AIRBORNE TELEMETRY TRENDS FOR THE 1990's

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ABSTRACT

Telemetry hardware technology and application requirements have undergone significant changes in the last 25 years. The trends have produced flight hardware which has had increasingly higher performance, flexibility, reliability and power efficiency while achieving smaller size and weight. This paper will review the evolution and attempt to forecast the direction and trends for future requirements and solutions through the 1990's.

INTRODUCTION

Aydin Vector Division has participated in the growth of the Airborne Telemetry industry since 1956. The company originally specialized in design and manufacturing RF Telemetry Transmitters and FM Multiplex components. As the business grew, the company developed a family of components and systems to become one of the major suppliers of Telemetry equipment in the free world. The Division intends to continue its long term commitment to support the flight test community with the most advanced and reliable products available. The paper outlines the changes in requirements and technology with their impact on the hardware supplier.

EARLY TELEMETRY SYSTEMS

While it may be interesting to many of our older industry members to reminisce about the days of electromechanical commutators, dyna-motors, sub-miniature vacuum tubes and many other archaeic components from the 1940's and 1950's, the industry grew from these humble beginnings to develop standards for time division multiplexing techniques, such as PAM and PDM and FM Multiplex techniques using VCO's and Mixer Amplifiers.

Typical telemetry frequencies were in the 216 to 265 MHz range. (VHF - P Band).

In the 1960's, the Inter-Range Instrumentation Group (IRIG) and in particular Naval Weapons Center Corona and China Lake, CA, were instrumental in moving the industry toward new components for the higher frequency 1435 to 1535 MHz (L-Band) and 2200-2300 MHz (S Band) UHF frequencies. Solid State PAM Multiplexers were produced with sample rates of 25,000 to 250,000 samples per second using 64 channel frames. Very large (80 cubic inches) S Band transmitters with "plumbing" were replaced with smaller and more efficient UHF transmitters (15 cubic inches).

At the same time, FM Multiplex components were micro-miniaturized using thick-film hybrid circuits and plug-in construction to provide a family of VCO modules with various mounts to configure a wide range of FM Systems for various measurement lists. Techniques were developed to mix FM and PAM data through the same RF Transmitter. This enabled the instrumentation engineer to obtain information with a range of signals from both wide band and low frequency sources.

Aydin Vector Division was a pioneer during the evolutionary period through the 1960's and early 1970's. (See Figure 1 for sample hardware). The application for this equipment was primarily for missile and rocket development, such as the larger Lance, Standard, Tartar-Talos-Terrier, Shrike and Honest John missiles and later the smaller diameter Sparrow and Sidewinders. Typical system accuracy was 3 to 5% for FM and 1 to 2% for PAM.

The same period also brought the development of PCM systems for testing of larger vehicles such as ICBM's, Space Craft and airplanes requiring many channels of data. Many of these units were as large as suitcases and in virtually all cases were customized, fixed format designs to meet the measurement list requirements of a particular vehicle. Typically, most systems accepted normalized 0-5 V data from separate signal conditioners located near the transducers. Typical high level accuracy was 1% and Low Level Accuracy (0-50 MV) was 2%. The number of data channels were 100 to 200 with bit rates of 50 to 200 K Bits. (See Figure 2 for typical late 1960 PCM System).

EVOLUTION AND EXPANSION PERIOD

During the period through the 1970's and early 1980's, our industry continued to grow and we accepted new challenges from the flight test community to provide increasing more sophisticated, higher performance systems. Along with this came the requirements for the designs to be producible in quantity, the configurations to be controlled, the parts selection and workmanship to meet rigid quality assurance standards and strict competitive procurement controls were required.

The Aydin Vector Division continued the development of the family of standard components while increasing the staff and resources to support major systems and major programs.

Our RF product line of Series 100 and 200 UHF Transmitters was accepted a standard for many programs providing a wide range of options to meet special needs. The design was refined to be produced economically in large quantities. Thousands of these transmitters have been used reliably in a wide range of severe environments. Most units were furnished with FM modulation although PM was available as an option. Typical Power Output levels of 2, 5, or 10 Watts were provided.

Companion airborne receivers, models RCC-100 and RCC-200, were also developed along with various tone decoders to support requirements for Command and Control Systems.

The FM Multiplex product line continued to expand, but with increased emphasis on systems applications as opposed to a standard product component business. The low cost, component market was primarily supported by small business with low overheads and with little or no margin. In some cases, even these companies could not survive the market pressures.

Aydin Vector successfully expanded business in this product area offering system solutions to program requirements and providing high reliability products. Typical applications included Wide Band FM Multiplexers for the Space Shuttle and specialized units for Re-Entry Vehicles, IUS Program and other similar applications. Significant System business growth occurred in the area of Warhead Replacement Telepaks and TM Systems for Stand- Off Weapon Development.

The most dramatic change during this period occurred in the Digital Product Line. Aydin Vector developed a unique, micro-modular, programmable PCM System. The Model MMP-600 was constructed with thick film hybrid circuits packaged in a frame .250 inches thick X 1.5 inches X 1.7 inches. The frame has a peripherical interconnect, hermophodite connector pin configuration, specifically designed by ITT Cannon for this product. This permitted modules to be stacked and replaced without cabling or structural changes. (See Figure 3).

This industry FIRST permitted systems to be easily built, modified, and expanded to meet changing measurement list requirements. A family of modules was available providing Analog Multiplexers, Bi-Level Digital Multiplexers and Low Level Signal Multiplexing (20, 50, and 100 MV Levels). These were expanded to include serial digital and frequency counter modules as well as other special modules all under the program control of E-PROM.

This product was particularly useful in expanding the instrumentation engineers solutions to gather more data in the small space available in sounding rockets, cruise missiles, bombs, and RPV’s. It was also ideal for standard product production, permitting economic lot buying of material and efficient manufacturing assembly and test procedures. For the first time, PCM engineers were not required to hand assembly and test their own designs. Several thousand systems were produced over a ten year period.

This eventually led to the development of an improved performance system providing more flexibility (channel by channel programming), higher bit rates (up to 1 megabit/ second), programmable gains and offsets and integral signal conditioning modules for both analog and digital data.

The model MMP-900 was a true, microminiature Digital Data Acquisition System capable of handling the range of standard housekeeping data from transducers and vehicle circuits, but also from various on board computers, processors, and BUS information.

Other Digital products developed during this period including a family of MIL-STD-1553 Bus Monitor products ARINIC 429, RS 422, and other Avionics interfaces, as well as the Model SP-900 Processor to accept a variety of digital inputs and initiate control signals and buffered outputs.

The larger Digital Data Acquisition systems required for testing aircraft and large missiles were improved during the period using E-PROMS, or core memories and plated wire memories to provide multiple formats and flight line reprogramming. The typical systems used distributed address bus architecture to achieve remote data acquisition under the control of a central unit. Systems used for the Flight Test of Aircraft such as the F-14, F-15, Tornado, Harrier, A6 and A7 during this period used printed circuit board construction packaged within rugged mechanical aluminum enclosures. Typical systems handle from 1000 to 10,000 inputs at 4 to 512 KBPS and sample rates up to 100 SPS. Typical accuracies of 1% for low-level data and 0.5% for high level data were achieved. The Aydin Vector model PDS-700, model DAS526 and 537 were typically larger systems furnished with a full family of signal conditioning and remote units. (See Figure 4)

THE EIGHTIES - OUR PRESENT

The RF Product Line was improved to provide smaller and more efficient transmitters (models 400, 700 and 800). (See Figure 5) Greater versatility to comply with frequency allocations was achieved with the model ST400 Series Synthesized Multifrequency Video Transmitters. (Frequency is selected over 100 MHz bandwidth in 1 MHz steps).

The need to transmit digital and Video data has also brought the development of TV versions of the standard transmitters capable of wideband response from 10 Hz to 10 MHz. A family of RF Power Amplifiers, model PA100, PA220, and PA440 to provide 10, 20 and 40 watts output when driven by standard 2 watts transmitters has increased telemetry link range for current flight test requirements.

Companion model RCC-200 and 300 Receivers were also developed with increased sensitivity and performance using frequency agile and synthesized local oscillators to support command/control, and various telemetry relay requirements including high rate digital data and video applications. (See Figure 6) Optional model VM-100 and VSD-100 Subcarrier/ Video Mixer and Discriminator/Demultiplexers were developed to multiplex audio, PAM, PCM, and FM with video data enhancing the capability of RF data links.

This capability was further expanded to satisfy critical Flight Termination Receiver/Decoder requirements to NAVAIR and Range Commander Council specifications (Doc. 313-80).

The model VFTR-300 and VFTR-301 series equipment was qualified and flown on Programs such as Vandal and AMMRAM.

The technology developed for the standard RF telemetry products has also been used to develop hardware used in GPS data links, video data links (Walleye and SLAM missiles) and Drone Control Transponders (model DXP-3000).

In addition, program requirements have mandated increasingly stringent controls on workmanship (WS-6536E and DOD-2000) and parts selection and design control (S Level and Custom S) on Programs such as Titan/Centaur.

The need for secure communications has also evolved with the development of Encryption support products, such as the model ISM-100 and ISM-800, to meet NACIM 5100A requirements for NSA KG-66 and KGV-68 Encryptors. These items are offered under the NSA Commercial COMSEC Endorsement Program (CCEP). Secure requirements and data link bandwidth limitations have also inspired the development of digitized video equipment, such as the model AVC-107, using advanced compression and enhancement techniques to optimize image transmission. Airborne Bit Synchronizers, such as the model SBS-200, are also available to support Digital Data Link requirements.

The Data Acquisition System requirements have expanded into the need to support tactical testing, training and quality assurance requirements for weapons currently in our inventory. Special telemeters such as the model FMT-770 have been developed to be installed in the production missile assembly between existing sections or as warhead replacement sections such as the AN/DKT-58 and ATI/DKT-31 Telepaks. Other strap-on telemeters have been provided. (See Figure 7)

Additional development work was performed for various US and overseas customers to supply Data Acquisition systems capable of meeting high shock environments from 155 mm projectiles and mortars.

Families of specialized signal conditioning amplifiers such as the 900 series Self Balancing Bridge Conditioning Module, the 200 Series Thermocouple Conditioning Multiplexers, the AGRA-100 Automatic Gain Ranging Amplifier, the SSC-2008 Super Signal Conditioner and a Series of Model PDF Programmable Data Amplifier/Filters have been developed to support Data Acquisition System requirements. Most of these designs use the latest monolithic circuits and thick film hybrid construction to achieve extremely stable performance in a very small size. (Figure 8.0)

Major Flight Test Program requirements for the Space Shuttle redesign SRB, the V-22 Tilt Rotor Aircraft, the Israeli LAVI Fighter, the German Tornado ECR Aircraft, Phantom F-4 Upgrades in the US, FRG and Israel have led to the development of the ADAS-7000 Series Distributed Digital Data Acquisiton System. (Figure 9.0)

This equipment permits the acquisition of up to 8000 data inputs from up to 24 remote units with programmable formats and 8 to 12 bits/word resolution under the control of the user via an RS-232 link. Output bit rates up to 2 Mbit/sec can be split on muliple tape recorder tracks or selected data can be observed on local displays in real-time with integral EU conversions or transmitted over RF links for safety-in-flight parameters.

The remote units acquire a variety of analog and digital signals and provide local signal conditioning, digitizing and formatting with flexible command response transmission to a central control unit. Time code and other reference information is formatted to simplify data processing and analysis. Data is also acquired and formatted from MIL-STD-1553, ARINC 429 and other specialized avionics Buses. Accuracies better than 0.5% over the full environment are achieved.

The 914 Series Distributed Data System was developed to support the F-14 and A6 upgrade Flight Test Program as well as the C-18 Joint Stars Program. This system was the first application of integral signal conditioning using Finite Impulse Response (FIR) Digital Programmable Filtering with multi-stage decimation over a wide environment range and in a very small size.

The most recent development further expands the DDAS capabilities into the micro-miniature construction techniques developed for the MMP-600 and 900 Series PCM Encoders. These distributed systems were used for the X-29 and T-45 Flight Test Programs and are currently being produced for the ATF Program. Accuracies better than 0.3% is obtained through the entire data system, including the integral conditioners, from the transducers, at bit rates up to 2 Mbit/Sec. The 800 Series Micro Data Systems are also offered for stand-alone missile applications. (Figure 10.0)

The AGRA-100 Development sponsored by WPAFB in 1982, was the basis for the design of a specialized digital Data Acquisition System to support the acquisition of Wide Band Flight Dynamic data. These systems provided selectable data bandwidth to 10 KHz with gains selectable to ranges up to 1024 and DC accuracies of ± 0.1%. A dynamic range in excess of 120 dB is achieved.

These systems have been used for critical Ground Vibration Tests of the F-16, an A-10 gun bay test and a special captive carry missile test. Current orders are in process to assist in the integration of the AMRRAM missile to high performance aircraft.

THE 1990’s - OUR FUTURE

The logical extension of our industry based upon our current and past experience indicates the following:

1) Budgets - The money available for our industry will bear a direct relationship to the money available from the DOD and overseas customers for Weapons development and maintenance of current inventories. Since tensions and economic factors indicate a reduced need, we should expect less overall money to be spent. Therefore, we must become more selective, more-efficient and more competitive in the allocation of our money and resources.

2) Technology - The advances in components and design tools should give the hardware designer unprecedented opportunties to make significant breakthrough in optimizing designs. The winners will allocate their efforts to new standard products with maximum multiple applications.

3) Applications - Greater synergism between the users, the component suppliers (transducers & sensors, telemetry component, recording and display) and the data analysis experts are needed to take a realistic, fresh look at the functions, interfaces and objectives to achieve optimum and realistic design targets.

4) Quality Assurance & Manufacturing - A more realistic partnership is needed to insure transition from the dreams of the user to the reality of production for his program. Schedules are critical.

5) Procurement - the procurement Process needs to be streamlined to place greater emphasis on the Program needs.

Currently the process is longer than the expected vendor delivery times. Everyone is concerned about many factors, however, the end user must still meet his milestones.

6) Hardware - We should expect some significant breakthroughs in the following areas:

a) RF Products - New developments in MMIC and RF Amplifier technology should enable the industry to obtain IRIG compatible 2 watt transmitters with the next 5 to 10 years in 2 to 4 cubic inch size. Similar improvements could be achieved in receivers and power amplifiers.

b) Telemetry Frequency Allocations - We should not expect a radical change in frequency allocations except for targets and other specialized military telemetry and control requirements which may be required in higher frequency band.

c) Frequency Modulation - Aydin Vector and Aydin Computer & Monitor Division have been investigating various modulation techniques to secure improved spectrum efficiency. MSK has been found to be more efficient, but costs more. PSK and QPSK offers other benefits. Scrambling and convolution encoding enhances link performance.

d) Digital and Video Data - Increased use of higher bit rate digital data and digitized video data will continue to challenge our RF transmission medium technology, close coordination with the users, the ground receivers and airborne antenna manufacturers is required to advance this capability.

e) Secure - Continued emphasis on secure transmission and embedded encryptors will be part of our future.

f) Fiber Optics - Increased use of fiber optic links and Buses will require a working knowledge and experience with these mediums so the TM hardware designer provides an optimum interface design.

g) Signal Conditioning - Closer relationships with sensor and transducer manufacturers and the users will result in measurement with reduced errors due to environmental drifts and long term offsets. Aydin Vector introduced self-balancing bridge conditioning modules (BCA=9000) for use on the Trident Missile Program as well as integral conditioners for a line of accelerometers. We believe that greater advances can be made if the telemetry hardware manufacturer can participate on the team to develop new solid state sensors for measurement of pressures, acceleration, and vibration. Present thermal measurements will continue to be refined. Techniques for local digitization and data filtering, as well as local I.D. references insertion need to be explored.

h) Analog Products - Increased use of monolithic analog and interface devices will continue to improve the reliability and performance of these products. Aydin Vector has found that many improvements were possible when a close relationship exists between the device manufacturer and our technical staff. Further size and cost improvements can be made by the use of semi-custom and ASIC devices to integrate multiple support and logic functions.

i) Digital Products - Higher speed processing and Bus architectures will continue to drive and expand the capability of these products. The ability to merge and format data from MIL-STD-1553 and other Avionics Buses will continue to challenge the equipment designer, particularly as the Bus rates increase to 20 MHz and higher. The ability to be compatible with MIL-STD-1750 on-board computers is a must. Greater compatibility with missile guidance and control systems is required.

j) GPS - Aydin Vector has provided various components to interface with GPS receivers and translators. The telemetry manufacturers will continue to refine and develop technique to utilize this data in the test programs. CPS will continue to expand its use and capability as not only an on board guidance input, but also as a vehicle performance parameter required to telemetered to the ground.

k) ATE and GSE - Increased use of automatic test equipment will insure the integrity of the flight hardware. Accurate evaluation of the equipment performance during initial acceptance test while under a range of environments has proven to be essential for flight worthiness. In addition, a line of ground support equipment with user friendly software permits rapid reconfiguration of the parameters to be measured and checkout of system installation integrity on the flight line. Integral telemetry BITE provides further pre-flight confidence where required.

l) Mechanical Design - The greatest challenges to support all of the above is to insure that the hardware design has accurately and adequately provided the structural integrity, the thermal profile and dissipation requirements, EMI protection, interconnect techniques and above all the ability to produce and service the equipment economically and easily. A unique combination of mechanical and electronic design disciplines is required.

7) Design Tools - Every engineer in our industry has become proficient with the PC today. Many have benefited from the use of computerized work stations with a variety of specialized programs and formats to produce schematics, select components and circuit elements, verify timing and performance parameters, calculate thermal and power requirements and a variety of other functions. In some cases, it is expected that bread-boarding or other validation is not required prior to design release. We need to encourage our hardware designers to use these tools, but like any good navigator, we must be able to validate and cross check our heading. We must continue to encourage our staffs to follow the process that has been proven to obtain mature designs. Bench validation tests over the environment, design reviews with your peers and seniors, prototyping and qualification are essential for design validation and finally production if of equal importance to assure the reproducibility of the design and the process.

8) Instrumentation Engineers - Many of the experienced engineers are retiring or have left the business. Younger engineers, in many cases, have been introduced to the profession, as new hires or transfers. Seldom have they had the luxery of specialized training in school or through apprentice programs offered by the company or the government. We must find ways to assure adequate and orderly transfer of this knowledge and experience. The ITC and other organizations are to be commended for encouraging young engineers to enter our field by the use of scholarships and awards. We must continue to improve this very important area by encouraging Universities to include curriculum on instrumentation, to offer workshops and seminars and certainly to continue to encourage participation in our professional conferences and organizations

CONCLUSION

The Airborne Telemetry Industry has undergone many changes over the years. The test program requirements have become more complex both from the application requirements and the programatic requirements. The procurement process, the quality assurance requirements, export and import license laws and procedures, and a host of other regulations and administrative requirements have made it very difficult for the innovative, technologist/entrepeneur to compete and survive.

It is no longer possible for the instrumentation engineer to design a system, pick a vendor and order hardware without significant justification and competition. As a result, the number of suppliers have diminished and the remaining suppliers have had to change the way of doing business and grow to provide all the resources and support required by the procurement system. This has increased the cost and decreased the quick-reaction, direct technical interchange necessary for optimum solutions to requirements. Ironically, the government has also imposed small business set-asides for telemetry while still imposing all the requirements for resources and support, further forcing these suppliers to accept contracts beyond their capabilities and placing programs in jeopardy.

Nevertheless, the products have continued to improve in performance and the flight test community has benefited from more flexible and reliable equipment. We will continue to become more creative and responsive into the 1990’s with the computer based design and manufacturing/test tools available, as well as with the significant improvements in the circuit components available.

However, we need to encourage the government budget makers and legislators to reduce the administrative and procedural burdens on the Flight Test Community and the Telemetry Industry which discourage the technologists from creativity and which impose increased costs and procurement/ delivery cycles. We have grown and matured primarily because the user and the hardware designer had achieved close technological synergism and the motivation to meet new challenges. We need to find ways to encourage new hardware development and user/designer teamwork with funds and contracts prior to and independent of Program Related Funds and schedules.

The various professional organizations such as ITC, SAE, ISA, SFTE, etc., as well as the RCC, IRIG, AFTRCC and other government groups including overseas groups and organizations with similar needs should continue to work together and find ways to improve our industry to meet the challenges of the 1990's.

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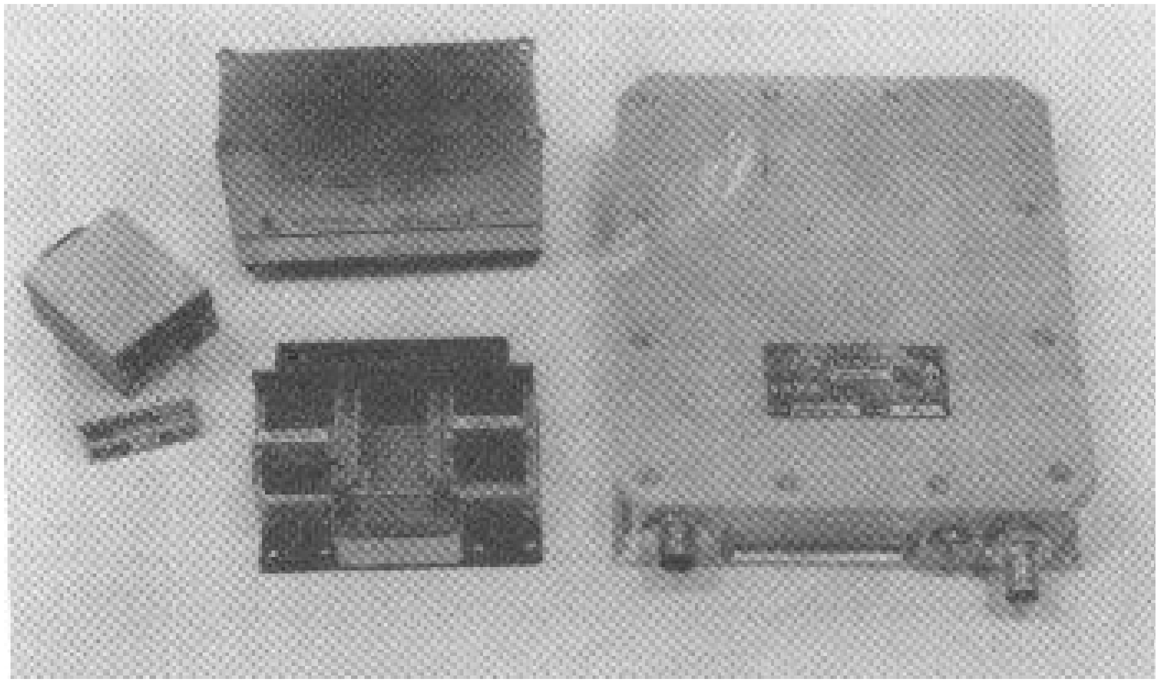

FIGURE 1 - EARLY PAM AND FM TELEMETRY COMPONENTS - 1960’S

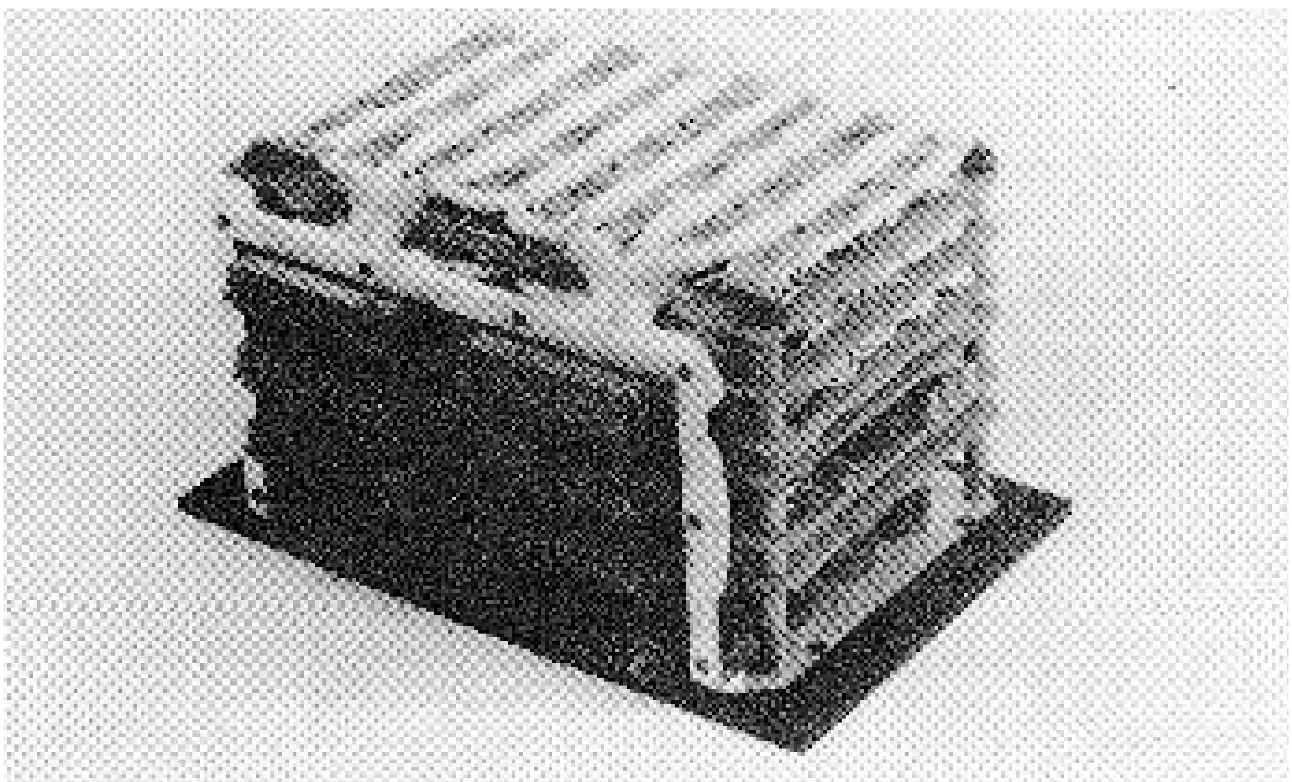

FIGURE 2 - EARLY PCM ENCODER - 1960’S

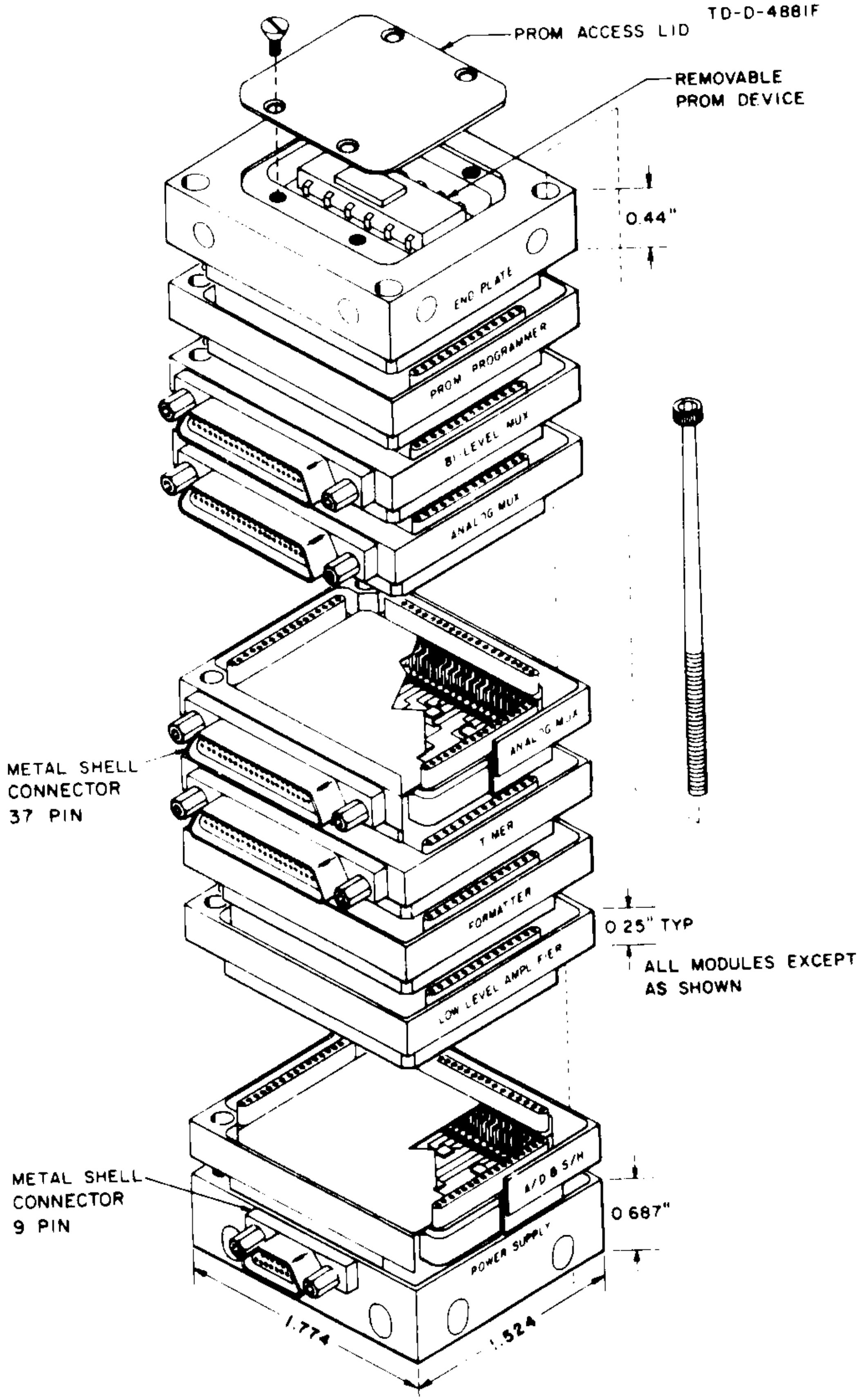

FIGURE 3 - MODEL MMP-600 MICRO-PCM ENCODER

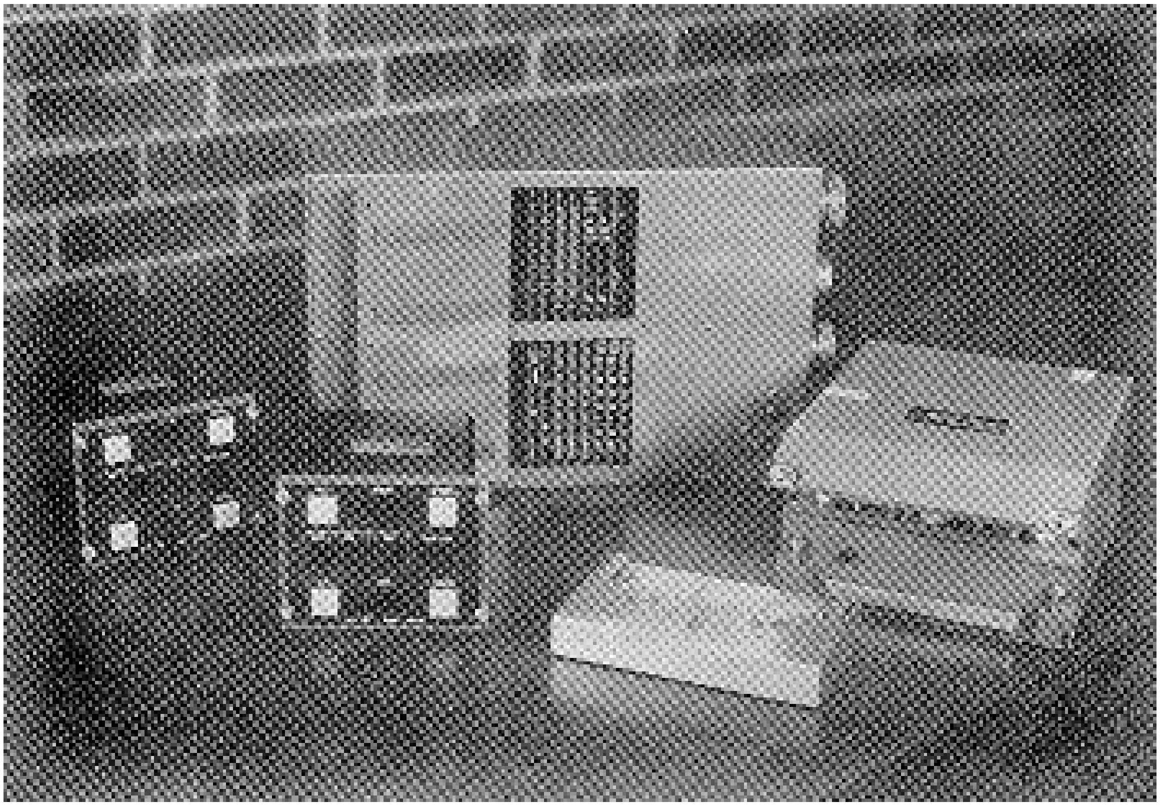

FIGURE 4 - MODEL DAS-537 AIRCRAFT DIGITAL DATA ACQUISITION SYSTEM

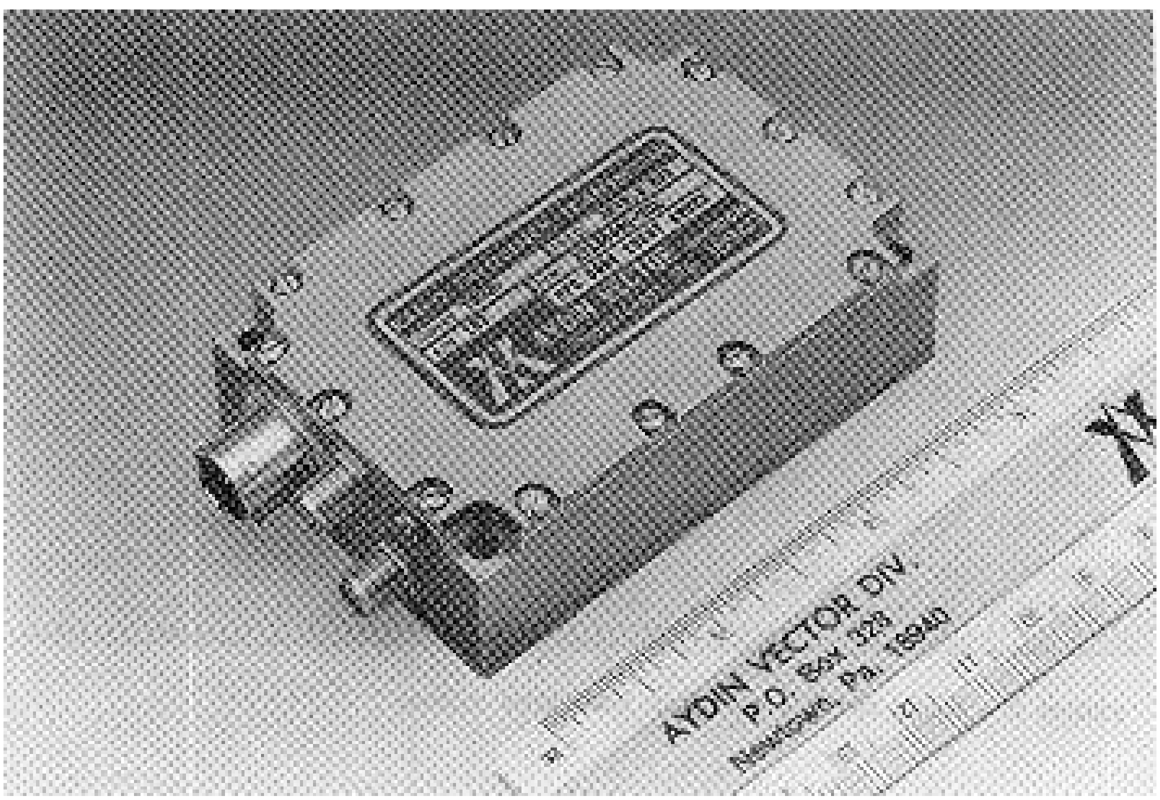

FIGURE 5 - MODEL T800 S-BAND TRANSMITTER (6 CUBIC INCHES)

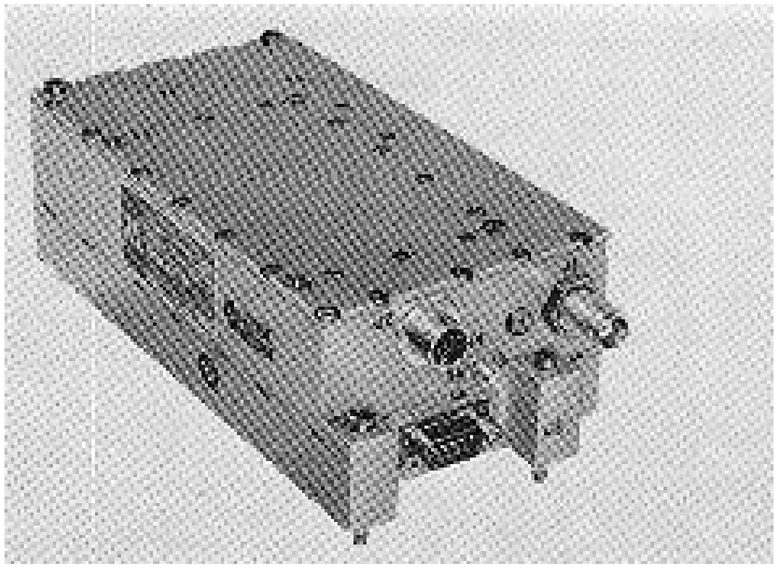

FIGURE 6 - MODEL RCC 300 SYN - 100 CHANNEL, FREQUENCY AGILE, SYNTHESIZED RECEIVER

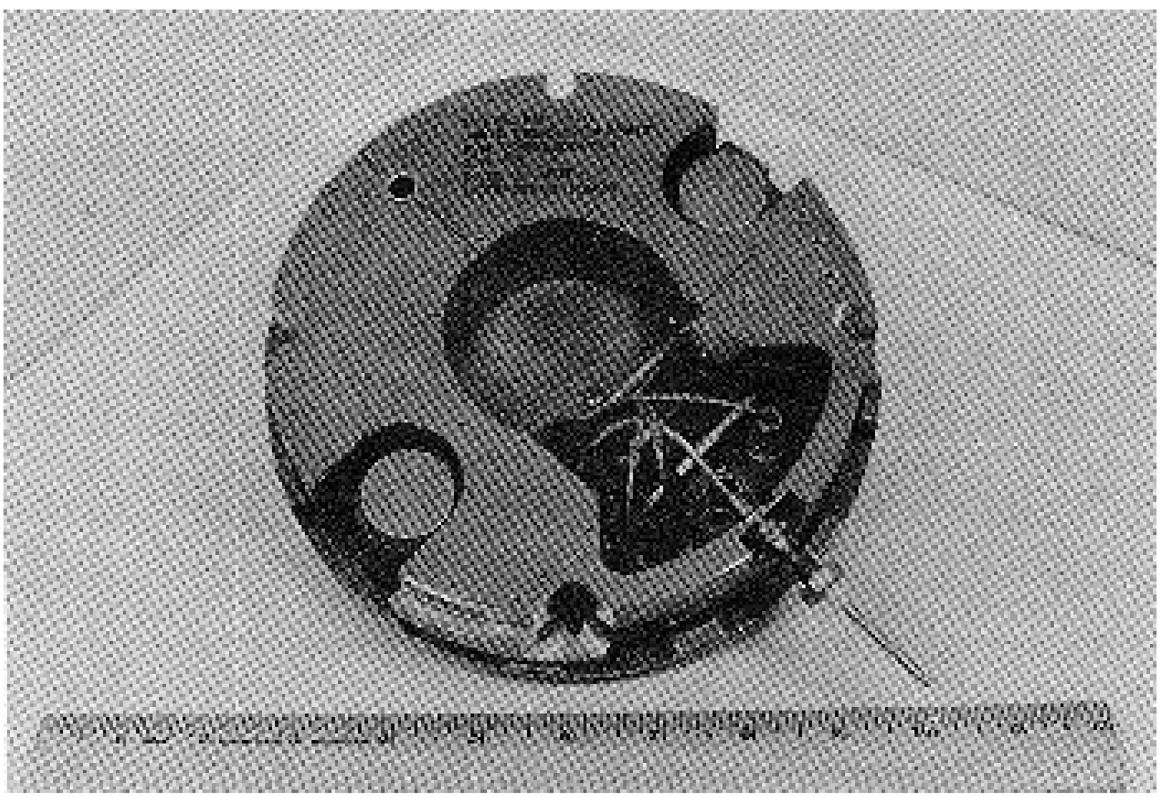

FIGURE 7 - MODEL FMT-770 TACTICAL SYSTEM

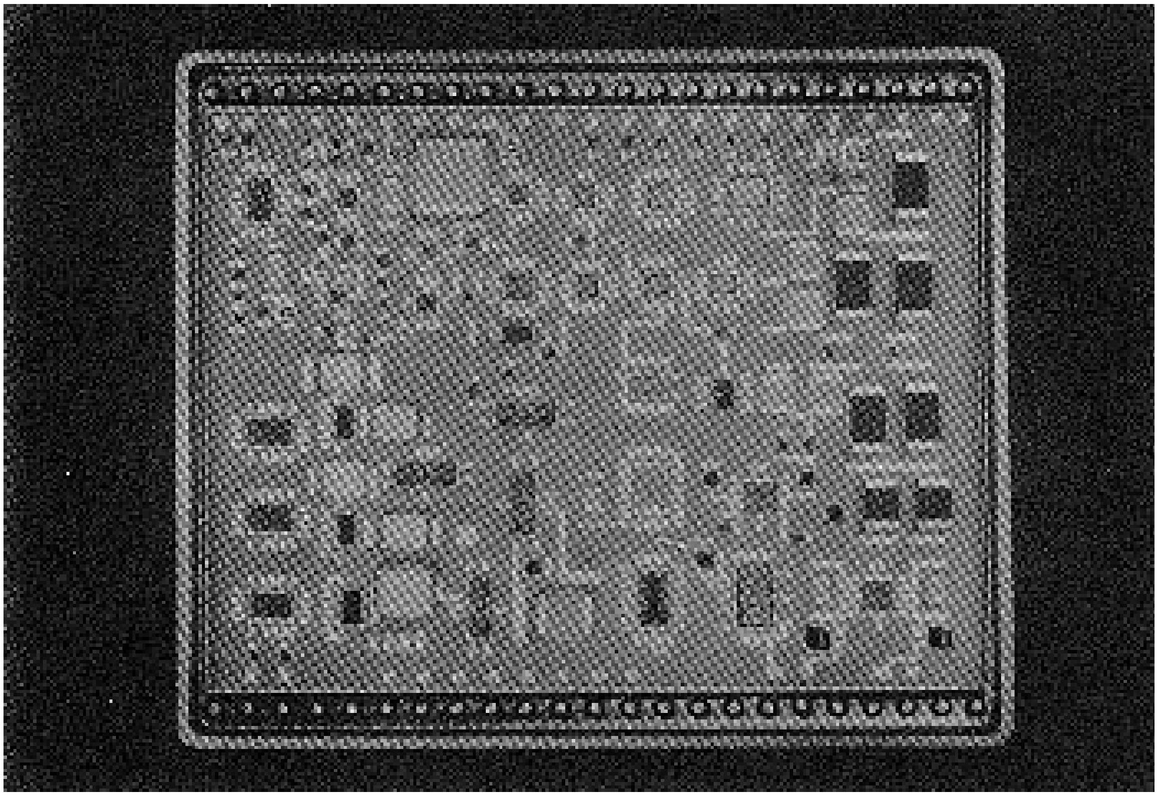

FIGURE 8 - MODEL AGRA-100 AUTOMATIC GAIN RANGING AMPLIFIER

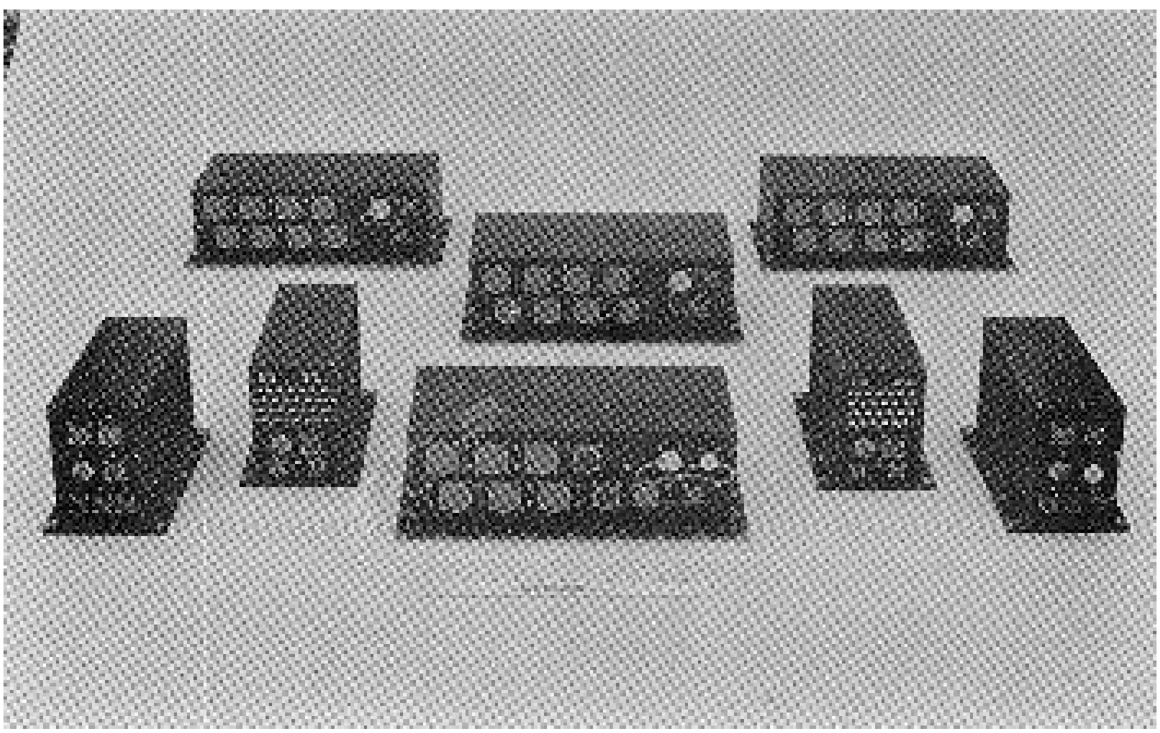

FIGURE 9 - MODEL ADAS-7000 DISTRIBUTED DATA ACQUISITION SYSTEM FOR NASA SPACE SHUTTLE SRB FLIGHT TEST

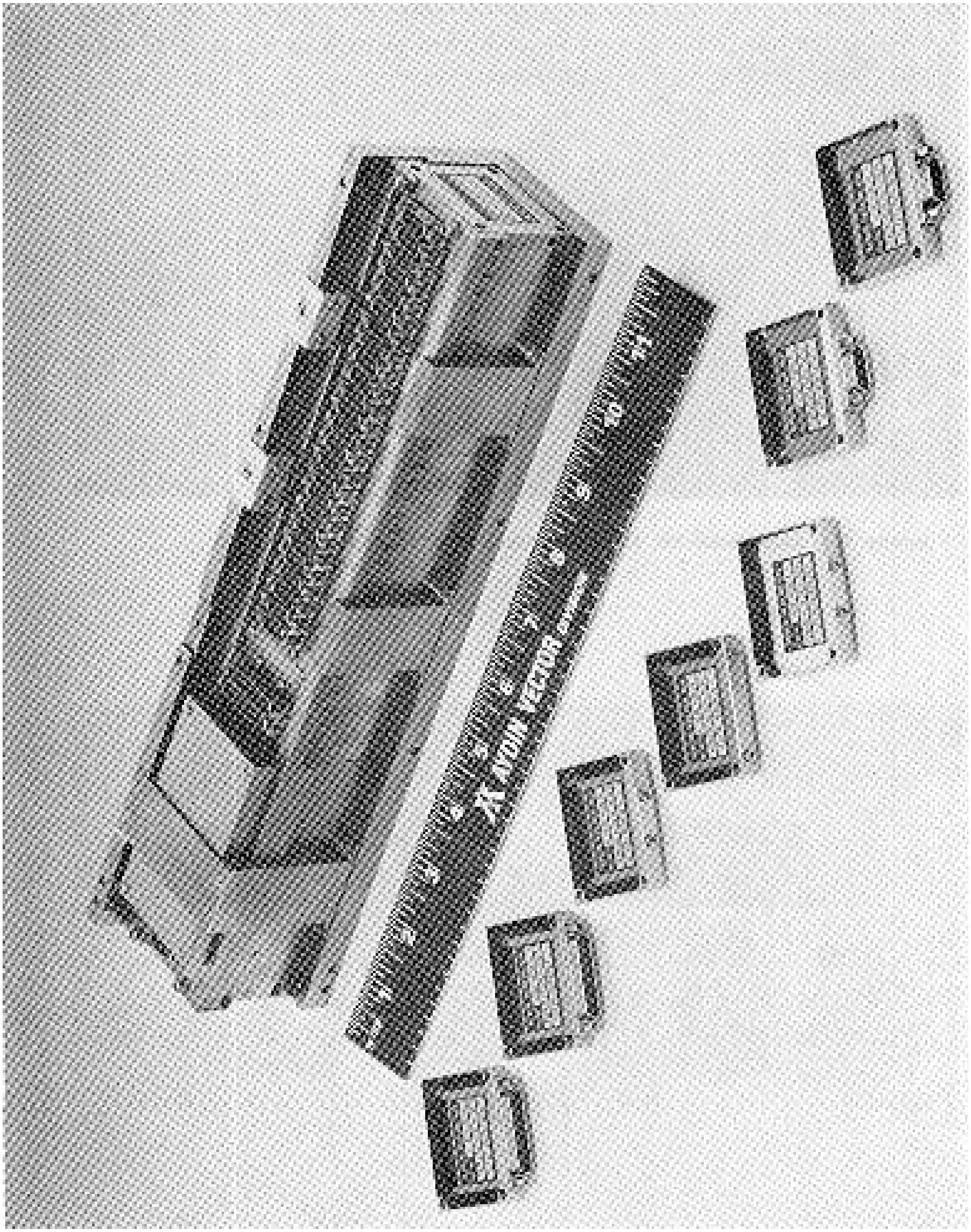

FIGURE 10 - MODEL 800 SERIES MICRO DIGITAL DATA ACQUISITION SYSTEM FOR ATF PROGRAM