RAND DOCUMENT

LODAR

John F. Nash, Jr.

D-2349

23 July 1954

Summary

This memorandum describes in general terms a system by which early warning can be given of approaching aircraft. The advantages of the system are: long range, especially over water, detection of low-flying planes, and economy and simplicity of the installations which are suited to remote control. The main disadvantage is the complexity of interpreting the data that would result from several different flight groups. In principle, the system gives the position (except altitude) and velocity of the planes in its range, working on the Doppler frequency shift of the reflected radiation.

Electronic design is not attempted, but the requirements, in terms of information theory considerations are indicated.

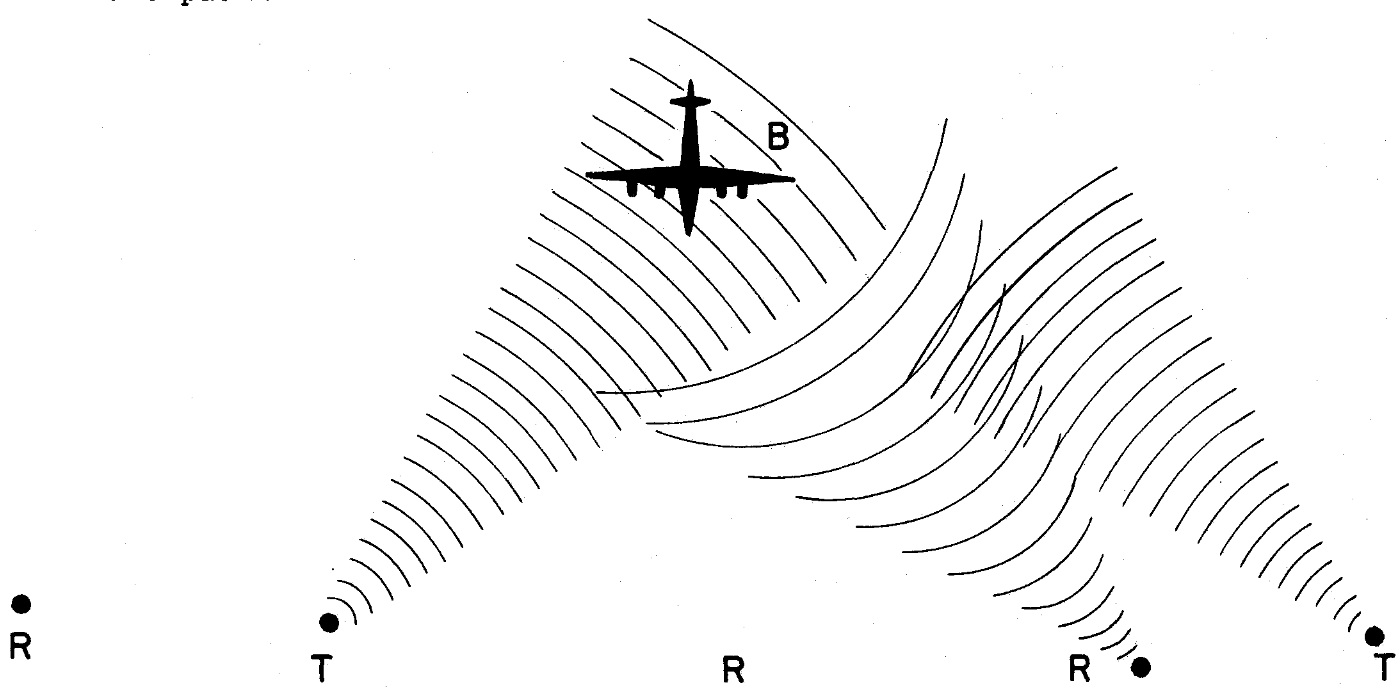
LODAR
or
Low Frequency Radio Aircraft Detection System

Low frequency radio waves have many advantages over the higher frequencies. They can be produced and detected with cheaper equipment and can often be made to travel farther. But they do not easily permit high resolution in direct application, such as with directional antennae.

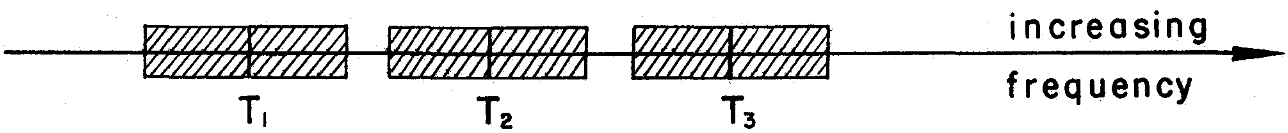
The system described here is intended primarily to detect the existence of approaching aircraft and not to locate them very precisely and especially not to handle a large number of craft flying in various directions at various locations. The advantages of the system are economy and long range, especially when used over sea, and perhaps most important, the ability to detect low-flying planes. One basic principle behind the use of lower frequencies is that to have a substantial proportion of the radiation incident on an electrically conductive aircraft reflected, we need only have the wave length of the radiation of the order of the aircraft size or smaller. Thus, for fighters, frequencies near the FM band are quite high enough. For bombers one can use still lower frequencies and get greater range, especially with the surface transmission over sea.

Let us consider the application to bombers for an early warning system. So we are using radiation at, say, 25 meters. What we use is a set of transmitters which broadcast continuously on slightly different rigidly fixed frequencies. These are to be nondirectional, although one might make them mildly directional so that most of the energy would be sent out in the direction from which enemy planes may be expected to approach.

The radiation reflected from moving aircraft will have a Doppler frequency shift. This will be the means both for detecting the reflected radiation and for deducing the position and velocity of the plane.



Typical layout



Transmitter frequencies and Doppler bands

The figures above indicate the general layout of a LODAR net and the way in which the transmitter frequencies should be spaced to prevent the maximum Doppler shifts of two different transmitter frequencies from being confused.

If we receive a reflected signal at R and know it began as a certain frequency sent out by T, then from the Doppler shift we know the rate at which the length of the broken line distance TBR is changing. This rate depends on the velocity and position of the plane. We can think of the velocity and position as described by 4 parameters so if we know 4 such independent Doppler shifts we should in general be able to fix the position and velocity of the plane.

The receivers must be very selective and this selectivity must be for varying basic frequencies. Also the selectivity must be variable. A receiver has to scan the narrow band of frequencies which could be formed by the Doppler effect on the frequency sent out by a transmitter and when a signal is picked up and linger at frequencies where a signal appears to be coming in to check and measure the frequency.

Instead of using a scanning system the receiver could have a broader channel amplifier and then heterodyne the signal down to an audio or lower frequency and use this to excite a large array of mechanically resonant objects, such as reeds. This method in principle gives the receiver a more continuous awareness, although it is suited primarily to a warning system rather than a system which locates the aircraft by measuring the Doppler shifts.

For measuring the Doppler shift the receiver could heterodyne the shifted frequency with the unshifted (received directly from the transmitter and separately amplified to the same power level) and then actually count the cycles per second of the difference frequency.

This equipment could be fairly easily made so as to operate unattended and telemeter information to control centers, the basic idea being to detect attacking planes without giving highly detailed information if many planes are present. The nature of the system is such that it tends to be harder to interpret the data if a large number of planes contribute reflected signals.

The great advantage of a Doppler-type system is that stationary objects give no signals so a low-flying plane with mountains in the background is detected just as easily as if it were higher, provided only that the transmitter and receiver are located in a way permitting radiation to pass from the transmitter to the plane and back to the receiver.

In mountainous country the transmitters and receivers should be located atop the mountains or ridges. There they would survey the adjacent valleys effectively and would also see planes flying over lower ridges. Thus with this system the problem of detection in rugged country is not so great.

The transmitters and receivers could be maintained by helicopter when necessary if on a mountain top location.

To secure added range, antennae supported by balloons might be employed. These have some fairly clear disadvantages.

Each receiver should check on the shifted reflected signals originating with three or four different transmitters. The writer could suggest ways of designing the receivers for their variable selectivity and scanning functions but he is not as competent on this as an electronics expert, so he only specifies the requirements on a general information theory basis. The transmitters are simple and just need a good crystal controlled frequency.

A receiver must detect signals of rather small amplitude. This will be possible only because the signals will be very very narrow band signals, analogous to the signals used in radio communication by code. Thus selectivity is essential to the detection of the signal in the midst of noise. However, high selectivity and rapid frequency scanning are antithetical and the best solution appears to be a moderate rate of frequency scanning which is interrupted when the signal level increases and slows down to examine the signal and stops to measure its frequency. This is quite feasible, especially if the signal level is measured by a less selective scanner and by averaging over a suitable time interval.

Some with whom this system was discussed have said that it would require a computer to interpret the data. For low traffic loads (friendly planes) I feel that humans working over maps would suffice. The point is that explanation of data produced by the system in terms of known flight plans is simpler than interpretation of the data from scratch. In any case it is easy to know the <u>number</u> of flight groups within the range of the net from the data without having to make the more complex interpretation of the data that would give the positions and velocities.