DMET COVERAGE

REPORT NO. 5791-8A
June 1959

Contract FAA/BRD-16
Task No. 8

Federal Aviation Agency
Bureau of Research and Development

Airborne Instruments Laboratory
A DIVISION OF CUTLER-HAMMER INC

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by

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Mineola, New York

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I. INTRODUCTION

The requirements for the Vortac coverage have been thoroughly investigated, both theoretically and experimentally. However, the requirements for coverage from a DMET facility have not been as well documented. The purpose of this investigation has been to explore the theoretical coverage of proposed low-power DMET (1 kw) facilities and to compare these coverages with those of other systems

A distance-only facility has a number of advantages in obtaining coverage over one supplying bearing. To obtain accurate bearing modulation of the antenna pattern over a large vertical angle, strict requirements are placed on the antenna design; these tend to widen the vertical pattern of the antenna and thereby reduce the gain. In addition, to reduce bearing errors from ground reflections, the radiation on the horizon has been reduced by tilting the peak of the beam upward as much as 6 degrees (resulting in a loss of 1 to 2 db on the horizon) Figure 1 shows that more than half of the space volume of interest is contained between the radio horizon and an elevation angle of 3 degrees. Another factor favoring greater coverage from a DMET is the lack of a requirement for bearing modulation of the antenna pattern. (See discussion on specification of sensitivity, page 5.)

The method of presentation is similar to that used by National Bureau of Standards (NBS) (reference 1). Figure 1 shows a set of contours of transmission loss, including the effect of the ground antenna The other system factors are then algebraically summed: transmitter power, transmission line losses, and the receiver sensitivity. This summation is the maximum allowable transmission loss Entering this value in the transmission loss curve gives the maximum range of the system as a function of altitude. Tables I and II compare a number of combinations of equipments. Two sets of range comparisons are made: one at an altitude of 40,000 feet and the other at 15,000 feet. The upper altitude permits comparisons within the radio horizon to the limits of the specified Vortac range (200 nautical miles). The lower altitude permits comparisons within the required limits (100 nautical miles) of the simplified airborne equipment.

In attempting range comparisons with other pulse type systems, such as the ATC beacon or the old DME, it was found that the test conditions would not permit valid comparisons. Flight tests were usually performed at low altitudes (below 20,000 feet), and the limiting range was often line-of-sight. Examination of Figure 1 shows that in the region of the radio horizon a difference of system performance of many decibels will result in a range difference of only a few miles. Furthermore, the propagation curves shown in Figure 1 are based on what can be considered a bad site (considering that the navigation system must be reliable on a large majority of potential sites). The 95-percent reliable range derived in Tables I and II, therefore, will be conservative compared with flight-test results on average sites.

II. PROPAGATION LOSS

Antennas that radiate appreciable energy at angles below the radio horizon are subject to considerable reduction of reliable range within the radio horizon because of interference effects between the direct ray and the ground-reflected ray. Where the earth is relatively smooth, the positions and amplitude of the lobes can be predicted However, for the general case, it is necessary to calculate coverage on a probability basis. Since the coverage of the navigation aid is defined as the space volume where a reliability of 95 percent or better is achieved, the propagation curves in this report are calculated on a basis of the transmission loss being equal to or less than the given value 95 percent of the time

The curves in Figure 1 are calculated by two means--each giving the least favorable case. The portion of the curve for each loss contour lying parallel to the radio horizon is calculated on a basis of specular reflection (180-degree phase reversal at ground, reflective coefficient limited to a maximum of 0 7). A 5 7-db standard deviation of loss about the calculated value is also assumed, this results in a 9-db increase of loss for 95-percent probability. This value is based on measurements made by NBS at VHF and UHF near the radio horizon (reference 2) The upper portion of each curve is based on the addition of a constant direct ray and a reflected ray with random phase This includes effects of nulls or scalloping in the vertical radiation pattern. These values of transmission loss are considerably greater than those usually predicted using median values (50 percent) or free space loss.

The curves of Figure 1 are calculated, using the antenna pattern of Figure 2, at a height of 28 feet and a frequency of 1000 Mc. In this report, to compare systems with different antenna patterns, ground antenna gains are referred to the FAA specified antenna gain, each at the horizon so that range comparisons can be made on the chart computed for the FAA antenna. This comparison is not strictly valid, but it will give reasonable comparisons without actual calculation of the propagation curves for each antenna.

In this report, airborne antenna gains are assumed to be zero db relative to the gain of an isotropic antenna. This assumption is based on measured radiation patterns of airborne antennas at 1000 Mc, which are extremely complex with lobes and nulls having only a few degrees of separation. The memory feature of DMET, combined with the aspect instability (in terms of a few degrees) of the aircraft, results in an effective antenna gain greater than that obtained by pattern integration The assumption of an isotropic gain is a conservative estimate of this effect

III EQUIPMENT CHARACTERISTICS

The transmitter power listed in Table I for Vortac and the FAA installations of the GRN-9 is the output of the beacon cabinet An additional loss of 1 3 db is included for the transmission lines and the TMC unit. The URN-3 installation includes a typical transmission line loss of 4 db The listing for the proposed DMET is the power delivered to the antenna

The antenna gain listed in Table I is the gain at the horizon relative to the gain of a Vortac antenna

The characteristics assumed for the airborne equipment are, in general, guided by "ARINC Characteristic No 521B." Two receiver characteristics were assumed, 116 dbw for a high-performance airborne equipment and 106 dbw for a simplified equipment The transmitter power output is minimum for standard conditions (800 watts peak) for the high-performance equipment For the simplified equipment an output of 50 watts peak is assumed Two values of the transmission cable loss were assumed; the 5-db value represents a maximum expected cable run of 50 to 60 feet, and the 2-db value represents a good installation For the simplified equipment, cable runs in excess of 25 feet are not expected, and a cable loss of 2 db was used in all comparisons in Tables I and II.

ARINC Characteristic No 521B specifies the airborne receiver sensitivity for the distance measuring function only When bearing modulation is present on the ground transmitted signal (Vortac), the difference between the interrogation rate of the airborne equipment and the rotation rate of the ground modulation pattern is such that the likelihood of a series of interrogations occurring during the minimum of the antenna pattern is very low This factor, combined with the memory feature of the distance function in the airborne receiver, results in a higher effective sensitivity for distance measurement than for bearing measurement When an aircraft is due west of a Vortac station, indicated bearing 90 degrees, the transmission of the north reference coincides with the minimum of the rotating bearing modulation pattern For a total modulation of 50 percent, the minimum amplitude of the antenna pattern is 6 db below the average amplitude. Based on these relations, the effective receiver sensitivity assumed for the bearing function in Table I is 6 db less than that for DME only

IV. CONCLUSION

Examination of Tables I and II indicate that a low-powered DMET can provide adequate service with either the high performance or the simplified airborne equipment.

V. REFERENCES

1 M T Decker, "Tacan Coverage and Channel Requirements," National Bureau of Standards, Report No. 5025, 29 October 1956

2 "Prediction of the Cumulative Distribution with Time of Ground Wave and Tropospheric Wave Transmission Loss," National Bureau of Standards, Report No 5582, 30 June 1958

TABLE I

REPLY LINK COMPARISONS

Ground Equipment			Airborne Equipment		Maximum Allowable Transmission Loss		Range (95 percent Probability) 40,000 ft		15,000 ft
System and Peak Transmitter Power	Antenna Power (dbw)	Antenna Gain Over Vortac (db)	Receiver Sensitivity (dbw)	Transmission Line Loss (db)	DME Only (db)	Bearing* (db)	DME Only (nautical miles)	Bearing (nautical miles)	DME Only (nautical miles)
Vortac	42.4	0	-116	5	153.4	147.4	>200	>200	>140.0
installation	42.4	0	-116	2	156.4	150.4	>200	>200	>140.0
23.5 kw	42.4	0	-106	2	146.4	140.4	>200	140	137.5
FAA GRN-9	37.5	-1.5	-116	5	147.0	141.0	>200	145	1[illegible]8.0
installation	37.5	-1.5	-116	2	150.0	144.0	>200	185	>140.0
7.5 kw	37.5	-1.5	-106	2	140.0	134.0	137	90	1[illegible]2.5
UPN-3 single	33.0	0.4	-116	5	144.4	138.4	[illegible]98	125	135.0
military	33.0	0.4	-116	2	147.4	141.4	>200	155	138.0
installation	33.0	0.4	-106	2	137.4	131.4	115	80	92.0
5.0 kw									
DMET with	42.4	+4.0	-116	5	157.4	—	>200	—	>140.0
DTB antenna	42.4	+4.0	-116	2	160.4	—	>200	—	>140.0
23.5 kw	42.4	+4.0	-106	2	150.4	—	>200	—	>140.0
DMET with	30.0	+4.0	-116	5	1[illegible].0	—	>200	—	137.0
DTB antenna	30.0	+4.0	-116	2	148.0	—	>200	—	139.0
1.0 kw	30.0	+4.0	-106	2	138.0	—	120	—	97.0
DMET with	30.0	+6.0	-116	5	147.0	—	>200	—	138.0
12.1 db	30.0	+6.0	-116	2	150.0	—	>200	—	>140.0
antenna	30.0	+6.0	-106	2	140.0	—	137	—	112.5
1.0 kw									

* Allowing 6-db bearing modulator loss

TABLE II

INTERROGATION LINK COMPARISONS

	Airborne Equipment				Ground Equipment			Range (95 percent Probability)	
System and Peak Airborne Transmitter Power	Transmitter Power (dbw)	Antenna Gain Over Isotropic (db)	Transmission Line Loss (db)	Effective Radiated Power (dbw)	Receiver Sensitivity (dbw)	Antenna Gain Relative to Vortac (db)	Maximum Allowable Transmission Loss (db)	40,000 ft (nautical miles)	15,000 ft (nautical miles)
A	29	0	5	24	-123 7	0	147 7	>200	139
	29	0	2	27	-123 7	0	150 7	>200	>140
B	29	0	5	24	-123 7	+6	153 7	>200	>140
	29	0	2	27	-123 7	+6	153 7	>200	>140
C	17	0	2	15	-123 7	0	138 7	125	103
D	17	0	2	15	-123 7	+6	144 7	>200	135

A = High-performance airborne equipment with Vortac ground antenna, 800 w

B = High-performance airborne equipment with 12 1-db ground antenna, 800 w

C = Simplified airborne equipment with Vortac ground antenna, 50 w

D = Simplified airborne equipment with 12 1-db ground antenna, 50 w

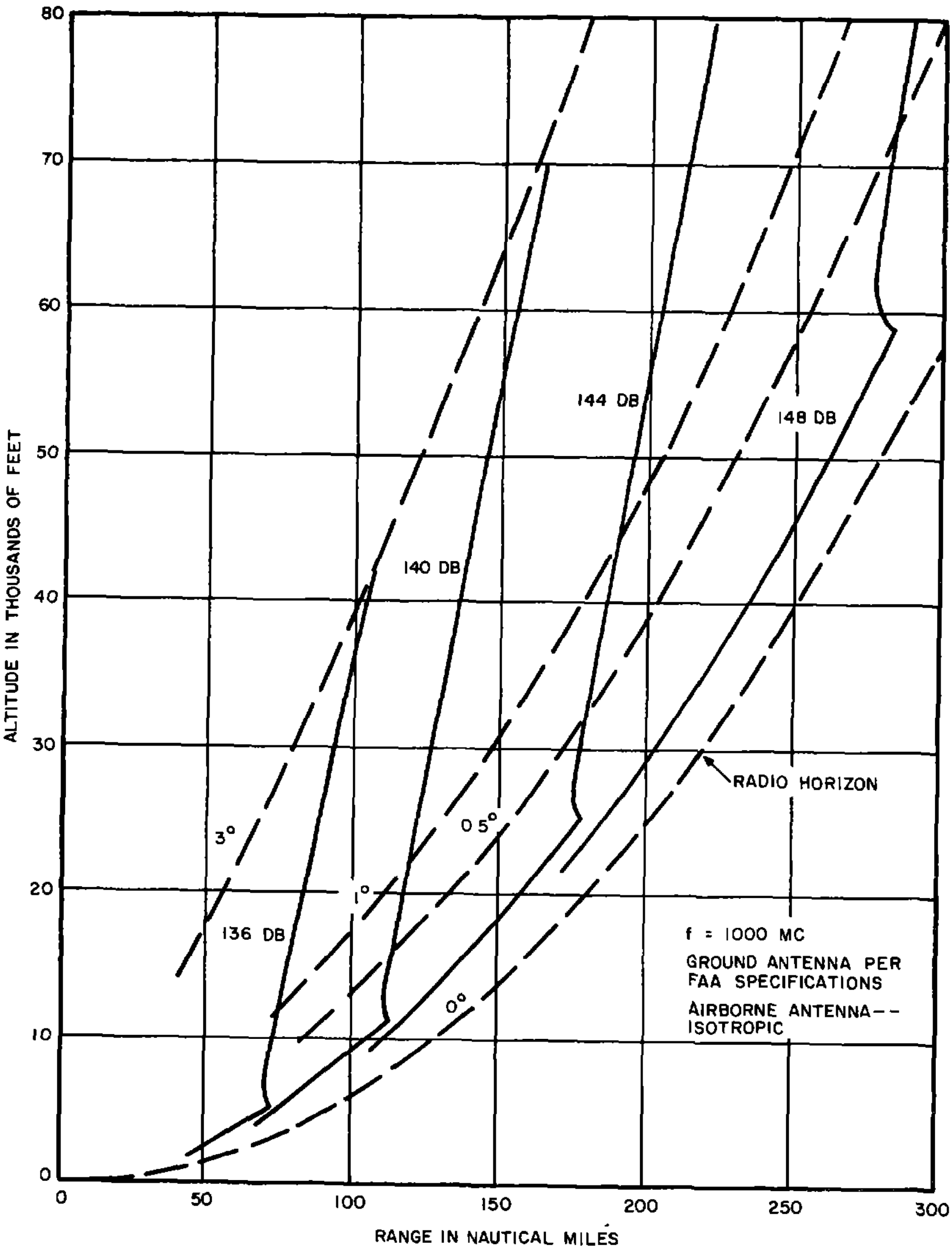

FIGURE 1 TRANSMISSION LOSS, 95 PERCENT PROBABILITY

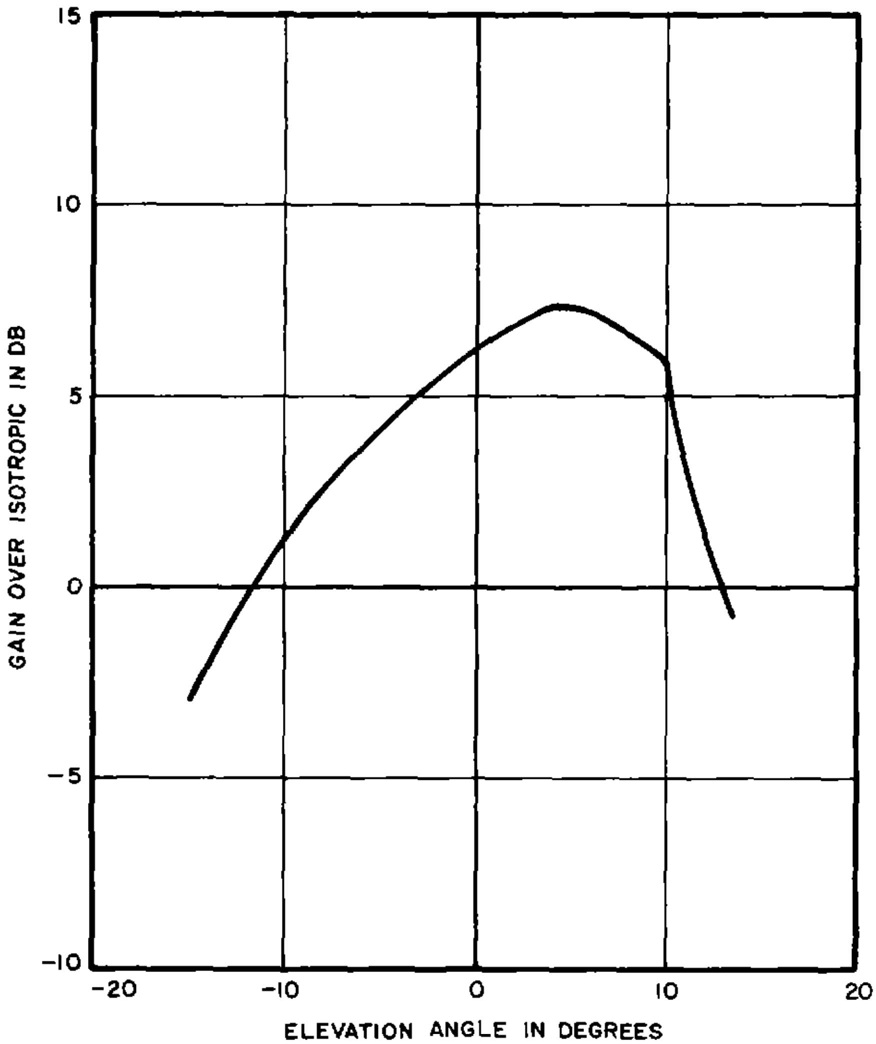

FIGURE 2 FAA SPECIFIED GAIN FOR VORTAC ANTENNA