N88-17627

AIRBORNE DOPPLER LIDAR DETECTION OF WIND SHEAR

RESULTS OF PERFORMANCE ANALYSIS

NASA LaRC/LOCKHEED PO#SEPAK 8630A

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COHERENT TECHNOLOGIES, INC.

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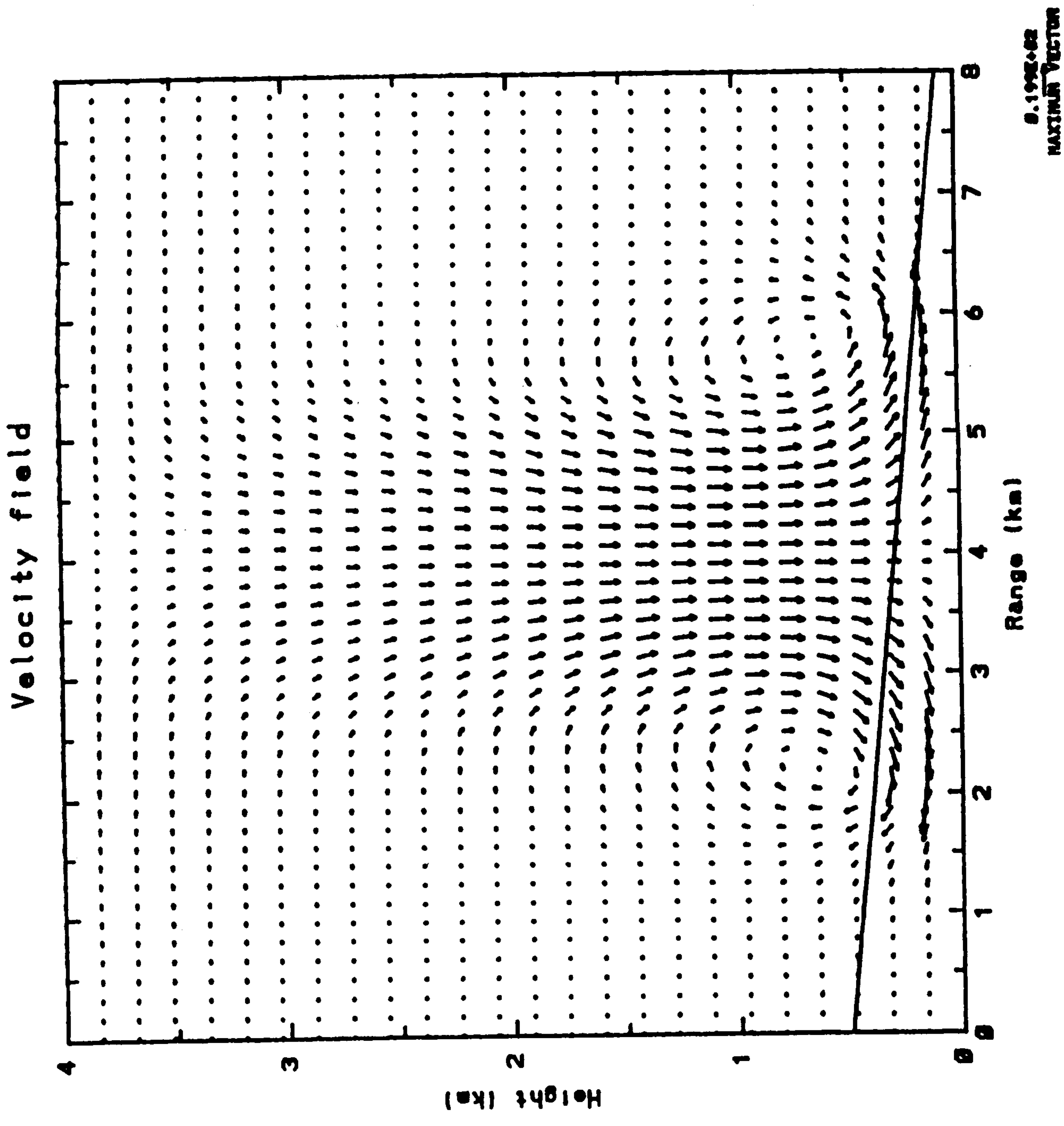

Velocity field
Range (km)
Height (km)
0
1
2
3
4
5
6
7
8
MAXIMUM VECTOR

AIRBORNE WIND SHEAR

LIDAR COMPUTER SIMULATION

* READ INPUT PARAMETERS

* SET UP MEASUREMENT GEOMETRY

  Z, θ, Φ, ΔR

* REALIZATION LOOP

* SHOT LOOP

* RANGE GATE LOOP

* CALCULATE α (AFGL HITRAN)
  INTERPOLATE β, C_n^2

* CALCULATE E {RECEIVED POWER}

* MULTIPLY BY SRF
  SPECKLE, REFRACTIVE TURBULENCE, PHASE FRONT
  MISMATCH

* INCOHERENT SAMPLE LOOP
  IF $C\tau/2 < \Delta R$) (USE SAME R FOR ALL)

* APPLY EXPONENTIAL FLUCTUATION TO E {POWER}
  X SRF
  SPECKLE DOMINATED PDF

* CALCULATE WIDE AND NARROWBAND SNR
  $B_w = 4\ V_{max}/\lambda;\ B_n = 1/\tau$

* INTERPOLATE TRUE RADIAL VELOCITY FROM
  MICROBURST, V_r

* CALCULATE ESTIMATED VELOCITY $\hat{V}_r$
  CONVOLVE V_r WITH GAUSSIAN TEMPORAL PULSE

* CALCULATE VELOCITY WIDTH
  SECOND MOMENT

* CALCULATE CRAMER-RAO E {VEL. ERROR} = σ_V
  USE SNR_W AND VEL. WIDTH

* CHECK IF $\sigma_V < V_{max}$ THRESHOLD?
  IF NO, THROW ESTIMATE AWAY

* IF YES, GENERATE A GAUSSIAN R.V. V_E
  MEAN = 0, STD DEV = σ_V

* CALCULATE $V_m = \hat{V}_r + V_E$

* COMPLETE INCOHERENT SAMPLE LOOP

* CALCULATE MEDIAN V_m and snr
  (IF EVEN NUMBER, AVE. TWO IN MIDDLE)

* COMPLETE RANGE GATE LOOP

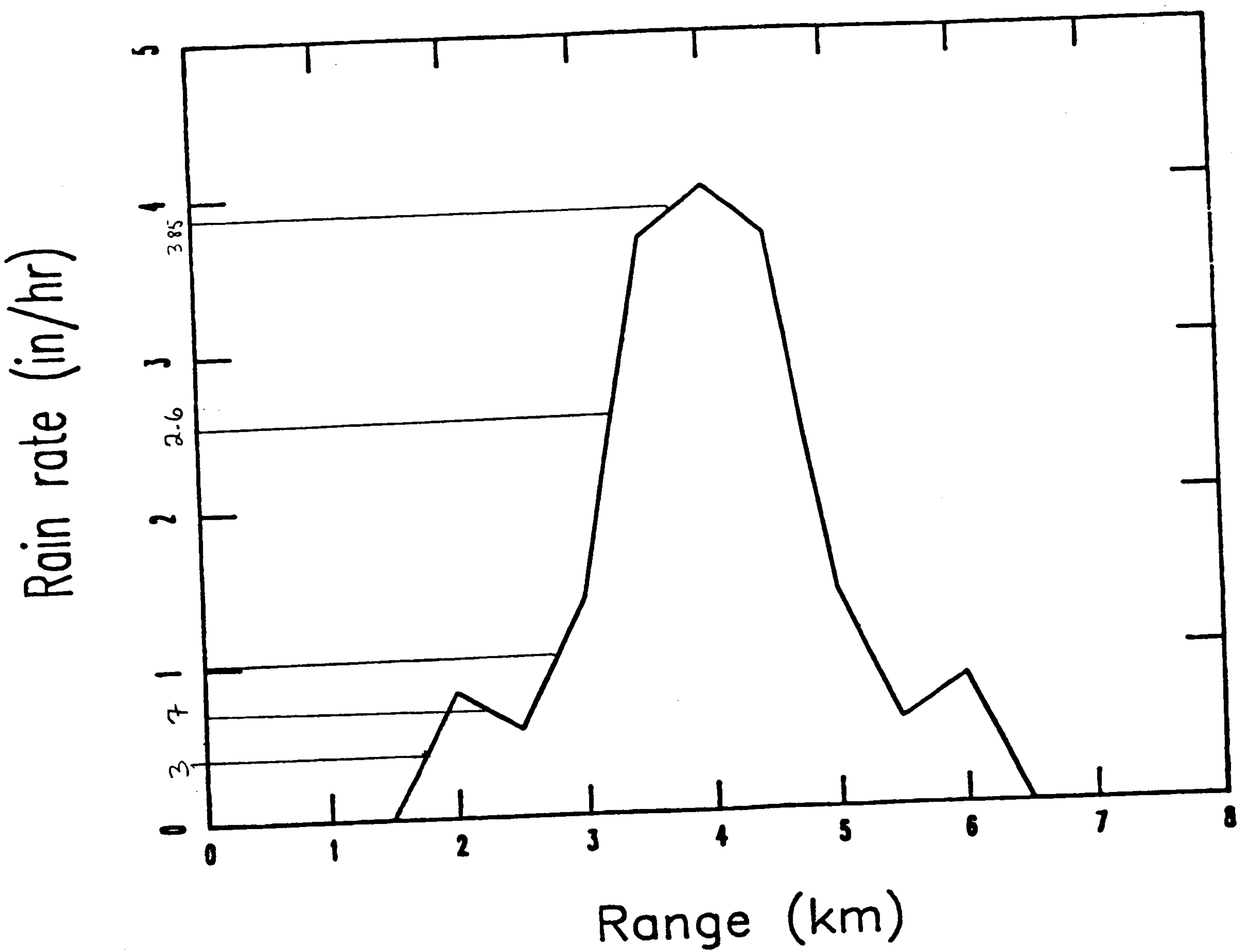
* COMPLETE SHOT LOOP

* CALCULATE $\overline{SNR}_n$, $\overline{V}_m$, $\overline{V}_E$, $\sigma_{V_E} / \sqrt{NSHOT}$

* COMPLETE REALIZATION LOOP

* CALCULATE $\sigma_{\overline{V}_E}$

CTI Wind Shear Simulation



AIRBORNE WINDSHEAR LIDAR BASE CASE PARAMETERS (CO_2 LASER)

ATMOSPHERIC PARAMETERS

LaRC PROVIDED MICROBURST FIELDS

NO RAIN, HAIL, CLOUDS

MID-LATITUDE SUMMER MODEL ATMOSPHERE

AEROSOL BACKSCATTER COEFFICIENT $\beta = 5 \times 10^{-8}$ $(m^{-1} \cdot sr^{-1})$

MODIFIED NOAA-WPL-37 C_n^2 PROFILE

LASER PARAMETERS

WAVELENGTH [CO_2 10P(20)] $\lambda = 10.591$ μm

PULSE ENERGY = 5 mJ

OVERALL OPTICAL EFFICIENCY = .1

PULSE DURATION = 2 μs

300 m RANGE RESOLUTION

10 PULSES AVERAGED

15 cm TELESCOPE DIAMETER (e^{-2} INTENSITY)

3 km FOCAL RANGE

AIRCRAFT POSITION AND LIDAR ANGLE PARAMETERS

4 km TO CENTER OF MICROBURST (ON-AXIS)

500 m HEIGHT ABOVE GROUND LEVEL

-3^0 LIDAR ELEVATION POINTING ANGLE

AIRBORNE WINDSHEAR LIDAR BASE CASE PARAMETERS (Ho:YAG LASER)

ATMOSPHERIC PARAMETERS

LaRC PROVIDED MICROBURST WIND FIELD

NO RAIN, HAIL, CLOUDS

MID-LATITUDE SUMMER MODEL ATMOSPHERE

AEROSOL BACKSCATTER COEFFICIENT $\beta = 1.25 \times 10^{-8}$ $(m^{-1} \cdot sr^{-1})$

MODIFIELD NOAA-WPL-37 C_n^2 PROFILE

LASER PARAMETERS

WAVELENGTH [Ho:YAG] $\lambda = 2.0913$ μm

PULSE ENERGY = 5 mJ

OVERALL OPTICAL EFFICIENCY = .2

PULSE DURATION = .5μs (4 SAMPLES AVERAGED INCOHERENTLY OVER 2 μs)

300 m RANGE RESOLUTION

10 PULSES AVERAGED

15 cm TELESCOPE DIAMETER (e^{-2} INTENSITY)

3 km FOCAL RANGE

AIRCRAFT POSITION AND LIDAR ANGLE PARAMETERS

4 km TO CENTER OF MICROBURST

500 m HEIGHT ABOVE GROUND LEVEL

-3^0 LIDAR ELEVATION POINTING ANGLE

CO_2 SYSTEMATIC PARAMETRIC ANALYSIS

Step 1: OPTIMIZE PULSE DURATION/RANGE RESOLUTION:

.5 μs, 1 μs, 2 μs, 3 μs, 5 μs, 6 μs
(75m), (150m), (300m), (450m), (750m), (900m)

Step 2: EXAMINE NUMBER OF SHOTS: 1, 2, 5, 10, 50, 100

Step 3: EXAMINE FOCUSING: $f = 3$ km, $f = \infty$

Step 4: EXAMINE OPTICAL DIAMETER: D = 7.5 cm, 15 cm, 20 cm

Step 5: EXAMINE REFRACTIVE TURBULENCE EFFECTS: C_n^2, $C_n^2 \times 10$

Step 6: EXAMINE PULSE ENERGIES:

1μJ, 50μJ, .5mJ, 5mJ, 10mJ, 15mJ, 20mJ, 100mJ

Step 7: EXAMINE AEROSOL BACKSCATTER EFFECTS:

$\beta = 5 \times 10^{-8}$, 10^{-8}, 10^{-9}, 10^{-10}, 10^{-11} $(m^{-1} \cdot sr^{-1})$

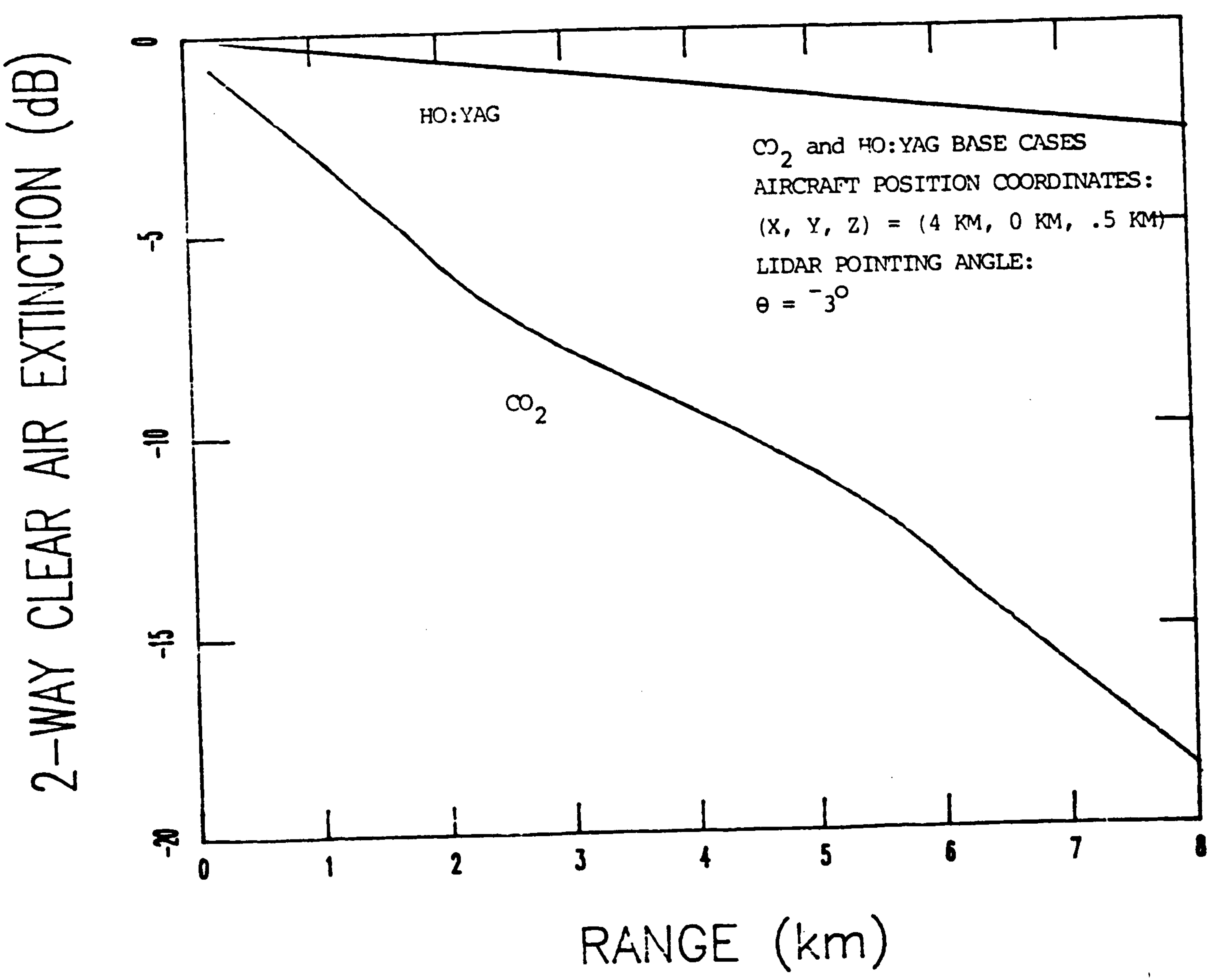
Step 8: EXAMINE WET MICROBURST

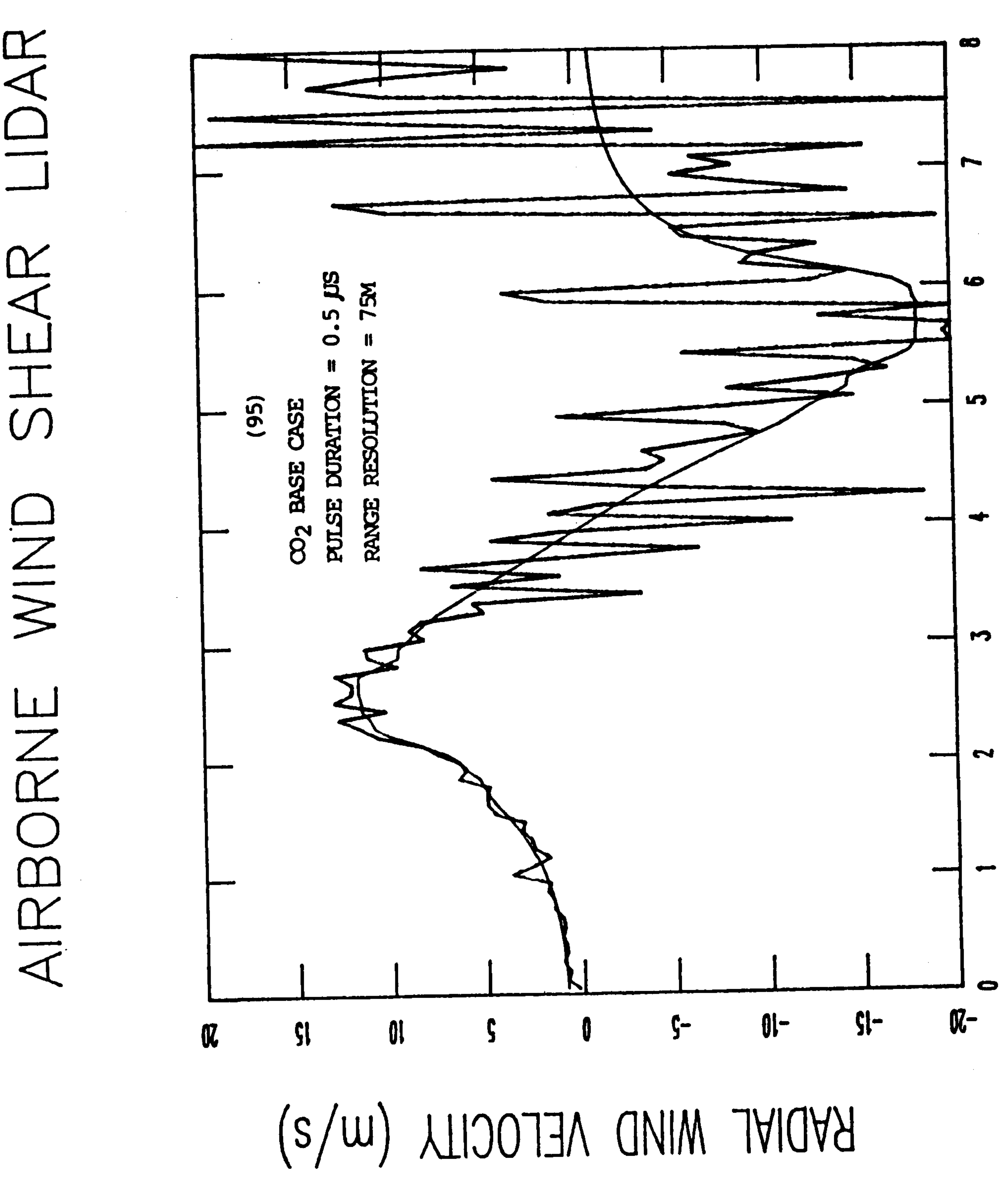
Step 9: EXAMINE AIRCRAFT POSITION: 4, 3, 2, 1 km FROM CENTER
TAKEOFF PROFILES
OFF-AXIS ENCOUNTERS

Step 10: EXAMINE AZIMUTHAL SCAN: ENCOMPASS ENTIRE WIND FIELD IN A 2-DIM PLANE AT 5^0 INCREMENTS

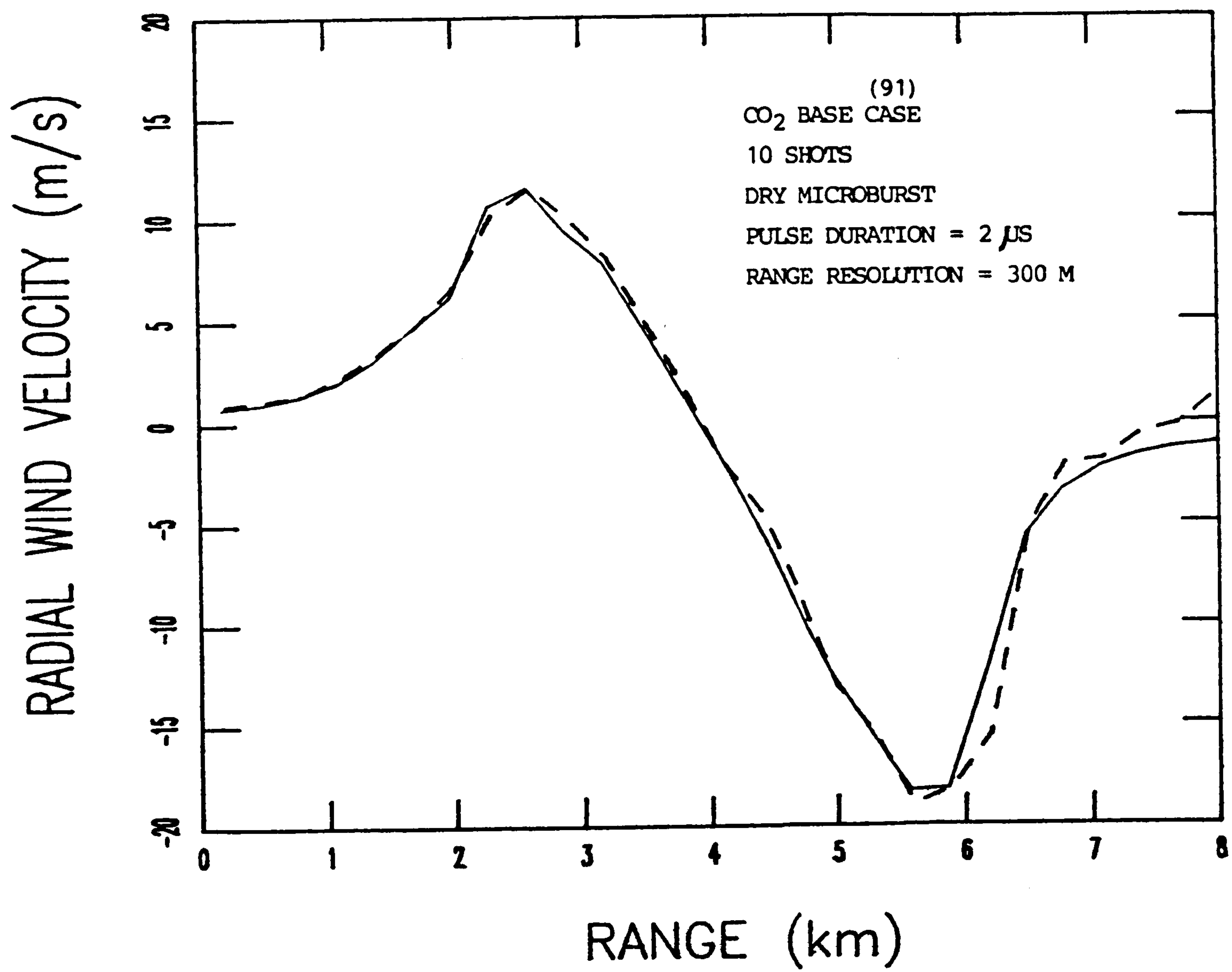
Step 11: MULTIPLE REALIZATIONS

AIRBORNE WIND SHEAR LIDAR




AIRBORNE WIND SHEAR LIDAR
(95)
CO_2 BASE CASE
PULSE DURATION = 0.5 μs
RANGE RESOLUTION = 75M
RADIAL WIND VELOCITY (m/s)
RANGE (km)
20
15
10
5
0
-5
-10
-15
-20
0
1
2
3
4
5
6
7
8

AIRBORNE WIND SHEAR LIDAR



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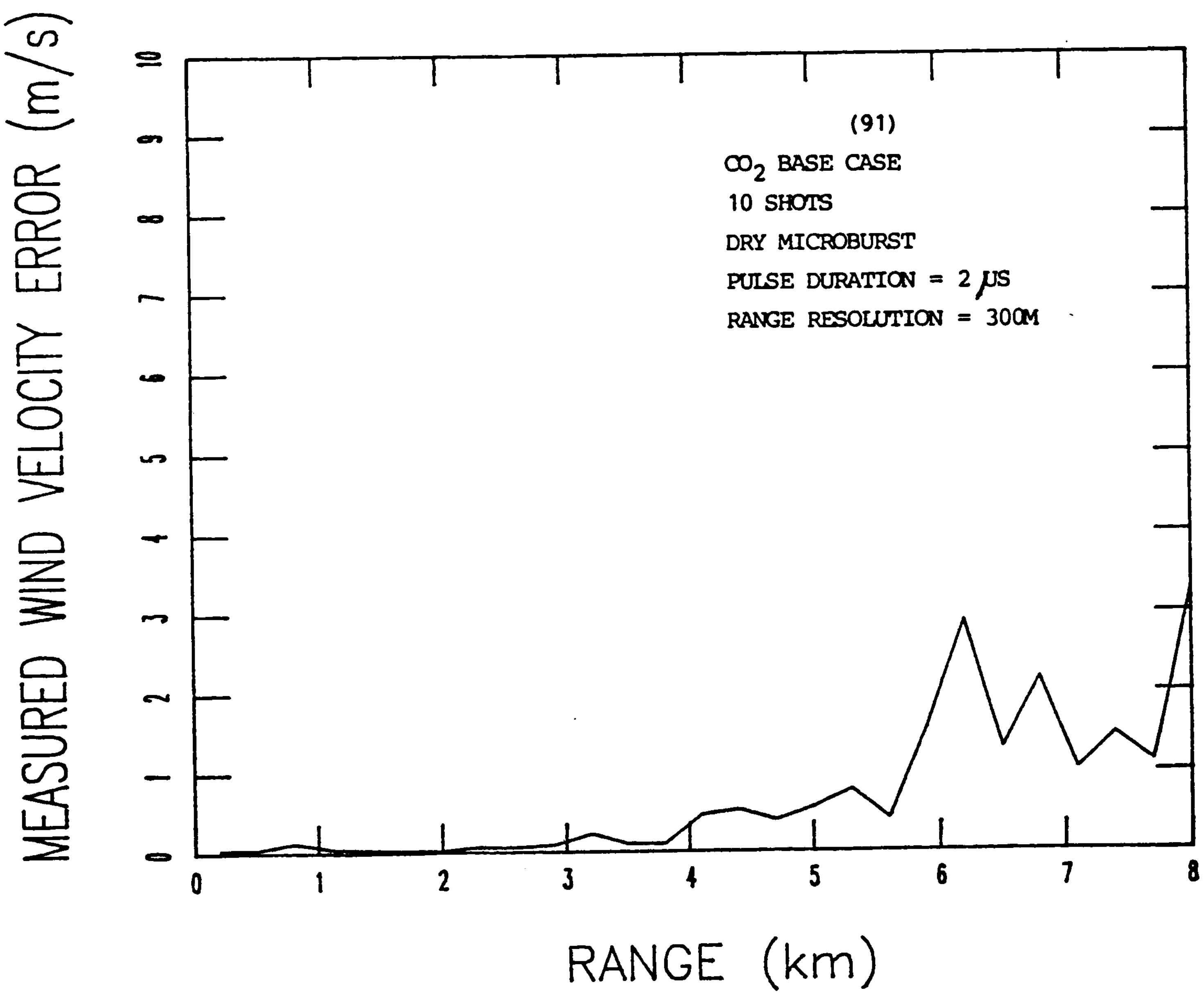

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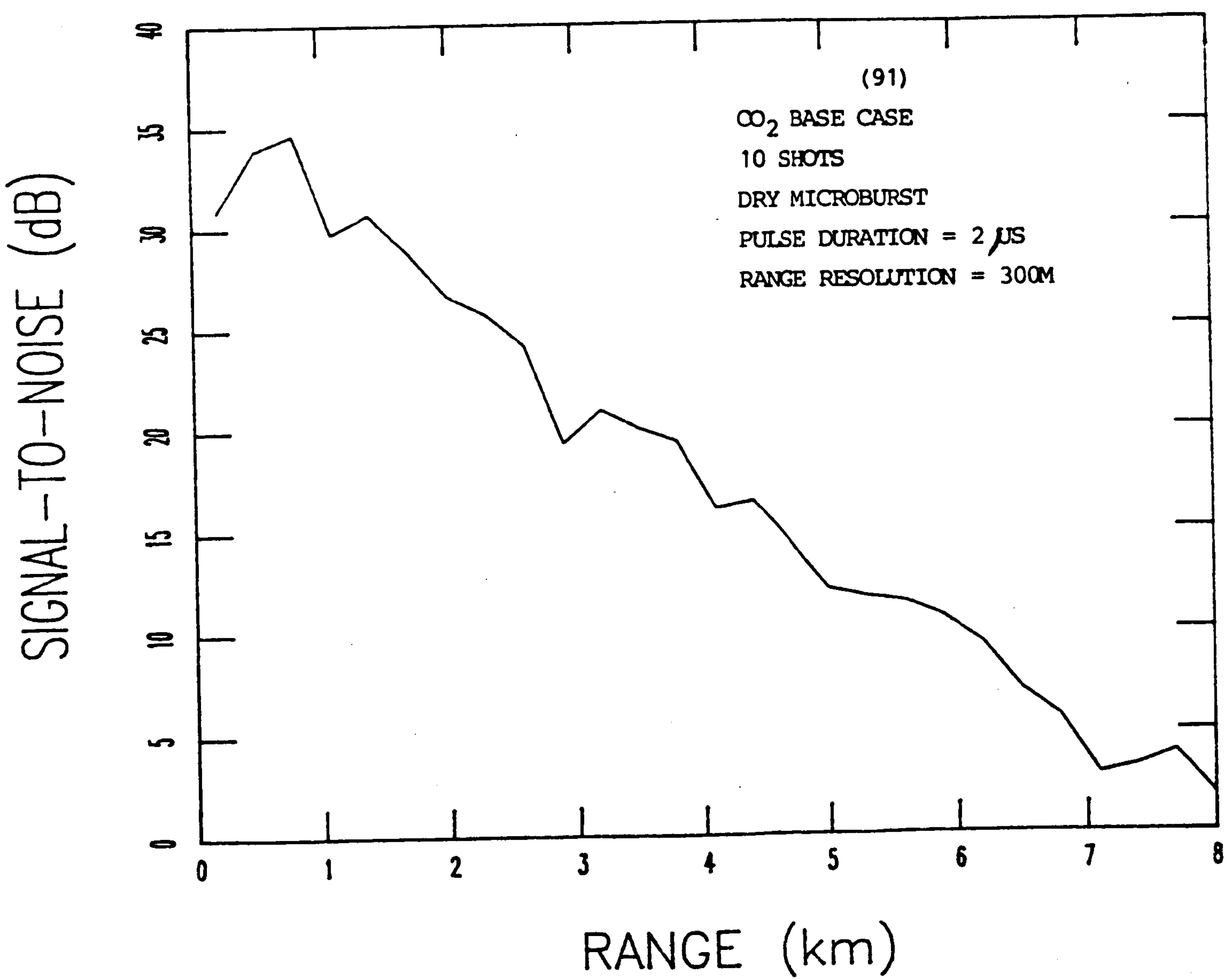
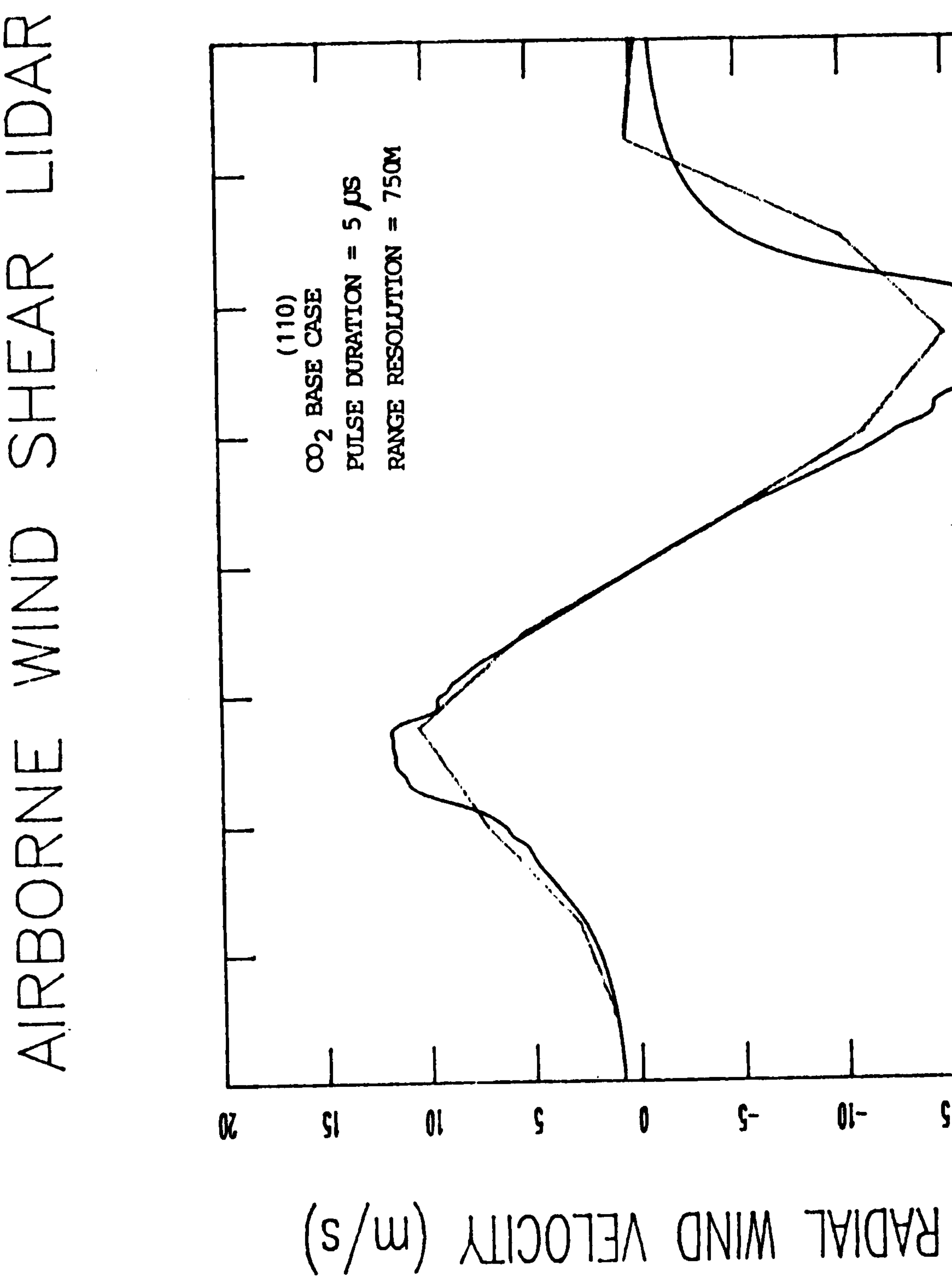
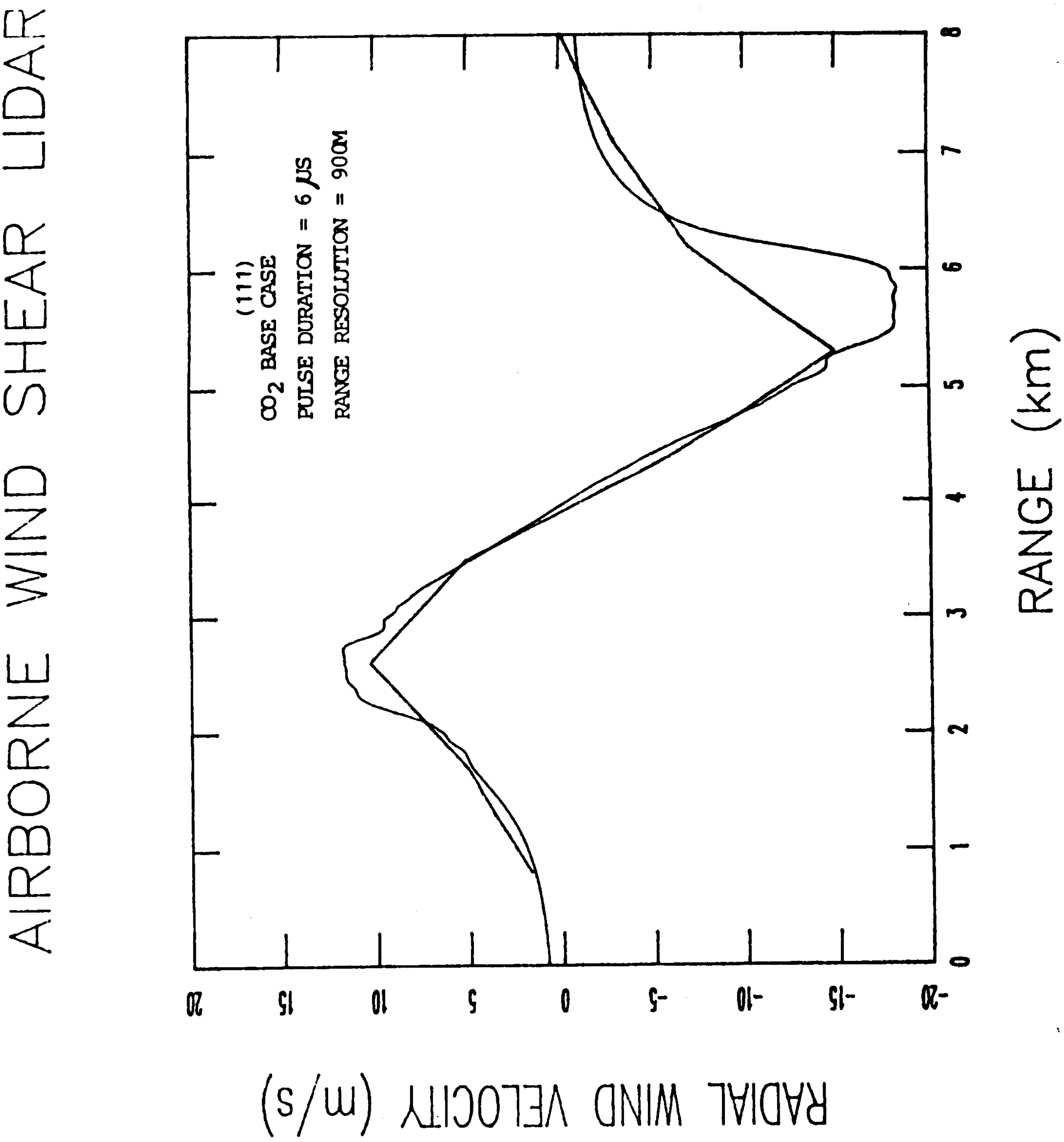
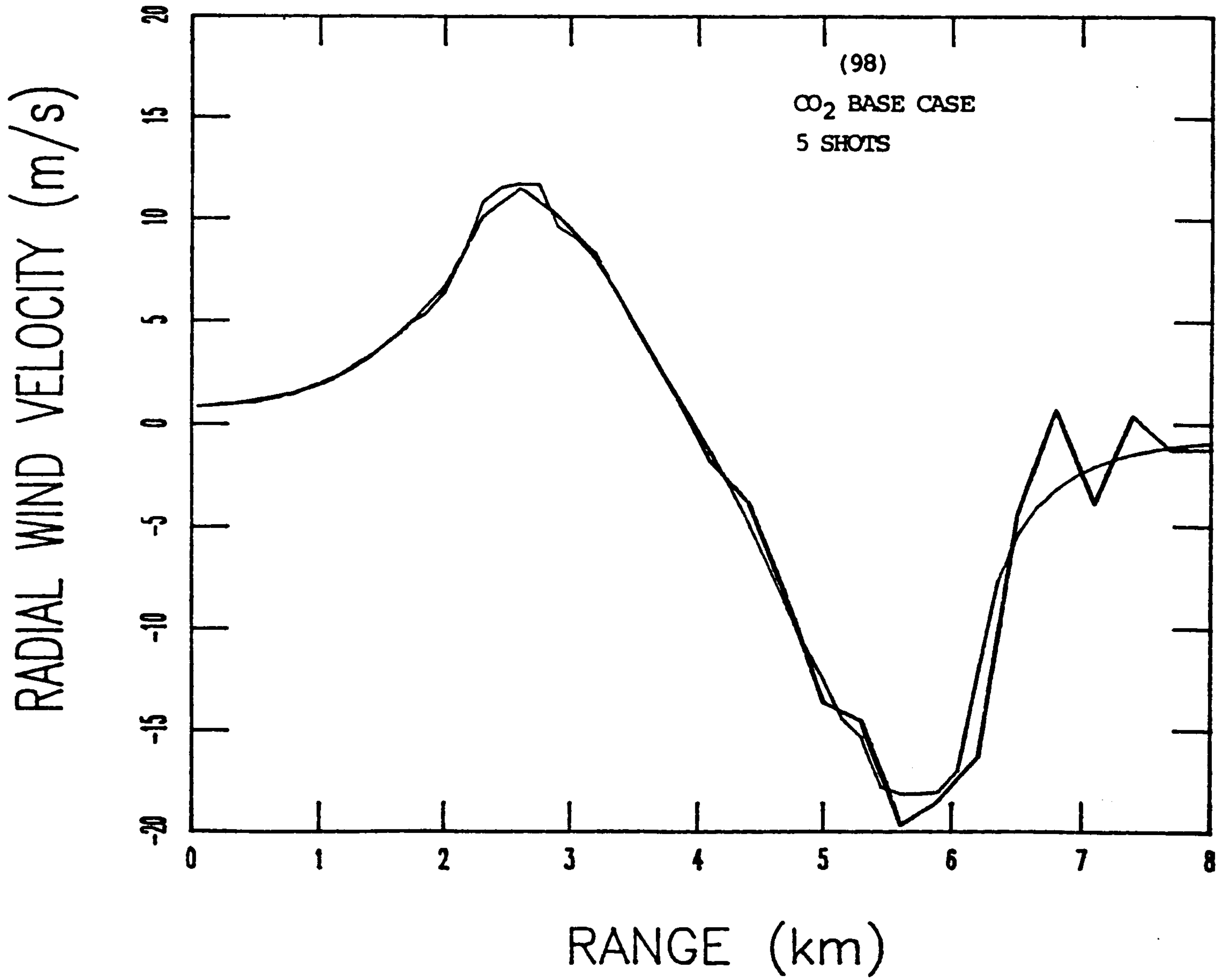



AIRBORNE WIND SHEAR LIDAR
(110)
CO_2 BASE CASE
PULSE DURATION = 5 μS
RANGE RESOLUTION = 750M
RANGE (km)
RADIAL WIND VELOCITY (m/s)
0
1
2
3
4
5
6
7
8
20
15
10
5
0
-5
-10
-15
-20


AIRBORNE WIND SHEAR LIDAR
(111)
CO_2 BASE CASE
PULSE DURATION = 6 μS
RANGE RESOLUTION = 900M
RANGE (km)
RADIAL WIND VELOCITY (m/s)
0
1
2
3
4
5
6
7
8
20
15
10
5
0
-5
-10
-15
-20

AIRBORNE WIND SHEAR LIDAR



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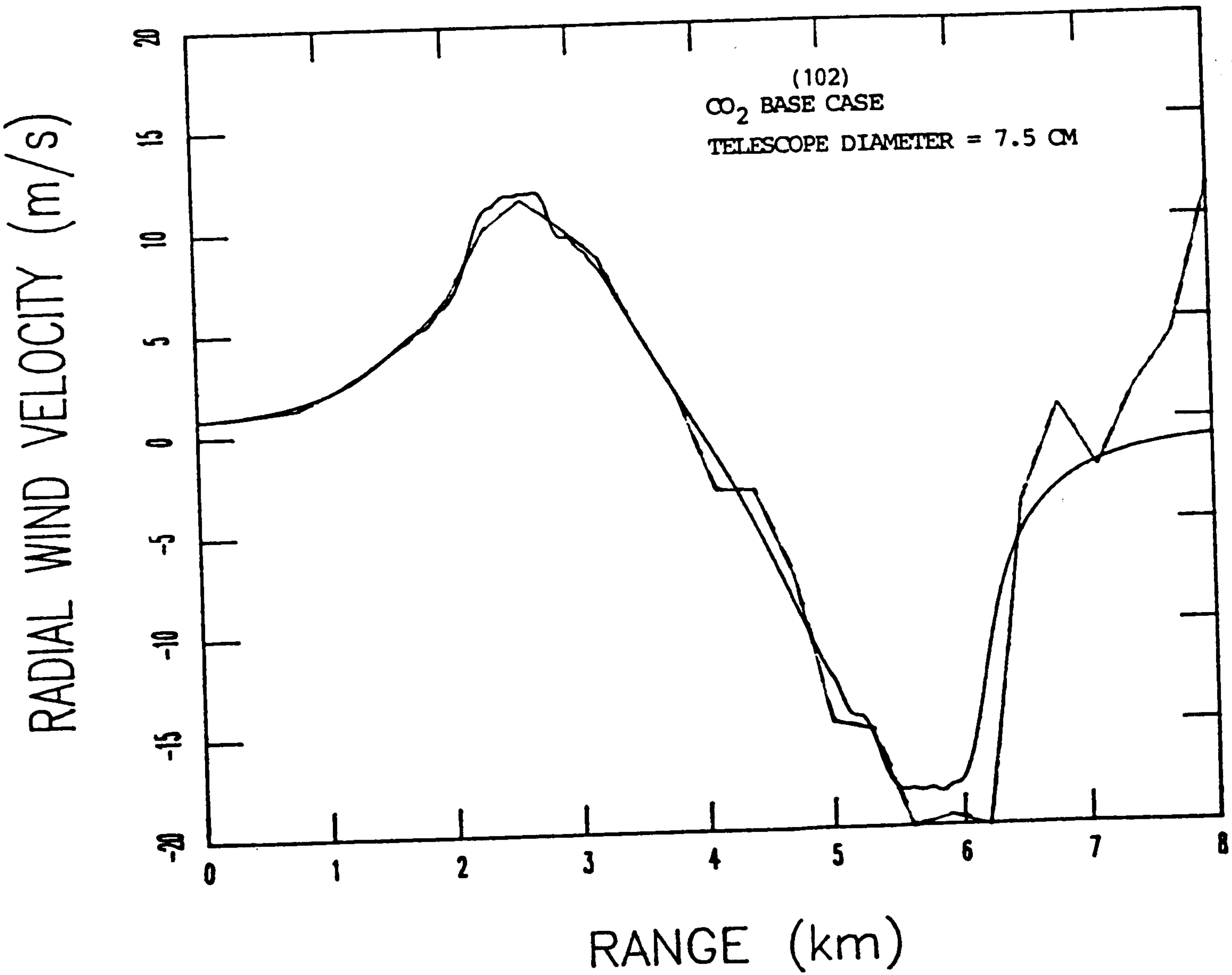
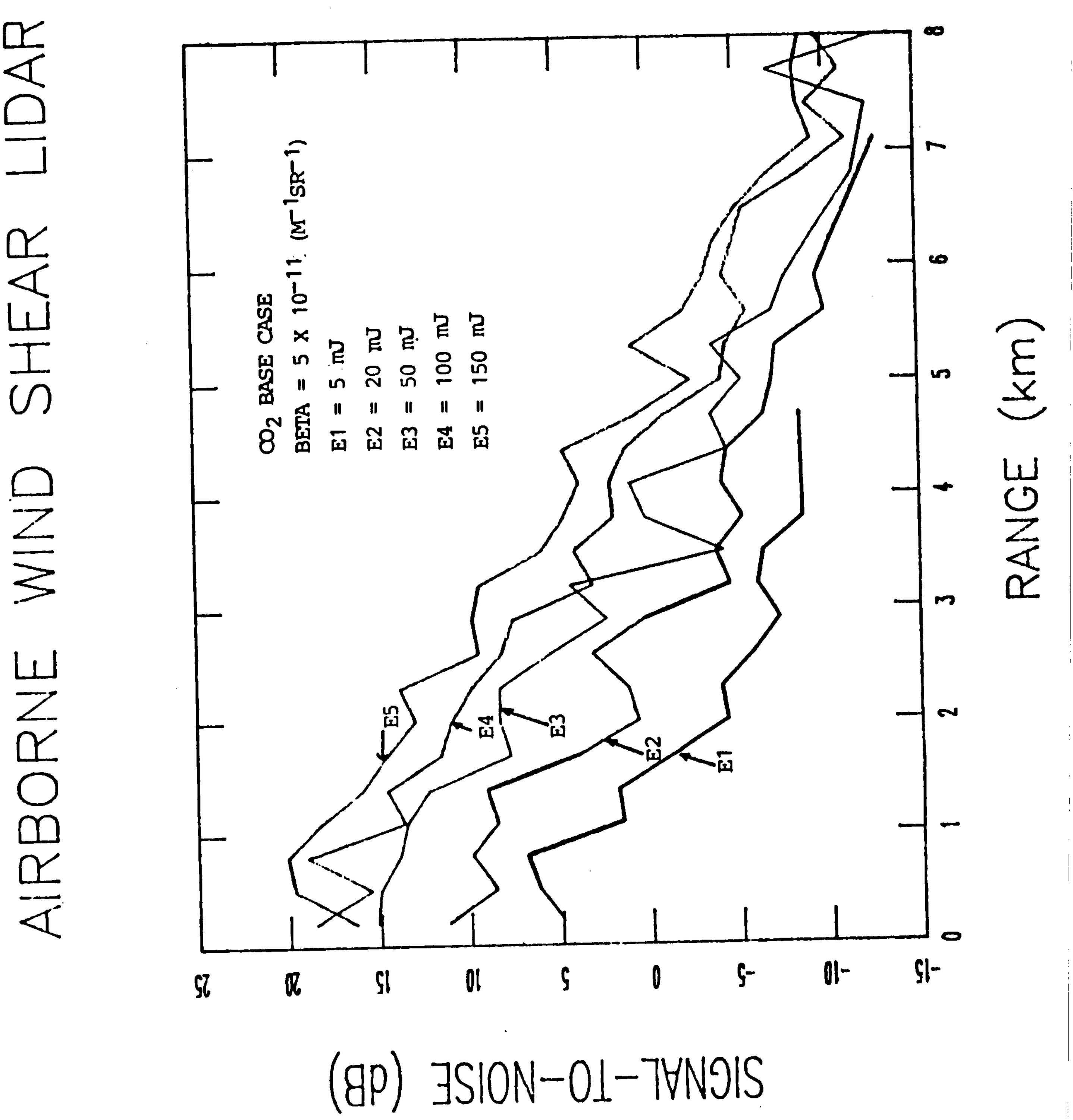
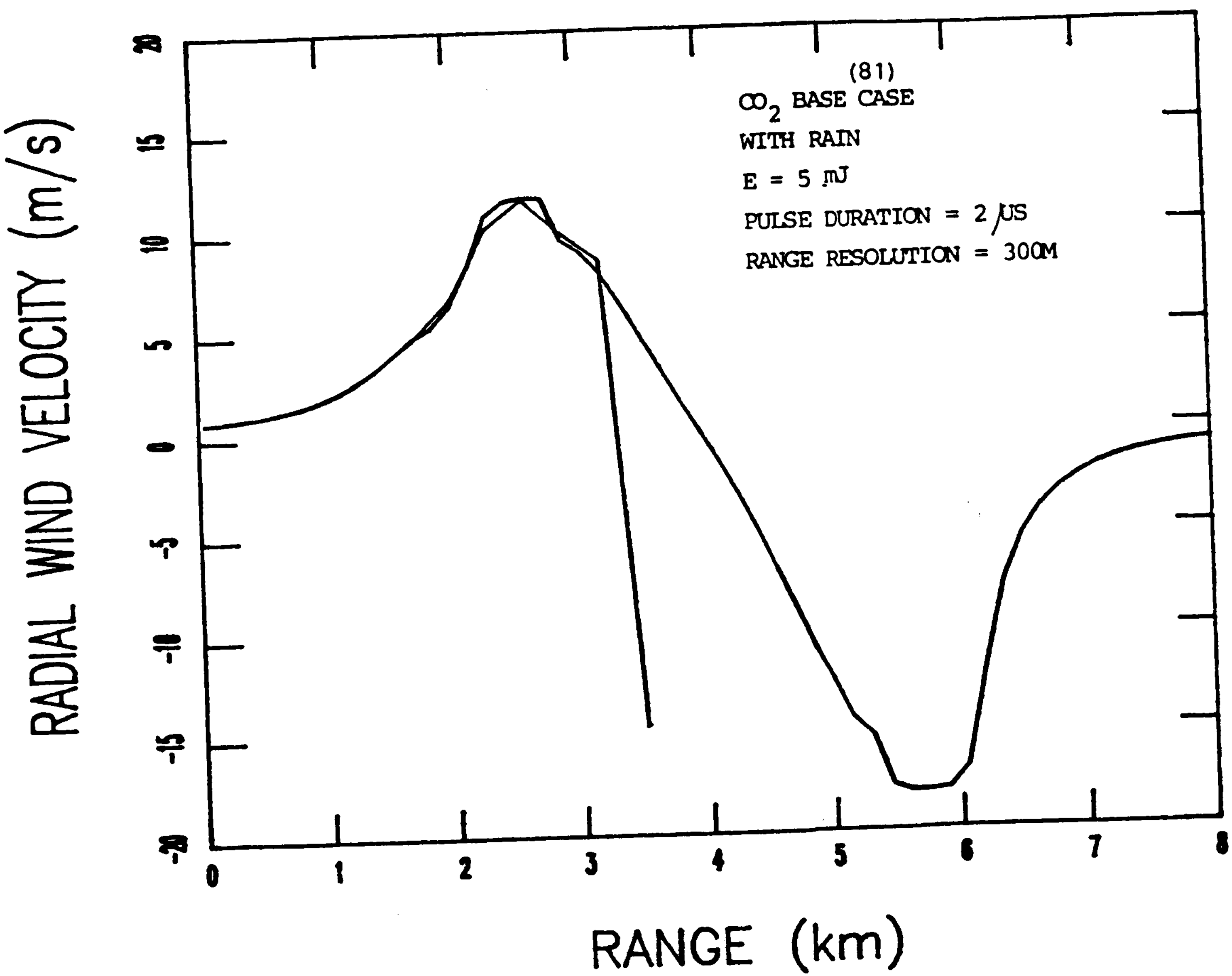



AIRBORNE WIND SHEAR LIDAR
CO_2 BASE CASE
BETA = 5 X 10^{-11} ($M^{-1}SR^{-1}$)
E1 = 5 mJ
E2 = 20 mJ
E3 = 50 mJ
E4 = 100 mJ
E5 = 150 mJ
E1
E2
E3
E4
E5
SIGNAL-TO-NOISE (dB)
25
20
15
10
5
0
-5
-10
-15
RANGE (km)
0
1
2
3
4
5
6
7
8

AIRBORNE WIND SHEAR LIDAR



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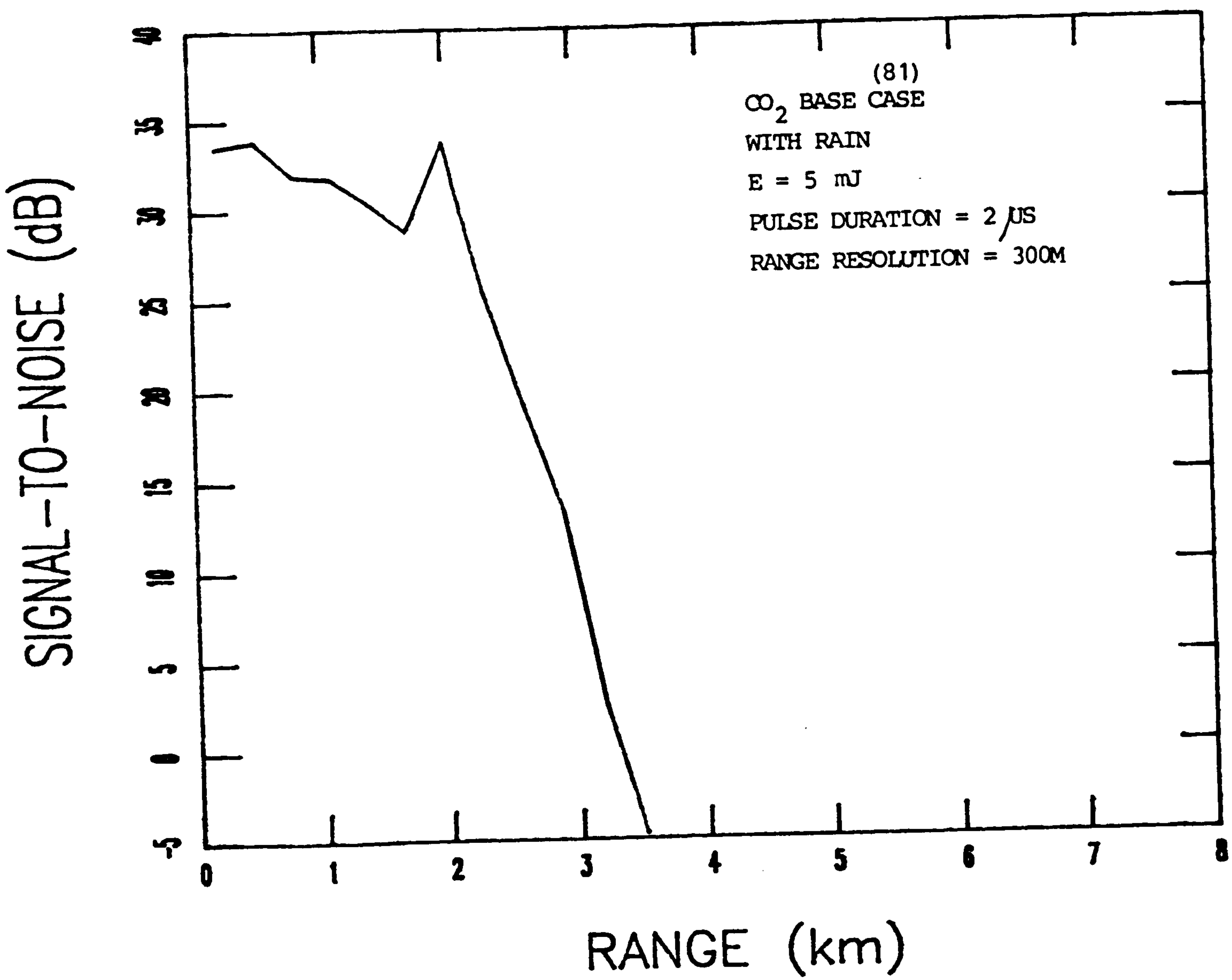

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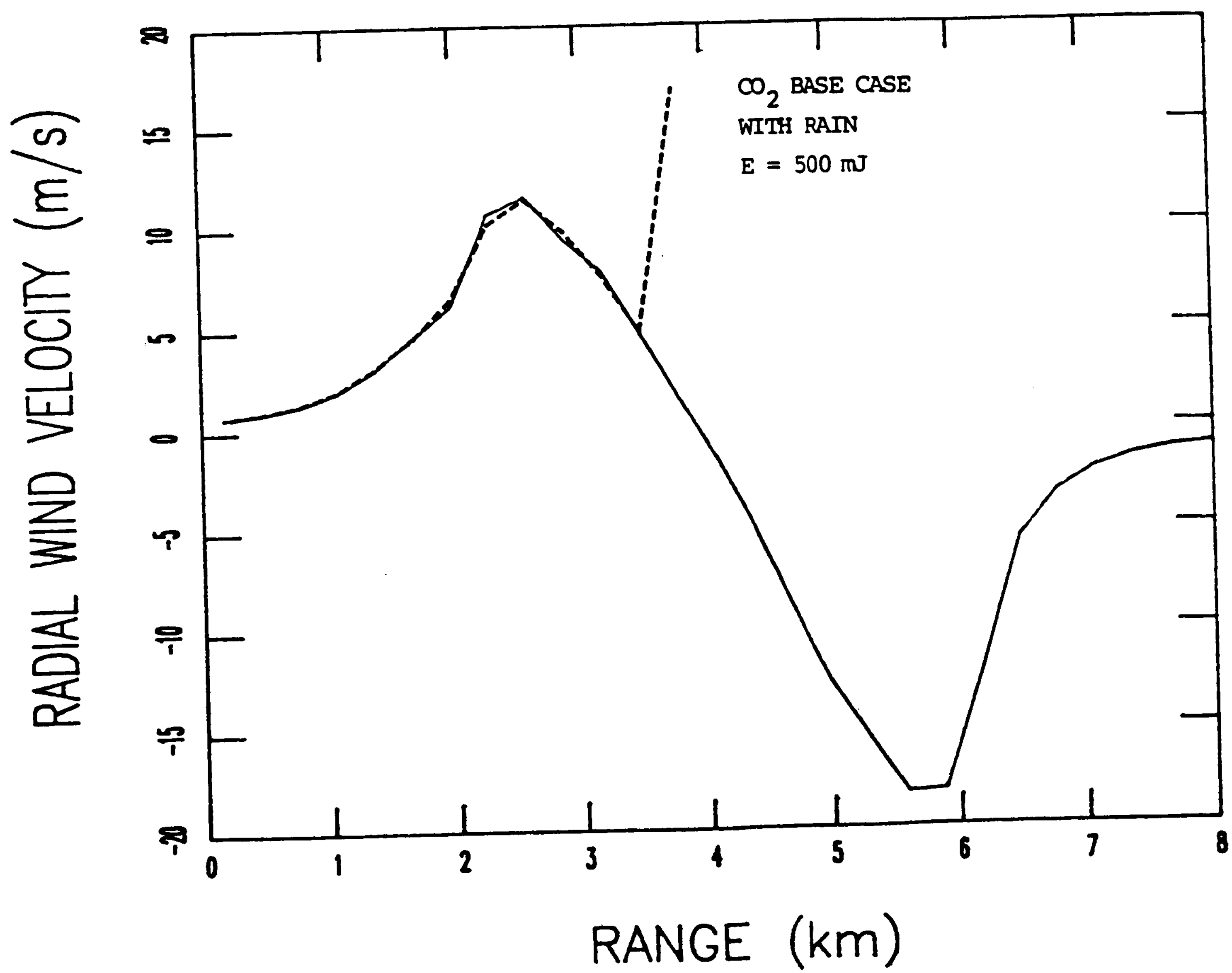

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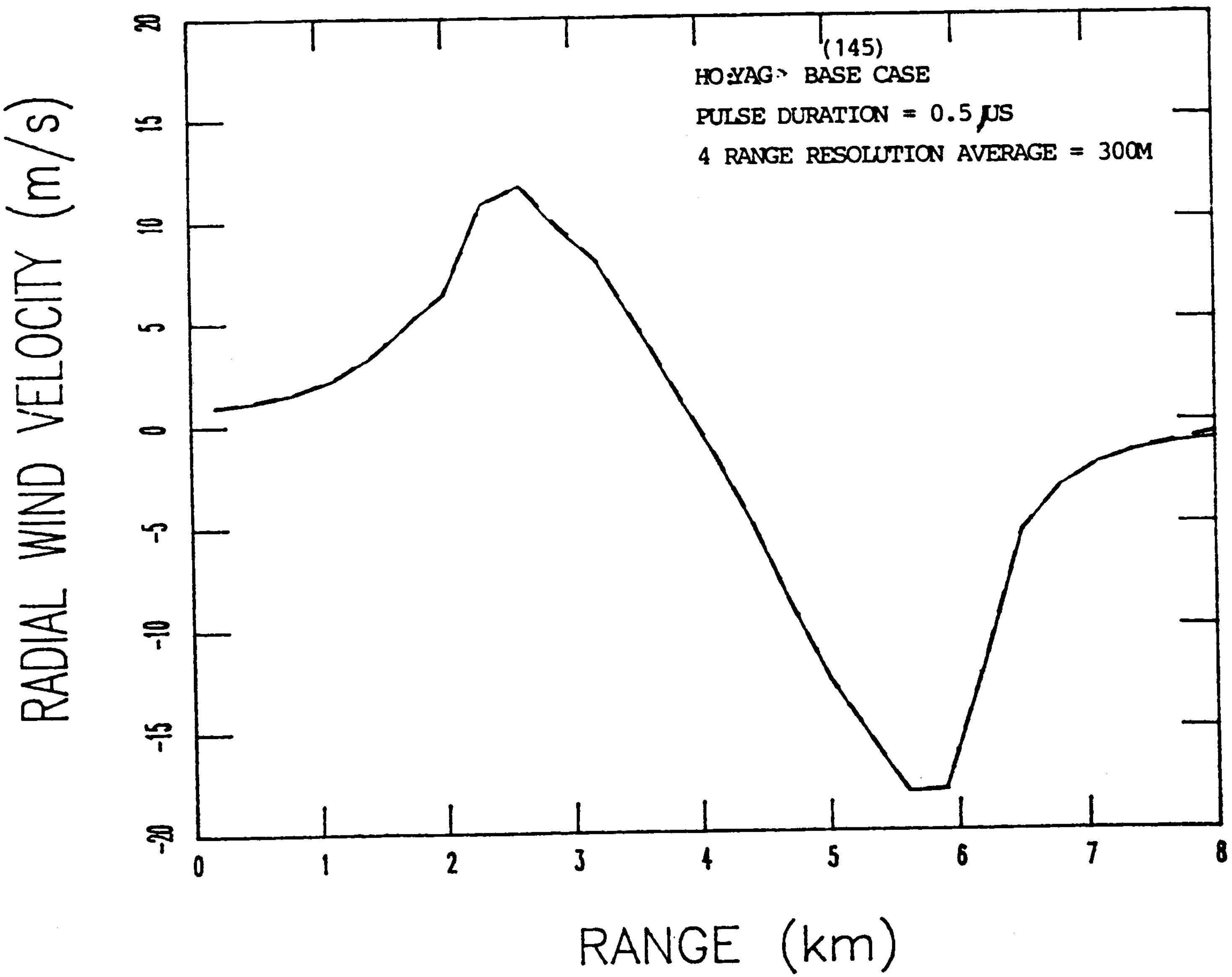

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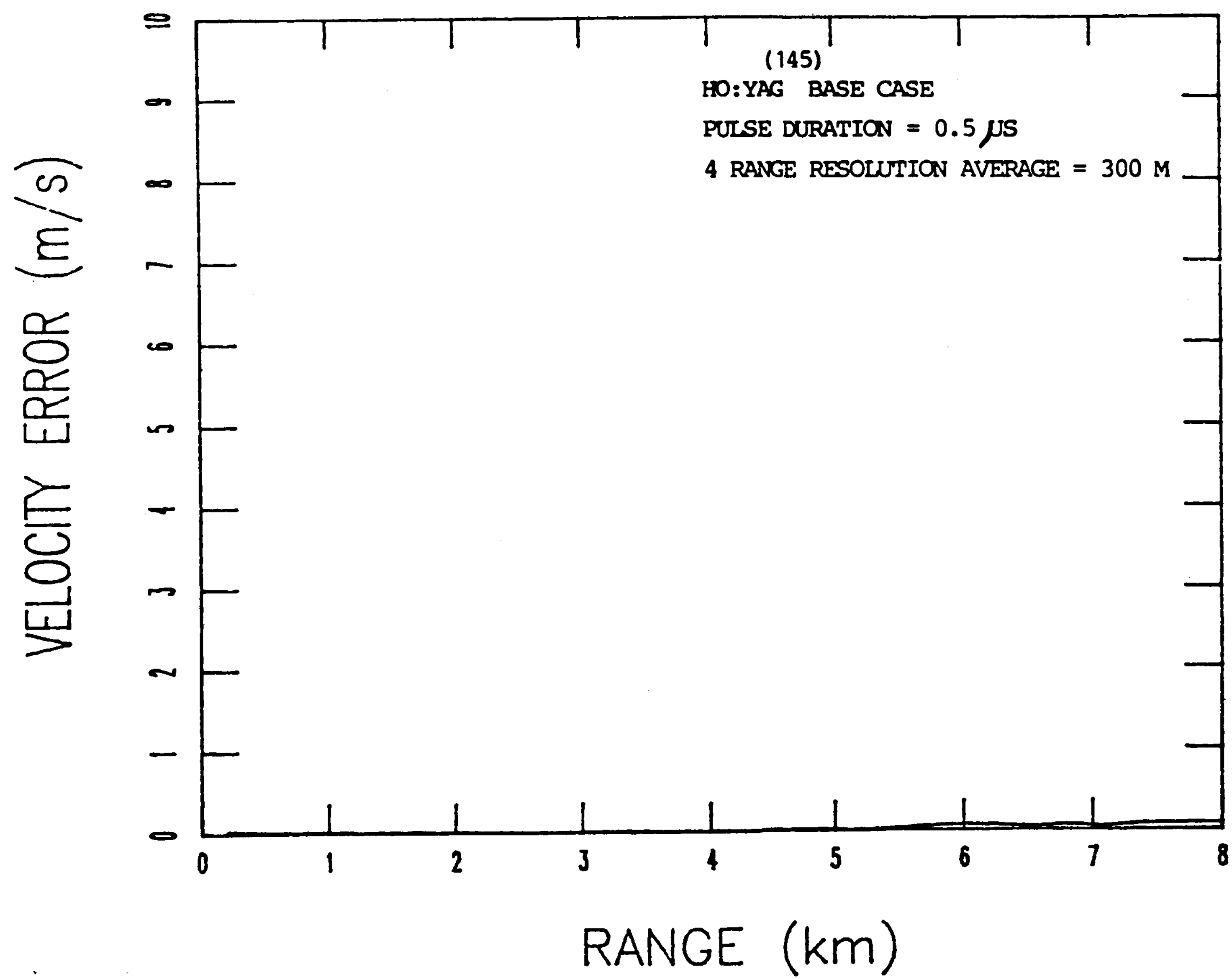
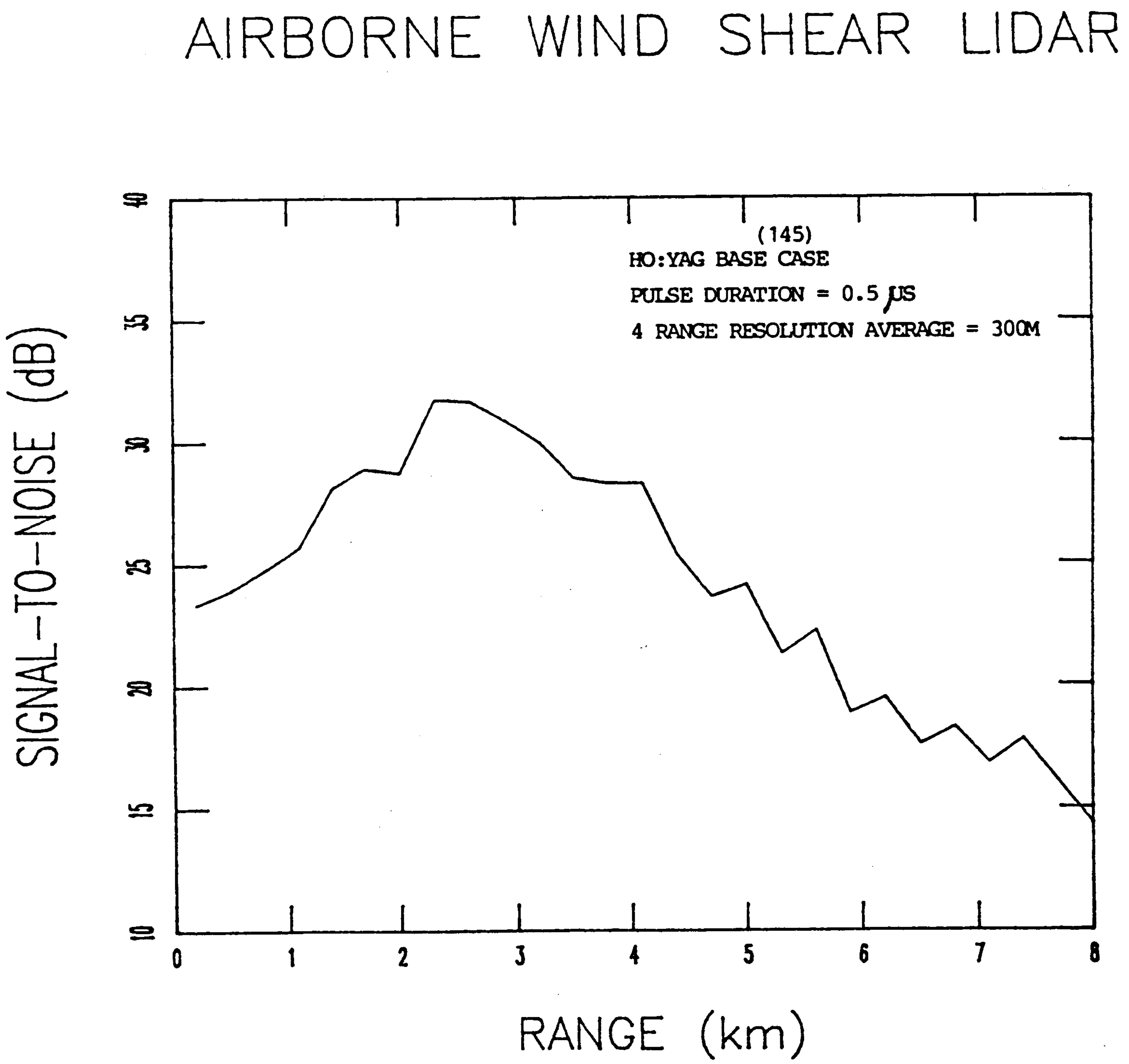
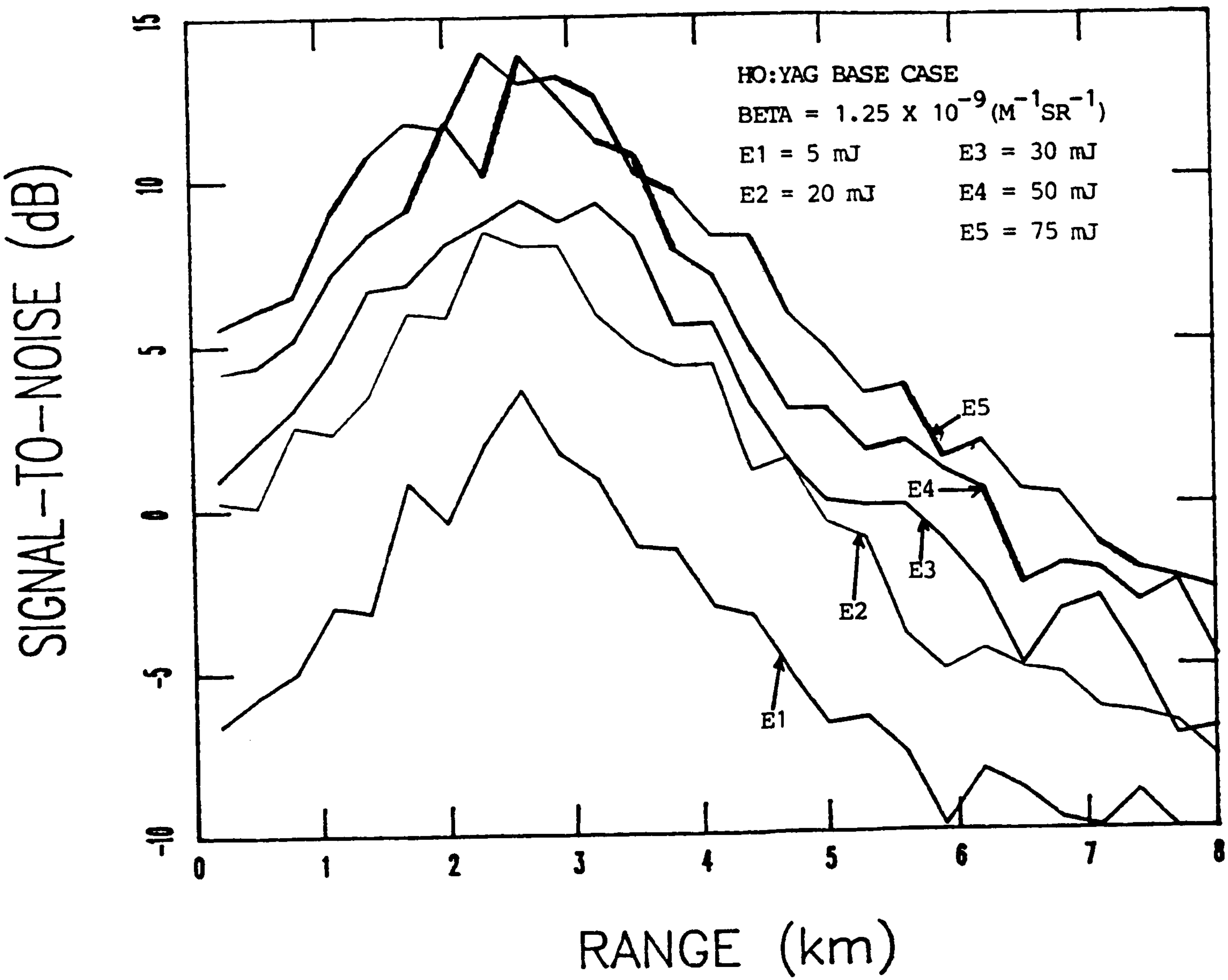



AIRBORNE WIND SHEAR LIDAR
(145)
HO:YAG BASE CASE
PULSE DURATION = 0.5 μS
4 RANGE RESOLUTION AVERAGE = 300M
SIGNAL-TO-NOISE (dB)
10
15
20
25
30
35
40
0
1
2
3
4
5
6
7
8
RANGE (km)

AIRBORNE WIND SHEAR LIDAR



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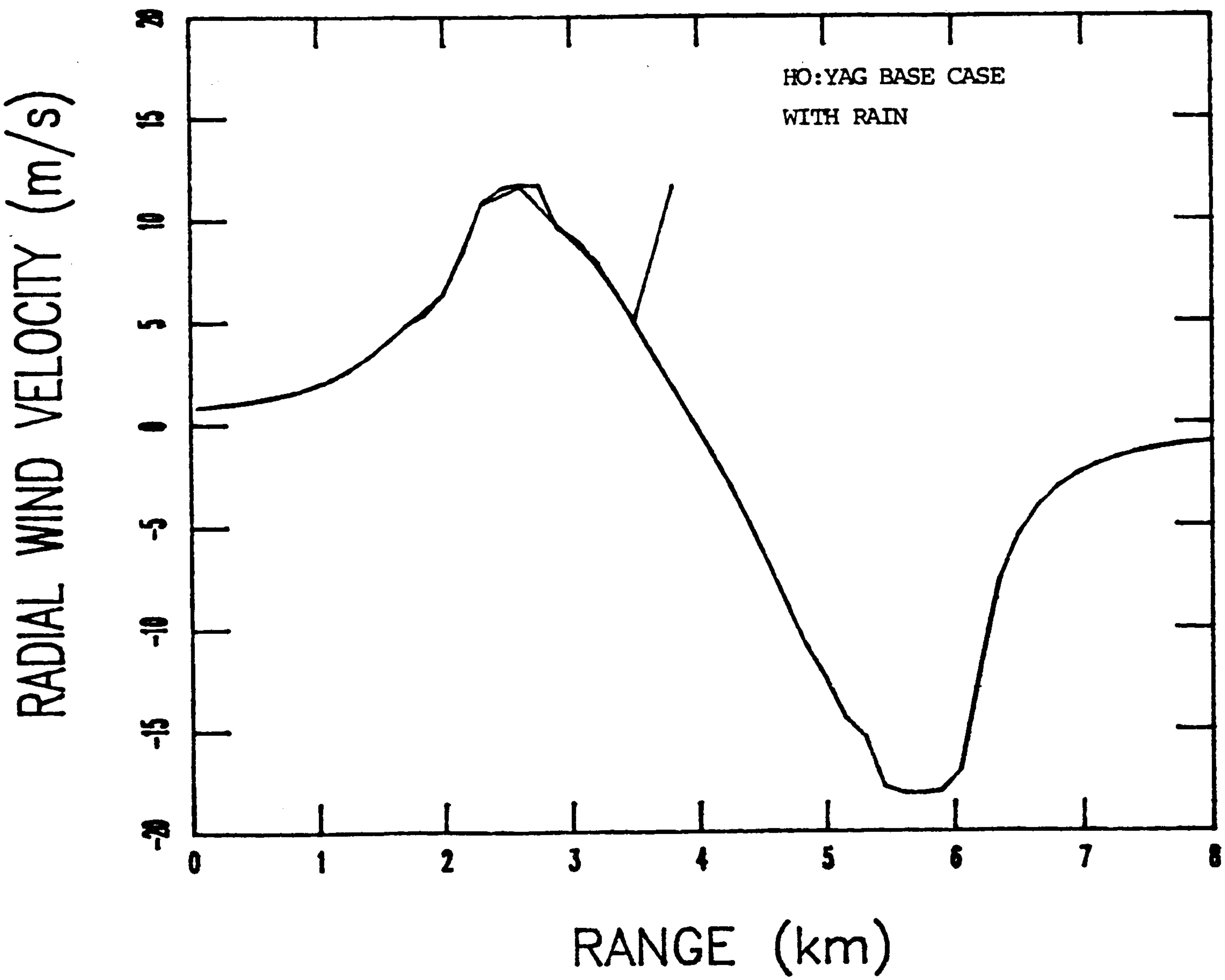
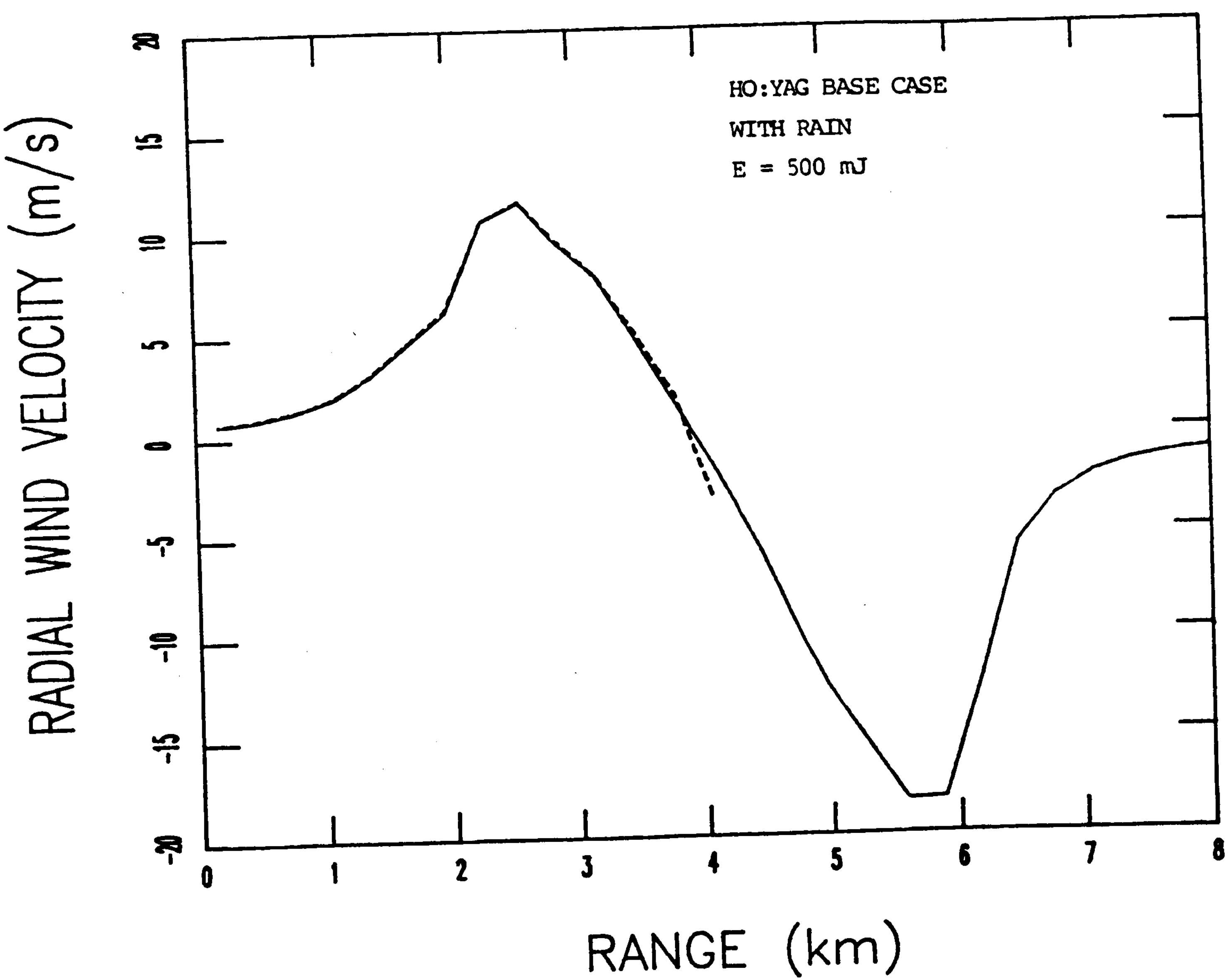


AIRBORNE WIND SHEAR LIDAR



SUMMARY OF PERFORMANCE

(LARC MICROBURST MODEL, 11:00 MIN.)

1. 20 MJ CO_2 LIDAR LINE-OF-SIGHT WIND VELOCITY ERROR <1 M/S TO 8 KM IN THE DRY MICROBURST TEST CASE.

2. 5 MJ HO:YAG LIDAR LINE-OF-SIGHT WIND VELOCITY ERROR $<.5$ M/S TO 8 KM IN THE DRY MICROBURST TEST CASE.

3. 5 MJ CO_2 LIDAR PENETRATES TO WITHIN 1 KM OF WET MICROBURST CENTER.

4. 5 MJ HO:YAG PENETRATES TO WITHIN .5 KM OF WET MICROBURST CENTER.

5. BOTH CO_2 (100 MJ) AND HO:YAG (10 MJ) PERFORM WELL TO 3 KM OPERATING OUTSIDE THE BOUNDARY LAYER WHERE:
   BETA (CO_2) = 5×10^{-11} $M^{-1} \cdot SR^{-1}$
   BETA (HO:YAG) = 1.25×10^{-9} $M^{-1} \cdot SR^{-1}$

6. LIDAR PERFORMANCE IN WET MICROBURST MODEL DOES NOT IMPROVE SIGNIFICANTLY WITH REASONABLE INCREASES IN LIDAR PARAMETERS.

CONCLUSIONS

1. BOTH CO_2 AND Ho:YAG ARE SHOWN FEASIBLE FOR AIRBORNE WIND SHEAR DETECTION FOR DRY MICROBURSTS WITH LIMITED PERFORMANCE IN WET MICROBURSTS.

2. Ho:YAG PERFORMS BETTER THAN CO_2 FOR A SET OF IDENTICAL LIDAR PARAMETERS.

3. THESE RESULTS ARE QUALIFIED BY THE LIMITED NUMBER OF TEST CASES.