FLIGHT INSTRUMENTATION TELEMETRY FOR AEROSPACE APPLICATION

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ABSTRACT.

In Aerospace missions it is often required to have a flexible telemetry system for carrying out flight test on aircraft, in which the bit rate, sampling rate and the number of channels can be programmed. This enables the pilot of the aircraft to reconfigure the telemetry system to suit any particular test missions. An L-Band PCM/FM Telemetry System containing a Stored Programme Multiplexer, 12 bit ADC and other digital interfaces for carrying out the measurements on Speed, Events, etc has been developed as a flight instrumentation telemetry for HAL, India. This paper not only presents complete details of the system, which was qualified to meet MIL-5422 levels but also the performance of the system during actual aircraft missions.

KEYWORDS.

Signal Conditioners, Stored Programme Multiplexer, NRZ(L)Data, L-Band Transmitter.

1.0 INTRODUCTION

A Telemetry System with capability for real time flight data analysis is a powerful tool for aircraft flight testing. It provides a method for integrated testing of multidisciplined flight data from aircraft. Flight test data mainly consists of the performance of the aircraft in terms of the speed, manoeuvre and the related parameters like damping, and drag coefficients, propulsion system performance, pressure and temperature at various locations, etc. A flexible telemetry system is required to monitor all the parameters as different flights will have different objectives. It was decided to design a flexible format, Stored Programme Telemetry system in which the bit rate, the number of channels, sampling rate and the output code could be varied to meet the requirements of any flight test.

2.0 DESIGN PHILOSOPHY

Due to severe constraints on power, weight and volume in the aircraft most of the digital subsystems were designed using CMOS ICs and TTLs were used only where 512 KHz signals are present. The analog subsystems like presampling filter, premodulation filter and the ADC were designed using IC operational amplifiers. For close tolerance and extreme stability metal film resistors and highly stable mylar capacitors were used wherever possible. As the system has to be qualified to meet MIL-STD 5422F specifications care was taken in the design to use atleast MIL-38510 Class B type of components. Choice of the modulation was obviously PCM/FM due to the fact that the system has to handle a large number of channels with an accuracy of better than 0.5%.

3.0 DESIGN DETAILS

The Airborne System as shown in Figures 1 to 4 consists of:

i) Signal Conditioners for acquiring the signal from different transducers.

ii) A Stored Programme Multiplexer for programming and monitoring information for the flight test.

iii) An Analog to Digital converter for converting the analog data into a 11 bit digital data.

iv) A Digital Interface Unit for formatting the information related to speed, ON/OFF status and other digital signals.

v) A formatter for formatting all the data for transmission.

vi) A premodulation filter for conditioning the bandwidth at the input of the transmitter.

vii) An L-Band transmitter and antennae for transmitting the data to ground using PCM/FM modulation.

The complete specification of the system is given in Appendix A.

3.1 Signal Conditioners

The Signal Conditioner module is a precision differential D.C. Amplifier providing a variable voltage gain upto 2200 designed for operation in a hostile aircraft environment. The gain of the amplifier is obtained with a preamplifier having a gain of 200, followed by a variable gain stage whose gain can be programmed from 1 to 11. This is followed by a Butterworth type presampling, low pass filter with different cut off frequencies. The total quantity developed per model is 128 numbers, having different low pass cut off frequencies from 10 Hz to 100 Hz.

3.2 Encoder

The PCM encoder consists of the following functional circuit groups. Clock generator, Stored Program Multiplexer, Digital Interface Unit, ADC and synchronization logic, and the Premodulation Filter (PMF). The master clock of the system is a 4.096 MHz crystal oscillator. All the different bit rate clocks namely 16 KHz to 512 KHz which are selectable on the front panel are derived from this master clock. Stored Program Multiplexer consists of an EPROM which stores the formats that are preprogrammed. All these formats are front panel selectable. The 256 channel analog multiplexer collects analog channels as per the program stored in the PROM and converts them into serial form for analog to digital conversion. The analog multiplexer is protected for an input voltage of ±20v under power ‘off’ mode also. Digital Interface Unit processes 6 speed type signals, 4 counter type signals and 110 ON/OFF status signals and formats the processed data as programmed in the PROM. The speed type of channels whose frequency range is 16 Hz to 100 Hz are processed by measuring the time period. Those having frequency range 500 to 2000 Hz are counted in a counter. Counter type of channels are processed by counting the event numbers. All status type of channels are passed through a parallel to serial converter. All the required control pulses are stored in the PROM. ADC and synchronization logic circuit consists of 11 bit ADC, signal mixing gate, parity bit generator, frame synchronization logic and code conversion logic. The ADC data, Digital Interface Unit data and the Frame Identification (ID) data are all mixed in the signal mixing gate and the output is subjected to parity bit generation. Frame synchronizing code is added to the bit stream. The NRZ(L) data is converted to BIØ(L) code and both the outputs are available on the front panel. PMF circuits consist of 2 premodulation filters, having the cutoff frequencies of 384 KHz and 768 KHz. Depending upon the bit rate any one of the filters is selected. To maintain a constant modulation index for all bit rates, the amplitude of the PMF is varied linearly for various bit rates as shown in the Table.

Bit Rate	Output Code	PMF cut off in KHz	Amplitude
512 KBPS	BiØ(L)	768	14 Vp-p
512 KBPS	NRZ(L)	384	14 Vp-p
256 KBPS	NRZ(L)	384	7 Vp-p

128 KBPS	NRZ(L)	384	3.5Vp-p
64 KBPS	NRZ(L)	384	1.8vp-p
32 KBPS	NRZ(L)	384	0.9vp-p
16 KBPS	NRZ(L)	384	0.45Vp-p

3.3 L-Band Transmitter

The transmitter design is fully solid state to deliver an output power of 10 watts at 1460 MHz. The transmitter carrier is derived from a 73 MHz crystal oscillator. The crystal oscillator is multiplied by an order of 20 to get the final frequency and indirect type of frequency modulation is used. The modulator is basically a phase modulator. An inverse frequency network used in the modulator enables FM from PM. This method has the advantage of permitting good frequency stability, linearity and low frequency response. The frequency multiplication is achieved in two stages. The first is a doubler to get a frequency of 146 MHz and then an SRD multiplier which gives the final output frequency at 25 mw power level. Three stages of transistor amplifiers driven by SRD multiplier provides an output of 16 watts. After the insertion loss of the bandpass filter and an isolator a minimum of 10 watts is available at the output. To increase the reliability and reproduction microstrip techniques were used in the design of L-Band Transistor amplifiers for increasing reliability and reproduction.

4.0 QUALIFICATION TEST

The evolution of the final Telemetry System has gone through many stages, such as Bread Board Model, Engineering Model and Proto Model. As the system has to be finally installed in an Aircraft it has to meet the stringent specifications of MIL-STD-5422F. The environmental test plan for the qualification program was as follows:

i) Temperature and Altitude Test

The packages were subjected to Temperature extreme of -62°C to +95°C and the altitude was varied from normal sea level to a height of 70,000 feet.

ii) Vibration Test:

The test was done in three phases with live electronics.

Resonance Search	Resonance Dwelling	Cycling
Amplitude : 0.5 g Frequency : 5 to 500Hz Sweep : 1 oct/mn	5 to 62 Hz : 0.01" D.A 62 to 500 Hz: 2g	Total duration : 30mts Sweep rate : 1 oct/min No.of cycles : 5-500-5Hz once. 5 to 62 Hz : 0.01" D.A 62 to 500 Hz : 2g

iii) Shock Test: Basic design test was done with live electronics.

	Basic Design Test	Crash Safety Test
Amplitude	15 g	30 g
Pulse	Half Sine	Half Sine
Duration in ms	11	11
No.of shocks	18	12

iv. Humidity Test

Stabilized Temperature : 71°C,28°C
Relative Humidity : 85% to 95%
Duration : 240 Hrs

v. Salt Fog Test

The packages were placed in the Test Chamber and exposed to Salt Fog for 48 hours. At the end of 48 hours, physical inspection was carried out for any corrosion. Then the packages were tested, operated and the performance verified.

vi. EMI/EMC Test

The conducted emission test (CEO2), Conducted susceptibility test (CS01-CS02)and the Radiated susceptibility test (RS01) were carriedout as per the specification MIL-STD-6181D.

All the packages were subjected to the above mentioned test and checked for their operational performances during the various stages of the test. The test levels for the proto model were slightly higher than those for the other model so that the packages could be tested for establishing the failure limits.

5.0 FLIGHT TEST PERFORMANCE

The performance of the PCM/FM Telemetry System was analysed using a JT05 Kiran Mark-I Aircraft. The Telemetry systems were installed in the aircraft and a total of 9 flights were carried out to validate and assess the performance. Around 120 channels were used for data acquisition covering the parameters related to system health, system validation and other miscellaneous aircraft parameters. The format used had 10 frames and each frame had 58 words. Provisions were made in the format for validating super commutation, main commutation and subcommutation. The end to end accuracy of the system was established using a known stable voltage as an input for some channels. The variation in the output from the initial value was used for computing the end to end accuracy. The bit error rate for the data has been measured for various ranges of the aircraft from the ground station and it was found that the bit error performance was within the limit of the specifications. The aircraft was made to perform various manoeuvres to establish consistency in the RF link performance. The link calculations are given in Appendix-B. The system performed well according to the specifications and hence established the feasibility of using such system for aircraft flights.

6.0 CONCLUSION

The validation trials indicated that the airborne system worked well without any problem. But ground system with the parabolic dish antenna could not be used for near range acquisition as there were propagation interference from ground. The data received during take off and landing at near ranges up to 10 nm is noisy eventhough the signal strength was quite high. From the results obtained it was concluded that the system met the overall requirements for flight test eventhough some problem exists during the near field data acquisition.

7.0 ACKNOWLEDGEMENT

The authors wish to express the appreciation of the effort made by the ISRO Engineers in the development and qualification of the system. They also appreciate the tremendous work carriedout by the joint Test and Evaluation Team consisting of engineers from HAL and ISRO in the flight qualification trials of this system.

APPENDIX A

Low level signal conditioners	:	Gains programmable. Filter cutoff 5 Hz,10 Hz, 20 Hz and 100 Hz.
High level signal conditioners	:	Unity gain.Filter cut off 5Hz, 10 Hz, 20 Hz and 100 Hz.
Programmable Encoder.		
Number of channels	:	256 - Analog, 10 - Digital 110 - On/Off type
Bit Rates	:	16 KBPS to 512 KBPS selectable.
Word Length	:	11 bits + parity
Output Code	:	NRZ-L and Bi∅-L
Transmitter	:	L band, 1460 or 1480 MHz
Power	:	10 watts
Antennae	:	Blade type -omni,linearly polarized.
Operating Voltage	:	Aircraft D.C supply (24 to 30v)
Environmental Specifications	:	MIL-T-5422

APPENDIX B

LINK CALCULATIONS

Transmitter Power	:	10 dBw
Onboard losses	:	-3dB
Transmitting Antenna gain	:	-5dB
EIRP	:	2 dBw
Path loss (300 KM)	:	-145 dB
Miscellaneous losses	:	-4dB
Ground Antenna gain (8° dish)	:	27 dB
Minimum received Power	:	120 dBw
Minimum signal power required (10dB S/N, 300°k)	:	126 dBW
Link Margin	:	6 dB

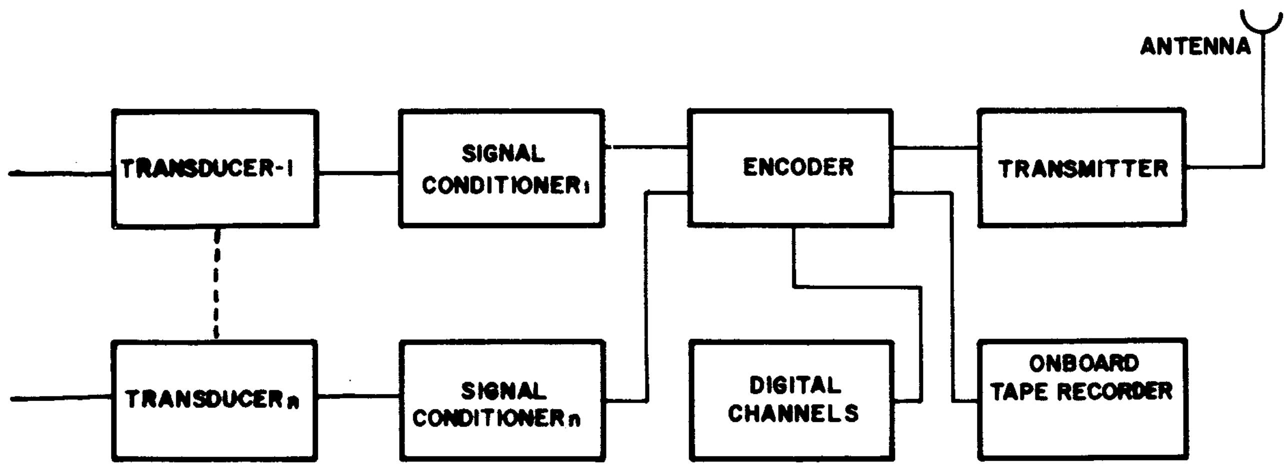

FIG.1.-BLOCK DIAGRAM OF PCM/FM AIRBORNE TELEMETRY SYSTEM

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PROJECT IRS GROUP TM.
DRG. NO. 2-013-04-3-0099

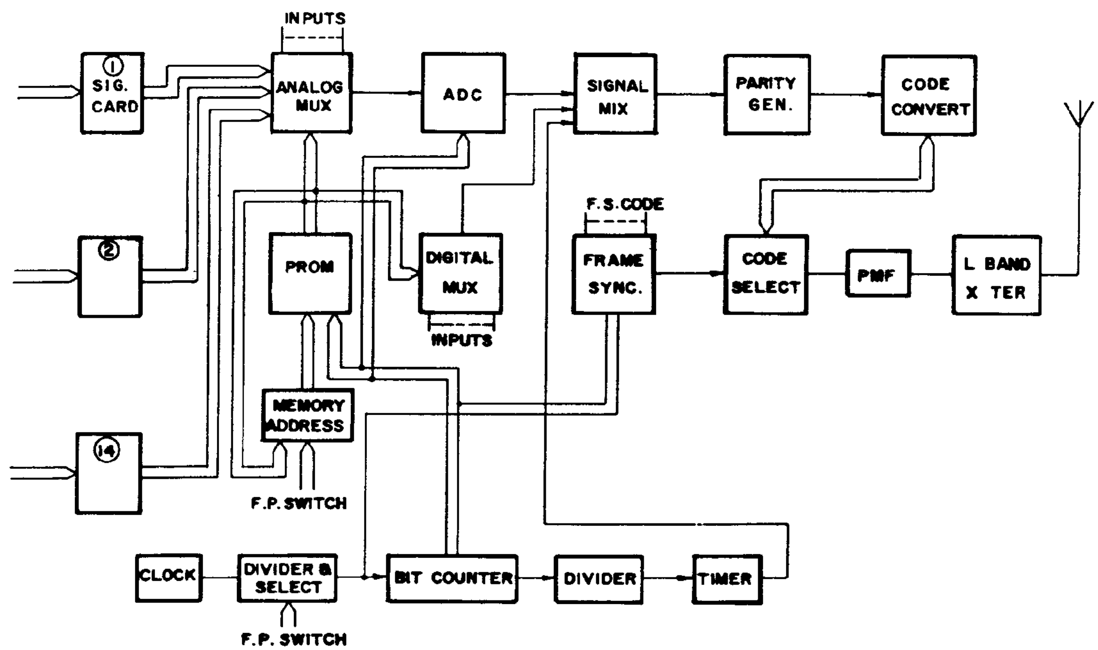

FIG. 2 BLOCK DIAGRAM OF BASE BAND SYSTEM

SCALE
FIG. NO
TITLE BLOCK DIAGRAM OF BASE BAND SYSTEM
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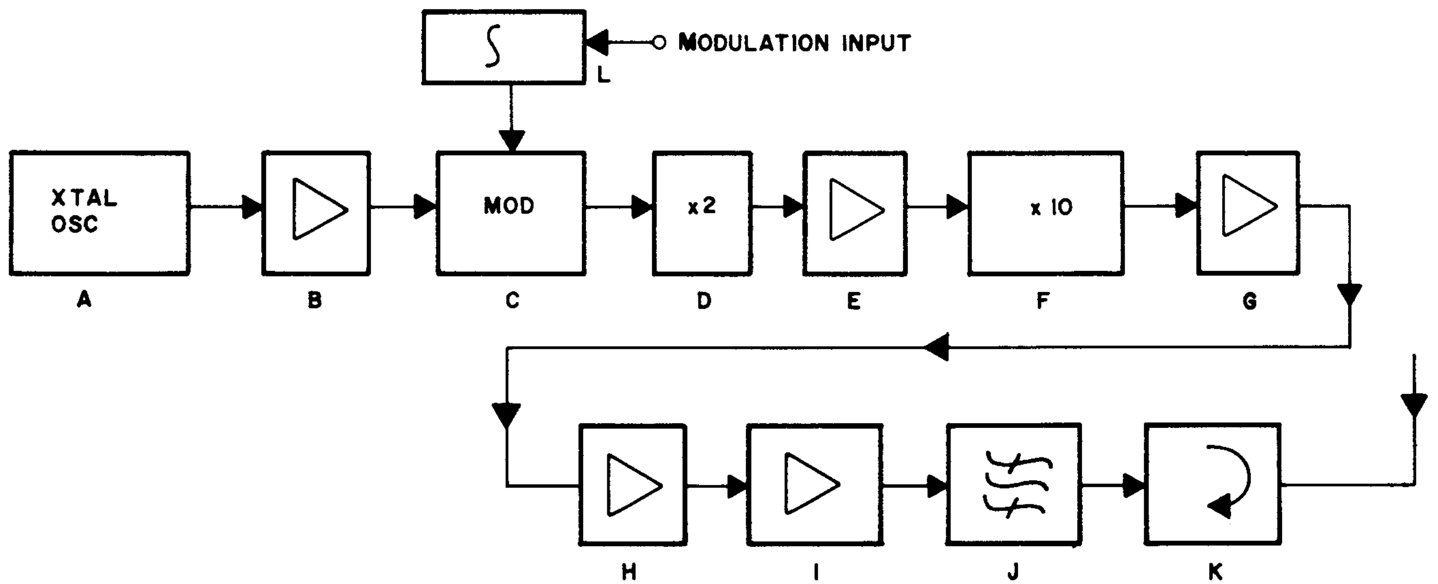

SUBSYSTEMS

A. CRYSTAL OSCILLATOR
B. BUFFER AMPLIFIER
C. PHASE MODULATOR
D. TRANSISTOR DOUBLER
E. VHF POWER AMPLIFIER
F. SRD FREQUENCY MULTIPLIER
G. LOW LEVEL TRANSISTOR AMPLIFIER
H. DRIVER TRANSISTOR AMPLIFIER
I. FINAL TRANSISTOR POWER AMPLIFIER
J. BAND PASS FILTER
K. ISOLATOR
L. INVERSE FREQUENCY NETWORK

FIG. 3 - SCHEMATIC BLOCK DIAGRAM OF TRANSMITTER

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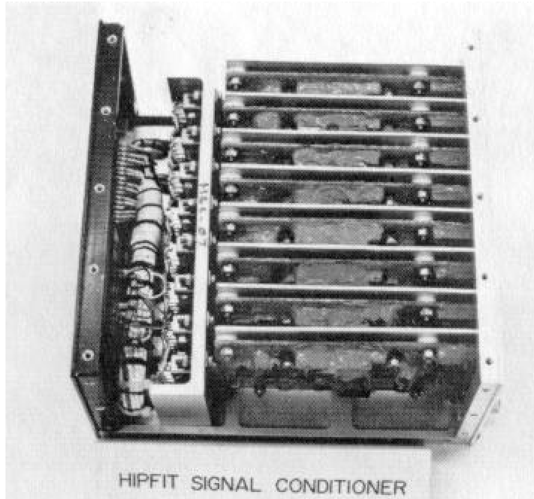
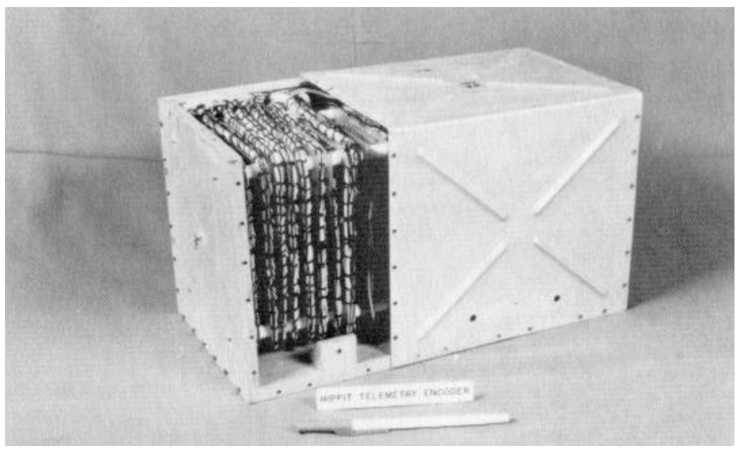
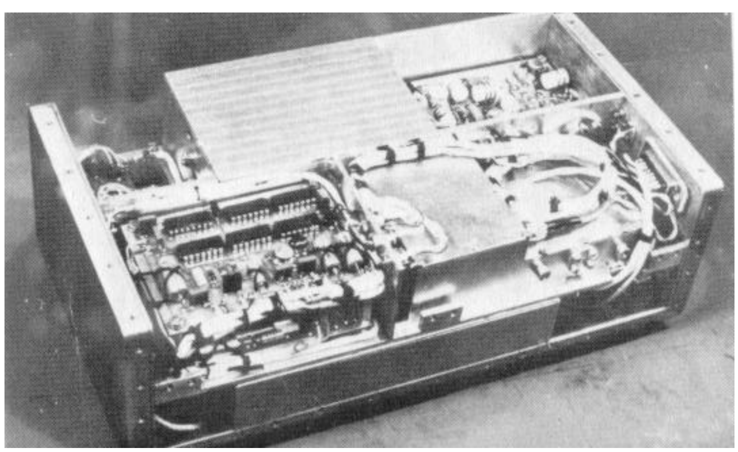


SIGNAL CONDITIONERS



STORED PROGRAM ENCODER



L - BAND TRANSMITTER

FIG. No. 4