MHz
Information Rate	17.422 Mbps without CCSDS ASM & FEC coding
Coding	(255, 223) Reed Solomon with I=4 Convolutional, R=1/2
Data Format	NRZ-M (Prior to convolutional encoder)
Randomization	$h(x) = x^8 + x^7 + x^5 + x^3 + 1$
Modulation with bit interleaving	SQPSK with square root raised cosine pulse shaping [alpha = 0.5]
Channel Data Rate	40 Mbps after coding (i.e., 20 Msps)
Polarization	RHCP
Minimum elevation angle	5.0 degrees
Minimum Signal Power at ground	See subsequent slide
Incident Axial Ratio	See subsequent slide
Nominal Ground Aperture Size	2.0 meters
BER after decoding	$\leq 10^{-8}$
Ideal Required E_b/N_o	2.62 dB
Worst Case Link Availability, using ITU-R P.618-8 orbit-averaging*	99.6%

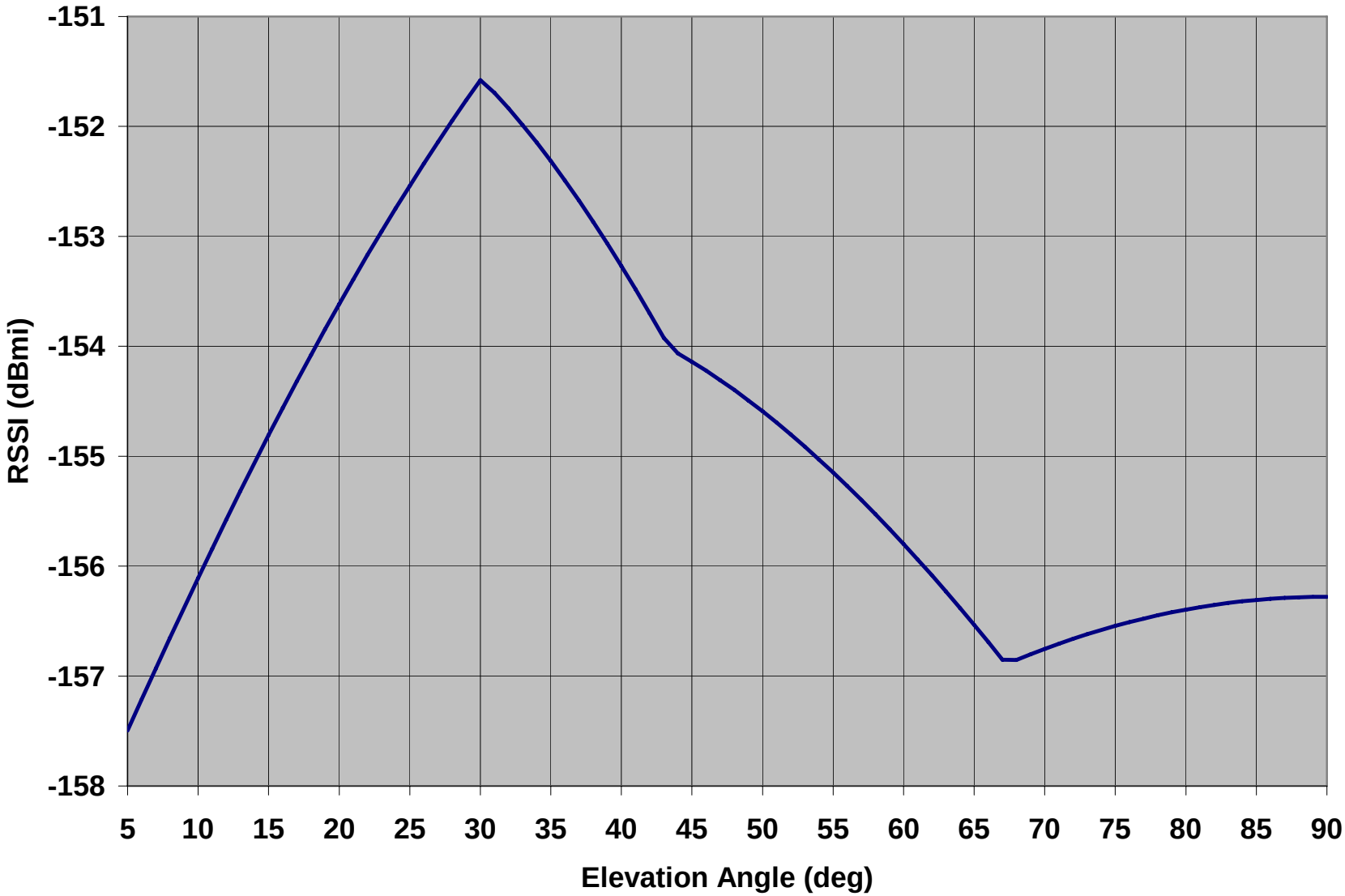
* NPOESS Orbit-averaged availability shall be verified by analysis at the worst case rain fade location (latitude of 4.5 deg, N and a longitude of 169.5 deg, E) using the method described in paragraphs 2.5 and 8 of ITU-R Recommendation P.618-8 using a reference ground terminal G/T of 17.2 dBi/K, an ideal ground terminal receiver, antenna diameter of 2 m, and ground terminal axial ratio of 2 dB.

HRD CCSDS & Error Correction Encoding



Min HRD Clear Air RSSI vs. Elevation Angle

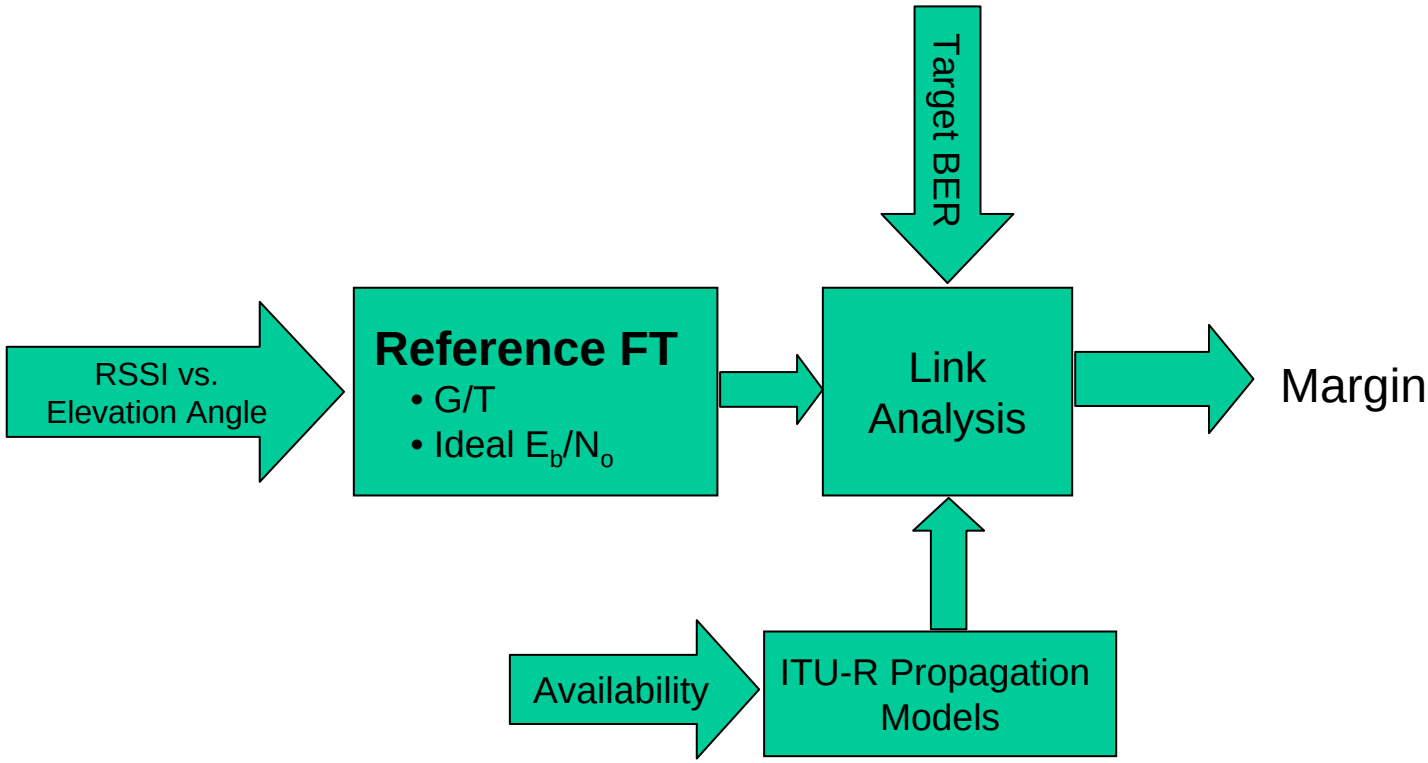
Spec Antenna Pattern



LRD and HRD Link Specifications

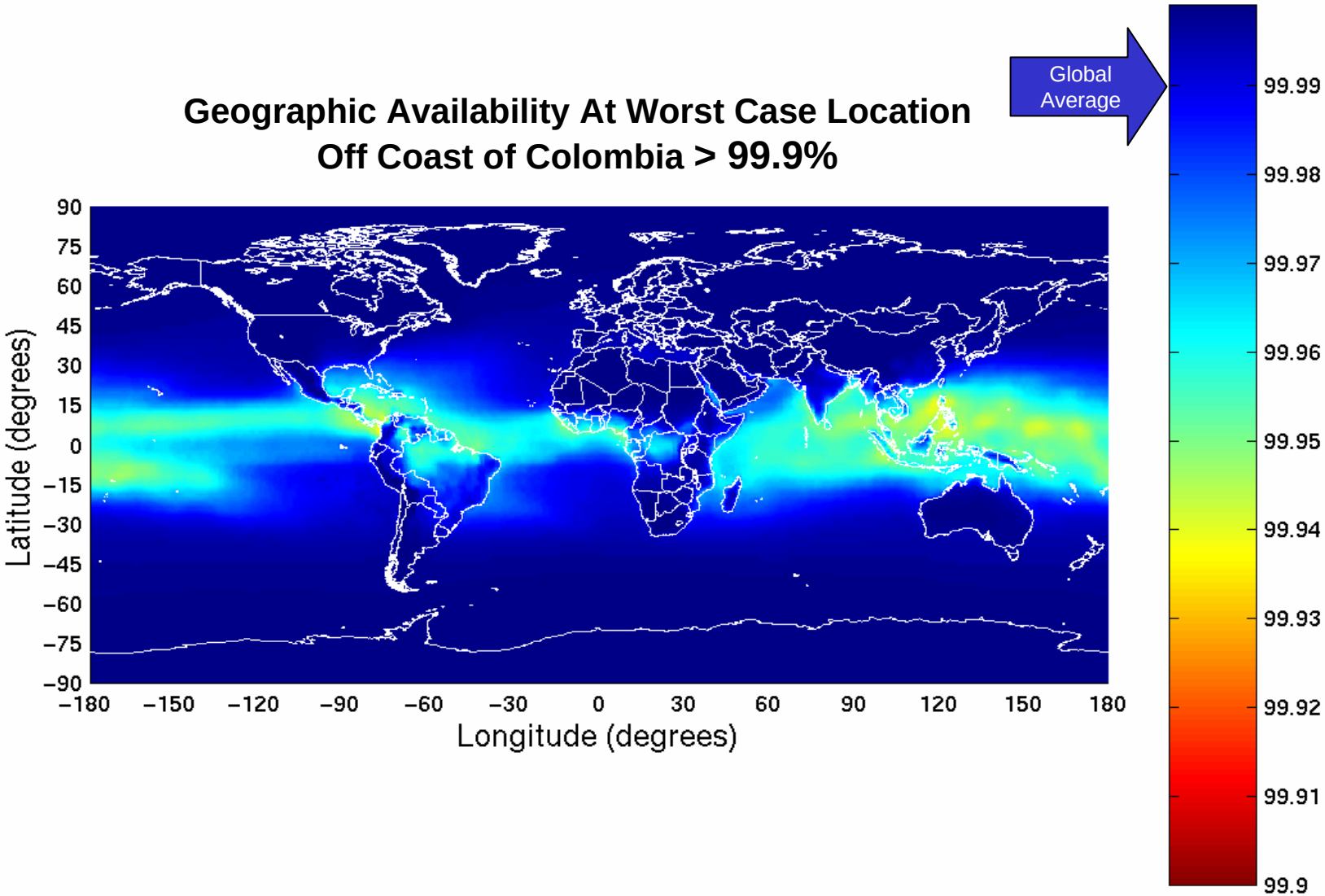
- Specified in terms of orbit-averaged availability (availability at each elevation angle weighted by probability of being at each elevation angle
  - LRD availability does not include ionospheric scintillation, which can be severe in the evening near the equator during the sunspot maximum
- Reference field terminal defined for the purpose of evaluating orbit-averaged availability requirement (real FT may be different)
  - G/T
    - LRD: -1.0 dB/K
    - HRD: 17.2 dB/K
  - Ideal ground terminal receiver (i.e., no implementation loss)
  - Antenna diameter
    - LRD: 1 m
    - HRD: 2 m
  - Axial ratio of 2 dB
- ITU-R Propagation Prediction Method
  - Gas (oxygen & water vapor), cloud, scintillation, rain losses

Reference Field Terminal Usage



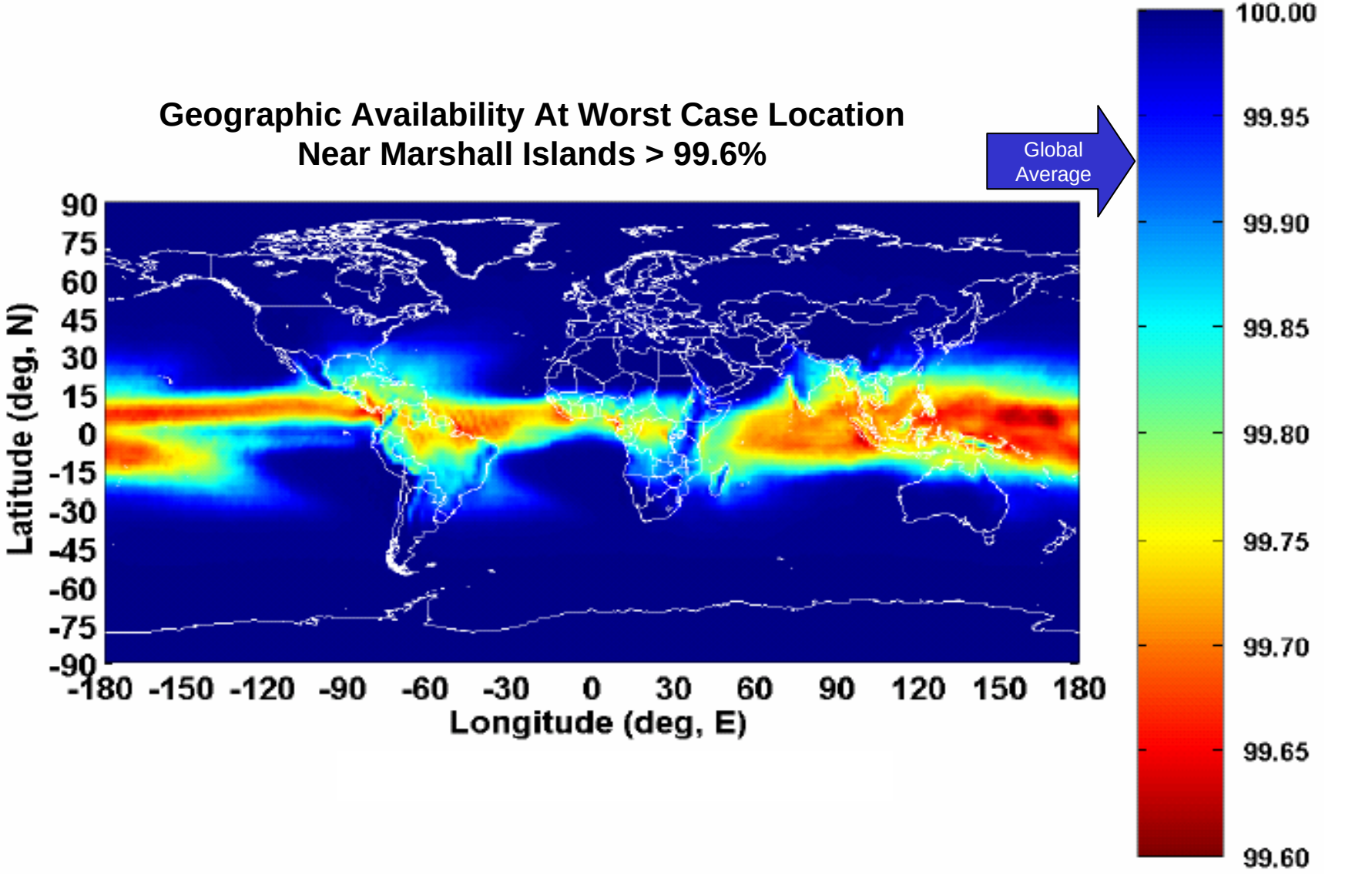
Orbit-Average Availability Calculates the Availability That Zeroes the Margin at Each Elevation Angle and Weights the Availabilities by the Probability of Being at Each Elevation Angle

LRD Orbit-Averaged Availability

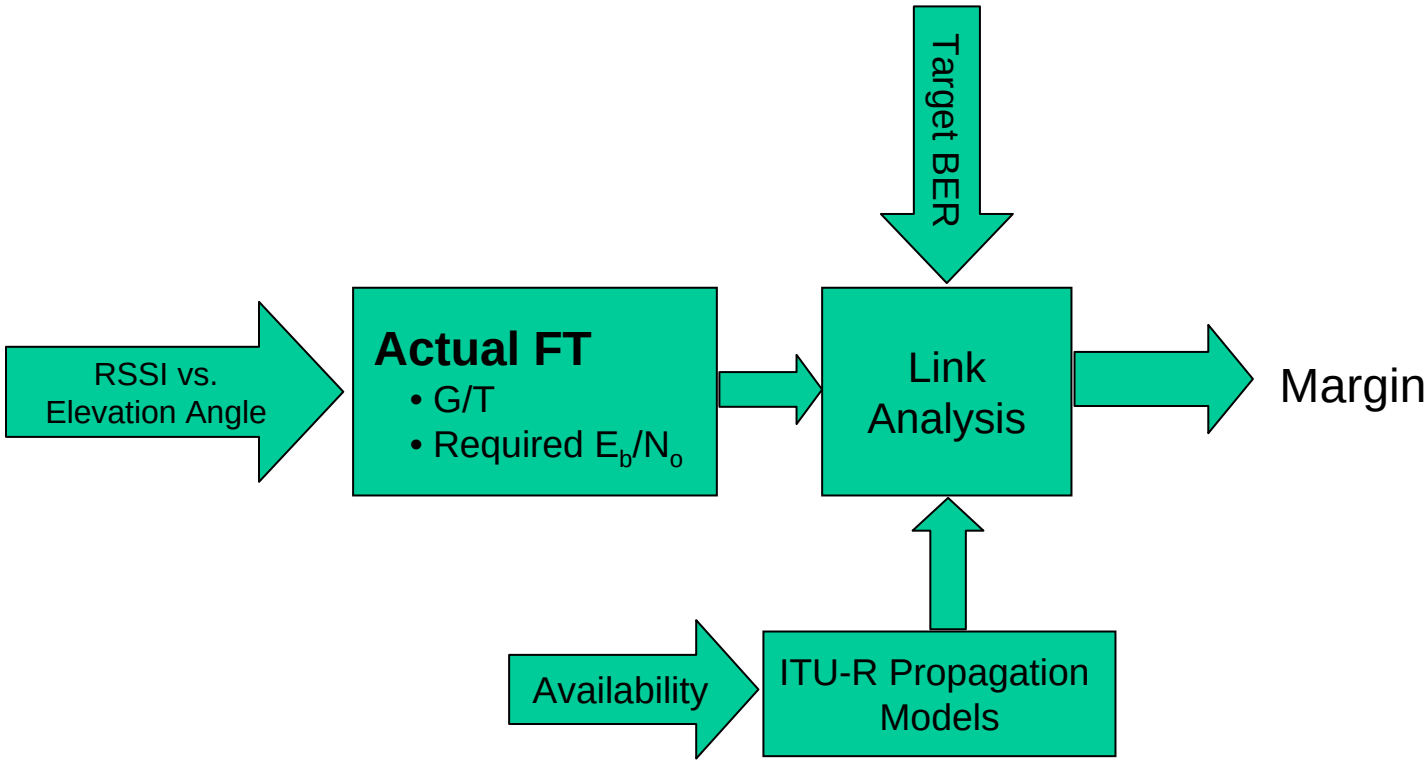


HRD Orbit-Averaged Availability

Geographic Availability At Worst Case Location
Near Marshall Islands > 99.6%



Actual Field Terminal

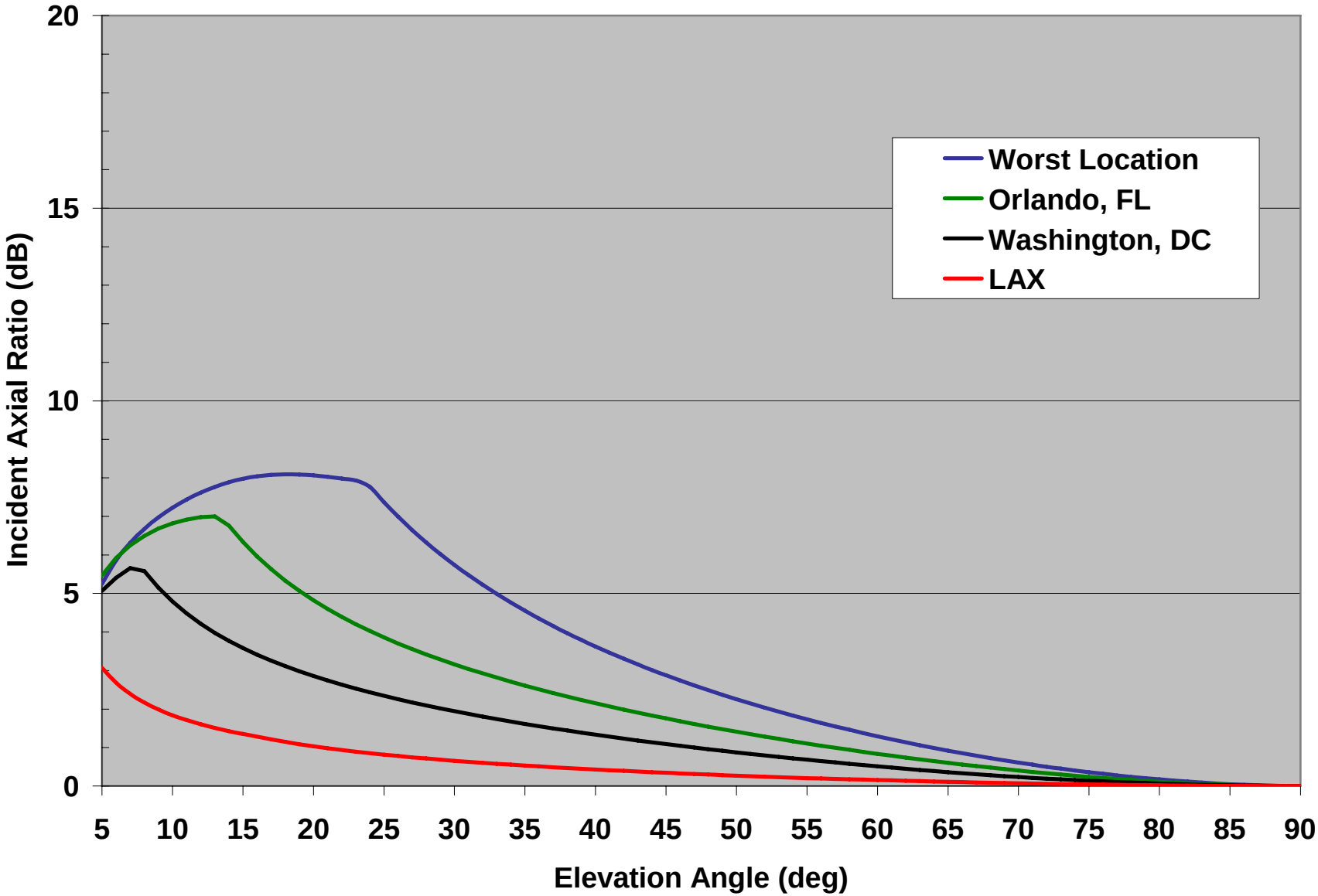


Field Terminal Supplier Can Select the FT Implementation that Results in the Desired Orbit-Average Availability for a Particular Location or Set of Locations

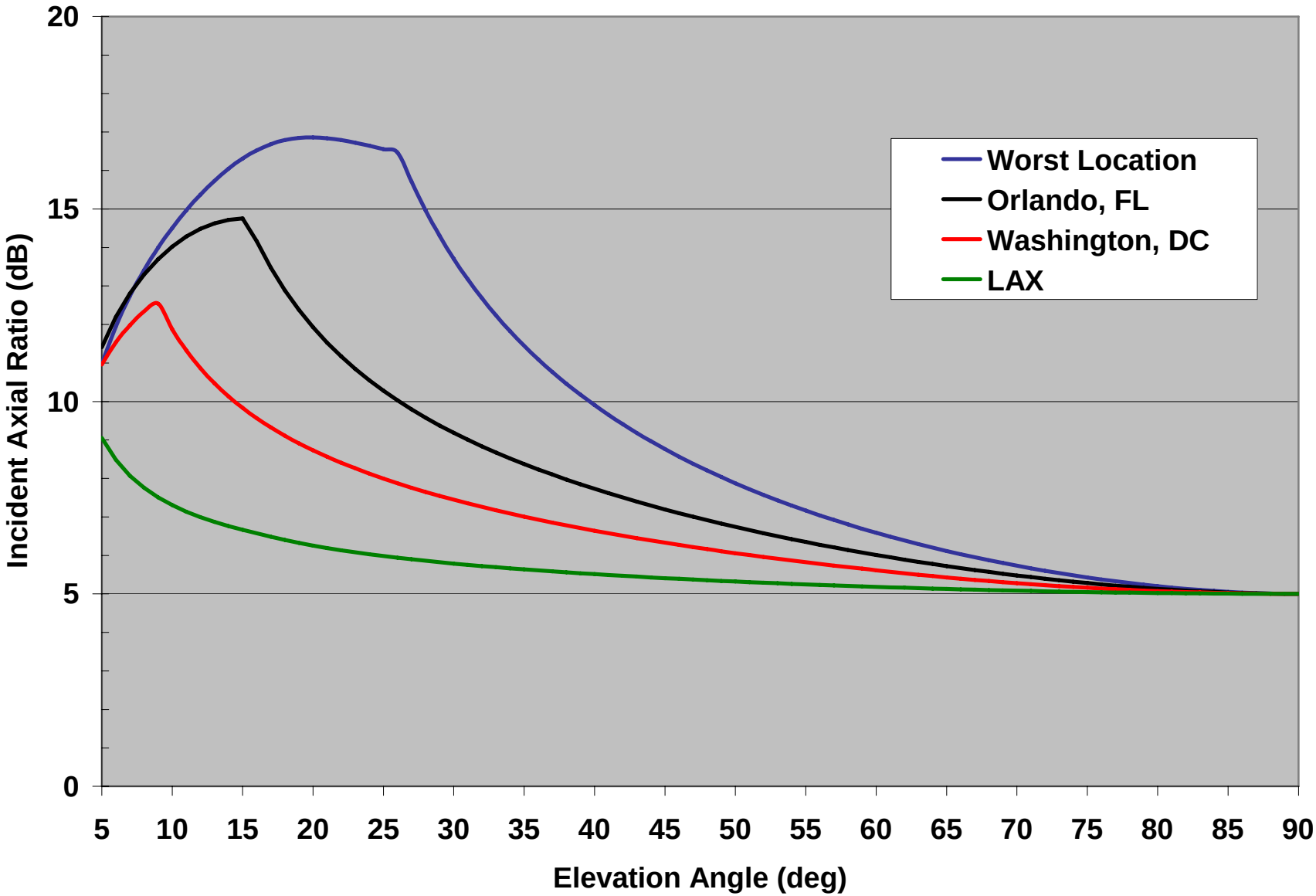
HRD Incident Axial Ratio

- Depending on the tracking method, the incident axial ratio may be important to the field terminal
- Incident axial ratio is a function of:
  - Free space axial ratio of spacecraft antenna
  - Spacecraft scattering
  - Atmospheric depolarization
- Free Space Axial Ratio of Spacecraft Antenna
  - ~5 dB due to physics of Earth-coverage antenna
- Spacecraft Scattering
  - Analysis in process. Sidelobes will be tailored as good as possible to minimize polarization distortion
- Atmospheric Depolarization
  - Due to oblate spheroidal raindrops
  - Modeled using ITU-R prediction methods (depends on location, probability of occurrence, and elevation angle) at the faded limit

HRD Incident Axial Ratio Assuming Perfect SC Antenna



HRD Incident Axial Ratio Assuming Realizable SC Antenna with No Spacecraft Scattering



Incident Signal Characteristics

- RSSIs vs. elevation angle are preliminary pending award of spacecraft antenna contracts and definitization of spacecraft scattering analysis
- Incident axial ratios due to combination of spacecraft antenna axial ratio, spacecraft scattering, and depolarization due to rain is likely to exceed 10 dB
- Spacecraft scattering analysis is in process and will degrade incident axial ratio. Expect to do as well as physically feasible
- Suggest that, if possible, HRD FTs use program track rather than autotrack