

FIS-B Service on 1090 MHz

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Topics

- **FIS-B Overview**
- **FIS-B broadcast encoding on 1090 MHz**
- **Sample encoding of recorded weather images**
- **Results of uplink squitter reception performance in LA Basin**
- **Link loading estimates**
- **Summary**



FIS-B Overview

- **FIS-B uses uplink broadcast technique to provide aviation related information to users, e.g.,**
 - Graphical weather, ATIS, wind shear alerts
- **FIS-B application is independent of the ADS-B function**
 - However, user advantage if ADS-B receiver can also be used for FIS-B
- **Provision of FIS-B via extended squitter requires**
 - Efficient coding (especially for graphical weather)
 - Coding algorithm that can tolerate moderate reception probability
 - Sufficient range in high density environments (40 to 80 NM)
 - Acceptable link loading



FIS-B Assumptions

- **FIS-B principally intended for GA aircraft**
- **FIS-B for advisory use only (no guarantee of delivery)**
 - not “real time”
 - not a substitute for airborne sensors, other alerting mechanisms
- **Key parameters:**
 - update rate - 300 seconds
 - range limited to 40 to 80 nmi to ensure low altitude coverage
 - product mix (based on information available now):

1- (512 pixel x 512 pixel) graphical images

720 x 720 NM, 2 km resolution

50,000 bits

ATIS

2000

Windshear alerts

2000

PIREPS/Special Use Airspace (SUA)

1000

Total:

55,000 bits

(About 200 BPS delivered)



Digital ATIS Assumptions

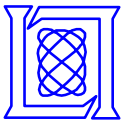
- **Use of standardized word dictionary (DLAC¹) for ATIS encoding**
 - expect to encode single airport information with 200 bits
 - information included:
 - time, altimeter setting, wx, wind direction and velocity, runway arrival and departure information, remarks.
 - Example:**
 - Hanscom information Q, 1945 Zulu, wind 340 at 25 knots gusting 35 knots, ceiling 1500 scattered, 3500 scattered, 7000 broken, altimeter setting 30.24, arrivals may expect hanscom 3 arrival, ils approach to runway 29, departures may expect runway 5, Hanscom 6 departure. Thunderstorms 5 nmi to the southeast of the field. Moderate bird activity all quadrants of the airport. Taxiways delta and echo closed between romeo and mike.**
 - **Up to 10 airports may be included in broadcast loop.**

1. Data Link Application Coding, developed by SICASP. DLAC supports both word and phrase coding.



PIREPS/SUA Assumptions

- **Similar to ATIS, DLAC phrase coding for more efficient coding**
- **Example:**
 - **time/location/altitude/type aircraft/weather report/remarks**
 - **0932Z/5dme northeast of BDR/8500/PA-28/cloud tops 4300, moderate turbulence from grnd to 3500, visibility 5 miles in haze at 8500/lots of buildups to north**



Graphical Image Assumptions

- **Single image may be encode losslessly with 40K-55K bits**
- **Modest (imperceptible) detail suppression allows 25% reduction**
 - **more aggressive filtering yields acceptable images at 50-70% reduction**
- **Image sizes for lossless encoding of actual weather images for 512 by 512 map (720 NM square): 46 to 53k bits**



FIS-B Encoding Algorithm

- **Assumptions:**
 - Broadcast loops are identified by time and location
 - Product is 4 level, 512 x 512 pixel precipitation map
 - Minimum number of “critical” packets (2 packets in baseline) essential for message decode
 - All packets may be decoded independently as long as the header packets are received
 - Partial map may be assembled from the packets that are correctly received and decoded within each broadcast
- **Approach**
 - Encode the 512 x 512 pixel map into 16 SuperPixels, send header packets that include max value in each SuperPixel, Huffman tables, message header information
 - Send subsequent coarse, fine message packets
 - Reconstruct map with header + message packets

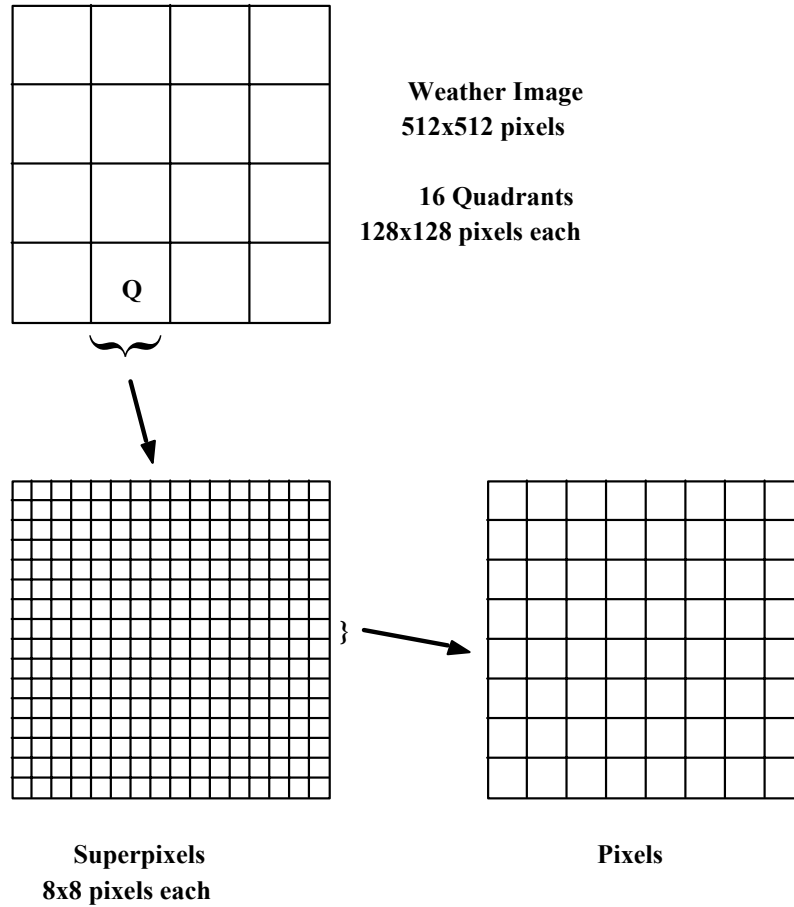


Details of FIS-B encoding algorithm

- **Start with 512 x 512 pixel image**
- **Phase I “Quadrant encoding”:**
 - **Encode maximum value within each of 16, 128x128 “quadrants” into “header squitters”**
- **Phase 2 “Superpixel encoding”:**
 - **Define “8x8 superpixel image” by finding maximum value within each block of 8x8 pixels**
 - **Runlength encode the 8x8 image and send in phase 2 squitters**
 - **4 shifted versions of the 8x8 superpixel image are created and sent to provide redundancy to cover squitter loss**
- **Phase 3 encoding:**
 - **Runlength encode the actual image and send in phase 3 squitters**

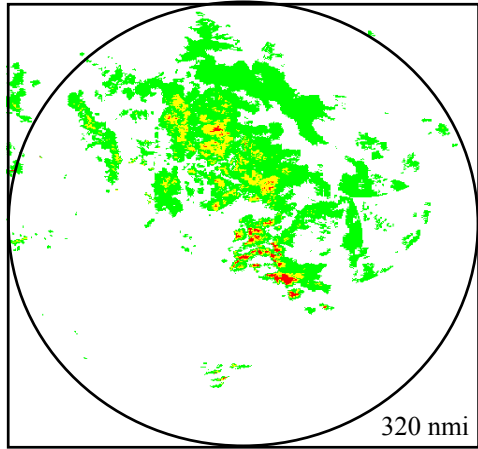


Hierarchy of pixel entities

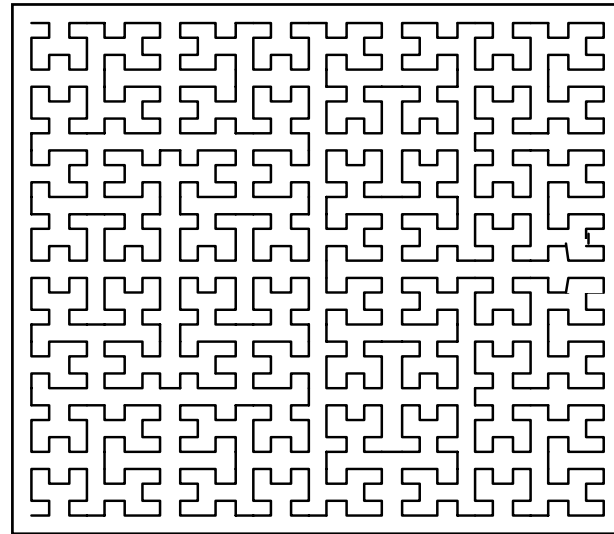




Phases 2 & 3 Encoding Details



Input Weather Image

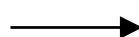


Hilbert Scan Pattern

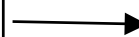
(Start_Pixel_position, Start_Level, runlength, transition, runlength.....)



Define Huffman Tables,
Encode, (using
information from
Quadrant values)



Packetization



Series of RunLength Data Squitters



FIS-B Formats

DF=18 squitter defined for non-transponder services

10010	CF:3	FIS-B Packets:80	PI:24
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CF Field current definition

CF= 0 indicates standard extended squitter formats from a non-transponder device

CF= 1 Reserved

CF= 2 to 4 TIS-B

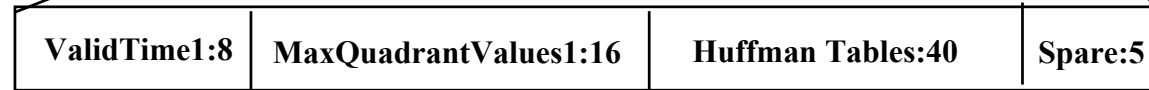
Propose CF = 5 for FIS-B messages



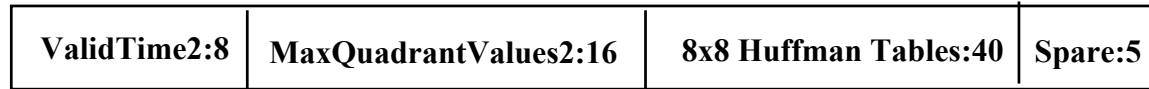
Detailed FIS-B formats



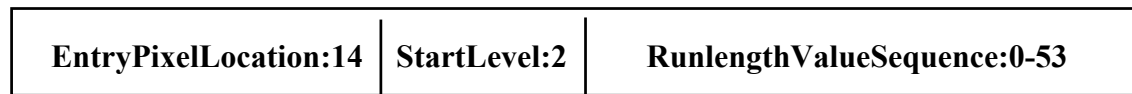
Header Squitter 1



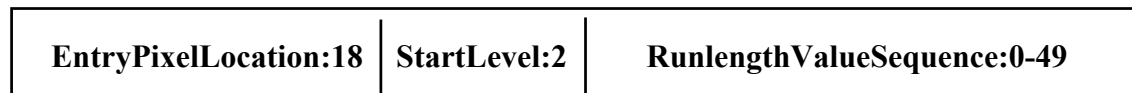
Header Squitter 2



SuperPixel Squitter



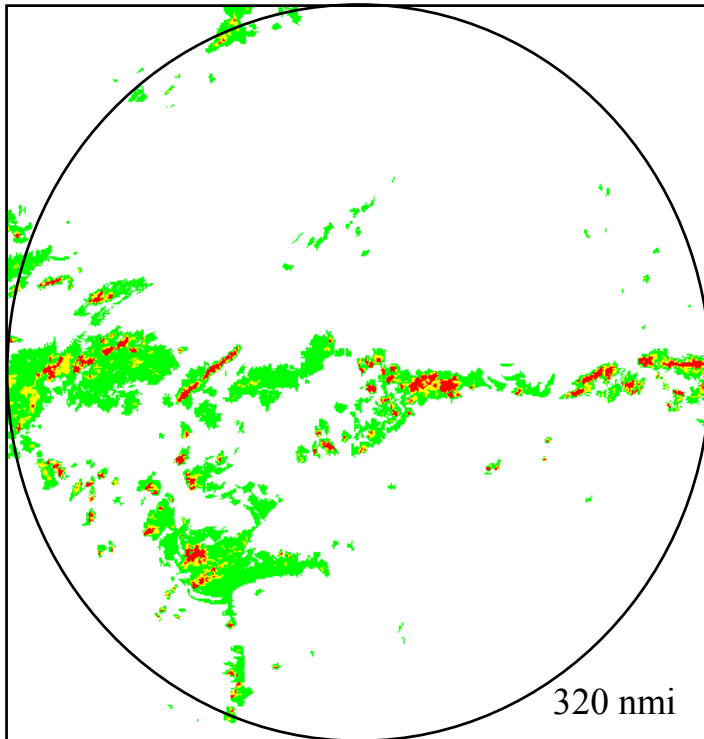
Runlength Squitter



Essential Header Squitters
Data Squitters (independent)



Houston, Texas 1745Z, 15 Jun 99

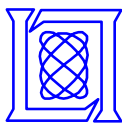


512 x 512 pixel (2 km per pixel)

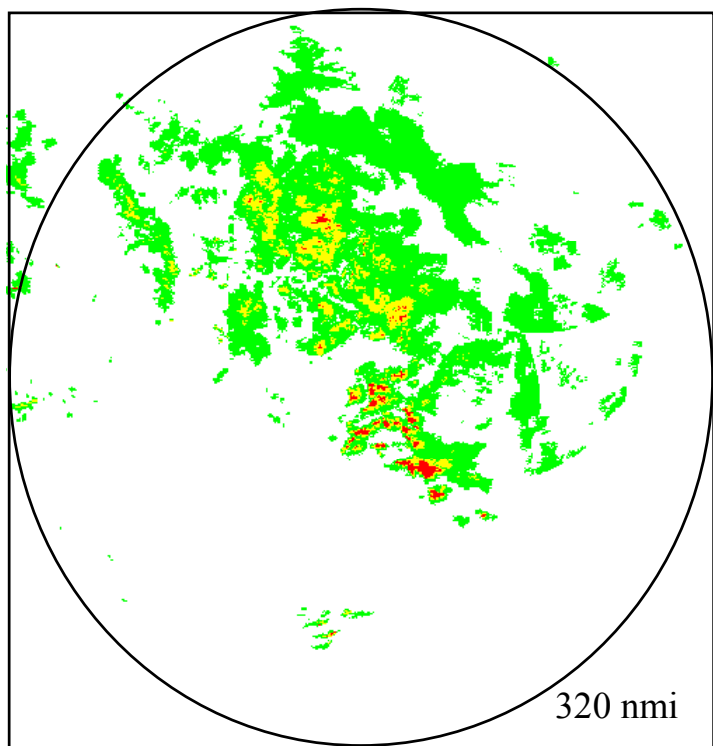
38382 bits for WH lossless encoding

4X59 squitters for SuperPixel encoding

1068 squitters in total FIS-B encoding



Bridgeport, Connecticut, 1415Z 11 May 95



512 x 512 pixel (2 km per pixel)

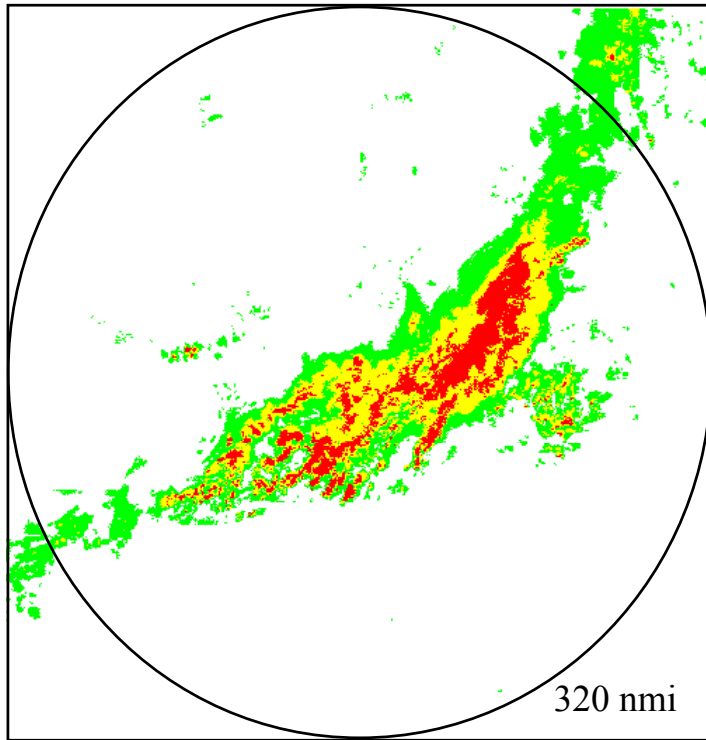
45921 bits for WH lossless encoding

4X32 squitters in SuperPixel encoding

1156 squitters in total FIS-B encoding



McAlister, Oklahoma, 1430Z 12 Sep 95

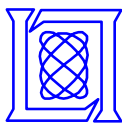


512 x 512 pixel (2 km per pixel)

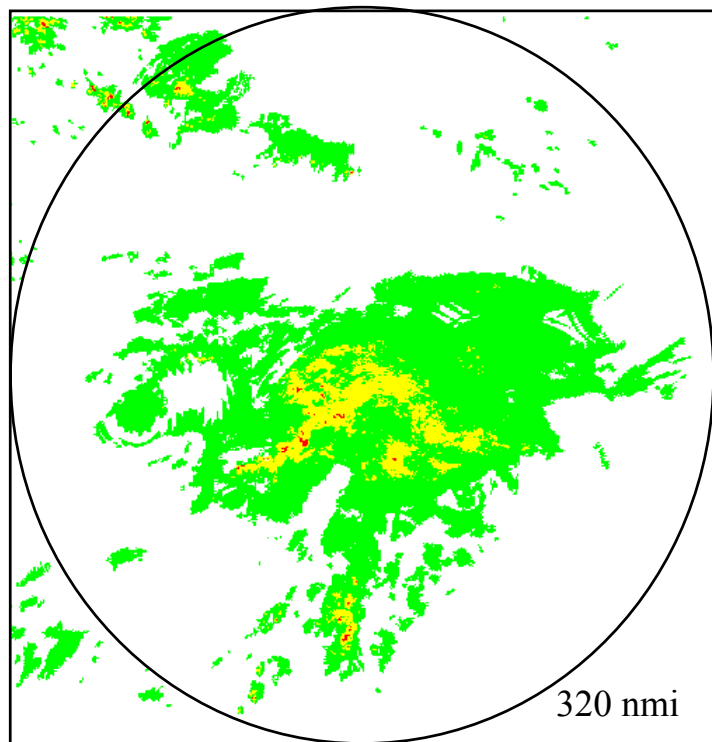
47247 bits for WH lossless encoding

4X45 squitters in SuperPixel encoding

1187 squitters in total FIS-B encoding



Sioux City, South Dakota, 1745Z 15 Jun 99



512 x 512 pixel (2 km per pixel)

47588 bits for WH lossless encoding

4X31 squitters in SuperPixel encoding

1185 squitters in total FIS-B encoding



Partial and Filtered Maps

- **Coarse map can be represented by super pixels only**
- **Coding provides partial image if not all segments received**
 - Not all or nothing as for some types of encoding
- **Filtering of map data can reduce file size with no perceptible difference in map**
 - Single level 1 pixel in level 0 field reduced to level 0
 - Single level N pixel in level N+1 field raised to higher level



Richmond, Virginia, 1745Z 15 Jun 99 (Initial Coding)

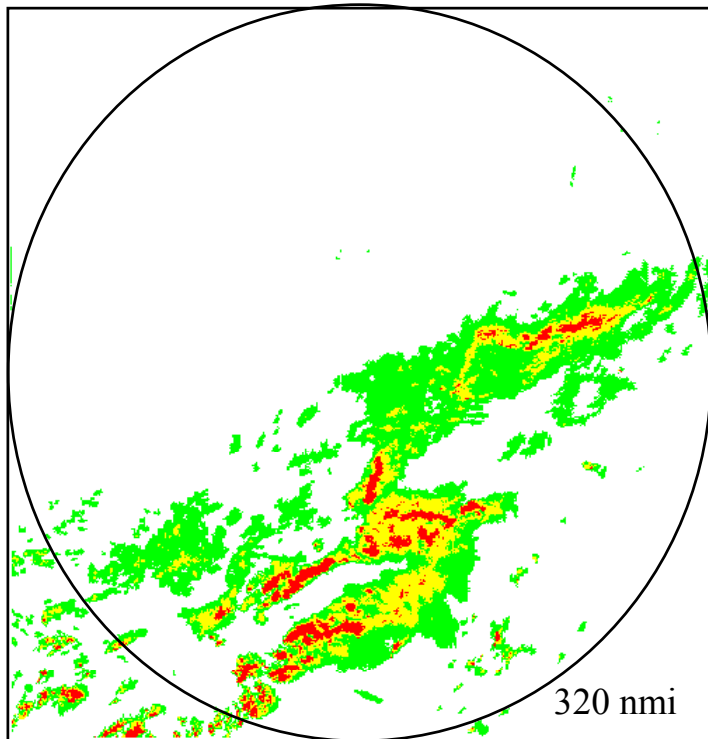
512 x 512 pixel (2 km per pixel)

53058 bits for WH lossless encoding

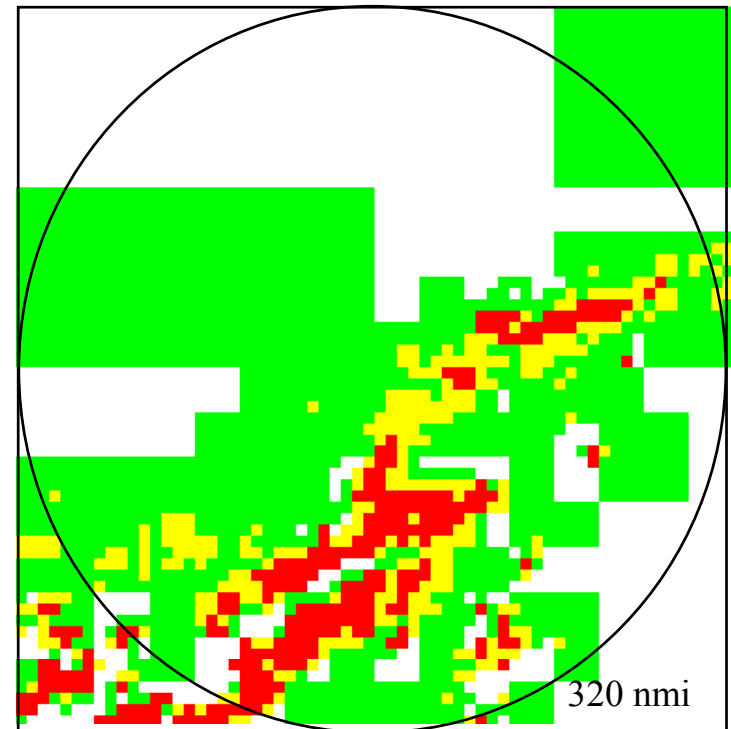
1191 squitters in total FIS-B encoding

60 squitters in SuperPixel encoding

All Bits



SuperPixels Only





Richmond, Virginia, 1745Z 15 Jun 99 (Revised Coding)

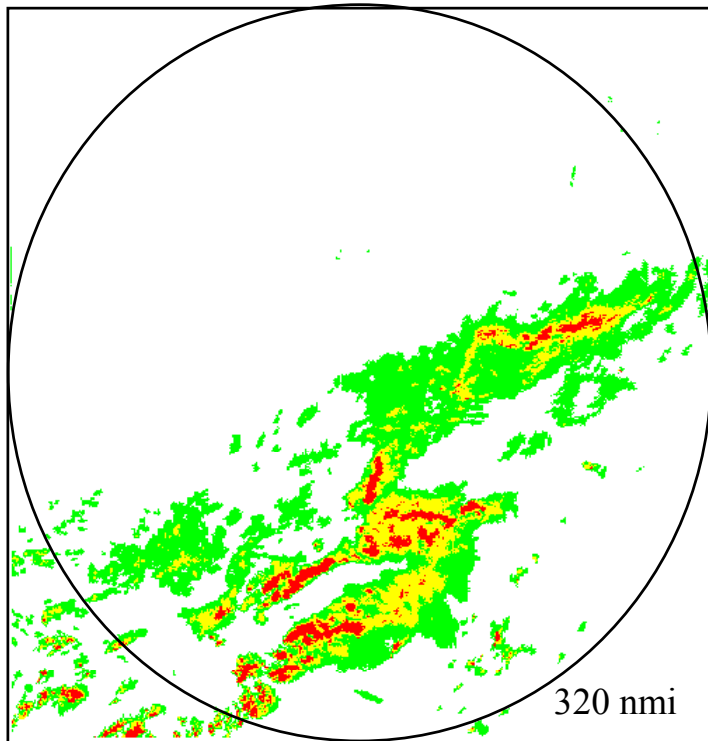
512 x 512 pixel (2 km per pixel)

53058 bits for WH lossless encoding

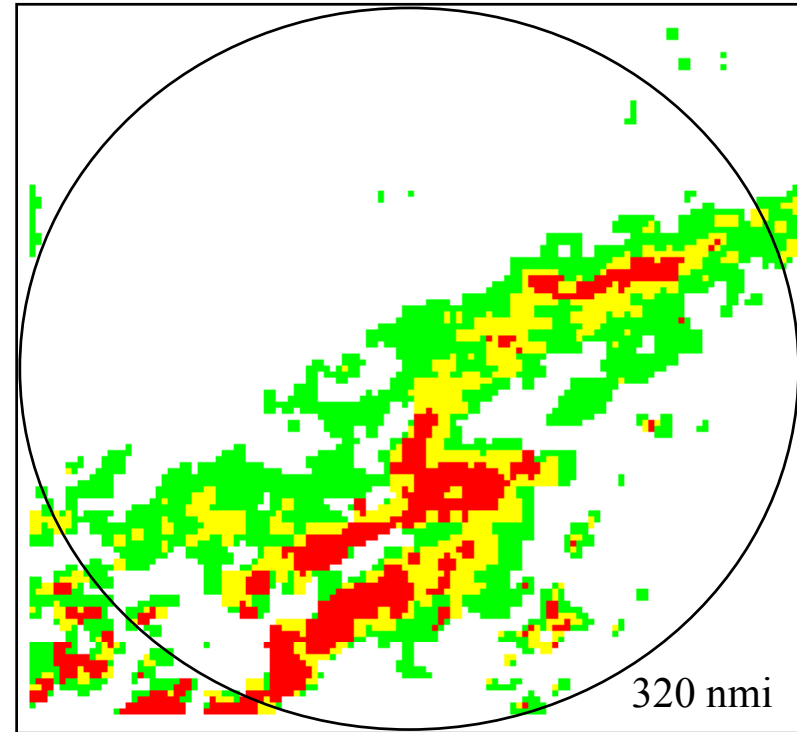
4X60 squitters in SuperPixel encoding

1371 squitters in total FIS-B encoding

All Bits



Superpixels Only





Examples of Partial Maps

Richmond, Virginia, 1745Z 15 Jun 99

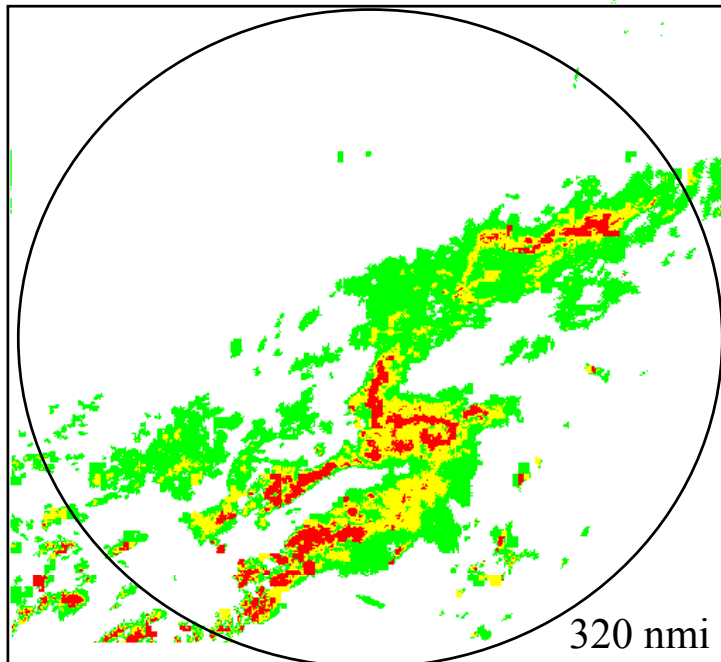
512 x 512 pixel (2 km per pixel)

53058 bits for WH lossless encoding

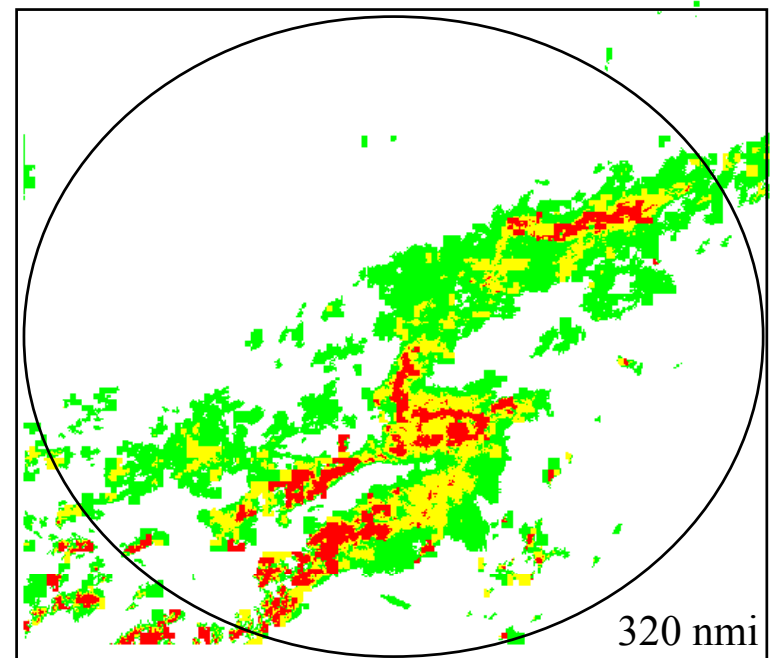
4X60 squitters in SuperPixel encoding

1371 squitters in total FIS-B encoding

90% Reception

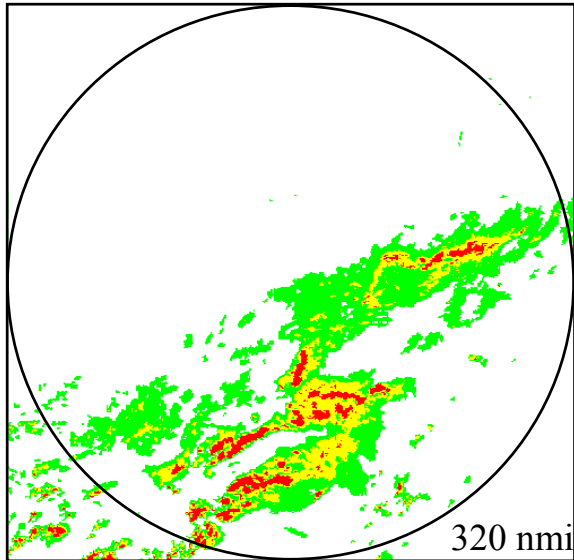


75% Reception



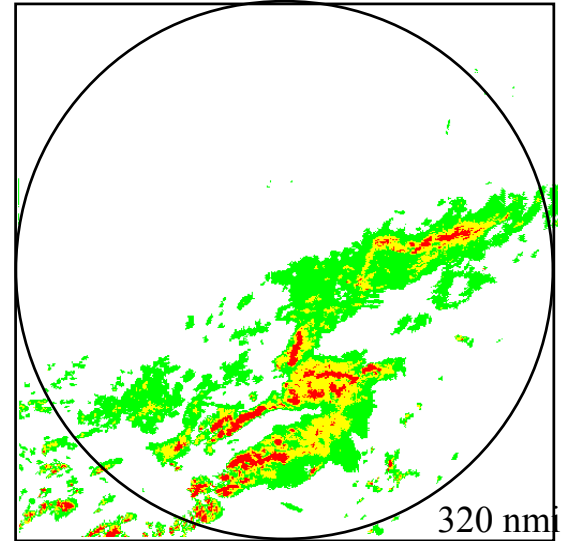


Examples of Filtered Maps

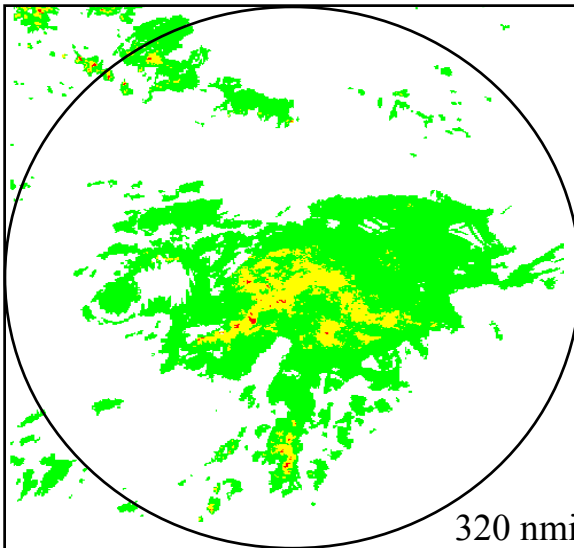


**1371 Squitters,
Lossless**

RIC

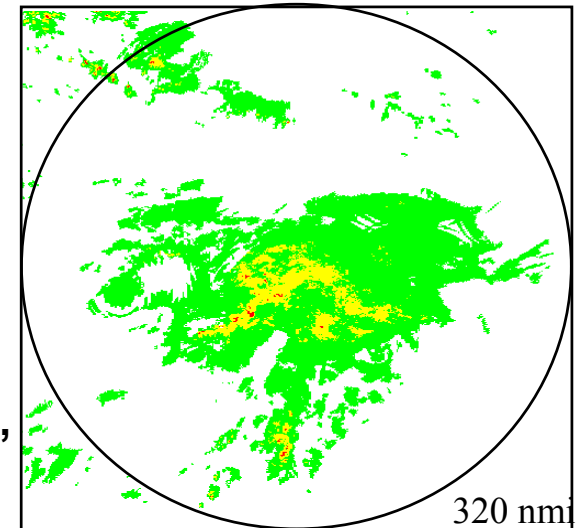


**1082 Squitters,
Filtered**



**1185 Squitters,
Lossless**

SUX

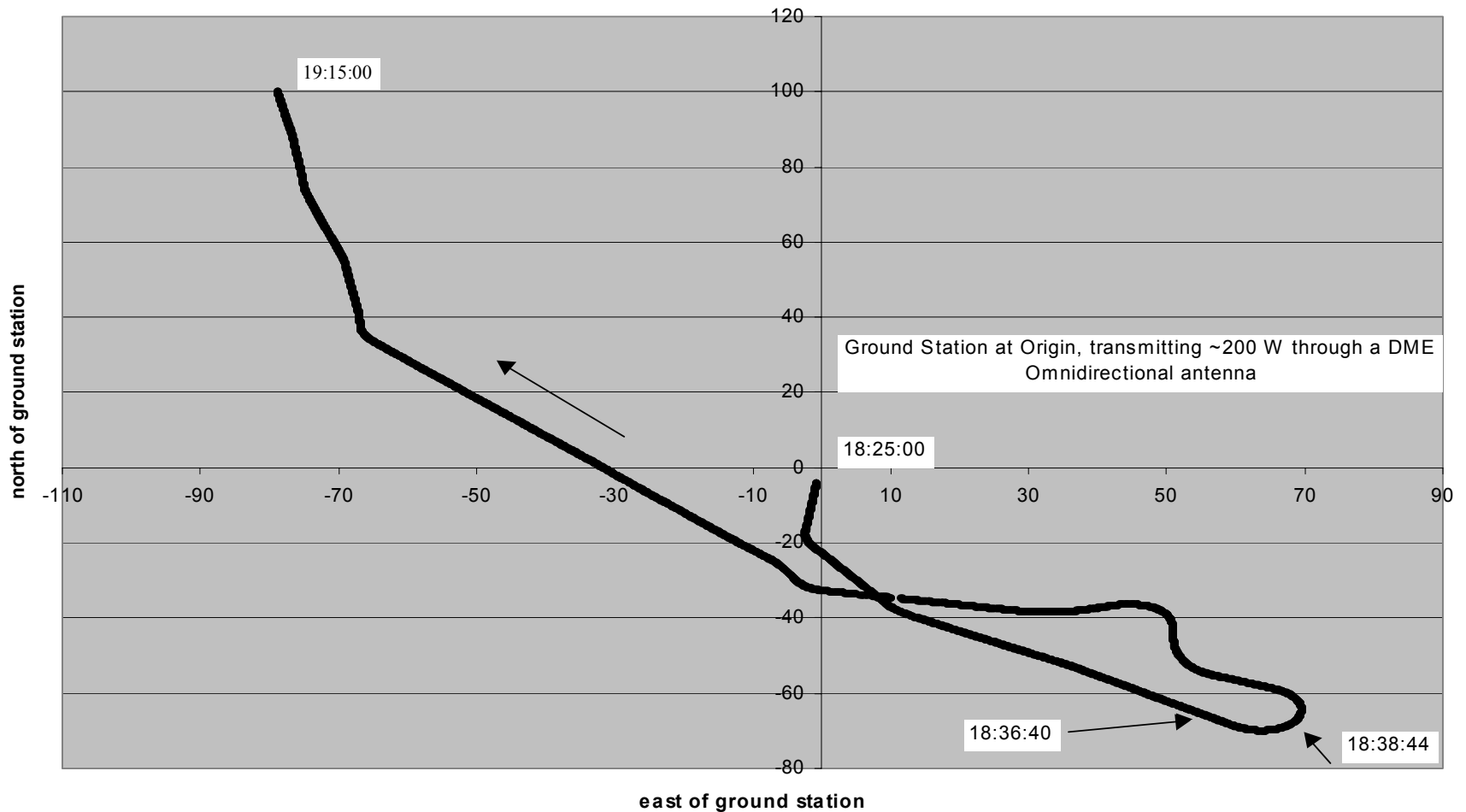


**883 Squitters,
Filtered**



UPS904 Ground Track

Ground Track N904UPS relative to ground station, Jun 17, in LA

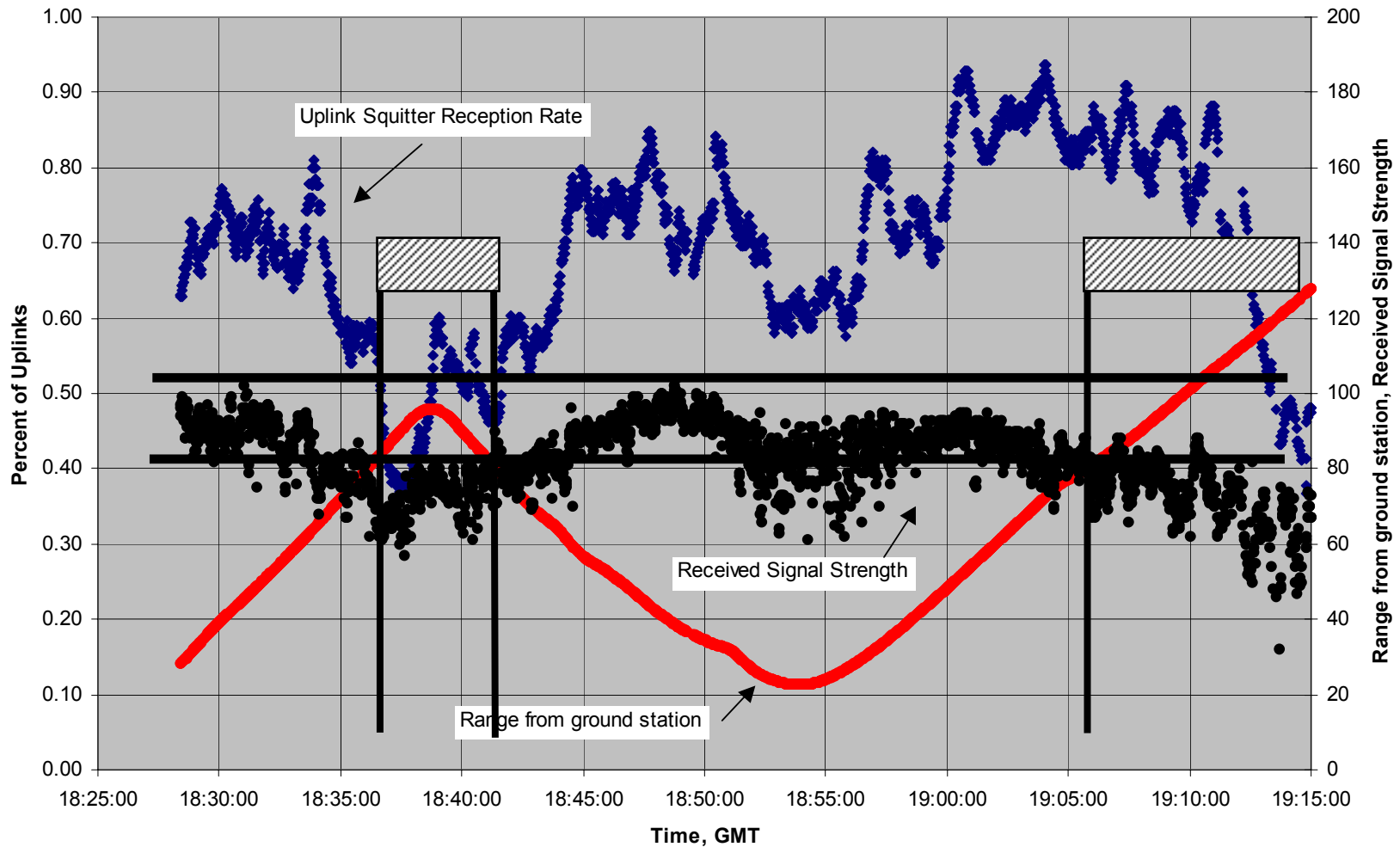


N904UPS at FL260-270



Example Uplink Reception in LA Basin

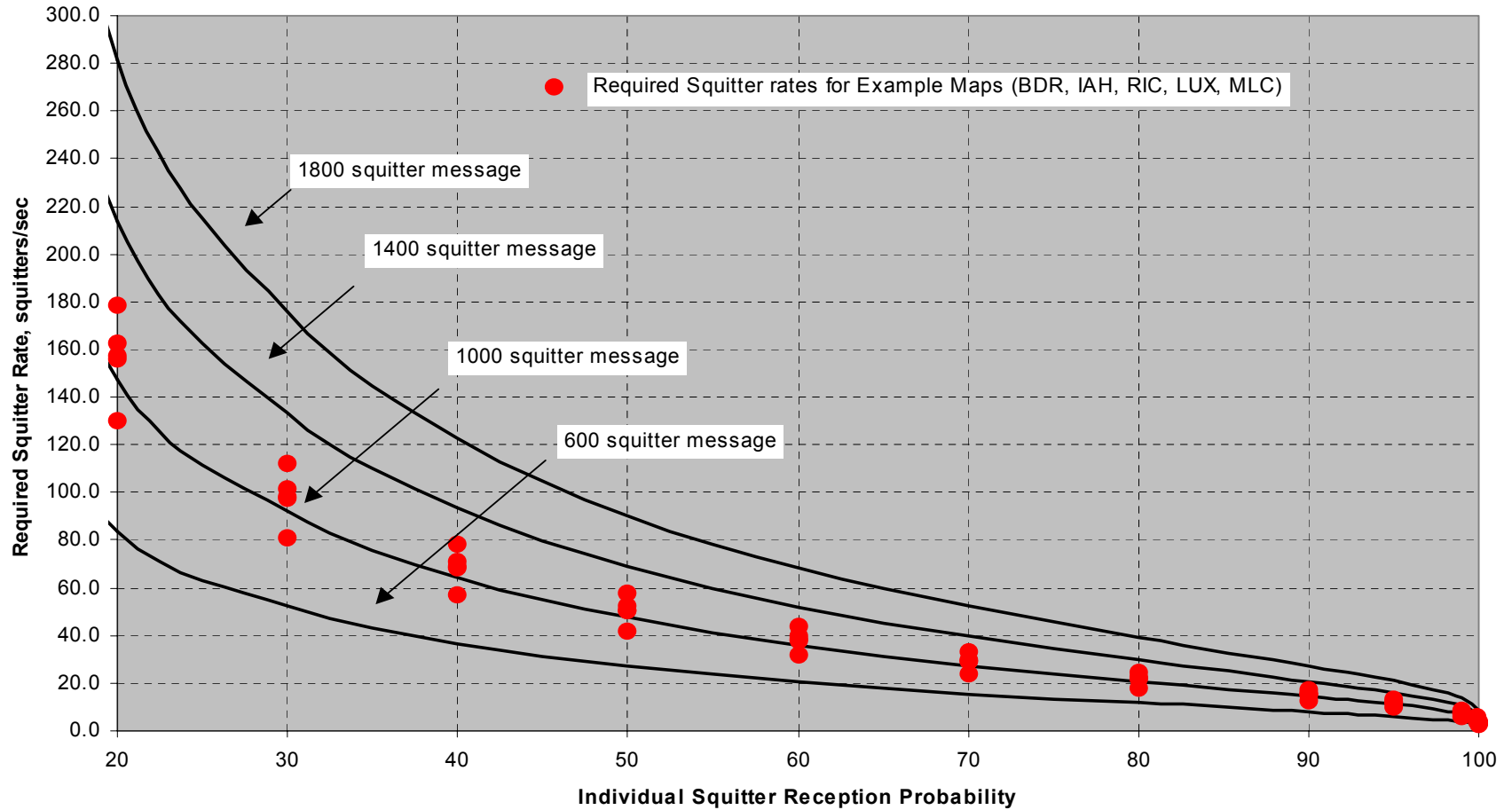
Uplinks Received on 904UPS, LAX Jun 17





Required Squitter Rates for 95% Image Receipt of Complete Weather Map

Raw Squitter Rate Necessary to Support 0.95 Probability of Image Delivery v. Individual Squitter Reception Probability

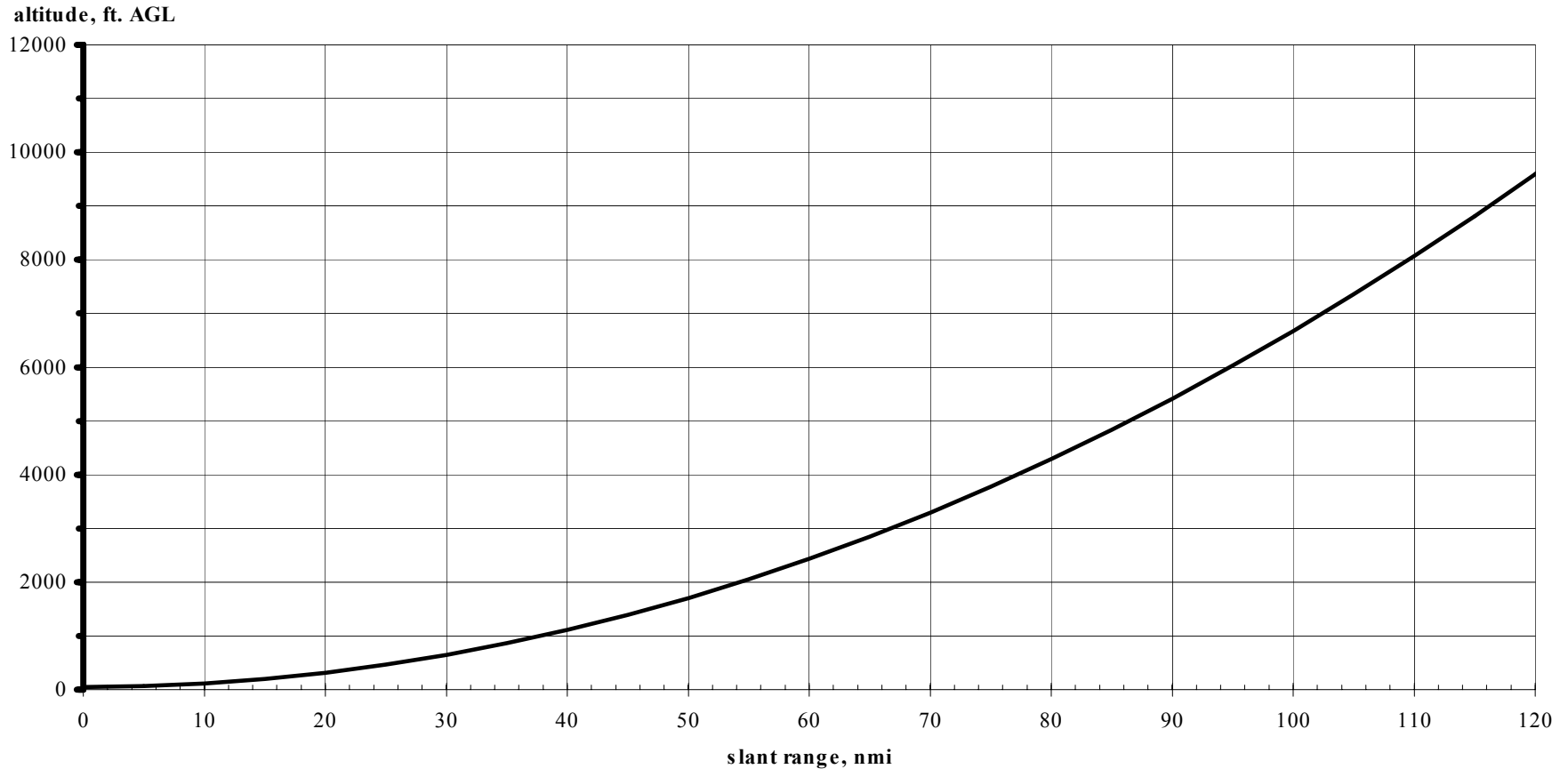


300 second update interval



Line of Sight Considerations

4/3 Earth Line of Sight from 50 ft. Transmitter Tower



0 degree elevation angle



FIS-B Link Loading

- **Net delivered bits/second ~50K/loop**
- **Operating with at least 70% uplink reliability a total squitter rate of 20-40 squitters/second is necessary**
 - **This load is equivalent to**
 - 5-10 aircraft extended squitter aircraft (in absence of ATCRBS fruit)**
 - 1 -2 aircraft in the Frankfurt area**
- **Estimate conservative with respect to:**
 - **resolution**
 - **use of filtering**
 - **update rate**
 - **range**



Summary

- **FIS-B requirements driven by communications channel error rate and desired update rate**
- **Fault tolerant uplink encoding required in absence of verification of image receipt**
 - **Candidate technique presented with examples taken from recorded weather images**
- **700 nmi, 2 km resolution image with 4 level weather can be encoded in ~1000 1090 MHz squitters**
 - **Lower resolution, lesser range, selective image filtering all show promise of substantial reduction in squitters/image**
 - **Preliminary results indicate FIS-B is compatible with 60+ mile range, even in LA Basin**