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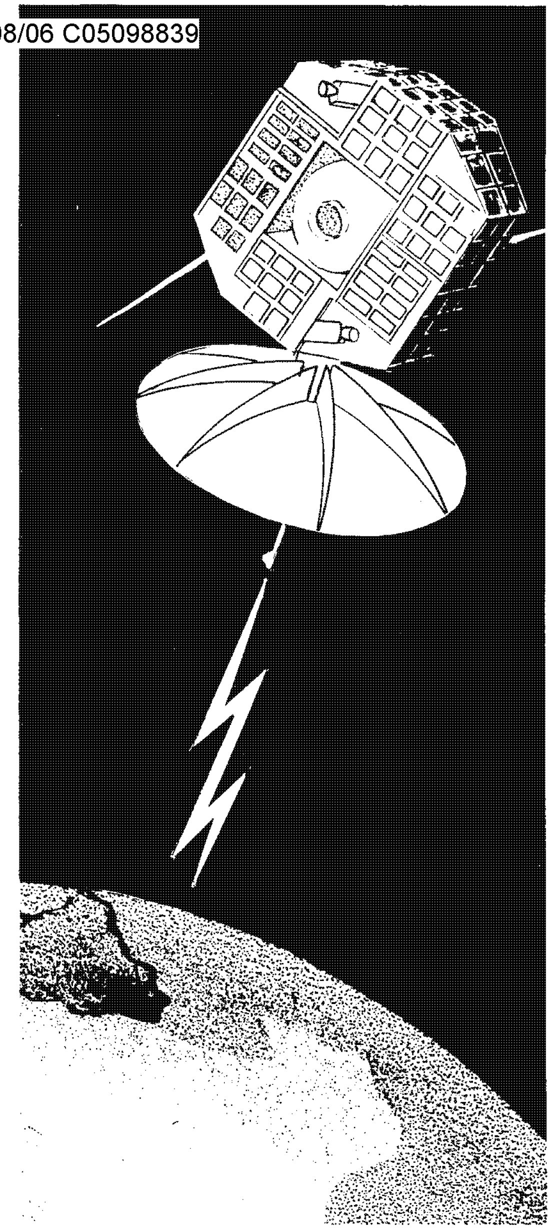

NATIONAL RECONNAISSANCE OFFICE

SATELLITE OPERATIONS CENTER

DESCRIPTION OF SIGINT MISSIONS 7332-7333

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SIGINT Missions 7332/7333 Mission Description

1. GENERAL INFORMATION

SIGINT Missions 7332/7333 are a dual payload intercept system which performs general search (GS) and electronic order of battle (EOB) for pulsed radars and continuous wave (CW) emitters operating in the 4 to 8 GHz (7332 - C-Band) and the 8 to 12 GHz (7333 - X-Band) frequency ranges (Figure 1.1). The radar parameters measured are frequency, pulsewidth, power, and PRF; the CW parameters measured are frequency and power. Both types of signals are geopositioned.

The radio frequency of pulsed emitters is measured on a pulse-by-pulse basis, permitting the detection and measurement of frequency-jumping emitters. The system will also measure the several frequencies of emitters operating at multiple frequencies, even though these frequencies are pulsed simultaneously. Up to three different frequencies can be measured on two successive pulses.

This description discusses the following:

- a. Antenna Subsystem
- b. Receiver Subsystem
- c. Frequency Measurement Subsystem
- d. CW Detection Subsystem
- e. Data Storage and Transmission Subsystem
- f. Ancillary Equipment

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2. ANTENNA SUBSYSTEM

The receiving antennas for each receiver subsystem consist of a pencil-beam direction-finding (DF) antenna and two broadbeam, omnidirectional inhibit antennas (see Figure 2.1). The signals from the inhibit antennas inhibit the sidelobe responses of the pencil-beam antenna in the DF receiver channel. The C-Band pencil-beam antenna has a sum pattern

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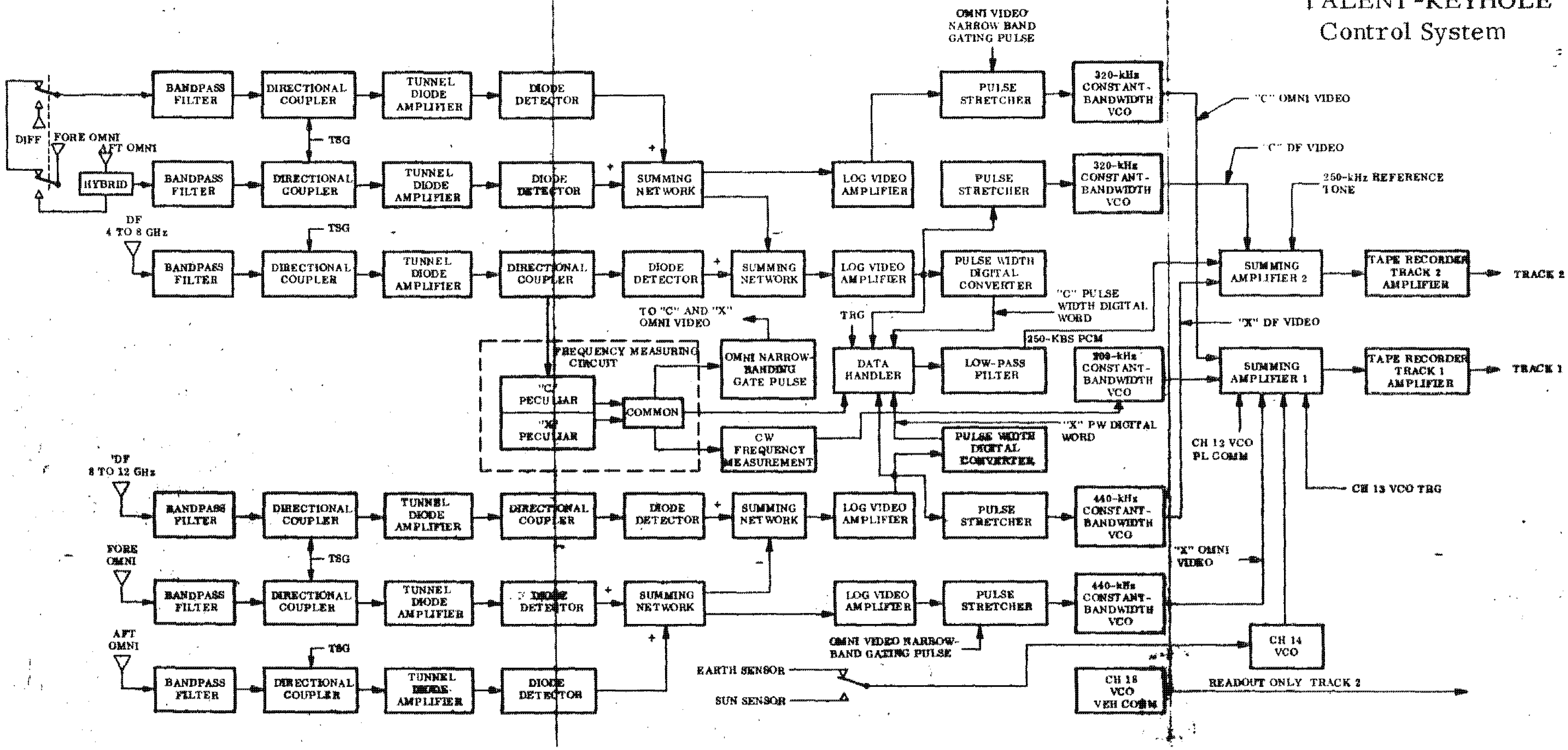

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Figure 1.1 Mission 7332/7333 Block Diagram

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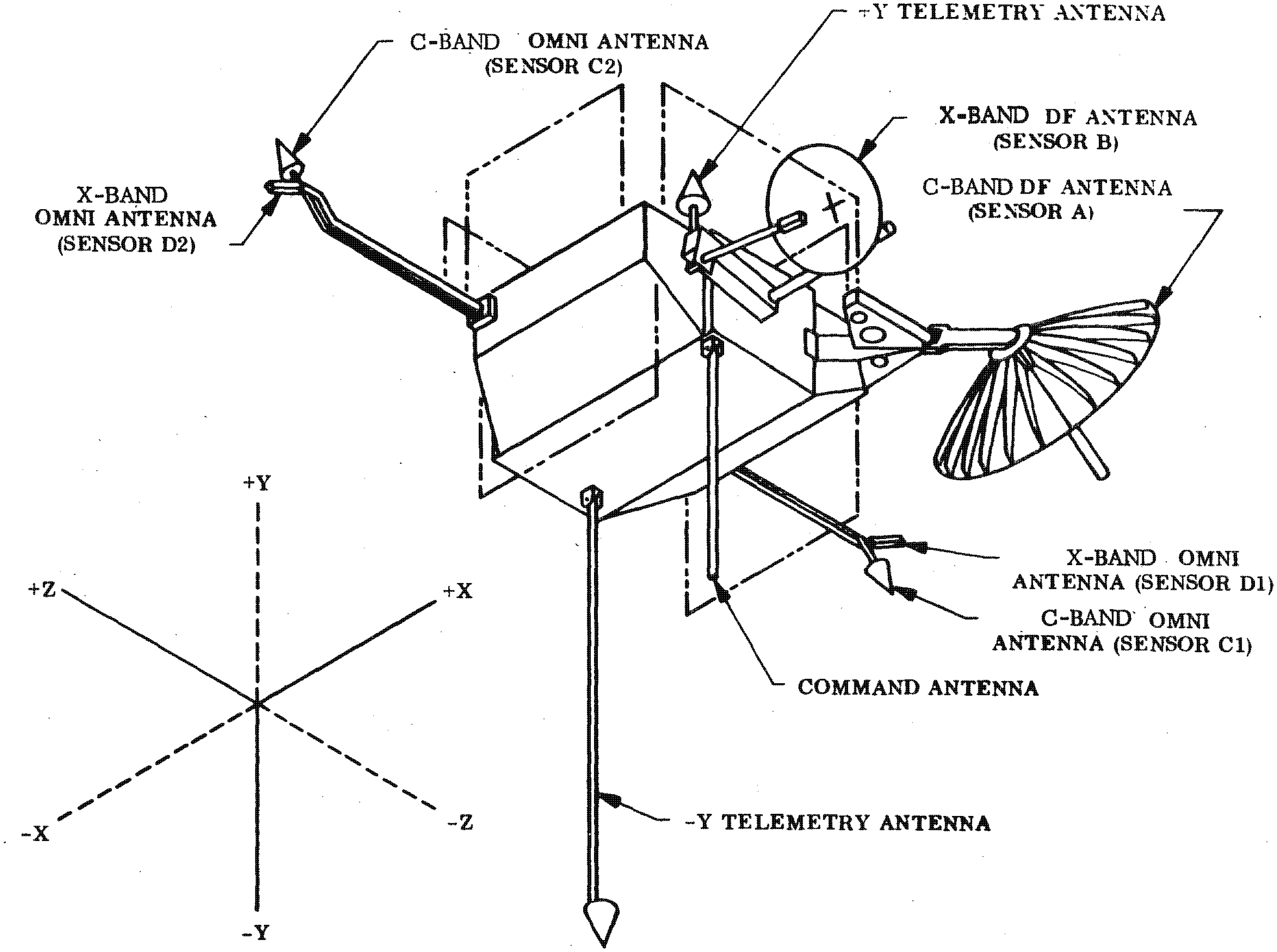

Fig. 2.1 Antenna Subsystem

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and a difference pattern with an output for each. The sum pattern is connected to the DF channel, and the difference pattern can be selected in lieu of the forward omnipattern to provide the above inhibit action. This beam-sharpening technique has been included to determine its effects on reducing direction finding errors due to centroiding. Also, this technique will aid in more accurately determining the position of rapidly scanning emitters. The primary mode of operation for C-Band will be to use both omniantennas for inhibit purposes.

2.1 C-Band

2.1.1 DF Antenna. The pencil-beam DF antenna is a 3-foot unfurlable paraboloid having flex ribs. The antenna has a sum pattern and a difference pattern output. Characteristics of this antenna are as follows:

a.	Frequency Range	4 to 8 GHz
b.	Gain (Matched Polarization)	
	4 GHz	24.5 db
	6 GHz	26.5 db
	8 GHz	29.5 db
c.	Beamwidth	3^{o} to 6^{o}
d.	Type of Feed	Conical Spiral
e.	Transmission Line	RG-142/U
f.	Boresight Axis Location	Along the -Z axis with a depression angle of 55^{o} (Angle from -Y axis).

2.1.2 Inhibit Antennas. The two inhibit antennas are boom-mounted conical spirals located 180 degrees apart on the spacecraft and co-linar with the pencil-beam antenna boresight axis. Antenna characteristics are as follows:

a.	Beam Pattern	Each antenna provides hemispheric coverage; combined antennas provide omnidirectional coverage.

b.	Polarization	Circular
c.	Transmission Line	RG-142/U

An RF switch permits selection of either the difference pattern of the pencil-beam antenna or the forward omniantenna pattern to be combined with the aft omnipattern for inhibiting of the sidelobe responses of the pencil-beam antenna.

2.2 X-Band

2.2.1 DF Antenna. The X-Band DF antenna is an 18-inch, solid magnesium paraboloid. Characteristics of this antenna are as follows:

a.	Frequency Range	8 to 12 GHz
b.	Gain (Matched Polarization)	
	8 GHz	29.0 db
	10 GHz	31.0 db
	12 GHz	32.0 db
c.	Beamwidth	4^{o} to 6^{o}
d.	Type of Feed	Waveguide with circular polarizing section
e.	Transmission Line	Rigid Waveguide
f.	Boresight Axis Location	Along the +Z axis with a depression angle of 55^{o} (Angle from −Y axis).

2.2.2 Inhibit Antennas. The two inhibit antennas are boom-mounted, rigid waveguides located 180 degrees apart (around the +Y −Y axis) on the spacecraft and co-linear with the pencil-beam antenna boresight axis. Antenna characteristics are as follows:

a.	Beam Pattern	Each antenna provides hemispheric coverage; combined antennas provide omnidirectional coverage.

b. Polarization — Circular

c. Transmission Line — RG-142/U

3. RECEIVER SUBSYSTEMS

Each receiver subsystem consists of three crystal-video receivers having RF amplifiers, crystal detectors, log-video amplifiers, pulse stretchers, and radio frequency and pulsewidth measurement circuits. Table 3-1 provides a summary of receiver parameters. Figure 3.1 shows the geopositioning accuracy of the receivers as a function of distance from nadir and antenna beamwidth. (Because of the electronic beam shaping techniques used, the effective beamwidth for C-Band was 3 degrees and for X-Band 2 degrees.) Both the C- and X-Band receivers are similar and only one will be described.

The signal received by the pencil-beam DF antenna is applied via a 30-db coupler to a tunnel-diode amplifier (TDA) through a 4- to 8-GHz bandpass filter in the C-Band receiver and an 8- to 12-GHz bandpass filter in the X-Band receiver. The TDA consists of four cascaded tunnel-diode and circulator combinations that provide a nominal gain of 32 db. The TDA output is coupled into a 10-db directional coupler to a tunnel-diode detector and a postdetection amplifier having a bandwidth of 2.3 ± 0.2 MHz. The output of the postdetection amplifier is summed with the outputs of the omnidirectional inhibit receivers and applied to a bipolar log-video amplifier. A portion of the RF energy from the DF channel is coupled through the 10-db directional coupler to the frequency measurement and CW detection circuits.

Signals received by the two inhibit antennas are coupled into two omnichannel receivers that are identical to the DF channel receiver. The outputs from the two omnichannels are summed and coupled to a summing network for the DF channel and to a log-video amplifier for the omnivideo outputs. The combined output is used to inhibit sidelobe responses from the pencil-beam antenna in the DF channel and to provide an output that is effectively omnidirectional in coverage.

The DF channel has two sensitivity modes: a high-gain (-73 dbm) mode and a normal-gain (-65 dbm) mode. The 8-db insertion loss required for the normal-gain mode is achieved by changing the bias on the TDA's in the DF channel by a relay closure initiated by external commands. The

TABLE 3-1

RECEIVER SUBSYSTEM PARAMETERS

PARAMETER	C-BAND	X-BAND
Frequency Range	4-8 GHz	8-12 GHz
Sensitivity		
DF Channel		
High-Gain Mode	-73 dbm ± 3 db	-73 dbm ± 3 db
Normal-Gain Mode	-65 dbm ± 3 db	-65 dbm ± 3 db
Omnichannels		
DF Inhibit Function	-75 dbm ± 3 db	-75 dbm ± 3 db
Omnivideo Output	-75 dbm ± 3 db	-75 dbm ± 3 db
Dynamic Range	35 db	35 db
DF Frequency Measurement		
With Temperature Calibration	±30 MHz	±30 MHz
Without Temperature Calibration	±34 MHz	±41 MHz
PW Measurement		
Range	0.25 to 11.5 usec	0.25 to 11.5 usec
Accuracy	±0.25 usec up to 4 usec PW ±0.5 usec from 4 to 11.5 usec	±0.25 usec up to 4 usec PW ±0.5 usec from 4 to 11.5 usec
Geopositioning Accuracy		
CW Frequency Measurement	±30 MHz	±30 MHz
CW Frequency Resolution	30 MHz	30 MHz
CW Dynamic Range	40 db	40 db
CW Sensitivity	-98 dbm ±3 db	-98 dbm ±3 db

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50X1

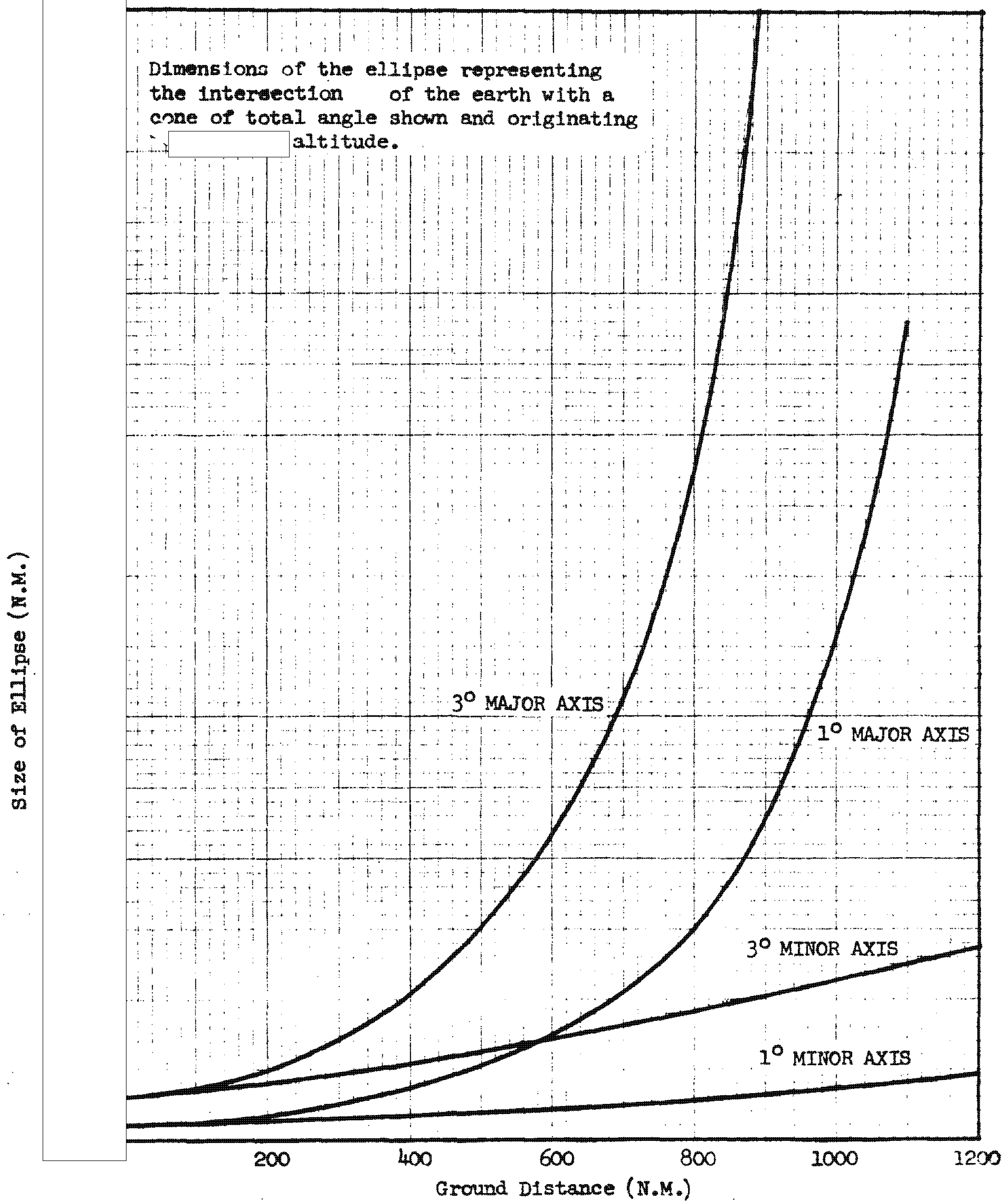

Figure 3.1 Size of 90 per cent confidence ellipse.

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8-db insertion loss provides an inhibit margin between the response of the DF and omniantennas required for keeping poke-through to a minimum. The summed outputs from the omnichannels are amplified in a log-video amplifier and applied to a pulse stretcher having a time constant of approximately 40 usec. The amplitude of the flat-top pulse stretcher is dependent upon the amplitude of the leading edge of the incoming pulse. If a second pulse having less amplitude is received while the pulse stretcher is processing the first pulse, the second pulse will be rejected. If the amplitude of the second pulse is greater than that of the first pulse, the flat top of the pulse stretcher will assume the amplitude of the second pulse for 40 usec. Both receiver systems use the same time constant for the omnipulse stretcher.

The omnivideo output is recorded directly on a VCO for wideband or narrowband omni. The 1000-MHz narrowband omni is derived by gating through only omnipulses that are present simultaneously in the omnichannel and in a selectable 1000-MHz coarse-frequency IF channel. A gating pulse is derived by detecting the IF output and applying it to an omnigate for each of C-Band and X-Band omni-outputs.

The DF pulse stretchers of both receiver systems operate in the same manner as the omnipulse stretcher.

The pulsewidth measurement circuitry converts the received video pulsewidth to a 5-bit digital word which is included in the payload PCM word.

4. FREQUENCY MEASUREMENT SUBSYSTEM (Figure 4.1)

The frequency measurement subsystem is common for each receiver subsystem with the exception of the frequency range covered. It can measure the frequency of a received pulse over the entire RF band during each spin of the vehicle with an accuracy of ±30 MHz (temperature compensated). A DF video signal having an S/N ratio of 15 db or greater is required to activate the frequency measurement subsystem encoder. The measurement subsystem consists of 8 superheterodyne receivers, 4 coarse-frequency filters, and 36 fine-frequency filters, fine-frequency shift registers, frequency encoder and associated control logic, and local oscillator controls.

RF energy from the DF channels is coupled through 10-db directional couplers to two 3-db hybrids, and from there to four 3-port circulators and eight interdigital filters, each having a bandwidth of 1.0 GHz. The outputs of the eight filters are separately applied to single-ended mixers and converted to an IF of 2.0 to 3.0 GHz.

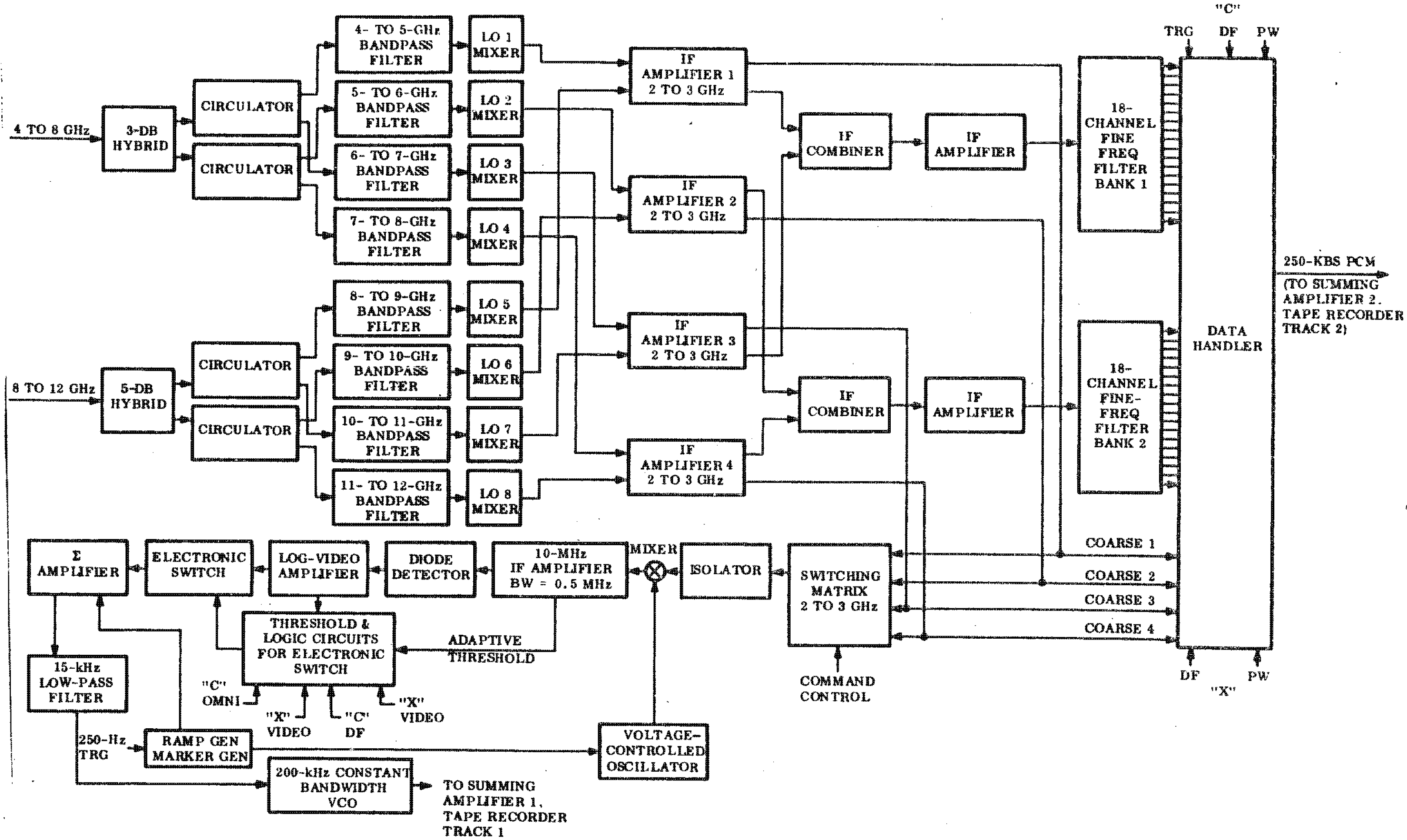


Fig. 4.1 Frequency Measurement Subsystem

The IF outputs of the C-Band receiver are combined with the IF outputs of the X-Band receiver in four 3-db hybrids and amplified in four 2.0- to 3.0-GHz IF amplifiers. Each of the the four IF amplifiers has two outputs, one of which is applied to the coarse-frequency measurement circuit and the other to the fine-frequency measurement circuit. The coarse-frequency measurement circuit contains a diode detector and threshold circuit for each of the four coarse-channel outputs. The outputs from these channels are stored in a 4-bit shift register. Fine-frequency IF outputs are applied to two 18-channel, fine-frequency filter banks. Each channel filter has a bandwidth of approximately 55 MHz.

Table 4-1 shows the center frequency of each filter and the local oscillator frequency assignments.

The outputs of the 18 fine-frequency filters are amplified and applied to threshold and comparison circuits in the frequency comparator. A processed signal in the frequency channel is recorded as a binary 1 in an 18-position shift register. To reduce the possibility of a strong signal recording a binary 1 through two adjacent filters, the output of a given filter is compared separately with its adjacent filters. If the output amplitude of the center filter exceeds that of the adjacent filters, a binary 1 is recorded in the proper shift register position.

The 18 filters associated with odd-numbered coarse-frequency channels are designated 1 thru 18, and the 18 filters associated with the even-numbered coarse-frequency channels are designated 19 thru 36. In the case of X-Band, channels 18 and 19 are adjacent, and the above technique applies to these two channels as though the two banks were one continuous 36-channel bank. There is a guard band filter below channel 1 and also above channel 36 to enable this comparison. In the case of C-Band channels 1 and 36 are adjacent because of the different technique of oscillator/signal mixing which places channel 1 at the high end of the IF bandwidth and channel 36 at the low end. Adjacent channel comparison takes place in this instance with channel 1 and 2 and 36 and with channel 36 and 1 and 35. Again, a guard band exists at an imaginary number above channel 18 and below channel 19.

The data stored in the coarse- and fine-frequency registers are converted into a PCM bipolar code by the frequency encoder. The encoder is activated by an AND circuit when the following conditions are met:

a. An input signal (S/N 15 db or greater) from either DF channel bipolar log-video amplifier is present.

b. A signal is present in one of the fine-frequency filter shift registers and coarse-frequency filter shift register.

TABLE 4-1

FILTER FREQUENCIES AND LOCAL OSCILLATOR FREQUENCY ASSIGNMENTS

Channel	Frequency (MHz)	Channel	Frequency (MHz)
1	2027.4	10	2527.8
2	2083.0	11	2583.4
3	2138.6	12	2639.0
4	2194.2	13	2694.6
5	2249.8	14	2750.2
6	2305.4	15	2805.8
7	2361.0	16	2861.4
8	2416.6	17	2917.0
9	2472.2	18	2972.6

Frequency Band No. and Range (GHz)		Local Oscillator Frequency (GHz)	IF Frequency Range (GHz)
T-1	4-5	7	3-2*
T-2	5-6**	8	3-2*
T-3	6**-7	9	3-2*
T-4	7-8	10	3-2*
S-1	8-9	6	2-3
S-2	9-10***	7	2-3
S-3	10***-11	8	2-3
S-4	11-12	9	2-3

* IF frequency range for bands T-1 thru T-4 are reversed due to LO frequency being above the received signal.

** C-Band receiver test signal generator frequency.

*** X-Band receiver test signal generator frequency.

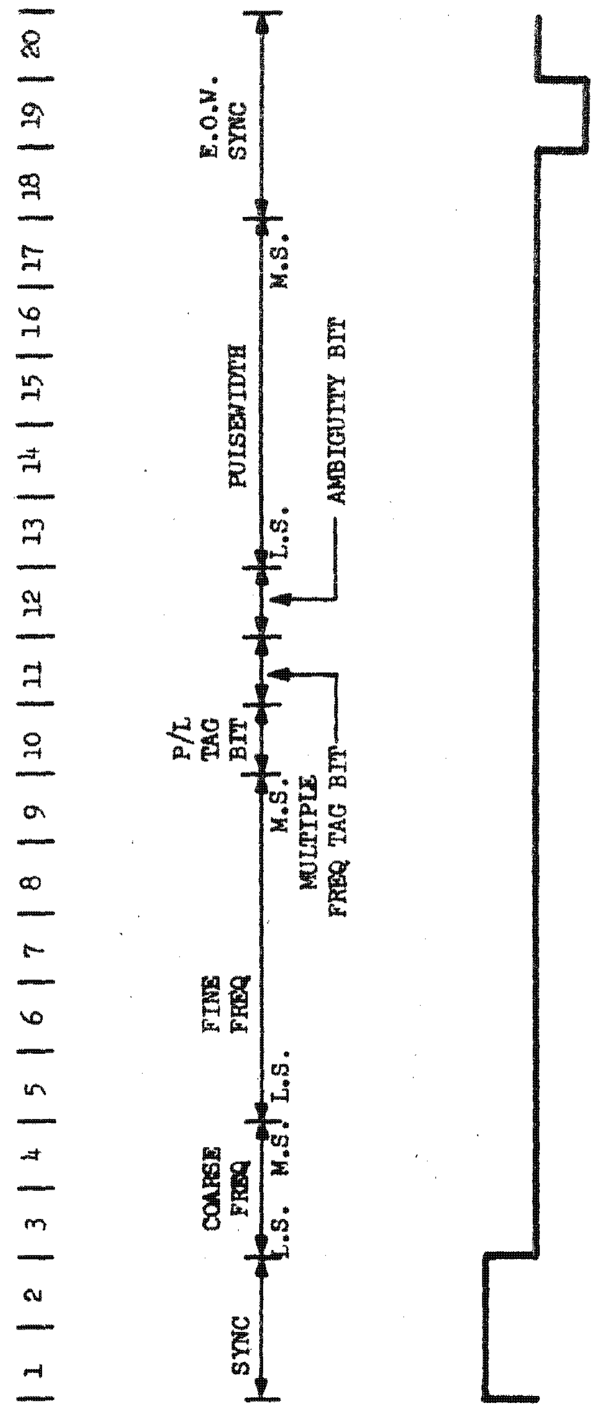
c. No singnal is presently being processed in the data handler.

The clock frequency of the fine-frequency shift register is 4 MHz. Figure 4.2 shows the PMC data format for the frequency measurement system and the pulsewidth measurement system. The data is 250 kbps, bit length is 4 usec, and the total word length is 20 bits (80 usec). The first two bits are word sync, the next eight bits are frequency information followed by the multiple frequency flag and ambiguity indicator bits. The next five bits are pulsewidth, and the last three bits are end-of-word sync. The data bit assignments are as follows:

a. Bits 3, 4	Coarse frequency
b. Bits 5, 6, 7, 8, 9	Fine frequency
c. Bit 10	Payload band indicator
d. Bit 11	Multiple frequency flag
e. Bit 12	Ambiguity indicator
f. Bits 13, 14, 15, 16, 17	Pulsewidth

At times, several of the fine-frequency filter outputs will record more than one binary bit in the shift register, denoting that several frequencies have been received. When this happens, the shift register is interrogated as follows. Assume that the system has intercepted an emitter having six multiple radio frequencies spaced between 8.0 and 10.0 GHz. The values of the six frequencies are denoted by binary 1's in the 2nd, 9th, 15th, 17th, 25th, and 31st positions of the 36-position fine-frequency shift register. The fine-frequency shift register is either interrogated starting with its 1st or 36th position and alternates on successive pulses.

After receipt of the first pulse, the shift register is sampled in the direction from position 1 to position 36. When the binary 1 is detected in position 2, the sampling process stops, and a frequency word is written for position 2 with the corresponding coarse channel which has been indicated in the coarse-frequency shift register. After the PCM word has been generated, sampling of the fine-frequency shift register continues. Upon detection of a binary 1 in position 9, another PCM word is generated. This process continues until three PCM words have been generated. At this time, the data handler is cleared and ready to accept the next pulse. Upon receipt of the next pulse, the fine-frequency shift register will be sampled starting from the 36th position, and



BIT LENGTH = 4 USEC
WORD LENGTH = 80 USEC
BIT RATE = 250 KBPS
WORD RATE = 12,000 WORDS/SEC

Figure 4.2 Payload PCM Word Format

PCM words will be generated for positions 31, 25, and 17 in that order. PCM words for channels 2, 9, and 15 will be generated on the next pulse received, etc. The second and third word of any group of three words from a single pulse as indicated above will record a binary 1 state in bit 11 of the PCM word. This indicates a multiple frequency.

5. CW DETECTION SUBSYSTEM

The CW detection subsystem operates similar to a spectrum analyzer. The input to the CW detection system is coupled through a solid-state switch from one of four IF amplifiers in the main frequency measurement system to a common 2- to 3-GHz amplifier. The output of the common IF is coupled to a mixer. Also coupled to the mixer is a sweeping LO which sweeps over a range of 2.010- to 3.010-GHz in 4 msec. This time includes a 0.2-msec fly-back period. The output of the mixer is coupled to an IF amplifier having a center frequency of 10 MHz and a bandwidth equal to 0.5 MHz (10 MHz $\pm$0.25 MHz). The output of the 10-MHz IF is detected and amplified in a log-video amplifier and then coupled to an electronic switch. The electronic switch under certain conditions allows the amplified signal to pass to a 55-usec pulse stretcher whose output is coupled to a summing amplifier. The second input to the summing amplifier is a sweep flyback marker pulse. The output of the summing amplifier is low-pass filtered and modulates a 200-KHz, constant-bandwidth VCO for recording on tape recorder track 1.

The electronic switch allows only CW signals (or extremely high duty cycle signals) to pass through to the output. The system is designed to accept CW emitter signals and to reject most pulse-modulated signals. This is accomplished as follows. When the LO is swept above and below the frequency of an intercept signal, two outputs are generated in the CW detection subsystem. These outputs are the image and real frequencies of the signal. When the image frequency is detected, a time delay of 65 usec is started. At the end of this time delay, the electronic switch closes for 20 usec. This 20-usec video window allows the video response to the real signal to pass through to the pulse stretcher. The elapsed time of the LO sweep between the image and real frequency video responses is approximately 75 usec. If a pulsed emitter is intercepted, the timing circuit is enabled, and 65 usec later, the video window is opened. No output is generated unless another pulse or CW emitter is received within this window. For a non-CW signal to have a finite probability to qualify as a CW signal, it must have a pulsewidth that exceeds 65 usec, and/or its apparent PRF must exceed approximately 11.8 KHz. The probability of generating false signals is further reduced by inhibiting the CW video output when pulsed signals are received in either the DF or omnivideo channels. The CW receiver sweep rate was chosen to allow a minimum of three receiver scans during the minimum dwell time of the spacecraft antenna on a target.

The CW detector output video (Figure 5.1) has a +1 volt reference baseline. The end of the LO sweep (start of flyback) is synchronous with the start of a 0-volt pulse. The trailing edge of this pulse is synchronous with the start of the LO sweep. A CW intercept appears as a +3 volt pulse (minimum) whose time with respect to 0-volts is proportional to frequency. The power level of the intercepted signal is indicated by the amplitude of the signal between the 3- and 5-volt levels. The 3-volt level will be calibrated for a receiver sensitivity of approximately -98 dbm. The start of the LO sweep (and, therefore, the trailing edge of the 0-volt sync pulse) is synchronized with a 250-Hz output of the TRG.

6. DATA STORAGE AND TRANSMISSION SYSTEM

Two channels of data storage are provided by a dual-channel, 1-MHz tape recorder. Two additional recorders are provided as backup units. Any two of the three recorders can be programmed for a consecutive readin capability that is twice the normal readin period. Two S-Band FM transmitters are used to relay the data to the ground tracking stations. The data formats during tape recorder readin and before-and-after tape recorder readout are shown in Figure 6.1.

6.1 C-Band Data Readin

Tape recorder track no. 1 records the following data from summing amplifier no. 1 (Figure 1.1):

(Maximum readin time is 11 minutes.)

a.	Payload commutator	Channel 12
b.	TRG time code	Channel 13
c.	Earth sensor or sun sensor	Channel 14
d.	CW Video--common to C- and X-Band	15-KHz BW VCO at 200 KHz center frequency
e.	Omnivideo	20-KHz BW VCO at 320 KHz center frequency

Tape recorder track no. 2 records the following data from summing amplifier no. 2:

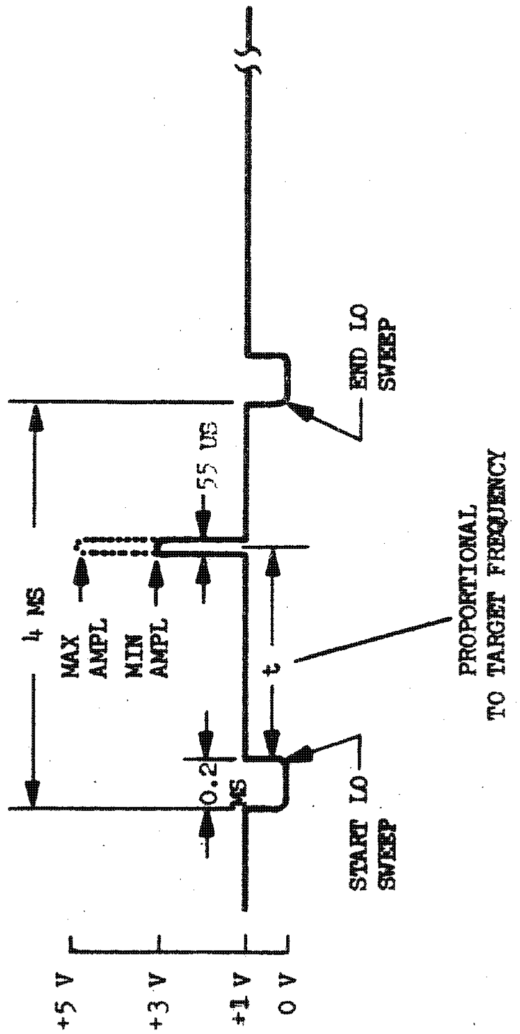


Figure 5.1 CW Detector Video Output

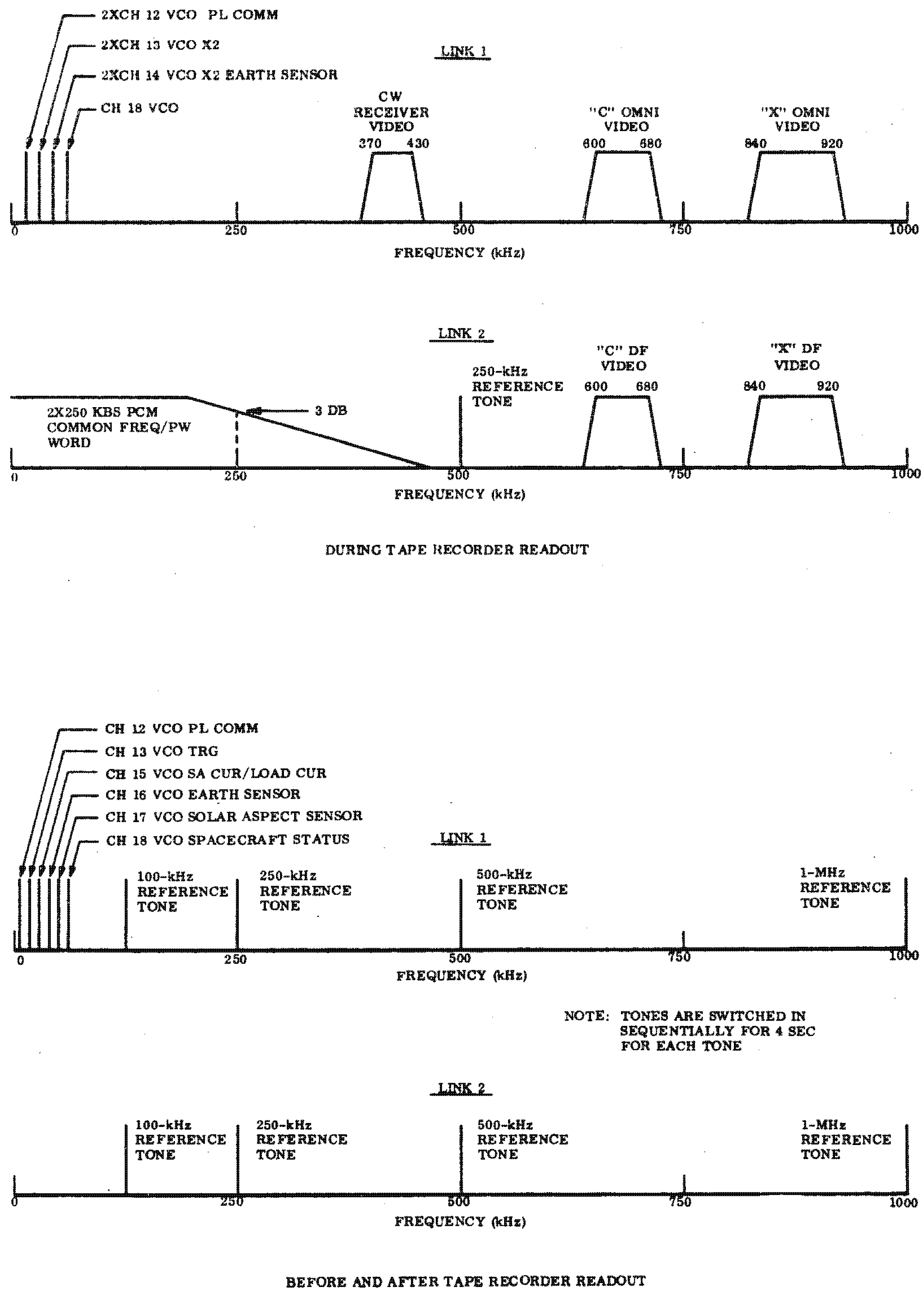


Fig. 6.1 Readout Data Format

a. DF channel frequency/pulsewidth measurement PCM word at a 250-kbps rate common to C- and X-Bands

b. 250-KHz reference tone

c. DF video (20-KHz BW VCO at 320-KHz center frequency).

6.2 X-Band Data Readin

Tape recorder track no. 1, in addition to the above C-Band information, contains omnivideo data (20-KHz BW VCO at 440-KHz center frequency) for X-Band. Tape recorder track no. 2 contains, in addition to the above information for C-Band, DF video data (20-KHz BW VCO at 440-KHz center frequency) for X-Band.

6.3 Tape Recorder Readout

Data from the tape recorder are read out attwice the readin speed. During the readout period, the vehicle 90-point status commutator is summed with the tape recorder track no. 1 output.

6.4 Tape Recorder Before-and-After Readout

Four reference tones are sequentially switched onto each data link for a period of four seconds each before-and-after tape recorder readout, and this is repeated for an entire before-and-after readout period. Link 1 also contains the following IRIG channels:

a. Channel 12 (Payload commutator)

b. Channel 13 (TRG time code)

c. Channel 15 (Solar array current)

d. Channel 16 (Earth sensor)

e. Channel 17 (Solar aspect sensor)

f. Channel 18 (Vehicle status)

Maximum readout time is 5.5 minutes.

7. ANCILLIARY EQUIPMENT

7.1 Payload Status Commutator

A single 45-point RZ format commutator provides status data for both the C- and X-Band payloads on an IRIG channel 12 VCO. Figure 7.1 illustrates the format for this commutator.

7.2 Time Reference Generator

The time reference generator (TRG) for both receivers is installed in the C-Band receiver subsystem. It is a 24-hour clock that provides a time word at the rate of one word per second. A 250-KHz signal from the TRG is applied to the frequency measurement subsystem for processing frequency data. This signal is passed through an astable oscillator which will continue at a slightly lower rate if the 250-KHz input signal is removed, providing a backup reference tone and PCM clock in the event that the TRG fails.

A 250-Hz signal is modulated by the AN/GSQ-53A time code word format and applied to a channel 13 VCO through a bandpass filter. Four reference tones (100 KHz, 250 KHz, 500 KHz, and 1 MHz) are supplied to a sequencer which steps through the tones at 4-second intervals for the tape recorder before-and-after readout mode.

7.3 Power Supplies

Redundant power supplies are incorporated within the payload. In case of failure with the preregulator or one of the six output regulators, a redundant regulator can be switched in. Switching logic circuitry for all regulators is negated when readin power is applied to the payload to prevent damage to the power supplies due to relay switching.

7.4 Payload Calibrator

A test signal derived from a 1000-pps, 2-usec pulsewidth generator (TSG) is coupled into each receiver channel to determine the proper functioning of all receiver channels and data measuring systems. The 1000-pps signal is coupled directly into the DF channel and is counted down by four before being coupled into one of the omnichannels. The test signal is applied to the receiver subsystem for 400 msec of every minute during tape recorder readin. It appears in each band every other minute and alternates between the two bands. The TSG frequency for each band is as follows:

a. C-Band 6.00 GHz

b. X-Band 10.0 GHz

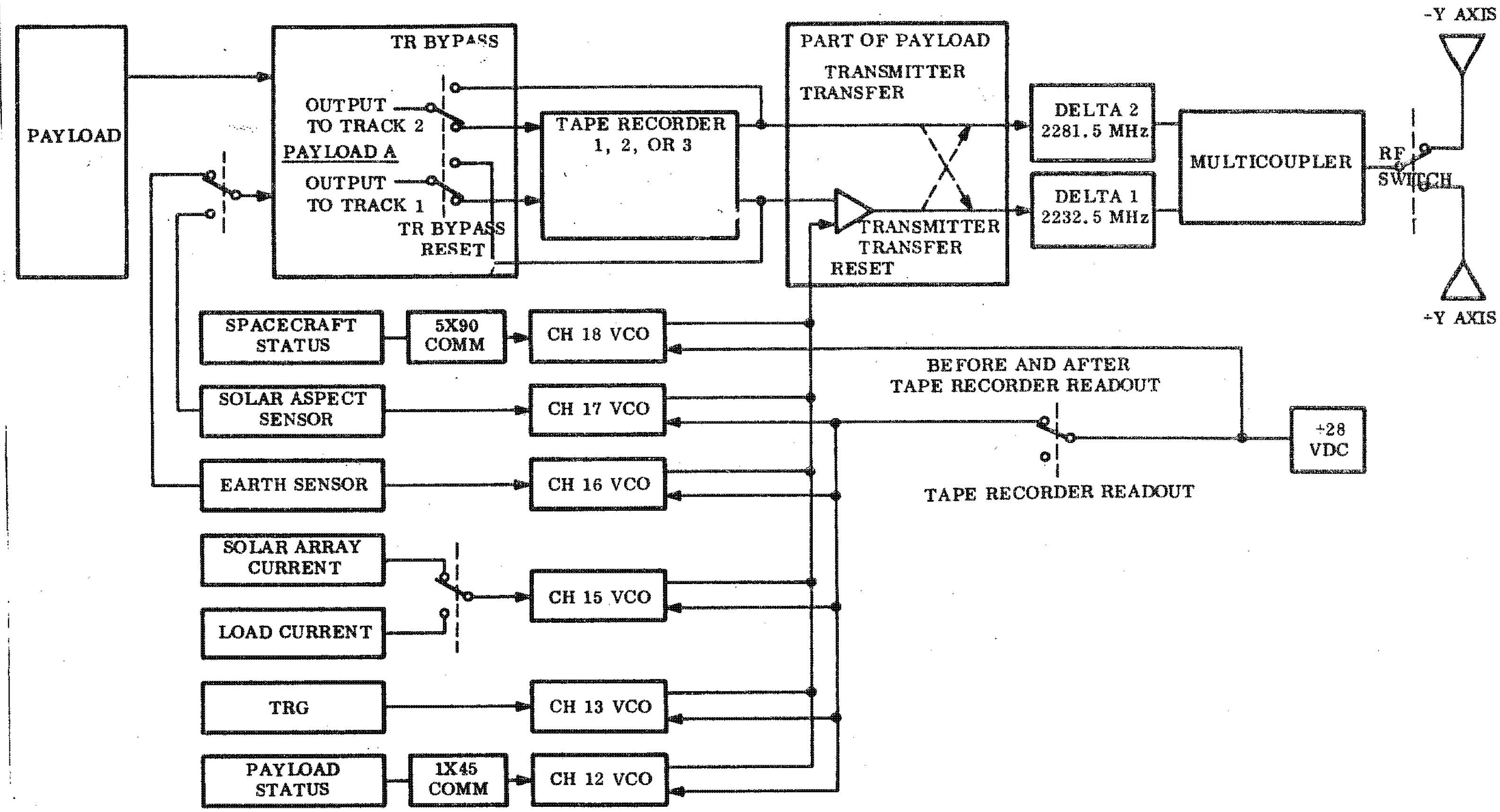


Fig. 7.1 Telemetry/Data Link Configuration

The rf test signal is followed by three video calibration pulses of 100-usec duration each and 100-usec separation. The amplitudes are at the following percentages of full dynamic range: 33, 66, and 100 percent (saturation). The video calibration signals are injected into the low-pass filters that follow the DF and omnivideo pulse stretchers. These signals provide a reference to processing personnel for setting thresholds for automatic ground processing and to data analysts for determining where in the dynamic range these thresholds were set.