# SensorFlock

An Airborne Wireless Sensor Network of Micro-Air Vehicles

Presented by J. Scott Miller

# Motivation

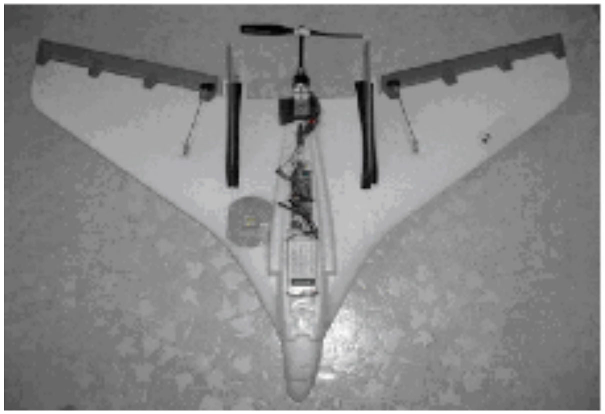
- Fully mobile autonomous motes have the potential to enhance the data available to a number of communities
  - Dispersion sampling/tracking
  - Weather and atmospheric sampling
  - Tagless animal tracking

# Current Methods

- Weather balloons
  - Static, cannot be easily routed to interesting areas
- Unmanned Ariel Vehicles
  - Costly ($10,000-$10 Millions)
  - Pose danger to aviation

# Micro-Air Vehicles (MAVs)

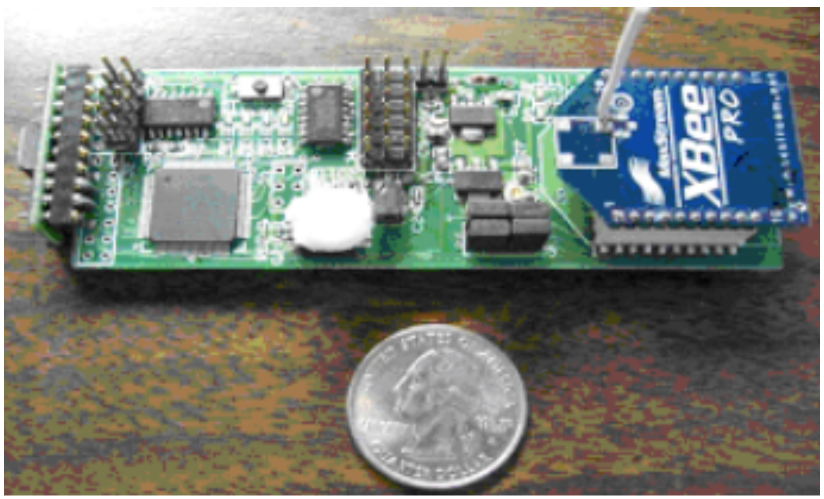
- Size of large bird
  - Pose little threat to aviation and ground
- Cheap
  - O($100s)
- Disposable
- Highly mobile
- Extremely resource constrained
- Challenging to control



# MAV Design

- MAV size fits within definition of Inert Debris
  - Mass < 500 grams
  - Maximum speed < 20 m/s
  - Foam construction, propeller on rear
- MAV cost < $600

# MAV Hardware




- PIC 8-Bit microcontroller
- RC receiver for manual operation in the event of control failure
- Pressure sensor, gyroscope
- GPS
- Zigbee radio
- Watchdog timer to reset stalled CPU

# Operation

- Launched from Plane-a-Pult
  - Interfaces with MAV to coordinate takeoff
  - Fully autonomous
  - Landing?
- In-flight Control via GPS
  - Control adjustments at 100Hz, course correction at 10Hz
  - MAV enters ‘loitering’ after reaching area of interest

# Wireless Evaluation

- Many studies exist studying static mote radios
  - Covers 802.11 protocols, traditional 900Mhz and more recent 802.15.4 radios
- No known studies evaluating these protocols on MAVs
- Thus begins the meat of the paper

# Wireless Configuration

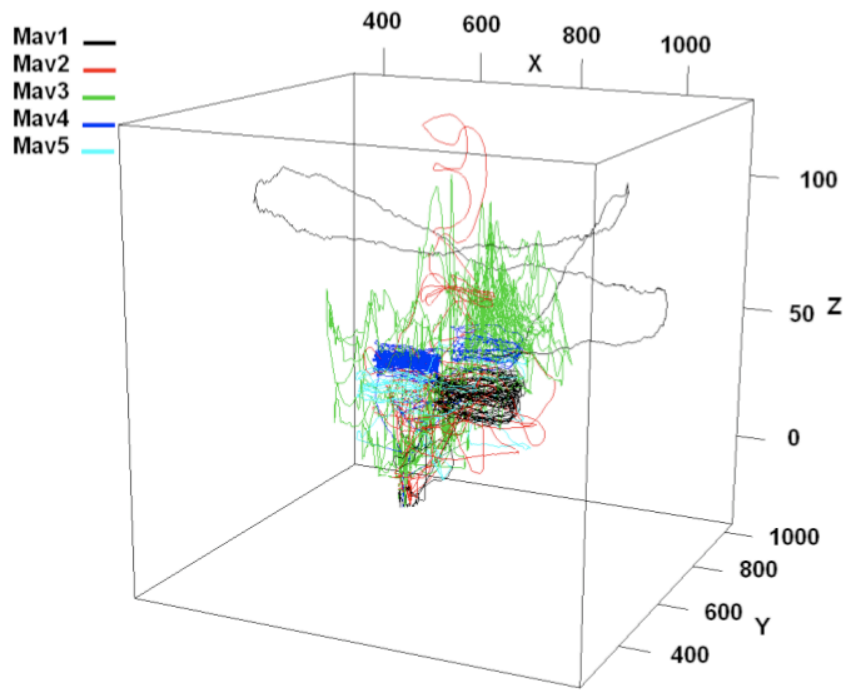
- MAV network architecture Largely designed to support system measurements
  - Radio strength
  - MAV location
  - Network paths
  - Packet loss
- Packets processed at 10Hz to mitigate CPU time

# Experimental Setup

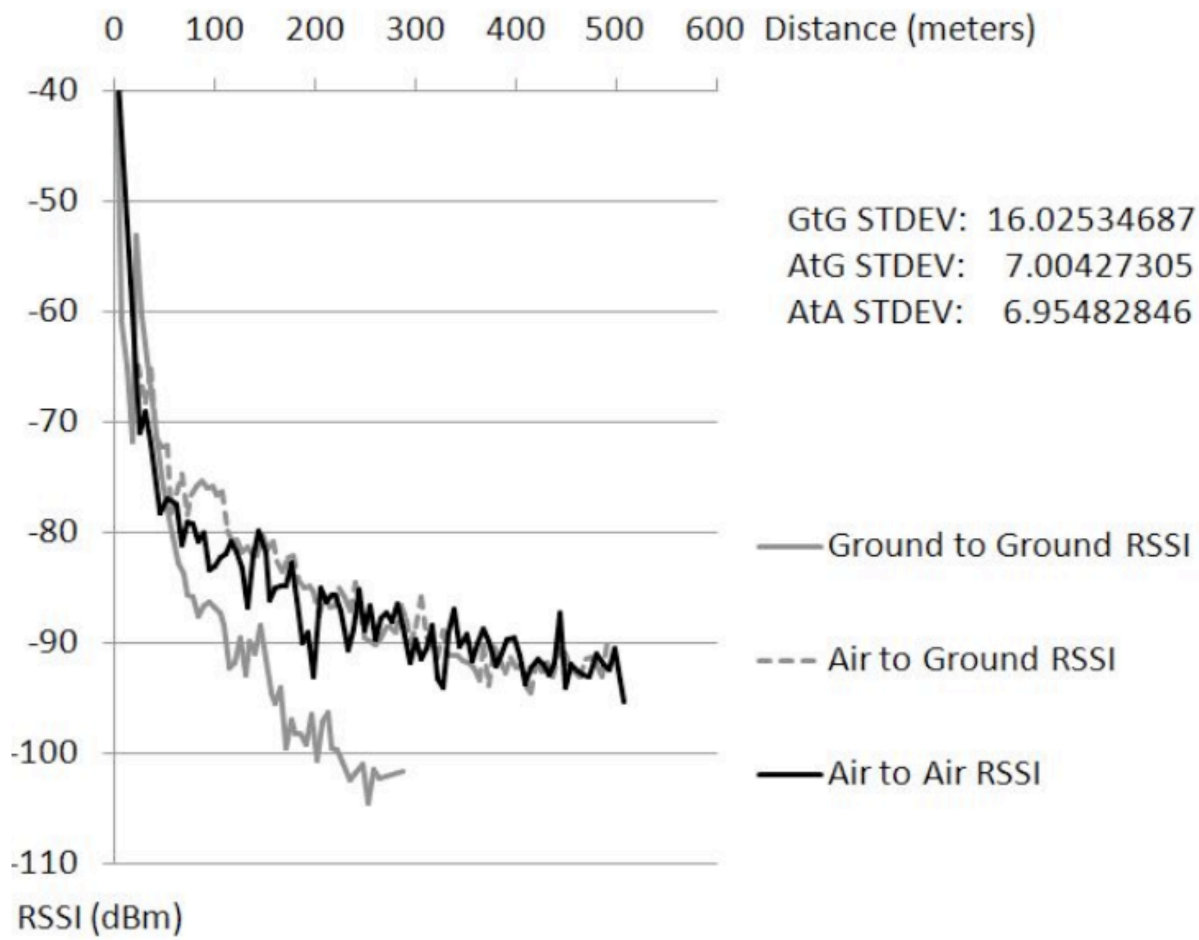
- MAV periodically floods network with data packets 5 times per second
- Packets full of network state
  - Source ID, GPS location, GPS time, hop count, sequence number, local sender idea, received signal strength indicator
  - Packet n is forwarded only after packet n-1 has arrived
  - MAVs append ID to all packets routed
- Packets collected at base station

# Experimental Setup (cont)

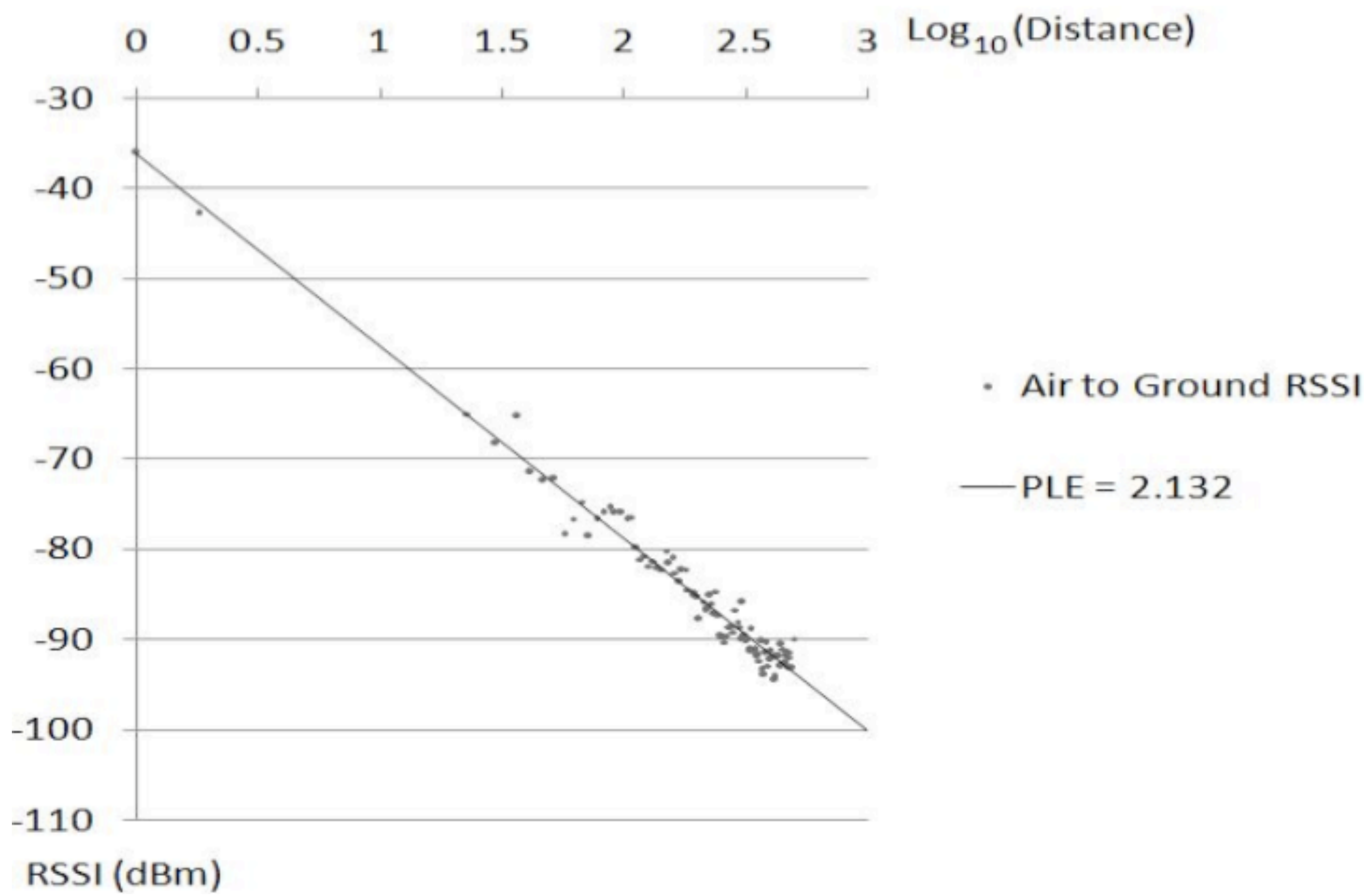
- 5 MAVs used
- 30 minutes of flight time
- Human pilots controlled MAV
  - Acted as fail-safe
- MAVs loitered at 50 meters
- Evaluated air-to-air, air-to-ground, and ground-to-ground communications
  - G to G by carrying MAVs



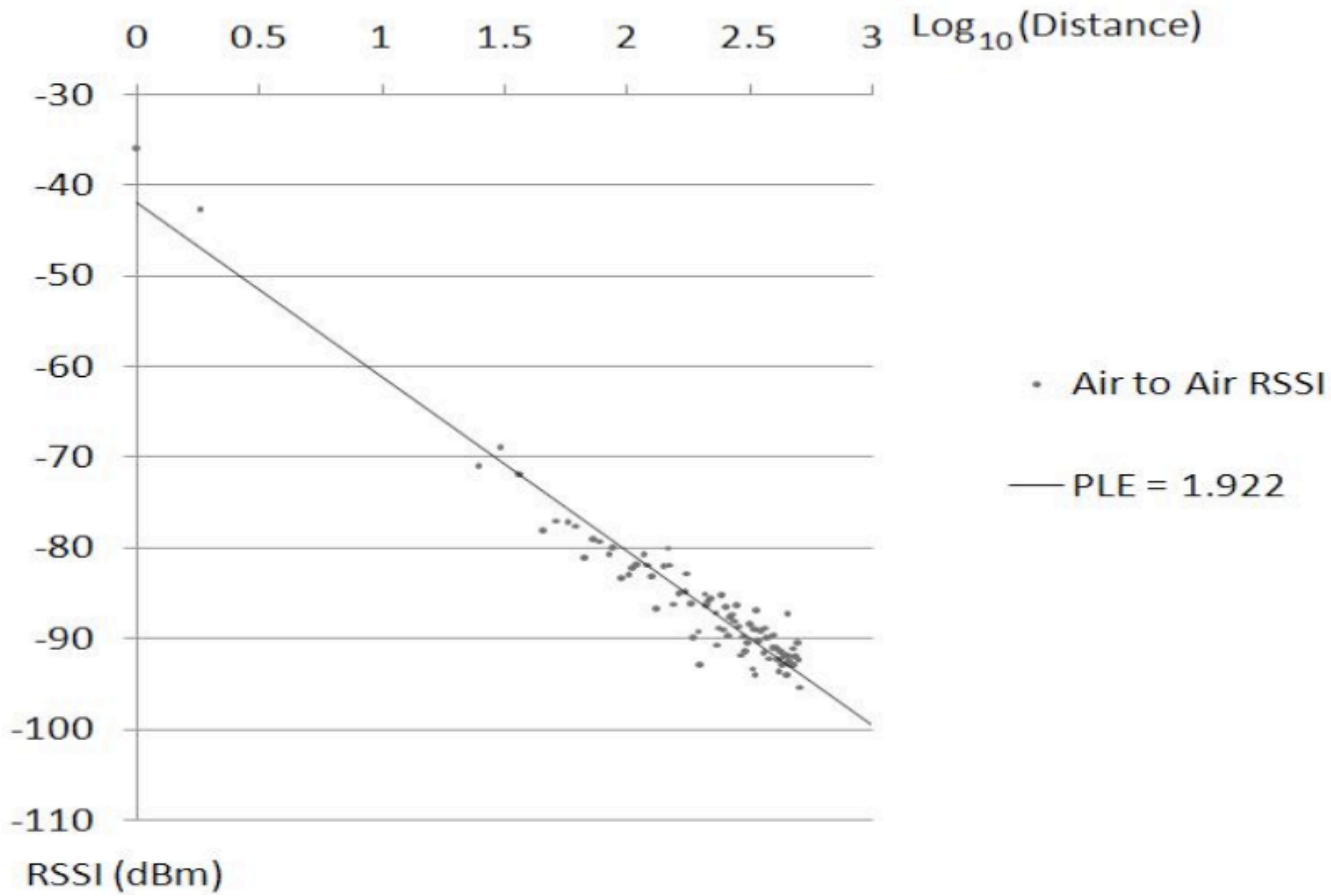
# Signal Strength by Distance



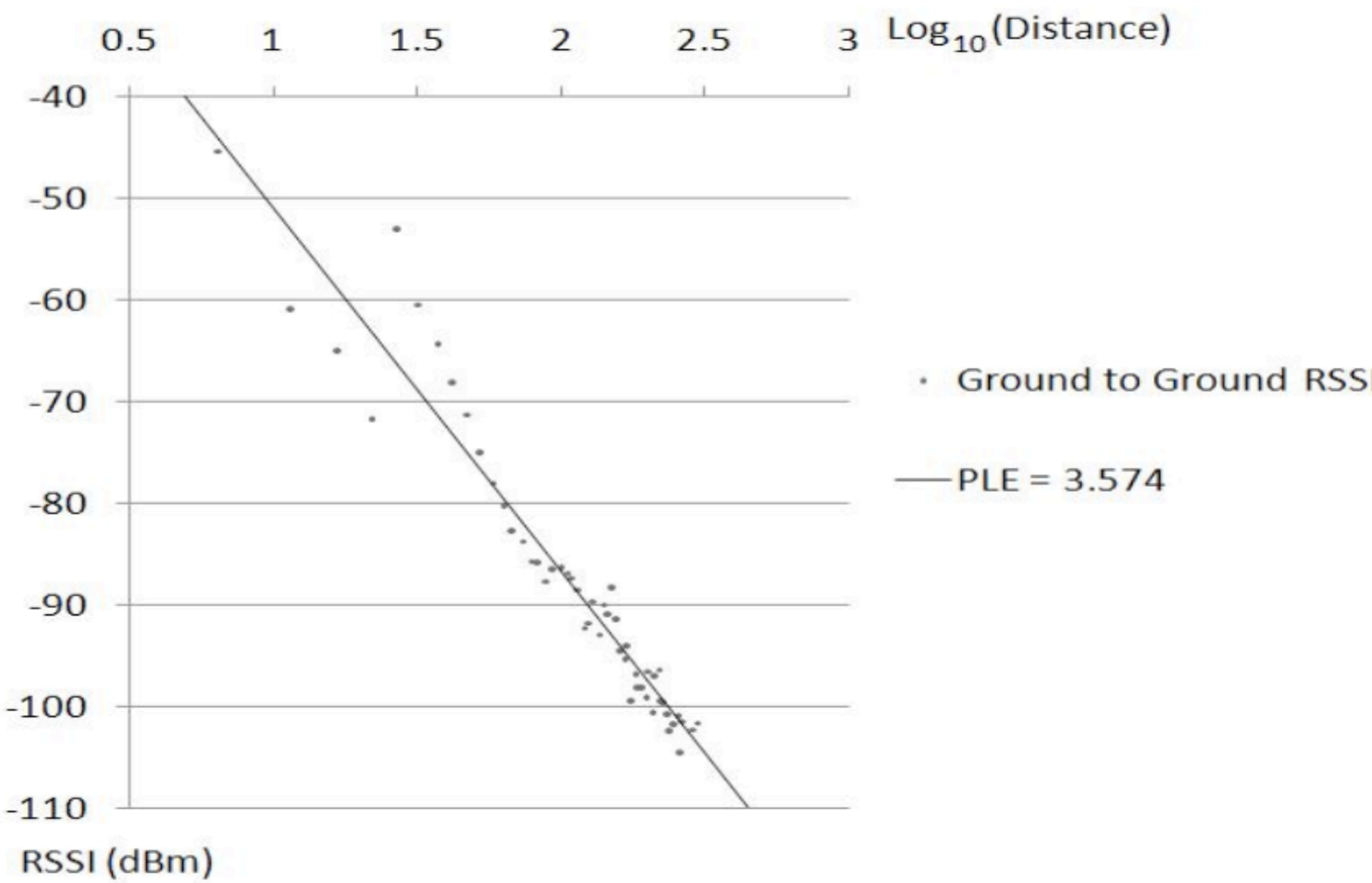
# Path Loss Exponents (A to G)



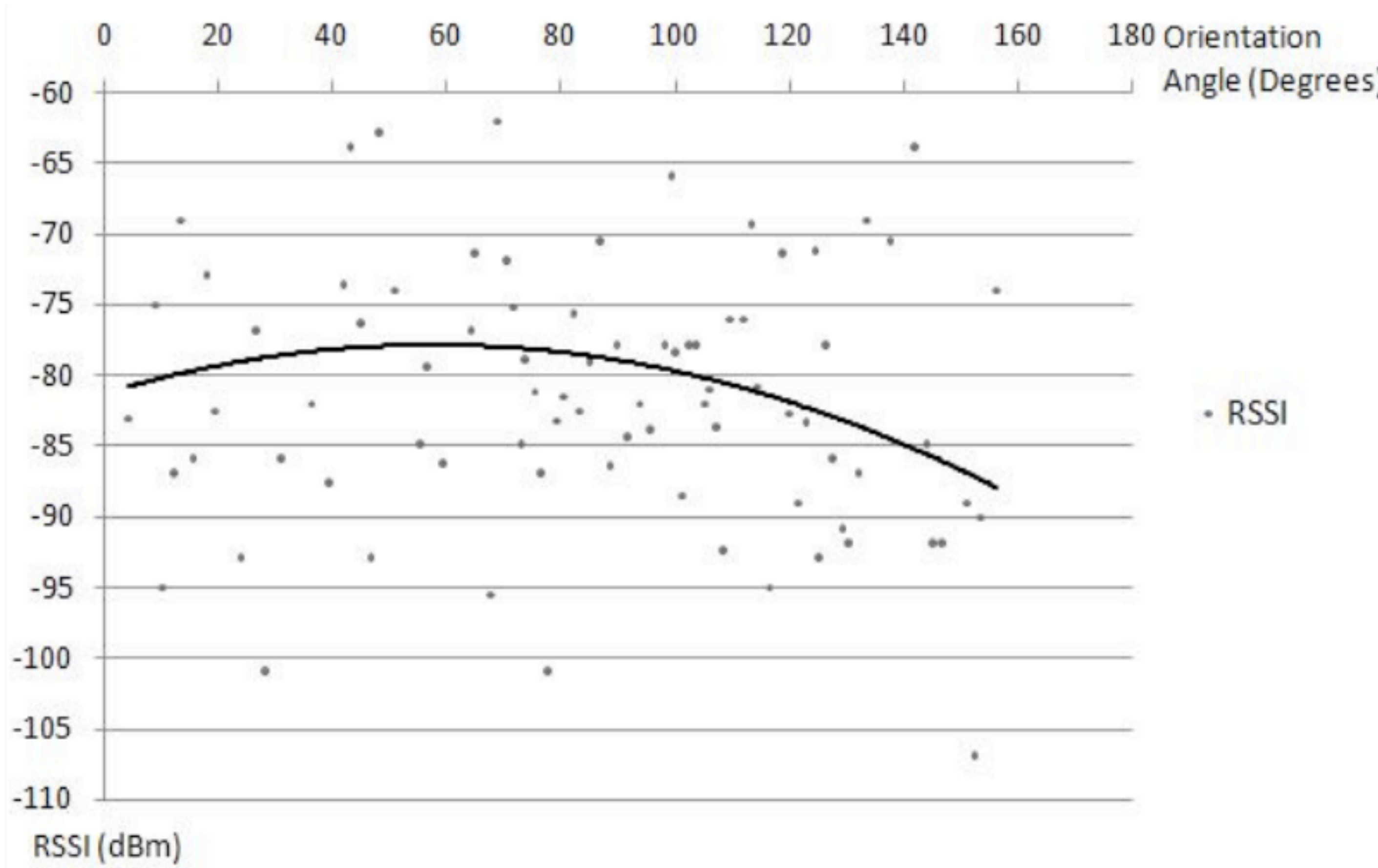
# Path Loss Exponents (A to A)



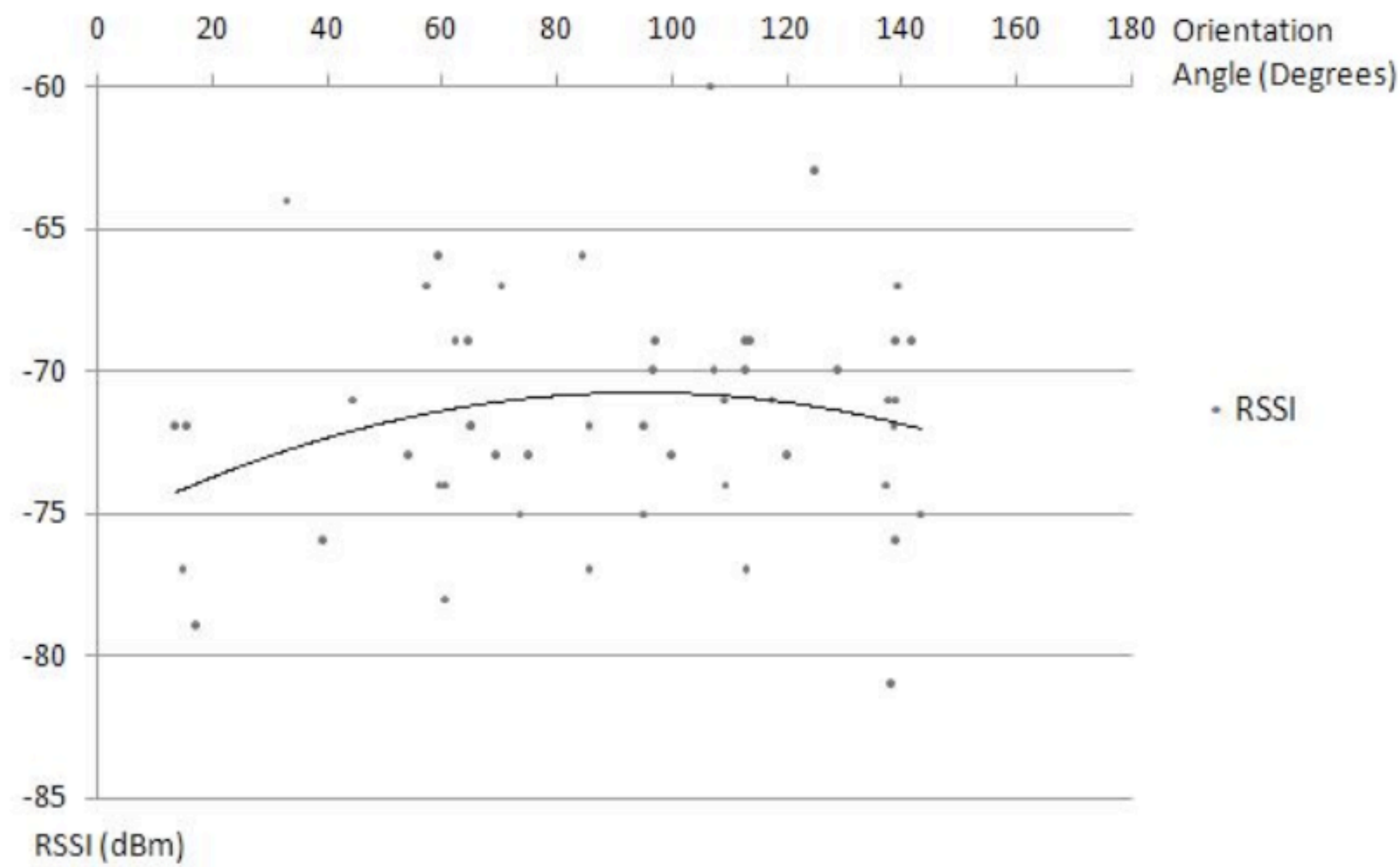
# Path Loss Exponents (G to G)



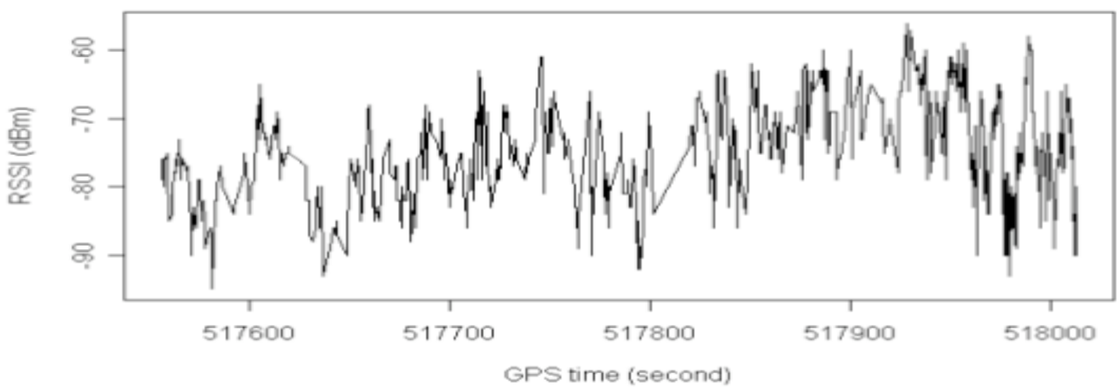
# RSSI by Orientation Angle (A to G)

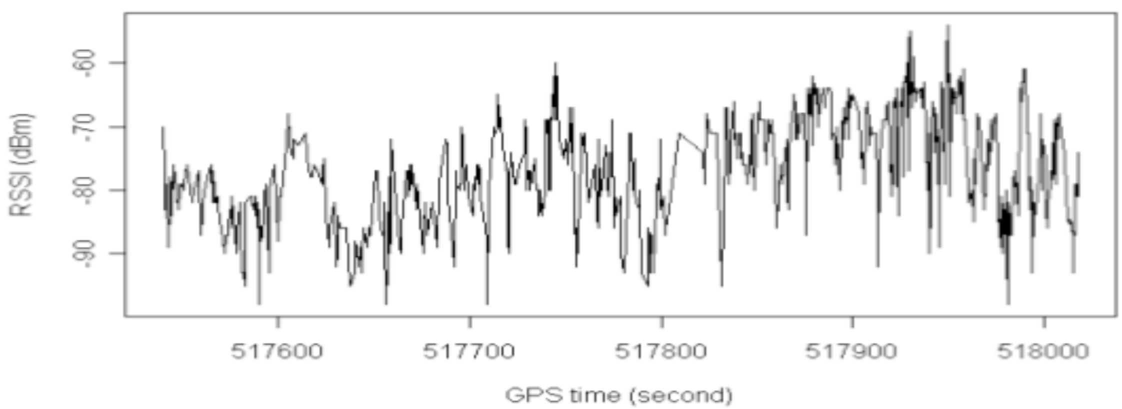


# RSSI by Orientation Angle (A to A)



# Forward vs. Reverse RSSI by Time



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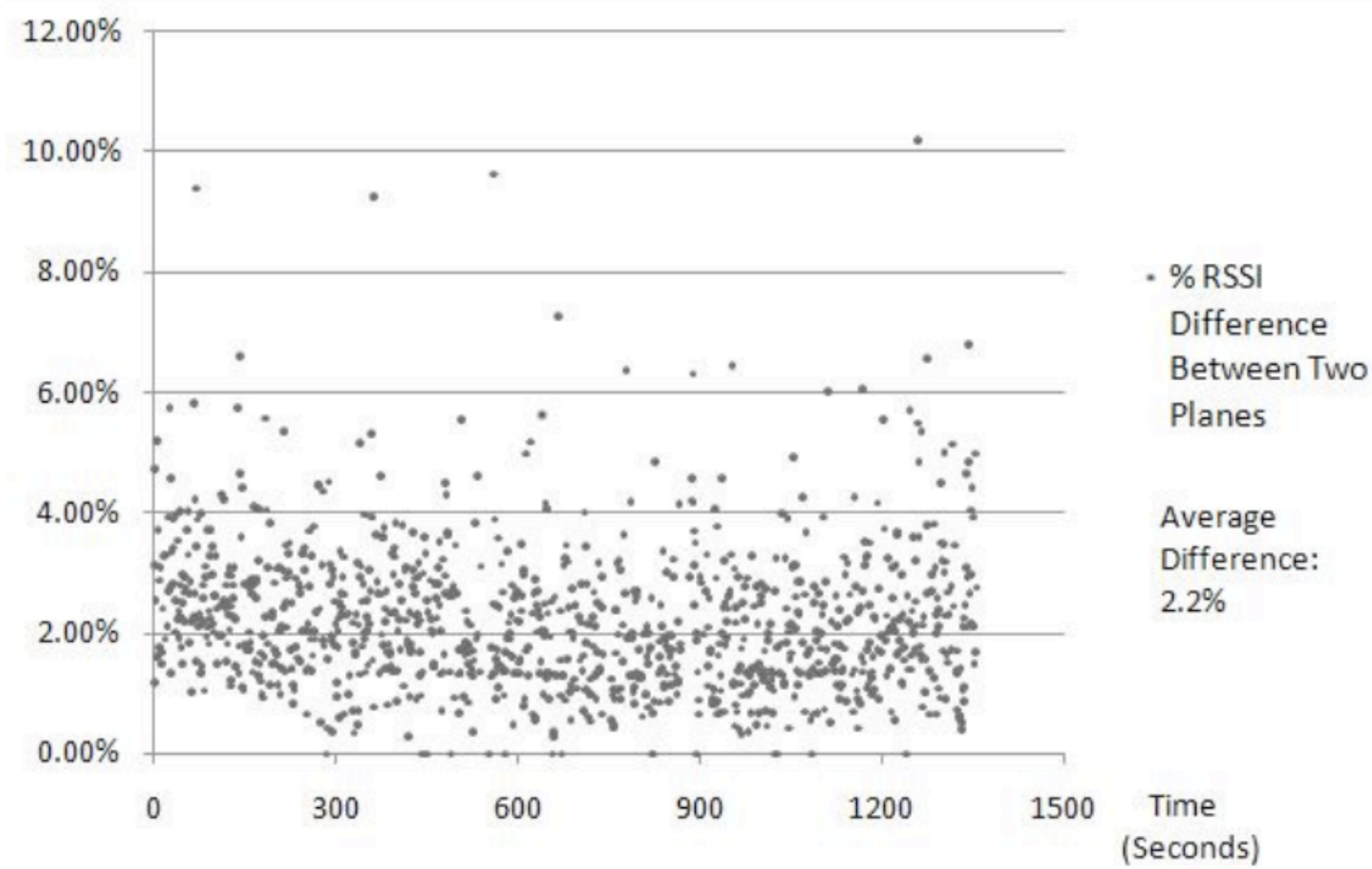
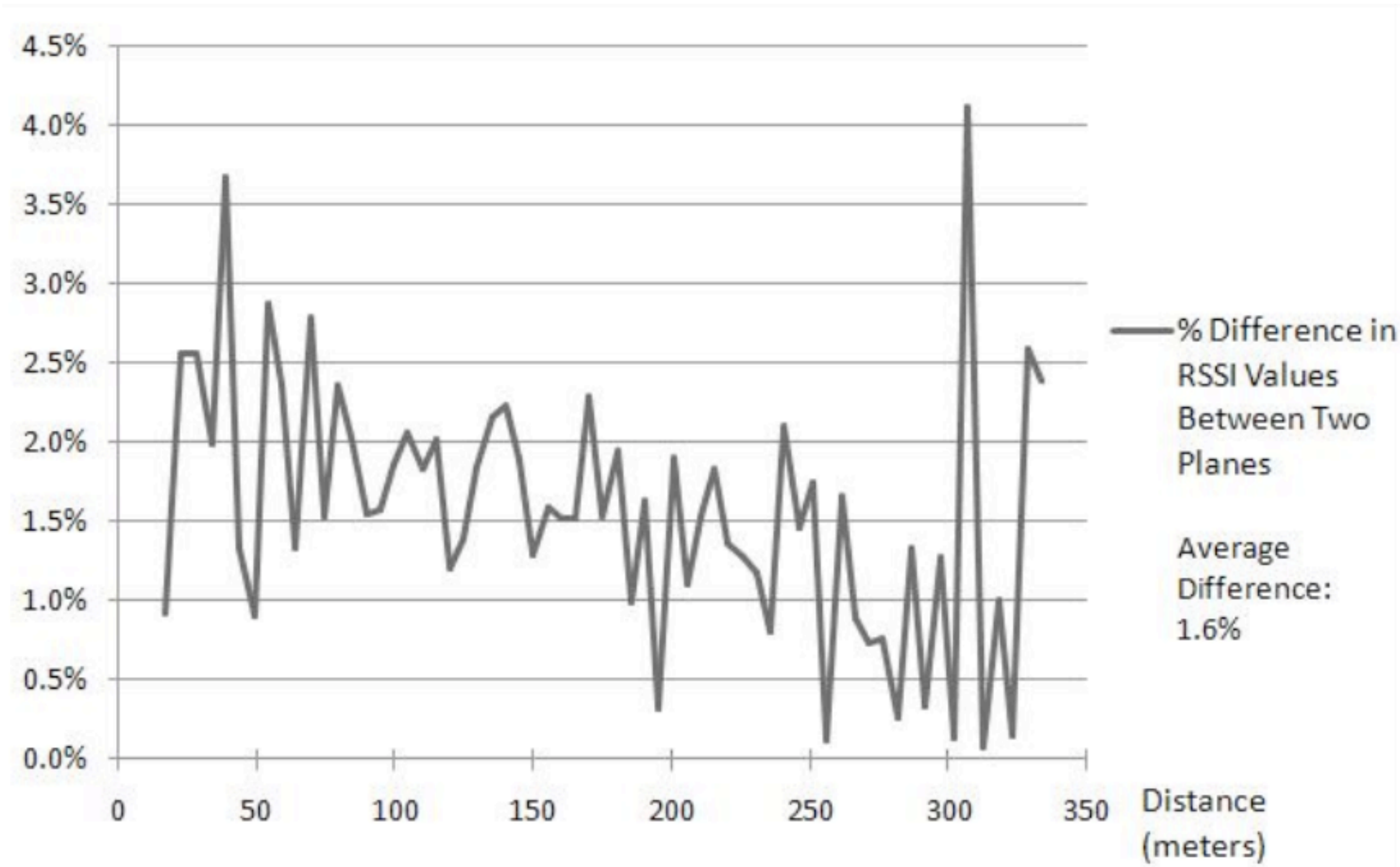
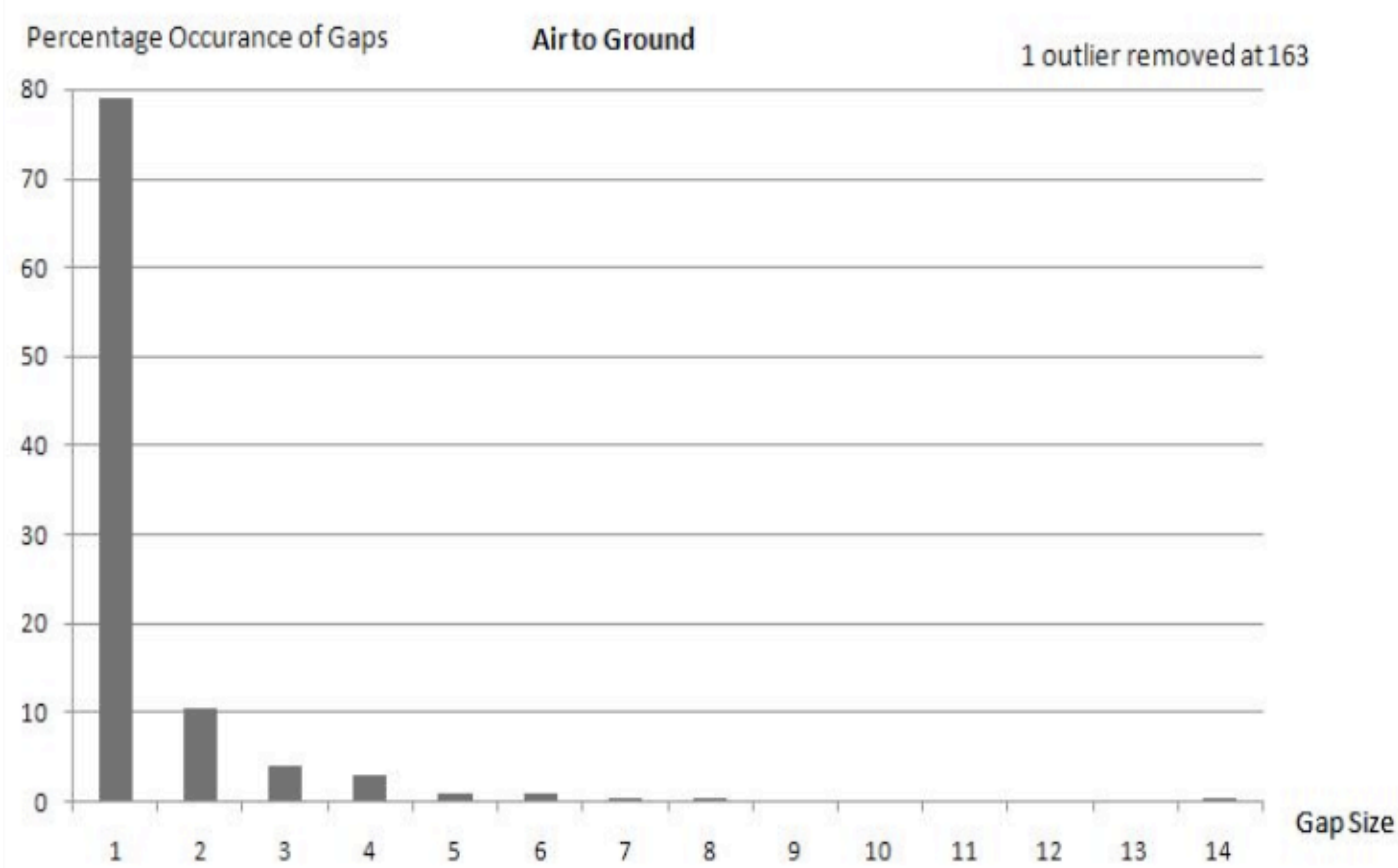


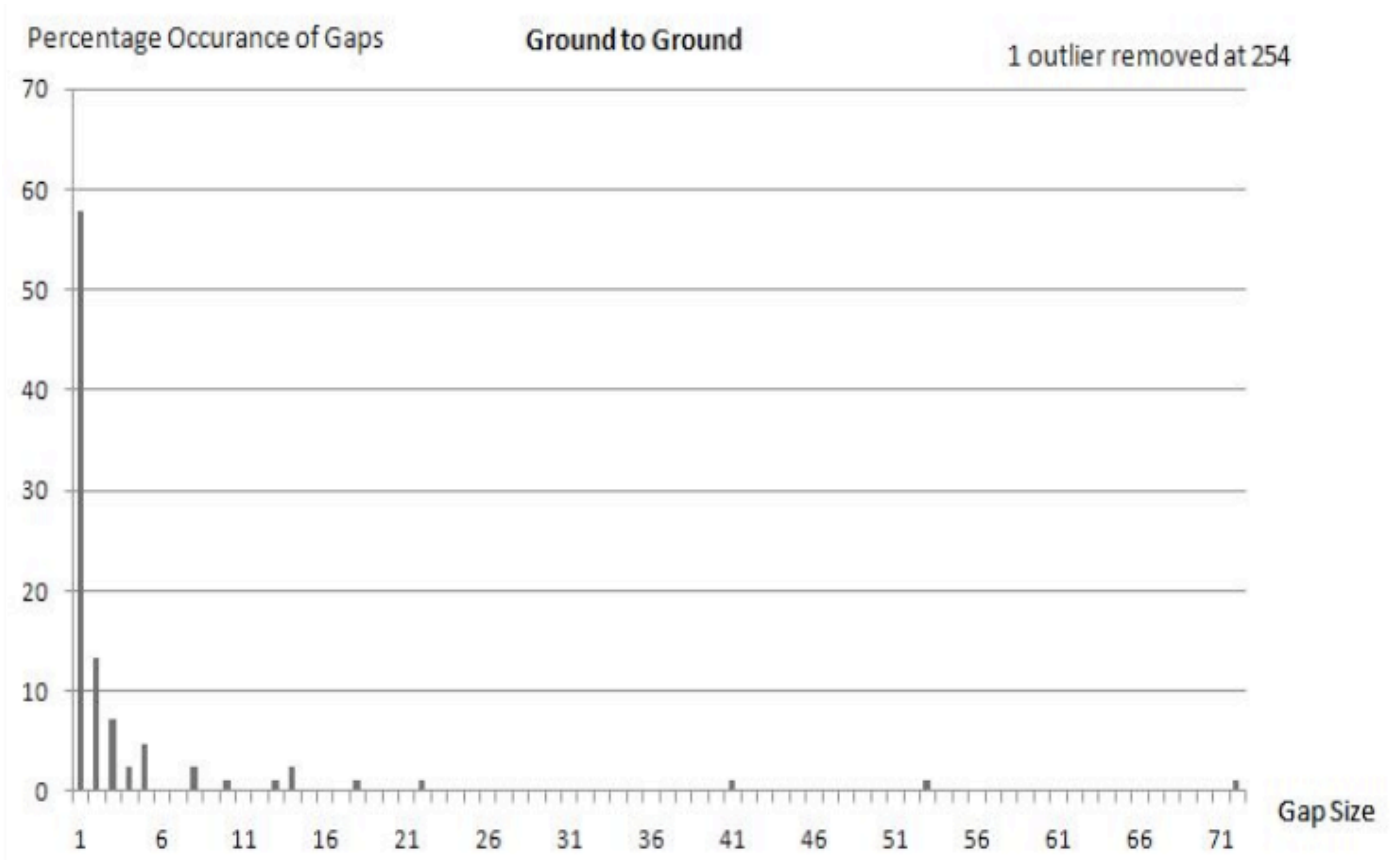
# Forward vs. Reverse RSSI by Distance

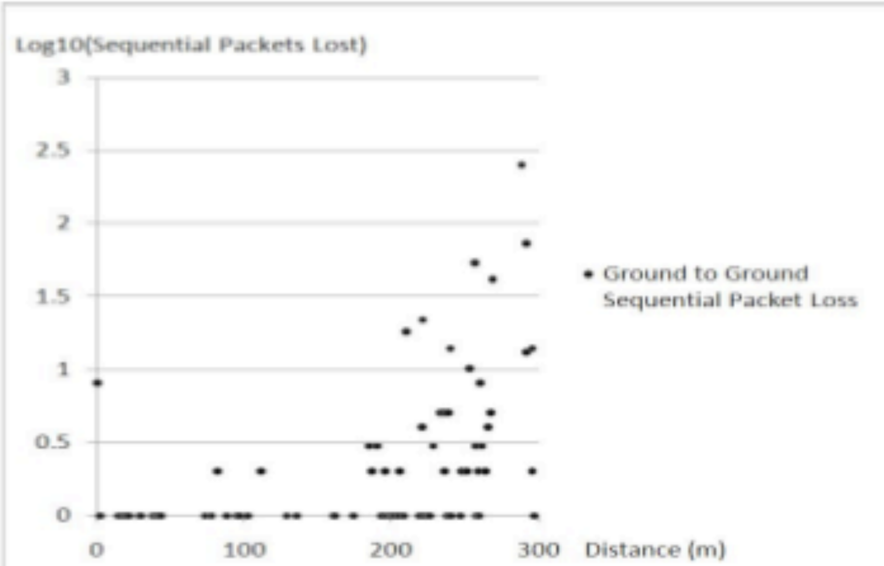


# Communication Gap Length (AtoG)

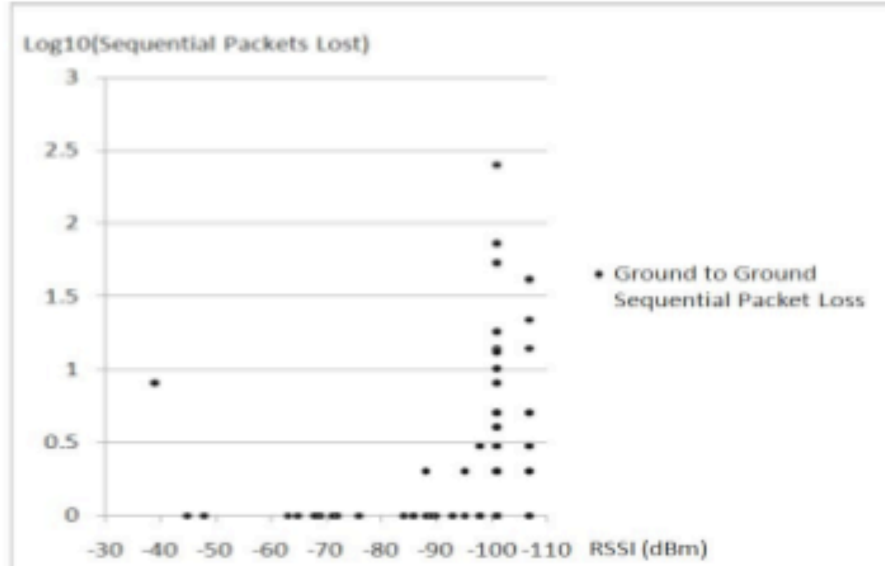


# Communication Gap Length (GtoG)

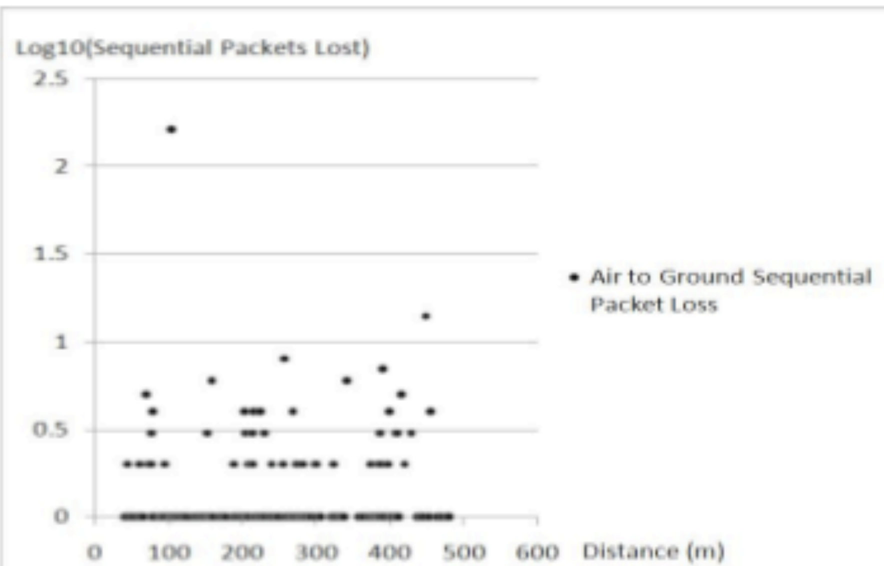




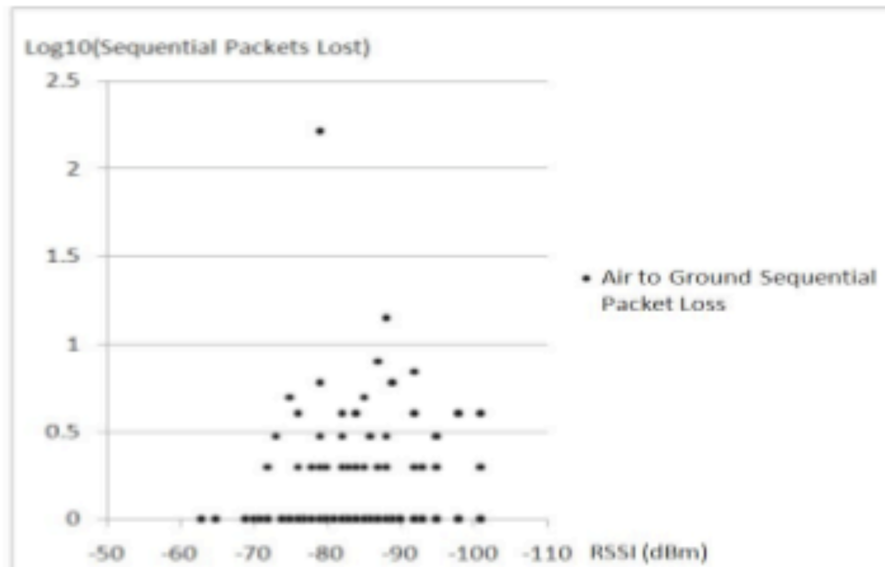

(a) GtoG scatter plot of packet loss gap size vs. distance.




(b) GtoG scatter plot of packet loss gap size vs. RSSI.

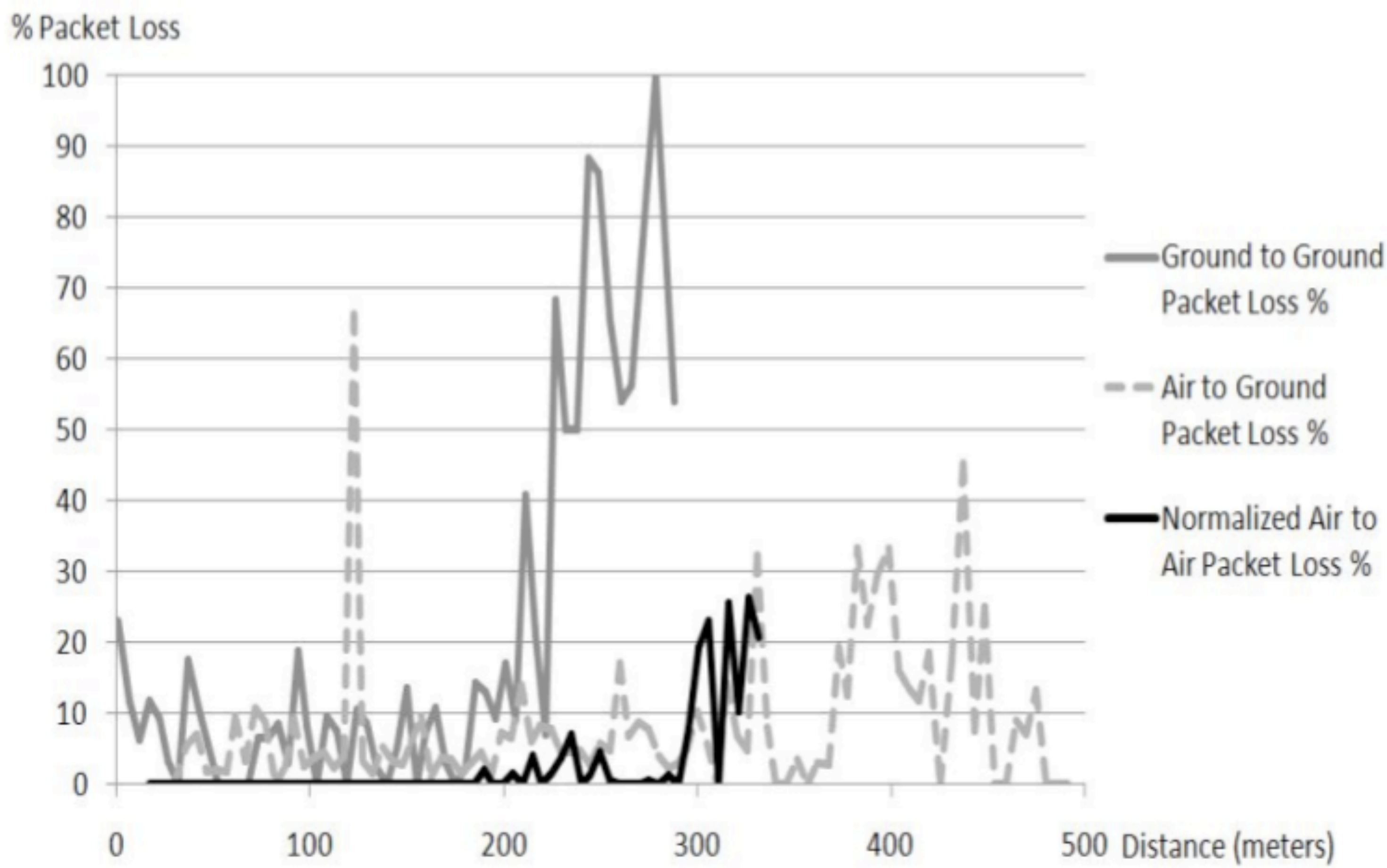



(c) AtoG scatter plot of packet loss gap size vs. distance.

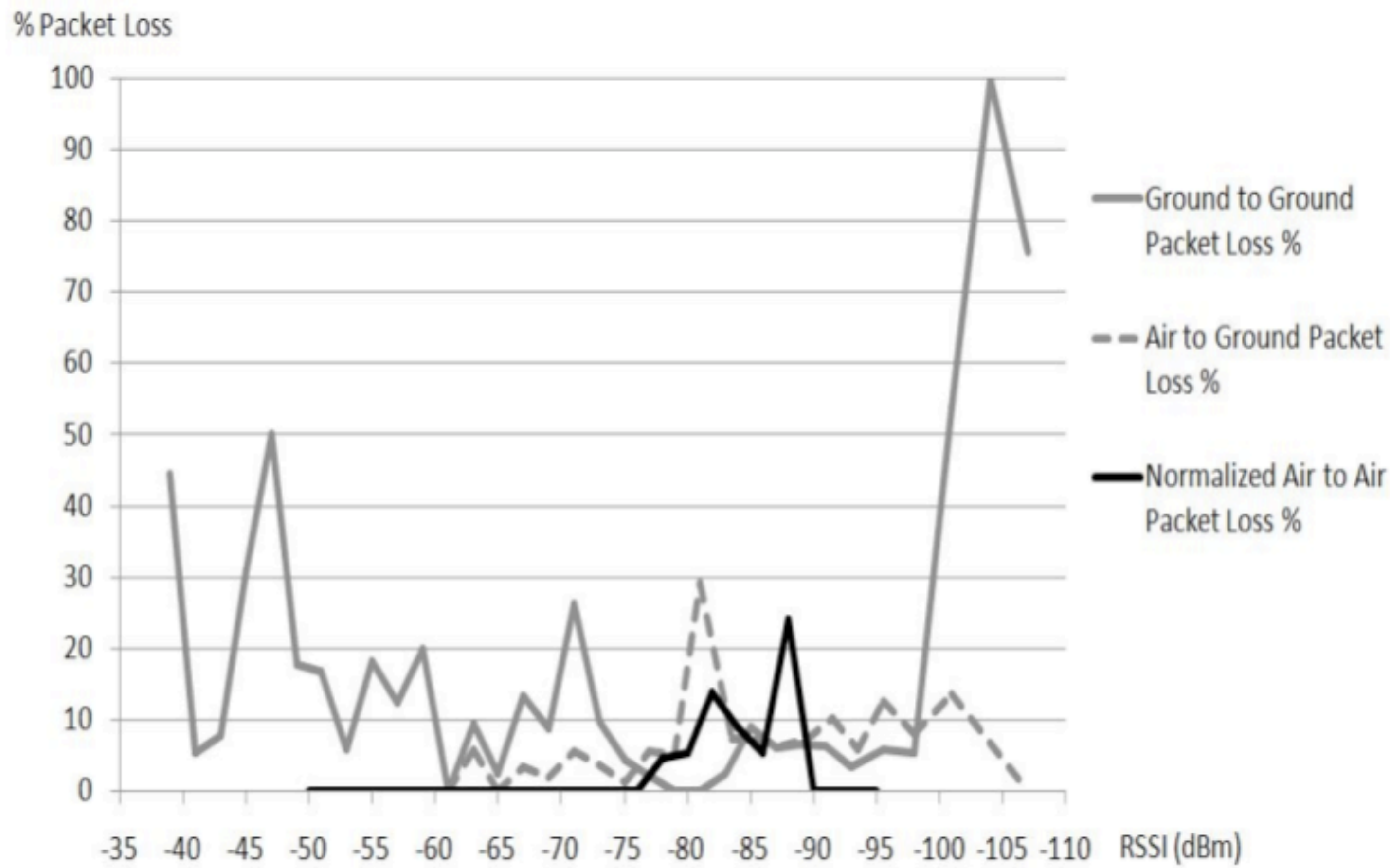



(d) AtoG scatter plot of packet loss gap size vs. RSSI.

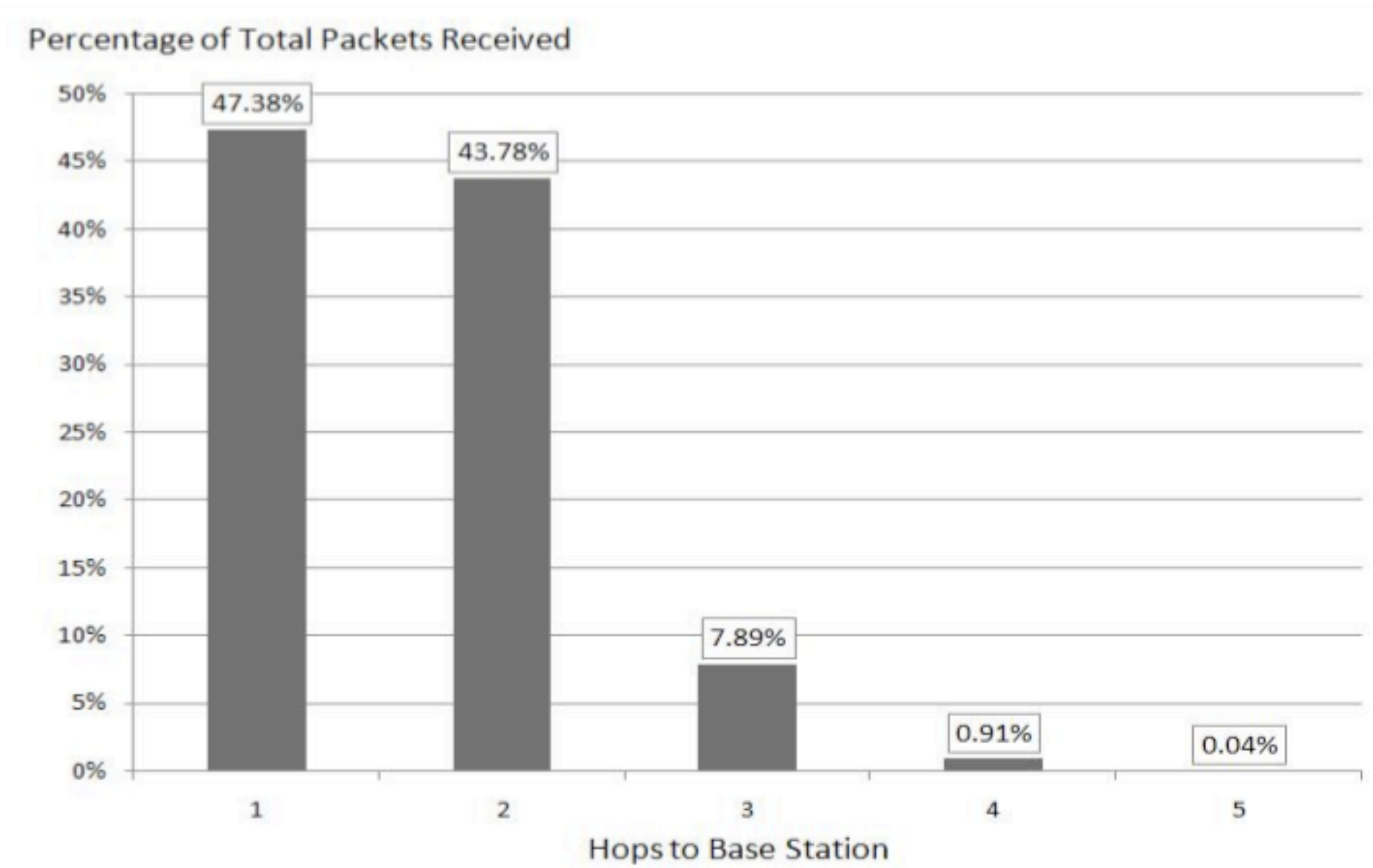
# Packet Loss by Distance



# Packet Loss by RSSI



# Extent of Network Routing



# Concluding Remarks

- Contributions
  - Prototype of MAV platform
  - Characterization of aerial wireless
- Future work
  - Use results to characterize aerial routing policies
  - Evaluate data collection viability