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AIROSCOPE TELEMETRY SYSTEM

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ABSTRACT

The AIROscope (Ames Infrared Observatory telescope) telemetry system is described from signal conditioning on the gondola to display and storage at the ground station. All analog and digital data from the systems and experiments on the gondola go to a PCM encoder which formats the data into 10-bit words. Therefore, 0.1-percent resolution is inherently available for experimental data. The Bi ϕ-L coded bit stream directly modulates the carrier of the FM transmitter.

To insure reliable transmission over a 650-km range an 11-watt FM transmitter operating at 1483.5 MHz is used on the gondola. Modulation is narrow band FM with a maximum deviation of ±500 kHz. The maximum modulation frequency is determined by the data bit rate which could be as high as 500 kbps. Presently, a rate of 20.48 kbps is used.

The ground station receiving system includes a steerable antenna (19-dB gain), preamplifier (21-dB gain) and receiver. The output from the receiver is a Bi ϕ-L bit stream like that on the gondola. This signal goes into the PCM decommutator unit which "locks" on and provides data dispaays (decimal digits, analog meters, or bit lamps) through several data word selector units. Also, selectable data words are routed to strip chart recorders for permanent data storage. All data are recorded on a tape recorder. The recorded signal then can be played back through the PCM decommutator unit at a later time for detailed data analysis by the experimenter.

GENERAL

This paper describes the telemetry system used on AIROscope. Topics covered will be signal conditioning, the RF down-link, data encoding and decoding, formatting, ground station data recovery and display, and tape recording/playback.

GONDOLA DATA GATHERING AND PROCESSING

All data, both scientific and engineering, are routed to a pulse code modulation (PCM) encoder unit to put them in a form that can be transmitted to the ground station. These data include:

(a) Science/experimental data
(b) TV star field data (see DeBoo, 1974)
(c) Battery power

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(d) Subsystem power status
(e) Telescope optical alignment and direction
(f) Limit switch positions
(g) Subsystem temperatures
(h) Optics control, i.e., focus and collimation
(i) Command verification (see Barrows, 1974)

Some of the data are generated by CMOS (Complementary Metal Oxide Semiconductor) logic which produces bi-level (0V, 5V) digital signals. Other data come in analog form (0 to 10V) which also can be encoded. With a 10-bit encoding scheme, a resolution of about 10 mV can be obtained. A half scale level, or 5V, is telemetered to give a convenient check on overall system operation.

The encoder can accommodate up to 290 channels, has a through-put rate of up to 500 kbps, and uses a format-controlled programmable read-only memory. Analog to digital conversion is performed where required. At present, approximately 150 analog and 100 digital channels are processed at 20.48 kbps. Figure 1 illustrates the gondola data handling system.

In order to be decoded when the signal reaches the ground station, the data must be transmitted in a standard format. This formatting is also done by the encoder. The present encoder format has 10 bits per word, 32 words per main frame. In addition, fifteen of the main frame words are divided into two-word subframes (fast), nine of the words are allotted to eight-word subframes (medium) and three main frame words are used for sixteen-word subframes (slow). Using the 20,480 bps rate, the following rates are obtained:

Word rate	-	2048 wps
Main frame rate	-	64 fps
Fast subframe rate	-	32 sfps
Medium subframe rate	-	8 sfps
Slow subframe rate	-	4 sfps

Two channels at the main frame rate are available for scientific data. TV data are commutated at the fast subframe rate. All other data are handled by the other subframes. The first two words in each main frame are used for frame synchronization. Also, one word is used for a subframe I.D. code and is incremented at the frame rate for immediate subframe identification.

The output of the PCM encoder is a non-return to zero level (NRZ-L) serial bit stream at 20,480 bps. This data stream goes to a code converter which converts this signal to bi-phase level (Bi Φ-L) code. This signal then directly modulates the RF carrier of the transmitter. Bi Φ-L is used because synchronization is easier when the data may contain a long string of 1's or 0's.

RF TRANSMISSION

The L-band transmitter on the gondola provides a 1.4835 GHz carrier which is narrow-band frequency modulated by the incoming data. Several of the more pertinent transmitter parameters are listed:

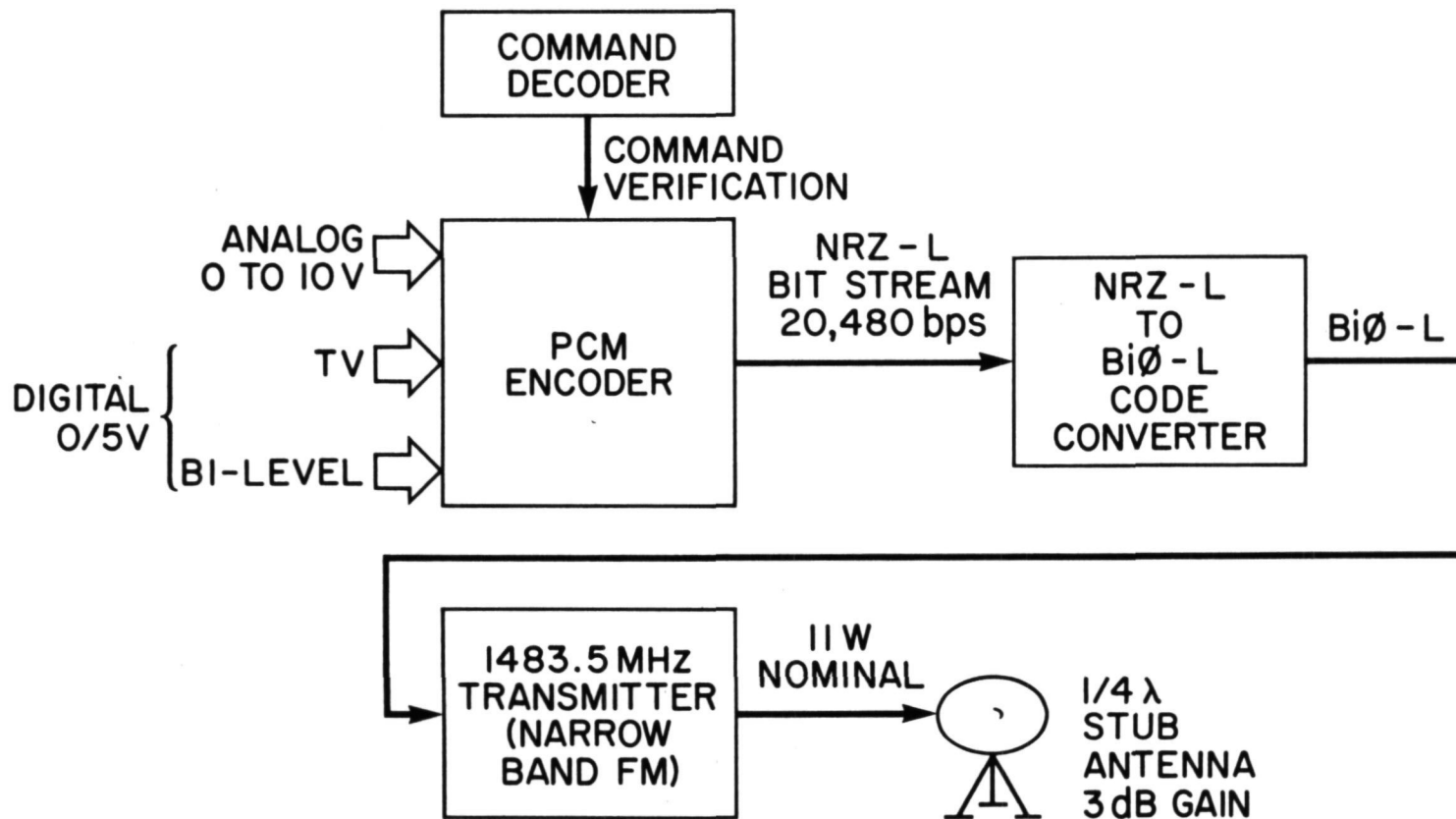|	
Typical power out	- 11 watts
Typical input power	- 28 VDC at 1.3A

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Figure 1. Gondola data gathering and encoding block diagram.

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Carrier frequency stability  - ±0.01 percent
Operating frequency          - 1.4835 GHz
Modulation characteristics
    Type                     - Narrow band FM
    Deviation sensitivity    - 500 kHz/VRMS
    Modulation bandwidth     - to 500 kHz 0 dB, -0.4 dB
    Spurious emissions       - Down 70 dB or better
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Transmitter power is applied to a 1/4 wave stub antenna which provides approximately 3 dB gain and a broad polar pattern for reliable down range reception.

The RF link just described has the capability of accepting 500 kbps and therefore can easily accommodate the 20,480 bps data rate for AIROscope. This rate is determined primarily by the digitized TV data (see DeBoo, 1974). Most other data vary at much slower rates.

GROUND STATION

The signal is received by a 19-dB parabolic antenna, amplified in an L-band preamplifier and presented to the FM receiver. See Figure 2.

The receiving antenna can be positioned so as to maximize the incoming signal. Some important receiver specifications are listed:

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Type                        - Double-conversion, crystal-controlled FM
Frequency stability         - ±0.003 percent
Sensitivity                 - 97 dBm at 10 dB quieting
Spurious signal rejection   - 60 dB or better
Noise figure                - 10 dB maximum
Demodulated bandwidth       - 10 Hz to 150 kHz, ±1.5 dB
Operating frequency         - 1.4835 GHz
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The receiver has the capability of adjustable output level and carrier detection. In addition, this receiver contains a spectrum analyzer so that the data spectrum and possible adjacent channel interference can be examined over a 6 MHz bandwidth centered at the first IF of 50 MHz. This bandwidth may be reduced to 100 kHz for increased spectral resolution. Selectable IF bandwidths and video (demodulated) bandwidths are available to optimize signal reception under adverse conditions. The combination of the receiving and transmitting systems is such that at a 650 km maximum range, a signal-to-noise ratio of 4 to 7 dB is expected.

The demodulated output of the receiver is of course contaminated by noise. This output is coupled to the bit synchronizer of the PCM decommutating unit. The bit synchronizer locks on the incoming signal and provides a "clean" serial bit stream and regenerated clock to the code converters. One converter provides NRZ-L to the format synchronizer. The other provides Miller code or DM for tape recording, which was selected because it eliminates the necessity to record DC which can occur when NRZ-L is used.

The format synchronizer operates in one of four modes: Search, Verify, Lock, or Check. Only when the synchronizer is in the Lock mode will valid NRZ-L data be routed to the rest of the ground station. For a flow chart description, refer to Figure 3. When in the Lock mode, the format synchronizer applies frame and word I.D., parallel data, and a strobe to a word select and
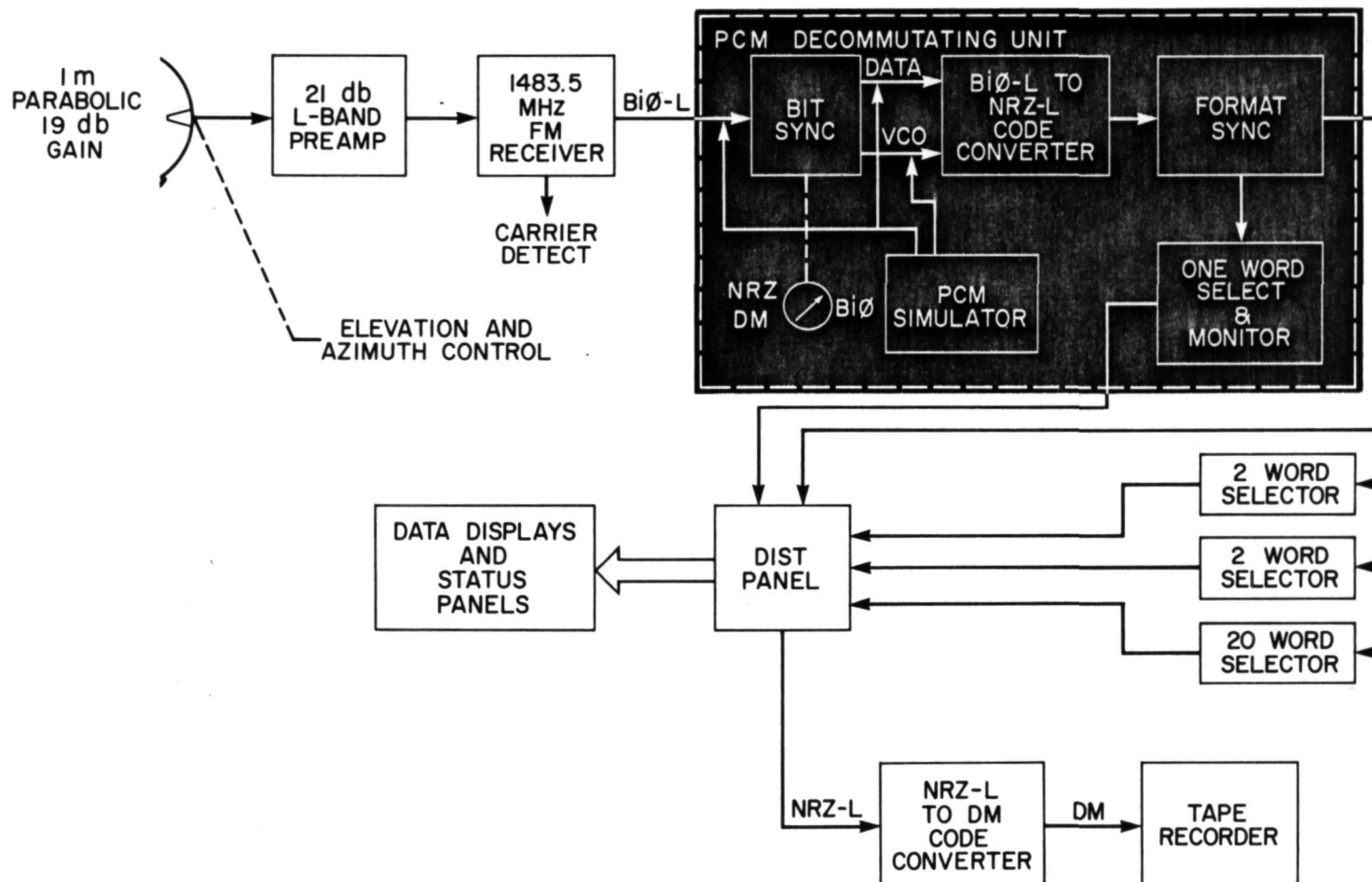
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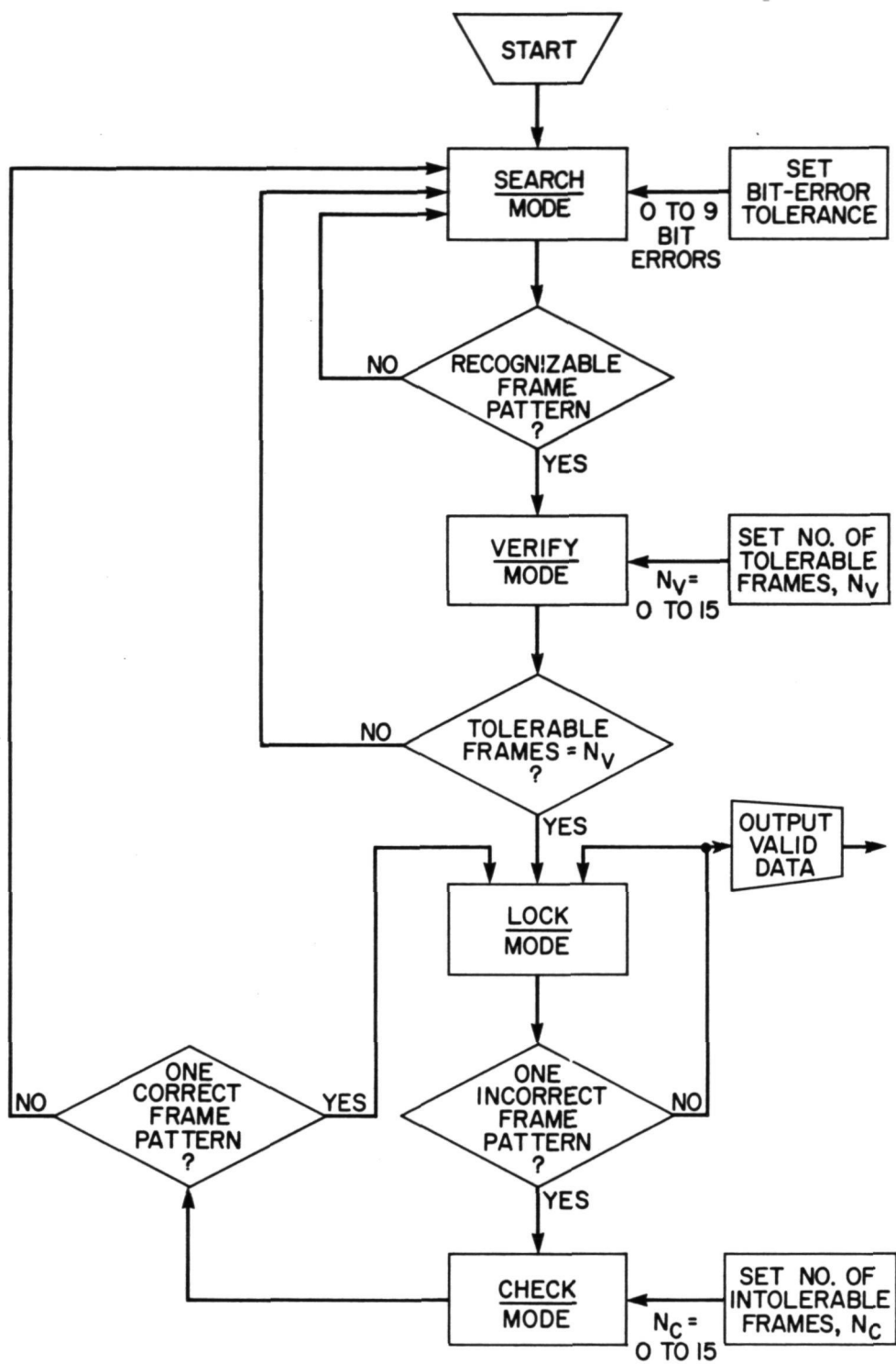Figure 2.   Ground station block diagram.

Figure 3.   Frame synchronization strategy.

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monitor unit. This unit will display the 10 bits of a selected data word on a binary lamp display and a meter. Also, three other word selectors are driven. Each of two of these will select, by thumb-wheel switches, two words and display them on a four decimal, 7-segment readout as well as on lamps and a meter. The third word selector will provide 20 words and is controlled by a punched card program for maximum flexibility. Three of these words are routed to the star field display electronics and the remaining 170 bits are distributed to the status panels and consoles. Therefore, at any one time, a total of 25 10-bit words may be selected by the operator. (See Figure 2.)

The PCM decoding/decommutating unit and associated word selectors utilize Series 7400 TTL and Series 830 DTL Integrated Circuit Logic.

Selected data can be displayed in four areas of the ground station racks, in addition to the word selector displays. These are:

(a) Bit Status Light Bank — The Bit Status Light Bank provides a quick-look at the health of AIROscope by examining data words on a bit-by-bit basis.

(b) Engineering Control — The Engineering Control Panel displays various housekeeping data such as optics alignment and subsystem power status.

(c) Pointing Control — Data displayed on the Pointing Control Panel is associated with the status of telescope pointing for target acquisition. For example, the telemetry will tell the operator whether the telescoping is moving left, right, up, down, or diagonally.

(d) Filter Spectrometer Control — Status of the IR experiment is displayed on the Filter Spectrometer Control area. Here, the experimenter monitors the state of a filter wheel and IR amplifier gain, as well as other experimental parameters.

In addition, the ground station contains a magnetic tape recorder, strip chart recorders and other devices for recording information and determining the performance of the system. See Figure 2.

When the operator places the input code selector switch on the PCM Decommutating Unit in the "DM" position (see Figure 4) the tape recorder can be used to play back a taped mission through the ground station. In this mode, the Miller Code serial data from the tape is converted back to NRZ-L and all the ground station data displays function as previously described.

CONCLUSION

The AIROscope telemetry system offers a large and expandable capacity, the capability to encode analog and digital data, and a variety of safeguards for reliability of data transmission and command verification. This paper has shown the versatility of the AIROscope system. Its versatility may be utilized to accommodate expanded scientific requirements in future balloon-borne infrared astronomy missions.
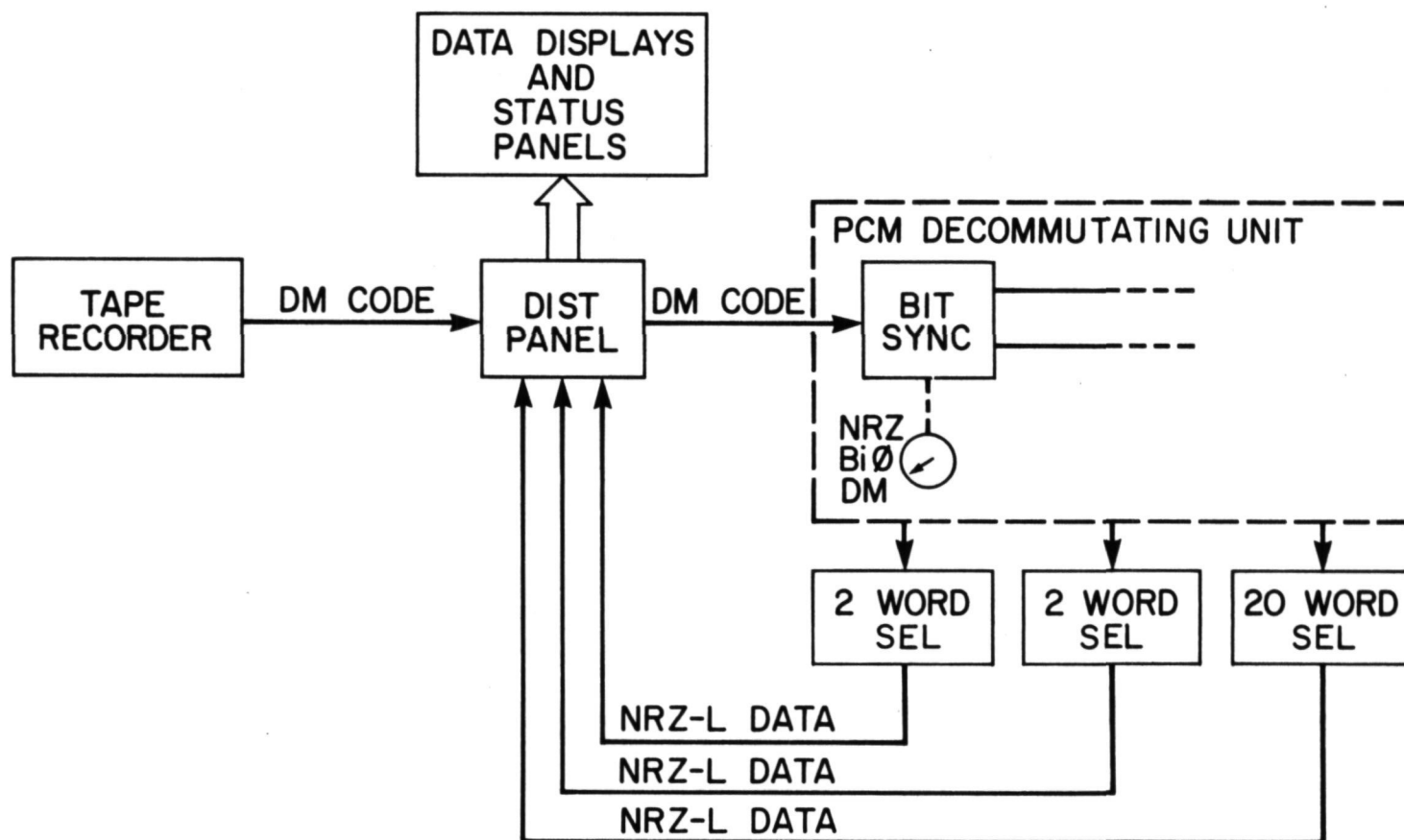
DATA DISPLAYS
AND
STATUS
PANELS

PCM DECOMMUTATING UNIT

TAPE
RECORDER

DM CODE

DIST
PANEL

DM CODE

BIT
SYNC

NRZ
BiØ
DM

2 WORD
SEL

2 WORD
SEL

20 WORD
SEL

NRZ-L DATA

NRZ-L DATA

NRZ-L DATA

Figure 4.   Data playback mode block diagram.

REFERENCES

Barrows, W. AIROscope Command System. These proceedings, 1974.

DeBoo, G., Hedlund, R., and Parra, G. AIROscope Stellar Acquisition System. These proceedings, 1974.

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DISCUSSION SUMMARY — PAPER 5.2

No discussion.