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~~TS~~ NATIONAL RECONNAISSANCE OFFICE

WASHINGTON, D.C.

HE NRO STAFF

20 January 1970

MEMORANDUM FOR CHAIRMAN, SIGINT OVERHEAD
RECONNAISSANCE SUBCOMMITTEE

SUBJECT: Mission Description of SIGINT Mission 7335 (TIVOLI III)

The mission description for TIVOLI III is forwarded as an attachment to this correspondence. This SIGINT reconnaissance system is designed to meet the requirements of USIB D-41.14/246, USIB S-10.9/2, USIB S-10.9/5, and USIB S-10.9/8.

Mission 7335 is a spin-stabilized P-989 satellite which is scheduled to be launched into a nominal 275-nautical mile circular orbit by a Thor/Agena booster. The TIVOLI III intercept system can perform directed search and a limited general search against signals using intra- and inter-pulse modulation within the 50 to 4020 MHz band. TIVOLI III system design is basically the same as TIVOLI I and TIVOLI II with certain design modifications which allow more flexible collection and provide additional intercept information. The attached mission description contains an outline of those aspects at variance with SORS 11./12, dated 18 January 1968 and SORS 11./34, dated 4 February 1969.

The planned launch date, predicated on launch of the primary payload is 18 February 1970. Mission lifetime is expected to be 9 months. A nominal 10 to 12 collection revs per day should be available for mission accomplishment. It would be meaningful to the National Reconnaissance Office if SORS collection guidance specifies geographic area/target coverage in priority order, referenced when possible to time of day.

EDWIN F. SWEENEY
Colonel, USAF
Deputy Director for
Satellite Operations

Attachment
Mission Description

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MISSION DESCRIPTION

TIVOLI III

1.   INTRODUCTION

     Mission 7335 (TIVOLI III) is a versatile, SIGINT satellite which will collect technical intelligence data in the 50 to 4020 MHz frequency band. The design of TIVOLI III is very similar to the design of TIVOLI I and II, and for that reason the reader should refer to the previous TIVOLI Mission Descriptions (SORS 11./34, BYE-1106-69 and SORS 11./12, BYE-1236-68) for detailed technical information. This mission description will list the new capabilities, provide a brief system review, and discuss the various operating modes and outputs of TIVOLI III.

     TIVOLI III has several new capabilities which the previous TIVOLI payloads did not have. These new capabilities are as follows:

    o   Main beam detection channel

    o   Selectable dwell times

    o   Selectable input attenuation

    o   Tape recorder calibration signal

    o   Programmed tape recorder selection

    o   Experimental attitude control system

A description of the above features appears later at appropriate places in this document.

     The preliminary orbital parameters and general system characteristics are as follows:

PRELIMINARY ORBITAL PARAMETERS

Altitude:	275 n.m.
Inclination Angle:	$90° \pm 20°$
Orbital Life:	9 months, minimum
Initial Spin Rate:	62 ± 3 rpm

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Mimimum Spin Rate After Nine
   Months on Orbit: 40 rpm

SYSTEM CHARACTERISTICS

Intercept System Frequency Range:	50 to 4020 MHz
Frequency Accuracy:	Maximum error, 0.01% of input frequency
Tuning (Digital):	a. Any one of 3970 integer frequencies.
	b. Tunable over various pre-selectable sectors in either 1-MHz or 4-MHz steps. The step dwell time is selectable at 1, 2, or 4 seconds.
Noise Figure:	9 dB at 50 MHz, increasing to 12 dB at 4000 MHz
RF Dynamic Range Main-Beam Channel:	-55 to -30 dBm*
Log IF Channels:	-95 to -55 dBm*
Effective RF Bandwidths:	
Main-beam Channel	290 MHz (nominal)
Wide IF	10 MHz
Narrow IF	1 MHz
Signal Outputs Available:	a. Envelope Detector
	b. FM Discriminator
	c. 750 MHz wideband video
	d. 1 MHz and 10 MHz Predetection
	e. Main-beam channel

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* By selecting the maximum attenuation prior to the preamplifiers, the maximum received signal can be changed by ∤ 30 dB.

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2.   GENERAL DESCRIPTION

The payload system contains five broad beamwidth receiving antennas, the TIVOLI III intercept system, three 1-MHz tape recorders, two UHF transmitters, a command receiver and decoder, earth and solar sensors, a spacecraft status subsystem, and a magnetic reaction spin axis attitude control system. A simple block diagram is given in Figure 1.

Five separate intercept system antennas are required to cover the frequency range from 50 to 4020 MHz. The intercept antennas are deployed on the spacecraft as shown in Figure 2. The antenna specifications are as follows:

Sensor C1 (Low-Frequency Monopole)

Frequency Range (Min.):	50 to 75 MHz
-3 db Gain:	-5 db
Beamwidth:	75 degrees (approximately)

Sensor C2 (High-Frequency Monopole)

Frequency Range (Min.):	75 to 100 MHz
-3 db Gain:	-5 db
Beamwidth:	75 degrees (approximately)

Sensor B (VHF Planar Spiral)

Frequency Range (Min.):	100 to 500 MHz
-3 db Gain, High Frequency:	0 db
-3 db Gain, Low Frequency:	0 to -18 db
Beamwidth:	80 degrees (bidirectional)

Sensor A2 (UHF Conical Spiral)

Frequency Range (Min.):	400 to 2020 MHz
-3 db Gain:	+ 3 db
Beamwidth:	90 degrees

Sensor A1 (S-Band Conical Spiral Array)

Frequency Range (Min.):	1980 to 4020 MHz
-3 db Gain, High Frequency:	+7.5 db
-3 db Gain, Low Frequency:	+5 db
Beamwidth:	40 degrees by 80 degrees

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A1

A2

B

C2

C1

PART OF PAYLOAD	
2-4 GHz	
0.5-2 GHz	
0.1-0.5 GHz	
72-99 MHz	
50-75 MHz	

PAYLOAD DATA

T/R SELECT LOGIC and SWITCH INPUT

T/R No. 1
T/R No. 2
T/R No. 3

T/R SELECT LOGIC and SWITCH

PAYLOAD DATA

Part of Pay-load

RF SWITCH

LINK I Transmitter

MULTI-COUPLER

LINK II Transmitter

+Y TLM ANTENNA

-Y TLM ANTENNA

PAYLOAD DATA

T/R BYPASS
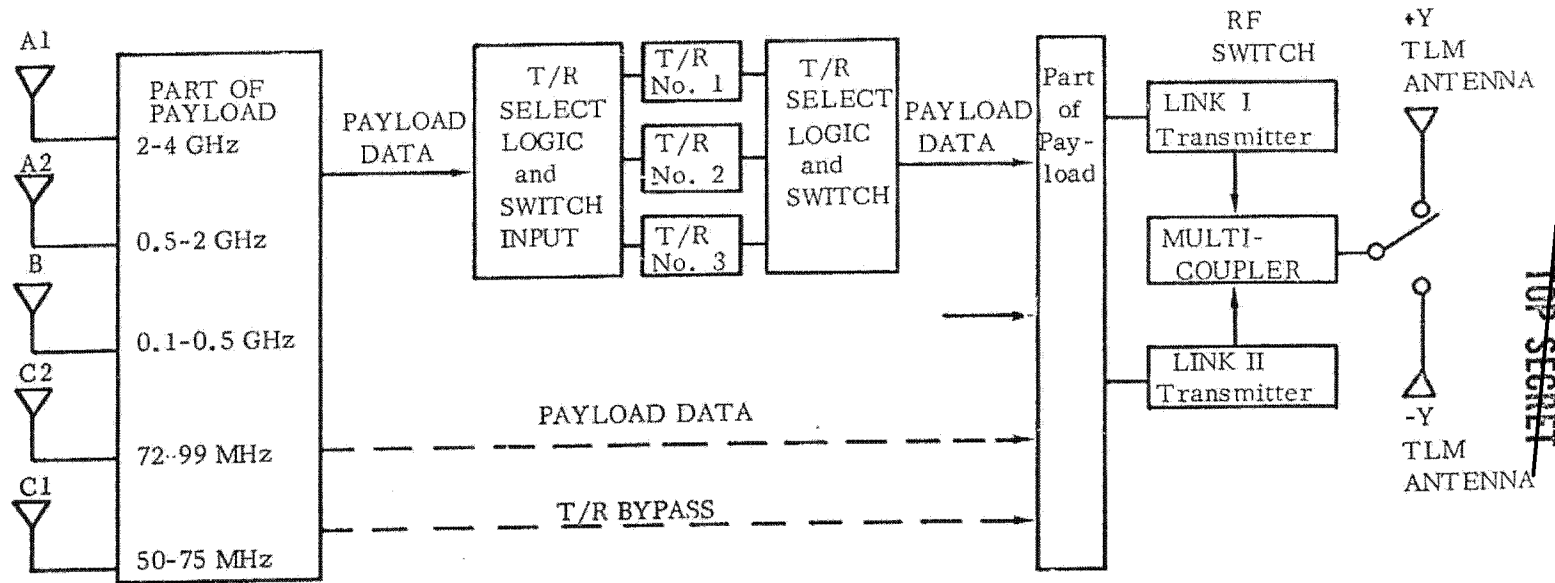
Figure 1.   Orbital Payload, Simplified Block Diagram

Sensor B

UHF TLM

Sensor A-1

Command Ant.

Earth Sensor

Sun Sensor

Sensor
C-2

Sensor A-2

Sensor C-1/
UHF TLM

35°

+Z
∅=90°
θ=90°

+Y
θ=90°
∅=0°

-Y
Spin Axis
θ=0°
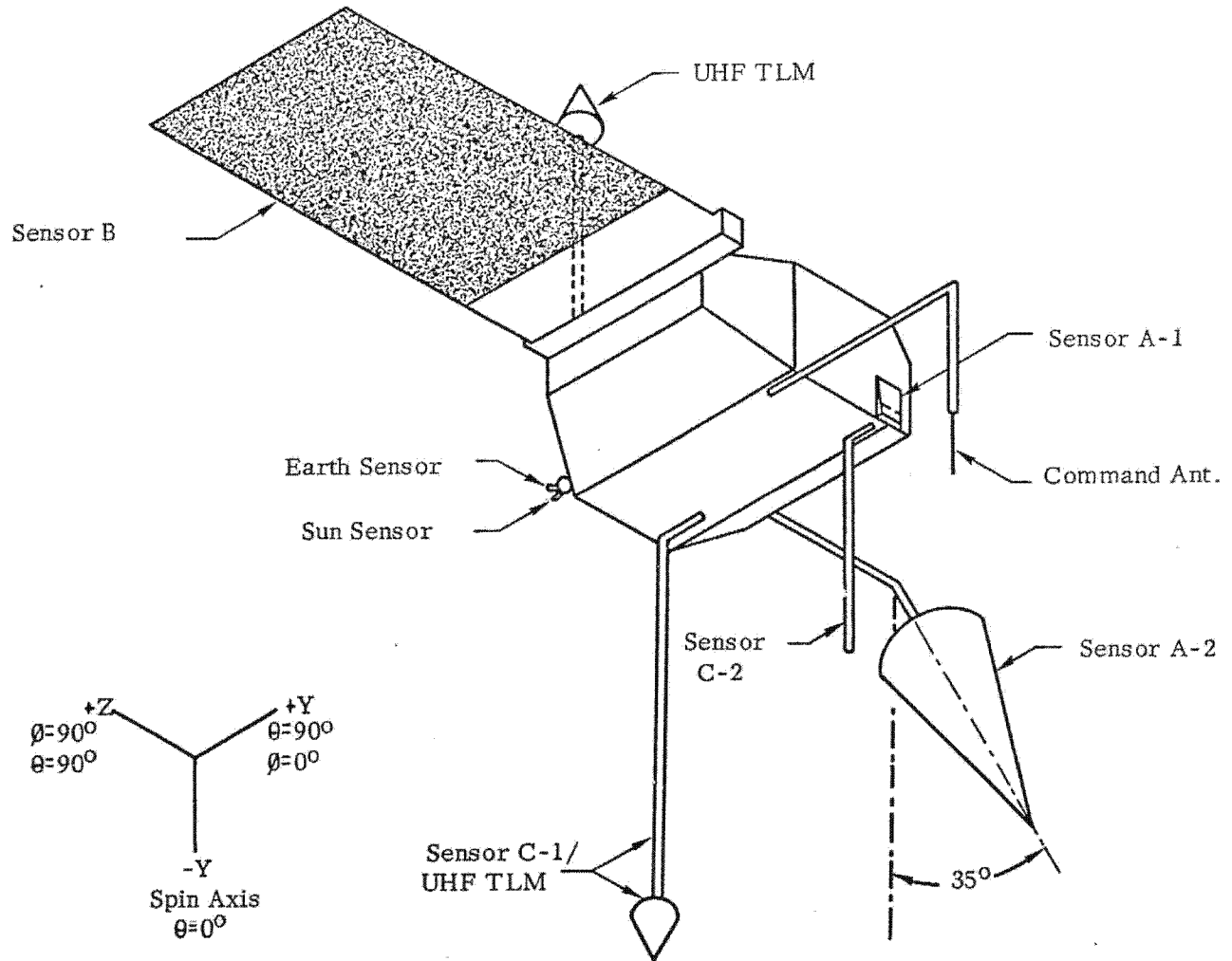
Figure 2.   Spacecraft Antenna Configuration

The intercept system uses a frequency translator to appropriately condition intercepts in the 50 to 4020 MHz frequency range to be accepted by a single-channel, VHF, superheterodyne receiver. The translator frequency bands are important because, in any one payload configuration, the payload cannot scan outside the selected translator band. The bands are as follows:

Frequency Band	Frequency Range (MHz)
0	100-500
1	480-770
2	730-1020
3	980-1270
4	1230-1520
5	1480-1770
6	1730-2020
7	1980-2270
8	2230-2520
9	2480-2770
10	2730-3020
11	2980-3270
12	3230-3520
13	3480-3770
14	3730-4020
15	50-307 $\begin{cases} 50\text{-}99 \\ 100\text{-}307 \end{cases}$

The receiver output is manipulated by the signal processer and various composite signals are available to be recorded. The specific outputs available are discussed in Section 4. A simplified block diagram of the intercept system is given in Figure 3.

The system uses three dual track, six minute capacity, 1-MHz tape recorders. This provides redundancy in case of failure and also allows multiple readins before requiring a readout. A new capability on TIVOLI III is the ability to switch tape recorders by stored program command; recorder selection was previously done by ground command. We may now use several recorders on a single rev or on successive revs with no intervening command station.

The UHF transmitters, command receiver and decoder, earth and solar sensors, and spacecraft status subsystem are not directly related to intercept system and will not be discussed in this description. The experimental, magnetic reaction spin axis attitude control system also is not directly related to the intercept system, but it will be discussed because it is a new capability in
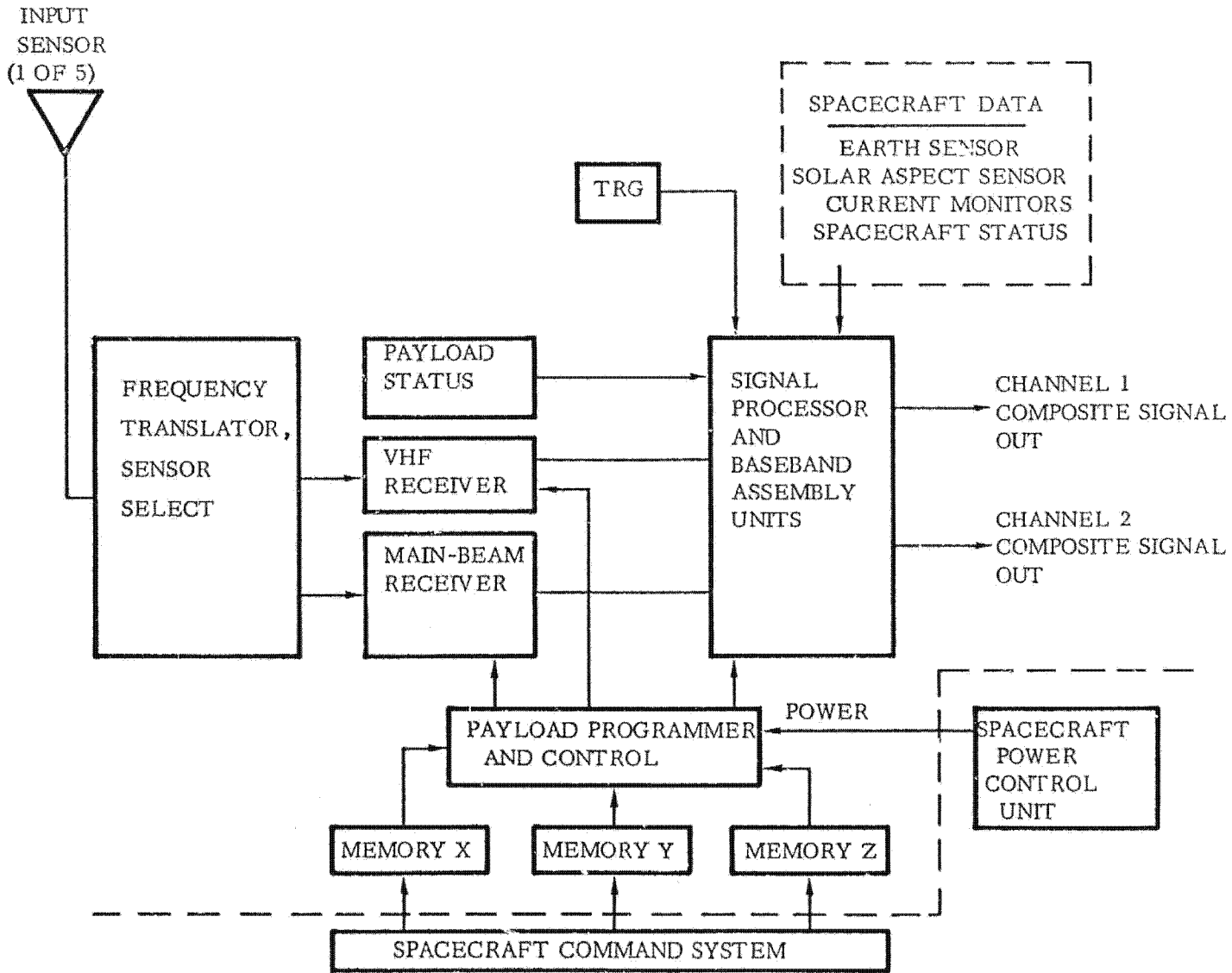
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Figure 3.   Intercept System, Simplified Block Diagram

TIVOLI III. There is no requirement to reorient the TIVOLI III spin axis, but a future Program 989 satellite, ARROYO, will require reorientation of the spin axis during flight. Therefore, the spin axis attitude control system was included on TIVOLI III for testing and demonstration in preparation for the launch of ARROYO (ARROYO is a COMINT mapping payload to be launched in March 1971

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(b)(3)

The TIVOLI III attitude control system uses a large coil of magnet wire fitting over the outside of the satellite structure to produce a magnetic field. This field reacts with the magnetic field of the earth and realigns the spin axis plus or minus 20 degrees around the nominal spin axis, which is parallel to the earth's axis of rotation. Reorientation of the satellite's spin axis will require approximately one day, and during that time, no SIGINT collection can be accomplished because of power constraints.

The use of the attitude control system on TIVOLI III will be primarily experimental, although it might be used to enhance collection against some targets. Such cases are few because of the near omni-directional characteristics of the TIVOLI antennas, but these cases are not nonexistent. For example, on TIVOLI II we attempted to intercept microwave poke throughs from Sary Shagan, but were unsuccessful because the signals were approaching the satellite nearly perpendicular to the axis of the intercept antenna. By adjusting the satellite spin axis, and thus the intercept antenna, it may be possible to intercept such signals. Generally, however, the spin axis reorientation should have no effect on the collection of SIGINT data.

3.   COLLECTION ADJUSTMENT

Numerous adjustments can be made to the TIVOLI III collection system to optimize intercept of a particular target signal. These different adjustments are discussed in the following paragraphs.

The first possible selection is the operating mode, which basically controls the RF and IF bandwidths. The four operating modes are as follows:

Mode A - Mode A should be used whenever a receiver bandwidth of 10 MHz is desired. Because of the limited bandwidth capability (1 MHz) of the telemetry system, the receiver IF is split into two channels, and an IF-folding technique is used to obtain the 10 MHz bandwidth. Mode A is most effective when receiving a signal whose carrier frequency changes as a function of time from ± 0.5 to ± 5.0 MHz about the center frequency to which the intercept system is tuned.

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Because of the IF-folding technique, course frequency measurements are made by an FM discriminator which appears on a channel H VCO on output channel 1A. Therefore, output channel 1A should be selected when in Mode A. Fine frequency measurements are made from the predetected output signals.

Mode B - Mode B provides unfolded predetection signals resulting from a 1 MHz predetection IF bandwidth. The bandwidth of the processed signal IF amplifier for this mode is 10 MHz, thus providing a 10-MHz discriminator and envelope detector as in Mode A.

Mode C - Mode C is characterized by a 1-MHz bandwidth preceding all log-IF amplifiers. Consequently, the envelope detector, the FM discriminator, and the predetection subsystem cover a 1 MHz band. Mode C should be used when:

    a. A higher intercept system sensitivity is desired. The sensitivity of the predetection subsystem is improved approximately 5 dB and the sensitivity of the envelope detector and FM discriminator subsystem is increased by about 10 dB.

    b. The intercept system is operated in a dense signal environment.

    c. A narrow 1-MHz tuning window is desired.

Mode D - Mode D is identical to Mode C except that the wideband video subsystem is automatically connected to the intercept system channel 1 output terminals. Also, the output bandwidth of the wideband video subsystem is reduced to 250 KHz and the pulse stretcher is bypassed. The Mode D capability was included in TIVOLI III to support a special collection exercise.

In modes A, B, or C, the intercept system may be fixed-tuned to any one of the integer frequencies within the intercept system passband or may be continuously step-tuned across any 10, 20, 40, 80, 160, or 290 MHz sector of bandwidth within any of the translator bands. Also, beginning at any arbitrary frequency within a translator band, the receiver will scan from this initial frequency to the band-edge. The band-edge frequency of each band is shown in Section 2. The receiver steps in increments of 1 or 4-MHz depending upon the width of the frequency spectrum which is being scanned. Selectable dwell times of 1, 2, or 4 seconds are available; on previous TIVOLI payloads, only a 4-second dwell time could be selected.

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The receiver may be operated in either automatic (AGC) or manual
(MGC) gain control. Normally, the AGC mode can be used to provide the opti-
mum intercept system output terminal noise level, thereby eliminating the
necessity of selecting a new MGC level whenever a new translator frequency
band is selected, as is required in the MGC mode. The noise-riding AGC, when
operated in a [   ] is subject to capture as a result of the
log-IF amplifier preceding the detector. As a result, its use should be avoided
if [   ] are expected. The MGC mode permits the intercept system
to be used in the presence of [   ] and also enhances the versatility
of the gain control circuit. There are eight levels of manual gain available,
ranging from plus 6 to minus 15 db in 3 db increments.

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(b)(3)

The sensitivity of the payload is selectable by real time command.
Four different levels are available, as opposed to only two on previous TIVOLI
payloads. By commanding different attenuator settings, the following sensitivities
are obtained.

-95 to -55 dbm
-85 to -45 dbm
-75 to -35 dbm
-65 to -25 dbm

The following calibration signals are available for transmission on
the UHF telemetry links or for recording on the payload tape recorders.

100-KHz sine-wave modulated with the AN/GSQ-53A time code
250-KHz sine-wave unmodulated
500-KHz sine-wave unmodulated
1-MHz sine-wave modulated with the AN/GSQ-53A time code
Composite IRIG channel 15, 16, and 17 VCO's.

On previous TIVOLI payloads, these signals could be transmitted, but could not
be recorded on the tape recorder.

4.   PAYLOAD OUTPUTS

The detailed, composite payload output signals are shown in Figure 4.
Channel 2 data is always being recorded; channel 1A or 1B data is selected for
recording by stored program command. The specific data available is as
follows:

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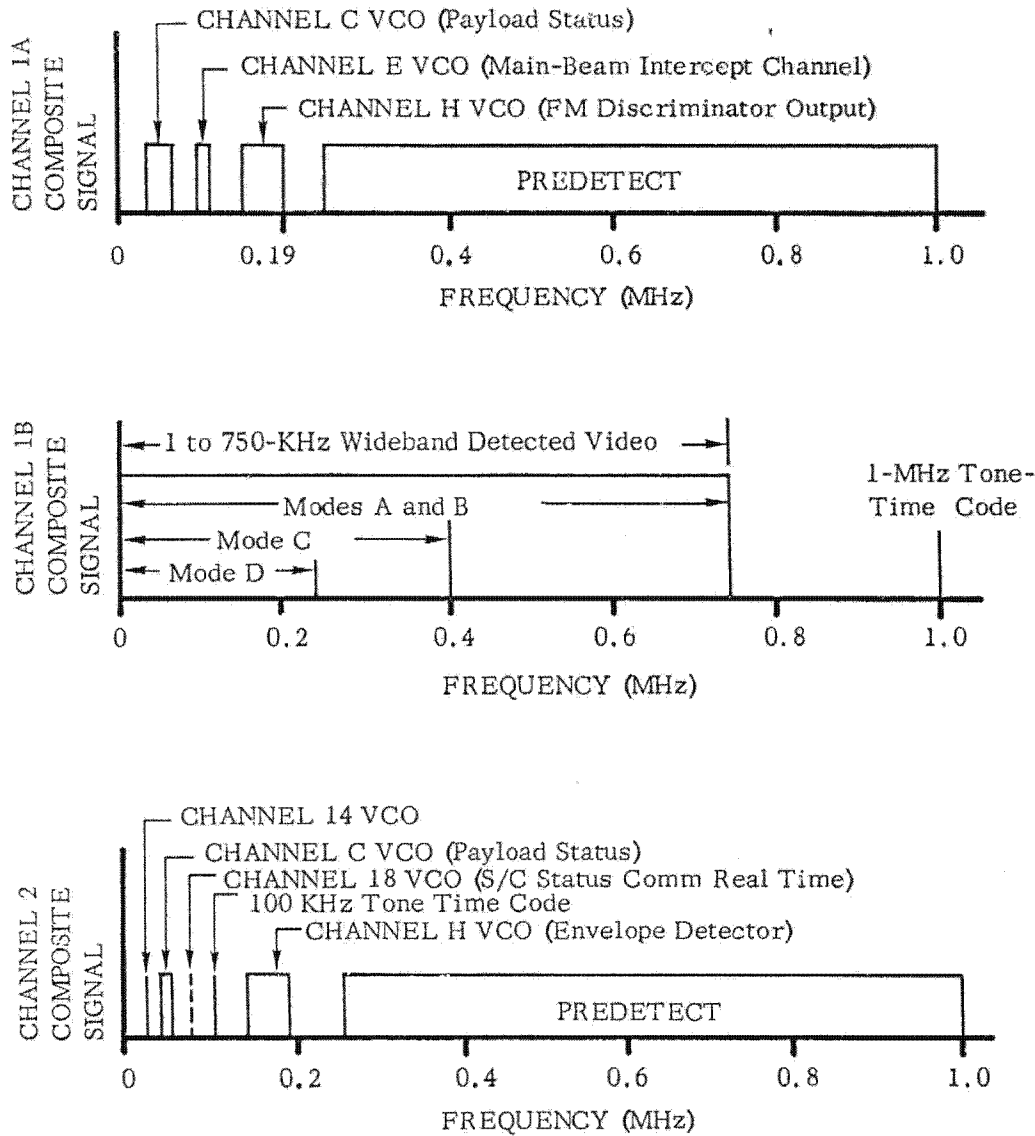
Figure 4. Frequency Multiplex Format

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Envelope Detector Subsystem

This subsystem continuously detects the peak envelope of received signals at the processed signal log-IF amplifier output terminals and conveys the information in terms of proportional signal voltage to the intercept system processed signal IF amplifier output terminals via a pulse stretcher and a channel H VCO. The flat-top pulse stretcher used will follow slowly rising signals and will extend the peak value for 60 usec. Hence, all narrow input pulses (i.e., in the order of 5-usec wide) will appear in the output as pulses approximating a

(b)(1)
(b)(3)

The stretching technique is used to reduce the frequency spectral width of the received pulse to a width that can be handled by the channel H VCO. The envelope detector subsystem also provides nonstretched wider bandwidth video outputs to the wideband video subsystem.

The envelope detector subsystem has two operational bandwidths: When the intercept system is in mode A or B, the predetection bandwidth is 10 MHz and the postdetection bandwidth is 4 MHz; in modes C and D, the bandwidths are 1.0 MHz and 400 KHz, respectively.

FM Discriminator Subsystem

This subsystem continuously detects the frequency modulation of received signals at the processed signal IF amplifier output terminals and conveys the frequency of the input signal(s) in terms of voltage amplitude to the intercept system channel 1A output terminals via a pulse stretcher, a 25-KHz low-pass filter, and a channel H VCO. The discriminator output signal is direct-coupled to the VCO. The pulse stretcher adds a 25-usec exponentially decaying tail to each pulse output from the discriminator. The nominal accuracy of the discriminator subsystem is better than ± 5 percent within the 10-MHz IF passband.

Similar to the envelope detector subsystem, the FM subsystem provides wider bandwidth outputs to the wideband video and also uses two operational bandwidths, with the wider bandwidths available in modes A and B. A common discriminator is used for modes A, B, C, and D; hence, the discriminator output is amplified in modes C and D to provide a signal voltage range compatible with modes A and B.

Wideband Video Subsystem

This subsystem accepts detected, nonstretched video signals from either the envelope detector or the FM discriminator subsystems and conveys them to the intercept system channel 1B output terminals via a pulse stretcher and a low-pass filter. In modes A and B, the filter has a cutoff frequency of 750 KHz; in mode C, 400 KHz; and in mode D, 250 KHz. The option exists to automatically alternate between the envelope detector and the FM discriminator with a dwell time equal to one-half the selected frequency dwell time.

Predetection Subsystem

A 750 MHz predetected output signal is available on channels 1A and 2. When in mode A, these two 750 MHz segments are sequentially switched to provide coverage of the entire 10 MHz frequency band selected. In mode B, these two segments overlap and provide a 1 MHz bandwidth.

Main Beam Receiver

The main beam intercept receiver output is continuously available on a channel E VCO on data channel 1A. The main beam receiver uses a low sensitivity, wideband envelope detector subsystem which permits estimation of received signal powers in the range of -55 to -30 dbm. The selectable input attenuators permit adjustment of this range to -25 to 0 dbm in increments of 10 db. Previous TIVOLI payloads did not have this capability.

Other

Payload and spacecraft status data appears on a channel C and a channel 18 VCO respectively. A 100 KHz and a 1 MHz timing tone also appears in the output data.