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RADAR CALIBRATION COURSE

Lecture no. 13

Title: A Review of Theoretical Considerations for Radar Calibration

Length of Lecture: 6 hours

Given to: Technical Section

Prepared By: Dr. T.J. Carrol, Technical Adviser A.W. Division
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Required Reference Reading:

Radar Performance Testing Manual; prepared by H.Q. Army Air Forces, Washington D.C. pp. 5 thru 33.

The Siting of SCR 270-271 for Long Range Aircraft Detection, prepared by AAF School of Applied Tactics, Orlando, Florida
pp. 3-6, 16, 17.

Suggested Reference Reading:
Radar Siting Manual prepared by AAF School of Applied Tactics Orlando, Florida Chapter I, II, III.

T.R.E. _____ to Calibrators; Section IV

PURPOSE AND HISTORY OF CALIBRATION

1. Operational need for numerical information about radar performance.

Operational radar systems for aircraft warning must know rather exactly how much coverage is obtained for a given type of target at any given height. It is not enough to know that the sets are "on the air" or "off the air", but it is operationally vital that there be some knowledge about how much the set is on the air, how far it can be relied upon to pick up a given type of target at a given height. The negative information that a target is for certain not present in a known region of space about a radar is just as important as good tracks when a target is reported. It is not possible to get on the field the measurements of transmitter power and receiver sensitivity which are needed to make reliable range estimates. In some cases, the effect of the site surrounding the set cannot be predicted. So far, only calibration by planes has made possible the numerical range information which is necessary operationally. It is quantitative rather than qualitative information which calibration supplies. A famous quotation of Lord Kelvin, one of the greatest 19th Century physicists, is a very appropriate motto: "I often say that when you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the stage of science."

2. Historical, forerunners to radar calibration.

A radar calibration is very much like a field strength survey, since it determines where in space the field strength is great enough to detect a given sized plane, field strength surveys around transmitters have been made since the earliest days of radio. Since the coming of commercial broadcasting, these surveys have been used to determine the effective service area of various stations, A. radar calibration is simply a field strength survey of all the space above the horizon, except that the field strength is not measured at the plane, but rather from the echo sent back to the radar. Many radiomen, familiar with the results of field strength surveys on the ground, are surprised at the regularity and simplicity of the observations on an elevated calibration plane, when ground irregularities have little disturbing influence on the results.

The first published field strength measurements on ultra high frequencies transmitted from a ground transmitter up to a plane were probably those by a Bell Labs group published in Proceedings of the I.R.E. in March, 1933 (flights in 1931). These airplane flights showed clearly that the ground reflected signal was practically as strong as the direct signal. Positions were noticed where the signal was almost zero, because the direct and reflected signals arrived at the plane and canceled each other by interference. Similarly, between two such null positions, the signal field was observed to rise to a value almost twice that which would have been expected in free space without reflection. (In this paper, incidentally, is published the first remark indicating that detection is possible by means of radio waves bouncing off a plane. Beats -were noticed in a receiver v/hen a plane was as far as five miles away.) The only other published field strength curves published on ultra high frequencies measured in .airplanes seem to be those of the R.C.A. group.

Field strength measurements made on communication frequencies below 10 mc. are not so useful or significant as measurements on ultra high frequencies for two reasons.

First, the amount of signal at low frequencies depends very often on the "sky wave", that is the amount of signal bounced back from the ion layers 50 to 150 miles above the earth. The strength of this sky wave changes between day and night and with the season of the year. In fact all pulsed radar has grown from the work of the late twenties and early thirties on measuring the height and properties of the ionosphere from returned radio pulses. On the ultra high frequencies, however, no signal is returned to earth by the ionosphere, so that this cause of changing field strength is not present.

Second, the rapid development of higher powered transmitters and more sensitive receivers made it rather unnecessary to know exactly the smallest field strengths needed in. communication work. But in Radar work, where the returned signals are, in principle, extremely small, the equipment must always be kept in peak operating condition in a way which has never been necessary for communication. In radio communication, it is usually enough to know that "it plays", and there is enough extra, power available to allow the equipment to work satisfactorily below its peak performance. In radar, however, equipment must always work near its peak performance, and there must be some means of proving this, namely calibration with fixed echo checks.

3. <u>Development of Radar Calibration in this country.</u>

It should be mentioned that the questions "how much range and how reliably" have only been urgently asked in the last year or so. In the early days of Radar (1938-41), the fact that a set saw planes at all was considered so remarkable that no critical questions were asked about re-liable ranges on different .sizes and heights of targets. It would have seemed like looking a gift horse in the mouth. So great has become the fame of Radar as a "Crystal Ball on a Truck" that some persons feel disillusioned and short changed when the limitations and precautions necessary to get information from radar are pointed out. The great task of calibration is the removal of the mystery and guesswork from radar performance, and. replacing it with hard, solid numerical fact. It aims to make a radar as reliable as a truck, and to let people know exactly how far it fails to be a "crystal ball".

Of course, test flights were used to test radars from the; very beginning, although planes were, always difficult to get, and good control over the plane by direct radio voice communication was rarely realized. The first systematic flying over a series of altitudes by a B-l7 with good communications with the radar set was done on two 270 sets in Maine, in November, 1941 (stopped by Pearl Harbor). Directives to calibrate all radar sets were issued early in 1942, but lack of planes, communications, and experience combined to present the beginning of systematic calibrations until about June of 1942, almost simultaneously at First Fighter Command, Panama, and here at AAFSAT (then Fighter Command School). The present plan for airborne detachments is the attempt to solve the prime difficulties of getting assigned planes and pilots, communication equipment and experienced personnel.

4. <u>Calibration in England.</u>

The prime importance of calibration of sets in a radar system was realized earlier in England, partly because of the lessons of war experience on the system, partly because certain British sets require calibration for reading both azimuth and height. It is believed that planes were available for this work on a rather hit or miss basis until about the fail of 1940. Up to this time, calibrations of R.A.F. stations were conducted by civilians from the T.R.E. research laboratory, and the plane was usually obtained by coaxing it out of a nearby airdrome. Around the end of 1940, calibration became the function of military personnel of "60 group", also responsible for siting, installation, and maintenance. Aircraft and pilots are now assigned for calibration work at each of the dozen or so wings (our "areas") into which the coastal chain is split up. (There is at least one plane, usually a Blenheim, at each wing.)

5. <u>Probable future of calibration.</u>

There is every indication that calibration is being realized to be an essential part of a functioning air defense system using radar. The demand is almost .insatiable for experimentally determined vertical coverage diagrams on all types of ground sets. Even laboratory designers have rarely seen how clearly the expected lobes come out in practice, because they have never had the opportunity, of seeing a systematic series of flights to determine the lobes. The procedures now available are capable of giving the operational answers needed. Of course, there, will be continuing effort to find better ways leading to a shorter process, but these improvements can come only slowly, and probably in large part from the calibration detachments themselves. Seeing the amount of fog which calibration can dispel about what radar actually does is one of the compensations of a calibration group for the labor and the care necessary to present reliable data.