LEGIBILITY NOTICE

A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

LA-UR

LA-UR--90-1434 --2

DE90 010616

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

TITLE: A LOW-COST INFRARED TELEMETRY SYSTEM FOR KILOHERTZ-BANDWIDTH DATA ACQUISITION

AUTHOR(S): Michael D. Holder

SUBMITTED TO Proceedings of the Test Technology Symposium III, 19-21 March 1990, Laurel, Maryland

Publishers: Science and Technology Corporation
101 Research Drive
Hampton, VA 23666-1340

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

A LOW-COST INFRARED TELEMETRY SYSTEM FOR KILOHERTZ-BANDWIDTH DATA ACQUISITION

M. D. Holder
Los Alamos National Laboratory
Los Alamos, NM 87545, USA

ABSTRACT

A telemetry system is described that transmits data from three 8-kHz analog inputs by means of an infrared-optical-digital communications channel. This system is used to acquire accelerometer data on a rocket sled during its 300-m flight. An optical communications channel at 950 nm is used to send digitally encoded analog signals from the sled to a fixed receiver. The signal is recorded and decoded by a computer. The transmitter includes a differential amplifier and low-pass filter for each input channel. Excitation for piezoresistive accelerometers is also provided. Each input channel is sampled and digitized at a 16-kHz rate. The transmitter is built on a single printed-circuit card measuring 7.5 cm by 23 cm, weighing less than 450 g including batteries. This system can be used on tests involving destruction of the transmitter because of its low cost.

1. INTRODUCTION

The Explosives Applications Group at Los Alamos has recently constructed a 300-m rocket sled track for missile warhead testing. Warhead packages are accelerated to speeds in excess of 300 m/s (see Fig.1). Information about the shock loading of warhead packages is needed for design purposes. Three 8-kHz channels for accelerometer signals are required.

Commercial equipment using radio-frequency channels is available for this type of testing. However, this equipment is expensive because robust construction is required to survive the extreme shock environment aboard the missile in flight, and an expensive ground station is required. The cost of the transmitter, which may be destroyed by the warhead being tested, could be 25-50% of the test cost. These potential costs motivated the development of a much less expensive system that could be destroyed without concern for its cost.

2. SYSTEM OVERVIEW

The telemetry system (Fig. 2) is based on an optical communications channel implemented with inexpensive infrared-emitting diodes, a simple receiver, and a PIN diode detector. The digitally encoded accelerometer signals are transmitted on this channel using pulse code modulation. A digital error detection scheme is included to provide noise rejection. The detected optical signal is connected, through a discriminator, to a computer, where it is recorded, decoded, and scaled to engineering units.

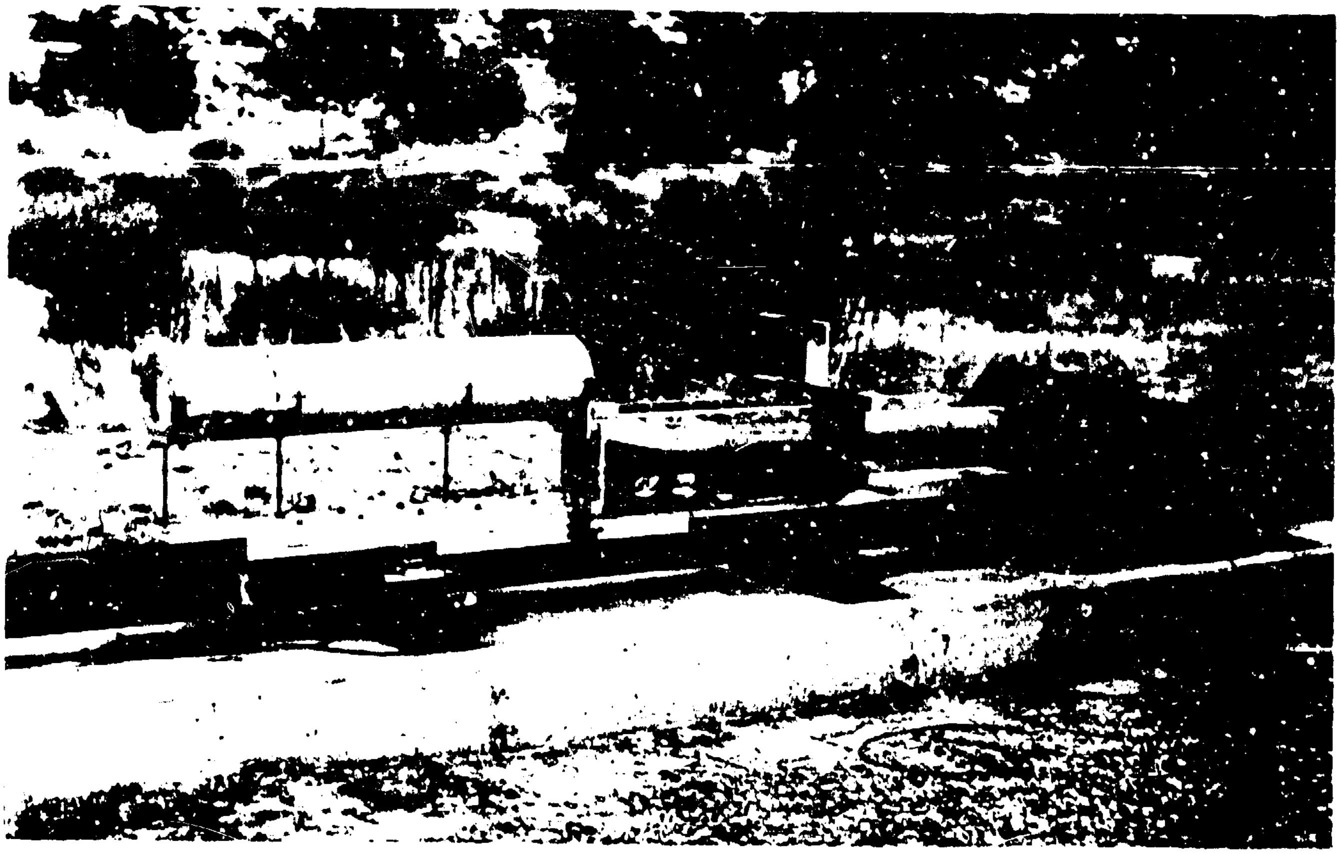

Figure 1. Rocket sled assembly.

3. OPTICAL CHANNEL

The Seimens SFH-400-3 infrared-emitting diode is the basis of the optical channel. This diode is specified to emit an optical intensity of 32 mW/sr at 100-mA drive current. However, if it is pulsed with 7 A for 300 ns, it produces a peak intensity of >500 mW/sr. An integral lens, which produces a 12° half-intensity beam, is the only optical element needed on the transmitter. An IRF640 Power metal oxide semiconductor field-effect transistor driven by a 300-ns pulse is used to switch the diode at the required current (Fig. 3).

An RCA CA30808 PIN photodiode is used in the photoconductive mode to detect the 950-nm pulses in the receiver (Fig. 4). A cascode amplifier (gain = 4×10^5 V/A) brings the signal to a useful level. The complete receiver exhibits a noise-equivalent optical power of approximately 20 nW.

A receiving lens is required to collect the transmitted light. The amount of light power collected is

$$P_c = \frac{I_d A_L}{D^2} \; ,$$

where I_d is the transmitter diode intensity in milliwatts per steradian, A_L is the area of the receiving lens in square meters, and D is the distance to the emitter in meters. A 0.5 m^2 plastic Fresnel lens is used to collect 1.4 μW of power at a distance of 300 m from the transmitter.

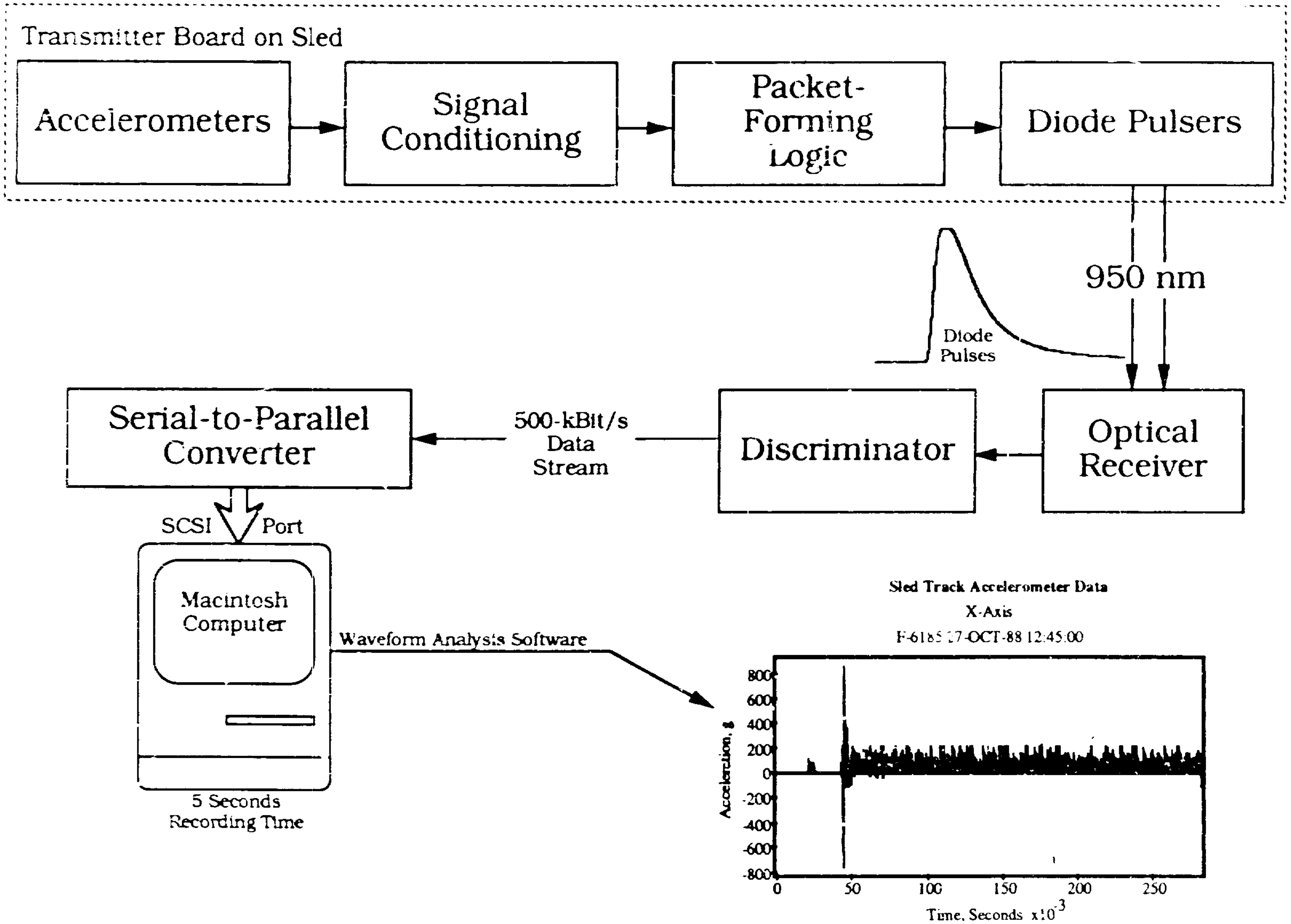

Figure 2. Low-cost infrared telemetry system.

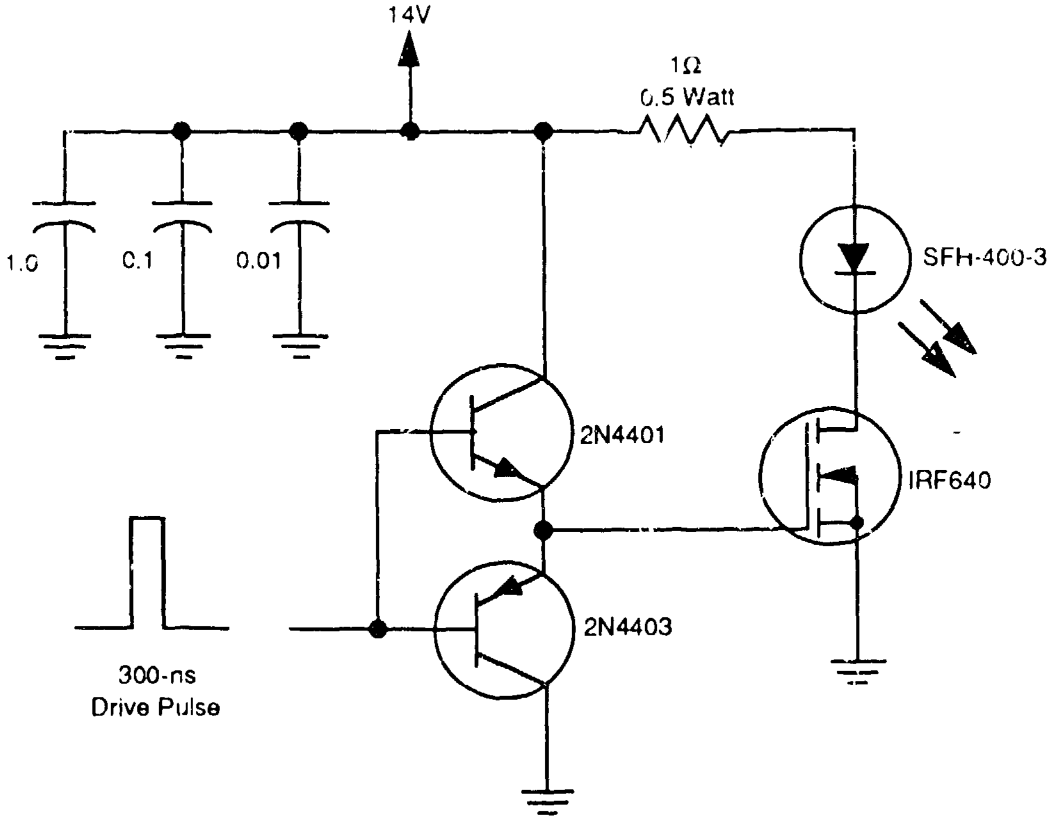

Figure 3. Power MOSFET diode pulser.

An RG-780 glass filter is used to reduce the quiescent current of the photodiode caused by ambient visible light. Shot noise caused by quiescent current is the largest single source of receiver noise.

Light produced by the rocket motors also affects the optical channel. The amplitude-modulation spectrum and intensity of this light were measured. Dominant frequencies of the amplitude modulation were below 30 kHz and are easily filtered out in the receiver amplifier by using three stages of gain. The first stage is a dc-coupled cascode amplifier circuit with a gain of 1000 V/A. The two remaining stages are ac-coupled common emitter circuits with a voltage gain of 25 each. The ac roll-off between stages attenuates the signal from the rocket motor plume while amplifying the short pulse from the transmitter.

4. TRANSMITTER

A single printed-circuit board contains the complete telemetry transmitter. This board measures 7.5 by 23 cm and weighs less than 450 g. A simple plywood mount is used to attach it to the rocket sled (Fig. 5). Power for the transmitter is provided by a 15-V Ni-Cd battery.

Three inputs are provided with 10-V excitation for piezoresistive accelerometers. A single-ended differential amplifier and 3-pole low-pass filter are included for each input. Each input signal is sampled at 16 kHz to 8 bits of accuracy ± 1/2 least significant bit. The 16-kHz sampling rate

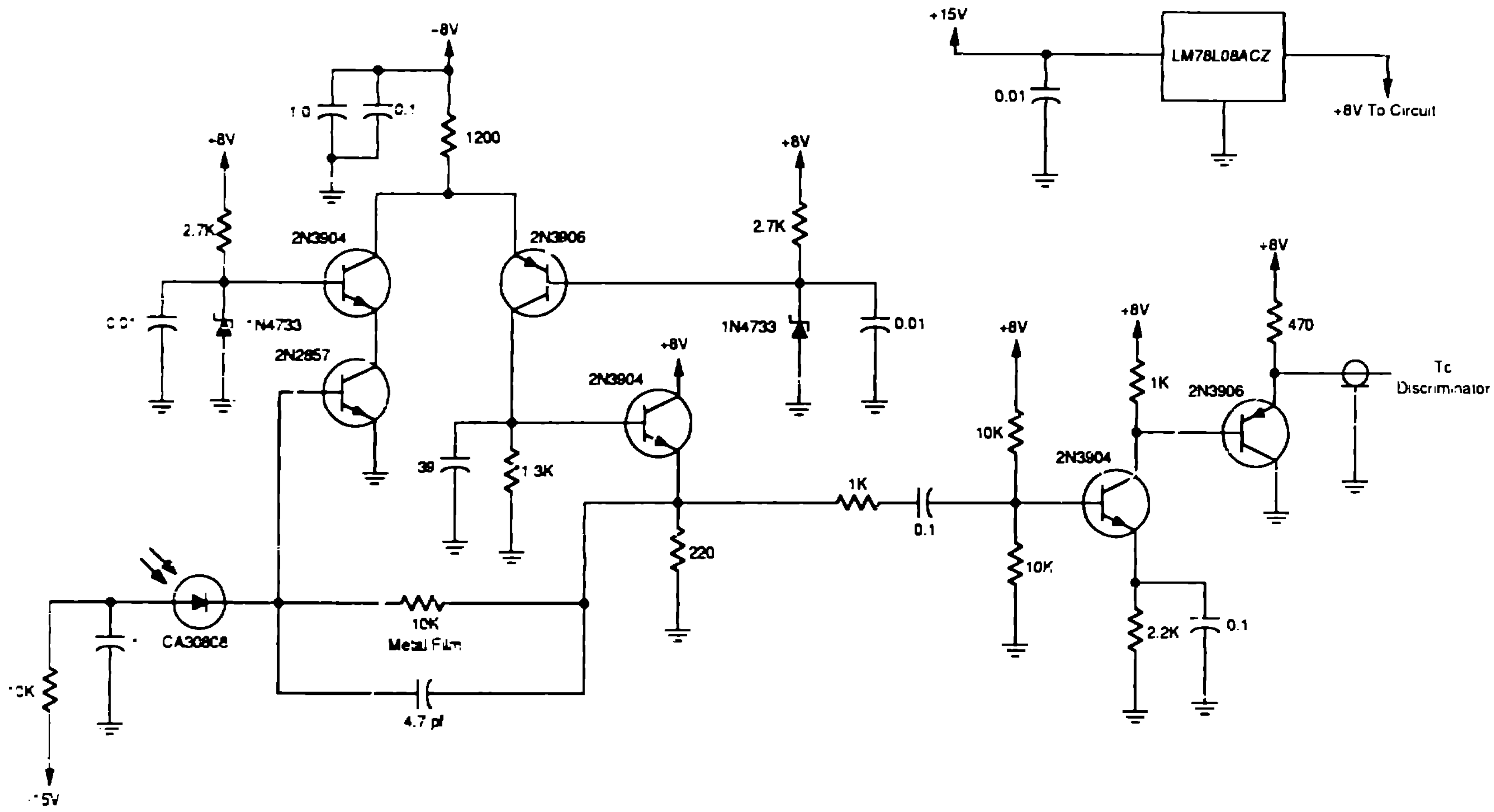

Figure 4. Optical detector/amplifier.

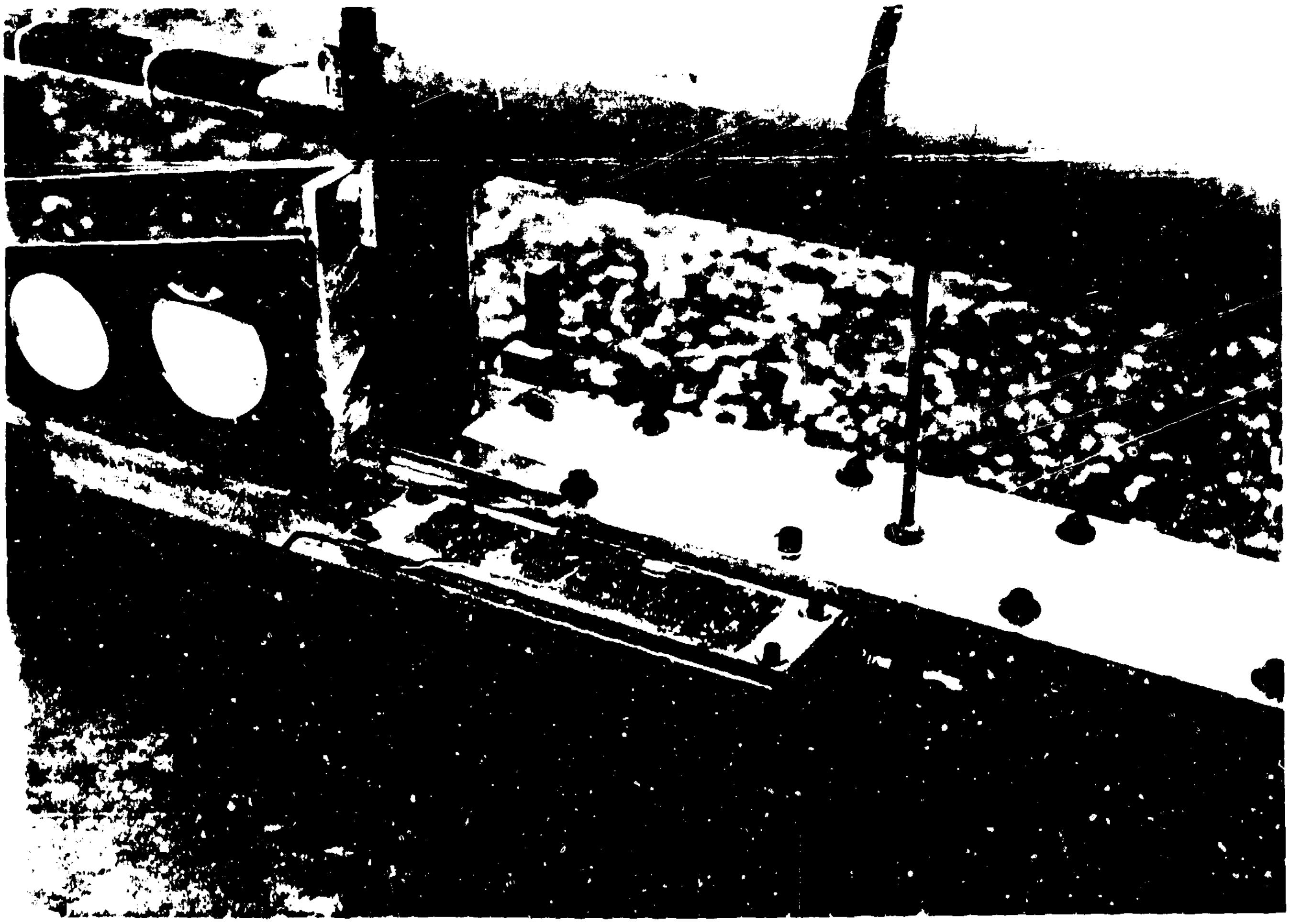

Figure 5. Typical transmitter mounting.

corresponds to the Nyquist sampling rate for 8-kHz bandwidth. The digitized samples of each channel are grouped into a 32-bit packet. A start bit, 24 data bits, a parity bit, and 6 stop bits are generated at 500 kBit/s. The bit stream is sampled, and two IR-emitting diodes are pulsed alternately, to produce 500-kBit/s data rate. Each diode, therefore, operates at only 250 kBit/s.

5. THE RECEIVER ASSEMBLY

The optical receiver assembly consists of the detector/amplifier, a 3-axis translation stage for fine alignment, and a 0.5 m^2 plastic Fresnel lens mounted in a plywood box (Fig. 6). This assembly is located at the target end of the sled track and is often subjected to warhead blast, as well as a bow shock from the sled. For this reason, the Fresnel lens is often broken and the plywood box destroyed. Sandbags placed behind the assembly protect the receiver components.

The receiver optics are aligned before a shot by placing a test emitter near the sled, facing the receiver at the target end. An oscilloscope measures the received signal, and it is maximized by adjusting the detector translation stages.

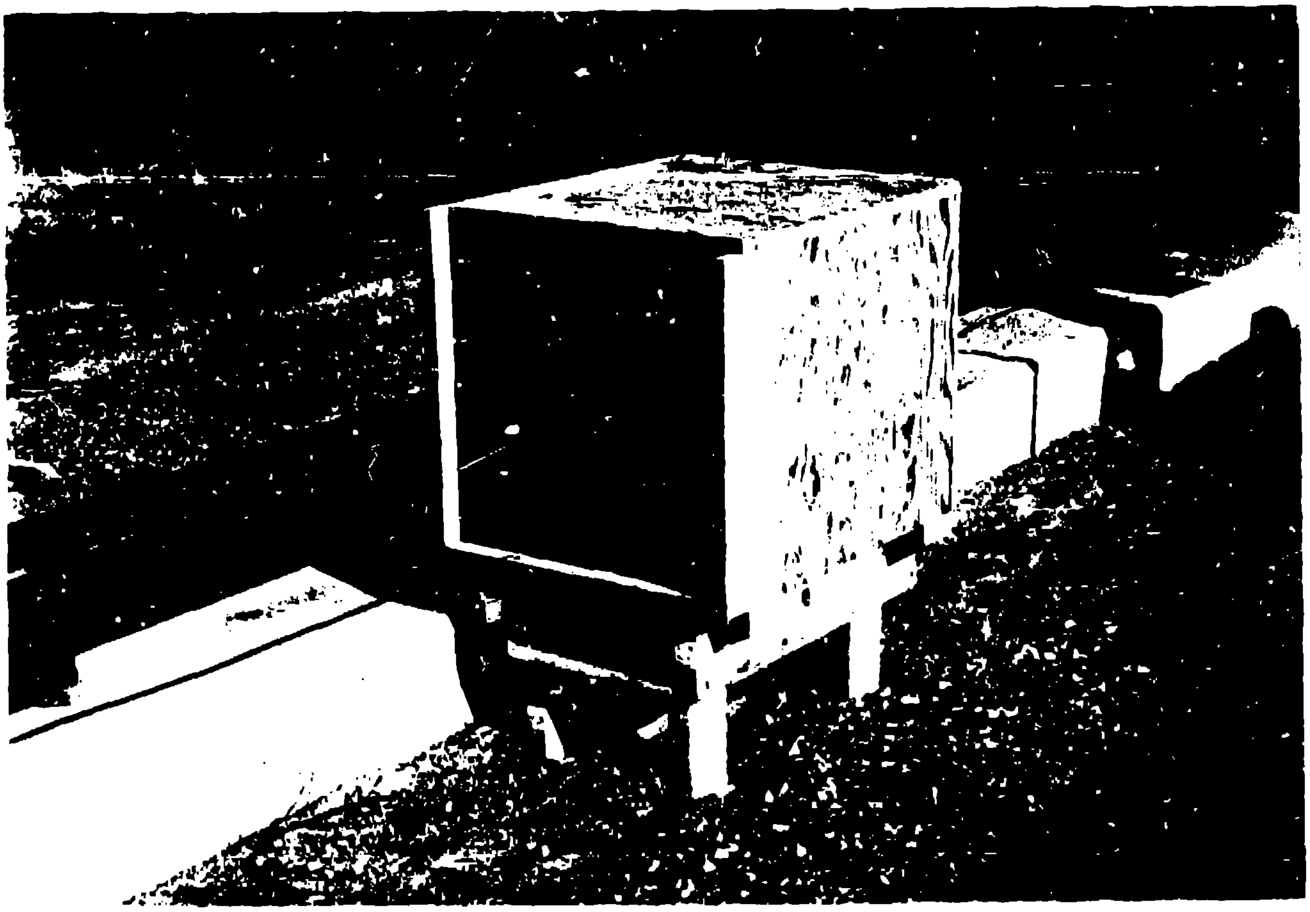

Figure 6. Receiver assembly

6. DATA RECORDING AND ANALYSIS

The output pulses from the receiver are restored to their original digital levels by a discriminator. The pulse lengths are stretched to 2 μs, which corresponds to the 500-kBit/s data rate. This bit stream is captured in a serial-to-parallel converter and recorded on a Macintosh computer. The bit stream is stored in a binary file to be decoded off line.

Decoding software converts the bit stream into binary numbers, along with a time for each number. These data can then be scaled to g's, based on the calibration data for the transmitter. Typical data reduction includes shock spectra and Fourier analysis (Fig. 7).

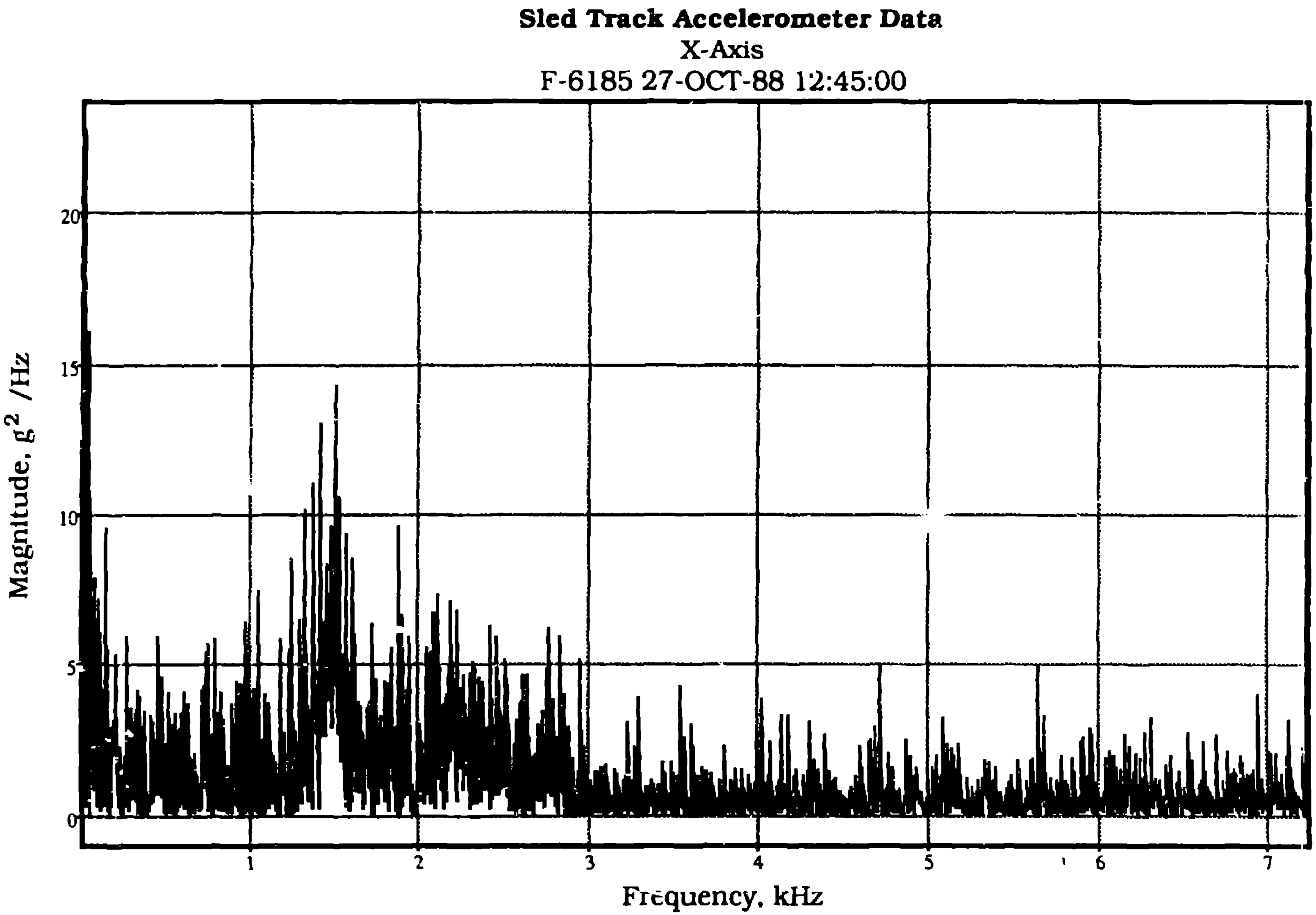

Figure 7. Spectral power-density analysis.