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TRACKING FLARE INSERTION LOSS TESTS AT 9.2 AND 24 kMc

[UNCLASSIFIED TITLE]

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ABSTRACT
[Confidential]

Insertion loss measurements at 9.2 and 24 kMc have been taken through the exhausts of tracking flares of the type used in the Navy Bullpup Missile System. These measurements were made in the NRL high-altitude facility, where the flares were fired at simulated altitudes in the 20 to 30 thousand feet region. For K-band transmission, a signal loss of 10 db/inch through the flare exhaust is typical in this altitude region.

PROBLEM STATUS

This is an interim report on one phase of the problem; work is continuing on other phases.

AUTHORIZATION

NRL Problem R07-07
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INTRODUCTION

The Navy Bullpup missile system incorporates command guidance by the fighter bomber in guiding the missile to the target. The pilot visually tracks the missile in its flight and thereby initiates the proper commands to the missile. Tracking flares on the tail of the missile aid the pilot in this procedure.

Part of the propagation path for the guidance signal can be through the flare, depending upon placement of flares and antenna. If the guidance signal suffers appreciable loss going through the exhaust, there exists the possibility that the pilot will lose control of the missile. Herein the term "exhaust" refers to that luminous volume expelled from the flare by burning. Figure 1 shows the missile exhaust fairing with two tracking flares and a K-band command link antenna situated on the periphery.

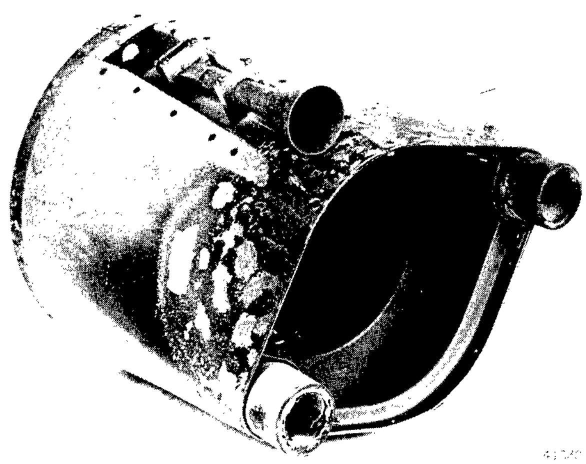

Fig. 1 - Bullpup missile exhaust fairing

For a number of years part of the research effort of the NRL Flame Laboratory has been in the field of electromagnetic propagation through missile exhausts. Rocket motors can be operated in the high-altitude chamber of the laboratory under ambient pressures from sea level to 150,000 ft. Electromagnetic probing systems have been developed which measure the attenuation of a signal passing perpendicularly through the exhaust while the signal beam is traversing across the exhaust axis or along it. Since our measurements are taken with the flare exhaust axis essentially horizontal, we describe loss profiles as being either horizontal or vertical.

METHOD OF INVESTIGATION

Figure 2 shows the probing system inside the altitude chamber. It consists of a movable focusing lens-horn assembly which can traverse either along or perpendicular to the exhaust axis. (A small rocket motor is shown where the tracking flares were positioned for these tests.) The chamber has interior dimensions 7 ft by 10 ft by 7 ft high. Figure 3 shows the insertion loss measuring system. Loss measurements were taken at 9.2 kMc (in the X band) and 24 kMc (in the K band). Figure 4 shows an expended flare. Its overall length is 10 inches. The flare is ignited by an electrical firing squib. During the 60-second flare burning period the probing system can make either three horizontal traverses along the exhaust axis or three vertical traverses at a given position along the exhaust axis. Insertion loss is determined by a substitution method. The focusing property of the lens-horn at K band is such that 90% of the energy from the klystron passes through a 3/4-inch circle at the focal point. At X band the circle is 2-1/2 inches. The movable rack is positioned so that the exhaust axis passes through the focal point.

Nine tracking flares were fired in the NRL high-altitude chamber with X-band loss measurements being taken on five of the runs and K-band loss measurements being taken on the remaining four (Table 1). A photograph showed that at 7 inches from the flare exit plane the exhaust is 3 inches in diameter at a pressure close to 300 mm Hg (24,000 feet). Observations were made in this region because here the flare exhaust diameter is larger than the focusing diameter of the 24-kMc lens-horn combination. Upon ignition the flare puts out enough smoke to prevent the taking of good exhaust pictures. From 300 mm Hg

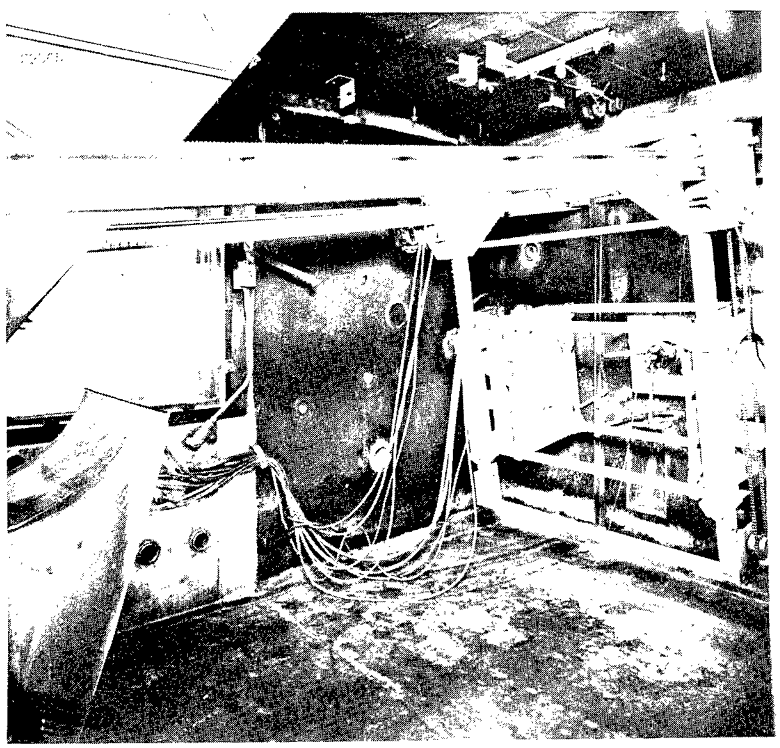

Fig. 2 - Probing assembly inside altitude chamber

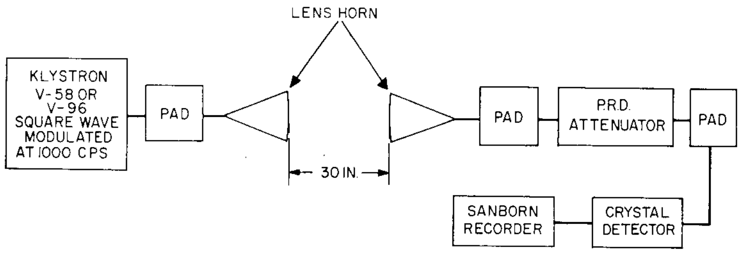

Fig. 3 - Insertion loss measuring system

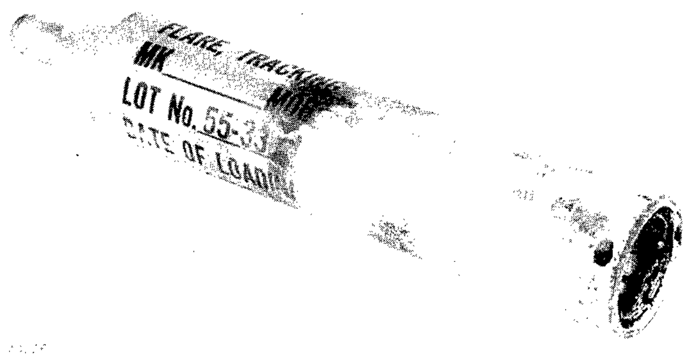

Fig. 4 - Expended tracking flare

(24,000 feet) to 210 mm Hg (30,700 feet), the change in the exhaust diameter will be less than the indeterminancy in the diameter measurement taken from a photograph. At 110 mm Hg (Test 3171) the exhaust diameter could not be determined from photographs; hence insertion loss in db/inch could not be calculated.

RESULTS

The high insertion losses observed indicated that the exhaust is probably reflecting as well as absorbing the impinging energy and that both may be of comparable magnitude. The loss values at 24 kMc appear to be higher than those at 9.2 kMc, although theory predicts the opposite. This theory assumes the loss mechanism to be due entirely to free electrons. No doubt there is ionization in the flare exhaust, but additional loss may be caused by dust-like particles in the exhaust. The poorer lens focusing at 9.2 kMc is another factor which will tend to result in insertion loss lower than the true value.

Figure 5 shows how the loss changes with distance from the flare exit plane at 9.2 kMc. Figure 6 is a typical vertical profile loss as a function of distance off the exhaust axis. Here the probe was stationed 7 inches from the exhaust exit plane and the frequency is 9.2 kMc. Figure 7 shows how the insertion loss varies with time alone. During this test the probe was fixed at 7 inches from the flare exit plane and the frequency was 24 kMc. All tests show some noise modulation of the signal and this effect has also been included in Table 1.

One test was attempted at a simulated altitude of 70,000 ft, but the flare would not ignite at this altitude. It was learned later that they are not expected to work satisfactorily above 35,000 ft.

Table 1
Summary of Tracking Flare Insertion Loss Tests

Test	Type of Profile*	Frequency (kMc)	Ambient Pressure (mm Hg)		Max. Loss		Noise, Peak to Peak (db)
			Fire	Cut	Db	Db/In.	
3141	H	9.2	300	210	26.6	8.9	4.2
3142	V 7 in. from exit plane	9.2	300	220	29.4	9.8	2.5
3171	H	9.2	110	110	31.0	—	4.4
341	H	9.2	300	210	27	9	3.8
342	H	9.2	300	210	off scale	—	—
3181	H	24	300	220	31.4	10.5	5.6
3182	V 7 in. from exit plane	24	300	220	29.4	9.8	limiting
3191	V 7 in. from exit plane	24	300	220	35.2	11.7	5.8
3261	Fixed position 7 in. from exit plane	24	300	250	35.5	11.8	5.3

* H is horizontal; V is vertical.

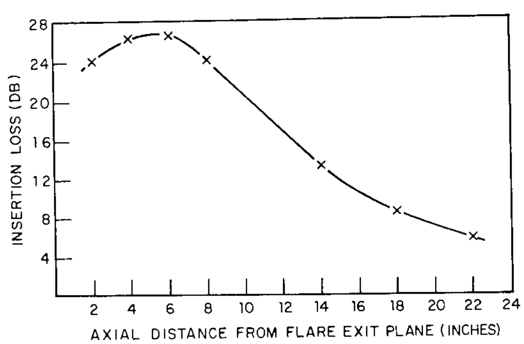

Fig. 5 - Horizontal profile of flare insertion loss at 9.2 kMc and ambient pressure of 300-210 mm Hg (Test 3141: see Table 1)

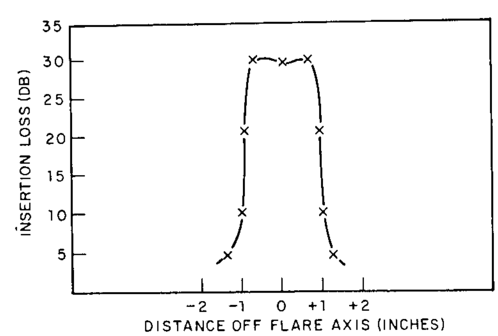

Fig. 6 - Vertical profile 7 inches from flare exit plane of flare insertion loss at 9.2 kMc and ambient pressure of 300-220 mm Hg (Test 3142)

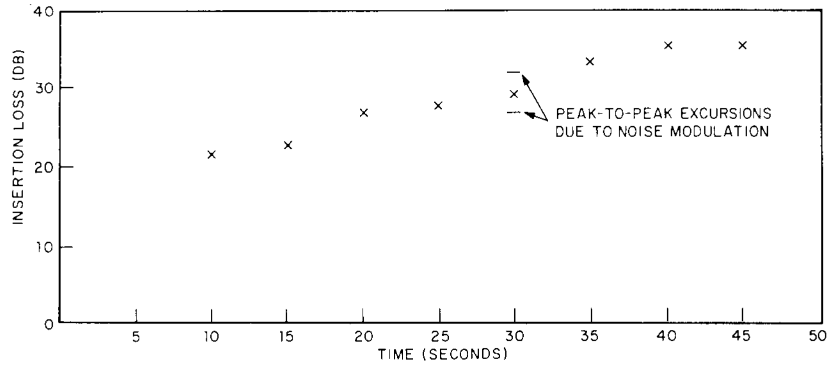

Fig. 7 - Time variation 7 inches from flare exit plane of flare insertion loss at 24 kMc and ambient pressure of 300 mm Hg at ignition and 250 mm Hg at burnout (Test 3261)

CONCLUSIONS

The measurements described very definitely show the high insertion loss experienced by X-band and K-band signals when they are forced to traverse the luminous volume trailing a Bullpup flare. Study of the geometry associated with guidance signals and the flare volume show that interference (signal loss and other effects) increases as distance between the guidance antennas and flare decreases. Actually the flare cannot appreciably shadow the signal path unless the signal antennas and flares are in close proximity such as when both are mounted on the exhaust fairing. If there are compelling reasons for mounting the microwave antenna near the flares a diversity system employing more than one antenna should reduce interference to an acceptable level.

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