ESD-TR-81-264

LEVEL II

Project Report

STK-114

E.M. Hauser

(12) 65

Millstone Hill Radar Satellite Tracking System

4 November 1981

Prepared for the Department of the Air Force
under Electronic Systems Division, Contract F19628-80-C-0002 by

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS

The work reported in this document was performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology, with the support of the Department of the Air Force under Contract F19628-95-C-0002.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Raymond L. Loiselle

Raymond L. Loiselle, Lt. Col., USAF
Chief, ESD Lincoln Laboratory Project Office

12

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

MILLSTONE HILL RADAR SATELLITE TRACKING SYSTEM

E.M. HAUSER
Group 91

PROJECT REPORT STK-114

4 NOVEMBER 1981

LEXINGTON MASSACHUSETTS

TABLE OF CONTENTS

LIST OF DIAGRAMS

1 INTRODUCTION

This document explains the hardware used to generate, receive and format radar data at the Millstone observatory. The material contained herein is current as of the summer of 1981.

The description begins with a discussion of the standards employed and progresses to discuss the signal generation, transmission and reception chain, specifically, the Exciter, Transmitter, Antenna, and Receiver.

Next, the two elements necessary to coordinate and synchronize the system, System Timing and the Command Interface, are discussed.

Finally, consideration is given to the hardware which translates and formats data for submission to the computer, in particular, the Data and Status Interfaces.

The ramp generator, the latest addition to the system, is not discussed here. Reference should be made to Lincoln Manual #130, Technical Description of ALTAIR Digital Waveform Generators and Their Interfaces with VAX-11/780 Computer, dated 15 April 1981, for information.

2 OVERALL SYSTEM DESCRIPTION

The radar system hardware can be subdivided for purposes of description into three functional areas. These deal with signal generation, transmission and reception; with timing and control; and lastly with data formatting and processing.

The subsystems which comprise the first area are: the Time and Frequency Standard, the Exciter, the Transmitter, the Antenna, and the Receiver. The subsystems which comprise the second area are: the Timing Generator and the Command Interface. The subsystems which comprise the final area are: the Data and Status Interfaces and the Computer. See Diagram 74004, SYSTEM, LEVEL I for a pictorial overview.

The Time and Frequency Standard produces standard and coherent frequencies for use throughout the system since without coherent phase relationships the radar could not operate. The three frequencies produced are 0.1 MHZ, 1 MHZ and 5 MHZ.

The Exciter uses all three of these frequencies to generate the signals necessary for producing the 1295 MHZ transmitted signal, for down converting the received signal and for calibration. The Exciter incorporates signals generated in the Digital Waveform Generator, in Timing and in the Data Interface into the 1295 MHZ generation path. It sends a number of signals to the Receiver for use there.

The 1295 MHZ signal is amplified in the Transmitter from approximately 100 milliwatts to the 2 MW (peak) which is delivered by the final pair of klystrons. Power levels throughout the transmitter chain are monitored to verify performance. These signals appear locally and in the Control Room.

The radar signal emanates from and is received by the Antenna. The antenna is an 84 foot parabolic reflector with an in-house designed 12 horn Cassegrain feed system. Its position is controlled by error signals produced in the Status Interface and amplified in the Control Room and by DC generators. Its position is read by shaft encoders and transmitted to the Status Interface. Part of the receiver chain, the Front End Shelter, is located on the antenna tower.

In the Front End Shelter, the received signals are amplified by low-noise paramps and down converted to 105 MHZ. Amplification close to the antenna is necessary to achieve a low system noise temperature. Also, the received signals are down converted to 105 MHZ in order to reduce signal attenuation over the long signal patns from the Antenna to the Receiver Room. Noise level and calibration signals may be introduced into the signal paths in the Front

End Shelter.

In the Receiver Room the signals are further down converted to 2 MHZ and doppler is removed; they are then sent to the Data Interface and digitized.

The Control Room has enable switches for the Transmitter and for the calibration signals. The system is monitored from here during tracking.

The Exciter, Transmitter and Receiver are all gated synchronously by signals produced in Timing. In addition to these, Timing produces gates for the Data and Status Interfaces.

The computer establishes the pulse repetition interval, controls the doppler and DC level corrections, and selects the data transfer medium. These commands are communicated to the system through the Command Interface.

The Data Interface converts and formats the received data for submission to the computer. A/D conversion occurs within the Data Interface as does some preprocessing. The Data Interface receives data from the Receiver and timing signals, most notably RANGE SYNC, from Timing.

System status data is prepared in the Status Interface and sent to the computer upon demand. The Status Interface has provision also for received data transfer to the computer should the Data Interface fail. Antenna pointing error is produced within the Status Interface as well as a RANGE SYNC signal.

3 DESCRIPTION OF SUBSYSTEMS

3.1 TIME AND FREQUENCY STANDARD

The Millstone Decimal Clock, or MOUSE (Millstone Observatory Ultra-stable Source and Time Ercoder), supplies a frequency standard for synchronization of all time and frequency generating functions of the system. Output information is generated in both electrical and visual form. Pulse outputs, ranging from 0.1 MHZ to one count in 24 hours, synchronize the Master Timing Generator, the Data and Status Interfaces and the computer to real time. Time readout to the nearest second is given by Nixie decade displays. MOUSE frequency standard outputs of 0.1 MHZ, 1 MHZ, and 5 MHZ are used in synthesizers elsewhere for production of local oscillator, I-F and transmitter frequencies.

MOUSE is housed in two standard equipment racks in the Time and Frequency Standards Room. Front and rear doors allow access to the logic subracks and associated equipment, which are forced-air cooled by rack fans. The clock logic component module cards are contained in standard 33-slot subracks. Plexiglass-paneled front doors allow visual monitoring of maintenance controls, indicator lamps, master time display, time monitoring controls and equipment, power supplies, jack panels and frequency standards. Except for a WWV receiver and a monitor scope, the MOUSE power requirement (110 V, 60 HZ, single phase) is provided by the site automatic transfer power supply. The receiver and scope are fed from the station regulated supply.

Reference Diagrams 74004-2 and -3 , TIME AND FREQUENCY STANDARD, LEVEL II AND III for a pictorial representation.

The frequency standard is an HP oscillator controlled and referenced to any one of three devices: a hydrogen maser, a Cesium standard, or DC steering. No switches are used to change from one to another. Rather, each device is hardwired and cables must be exchanged when a change is desired. This is to minimize any errors which might be associated with switches.

The oscillator has a number of outputs: 0.1 MHZ, 1 MHZ, and 5 MHZ. The 5 MHZ signal is used to compare with the standard in a phase-locked loop. In addition the 5 MHZ signal is sent to a high quality distribution system to be used for system synchronization. The 0.1 MHZ and the 1 MHZ signals are distributed through a separate distribution system.

The error associated with the time standard is typically better than 1E-12.

Two clock sources in the MOUSE accept and use the 0.1 MHZ signal from the precision oscillator. Each source is a synchronized pulse generator providing high power pulses from a low impedance driver. The pulses are required to be high power because they drive many decades in parallel. The clock sources contain provision for manual advance and retard. Outputs of the sources separately feed the two clocks, each a series of divide-by-10, divide-by-6, divide-by-3 counters which successively divide the 0.1 MHZ pulse frequency to one count in 24 hours.

A counter consists of cascaded BCD-to-decimal matrices for displays, networks for 24 hour, 5 minute and 0.5 second levels and switching circuitry for single digit display advancement.

Each divider in a counter has three information inputs: the 0.1 MHZ clock, whose falling edge triggers flip flop state changes, an external advance and, with the exception of the first decade, a carry enable level from the preceding decade. In each divider, gates for itself and for the next divider enable gate are produced by AND-ing the divider count state with its own enable input. Hence, no divider can be enabled unless all those preceding it are. All enable levels have a duration of 10 microseconds and begin and end slightly after the clock falling edge.

Each clock system contains a 24-hour logic network in the tens-of-hours counter to provide midnight reset. The 24 hour clock pulse is delayed 10 microseconds from other pulses and the clock never registers 0 hours, i.e. it stays at 24 hours for 10 microseconds and then advances to 0.00001 seconds.

Time-of-day in decimal form is provided to the master and site time displays from the clock counters through BCD-to-decimal matrices. The time is provided to the nearest tenth of a second but is used only to the nearest second. In addition, 5 minute and 24 hour levels, as well as any special levels as may be required, are supplied. The clocked pulse amplifier outputs to the site are 0.5 microsecond pulses supplied on 120 ohm impedance twisted pair lines.

Under normal operating conditions, clock 1 is the master reference and drives only the master time display while clock 2 provides the timing pulses and gating levels for the system.

Most logic packages in the MOUSE use trailing edge logic, i.e. flipflops, blocking oscillators, clocked pulse amplifiers, gating generators, etc, which are triggered by the trailing edge of a clock or a gating level. Logic levels are plus/minus 5 VDC.

Sensing circuits protect the MOUSE from excessive variation in any of the logic power supply voltages. In addition, in the event of a commercial power failure, the site automatic transfer supply provides emergency AC, primarily for the ultrastable oscillators.

Each clock source may be corrected individually at a variable rate. Time reference is made using an oscilloscope by comparing clock outputs with 1 second time ticks from WWV (or other external time standards). The advance and retard pushbuttons correct each clock source. Each source may be corrected individually at a variable rate. Major time corrections are made at a 2 PPS rate. These correction buttons are locked out during normal operation.

The monitor switching system receives all source and decade outputs (except the derived 5 minute, 2 PPS, and 20 PPS signals) from both clocks as well as external reference signals (including WWV). Any two inputs to the monitor system can be fed to the A and B trace inputs of a Tektronix RM 15 oscilloscope for comparison by means of selector switches. Normally, WWV is selected as one input. Furthermore, the scope may be synched to 0.1 MHZ from either clock or the leading or trailing edge of any decade gate output (sync to a trailing edge is produced by AND-ing the gate with 0.1 MHZ from the same clock).

A Loran receiver is used to receive phase and time information to maintain the frequency standards. Phase tracking yields frequency offset data to 2E-13. Time tracking yields local time to plus/minus 0.4 microseconds. The Loran receiver operates at an interpulse period of 99,600 microseconds. WWV and published ephemeris tables are used to resolve the ambiguity to real time.

Logic levels in the synch pulse selection are somewhat different from those encountered elsewhere in MOUSE and are described in the CG-24 buffer manual (No. 43).

Several logic components used in the MOUSE are also used in the Status Interface and assosciated equipment. For more detailed information refer to the CG-24 operation manual. The CG-24 magnetic tape system manual (chap. 5) describes the clocked pulse amplifier (CPA). The complete description of the Time Standard, with diagrams, s to be found in Lincoln Manual #51.

3.2 EXCITER

The Exciter supplies low-power signals of precise frequency to the Transmitter and Receiver. All output frequencies are coherent, being derived from the station frequency and time standard. Except for a multiplier and an amplifier installed in the Front End Shelter on the antenna tower, all Exciter components are housed in two equipment racks in the Receiver Room. All outputs are 50 ohm impedances.

The Exciter accepts 0.1 MHZ, 1 MHZ, and 5 MHZ as inputs from Time and Frequency Standards. The 1295 MHZ Exciter signal, which is sent to the Transmitter for amplification, is derived by adding a CW 75 MHZ signal, which comes from the Waveform Generator, an 1190 MHZ signal, generated within, and a 30 MHZ (Barker coded) signal. The signal generation path can be understood most clearly through reference to Diagram 74004-5 and -6, EXCITER/CAL SYN, LEVEL III.

The 75 MHZ is generated originally in the Exciter through a phase locked loop, referenced to the 5 MHZ standard. It is sent to the Waveform Generator through a manual switch located on the Exciter chassis marked "NORMAL/RAMP."

Under normal operation, the switch is engaged and the 75 MHZ signal is diverted to the Waveform Generator to be modified with a gated frequency chirp, if desired, and returned for inclusion in the 1295 MHZ generation path (a CW gate can also be applied by the Waveform Generator). The switch is disengaged for calibration purposes.

The 1190 MHZ signal is produced by multiplying the 1 MHZ input by 7, dividing the product by 4, mixing the resultant 1.75 MHZ with 28 MHZ, and multiplying the sum by 5 and then by 3.

The 30 MHZ signal is derived by mixing 28 MHZ and a pulsed 2 MHZ from the Timing Generator. If the Barker code is to be included, it is entered through this 2 MHZ signal.

The 28 MHZ L.O. is derived by multiplying the 1 MHZ input by 7 and then by 4.

A 1.8 MHZ L.O., required in the Receiver for the conversion from 2 MHZ to 0.2 MHZ, is produced by doubling both the 1 MHZ and the 0.1 MHZ inputs, then mixing and selecting the lower sideband.

The resulting 1.8 MHZ is also used to help synthesize a doppler-corrected L.O., which is required by the Receiver, at a frequency of 28 MHZ. Specifically, the 1.8 MHZ and the 28 MHZ are mixed in the Exciter to produce a 26.2 MHZ signal. This 26.2 MHZ signal is then mixed with a 1.8 MHZ plus doppler input signal from the Data Interface to produce the 28 MHZ plus doppler L.O.

Either a 28 MHZ with doppler signal or a 28 MHZ without doppler signal is sent to the Receiver. A manual switch located on the Exciter chassis labeled "ZERO/DOPPLER" controls selection.

Each of these steps involves stages of amplification and filtering to yield pure sine wave signals of appropriate amplitudes.

"RF ON/OFF" signals are sent to the Exciter from the Timing Generator to turn off the 1295 MHZ generation during receive. This is to eliminate noise pickup from the Exciter in the Receiver.

3.2.1 CALIBRATION SYNTHESIZER

The Calibration Synthesizer is a precision oscillator set to 28.777628 MHZ, referenced to the 5 MHZ system standard. This signal is used at the start-up of each tracking session for calibration. The enable switch is located in the Control Room. The timing of the device is controlled by the Timing Generator which sends "CAL ON/OFF signals. The Calibration Synthesizer is any one of three synthesizers located in the Receiver Room.

The 28.777628 MHZ signal is continuous within the period that it is turned on and is not coded or phase shifted. After being multiplied by 45 to 1295 MHZ in the Front End Shelter, the calibration signal is introduced to the receiver system at the 40 db couplers which are at the converters between the waveguide and the coaxial lines in the Front End Shelter. Thus, the calibration signal traverses the entire receiver chain with the exception only of the antenna and the waveguide plumbing. The injected signal level is equivalent to the system noise level, measured previously. The signal is integrated in the computer to 30 dB and compared to expected values.

28.777628 MHZ is arbitrarily selected to yield a final frequency offset from 0 Hz (-6 KHZ). A frequency offset from zero is desired to enable detection of errors which might not be apparent at 0 Hz . The calibration synthesizer is not restricted to this frequency and the complete bandwidth of the system can be tested.

3.3 L-BAND TRANSMITTER

The L-band Transmitter is responsible for amplifying the 1295 MHZ signal level from approximately 200 milliwatts to the 2 MW which are radiated. Reference Diagram 74004-8, TRANSMITTER, LEVEL III for details. The two klystrons are enclosed within lead shielding to contain the X-ray radiation which they generate. Most of the control equipment for the Transmitter is located in the Control Room.

The 1295 MHZ signal enters the Transmitter from the Exciter. It is amplified twice before being sent to the Antenna. The first amplification occurs in a travelling wave tube driver which raises the signal level from the 100 to 200 milliwatts entering from the Exciter to approximately 2000 W, sufficient to drive two Varian model x780 klystrons. This signal is divided by a power divider and sent on to the two klystrons.

The two final klystrons further amplify the signal level; their outputs are combined in phase and sent on to the Antenna with a combined power level of approximately 2 MW peak.

The klystrons are controlled by a modulator which, in turn, is controlled by Timing. The modulator functions as a series switch between the power supply and the klystrons' anodes. It is insulated for safety through immersion in oil.

The modulator is coupled to the Timing "ON" pulse through a 5 MHZ inductive link. This link will eventually be supplanted with an optical link.

Located along the signal path are numerous directional couplers which measure signal levels. Some of these measurement signals are used locally for calibration while others are sent to the Control Room. See Diagram 74004-B, TRANSMITTER, LEVEL III for coupler placement and signal selection.

The output signal from each of the final stage klystrons passes through a harmonic absorption filter before combining. The filter is a waveguide structure approximately 6 feet in length with heat dissipation fins.

Before being sent to the Antenna, the signal can be diverted to a water load. The switching is achieved through phasing of the two klystron outputs relative to one another. The phasing is controlled in the Control Room and is accomplished though cable length adjustment after the power splitter ahead of one of the klystrons.

Between the combiner and the antenna is a reverse power detector. This detector provides a measure of reverse power to Control where it is compared to a preset level. If reverse power exceeds that level, a signal is sent to the Transmitter which turns on a pin diode switch located at the input to the driver. This diode shorts the 1295 MHZ signal path to ground and thereby protects the klystrons. An excess of reverse power can be attributed to obstructions such as water in the line or other similar causes.

A reference manual for the klystrons is available. The name of the manual and the address of the manufacturer are:

Care and Feeding of Eimac x780
Pulse Amplifier Klystron and H145 Circuit Assembly

Eitel Mccullough, Inc.
301 Industrial Way
San Carlos, Ca 94071
Attn: High Power Microwave Devices Applications
Engineering

This company has since absorbed by:

VARIAN
611 Hansen Way
Palo Alto, Ca 94303

The harmonic absorption filters are called and built by:

Microwave Power Filter
Serial #11 PF 1007
Model #2

General Electric
Travelling Wave Tube Section
Power Tube Department
Palo Alto, Ca 94303

3.4 ANTENNA

The antenna is an 84 foot parabolic reflector with an in-house designed 12 horn Cassegrain feed system. It is fully described in Technical Report #393: 12 Horn Monopulse Antenna System For Millstone Hill Radar, by C.A. Lindberg dated 15 June 1965. Refer to Diagram 74004-10, ANTENNA/PEDESTAL, LEVEL III for the horn configuration.

The determination of antenna position is performed by Wayne-George model Digisec RAL-17/60S 17 bit optical encoders arranged with a separate electronics package and serial output. These give 0.00275 degree resolution. They are read out by a strobe and clock command from the Status Interface each interpulse period.

The elevation position is determined by a shaft which connects a "spider" welded inside the elevation axis torque tube to the elevation encoder.

The azimuth position is determined through a novel cam-follower arrangement that allows the azimuth encoder to be mounted off-axis. The system utilizes two octagonal cams, one inscribed within the other. The outer cam consists of eight precisely machined steel bars, or "rails," attached to the rotating structure at the level of the main bearing. The rails are mounted alternately above and below one another so that no true corners are produced where they meet. The angle included by any adjacent pair of rails is adjusted to exactly 135 degrees.

The inner cam is a follower unit attached to the sidewall of the antenna tower. It consists of a small rotating octagon which is held against the inner surface of the large outer octagon. In this configuration, one rotation of the small inner octagon is produced for each complete revolution of the antenna. Accordingly, the digital encoder can be directly coupled to the shaft of the follower cam and will be turned one revolution for each revolution of the antenna. In order to allow the follower to move back and forth as the large octagon moves by, the follower assembly slides on ball bearings along a pair of cylindrical shafts. A pulley gravity shot-bucket combination holds the two surfaces in intimate contact.

The worst case error of the rail system as measured in the laboratory is plus/minus 4 LSB's peak or approximately 0.01 degrees. The RMS error is about 0.003 degrees.

Determination of "tower tilt" is through two commmercially available electronic level sensors (Brunson model 455-1). These devices use the position of an air bubble in a spirit level. The spirit level constitutes one arm in a low frequency A.C. bridge. When the device is level, two capacitances are equal and the bridge circuit is in balance. Any tilting of the device leads to an imbalance of the bridge circuit and a consequent change in the AC ouput voltage. These signals are rectified to yield a direct measure of the amount of tower tilt. These DC analog signals are brought to the Data Interface on two coaxial cables contained in the cable wrap. There, the signal levels are adjusted to be compatible with the A/D converters and are filtered to remove any voltage spikes. The first device, the "principal" tiltmeter, is aligned along the projection of the boresight axis onto the azimuth plane. The other, the "orthogonal" tiltmeter, is mounted at a right angle to the first. The output level range of the tiltmeters is plus/minus 5 VDC.

By convention, any tower tilt which tends to lower the radar beam is considered to be positive and any tilt tending to raise the beam is considered to be negative. Therefore, apparent elevation = true elevation plus tilt.

The antenna servos are controlled by error signals produced in the Status Interface. These signals appear in the Control Room. The error is produced by subtracting the antenna's position from a computer commanded position. This difference is converted to analog form, amplified in the Control Room and sent to DC generators which drive the antenna servos. Two 30 HP motors in each axis, azimuth and elevation, move the antenna. Servo specifications for both axes are listed in Table I.

TABLE I

CHARACTERISTICS OF MILLSTONE ANTENNA POWER DRIVE SYSTEM

System Inertia	1.0 slug-ft squared
Back EMF of Motors, Kv	1.2 v/rad/sec
Torque Sensitivity, Kt	0.9 ft-lbs/a
Armature Resistance, Ra	1.0 ohm
Armature Inductance, La	1.5 millihenries
Control Field Resistance, Rf	7.1 ohms (both windings in parallel)
Control Field Inductance, Lf	180 millihenries
Gear Train Ratio, N	2147 in azimuth/2230 in elevation
Generator Gain, Kg	46 v/z (open circuit)
Control Field Time Constant, Tf = Lf/Rf	26 msec
Armature Circuit Time Constant Ta = La/Ra	1.5 msec
Mechanical Time Constant, Tm = Jra/Kv*Kt	1.0 msec
Antenna No-load Velocity (at 1750 RPM motor speed)	5.0 deg/sec
Max Acceleration (at 225 A torque current and 1 slug-ft squared inertia)	5.0 deg/sec squared

The position encoders, tiltmeters, and servos are completely described in Technical Report #507, Millstone Hill Radar Propagation Study: Instrumentation, by J.C. Ghiloni dated 20 September 1973. The RF plumbing and the torque system are described in Lincoln Manual #51, chapters 6 and 10.

Transmission will not occur when the antenna is pointing towards the Haystack installation (Haystack Sector Blanking). The blanking sector is a rectangle approximately 2 degrees high and 6 degrees wide centered at 1 degree elevation and 19 degrees azimuth.

The cable wrap imposes limits on the antenna's travel. The antenna may revolve 540 degrees before reaching its limit. 0 degrees indicates north and the cable wrap is centered at 180 degrees (south). (See 1).

Thus, (with 360 degrees from position 180 degrees traversed);

CW warning operates at 257 degrees
CW limit operates at 270 degrees
CW overtravel operates between 180 and 285 degrees
CCW warning operates at 103 degrees
CCW limit operates at 90 degrees
CCW overtravel operates between 180 and 75 degrees

"Overtravel" is defined as the additional cable supplied for travel after 360 degrees of revolution.

See Diagram 74004-11, ANTENNA/PEDESTAL, CABLE WRAP LIMITS, LEVEL III for a pictorial representation.

In the elevation axis, the antenna may ascend up to 90 degrees.

3.5 RECEIVER

The Receiver is responsible for amplifying and down converting the received signals from the Antenna for submission to the Data Interface. Reference Diagrams 74004-13 and -14, RECEIVER, LEVEL III for a pictorial representation.

Presently, only 3 channels are processed: Delta Azimuth, Delta Elevation, and Left Circular Sum. The fourth channel, Right Circular Sum, is sent over the azimuth line

---

1 Since this writing, the cable wrap has been removed and the system utilizes the original data transmission paths which employ pancake rotary joints. These are described in Lincoln Manual #51, Chapter 6.

when it is desired. A switch for this is located in the Front End Shelter immediately after the conversion from waveguide to coax. It is controlled from the Control Room with a switch labelled "XPOL/AZ."

The first half of the receiving chain is located on the Antenna tower in the Front End Shelter. There, the received signals are transferred from waveguide to coaxial cables. After this, the signals are amplified by room temperature, low noise paramps (Scientific Communications, Inc., model SCP-511), mixed down to 105 MHZ and sent to the Receiver Room. See Table II, PARAMP SPECIFICATIONS for specifications.

In the Receiver Room, the signals are mixed down further from 105 MHZ to 2 MHZ. These 2 MHZ signals are then sent to the Data Interface. 0.2 MHZ signals are also generated for use in local monitors. Along the path, a phase shifted L.O. from the Exciter (which is controlled by the computer) can be switched in.

Specifically, the 105 MHZ is mixed down to 30 MHZ with a 75 MHZ signal from the Exciter. This 75 MHZ signal can be added at 0 degrees or at 180 degrees. The selection is controlled by the computer (75 0/180 DEGREES SELECT, bit 20 in the elevation command word) while the phasing is accomplished by switching between two cables of appropriate length. The signal is randomly flipped to reduce the effect of A/D converter DC bias in the signal integration. This random flipping is recorded by the computer which subsequently removes it from the signal processing. After this, the signal is mixed with 28 MHZ, with or without doppler, to yield 2 MHZ. This 2 MHZ signal is amplified and sent to the Data Interface.

In addition, a 1.8 MHZ signal is mixed with a second 2 MHZ output of the line amplifiers to produce 0.2 MHZ signals for local monitoring.

All of the L.O.'S used are produced in the Exciter from the standard frequencies and are therefore coherent with one another.

In the Front End Shelter are the inputs for the calibration signals which are turned on and processed at start-up of each tracking session. The first signal, 28.777628 MHZ, is sent from the Calibration Synthesizer. It is multiplied by 45 and introduced into the system immediately after the TR tubes. Thus, the signal traverses the entire receiver chain with the exception only of the Antenna and the waveguide run. Noise calibration signals are produced in each receiver channel by diodes attached to the coaxial lines. The noise signals provide a check for determining the noise temperature in each channel.

TABLE II

PARAMP SPECIFICATIONS

Electrical Specifications

Frequency Range	1.295 GHZ
RF Gain	23 dB minimum, 25 dB maximum, 24 dB typical
Bandwidth	20 MHZ(minimum) at the 3.0 dB points
Noise Temperature	45 degrees Kelvin, 35 degrees Kelvin typical
Gain Compression	Less than 0.1 dB at -55 dBm input level
Gain Stability	Plus/minus 0.3 dB/day, plus/minus 0.3 dB over temperature range
Input/Output connnector	Type "N" Female
Gain Flatness over the 20 MHZ bandwidth	0.5 dB P-P maximum measured from a smooth, symmetric reference curve with monotonic slope centered at 1.295 GHZ
VSWR Input/Output over the 20 MHZ bandwidth	1.3:1 maximum
Pump Source	Gunn Oscillator
Input Power	115 VAC plus/minus 10%, 60 Hz plus/minus 10%, single phase, 450 watts

Environmental Specifications

Temperature Operating Range	-30 degrees to 120 degrees F
Altitude, Operating	0 to 10,000 Feet
Altitude, Non-operating	0 to 40,000 Feet
Relative Humidity	Up to 95%
Vibration and Shock	Air transportation and surface transportation over unimproved roads. Will withstand 1 g linear acceleration.

Protection circuitry includes a TR tube located in the Front End Shelter in the RC waveguide run before the takeoff to the coaxial line in each channel. This device detects high power levels and shorts the path through it to ground.

Additional protection is afforded by gating the receiver channels. The gates are driven by two signals from Timing, "RECEIVER ON" and "RECEIVER OFF," and are located at the inputs from the Front End Shelter to the Receiver Room.

The manual and the manufacturer for the paramps are:

Operation and Maintenance Manual
Model SCP-311
Manual P/N 412-135-000

Scientific Communication, Inc.
3425 Kingsley
Garland, Texas 75041

3.6 TIMING GENERATOR

The Timing Generator is responsible for producing the proper sequence of gates for use by various parts of the system. The Timing Generator is housed in cabinet B1 in the Signal Processing Room. See Diagram 74004-1, SYSTEM, EQUIPMENT LAYOUT. a standby generator exists and is located adjacent to the primary generator.

On the average, the interpulse period is 37 milliseconds. This period is variable and is chosen by the computer through the Command Interface. Each timing pulse sent out by the Timing Generator is 1 microsecond long. See Diagram 74004-19, COMMAND INTERFACE, LEVEL II, for word and bit assignments.

A typical sequence might be as follows:

TIME (MSEC)	SIGNAL
0.010	SYSTEM SYNC
0.010	SYSTEM SYNC
1.800	TRANSMITTER DC ON
1.820	RECEIVER OFF
1.960	EXCITER RF ON
3.000	EXCITER RF OFF
3.000	TRANSMITTER DC OFF
3.500	RECEIVER ON
11.960	CAL CW ON
11.960	CAL NOISE ON
13.000	CAL CW OFF
13.000	CAL NOISE OFF
37.000	SYSTEM REP RATE

Reference Diagram 74004-18, TIMING GENERATOR, TIMING, LEVEL IV.

"SYSTEM SYNC" is a reference signal for the monitor oscilloscopes. The Transmitter video pulse is turned on 0.16 milliseconds before the Exciter to allow for its rise time. The Receiver is turned off during transmission to protect the circuitry from the high power levels experienced. The Exciter 1295 MHZ signal generation is only turned on for the 1.04 milliseconds of transmission to reduce noise pickup from it during receive. The "NOISE ON/OFF" and "CAL ON/OFF" pulses are enabled in the control room and are used only at the start-up of each tracking session for calibration.

The Receiver is not turned on immediately after transmission in order to allow noise and clutter levels to subside.

Each On or Off pulse travels over a distinct line to its destination. The pulses are sent this way to avoid any phasing errors which might occur in the equipment. For example, the Transmitter might miss an ON pulse and would consider the following OFF pulse to be an ON pulse were they to travel over the same line.

Three additional pulses which are sent out are "RANGE GATE RESET," "RANGE GATE START" and "RANGE CENTER RESET." These go to the Status Interface to reset and initiate the Range Counter and to reset the Range Position Counter (word 1). See Diagram 74004-26.

The "RANGE SYNC" pulse, which is distributed through the Timing generator, originates either in the Waveform Generator or in the Status Interface. The selection is controlled by a manual switch located on the bottom right of the Timing Generator chassis.

A time comb which goes to the Data Interface originates here. It is set in the hardware to 10 microseconds (although not restricted to this) and is referenced to a 5 MHZ signal from either Time Standard or the Waveform Generator. The 5 MHZ signal from the Waveform Generator is synchronized with "RANGE SYNC." In backup mode, when data from the A/D converters to the computer passes through the Status Interface, the time comb is set to 500 microseconds.

The Barker coded gated 2 MHZ signal to the Exciter is generated in the Timing Generator in the Digital Exciter. It is referenced to an internally generated 4 MHZ signal, is turned on and off by the "RF ON/OFF' signals and is driven by a code set on a diode matrix. The 4 MHZ signal is referenced to a 5 MHZ signal from either Time Standard or the Waveform Generator in a phase-locked loop. The 5 MHZ signal from the Waveform Generator is synchronized with the IPP. Three modes of operation for the Digital Exciter can be set: "CW," "Modulate" and "Inhibit." The Barker code used

has 13 elements and the width of each baud is 80 microseconds. The peak sidelobe ratio is -22.3 dB.

One final signal which is received by the Timing Generator is a pretrigger pulse from the Waveform Generator. This signal is used to preset old hardware, such as the Digital Exciter, to cause them to initiate correctly at transmit time. This pulse is programmable to meet the requirements of the older hardware.

The manual for the Timing Generator is located in the Signal Processing Room and is called and built by:

Instruction Manual
Model 6600
Pulse Timing System

Astrodata
240 E. Palais Road
Anaheim, Ca

3.7 COMMAND INTERFACE

The Command Interface is responsible for communicating mode selection, operational parameters, antenna commanded position and range gate start time from the computer to the Data and Status Interfaces.

The Command Interface is comprised of a single 24 bit computer output data bus and a 4 bit address bus. It is comprised also of a variety of cable drivers and decoding equipment necessary to match old and new hardware.

At present, only the A/D converters, the Array Processor, and the Address Selector in the Data Interface use TTL logic. The Hybrid Correlator, the HP 5100, and the Status Interface use discrete logic. To adjust levels, a Logic Level Translator is located in the bus line. The devices which require discrete levels are all located ahead of the translator while those devices which require TTL levels are located behind it.

At each destination is an address decoder and a memory register to store the command. Level converters are at those locations where TTL logic is not used. The Antenna Directors (in the Status Interface) use plus/minus 5 volts; the Range Gate Counter (in the Status Interface) and the HP 5100 (in the Data Interface) use 0 to minus 6 volts.

Commands are not necessarily updated each interpulse period.

Bit positions and word assignments are depicted in Diagram 74004-19, COMMAND INTERFACE, LEVEL II.

In addition to adjusting the level, the Translator recognizes and extracts bit commands for the Timing Generator and the Receiver from the words in which they are embedded. "AUXILIARY REPETITION RATE" and "AUXILIARY REPETITION RATE ENABLE" are the commands recognized for and sent to the Timing Generator. "75 0/180 DEGREES SELECT" is recognized for and sent to the Receiver.

The two "1.8 DOPPLER CONTROL" words can adjust the full frequency range (0-50 MHZ, 0.01 Hz accuracy or 0-5 MHZ, 0.001 Hz accuracy) of the HP 5100 in the Data Interface.

3.8 DATA INTERFACE

The Data Interface accepts data from the Receiver and formats and/or processes it for submission to the computer. It is managed by the computer which accesses information from and sends commands to it. Within the Data Interface are two data processing units, the Hybrid Correlator and the Array Processor. Currently, all data passes through the Hybrid Correlator which essentially serves as a formatter and (in one mode) as a presummer. Eventually, the Array Processor will be used exclusively. The Status Interface can be used as a backup route for data transfer to the computer from the A/D converters.

The Data Interface is housed in a number of racks in the Signal Processing Room. See Diagram 74004-1, SYSTEM, EQUIPMENT LAYOUT for cabinet assignments. A translator for the Command Bus is located within the Data Interface in the A/D converter chassis, as is the HP 5100 which supplies the 1.8 MHZ PLUS/MINUS DOPPLER signal to the Exciter.

The HP 5100 synthesizer is controlled by two words from the Command Interface. See Diagram 74004-19, COMMAND INTERFACE, LEVEL II.

Diagram 74004-21, DATA INTERFACE, LEVEL III must be referenced for a complete understanding of the Data Interface's operation.

The received data enters the Data Interface from the Receiver as 2 MHZ I.F. signals. Presently, three channels are processed: Delta Az, Delta El, and Left Circular Sum. These signals are first converted to baseband by Quadrature Video Detectors (phase/amplitude detectors) to obtain the real and imaginary parts, then digitized in A/D converters, and stored as 20 bit words (10 bits I; 10 bits Q). At present, tiltmeter information from the Antenna is processed in a fourth line.

The 10 bit A/D converters (Pastoriza Custom 8 Channel A/D System) can operate up to a 0.1 MHZ sample rate. Their outputs are switched in parallel into memory registers by a switch (marked "1 PULSE/4 PULSE COUNTER on Diagram 74004-21) driven by a time comb from the Timing Generator. This comb is variable but is normally run as a 10 microsecond comb. The switch is run as a 4 count switch or as a 1 count switch. The mode is selected by the computer through the Command Interface. The 4 count mode is selected when the Hybrid Correlator is in use while the 1 count mode is selected when either the backup or the Array Processor is in use.

From the A/D converter registers, the data is multiplexed out to one of three destinations; the Hybrid Correlator, the Status Interface, or the Array Processor. Reference Diagram 74004-22, DATA INTERFACE, A/D REGISTERS, TIMING, LEVEL IV for illustration of register readout timing in the various modes.

If the mode selected is for the Hybrid Correlator, the A/D converters will be strobed at 40 microsecond intervals and the registers will be read out at 10 microsecond intervals (40 microseconds for 4 channels). In this mode, the address selector is driven by a 10 microsecond comb from Timing.

If back up mode is selected, with the data to be sent to the computer though the Status Interface as words 7 through 10, the A/D converters will be strobed and the registers will be read once each 500 microseconds. In this mode, the address selector is driven by a read strobe signal from the computer.

If the data is to be sent only to the Array Processor, the addressing of the multiplexer is directly controlled by the Array Processor. The A/D converters are strobed at a 100 KHZ rate by the switch, operating as a one count, and the registers are read out by the Array Processor in 6.4 microseconds.

Data is always sent to the Array Processor regardless of which mode is selected.

Immediately following the A/D register multiplexer is a translator which shifts the logic levels from RTL to TTL for submission to the Array Processor. This data is also fed through to a discrete translator to prepare it for submission either to the Hybrid Correlator or to the Status Interface. The mode is selected through the Command Interface. The logic level between the two translators is plus/minus 2 volts. When data is sent to the Status Interface it is sign extended in the discrete translator from 10 to 12 bits and is level shifted to 0 to 5 volts logic.

The Hybrid Correlator performs many functions. It serves as an interface between the A/D converters, which operate on the range clock frequency, and the computer, which operates at its own data rate. In addition, the Hybrid Correlator performs sign extension. It can also presum the data before sending it to the computer. The data can be sent in packed or unpacked mode.

By presumming the data before sending it to the computer, the Hybrid Correlator reduces the amount of data which is sent to the computer, thus decreasing the amount of memory and the speed required for processing.

Two 24 bit command words from the Command Interface are accepted by the Hybrid Correlator and stored in Prom Control and Timing. In addition to selecting the mode of operation, these two words select the number of channels to be processed, the range gate start time, and the number of samples to be presummed (if operating in that mode). Three modes of operation are possible: "Correlate," "Integrate" and "Pass-through."

A total of 999 words can be entered into the Hybrid Correlator. The number of words which can be summed is a function of the number of channels, the number of terms, and the throughput time. The maximum number of channels is 32. If using 4 channels, the maximum number of terms would be 249.

The Hybrid Correlator has two identical data paths, each comprised of an ALU and three memory registers: an input memory, a sum memory and an output memory. See Diagram 74004-21, DATA INTERFACE, LEVEL III.

The input and sum memories each have 32 words of memory, 24 bits wide, while the output memory has 67 words of memory, 24 bits wide. Readout is controlled from the computer which strobes the read-out control when it is ready for data. Each device within the Hybrid Correlator receives mode and prompting commands from Mode Control and Timing.

The Hybrid Correlator accepts one 20 bit data word from the Discrete Translator each 10 microseconds. This 20 bit word is comprised of two 10 bit fields, I and Q, respectively. The first stage of the Hybrid Correlator is a Data Distributer which, as its name implies, distributes the received data within the Correlator. Sign extension occurs within the Data Distributer as well.

Two modes of data submission are possible; packed and unpacked. When operating in packed mode, the Data Distributer sign extends each 10 bit field to 12 bits and sends the single 24 bit word over one path. When operating in unpacked mode, the Data Distributer sign extends each 10 bit field to 24 bits and sends the two 24 bit words over the two paths, one word to each path.

The Array Processor is more versatile than the Hybrid Correlator in preparing and preprocessing data for the computer. Its theory is described in Project Report #STK-104, Millstone Signal Processing, by R.A. Ford., dated 20 September 1979.

The Array Processor receives data through the Data Formatter. The Data Formatter reads the A/D registers at a 0.1 MHZ rate. Each block of 4 A/D sample pairs is then outputted to the Array Processor in a 6.4 microsecond interval. The Data Formatter can submit data to the GPIOP in either packed or unpacked mode. It receives one 20 bit word from the A/D registers through the TTL translator which is comprised of two 10 bit fields, I and Q. When operating in packed mode, each 10 bit field is sign extended in the Data Formatter to 16 bits and both 16 bit fields are submitted to the GPIOP as a single 32 bit word. When operating in unpacked mode, each 10 bit field is sign extended to 32 bits and submitted serially to the GPIOP as two words.

In packed mode, one 32 bit I/Q pair word is submitted to the GPIOP from the Data Formatter each 1.6 microseconds and four such words are submitted each 10 microseconds (the limiting speed of the A/D converters). In unpacked mode, one 32 bit word is submitted to the GPIOP from the Data Formatter each 800 nanoseconds and eight such words are submitted each 10 microseconds. See Diagram 74004-23, DATA INTERFACE, A.P. GPIOP, TIMING, LEVEL IV.

Four control signals are exchanged between the Array Processor and the Data Formatter: DC 11, INT 0, IB Load and IB Busy. DC 11 is a data transfer disable DC level from the GPIOP to the Data Formatter. INT 0 is a data flow commence pulse to the GPIOP from the Data Formatter. IB Load and IB Busy are hardware handshaking signals to respectively commence and confirm data transfer to and from the GPIOP. IB Load is a pulse while IB Busy is a DC level. Command information from the computer is fed to the Array Processor though an I/O bus.

The Array Processor receives the "RANGE SYNC" signal from Timing to coordinate its data processing schedual with that of the radar. The Array Processor operates on a 6 MHZ clock which is asynchronous with respect to the master clock.

The reference manual for the Array Processor is:

GPIOP Software Reference Manual, Volume 2
(CPROC)
860-7430-000
Floating Point Systems, Inc.

Additional software manuals for the Array Processor are available.

The reference manual for the A/D converters is:

High Speed A-D System
SN No. 2771
M.I.T. Lincoln Laboratory

Pastoriza Electronics, Inc.
385 Elliot Street
Newton Upper Falls, Ma 02164

3.9 STATUS INTERFACE

The Status Interface collects data from several sources for orderly submission to the computer. This data includes: a range word, time of day, antenna position and system status. In addition, a backup route for the received data from the A/D converters through the Interface is provided. Refer to Diagram 74004-25, STATUS INTERFACE, LEVEL III.

The Status Interface is distributed among a number of racks in the Signal Processing Room. See Diagram 74004-1, SYSTEM, EQUIPMENT LAYOUT for cabinet assignments.

Twelve words are collected and sent through a multiplexer to the computer. See Diagram 74004-26, STATUS INTERFACE, WORD FORMAT, LEVEL III, for word assignments. Words 2, 11, and 12 are blank at this time.

Word one is a range count. This is used as a check to confirm that the range gate was initiated when requested. It is produced by the Range Position Counter and is driven by two signals from Timing: "RANGE CENTER RESET" and "RANGE SYNC."

"RANGE CENTER RESET" sets the Range Position Counter to zero. The counter then counts until it receives "RANGE SYNC" from Timing. Thus, a check count is generated and used by the computer to confirm proper range sync initiation.

Words three and four are the azimuth and elevation positions of the antenna, respectively. To obtain the positions, a strobe and a clock counter signal are sent over two lines to the shaft encoders which transmit the information in bit serial form. The strobe and clock are initiated each PRI by "RANGE SYNC" from Timing. This information is converted to parallel form, has system status bits added, and is stored. It is also sent to the Digital Antenna Directors for use in pointing the antenna. The system status bits are generated in the Control Room by relays and include data on operation mode, cable wrap direction, cable overwind, and a "transmitter-on" check. This last signal is called "RF ON" and appears in the

Control Room on the Transmitter Control chassis. The relay logic is translated and introduced to the azimuth and elevation position words in the Level Converters.

Words five and six represent time in the form of an unnormalized number . The mantissa consists of 30 bits (23 to 0 in word five and 23 to 18 in word six). In word six, bits 0 to 7 constitute an 8 bit representation of the exponent which is set to octal 36. The exponent field is not interpreted as an exponent but as a notification to the computer of the clock word length. This word is driven by a local clock, referenced to a 1 MHZ signal (multiplied to 2 MHZ for greater accuracy) and a 5 minute signal from Time Standard. The 2 MHZ is divided down to 0.01 MHZ to yield 100 microsecond accuracy. Higher accuracy, to about 50 microseconds, is possible. A local clock is used because it operates in binary whereas the Time Standard operates in BCD.

Words seven through ten are reserved for data from the A/D converters in the Data Interface. Data is sent this way when the Hybrid Correlator is not operating satisfactorily. When no data is sent through the Status Interface, 0's are read out. Selection between the Hybrid Correlator and the Status Interface is controlled by the computer through the Command Interface.

Status data is called and multiplexed out by the computer program every 500 microseconds. 24 microseconds are required to read out the entire 12 word buffer register. The limiting factor in readout is attributable to words 3 and 4 which take 350 microseconds to transmit serially from the antenna position encoders to the Interface registers.

The azimuth and elevation error signals, used for pointing the antenna, are generated within the Status Interface in the Digital Antenna Directors. Thus, when the antenna position is transmitted from the Encoders, it is compared to a computer commanded position in the Digital Antenna Directors. The difference is converted to analog form and sent as a DC level to the Control Room, amplified, and sent to DC generators which drive the antenna servos. A switch for manual control of the antenna is located in rack B15, across from the Serial-to-Parallel Converters and is labelled "MANUAL."

In addition, a "RANGE SYNC" signal is generated in the Status Interface, in the Range Gate Counter by comparing a computer commanded time to a time counted from the "RANGE GATE START" signal which originates in Timing. The counter is reset by the "RANGE GATE RESET" signal from Timing. This "RANGE SYNC" pulse is sent to Timing distribution.

"RANGE GATE START" and "RANGE GATE RESET" are offset by a few microseconds to account for a timing delay in the Range Gate Counter.

3.10 COMPUTER

The Computer, either one of two Harris Model S220 computers, processes the radar data and operates the system. Radar and system data is collected through the Data and Status Interfaces while commands are issued through the Command Interface. See Diagram 74004-29, COMPUTER, LEVEL II.

The first of these computers operates the radar full-time while the second computer is used for development and as a backup to the first. Both computers are based on the Harris/7 CPU which has virtual memory, demand paging hardware. The multitasking VULCAN operating system permits concurrent real-time processing, time-sharing, and batch processing. The configurations of both computers are nearly identical and include the following major components:

1. 192K 24-bit words of interleaved core-memory (to be expanded to 256K words) with an effective memory-cycle time of 675 nanoseconds.

2. Twelve input/output channels including both programmed and DMA (direct memory access) channels to support high speed data transfer to and from the Data and Status Interfaces.

3. 24 priority interrupts.

4. 80 megabyte moving head disk drive and controller with 1.2 megabyte/second transfer rate.

5. 40 megabyte moving head disk drive and controller with 1.2 megabyte/second transfer rate.

6. Two 75 IPS dual density (800/1600 BPI) 9-track magnetic tape drives with associated controller (45 IPS drives on S220-Beta).

7. 600 LPM printer.

8. 300 CPM card reader.

9. 8 terminals with associated DMA or programmed I/O interfaces.

10. A Sanders Graphic 7 Display System used for

real-time display and post-processing of tracking data, as well as additional applications which include:

A. Two display tubes and keyboards per system.

B. 16 kilobytes of local memory for refresh data.

C. Flexible graphic display instruction set.

D. Vector refresh at rates up to 60 Hz including up to 10,000 inches of vectors.

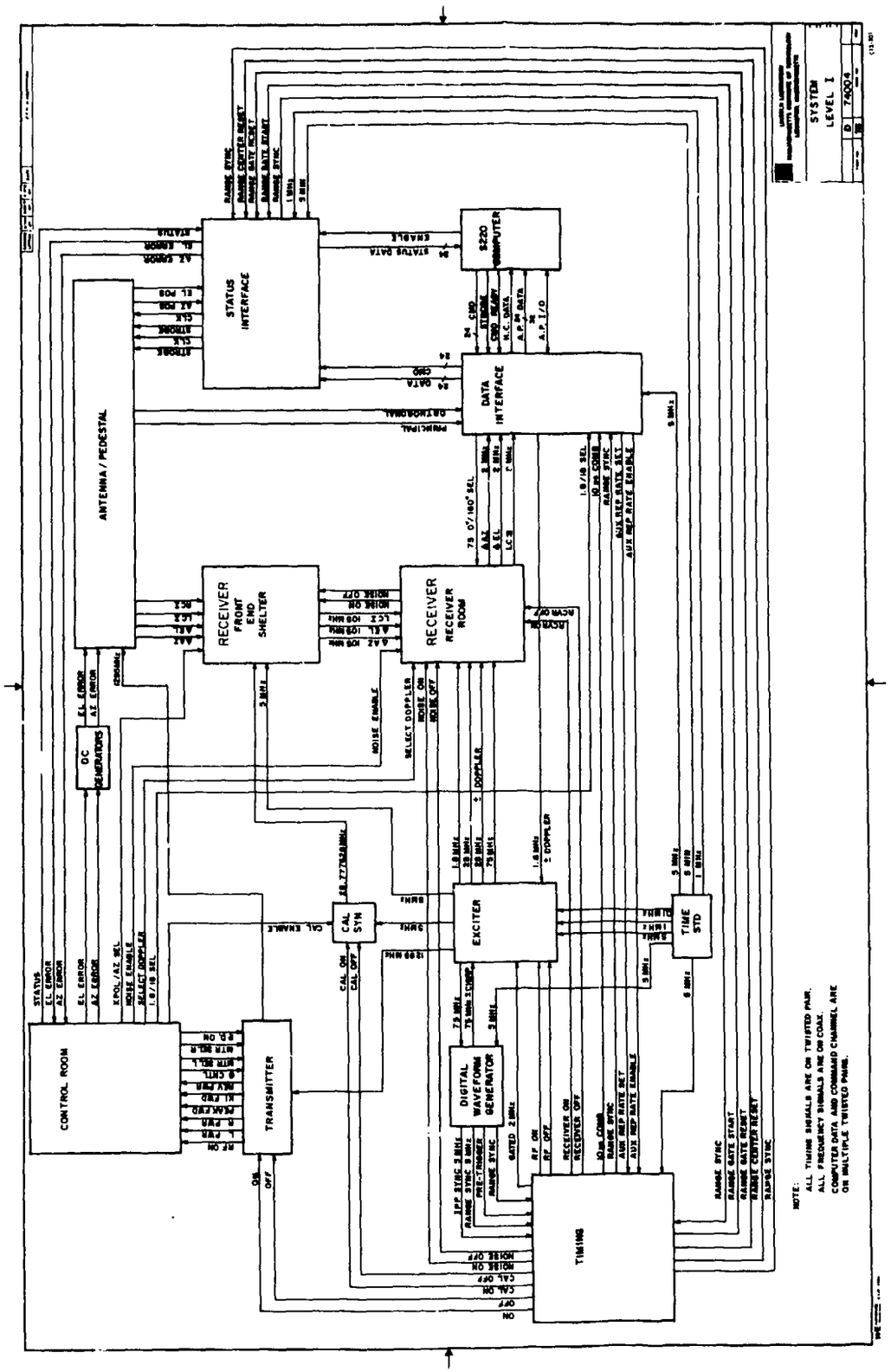
11. A paper-tape reader/punch shared between both systems which is used for communications with the Cheyenne Mt. NORAD Computer System.

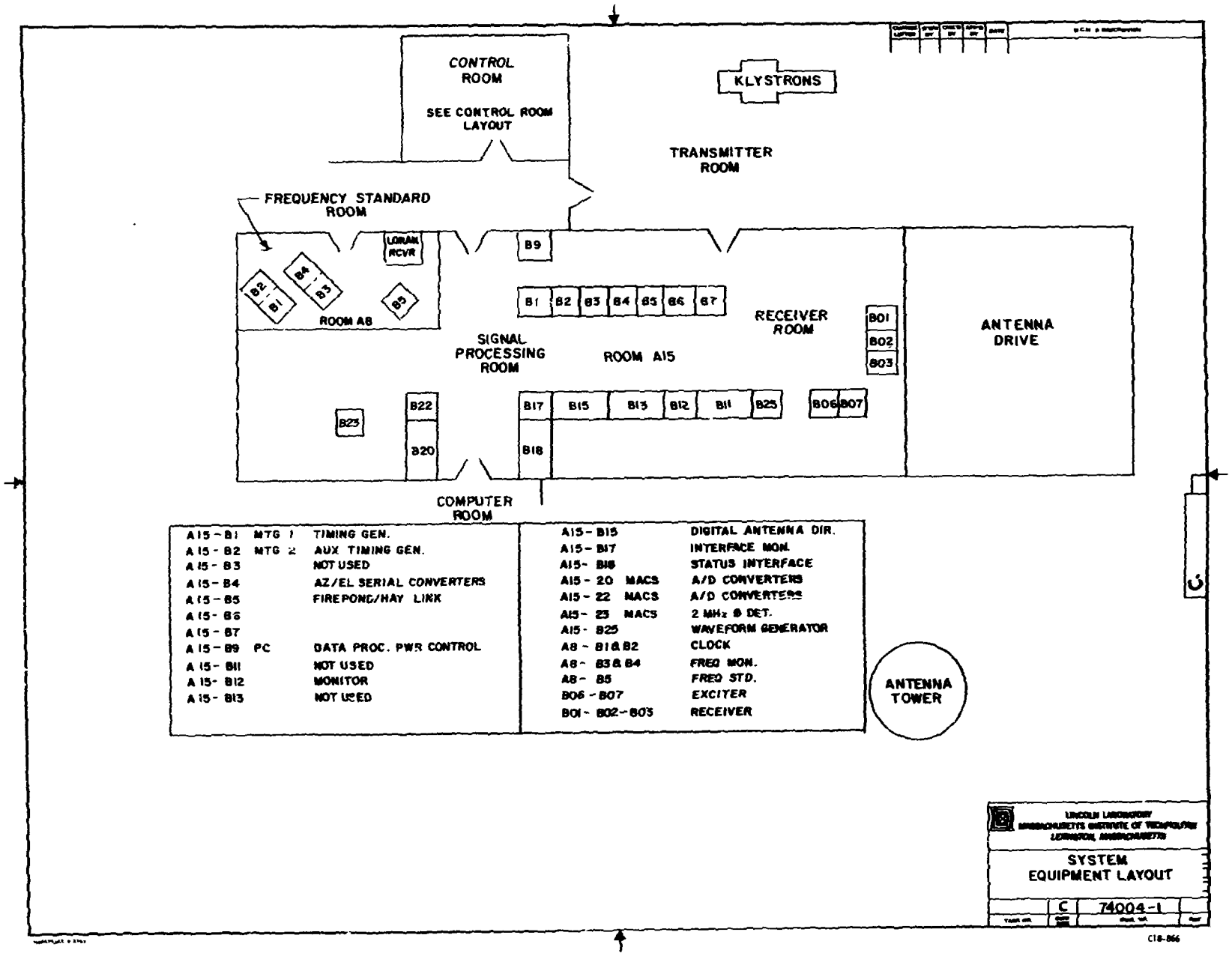
The Cheyenne Mt. communications system is being upgraded to a 4800 Baud direct-line, utilizing Autodin Mode I protocol, which will connect directly to the site's on-line S220 through a TLC-100 Interface Unit supplied by Analytics, Inc. of McClean, Va.

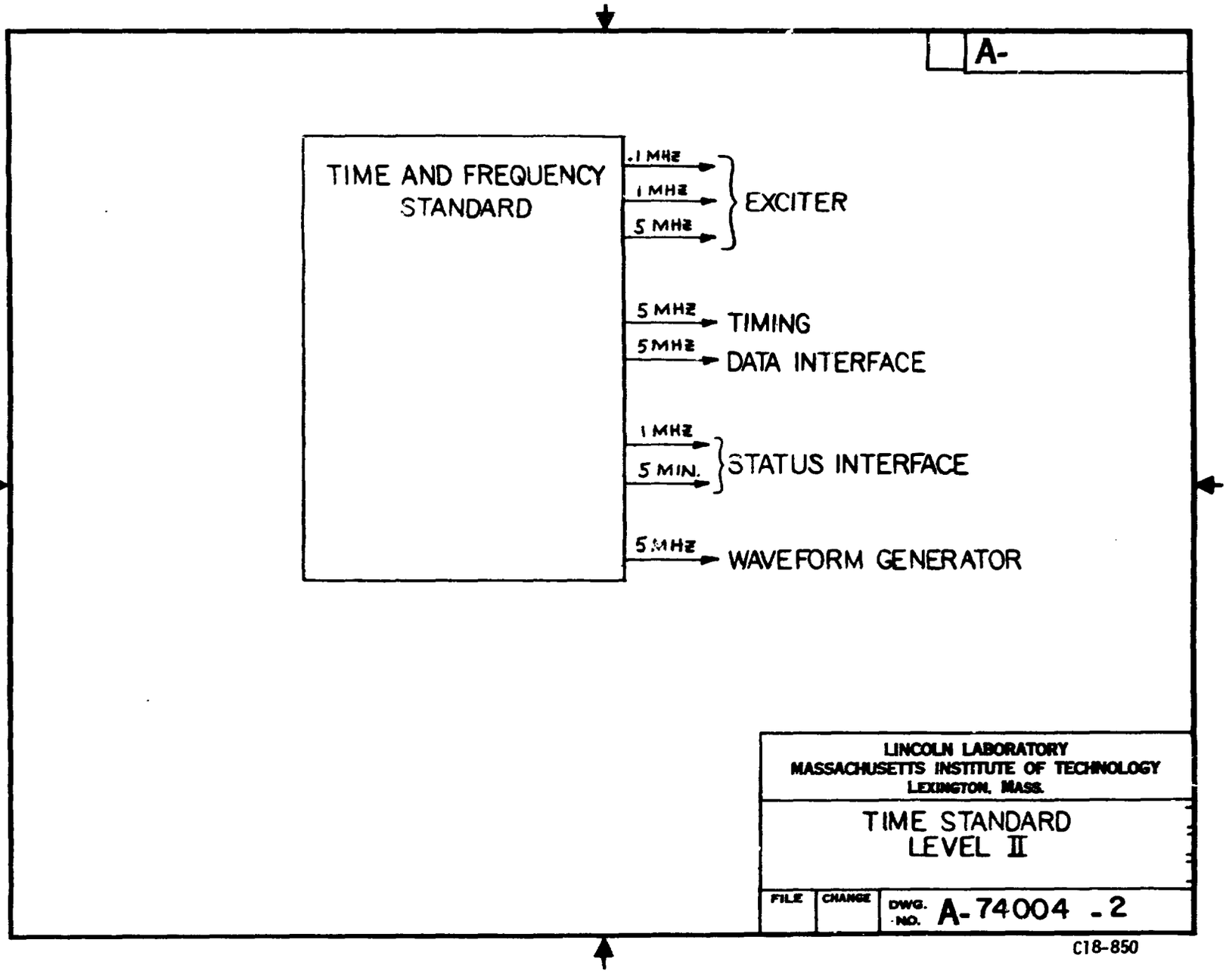
The software for the control of the system is called SATCIT (Satellite Acquisition and Tracking using Coherent Integration Techniques) and will be documented separately.

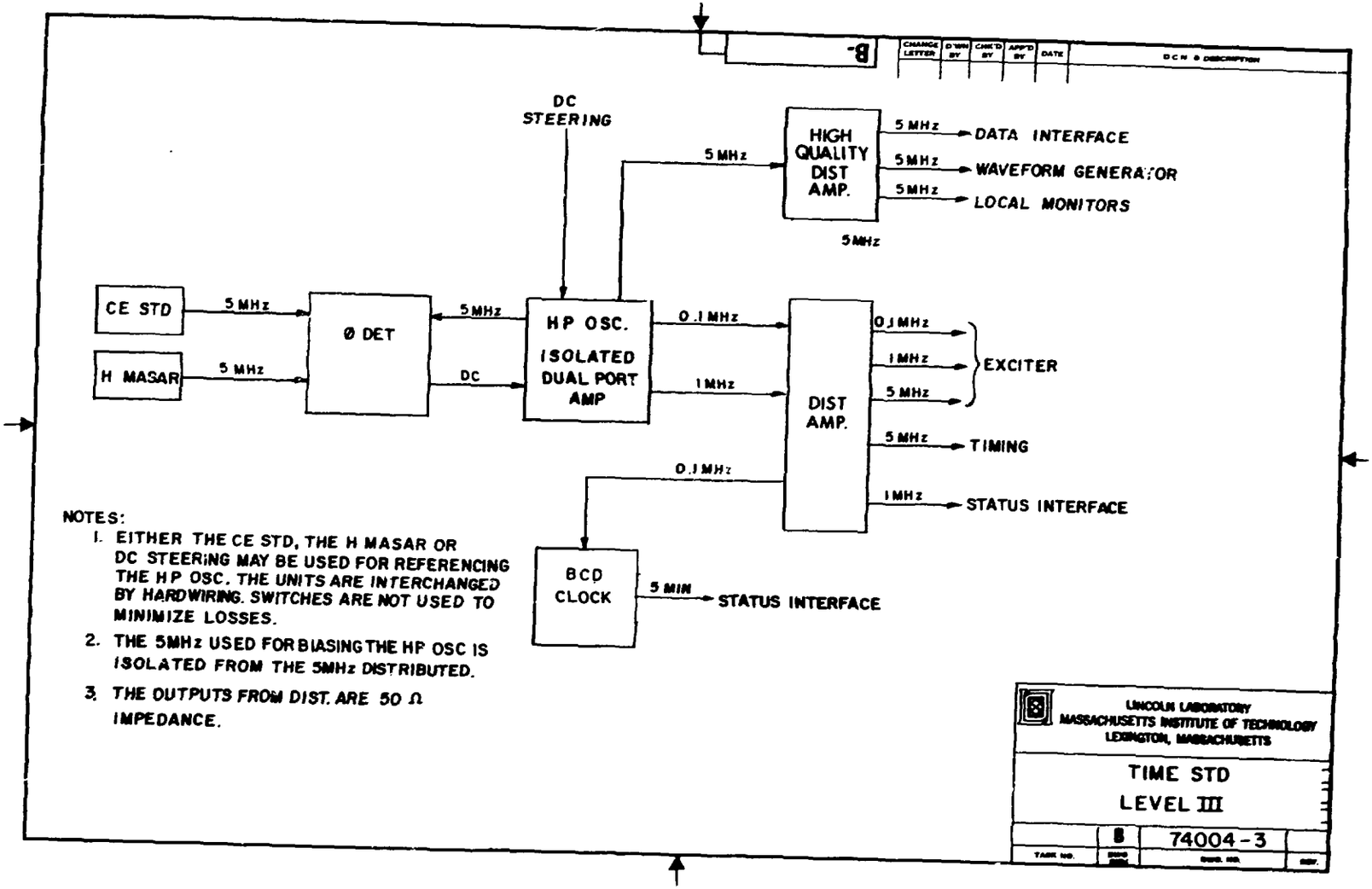
The following collection of diagrams illustrate the Millstone radar system. First, a system overview is presented. Then, each subsection appears in the order in which it is discussed in the text.

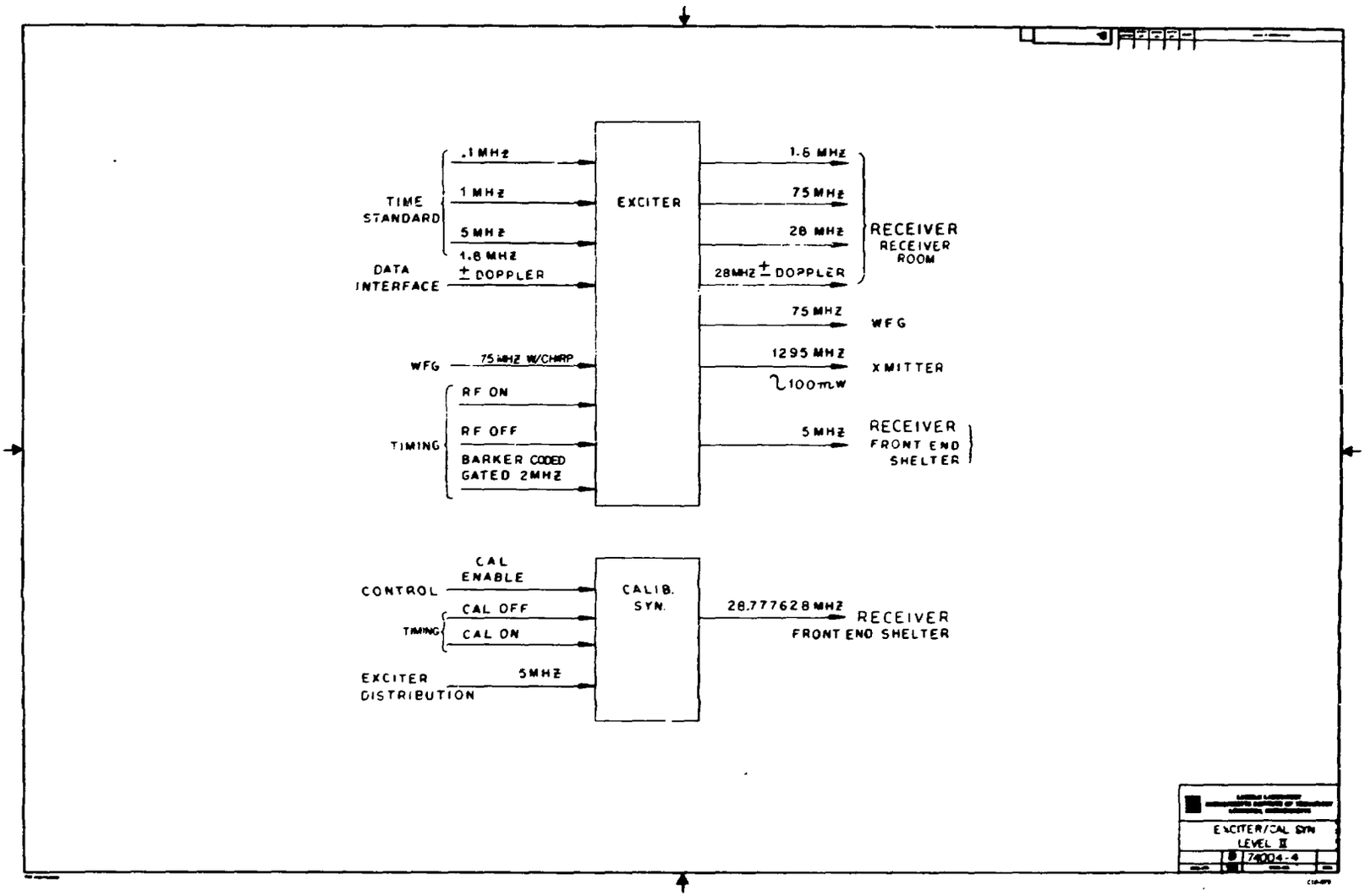
Four "levels" are referenced. Level I is designated for the system overview. Level II is used for system level block diagrams. Level III is defined for use in subsystem level block diagrams. And, finally, Level IV is reserved for timing diagrams.

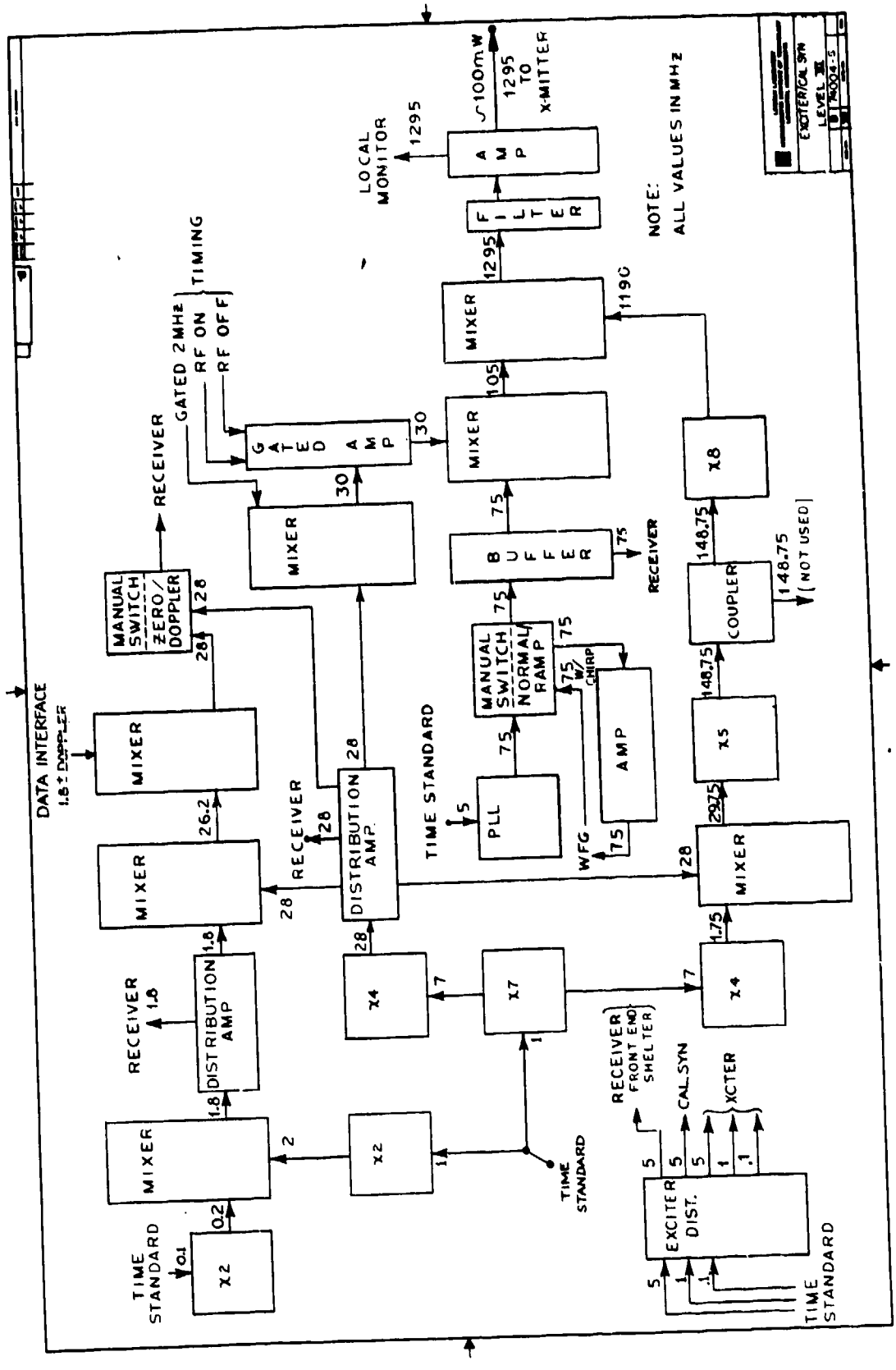

SYSTEM
LEVEL I
STATUS INTERFACE
S220 COMPUTER
DATA INTERFACE
ANTENNA / PEDESTAL
RECEIVER FRONT END SHELTER
RECEIVER RECEIVER ROOM
DC GENERATORS
CONTROL ROOM
TRANSMITTER
CAL SYN
EXCITER
TIME STD
DIGITAL WAVEFORM GENERATOR
TIMING
NOTE:
ALL TIMING SIGNALS ARE ON TWISTED PAIR.
ALL FREQUENCY SIGNALS ARE ON COAX.
COMPUTER DATA AND COMMAND CHANNEL ARE ON MULTIPLE TWISTED PAIRS.

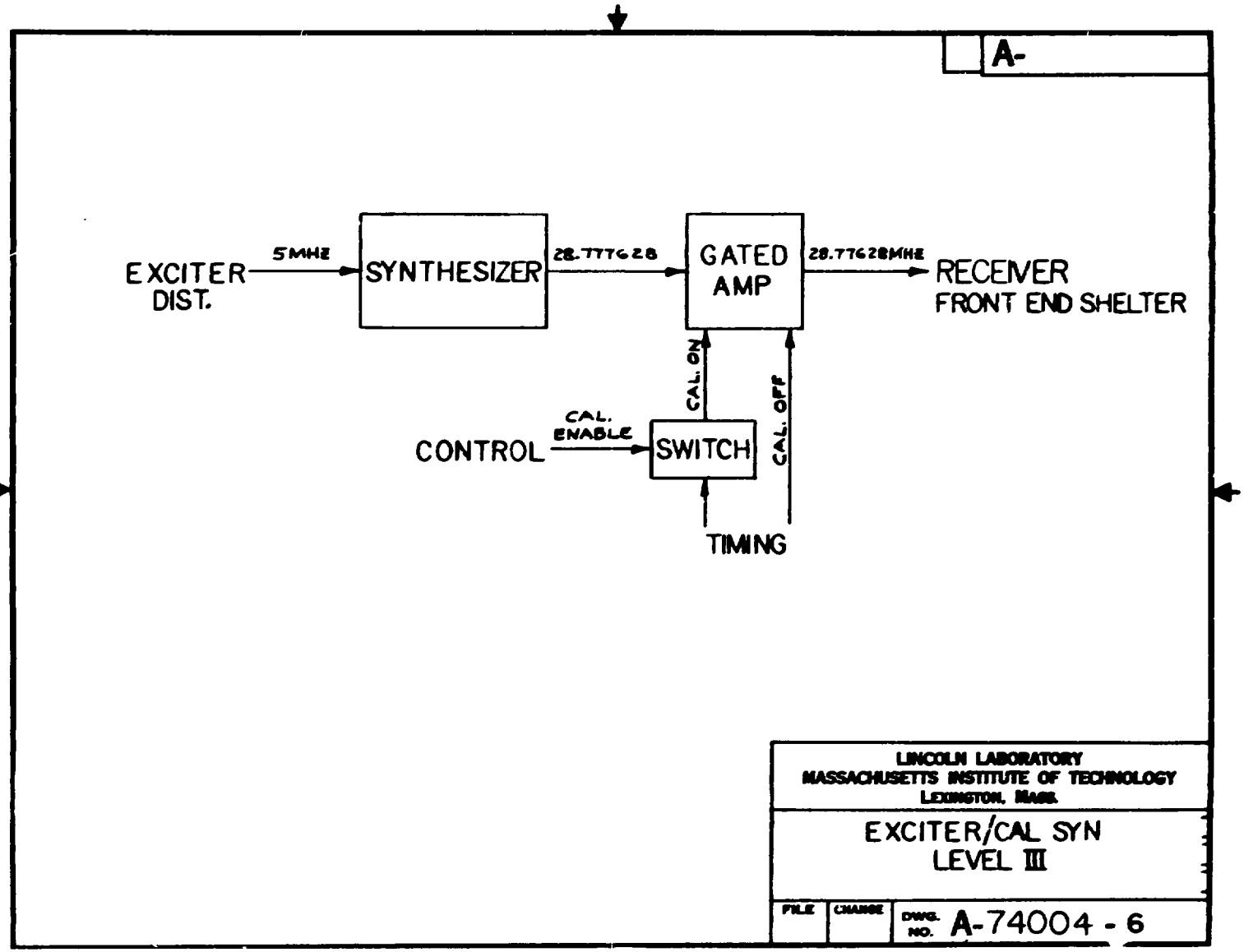

CONTROL ROOM
SEE CONTROL ROOM LAYOUT
KLYSTRONS
TRANSMITTER ROOM
FREQUENCY STANDARD ROOM
LORAN RCVR
B9
B1 B2 B3 B4 B5 B6 B7
B801 B802 B803
RECEIVER ROOM
ANTENNA DRIVE
B2 B1 B4 B3 B5
ROOM A8
SIGNAL PROCESSING ROOM
ROOM A15
B23 B22 B20 B17 B18 B15 B13 B12 B11 B25 B806 B807
COMPUTER ROOM
ANTENNA TOWER
A15-B1 MTG 1 TIMING GEN.
A15-B2 MTG 2 AUX TIMING GEN.
A15-B3 NOT USED
A15-B4 AZ/EL SERIAL CONVERTERS
A15-B5 FIREPOND/HAY LINK
A15-B6
A15-B7
A15-B9 PC DATA PROC. PWR CONTROL
A15-B11 NOT USED
A15-B12 MONITOR
A15-B13 NOT USED
A15-B15 DIGITAL ANTENNA DIR.
A15-B17 INTERFACE MON.
A15-B18 STATUS INTERFACE
A15-20 MACS A/D CONVERTERS
A15-22 MACS A/D CONVERTERS
A15-25 MACS 2 MHz Φ DET.
A15-B25 WAVEFORM GENERATOR
A8-B1&B2 CLOCK
A8-B3&B4 FREQ MON.
A8-B5 FREQ STD.
B06-B07 EXCITER
B01-B02-B03 RECEIVER
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS
SYSTEM EQUIPMENT LAYOUT
C
74004-1
C18-866

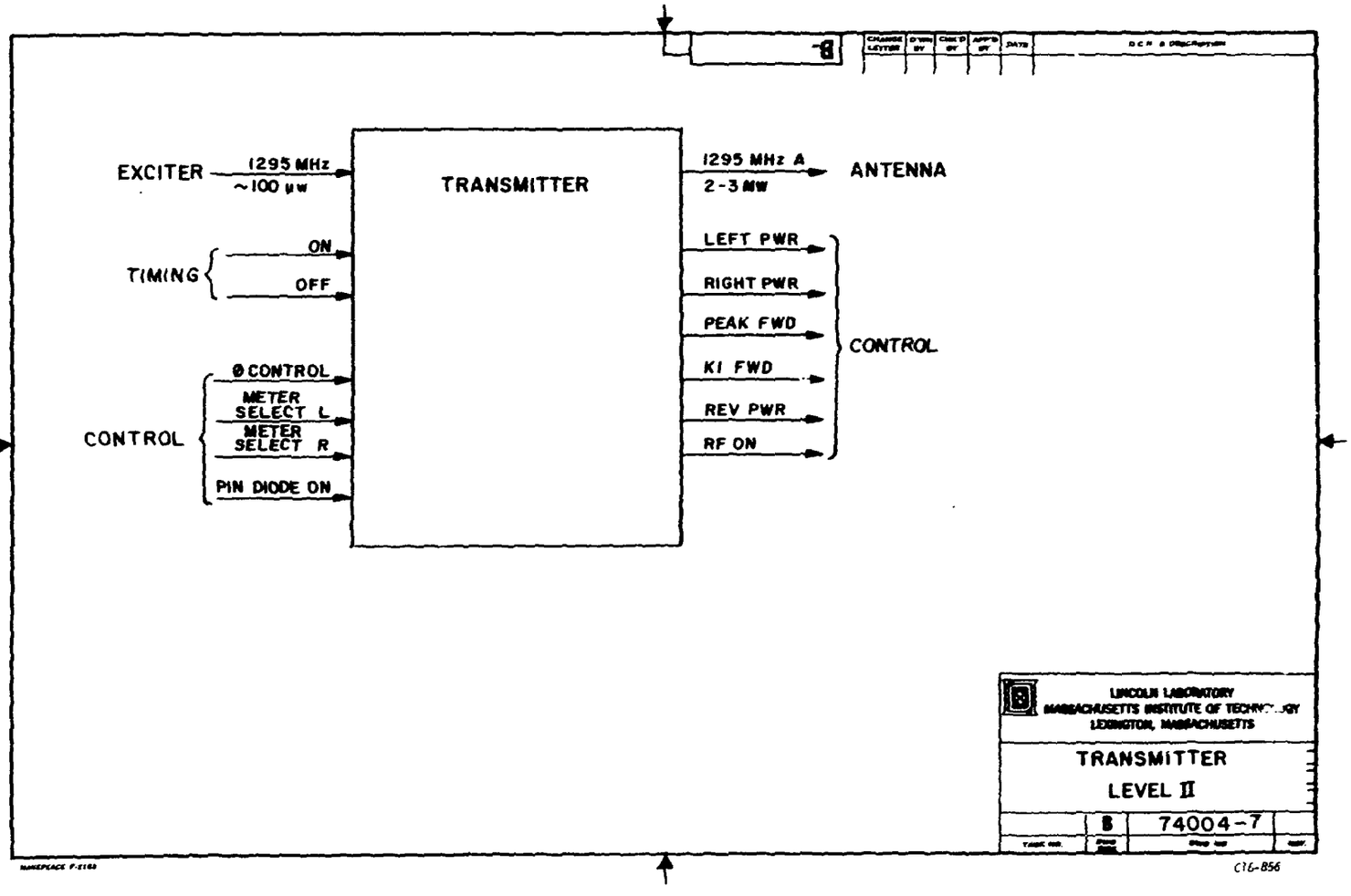

A-
TIME AND FREQUENCY STANDARD
.1 MHz
1 MHz
5 MHz
EXCITER
5 MHz
TIMING
5 MHz
DATA INTERFACE
1 MHz
5 MIN.
STATUS INTERFACE
5 MHz
WAVEFORM GENERATOR
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.
TIME STANDARD
LEVEL II
FILE
CHANGE
DWG. NO. A-74004 -2
C18-850

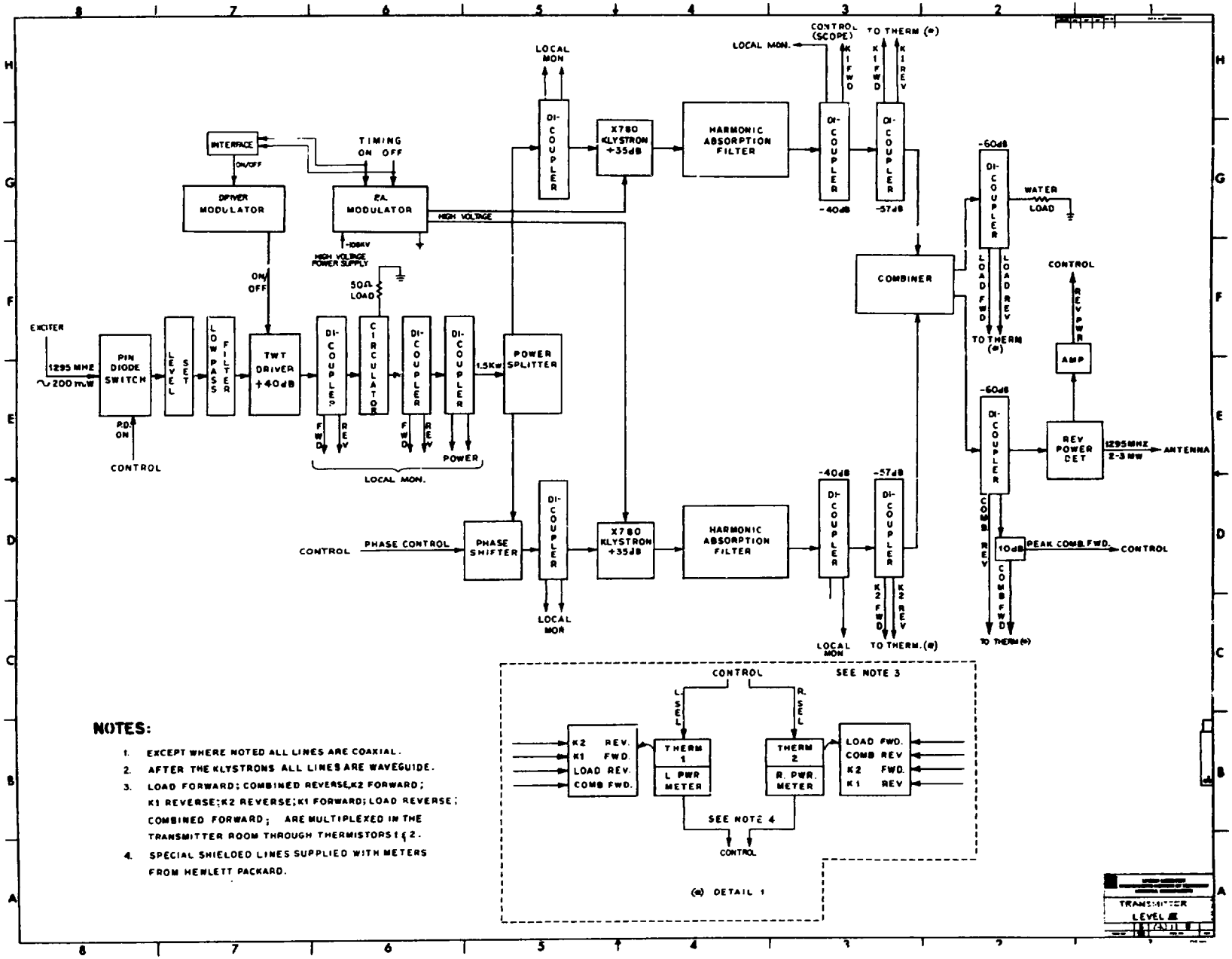

B
CHANGE LETTER
D'WN BY
CHK'D BY
APP'D BY
DATE
DCN & DESCRIPTION
DC STEERING
5 MHz
HIGH QUALITY DIST AMP.
5 MHz
DATA INTERFACE
5 MHz
WAVEFORM GENERATOR
5 MHz
LOCAL MONITORS
5 MHz
CE STD
5 MHz
H MASAR
5 MHz
Ø DET
5 MHz
DC
HP OSC.
ISOLATED DUAL PORT AMP
0.1 MHz
1 MHz
DIST AMP.
0.1 MHz
1 MHz
5 MHz
EXCITER
5 MHz
TIMING
0.1 MHz
1 MHz
STATUS INTERFACE
BCD CLOCK
5 MIN
STATUS INTERFACE
NOTES:
1. EITHER THE CE STD, THE H MASAR OR DC STEERING MAY BE USED FOR REFERENCING THE HP OSC. THE UNITS ARE INTERCHANGED BY HARDWIRING. SWITCHES ARE NOT USED TO MINIMIZE LOSSES.
2. THE 5MHz USED FOR BIASING THE HP OSC IS ISOLATED FROM THE 5MHz DISTRIBUTED.
3. THE OUTPUTS FROM DIST. ARE 50 Ω IMPEDANCE.
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS
TIME STD
LEVEL III
TASK NO.
8
74004-3
DWG. NO.
REV.


.1 MHz
1 MHz
5 MHz
1.8 MHz ± DOPPLER
TIME STANDARD
DATA INTERFACE
EXCITER
1.6 MHz
75 MHz
28 MHz
28MHz ± DOPPLER
RECEIVER
RECEIVER ROOM
75 MHz
WFG
1295 MHz
XMITTER
100mW
5 MHz
RECEIVER
FRONT END SHELTER
WFG
75 MHz W/CHIRP
TIMING
RF ON
RF OFF
BARKER CODED GATED 2MHz
CONTROL
CAL ENABLE
TIMING
CAL OFF
CAL ON
EXCITER DISTRIBUTION
5MHz
CALIB. SYN.
28.777628MHz
RECEIVER
FRONT END SHELTER
EXCITER/CAL SYN
LEVEL II
74004-4


EXCITER SYN
LEVEL II
NOTE:
ALL VALUES IN MHz
TIME STANDARD
X2
0.1
0.2
MIXER
2
X2
1
TIME STANDARD
EXCITER DIST.
5
1
.1
TIME STANDARD
5
5
5
1
.1
CAL SYN
XCTER
RECEIVER FRONT END SHELTER
7
X7
1
7
X4
1.75
X4
28
MIXER
2975
X5
148.75
COUPLER
148.75
(NOT USED)
X8
1190
MIXER
1295
FILTER
AMP
≥100mW
1295
TO X-MITTER
LOCAL MONITOR
1295
MIXER
105
MIXER
30
GATED AMP
30
MIXER
28
MANUAL SWITCH ZERO/ DOPPLER
28
RECEIVER
GATED 2MHz
RF ON
RF OFF
TIMING
28
MIXER
26.2
MIXER
28
DISTRIBUTION AMP
28
RECEIVER
1.8
DISTRIBUTION AMP
1.8
1.8
RECEIVER
1.8
DATA INTERFACE
1.8± DOPPLER
TIME STANDARD
5
PLL
75
MANUAL SWITCH NORMAL RAMP
75
75
W/ CHIRP
AMP
75
WFG
75
BUFFER
75
RECEIVER
75

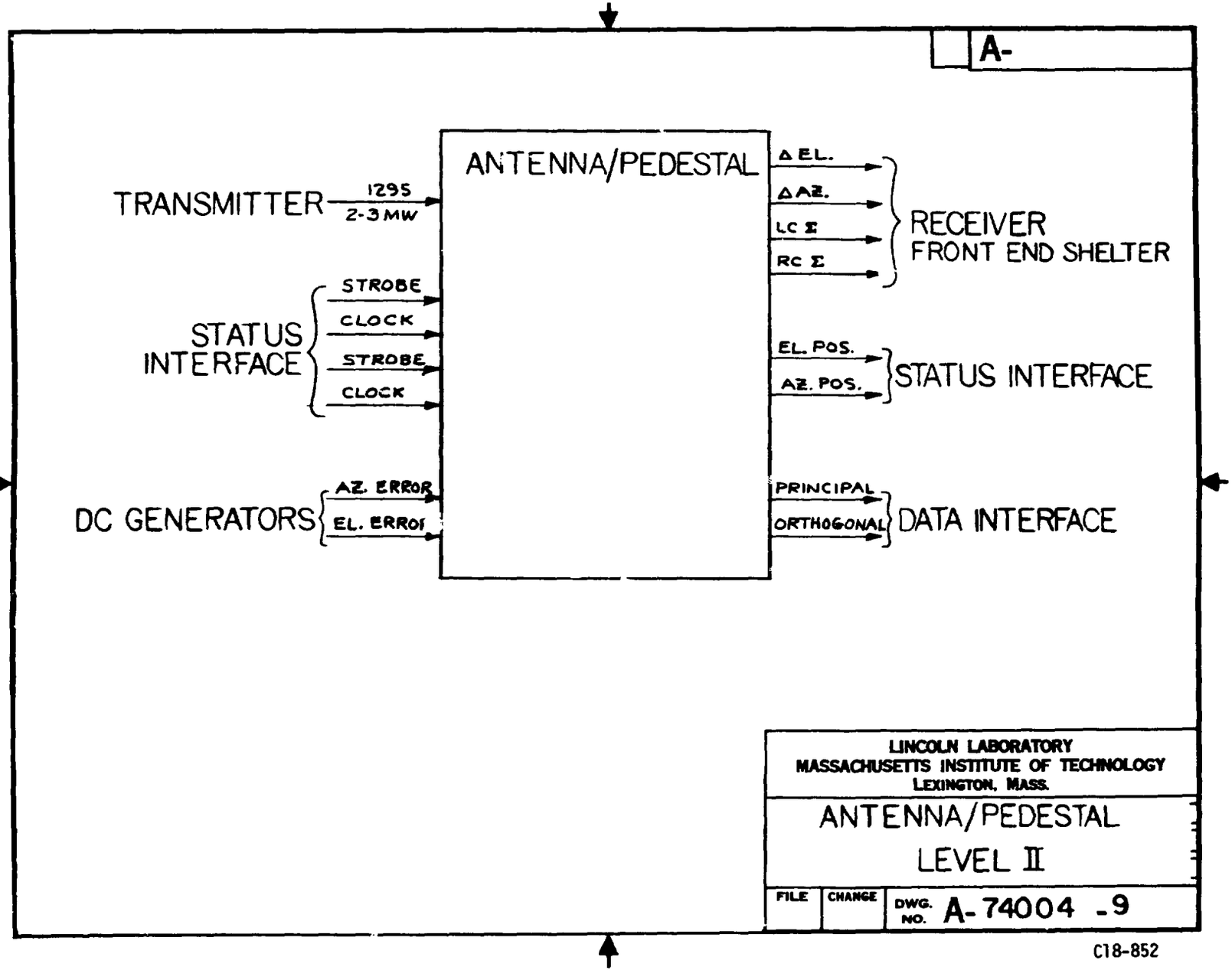

A-
EXCITER DIST.
5MHZ
SYNTHESIZER
28.77628
GATED AMP
28.77628MHZ
RECEIVER FRONT END SHELTER
CAL. ON
CAL. OFF
CONTROL
CAL. ENABLE
SWITCH
TIMING
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.
EXCITER/CAL SYN
LEVEL III
FILE
CHANGE
DWG. NO. A-74004 - 6

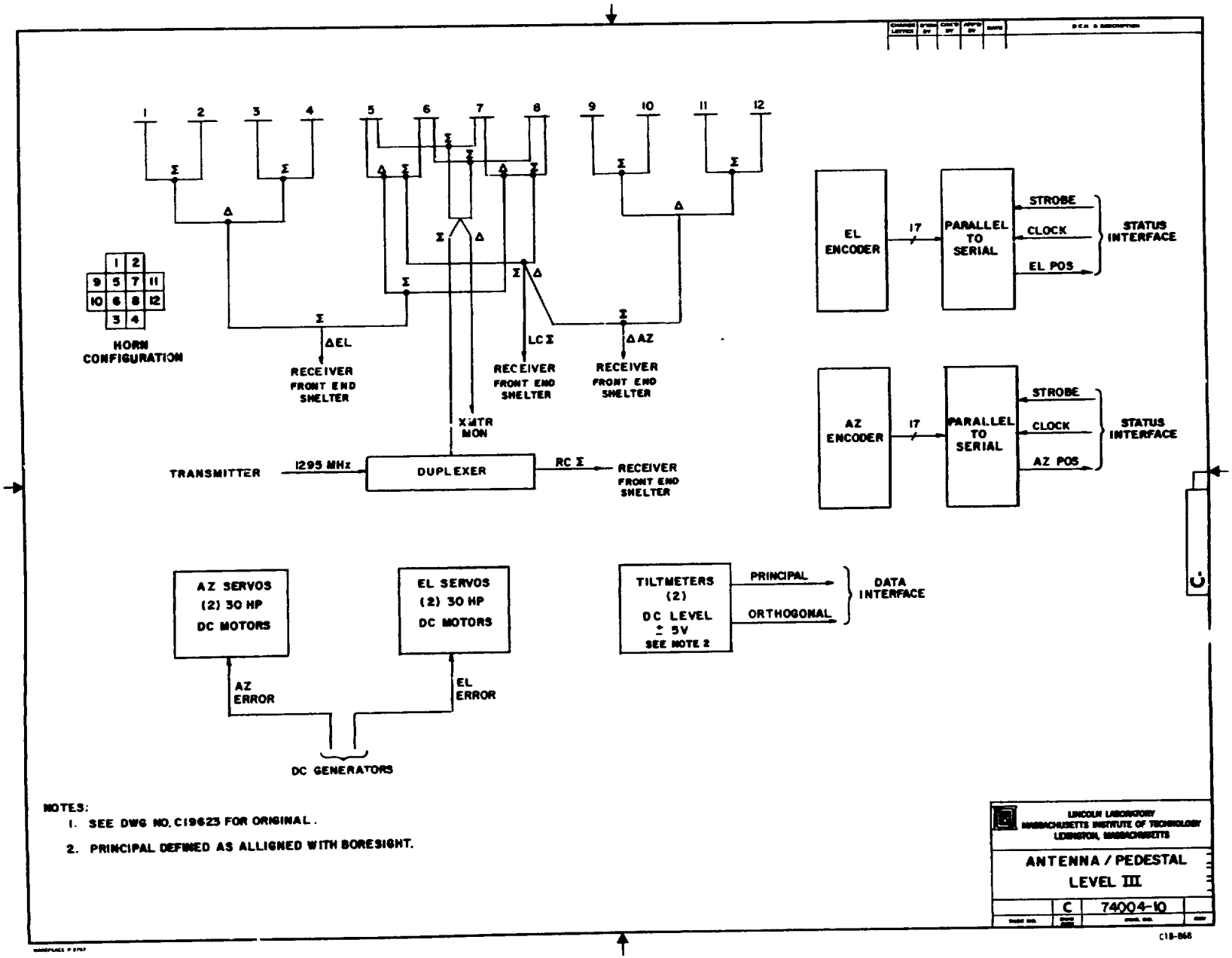

EXCITER
1295 MHz
~100 μw
TRANSMITTER
1295 MHz A
2-3 MW
ANTENNA
TIMING
ON
OFF
CONTROL
Ø CONTROL
METER SELECT L
METER SELECT R
PIN DIODE ON
LEFT PWR
RIGHT PWR
PEAK FWD
KI FWD
REV PWR
RF ON
CONTROL
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS
TRANSMITTER
LEVEL II
B
74004-7
C16-856



NOTES:

1. EXCEPT WHERE NOTED ALL LINES ARE COAXIAL.
2. AFTER THE KLYSTRONS ALL LINES ARE WAVEGUIDE.
3. LOAD FORWARD; COMBINED REVERSE, K2 FORWARD; K1 REVERSE; K2 REVERSE; K1 FORWARD; LOAD REVERSE; COMBINED FORWARD; ARE MULTIPLEXED IN THE TRANSMITTER ROOM THROUGH THERMISTORS 1 & 2.
4. SPECIAL SHIELDED LINES SUPPLIED WITH METERS FROM HEWLETT PACKARD.


A-
ANTENNA/PEDESTAL
TRANSMITTER
1295
2-3 MW
STATUS INTERFACE
STROBE
CLOCK
STROBE
CLOCK
DC GENERATORS
AZ. ERROR
EL. ERROR
Δ EL.
Δ AZ.
LC Σ
RC Σ
RECEIVER FRONT END SHELTER
EL. POS.
AZ. POS.
STATUS INTERFACE
PRINCIPAL
ORTHOGONAL
DATA INTERFACE
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.
ANTENNA/PEDESTAL
LEVEL II
FILE
CHANGE
DWG. NO. A-74004 -9
C18-852



NOTES:

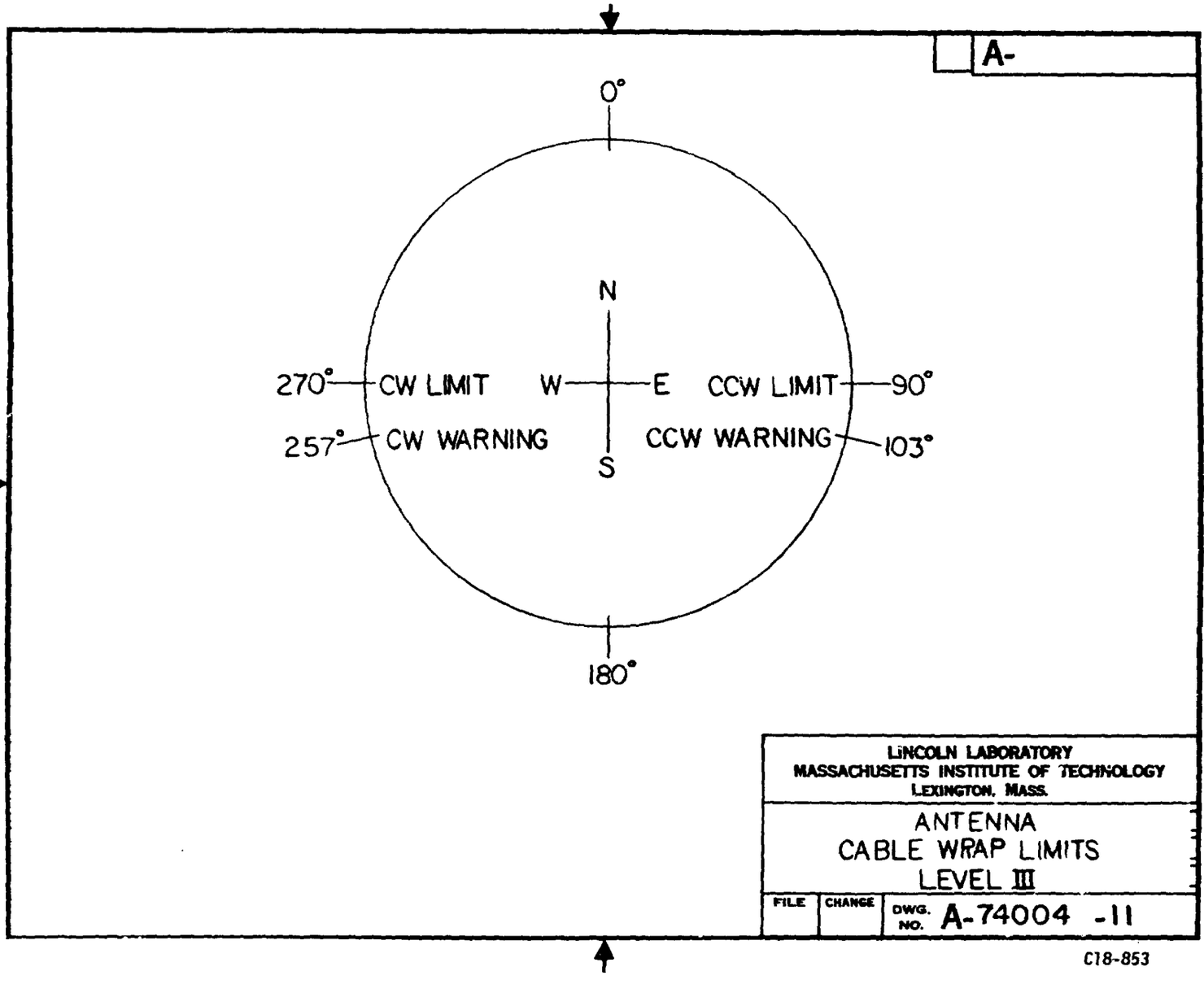
1. SEE DWG NO. C19623 FOR ORIGINAL.
2. PRINCIPAL DEFINED AS ALLIGNED WITH BORESIGHT.

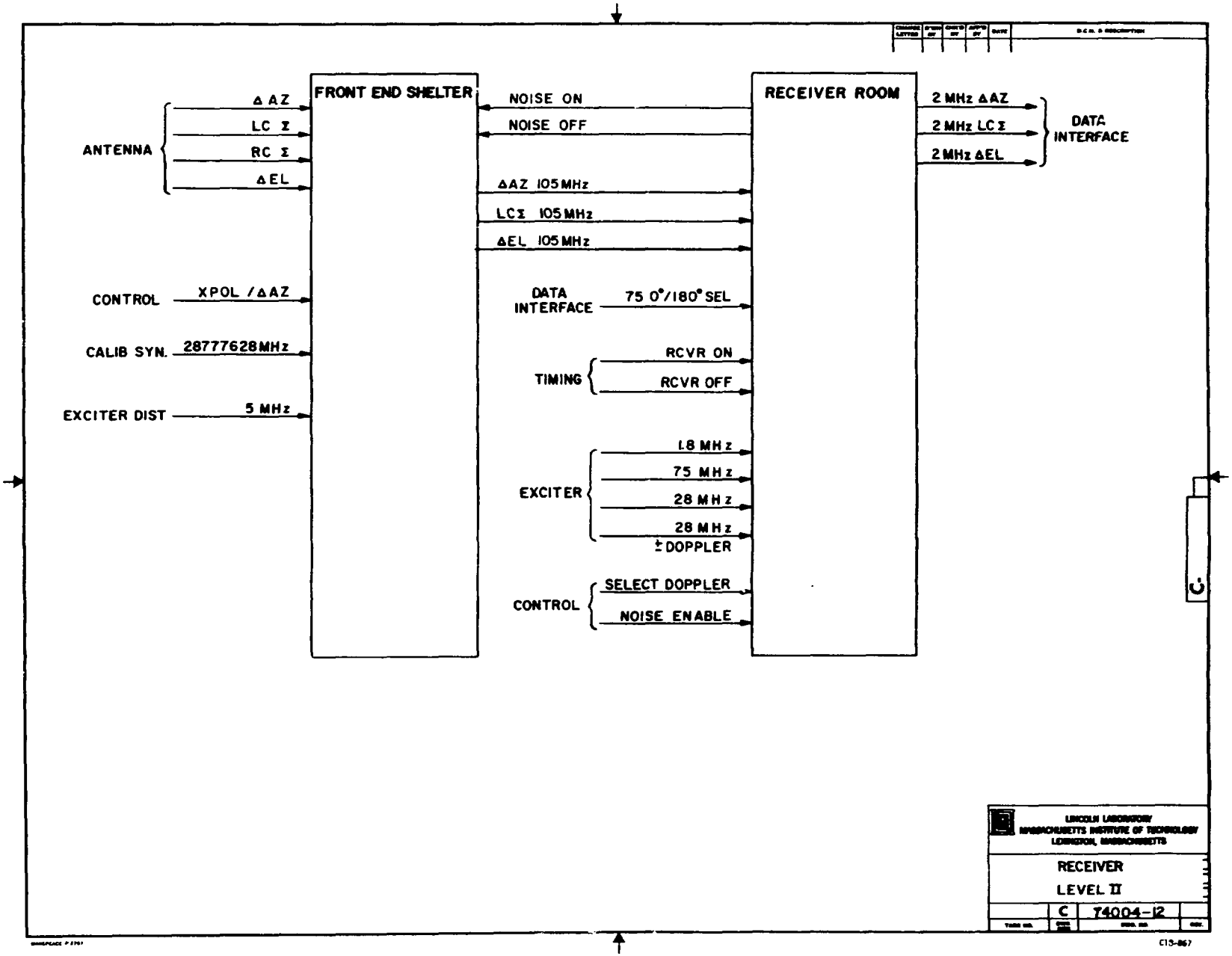
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS

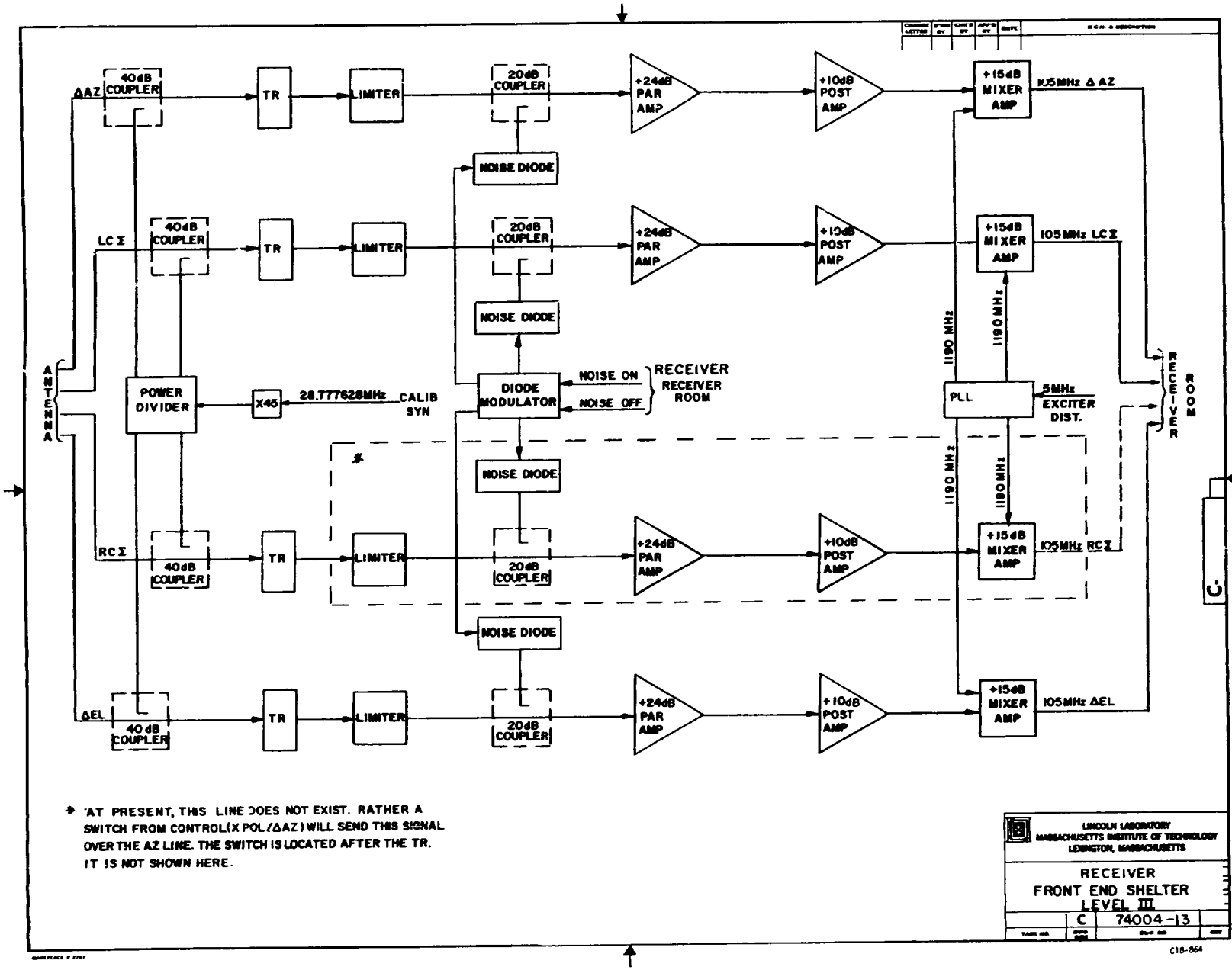
ANTENNA / PEDESTAL
LEVEL III

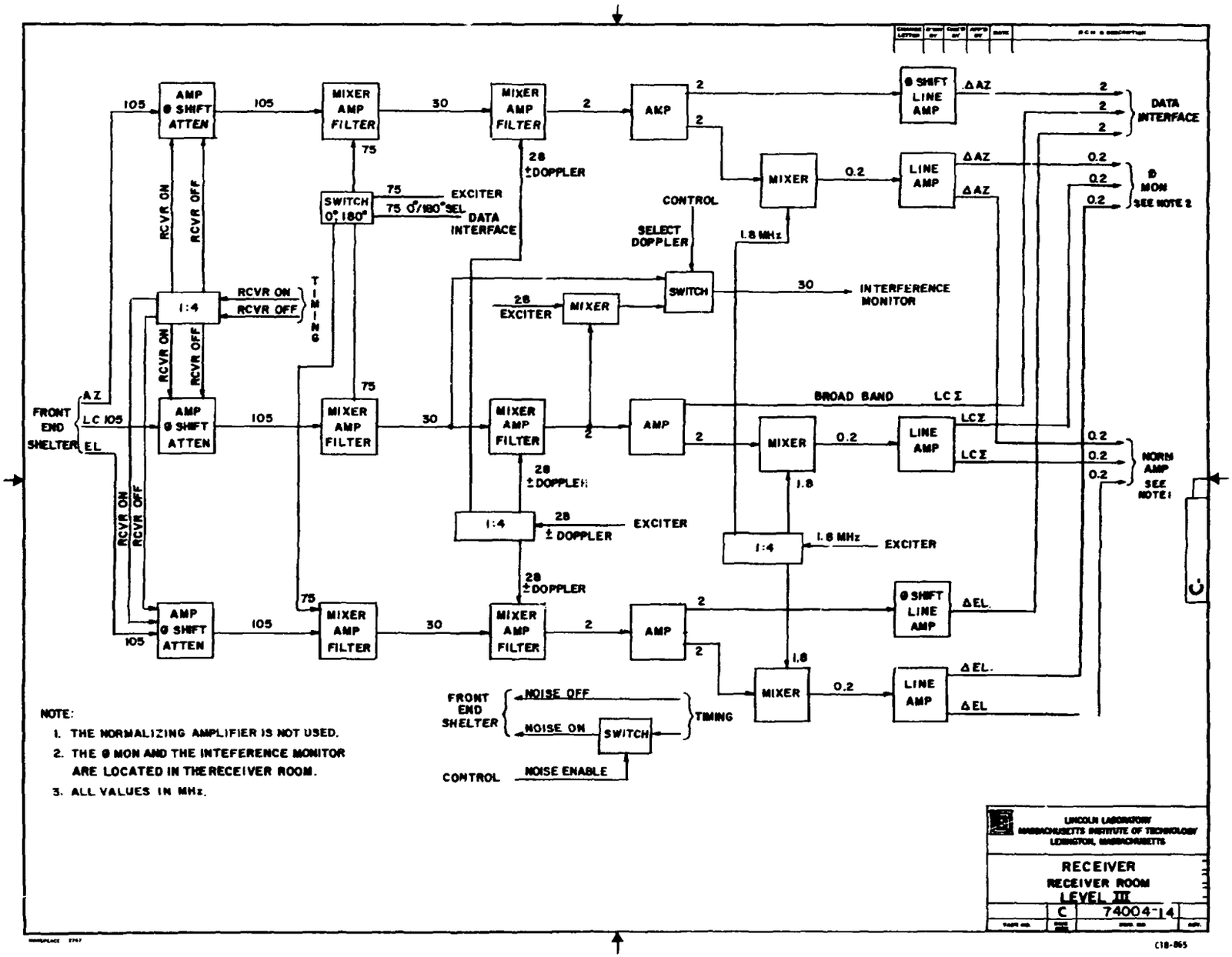
C 74004-10

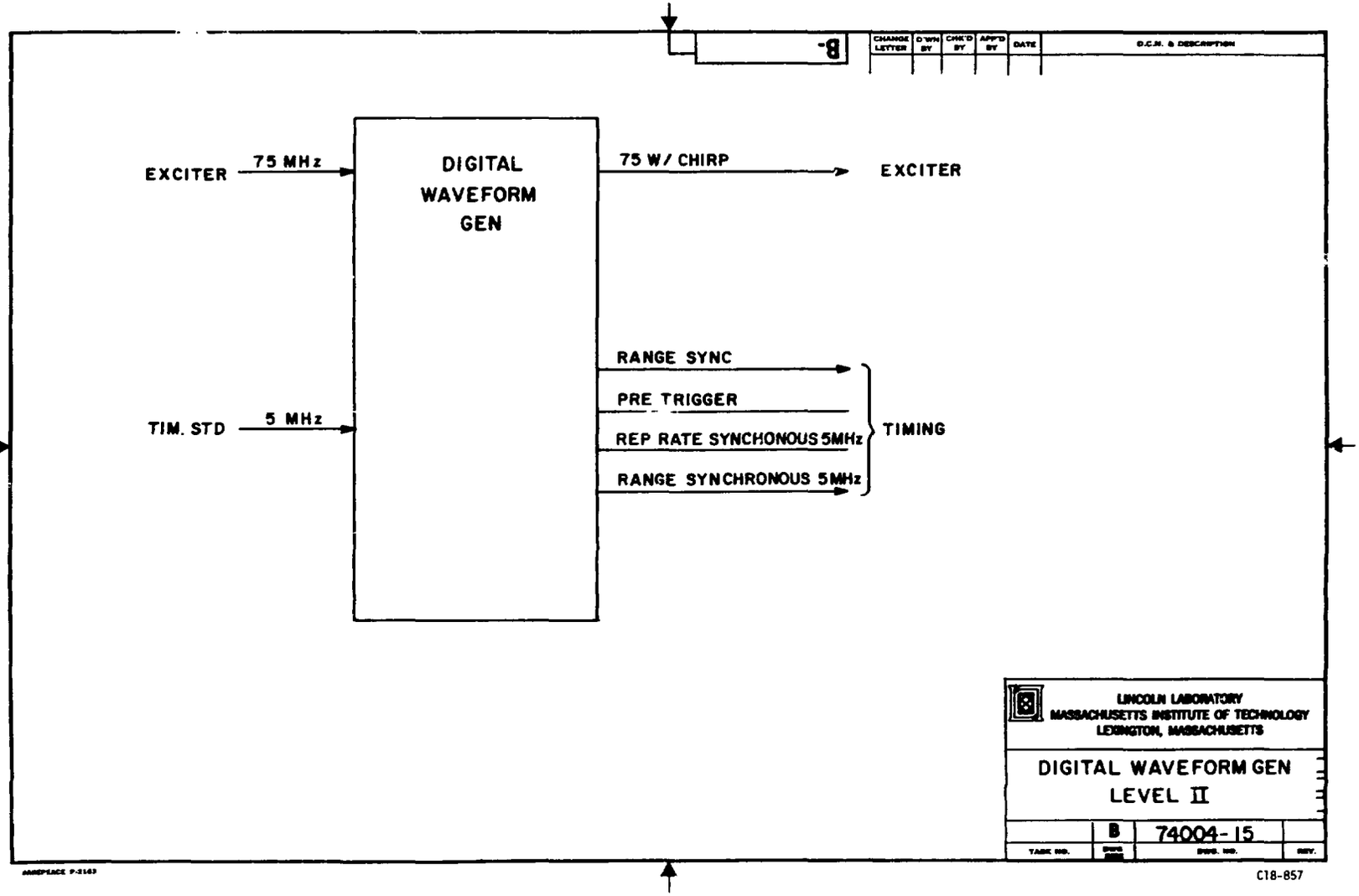
C18-868

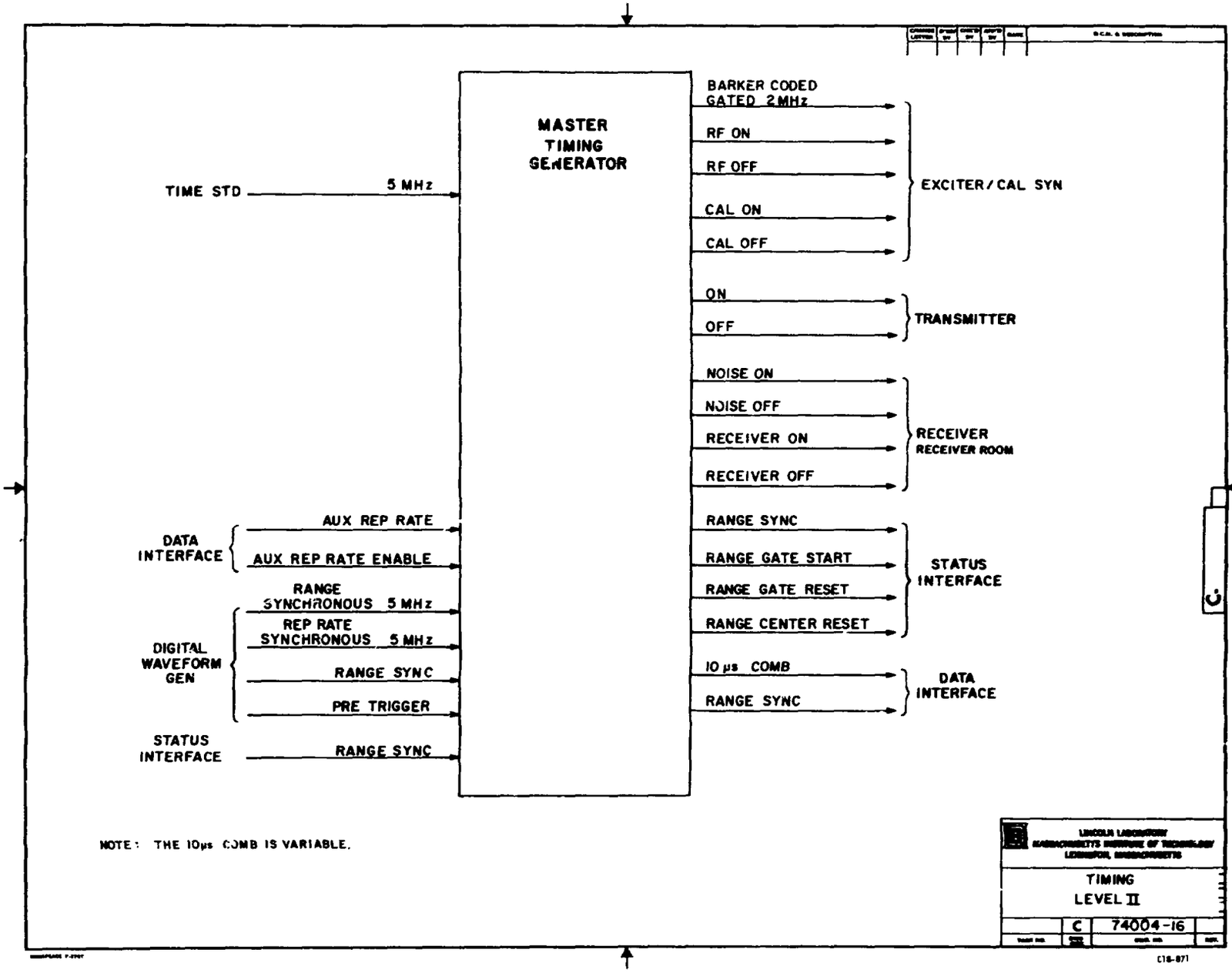

A-
0°
N
270°
CW LIMIT
W
E
CCW LIMIT
90°
257°
CW WARNING
CCW WARNING
103°
S
180°
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.
ANTENNA
CABLE WRAP LIMITS
LEVEL III
FILE
CHANGE
DWG. NO. A-74004 -11
C18-853

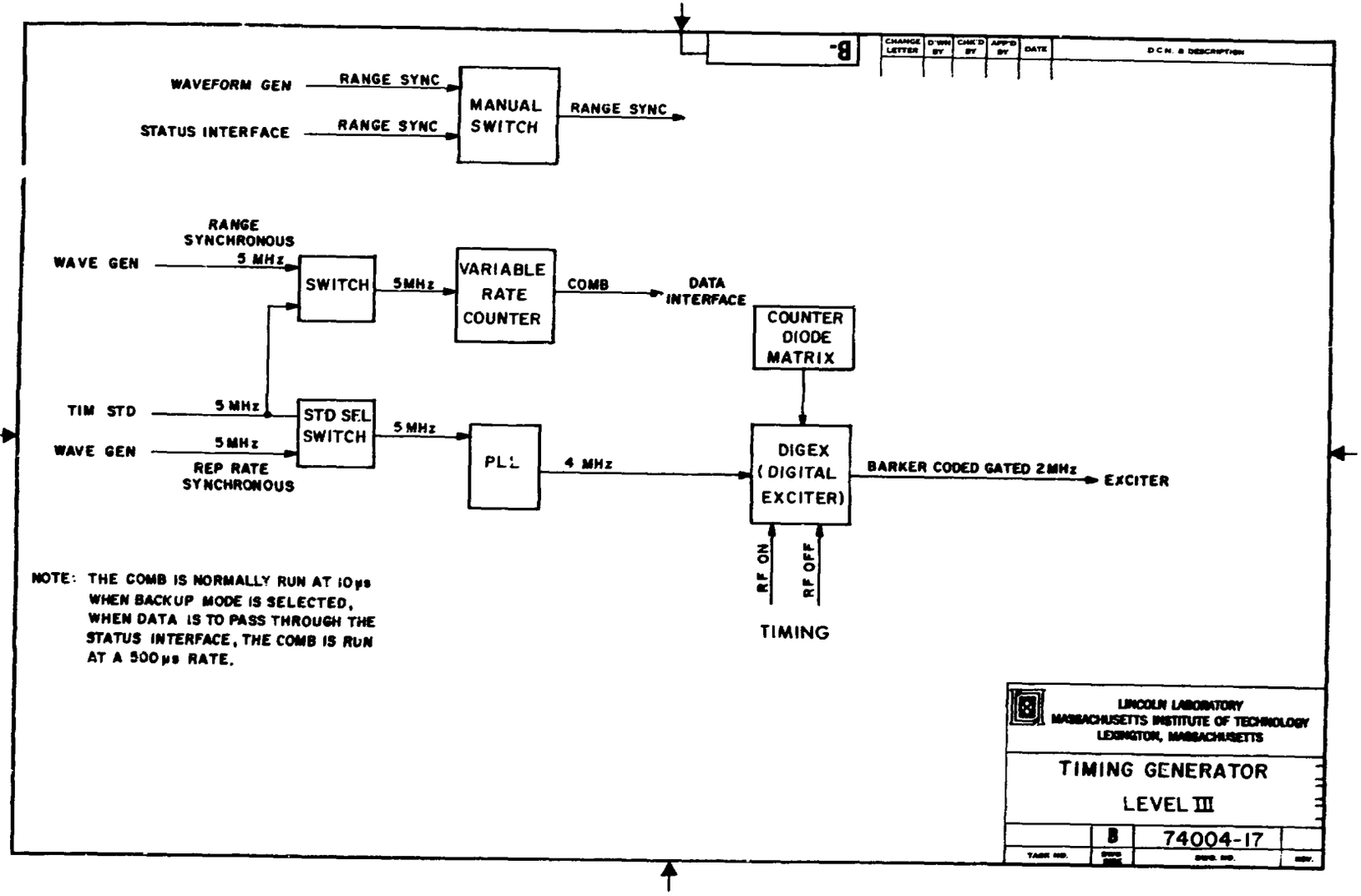

FRONT END SHELTER
RECEIVER ROOM
ANTENNA
Δ AZ
LC Σ
RC Σ
Δ EL
CONTROL
XPOL / Δ AZ
CALIB SYN.
28777628 MHz
EXCITER DIST
5 MHz
NOISE ON
NOISE OFF
Δ AZ 105 MHz
LC Σ 105 MHz
Δ EL 105 MHz
DATA INTERFACE
75 0°/180° SEL
TIMING
RCVR ON
RCVR OFF
EXCITER
L8 MHz
75 MHz
28 MHz
28 MHz ± DOPPLER
CONTROL
SELECT DOPPLER
NOISE ENABLE
2 MHz Δ AZ
2 MHz LC Σ
2 MHz Δ EL
DATA INTERFACE
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS
RECEIVER
LEVEL II
C
74004-12
C15-867

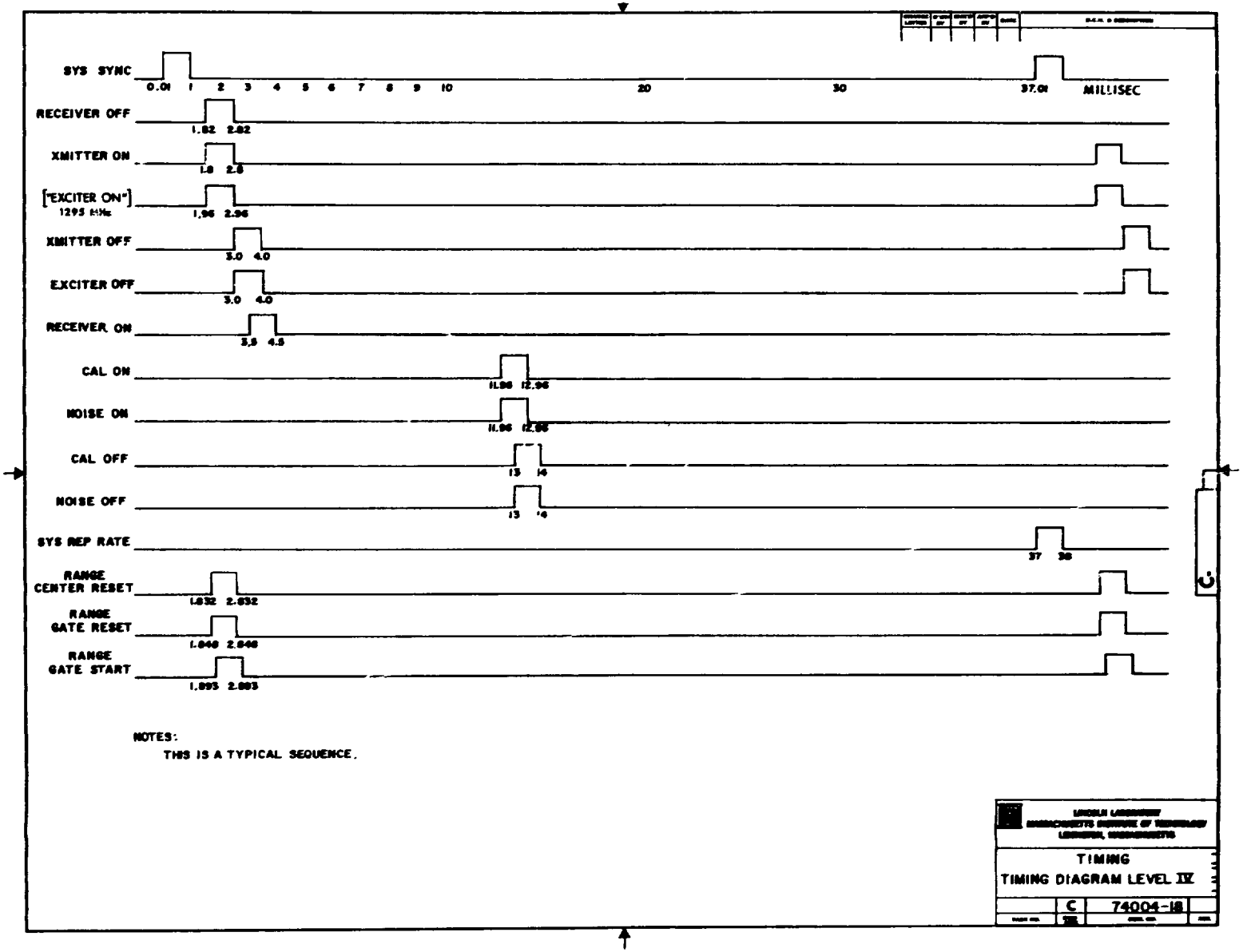

ΔAZ
40dB COUPLER
TR
LIMITER
20dB COUPLER
+24dB PAR AMP
+10dB POST AMP
+15dB MIXER AMP
105MHz Δ AZ
NOISE DIODE
LC Σ
105MHz LC Σ
1190 MHz
ANTENNA
POWER DIVIDER
X45
28.777628MHz
CALIB SYN
DIODE MODULATOR
NOISE ON
NOISE OFF
RECEIVER
RECEIVER ROOM
PLL
5MHz EXCITER DIST.
RC Σ
105MHz RC Σ
ΔEL
105MHz ΔEL
AT PRESENT, THIS LINE DOES NOT EXIST. RATHER A SWITCH FROM CONTROL(X POL/ΔAZ) WILL SEND THIS SIGNAL OVER THE AZ LINE. THE SWITCH IS LOCATED AFTER THE TR. IT IS NOT SHOWN HERE.
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS
RECEIVER
FRONT END SHELTER
LEVEL III
C
74004-13
C18-864

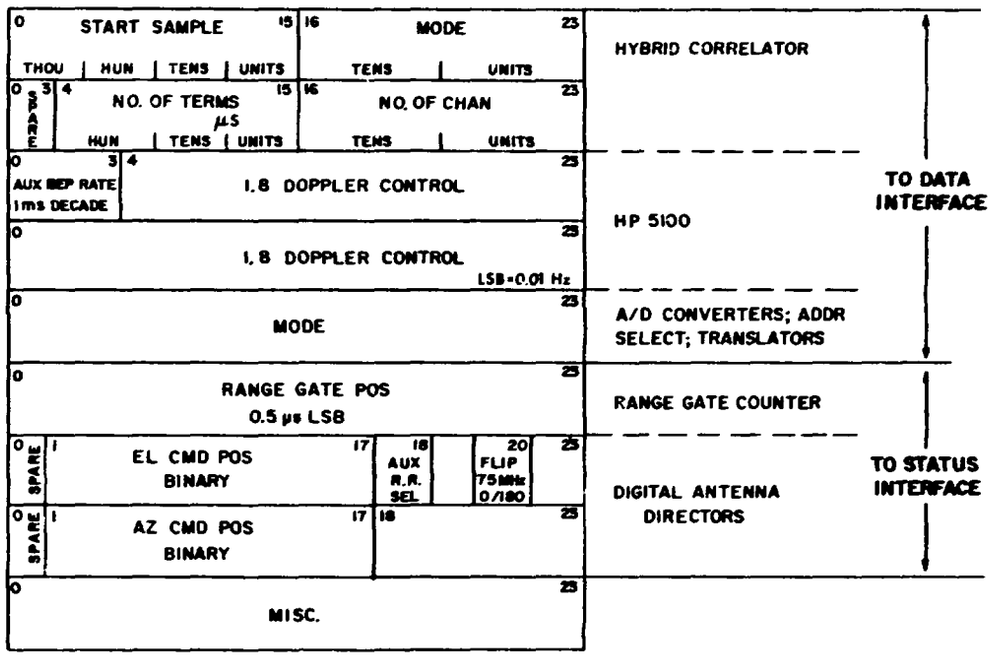

AMP Ø SHIFT ATTEN
105
MIXER AMP FILTER
30
2
AMP
Ø SHIFT LINE AMP
ΔAZ
DATA INTERFACE
75
28 ±DOPPLER
SWITCH 0° 180°
75 EXCITER
75 0°/180° SEL DATA INTERFACE
MIXER
0.2
LINE AMP
ΔAZ
Ø MON SEE NOTE 2
CONTROL
SELECT DOPPLER
1.8 MHz
RCVR ON
RCVR OFF
1:4
TIMING
28 EXCITER
SWITCH
30
INTERFERENCE MONITOR
FRONT END SHELTER
AZ
LC 105
EL
BROAD BAND
LCΣ
NORM AMP SEE NOTE 1
1.8
ΔEL
NOISE OFF
NOISE ON
NOISE ENABLE
NOTE:
1. THE NORMALIZING AMPLIFIER IS NOT USED.
2. THE Ø MON AND THE INTEFERENCE MONITOR ARE LOCATED IN THE RECEIVER ROOM.
3. ALL VALUES IN MHz.
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS
RECEIVER
RECEIVER ROOM
LEVEL III
C
74004-14
C18-865


B
CHANGE LETTER
D'WN BY
CHK'D BY
APP'D BY
DATE
D.C.N. & DESCRIPTION
EXCITER
75 MHz
DIGITAL WAVEFORM GEN
75 W/ CHIRP
EXCITER
RANGE SYNC
PRE TRIGGER
TIM. STD
5 MHz
REP RATE SYNCHONOUS 5MHz
RANGE SYNCHRONOUS 5MHz
TIMING
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS
DIGITAL WAVEFORM GEN
LEVEL II
B
74004-15
TASK NO.
DWG. NO.
REV.
C18-857


MASTER TIMING GENERATOR
TIME STD
5 MHz
BARKER CODED GATED 2MHz
RF ON
RF OFF
CAL ON
CAL OFF
EXCITER/CAL SYN
ON
OFF
TRANSMITTER
NOISE ON
NOISE OFF
RECEIVER ON
RECEIVER OFF
RECEIVER
RECEIVER ROOM
DATA INTERFACE
AUX REP RATE
AUX REP RATE ENABLE
RANGE SYNC
RANGE GATE START
RANGE GATE RESET
RANGE CENTER RESET
STATUS INTERFACE
DIGITAL WAVEFORM GEN
RANGE SYNCHRONOUS 5 MHz
REP RATE SYNCHRONOUS 5 MHz
RANGE SYNC
PRE TRIGGER
10 μs COMB
RANGE SYNC
DATA INTERFACE
STATUS INTERFACE
RANGE SYNC
NOTE: THE 10μs COMB IS VARIABLE.
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS
TIMING
LEVEL II
C
74004-16
C18-871


B-
CHANGE LETTER
D'WN BY
CHK'D BY
APP'D BY
DATE
D C N. & DESCRIPTION
WAVEFORM GEN
RANGE SYNC
STATUS INTERFACE
RANGE SYNC
MANUAL SWITCH
RANGE SYNC
RANGE SYNCHRONOUS
WAVE GEN
5 MHz
SWITCH
5MHz
VARIABLE RATE COUNTER
COMB
DATA INTERFACE
COUNTER DIODE MATRIX
TIM STD
5 MHz
WAVE GEN
5 MHz
REP RATE SYNCHRONOUS
STD SEL SWITCH
5 MHz
PLL
4 MHz
DIGEX (DIGITAL EXCITER)
BARKER CODED GATED 2MHz
EXCITER
RF ON
RF OFF
TIMING
NOTE: THE COMB IS NORMALLY RUN AT 10μs WHEN BACKUP MODE IS SELECTED, WHEN DATA IS TO PASS THROUGH THE STATUS INTERFACE, THE COMB IS RUN AT A 500μs RATE.
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS
TIMING GENERATOR
LEVEL III
B
74004-17


SYS SYNC
0.01 1 2 3 4 5 6 7 8 9 10 20 30 37.01 MILLISEC
RECEIVER OFF
1.82 2.82
XMITTER ON
1.8 2.8
["EXCITER ON"]
1295 MHz
1.96 2.96
XMITTER OFF
3.0 4.0
EXCITER OFF
3.0 4.0
RECEIVER ON
3.8 4.8
CAL ON
11.96 12.96
NOISE ON
11.96 12.96
CAL OFF
13 14
NOISE OFF
13 14
SYS REP RATE
37 38
RANGE CENTER RESET
1.832 2.832
RANGE GATE RESET
1.848 2.848
RANGE GATE START
1.893 2.893
NOTES:
THIS IS A TYPICAL SEQUENCE.
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS
TIMING
TIMING DIAGRAM LEVEL IV
C
74004-18

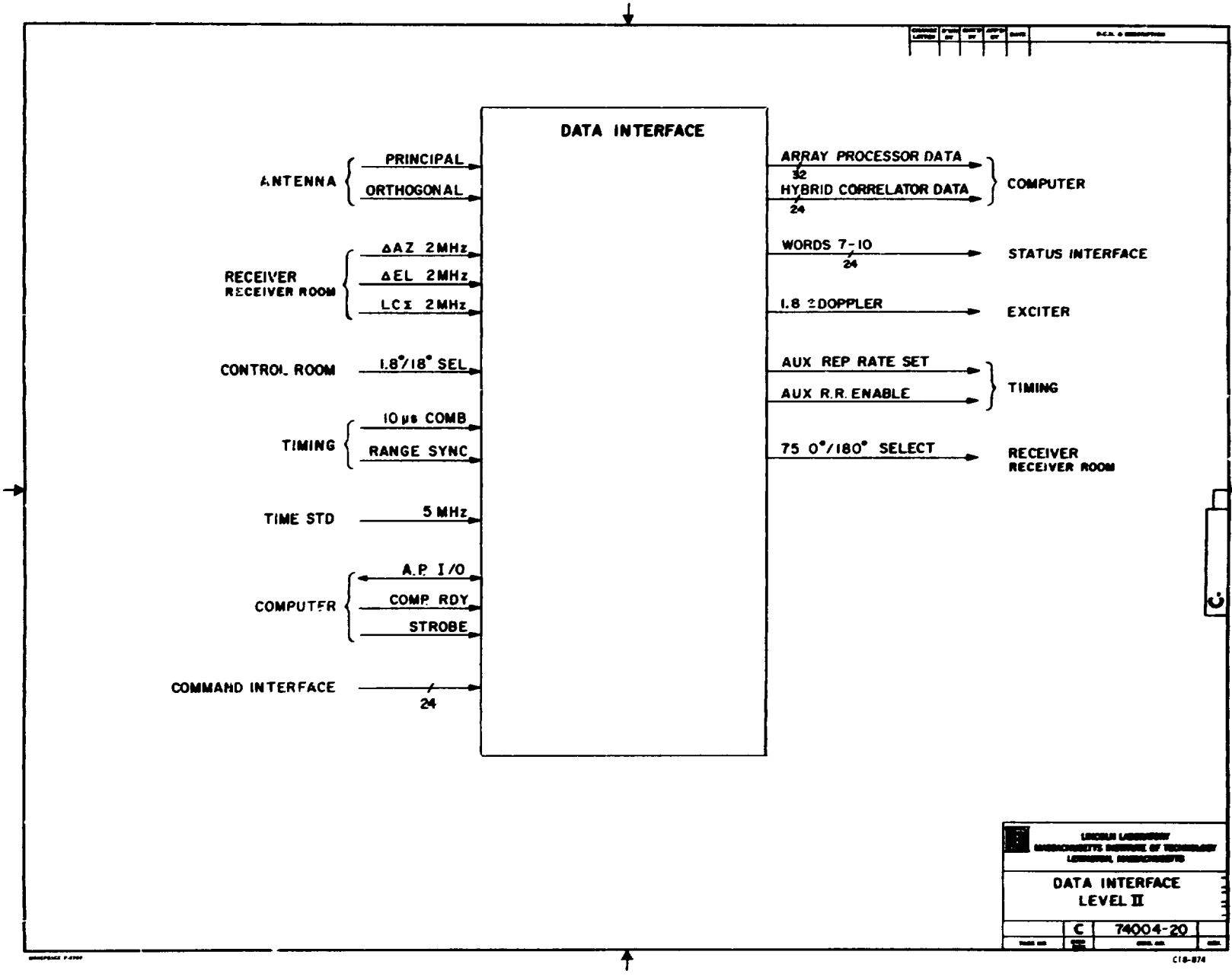


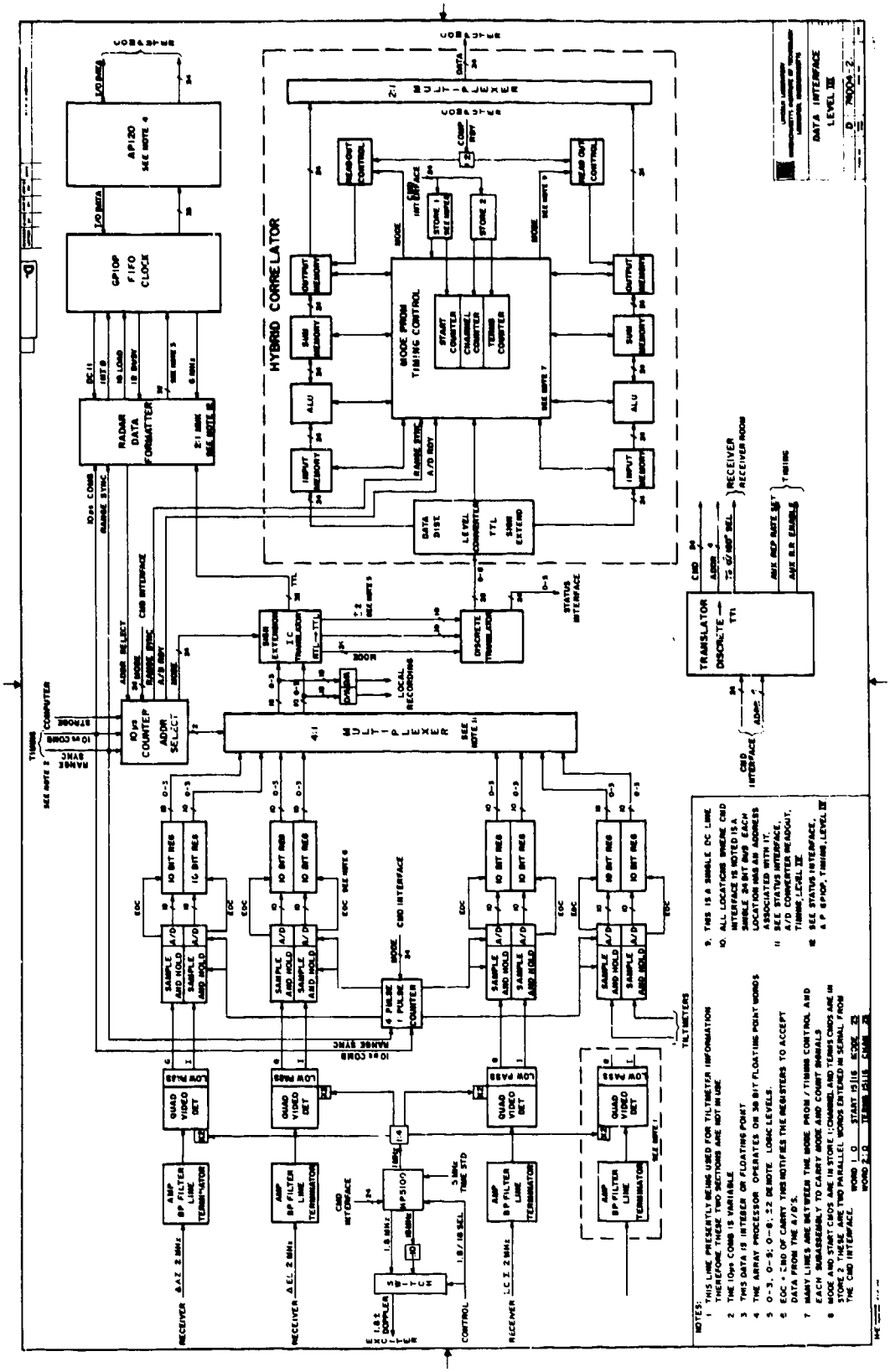
NOTE: THE 1.8 MHz ± DOPPLER CONTROL WORD IS LARGE ENOUGH TO CONTROL THE FULL FREQUENCY RANGE OF THE HP 5100.

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS

COMMAND INTERFACE
LEVEL II

C 74004-19

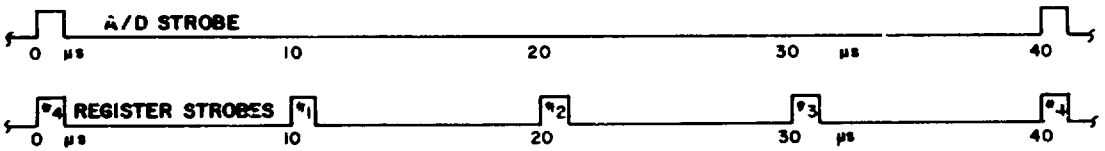

DATA INTERFACE
ANTENNA
PRINCIPAL
ORTHOGONAL
RECEIVER
RECEIVER ROOM
ΔAZ 2MHz
ΔEL 2MHz
LCΣ 2MHz
CONTROL ROOM
1.8°/18° SEL
TIMING
10 μs COMB
RANGE SYNC
TIME STD
5 MHz
COMPUTER
A.P. I/O
COMP. RDY
STROBE
COMMAND INTERFACE
24
ARRAY PROCESSOR DATA
32
HYBRID CORRELATOR DATA
24
COMPUTER
WORDS 7-10
24
STATUS INTERFACE
1.8 ±DOPPLER
EXCITER
AUX REP RATE SET
AUX R.R. ENABLE
TIMING
75 0°/180° SELECT
RECEIVER
RECEIVER ROOM
DATA INTERFACE
LEVEL II
C
74004-20


HYBRID CORRELATOR
MODE PROM TIMING CONTROL
RADAR DATA FORMATTER
AP120
GP10P FIFO CLOCK
MULTIPLEXER
TRANSLATOR DISCRETE — TTL
RECEIVER
DATA INTERFACE LEVEL III
NOTES:
1. THIS LINE PRESENTLY BEING USED FOR TILTMETER INFORMATION THEREFORE THESE TWO SECTORS ARE NOT IN USE
2. THE 10ps COMB IS VARIABLE
3. THIS DATA IS INTEGER OR FLOATING POINT
4. THE ARRAY PROCESSOR OPERATES ON 38 BIT FLOATING POINT WORDS
5. 0-3, 0-5; 0-8, 22 DENOTE LOGIC LEVELS.
6. EOC = END OF CONV. THIS NOTIFIES THE REGISTERS TO ACCEPT DATA FROM THE A/D'S.
7. MANY LINES ARE BETWEEN THE MODE PROM / TIMING CONTROL AND EACH ASSEMBLY TO CARRY MODE AND COUNT SIGNALS
8. MODE AND START CHOP ARE IN STORE 1 CHANNEL AND TERMS CHOP ARE IN STORE 2. THESE ARE TWO PARALLEL WORDS FETCHED IN SERIAL FROM THE CMD INTERFACE.
9. THIS IS A SINGLE DC LINE.
10. ALL LOCATIONS WHERE CMD INTERFACE IS NOTED IS A SINGLE 24 BIT R/W. EACH LOCATION HAS AN ADDRESS ASSOCIATED WITH IT.
11. SEE STATUS INTERFACE, A/D CONVERTER READOUT, TIMING LEVEL III
12. SEE STATUS INTERFACE, A P 6P10P, TIMING LEVEL III

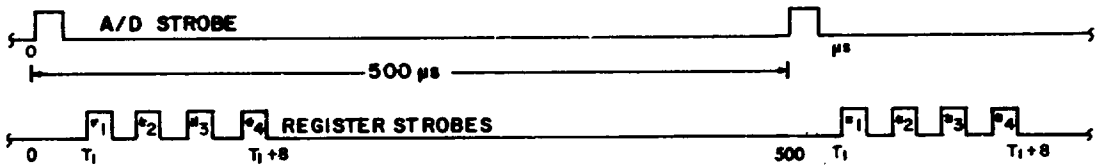
-B

CHANGE LETTER	D'WN BY	CHK'D BY	APP'D BY	DATE	D.C.N. & DESCRIPTION

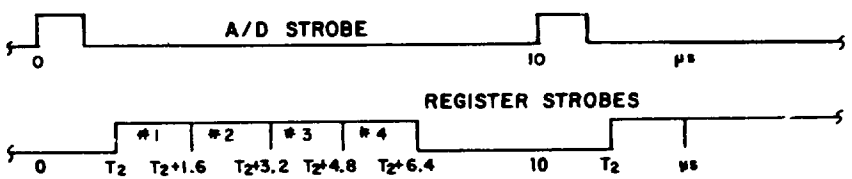
TO HYBRID CORRELATOR



TO STATUS INTERFACE



TO ARRAY PROCESSOR



NOTE:
$T_1 \approx 30\,\mu s$
$T_2 \approx 200-300$ NANOSECONDS
IN ARRAY PROCESSOR MODE, A/D REGISTERS ARE READ EACH 10μs. READOUT PER CHANNEL IS 1.6μs. THE ADDRESS IS COMING FROM THE DATA FORMATTER. THE A/D SWITCH OPERATES AS A ONE COUNT.

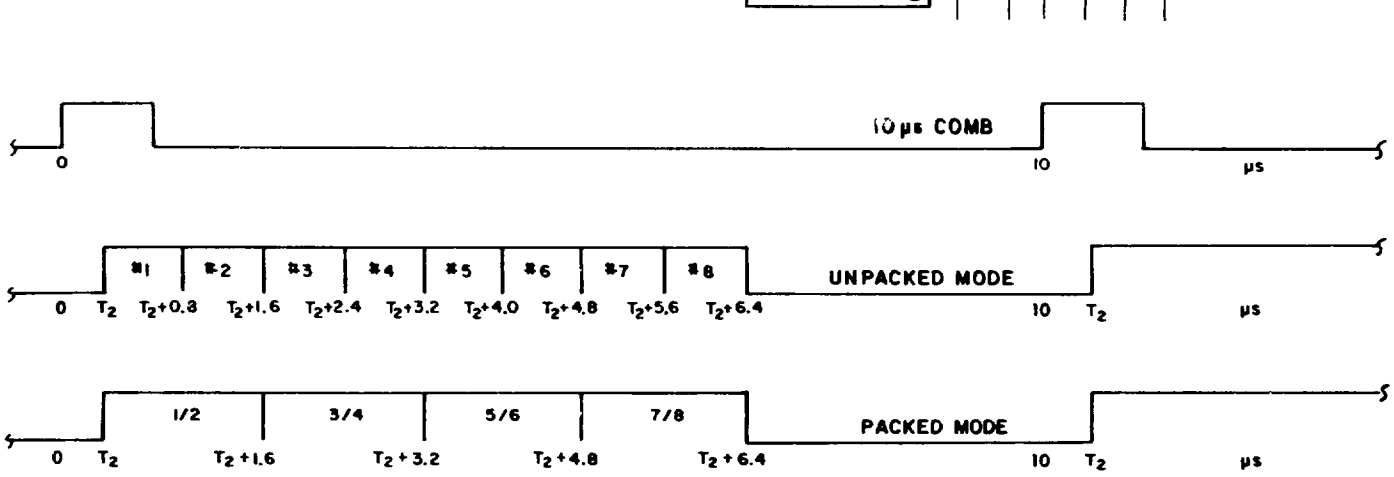
NOTE:
φ1, φ2, φ3, φ4, REFER TO A/D REGISTERS READ.
IN HYBRID CORRELATOR MODE THE A/D REGISTERS ARE READ EACH 10μs. THE ADDRESS SELECTOR IS DRIVEN BY A 10μs. COMB. THE A/D SWITCH OPERATES AS A FOUR COUNT.
IN STATUS INTERFACE, BACKUP, MODE. THE A/D REGISTERS ARE READ EACH 500μs, WITH READOUT TAKING 8μs. THE ADDRESS SELECTOR IS DRIVEN BY A COMPUTER STROBE AT THIS RATE. THE 10μs COMB FROM TIMING WHICH DRIVES THE A/D SWITCH IS CHANGED TO A 500μs COMB AND THE A/D SWITCH OPERATES AS A ONE COUNT.

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS

DATA INTERFACE A/D CONVERTER READOUT TIMING DIAGRAM LEVEL IV

TASK NO.	DWG. SIZE	DWG. NO.	REV.
	B	74004-22	

CHANGE LETTER	D WN BY	CHK D BY	APP'D BY	DATE	D C N & DESCRIPTION
B-					



NOTE: #1, #2, #3, #4, #5, #6, #7, #8 REFER TO 32 BIT WORDS

1/2, 3/4, 5/6, 7/8 REFER TO 16 BIT WORD PAIRS (32 BITS PER PAIR)

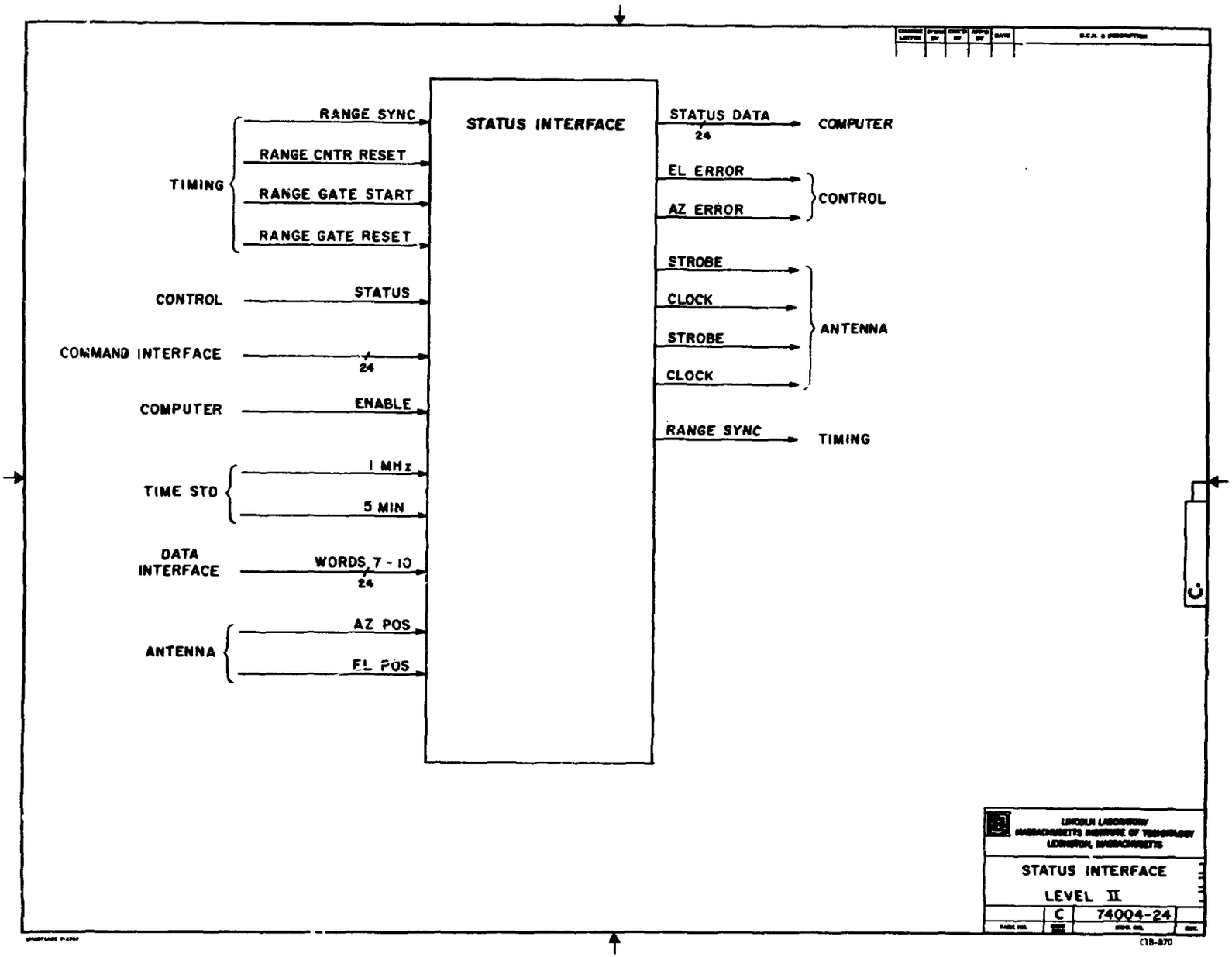
DATA TRANSFER IS FROM THE DATA FORMATTER TO THE GPIOP.

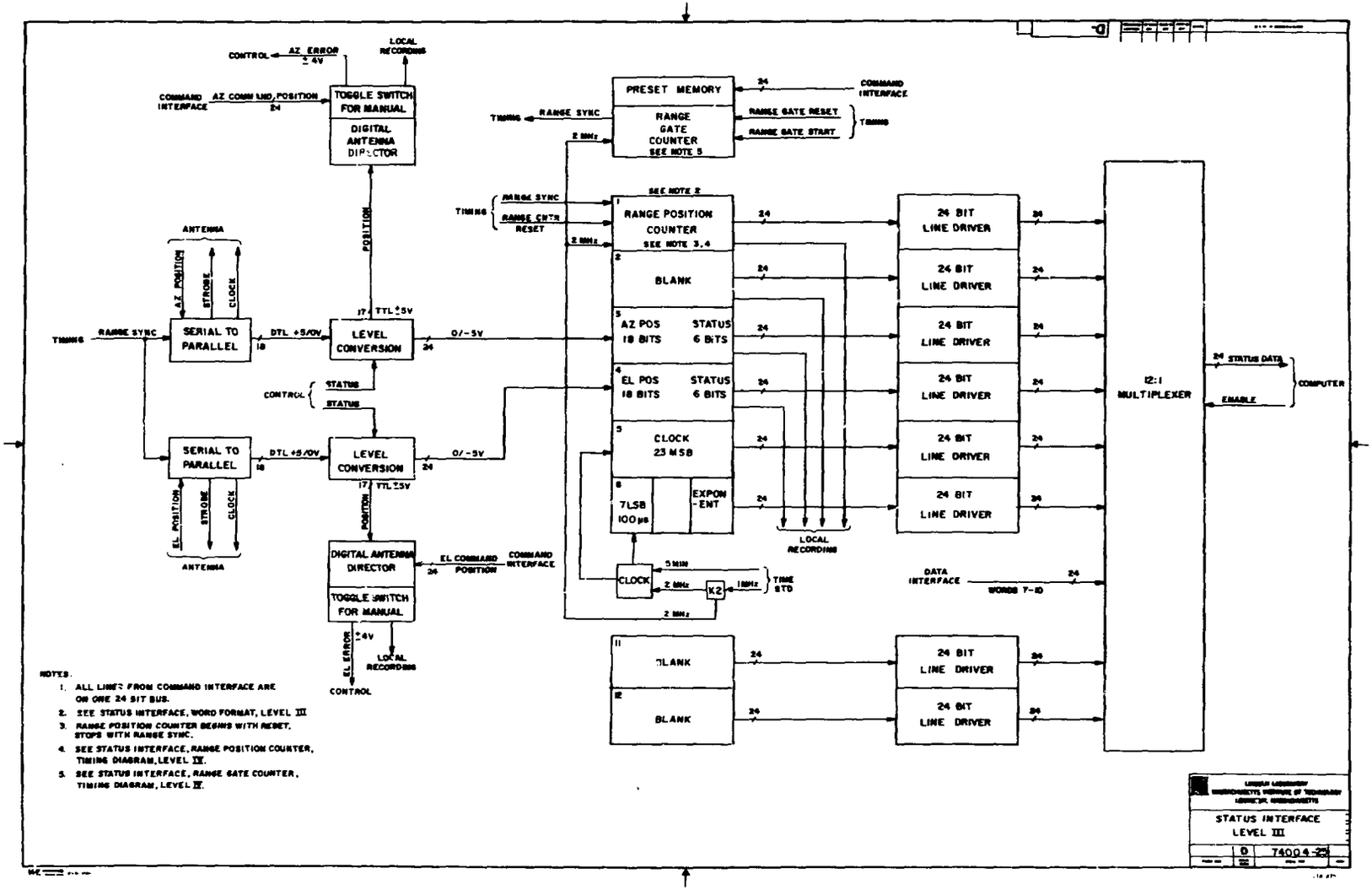
T_2 = >200 – 300 NANOSECONDS

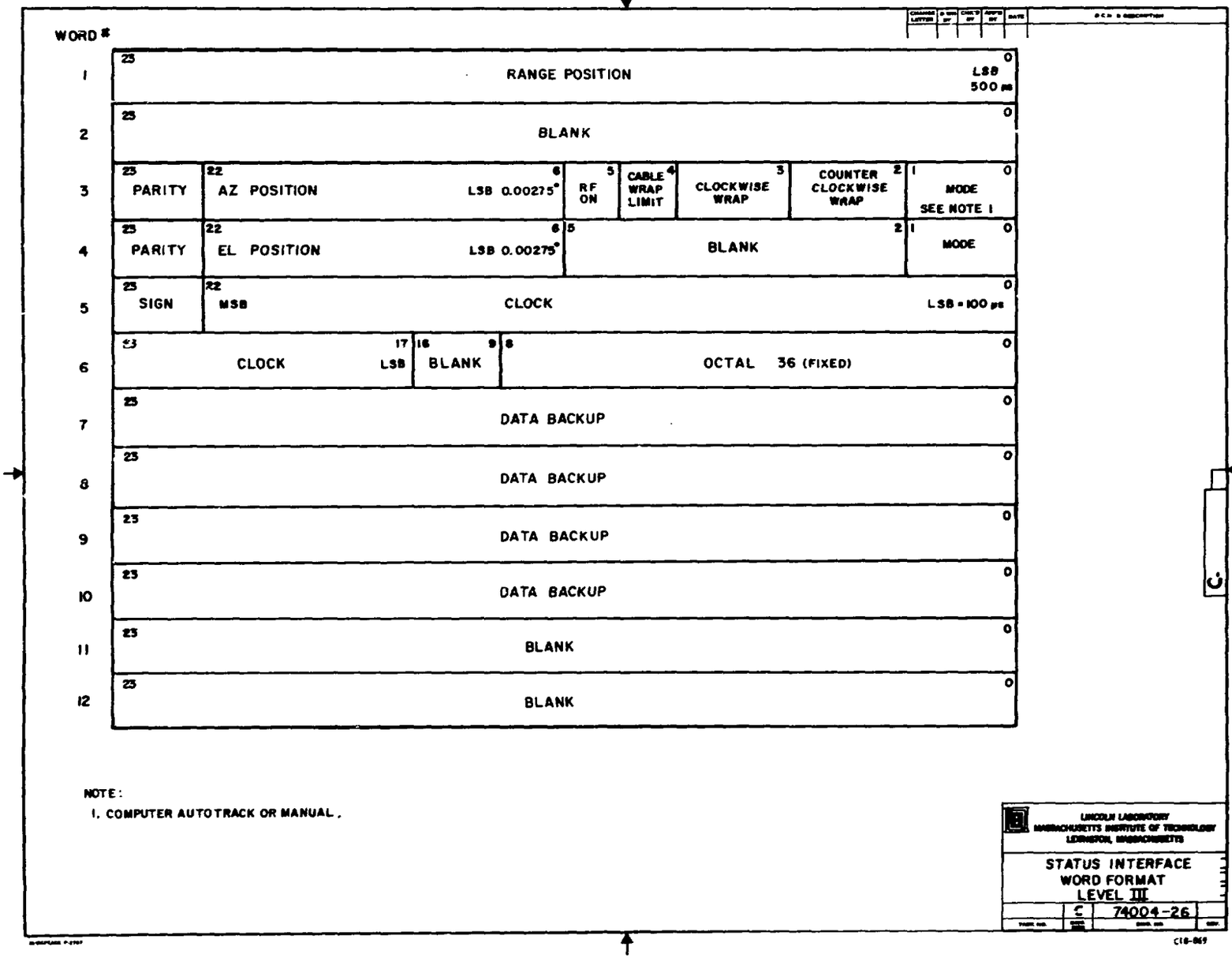
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS

DATA INTERFACE ARRAY PROCESSOR GPIOP TIMING DIAGRAM LEVEL IV

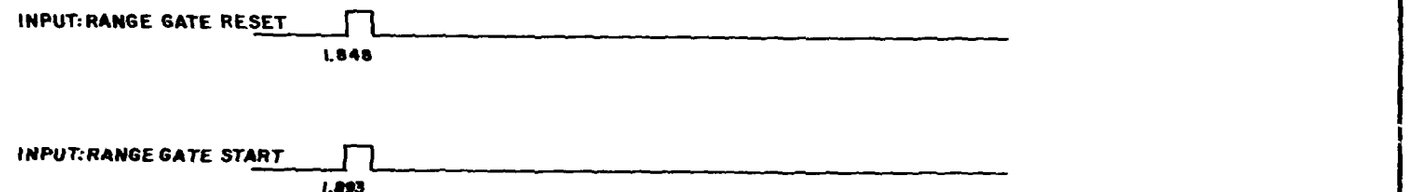
TASK NO.	SIZE	DWG. NO.	REV.
	B	74004-23	


STATUS INTERFACE
TIMING
RANGE SYNC
RANGE CNTR RESET
RANGE GATE START
RANGE GATE RESET
CONTROL
STATUS
COMMAND INTERFACE
24
COMPUTER
ENABLE
TIME STD
1 MHz
5 MIN
DATA INTERFACE
WORDS 7 - 10
24
ANTENNA
AZ POS
EL POS
STATUS DATA
24
COMPUTER
EL ERROR
AZ ERROR
CONTROL
STROBE
CLOCK
STROBE
CLOCK
ANTENNA
RANGE SYNC
TIMING
C
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS
STATUS INTERFACE
LEVEL II
C
74004-24
C18-870


CONTROL
AZ ERROR ±4V
LOCAL RECORDING
COMMAND INTERFACE
AZ COMMAND, POSITION 24
TOGGLE SWITCH FOR MANUAL
DIGITAL ANTENNA DIRECTOR
POSITION
ANTENNA
AZ POSITION
STROBE
CLOCK
TIMING
RANGE SYNC
SERIAL TO PARALLEL
DTL +5/0V
18
LEVEL CONVERSION
17 TTL ±5V
0/-5V
24
CONTROL
STATUS
STATUS
SERIAL TO PARALLEL
DTL +5/0V
18
LEVEL CONVERSION
0/-5V
24
17 TTL ±5V
EL POSITION
STROBE
CLOCK
ANTENNA
POSITION
DIGITAL ANTENNA DIRECTOR
EL COMMAND POSITION
24
COMMAND INTERFACE
TOGGLE SWITCH FOR MANUAL
EL ERROR ±4V
LOCAL RECORDING
CONTROL
PRESET MEMORY
24
COMMAND INTERFACE
TIMING
RANGE SYNC
RANGE GATE RESET
RANGE GATE START
TIMING
RANGE GATE COUNTER
SEE NOTE 5
2 MHz
SEE NOTE 2
TIMING
RANGE SYNC
RANGE CNTR RESET
2 MHz
1 RANGE POSITION COUNTER
SEE NOTE 3,4
2 BLANK
3 AZ POS 18 BITS STATUS 6 BITS
4 EL POS 18 BITS STATUS 6 BITS
5 CLOCK 23 MSB
6 7LSB 100 μs EXPON-ENT
24
LOCAL RECORDING
CLOCK
5 MHz
2 MHz
K2
1 MHz
TIME STD
2 MHz
11 BLANK
12 BLANK
24 BIT LINE DRIVER
24 BIT LINE DRIVER
24 BIT LINE DRIVER
24 BIT LINE DRIVER
24 BIT LINE DRIVER
24 BIT LINE DRIVER
24 BIT LINE DRIVER
12:1 MULTIPLEXER
24 STATUS DATA
ENABLE
COMPUTER
DATA INTERFACE
24
WORDS 7-10
NOTES:
1. ALL LINES FROM COMMAND INTERFACE ARE ON ONE 24 BIT BUS.
2. SEE STATUS INTERFACE, WORD FORMAT, LEVEL III
3. RANGE POSITION COUNTER BEGINS WITH RESET, STOPS WITH RANGE SYNC.
4. SEE STATUS INTERFACE, RANGE POSITION COUNTER, TIMING DIAGRAM, LEVEL IV.
5. SEE STATUS INTERFACE, RANGE GATE COUNTER, TIMING DIAGRAM, LEVEL IV.
STATUS INTERFACE
LEVEL III
D
74004-25


WORD #
1
RANGE POSITION
LSB 500 μs
2
BLANK
3
PARITY
AZ POSITION
LSB 0.00275°
RF ON
CABLE WRAP LIMIT
CLOCKWISE WRAP
COUNTER CLOCKWISE WRAP
MODE
SEE NOTE 1
4
PARITY
EL POSITION
LSB 0.00275°
BLANK
MODE
5
SIGN
MSB
CLOCK
LSB = 100 μs
6
CLOCK
LSB
BLANK
OCTAL 36 (FIXED)
7
DATA BACKUP
8
DATA BACKUP
9
DATA BACKUP
10
DATA BACKUP
11
BLANK
12
BLANK
NOTE:
1. COMPUTER AUTOTRACK OR MANUAL.
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS
STATUS INTERFACE
WORD FORMAT
LEVEL III
C
74004-26

CHANGE LETTER	D'WN BY	CHK'D BY	APP'D BY	DATE	D.C.N. & DESCRIPTION
B					



NOTE: "RANGE GATE RESET" SETS THE COUNTER TO ZERO.
"RANGE GATE START" BEGINS THE COUNTER
THE DEVICE COUNTS UP UNTIL REACHING THE
COMPUTER COMMANDED POS. AT WHICH POINT
IT SENDS "THE RANGE SYNC" SIGNAL TO TIMING.

THESE VALUES ARE TYPICAL AND
CAN BE CHANGED.

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS

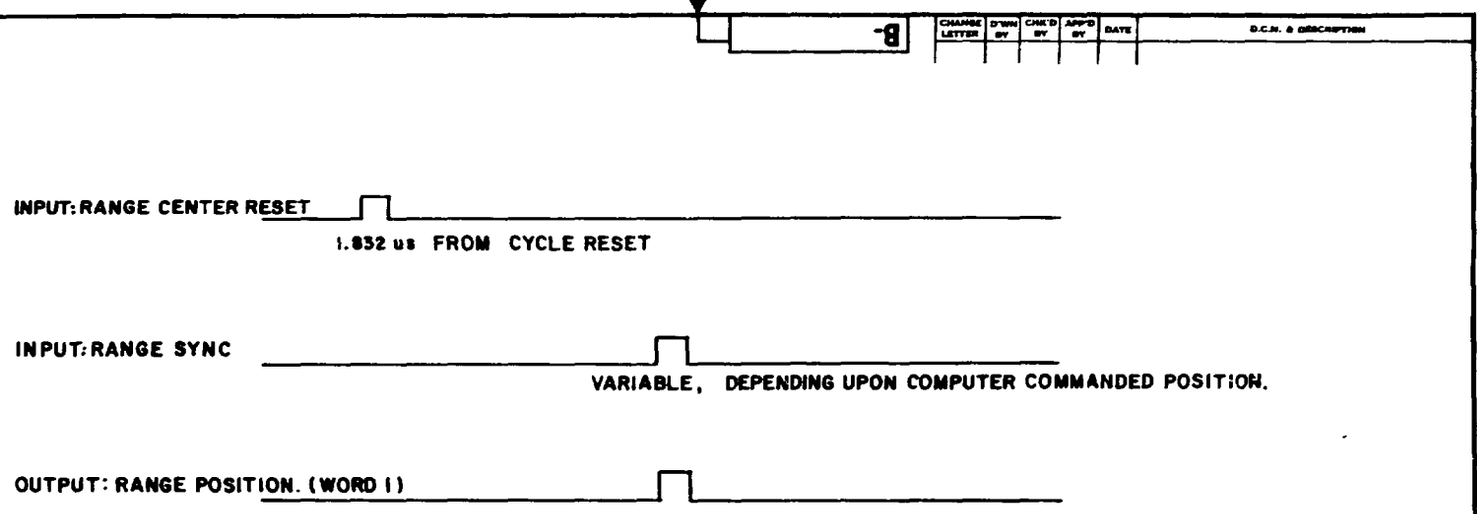
STATUS INTERFACE
RANGE GATE COUNTER
TIMING DIAGRAM LEVEL IV

TAPE NO.	Board Rev.	DWG. NO.	REV.
	B	74004-27	

MAREPEACE P-2183

C18-861

CHANGE LETTER	D'WN BY	CHK'D BY	APP'D BY	DATE	D.C.N. & DESCRIPTION
-B					



NOTE: "RANGE CENTER RESET" SETS THE COUNTER TO ZERO. THE COUNTER COUNTS UNTIL THE "RANGE SYNC" SIGNAL FROM TIMING.

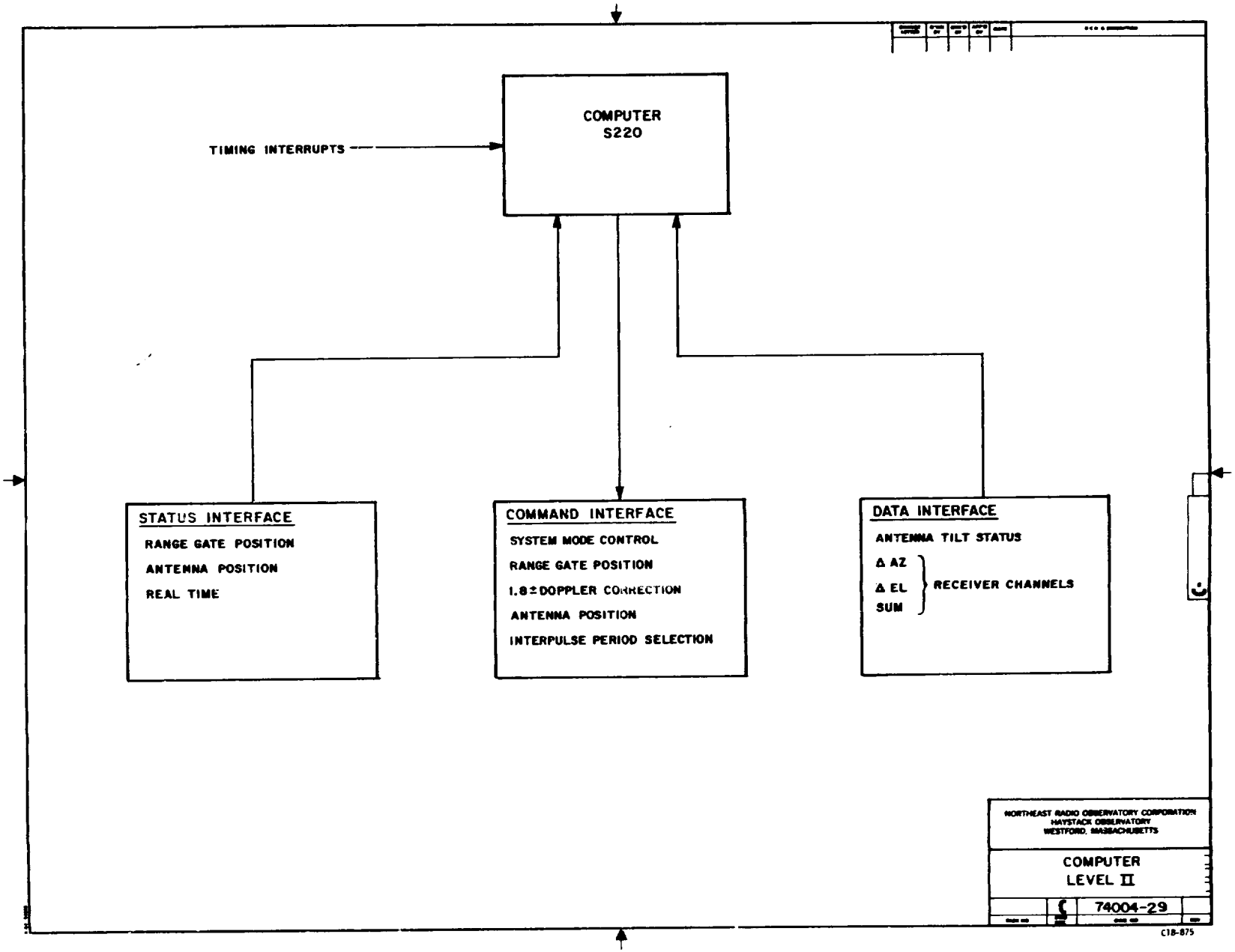
THIS VALUE IS TYPICAL AND CAN BE CHANGED.

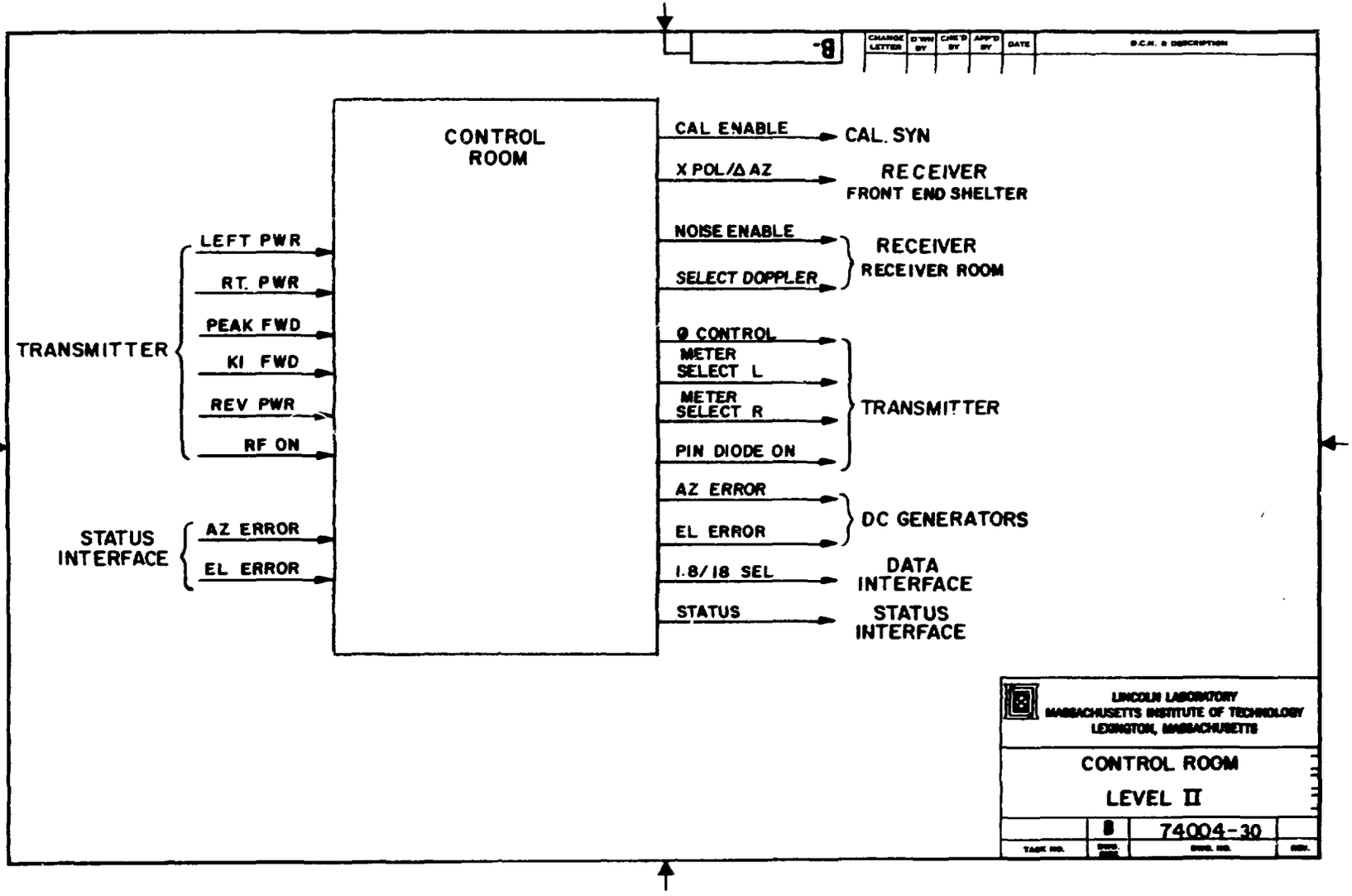
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS

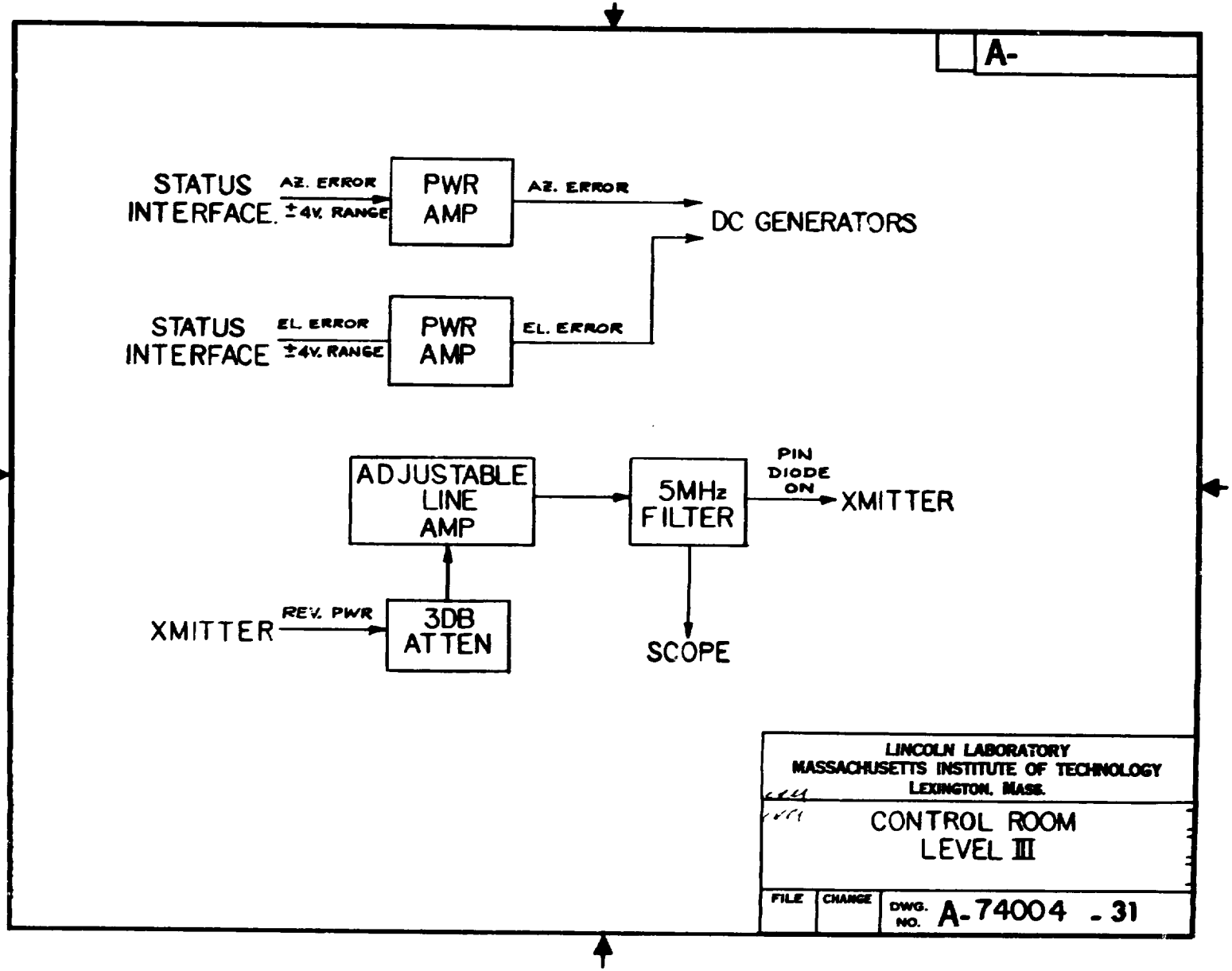
STATUS INTERFACE
RANGE POS. COUNTER
TIMING DIAGRAM LEVEL IV

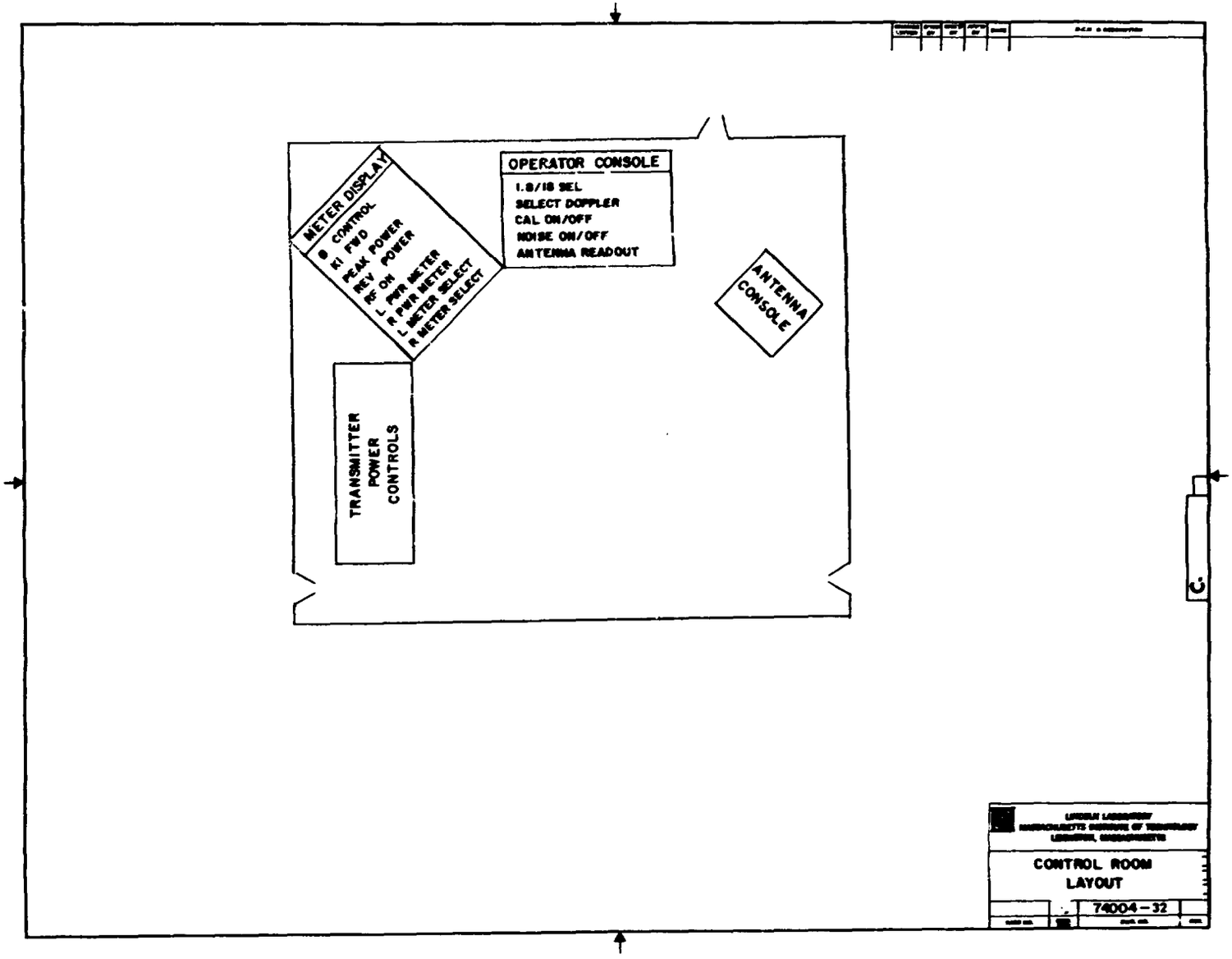
TASK NO.	SIZE	DWG. NO.	REV.
	B	74004-28	

C18-862


COMPUTER
S220
TIMING INTERRUPTS
STATUS INTERFACE
RANGE GATE POSITION
ANTENNA POSITION
REAL TIME
COMMAND INTERFACE
SYSTEM MODE CONTROL
RANGE GATE POSITION
1.8±DOPPLER CORRECTION
ANTENNA POSITION
INTERPULSE PERIOD SELECTION
DATA INTERFACE
ANTENNA TILT STATUS
Δ AZ
Δ EL
SUM
RECEIVER CHANNELS
NORTHEAST RADIO OBSERVATORY CORPORATION
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS
COMPUTER
LEVEL II
74004-29
C18-875


-B
CHANGE LETTER
D'WN BY
CHK'D BY
APP'D BY
DATE
B.C.N. & DESCRIPTION
CONTROL ROOM
CAL ENABLE
CAL. SYN
X POL/Δ AZ
RECEIVER
FRONT END SHELTER
NOISE ENABLE
SELECT DOPPLER
RECEIVER
RECEIVER ROOM
LEFT PWR
RT. PWR
PEAK FWD
KI FWD
REV PWR
RF ON
TRANSMITTER
Ø CONTROL
METER SELECT L
METER SELECT R
PIN DIODE ON
TRANSMITTER
AZ ERROR
EL ERROR
DC GENERATORS
STATUS INTERFACE
AZ ERROR
EL ERROR
I.8/I8 SEL
DATA INTERFACE
STATUS
STATUS INTERFACE
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS
CONTROL ROOM
LEVEL II
B
74004-30
TASK NO.
DWG. SIZE
DWG. NO.
SHT.


A-
STATUS INTERFACE
AZ. ERROR ±4V. RANGE
PWR AMP
AZ. ERROR
DC GENERATORS
STATUS INTERFACE
EL. ERROR ±4V. RANGE
PWR AMP
EL. ERROR
ADJUSTABLE LINE AMP
5MHz FILTER
PIN DIODE ON
XMITTER
XMITTER
REV. PWR
3DB ATTEN
SCOPE
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.
CONTROL ROOM
LEVEL III
FILE
CHANGE
DWG. NO. A-74004 - 31


METER DISPLAY
CONTROL
KI FWD
PEAK POWER
REV POWER
RF ON
L PWR METER
R PWR METER
L METER SELECT
R METER SELECT
OPERATOR CONSOLE
1.8/18 SEL
SELECT DOPPLER
CAL ON/OFF
NOISE ON/OFF
ANTENNA READOUT
ANTENNA CONSOLE
TRANSMITTER POWER CONTROLS
CONTROL ROOM LAYOUT
74004-32

09

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ESD-TR-81-298	2. GOVT ACCESSION NO. AD-A109279	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Millstone Hill Radar Satellite Tracking System		5. TYPE OF REPORT & PERIOD COVERED Project Report
		6. PERFORMING ORG. REPORT NUMBER Project Report STK-114
7. AUTHOR(s) Eli M. Hauser		8. CONTRACT OR GRANT NUMBER(s) F19628-80-C-0002
9. PERFORMING ORGANIZATION NAME AND ADDRESS Lincoln Laboratory, M.I.T. P.O. Box 73 Lexington, MA 02173		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element Nos. 12424F and 63439F Project Nos. 2296 and 2750
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Systems Command, USAF Andrews AFB Washington, DC 20331		12. REPORT DATE 4 November 1981
		13. NUMBER OF PAGES 66
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Electronic Systems Division Hanscom AFB Bedford, MA 01731		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

None

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Millstone | L-band radar | long range tracking radar

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document describes the hardware utilized at the Lincoln Laboratory Millstone radar facility. A system overview is presented which explains the function each subsystem fulfills and its interaction with the system. A detailed analysis of each subsystem follows. Diagrams for each level of consideration are included. This document is current as of 1 September 1981.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)