TELEMETRY SYSTEMS AND MEASUREMENT TECHNIQUES ASSOCIATED WITH ARTILLERY PROJECTILES

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ABSTRACT

The Israel Military Industries (IMI), Systems Division, has had requirements for telemetry systems and measurements techniques to obtain data regarding projectiles performance in-flight and in-bore. This paper presents a brief description of a new programmble PCM telemetry system which employs several novel techniques like flexible multiplexing, programmable signal conditioner on a channel per channel basis for multiple gains and offsets), and a miniature size due to thick film hybrid construction and all thses along with very high shock survivability and long term reliability.

This paper also presents a description of a very low cost telemetry package for measuring the in-flight spin rate using a specially designed transmitting antenna, a telemetry package for measuring event type phenomena and analog data (acceleration, pressure, strains, etc.) while the projectile is traveling in-bore.

Examples of data obtained during actual firings are presented and discussed.

INTRODUCTION

As Weapons technology advances and the weapons and projectiles become more sophisticated, more advanced experimental tools and techniques are required. Measurements made of the behavior of the projectile during launch and in flight using telemetry sytems is found to be the best technique. Various on board sophisticated electronic subassemblies, special delicate electromechanical devices etc., has resulated in a need for telemetry systems and measurement techniques in order to evaluate the in-bore environment and the operation of the on-board subassemblies and to monitor the in-flight performance of the projectiles and its subsystems.

The in-bore environment was found to be very severe to standard telemetry packages, and they would not survive such an environment. The typical acceleration forces associated with projectile firing (the kind this paper intends to describe) are of levels of 10,000 g with angular acceleraion of more than 250,000 radians per second squared. Many projectile anomalies have been proven to have occurred during this in-bore environment and therefore, there has been increased interest in obtaining the in-bore telemetry data. Thus, the in-bore telemetry packages are designed to survive and operate during the gun firing contrary to the in-flight telemetry systems which have only to survive the gun firing.

This paper reviews several in-flight telemetry systems, from a very simple one, which tests only one flight parameter, to one very advenced, which is a programmable PCM telemetry systems, along with some special purpose in-bore telemetry packages.

PROGRAMMABLE PCM ENCODER

The Programmble PCM Encoder was developed in collaboration with Aydin Vector Division, Newtown Pa. 19840 and with the assitance of Mr. Lee Glass and Mr. David Everswick from Technical Support Directorate, US ARRADCOM, Dover, NJ 07801.

The programmable PCM Encoder (Aydin Vector Series MMP-671-HS) Fig 1 has been designed to provide the user sufficient flexiblity in the field to accomodate most changes in data sampling rates and data field formats typically encountered in a test and evaluation program of smart projectile. Programming amplifier gains and offsets and of multiplexer mode selection for single-ended or differential operation is provided. Additionally, the stored program can be erased and reprogrammed without removal of any component. This is accomplished by the use of a Programmble Read only Memory (E-PROM) in conjunction with uniquely designed micro-processor control circuit.

The construction of the PCM Encoder is based upon standard hermetic hybrid modules (Fig 2 and Fig 3).The construction of the modules is based on chip and wire technique. This technique was selected after consideration and testing all viable construction methods in order to survive the high shock firing.

The functional block diagram of the PCM Encoder is shown in Fig 11.

Any combination of single ended and differential analog and bi-level (discrete) data inputs are accepted by this system. Single ended high elvel analog inputs are time-division multiplexed by the MP-601/608 modules. Differential analog inputs, which can be low level or high level, are multiplexed by the same modules, when S/E or D/E mode is selected via the EPROM program. The multiplexed analog signal is further conditioned by the SC-632 differential amplifier and merged with the high level PAM signal which is fed to the AD-606 sample and hold and analog-to-digital converter module. The A to D convereter digitizes each analog sample into a binary number with up to 10-bit resolution (one part in 1024). This data is fed into the formatter module, FM-618, which also receives the multiplexed bi-level data from MP-602 modules. The formatter provides accurate threshold detection for bi-level inputs, merges them with the digitized analog data, inserts frame and subframe synchronization words and feeds the resulting composite multiplex data to the timer module, TM-615P in serial form. The timer converts this data to the desired PCM codes (NRZ or Bi-ϕ), generates parity bit if required and provides premodulation filtering. Test outputs such as bit clock, word clock and frame sync pulses are also provided by the timer module.

The operation and timing of the entire system is under the control of the processor module, PR-614, which functions as a microprocessor executing the software program entered into a 512 x 8 programmable read only memory (PROM).

The PCM Encoder employs a synchronous isolated power supply, the PS-607 module, which also contains the basic system clock with four externally programmable bit rates. A second pre-modulation filter is provided, which has an adjustable level output. Five of the PCM Encoders have been field tested and fired in 155 mm howitzers with very good results.

IN-BORE TELEMETRY PACKAGES

Two systems were designed in order to gather in-bore data.

The first system, TM-M Series, (Fig 4 & 5) is intended to measure event type phenomena data during in-bore travel and a short time after projectile exits from the gun barrel. This system was designed to acquire data regarding the function of safe & arm devices or a fin deployment aparatus, thus the data is event type, i.e. when something happened and if at all. The system consists of a multiplexer of six channels, a memory device (a CMOS RAM-Random Access Memory) a timing and control section, a very low cost transmitter and a power source which is built from four lithium batteries.

The data is collected in the six channels from the projectile as it starts its travel through the barrel and during a time period of 125 ms (with a resolution of 240 µs and accuracy of 0.1% or better). Then, the system is automatically switched to the transmitting mode, and all the data stored in the on-board memory is serially transmitted with a unique synchronization pattern. The data is transmitted in a recyclly manner, thus, the data is trasmitted many times during the projectiles flight and as such, the reliability of the receiving decoding and processing is increased. A special purpose decoding system is used in order to make the data reduction. In Fig. 14 are shown test results from TM-M telemetry.

The second system, TM-AM Series, fig. 7 is also a memory based telemetry package, based on a modular design which enables construction of systems having any number of analog channels. Each channel is processed by a separate and independent module. The module can handle a wide range of unipolar or bipolar analog input voltages. Input signal conditioning is available for a wide variety of piezoelectric transducers (e.g. PCB 305A series accelerometers). The system enable data collection in places form which transmission is impossible or unreliable. This is accomplished by storing the data in an internal memory.

The system was designed to withstand stringent environment and especially very high shock conditions, and to be reusable. Therefor, it is especially suitable for measuring events inside an artillery fired projectile during its movement along a gun barrel or in a soft-recovery facility. (Fig 8).

The analog input data of any channel is sampled at preselected sampling rate (one of eight possible rates from 30 μs to 4 ms) and is being converted to a digital form. An impact switch provides trigger for start of storage cycle. 2048 Converted samples are then stored in a RAM. The controller of every channel is capable of responding to an unlimited number of storage cycle starting triggers provided the duration between two consecutive triggers is longer than a prechosen minimum duration. (This is done in order to prevent system turn on during undesired movement of the measured body or its falling).

Power is supplied to the system from an internal 12V nicad rechargeable battery pack. One of two standard battery packs is available, one having 1.2 AH capacity and a smaller one of 225 mAH. For longer operating time the system can be furnished with two packs of any type. For other applications a suitable battery pack can be provided to ensure a continuous operation between half an hour to two hours without recharging.

The telemetry system can include as an option a multiplexer/formatter unit that converts the byte serial output of all the channels to one serial data stream with synchronization pattern (according to IRIG standard PCM format) for transmitting purposes.

A TMD-AM multi-purpose peocessing system for the telemetry package is used. This processing system consists of a decoder, a simulator and a testing unit. After the test the telemetry package is connected to the processing system. The decoder of the processing system converts the digital data back to analog form. It also enables to feed the raw digital data, the control signals and the restored analog data onto magnetic tape or paper tape Recorder.

The restoring rate in the decoder can be accelerated or deaccelerated relatively to the sampling rate. The simulator and the tester in the processing system enable telemetry simuation and dynamic test of the telemetry system during the assembly process and before operation. The processing system is also an effecient tool in troubleshooting and field testing of the telemetry system.

Fig. 9 and Fig. 10 are examples of data taken by TM-AM Series telemetry system, fired in the IMI Soft Recovery Facility (Fig. 8). Soft recovery of the projectile is obtained by attaching a Waterscoop to the test projectile and firing the projectile into a water trough, inclined at s small angle to present an ever-increasing depth of water to the advancing projectile. The momentum of the projectile is then transferred to the water ejected forward by the scoop on the projectile. As seen in Fig. 9 and Fig. 10 some accelerations are induced into the instrumented projectile. while traveling in the soft recovery system. Much effort is given to understand these phenomena and to recommend measures that should be taken in order to maintain lower induced accelerations.

SPIN RATE TELEMETRY PACKAGES

The knowledge of spin rate of a projectile during flight is essential in the development of new projectiles.

IMI Systems Division has designed a unique telemetry package, TM-S Series, to measure the spin rate of a projectile during flight. The TM-S telemetry package is a device installed in a projectile in place of the fuze. It transmitts information to a ground receiving station while the projectile is in flight (Fig. 6).

The TM-S components are a specially designed transmitter with an antenna, and a power source which is built from 4 lithium batteries. The roll plane antenna pattern (Fig. 11)has two lobes and two zeros, thus, on each rotation of the projectile the ground receiving station will recieve two peaks in magnitude. Recording the AGC Level of the receiver (or using other technique to record the magnitude of coming RF signal) and processing it by counting the number of peaks per second and dividing it by 2, will give the exact spin rate of the projectile (Fig. 13).

The same transmitter and antenna is used on TM-M and TM-AM telemetry packages (when used in actual firing and not in a soft Recovery System) thus, providing spin rate data along with in bore data on the same projectile and firing.

IMI, Systems Division has been using these telemetry sytems for several years. About one hundred packages were fired successfully without malfunction. (Example of data as compared to simulation is shown on Fig. 13

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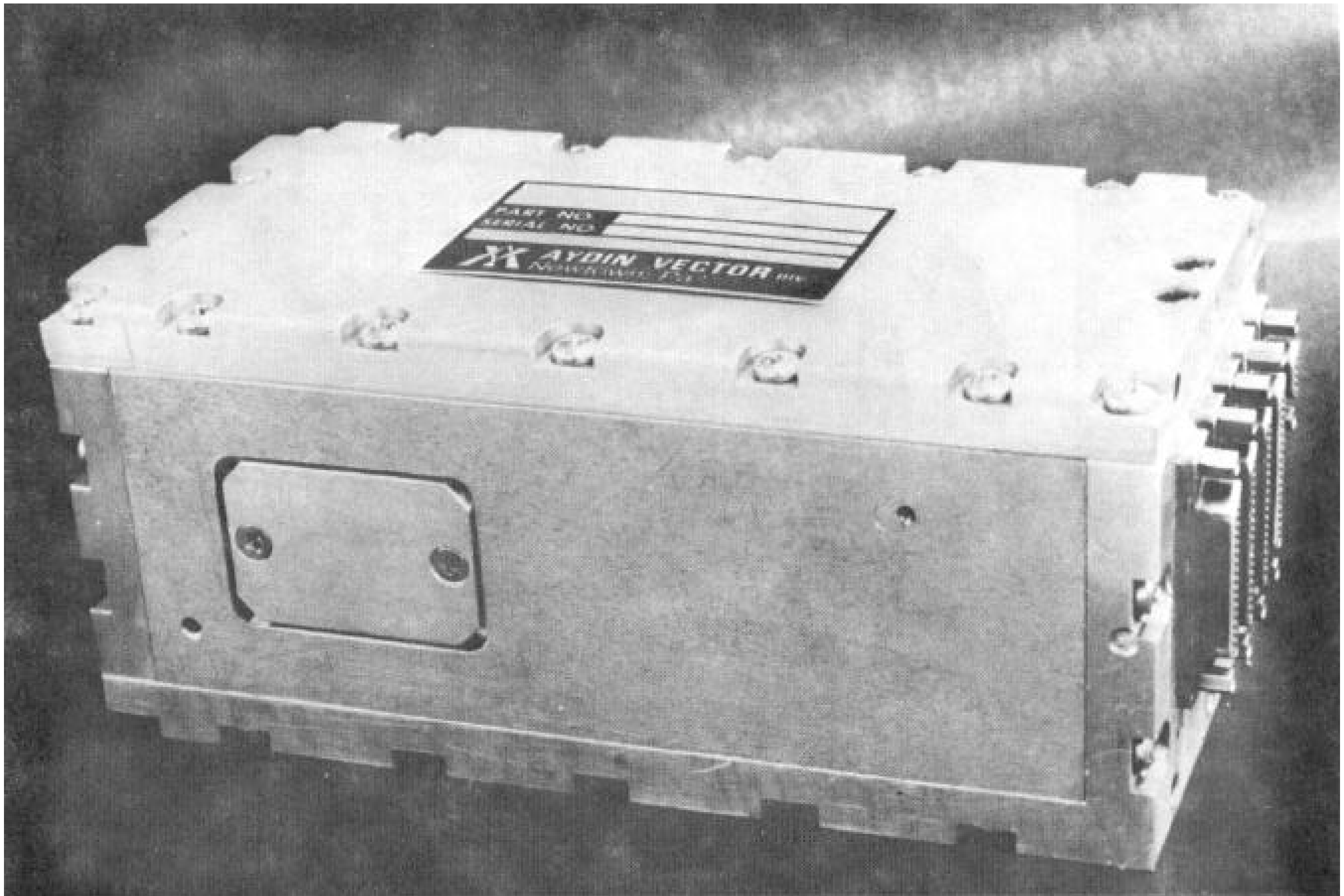


Fig 1: Programmable PCM ENCODER for high shock telemetry (MMP-671 HS)

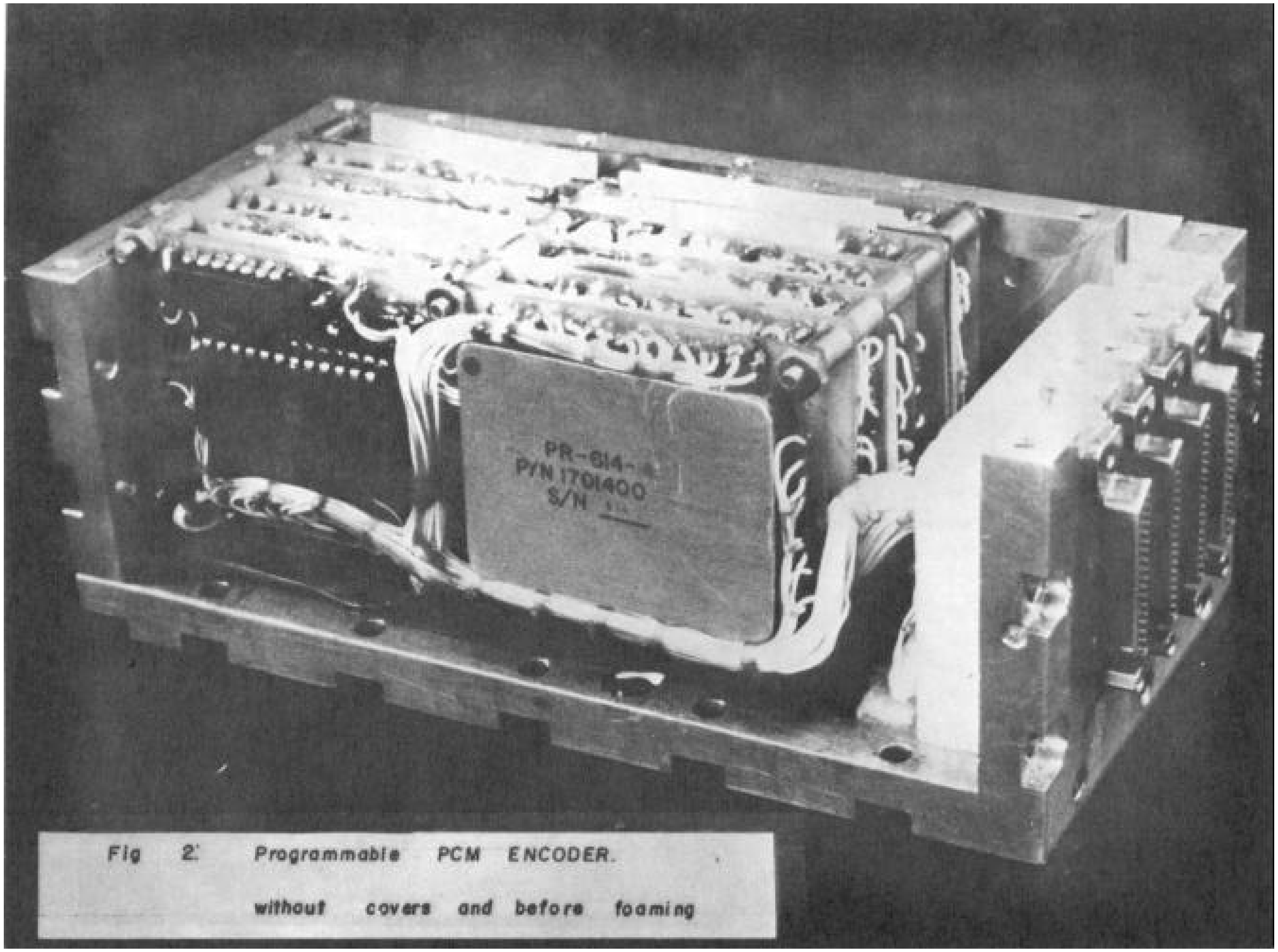


Fig 2: Programmable PCM ENCODER.
without covers and before foaming

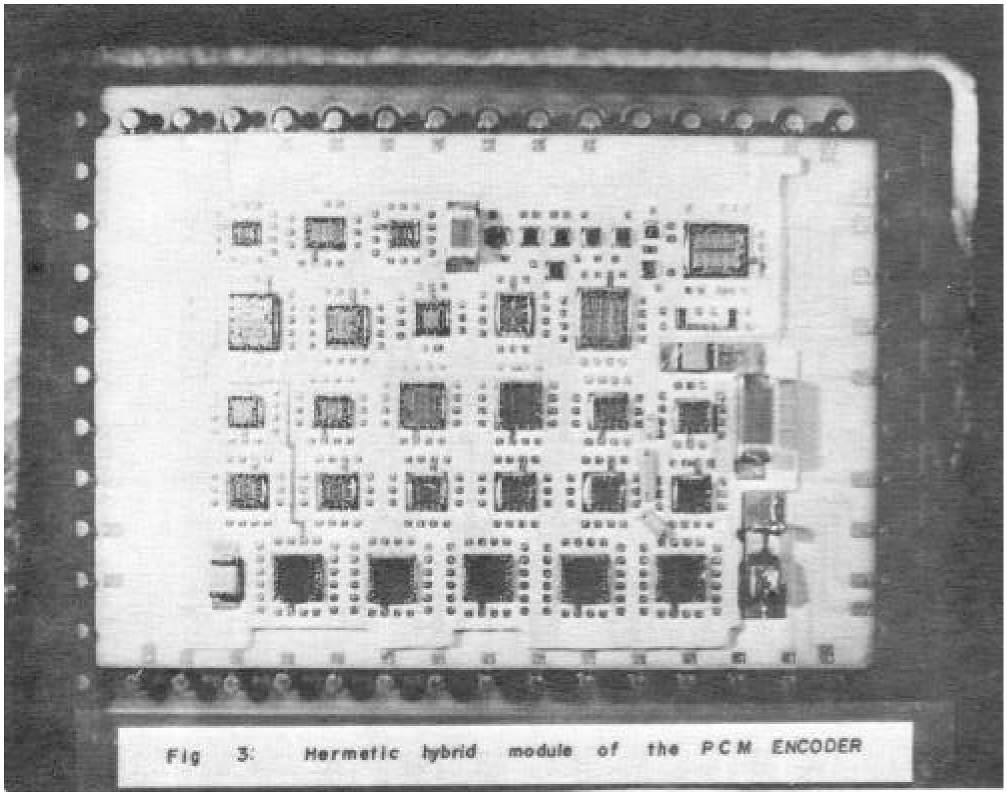


Fig 3: Hermetic hybrid module of the PCM ENCODER

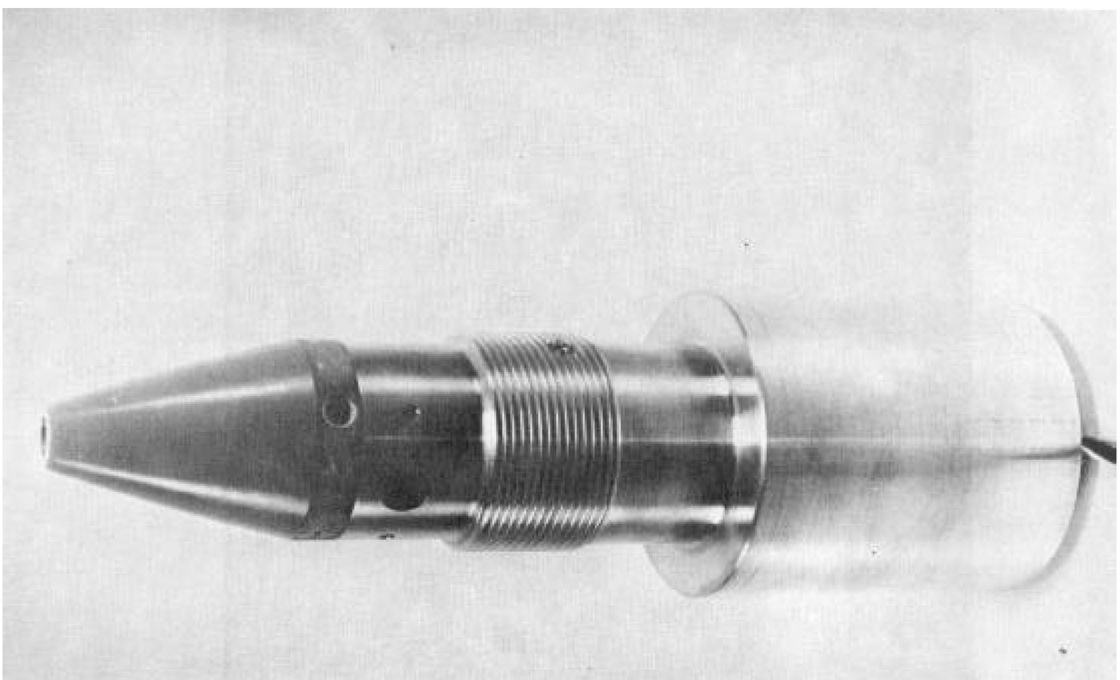


Fig 4: TM-M Series telemetry Package for measurment event type phenomena.

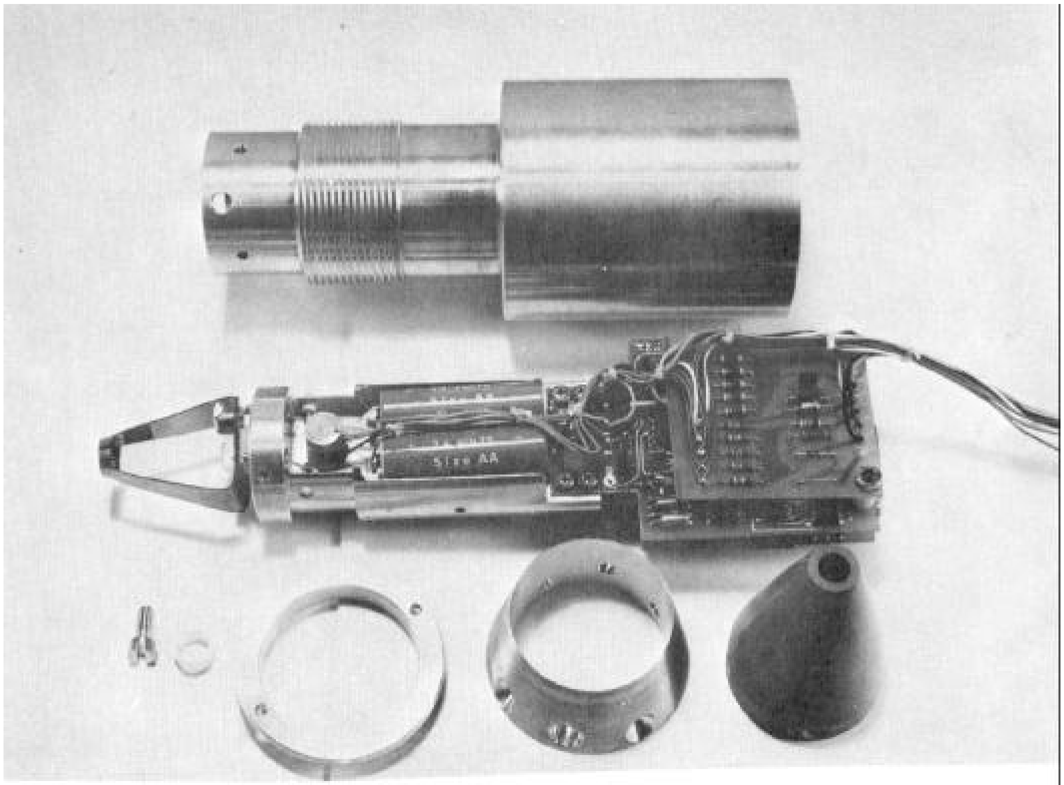


Fig 5: TM-M Series telemetry package Internal componenets.

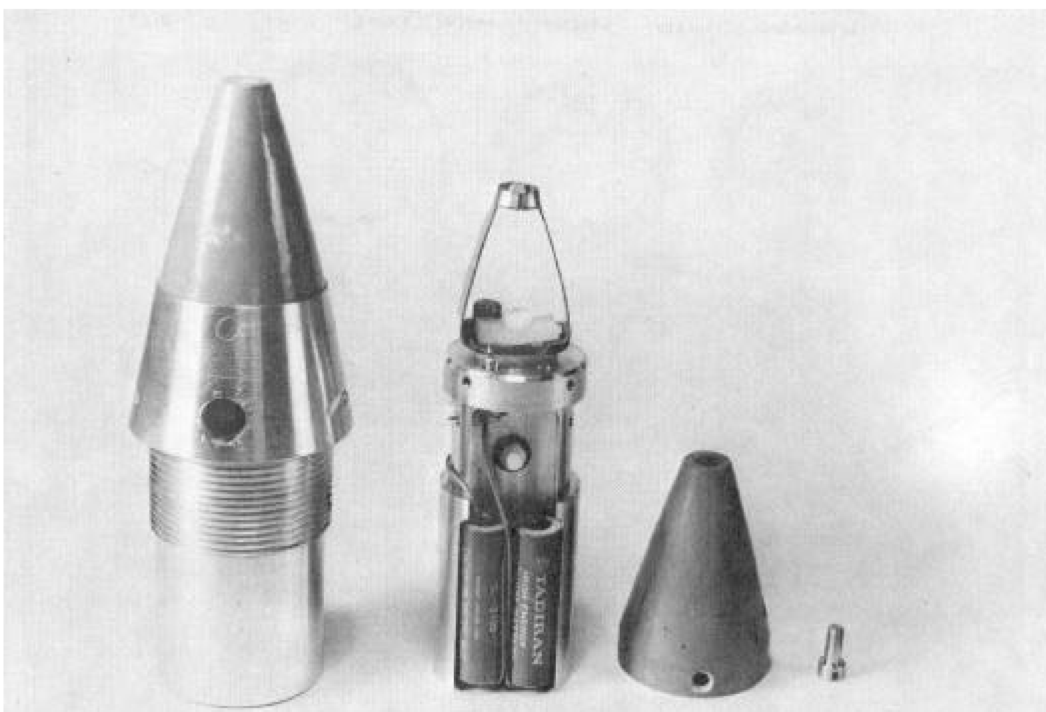


Fig 6: TM-S Series telemetry package for measurement the spih rate of projectile during flight.

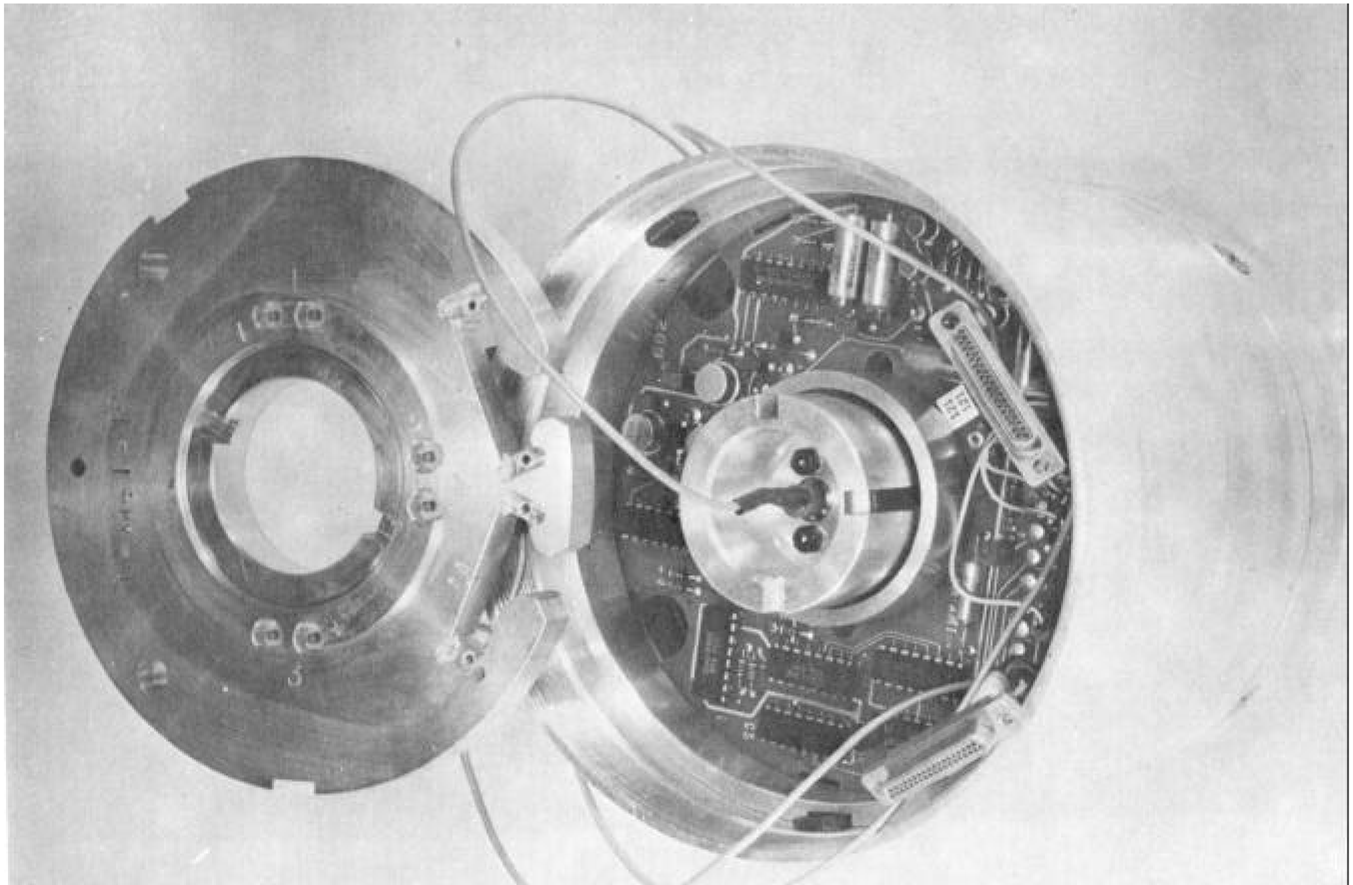
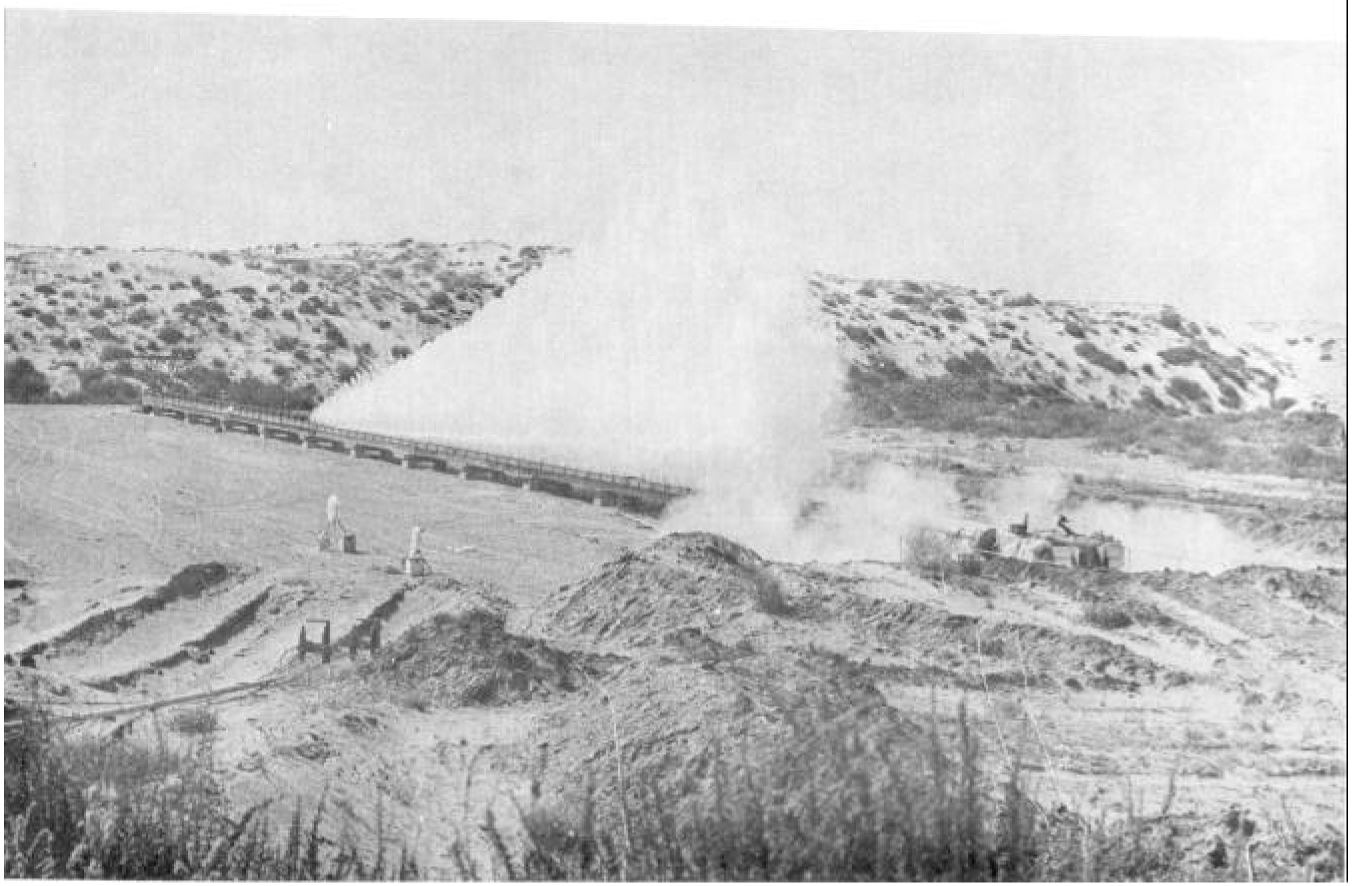


Fig 7. TM - AM Series telemetry package for measurement analog in bore data (acceleratian, pressure etc)

Fig 8: IMI, Systems Divisin's Soft Recovery Facility in operation



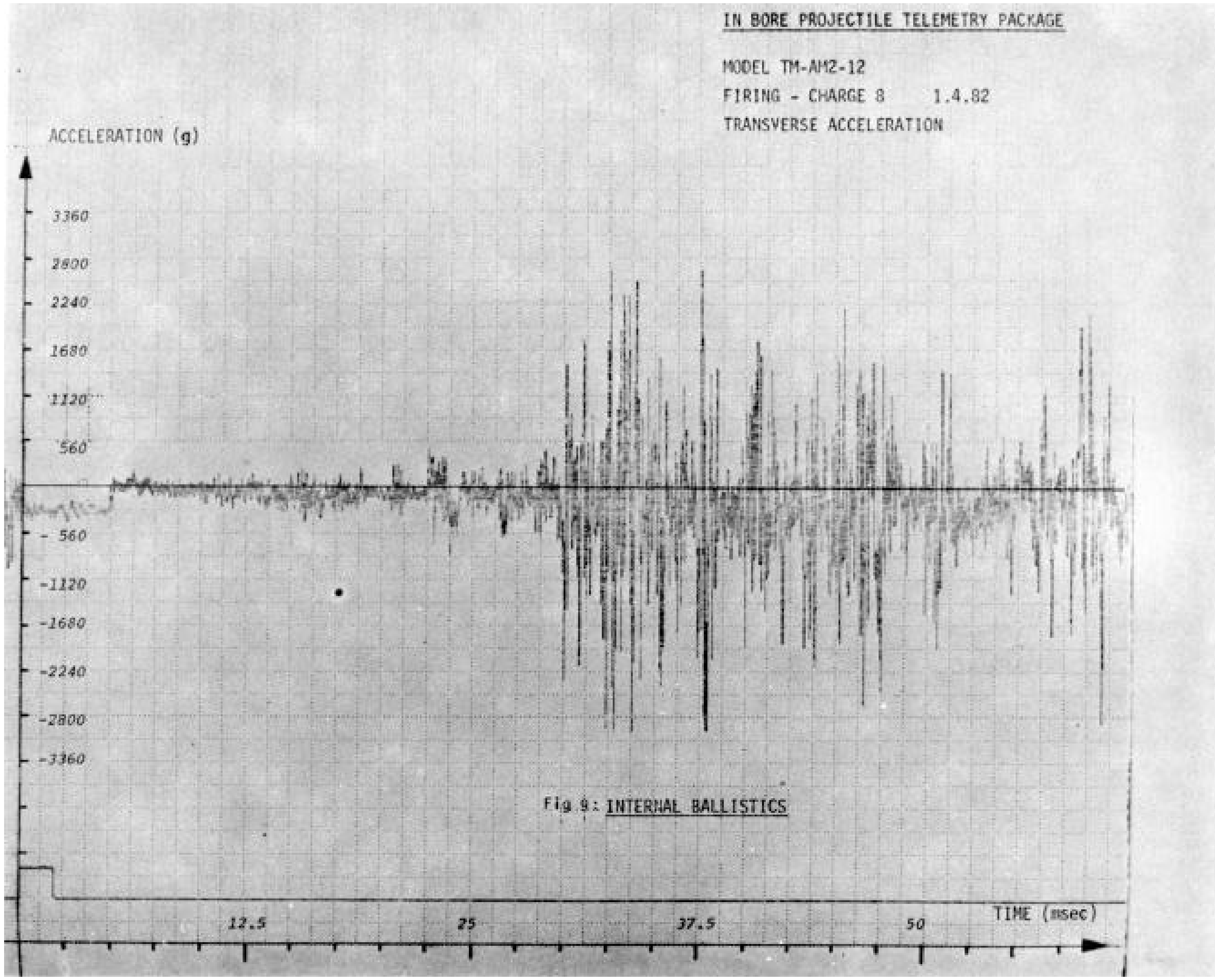


Fig.9: INTERNAL BALLISTICS

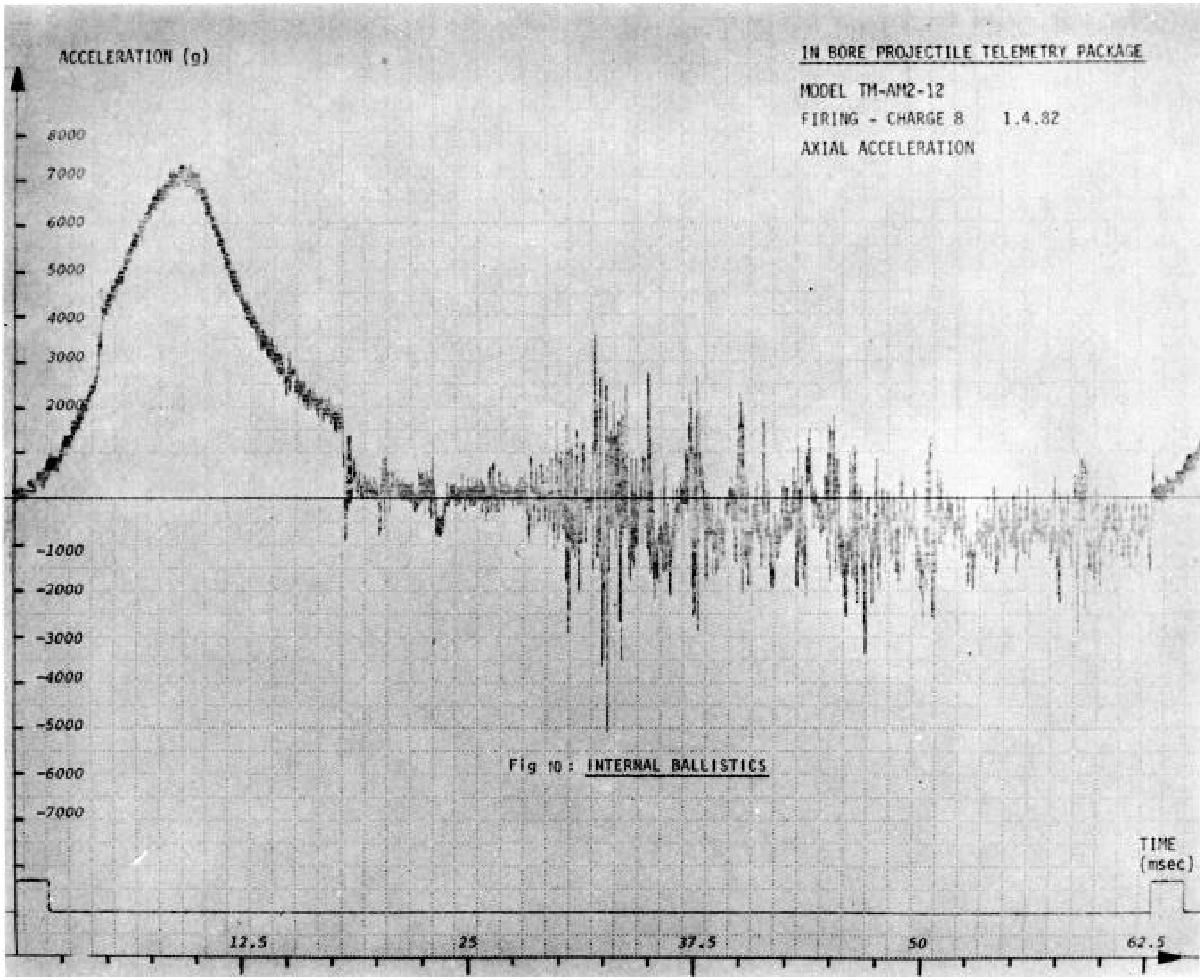


Fig 10 : **INTERNAL BALLISTICS**

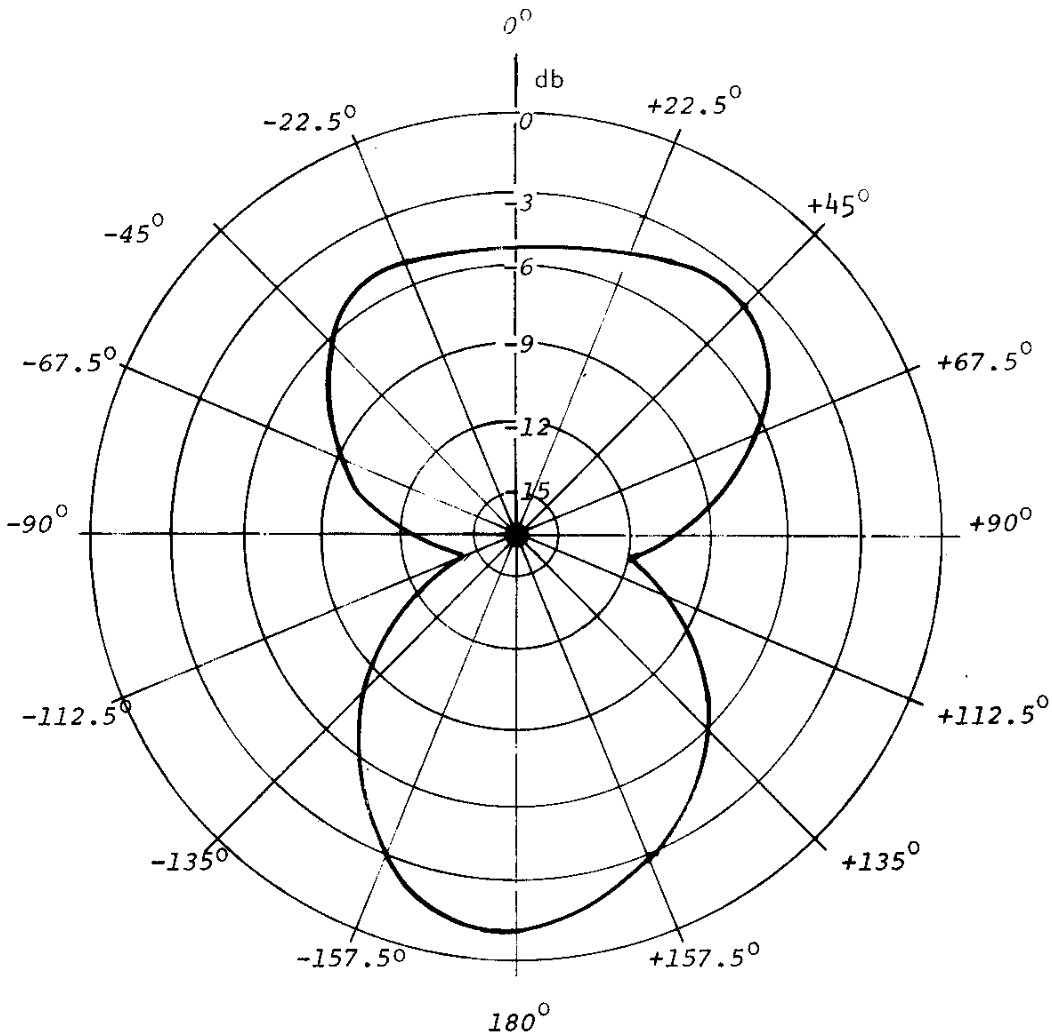


Fig 11 : Roll plane pattern of the transmitting antenna of TM-S and TM-M telemetry systems.

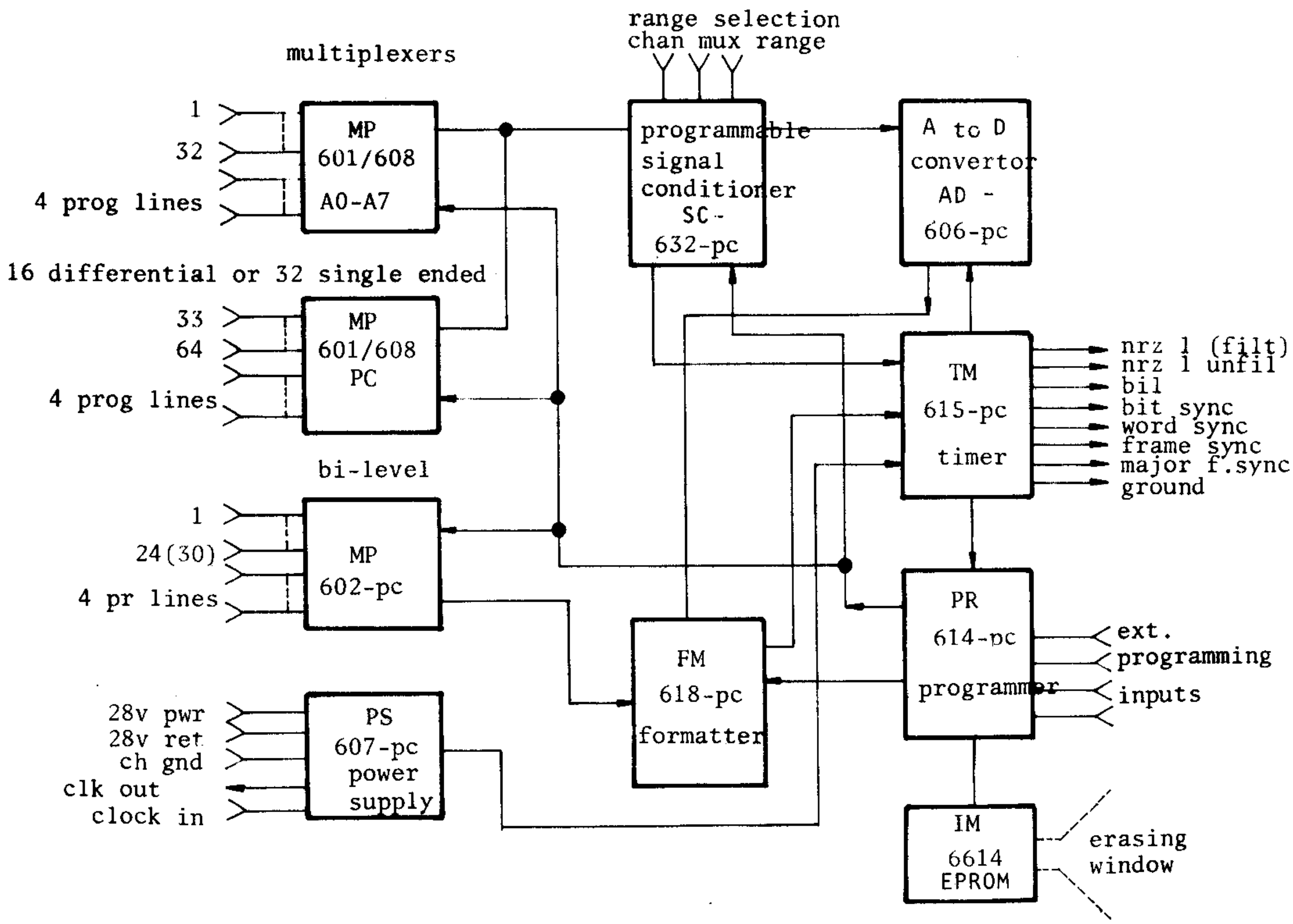


FIG. 12: PCM ENCODER FUNCTIONAL BLOCK DIAGRAM.

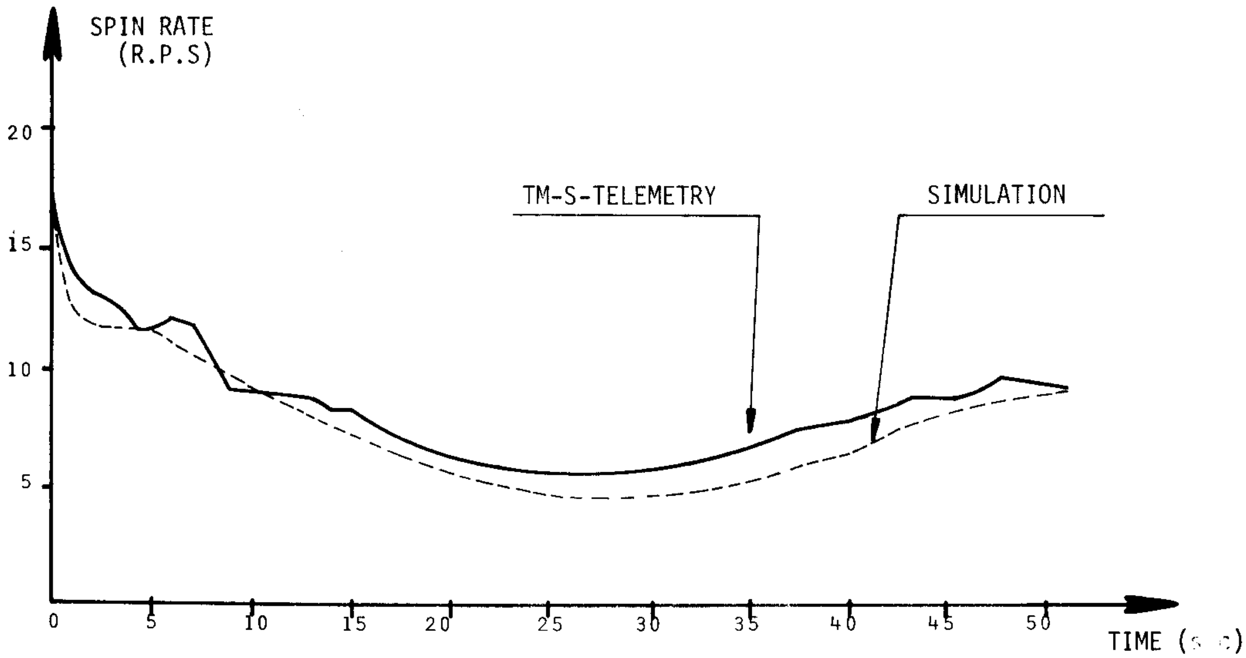


Fig 13 : SPIN RATE OF PROJECTILE DURING FLIGHT

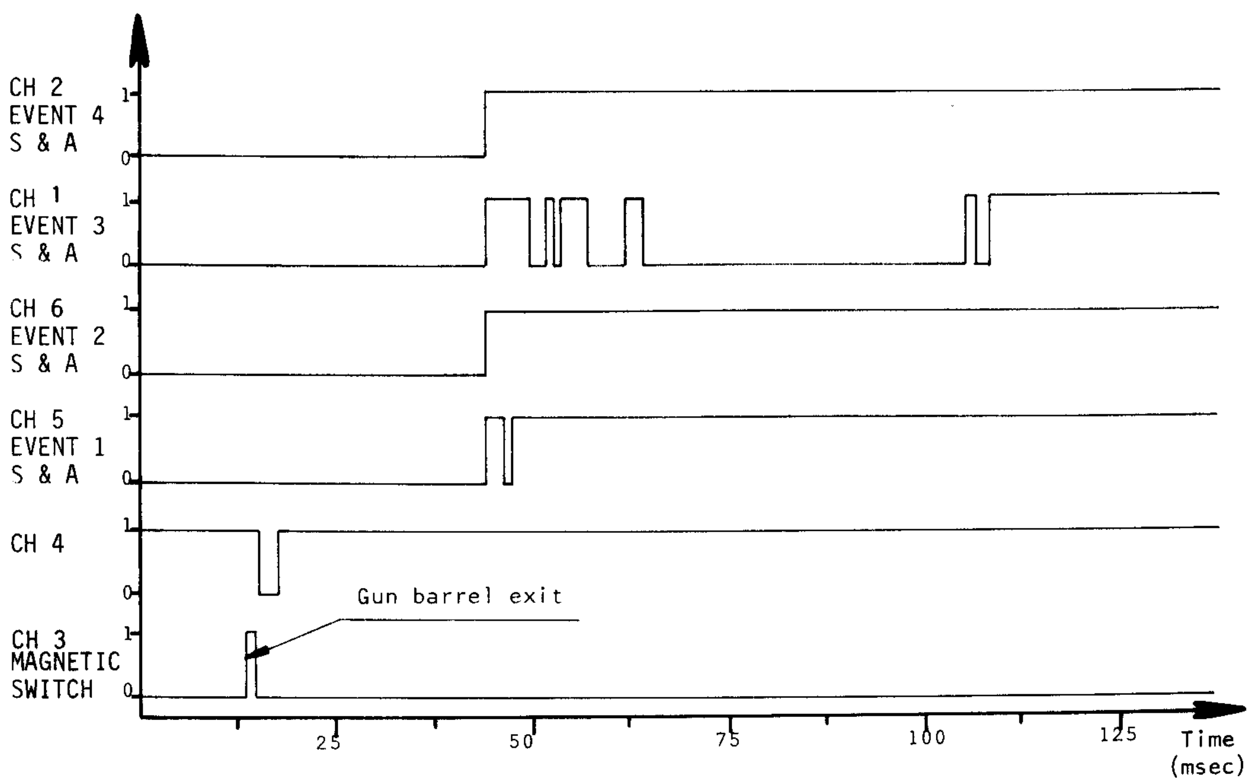


Fig 14 : DECODED DATA FROM TM-M TELEMETRY (S & A DEVICE)