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

PROGRESS REPORT

by

R. E. Rinehart

November 1966

ECOM

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

Report No. 5

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PURPOSE

The purpose of this contract is to evaluate the capability of the maser-equipped 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 areal 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

A summary of the maintenance and operation of the MPS-34 is given. Little progress has been made with the APMI because of a power supply failure and the lack of the required replacement. Analysis of the radar snow data collected during the previous quarter has been carried on as the primary activity of the quarter. Comparisons were made between the radar data and airways synoptic data and precipitation data from the East Central Illinois raingage network. The comparison between the airways and radar data indicated that a good quantitative relationship was not obtainable, primarily because of frequent observations having precipitation or radar echo, but not both. In the precipitation data comparison, the correlation was too low to provide reliable Z-R relationships for snow. A third preliminary study indicated, in a sample case, that a 10-db decrease in the receiver MDS provided an average increase in the maximum range of echo detection of 22 percent (as compared with a theoretically possible increase of 216 percent). The effects of attenuation are considered briefly to indicate what effect the additional gain might have in partially compensating for attenuation. The maser gain easily compensates for normal gas and cloud attenuations, but precipitation attenuation may exceed the maser gain.

INTRODUCTION

The primary accomplishment during the fifth quarter was the continuation of the analysis of the data collected during the winter storms of 1966. Only about 12 hours of additional data were collected with the maser-equipped AN/MPS-34 radar system. In addition to the analysis and collection of data, considerable effort was expended on the MPS-34 to get the optimum gain out of the maser. Very little effort was expended on the APMI during the quarter, primarily for lack of a power supply transformer. The following sections discuss in more detail the specific results in each of these areas.

Corrigendum

Before proceeding with the fifth quarter's results, it should be noted that an error has been found in the computations used for Figure 6, page 22, Third Quarterly Progress Report for this contract. On a single picture examined in detail, the maximum range of detection of any bird echo in the 20 August 1965 data was 7 n. mi. It was shown in the Third Quarterly Report 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. The relationship between weight and area is $A = 7.0 \times 10^{-3} W^{2/3}$ when area, A, is in m^2 and weight, W, is in pounds. The original calculations required a total of about 2000 lbs of birds (back scattering cross-sectional area of 1 m^2) to account for this echo. The corrected computations suggest that one 0.27-ounce bird (back-scattering cross-sectional area of about 4×10^{-4} m^2) could have produced this echo. Figure 1 shows the corrected figure and indicates that the MPS-34 (without the maser) is considerably more sensitive for bird detection than previously indicated.

Mr. Frank Bellrose, Aquatic Waterfowl Specialist with the Illinois Natural History Survey, indicated that the birds which would have been migrating over

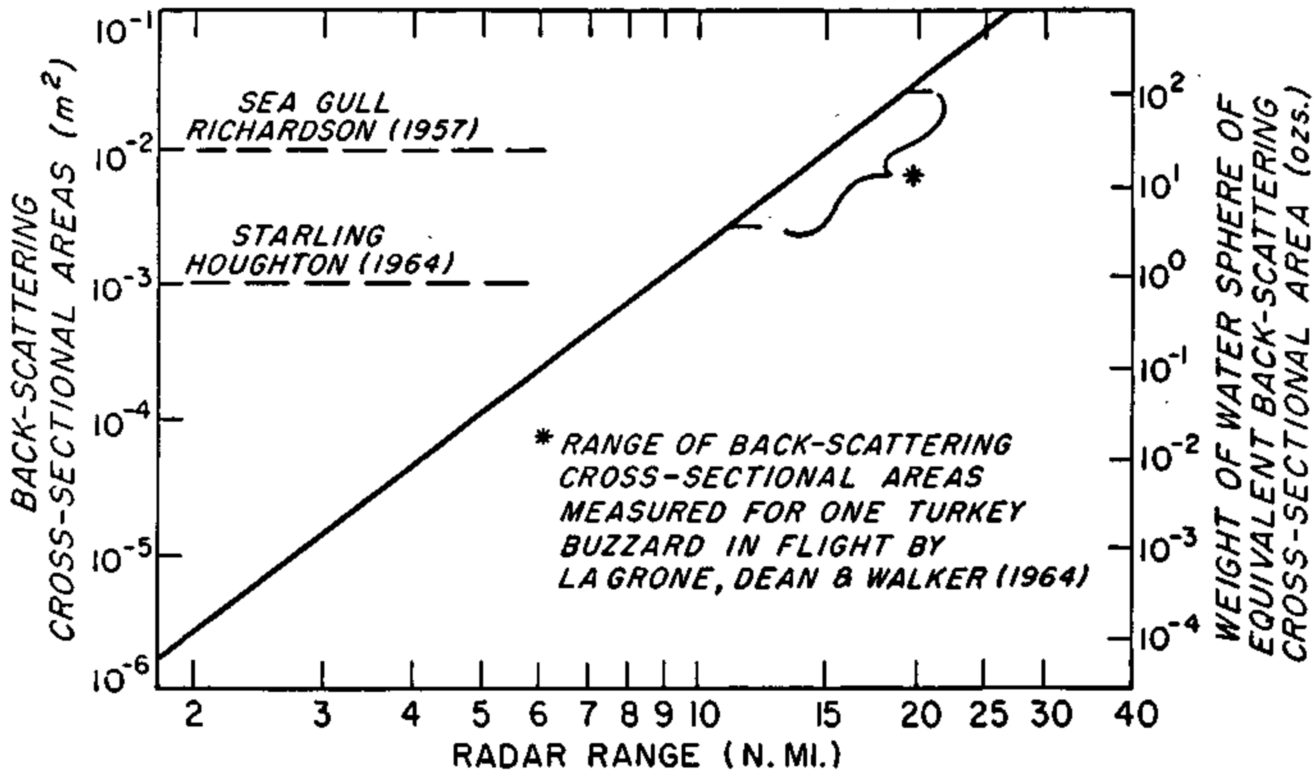

Fig. 1 The variation with range of the back-scattering cross-sectional areas required to just be detectable by the AN/MPS-34 radar ($\overline{P}_r$ = -103 dbm, Pt = 85.3 dbm)

New Mexico during August were probably warblers, thrushes, and other small birds whose weights range from 1/2 to 1 ounce. These should have been detectable at ranges up to 8.7 n. mi. Thus, the agreement is quite good when it is borne in mind that, at 15° tilt, 8.7 n. mi. was nearly 21,000 feet above mean sea Level. Further, since only one frame of full gain data was examined in detail for this study, echoes beyond 7 n. mi. might have existed elsewhere in the data.

RADAR MAINTENANCE AND OPERATION

A power supply choke on the receiver power supply failed and was temporarily replaced with a commercial choke. A replacement choke was requested from USAECOM and, when obtained, it was found that, although the part numbers corresponded, the choke specifications differed. Operation is continuing with the commercial choke.

A waveguide horn was installed so that a continuous monitoring of relative sensitivity can be made while data are being gathered.

The maser was removed and the magnet angle readjusted in April. The maser operated, but the magnet will not remain with the appropriate field strength without continuous bias current. The radar will be operated with a bias current of about 125 milliamperes. A maser gain of 17 db has been achieved.

The gain with the radar transmitter on is always less than the maser gain with the' transmitter off. The loss in gain amounts to about 2-3 db. The pulsed isolator has been checked and found to be satisfactory.

Despite good maser gain the minimum discernible signal is only about -113 dbm. It is assumed that the receiver on the transmitter was not working as well as equipment specifications state. Trouble shooting of the receiver has not resulted in any improvement. A new receiver has been requested from USAECOM.

The radar was transported to Chanute Air Force Base on 20 June 1966 for routine van maintenance and servicing in preparation for a trip to Flagstaff, Arizona. The radar was shipped to Flagstaff on 30 June 1966, for use on contract AMC-02376.

Operation of the MPS-34 was limited to four periods during which a total of 12-1/2 hours of data were collected. Two periods were normal weather situations, another was a period of northward bird migration, and the last was an attempt to detect radiation (by virtue of its temperature) directly from the sun.

SNOW DETECTION

Most of the analysis performed during the last quarter was accomplished with data collected during periods of snowfall. These data constitute the primary source of reliable data available for analysis at the present time. The 20-hour period from 1854 CST, 31 January 1966, to 1520 CST, 1 February 1966, proved to have the most reliable radar data, and, consequently, was investigated in greatest detail. Results of completed analyses of this storm are presented in the following paragraphs.

Data to evaluate the capability of radar for snow detection have been obtained from two general sources. Airways teletype data have provided areal and time distributions of the usual weather parameters and general information as to weather conditions in the radar field of view. Secondly, precipitation data from the East Central Illinois network have been used in an attempt to quantitatively determine snowfall rates.

Synoptic Situation

Briefly, the principal cause of precipitation in Illinois was a low pressure system which passed across the southern tip of Illinois about mid-day on 1 February 1966. An E-W oriented warm front extended from the low as it passed through Illinois. Over 6 inches of snow fell in the extreme southern part of the state and up to 1 inch of snow near the radar site in the east-central part of the state. Temperatures during the period of radar operation were well below freezing, dipping to below 0°F in some areas north of the radar site and resulting in very dry snow.

Comparison of Radar and Airways Weather Data

The type and intensity of precipitation reported by the airways stations should be related to the radar observations. The rules used in reporting precipitation intensity on the airways circuit are based upon rain rates. They are, in fact, obtained from raingage charts for transmission on the teletype circuits wherever possible. Hourly airways reports provide a measure of the various weather parameters during a 5-minute period from 5 minutes before the hour to the hour. MPS-34 radar tracings were made of the echoes on the radar film over the airways network, in this time period, and radar reflectivities were calculated for each station for each tracing.

To develop a factor from the weather data which should be related to the radar reflectivity, an equation of the following form has been used:

$$F = P_f V_f$$

where F is a factor related to precipitation type and intensity (P_f) and visibility (V_f).

Radar reflectivity should be closely related to the rain rate, so the inclusion of a factor related to precipitation (P_f) is obvious. However, a synoptic report of heavy rain, for example, covers all rain with rates equal to or greater than 0.30 in/hr. Since rain rates as high as 28 in/hr (722 mm/hr) as measured by the State Water Survey raindrop camera in Miami, Florida (Mueller, 1962) have been reported, some means of adjusting the factor (F) to account, at least in part, for these variations is desirable. If precipitation is the only obstruction to visibility and the visibility decreases, the precipitation rate has probably increased. For east of computation and because no other known relationship exists, the visibility factor Vf was chosen such that $V_f = 1$ when the visibility equalled or exceeded 16 miles and $V_f = \frac{16}{\text{visibility (mi)}}$ when the visibility was less than 16 miles. This doubles F each time the visibility decreases to half its initial value.

As an example of the effect of this visibility factor on F, consider the extreme case where heavy rain (R+, RW+, TRW+, ZR+, E+, or EW+) is falling with a visibility of 1/16 mile. The reflectivity from the Z-R relationship would be 8×10^3 mm^6 m^{-3}; correcting by use of Vf would give 2×10^6 mm^6 m^{-3}, equivalent to a rain rate of 17 in/hr. Again, for comparison, the greatest observed rainfall rate for a 1-minute interval on the East Central Illinois network was 13.8 in/hr (Huff and Neill, 1957). A reflectivity of 10^6 mm^6 m^{-3} is probably more characteristic of very heavy rain than is a reflectivity of 10^4 mm^6 m^{-3}. Thus, it seems reasonable that the precipitation and visibility related factor F should be more nearly related to the radar reflectivity as measured by the radar than the reflectivities based on the uncorrected (minimum) rates underlying the qualitative airways reports of precipitation intensity.

For a first trial, the minimum rain rates for each intensity of precipitation (from WBAN Circular N) were converted to radar reflectivities by use of the Z-R relationship, $Z = 485R^{1.37} = P_f$. This value was used as the factor related to precipitation type and intensity (P_f) for liquid forms of precipitation. Snow intensities are defined in terms of visibilities directly rather than liquid water amount per hour. P_f factors for snow, snow pellets, snow grains, and small hail were determined by multiplying the P_f factor for the corresponding intensity of rain (light, moderate, or heavy) by the ratio

$$\frac{|K_{ice}|^2}{|K_w|^2} \quad \text{where} \quad |K_{ice}|^2 = \left|\frac{m^2 - 1}{m^2 + 2}\right|^2 \text{ for ice and } |K_w|^2 = \left|\frac{m^2 - 1}{m^2 + 2}\right|^2 \text{ for water,}$$

where m = complex index of refraction.

The factors (F) related to precipitation and visibility were then determined from a nomogram relating these two parameters according to the above rules and rules to cover such observations as two or more obstructions to visibility and intensities of "very light" precipitation. Figure 2 shows the nomogram used. Those stations which had precipitation (i.e., a factor not equal to zero) and radar echo over the station were used to determine the correlation between radar echo intensity and precipitation type and intensity. Using data for 1 February 1966, 91 pairs of values were tested and a correlation coefficient of 0.31 was determined.

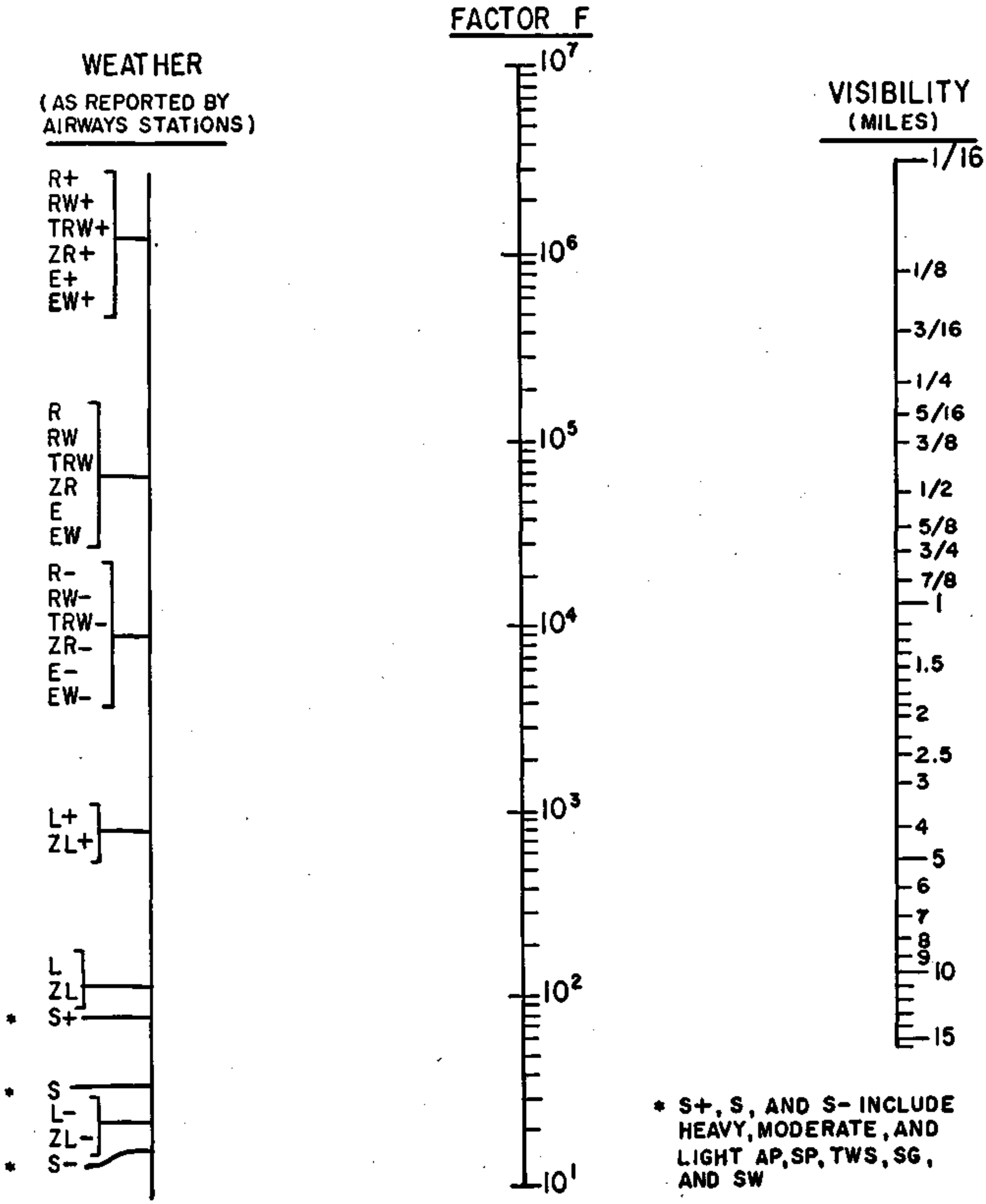

Fig. 2 Nomogram used to determine the factor F related to precipitation and visibility

The poor correlation may be due to the fairly limited range of factors and reflectivities used. These in turn were restricted by the weather conditions for this day which resulted in generally uniform snowfall rates with little variation during much of the time over the field of view of the radar. Perhaps the use of a greater range of values associated with heavier types of precipitation might increase the correlation somewhat.

The only data used in the correlation calculation were for those stations which reported precipitation and radar echo. On the average, however, 46 percent of all stations reported precipitation while only 16 percent had echoes over them, a result which could be caused by at least two factors. One is the small reflectivities the storm produced. The average radar reflectivity factor for the data used in the correlation calculation was 6×10^2 mm^6 m^{-3}. Echoes of this intensity were just marginally detectable at some stations. Secondly, a range effect is definitely present in the data. This effect results from the spreading of the radar energy as it travels away from the radar (and away from the target moving back toward the radar) and from the earth's curvature. Figure 3 illustrates the decrease with distance in the percent of stations that have echo over them. All stations within each 50 n. mi.-interval are averaged together and plotted at the average range of the interval. Note that the percent of stations with weather (i.e., precipitation) remains nearly constant with distance. Also plotted in Figure 3 is a curve which shows the percent of stations that have weather but do not have echo, indicating that at the average distance of 175 n. mi. almost no echoes occurred over stations reporting precipitation.

Thus, with such a poor relationship between the existence of precipitation and echo, there is little reason to expect a strong quantitative correlation between radar reflectivity and the factor F on a large scale. The factor F probably relates more nearly to the radar reflectivity at close

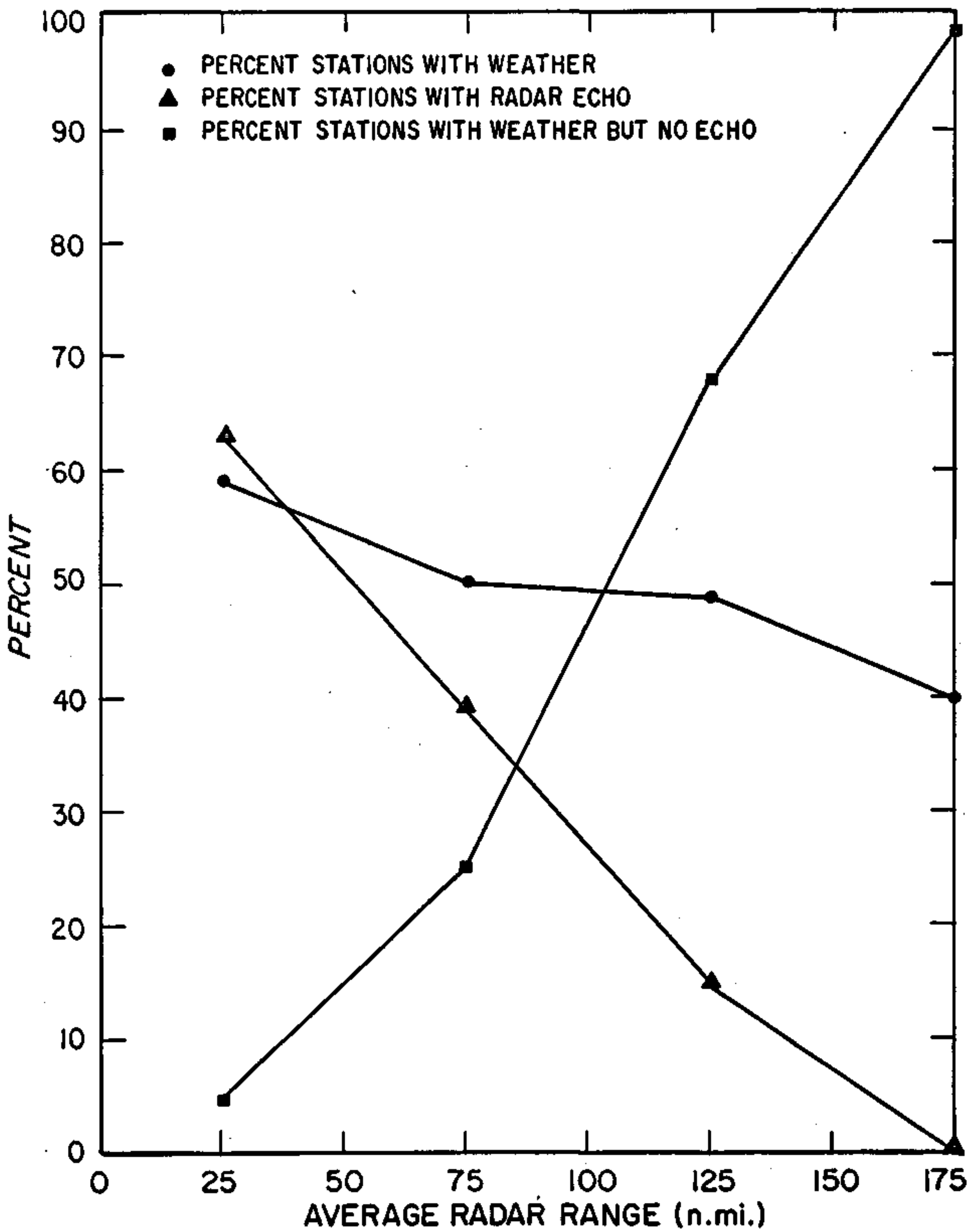

Fig. 3 Range dependence of weather and radar echo

range than indicated by the correlation calculation, but this has not as yet been quantitatively determined.

Raingage-Radar Comparison

Using data from the East Central Illinois raingage network and the MPS-34 radar, an attempt was made to obtain a Z-R relationship for the snowfall of 31 January - 1 February 1966. Weekly raingage charts of 25 weighing bucket raingages using 12-inch tops were read for half-hourly amounts during the snowfall period. All possible radar tracings of the network area were made in each 30-minute period, and the average reflectivity was determined by averaging the individual reflectivities available at each gage within each half-hour period. In the calculations, 403 pairs of snow rates and radar reflectivities were used.

The results of the calculations indicate that there was insignificant correlation (correlation coefficient = 0.18) between the data to obtain a meaningful Z-R relationship. This again may be partially a result of the uniform synoptic situation which existed during the storm. Snowfall rates for the half-hour period, i.e., equivalent amount of liquid water, ranged from 0.04 to 2.5 mm hr^{-1} (average of 0.34 mm hr^{-1}), a factor of 60, while reflectivities ranged from 2.7×10^1 to 7×10^5 $mm^6 \, m^{-3}$ (average of 3.4×10^4 $mm^6 \, m^{-3}$), a factor of 25,000. Another reason for the poor correlation is in the quality of the data. Water equivalent of the snowfall amounts were read to the nearest 0.01 inch. With the charts and drives used on the gages, errors of several minutes in time and up to 0.01 inch in rainfall amount are difficult to avoid. In snowfall the measurement errors are. likely to be much larger, due to the poor catch efficiency of raingages in snowstorms, especially if the wind speed is moderate to strong. The uniform rates tended to reduce the effects of timing errors most of the time.

However, with one-third of the gages receiving snowfalls equivalent to 0.1 inch water or less, the errors in reading amounts could be relatively large. Also, snowfall rates less than and greater than the extremes cited above probably existed in the storm, but the necessary use of half-hourly amounts tended to average these extremes out of the data. The greatest error introduced by the radar is due to the coarseness of the steps on the step-gain control.

As mentioned earlier, the average reflectivity used for the reflectivity for each station for each half-hourly period was the arithmetic average. The correlation calculations were repeated using reflectivities obtained by averaging the logarithms of the individual reflectivities and then taking the antilog to obtain an average reflectivity. The result of this calculation was a correlation coefficient between the radar reflectivity and the raingage snowfall rate of 0.21, just slightly better than the 0.18 obtained with the arithmetically averaged reflectivities.

INCREASE IN ECHO DETECTION WITH THE MASER

A maser RF amplifier on a radar should increase the amount of echoes detected in proportion to the maser gain. Various means of measuring the amount of increased echo detection might be employed. Before considering the technique used in the following studies, the radar equation as it applies to a given radar and type of precipitation will be introduced.

The radar equation may be written in the form (assuming the Rayleigh Law to be valid)

$$P_r = \frac{CZ\alpha}{r^2} \qquad (1)$$

Where P_r is the average received power from a beam-filling meteorological target of radar reflectivity Z at a distance r from the radar antenna. The term α is the total two-way attenuation (generally neglected) between the antenna and the point of interest in the target caused by gases in the atmosphere and precipitation hydrometeors in the target itself. C is a constant dependent in part on the radar being used, and, for the MPS-34, $C = 1.01 \times 10^{-11}$ n. mi.^{2} watt mm^{-6} m^3. For a given target and radar, all that is needed to measure Z is a measure of P_r.

The increase in area of precipitation echoes detected by the maser-equipped MPS-34 radar can be obtained directly by measuring the echo area detected on a PPI display with and without the maser. Similarly, since the equation above related P_r and Z (through a constant), an indication of the increased echo area detected by using a maser of X db gain can be made by using a receiver with X db attenuation in it, as when using a step-gain control.

A study was made of the increased area of precipitation echoes detected with the maser by comparing the area of precipitation detected on gain step 1 with that detected on gain step 2. Also compared were steps 2 to 3 and 3 to 4. The step-gain control introduced 10, 12, and 20 db of attenuation from the preceding step on steps 2, 3, and 4, respectively, step 1 being full gain.

Table 1. List of days on which areas were measured, number of tracings used, type of echo measured, and MPS-34 receiver MDS

Date	MPS-34 MDS (-dbm)	Number of Tracings	Echoes Used	Average Step 1 Area (n. mi.^{2})
17 August 1965	109*	4	Single Cumulonimbus	18.1
31 Jan - 1 Feb 1966	111	16	All Echoes (snow)	5460
5 March 1966	110**	3	All Echoes (snow)	955

*At maximum

**On 4 March 1966

Table 1 lists the days on which precipitation echoes were measured on the PPI tracings and indicates the receiver MDS (the maser was operating on all three days), the number of tracings used, the type of echoes on the tracings, and the average total step 1 area. Each radar tracing is a composite of all echoes on each of the individual gain steps drawn onto one sheet of tracing paper. The time represented by each tracing is dependent upon the number of steps used as each step originally required about 10 seconds to complete.

Figure 4 shows the average precipitation echo areas detected on each gain step normalized to the step 1 area. The three areas used to get the average for 5 March 1966 are also shown to illustrate the variability that individual curves might have. The spread in the curves indicates to some degree the variation in proportions of strong to weak regions in natural storms.

With a given radar, the use of the maser increases the area of echo detected at each gain step, especially at the full-gain end of the dynamic range as indicated by the concave upward bend at step 2 on each of the average curves of Figure 4. The added echo obtained by improving the MDS of the radar is probably not too useful if moderate or greater rainfall rates are of primary interest. For example, at 150 n. mi. at -111 dbm, the MPS-34 detects a rain rate of 0.10 mm hr^{-1} (based on $Z = 396R^{1.35}$) while at -101 dbm the rain rate would be 0.55 mm hr^{-1}. However, if knowledge of the presence of any echo/is important this added gain might be worthwhile. Again, at 150 n. mi. and -111 dbm MDS the reflectivity would be 1.75×10^1 mm^6 m^{-3} while at -101 dbm it would be 1.75×10^2 mm^6 m^{-3}. While both these reflectivities would be produced by relatively weak storms, the detection of any signal would positively indicate the presence of a precipitation-cloud system; the failure to detect a signal would not, however, conclusively indicate the absence of any precipitation.

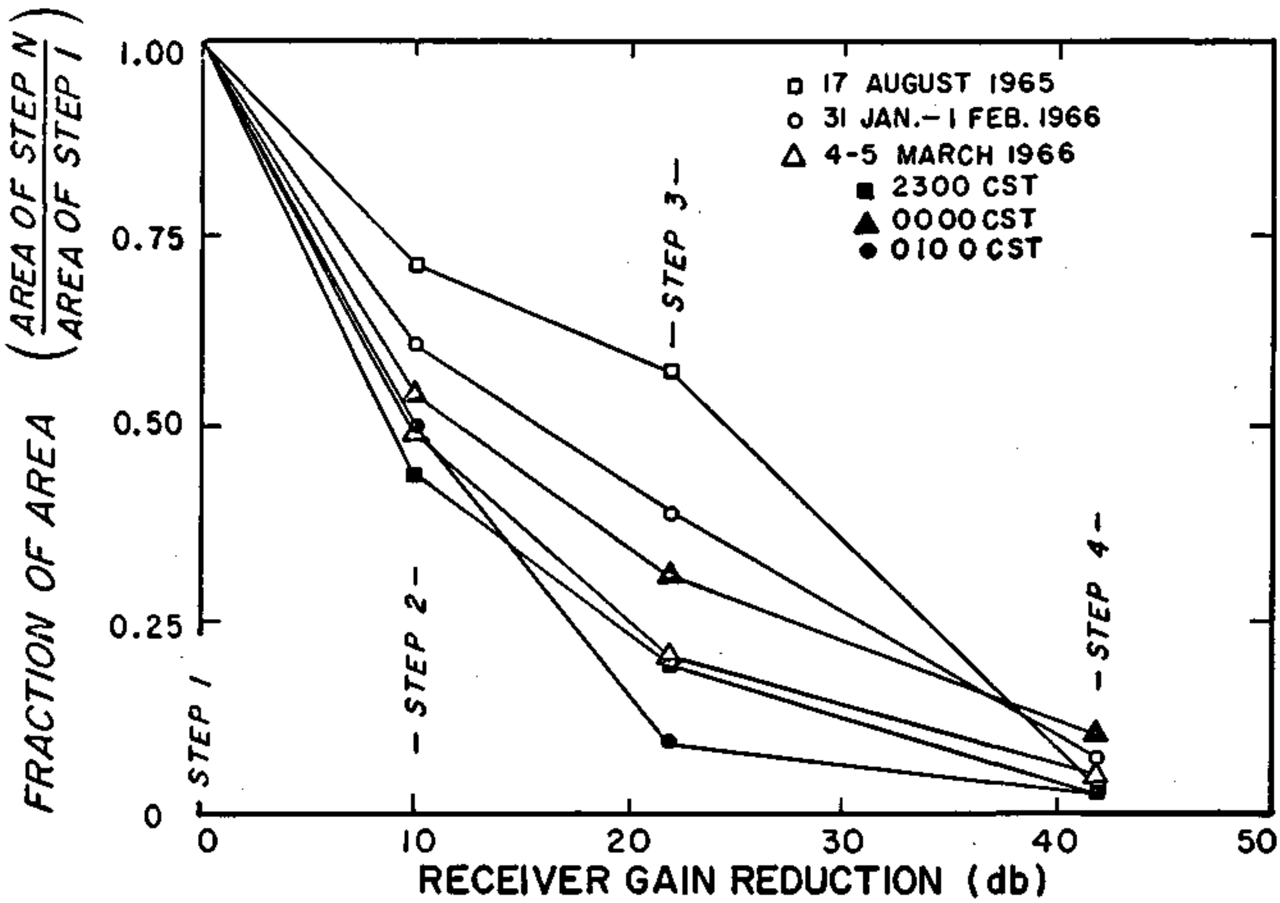

Fig. 4 Variation of area detected as a function of receiver gain reduction; the total attenuation introduced by each gain step is indicated.

The percentage of cases which would fall entirely into the marginal category is probably small, but the extended range of detection of echoes would certainly prove worthwhile in some cases. At 0502 CST, 1 February 1966, the average maximum range at 8 azimuths (45° apart) of the detection of snow (1° tilt) was 102 n. mi. on full gain, 82 n. mi. on step 2, 66 n. mi. on step 3, and 31 n. mi. on step 4. Thus, a 10-db increase in MDS resulted, for this case, in a 22 percent greater maximum range of echo detection. It should be noted that this type of comparison is not quite valid as the intensity of a storm increases from zero outside its boundary to some maximum value within the boundary, suggesting that the maximum ranges of echo detection indicated above were really for different values of reflectivity. From equation (1), a difference of 10 db in P_r with Z a constant would cause the range of detection to increase from 82 n. mi. to 259 n. mi., an increase of 3.16 times (216 percent). The maximum range at this time in any one direction was 153 n. mi. The antenna beam height at this range corresponds well to the 30,000-foot tops of the echoes measured at closer ranges using higher tilt angles. Thus, the actual case is limited by the earth's curvature to ranges less than the maximum indicated strictly from theory, that is, the radar was looking through the top of the echo rather than the farthest edge of the echo. It is unlikely that a 10-db improvement in sensitivity would ever give a 216 percent increase in the maximum range at which echoes are detected, except perhaps relatively close to the radar.

For strong storms with reflectivities on the order of 10^5 to 10^6 mm^6 m^{-3} it is necessary to consider detection near the least sensitive end of the dynamic range. The closest range at which the intensity of an echo with 10^6 mm^6 m^{-3} reflectivity could be measured if the receiver has a dynamic range of 60 db, an MDS of -111 dbm, and a gain reduction of 60 db is 11.4 n. mi. Within that distance, the storm would saturate the receiver, making quantitative measurements impossible. However, this is probably not a serious limitation because storms of this intensity are only infrequently that close to a given radar location.

Attenuation Compensation

Besides increasing the area of echoes detected, the added gain produced by the maser should prove useful in partially compensating for the effects of attenuation of the radar energy by atmospheric gases and hydrometeors.

Attenuation by gases is generally small. Water vapor attenuation at 3.2 cm wavelength over a 100 n. mi. (two-way) path is about 3 db based on a moist atmosphere of 10 g/kg water vapor content. Beyond 100 miles the beam is probably high enough that little additional attenuation would result because of the presence of water vapor. The attenuation by oxygen at $\lambda = 3.2$ cm is about 3 db for a two-way 100 n. mi. path. Table 2 gives the average - total attenuation by gases during winter and summer for two-way path lengths of 50, 100, and 150 n. mi. Also included in the table is the attenuation for clouds, assuming there were no clouds within 25 n. mi. because the beam is at low levels, and that the average liquid water content beyond 25 n. mi. was 0.lg m^{-3} for heights up to 15,000 feet. Table 2 and the discussion of it are based on information in General Application of Meteorological Radar Sets, Air Weather Service, Technical Report 184, April 1965.

Table 2. Estimated two-way atmospheric and cloud attenuation (db) for 3.2 cm wavelength radar

Range (n. mi.)	Atmospheric Attenuation		Cloud Attenuation
	Winter	Summer	
50	2.2	2.9	0.8
100	3.5	4.7	2.4
150	4.2	5.6	3.6

Gases are always absorbing and scattering the radar energy, and the amount of attenuation thus produced for a 100 n. mi. two-way path, for example, is generally within two or three decibels of the average value, even when including the effects of cloud attenuation.

The attenuation resulting from liquid precipitation, however, is highly variable, depending primarily on the rate of precipitation. For the sake of illustration, the empirical relationship given by Gunn and East (1954) will serve to provide some numerical examples. This relationship is

$$k_p = 7.4 \times 10^{-3} R^{1.31}$$

when R is the rain rate in mm/hr and k_p is the attenuation due to precipitation in db/km.

Light precipitation with rates less than 10 mm/hr would produce a two-way attenuation less than 0.30 db/km of path length. Widespread areas of light precipitation are characteristic of some types of storms and could produce large total effects. A 50 n. mi. extent of 10 mm/hr rain would produce 28 db total attenuation.

On the other hand, heavy rains, while usually less extensive, produce greater attenuations per unit length. A 5 n. mi. extent of 100 mm/hr rain would result in a 58-db attenuation, again the total for two-way transmission. Thus, the effects of attenuation can be quite large and highly variable.

The added gain from the maser easily compensates for gas and cloud attenuation within most useful radar ranges. Certainly, a 10-db or greater maser gain also contributes additional information normally lost because of attenuation by precipitation, but it appears from the numerical examples that attenuation due to precipitation would often exceed this gain.

The discussion of precipitation attenuation above applies only to rain. Attenuation by snow is less well understood and is not as easily estimated quantitatively. Gunn and East's (1954) calculations indicate that attenuation by snow is probably more than an order of magnitude less than that for liquid precipitation at the same rain (liquid water) rate.' In addition, the water equivalent rain rate of snow is generally less than that for liquid forms of precipitation. Thus, except for the case of melting snowflakes, attenuation due to snow may generally be neglected without serious error.

CONCLUSIONS

The addition of a maser RF amplifier on a radar certainly increases the capability of that radar to detect meteorological targets. The magnitude of this increase is dependent upon the gain introduced by the maser amplifier.

The measurement of the increase in the average maximum range of detection of echoes in one snow storm indicated that, for a 10-db change in the receiver MDS, an increase of 22 percent was obtained.

In another approach to measuring the increase in echo detection, the area of echoes on the PPI scope were measured on each of the gain steps to determine the increased area obtained. From 30 to 60 percent additional area was detected on step 1 (full gain) as compared with step 2 (10 db below full gain).

The effects of attenuation are to reduce the signals detected compared with those that would be detected without attenuation. While gas, cloud, and snow attenuation are generally negligible, precipitation attenuation might often exceed the gain produced by the maser on the MPS-34. Nevertheless, the maser gain would tend to compensate to some extent for these losses.

PROGRAM FOR THE NEXT INTERVAL

The APMI has recently been moved adjacent to the Meteorological Laboratory at the University of Illinois Airport (about 1/2-mile north of its former location) where it will be connected to the CPS-9 radar for the summer. Work will continue on the APMI to improve its operating condition until reasonably reliable data may be collected with it. A calibration of the intensity levels has yet to be performed. As data become available from the APMI, the records will be analyzed.

Analysis of the data from the maser-equipped AN/MPS-34 will continue with the primary purpose of determining further the advantages of the increased sensitivity produced by the maser.

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PERSONNEL

Name and Title	Starting Date	Hours Worked	Terminated
G. E. Stout Project Director	4/1/65	51	
E. A. Mueller Project Engineer	4/1/65	128	
D. M. A. Jones Project Meteorologist	4/1/65	160	
R. E. Rinehart Assistant Project Meteorologist	4/26/65	510	
D. W. Staggs Electrical Engineer	4/1/65	400	
Eberhard H. Brieschke Meteorological Aide I	10/1/65	510	
Edward J. Silha, Jr. Engineering Assistant	2/1/66	326	
Joseph C. Coons Meteorological Aide II	3/7/66	510	
Edna M. Anderson Meteorological Aide II	4/1/66	255	
James N. Black Meteorological Aide I	4/1/66	510	
Morton L. Epstein Meteorological Aide II	5/22/65	120	4/21/66
Karen S. Adair Technical Assistant	6/6/66	119	

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13. ABSTRACT

A summary of the maintenance and operation of the MPS-34 is given. Little progress has been made with the APMI because of a power supply failure and the lack of the required replacement. Analysis of the radar snow data collected during the previous quarter has been carried on as the primary activity of the quarter. Comparisons were made between the radar data and airways synoptic data and precipitation data from the East Central Illinois raingage network. The comparison between the airways and radar data indicated that a good quantitative relationship did not exist, primarily because of frequent observations having precipitation or radar echo, but not both. In the precipitation data comparison the correlation was too low to provide reliable Z-R relationships for snow. A third preliminary study indicated, in a sample case, that a 10-db change in the receiver MDS provided an average increase in the maximum range of echo detection of 22 percent (as compared with a theoretically possible increase of 216 percent). The effects of attenuation are considered briefly to indicate what effect the additional gain might have in partially compensating for attenuation. The maser gain easily compensates for normal gas and cloud attenuations, but precipitation attenuation often exceeds the maser gain.

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