A COMPACT AIRBORNE KA-BAND PRECIPITATION PMS PROBE RADAR (KPR)

Andrew L. Pazmany, James B. Mead and Ivan Popstefanija
ProSensing Inc., Amherst, MA

PROSENSING
SYSTEMS ENGINEERING FOR ENVIRONMENTAL REMOTE SENSING

Background

- 2005: ProSensing developed a compact G-band (183 GHz) water Vapor radiometer (GVR) packaged in a standard PMS probe canister


GVR
National
Science
Where Discoveries Begin
Research Aviation Facility

Background (cont.)

- 2011-2013: ProSensing delivered six compact Ka-band (35 GHz) solid state range finding radars

Objectives

- Develop a precipitation radar that can operate from a standard PMS probe canister

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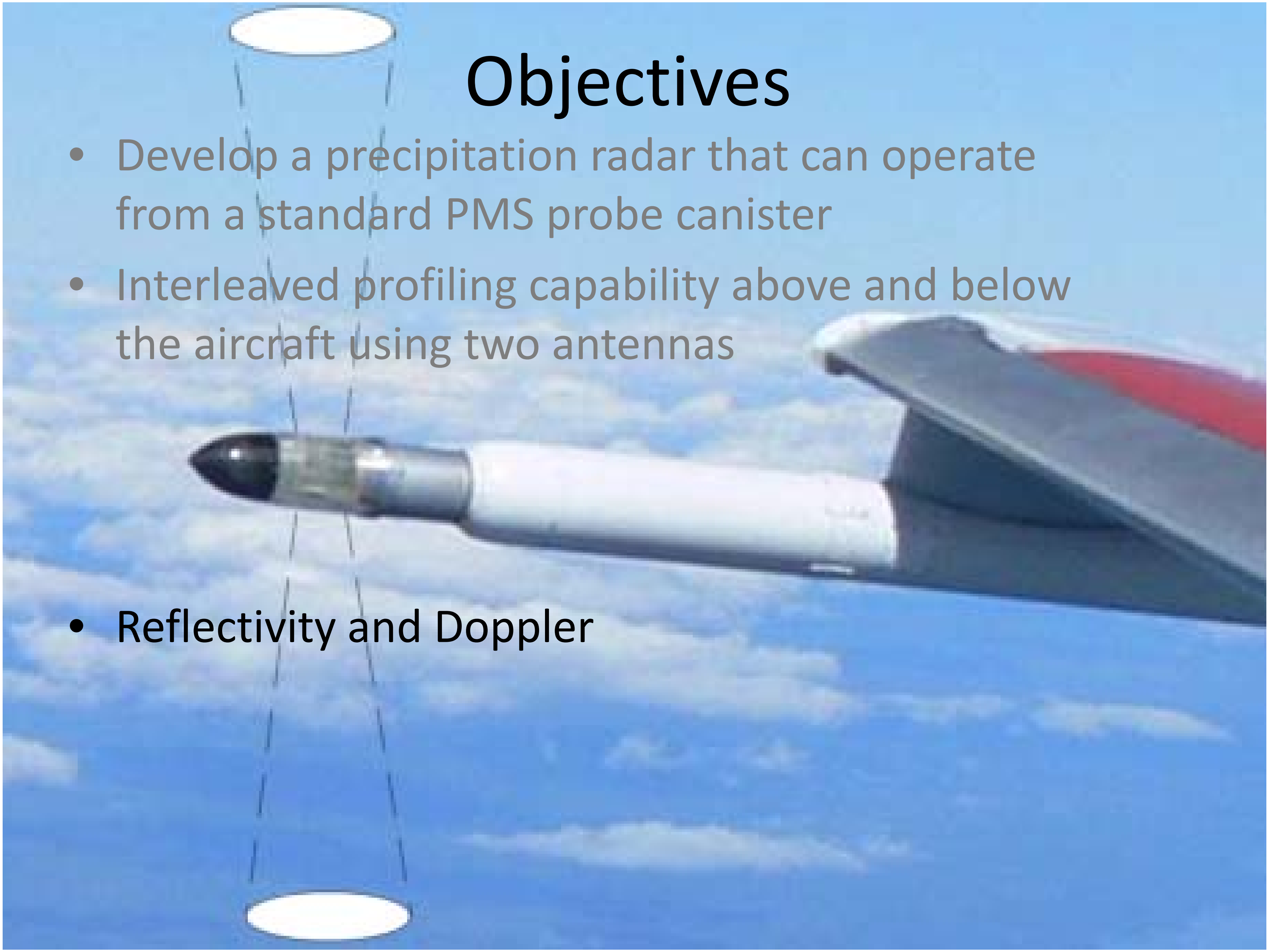

- Reflectivity and Doppler

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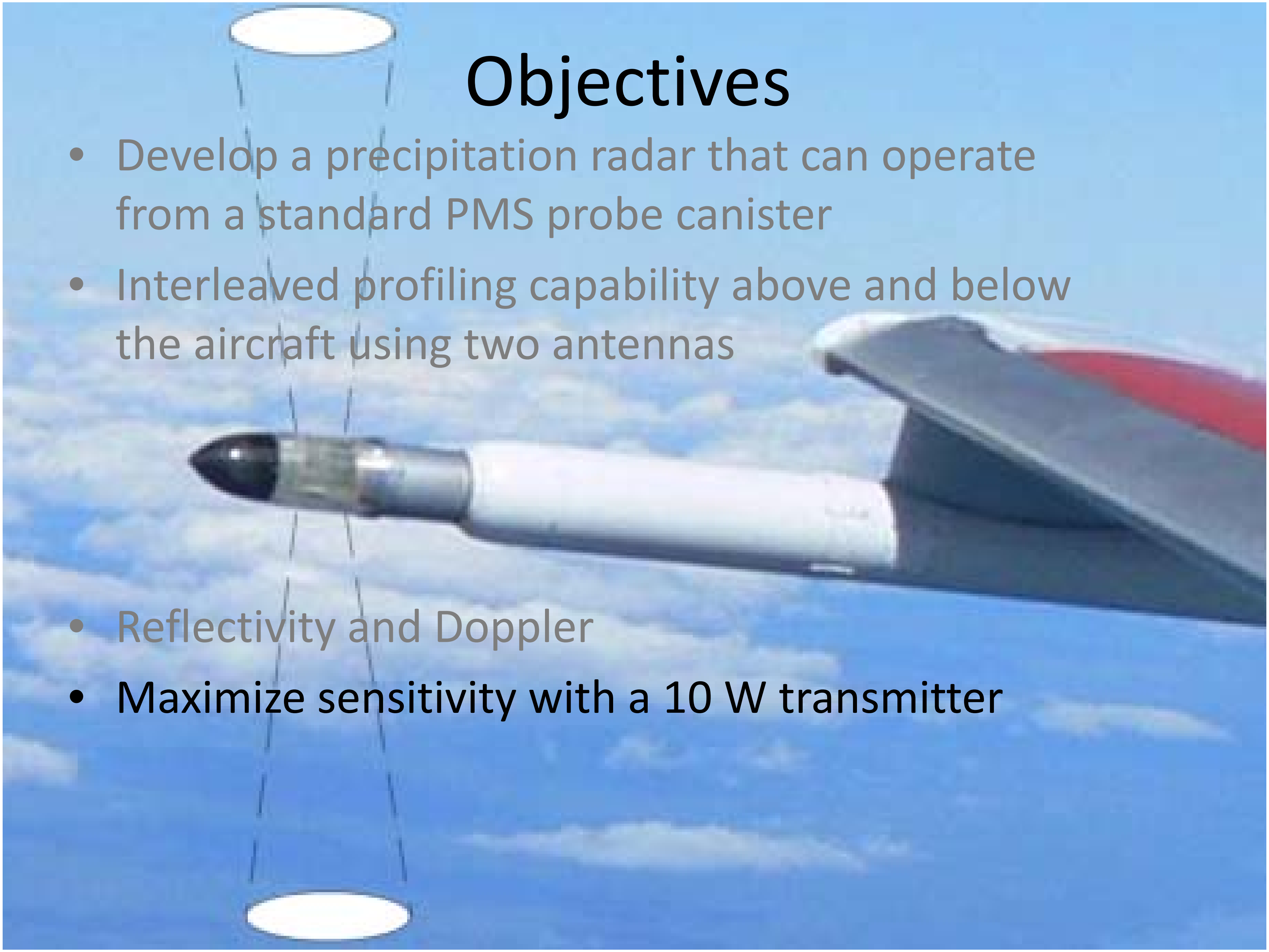

- Reflectivity and Doppler
- Maximize sensitivity with a 10 W transmitter

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- Measure close to the aircraft (~100 m)

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- Reflectivity and Doppler
- Maximize sensitivity with a 10 W transmitter
- Measure close to the aircraft (~100 m)
- Radiometer (in the Zenith beam)

Key Enabling Component

- Compact 10 W, pulsed, solid state Ka-band power amplifier

Size: 5”x3”x1”

Design Features

- Interleaved profiling capability above and below the aircraft using two antennas -> T/R switch network and dual-antennas

- ➢ ~ 0.2 dB loss per junction
- ➢ ~ 30 dB isolation per junction
- ➢ ~ 200 ns transition time
- ➢ 20 kHz max. PRF rate (40 kHz events)

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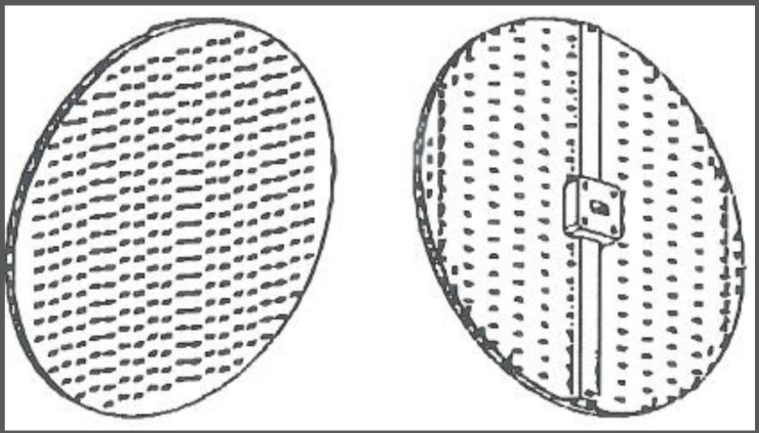

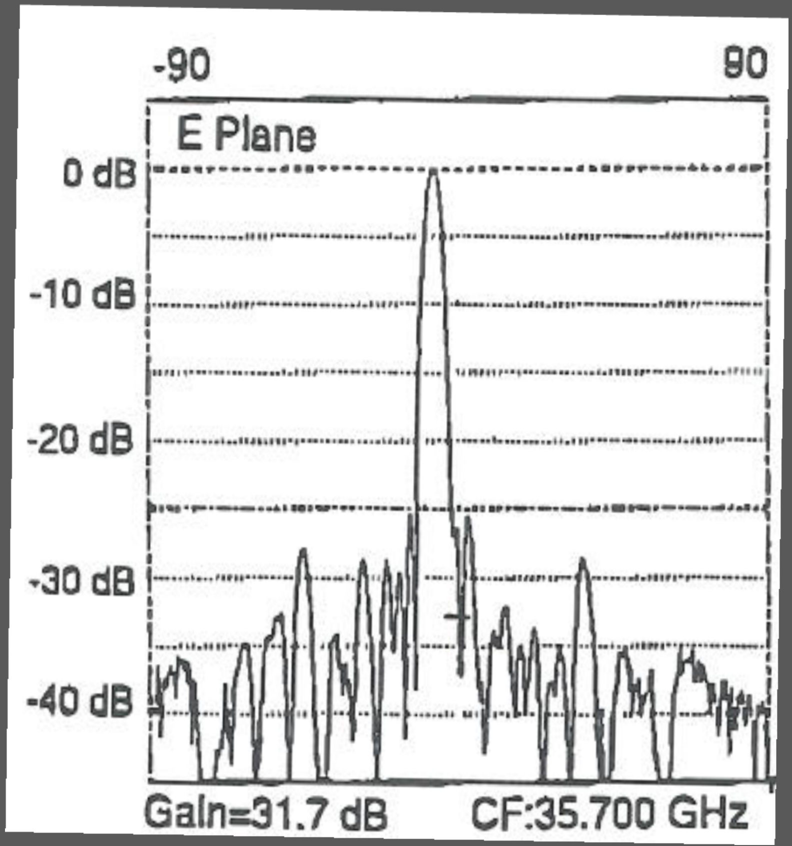

- ➢ Slotted Waveguide Array
- ➢ 35.5 – 35.9 GHz Freq. Range
- ➢ 4.2 Beamwidth
- ➢ 31.7 dB Gain

Design Features

- Interleaved profiling capability above and below the aircraft using two antennas ->
  T/R switch network and dual-antennas
- Reflectivity and Doppler measurements ->
  Integrated Analog Devices ADIS16375 IMU

- 3-axis gyroscope: ± 300˚/sec
- 3-axis accelerometer: ±5g
- Temperature range: -40 ˚C to +105 ˚C
- Bandwidth: 330 Hz; 2.4 kHz sampling

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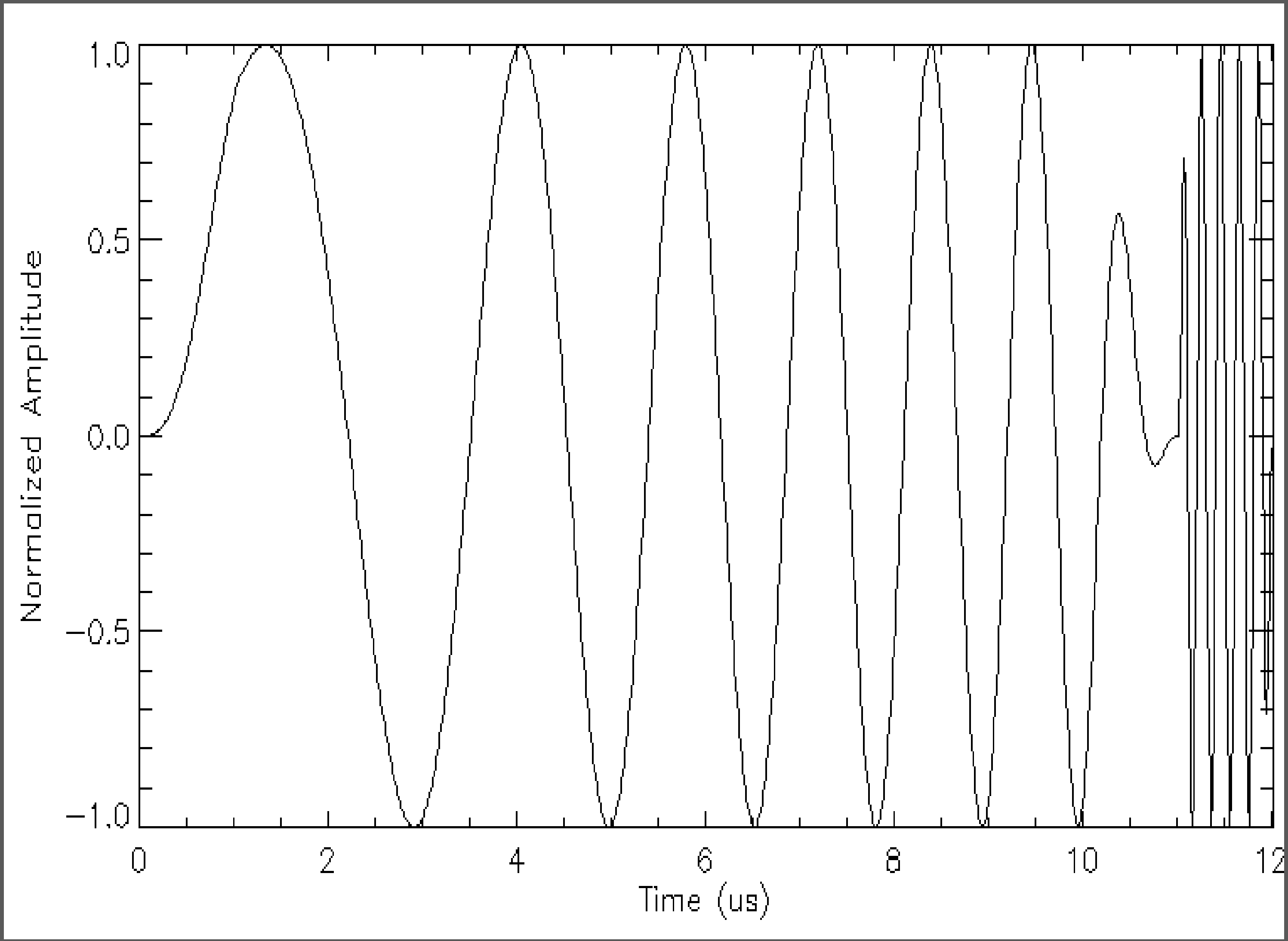
- Maximize sensitivity with a 10 W transmitter -> Pulse compression

Design Features

- Interleaved profiling capability above and below the aircraft using two antennas -> T/R switch network and dual-antennas
- Reflectivity and Doppler measurements -> Integrated Analog Devices ADIS16375 IMU
- Maximize sensitivity with a 10 W transmitter -> Pulse compression
- Measure close to the aircraft (~100 m) -> Combined offset frequency short/chirped TX pulse Wide-band RF; dual-channel IF receiver and data system

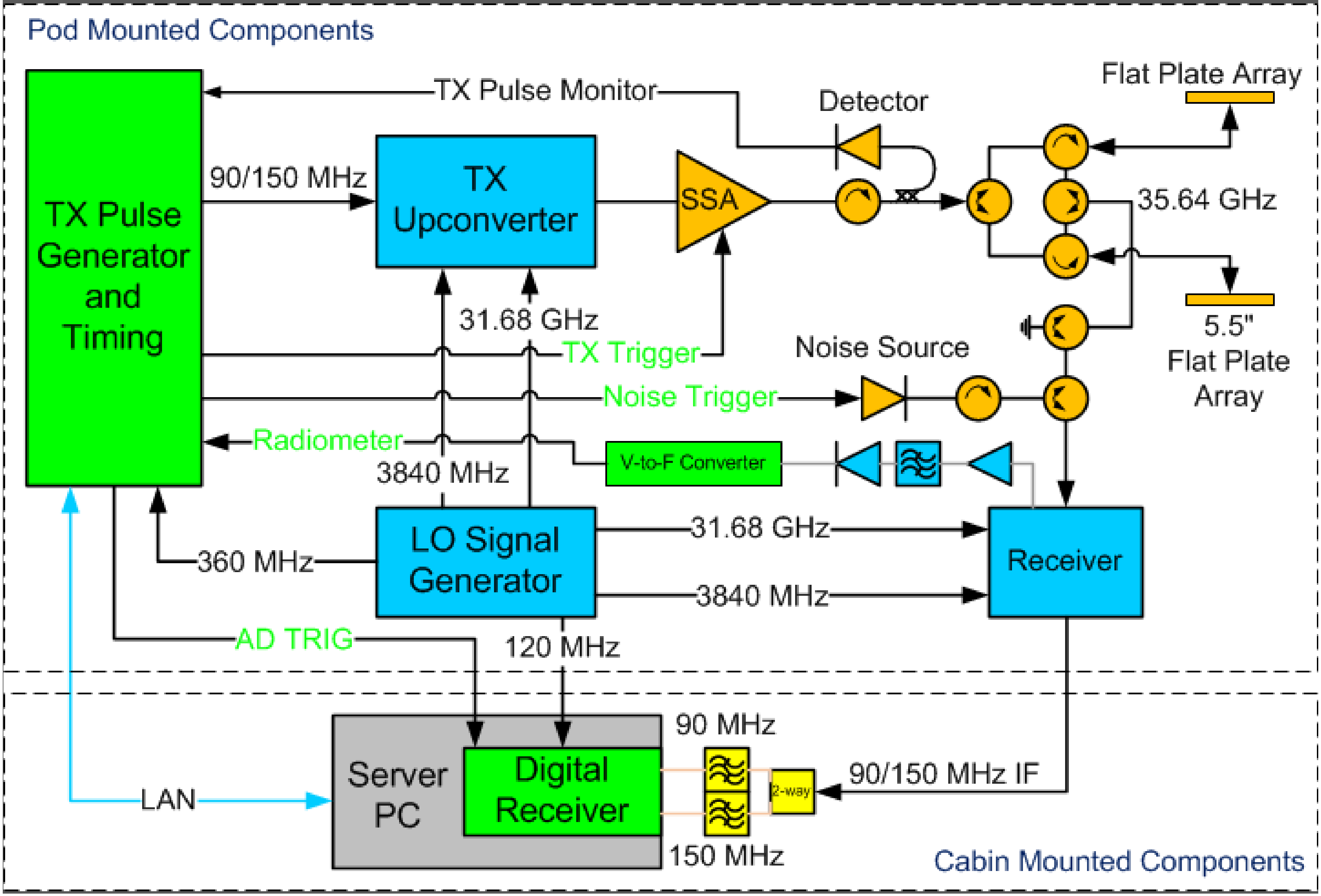
Combined Chirp/Short pulse

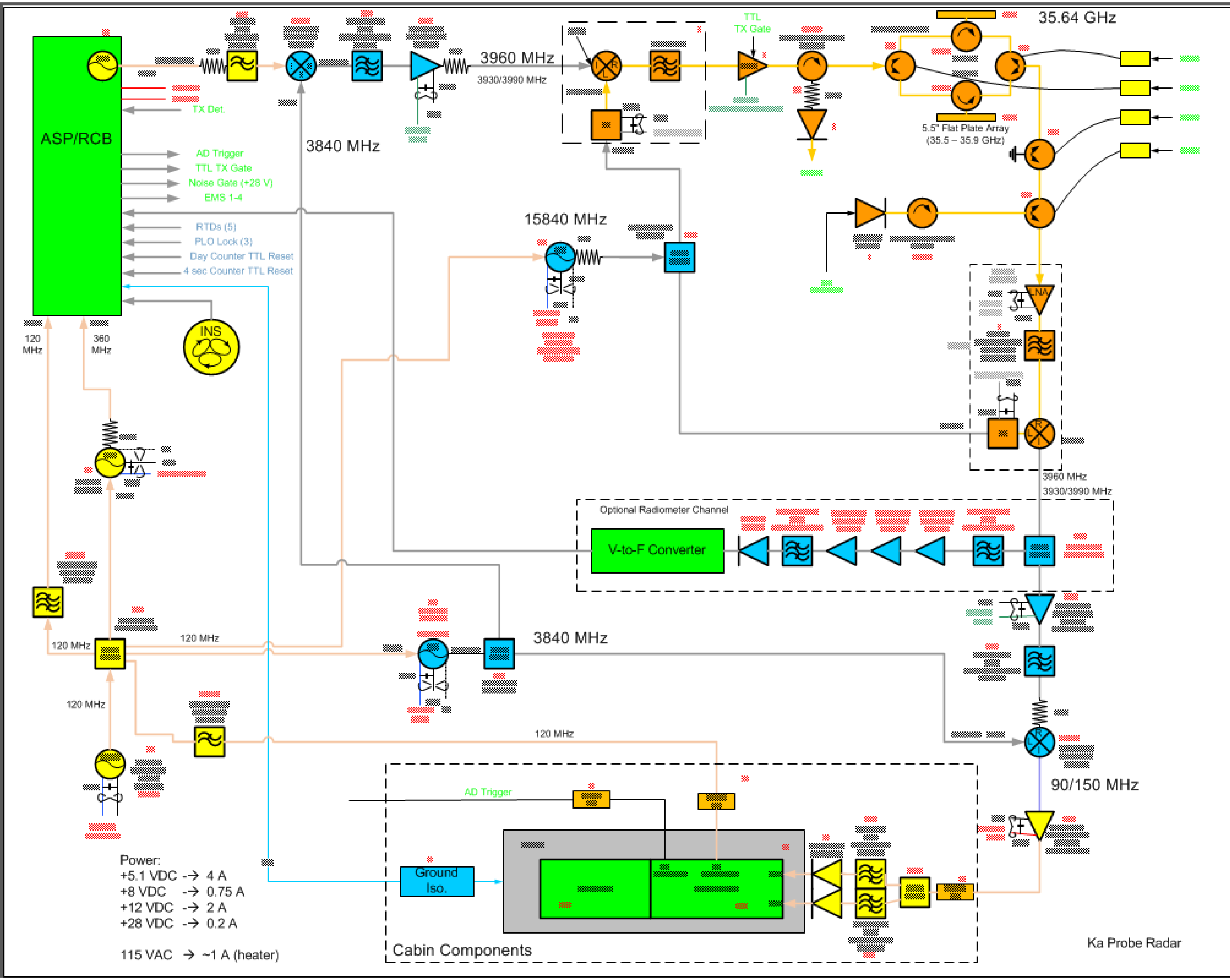


Design Features

- Interleaved profiling capability above and below the aircraft using two antennas -> T/R switch network and dual-antennas.
- Reflectivity and Doppler measurements -> Integrated Analog Devices ADIS16375 IMU
- Maximize sensitivity with a 10 W transmitter -> Pulse compression.
- Measure close to the aircraft (~100 m) -> Combined offset frequency short/chirped TX pulse.
- Radiometric measurement capability (in Zenith beam) -> Integrated noise source and wide band radiometer receiver

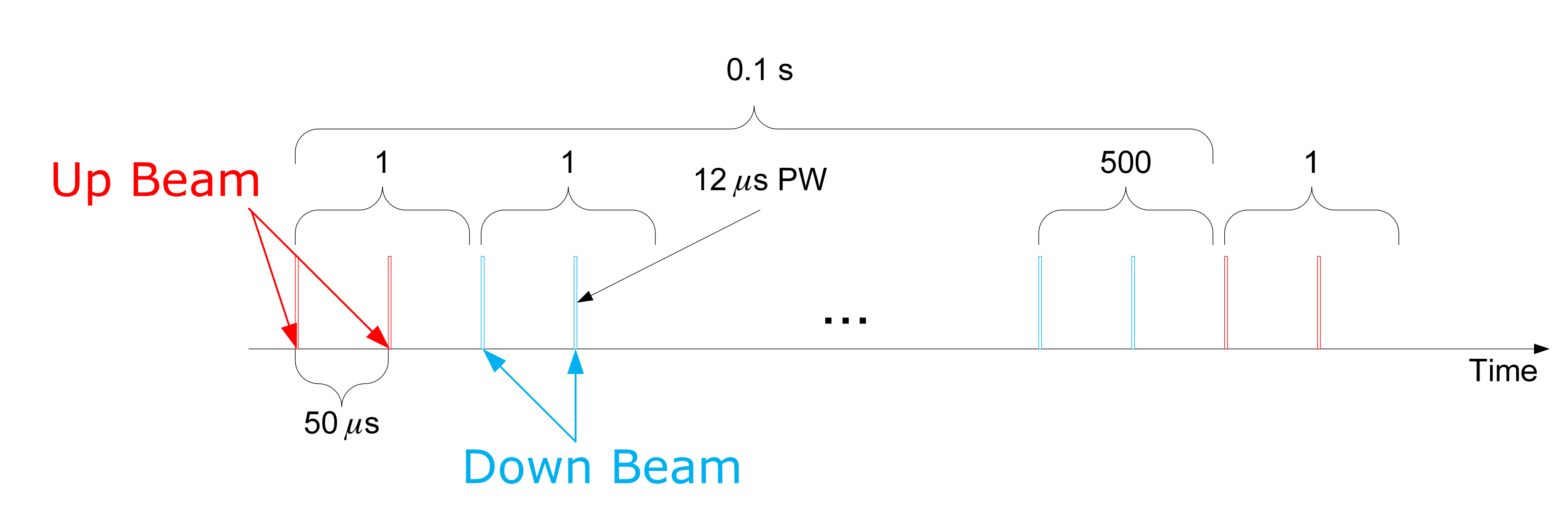
Simplified Component Level Diagram





ASP/RCB
TX Det.
AD Trigger
TTL TX Gate
Noise Gate (+28 V)
EMS 1-4
RTDs (5)
PLO Lock (3)
Day Counter TTL Reset
4 sec Counter TTL Reset
INS
120 MHz
360 MHz
3960 MHz
3930/3990 MHz
3840 MHz
TTL
TX Gate
35.64 GHz
5.5" Flat Plate Array
(35.5 – 35.9 GHz)
15840 MHz
LNA
3960 MHz
3930/3990 MHz
Optional Radiometer Channel
V-to-F Converter
3840 MHz
120 MHz
120 MHz
120 MHz
120 MHz
90/150 MHz
AD Trigger
Ground Iso.
Cabin Components
Power:
+5.1 VDC -> 4 A
+8 VDC -> 0.75 A
+12 VDC -> 2 A
+28 VDC -> 0.2 A
115 VAC -> ~1 A (heater)
Ka Probe Radar

Radar Pulsing



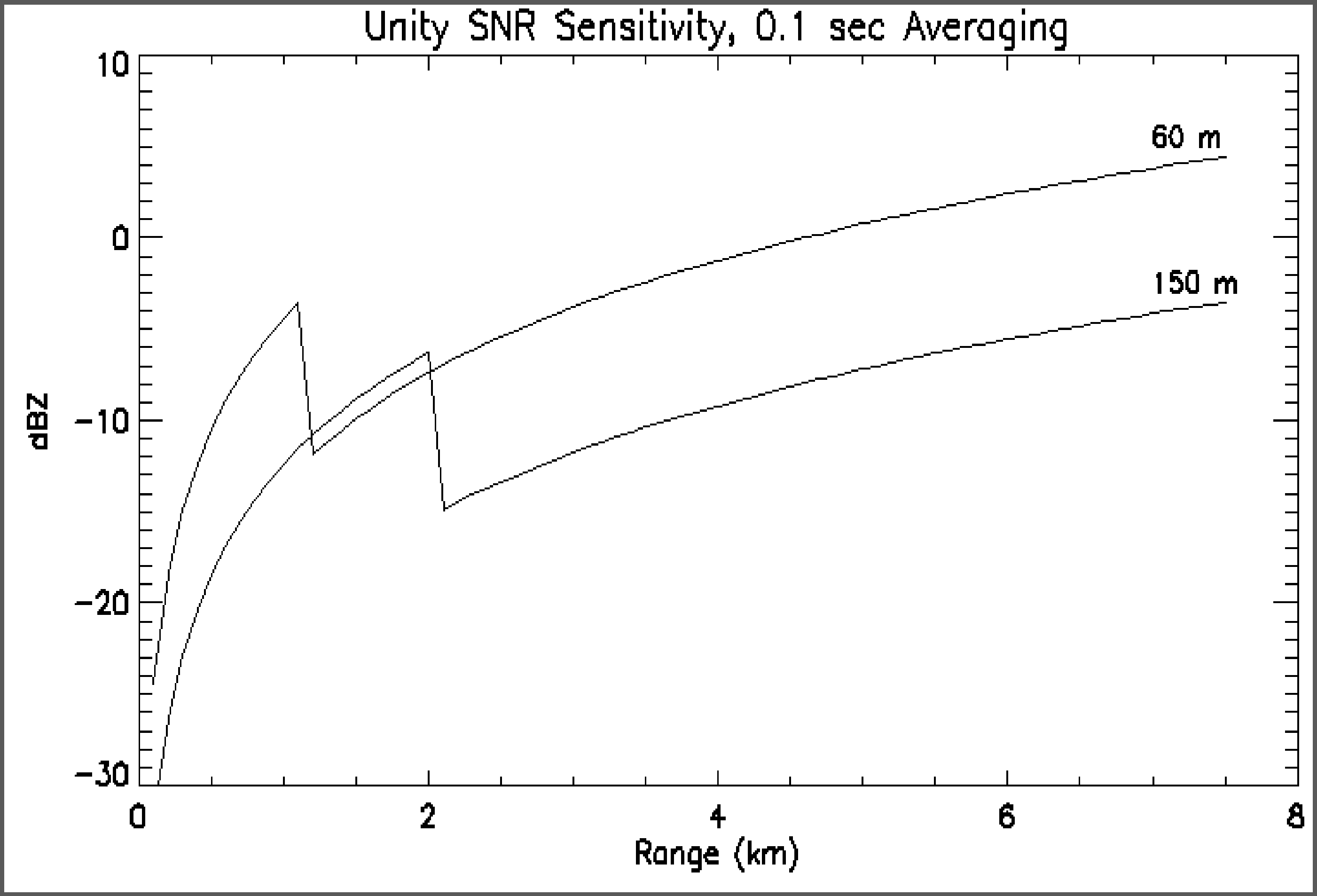
PRI = 50 us <-> PRF= 20 kHz

Pulse Pair Group Frequency = 5 kHz

T_{INT} = 0.1 sec

N = 5000 * 0.1 = 500

Sensitivity



P_t = 40 dBm

F_S = 5 kHz

T_{INT} = 0.1 sec

N=500

Comp. = 10x

Interleaved Radiometer Measurements

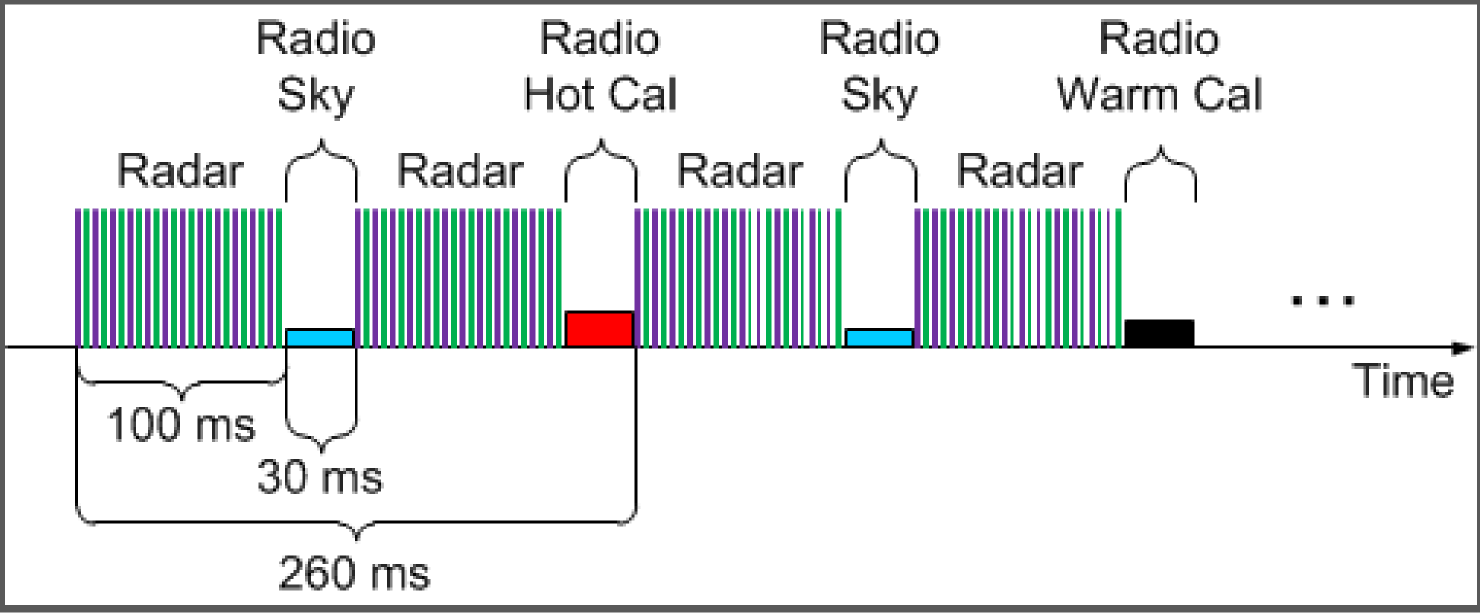
- LWP precision < ~0.02 mm (< ~20 g/m^2)
- Requires a $\Delta T_B < 0.5$ K
- $\Delta T_B = \frac{T_{ANT}+T_{SYS}}{\sqrt{B\tau}} \approx \frac{1000}{\sqrt{B\tau}}$
- $B\tau >$ 4e6
- with Radar Data System:

  B = 40 MHz, then $\tau >$ 100 ms
- with dedicated Radiometer Receiver:

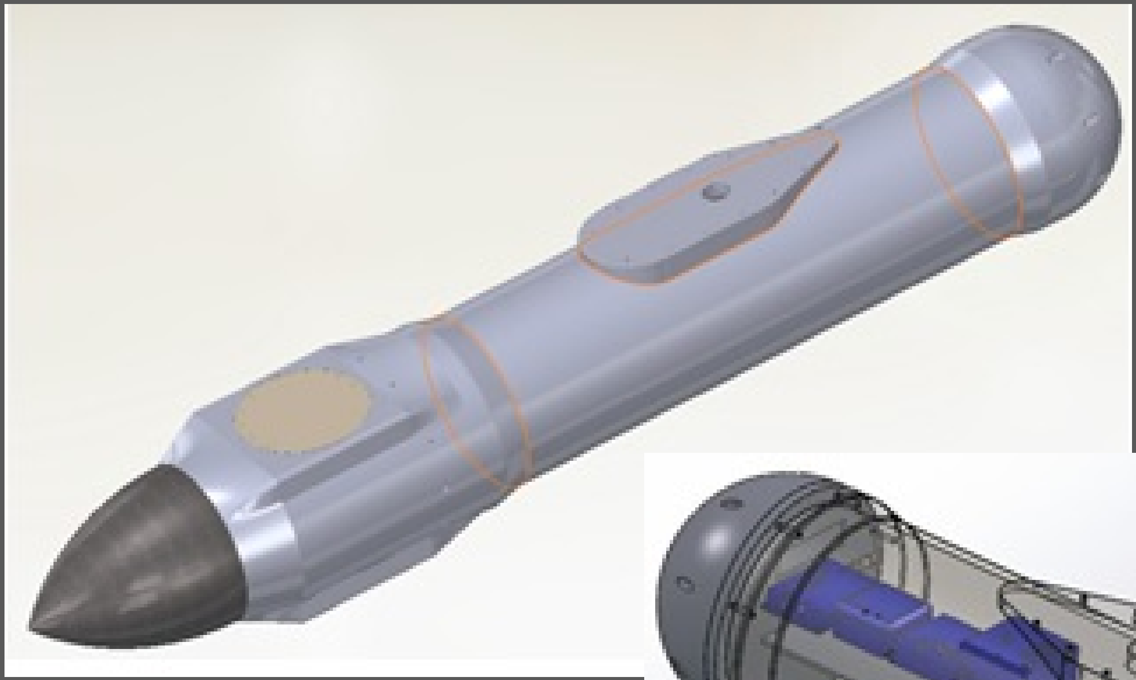
  B = 200 MHz, then $\tau >$ 20 ms

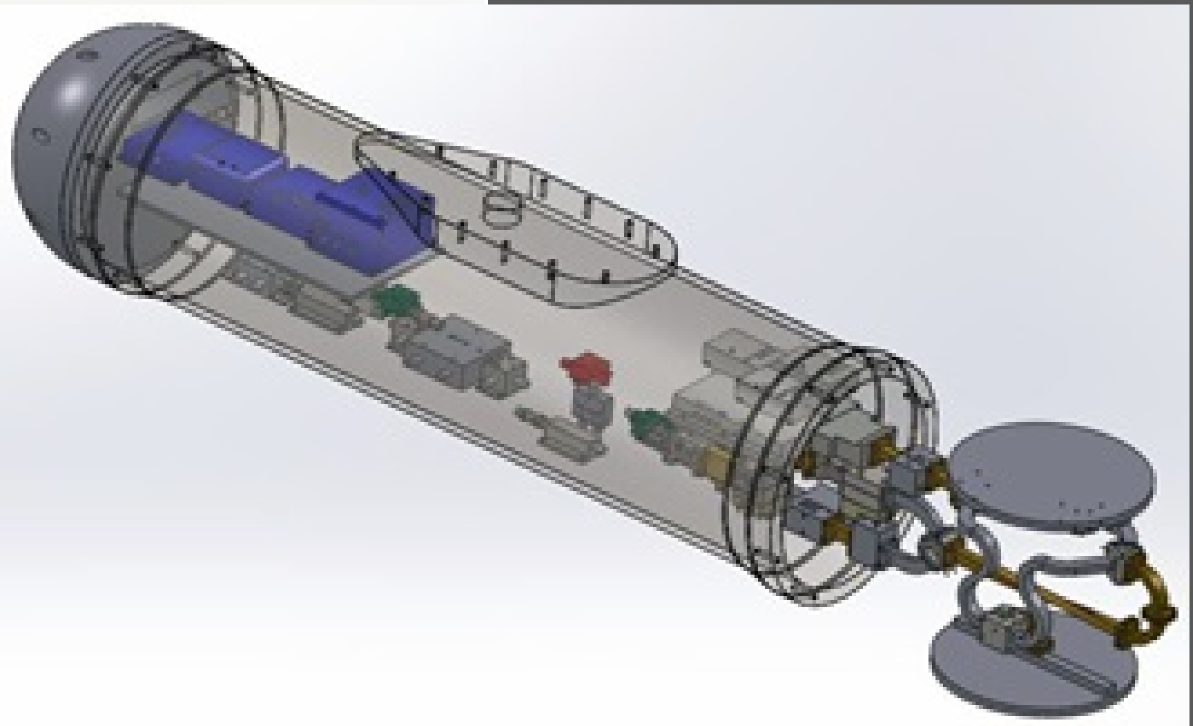
Interleaved Radiometer Measurements

- 100 ms Integration-> 10-15 m Flight Distance
- 4.2˚ BW Antenna -> ~75 m footprint @ 1 km
- 150 ms radar period: 15-20 m flight distance
- 300 ms radiometer period: 30-45 m distance

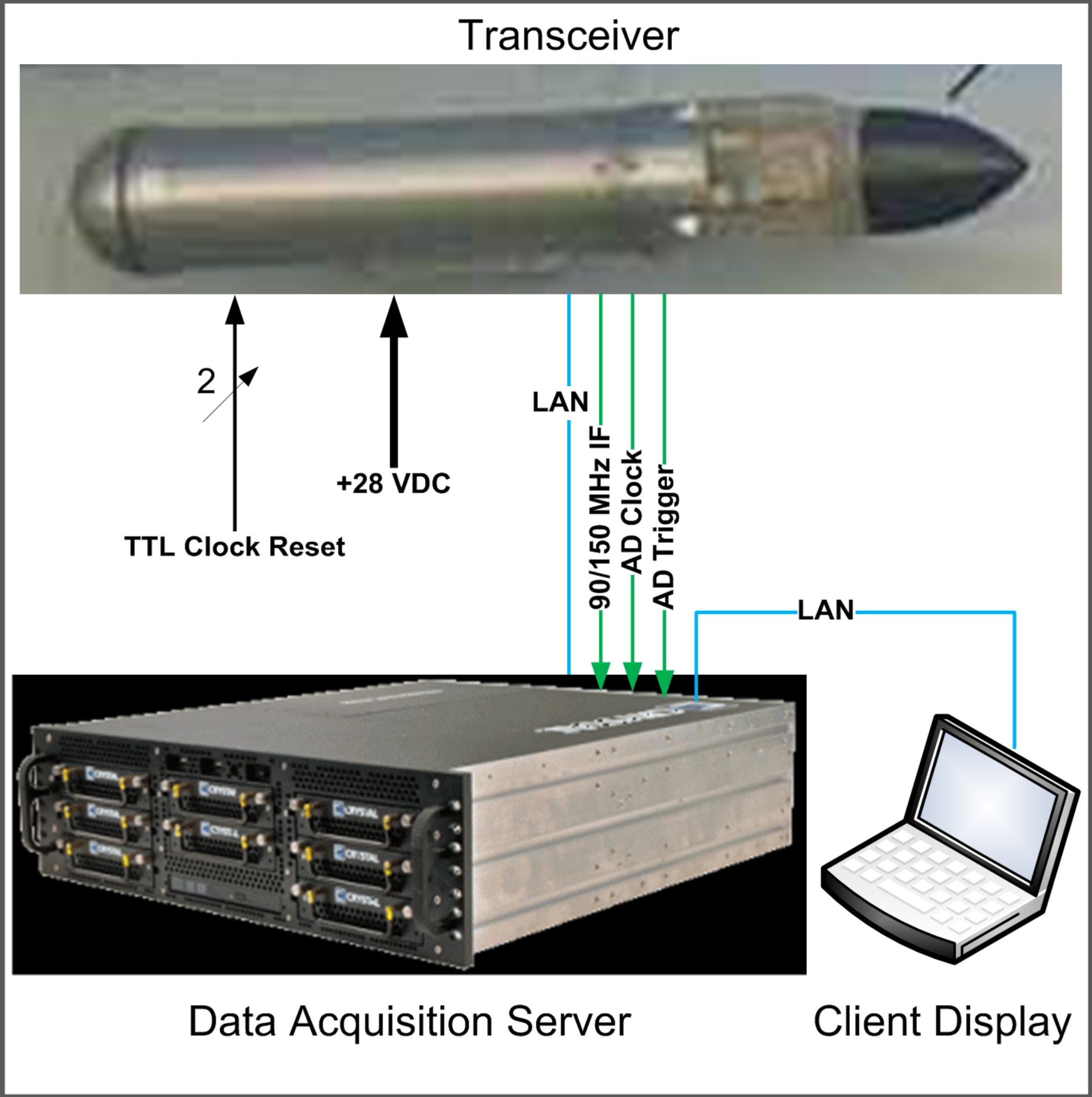


CAD Design





System Diagram



The development of the first unit is being funded by NASA EPSCoR grant NNX13AN09A to the University of Wyoming.

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Interleaved Radiometer Measurements

- The observed brightness temperature can be estimated as
  $T_B = T_{BG} + (1 - L)T_{AT}$
  where
  T_{BG} = ~2.7 K; T_{AT} = ~ 280 K
  $L = exp(-0.23\alpha\Delta x) = exp(-0.23\kappa LWP)$
  Δx = attenuating distance in km
  α = attenuation rate in dB/km
  κ = attenuation coefficient; ~0.6 dB km^{-1} g^{-1} m^3 liquid cloud at Ka-band
  m_V = liquid water content (g m^{-3})
  LWP (Liquid Water Path in units of g m^{-2}) = 1000 m_V (g m^{-3}) * Δx (km)
  LWP (mm) = m_V (g m^{-3}) * Δx (km)
- $\Delta T_B \cong 0.13\Delta LWP \times T_{AT} exp(-0.13 \times LWP)$
- $\Delta T_B \cong$ 0.3 K, if $\Delta LWP = 0.01$ mm or 10 g/m^2