MONOLITHIC MINIATURIZED TELEMETRY SYSTEM

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ABSTRACT

This paper describes developments in miniature, high shock telemetry at ARDEC using monolithic millimeter wave integrated circuit (MMIC) technology. Telemetry systems using this technology have been fabricated and gun tested at 60,000 g's with excellent results.

Efforts to develop rugged telemetry systems to support testing at very high "G" levels have been underway since 1984. The initial effort was targeted at developing rugged telemetry instrumentation to engineer high performance munitions such as the 105mm and the 120mm Armor Piercing Fin Stabilized Discarding Sabot (APFSDS) which produce very high in-bore accelerations. The initial result demonstrated circuit stability and operation during very high accelerations (60,000 g's). A second phase was launched to develop a telemetry system consisting of an FM multiplex, a summing amplifier and a transmitter. These efforts demonstrated that telemetry data could be transmitted during acceleration thrust, through the ionized gases and could provide the real time projectile performance data.

This paper presents the results of the work done to date and the potential for broad application in families of high performance munitions systems throughout the testing community.

INTRODUCTION

It has been demonstrated that as weapon systems become increasingly intricate, the telemetry instrumentation technology used in the development and testing of these complicated systems need to be miniaturized and ruggedized while keeping instrumentation costs low.

The monolithic technology meets the requirements of the advancements in hypervelocity weapon systems with a decreasing amount of volume available to integrate instrumentation. The latest weapon systems require a small light weight complete instrumentation package capable of transmitting data in the harsh environments of hypervelocity guns. These challenges placed a major emphasis on the research, development and fabrication of high shock micro-miniature instrumentation packages.

Since 1988, the Telemetry Section at ARDEC has pursued the development of a high-shock, micro-miniature, telemetry system. . This system is a frequency modulation/phase modulation, surface acoustic wave (SAW) stabilized telemeter that utilized monolithic microwave integrated circuit (MMIC) technologies to achieve a very small instrumentation package.

The testing and evaluation of monolithic SAW stabilized technology and its application to instrumentation systems was initiated at ARDEC in 1988. In November 1990 a monolithic micro-miniature transmitter was fired in the 105mm gun. The objective of this test was to prove transmission through the ionized gases and to determine the amount of frequency shift which would result from subjecting the instrumentation to the 105mm gun environment. The device fired in 1990 was an RF transmitter stabilized by a surface acoustic wave (SAW) element and it was successfully fired at an acceleration force of 67,400 g's. More information about this early development can be obtained from references 1 and 2.

The success of the first phase launched the micro-miniature monolithic development into a second phase which was tested in early 1992 in the 105mm environment at 50,000 g's. Figure 1 shows a block diagram for this telemetry system. It consisted of a six channel frequency modulated (FM) multiplex, a subcarrier mixer, an S-band transmitter, an antenna and a capacitor bank which provided power to the electronics for 20 milliseconds. The data received was collected by a ground station and recorded on magnetic tape for further analysis.

The successful conclusion of this second phase establishes a significant accomplishment in the development of state-of-the-art microminiature instrumentation. Typically, the application of monolithic technology in the development of micro-miniature telemetry has introduced a high risk element to the integration of instrumentation in ongoing weapon developments. In combination with this high risk element research dollars have also been scarce, which has hindered the development of this innovative approach to instrumentation. However, after these two successful firings, the interest in this new technology has been activated and recent efforts show that this technology will be a serious participant in the instrumentation of future weapon systems developments.

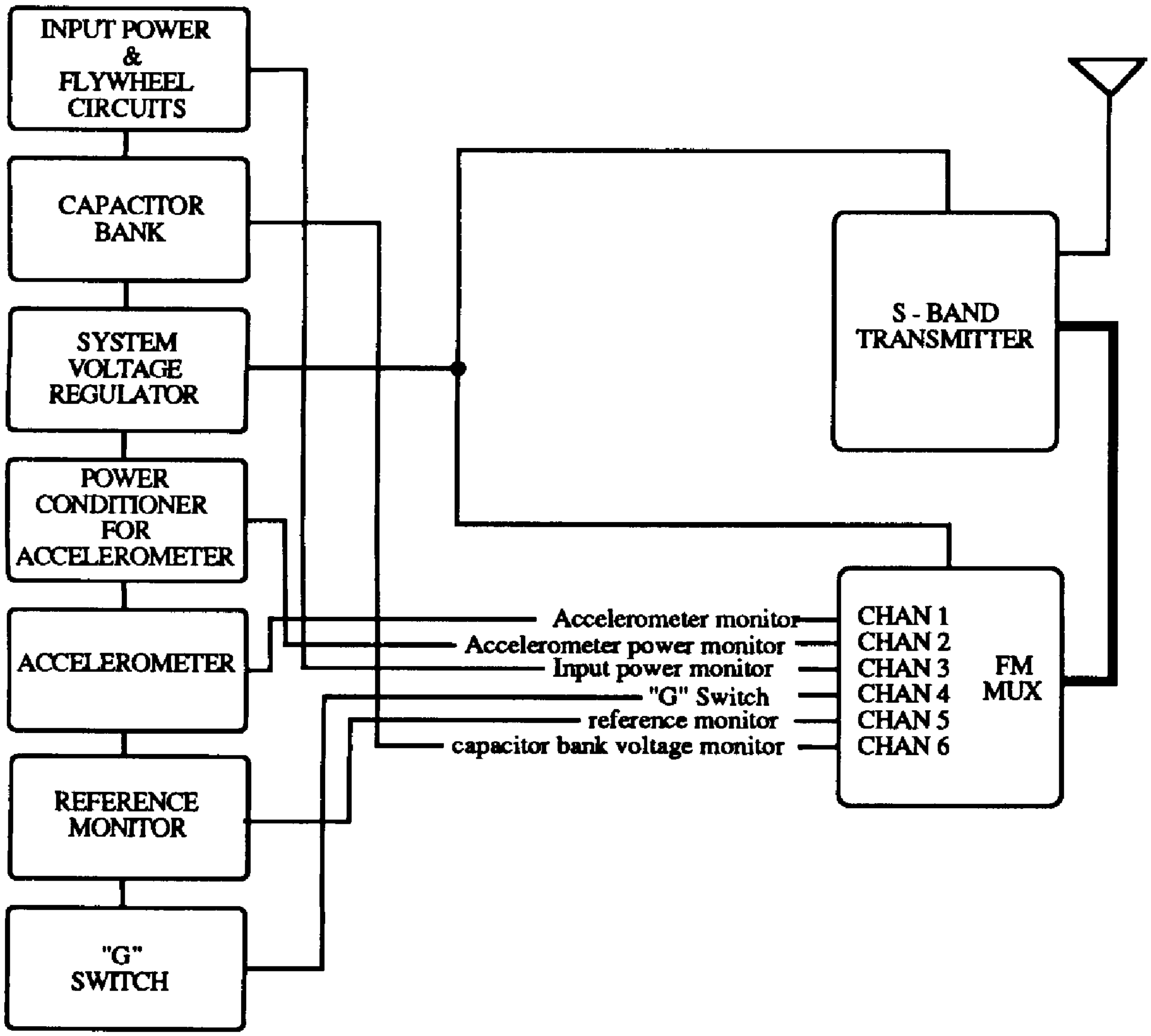

FIGURE 1

SYSTEM DESIGN OVERVIEW

Figure 2 shows the hardware used in the high "g" telemetry system integration. It shows three hardware cavities: the multiplexer/transmitter cavity, the power conditioning board cavity and the capacitor bank cavity. The three plates shown separate the cavities and provide a systematic approach to the system build up.

The power supply consisted of a capacitor bank with twelve capacitors and protection diodes. The components were assembled on a printed circuit board and inserted into the capacitor bank cavity with a high "g" pad to soften the setback forces. The unused volume inside the capacitor bank cavity was filled with hard potting compound and the wires were inserted through a hole located at the center of plate #3.

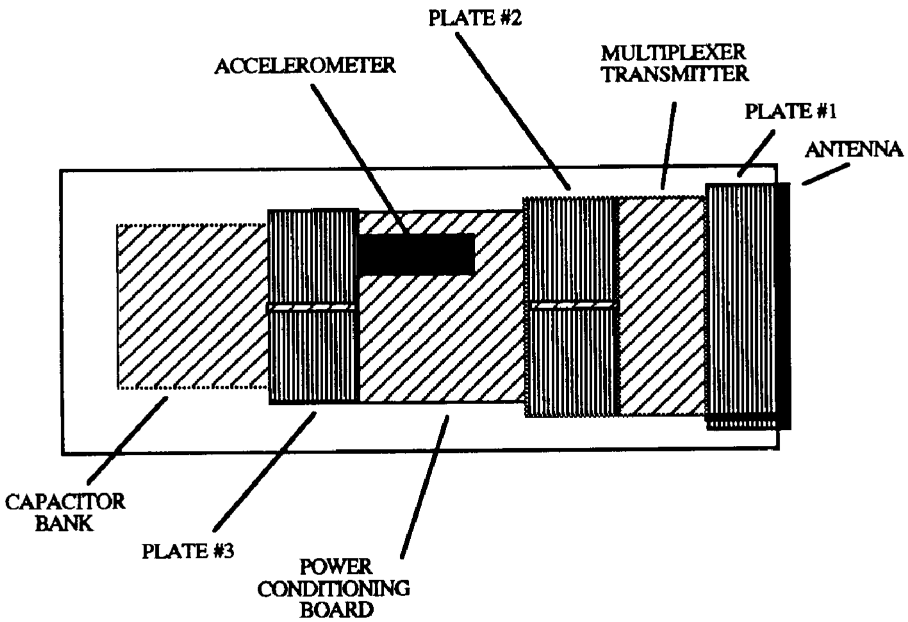

FIGURE 2

The power/signal conditioning board consisted of the dc power regulation and signal conditioning circuitry. The power conditioning circuitry regulated a 15 volt input to an 8 volt power source used to power the multiplexer and the transmitter. The capacitor bank was charged to a voltage of 15 volts and used the energy between 15 volts and 8 volts to power the electronics. The unused volume inside the power/signal conditioning board cavity was filled with the same potting compound as the capacitor bank cavity.

The transmitter/multiplexer cavity contained the CMOS multiplexer, the MMIC transmitter chip and the SAW stabilizing element. Also the unused volume was filled with hard potting compound.

All electrical connections between the three cavities were performed during the fabrication process and using the small through hole in the center of the plates for the feed through connections. The patch antenna was glued to plate #1 and connected to the transmitter with a very small semi-rigid coaxial cable.

INITIAL BENCH TESTS

Before any environmental testing is done, a bench test is done to record all initial system settings. These include input power requirements, the received RF power and carrier and subcarrier frequencies. These values give us a basis of comparison after successive environmental tests. A summary of the system parameters for the two telemeters is as follows:

TABLE 1

Telemeter #1

V_{in}=9.0 Volts
I_{in}=200mA
RF Power=20 dBm
Transmitter Freq.=2285.803 MHz

Subcarrier Freq.	Low Band(KHZ)	Center Band(KHZ)	High Band(KHZ)
347.5 KHZ ± 6.5%	325	347.5	370
257.0 KHZ ± 6.2%	241	257	273
206.0 KHZ ± 5.8%	194	206	218
118.5 KHZ ± 6.3%	111	118.5	126

Telemeter #2

V_{in}=9.0 Volts
I_{in}=200mA
RF Power=20 dBm
Transmitter Freq.=2286.017 MHz

Subcarrier Freq.	Low Band(KHZ)	Center Band(KHZ)	High Band(KHZ)
349.0 KHZ ± 4.4%	334	349	365
250.0 KHZ ± 3.2%	249	250	266
234.0 KHZ ± 2.8%	228	234	241
128.0 KHZ ± 7.8%	116	128	136

AIRGUN TESTS

After all bench tests were completed, the micro telemeters were subjected to live airgun tests. External power was supplied through a Port in the barrel. When these wires get sheared, the internal capacitor bank stores enough energy to power the system throughout the firing. The capacitor bank is comprised of 12 solid tantalum 47uF capacitors which provide power for at least 20 msecs. The test fixture used was designed to yield maximum accelerations in the ARDEC 155mm airgun. This gun provides the slowest rise time and longest pulsewidth associated with airguns. G-levels obtained were on the order of 17,000 g's with a pulsewidth of 3 msec.

POST AIRGUN BENCH CHECKS

Post airgun bench checks insure that previous channel settings (Table # 1) did not deviate after g-hardening. Slight variations in channel frequencies occurred after the airgun tests. This is mainly due to component settling, however this characteristic will be addressed in the next generation of telemetry systems.

l05MM GUN TESTS

A telemeter carrier was designed to allow testing in a 105mm powder gun. The telemetry systems will be destroyed in this phase of testing. It was essential to design a setup that would yield the greatest amount of redundancy. This was accomplished using four receivers and three antennas arranged as in figure 3. Each antenna had an RF preamplifier (30 dB gain) to compensate for losses in the long coaxial cables. All four S-band receiver's video and automatic gain control (AGC) outputs were recorded on two 14 track magnetic tape recorders. Also recorded were the predetection outputs from two of the receivers, IRIG timing and a T-0 pulse provided from the gun control room. Two telemetry systems were fired in a 105mm gun at Picatinny Arsenal's test area. These systems were powered externally in the same manner as the airgun. Both systems provided excellent data results, as can be seen from the enclosed data plots.

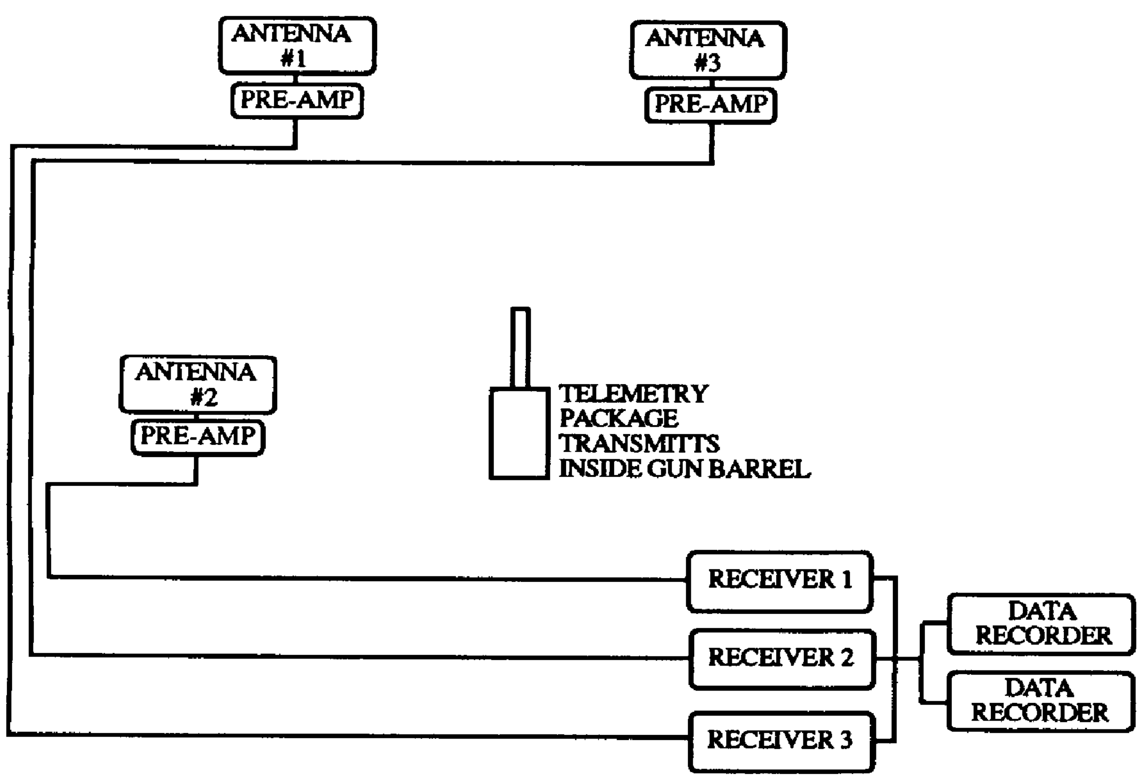

FIGURE 3

RESULTS

The following eight plots describe in-flight data collected from the two telemetry units fired in the 105mm gun at ARDEC.

The piezoelectric accelerometer outputs are shown in figures 4 and 8 for test shots #1 and #2 respectively. This data was modulated on the highest subcarrier. The low pass filter of the frequency discriminator was set to 6.4 KHZ. (This filter could be dropped to 3.2 KHZ in order to have a smooth curve.) Notice that the noise level before the acceleration pulse is carried throughout the test.

The data from the internal switch which was activated by a level of 100 g's of acceleration is shown in figures 5 and 9 respectively. This switch is used as a T-Zero mark. The 6.4 KHZ low pass filter passes switch chatter.

The automatic gain control (AGC) output of the receiver is shown in figures 6 and 10. The AGC is linearly related to the received signal strength into the receiver.

The capacitor bank supply voltage is shown in figures 7 and 11.

Actual low pass filters (LPF) needed for a modulation index of 5:

Shot #1

Frequency (KHz)	Channel	Required LPF (KHz)	Used LPF (KHZ)
347.5	Accelerometer	4.5	6.4
257.0	Accel Regulator Voltage	3.18	6.4
206,0	G-Switch	2.39	6.4
118.5	Capacitor Bank Voltage	1.49	6.4

Shot #2

Frequency (KHz)	Channel	Required LPF (KHz)	Used LPF (KHZ)
349	Accelerometer	3.07	6.4
250	Accel. Regulator Voltage	1.60	6.4
234	G-Switch	1.31	6.4
128	Capacitor Bank Voltage	2.00	6.4

Low pass filters could be reduced in order to obtain smoother plots.

CONTINUING EFFORTS

The telemetry system will be repackaged to fit in a 1.000 inch outside diameter housing. The transmitter and multiplexer components will incorporate the shortest and fewest bond wires possible by use of an interconnect circuit board. The external power supply and capacitor bank system will be replaced with a self-contained battery pack. The final system design will be fabricated and then tested in the ARDEC Electromagnetic gun facility at Picatinny Arsenal, New Jersey.

REFERENCES

1. Ferguson D., Meyers D., Gemmill P., and Pereira C. International Telemetering Conference Proceedings. 1990. Volume XXVI, Instrument Society of America, Research Triangle Park, North Carolina, 1990, Pages 497-505.

2. Pereira, Carlos. "High "G" Transmitter Test and Evaluation". Technical Report ARAED-TR-90024. U.S. Army Armament Research, Development and Engineering Center, Picatinny Arsenal, NJ. November 1990.

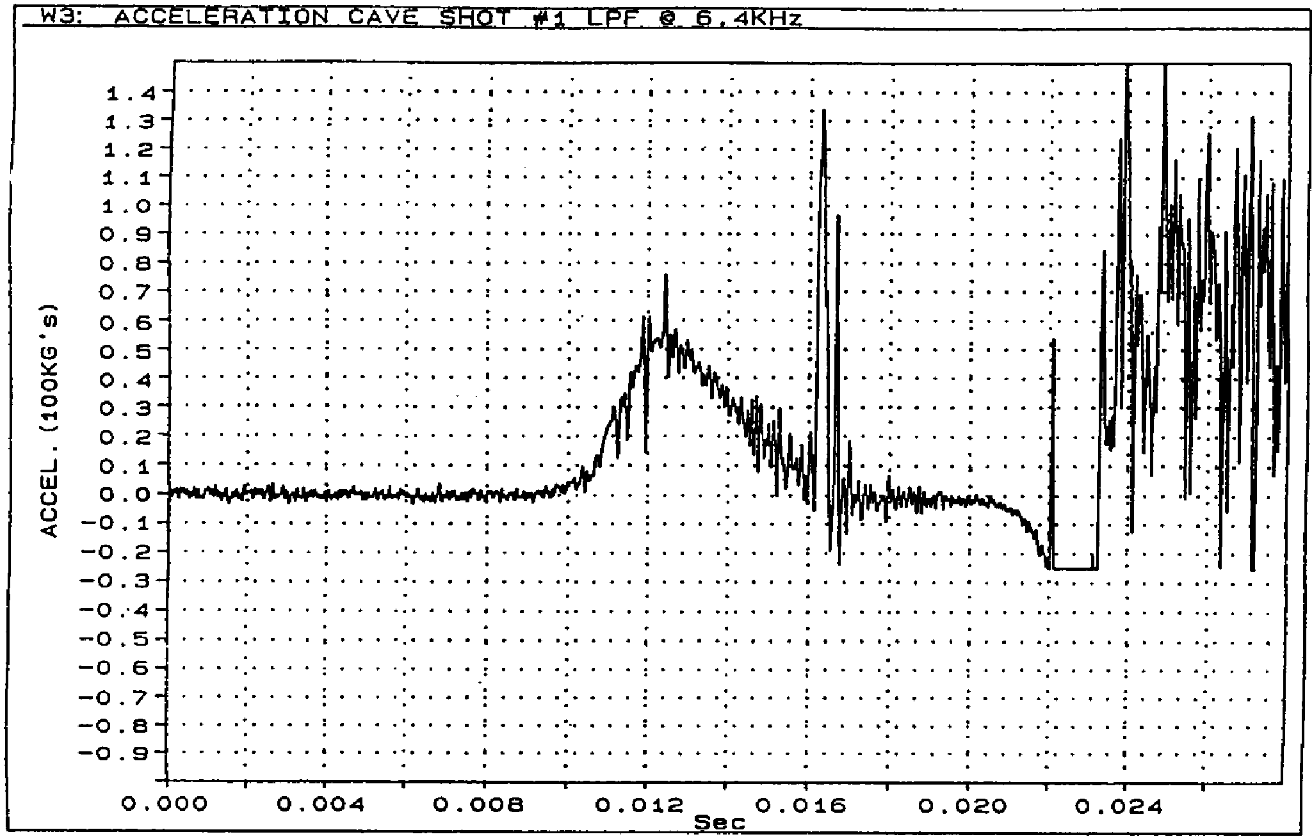

FIGURE 4

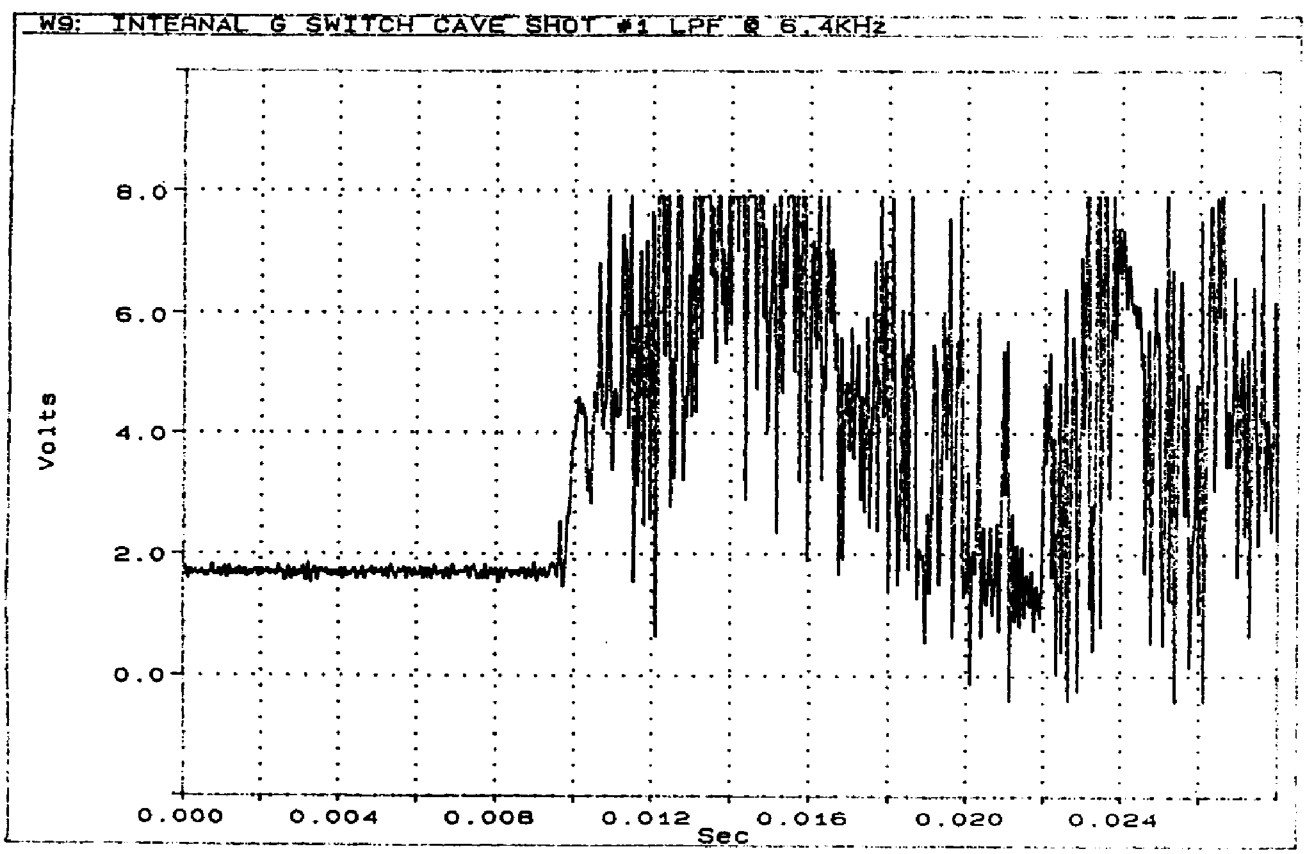

FIGURE 5

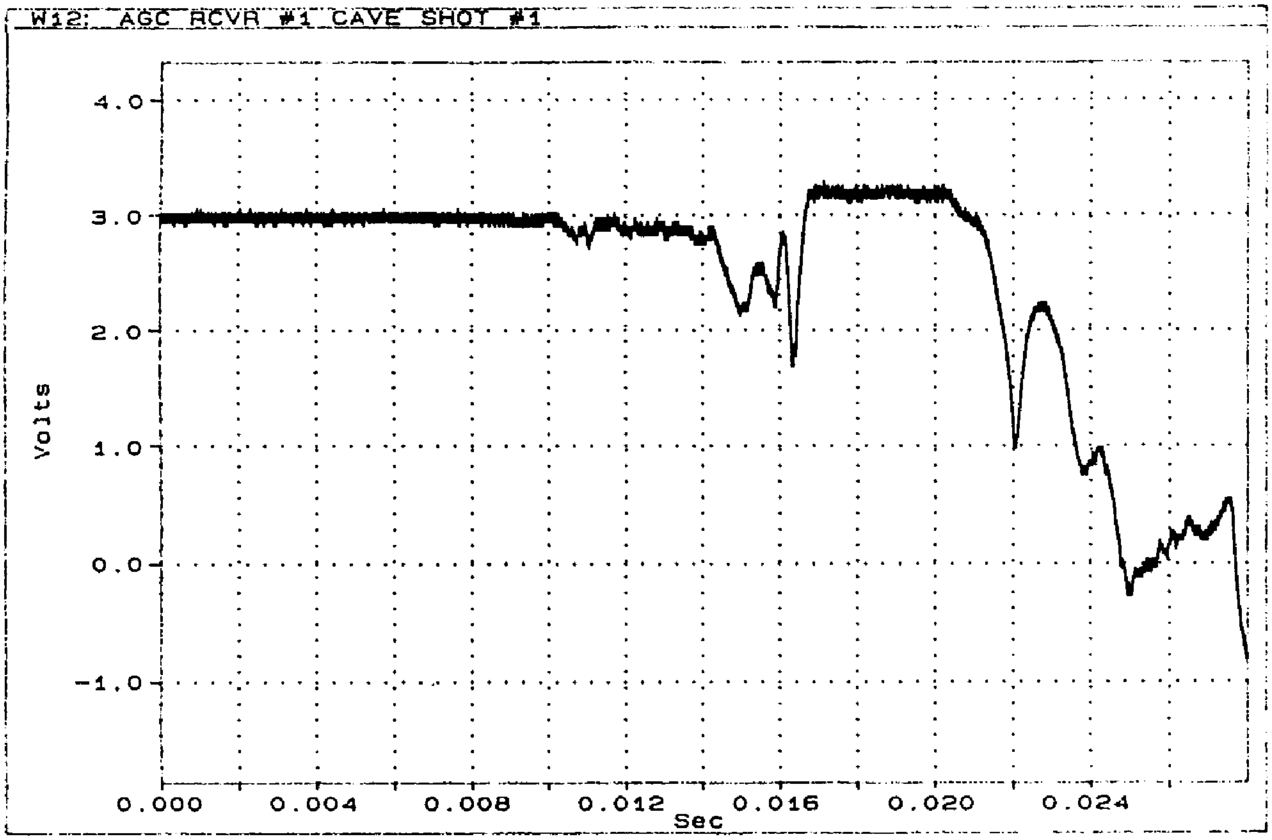

FIGURE 6

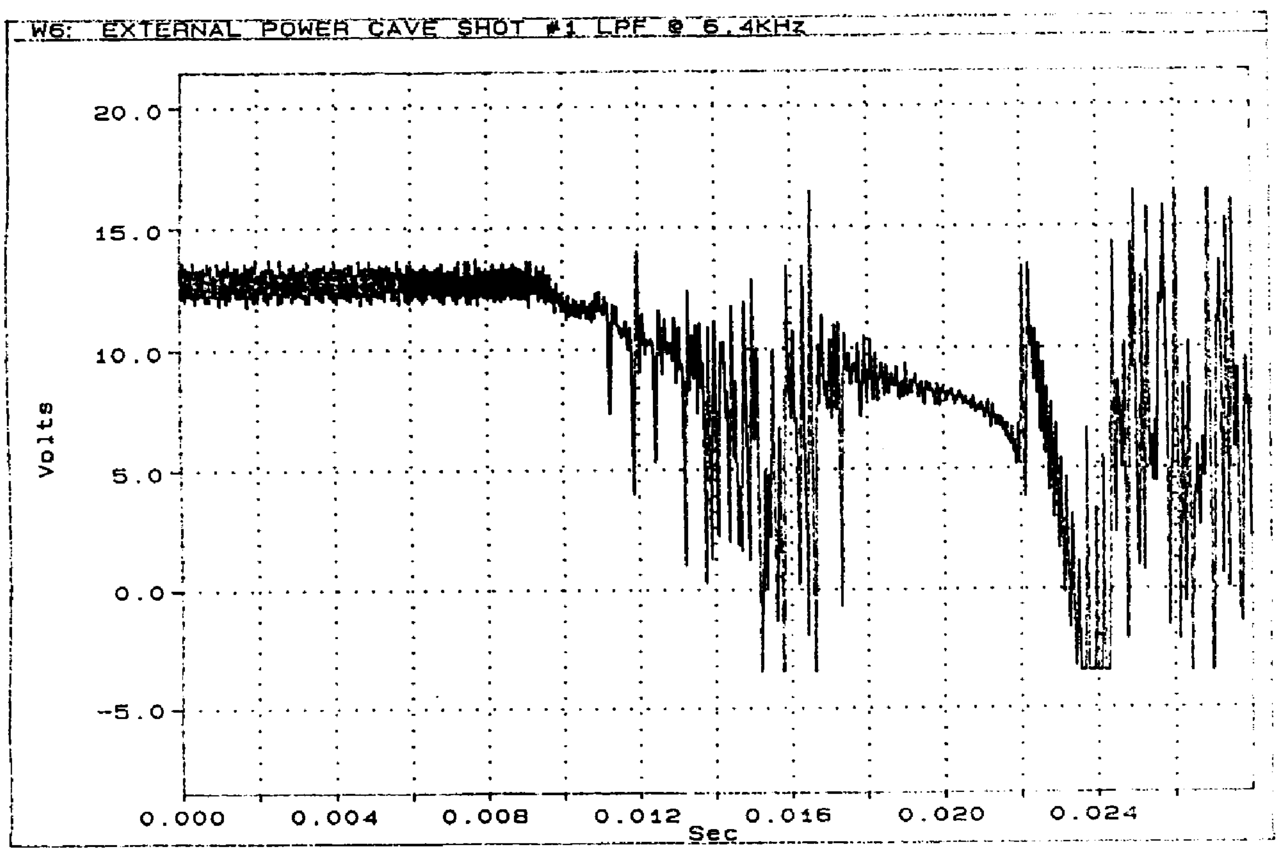

FIGURE 7

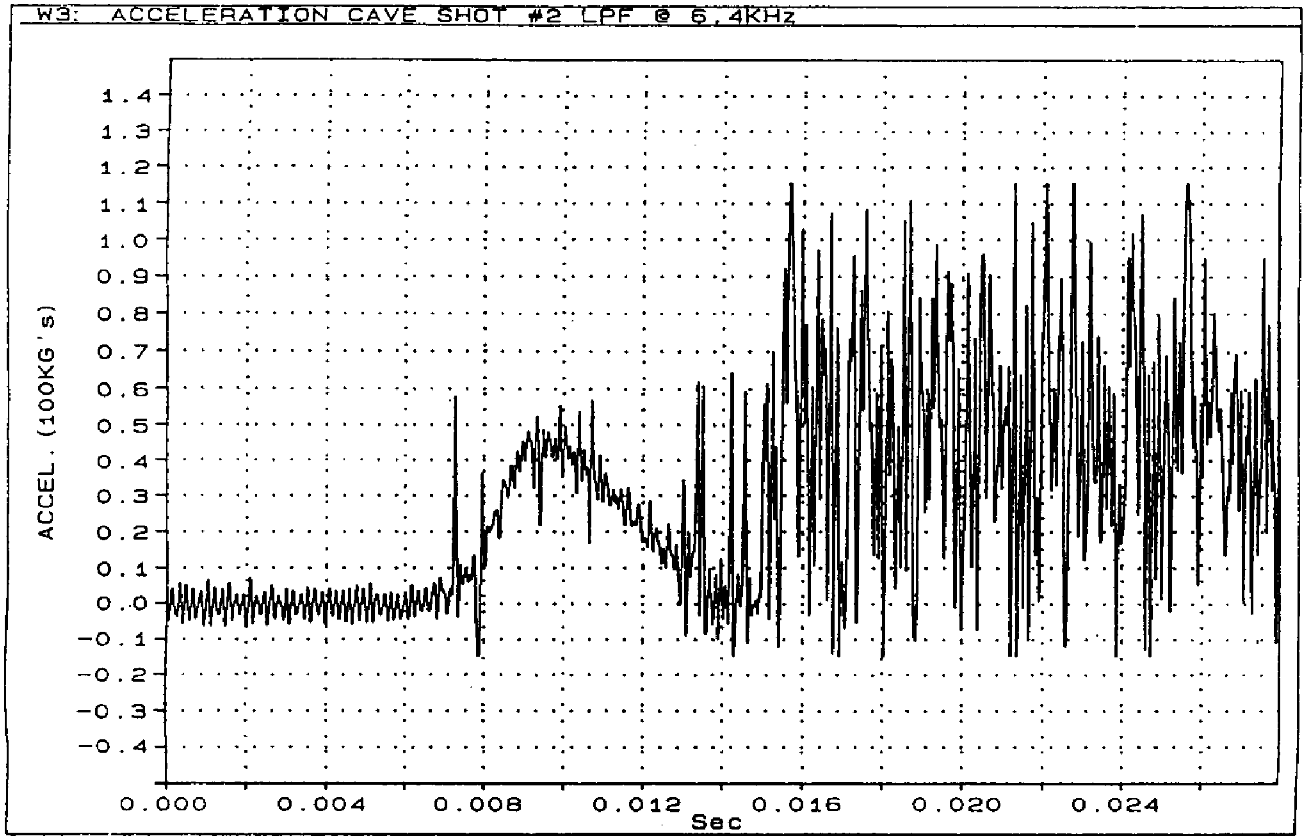

FIGURE 8

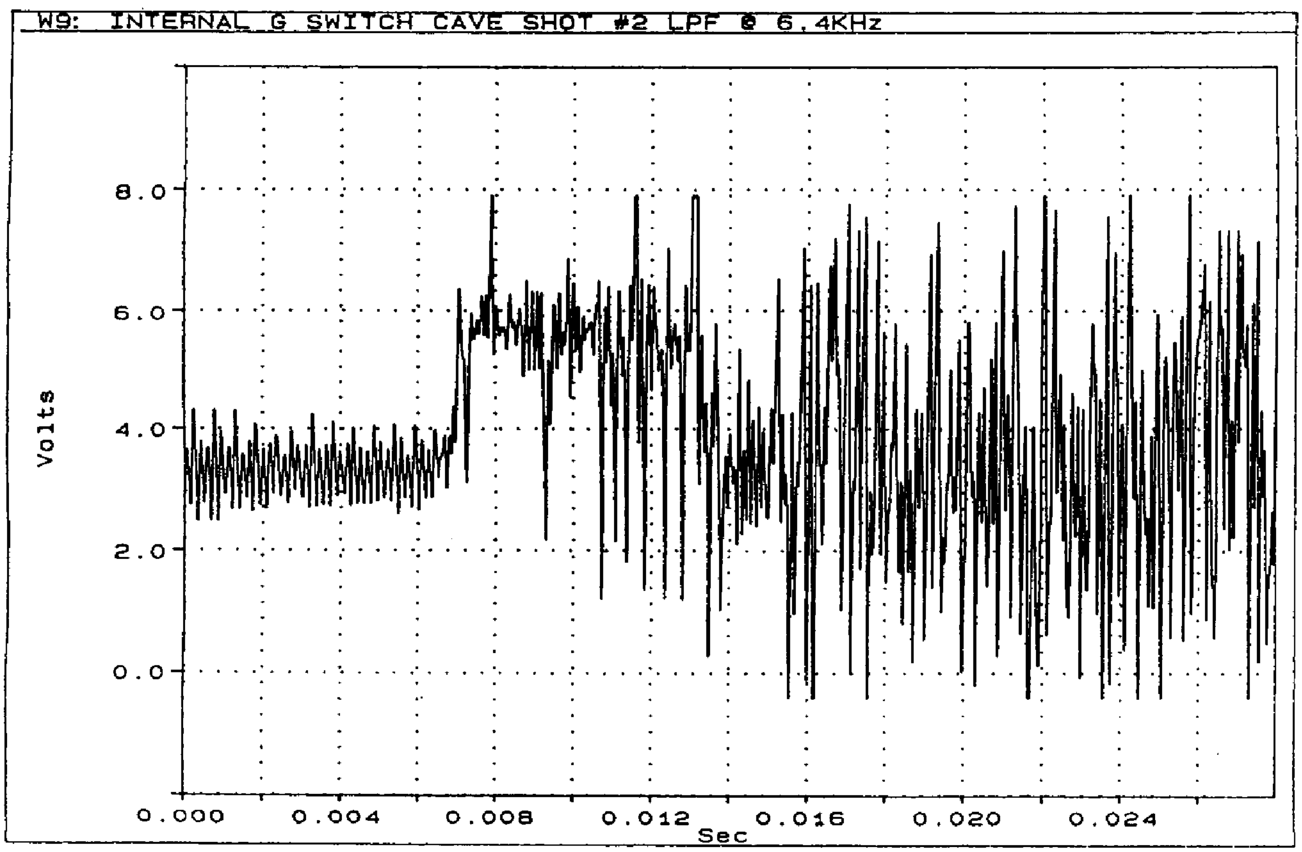

FIGURE 9

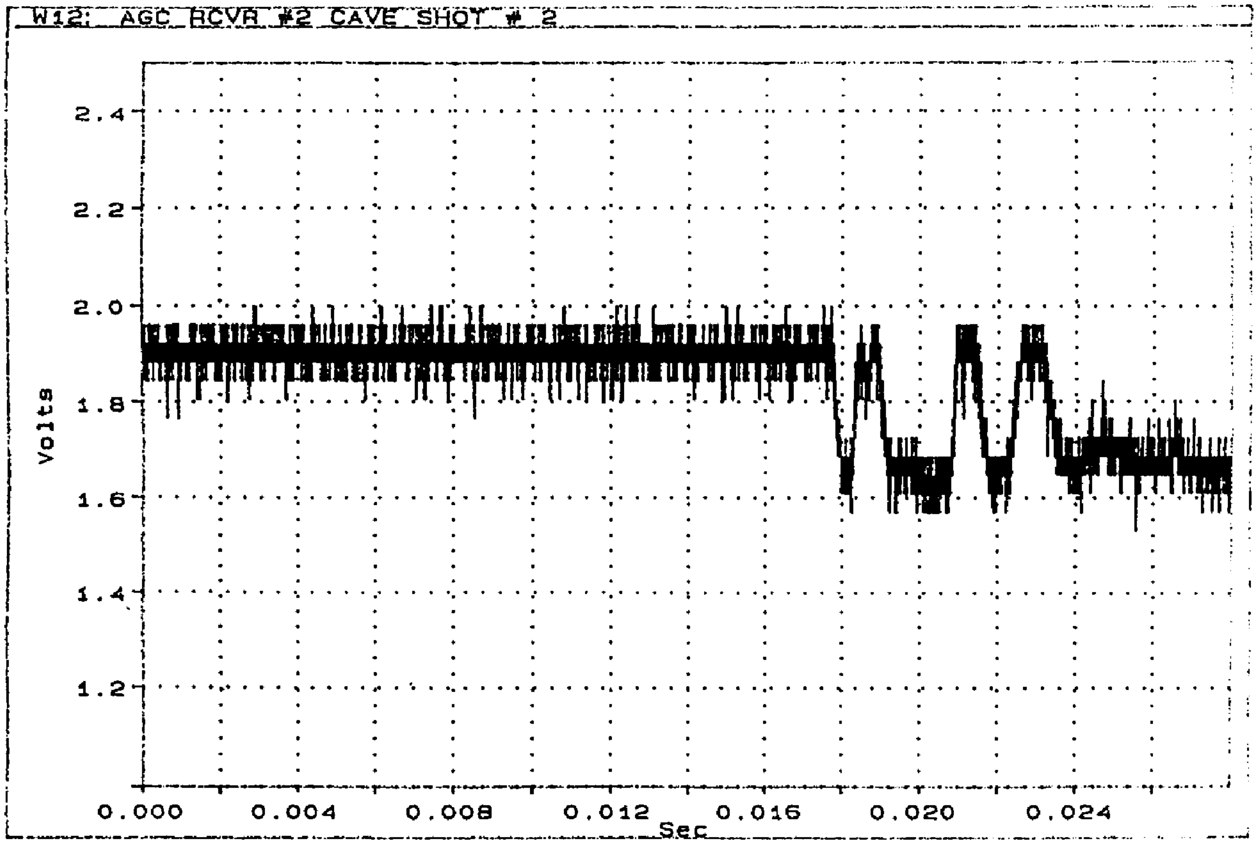

FIGURE 10

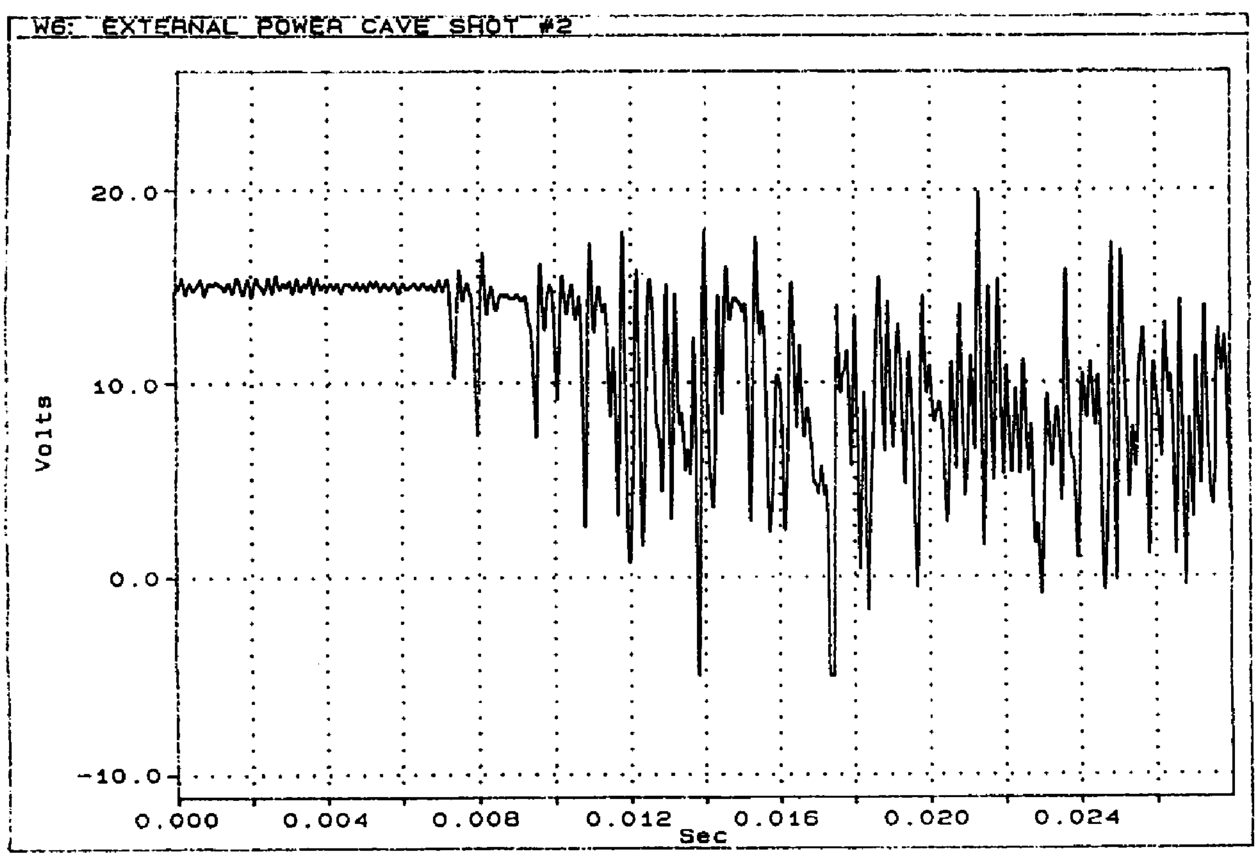

FIGURE 11