

SUBMINIATURE TELEMETRY TECHNOLOGY

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ABSTRACT

Current telemetry instrumentation systems are subject to space and weight limitations for use in bombs, dispensers, submunitions, projectiles and other tactical weapon systems. It is not now feasible to instrument submunitions and projectiles for weapon effectiveness data because state-of-the-art telemetry devices cannot be rapidly and cost effectively installed in unmodified munitions. Furthermore, aircraft modifications for flutter/loads testing are extremely expensive and time consuming. This program will develop a low cost telemetry chip-set consisting of integrated sensors, signal conditioning, transmitters and encryptors. "Peel-and-Stick" (See Figure 1) telemetry devices, containing a specific chip-set with integrated sensors, a battery, and antenna in an extremely small package, will also be developed.

Subminiature Telemetry Technology (SMT) will directly impact all future tactical submunition development programs during pre-production RDT&E. This program will also support compatibility and safe separation testing done in the Air Force SEEK EAGLE program. Conventional and kinetic energy projectile programs and advanced missile programs will have long-term benefit. Telemetry and encryption designs developed in this program will advance the state-of-the-art in telemetry fabrication from hybrid to monolithic providing smaller, more shock resistant systems at a much lower cost. Subminiature telemetry devices could be integrated with the weapon system during its development allowing for a non-destructive, non-contaminating test of the system. This will greatly reduce the cost and logistics of determining weapon readiness and health status during long time periods of storage.

INTRODUCTION

The Air Force Armament Laboratory has recently completed three separate efforts to study the possibility of developing subminiature telemetry for use in munitions and submunitions. Areas of investigation included: state-of-the-art MMIC technology and its applications

toward the SMT transmitter; a link analysis to determine the best modulation techniques to simultaneously telemeter data from up to 100 separate munitions; and techniques to optimize the antenna design for these applications (See Figure 2). In January 1989, an RFP was released to award a follow-on contract for a basic SMT development effort along with four options. The basic effort includes an applications analysis and breadboard level development of a chip-set design, packaging design, receiver design, and a technology demonstration. The four options are “peel-and-stick” breadboard design; brassboard development of the basic effort designs and flight tests of these designs; “peel-and-stick” brassboard development and test; and encryption chip brassboard development. The RFP calls for the delivery of brassboard designs and hardware.

THE TECHNOLOGY

Subminiature Telemetry Technology will provide, for the first time a means of obtaining telemetry data during live munition and submunition testing. Historically, collecting data during live warhead tests without modifying the weapon or munition has been all but impossible. Occasionally, a weapon under test will have just enough empty space to allow insertion of some type of data collecting system without affecting its performance. Rarely do we have this luxury, especially since many new weapons are getting smaller, smarter, and consequently, more complex. With the advent of modern Monolithic Microwave Integrated Circuit (MMIC) RF circuit development techniques, advances in spread spectrum communication and computer aided workstations, Subminiature Telemetry can be realized in everyday testing (See Figure 3). The advantage of being able to obtain critical data signals without extensive system modification will be a revolutionary step in weapon system development and is the goal of the basic program development.

An additional application of these technologies and goals is “peel-and-stick” development proposed in Options 1 and 3 of the RFP. “Peel-and-stick” development is targeted for applications which require telemetry instrumentation to be mounted on the surface of the test item as opposed to internally as pursued in the basic development (See Figure 5). Aircraft flutter/loads testing, as performed by the USAF SEEK EAGLE office, is the target application for peel-and-stick. In this application, peel-and-stick TM devices would be mounted on the surface of the aircraft, where vibration and stress measurements are required. These devices could then be remotely activated to transmit data to an aircraft mounted receiver. The resulting data could be retransmitted to the ground and processed for a real-time flutter solution.

TECHNOLOGY APPROACH

During the first phase of the contract, several development areas will be initiated. The development of a standard macrocell library of component functions including modules

such as transmit/receive, frequency source, filtering, multiplexing and power control will be developed and tested. Each of these “macrocells” will be designed to be universally compatible with each other in the manner of VLSI standard cells. Several modulation schemes were evaluated during the initial effort. The technique selected for development will have the capability to transmit and receive from up to 100 different telemetry links with minimal or no modifications to the ground station.

APPLICATIONS OF SUBMINIATURE TELEMETRY TECHNOLOGY

Subminiature Telemetry Technology will allow collection of critical data to speed up the Research, Development Test & Evaluation (RDT&E) of many of our weapon systems. Subminiature Telemetry systems could be designed into each weapon system during its initial development. The cost of including this telemetry instrumentation “up-front” in each weapon system will be very minor compared to the additional cost incurred throughout the development, testing, and fielding of these weapons if telemetry instrumentation has to be designed and installed “after-the-fact”. In many applications, the data necessary to evaluate the performance of the weapon is already present in the system. With telemetry instrumentation built into the weapon, critical data points can be monitored throughout development and testing of the system. Since warheads will not be required to be removed, time and money will be saved during all phases of development. After the weapon is fully developed and in production, critical data points can be monitored without opening up the weapon or opening the storage containers in which many weapons are in. The implementation of verifying “status” of each weapon during shelf life will be greatly simplified. As weapons become smaller and more sophisticated, telemetry will become a “must” to verify performance.

MODULATION TECHNIQUE

A modulation technique which permits simultaneous transmission from up to 100 munitions is a requirement for the Subminiature Telemetry System (See Figure 2). There are basically two drivers for this requirement: the full-up submunition test scenario and the aircraft flutter test scenario. In each case, a large number of individual transmitters must broadcast unique data at the same time.

The three most apparent modulation techniques, Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA) and Code Division Multiple Access (CDMA) all have problems when considered by themselves. TDMA requires a burst or “packet” of data to be transmitted from each munition during non-overlapping periodic intervals. However, since the telemetered munition’s end goal is to detonate, the transmitter may have exploded before a packet could be transmitted, resulting in lost data. FDMA requires that each transmitter have it’s own unique frequency assignment. Not only

is this a logistics problem to implement, but with narrow band data, frequency drift tolerance is quite stringent. TDMA requires a unique Pseudo-random Noise (PN) code for each transmitter to “chip” the data into a widely spread band. Each channel, broadcasting on the same center frequency, can then be correlated out of the spread band by de-chipping using the unique PN code. However, for 100 transmitters, the PN code sequence required becomes very large and the chip rate required is very fast, which leads to unacceptable acquisition times.

A solution for our application may be a hybrid of FDMA and CDMA techniques (See Figure 4). Moderately wide-band frequency allocations between 2200 - 2400MHz are selected for a given application. Within each frequency assignment, N CDMA channels are allocated so that:

$$\text{Total \#channels} = M * N$$

The required number of frequency allocations (CDMA block) and CDMA channels selected is determined from the test item data bandwidths and total number of items.

The advantages of the hybrid FDMA/CDMA system are many. Not only does the technique permit reliable recovery of the data but also permits a modular design approach that can be used for a large number of applications with widely varying requirements. The hybrid technique acquires the signal faster than a pure CDMA system would (due to a smaller number of transmitters per block) and has less stringent frequency accuracy requirements than a pure FDMA system. Any number of munitions between one and 100 can be instrumented by trading-off data bandwidth for number of channels or vice versa.

SUBMINIATURE TELEMETRY TECHNOLOGY

PEEL-AND-STICK

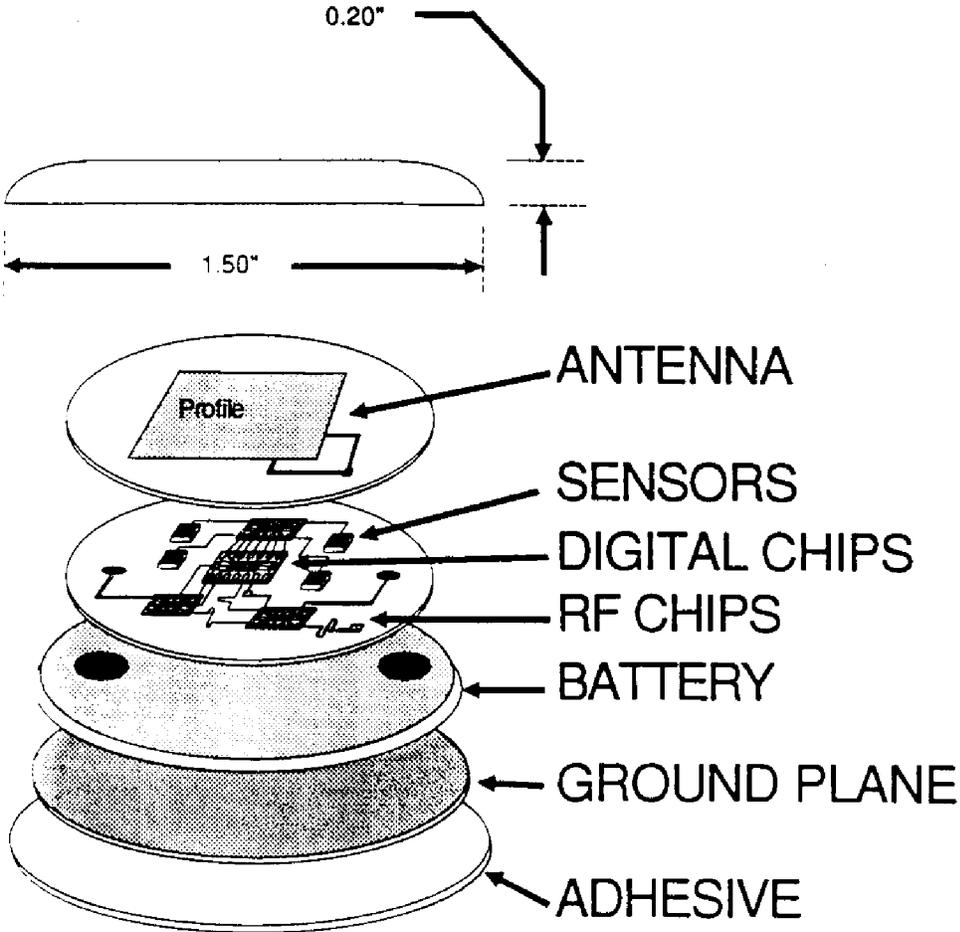


FIGURE 1: "PEEL-N-STICK"

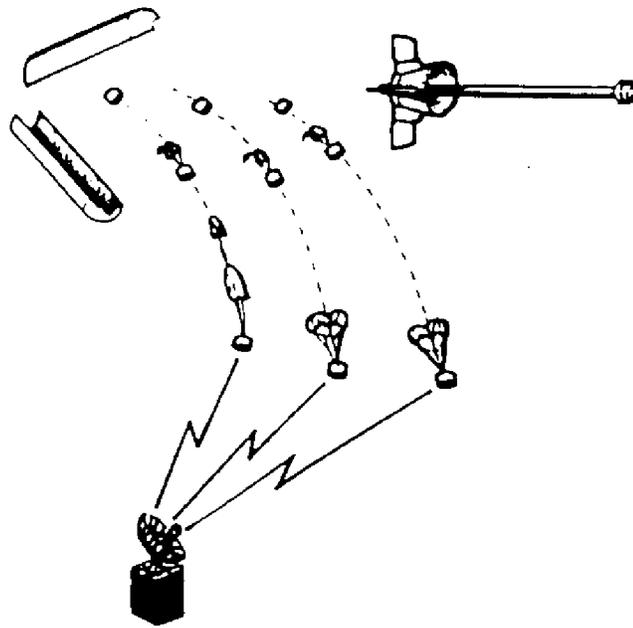
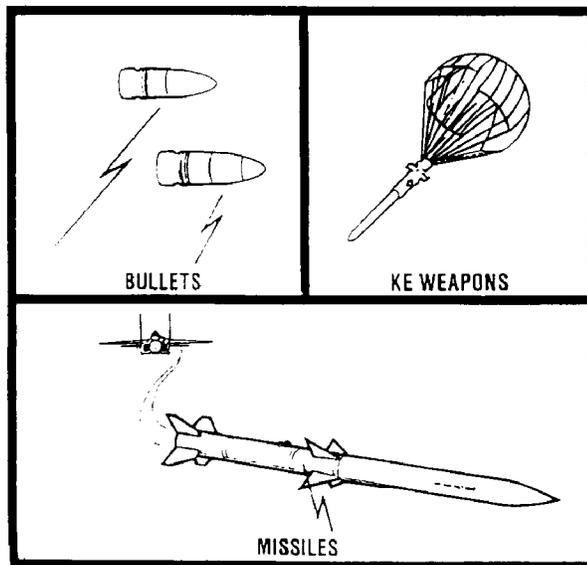


FIGURE 2: TELEMETRY FROM MULTIPLE MUNITIONS
(up to 100 simultaneously)



OTHER APPLICATIONS

- PROJECTILE VELOCITIES
- DATA WITHOUT WARHEAD REMOVAL
- INTEGRATED INSTRUMENTATION
- MULTIPLE GUIDANCE/FUZING EVENTS

FIGURE 3: OTHER APPLICATIONS (Bullets, Kinetic Weapons, Missiles)

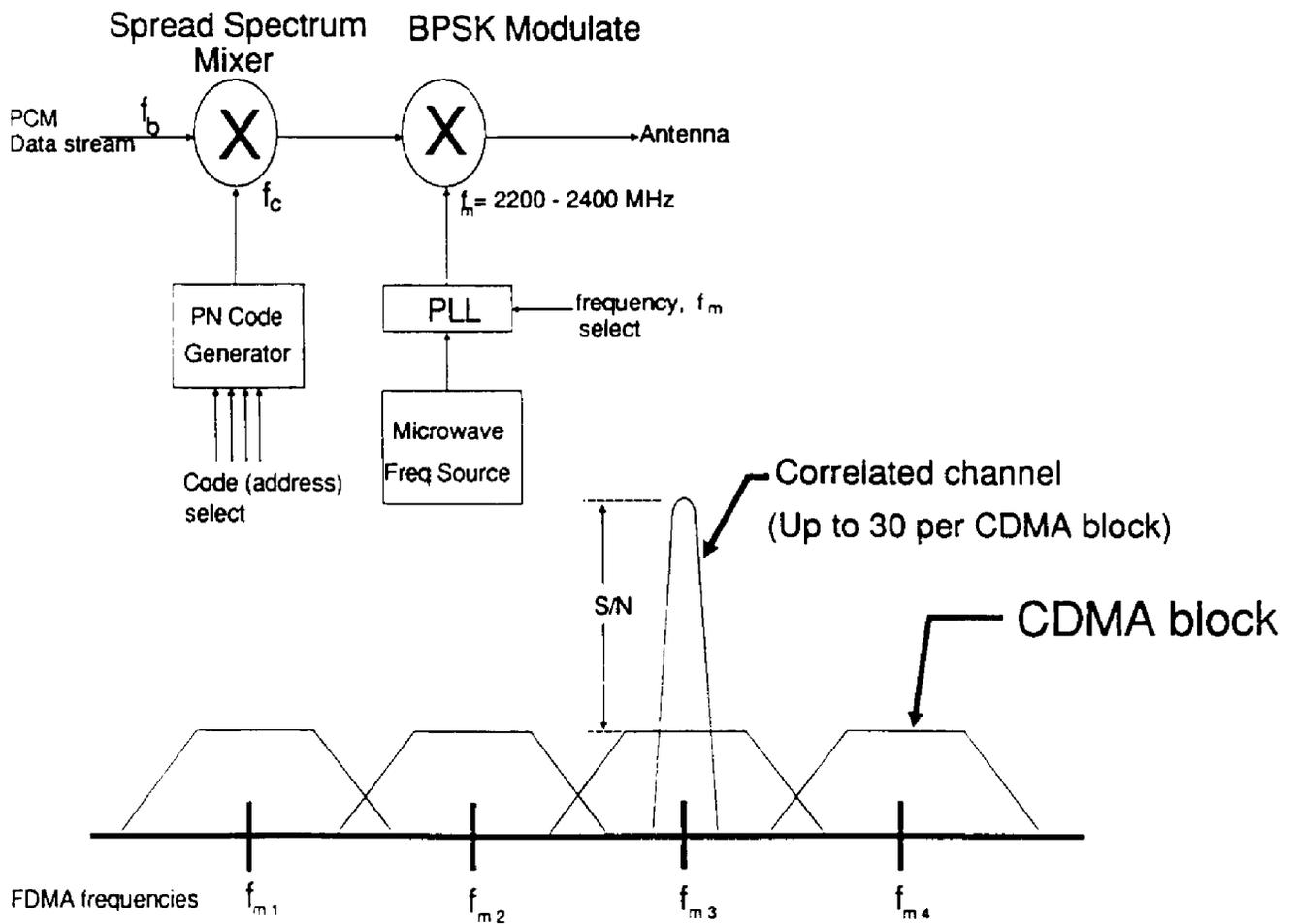


FIGURE 4: MODULATION TECHNIQUE

SUBMINATURE INSTRUMENTATION AIRBORNE TEST APPLICATIONS

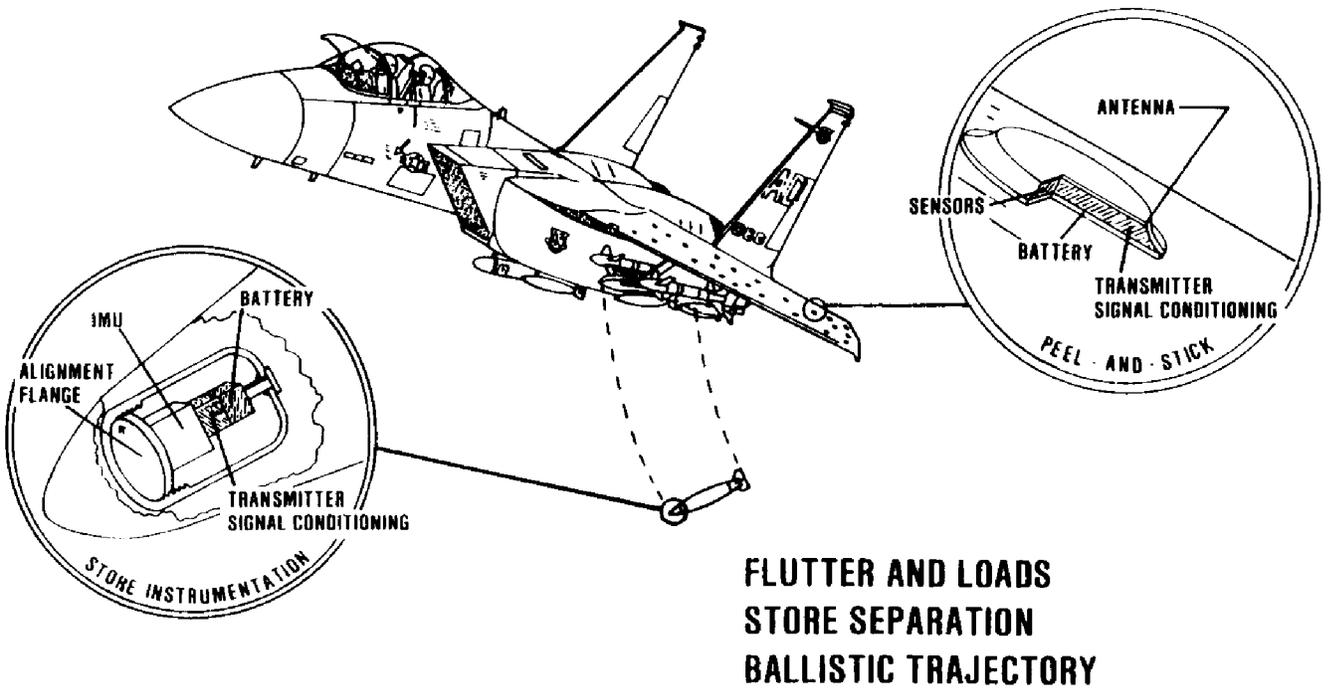


FIGURE 5: AIRBORNE TEST APPLICATIONS