# The Uses of Radar in the Weather Service

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THIS article briefly introduces to the non-specialist reader the uses of radar now made possible in a weather service. Detailed descriptions of the several different phases of activity are to be found in more technical papers. Herein the use of micro-wave radar, i.e. sets operating on wave lengths of less than a meter, is assumed.

In general, three phases of radar performance are of interest to a meteorologist. The first, which is the most prominent in the mind of the forecaster, is the ability to furnish information on the velocity of winds aloft in all kinds of weather. The second is the ability to distingush heavy precipitation areas aloft. The third attribute, about which there are many erroneous impressions, is referred to as the effect of the atmosphere on the propagation of electro-magnetic waves. As might be expected, it is the abnormal propagation effects caused by special weather conditions that are of most interest; hence that term is used to describe that phase. Other phases of the performance of radar will be of use in the future, but insufficient information for publication is available at this time.

## RAWINS[1]

The tracking of ballon-borne reflectors has been practiced from the beginning of the use of mobile radar sets. Such sets, as well as others which can determine elevation, can follow a so-called corner reflector, made up of three intersecting planes of conducting material, each of say one square yard in area. Such "corners" weigh several hundred grams and require at least a 100-gram-sized balloon to lift them. They may be followed to the limit of the radar set's range on a comparable target such as an airplane. Improved performance may be secured by using smaller reflectors of better return which will allow a balloon of the same size to ascend more rapidly and reach higher levels. Oddly enough, a suitable train added to a balloon may cut down the drag and make the balloon appear to rise faster, because of the streamlining of the airflow.

Three men using a set arranged for convenient operation can make and work up a run to 30,000 feet in about half an hour. Where so-called automatic tracking is built into the radar set the crew can be reduced and one-man runs are feasible under certain conditions. If winds to a lower elevation suffice, a 30-gram-sized balloon with a special light-weight reflector can be used. To save time in this case a 60-gram balloon is desirable.

As compared with the old pilot balloon triangulation measurements, a high order of accuracy is available in radar because the distance to the target is determined by the set. The computation of horizontal distance involves no assumptions regarding the rate of ascent of the balloon. Here, the accuracy obtained will depend upon the type of equipment used, the effectiveness of its operation and the wind velocity. Operators who work as a team can produce, with comparatively simple equipment, results that can only be exceeded by the more expensive automatic-tracking devices. The more powerful the set, the better the target and its presentation and the closer it is, the more accurate the data. Probable figures for error computed for a high-performance set are tabulated as follows:[2]

| | Speed (mph) | Max. Direction Error in Degrees | | | |
|---|---|---|---|---|---|
| **Range Yards** | **Max. Error** | **at 10 mph** | **at 30 mph** | **at 50 mph** | **at 100 mph** |
| 20,000 | 2½ | 0.2 | 0.2 | 0.3 | 0.7 |
| 40,000 | 3 | 0.3 | 0.4 | 0.6 | 1.4 |
| 50,000 | 4 | 0.4 | 0.6 | 0.9 | 2.0 |
| 60,000 | 4 | 0.6 | 0.8 | 1.2 | 2.7 |

These figures do not include a margin for operator's errors. It is probable that this accuracy would not be achieved at the start of a wind-finding program, but it would be possible to achieve higher accuracies, were automatic tracking and computing machinery economically feasible.

According to the table given above, a balloon ascending at a rate of 1000 feet per minute, with a radial wind speed of 10 miles per hour, at 30,000 feet could be observed to about two miles per hour and a small fraction of a degree in its velocity vector. A run to 20,000 feet with a radial wind of 100 miles per hour would have errors of about four miles per hour and three degrees.

## STORM DETECTION

The ability of micro-wave radar to detect precipitation areas is believed to be due mainly to the reflective properties of water droplets and snow flakes. Limiting this ability is the fact that only the greater water concentrations cause observable reflections with present sets. This precludes the observation of stratus, ordinary fair-weather cumulus and cirriform clouds; hence it is a misnomer to say that the set "sees" clouds. Only clouds "laden with moisture," as the saying goes, appear on the observing screen or 'scope of the receiver. But the moisture seen by its echo is associated with convective activity, usually resulting in precipitation. This makes radar an excellent tool for local forecasting, since thunderstorms

1 The term RAWIN has been designated by the services to define information secured about winds aloft by electronic means. This covers the use of radar and balloon-borne target described in this article and also the method which uses a balloon-borne transmitter with or without radiosonde, an instrument transmitting meteorological information by radio, together with an RDF (radio-direction finding) set on the ground. Sometimes the first level of a RAWIN report is taken from an optical measurement of the balloon by theodolite (a PIBAL) because the radar or the RDF sets in use have a limiting minimum distance or height at which they can operate.

2 From a nomogram devised by Captain George E. Austin, A. C.

and heavy showers are easily tracked and warm-front precipitation (warm-front action refers to over-running of one air mass by another) often can also be observed.

It is easy to see that local-weather short-term forecasting for precipitation takes on an entirely different aspect, if a glance at the 'scope in his office shows the forecaster even a limited local distribution of precipitation. The telephone weather service can be so improved thereby that from the user's standpoint the other aids to forecasting are academic when a person is only interested in the question of rain in the next hour or two.

The maximum distance from which precipitation areas return a signal is the factor that determines the effective use of radar for such a purpose. At the very high frequencies used in radar, propagation is line-of-sight to a slightly greater distance than light rays, because of greater refraction in the atmosphere. Under conditions of abnormal refraction, this range is considerably increased. The higher the location of the set and the higher the water-laden droplets in the tops of the clouds, the greater the range will be. The power and sensitivity of the set as well as the height of the location impose limits. Raising the height of the set may, in fact, have a disadvantage, since the additional ground targets seen tend to "clutter-up" the screen and obscure low lying close-in echoes. A typical installation on an airplane hangar roof, where the 'scope can be conveniently located in a second-floor office, can cover an area of more than 75 miles in radius. This depends upon the power of the equipment, for the most powerful sets do observe severe storms to a range of about 200 miles.

The choice of a suitable site depends upon economic as well as geographical considerations. If a radar installation becomes practical on a city weather station building, such an office can handle the important forecasting of local precipitation, removing a load from an airport forecast station. The building chosen need not be the highest one; it is enough that it be free from too many local obstructions to the view of the horizon. The Empire State Building, for instance, first suggests itself as a site, but other tall buildings hardly considered in the skyscraper class in New York City would serve satisfactorily in that location.

One observed factor is that precipitation echoes attenuate signals from objects behind them at a greater range, as well as obscuring echoes within the clouds. It is possible, therefore, that echoes from RAWIN reflectors may be lost in storm clouds. The amount of time in which this happens with skilled operators and adequate equipment is, however, a small percentage of the time covered by a given storm. Radio direction-finding sets following airborne transmitters, such as the combined RAWIN and radiosondes (Rawinsonde), do not "see" precipitation echoes and so are not bothered by them. It may be said that the same principles can be applied to the development of the radar-sondes.

This is essentially a short-range device for storm detection, as far as the meteorologist is concerned. It is not to be confused with the long-range location of the source of atmospheric static, given the name "Sferics" by a network of RDF stations.

## ABNORMAL PROPAGATION EFFECTS

Much misinformation about the effects of the atmosphere on propagation of electric waves has been widespread. This will only be corrected by the dissemination of the information on the subject gained during the war, when it was a subject of intensive study. Such information is of importance to television and communication as well as radar. It so happens that radar development sponsored much of the research in micro-structure of the atmosphere.

Briefly, as mentioned above, the earth's atmosphere refracts the radio or radar electromagnetic waves just as it effects the transmission of light and sound. The vertical distribution of density of the overlying atmosphere changes with the weather, and as a result the coverage of a given set varies from day to day. However, when the gradients become extreme, the energy acts as though it were reflected from such layers and the results are long ranges. The analogue is also used to say that the energy is "trapped" by "super-refraction," but the result is still called "anomalous propagation."

It has been suggested that by studying the propagation of radio waves in the atmosphere, information can be gained about the thermal and moisture distribution aloft. For instance, the use of reflections from discontinuities in temperature and humidity aloft, as discussed in pre-war meteorological and radio journals[3], seemed an attractive possibility, but until a better understanding of the quasi-optical physics involved is reached, no new information on the atmosphere can be gained in this way. Also in the past, empirical attempts to relate positions of Highs and Lows with radio-signal strengths met with some success.[4] Such pressure gradients have no effect on microwave propagation.

Work in this field has been a boon to meteorology in one respect, since it has really developed the science of micro-structure of the atmosphere. This is of perhaps greater interest and importance in the other research fields of meteorology and oceanography.

In regard to the atmospheric effects on radio-wave propagation, the position of the meteorologist is not an enviable one. His field of activity, the atmosphere, can now be held responsible for "anomalous" propagation, which allows radio signals to come from or appear in unexpected places. The result may be an interference with, or an interruption in, the communication, broadcast, television services being proposed, as well as in radar. Under certain conditions this phenomenon can be taken advantage of to extend the range of present sets. Now these effects in our troposphere can be likened to the reflections from the Kennelly-Heaviside Layer in the ionosphere of which the radio engineer is cognizant. But here the radio engineer not only asks the forecaster what the state of the atmosphere will be, but further inquires what will be the effect on propagation. All this is a challenge to the meteorologist, but one which he can make the most of only when he has the radar set at his disposal[5].

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**3 See Friend, Bull. Amer. Met. Soc. 22(2):53-60, 1941. The reflection is a function of the vertical dielectric-constant gradient, but the effects of temperature and humidity on the dielectric-constant or its corrolary, refraction index, cannot be separately distinguished by radio means alone.**

**4 A.M.S. Bulletin March 1946: p. 114.**

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