DATA COLLECTION PLATFORM RADIO SET

DESIGN PLAN

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1.0 INTRODUCTION

1.1 Purpose

This document has been generated in accordance with DOC Contract 1-35287 and constitutes the required Design Plan documentation.

1.2 Design Plan Objectives

The objectives of the design plan are to provide the following:

1.2.1 Electrical Design Specifications

(a) A detailed block diagram which separates the system into physically and functionally identifiable hardware assemblies.

(b) Design and performance specifications, which include a functional description, theoretical design analysis, and a detailed interface specification.

1.2.2 Mechanical Design Specifications

(a) A detailed description of the design techniques that will be used for the various modules and trays.

(b) A detailed description of the overall packaging concept.

1.2.3 Schedule Charts

A detailed schedule diagram is provided, relating the hardware design, fabrication, documentation, and test at all levels of functional assembly, and showing predicted completion dates.

1.3 Brief Description of the DCPRS

1.3.1 General Description

The design presented in this design plan can be implemented within the present state-of-the-art and in the allowed schedule. It will meet or exceed the minimum specified requirements, including the desired areas of coherent reception and transmission, synthesized channelization of the transmitter, tunability of the receiver, modular construction, and special emergency monitoring of sensor data or prime power status. These and all other important areas of equipment design have been carefully analyzed in this design plan to assure the evolution of an optimum design approach that is consistent with cost and schedule objectives. Special attention was directed toward achieving a flexible design concept to allow for expandable capability to satisfy as many varied users as possible. Salient features of the design are:

(a) Coherent reception and retransmission

(b) Synthesized 100-channel transmitter

(c) Error cancelling receiver injection system to minimize self-jamming

(d) Modular construction allowing interchangeability, and the same chassis design to serve both the self-timed and interrogated DCPRS.

(e) Computer-aided design of all active stages, using the Magnavox AMPCAL program, to assure stable performance over the full range of environmental and operational conditions.

Tables 1-1 and 1-2, respectively, give a listing of the major specifications for the Interrogated DCPRS and for the self-timed DCPRS.

TABLE 1-1. INTERROGATED DCPRS SPECIFICATIONS

OPERATING FREQUENCIES	
Receive Transmit	468,825,000 Hz 401,849,588 to 401,998,095 Hz
CHANNEL SPACING	1500.04 Hz
NUMBER OF CHANNELS	100
POWER OUTPUT	5.0 watts minimum
SPURIOUS RESPONSE	Non Harmonic down 50 dB 2nd Harmonic -26 dB 3rd Harmonic -35 dB 4th Harmonic -50 dB
FREQUENCY STABILITY	1×10^{-9}/.25 Sec. short term long term equal to received carrier (Coherent System)
MODULATION	
Receive Transmit	±70° PSK Manchester coded Data ±70° PSK Manchester coded Data
CODE FORMAT FOR TRANSMISSION	ANSCII format at 110 baud.
SENSITIVITY	-130 dBm

TABLE 1-1. INTERROGATED DCPRS SPECIFICATION (CONT)

BIT ERROR PROBABILITY	1×10^{-6}
BIT RATE (RECEIVE)	100 BIT/sec
CODE ADDRESS	15 BIT MLS Message Sync 31 BIT Command
STANDBY POWER DISSIPATION	Less than 200 mW
SUPPLY VOLTAGES	+5V and +12.5V
ANTENNA	60^{o} beam width (maximum) at -3dB points, 13 dB gain, right hand circular polarization, 50-watt rating, and 50 ohm nominal impedance
TEMPERATURE RANGE	$-20^{o}C$ to $+50^{o}C$
SIZE AND WEIGHT	15.63 x 21.63 x 12.88 in. -17.07 lb

TABLE 1-2. SELF-TIMED DCPRS SPECIFICATION

OPERATING FREQUENCIES	401,702,521 Hz to 401,847,928 Hz
CHANNEL SPACING	3.0 kHz
NUMBER OF CHANNELS	50
POWER OUTPUT	5 watts minimum
SPURIOUS RESPONSE	Non Harmonic down 50 dB 2nd Harmonic -26 dB 3rd Harmonic -35 dB 4th Harmonic -50 dB
FREQUENCY STABILITY	5×10^{-7} over temperature 1×10^{-6} aging per year 1×10^{-9}/.25 sec. short term
TIMING	1 to 12 hour reporting intervals in 1 hour increments; may be set to any 30-second period in the 1 to 12 hour interval.
MODULATION	$\pm 70^{o}$ PSK Manchester Coded Data

TABLE 1-2. SELF-TIMED DCPRS SPECIFICATION (CONT)

CODE FORMAT	ANSCII format at 110 baud
ANTENNA	60^{o} beam width (maximum) at -3 dB points 13 dB gain righthand circular polarization 50 watt rating 50 ohm nominal impedance
STANDBY POWER DISSIPATION	Less than 100 mW
SUPPLY VOLTAGES	+5V and +12.5V
TEMPERATURE	$-20^{o}C$ to $+50^{o}C$
SIZE AND WEIGHT	15.63 x 21.63 x 12.88 in. -12.07 lb

The proposed DCPRS is illustrated in Figure 1-1. The unit contains all the interconnection circuitry necessary to function as either a self-timed or interrogated DCPRS. The overall dimensions are 15.63 in. wide by 21.63 in. long by 12.88 in. deep. The water tight lid is held in place by eight tamper-proof beveled nuts requiring a special spanner type wrench to loosen. In addition, a hasp arrangement and padlock prevent unauthorized entry. Inputs and outputs are made through a conduit at the base of the box. Mounting provisions are for either a 9 in. utility pole or flush mounting against a wall surface.

The antenna to be provided with the radio sets (Figure 1-2) meets all the electrical and environmental requirements of the government. Particular emphasis has been placed on size: sufficient to provide the required gain, but small enough to preclude excessive windloading that would necessitate an expensive mount scheme. The single axial mode helix antenna was selected as the most cost effective design of the various configurations evaluated. The antenna is supplied with an adjustable base plate permitting the set to be directive in both azimuth and elevation. Magnavox has elected to sub-contract to the Andrew Corporation for the manufacture of the antenna assembly. Figure 1-3 shows a typical DCP Installation.

Figures 1-4 and 1-5 are simplified block diagrams of the self-timed and interrogated DCPRS, respectively. The self-timed DCPRS consists of the following four modules which plug into the main chassis:

(a) Power Amplifier Module
(b) Synthesizer Module
(c) Clock and Control Module
(d) Diplexer/Filter Module

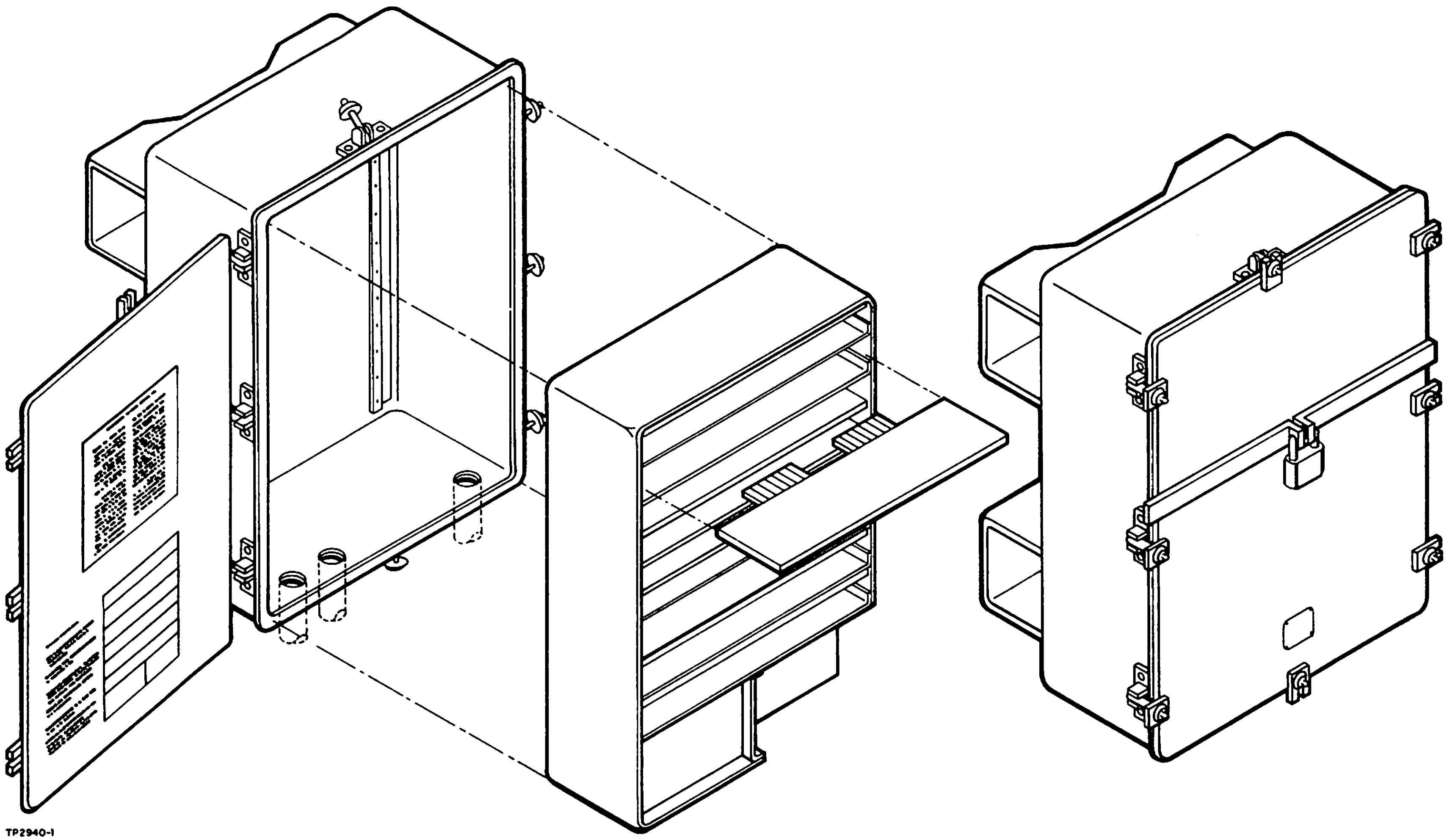

Figure 1-1. Open and Closed Views, DCPRS

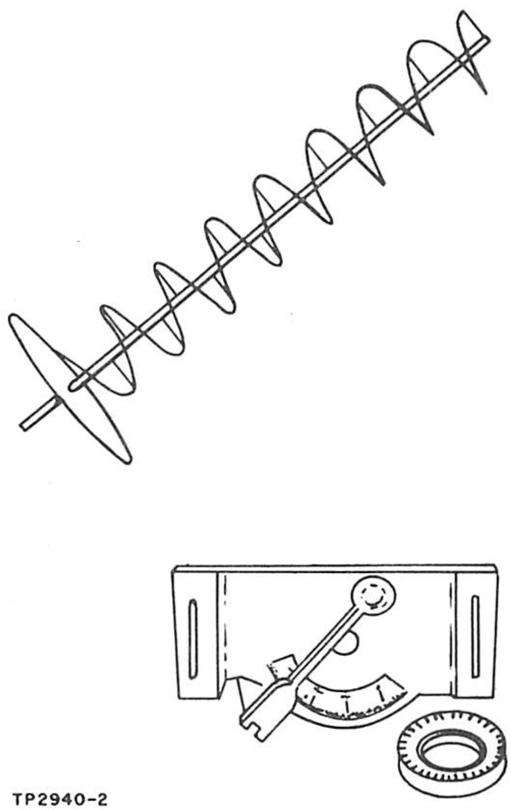

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Figure 1-2. Antenna System, DCPRS

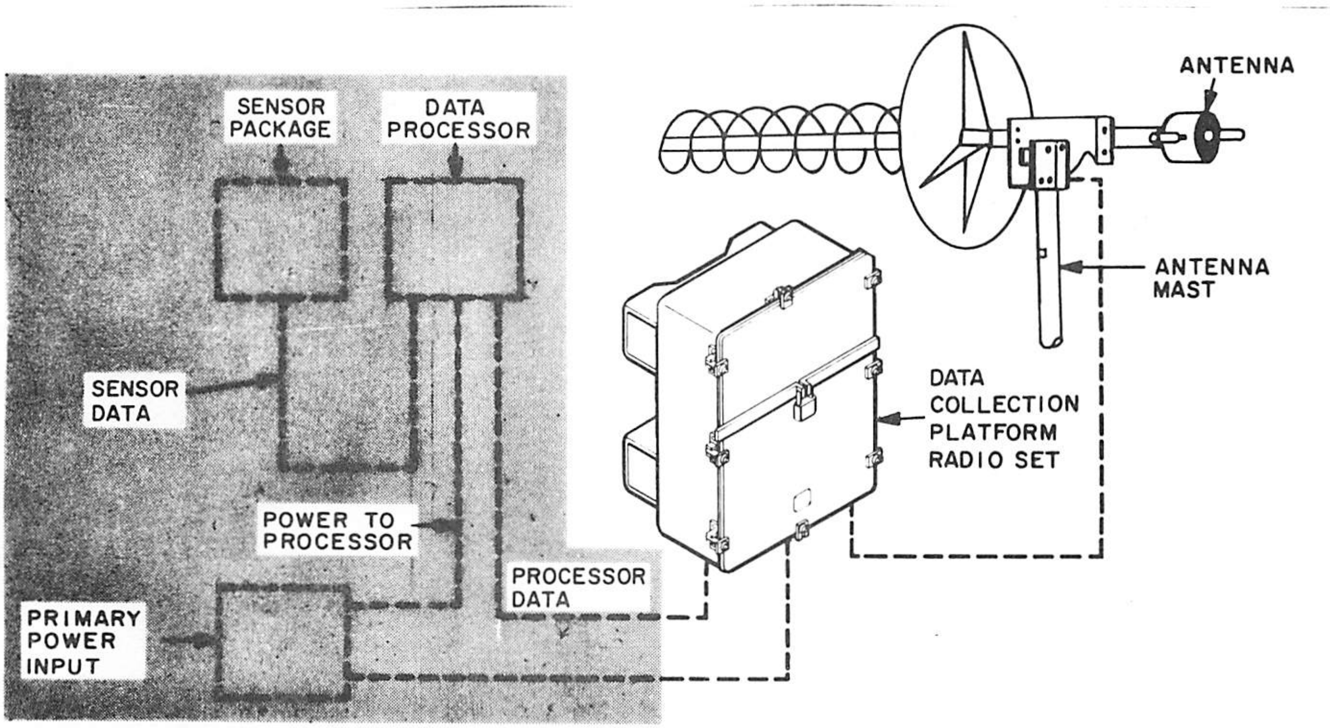

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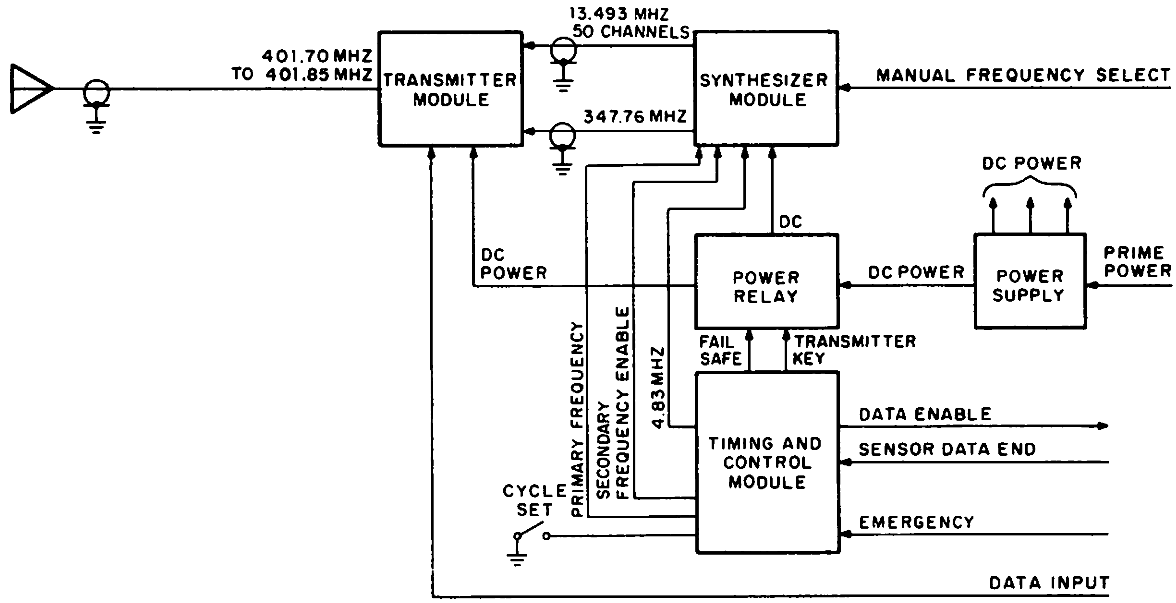
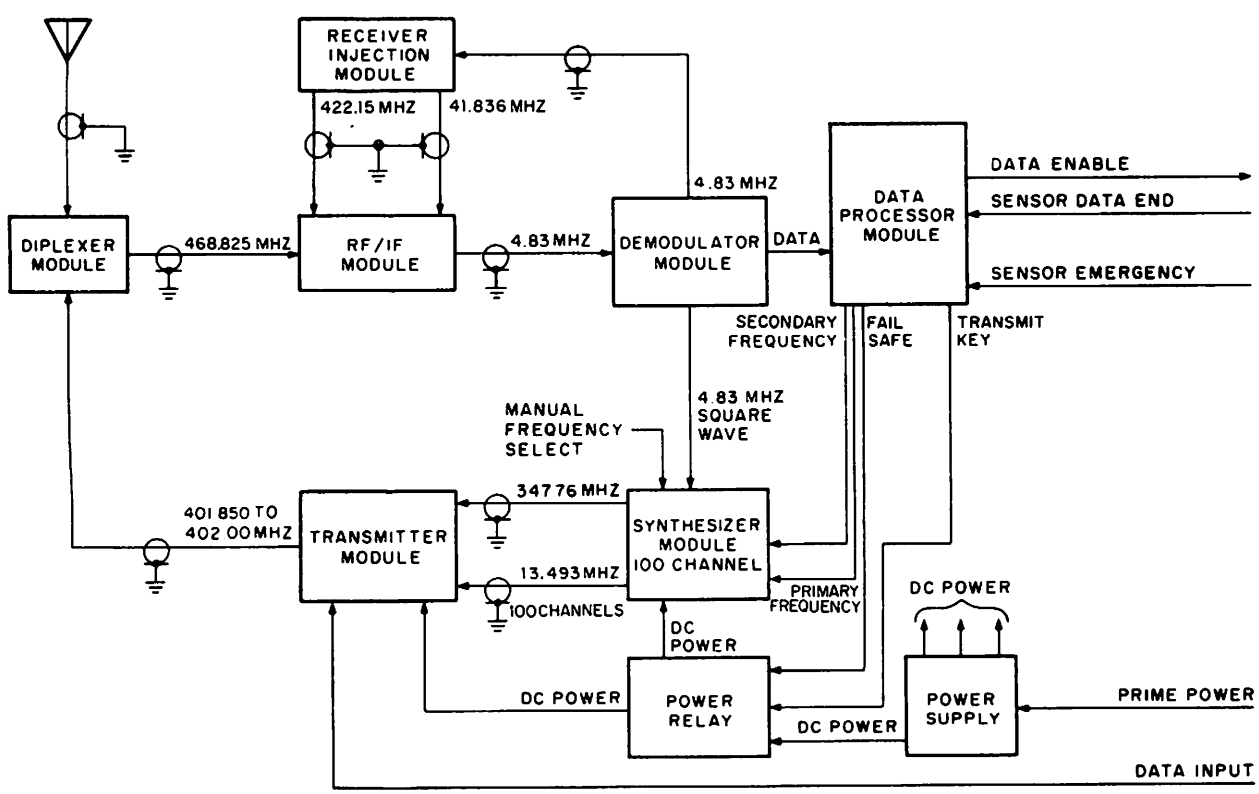
Figure 1-3. Typical Data Collection Platform Installation



Self-Timed DCPRS, Simplified Block Diagram



Interrogated DCPRS, Simplified Block Diagram

The interrogated DCPRS consists of seven modules which plug into the same chassis as the self-timed unit. A self-timed DCPRS is converted to an interrogated unit by removing the clock and control module and installing the RF/IF module, Demodulator module, and Data Processor module.

1.3.2 Performance

Reliable performance and ease of maintainability are assured through the use of integrated circuits, modular construction, and computer aided design. Other factors that will contribute to good performance are care in design, parts selection, and manufacturing. The integration of all of the above factors into the design and construction of the DCPRS will result in equipment that will meet the high standards of the U. S. Government.

1.3.3 Low Cost

Magnavox has had extensive experience in developing and manufacturing equipments requiring the type of cost consciousness demanded for the DCPRS. The design presented in this plan design has been optimized for cost, consistent with the stated requirements.

1.3.4 Low Power Drain

The problem of power drain is recognized to be acute and steps have been taken in the design to minimize the power consumption for both the self-timed and interrogated DCPRS's. These include

(a) Use of COS/MOS logic

(b) Use of low power amplifier techniques

(c) Application of power only when needed in the transmitter

(d) Use of fail-safe circuits to prevent inadvertent transmission

2.0 DCPRS DESIGN APPROACH

2.1 General

The purpose of this section is to discuss briefly the GOES System Requirements as they pertain to the DCPRS design.

The requirement for data collection from many widely separated meteorological sensor platforms and for transmission of the data via satellite to a few central collection centers in a synoptic or "on-demand" manner is one of the many operational requirements of the GOES (Geostationary Operational Environmental Satellite) System. To properly design the radio set for the communication link between the sensor platforms and the spacecraft requires an understanding of the GOES System requirements, of the manner in which the Data Collection System (DCS) will interface with the spacecraft, and of user demands. This section briefly describes the purpose and the capabilities of the GOES System, presents a review of the communications package aboard the spacecraft, and presents a DCS scenario. The section will end with a description of the interrogation signal format, the data response format, and a discussion of how the NBS time code can be recovered at the DCPRS.

The interrogation response formats presented are compatible with the proposed DCPRS design and meet the information reliability requirements in the Specification.

2.2 System Goals and Spacecraft Capabilities

The goal of the GOES System is to monitor atmospheric and surface environmental conditions on a continuous real-time basis. This goal requires the following spacecraft capabilities:

Radiometer (VISSR). - The use of a visible and infrared spin-scan radiometer (VISSR) to view the earth surface and cloud cover. It is done virtually in real time by visual techniques for daytime viewing and infrared for night.

Transmission of Data. - The VISSR data relay capability permits transmission of the observed data on the spacecraft to the Command and Data Acquisition (CDA) station at Wallops Station, Virginia, where it is reformatted for user purposes and retransmitted through the spacecraft to those Data Utilization Stations (DUS) within view of the spacecraft. To date, these DUS activities are located at San Francisco, California; Kansas City, Missouri; Miami, Florida; and Suitland, Maryland. From these major terminals, the data can be distributed to the Weather Forecast Stations located throughout the United States.

Retransmission of WEFAX. - The spacecraft will retransmit weather facsimile (WEFAX) cloud cover pictures to ships at sea, aircraft, and weather forecast stations located within view of the spacecraft. The FAX signal is sent by land line from NESS at Suitland, Maryland, to the Wallops Station CDA. From the CDA the data is transmitted to the users through the spacecraft.

Space Environment Monitoring System (SEM). - A Space Environment Monitoring (SEM) System will measure particle trajectory and energy content near the spacecraft and transmit that data to the Space Disturbance Forecast Center at Boulder, Colorado. The information can be used to predict major solar events, proton energy level content and magnetic vector field strengths. This data can then be distributed to research facilities concerned with the prediction and analysis of deep space phenomena. The Manned Space Flight Center will use this data to determine whether hazards exist for future manned space flights.

Data Collection Capability. - The Data Collection capability will enable remotely located, earth based environmental platforms to transmit data back to the CDA station through the spacecraft in a synoptic or commanded manner. As presently conceived, this data will then be relayed to NESS Suitland for dissemination to users. The DCPRS provides the communication interface between the remote platforms and the spacecraft. The spacecraft contains what is commonly referred to as a cross-strapped transponder; transmissions between the CDA and spacecraft at S-Band, while transmissions between the DCP field and spacecraft are at UHF.

2.3 Spacecraft Communication Transponder

2.3.1 Transponder

The block diagram of the spacecraft's communication transponder in Figure 2-1 reflects present understanding of The Magnavox Company.

2.3.2 Frequency Management Plan

The frequency plan for the various functions to be performed, as it is understood by Magnavox, is given in Figure 2-2 and 2-3. Figure 2-2 is the complete frequency plan for the GOES satellite system; Figure 2-3 shows the frequency plan for the data collection function of the GOES system.

2.4 Data Collection System (DCS)

The fundamental elements of the DCS are the remotely located DCP's, the GOES/SMS spacecraft, and the CDA Station (see the scenario of Figure 2-4). The two basic types of DCP's shown in the scenario are the self-timed and interrogated platforms. The type of DCP depends on how the user wishes data to be reported.

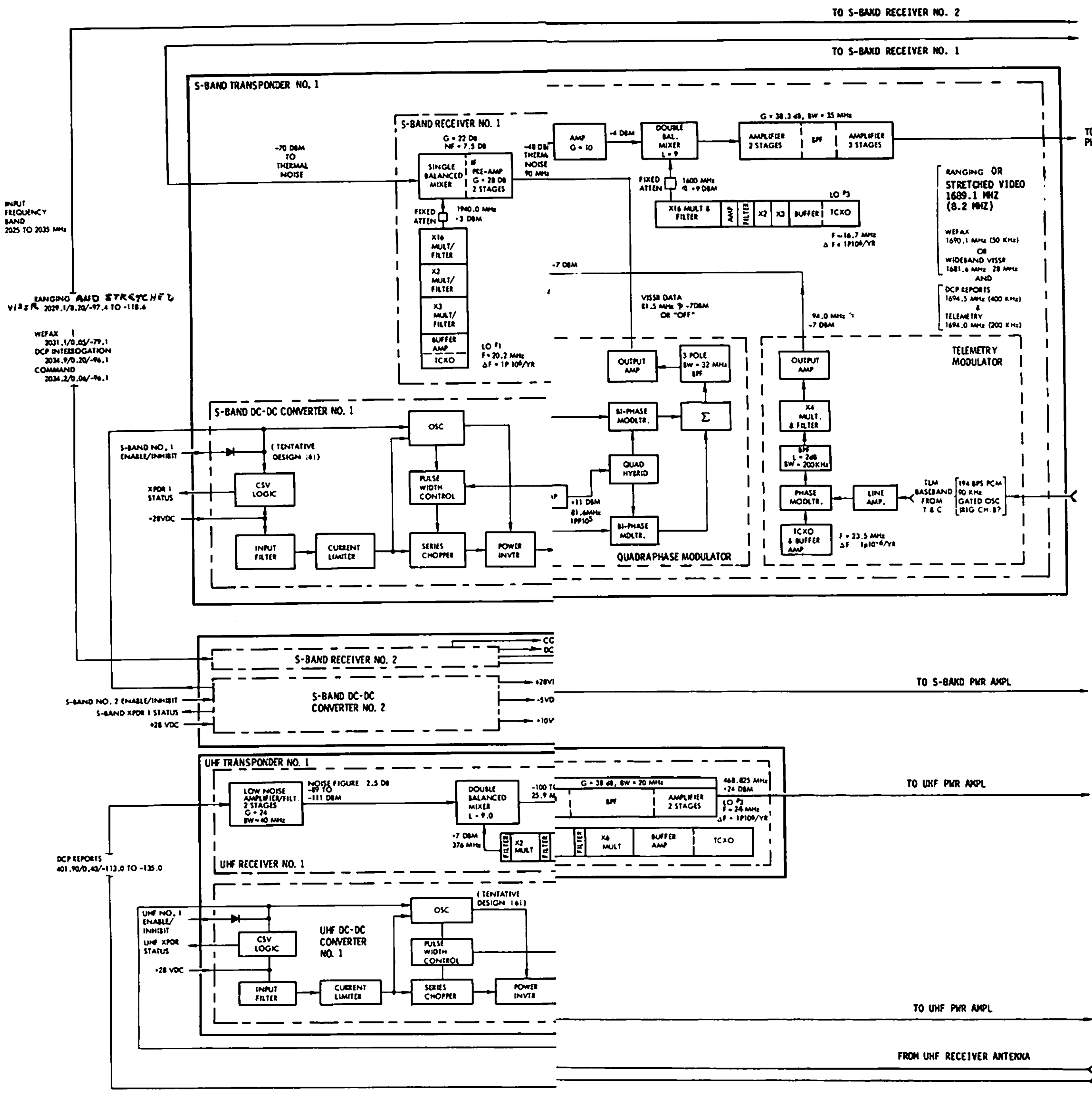
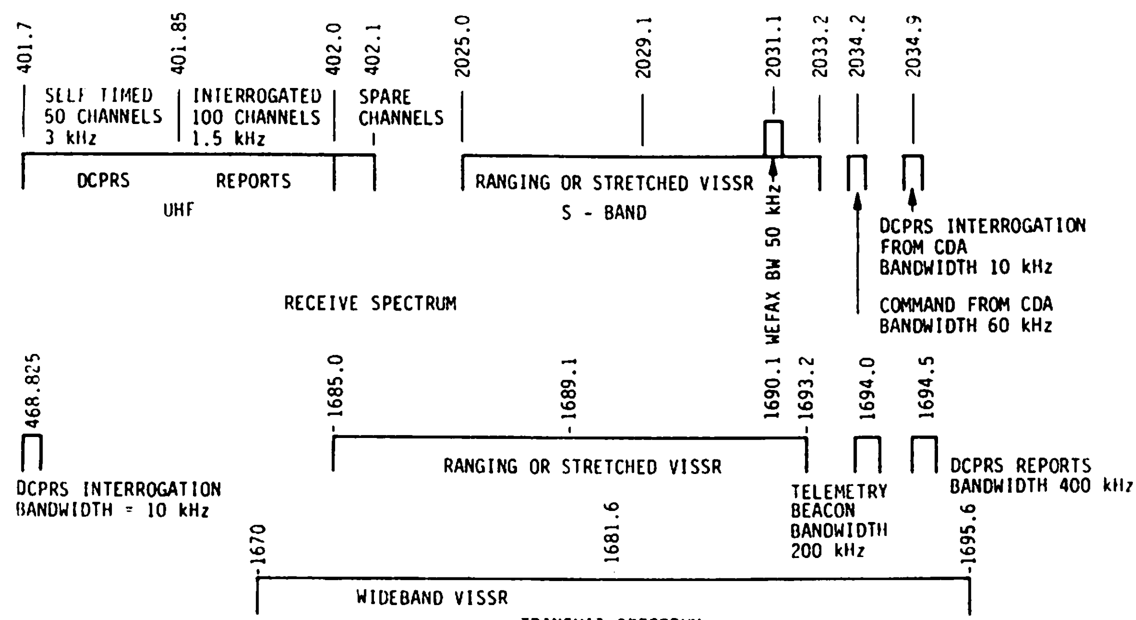


Figure 2-1. Spacecraft's Communication Transponder, Block Diagram



NOTES: 1. All frequencies in MHz
2. Wideband VISSR, stretched VISSR, ranging and WEFAX are time-shared functions

Figure 2-2. GOES Frequency Plan

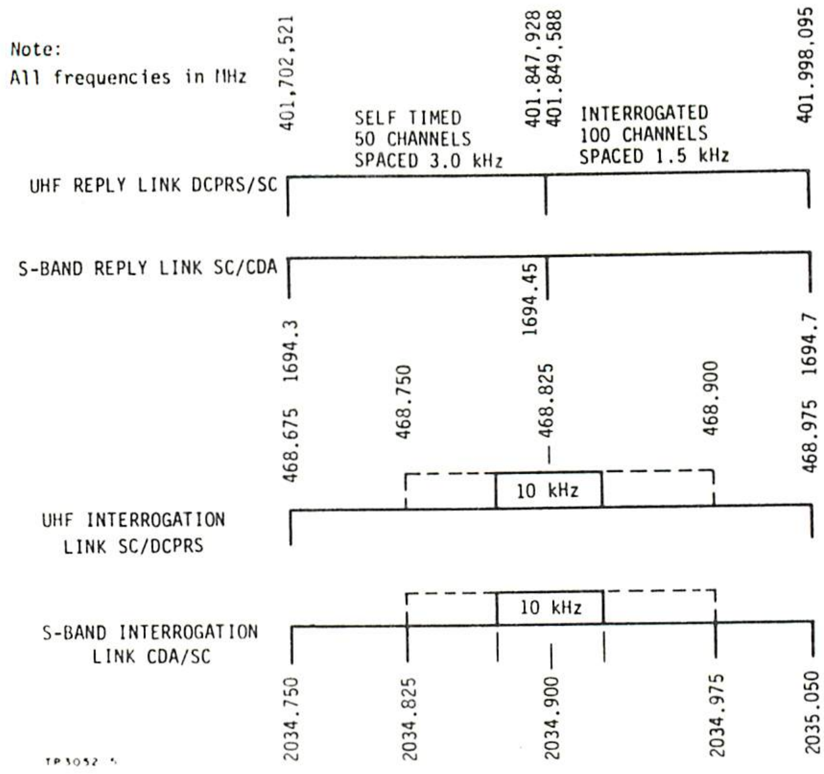


Figure 2-3. DCPRS/SC/CDA Detailed Frequency Plan

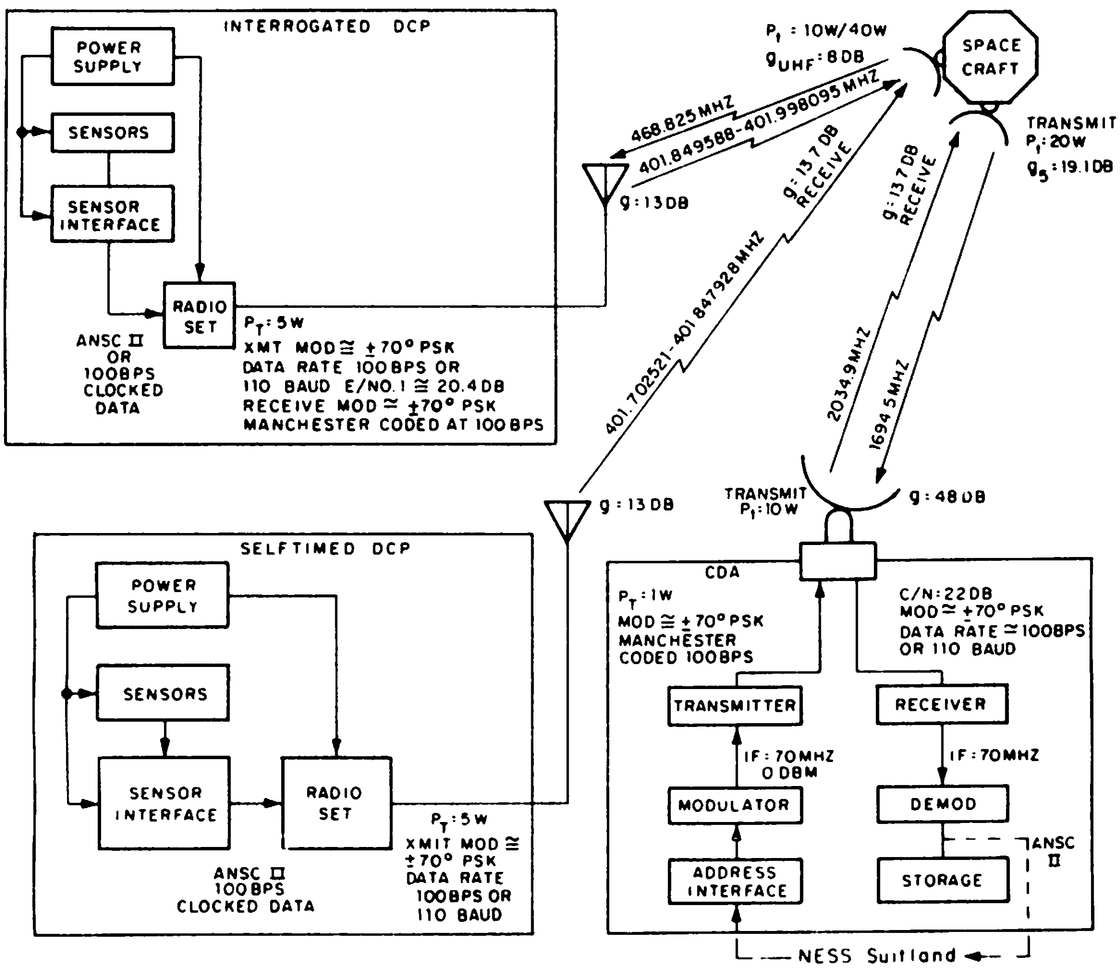


Figure 2-4. DCS Scenario

2.4.1 Self-Timed DCPRS

The self-timed DCPRS has a clock that synoptically turns on the transmitter in one- to twelve-hour reporting intervals in 1 hour increments and settable to any period in the 1 to 12 hour interval.

When not transmitting, the DCPRS is in a "power down" mode in which only the synoptic clock is operating. When the synoptic time period is reached, sensor data enters the DCPRS and the transmitter carrier is phase-shift keyed by the data. The operating frequency is selectable at the DCPRS for any one of 50 channels spaced 3000 Hz apart in the band from 401.699 521* to 401.847 928 MHz. At the end of data transmission, the set is "powered down" to its clocking mode. Provisions are made for an emergency frequency channel to transmit emergency data. Transmission times, dependent upon the type of DCP sensors, should average approximately 30 seconds. The DCPRS-to-spacecraft up-link at UHF is provided by a 5-watt transmitter driving a 13 dB gain antenna system.

2.4.2 Interrogated DCPRS

In the interrogated DCPRS operation a command initiated at the CDA reaches the DCP field through the GOES/SMS spacecraft. At the DCPRS it is received, demodulated and decoded. If the decoded address agrees with the address stored in the DCPRS, the set is placed into an active mode for transmission of data in a manner identical to the self-timed DCPRS. Interrogation and data response duration are dependent on the DCP sensors. Interrogation will be on a random, or as needed, basis. Transmissions will be spaced 1500 Hz in the band 401.849 588 to 401.998 095 MHz, and the received signals will be at the assigned UHF interrogation frequency of 468.825 MHz. The transmitter and antenna systems for the interrogated DCPRS is the same as that used in the self timed system, 5 watt transmitter and 13 dB gain antenna.

2.4.3 The Spacecraft

The GOES/SMS transponder and the Spacecraft (Figure 2-5) will be in an equatorial orbit approximately 100^{o} west longitude. The earth-looking antennas will provide coverage from approximately 25^{o} to 175^{o} west longitude and 70^{o} north to 70^{o} south latitude. For the spacecraft DCP UHF down-link, and 8-dB earth coverage antenna is fed by a 10-watt or 40-watt transmitter commanded by the CDA. For the Spacecraft CDA S-band down-link, a 19.1-dB gain antenna is fed by a 20-watt transmitter. When receiving the DCPRS UHF up-link reply, the spacecraft antenna provides 7.3 dB of gain. When receiving the CDA S-band interrogation, the spacecraft S-band antenna provides 13.7 dB gain.

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*The transmitter is capable of tuning to this frequency, but the lowest frequency used will be 401.702,521 MHz.

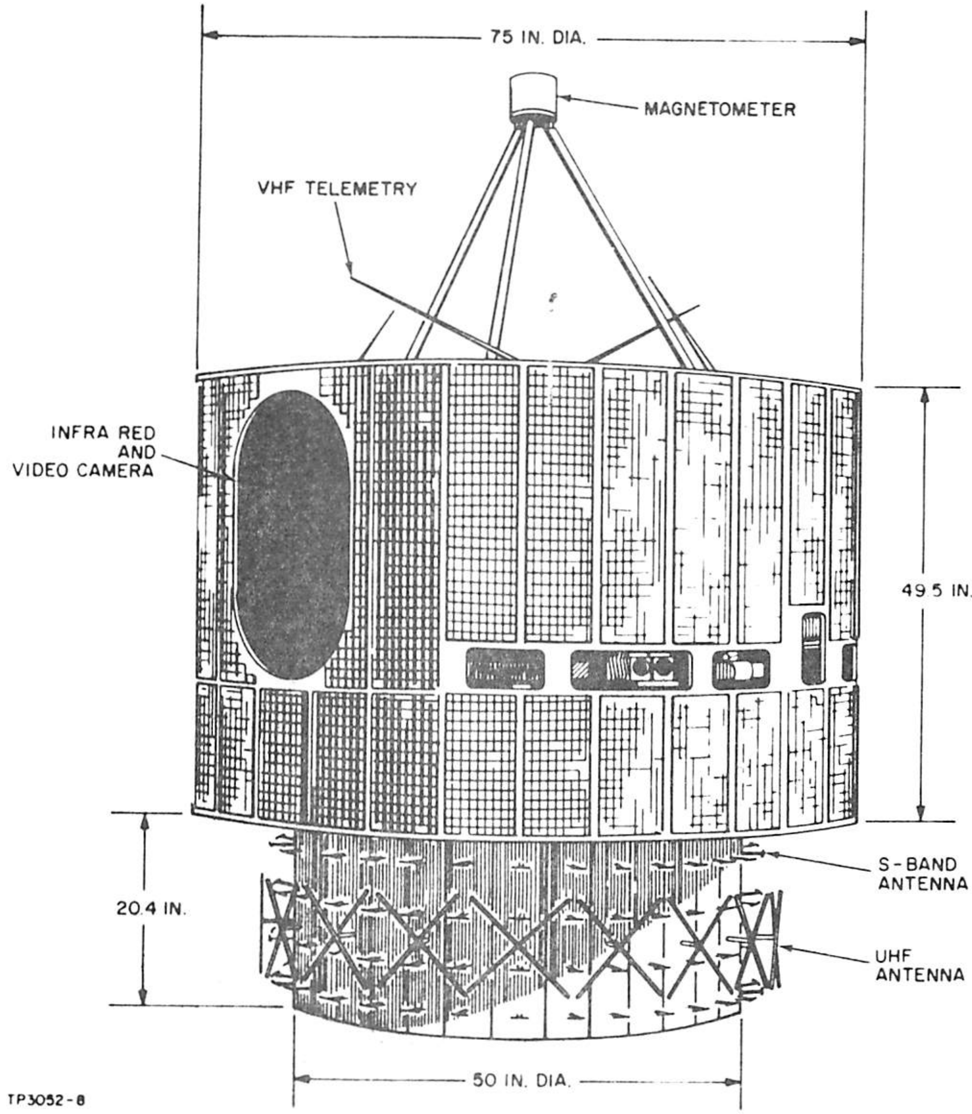

Figure 2-5. GOES Spacecraft

2.4.4 The CDA Station

2.4.4.1 Transmission

Present planning indicates that a 10-watt transmitter with 48-dB gain antenna at the assigned S-band frequencies will be used at the CDA. A 60 foot antenna is being installed for the GOES system. This antenna location would be adjacent to the new structure which is to be added to the existing Wallops Station for the purpose of supporting the GOES/SMS program. Interrogation commands may originate at NESS Suitland, and be transmitted to the CDA over existing land lines. The signals may be conditioned for proper insertion into the CDA Interrogation Modulator. An alternate method is to store DCP addresses at the

CDA. Upon request by a user or NESS, the CDA initiates the interrogation. Such functions would be performed for subscribers, oceanographers, hydrologists, meteorologists, and seismologists. Suitland performs the functions of data reduction and distribution.

There is a clear interface between the modulator and the addressing format. The modulator set required will Manchester-code and PSK-modulate a carrier at a predetermined modulation index (nominally ±70°) with the interrogation command. It is a simple task to multiplex the NBS time code into this signal to be transmitted (see paragraph 2.4.5). The carrier frequency for the modulator will be 74.5 MHz.

This frequency provides a convenient interface to the S-band transmitter. The signal provided to the transmitter can be at any convenient level such as 0 dBm. The transmitter performs the function of translating the frequency to 2034.9 MHz and of amplifying the signal to provide a 10-watt level at the antenna.

2.4.4.2 Reception

The 48-dB gain antenna will accept the DCP data from the spacecraft, and this signal will be delivered to the receiver terminal at the CDA. The channelized receiver will receive this data at a signal level of approximately -121 dBm. It is then amplified and converted to the 4.833247 MHz interface frequency for delivery to a demodulator. The output of the demodulator consists of the DCP address and the sensor data, all at an ANSCII code format and at 100 bps. The data will either be stored at the CDA or converted (if necessary) for transfer to NESS over the existing teletype circuits or by a microwave terminal that exists between Wallops Station and Suitland. Clear channel will be maintained for emergency responses from the DCP field.

2.4.4.3 Interrogation Format

The interrogation format is required to have sufficient length to address 100,000 sensor locations. It can be done with 17 bits in the absence of any errors. A 31, 21 BCH code is used to provide 2^{21} separate address commands allowing a maximum of two errors in each command. This coding sequence will provide over two million separate usable commands. A typical message is shown in Figure 2-6. In addition, a 15 bit MLS coded message precedes the 31, 21 BCH code to provide synchronization.

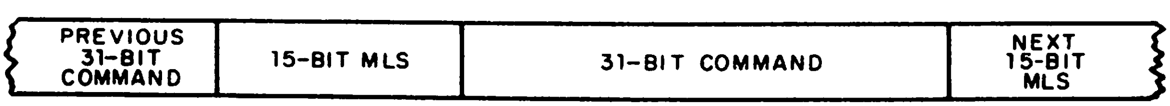

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Figure 2-6. Typical Interrogation Message

Since the DCP's in this case are assumed to be ground-based, a directional antenna (minimum gain of 10 dB at the pattern-3 dB points), along with a minimal amount of multipath-induced fading, enables the equipment to easily satisfy the bit error probability requirement of $P_e = 1 \times 10^{-6}$. It remains to meet the additional requirements of

$$P\ (\text{correct response}) \geq 1 - 3.44 \times 10^{-5}$$

$$P\ (\text{false response}) \leq 1.36 \times 10^{-10}$$

Since nothing can be done at the DCP until bit and frame sync have been achieved, it is not possible to protect these bits by error control coding. Thus, only the DCPRS address bits will receive protection. Since each DCP obviously "knows" its own address, the code word representing the encoded command bits will be wired into the decoder. A block code should be used for error control in which the distance properties of the code are exploited without the need for the usual decoding circuitry (feedback shift registers, finite field arithmetic, etc.). Thus, there will be a single comparator in which the received (possibly corrupted) code word will be compared on a bit-by-bit basis with the wired-in word. As long as the two words do not differ by more than the maximum number of correctable errors for the chosen code, correct reception will be assumed.

The DCP message sync is accomplished by comparing the incoming data using 15 paralled bits. The data is compared to the 15 bit MLS code and also its inverse. This provides both bit and message sync. No errors are permitted in the message sync word. The use of this method implies the possibility of missing a message sync word due to a transmission error. The probability of missing a message sync word due to a transmission error is the probability of one bit error in 15 bits with a system error rate of 1×10^{-6}.

$$P\ (\text{missing word}) = \binom{15}{1} \times 10^{-6} \times (1 - 10^{-6})^{14}$$

$$\simeq 15 \times 10^{-6}$$

Since only the 15 bit words are not error corrected, this means that a message will be missed one out of every $\dfrac{1}{15 \times 10^{-6}}$ interrogations.

Therefore, any given DCPRS will miss its message sync only one out of every 67,000 times.

The probability of a false response is no greater than the probability of more than three errors in a code word. The channel bit error probability is $p = 10^{-6}$. Thus, the probability of three errors in a 31-bit code word is:

$$P\ (3\ \text{errors}) = \binom{31}{1} p^3(1-p)^{28} < 31 \times 5 \times 29 \times 10^{-18}$$
$$\simeq 4.5 \times 10^{-15}$$

while $\quad P\ (e\ \text{errors}) \ll P(3\ \text{errors})$ for any $e > 3$.

Therefore, $\quad P\ (\text{false response}) = 4.5 \times 10^{-15} \ll 1.36 \times 10^{-10}$,

and this requirement is easily met by the recommended code.

Since

$$P\ (\text{correct response}) = 1\text{-}P(\text{false response}) - P(\text{no response from any DCP})$$

or $\quad P_c = 1-P_F-P_N$

and $\quad P_F+P_N = P(3\ \text{or more errors})$,

it follows that $\quad P_c = 1 \quad 4.5 \times 10^{-15} > 1 \quad 3.44 \times 10^{-5}$,

where the last quantity is the required probability of correct response.

2.5 Data Response Format

The proposed data response format consists of the 31-bit BCH code word used for interrogation, followed by the sensor data. This format includes no error control other than that embodied in the 31-bit BCH code word, which constitutes verification of the DCP address.

For the 100 bps data, the up link analysis of Table 2-1 is presented. The margin of 13.1 dB is considered adequate.

If the data rate is increased to 500 bps, this margin will be reduced by 7 dB to 6.1 dB, which should still be adequate. However, tests have been performed between fixed platforms and high orbiting spacecraft where fades in excess of 7 to 10 dB were encountered. It is believed these fades are caused by magnetic storms. With fades such as these, the 13.1 dB margin for 100 bps data should still be adequate; but if data rates of 500 bps are used, it may be necessary to consider increasing the margin by antenna gain transmitter power, and/or adding error correcting codes.

Table 2-2 is the down link analysis which shows a 13.8 dB margin. Again this is considered to be adequate for land based platforms.

TABLE 2-1. POWER BUDGET S/C TO LAND BASED DCPRS AT 468.85 MHz

Spacecraft Transmitter (10W)	40.0 dBm
Spacecraft Transmitter Feed Loss	-1.6 dB
Spacecraft Antenna Gain	8.0 dB
Spacecraft Antenna off-beam-center Loss	-2.5 dB
Free Space Loss	-178.3 dB
Polarization Loss	0.0 dB
Rain and Atmospheric Absorbtion Loss	0.0 dB
Ground Antenna Gain	13.0 dB
Ground Antenna off-beam-center Loss	-1.0 dB
Received Signal Power at Ground	-122.4 dBm
Ground Receiving System Noise Temperature (T = 636°K) NF 4.4 dB	28 dB
Boltzman's Constant	-198.6 dBm/Hz-°K
Ground Noise Power Density	-170.0 dBm/Hz
Down Link Signal to Noise ratio	47.6 dB-Hz
Bandwidth 200 Hz	23.0 dB-Hz
Overall Signal-to-Noise ratio	24.6 dB
Required Signal to noise ratio (PSK ±70°)	11.5 dB
System Margin	13.1 dB*

*NOTE: Link margin may be degraded an additional 1.4 dB due to spacecraft spin modulation.

TABLE 2-2. POWER BUDGET DCPRS TO S/C AT 402 MHz

Ground Transmitter (5W)	37.0 dBm
DCPRS Antenna Gain	13.0 dB
Pointing Loss	0.0 dB
Free Space Path Loss	-177.0 dB
Polarization Loss	0.0 dB
Spacecraft Antenna Gain	7.3 dB
Spacecraft Antenna off-beam Center Loss	-2.5 dB
Spacecraft Receiver Feed Loss	-1.6 dB
Received Carrier Power in Spacecraft	-123.1 dBm
Spacecraft Receiving System Noise Temperature TE = 516°K, NF = 2.5 dB	27.2 dB-$^{\circ}$K
Boltzman's Constant	-198.6 dBm/Hz-$^{\circ}$K
Spacecraft Noise Power Density	-171.4 dBm/Hz
Up-Link Signal to Noise Ratio	48.3 dB
Bandwidth 200 Hz	23.0 dB
Overall Signal to Noise Ratio	25.3 dB
Required Signal to Noise Ratio (PSK)	11.5 dB
System Margin	13.8 dB*

2.6 NBS Time Code Reception

There is a need for some DCP's to receive and use the NBS time codes. The DCPRS sets proposed are building block units, and thus are readily expandable to include additional capability such as demodulation of the NBS time code. However, it is impracticable to present a design for the DCPRS which includes the capability of demodulating the NBS time code without considering its impact on the CDA. For this reason, Figure 2-7 shows the manner in which Magnavox recommends that the NBS time code be multiplexed into the transmitted signal of the CDA, and Figure 2-8 is

*NOTE: Link margin may be degraded an additional 1.4 dB due to spacecraft spin modulation.

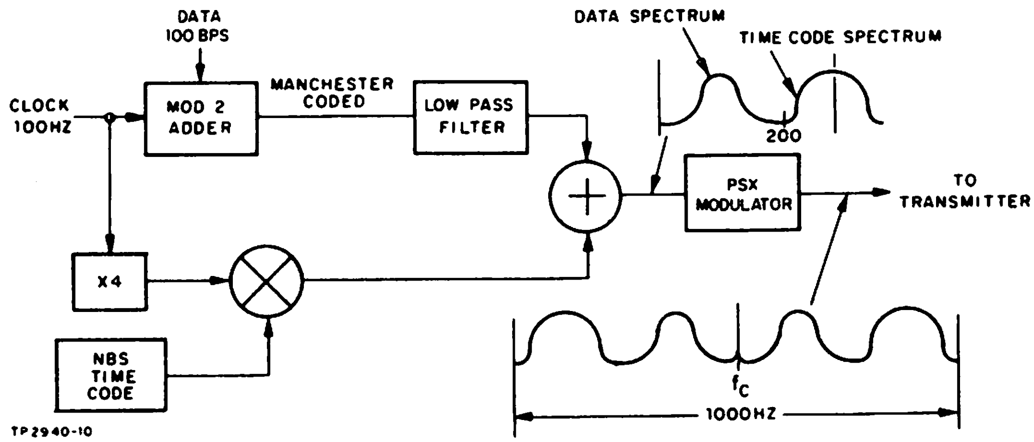


Figure 2-7. Transmitting Data and NBS Time Code at CDA

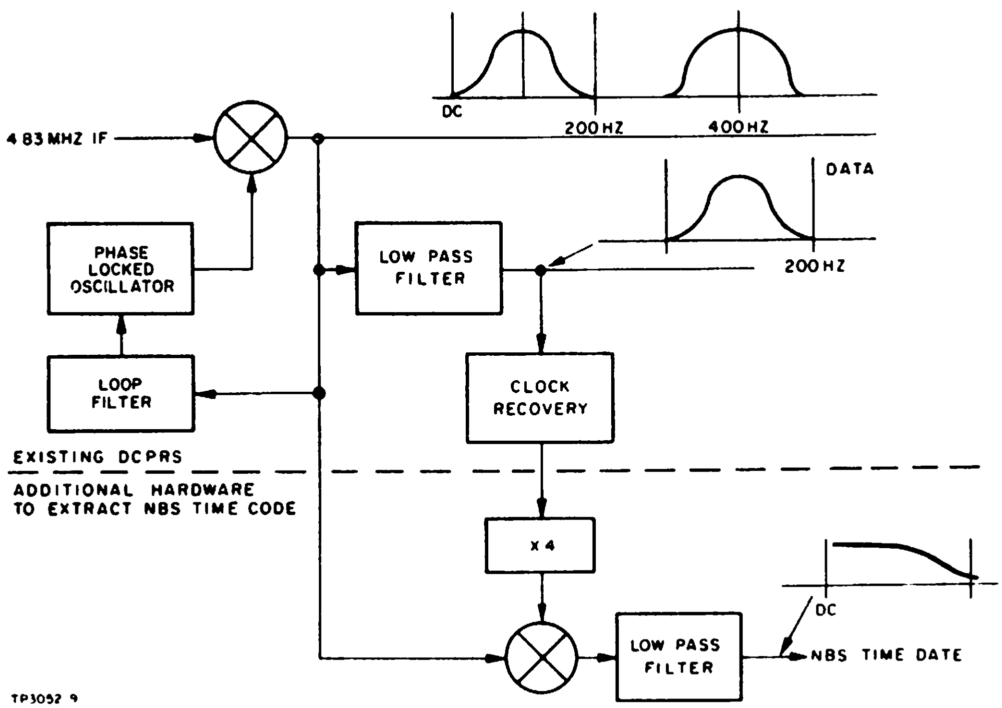


Figure 2-8. Demodulation of Data and NBS Time Code at DCPRS

a block diagram indicating the minimal additional hardware required in the DCPRS to extract this time code. The format recommended has no impact on the addressing of the transmitted interrogation message and is ignored by the DCPRS decoder searching for the proper DCP address.

2.7 Sensor Interface Requirements

It is necessary for the DCPRS to interface with different sensor types where data is measured in various formats. This section discusses the interface requirements between the DCPRS proposed and the environmental sensors.

At attended sites, synoptic data may be punched on paper tape in an ANSCII format prior to interrogation. At the specified transmission time the paper tape reader will be enabled to provide a 110-baud serial data stream to the phase modulator of the DCPRS. At other sites, the data may be presented in real time, or read from solid state or magnetic core storage. Upon interrogation or at the specified synoptic interval, the memory contents will be clocked out at a 100 bps rate and applied to the DCPRS phase modulator.

In each of the previously mentioned conditions, the data applied to the DCP is from a single source. Only the digital data need be applied to a Manchester coder before being applied to the modulator of the DCPRS.

2.8 DCPRS Block Diagram Description

2.8.1 Modular Design

The Magnavox Company plans to supply the Dept. of Commerce NOAA with a highly flexible design for the DCPRS. The key to this flexibility is the modular packaging concept and a judicious choice of operating frequencies.

The design begins with a self-timed DCPRS expandable to an interrogated coherent DCPRS by adding a receiver system to the basic self-timed set while removing the timing module associated with the self-timed configuration. The transmitter synthesizer operates from a 4.83 MHz TCXO reference source in the self-timed configuration. The TC/VCXO in the receiver operates at 4.833247 MHz, thus the receiver TC/VCXO becomes the coherent transmitter reference source in the interrogated unit. When the receiver is tuned, coherence is maintained in the transmitter, and the commonality between the self-timed and interrogated systems is preserved, as will be explained.

Table 2-3 is a listing of the basic modules used in the DCPRS. The modules are tabulated to show how they could be combined to provide DCPRS units with a variety of capabilities.

TABLE 2-3. DCPRS MODULES AND THEIR FUNCTIONS

Unit	Function
DIPLEXER MODULE	Couples transmitter and receiver to antenna.
	Filters transmitter wideband noise.
	Filters transmitter output from receiver RF stages.
RF/IF MODULE	Provides receiver gain
	Provides channel selectivity
RECEIVER INJECTION MODULE	Generates injection frequencies for 1st and 2nd receiver mixers
	Provides error cancelling oscillator to eliminate self jamming
DEMODULATOR	Locks receiver to carrier
	Provides demodulated data to the Data Processor Module
	Provides the 4.833247 MHz reference for the Receiver Injection Module
DATA PROCESSOR MODULE	Recovers Bit Rate
	Decodes Manchester coded data into "1" and "0"
	Obtains bit synchronization
	Obtains Message synchronization

TABLE 2-3. DCPRS MODULES AND THEIR FUNCTIONS (CONT)

Unit	Function
DATA PROCESSOR MODULE (CONT)	Decodes DCPRS address
	Commands transmitter to proper reply in the interrogated mode
SYNTHESIZER MODULE	Provides 100 channels locked to the received carrier or to the fixed TCXO in the self-timed case
	Provides for selection of one emergency frequency in either the self-timed or interrogated mode
TRANSMITTER POWER AMPLIFIER MODULE	Provides RF power for transmission
	Manchester-codes digital data
	Modulates carrier with serial data bit stream
TIMING AND CONTROL MODULE	Commands transmitter to proper reply
	Provides synthesizer reference for self-timed case
	Provides fail safe function for self-timed case

2.8.2 Self-Timed DCPRS

Figure 2-9 is a block diagram of the self-timed DCPRS. The self-timed DCPRS consists of the following modules and subassemblies:

(a) Power Amplifier Module

(b) Synthesizer Module

(c) Clock and Control Module

(d) Antenna

2.8.2.1 Timing and Frequency Control

The basic timing and frequency control is provided by a TCXO operating at 4.83 MHz. This frequency is multiplied by 72 to 347.9938 MHz and mixed with a phase modulated frequency from the phase modulator. The output frequency from the phase modulator is nominally 53.972 MHz but can be set to any of 50 channels spaced 3 kHz apart to provide a transmitter output which is nominally 401.775 ± 75 kHz in 3.0 kHz steps. The frequency synthesizer, which generates the 53.972 MHz frequency, is a digital type unit consisting of a VCXO, programmable divider, and phase lock loop. Changing the operating frequency in the field is done by simply changing jumper wires to control the programmable counter. The reference frequency for the synthesizer is provided by dividing the reference frequency of 4.83 by 3222 to a base frequency of 1.5 kHz.

The output from the mixer in the transmitter is amplified up to 6.3 watts and filtered to limit spurious emissions and is then applied to the antenna at a 5-watt level minimum.

2.8.2.2 Transmission of Data

The data to be transmitted is applied to the modulator upon command from the timing circuits. Simultaneously the synthesizer and power amplifiers are turned on for transmission. After the transmission interval, the set reverts to standby condition to conserve power. The control circuits contain a fail-safe provision to prevent the transmitter from failing in the "on" condition.

2.8.2.3 Functions

The timing and control circuitry has the following functions:

(a) Provides for a start of timing in 30-second steps

(b) Provides for timing interval of 1 to 12 hours in 1 hour steps

(c) Turns on transmitter

(d) Accepts turn off pulse at end of data to turn off transmitter

(e) Accepts emergency status indication

(f) Commands to emergency frequency transmission when low prime power or sensor emergency develops

(g) Provides fail safe to prevent inadvertent transmission

(h) Provides command pulse to turn on sensor data

2.8.3 Interrogated DCPRS

The interrogated DCPRS (Figure 2-10) operates much the same as the self-timed unit except that the turn-on signal is provided remotely by a satellite link. The interrogated DCPRS consists of the following modules and subassemblies:

(a) Power Amplifier Module

(b) Synthesizer Module

(c) RF/IF Module

(d) Receiver Injection Module

(e) Demodulator Module

(f) Data Processor Module

(g) Diplexer Module

(h) Antenna

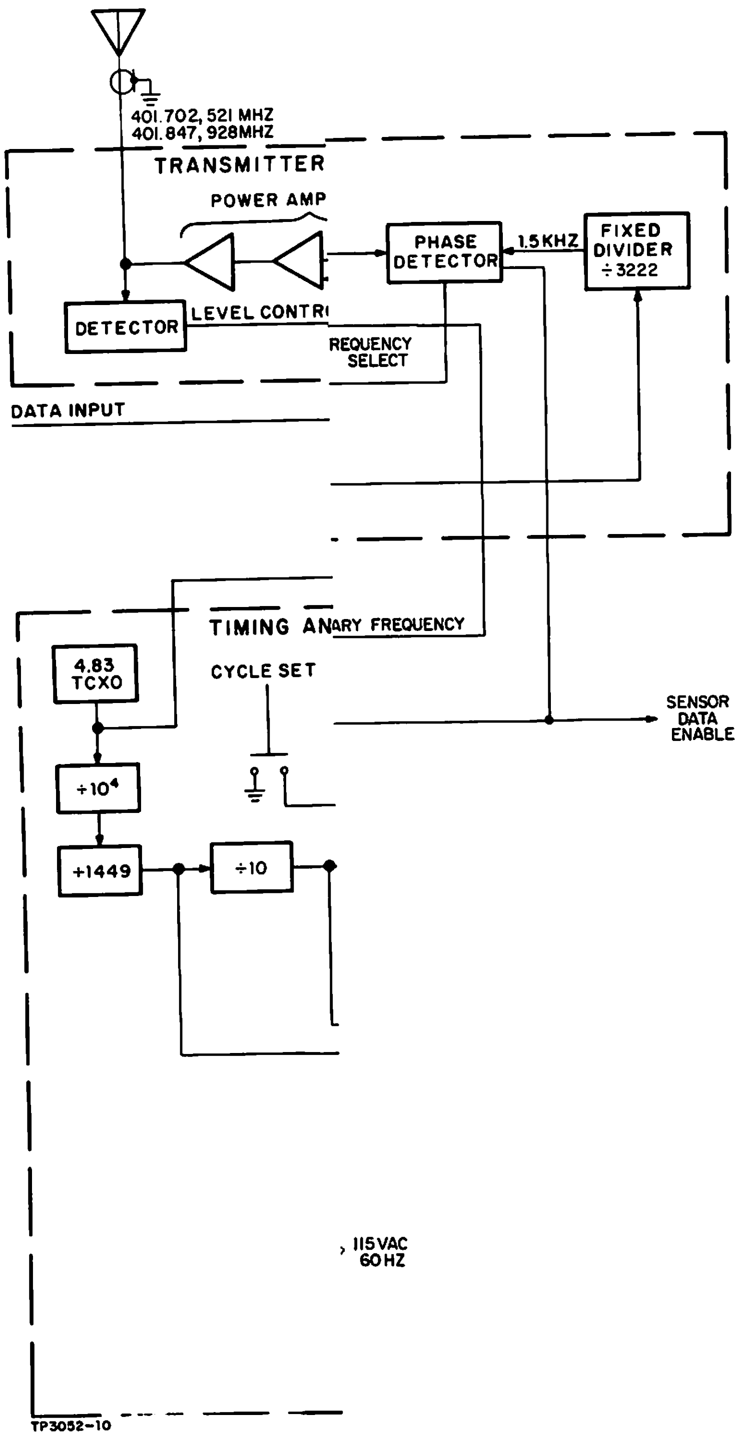
The Power Amplifier, Antenna and Synthesizer Modules for the interrogated unit are the same as for the self-timed DCPRS. To this basic unit, then is added the RF/IF module, Demodulator, Data Processor, Receiver Injection Module, and Diplexer.

2.8.3.1 Coherent Design

The requirement that the interrogated DCPRS be coherent affects the design in two basic ways: first, the transmitter and receiver must be operated simultaneously for the transmitter to receive its reference frequency from the receiver TC/VCXO. This requires a diplexer unit between the receiver and transmitter. The diplexer is capable of isolating the two units to prevent overload of the receiver by the 5-watt transmitter.

Although the receiver is not channelized, it is tunable in the coherent mode. The operating frequencies were chosen to avoid the band of 465 to 466 MHz where marginal performance could occur because of unintentional interference from a variety of emitters. The received frequency is 468.825 MHz as specified.

The input signal from the Diplexer is applied to the RF/IF module, which is a dual conversion superheterodyne receiver. The signal is amplified in two RF amplifier stages tuned to the 468.825 MHz band. The RF signal



-Timed DCPRS, Block Diagram

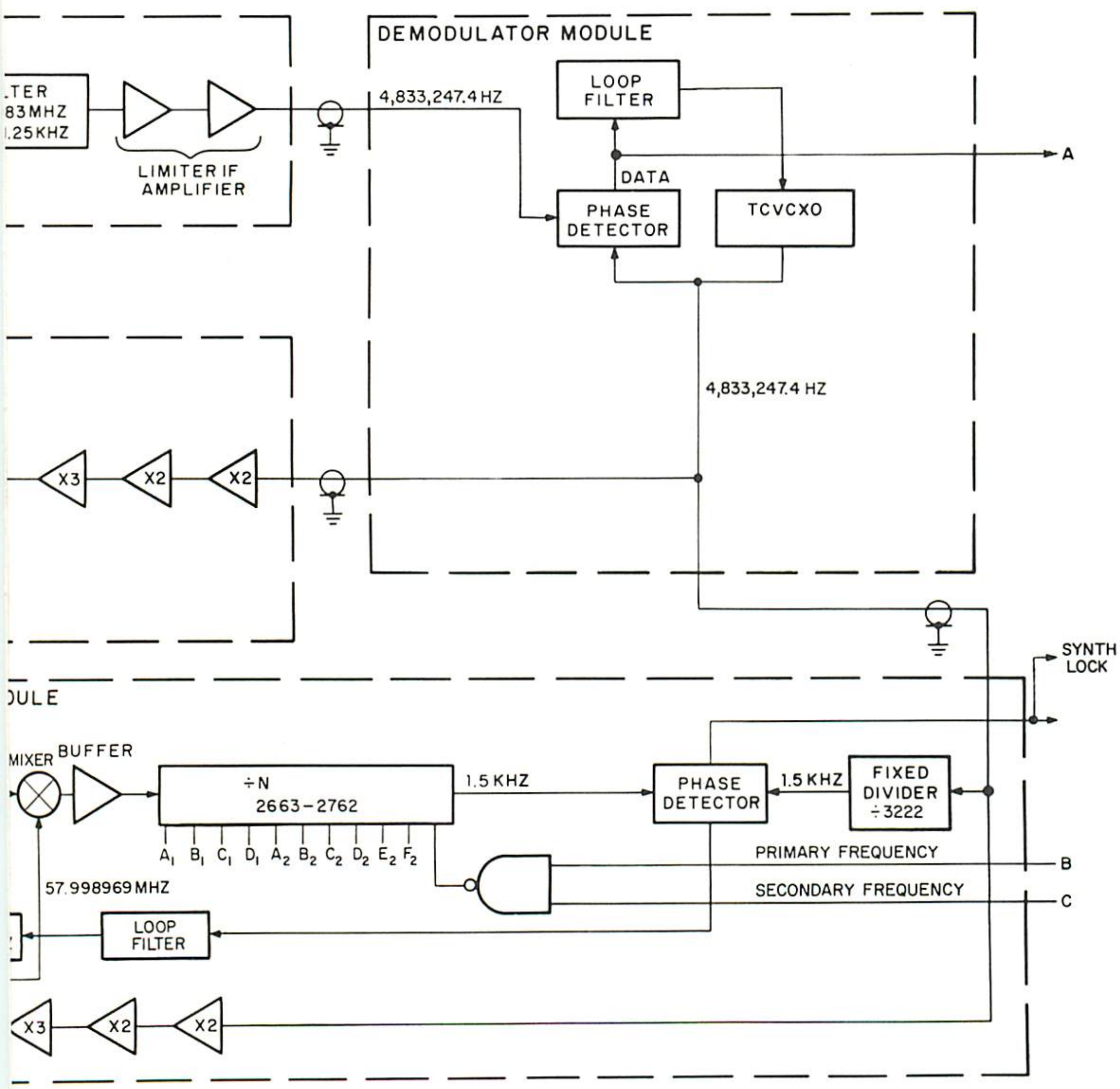


Figure 2-10. Interrogated DCPRS, Block Diagram (Sheet 1 of 2)

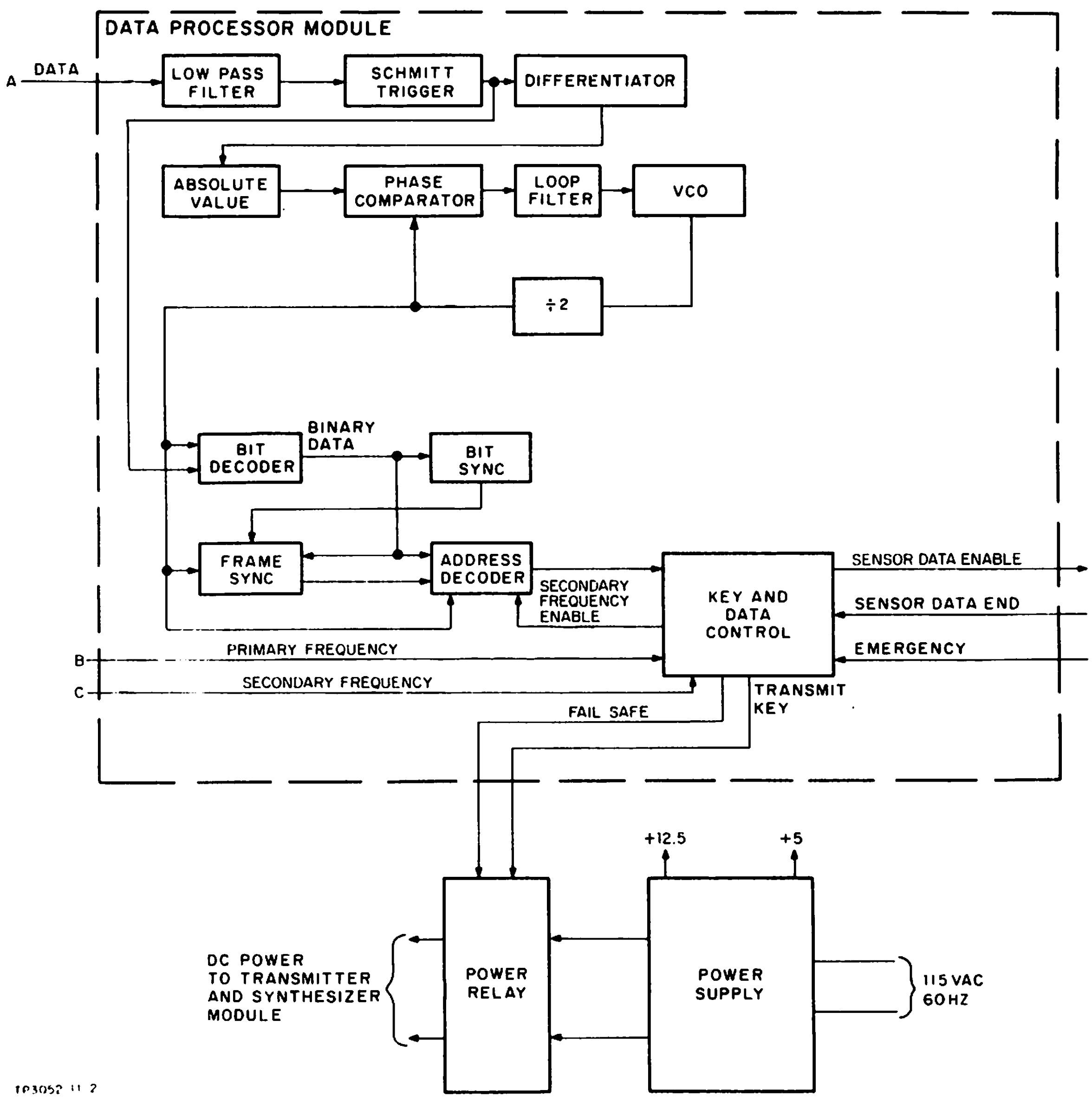


Figure 2-10. Interrogated DCPRS, Block Diagram (Sheet 2 of 2)

is converted to the first IF frequency of 46.67 MHz by the first mixer and is filtered in a crystal filter. The 1st IF is a 3-stage amplifier and provides the bulk of the receiver gain. The first IF frequency is converted to the final IF frequency 4,833,247.4 Hz where additional gain is provided up to limiting. The limiter output, which is applied to the demodulator module, is a nominal 0 dBm.

Injection for the RF/IF is obtained from the Receiver Injection Module. The 4.833,247.4 Hz signal from the TC/VCXO in the Demodulator Module is multiplied by 48 in four doublers and one tripler circuit to a frequency of 231,995,875.2 Hz. This method of frequency multiplication is preferred in this type of receiver over a step recovery diode or similar impulse generator technique because only low order harmonics are generated. This technique reduces the self jamming problem.

The 231,995,875.2 Hz signal is mixed with 190,162,458.2 Hz from an idling crystal oscillator to provide two sidebands, one at 41.84 MHz and one at 421.84 MHz. These two signals are filtered and buffered to give low side injection to the first and second mixers. The method of injection cancels any drift from the 190 MHz oscillator and thus the system remains coherent.

A phase-lock loop demodulates the received signal in the demodulator module. The 4,833,247.4 Hz IF is applied to a phase comparator for comparison with a signal derived from the TC/VCXO to develop an error signal. The loop is closed back on the TC/VCXO; through a loop filter. The data, which is present on the phase line, is taken prior to filtering in the loop filter and is applied to the Data Processor module.

In addition to the data output from the Demodulator Module, a coherent replica of the input received signal (namely, the TC/VCXO output) is provided for reference in the Synthesizer Module to make the reply signal coherent with the received signal.

The Data Processor Module performs the following functions:

(a) Recovers Clock Rate

(b) Decodes Manchester signal into binary data

(c) Acquires bit synchronization

(d) Acquires message synchronization

(e) Decodes address

(f) Generates frequency select bit

(g) Generates reply command to turn on transmitter

The Manchester* coded stream of data from the Demodulator Module is applied to the data decoder and time recovery circuits in the Data Processor module. This signal includes a framing code and the command data. The time recovery circuit extracts the bit rate clock signal from the data stream. The bit rate clock is then used to synchronously decode the data into binary bits. The bit and message sync circuits operate at the first 15 bits of the interrogation format. The sync data is a 15 bit MLS code, which is a pseudo-random code commonly used for synchronization processes due to optimum correlation properties. The detection of this data is the indication that the next bits are the command bits.

As soon as the message synchronization occurs, the command decoder is started. The command word (the word that is the address of the DCP to be interrogated) consists of 31 binary bits. These bits are serially shifted into the command decoder and compared with the "local" DCP address. A correct address is assumed if there are two or fewer total disagreements between the command word and the local address.

Once the correct command word is obtained, the synthesizer is commanded to tune to the correct frequency, and the transmitter system is turned on.

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* Manchester coding is often referred to as diphase or split phase coding.