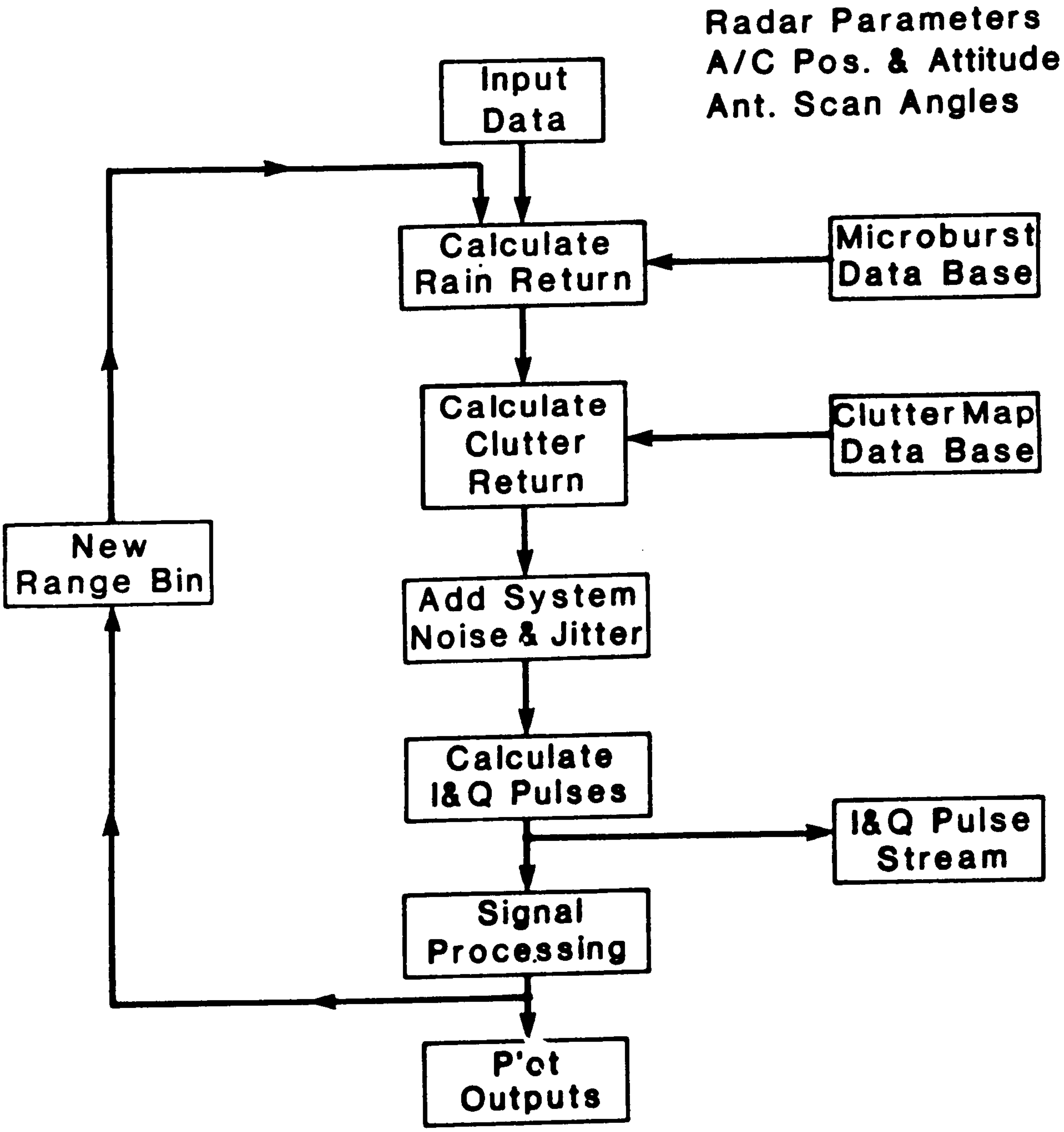
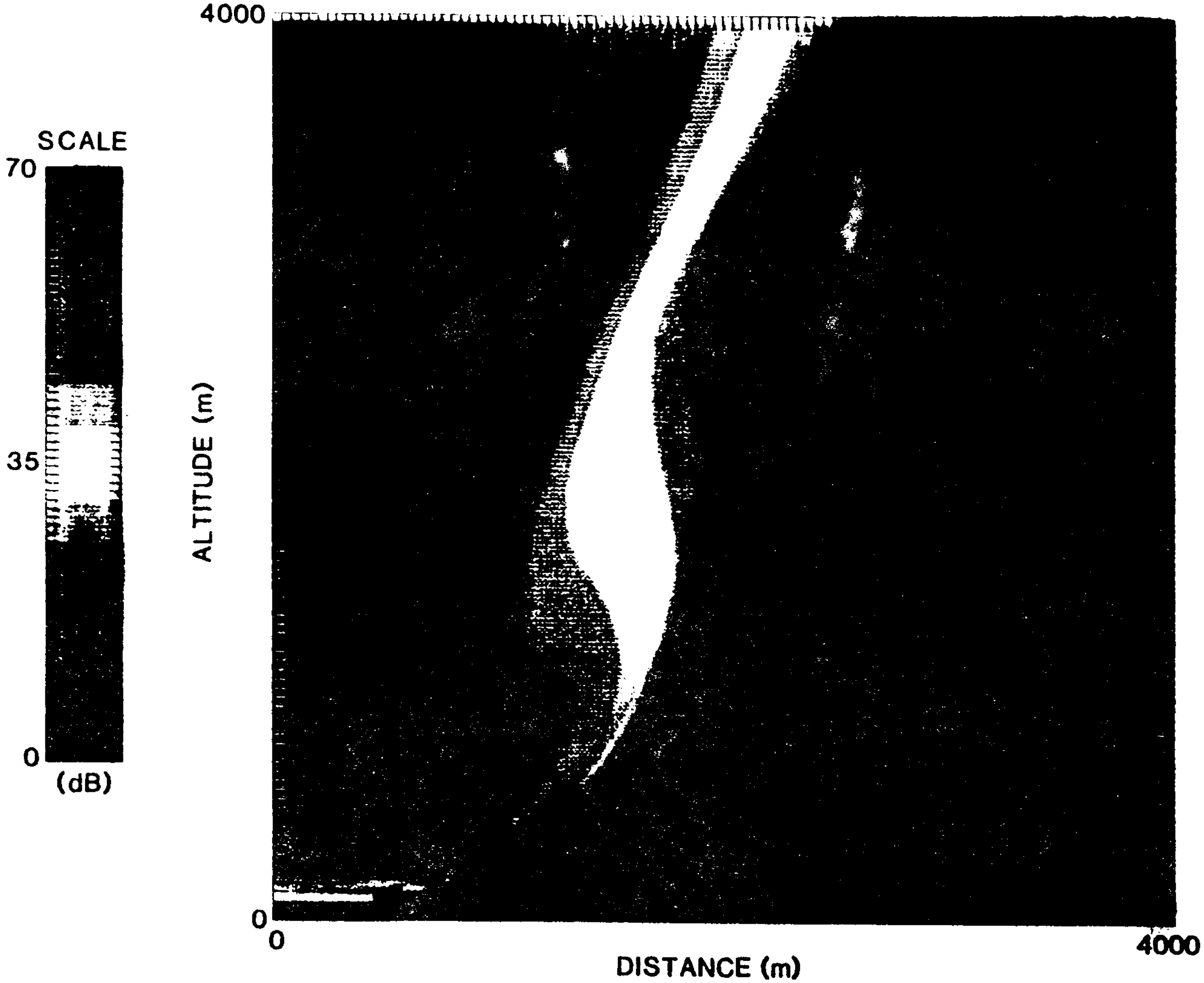
WIND SHEAR RADAR SIMULATION

Charles L. Britt, Ph.D
Research Triangle Institute

RADAR SIMULATION

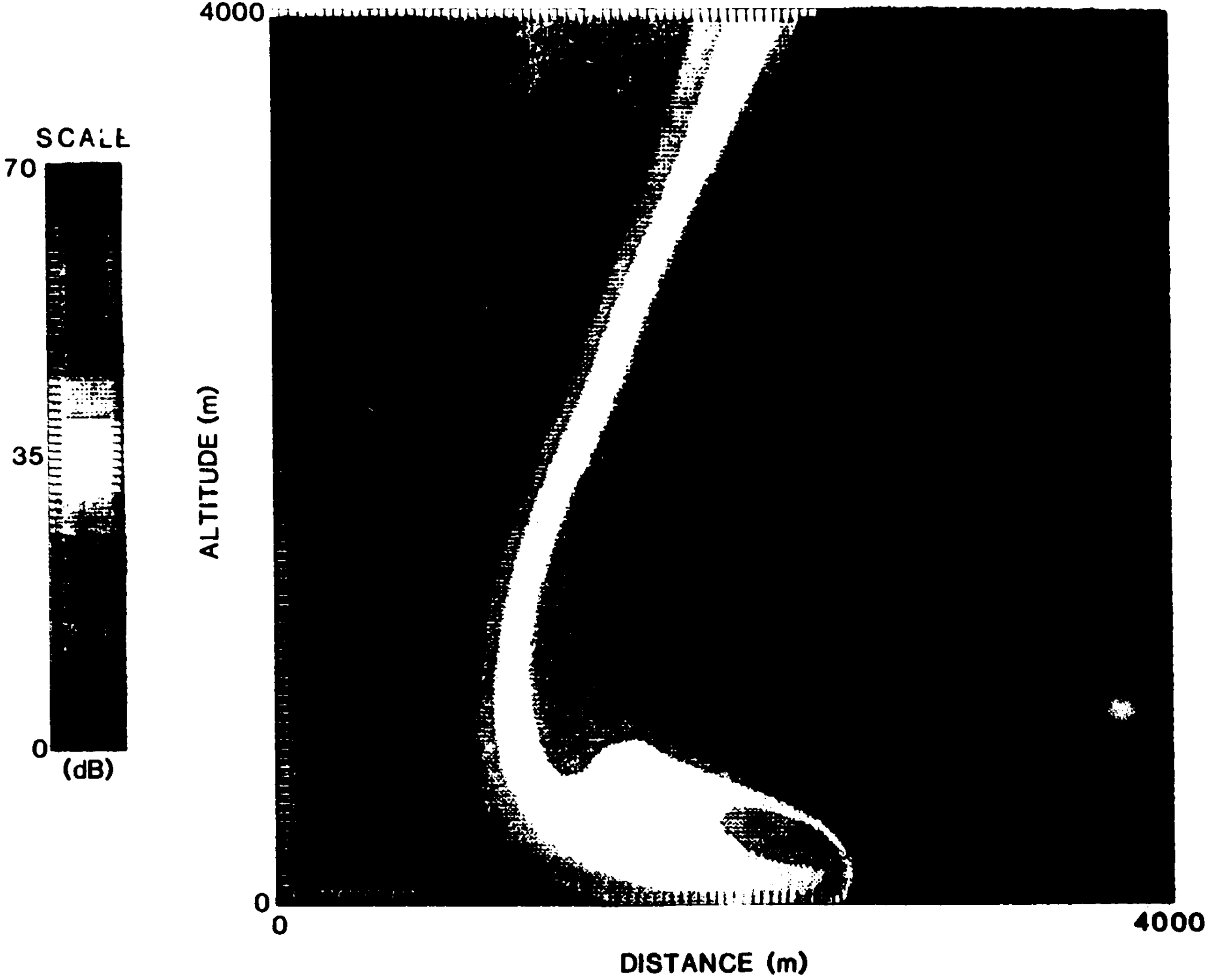


MICROBURST MODEL
RADAR REFLECTIVITY (A9)



MICROBURST MODEL

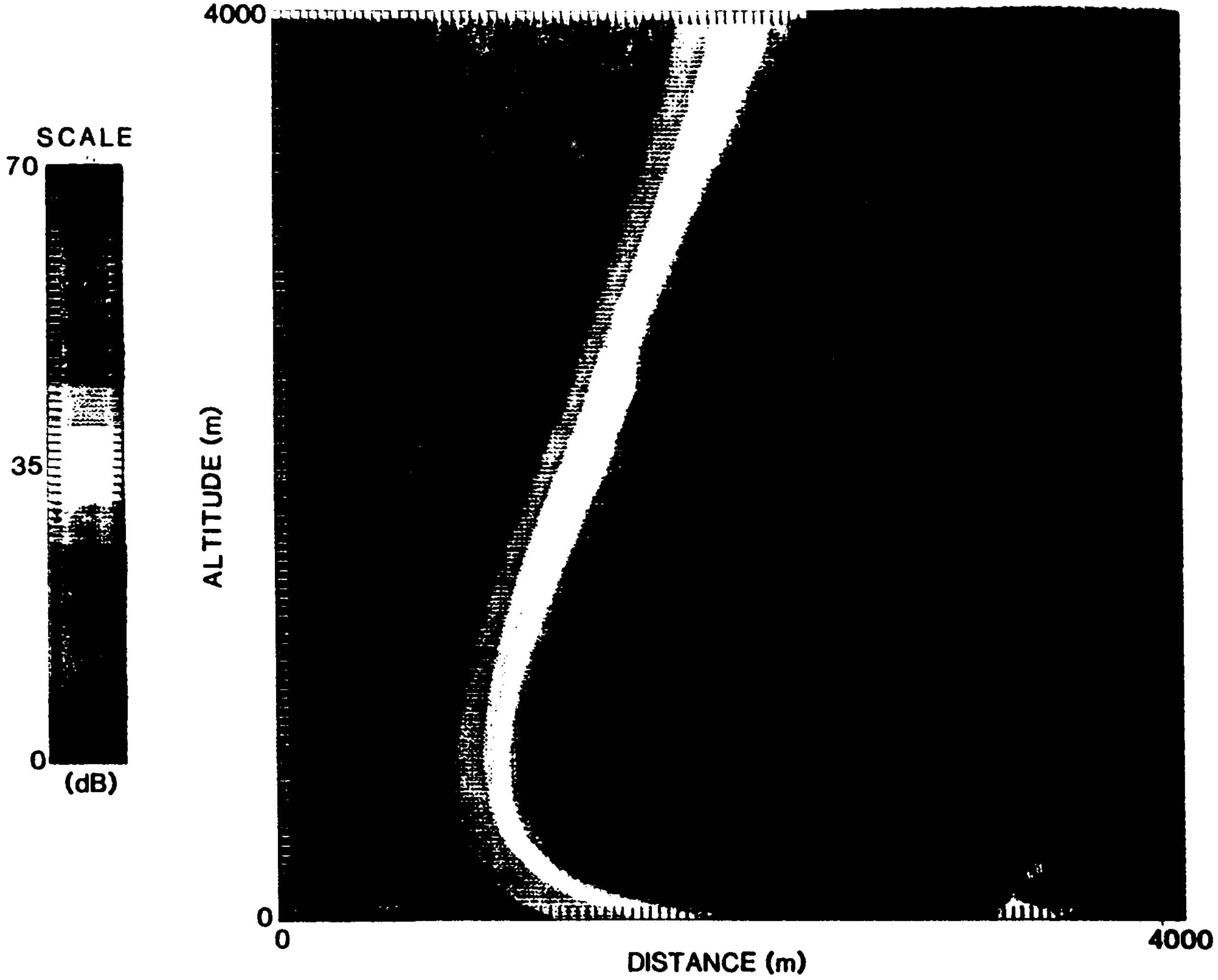
RADAR REFLECTIVITY (A11)



ORIGINAL PAGE IS
OF POOR QUALITY

MICROBURST MODEL

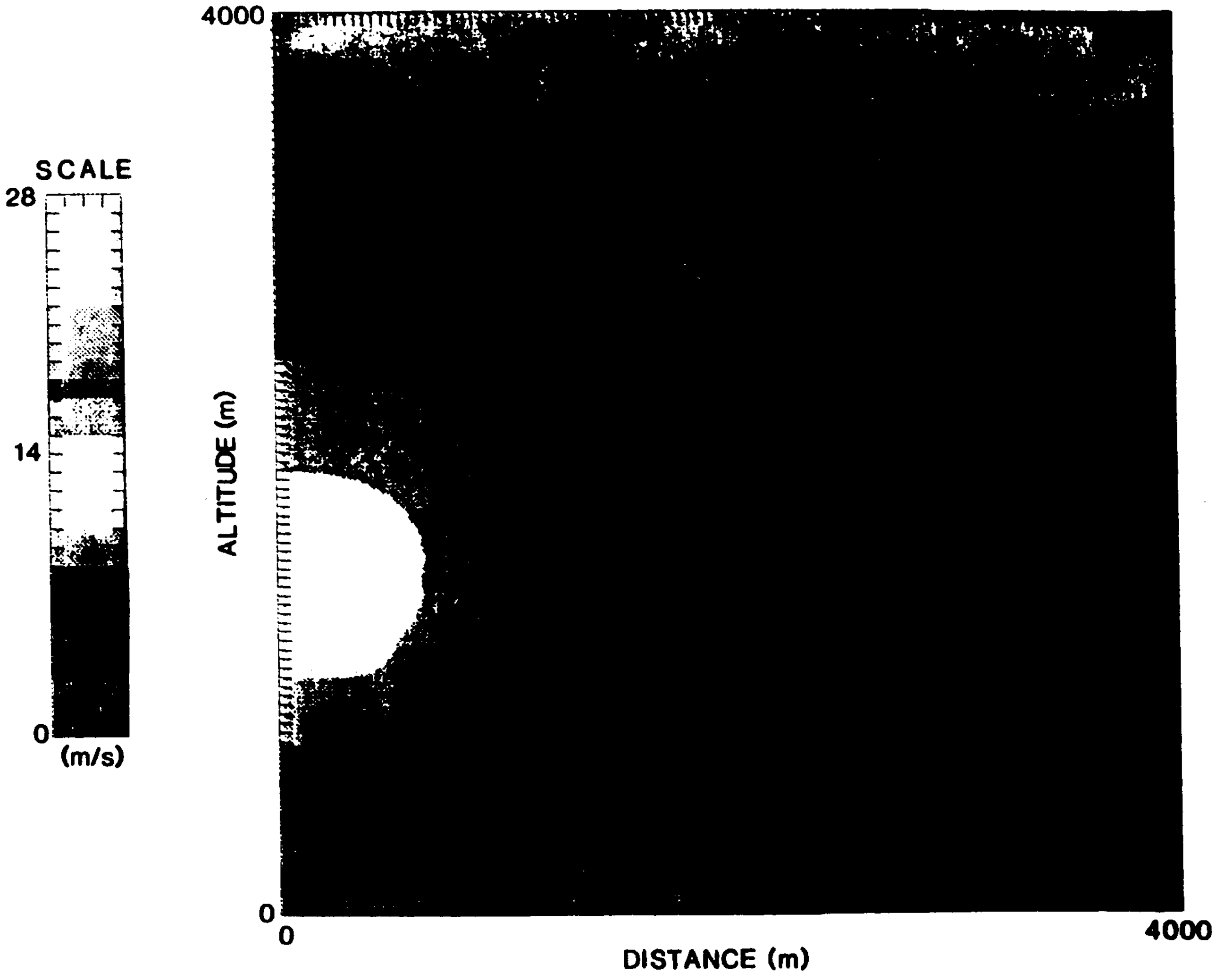
RADAR REFLECTIVITY (A13)



ORIGINAL PAGE IS
OF POOR QUALITY

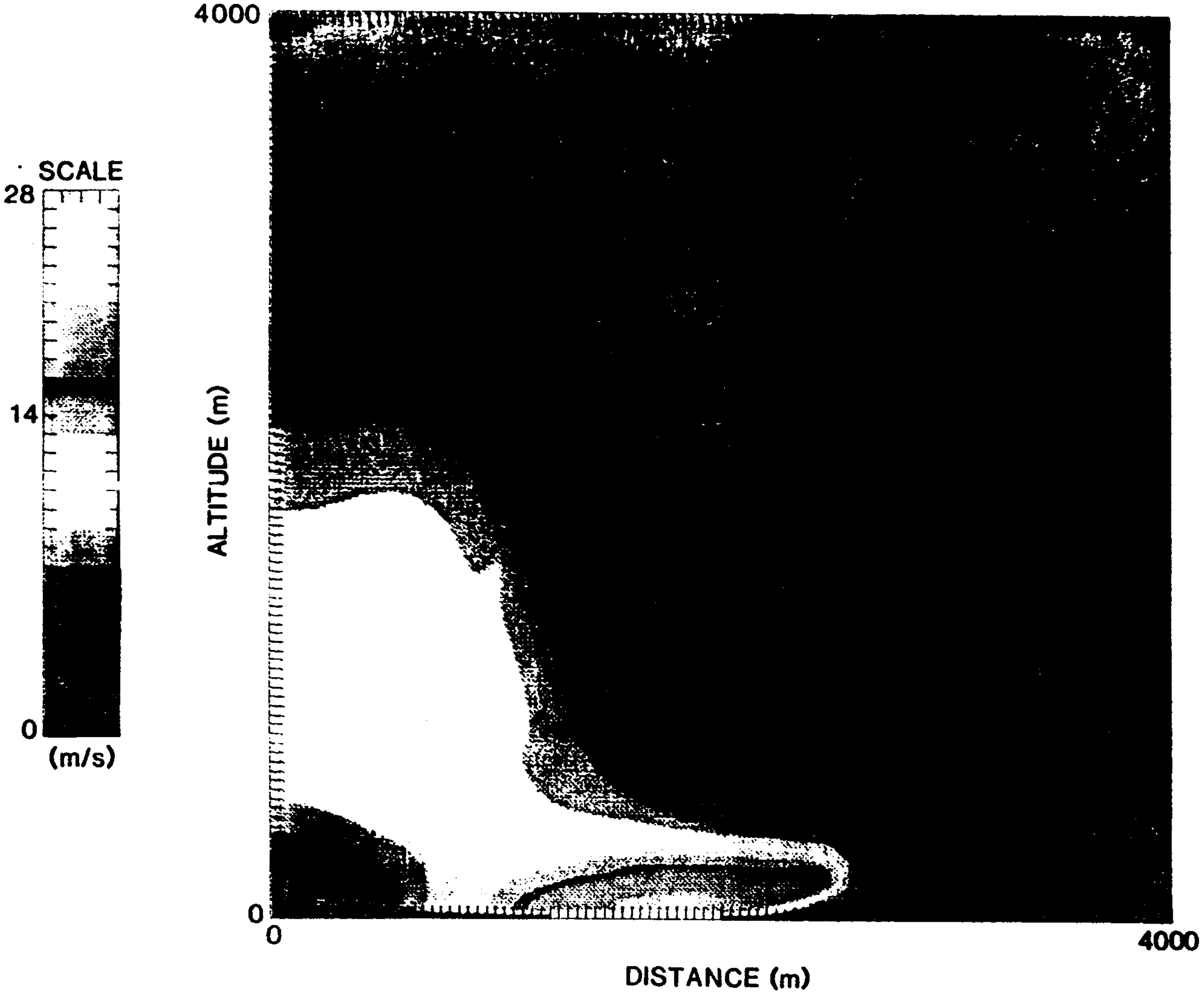
MICROBURST MODEL

MAGNITUDE WIND VELOCITY (A9)



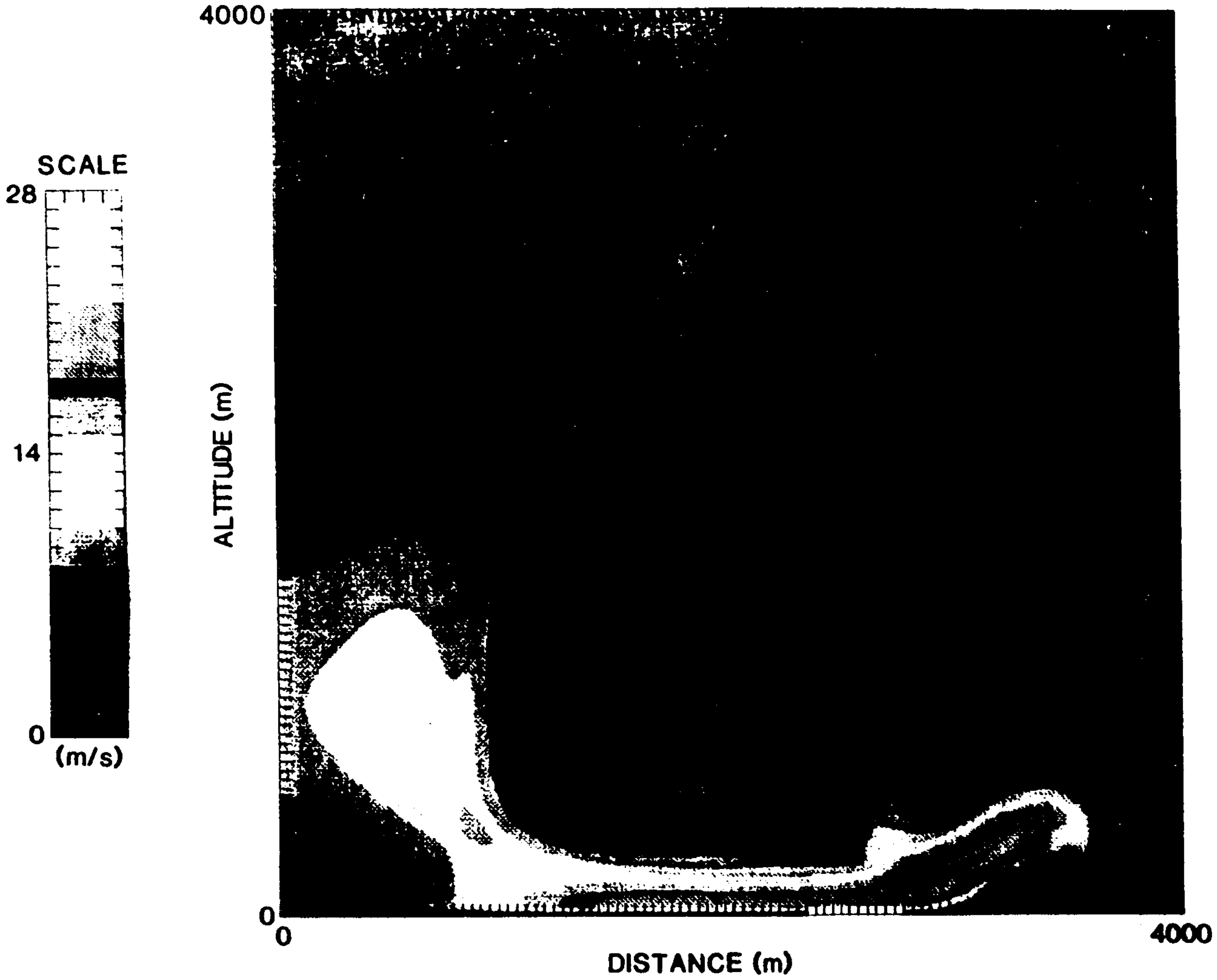
MICROBURST MODEL

MAGNITUDE WIND VELOCITY (A11)



MICROBURST MODEL

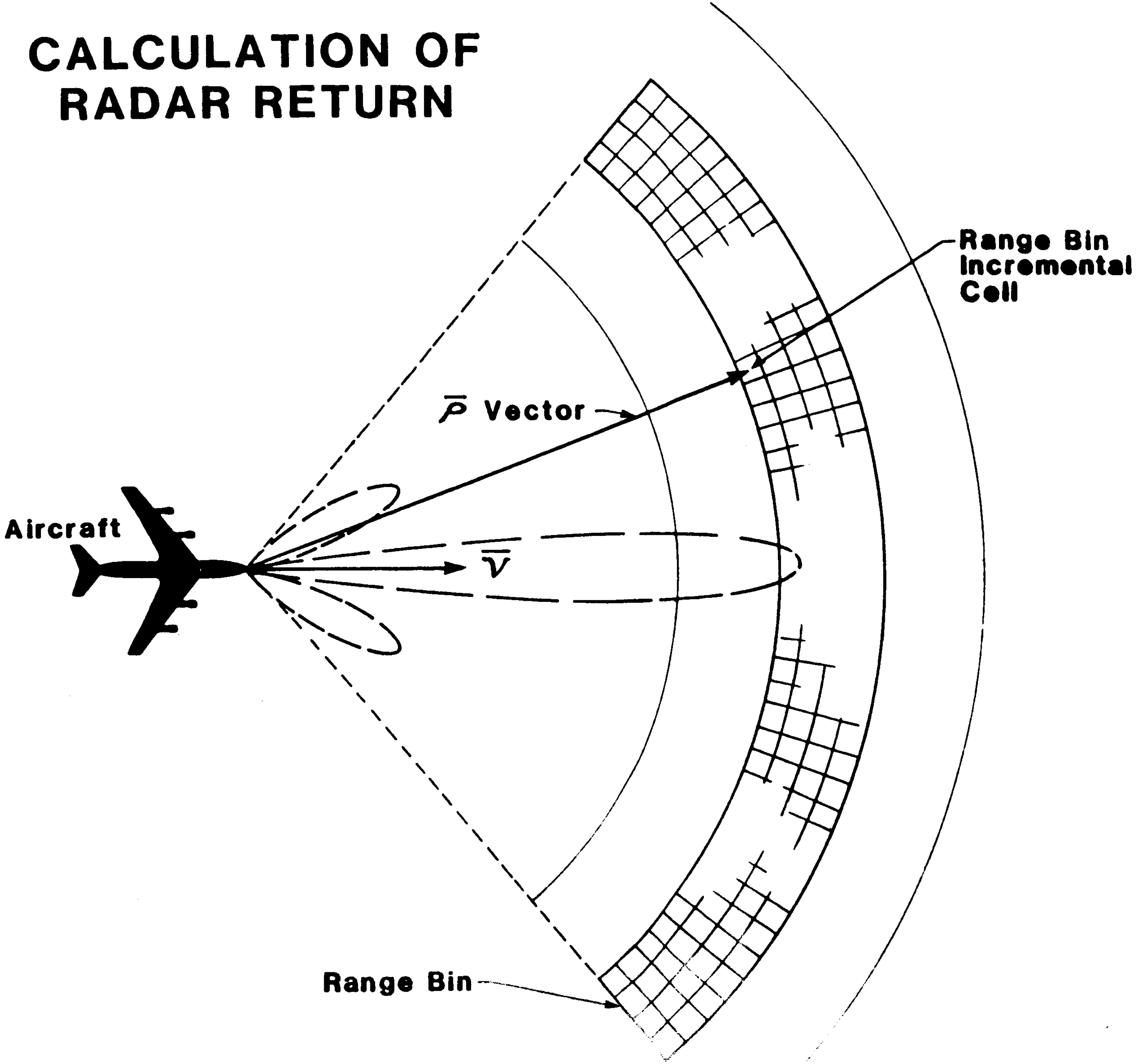
MAGNITUDE WIND VELOCITY (A13)



ORIGINAL PAGE IS
OF POOR QUALITY

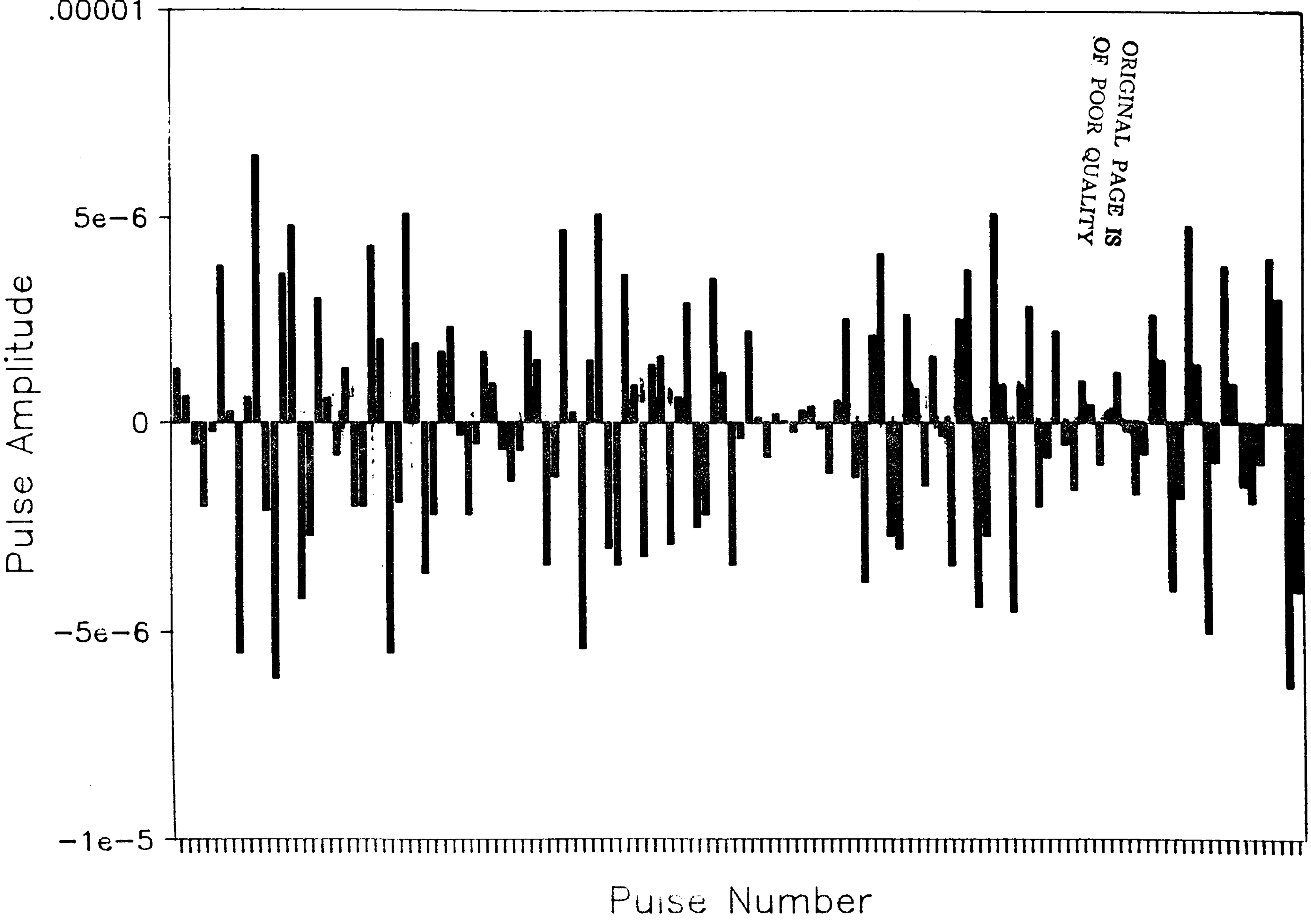

LOOK ANGLE
1 mi
35°
10°

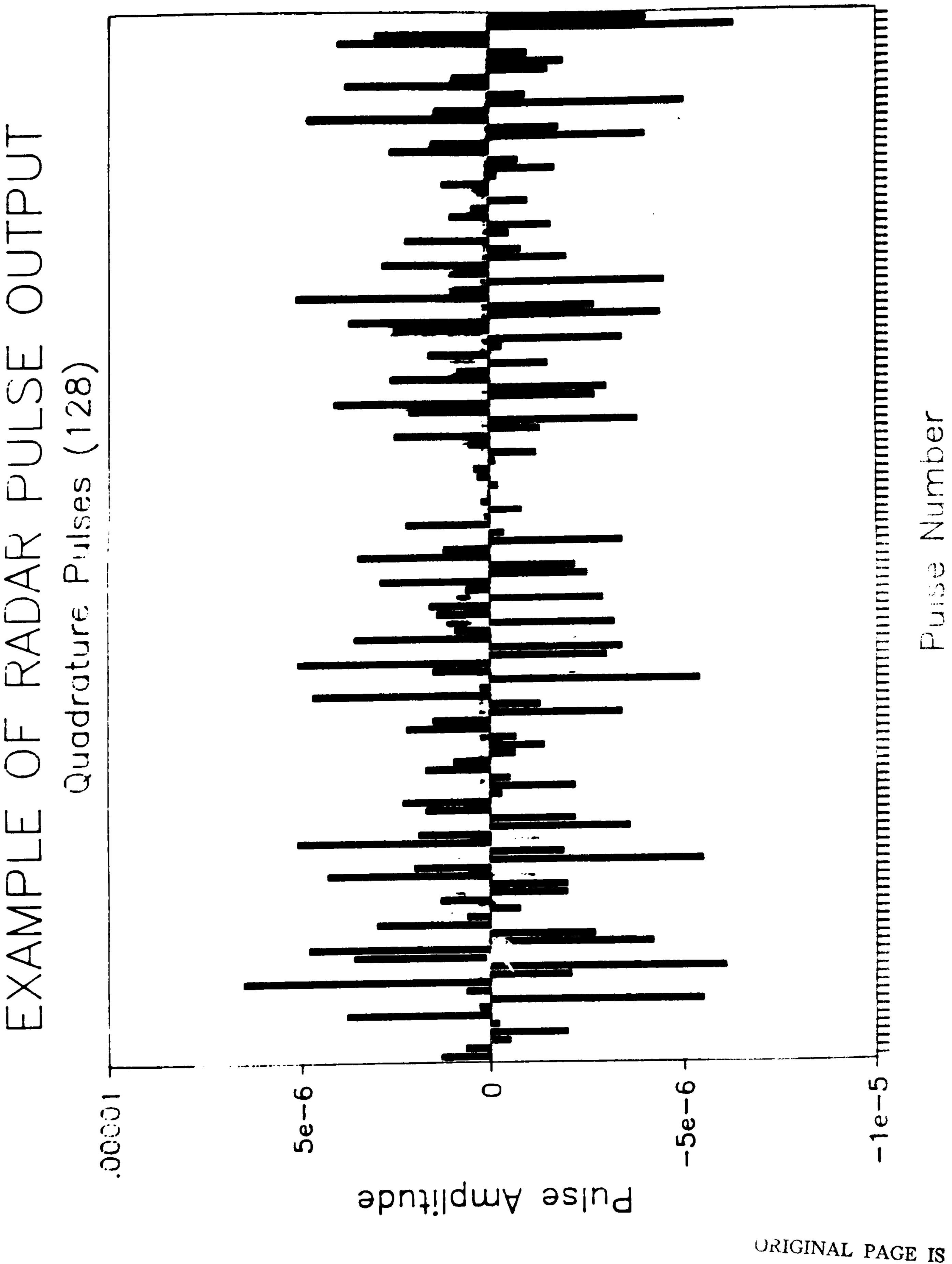
CALCULATION OF RADAR RETURN



EXAMPLE OF RADAR PULSE OUTPUT

Quadrature Pulses (128)





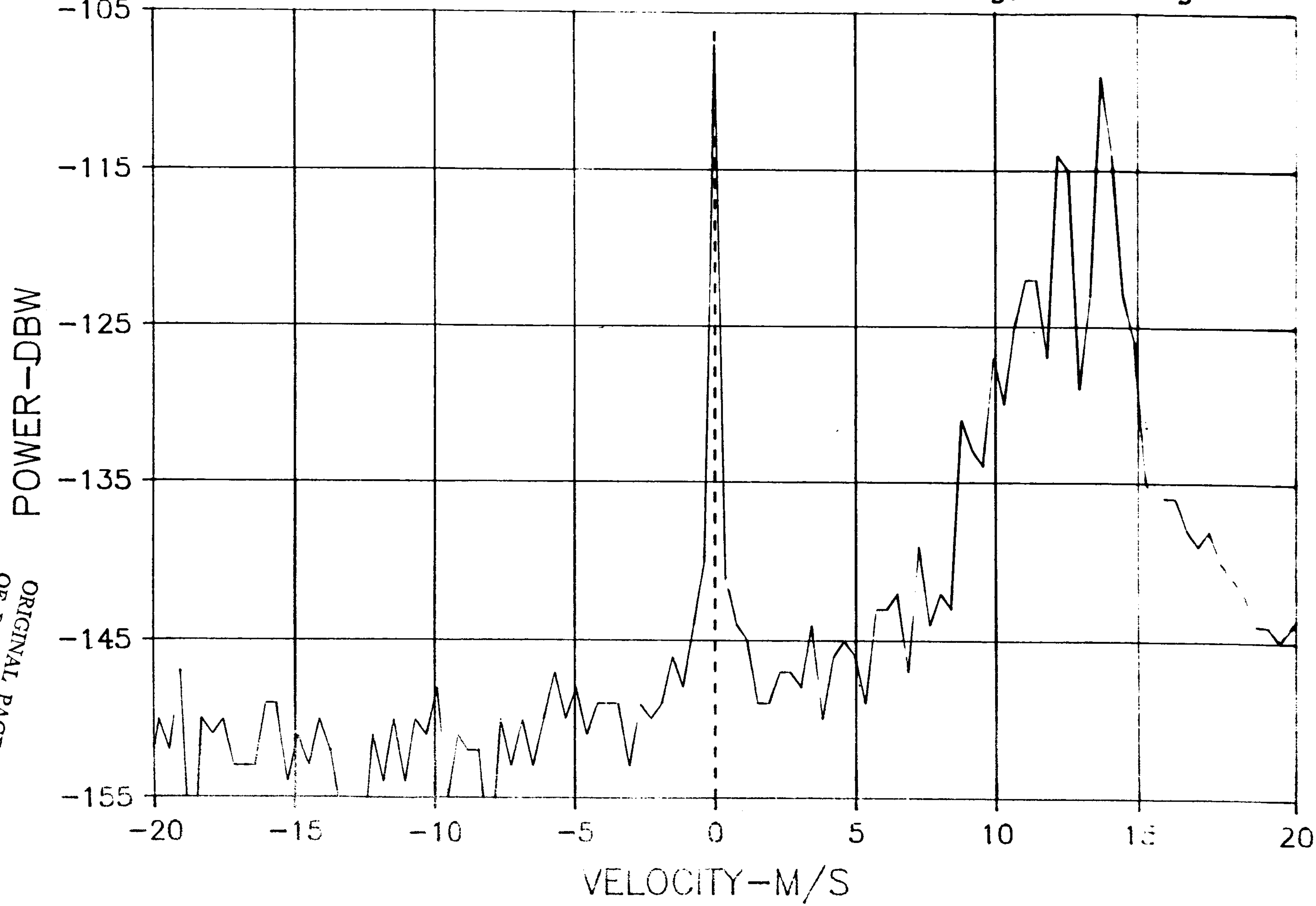
EXAMPLE OF RADAR PULSE OUTPUT

Quadrature Pulses (128)

ORIGINAL PAGE IS
OF POOR QUALITY

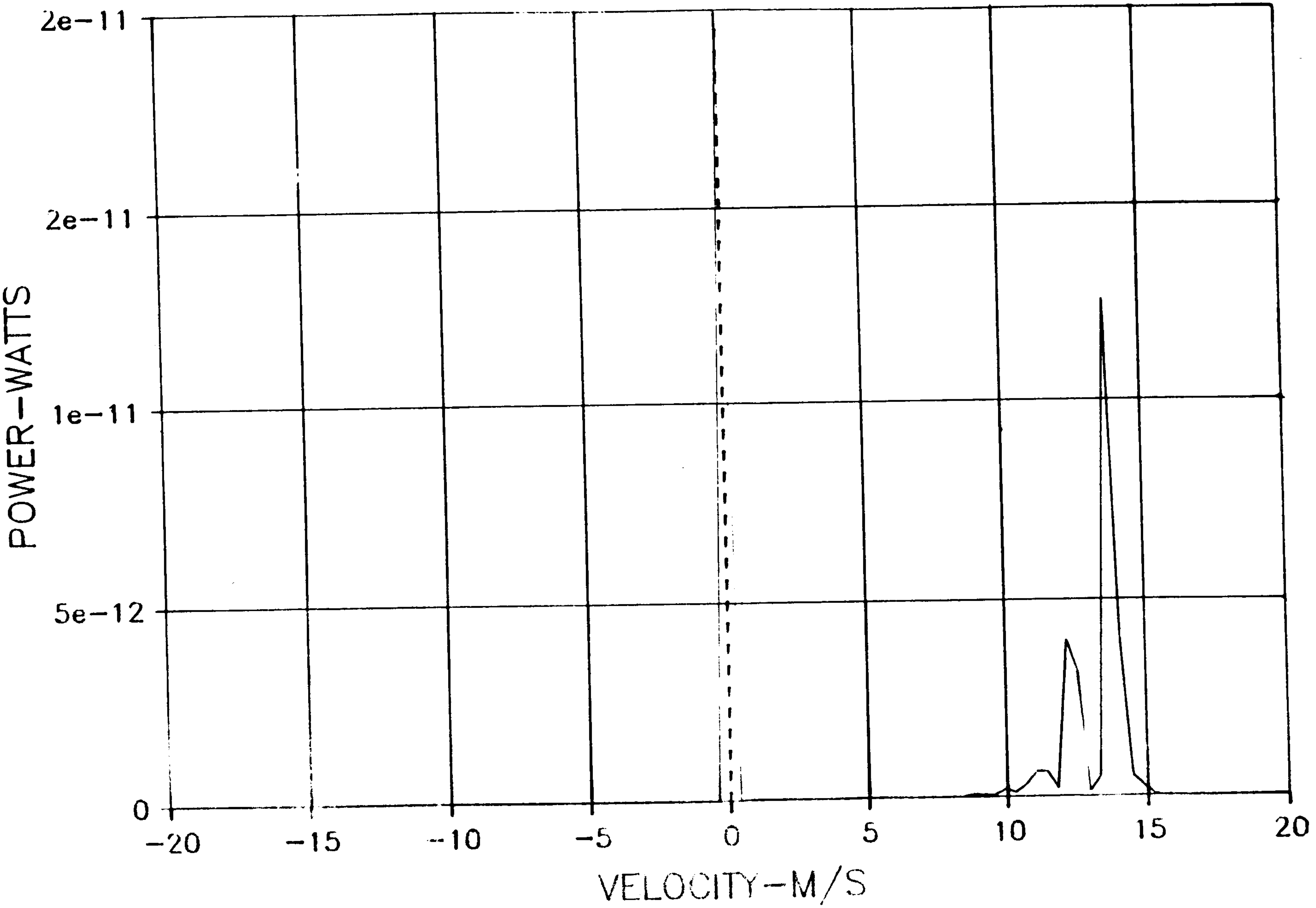
POWER SPECTRUM–MICROBURST A1 1

VEL=140kts,RG=10km,RGBIN=9km,EL=0deg,AZ=0deg



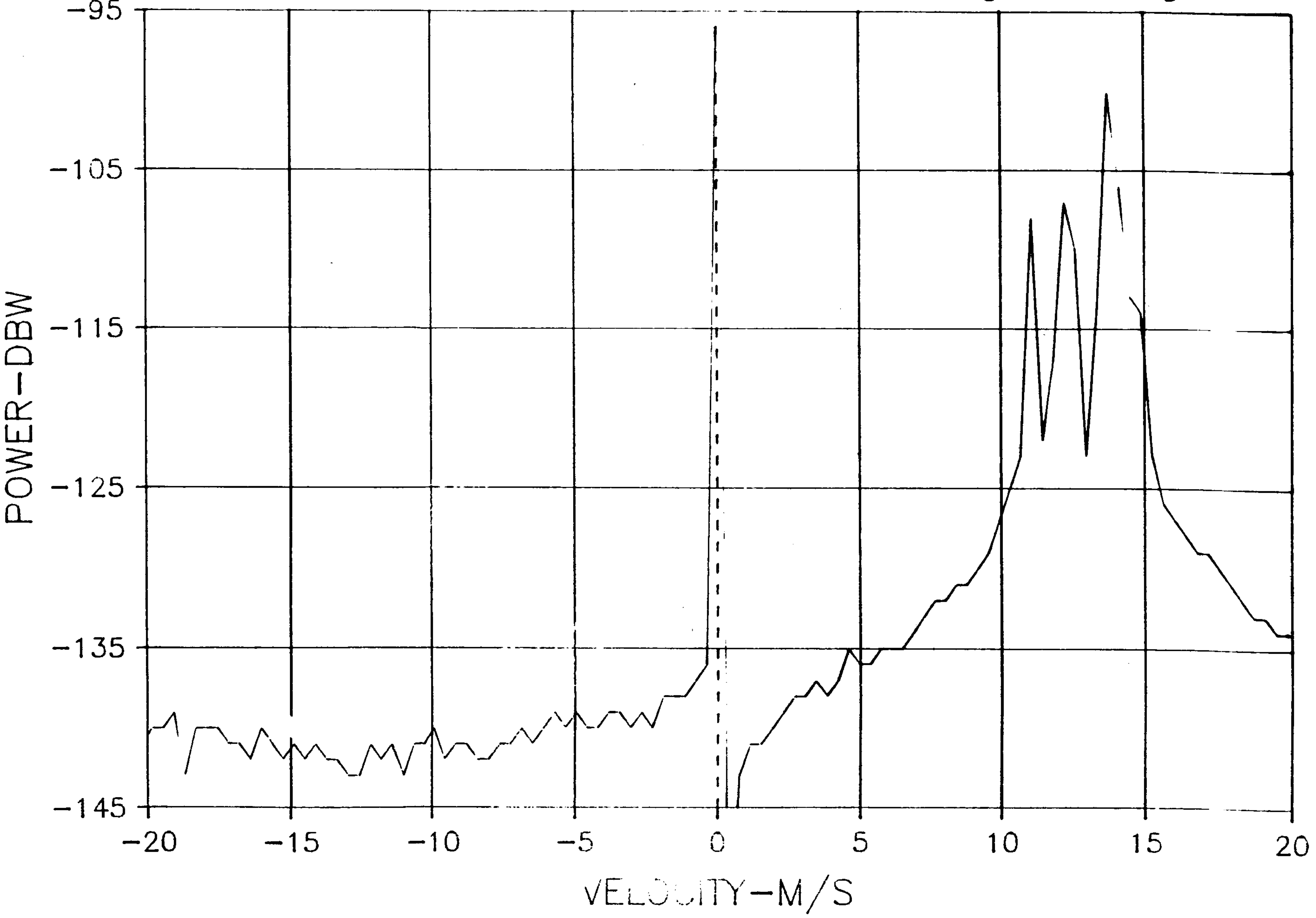
POWER SPECTRUM—MICROBURST A11

VEL=140kts,RG=10km,RGBIN=9km,EL=0deg,AZ=0deg



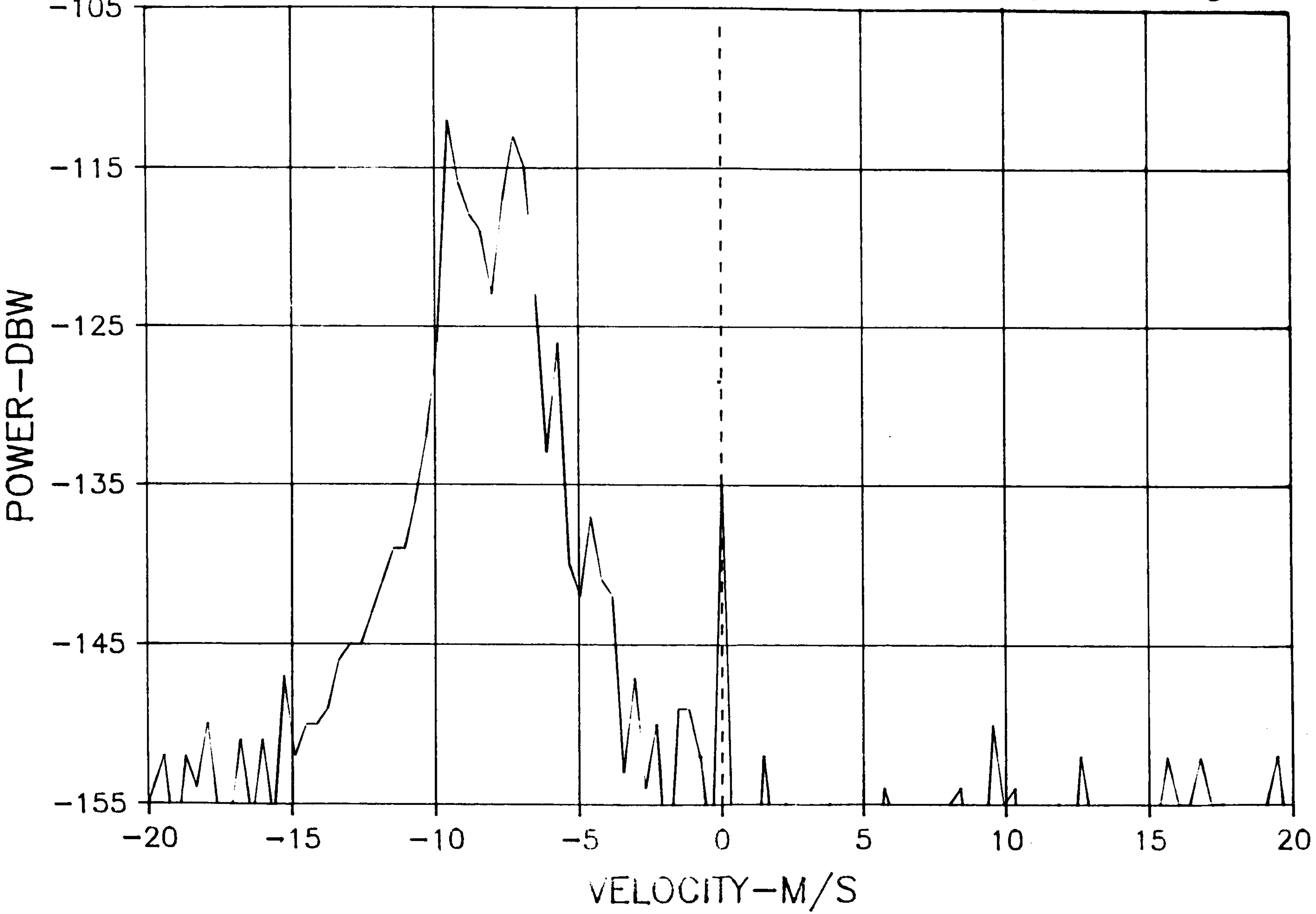
POWER SPECTRUM—MICROBURST A11

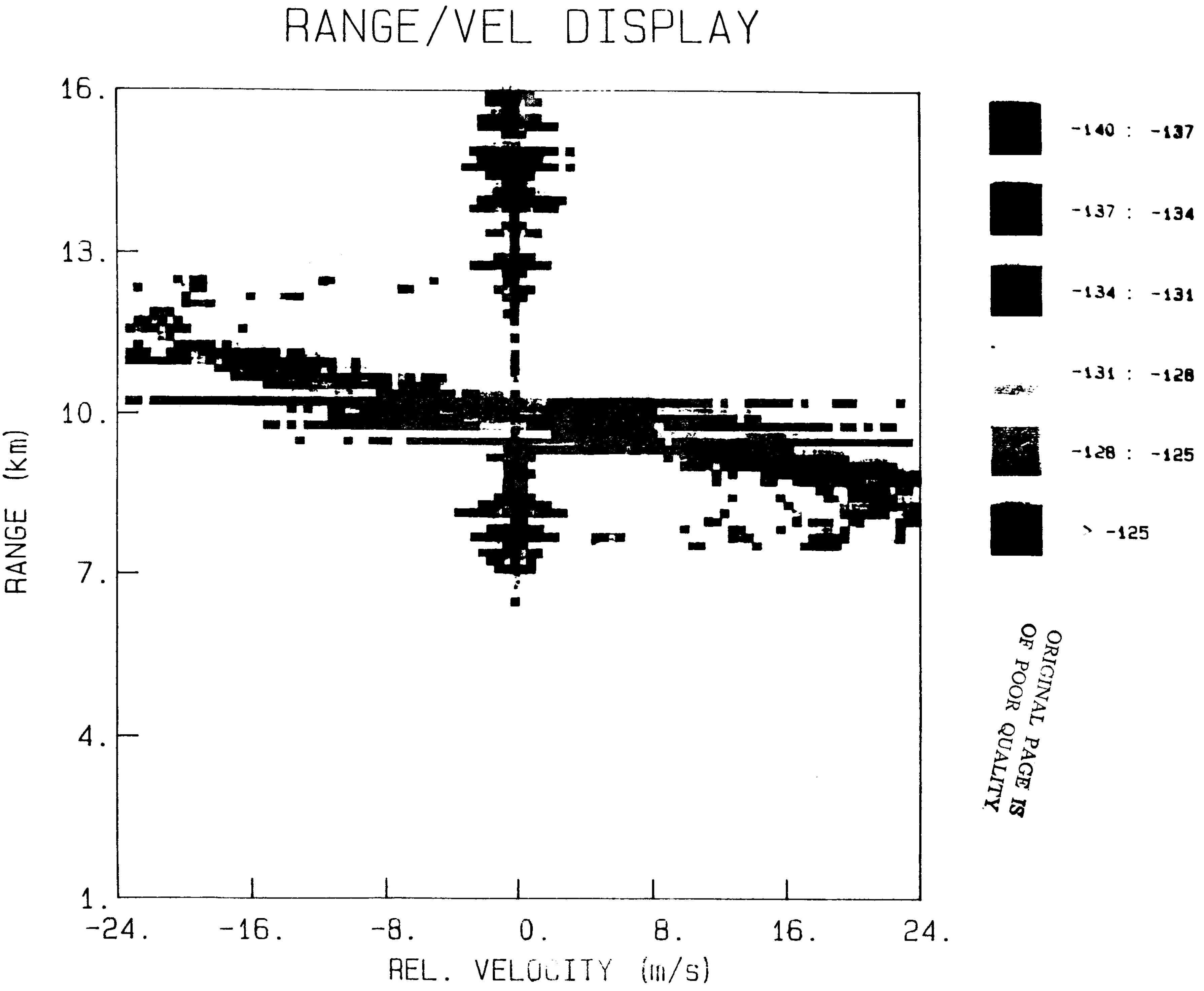
VEL=140kts,RG=5km,RGBIN=4km,EL=0deg,AZ=0deg



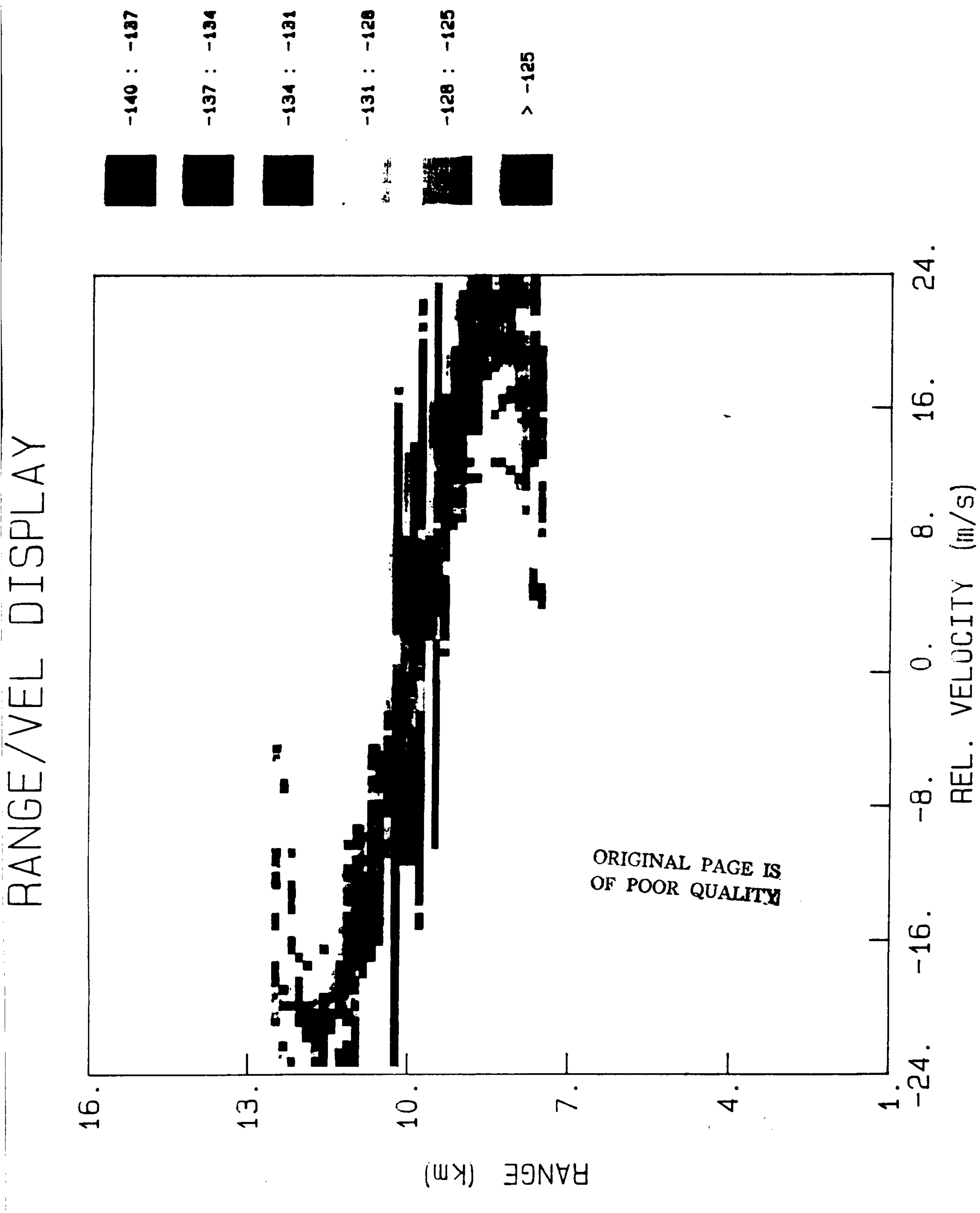
POWER SPECTRUM—MICROBURST A11

VEL=140kts,RG=10km,RGBIN=10.5km,EL=0deg,AZ=0deg




RANGE/VEL DISPLAY

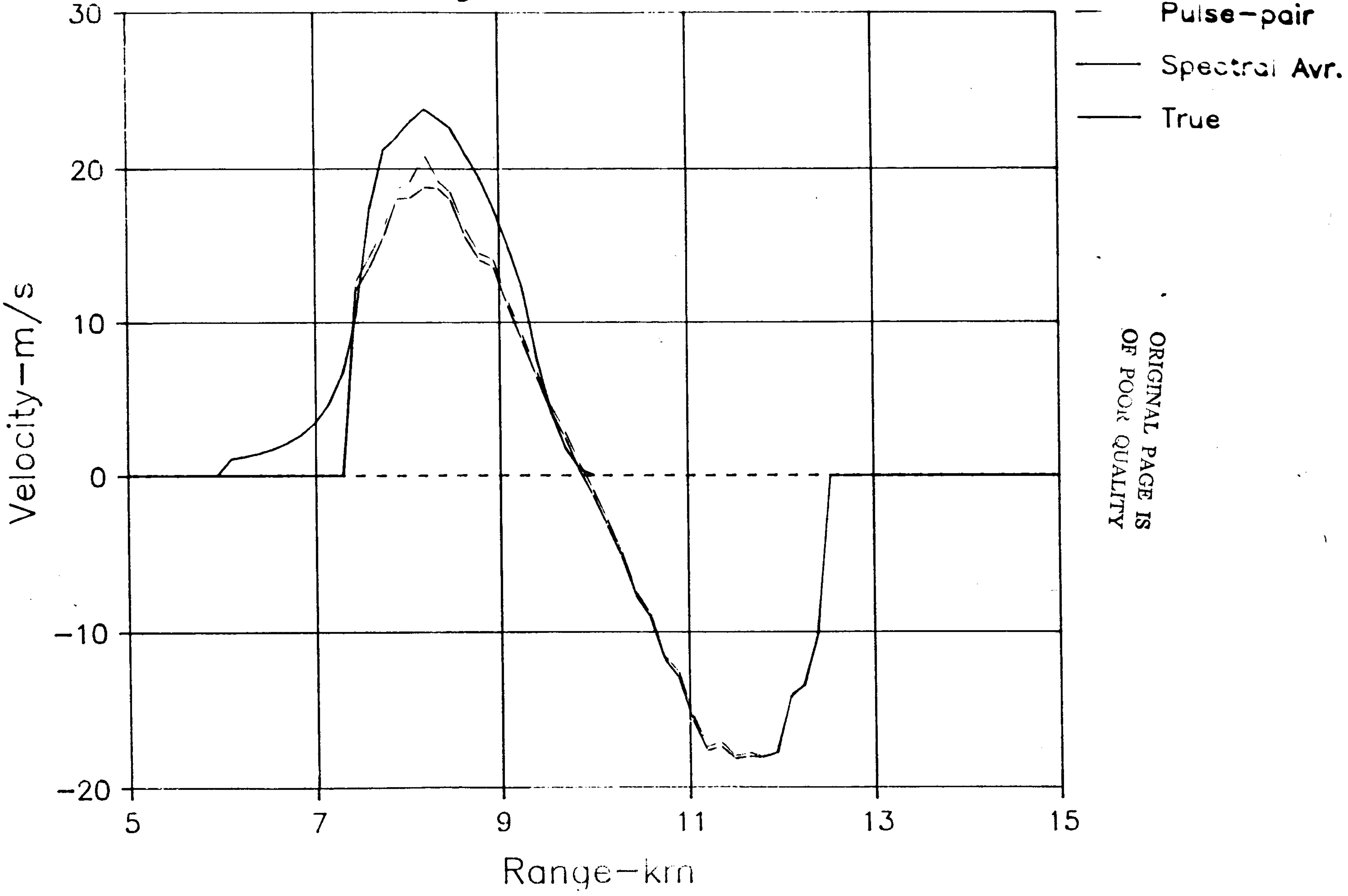
ORIGINAL PAGE IS OF POOR QUALITY



ORIGINAL PAGE IS
OF POOR QUALITY

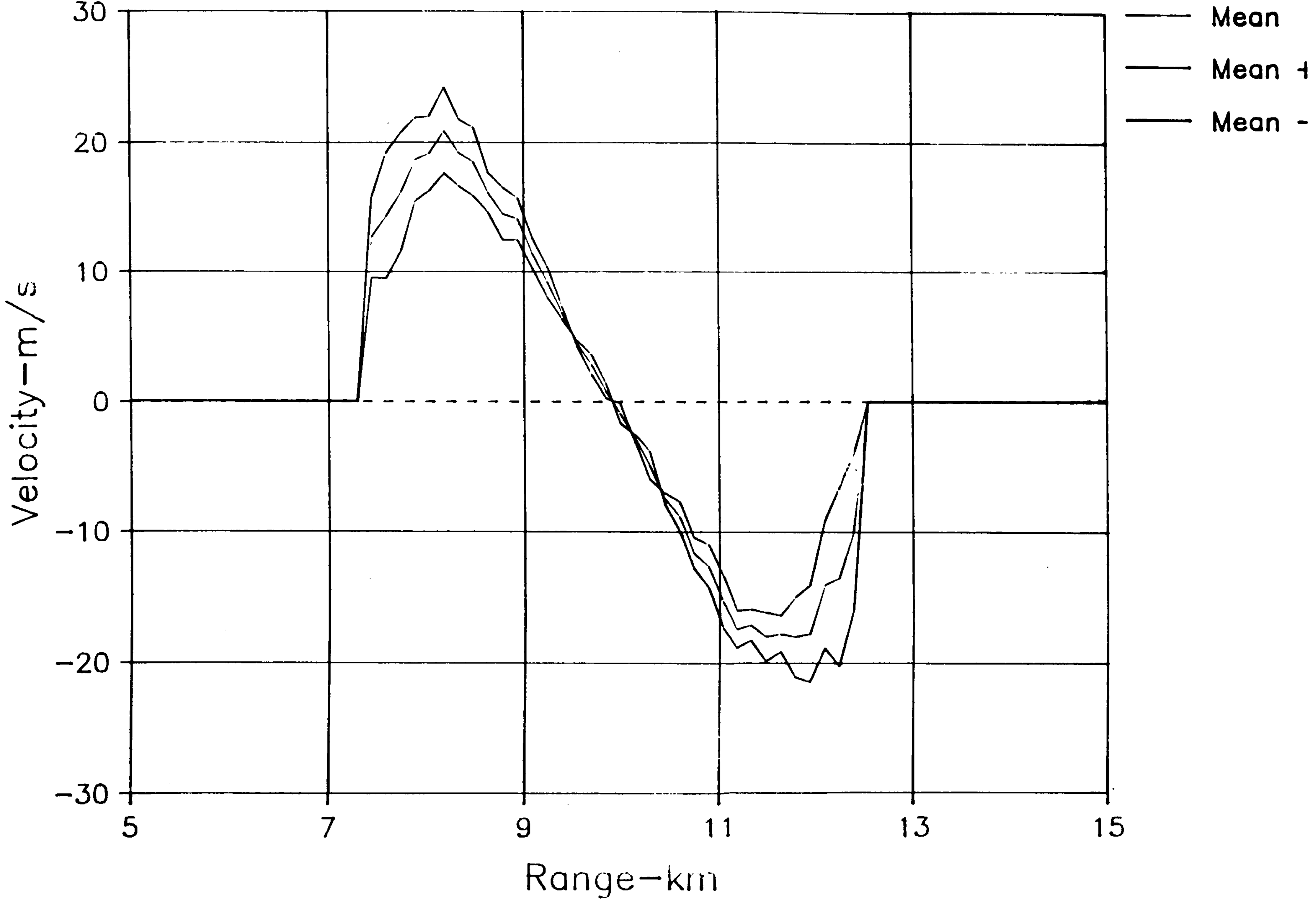
MEAN VELOCITY VS. RANGE, MICROBURST A11

Vel=140kts,Rg=10km,El=0,Az=0,Roll,Pitch,Yaw=0.



MEAN VELOCITY AND SPECTRUM WIDTH (PPP)

Vel=140kts,Rg=10km,El=0,Az=0,Roll,Pitch,Yaw=0.



SIMULATION PLANS

- **PARAMETER STUDIES**

  Radar Power, PRF, Pulse Width, # Pulses, Frequency, Pulse Jitter, Noise Figure, Polarization, Antenna Size & Illumination, Scan Angles & Rates, STC & AGC Techniques, Quantization, Etc...

- **TECHNIQUE & ALGORITHM EVALUATION**

  Clutter Suppression
  Mean & Peak Velocity Estimation
  Spectral Width Estimation
  Hazard Estimation
  Direct Shear Measurements
  Alarm Algorithms

- **DISPLAY GENERATION**

  Static
  Dynamic

- **PERFORMANCE EVALUATION** (With Various Microburst & Clutter Models or Real Data)

  Detection Or Display of Hazard
  False Alarms
  Missed Alarms

QUESTIONS AND ANSWERS

RUSS TARG (Lockheed R&D) - I have a general question about signal to noise ratio. Everybody working in forward looking remote sensors is concerned about signal to noise ratio. I would like an idea of the magnitude of the clutter to signal that you are dealing with and the corollary to that would be in half the microbursts that we study at least, they are full of water and the other half they are so called dry microbursts. How is the algorithm you're developing deal with the so called dry microbursts and what are the general signal to noise situation with regard to clutter to return in the two kinds of microbursts you are studying?

CHARLES BRITT (Research Triangle Inst.) - Let me point out again that we are not to the point of coming out with signal to clutter ratios and signal to noise ratios, we are still developing the simulation and we haven't got good clutter data. I will make that point again. Maybe in a couple of weeks, when we get some reasonable clutter data we will be able to answer some of these questions, but I would not say now. I would generally say that clutter data is considerably more than the signal. Does that answer the question?

RUSSELL TARG (Lockheed) - It really didn't answer the questions. The last time we had a meeting here, six months ago, people were talking about 60 to 70 db clutter greater than signal. I wondered if any algorithms were developed? I know you are working on that to try and do something to filter out the clutter and obviously what you are working on 50-60 db seems like quite a deficit, particularly in the favorable case where you are looking at a wet microburst. We are having to look at both wet and dry and I know that there is a huge difference in the return that you get from wet or dry microbursts. And I wondered if the microwave approach you are looking at deals, at all, with the reduced signal that you get from the dry case?

CHARLES BRITT (Research Triangle Inst.) - Yes. The signal level comes from the microburst model that is generated by Doctor Proctor. He has generated a high level of dbz level initially. I understand he is developing one at a low dbz level which we will work with. There will be a threshold where we can't see. That is what we will find out.

E. BRACALENTE (NASA LaRC) - That 60 or 70 db number you saw was based on this model. We scanned that radar image, digitized it and then put in a calibration where the backscatter sigma zero ran from -5 db to -40 or -50 db depending on the ground target. And that was the basis. We haven't really got involved in algorithm development yet. We'll not until we get some real data and really know what we've got. But obviously there are techniques that can be applied. A lot of filtering schemes will be looked at.

[1] In response to Russell Targs's second question. The clutter-to-signal (CSR) ratios mentioned at the previous meeting were in the 50 to 60 db range relative to a 0 dbz signal reflectivity. This is for the antenna pointed down along the glide slope and a range gate 5 Km from the a/c, where the main beam touches the ground. At shorter range gates, under 3 Km, the CSR falls below 30 db. With a 20 dbz or greater signal, typical of wet micro-burst, the CSR for the worst case will be below 40 db, and for the shorter ranges below 10 db. These CSR are within a range that present day radar and filtering designs could handle. For the dry microbust, where the reflectivity is below 10 dbz proper antenna pointing, range limiting, higher powers and higher frequencies may have to be employed. These trade-offs will be assessed to determine the performance and limitations of Doppler radars.

PAT ADAMSON (Turbulence Prediction) - At any point have you addressed the asymmetric cases for an airborne radar? It seems to me that that is a problem. I don't see it in any of the stuff that has been put up.

CHARLES BRITT (RTI) - We haven't yet. The data bases we have are symmetrical. The first thing to do is move those off center and then look at those and then we will get into the asymmetric cases.

E. BRACALENTE (NASA LaRC) - We just started looking at that and that is the first model we've got to work with and we will be looking at all the different cases. Wet, dry, symmetrical, etc. But we are trying to get the model for the simulation program developed to the point where we can start looking at all this.

JIM EVANS (MIT Lincoln Lab) - Let me make a couple of comments. The question of what the reflectivities are to microburst, I would represent, you don't need a simulation model. There have been enough field measurements run in wet and dry environments so that if you don't know what the dbz levels are by now your model will never tell you anything different. Because people have been measuring them now for 5-6-7 years and there are probably over 1000 microbursts that have been measured. And I dare say that anybody who claims that a simulation model is going to improve on the thousands of measured events is crazy. It is very simple to go through and compute the signal to noise ratio at X band for the presumed operation. And

---

1. E. BRACALENTE has asked that the following comments be added.

I'm hoping somebody has done--I'm sure John Chisholm has done and could share that result. If you plug in a typical sigma zero without getting into great exotic behavior ERIM's existing data base isn't applicable because, the crazy angles of incidence are really things like 3 degrees and below. And the sigma zero go up radically. The case you gave, the grazing angle and the scenario you have pointed out, is 3 degrees, not 10 degrees. Anybody who has ever looked at airborne data knows the cross sections go up very fast as the grazing angles gets down near 0 and below 5 degrees in particular. My rough guess is if it can't work in an urban environment people are never going to buy it. Almost every airport I can imagine has at least one approach or two that are over an urban environment and I mean houses and so on. Just look out next time you go into a major airport. So forget all the other stuff, if you can't work over an urban environment you probably don't have a viable system.

E. BRACALENTE (NASA LaRC) - That is exactly what we are doing. The data from ERIM that we are going to be getting, is at 3 degrees.

[2] In response to Jim Evans' first comment. The purpose of the microbust simulation model is not to answer the question of what reflectivities or windspeeds are in a microbust, or to improve on the thousands of measured events, but to provide a high resolution spatiallly distributed data base of windspeeds and reflectivities representative of a typical microburst. These models can then be used by e aerodynamicist to evaluate its effects on a/c performance, and by sensor developers to evaluate sensor design trade-offs and performance. --- Generally, sigma zero does not go up as the grazing angle decreases. In fact for most targets such as runways, grass, water, farm lands, and forests the sigma zero decreases significantly with decreasing grazing angle. For urban environments sigma zero tends to be more constant as a function of grazing angle, with a mean value around -10db, and decreases slightly with decreasing grazing angle. Only when the grazing angle approaches 0 to 1 degree does sigma zero sometimes increase due to multipath scattering and specular reflection from the flat sides of buildings. These extremely low grazing angles will not occur in the range gates that would be processed in an airborne radar. -- It has never been suggested that an airborne radar is being developed to work only in non-urban area around airports. It is because of the urban environment around most airports that we're obtaining the ERIM SAR data at low grazing angles. This data will help us evaluate the severity of the urban clutter and to investigate radar configurations that may be able to work within this

---

2. E. BRACALENTE has asked that the following comments be added.

environment.

JIM EVANS - Okay. Let me make a comment. If you take a -10 db sigma zero (which isn't a reasonable guess) and you work out the math for 10 kilometers, you are going to find your clutter is probably 70 or 80 db above your signal. That is just the way the numbers work out, and I think John Chisholm will verify that. At 10 kilometers I don't think you have a viable system. Not if you take the simulation model and you believe that the microburst are only 2 or 300 meters thick and you believe that you have to function over an urban environment, I don't think you are even in the ball park. And I'll make that as a simple challenge and you can plug it into the sigma zero numbers and carry them out, John Chisholm has done that and I'm sure has drawn the same conclusion.

[3] In response to Jim Evans's second comment. I think you will find that the numbers you have given are significantly in error. Specifically, for an a/c at 10 Km from touchdown and an altitude of 525 meters, using a 3 deg. beamwidth antenna looking down the glide slope (-3 deg.) at a 20 dbz reflectivity (a reasonable number for a wet microburst) and a ground backscatter sigma zero of -10 db (a reasonable estimate for urban clutter) the clutter will be about 45 db above the signal, not 70-80 db. (Which agrees approximately with the numbers John Chisholm computed. See his comment which follows.) At the 5 km range gate, which provides adequate warning time to the pilot, the clutter is about 26 db above the signal. At shorter ranges and with proper antenna pointing management the clutter levels can be reduced significantly further. These lower clutter-to-signal ratios are well within the limits that present day processors and radar designs can handle.

---

[3] E. BRACALANTE has asked that the following comments be added.