It is seen from Eq. (45) that the optimal search density is moving with the probability cloud. At time t the search density is equal to $\rho_0\hat{\rho}_0$ throughout ellipsoid

$$[x - x_c(t)]^2/\sigma_{2t}^2 + y^2/\sigma_1^2 + z^2/\sigma_1^2 = \rho_0^2$$

where $x_c(t) = x_c(0)(1 + \alpha_1 t)^{2/3}$ and $\sigma_{2t} = \sigma_1(1 + \alpha_1 t)^{-1/3}$. Our result is related to one of the examples by Arkin,[4] although in our case the target is moving.

References

[1] Koopman, B. O., "Search and Screening," Rept. 56 (ATI 64627), 1946, Operations Evaluation Group, Office of the Chief of Naval Operations, Washington, D.C.

[2] Hellman, O., "On the Optimal Search for a Randomly Moving Target," 69-33, Oct. 1969, Operations Research Center, College of Engineering, Univ. of California, Berkeley, Calif.

[3] Hellman, O., "On the Effect of a Search upon the Probability Distribution of a Target whose Motion is a Diffusion Process," Rept. 2, Jan. 1969, Institute for Applied Mathematics, Univ. of Turku, Turku, Finland.

[4] Arkin, V., "Uniformly-optimal strategies in search theory," *Theory of Probability and Applications*, Vol. 9, No. 4, June 1965, pp. 746–753.

RFI Measurements on a LES-7 Prototype Pulsed Plasma Thruster

R. E. Dolbec*

Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Mass.

In recent years electric propulsion technology has been successfully used in space application. Pulsed plasma thrusters (PPT) were flown on the LES-6 satellite to provide thrust for station-keeping and station-changing functions. A thruster with ten times as much power is being developed for LES-7. These units are manufactured by the Republic Division of Fairchild-Hiller Corporation for Lincoln Laboratory. Possible interference with the communication system is a matter of concern. The operation of PPT's is inherently "noisy" and radio frequency interference (RFI) effects on the communication system are now well-known. Although observations indicate that RFI did not significantly affect system performance of LES-6, there is greater concern over RFI emitted from the more powerful units. This Note gives the result of RFI measurements made at X-band on a LES-7 prototype thruster.

Measurement of RFI

The LES-7 prototype used in these measurements was developed for the Wright-Patterson Air Force Base, Aero Propulsion Laboratory. The unit was measured as received without a metal case to suppress RFI. It was mounted in a 4-ft-diam vacuum chamber that was lined with broadband absorber material (Fig. 1). Thus, the measurements are relatively free from chamber resonances or other extraneous signals.

The PPT was operated under normal operating conditions firing once very 1.5 sec and was measured as though it were a transmitter emitting a pulse of noise at some time set by the trigger.

Basically the thruster consists of a 20-joule storage capacitor shunted across the upper and lower electrodes (the cathode and anode) of the output nozzle. Behind this nozzle is a teflon fuel bar 5 in. long and 1 in. × 1 in. in cross section. Just in front of each fuel bar and located in the upper electrode is a spark plug which is used to initiate the high-voltage discharge of the capacitor. Within 3 μsec the main capacitor discharges all of its energy, ionizing teflon particles and accelerating the ionized particles through the nozzle to provide thrust. After recharge, a pulse reinitiates the process and it is repeated at a regular pulse frequency.

Received March 2, 1970; revision received March 30, 1970. This work was sponsored by the Department of the Air Force.

* Engineering Assistant, Space Communication Group.

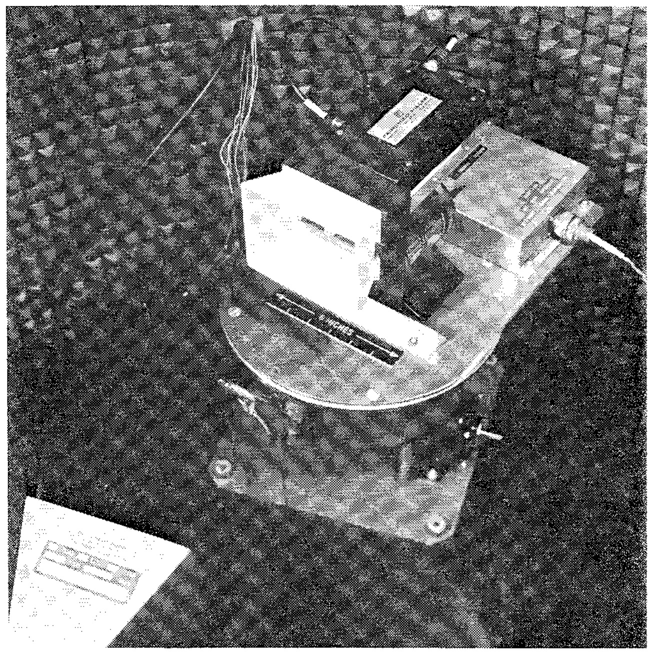

Fig. 1 Thruster in chamber.

Initially, a low noise receiver was used with a Hewlett-Packard spectrum analyzer. These measurements, at UHF and at X band, did not provide reliable data for a number of reasons. There was no way to synchronize the PPT firing with a spectral display, and the noise was so broad that components could be isolated almost anywhere from 100 MHz to 10 GHz. Attempts to measure the individual pulses constituting the RFI also failed, because of instrument limitations. However, it appeared that most of the RFI was associated with the main capacitor discharge, because both occurred 2.0 μsec after the triggering process; on the other hand, it was not contained in the ensuing plasma cloud, because its duration was ~1 μsec, whereas the luminescence of the plasma cloud persists for 15 to 20 μsec. The level of the RFI changes 5 to 10 db with successive discharges, in random fashion; this phenomenon may or may not indicate that the thrust of the PPT varies with successive discharges. The measurement block diagram that was finally used to measure the characteristics of the RFI is shown in Fig. 2.

Figure 2 shows the X-band horn, a 100-MHz bandwidth filter centered at 8 GHz and an X-band detector with 100-MHz video bandwidth. The scope display was triggered by the PPT trigger pulse. The noise pulses were recorded to be of 1.0-μsec duration with a peak power of +4.5 dbm at the PPT. The noise from the thruster is directional; it emanates from the throat in a cardioidal pattern in the horizontal plane.

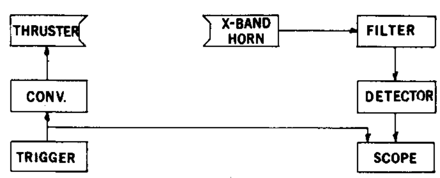

Fig. 2 Block diagram.

This measurement was obtained, only in the horizontal plane, by rotating the thruster in 10° increments.

Results and Conclusions

As can be seen in Fig. 3, the peak noise power occurred at ±25° from boresight and was minimal (limited by the 10 db dynamic range of the measurement) at ±90° from boresight. The noise is not polarized; no change in level was observed when rotating the horn on its own axis. The photos in Fig. 3 were obtained by opening the camera lens and allowing 15 firings for each picture. The calibration in these photos is 0.0 dbm = 1 div (5 mv), + 3.0 dbm = 2 div, + 4.2 dbm = 3 div.

These measurements, made in a narrow band of interest at X band, provide data that can be used in the initial design of the LES-7 communication system. These data indicate the noise relative to the thruster; they do not allow for satellite antenna gain characteristics or the coupling of the noise with these antennae. Thus, future measurements will have to be made on the actual satellite antennae models and systems when they become available.

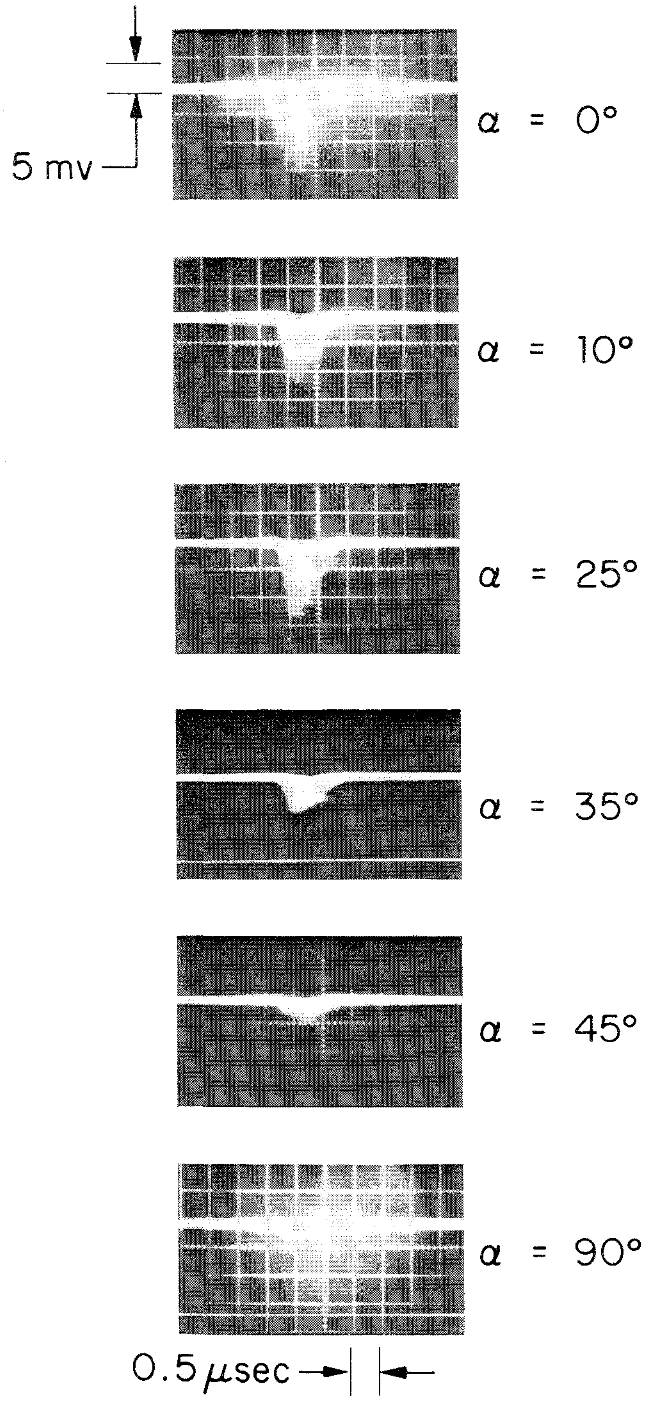

Fig. 3 Measured RFI for various angles α between thruster discharge axis and X-band antenna.

Calculation of Real-Gas Effects in the Depressurization of Air Storage Cylinders

THEO GORDON KEITH JR.*
Naval Ship Research and Development Laboratory, Annapolis, Md.

AND

JAMES E. A. JOHN†
Department of Mechanical Engineering, University of Maryland, College Park, Md.

Nomenclature

A_i	= interior surface area of cylinder
$A_i(T)$	= functional relation of temperature dependent density coefficients
A_t	= cross-sectional area of nozzle throat
a	= speed of sound
a_{ij}	= subscripted virial coefficients
c_k	= coefficients in the $c_{p,0}$ series of Appendix
c_p	= specific heat at constant pressure
$c_{p,0}$	= perfect-gas specific heat at constant pressure
D_i,D_t	= inside diameter and throat diameter of cylinder
$f_i(\rho,T)$	= functions of $Z = Z(\rho,T)$, Appendix, $i = 1,2,\ldots,6$
Gr	= Grashof number, $D_i^3\rho^2 g\beta\Delta T/\mu^2$
g	= acceleration of gravity
$g_i(T_2,T_1)$	= specific heat functions, Appendix, $i = 1,2,3$
h	= specific enthalpy
h_i	= heat-transfer coefficient at interior of cylinder
k_0	= thermal conductivity of flask gas
M_t	= Mach number evaluated at nozzle throat
$M_{t,j}$	= jth estimate of M_t (j = I,II,...)
$m,\dot{m}_0$	= mass and mass flow rate of cylinder gas
m_w	= mass of cylinder wall
P_{0i}	= initial pressure of cylinder gas
Pr	= Prandtl number, $c_p\mu/k$
q_i	= heat-transfer rate at interior of cylinder
R	= gas constant
$R(\rho_t)$	= residual in iteration for ρ_t, Eq. (9)
s	= specific entropy
T_{0i}	= initial temperature of cylinder gas
$T_{t,j}$	= jth estimate of T_t (j = I,II,...)
U_0,u_0	= total and specific flask gas internal energies
V,v	= volume and specific volume
w	= velocity
Z	= compressibility factor
β_0	= volumetric expansion coefficient of cylinder gas
γ	= ratio of specific heats
ϵ	= tolerance used for successive approximations
θ,θ_c	= time, and critical time required for P_t to reach P_∞
μ_0	= dynamic viscosity of cylinder gas
ρ	= density
$\rho_{t,I},\rho_{t,j}$	= first and jth estimations of ρ_t
$\overline{(\ )}$	= arithmetic average of ( ) over one time interval

Received November 7, 1969; revision received March 9, 1970.

* Mechanical Engineer.

† Professor.