PAYLOAD CCMMAND
RECEIVER/DOPPLER TRANSPONDER

By

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PAYLOAD COMMAND RECEIVER/DOPPLER TRANSPONDER

The command receiver/doppler transponder used in Explorer VI and Pioneer V provides for two-way communications with these space vehicles. The transponder provides a coherent retransmission of the ground-transmitted carrier in order to allow determination of the vehicle velocity, by doppler measurements, and direction by angle tracking of the ground received signal.

A simplified block diagram of the transponder is shown in Figure 1. This system is composed of the following units:

a) Diplexer

b) Receiver

c) Digital decoder

d) Transmitter

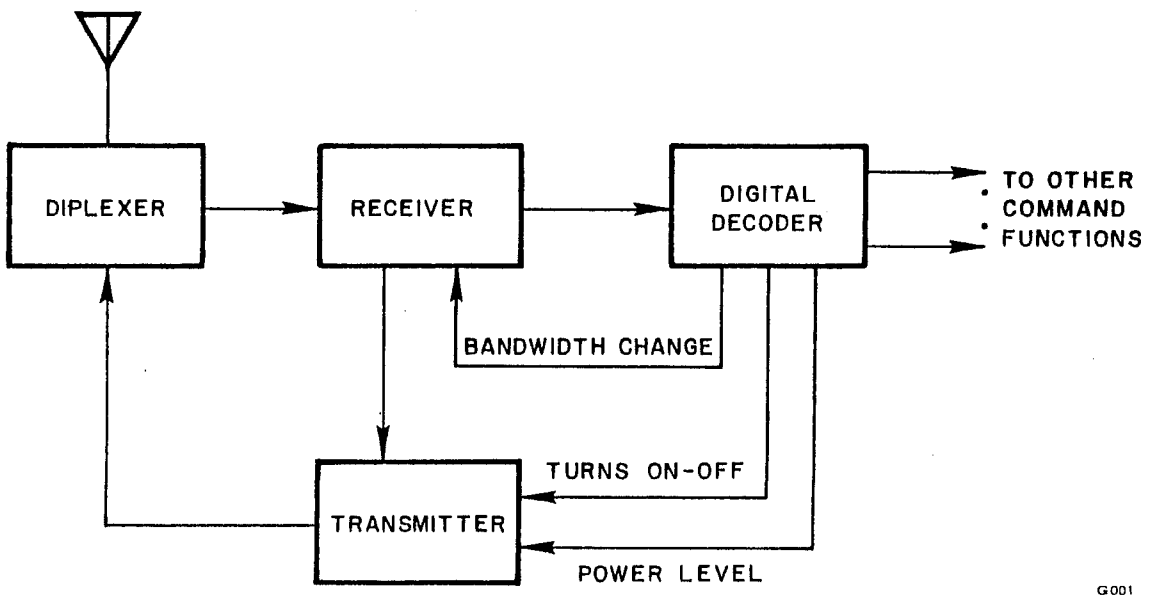

Figure 1

In operation, the receiver automatically searches for and acquires the ground transmitted signal. After acquisition, the receiver provides a coherent drive to the transmitter causing it to retransmit at a rational fraction of the received frequency. Digital commands are transmitted to the payload by phase modulating the ground transmitter with a 512-cps subcarrier. This subcarrier is in turn amplitude modulated with the digital command code.

The receiver is a transistorized double conversion, phase-lock-loop unit which produces a coherent output at 2/17 of the received frequency. The transponder operates in the uhf range (400 megacycles). It can be operated with either a 250-cps or 40-cps loop noise bandwidth selectable on command. The receiver operates continuously and, since its bandwidth is considerably less than the frequency uncertainty of the received signal, it repeatedly sweeps over a range of 30 kilocycles searching for a carrier. The sweep period is 10 seconds for the wideband mode and 3 minutes for the narrowband mode. When the receiver acquires a signal from the earth, a signal-present circuit is activated, which stops the sweep.

A detailed block diagram of the receiver is shown in Figure 2. The received frequency (17 f_1) is multiplied in the first mixer with a locally generated signal whose frequency is approximately 16 f_1. The difference frequency ($\approx f_1$) is amplified and band-limited in the first i-f amplifier. The signal is then mixed with the voltage-controlled oscillator (VCO) frequency, f_2, to produce a difference frequency of approximately f_2-f_1. After amplification in the second if amplifier, this signal is applied to the loop and quadrature phase detectors. The reference input to the phase detectors is the reference oscillator (RO) signal f_2-f_1. The outputs of the VCO and RO are doubled and then mixed in the third mixer to produce an output of approximately 2 f_1. This signal is amplified, multiplied by 8, and applied to the first mixer. The output of the loop-phase detector is amplified, filtered, and applied to the VCO-control input to complete the feedback loop. The feedback controls the VCO frequency such that the first if signal becomes exactly 1/17 of the received frequency and the transmitter drive, at the output of the third mixer, exactly 2/17 of the received frequency.

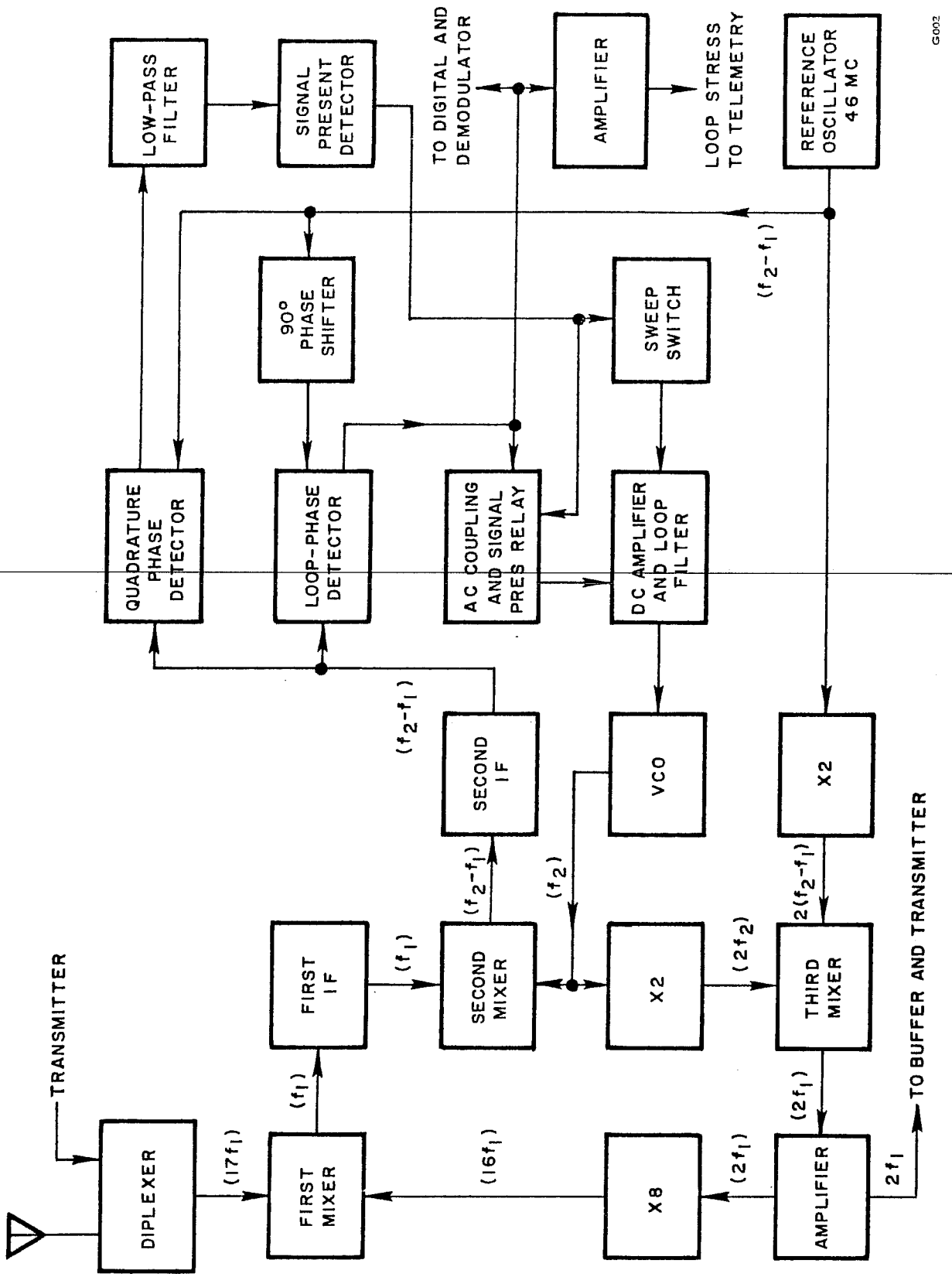
LOW-PASS FILTER
SIGNAL PRESENT DETECTOR
TO DIGITAL AND DEMODULATOR
AMPLIFIER
LOOP STRESS TO TELEMETRY
REFERENCE OSCILLATOR 46 MC
G002
90° PHASE SHIFTER
SWEEP SWITCH
(f_2-f_1)
QUADRATURE PHASE DETECTOR
LOOP-PHASE DETECTOR
AC COUPLING AND SIGNAL PRES RELAY
DC AMPLIFIER AND LOOP FILTER
SECOND IF
VCO
X2
(f_2-f_1)
(f_2)
$2(f_2-f_1)$
FIRST IF
(f_1)
SECOND MIXER
X2
$(2f_2)$
THIRD MIXER
TRANSMITTER
(f_1)
$(2f_1)$
TO BUFFER AND TRANSMITTER
DIPLEXER
$(17f_1)$
FIRST MIXER
$(16f_1)$
X8
$(2f_1)$
AMPLIFIER
$2f_1$

Figure 2

Since the command modulation frequency (512 cps) is outside the loop bandwidth, the loop does not track this frequency and the command signal is detected by the loop-phase detector and applied to the input of the digital decoder.

The command signal is a 512-cps subcarrier which phase modulates the carrier. This tone is keyed on and off by the 13-bit binary command sequence. The bit rate used is 1 bit per second. The command sequence consists of a sync pulse followed by a 6-bit command and an additional 6-bit complement of the command. The presence of the tone is interpreted as a "1" and the absence as a "0".

A simplified block diagram of the digital decoder is shown in Figure 3. This transisterized unit takes the command modulated subcarrier and converts it to command relay closures. The subcarrier is filtered in a 10-cycle bandwidth predetection bandpass filter, amplitude detected, and further filtered in a 1-cps post detection low-pass filter. This signal is then applied to the threshold detector which determines if a "1" or a "0" is being received. The programmer serves to generate a synchronous clock pulse and to shift the message into the 6-stage shift register. The second 6 bits are compared, as they are received, with the first 6 bits and, if a legitimate message (second 6 bits are the compliment of the first 6) is received, the programmer enables the command matrix, and the command is then executed. The 6-bit shift register and an 8 by 8 command matrix give a 64-channel command capability.

The coherent output of the receiver is multiplied by 8 in the transmitter producing an output frequency which is exactly 16/17 of the received signal. A phase modulator in the transmitter provides for modulation of the retransmitted carrier with digital telemetry information.

The diplexer allows the receiver and transmitter to share a common antenna and also serves as a preselector for the receiver.

Table 1 lists the performance data on the command receiver and digital decoder.

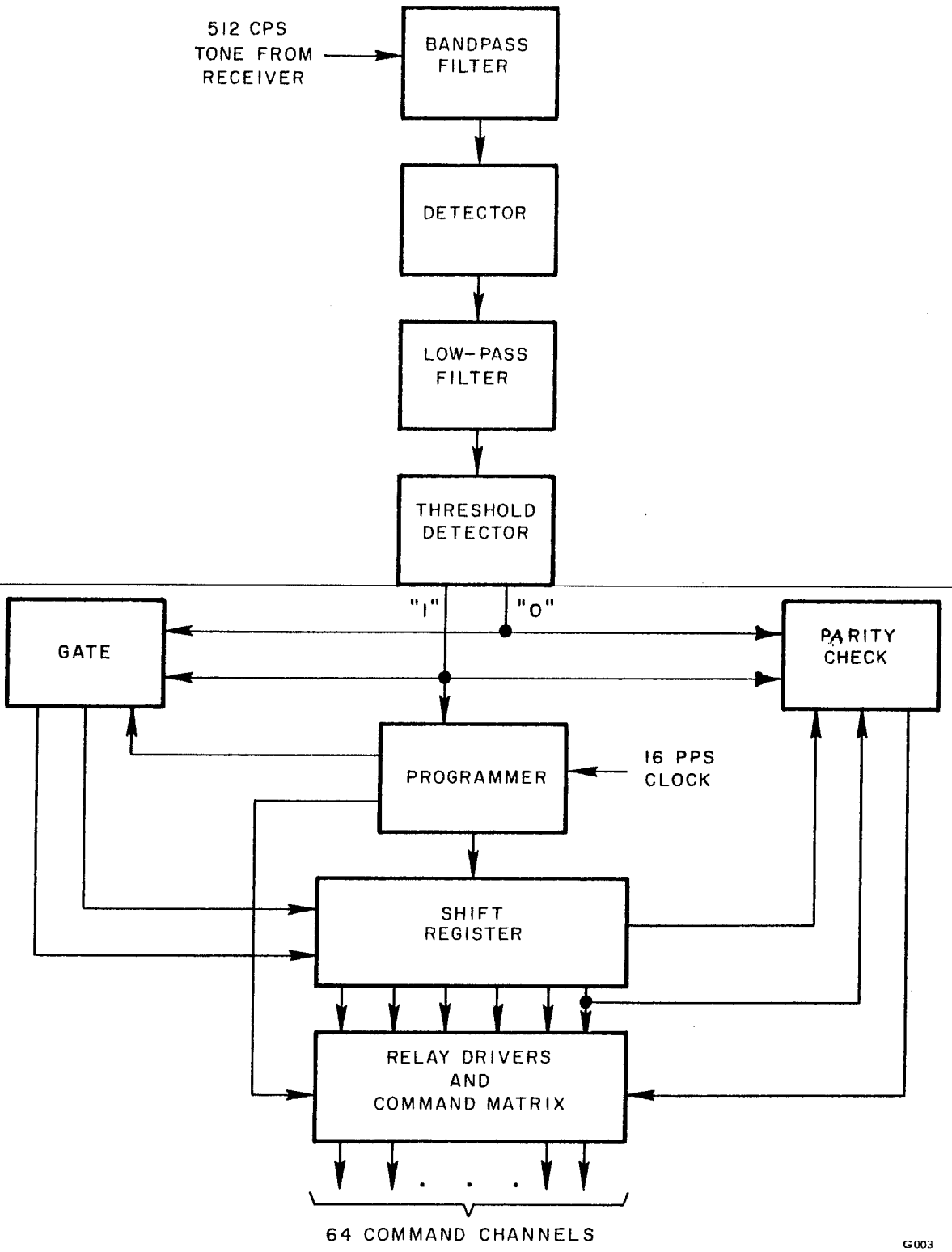
512 CPS
TONE FROM
RECEIVER
BANDPASS
FILTER
DETECTOR
LOW-PASS
FILTER
THRESHOLD
DETECTOR
"1"
"0"
GATE
PARITY
CHECK
PROGRAMMER
16 PPS
CLOCK
SHIFT
REGISTER
RELAY DRIVERS
AND
COMMAND MATRIX
64 COMMAND CHANNELS
G003

Figure 3

Table 1

1.	Received Frequency	401.848 mc nominal
2.	Coherent Output Frequency	47.276 mc nominal
3.	Acquisition Sensitivity	-140 dbm (BW - 40 cps) -130 dbm (BW - 250 cps)
4.	Command Sensitivity	-140 dbm (BW - 40 cps) -130 dbm (BW - 250 cps)
5.	Maximum Input Signal	0 dbm
6.	Image Rejection	50 db thru diplex
7.	I-F Bandwidth	5 kc
8.	Acquisition Time	180 sec (BW - 40 cps) 10 sec (BW - 250 cps)
9.	Acquisition Range	+5.0 to -21 kc from nominal - wide band +5.0 to -8.0 kc from nominal - narrow band
10.	Power Output at Transmitter Drive	1.0 mw
11.	Receiver Input Impedance	50 ohms
12.	Receiver Weight	4.0 lb
13.	Receiver Power Input	70 ma, 16 v search 80 ma, 16 v lock-on
14.	Receiver Dimensions	2-7/8 x 7.0 x 6-1/2"
15.	Decoder Input Impedance	100 k
16.	Command System	6 bit binary plus 7 bits for synchronization and error detection
17.	Command Relay Contact Rating	2 amps, 28 vdc
18.	Decoder Power Input	30 ma, 16 v
19.	Decoder Size	60 cu in.
20.	Decoder Weight	2.4 lb
21.	Diplexer Weight	1.5 lb
22.	Two Watt Transmitter Weight	1.5 lb