# Modeling & Simulation of FIS-B on the ADS-B Candidate Links

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# FIS-B and ADS-B

- Flight Information Service - Broadcast is data that will be delivered to aircraft to assist flight operations
  - Content of data not fully determined – likely to include weather information and NAS Status
- Automatic Dependent Surveillance - Broadcast is a network of transceivers periodically broadcasting state vector and other information
- ADS-B Candidate Systems
  - VHF Data Link, Mode 4 (VDL Mode 4)
  - 1090 Mode-S Extended Squitter (1090ES)
  - Universal Access Transceiver (UAT)

# TLAT Assumptions

- Starting point for model is ADS-B Technical Link Assessment Team (TLAT)
  - LA Basin traffic model scaled for 2007
    - Air traffic affects 1090 ES – no protected transmissions
    - Ground broadcast segment on VDL4 and UAT with 7-cell slotted reuse pattern
  - Hex. grid of ground stations with 60 nmi inter-site spacing (120 nmi also simulated)
  - Uplink Rates

    VDL4 - 4 / second  1090ES - 10 / second

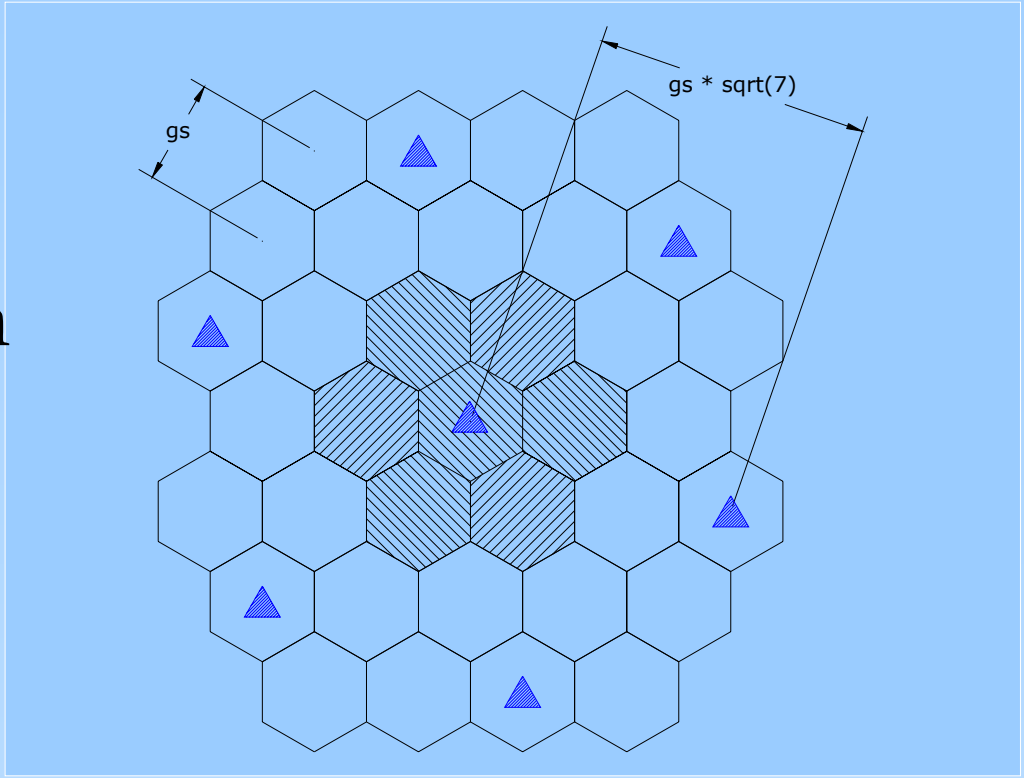
    UAT - 4 / second

# Assumptions

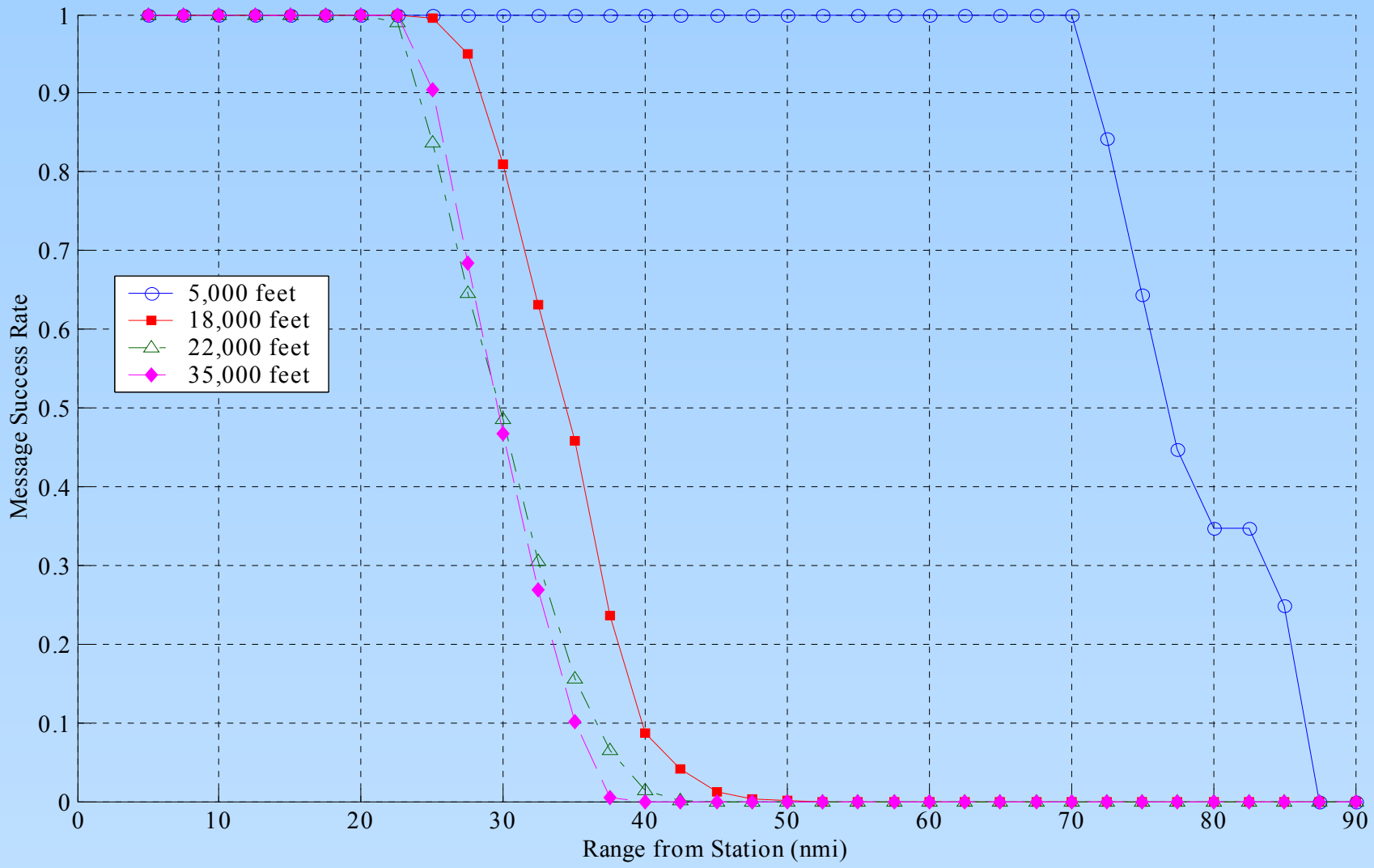
- 4 representative receivers examined
  - A0 receiver at 5,000 feet
  - A1 receiver at 18,000 feet
  - A2 receiver at 23,000 feet
  - A3 receiver at 35,000 feet
- Metric – average time to receive arbitrarily sized products
- FIS-B Product Size is undetermined

# FIS-B on VDL Mode 4

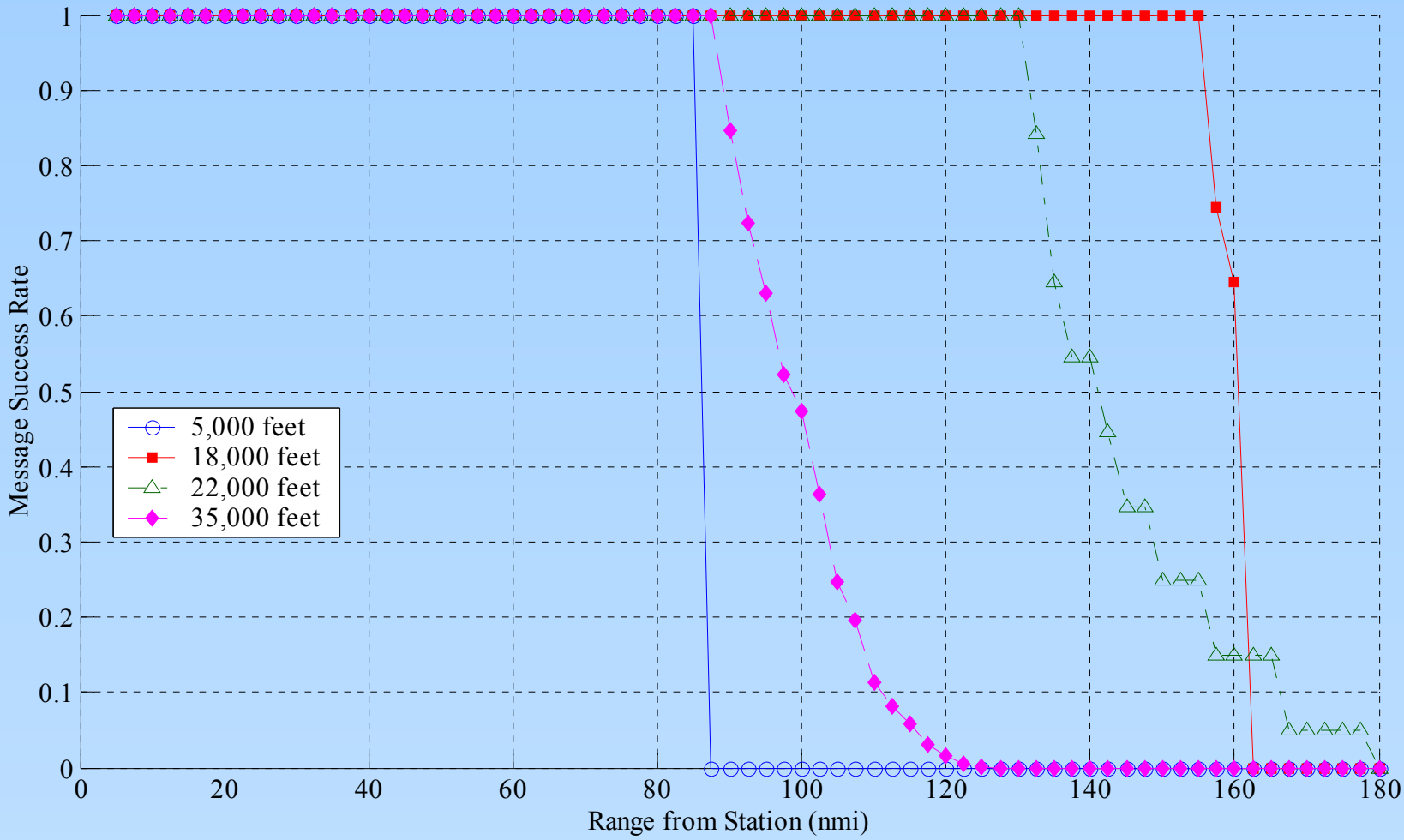
- Uplink in dedicated ground slots
- 7-cell reuse pattern
- Interference is only other VDL4 ground transmitters



# VDL Mode 4 Simulation Results for 60 nmi grid



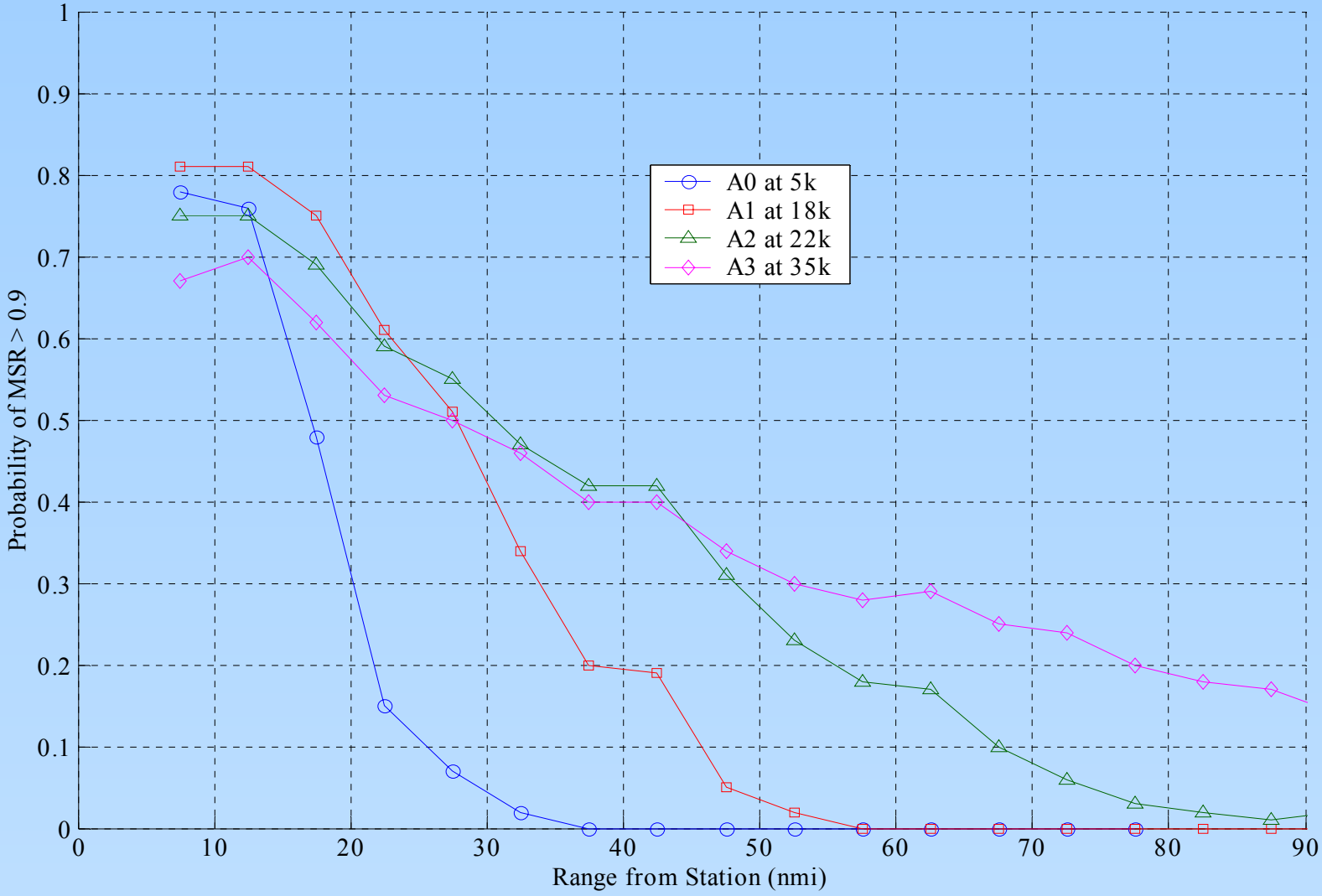
# VDL Mode 4 Simulation Results for 120 nmi grid



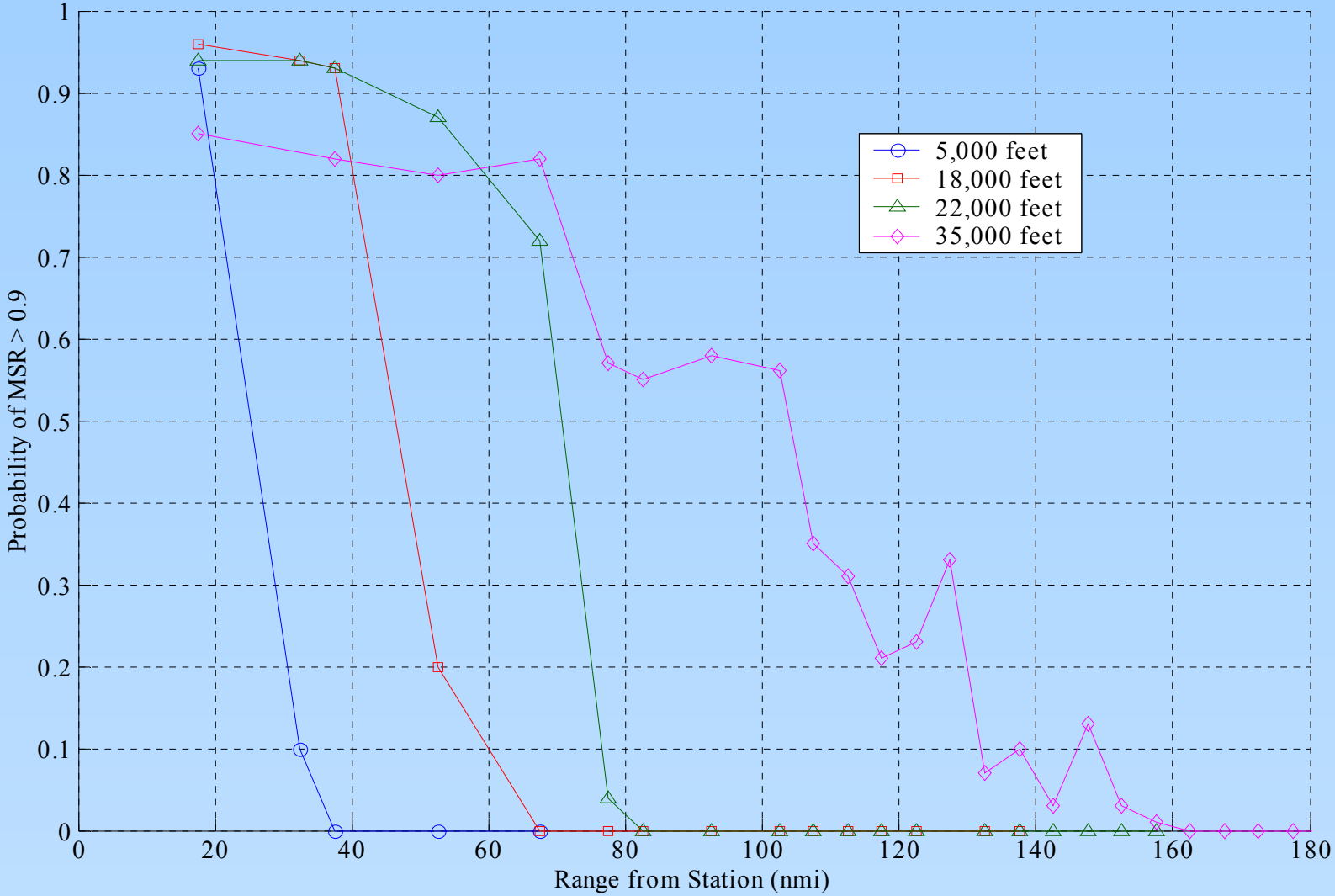
# FIS-B on Extended Squitter

- Random Access Transmissions – no reuse
- 10 FIS-B squitters per second per ground station (100 Squitters was also simulated)
- Sources of Interference
  - Extended squitter GBTs
  - ATCRBS, Mode S, and TCAS replies
  - ADS-B messages
  - Co-site transmissions - DME, ATCRBS, TCAS, Mode S

# Extended Squitter Simulation Results for 60 nmi Grid – No Repeats



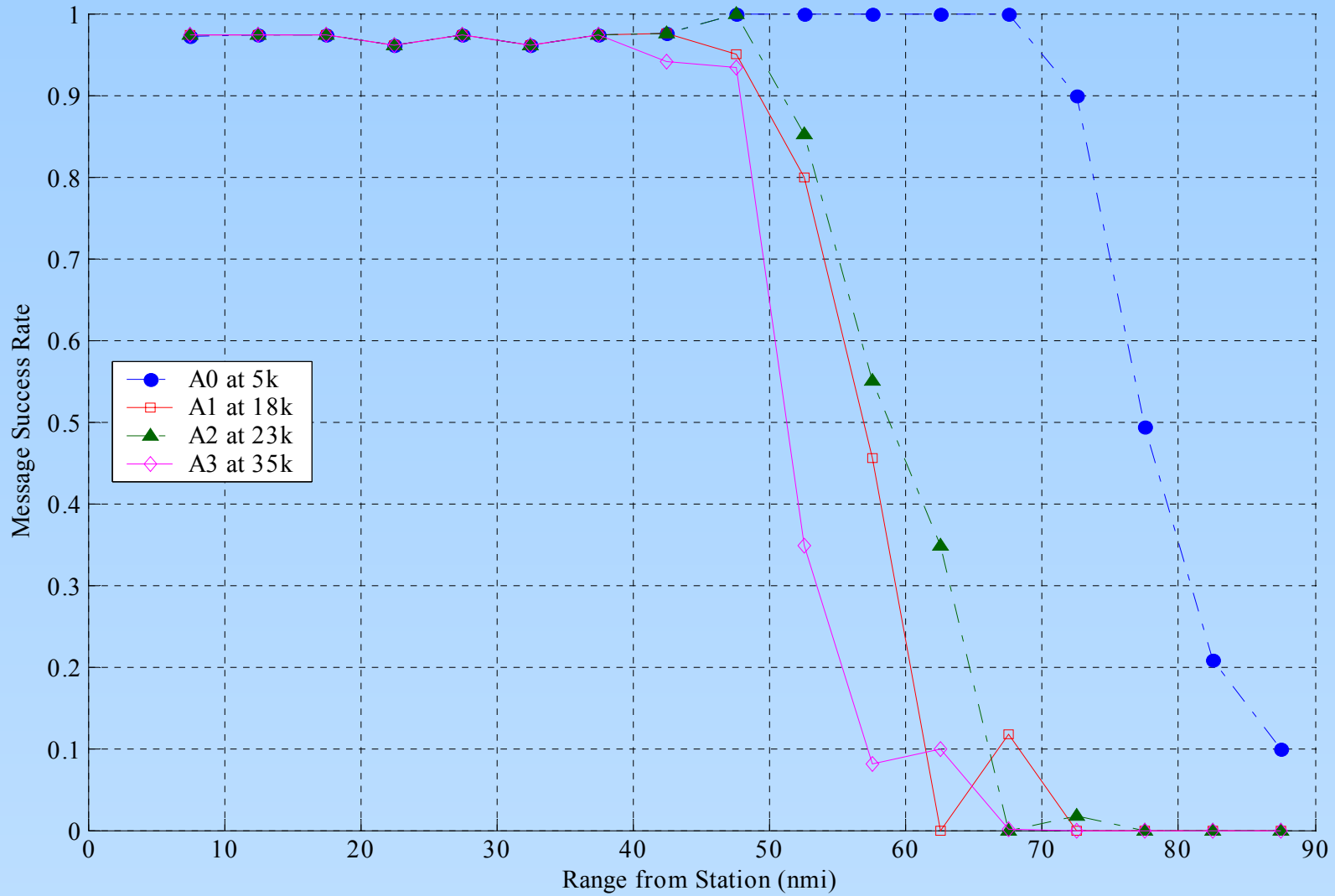
# Extended Squitter Simulation Results for 120 nmi Grid – No Repeats



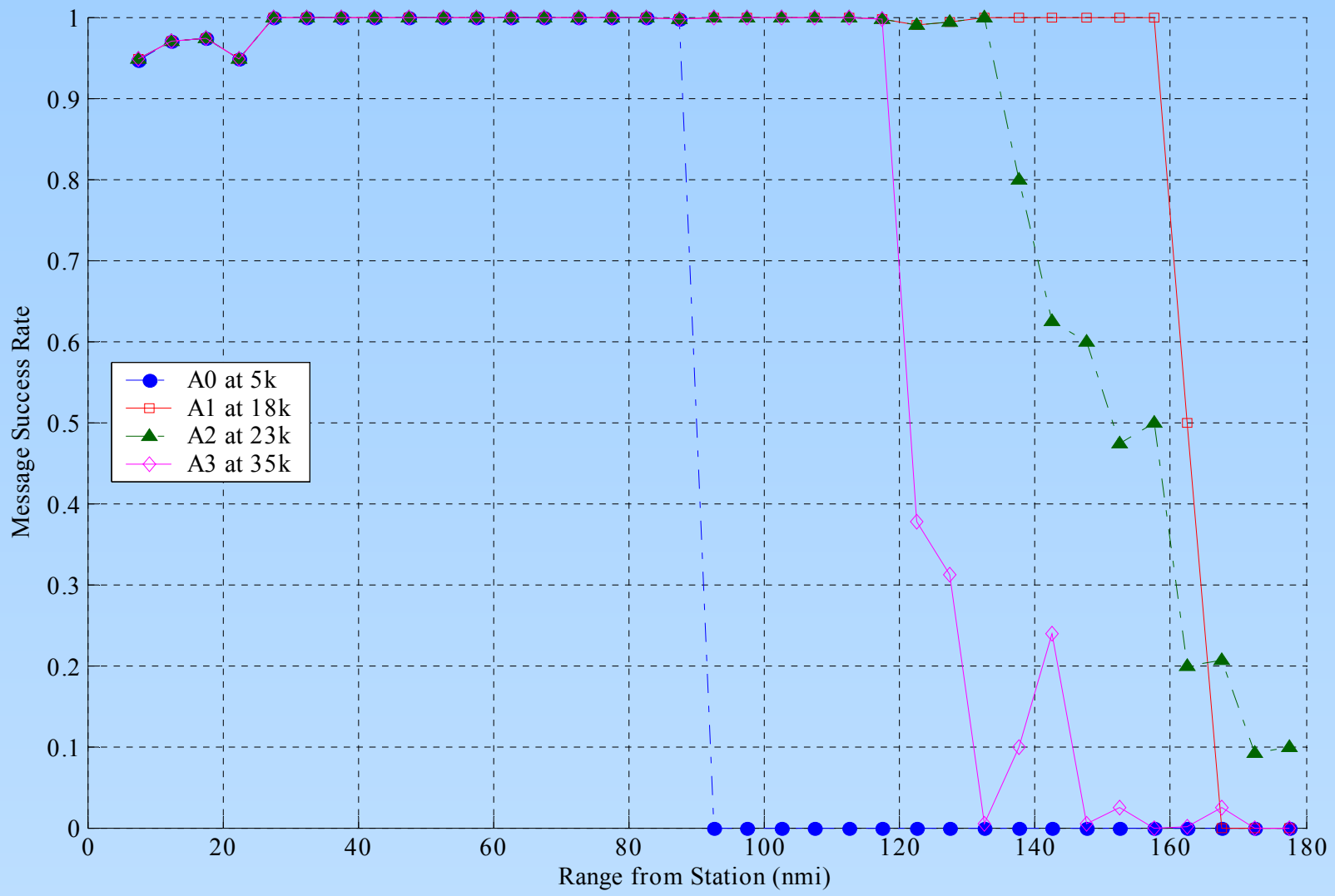
# FIS-B on UAT

- Uplink occurs in protected time, no ADS-B interference
- Interleaved Reed-Solomon (92,72) encoding
- 3.2 kbit data in uplink message
- Sources of Interference
  - Other UAT GBTs
  - Co-site transmissions (on-board DME, ATCRBS, TCAS, Mode S)

# UAT Simulation Results for a 60 nmi grid



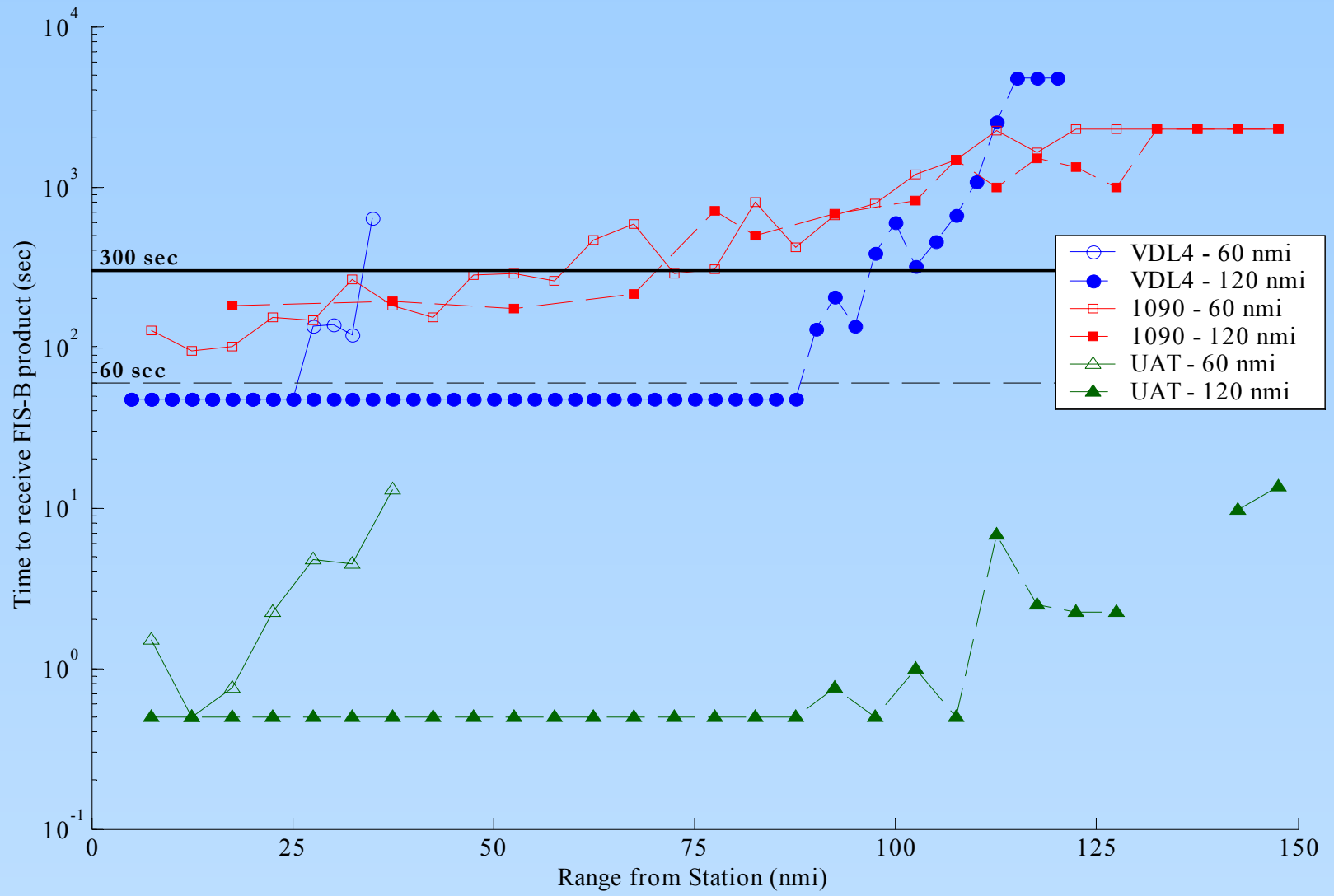
# UAT Simulation Results for a 120 nmi grid



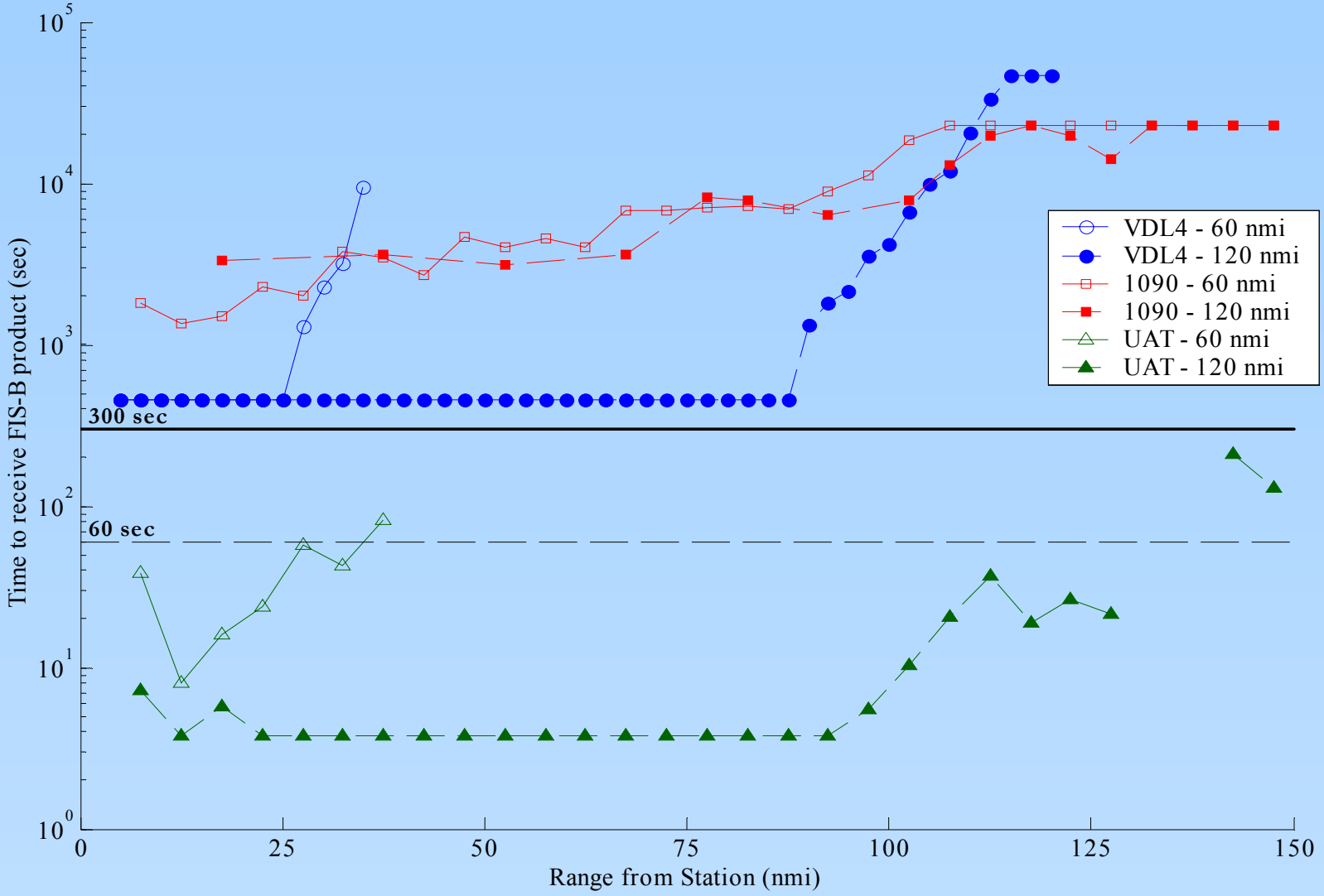
# Raw Bandwidth

| System | Messages /sec | Data bits | Uplinked bps |
|---|---|---|---|
| VDL4 | 4 | 152 | 608 |
| 1090ES | 10 (100) | 56 | 560 (5600) |
| UAT | 4 | 3184 | 12736 |

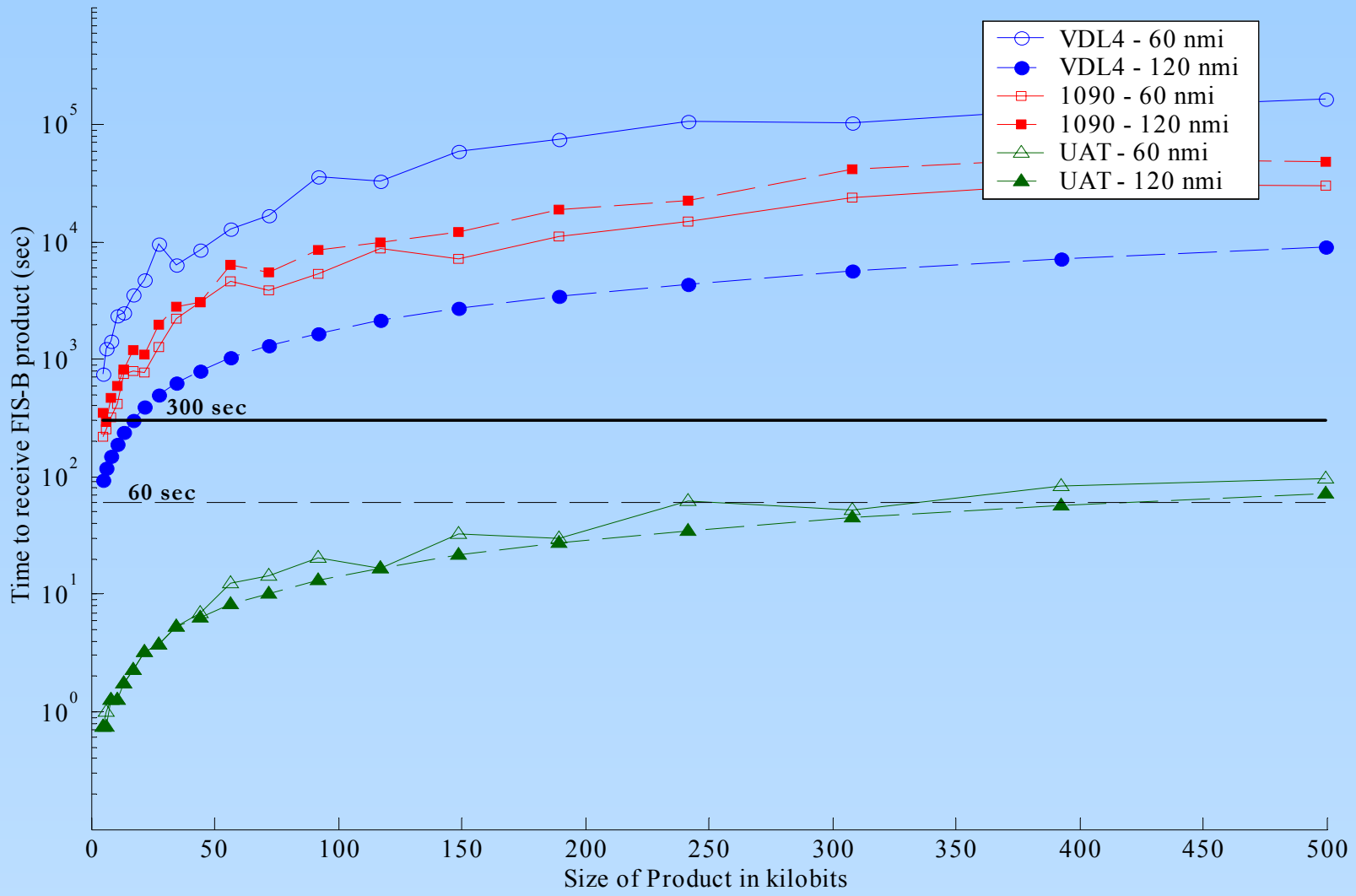
# Average Time for A3 at 35,000 feet to Receive 5 kbit



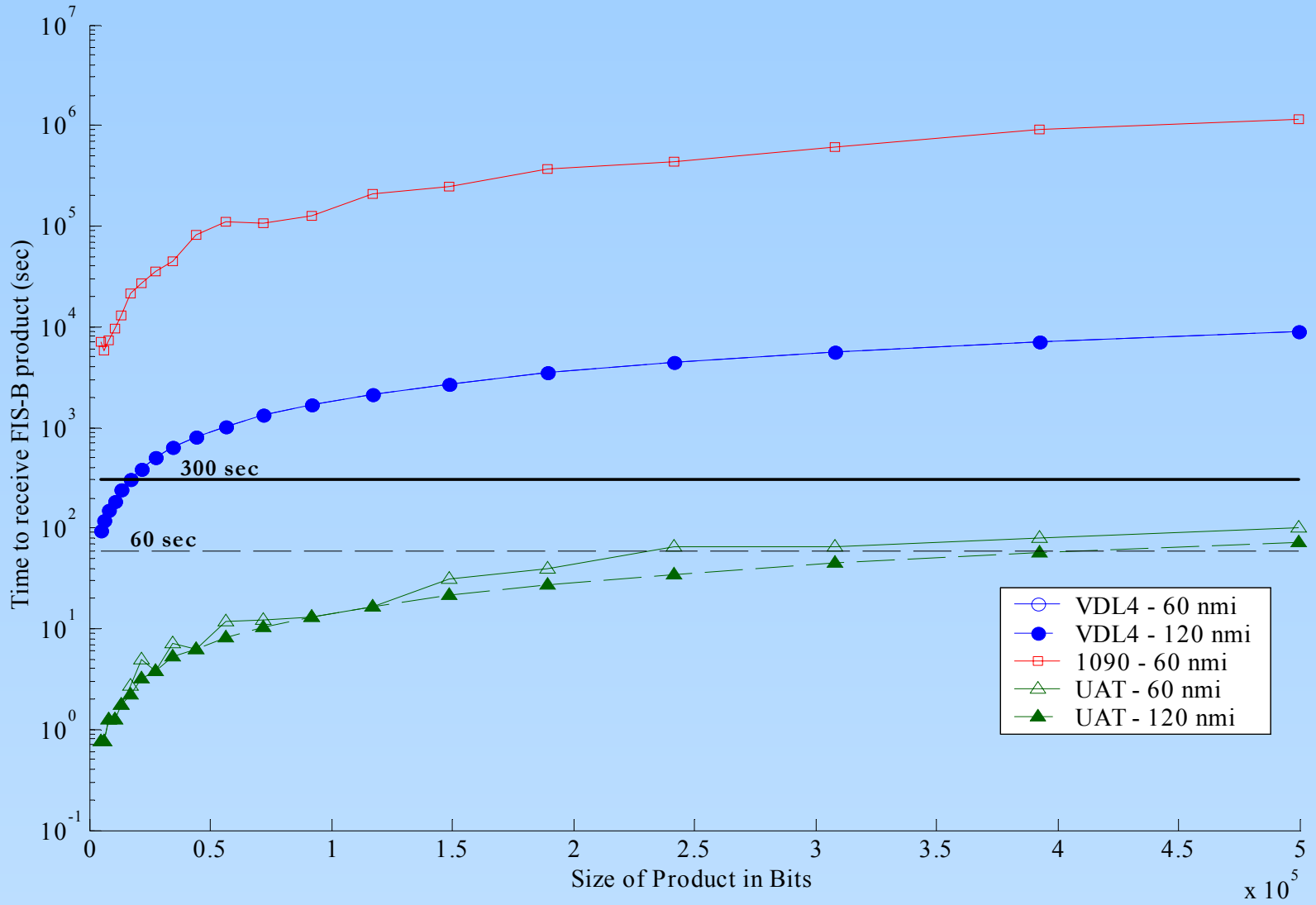
# Average Time for A3 at 35,000 feet to Receive 50 kbit



# Average Time for A3 at 35kft to Receive Data at Max. Range



# Average Time for A0 at 5kft to Receive Data at Max. Range



# Unique Data Received in 5 Minutes (kbits)

| Receiver | VDL Mode 4 | | 1090 ES | | UAT | |
|---|---|---|---|---|---|---|
| | 60 nmi | 120 nmi | 60 nmi | 120 nmi | 60 nmi | 120 nmi |
| A0 | 26 | 26 | - | - | 1680 | 3820 |
| A1 | 7.8 | 26 | 280 | - | 1520 | 3820 |
| A2 | 5 | 26 | 580 | 70 | 1650 | 3820 |
| A3 | 4 | 26 | 580 | 250 | 1500 | 3820 |

# Limitations

- Practical considerations will drive ground station locations - could be better, unlikely to be worse
- No service volumes
- Each system has room to be optimized
- FIS-B products & architecture is undetermined

# Findings

- VDL4 has high MSR, but low bandwidth for uplink
- 1090 ES has low MSR, but high uplink rates
- UAT appears to have greatest capacity for FIS-B uplink – high MSR x high bandwidth
- Time to deliver FIS-B data scales with size of the product for all three links
- Future Work
  - Simulating realistic ground station deployments
  - Engineering appropriate service volumes
  - Specifying FIS-B products and architecture