S/X-Band Experiment: Development of Special Telecommunications Development Laboratory Support Test Equipment

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This article documents the design of an X-band down converter and a doppler extractor receiver that were specially developed and supplied to the Telecommunications Development Laboratory in July 1971. The special equipment enabled preliminary tests to be made on the performance of a combined S/X-band radio system similar to that which will be used for the Mariner Venus/Mercury 1973 mission.

I. Introduction

The S/X-band experiment to be performed with the Mariner Venus/Mercury 1973 (MVM 73) spacecraft is a dual-frequency experiment to measure the electron content of the interplanetary media between Earth and the planets Venus and Mercury (Ref. 1). An uplink signal of approximately 2113 MHz will be transmitted to the spacecraft from the 64-m-diameter antenna at DSS 14. This uplink signal as received by the spacecraft radio system will be coherently multiplied by ratios of 240/221 and 880/221 to produce S- and X-band carrier frequencies of approximately 2295 MHz and 8415 MHz. The coherent S- and X-band signals will then be transmitted back to the DSS 14 ground system. A measurement of the dispersiveness of the S- and X-band phase and range data as received back at the ground station provides scientific information required for determining total interplanetary electron content.

A Block IV ground radio system currently being developed by the Division will be installed at DSS 14 for the S/X experiment. The Block IV system will be a phase-stabilized system enabling simultaneous reception of S- and X-band frequencies and will yield dispersive S/X doppler and S/X range data.

At the time the preliminary tests were conducted (September through October 1971), the Block IV system having S/X capability was not yet available. Therefore, it was necessary to utilize a Block III system that had only S-band capability. The Block III system was converted into an X-band phase-locked loop receiver by means of an X-band to 50-MHz down converter, which will be described in this article. As was shown in a report by Brunn (Ref. 2), the preliminary ranging and carrier phase test data were successfully obtained.

II. X-Band Down Converter

A block diagram of the X-band down converter is shown in Fig. 1. An input X-band signal (in the frequency range of 8400 to 8450 MHz) is down converted to produce a 50-MHz intermediate frequency (IF) output signal. This output signal is then fed into the 50-MHz IF input stage of a Block III receiver. The Block III phase-locked loop VCO output (nominally 23.4 MHz) is fed back into the down converter assembly, doubled, and then added to a coherent bias signal of approximately 51.7 MHz, which is produced by a frequency synthesizer and a 5-MHz frequency standard. An output signal of approximately 98.6 MHz is then filtered and multiplied by 85 to provide a phase-locked local oscillator frequency that is 50 MHz lower than the input X-band signal. Many of the mixers, amplifiers, and multipliers are of the same design as those implemented in the Block IV system. The Telecommunications Development Laboratory (TDL) X-band receiver system was purposely designed to be similar to the Block IV system so that preliminary test data would give a valid indication of MVM 73 S/X radio system performance.

Figure 2 shows the front, top, and rear views of the fabricated assembly. Table 1 shows typical noise figure and image rejection data of this assembly as measured in the laboratory. After installation at the TDL, a noise figure measurement was again made on the X-band down converter. The single sideband noise figure of the converter for the Channel 19 X-band input frequency (8421.79 MHz) was determined to be (10.2 ± 0.5) dB as defined at the Type N input port of the converter assembly. The increase in noise figure was attributed to minor adjustments made after data of Table 1 had been obtained.

III. X-Band Doppler Extractor Receiver

X-band doppler data were obtained by use of an S/X translator and an X-band doppler extractor receiver similar to that which will be used in the Block IV system.

A block diagram of the TDL X-band doppler extractor system is shown in Fig. 3. The doppler extraction method is similar to that of the Block IV system except that the first IF is 50 MHz instead of 325 MHz.

Figure 4 shows the fabricated receiver portion of the TDL X-band doppler extractor system. A special purpose S/X translator (zero delay device) is currently being fabricated and will be supplied to TDL for S/X test purposes.

IV. Acknowledgment

The equipment described in this article was developed with the cooperation and assistance of R. MacClellan, C. Johns, and H. Donnelly of the RF Systems Development Section. R. Clauss of the Communications Elements Research Section developed the low-loss waveguide X-band filter.

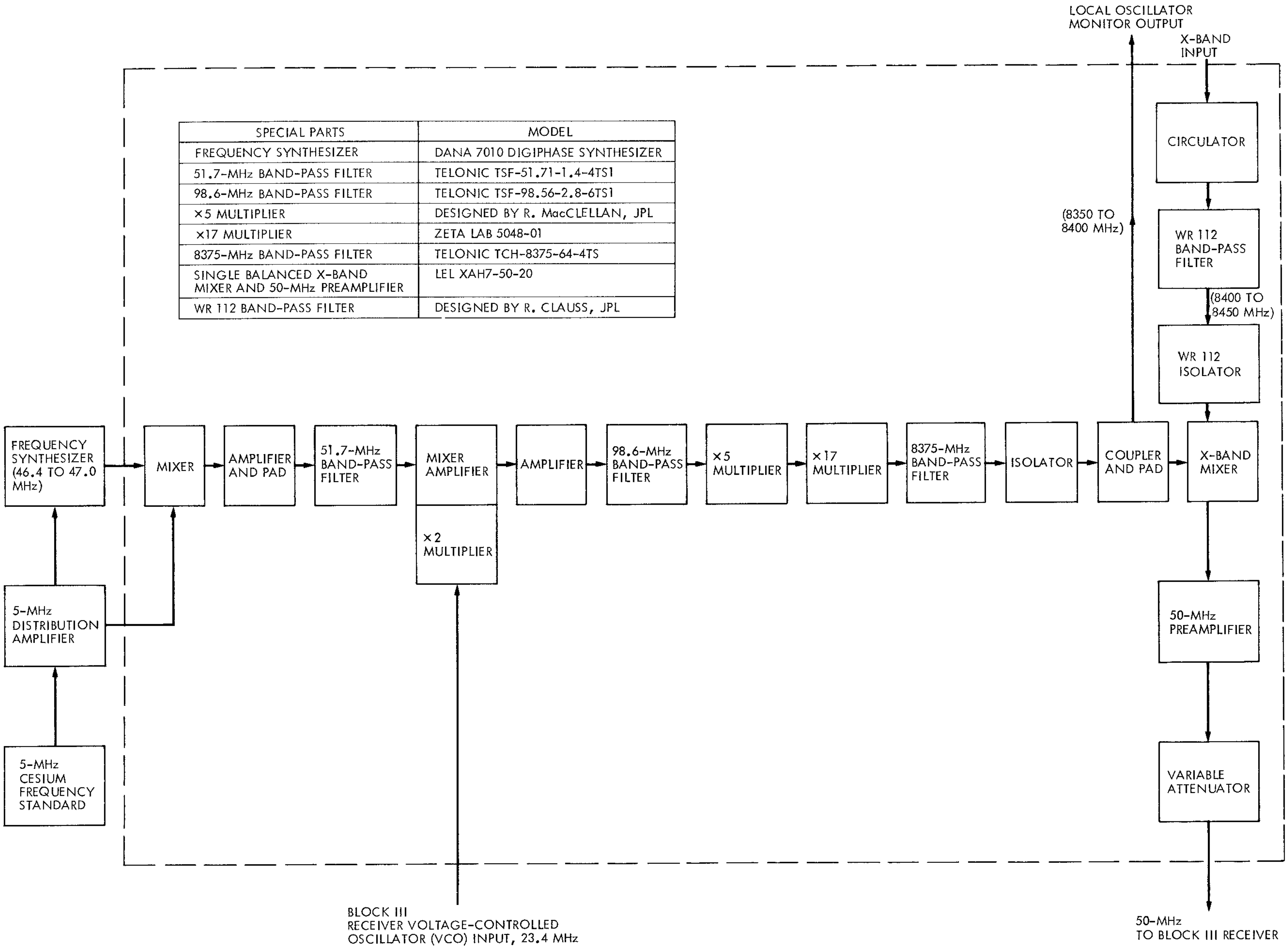
References

1. Levy, G., Dickinson, R., and Stelzried, C., "RF Techniques Research: S/X Band Experiment," in *Supporting Research and Advanced Development,* Space Programs Summary 37-61, Vol. III, pp. 93–95, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 20, 1970.

2. Brunn, D. L., "S/X Band Ranging and Phase Tests," Interoffice Memo No. 3396-72-060, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 23, 1972 (JPL internal document).

Table 1. Noise figures and image rejections of X-band down converter

Frequency, MHz	Single-sideband noise figure, dB	Image rejection, dB
8400	12.2	41
8405	11.2	39
8410	11.0	37
8415	10.6	37
8420	9.6	36
8425	8.6	35
8430	8.5	34
8435	9.2	31
8440	10.0	30
8445	11.2	28
8450	12.4	25



SPECIAL PARTS	MODEL
FREQUENCY SYNTHESIZER	DANA 7010 DIGIPHASE SYNTHESIZER
51.7-MHz BAND-PASS FILTER	TELONIC TSF-51.71-1.4-4TS1
98.6-MHz BAND-PASS FILTER	TELONIC TSF-98.56-2.8-6TS1
×5 MULTIPLIER	DESIGNED BY R. MacCLELLAN, JPL
×17 MULTIPLIER	ZETA LAB 5048-01
8375-MHz BAND-PASS FILTER	TELONIC TCH-8375-64-4TS
SINGLE BALANCED X-BAND MIXER AND 50-MHz PREAMPLIFIER	LEL XAH7-50-20
WR 112 BAND-PASS FILTER	DESIGNED BY R. CLAUSS, JPL

Fig. 1. Block diagram of TDL X-band to 50-MHz down converter

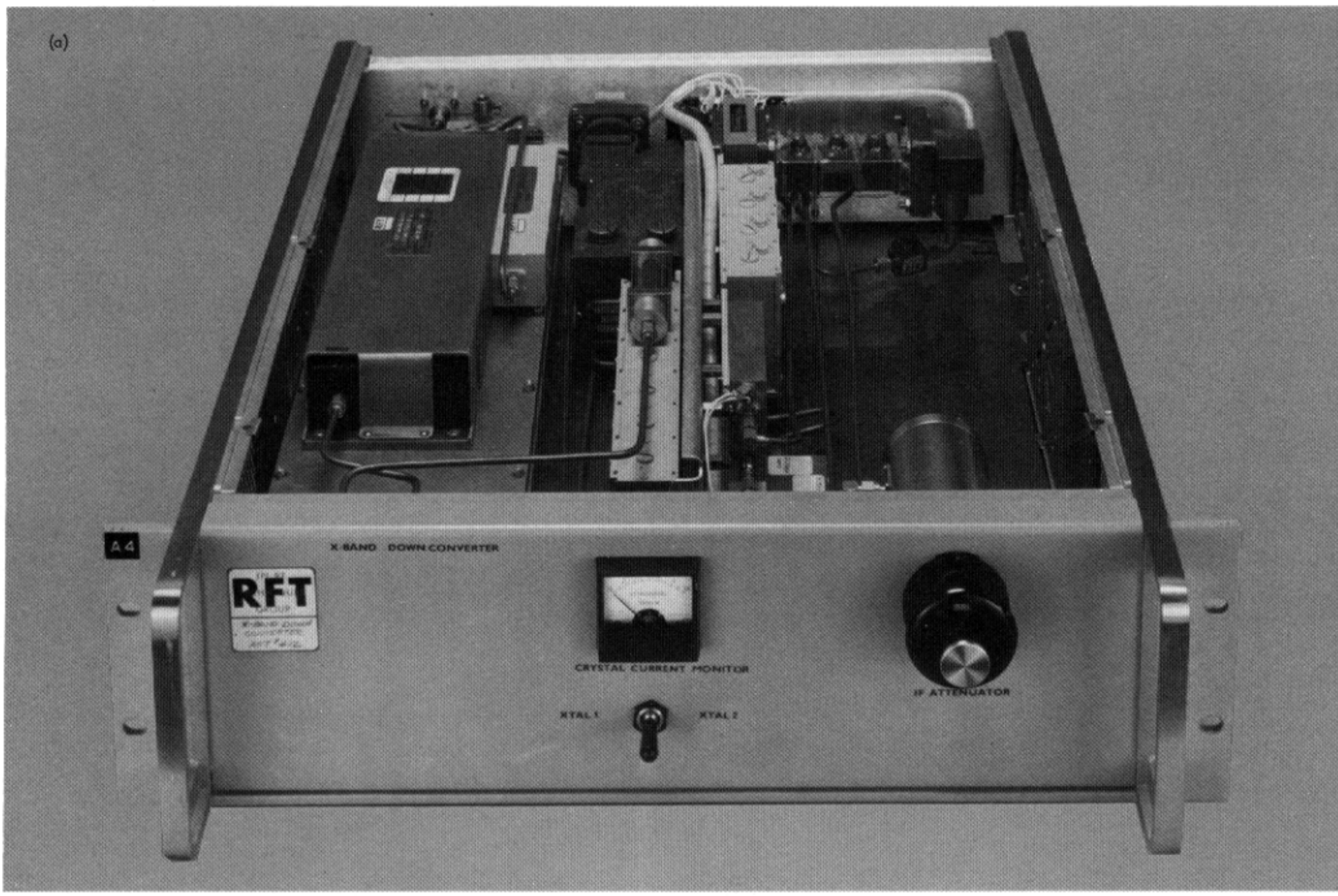


Fig. 2. TDL X-Band to 50-MHz down converter: (a) front view; (b) top view; (c) rear view

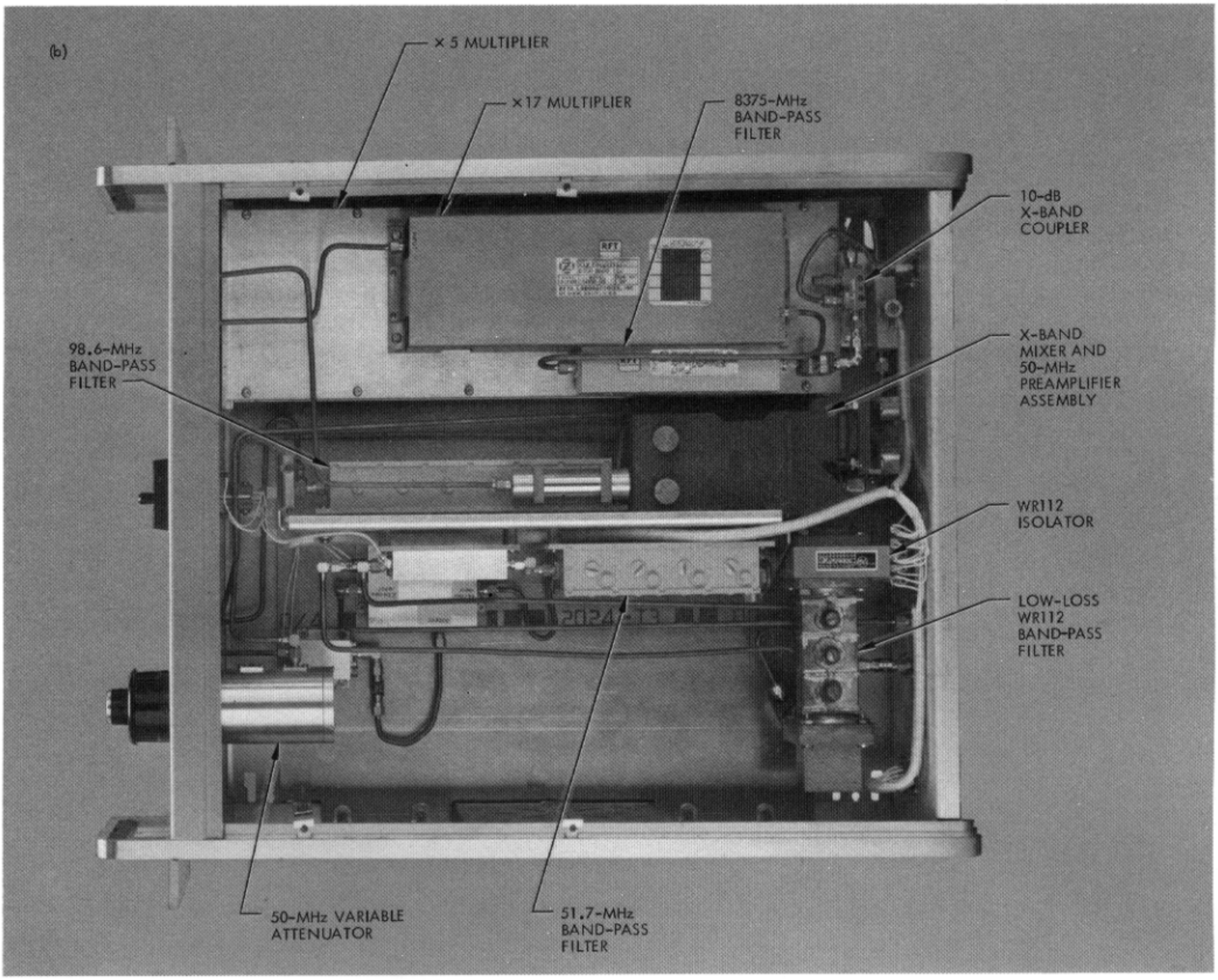

(b)
× 5 MULTIPLIER
× 17 MULTIPLIER
8375-MHz BAND-PASS FILTER
10-dB X-BAND COUPLER
98.6-MHz BAND-PASS FILTER
X-BAND MIXER AND 50-MHz PREAMPLIFIER ASSEMBLY
WR112 ISOLATOR
LOW-LOSS WR112 BAND-PASS FILTER
50-MHz VARIABLE ATTENUATOR
51.7-MHz BAND-PASS FILTER

Fig. 2 (contd)

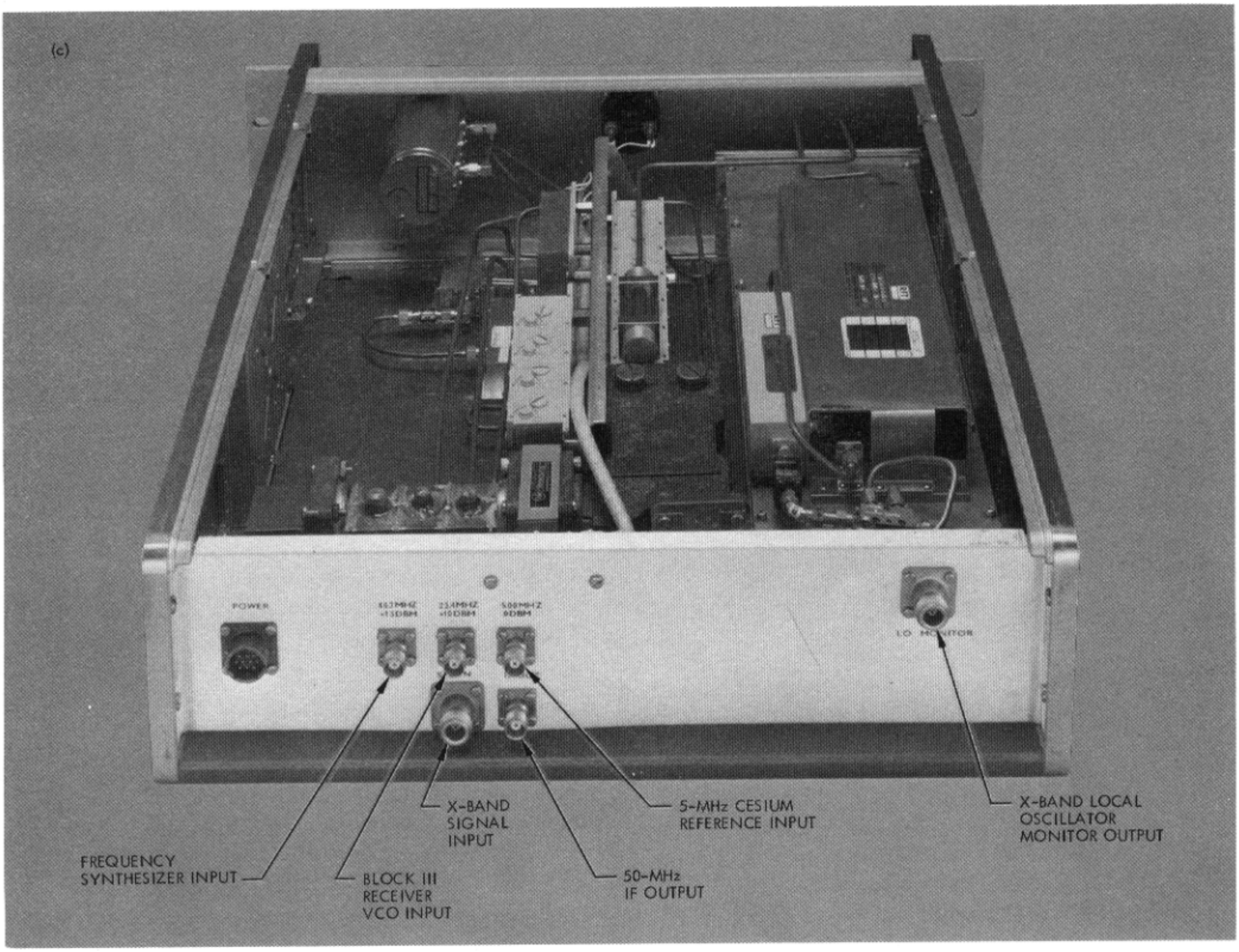

(c)
POWER
X-BAND SIGNAL INPUT
5-MHz CESIUM REFERENCE INPUT
X-BAND LOCAL OSCILLATOR MONITOR OUTPUT
FREQUENCY SYNTHESIZER INPUT
BLOCK III RECEIVER VCO INPUT
50-MHz IF OUTPUT

Fig. 2 (contd)

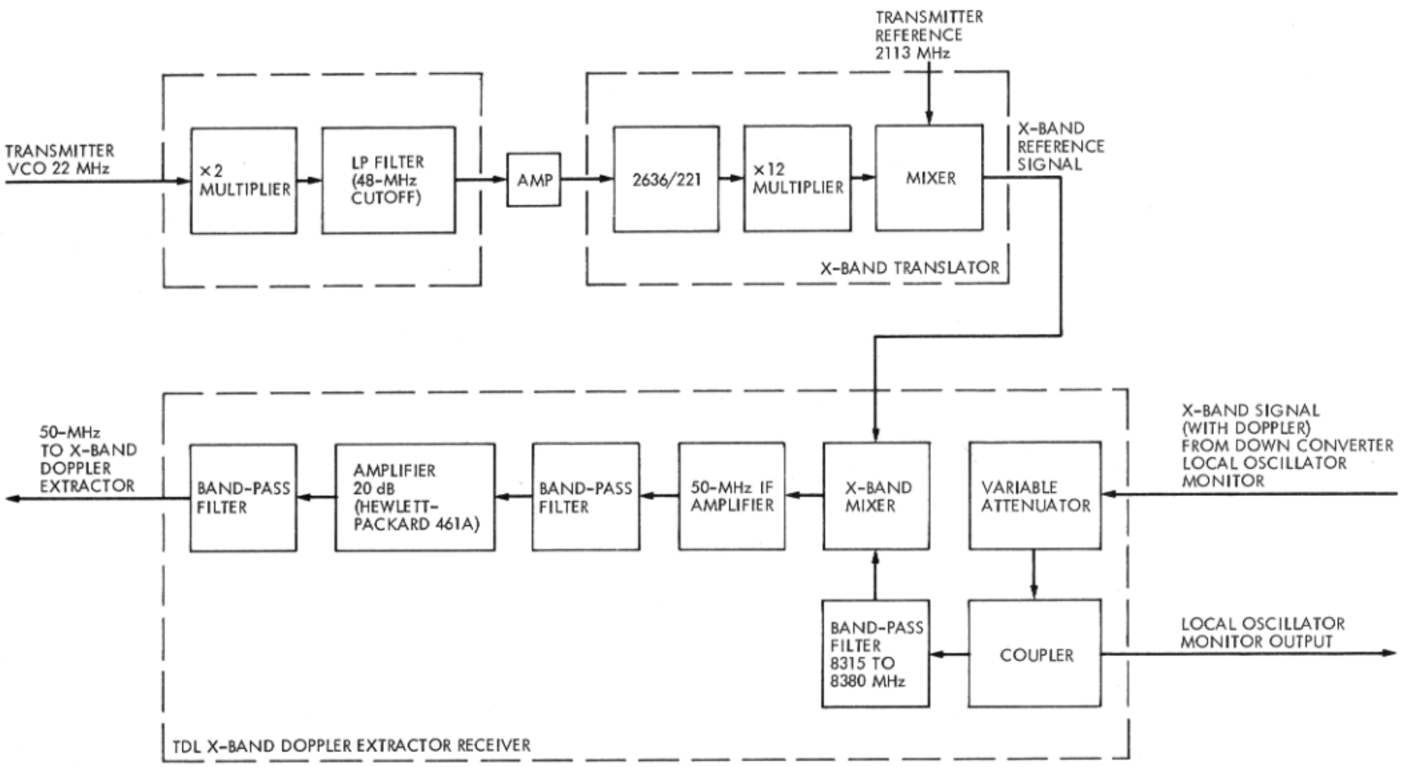


Fig. 3. Block diagram of TDL X-band doppler extractor system

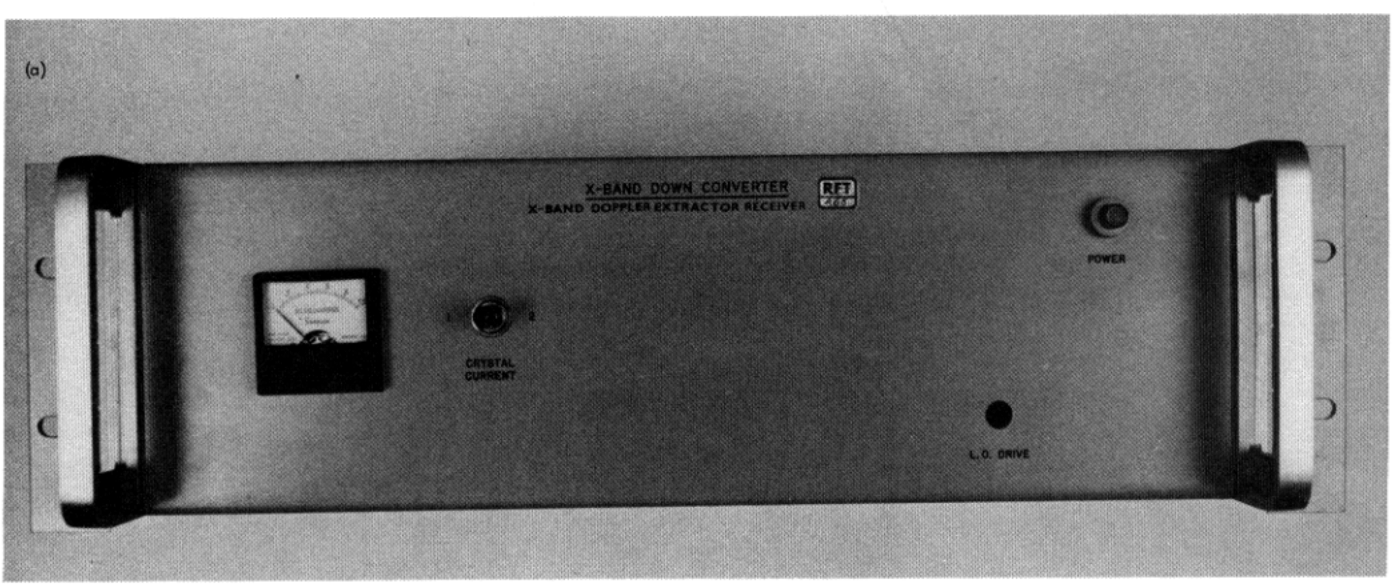


Fig. 4. TDL X-band doppler extractor receiver: (a) front view; (b) top view; (c) rear view

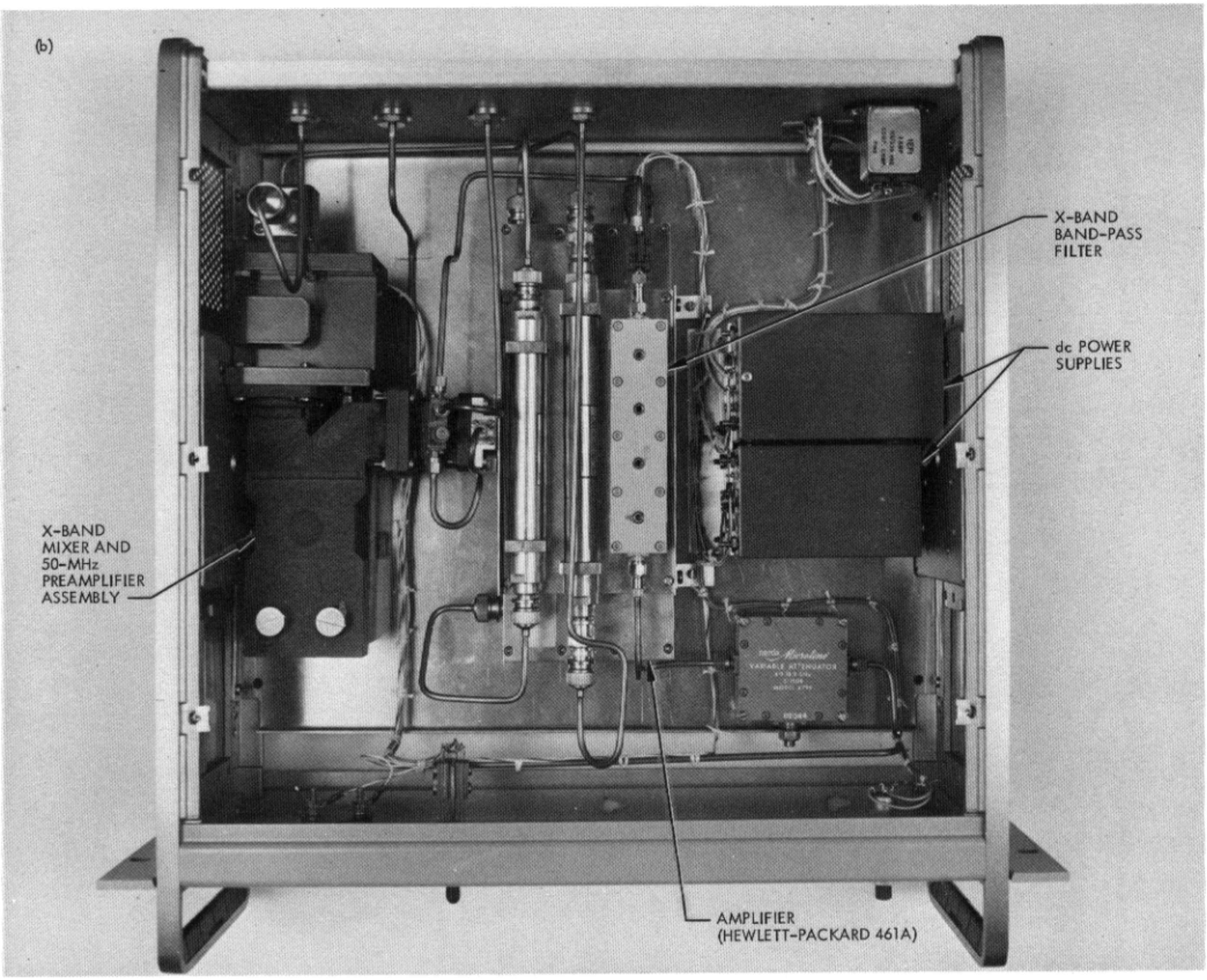

(b)
X-BAND
BAND-PASS
FILTER
dc POWER
SUPPLIES
X-BAND
MIXER AND
50-MHz
PREAMPLIFIER
ASSEMBLY
AMPLIFIER
(HEWLETT-PACKARD 461A)
VARIABLE ATTENUATOR

Fig. 4 (contd)

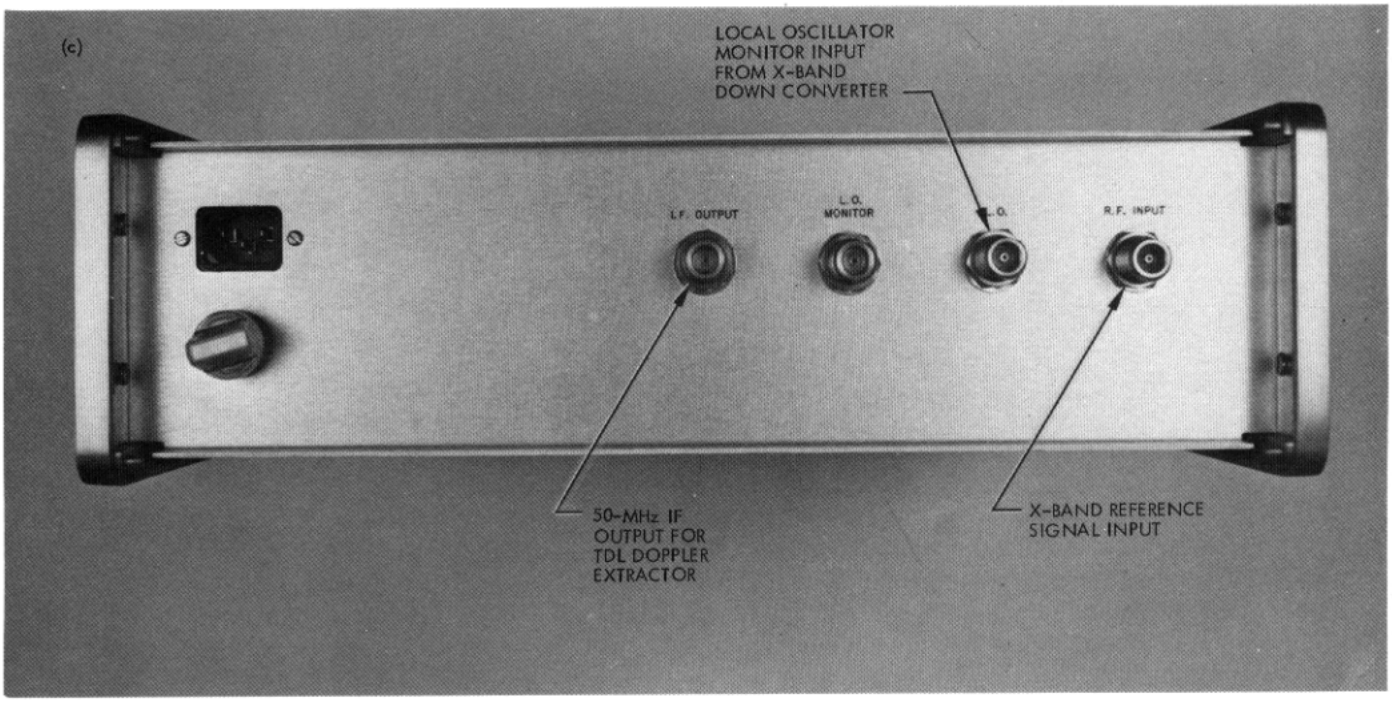

(c)
LOCAL OSCILLATOR
MONITOR INPUT
FROM X-BAND
DOWN CONVERTER
I.F. OUTPUT
L. O.
MONITOR
L. O.
R.F. INPUT
50-MHz IF
OUTPUT FOR
TDL DOPPLER
EXTRACTOR
X-BAND REFERENCE
SIGNAL INPUT

Fig. 4 (contd)