Wireless Measurement System for an Aerial Refueling Basket Force Gauge Measurement

23rd Transducer Workshop
17 June 2008

Brian Keating
Nitish Sinha

Background

- Flight test requirement to measure the strain experienced between the refueling hose and the drogue (refueling basket), with an embedded force gauge load cell
- A wired system would have been the optimum choice to perform this measurement
  - Safety and reliability Issues with running wire down fuel hose
  - Deploying and reeling in the drogue would destroy the wire
- After exhausting all possibilities of a wired system it was determined that a wireless system would be needed to make this measurement

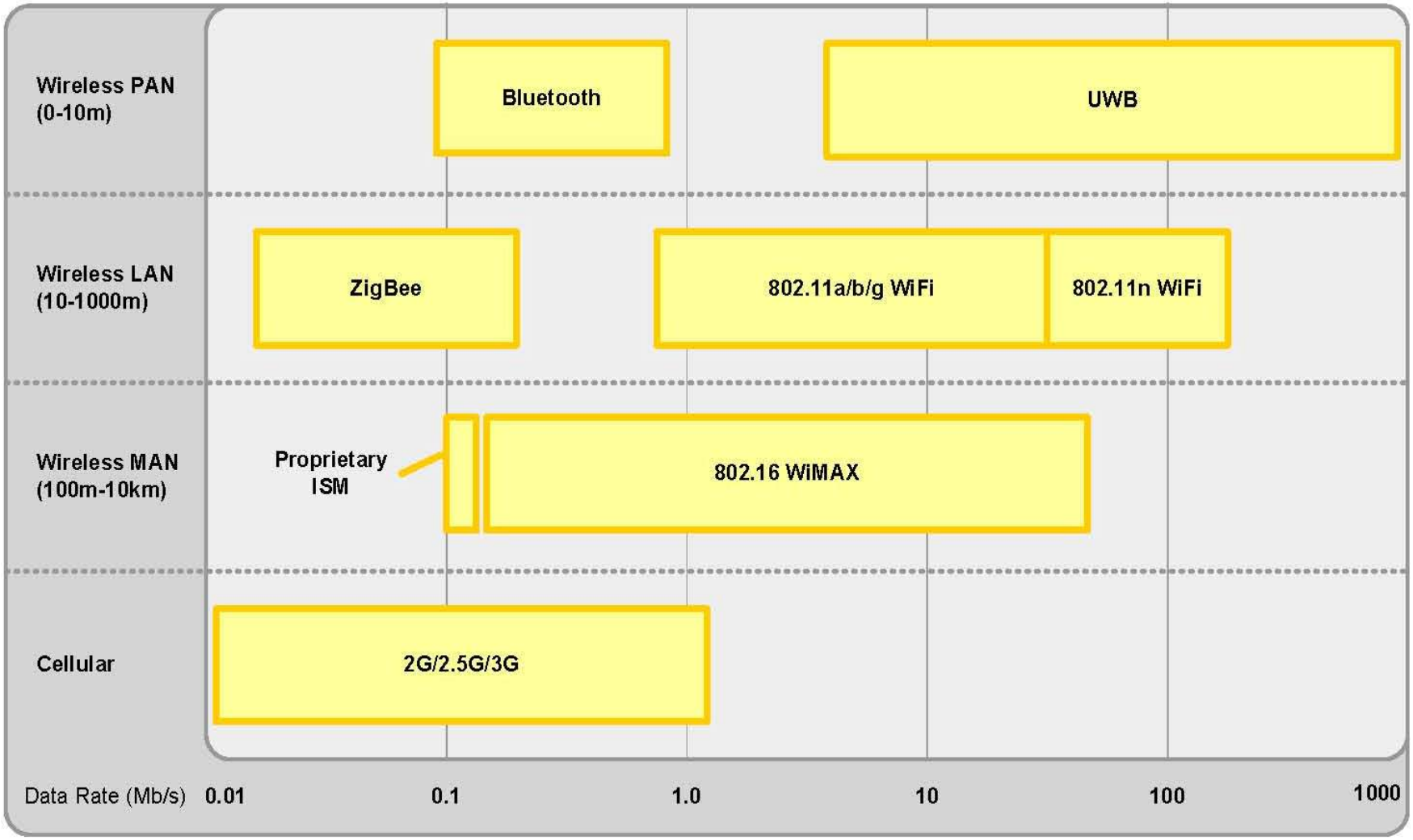
Requirements

- Small transceiver footprint – two cubic inches or less
- Interface with and provide power to a strain gauge force sensor
- Battery powered for minimum of three hours
- Reliable data transmission to 100 feet or more
- Receiver base station for on-board data system

Airborne Wireless Technology

- Limited wireless technology available for flight test vehicle measurements
- Most existing wireless technology is not robust enough for the flight test environment
- New technology is being developed but not fast enough to satisfy current measurement requirements
- Existing wireless systems and technology were explored to determine the feasibility of performing this measurement

Wireless Technology Comparison



Wireless Technology Comparison

	Bluetooth	UWB	ZigBee	802.11a/b/g	802.11n	Proprietary	802.16a	2G/2.5G/3G
Typical Range	< 10m	10-30m	70-300m	100m	100m	10km	50km	Cellular Network
Modulation	Adaptive FHSS	OFDM or DS-UWB	DSSS	DSSS	DSSS	FHSS	QAM	CDMA/GSM/ AMPS
Freq. Range	2.4GHz	3.1-10.6GHz	868/915MHz 2.4GHz	2.4GHz -b/g 5.8GHz - a	2.4GHz	915MHz & 2.4GHz	2-11GHz	869-894MHz
Network	P2P	P2P	Mesh	IP & P2P	IP & P2P	P2P	IP	IP
IT Network Connectivity	No	No	No	Yes	Yes	No	Yes	Yes
Cost of Data	Free	Free	Free	Free	Free	Free	Free	Monthly Charge
Application	Cable replacement	Sync and Transmission of video/ audio data	Sensor networks	LAN, Internet	LAN, Internet	Point to point connectivity	Metro area broadband Internet connectivity	Celular telephones and telemetry

Wireless System Examples

- Teletronics Technology Corp., SWSC-103(E) wireless system being developed for the ASMT program
  - Uses Bluetooth transceiver
  - Current off-the-shelf version did not meet the requirements for this measurement
- Microstrain Inc., SG-Link wireless system
  - Uses 802.15.4 Zigbee transceiver

MicroStrain SG-Link System

- 2.4 GHz direct sequence spread spectrum radio is license free worldwide
- IEEE 802.15.4 open communication architecture
- Supports simultaneous streaming from multiple nodes to PC
- Data logging rates up to 2048 Hz
- Real-time streaming rates up to 4 KHz
- On-board memory stores up to 1,000,000 measurements
- Communication range up to 70m line-of-sight, 300m with high gain antennas
- Regulated 3 volt sensor excitation supports most analog sensors
- On-board bridge completion resistors
- Includes internal resistor for wireless shunt calibration
- Low power consumption for extended use
- Internal rechargeable battery

MicroStrain SG-Link System

The Issue

- Currently the KC-130J has a low and high speed drogue used respectively for low and high speed aircraft.
  - Low speed (105-130 knots) indicating aircraft such as helicopters and other newer aircraft like the V-22.
  - High speed (185-250 knots) indicating aircraft like the F-18 and newer aircraft such as the UAV and JSF.
- Logically there is now an effort to consolidate design in to a variable speed drogue that would accommodate all aircraft.
  - This would eliminate the need to change drogues for different aircraft and to basically cover a greater spectrum of speeds to adapt to all aircraft.

KC-130J Refueling

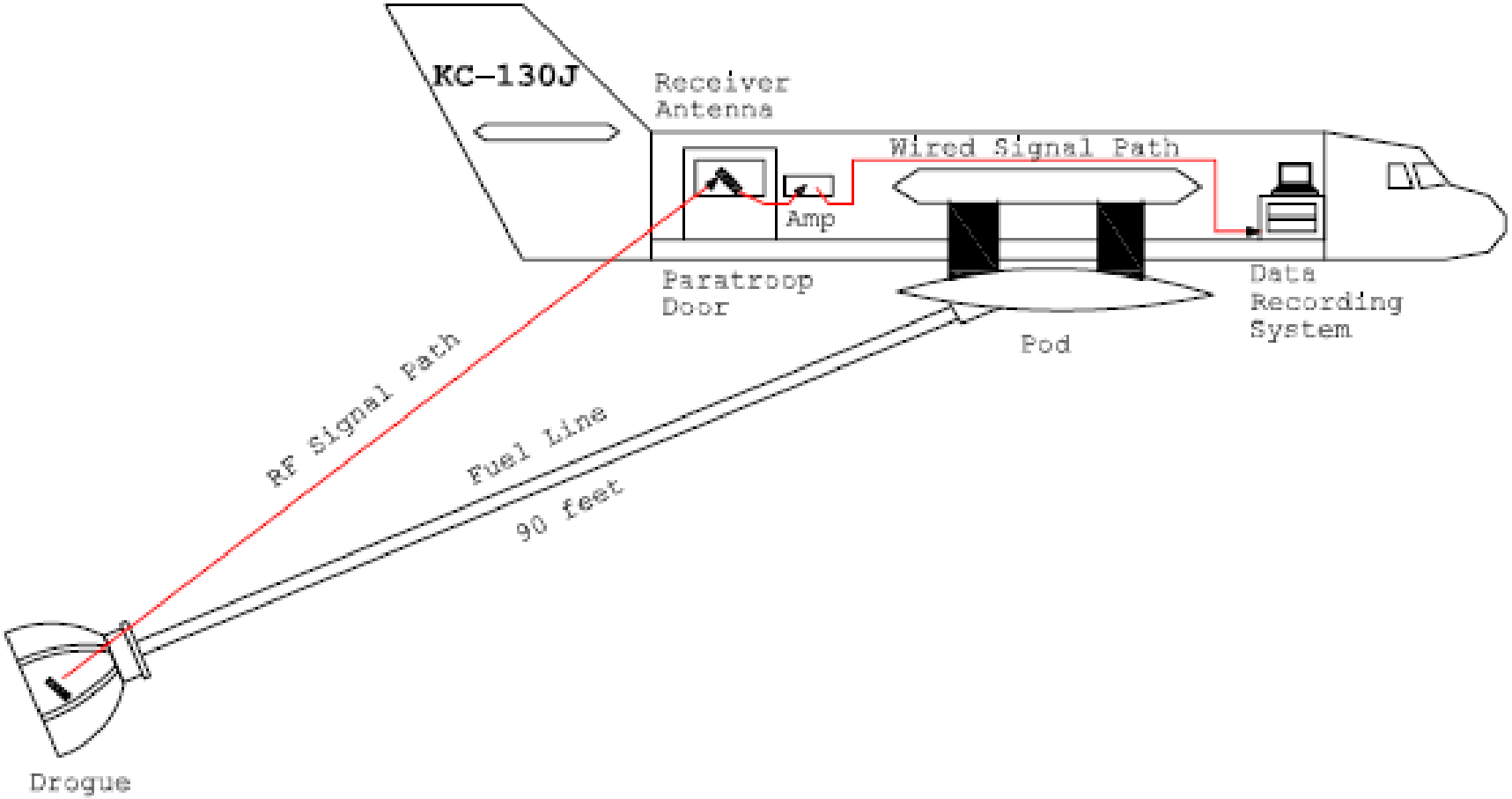
The Measurement

- It was determined by the KC-130J Test Team that the best way to measure different levels of drag from the drogue was to measure the level of strain between the refueling line and the drogue itself.

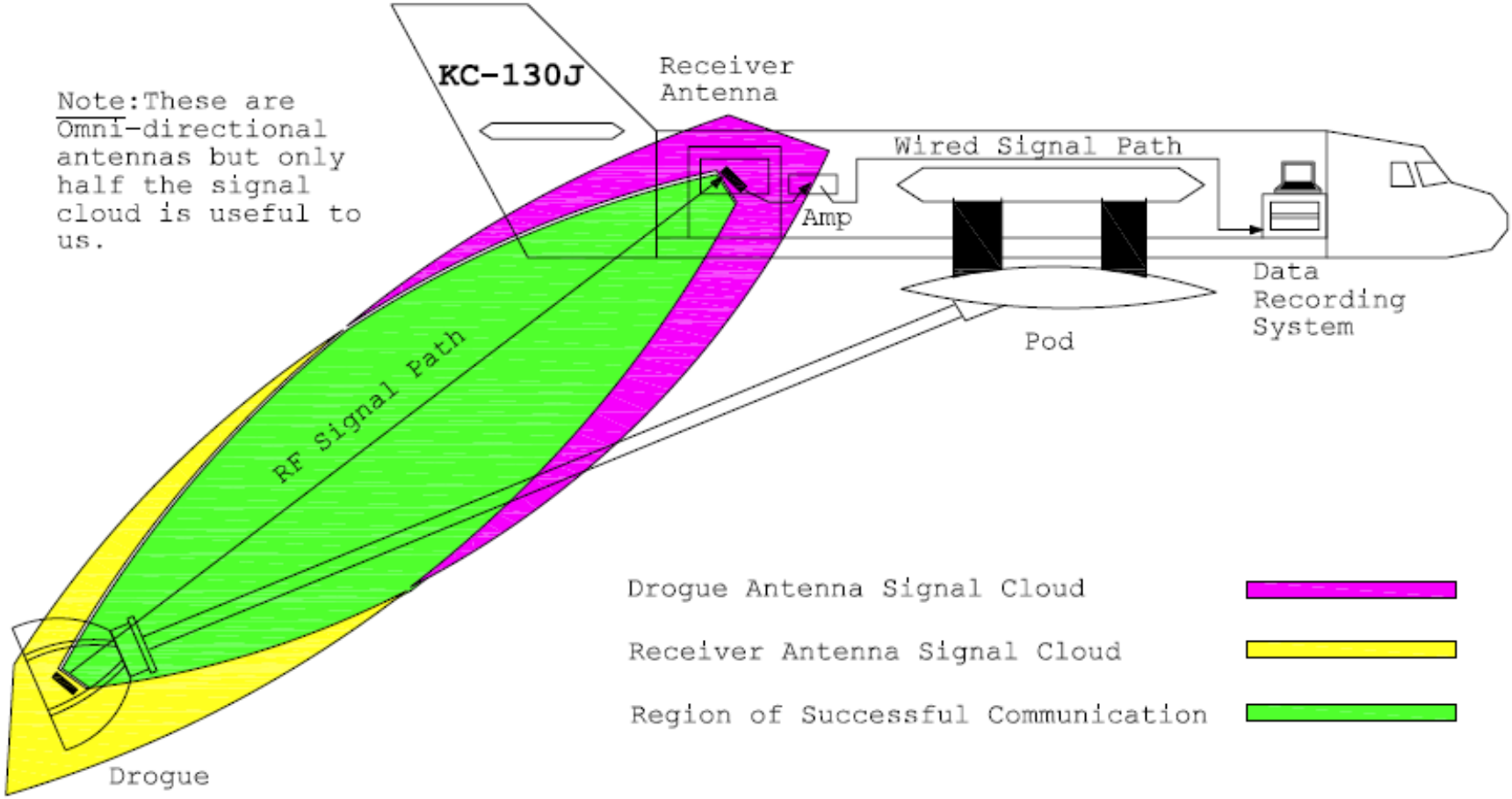
The Difficulties

- Data transmitted from Drogue antenna to on board antenna
  - Transmission material.
    - Original rubber
    - Clear Tecanat GF20 (windows design)
    - Shaded Tecanat GF20 (entire shield)
  - Angle of Antennas to maximize signal strength with receiver antenna on aircraft.
- Signal strength is weak at receiver on board window antenna

Physical System Diagram

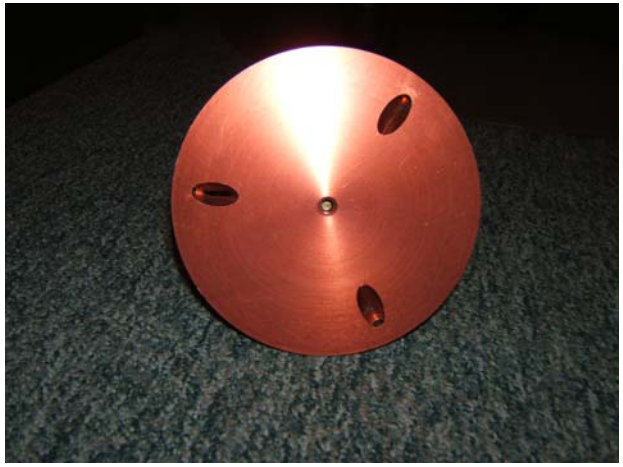


Wireless Signal Cloud

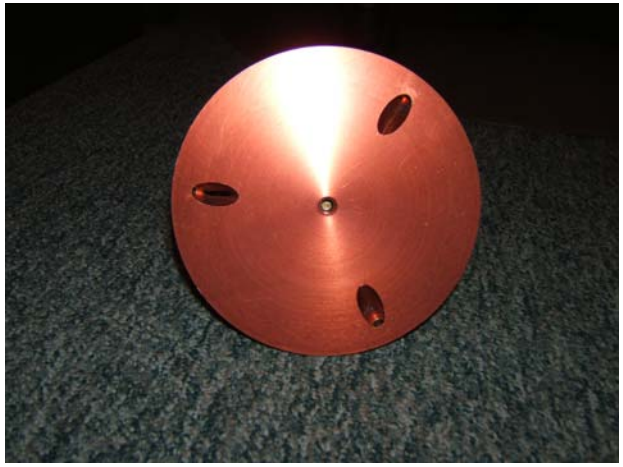


Drogue Evolution

Drogue Instrumentation Package

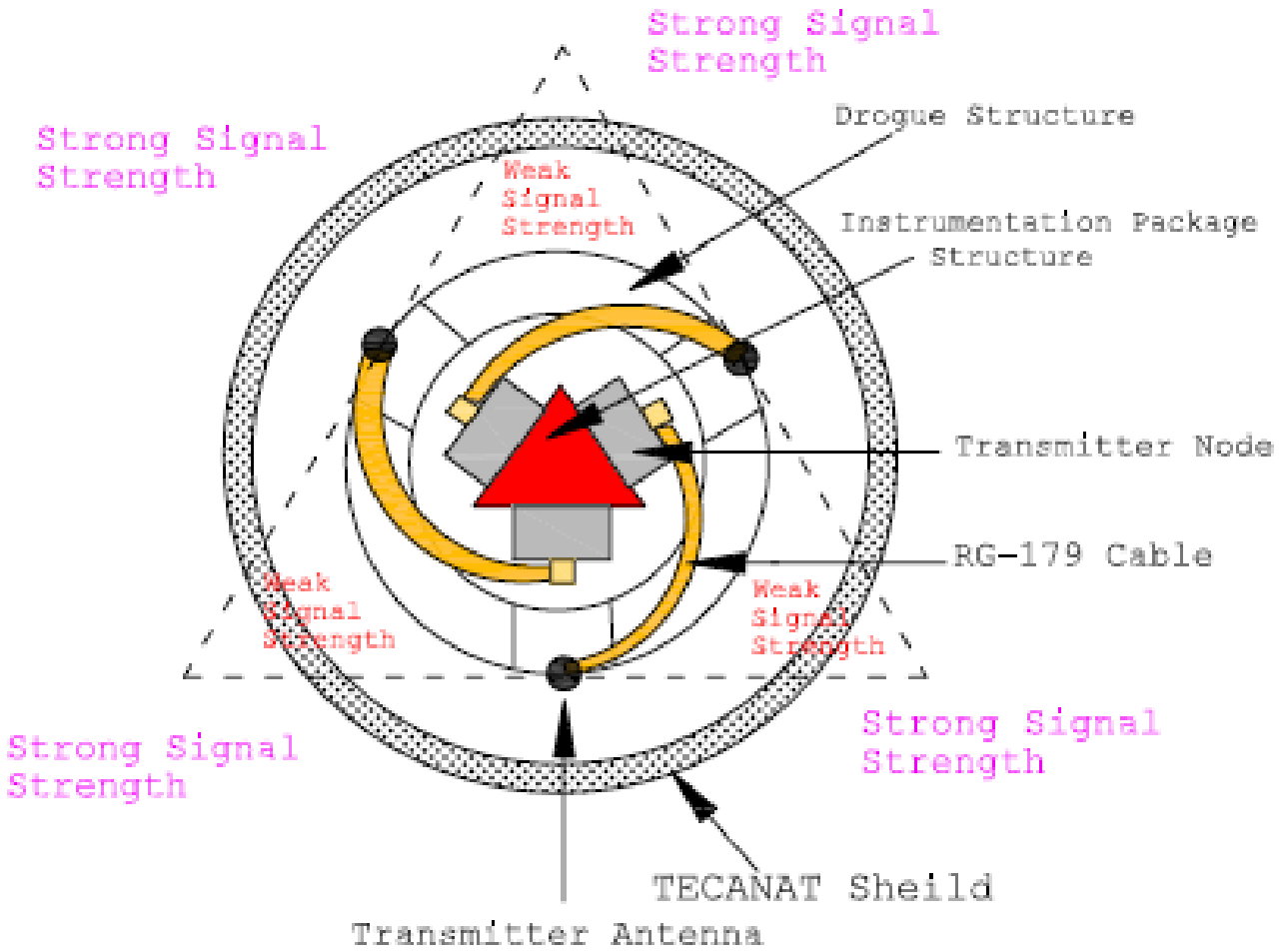


Drogue Instrumentation Package

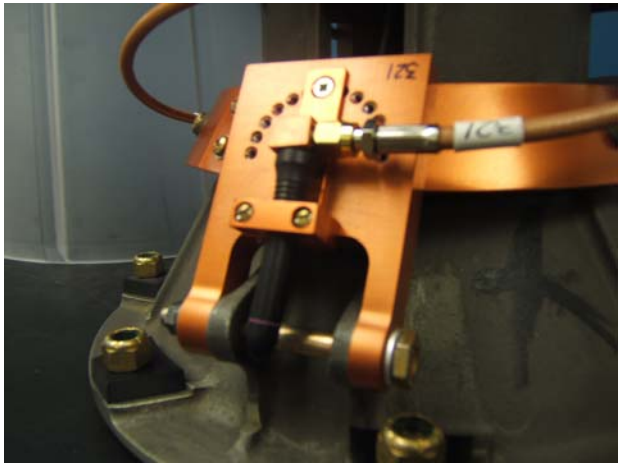


Drogue Antennas Transmission Region

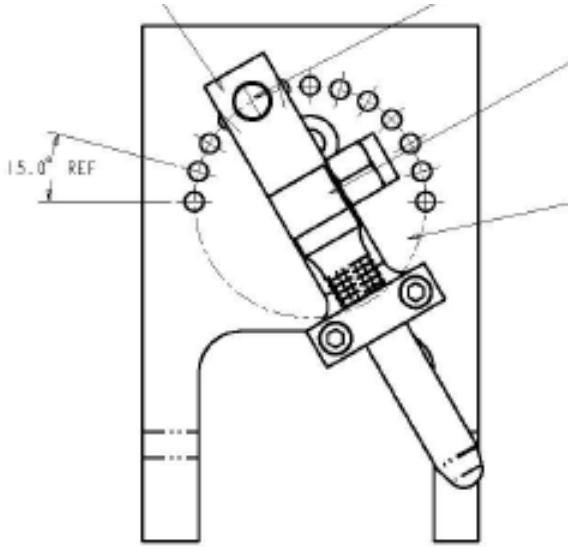
Any Region outside the Triangle indicates strong RF signal strength.



Variation of Antenna Angle



- Drogue antennas can be adjusted from 0 to 180 degrees from the horizontal in 15 degree increments.



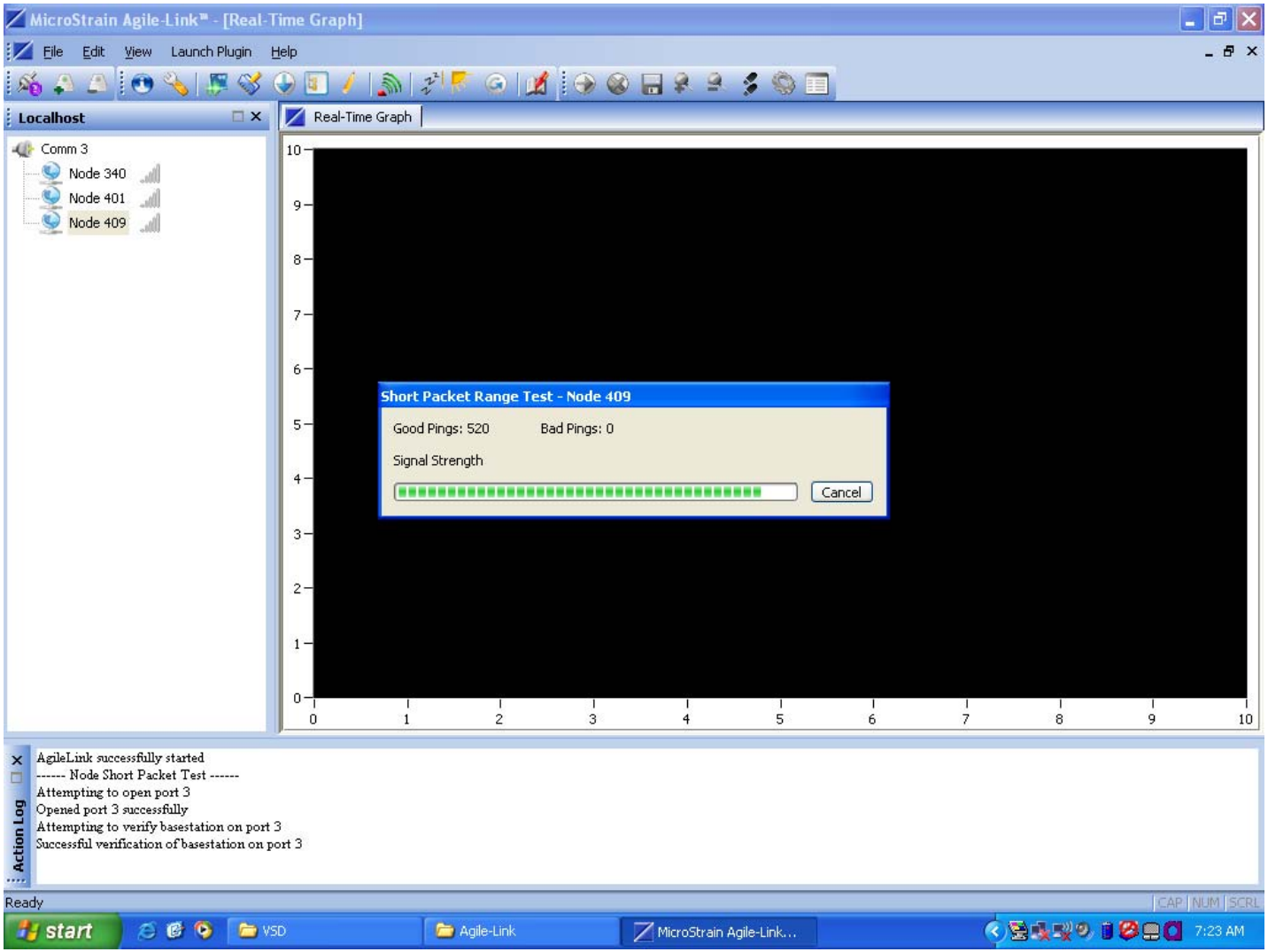
Drogue Shield

- TECANAT GF20
  - 20% glass reinforced polycarbonate
- Similar weight, strength, and thermal properties to original PVC
- 10-20% loss in signal strength compared to open air.

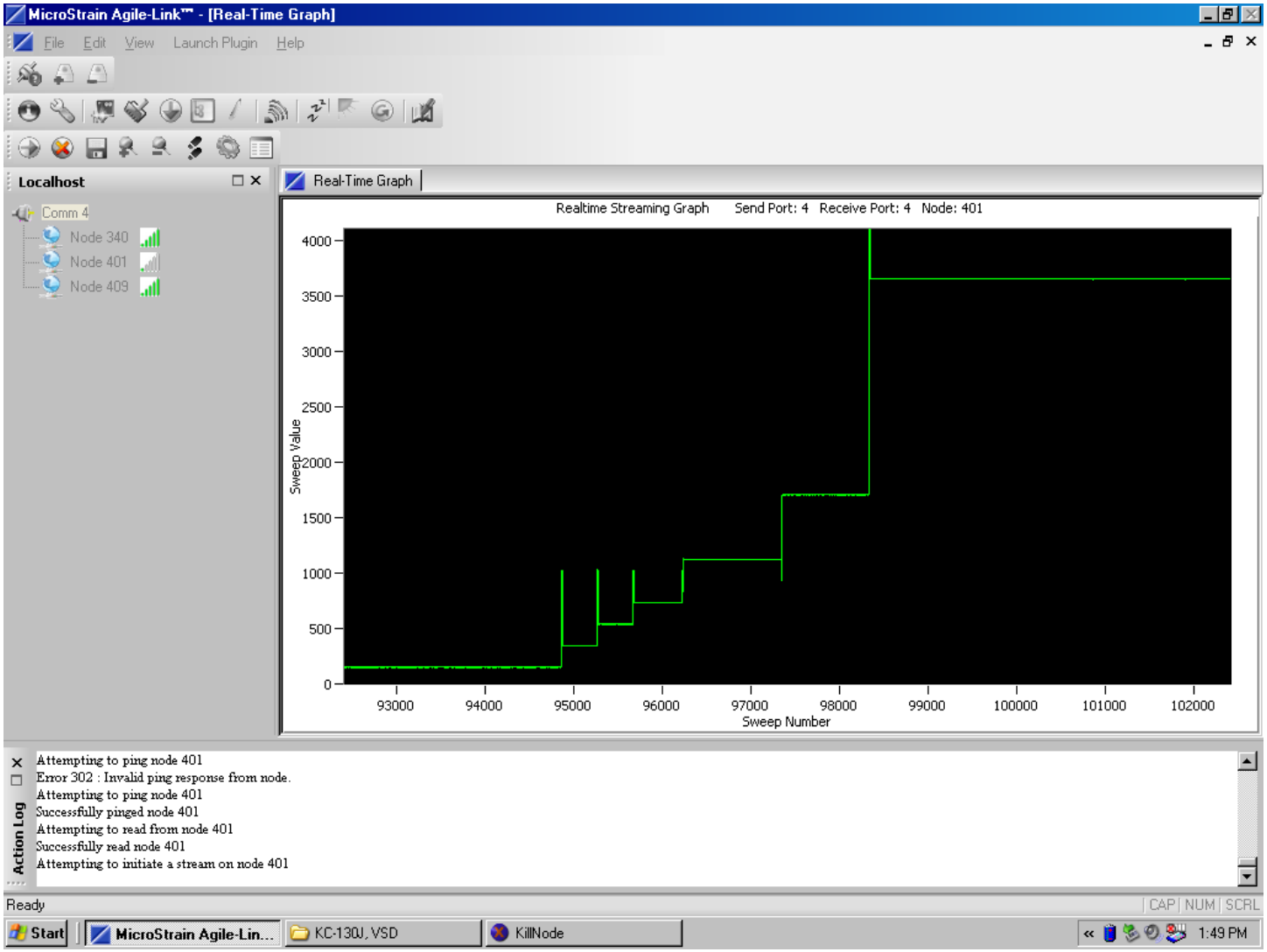
Application Software

- MicroStrain Inc.
  - Agilelink – Wireless node interface software
- Uses of Software for our Instrumentation Setup
  - Test Signal strength between node and basestation
    - Choose best of three nodes for data stream
    - Choose best of two other nodes in case of loss of communication with data streaming node during flight
  - To initiate and monitor data stream during flight

Application Software: Signal Strength



Application Software: Stream



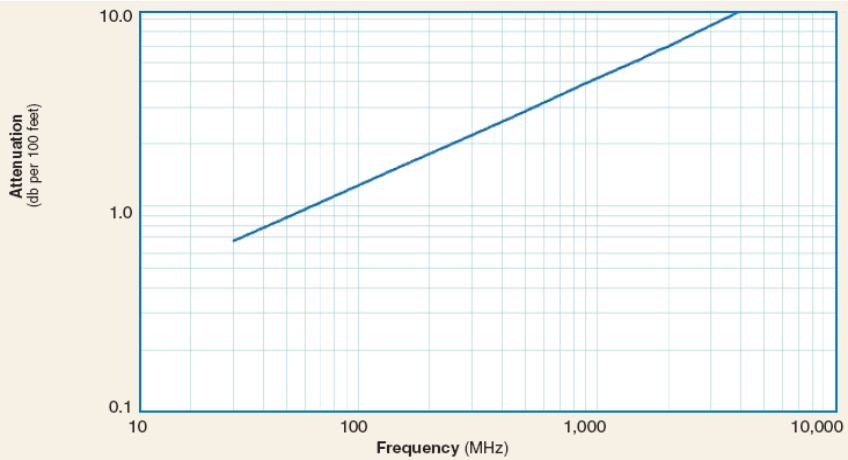
Data Recording System

- Data is viewed real time on computer
- Data is recorded on solid state recorder
- Base Station captures the data from the drogue via extreme low loss cable

Analog Basestation

- Basestation receives antenna signal from extreme low loss cable.
- Basestation transmits analog data from channel ports on back to CDAU, CAIS Data Acquisition Unit.

Extremely Low Loss Cable



Comparison Chart

	RG-393	LM-400-FR
dB Loss per 100 feet for 2.4 GHz	12.237 dB	6.614 dB
Diameter	.390 in.	.405 in.
Bend Radius	2 in.	1 in.
Cost per foot	$0.88	$1.40
Operating Temperature	-55/200 deg C	-40/+85 deg C

- LMR-400-FR
  - Times Microwave Systems Corporation
  - Non-toxic, low smoke, fire retardant

Conclusions

- Prototype mock up was run on the ground has successful system communication up to 120 feet antenna separation.
- TECANAT GF20 is a strong material that can be cut in to various shapes and allows for RF communication with a low loss of signal strength.
- Antennas communicate best when parallel to each other and lie on the same plane.
- Further and far more results will be substantiated when the system flies as planned this summer.

References

- www.timemicrowave.com
- www.microstrain.com
- http://www.dpactech.com/evaluation_support/wireless_technology_comparison.php