# A NEW WEATHER RADAR FOR GENERAL AVIATION

George C. Jung

RCA Corporation
Aviation Equipment Department
Van Nuys, California

## Summary

An analysis of the operational parameters of an airborne weather radar has resulted in the design of a far superior unit. A general outline of some of the most important factors is presented with an emphasis on the microwave area.

## Introduction

There are several good reasons for using a weather radar aboard an aircraft. Certain storm centers can generate enough energy to disintegrate the airframe, or at least cause severe structural damage. Other smaller storms can make the flight very uncomfortable for passengers and crew. In addition, the radar can be used for ground mapping to facilitate navigation and detection of high ground ahead of the aircraft.

When there are large storm areas to be avoided, it is advantageous to be able to detect them as far in advance as possible. They then can be circumnavigated with a minimum loss in time.

If avoidance is not possible, then it is necessary to identify areas with a low amount of turbulence to make penetration not unduly dangerous.

The design of a radar which will yield optimum performance under the given set of constraints requires some fairly sophisticated mathematical models. However, owing to the limited space available, only a very small amount of the total design effort can be discussed within the context of this paper.

## Target Parameters

Water particles account for most of the energy reflected from meteorological targets. The selection of a particular frequency band is a compromise between resolution and target penetration. A thunderstorm model was evaluated both at X and C band. The amount of target information obtained at C band was several times greater than at X band and, in fact, the X-band data was insufficient for many practical situations. On the other hand, as the size of the antenna is limited by the airframe, it is found that C band is not usable because of insufficient resolution when used on aircraft in the category for which this radar was designed.

If the wavelength is large compared to the circumference of the scattering particle, then the radar cross section is proportional to the sixth power of the diameter (Rayleigh scattering). This is applicable to X-band energy incident upon raindrops. As a consequence, a weather target can have a dynamic range of over 60 dB, and the system must be able to maintain its resolution under these conditions.

## Antenna

When an aircraft is navigated through an area containing a large number of meteorological disturbances, it will be surrounded by a great number of high-density targets. As was stated before, these targets can have a dynamic range of over 60 dB. Under these circumstances it is mandatory that the radar display an accurate picture of the storm cells around, with a minimum number of false targets.

When these requirements are regarded in the light of the typical performance characteristics of the rear fed paraboloid used so far with this type of radar, it becomes evident that this arrangement is inadequate. These limitations do not apply, or are reduced to a large extent, when a phased array is used. In this case a low sidelobe level can be obtained without a large increase in beam width and a consequent reduction in directivity.

To verify the results of the analysis, a 30-inch C-band phased array was built which was as close to the ideal antenna as practical. Next this new antenna was substituted for the present dish and feed used by some major airlines. One test route was the Berlin air-corridor. The weather is notably bad in this area; the aircraft are limited to a narrow path to be followed under all circumstances and the altitude cannot exceed 12,000 feet. The improvement was quite dramatic. At short range where the picture presented by the indicator was useless before because of excessive clutter, all targets were now clear and well defined. In addition, due to the higher gain of the new antenna, the range was increased significantly. Obviously this made it clear which approach to take in designing the antenna for the AVQ-21.

## Microwave System

Fig. 1 shows the microwave system.

Microwave System (cont'd)

Clearly a lot of information is lost due to the large difference in effective noise temperature between the antenna and the receiver. Work is presently in progress to develop a parametric amplifier to change this situation. Also a ferrite limiter is being designed to replace the T-R limiter. A detailed diagram of the microwave part of the receiver is shown in Fig. 2.

The signal mixer uses both image and sum terminations. An improvement of about 1.0 dB in system noise figure is obtained with this configuration. All components shown in Fig. 2 plus the local oscillator have been combined into a compact air-strip module.

## Local Oscillator

A cross section of the local oscillator is shown in Fig. 3.

Several different configurations were evaluated with respect to electrical performance, resistance to vibration, cost and manufacturing problems. In all cases the present oscillator was either equal or superior in every aspect.

At X-band frequencies the design of an electronically tunable oscillator presents some special problems because diode packages exhibit resonances in this frequency range. To have a successful design it is necessary to have a well-defined synthesis technique which accounts for all dynamically independent variables. For this reason a lumped constant equivalent circuit was developed with the cavity center line as a reference. An exact calculation of the microwave parameters would be a formidable task, but it is found that the lumped parameter approach yields results which are close to the design goals. Some small changes will then suffice to arrive at the correct values.

The cavity itself operates in the TM 010 mode. Electronic tuning varies the frequency by ± 30 MHz with a center frequency of 9.285 GHz. Power output is typically 25 mW.

## System Performance

Overall this new radar represents a significant improvement. Although the output power is only 7.0 KW, the total range performance exceeds that of the 20.0-KW radar it replaces. Commensurate reductions in size and weight and improvement of reliability are additional dividends. The reduction in spurious responses due to the new antenna allows operation of the airplane with a much greater safety margin.

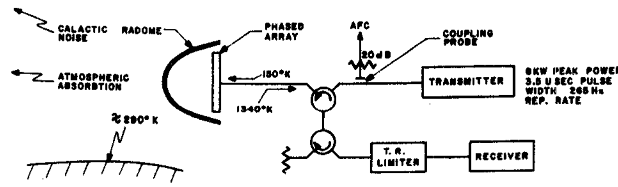



FIG. 1

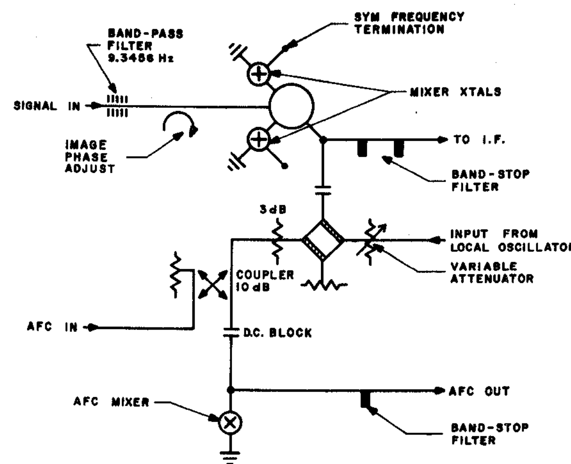
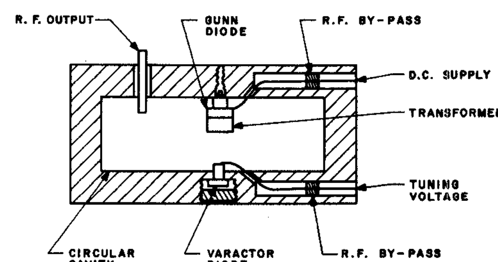



FIG. 2

FIG. 3



# Notes