XIII. VHF-HF Omnidirectional Balloon Locating System

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Abstract

The design, development, and testing of an experimental Balloon Locating System and a proposed operational Balloon Locating System are presented. This presentation includes the following phases of the Locating System: VOR Theory, Encoding and HF Telemetry Technique, Flight Test Results, a New Airborne Unit, and a New Plotting Method.

1. INTRODUCTION

At last year's Symposium*, Mr. Ralph Cowie described in detail a balloon-borne navigational system giving nationwide coverage with an expected accuracy better than 5 miles. This VHF-HF Omnidirectional Balloon Tracking System makes use of the VOR ground-station network being operated by the FAA for aircraft navigation and the existing AFCRL balloon telemetry system. The only new instrumentation required was a special balloon-borne "VOR" receiver and encoder.

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*Proceedings, 1964 AFCRL Scientific Balloon Symposium, pp. 169-186.

In brief, the system operates in the following way. The complex signal from a VOR ground station is detected by the balloon-VOR receiver as a phase shift that measures the magnetic bearing, that is, the angle between the direction of magnetic North and the line joining the VOR ground-station and the balloon. Each station is identified by its carrier frequency. The station frequency and the magnetic-bearing measurement are encoded in a five-letter group of Morse code letters and transmitted via the same AFCRL telemetry system that routinely transmits the scientific data for our balloon-borne experiments. The balloon VOR data are recorded by the AFCRL ground control station and the nationwide FCC ground-station network that also serve our experimental programs*. Simultaneous bearings from at least two VOR stations, of course, are needed to locate the balloon.

2. VOR NETWORK

There are approximately 900 VOR stations across the USA, operating on 600 channels in the 112 to 118 mc band (Figure 1). Our studies show that complete

Source: SHORT DISTANCE RADIO NAVIGATION
Prepared by U.S. Air Coordinating Committee

Figure 1. VOR Station Distribution in 1965

coverage of the U.S. and bordering areas for a balloon at 80,000 ft can be obtained by using just 12 of these channels.

The radiation from a VOR station is a vertical cone that can be received when the balloon-borne receiver is in line of sight of the VOR transmitter. Stations are separated by sufficient distances and their power output is controlled (50 to 200 W) in order to minimize interference between the vertical cones. Above certain altitudes and within limited areas some confusion may exist, but it was found by flight tests early in the program that such interference is easily detected.

3. BALLOON POSITION PLOTTING

The VOR balloon-borne encoder provides a total of 512 three-letter Morse code combinations to encode the 360 deg of bearing information; that is, the angular resolution is 0.7 deg. A dictionary containing the 512 bearing code combinations and the station-identifying code is available at the ground-monitoring stations. By using standard operational navigation charts, unskilled personnel at each receiving station can accurately locate the balloon.

To eliminate the problem of having to combine many navigational charts in order to plot the entire lengths of the radials drawn from distant stations, the AFCRL balloon branch has devised an efficient method for locating the intersection of the radials, using only the one map that includes the general location of the balloon in conjunction with a set of auxiliary tables. These tables (being compiled by computer) list the latitude and longitude crossings for each of the 512 VOR radials from each station selected for balloon tracking. These crossings will be computed for a maximum range of 350 miles, with an accuracy of 0.1 deg.

By noting the latitude-longitude coordinates for the last known position of the balloon, the operator can readily turn to the pertinent section of his table to find two nearby sets of latitude-longitude crossings for the new bearing. Thus he can locate on his map just the useful segment of the radial line. Repeating the process for at least one bearing from another station, he finds the intersection of the two radial segments, which, of course, locates the balloon. This method of plotting permits the use of any map scale, provided that it is a Lambert-conformant type projection.

At the present time, tables have been computed for stations in the Chico, California, and Holloman AFB, New Mexico, regions, as indicated by the inner circles drawn about the Chico and Holloman launch sites, Figure 2. (The outer circles enclose other VOR stations having radials that extend within the boundaries of the primary plotting areas.) This new plotting method will soon be tested on flights in these primary plotting areas.

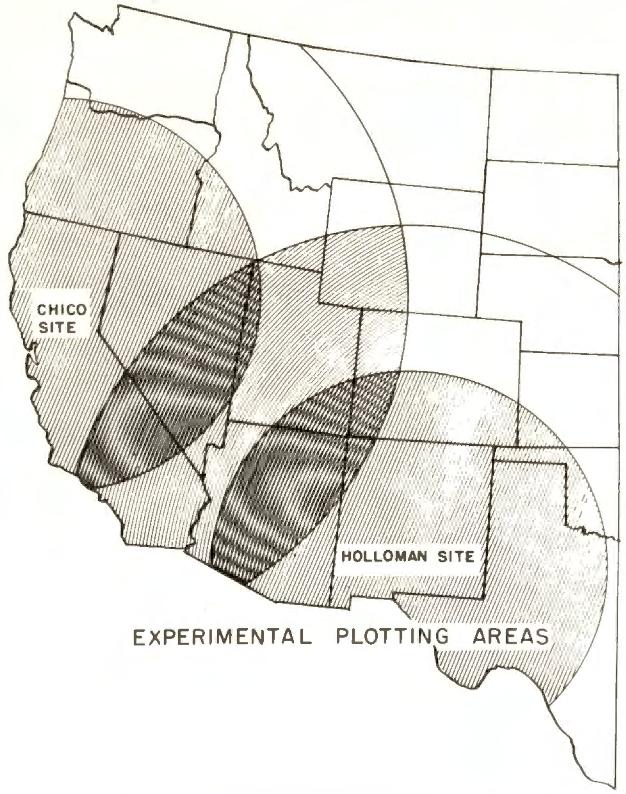

Figure 2. Experimental Plotting Areas

Figure 3. Test Results of Long Flight

4. FLIGHT TESTS

During the past year, we have conducted test flights of an all-transistorized vhf-hf prototype system from our Chico and Holloman launching facilities. Flight results confirm the 5-mile or better accuracy that was indicated in the early tests. Table 1 shows the variation of plots from different fixes selected at random from one flight record. These variations and plot accuracies were repeated in the trajectory of the long flight shown in Figure 3, using a tracking-radar plot as a standard.

Table 1. Variation of Plots from Fixes

Fixes	Bearing Distance From Fix (Miles)	Distance From Station (Miles)
#1	7.5	190
	0.5	170
	2.0	215
	1.0	175
	0.5	212
	0.5	225
	0.4	340
#2	9.0	192
	0.4	190
	2.0	205
	0.1	195
	0.4	212
	0.4	220
	5.0	335
#6	3.0	218
	2.0	235
	5.0	160
	1.0	245
	0.5	207
	0.5	215

5. FUTURE PLANS

Figure 4 shows the type of VOR receiving antenna used in these tests. This antenna will be replaced in future flights by the balanced-loop antenna shown in Figure 5. The new antenna minimizes bearing errors, has more gain at the horizon, has a greater discrimination against vertically polarized signals, and presents fewer mounting problems.

Seven operational units currently under development at Zenith Radio Corporation will be test flown in March 1966. It is expected that the new units will become operational by the end of 1966.

Figure 4. Rams Horn Antenna

Figure 5. Balanced-Loop Antenna