Summary The development of a UHF telemetry system that will withstand the high shock (50,000 g) of gun launched vertical sounding probes is described. The associated development of a ground based automatic angle and range tracking and receiving system using a modified AN/GMD-1A Rawin set is also presented.

Introduction Several years ago it was envisioned that a gun could be used as a launcher for vertical sounding probes. It was calculated that altitudes above that attainable by balloons could he reached with gun launched probes carrying nominal payloads of 1 to 5 pounds. A number of soundings have been made to date, but most of the payloads have contained passive devices such as radar chaff, inflatable metal spheres, and also various pyrotechnic devices. Electronic payloads, especially those suited for making meteorological measurements, were desired since a gun launched probe could provide a carrier vehicle inexpensive compared to a rocket system and the impact dispersion of the probe would be very low, permitting firings in relatively congested areas. Since the AN/GMD-1 Rawin set was being used as the standard meteorological tracker, it was deemed desirable to design the airborne system so that it would be compatible with this ground tracker. Figure 1 depicts the gun launch system and the ground tracker. It was also envisioned that if the 5-inch gun probe system proved feasible, larger guns with increased payload capabilities would be possible. At present there are plans for using a gunrocket system to launch nominal payloads of 50 pounds into a trajectory of several hundred miles altitude (with orbital capabilities) at a very low cost compared to a full rocket system.

Discussion of Problem and Objectives The initial task assigned was to develop a complete telemeter for the 5-inch gun projectile. Later design objectives were the addition of a ranging system that could be used in larger projectiles. A block diagram of the complete telemetry, tracking and ranging system is shown in Figure 2. The telemeter consists of a transmitter, sub-carrier oscillator (SCO), commutator, batteries, acceleration switch, antenna, and temperature gages. The electronics are contained in a space 1.8 inches in diameter and 6 1/2 inches long. The greatest problem in the design and development of the telemeter was the shock associated with launching the gun probes. In
the 5-inch gun system, the equipment had to survive a peak launch acceleration of 50,000 g’s and an average acceleration of 25,000 g’s for 3 milliseconds. The total time in the gun barrel was 12 milliseconds.

Compatibility with the AN/GMD Rawin set restricted the use of RF frequencies to between 1650 and 1750 mc/s. The extreme launching shock dictated the use of all solid state components and complete potting of every void space. Various solid state sub-carrier oscillators and commutators have been designed and tested at the high g levels involved and have not presented too much of a problem. Batteries and acceleration switches are available and some configurations have been successfully tested. The most difficult task was the development of a small solid state transmitter capable of delivering approximately 200 milliwatts of RF power at 1750 mc/s. A high g system that closely simulated gun launch acceleration magnitude was also developed for testing individual components and flight payloads.

**Airborne Instrumentation** In order to insure the success of any gun probe telemeter fired, it was found necessary to test all components and systems under the same environmental conditions as in the gun. Individual components such as resistors, transistors, capacitors and diodes, that made up the transmitter, SCO, and commutator were tested. The test procedure consisted of potting the various components into a projectile as shown in Figure 3. This projectile was then fired from a 5-inch gun at point blank range (20 feet) into a series of cast lead blocks. Figure 4 depicts this setup with the lead blocks shown on the smaller concrete pier at the left of the photograph. The projectile was fired at low velocity (1000 fps), and the sudden deceleration it encountered provided peak acceleration conditions that simulated the active gun launching. Various nose shapes on the test projectile, shown in Figure 5, provided different peak decelerations and transit times within the lead blocks. This test assured 100% recovery of all projectiles for post firing examination and testing. The maximum deceleration times were 2-3 millisecond compared to 10-12 milliseconds for an actual gun launching. A test projectile and lead blocks after firing are shown in Figure 6.

The requirements for the transmitter were that it be small, preferably solid state, and capable of an output power between 150 and 200 milliwatts at a frequency of 1750 mc/s. This frequency was selected for test purposes so as not to interfere with current operations in the 16601700 mc/s meteorological band.

It was realized that a transmitter using the conventional technique of a low frequency oscillator with transistor and varactor multiplier stages would result in a system that was large and contain too many parts that were subject to failure. It was envisioned that a simple transmitter would be necessary. At that time, the Radio Corporation of America (RCA) in Princeton was developing a tunnel diode oscillator for the Signal Agency at Fort Monmouth, and this device was investigated. Several units were fabricated for
testing but the power output was limited to approximately 30 milliwatts and the device had low efficiency, requiring a regulated source of 0.5 volts at 1.5 amperes. One oscillator-TM modulator unit survived a test firing of 50,000 g’s, but because of the limited power output, low efficiency and poor frequency stability, work on the tunnel diode transmitter was discontinued.

A new device, called the “Solistron”, developed by the Western Microwave Laboratory, was then being put on the market which looked like an ideal answer to the transmitter problem. The initial device available had a 20 milliwatt output at 1400 mc/s and was contained in a 2 inch cube. A contract was let to WML to develop a higher power, higher frequency device that would withstand the extreme gun environment. Two prototype units have been developed and are shown in Figure 7. The original prototype shown in the photograph is the larger unit which is 1.8 inches in diameter, 0.75 inches long and capable of delivering 175 mw of power at 1750 mc/s. The smaller unit is a modification of the original and is 1.1 inches in diameter, 1 inch long and capable of delivering 100 mw of power Both units are capable of being frequency modulated at a deviation of ±5.0 mc/s.

When the tunnel diode work at RCA was stopped, the effort was re oriented to the development of a high power transistor oscillator coupled with a single varactor diode multiplier. A technique for eliminating the varactor diode was evolved and a transmitter is being developed in which oscillation and multiplication is accomplished in a single transistor chip. This unit has a 200 mw capability, with higher power levels possible by the use of proper heat sinks.

A sub-carrier oscillator (SCO) and commutator unit has been designed and fabricated using conventional but selected components that have been test fired as previously explained. An SCO frequency of 10.5 kc/s with a deviation of ±7.5% of center frequency has been selected to operate with a 5 channel, 5 frame Per second commutator. Figure 8 shows this unit before and after potting. One channel of the commutator is double width for identification purposes. Three temperature sensors and two calibration voltages were selected for monitoring by the commutator.

Various battery types have been investigated. Mercury batteries have been fired successfully in the past but they do not have the current capacity needed for the payloads. Yardney silver-cells in plastic cases performed satisfactorily when potted as individual cells. In some tests the cell cases cracked, which did not alter the cell performance, but when a number of cells were mounted together and fired, the cracked cases allowed electrolyte to seep between cells and cause serious internal shorts. The Gulton VO-250 nickel-cadmium button cells have successfully survived 40 Kg tests and were used on the two initial 5-inch flights. A single cell and a potted battery pack are shown in Figure 9.
An acceleration switch was used as a turn on device for all electronics. This switch with the battery pack is shown in Figure 10 and is an Aerodyne Co. Model No. 496-5-000.

A three turn helix antenna imbedded in a fiberglass nose tip was used on the 5-inch probe. This design was fabricated by making an undersized tip of laminated fiberglass grooving a spiral around the tip, and then placing the antenna wire within this groove. Figure 11 shows the antenna wire before it was covered, and Figure 12 shows the complete payload assembly with the antenna imbedded under the wrapped fiberglass. This laminating and wrapping of the nose tip provided a strong non-metallic tip that withstood the gun launch environment.

Figures 13, 14 and 15 show the 5-inch, 7-inch and 16-inch gun projectiles respectively. The 5-inch and the 16-inch projectiles have been fired successfully, and the 7-inch is currently going through initial flight tests.

At present the 415 mc/s ranging receiver in the system shown in Figure 2 is under development and will be used on later flights of the 7-inch and 16-inch probes. A prototype unit 2 inches in diameter and 2 3/4 inches long has been designed and is undergoing system checks. The design goal for this receiver is one that has a sensitivity of -85 dbm, a local oscillator that will not shift frequency with a 30 Kg shock, and a phase shift less than 3-degrees on the 22 Kc/s modulation over a 60 db dynamic input range.

**Ground Instrumentation** The ground station for the high altitude gun probe system consists of a complete telemetry receiving, tracking, demodulating and recording system housed in a 10 x 20 foot mobile van. Figure 16 and Figure 17 are photographs of the outside and inside of the van. Figure 18 shows a block diagram of the system in the van. Conventional FM/FM telemetry techniques were used throughout the system.

A modified AN/GMD-1 Rawin set is used for automatic tracking of the gun probe and is shown in Figure 19. The modification consisted of discarding the normal GMD receiving system and using an improved receiver and preamplifier. The preamplifier was a Microstate tunnel diode unit having a noise figure of 3.8 db with a gain of 18 db and was mounted in the receiver drawer. A directional coupler was placed between the preamplifier input and antenna to facilitate pre-flight calibration of the receiving AGC system. A standard Defense Electronics type TMR-5A telemetry receiver was used with the GMD but was placed inside the van instead of on the tracker. Type RG-17/U cable was used between the preamplifier and receiver to minimize signal loss and noise figure degradation. The tracking error signal for conical scan was obtained from the receiver AM detector and fed back to the tracking mount.
The ranging system that will be used on future 7-inch and 16-inch firings is an adaptation of the Sandia AME/DME system. This ranging technique consists of transmitting two tones, nominally 22 and 24 kc/s, to the probe where they are received, demodulated and then re-transmitted back to the ground station. These tones are then compared in phase with the original tones. The resulting phase difference is proportional to slant range. The two tones used were 24,589 and 22,131 cps where the higher of the two gives a distance of 20,000 feet per cycle, and the difference gives a distance of 200,000 feet per cycle.

At present, plans are being made to fire vertical probes in three types of artillery pieces. Figure 20 shows a pair of 5-inch guns now in use at Wallops Island. Figure 21 shows the 7-inch gun which has recently been developed. The 16-inch gun at Barbados is shown in Figure 22 and has fired many successful Martlet payloads. The 5-inch gun has an altitude capability of 200,000 feet with a 2 lb payload, and the 7-inch gun will place 10 lbs up to 325,000 feet. The 16-inch gun capability is 50 lbs to an altitude of 400,000 feet.

**Firing Test Results**  Two 5-inch probe payloads were fired at Wallops Island, Virginia on 13 October 1964. Figure 23 shows the telemetry components in the projectile. Payload No. 1 was fired at a muzzle velocity of 4700 fps resulting in a launching shock of 40,000 g’s. Payload No. 2 was fired at a muzzle velocity of 4900 fps resulting in a launching shock of 45,000 g1s. Both payloads were fired at a gun elevation of 80° on a true azimuth of 130°. All electronic components of both payloads survived the gun launch shock and functioned normally. Aerodynamic heating of the projectile body caused the Solistron transmitter frequency to decrease rapidly. Therefore, reception was terminated early during both flights because of the limited tuning range of the ground receiver.

Intelligible telemetry data were received during the periods of 2-17 and 44-65 seconds from the first payload and during the period of 3-26 seconds from the second payload. The temperature vs time plot from the first payload is shown in Figure 24.

**Conclusions**  Aerodynamic heating was the most serious problem that was encountered on the two flights. The corrective measures that will be used on future flights will be the use of the smaller diameter Solistron with additional insulation between the transmitter and the projectile body, and temperature compensating capacitors within the transmitter to offset frequency drift. A 20 db margin between received signal level and receiver threshold was measured at peak altitude. The transmitter power will be reduced by 3-5 db on future flights. This will reduce some of the internal heating which is also a major factor causing frequency shift.

The helix antenna pattern was degraded seriously by the fiberglas covering and the radiation off the tail was contained in quite a narrow lobe, A modified dipole or “Bow
Tie” antenna will be used on future flights. Due to the linear polarization obtained from the Bow Tie antenna, the ground receiving antenna feed will be converted from a dipole to a circularly polarized antenna.

Future work on the 5-inch probes will be directed toward smaller payloads and the use of integrated circuits where practical. This will provide more space for upper air experiments and ultimately a parachute system. The final system with a parachute will probably be more useful for obtaining meteorological data.

Bibliography


Fig 1 Pictorial of Gun Probe System
Fig 2 Block Diagram of Telemetry and Ranging System
Fig 3 Lead Test Projectile

Fig 4 Lead Test Gun Setup

Fig 5 Lead Test Projectiles and Blocks

Fig 6 Fired Lead Test Projectile and Blocks

Fig 7 Solistrons

Fig 8 Sub-Carrier Oscillator and Commutator
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Fig 10 Battery Pack and Acceleration Switch

Fig 11 Antenna Before Wrapping

Fig 12 Telemeter Payload for 5" Gun Projection
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Fig 14  7" Projectiles
Fig 15  16" Martlet Projectile
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Fig 17  Telemetry and Tracking Van (Inside)
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Fig 20  5" Guns at Wallops Island, Virginia
Fig 21  7" Gun at Wallops Island, Virginia

Fig 22  16" Gun at Barbados
Fig 23  Component Layout in 5" Probe
Fig 24  Temperature vs Time Plot, 5" Probe