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EVALUATION OF THE MASER-EQUIPPED RADAR SET AN/MPS-34 AND AREA PRECIPITATION MEASUREMENT INDICATOR

Report No. 3
Contract No. DA 28-043 AMC-01257(E)
DA Project No. 1V0.25001.A126

THIRD QUARTERLY PROGRESS REPORT

1 October 1965 to 31 December 1965

Illinois State Water Survey
Atmospheric Sciences Section
at the
University of Illinois
Urbana, Illinois 61801

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Sponsored by
U. S. Army Electronics Laboratories
Port Monmouth, New Jersey 07703

To evaluate the maser-equipped AN/MPS-34 radar and Area Precipitation Measurement Indicator (APMI) for their meteorological usefulness to the Army.

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PURPOSE

The purpose of this contract is to evaluate the capability of the maser-equipped weather radar set AN/MPS-34. and the Area Precipitation Measurement Indicator (APMI) to operate as a highly sensitive meteorological sensing device and as a system for rapidly measuring, integrating, and displaying area precipitation; determine what meteorological phenomena not detectable by other radar may now be detected, measured, and displayed by this equipment; and determine the general utility of these units for Army meteorological purposes.

ABSTRACT

Data have been collected for three storms using the APMI; one storm has been analyzed in some detail. A discussion of the problem related to calibration of the APMI gain steps is included. The maser has been restored to operating condition with the installation of a replacement pump klystron. The speckle analysis that was started last quarter has been completed. The speeds, directions, back-scattering cross-sectional areas, heights, and areal densities of the echoes, caused by birds, have been determined. A study of the growth of echoes as detected by the maser-equipped radar has begun, but results will be reported later. Plans for the fourth quarter are outlined.

CONTENTS

PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

On 4-8 October 1965, W. G. Stone worked on the APMI at the State Water Survey.

On 9-10 November 1965, R. L. Robbiani visited the State Water Survey to review the results of analysis completed as of • that date and to discuss future plans of the project.

INTRODUCTION

Work during the third quarter has been in three general areas. Considerable effort has been expended on the APMI to get it into a more reliable operating condition. It has been used to collect data for which preliminary analysis has begun. The maser has been restored to operating condition with the arrival and installation of the replacement pump klystron in late December. It has been reinstalled on the MPS-34 and is now being readied for operation. The third general area of endeavor has been the analysis of the New Mexico data. The speckle analysis that started last quarter has been completed, and the results are given herein. A second study, which concerns the growth of echoes as observed by the radar with and without the maser operating, is far from complete, and only preliminary results can be reported at present.

APMI

Data Analysis

The Areal Precipitation Measurement Indicator (APMI) was operated during three storms. Detailed analysis has been performed for 1 hour and 53 minutes of data collected on 24 November 1965. The analysis has been directed toward an evaluation of the APMI as an automatic radar operator rather than as a precipitation measuring device. This was done because of the need for evaluating the equipment and because the storm of interest did not occur over the dense raingage network. Even had the storm occurred over the network, the means of calibrating the APMI had not been developed.

In considering the APMI as an automatic radar operator the question becomes, "What significance can be attached to the number displayed by the APMI?" This can be viewed from different aspects, such as: 1) Does every number printed by the APMI have an associated radar echo? 2) Does every radar echo have an associated APMI output? 3) Prom radar scan to radar scan, does the same echo strength produce the same number? The first and third questions are answered in the following sections. No comparison has yet been made to determine if every radar echo has an associated APMI output.

The first question can be related to what has been referred to as the false alarm rate. Exact calibration of the level to which the APMI was set has not been made for reasons discussed under APMI calibration. As a first approximation, the level was set so that no l's were occurring with the normal grass from the receiver. For analysis of the two hours of operation, 119 frames of radar data from a radar camera were compared with 119 frames of data from a camera photographing the character display of the APMI.

The APMI was operated on 75-mile range, low PRP, and PPI mode. Usually, one azimuth scan of the radar was made and a picture taken during the following scan. The computer was then reset, and data gathered on the next scan. As a result every other radar scan provided APMI data. The radar was operated on maximum receiver sensitivity, and a picture obtained on every scan. Unfortunately, no step gain or receiver reduction was performed, since the radar gain control affects the gain of the APMI receiver.

Figure 1 shows a bar graph of the false alarm rate. The ordinate represents the percentage of the total number of APMI squares of each sensitivity printing numbers that could not be associated with a radar echo. For intensity levels 1 and 2 the false alarm rate was 20 percent so that one of five was fallacious. These spurious readings may have two causes: they may be a result of noise in the APMI, or they may be a result of the peak detection process used in the integrator. The false alarm rate reduces as the discrimination level rises and thus is negligibly small on levels 5 through 9. Level 0 has an increased

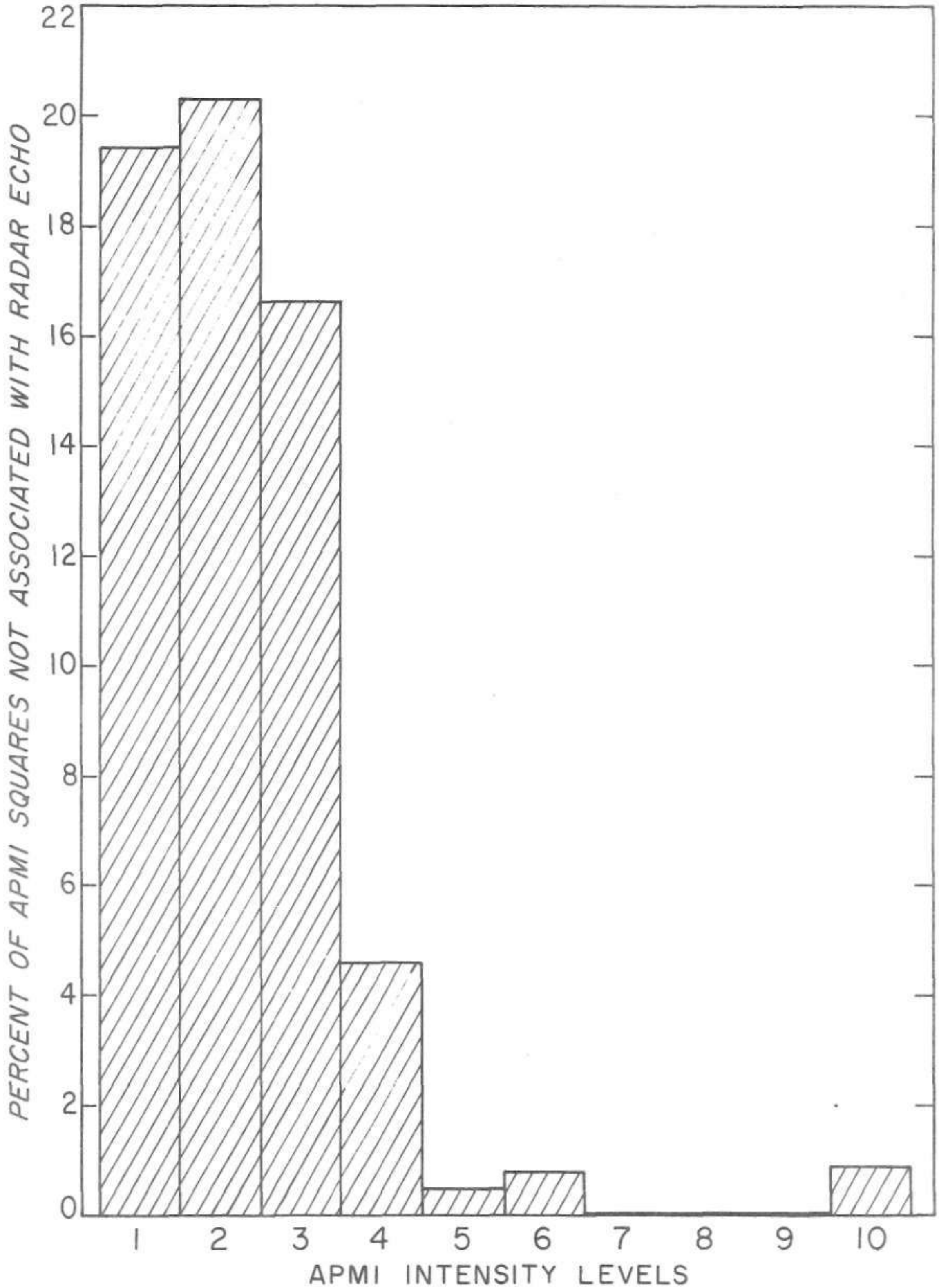

Figure I. COMPARISON OF FALSE ALARM RATE WITH APMI INTENSITY LEVELS ON 24 NOVEMBER 1965 false alarm rate primarily because the APMI occasionally printed the stored 0 from the memory improperly. The memory is loaded with O's during computer reset and until valid intensity data are stored, the printing is inhibited. However, this inhibition occasionally fails to operate, and O's are printed improperly.

Table 1 shows the number of squares with and without radar echo for each APMI intensity level.

Table 1. Comparison of APMI and Radar for 24 November 1965

APMI Intensity level	Total Squares	Squares with radar	Squares without radar	Percentage false alarm
1	2870	2314	556	19.4
2	1604	1279	325	20.3
3	941	785	156	16.6
4	628	599	29	4.6
5	377	375	2	0.5
6	123	122	1	0.8
7	52	52	0	0
8	9	9	0	0
9	17	17	0	0
10	451	447	4	0.9

Two anomalies in the APMI data and operation were observed. The discussion of them that follows does not fully answer the third question but indicates two ways scan-to-scan variations of APMI numbers are produced.

It was noted that the false alarm rate was very high in an area about 30 miles southwest of the radar. Very frequently one-to three square's had APMI numbers, but at no time could a radar echo be identified in this region. The explanation of this anomaly is not known. It is doubtful that it is a result of noise within the integrator since the necessary synchronization with both the antenna azimuth and the radar PRF is doubtful. Possibly there was echo just below the detectability of the radar which, as a result of the peak detection process in the integrator, was detected. If this is so, the interpretation of the APMI for rainfall amounts will be impossible.

Since it appeared that some portions of the APMI intensity levels were printed on the second revolution after recycling, eight sets of data were collected on both the first and the second revolution after recycling; i.e., separate photographs of the APMI scope were made for two consecutive revolutions of the antenna after recycling. Figure 2 shows the distribution of the average number of locations on the APMI with each intensity level plotted against the APMI levels for the first revolution (top curve) and for the second revolution (lower curve). Some additional l's and 2's might be expected from the system noise, but additional 3's and 4's should not be observed. At least one additional 5 was observed but not recorded on film.

Calibration

The calibration of the APMI is a major problem which appears to have received little attention previously. There are several problems associated with calibration techniques that must be considered. To discuss these problems it is necessary to review the manner in which the APMI performs the analog-to-digital conversion and the resulting integration.

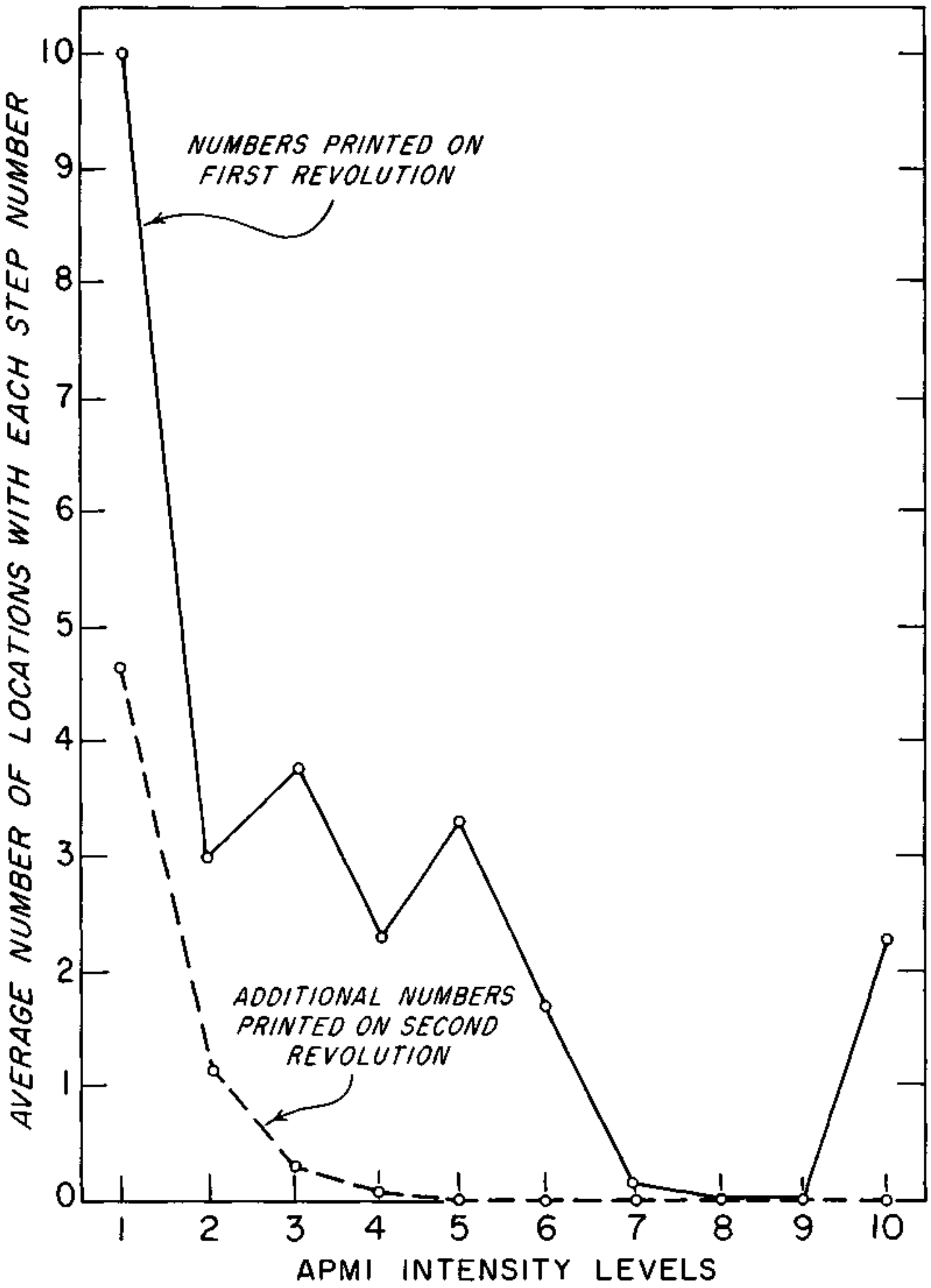

Figure 2. DISTRIBUTION OF THE AVERAGE NUMBER OF APMI INTENSITY LEVELS PRINTED OUT ON THE FIRST AND SECOND REVOLUTIONS OF THE RADAR ANTENNA AFTER RECYCLING

The APMI performs a peak detecting process for a range gate of variable length. The highest instantaneous value of the video signal obtained within this range gate is then converted to a digital number. This number is determined by the preset level of the intensity adjustment parameters. The peak video level is proportioned to the logarithm of the peak return power in the range gate. On the first radar sweep for each area of echo this number is placed in the digital memory. On the second and succeeding radar sweeps the digital number is added algebraically to the number already in storage. Finally, after 8 or 16 such sweeps, the number from memory is recalled and divided by 8 or 16, as appropriate, to obtain the result for printing. It is inherent in such a scheme that the preset intensity levels must be related to each other so that the average of these numbers can be interpreted. An example may serve to illustrate the difficulty.

Suppose that intensity level 1 is such that a signal of -90 dbm is sufficient to obtain a 1, level 2 has a sensitivity of -85 dbm, and level 3 a sensitivity of -70 dbm. Now if a set of 8 observations has 4 ones, 2 twos, and 2 threes, the result of the APMI averaging would be

$$4(1) + 2(2) + 2(3) = 14$$

which when divided by 8 yields a result of 1.75, or since the APMI averages downward, a level value of 1 would be printed. The true average power would be

$$4(10^{-12}) + 2(10^{-11.5}) + 2(10^{-10}) = 2.0734 \times 10^{-10} \text{ watts}$$

The average of this is 2.59 $\times 10^{-11}$w or -75.86 dbm. This should have been a level 2 value since it lies between levels 2 and 3. In actuality the theory of rainfall measurement would dictate that this is the desirable result. However, because of electronic difficulties with dynamic range, a second form of averaging is considered to be adequate. This consists of averaging the logarithms of the power return rather than the power itself and then applying a correction of several db to the results. This method has been used at Massachusetts Institute of Technology. In the example, this average would be

$$4(-90) + 2(-85) + 2(-70) = -670$$

which when divided by 8 yields -83 dbm. This requires the APMI to produce a level 2 as a result. This example serves to illustrate that the separation of intensity levels must be adjusted in an orderly manner if the results are to be interpreted.

One way of setting the levels would be to make the differential between levels a constant. In this case, the result could be interpreted as the average of the logarithms of the signal. As long as all sweeps then have a peak signal that is greater than the amplitude of level 1, the result is valid. However, if one or more sweeps occur with a signal equal to or less than level 1, difficulties are again encountered. Here, the peak detecting device becomes an asset by making the possibility of a zero remote. A less practical solution is to set the levels so that the differential between levels represents a constant difference in real power return to the antenna. As an example, suppose that level 1 represents a power of 10^{-12} watts. If a differential of 2.10^{-12} watts is chosen, level 2 has an amplitude of 3.10^{-12} watts, level 4 has an amplitude of 5.10^{-12}, and level 0 (lowest sensitivity) an amplitude of only $1.9.10^{-11}$ This value is very frequently exceeded. It also might be noted that the db differential between level 9 and level 0 is only 0.5 db, but the differential between level 1 and level 2 is 4.8 db. Since it is not practical to attempt to set the levels to within 0.5 db, this system is not feasible with this type of integration as attractive as it is theoretically.

The second problem in interpreting the results is due to the peak detection built into the integrator before averaging takes place. This problem is being investigated and will be reported on in detail in the next report. An attempt is being made to determine theoretically the most likely value of average power when the value of the average of the peak values on each radar sweep is given.

A final problem is the use of a coherent signal generator to determine and set the levels. This difficulty may have resulted in part from malfunctioning of the APMI. It has been observed that as the signal from the generator is increased, a sharp break between levels does not occur. In other words, the same signal level can convert as different numbers. This appears to occur for several db difference in signal generator level. Further checking of this difficulty will be pursued in the coming quarter.

MASER PROGRESS

On 10 December 1965 two replacement pump klystrons arrived from the manufacturer. The pump klystrons and their associated k-band waveguide components were tested on the bench to determine their operating characteristics before attempting any masering. After the proper operation of each component was assured, the maser was charged and alignment procedures begun. A net gain of 18 db was obtained on 22 December, but this dropped to 15 db after the maser was warmed, the magnet locked into place, and the maser re-cooled. When the maser was installed on the MPS-34 radar, the gain was found to be below an acceptable value requiring an additional complete alignment on the radar. As of the end of the Third Quarter this was nearly completed, but no data were collected using the maser-equipped MPS-34 radar during the period.

SPECKLE ANALYSIS

In the Second Quarterly Report preliminary observations were given about the speckles observed by the MPS-34 radar in New Mexico, and the conclusion was that the speckles were caused by birds. After a more complete investigation, this conclusion "remains the most likely explanation of these speckle echoes.

Birds have been observed on radars by several researchers, and reports of these are found in the literature of the past few years (see, for example, Richardson et al., 1958). The difficulty of identifying birds on radar has probably caused fewer reports of birds than actually occurred. Weather radar, especially, is used primarily during conditions when weather echoes are appearing on the scope. By concentrating on these larger, more persistent echoes, operating personnel could quite easily ignore the smaller, less noticeable echoes caused by birds. Indeed, during the New Mexico operations of the MPS-34 radar, specular echoes were recorded for five days on the radar film before they were observed by the operators on the radar scope. The day on which they were first observed (20 August 1965) was a day with no weather echoes on the scope. After becoming conscious of the speckles, operators subsequently observed their presence and noted it on the radar log on three of the other five days of radar detection. Table 2 gives the days on which speckles appeared on film and were observed by the operators.

On the days listed in Table 2 only three have been studied in detail. These are 14, 20, and 30 August. The other days were not used because there were too few speckles present, the range setting of the VE Repeater-Indicator made accurate measurements difficult, weather echoes on the film would have interfered with the speckle analysis, or a combination of these. When the speckles were first

Table 2. Days on which Speckles Were Observed

Date(1965)	On film	By radar operators
11 August	Yes	No
13 August	Yes	No
14 August	Yes	No
16 August	Yes	No
19 August	Yes	No
20 August	Yes	Yes
25 August	Yes	No
28 August	Yes	No
29 August	Yes	Yes
30 August	Yes	Yes
31 August	Yes	Yes

noticed, data were collected on the shortest possible range both with and without the step-gain operating. The 20 August data taken on 8-n.mi. range provide the best sequence of speckle data collected during the field operation in New Mexico. Because of this, data from this date were used for the major portion of the speckle investigation. Thus, unless indicated to the contrary, all results reported herein refer to 20 August 1965.

Several questions might be asked about the appearance of speckles on the radar. These include: 1) How large are the speckles? 2) Could the large numbers of speckles detected on certain days be attributed to birds? 3) Are the back-scattered signals reasonable for the sizes of the birds? 4) Are the heights detected consistent with the known flight patterns of birds? 5) Are the speeds measured from the data within the range of known bird speeds? 6) If any predominant directions occur, are these consistent with known flight patterns, as during migration? The following sections will deal with these questions individually.

Size

The speckles generally appeared on the films as point targets. Figure 3 shows the appearance of speckles on the radar with a tilt angle of 15°. The range ring interval is 1 n.mi. The minimum size a target can have on short pulse is one-half the radar pulse length or 246 feet. The size of echo displayed on a CRT depends in part upon the reflectivity of the target, with targets saturating the CRT producing somewhat larger echoes than targets whose reflectivities are just detectable. Prom one frame of film (frame number 9199 of 20 August 1965) 201 speckles were traced as close to their apparent size as possible; their diameters were measured to the nearest 0.5 mm on the tracing; and the average diameter was determined. The average diameter was about 360 feet. The difference between the observed-target size and the point-target size can be attributed to the inaccuracy of tracing the echoes, which averaged just 1.09 mm on the tracings; the tendency of the CRT to expand the size of saturated targets; and the likelihood that some of the speckles were not really point targets; i.e., some or many of the speckles could have been produced by flocks of migrating birds flying in loose formation. However, the average size does not vary markedly from the size a point target should have.

Density

The areal distribution of the speckles has some interesting features, among these the seemingly large numbers of speckles

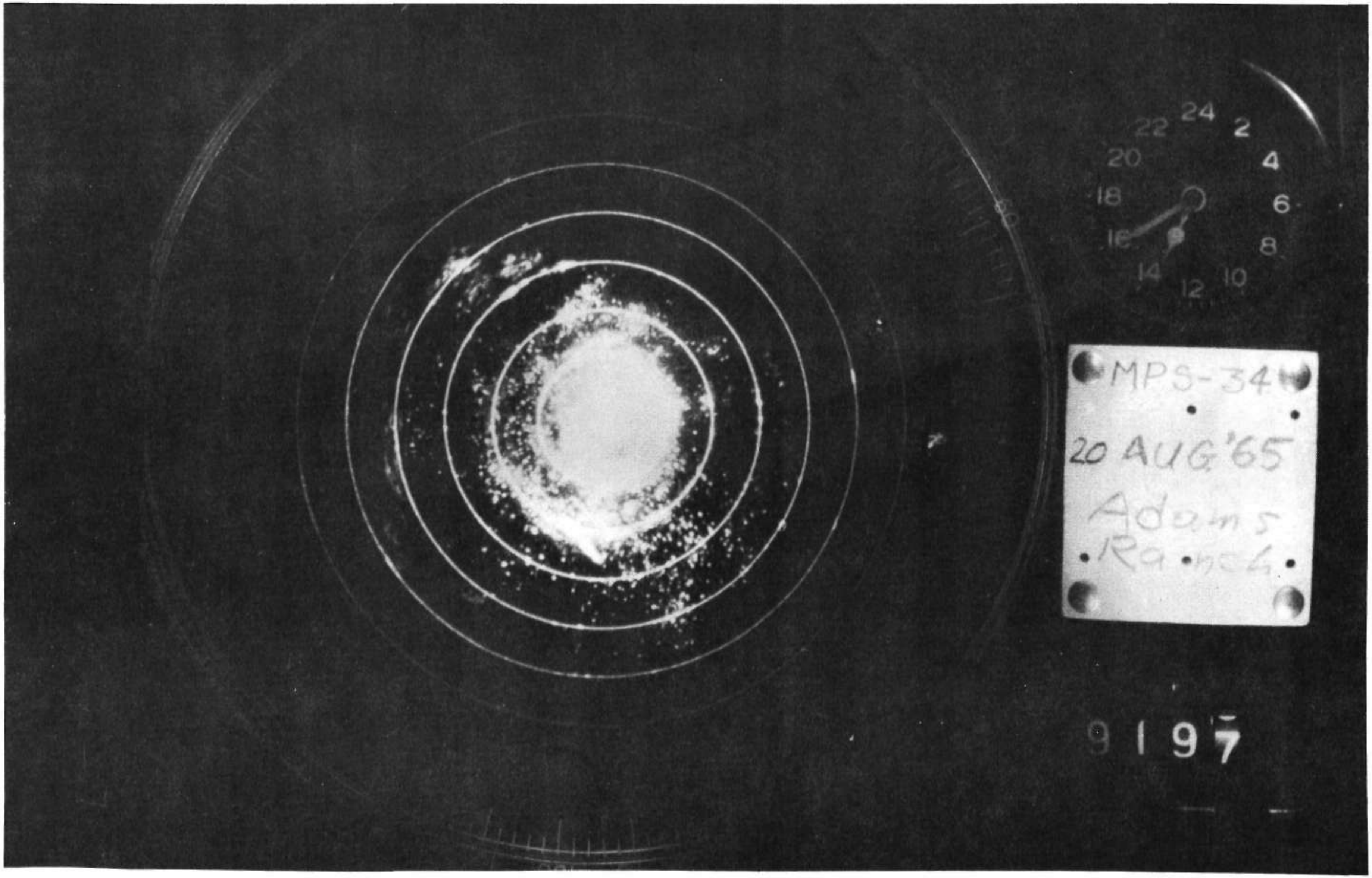

Figure 3. SPECKLES AS THEY APPEARED ON THE MPS-34 RADAR SCOPE ON 20 AUGUST 1965 (1 n.mi. RANGE RINGS)

observed. Tracings of speckles on three consecutive step-gain frames (frame number 9197, gain step 1, full gain; frame number 9198, gain step 2, 10 db below step 1; frame number 9199, gain step 3, 12 db below step 2) produced 658, 330, and 201 speckles per frame, respectively. These numbers are not necessarily the total number of speckles on the frames but only those that could be detected. Some areas of high speckle concentration and/or ground clutter targets were excluded from the study because of the impossibility of getting meaningful data in these areas. Speckle densities (i.e., number of speckles/n.mi.^{2}) as shown in Figure 4 were determined by dividing the area on the scope into rings 1 n.mi. in extent and counting the speckles within the ring, then correcting these values for the usable area on the scope, the slightly non-linear display of the scope, and the area covered by range rings. The decrease in density with range is probably primarily a function of   although there is an inseparable dependence on height because the data were taken at l5° tilt.

If the curve on Figure 4 for gain step 1 were extrapolated back to the interval between the radar ,and 1 n.mi., over 40 speckles/n.mi. would be indicated. This would imply 1 bird for every 16 acres . However, because of the narrow beam width of the MPS-34 only a small volume of the atmosphere was being sampled. Correcting for the effects of the volume of the beam, the volumetric speckle densities were determined, as shown in Figure 5. In clear weather during the daytime most birds fly below 5000 feet

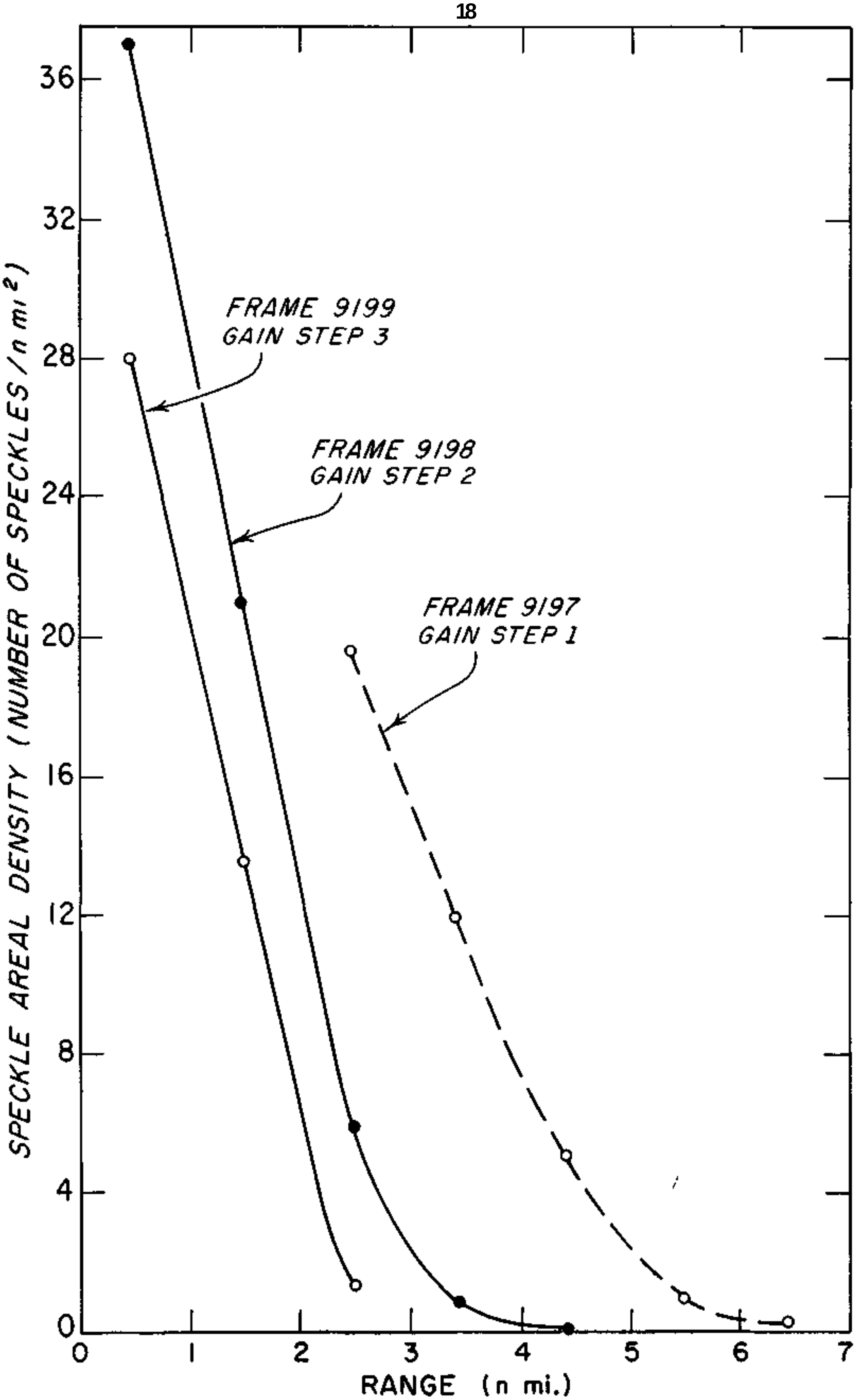

Figure 4. SPECKLE AREAL DENSITY VERSUS RADAR RANGE FOR 20 AUGUST 1965

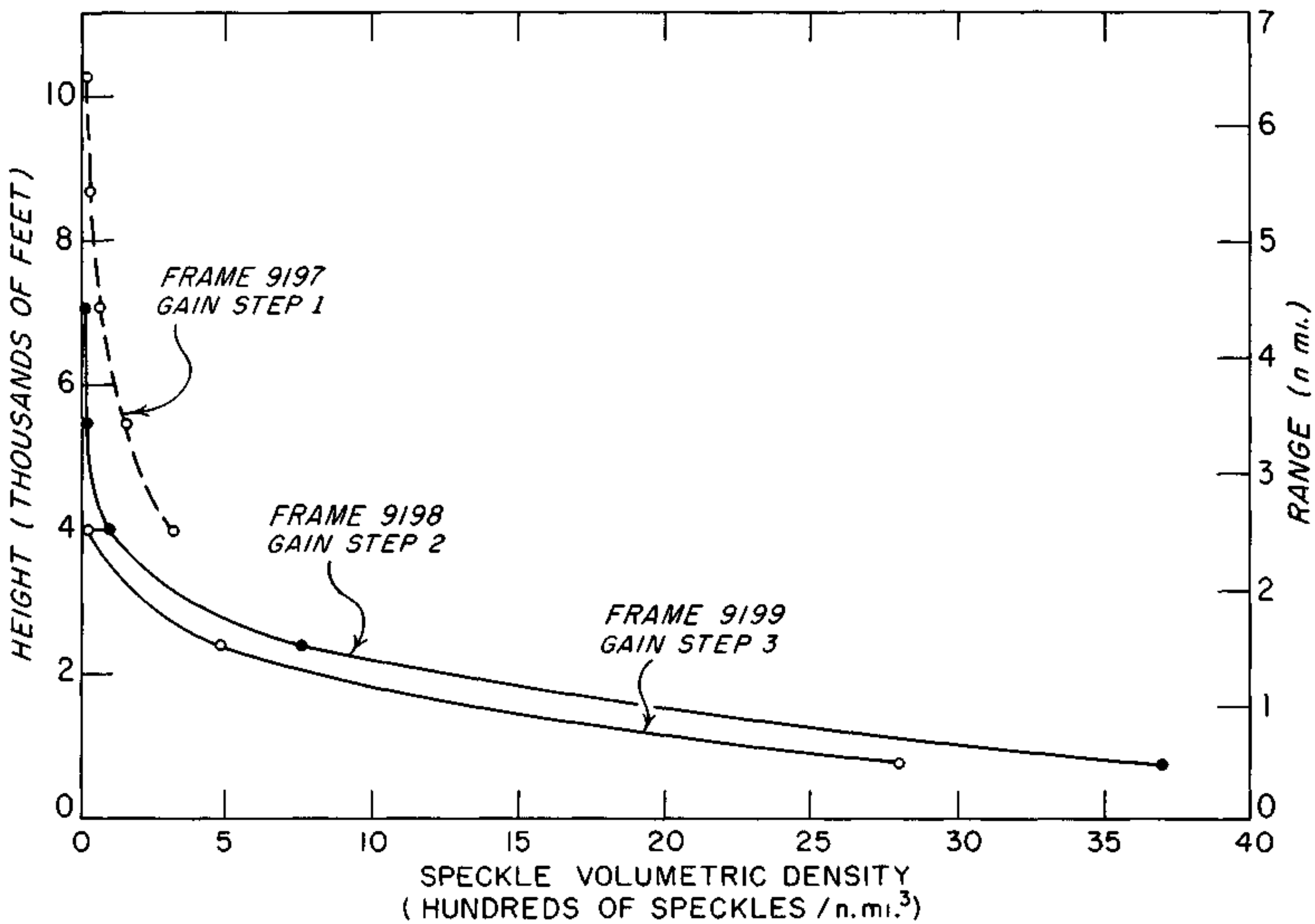

Figure 5 SPECKLE VOLUMETRIC DENSITY VERSUS HEIGHT AND RANGE ON 20 AUGUST 1965

(Lack, 1960). Thus, by extrapolating the line for gain step 1> down to the minimum range (0.5 n.mi.), accomplished by keeping the line equidistant from the gain step 2 line and integrating the curve below 1 n.mi. for gain step 1 (see Figure 5), the average volumetric density of 1670 speckles/n.mi.3 were determined. Assuming that all these speckles from the surface to 6080 feet were birds, the density at the surface if all landed would be 2.6 birds/acre.

In order to determine if this areal density is reasonable, it can be compared with a known value. Graber and Graber (1963) found an average breeding bird population during 1957-1958 for Illinois of 1.2 birds/acre. Breeding birds are those birds that live in the area, as opposed to migrant birds. The New Mexico areal density contains birds from both population. For direct comparisons the New Mexico areal density of 2.6 birds/acre would have to be reduced to correct for the fraction of the total number of birds that were migrating birds. A quantitative correction cannot be made with the available data. Also, the extreme differences in climate and vegetation between Illinois and New Mexico would make such comparisons very unreliable. Nevertheless, the orders of magnitude involved do compare fairly well.

Back-Scattering Cross-Sectional Areas

The discussion thus far has implied a one-to-one relationship between the appearance of a speckle and the presence of a single bird. This leads to the questions of just how large the radar back-scattering cross-section of a bird is and how far a single bird can be detected on the MPS-34. Houghton (1964) found that the best simple estimate of a bird's cross-sectional area can be made by determining the back-scattering cross-section of a sphere of water whose mass is equal to that of the bird being considered. Because the back-scattering cross-section from a bird depends on its orientation relative to the axis of the radar beam, this method is only approximate.

Figure 6 shows the minimum back-scattering cross-sectional area a target can have to be just detectable which is plotted against range for the MPS-34 (using values of P_r = -103 dbm, P_t = 48.4 dbm, and antenna gain = 37 db). Coves (1903) gives the weights of turkey vultures at 4 to 5 pounds, a size that would make them detectable out to about 3 miles. Prom the measured cross-sectional areas of a "turkey buzzard" by LaGrone, Dean, and Walker (1964) it would appear that the estimate of cross-sectional area made by the equivalent weight sphere method gives the maximum signal returned, not necessarily the average signal returned. Also plotted on Figure 6 are the back-scattering cross-sectional areas of a sea gull measured by Richardson, et al. (1958) and a starling measured by Houghton (1964).

Figure 6 indicates that it is unlikely that a single bird can be detected beyond about 3 miles. Thus, many of the echoes, if attributable to birds at all, must be attributed to flocks of birds. The farthest detectable speckle on the three step gain

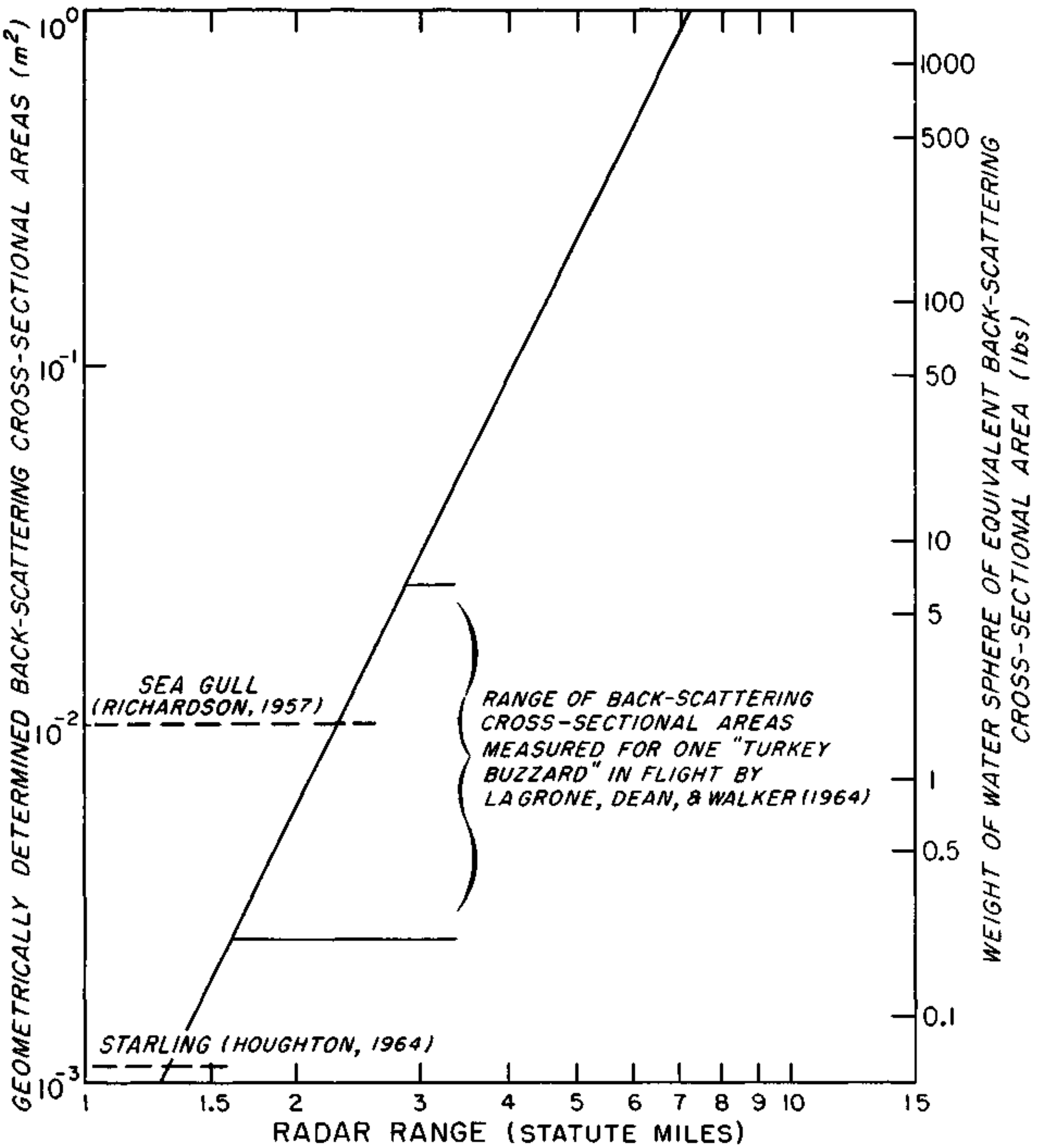

Figure 6 RADAR BACK-SCATTERING CROSS-SECTIONAL AREAS VERSUS RANGE FOR TARGETS JUST BARELY DETECTABLE BY MPS-34 RADAR

frames used earlier was at 7.0 n.mi. This would require on the order of 1000 to 2000 pounds of birds in one flock, an amount obtainable from approximately 500 to 1000 ducks in a flock. Perhaps this large a flock is unrealistic since Bellrose (1957) reported flock sizes of from 10 to 500 birds with an average of 50 to 100 during the spectacular migration down the Mississippi Plyway from 31 October to 3 November 1955 in which more than 2.25 million birds took part during the four-day period. Probably these flock figures do not apply to New Mexico, but they do indicate orders of magnitude.

Heights

Although Lack (1960) reports that most of the birds he detected with radar flew below 5000 feet, he also has detected some birds at heights up to 21,000 feet without attempting to find exceptional cases. Thus, the maximum heights of 15,000 feet detected in New Mexico are within reason even when adding the 7000 feet ground level elevation. Radio contact with the South Baldy radar at the time of detection on 20 August 1965 indicated that the speckles were about 3000 feet above Baldy's 10,800-foot elevation, or nearly the same elevation as those being detected by the MPS-34 at that time. It is interesting to note that the highest birds detected by Lack were presumed to be warblers, chats, and fly catchers, some of the smaller migrating birds.

Speeds and Directions

Houghton (1964) gives a range of speeds for several kinds of birds. Speeds ranged from 14 to 44 knots with the average being

27.8 knots. Speeds and directions were determined for a number of speckles on 14, 20, and 30 August. Because of the difficulties involved in tracking speckles from one frame to the next on the time-lapse movies, only those that lasted three frames or longer were used in this part of the study. There is a likelihood that different speckles lasting only one frame might show on consecutive frames in such a way as to appear to be one moving speckle. The probability of this happening decreases considerably for three or more consecutive frames. Even more reliable information is obtained from using only those speckles that last 1 minute (six frames) or longer. Table 3 gives the range of speeds, the average speeds, the average vector velocities and the number of speckles tracked. These are categorized by day (and by quadrant on 20 August) and by the interval of time the speckles lasted on l4, 20, and 30 August 1965.

The range of speeds (5 to 70 knots) given for speckles lasting 60 seconds or more is not completely unreasonable. Certainly, an average speed of 25 knots is reasonable. The maximum speed of 240 knots from the first part of Table 3 does seem high and could have been produced either by an airplane nearby or by the erroneous tracking of separate speckles since this track lasted only four frames. In spite of this speed and two other speckle speeds over 100 knots (one of these lasted just three frames, the other four frames), an average speed of 31 knots for all speckles lasting three frames or longer is also reasonable.

The average velocity is the average speed and direction of all speckles, determined by taking the vector sum of the individual velocities and averaging them. An estimate of the degree to which the speckles traveled in similar directions can be obtained by comparing the average vector speed with the average speed; the larger the vector speed compared with the average speed, the more uniform the directions of travel of the speckles composing these averages. For example, on 14 August (for all speckles lasting three frames or more) the average vector speed is only 18 percent of the average speed, indicating the vector speed is composed of velocities in many different directions. The overall average vector speed for 20 August (three frames and over) is 8l percent of the average speed, indicating a more uniform direction of travel for speckles on that day.

The general uniformity of direction shown in Table 3 could be the result of at least two things: The speckles could have been caused by many birds and flocks of migrating birds flying in similar directions, or they could have been caused by birds flying in less uniform directions but being carried in a uniform direction by the prevailing winds. To date, no wind data have been obtained so it is impossible to separate these possibilities at present. However, because the data were taken in the last half of August it would seem likely that any migrating birds passing over the radar site would be traveling in a southerly direction, which agrees with the directions on 20 and 30 August quite well.

Table 3. Range of Speeds, AveragesSpeeds, and Average Vector Velocities for Speckles Observed on 14, 20, and 30 August in New Mexico

Date (1965)	Quadrant (degree azimuth)	Range of speed (knots) low	high	Average speed (knots)	Average velocity speed (knots)	Average velocity heading (degrees)	Number of Speckles tracked
(all speckles lasting 3 frames or more)							
111. August	all	6	33	21	4	25	36
20 August	0-90	12	53	20	26	177	25
	90-180	5	87	27	21	179	16
	180-270	8	78	25	21	138	36
	270-360	8	85	29	25	164	23
	all	5	87	28	23	160	100
30 August	all	15	240	49	23	129	38
Extremes, averages, or totals		5	240	30.9	16.8	150	174
(all speckles lasting 60 seconds or longer)							
14 August	-all	6	33	21	13	354	17
20 August	0-90	12	53	30	26	182	18
	90-180	5	59	21	19	178	10
	180-270	8	70	24	21	172	24
	270-360	8	68	22	18	164	17
	all	5	70	25	21	165	69
30 August	all	15	47	28	24	136	19
Extremes, averages, or totals		5	70	24.8	15.2	156	105

Discussion

The results of the" speckle analysis indicate the likelihood that the echoes were paused by birds. The heights and velocities of travel, and numbers of speckles detected are all reasonably explained as being caused by birds. The fact that no birds were actually observed and correlated with specific speckles might tend to cast some doubt on this explanation. However, it would have been possible to attempt such correlations only on days when the speckles were observed on the scope and there were only four such days. Also, the probability that the speckles were caused by birds was not fully realized until returning from the field expedition. Thus, although visual observations were made for any unusual phenomenon when the speckles were observed on the scope, no evidence of an abundance of birds was detected. Lack (1960) quotes Sutter (1950) as saying that high flying migrating birds cannot be seen during the day, even with military optical equipment. This agrees with the statement made by Mr. Frank Bellrose, Aquatic Waterfowl Specialist with the Illinois Natural History Survey, that many more birds are generally flying over an area than are ever observed at the ground. Thus, the failure to observe the birds causing the speckles is not adequate reason to discount the conclusion that birds caused the speckles. All other evidence indicates this conclusion is reasonable.

ECHO GROWTH ANALYSIS

An investigation is presently underway using the New Mexico data to determine the possibility of detecting differences between the initial stages of growth of precipitation systems as indicated by the radar with and without the maser. The use of the maser on the MPS-34 radar should allow detection of initial echoes sooner than the MPS-34 used without the maser.

The life cycles of rainstorms as determined by radar have generally shown steady increases in radar reflectivity after initial detection until near the peaks of the storms, after which the intensities decrease. In New Mexico it was visually observed that some of the clouds which grew to ram-producing size had initial periods of slow growth followed by later periods of more rapid growth. As most radars do not detect the early cloud development stages, these slower starting storms might not be detected until the later, faster growth stages. It was thought that with the maser operating on storms at short ranges, as used in New Mexico, the initially detected echoes might show a gradual increase in reflectivity corresponding to the visually observed cloud growths. For this reason, the New Mexico data are being analyzed in an attempt to find some growth patterns which correspond to the observed slow starting clouds. Of the echoes studied to date no such patterns have been found. One of the problems so far has been in separating apparent growth caused by echoes moving through the radar beam (data were generally taken at 15° tilt in New Mexico) from real growth. The movements of the echoes being studied are now being determined to separate the moving-growing echoes from the growing echoes.

This analysis will be completed during the next interval and reported in the Fourth Quarterly Report.

CONCLUSIONS

The APMI appears to be working as designed, other than that a few extraneous signals occasionally occur. The intensity levels need to be set to some calibrated signal in order to provide meaningful data, but the proper method of calibration has yet to be selected.

The replacement of the pump klystron resolved the lack of gain from the maser, and the maser has been reinstalled upon the radar. Data collection with the maser operating on the radar will be performed in the coming quarter.

The speckle echoes observed and recorded in New Mexico have been analyzed with the following results:

Average echo diameter on PPI - 360 feet

Areal density - greater than 40 speckles/n.mi.^{2}

Maximum height above radar - 15,000 feet

Average speed - 25 knots

Average azimuth heading - 156°

The most reasonable conclusion as to the origin of the specular echoes is that they were the reflections from birds. However, the intensity of the echoes would require unusually large flocks of birds, and as with other investigators, no visual confirmation of the presence of such a large number of birds was available.

PROGRAM FOR THE NEXT INTERVAL

Data collection with both the APMI and the maser-equipped MPS-34 will continue as the primary goal during the next quarter. Insofar as possible every winter storm situation involving the passage of the low pressure center close to the radar will be sampled in order to study the pattern of clouds and precipitation detectable with the extra sensitivity of the radar.

Further study will be made to determine the best practical method for calibrating the APMI thresholds of intensity levels. Additional debugging of the circuitry of the APMI will also continue into the next quarter.

The echo growth analysis of the New Mexico data will be concluded in the next period so far as the available data will permit. When the supporting data requested from the other groups cooperating in the New Mexico study become available, the growth analysis will be enlarged to incorporate this additional data.

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13 ABSTRACT

Difficulties encountered with the APMI and progress in overcoming these problems are discussed briefly.

Data have been collected for three storms using the APMI, one storm has been analyzed in some detail. A discussion of the problem related to calibration of die APMI gain steps is included. The maser has been restored to operating condition with the installation of a replacement pump klystron. The speckle analysis that was started last quarter has been completed. The speeds, directions, back-scattering cross-sectional areas, heights, and areal densities of the echoes, caused by birds, have been determined. A study of the growth of echoes as detected by the maser-equipped radar has begun, but results will be reported later. Plans for the fourth quarter are outlined.

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Weather Radar Detectability Precipitation Analysis						

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