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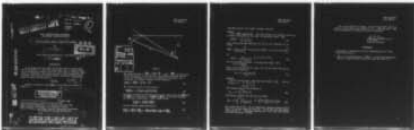
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THE LLOYD MIRROR EFFECT ON EXPLOSIVE SOURCES.

by

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B. F./Cron

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INTRODUCTION

It is assumed that the reader is familiar with the Lloyd mirror effect (Reference 1). When this effect takes place a single source can be replaced by a dipole source. In this study, a transient signal source is considered. The energy spectrum of the received pulse is obtained. The equations for the filtered, integrated energy versus angle of arrival are also given.

ANALYSIS

⑫ 4 p.

Consider an impulsive source  $\delta(t)$  and the geometry as given in Figure 1.

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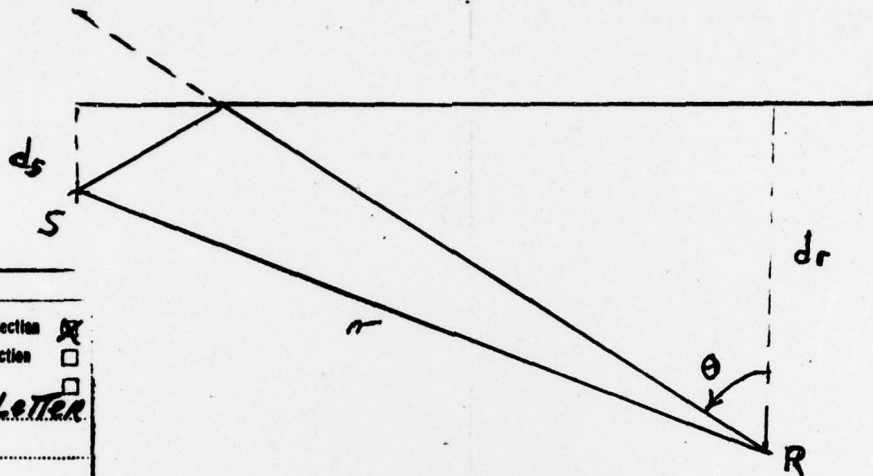
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Figure 1

The received pulse is  $\delta(t) - \delta(t - \tau)$ , where  $\delta(t)$  is due to the direct arrival and  $-\delta(t - \tau)$  is due to the surface reflected arrival.

$\tau$  is the difference in travel time between the two paths. By definition, the impulse response of this system is

$$h(t) = \delta(t) - \delta(t - \tau) \quad (1)$$

The transfer function of the system is

$$H(f) = 1 - \exp(-j2\pi f\tau) \quad (2)$$

Let us now consider an arbitrary pulse at the source given by  $x(t)$  and let  $X(f)$  be its spectrum. Let  $y(t)$  and  $Y(f)$  be the received waveform and spectrum, respectively. For a linear system,

$$Y(f) = H(f) X(f) \quad (3)$$

and the received energy spectrum is

$$E(f) = Y(f) Y^*(f) = H(f) H^*(f) X(f) X^*(f) \quad (4)$$

where  $*$  represents the complex conjugate operator.

EXAMPLE

Let  $x(t) = \exp(-at)$ . The time history of an explosive source is sometimes represented by this type of exponential pulse. Then

$$X(f) = \frac{1}{a + j2\pi f} \quad (5)$$

Then substituting from equations (5) and (2) into equation (4), we obtain

$$E(f) = \frac{1}{a^2 + (2\pi f)^2} \left[ (1 - \exp(-j2\pi f\tau))(1 - \exp(j2\pi f\tau)) \right]$$

or

$$E(f) = \frac{4}{a^2 + (2\pi f)^2} \sin^2(\pi f \tau) \quad (6)$$

From the geometry in Figure 1, if  $r \gg d_s$  and  $r \gg d_R$ , then

$$\tau \approx \frac{2d_s d_R}{rc}$$

where  $c$  is the velocity of sound. For the far field, this may be approximated further by

$$\tau \approx \frac{2d_s \cos \theta}{c} \quad (7)$$

RECEIVER

Let the receiver have a flat pass band from  $f_1$  to  $f_2$ . That is,  
 $H_R(f) = K, \quad f_1 \leq f \leq f_2$   
 $-f_2 \leq f \leq -f_1$

The energy output of this receiver is

$$E_o = K^2 2 \int_{f_1}^{f_2} E(f) df \quad (8)$$

Substituting equation (6) into (8), we obtain

$$E_o = K^2 2 \int_{f_1}^{f_2} \frac{4}{a^2 + (2\pi f)^2} \sin^2\left(\frac{\pi f 2d_s \cos \theta}{c}\right) df \quad (9)$$

For a given  $f_1$  and  $f_2$ , we can numerically integrate equation (9) to obtain the energy output for given  $\theta$ . We can then plot the energy output versus  $\theta$ . Numerical integrations of this type were made in the PARKA (Reference 2) study.

For a sharp pulse,  $Q$  is large. If the frequencies  $f_1$  and  $f_2$  in equation (9) are small, such that  $Q \gg 2\pi f$ , then the  $2\pi f$  term in the denominator of equation (9) may be eliminated.

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1. "Principles of Underwater Sound for Engineers," by R.J. Urick, McGraw Hill Book Co.
2. Hasse, R.W. and Martin R.L., "PARKA I - Acoustic Processing and Results," NUSL Tech Memo 2210-015-69, July 28, 1969. (C)