

# S-X Conversion for the Block III Receiver-Exciter

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*An S-X conversion modification has been designed for the Block III receiver-exciter to be used in the 26-meter S-X Conversion Project. The description, design, specifications and data are presented.*

## I. Introduction

The basic purpose of adding an X-band receive capability to the existing DSN 26-meter subnetwork is to maintain the DSN capability to support NASA flight projects – both those currently approved and those that are anticipated to be initiated in the near future.

Deep space missions are phasing over their downlink radio frequency communications from S-band to X-band in order to meet mission navigation and science data return requirements, particularly from the planet Jupiter and beyond. Equally important is the need for spacecraft transmission frequencies that are (presently) clear of other users. The extremely weak signals received from spacecraft in deep space are highly susceptible to radio interference from spacecraft located closer to Earth, such as those in Earth orbit. These two factors – adequate data returns from the outer planets and protection from radio frequency interference – are sufficient cause for space flight projects to employ X-band in addition to S-band.

At the present time, only the three DSN 64-meter-diameter antenna stations are equipped with X-band receive capability. The increasing requirements for X-band support creates an overload on these stations while simultaneously creating an underload on the two 26-meter station subnets. The purpose

of the 26-meter S-X Conversion Project is to relieve the 64-meter subnet overload by adding X-band capability to one of the existing 26-meter subnets.

The 26-meter S-X Conversion Project which will provide X-band receiver capability (Ref. 1) includes a modification to the Block III receiver-exciter subsystem. The receiver changes required to accomplish this modification are described in this article.

## II. Overall Description

To provide X-band receive capability in the Block III receivers at the 26-meter stations in the most cost-effective manner, two basic guidelines were followed: namely, to maximize the use of existing station equipment that is consistent with performance and/or lifetime requirements, and minimize the maintenance cost impact through the utilization of X-band equipments already in service at the 64-meter stations. The Block III receiver can be used as is, if a down converter from X- to S-band is inserted ahead of it. This approach was used. Three methods of down-converting were examined (Fig. 1). These differ in the technique used to derive the reference signal and are discussed below.

### Method 1, Fixed Frequency Reference Signal

In this method the full 35-MHz bandwidth of the X-band signal is translated to S-band. The Block III receiver does not have the capability of handling this bandwidth and modifications to the first local oscillators and receiver front end would be required.

### Method 2, Adjustable Frequency Reference Signal

By providing the capability of selecting the frequency of the reference signal, the converter output frequency can always be adjusted to fall within the Block III receiver input bandwidth. However, this mechanization would add complexity to the doppler extractor.

### Method 3, Coherent Frequency Reference Signal

Generating a reference signal whose frequency is coherently related to the exciter will provide an output frequency from the down-converter that is always within the receiver passband and yet not add any complexity to the doppler extractor.

Method 3 was selected for the down-converter design and is discussed in more detail later in the article.

In addition to a down-converter, it is necessary to add an X-band doppler extractor and a coherent X-band test signal (for receiver testing) to make the modification complete. The functional block diagram of the 26 meter S-X conversion of the Block III receiver-exciter is presented in Fig. 2. The new assemblies required for the S-X conversion are shown in solid squares while the existing equipment is shown in broken lined squares. Each of these assemblies is also discussed in more detail.

The general requirements for the X-S conversion is that the performance at X-band shall be equivalent to or better than the present performance of the Block III receiver-exciter at S-band. Table 1 presents the functional requirements, specifications, and test data for the S-X conversion performance.

## III. Detailed Description

### A. X-S Converter

Figure 3 shows the simplified block diagram of the X-S down-converter. The coherent reference to the down-converter appears at the output of the  $\times 96$  frequency multiplier. The input signal to the times-96 frequency multiplier ( $\times 96$ ) is obtained from the 320/221 frequency shifter (320/221), which in turn is driven by the exciter synthesizer multiplied by

$\times 2$ . Therefore, the frequency at the input to the  $\times 96$  multiplier is  $f_T/48 \times 320/221$  where  $f_T$  is the S-band transmitted frequency. The  $\times 96$  module is a commercial multiplier that was developed for JPL by Zeta Lab. Special attention was given to the method of mechanizing the  $\times 96$  multiplier to assure that no coherent S-band output appears such as the  $\times 36$  harmonic.

The output of the  $\times 96$  is followed by a bandpass filter to remove any undesired harmonics, and the signal is then applied to the mixer as the local-oscillator signal. The signal at this point is  $f_T/48 \times 320/221 \times 96$ , or  $f_T 640/221$ .

The input signal received from the X-band maser is applied to a commercial amplifier. This amplifier was selected both for the low noise figure and to provide sufficient gain to mask the losses of the mixer, power divider, and cables, plus the Block III receiver noise figure. The amplifier is followed by a bandpass filter used as a preselector, and the output of the filter is applied to the mixer. This input signal is coherent with the transmitted signal and is  $f_T 880/221 \pm D_x$ , where  $D_x$  is X-band doppler.

The output of the mixer when mixed with the local-oscillator signal  $f_T 640/221$  is  $f_T 240/221 \pm D_x$ . The output of the mixer is applied to a power divider and each output of this power divider is then applied to a switch. As can be seen from Fig. 2, each receiver may either select an S-band signal from the maser or an X-band signal that has been down converted to S-band.

Figure 4 is a photo of the X-S Converter Assembly with the door removed. The module at the top right is the  $\times 96$  frequency multiplier while the module located top-left is the X-band amplifier. The X-band mixer is the dark square module located at bottom left. The dc voltages required for this assembly are supplied by power supplies located in the X-S Translator Assembly. The X-S Converter Assembly will be mounted in the antenna dec house close to the existing Block III receiver-exciter.

### B. Doppler Extractor

Figure 5 shows the block diagram of receiver 1 doppler extractor. A second output that is used for receiver 2 doppler extractor is shown for the 240/220 output of the 320/221 module and also for the 45-MHz synthesizer and the 49/51 reference modules. These doppler extractor modules are mounted in the Block III receiver located in the control room.

The reference frequency for the doppler extractor applied to the input of the 320/221 frequency shifter is  $f_T/48$  and the

output of the 240/221 port is then  $f_T/48 \times 240/221$ . This reference signal is applied to the doppler mixer. The doppler signal applied to the doppler mixer is derived from the receiver VCO through a  $\times 2$  frequency multiplier. This doppler signal is  $[f_T 240/221 - 50 \pm D] 1/48$ , where  $(240/221 f_T - 50)$  is the first local oscillator signal. When these two signals are applied to the doppler mixer as well as the 49/51-MHz and the 45-MHz references, the mixer produces doppler biased at both 1 MHz and 5 MHz.

### C. S-X Band Translator

Figure 6 shows the simplified block diagram of the translator. The signal applied to the 2636/221 frequency shifter is obtained from the exciter distribution amplifier and is  $f_T/48$ . The output of the frequency shifter is then amplified by the UHF amplifier and applied to the  $\times 12$  frequency multiplier. The output of the  $\times 12$  is applied to the mixer as the local oscillator (LO) signal and is identified as  $f_T/48 \times 2636/221 \times 12$ , or  $f_T 659/221$ .

The signal for the mixer may be obtained either directly from the exciter or after the exciter output has been amplified by the transmitter. This signal is  $f_T$ . When these two signals are

present, the output of the mixer is  $f_T 659/221 + f_T$ , or  $f_T 880/221$ , which is the spacecraft transponder ratio, and this signal is identified as the X-band receiver test signal.

The design of the S-X translator assembly is adapted from the Block IV receiver-exciter design and uses the same components. The S-X translator assembly is shown in Fig. 7 with the door removed. The three square modules at the top are power supplies; the large module to the left is the 2636/221 frequency shifter. The small module in the bottom center is the UHF amplifier, while the module at bottom right is the  $\times 12$  frequency multiplier and the horizontal module located in the center is the mixer.

## IV. Conclusion

The evaluation of an engineering model has been completed. The fabrication of the first production system is in process and is scheduled for completion by January 1, 1978. The hardware will be installed in the lab receiver for testing and then shipped on March 1, 1978, for installation at DSS 12.

## Reference

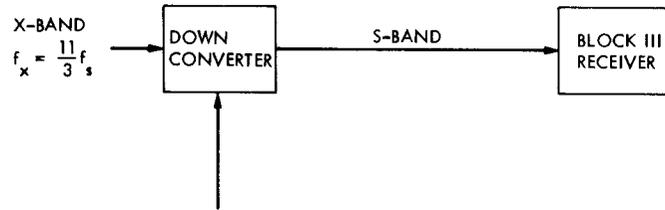
1. Lobb, V. B., "26-Meter S-X Conversion Project," in *The Deep Space Network Progress Report 42-39*, pp. 157-167, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1977.

**Table 1. Functional requirements, specifications, and test data**

Parameter	Requirements	Specifications	Test data
Frequency range	8.4 – 8.44 GHz	8.4 – 8.44 GHz	8.4 – 8.43 GHz <sup>a</sup>
Noise figure	≤ 10 dB	≤ 10 dB	8.0 dB
Doppler phase error noise	< 12 deg	< 12 deg	8 deg
Doppler shift during mission lifetime	80 km/sec	80 km/sec (X = 4.51 MHz) (S = 1.267 MHz)	X = 4.6 MHz S = 4.6 MHz
Doppler shift during single pass	1.0 km/sec	1.0 km/sec (X = 56.3 kHz) (S = 15.4 kHz)	150 kHz
Doppler rate near Earth	100 m/sec <sup>2</sup>	100 m/sec <sup>2</sup> (X = 5630 Hz/sec) (S = 1540 Hz/sec)	5630 Hz/sec with 32 deg phase error
Doppler rate planetary encounter or orbit	0.1 m/sec <sup>2</sup> (< 10° error when 10 dB above receiver 12 Hz threshold)	0.1 m/sec <sup>2</sup> (X = 5.63 Hz/sec) (S = 1.54 Hz/sec)	< 10 deg phase error
Doppler stability 5 × 10 <sup>4</sup> second averaging	0.4 m	0.4 m x = 8100 deg	0.4 m 625 deg <sup>b</sup>
Group delay	1.4 m	1.4 m (9.3 nanosec)	0.5 ns <sup>b</sup>

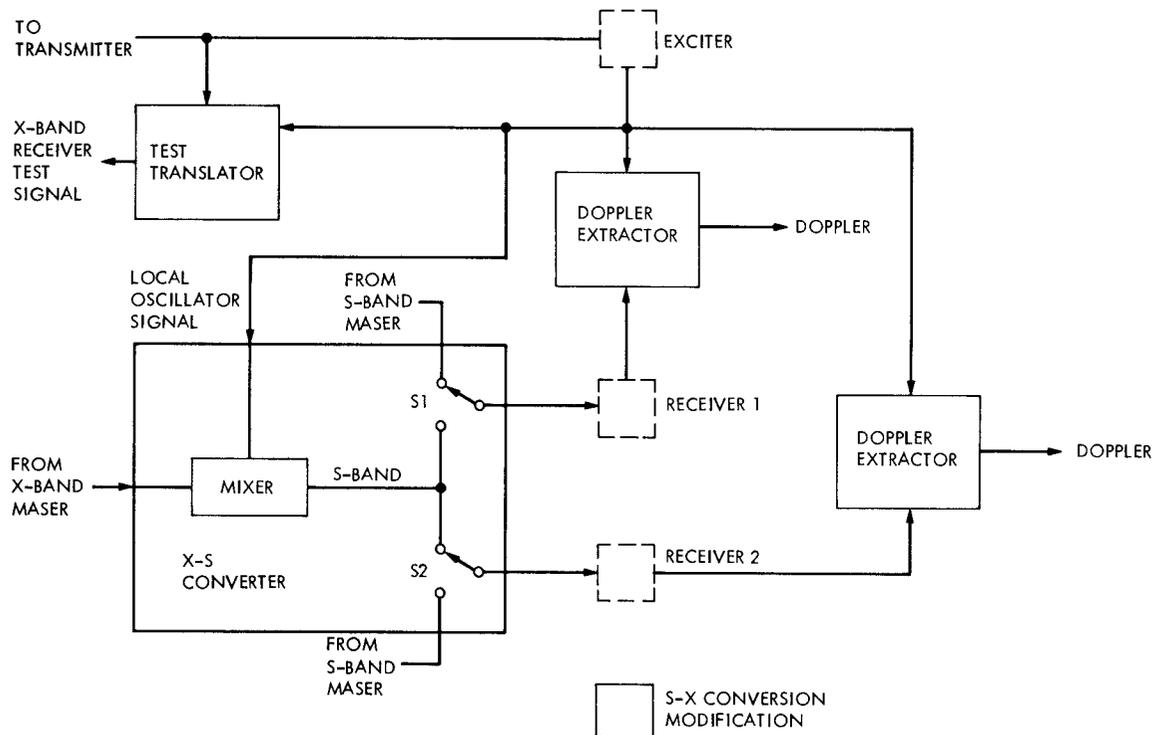
<sup>a</sup>8.43 – 8.44 GHz noncoherent mode.

<sup>b</sup>Added instability due to S-X conversion over  $\Delta t$  of 5°C.



- METHOD A. FIXED FREQUENCY REFERENCE
- METHOD B. ADJUSTABLE FREQUENCY REFERENCE
- METHOD C. COHERENT FREQUENCY REFERENCE ( $\frac{8}{3} f_s$ )

**Fig. 1. Down-conversion techniques**



**Fig. 2. S-X conversion modification – functional block diagram**

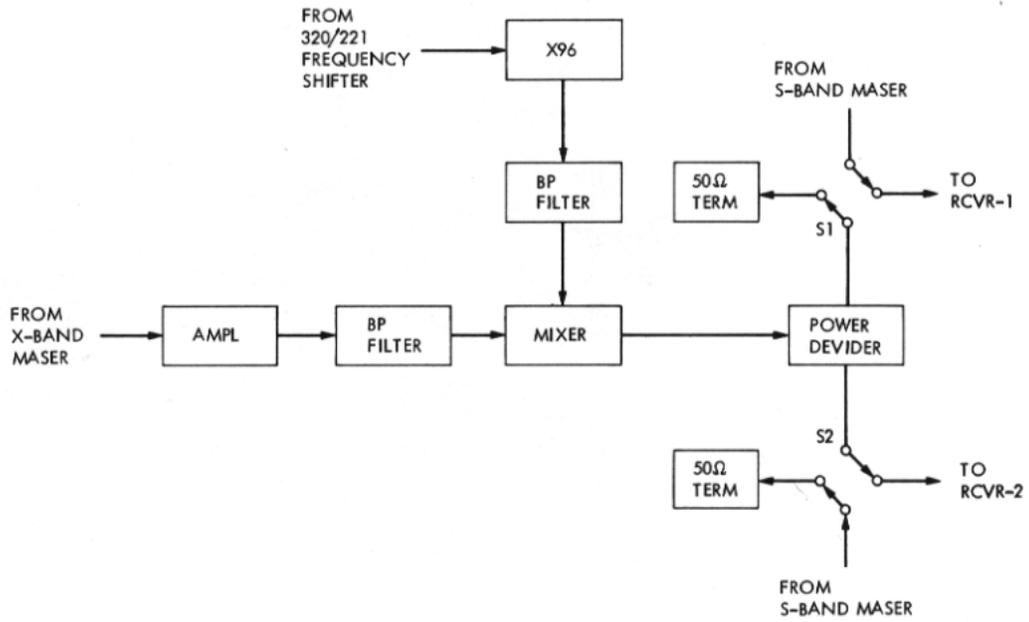


Fig. 3. X-S converter simplified block diagram

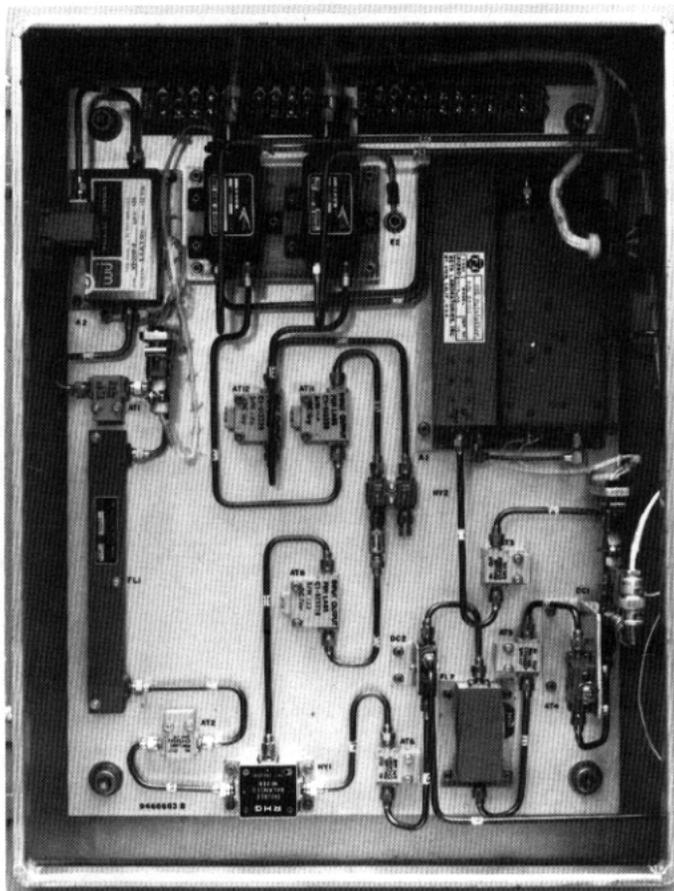


Fig. 4. X-S converter assembly with door removed

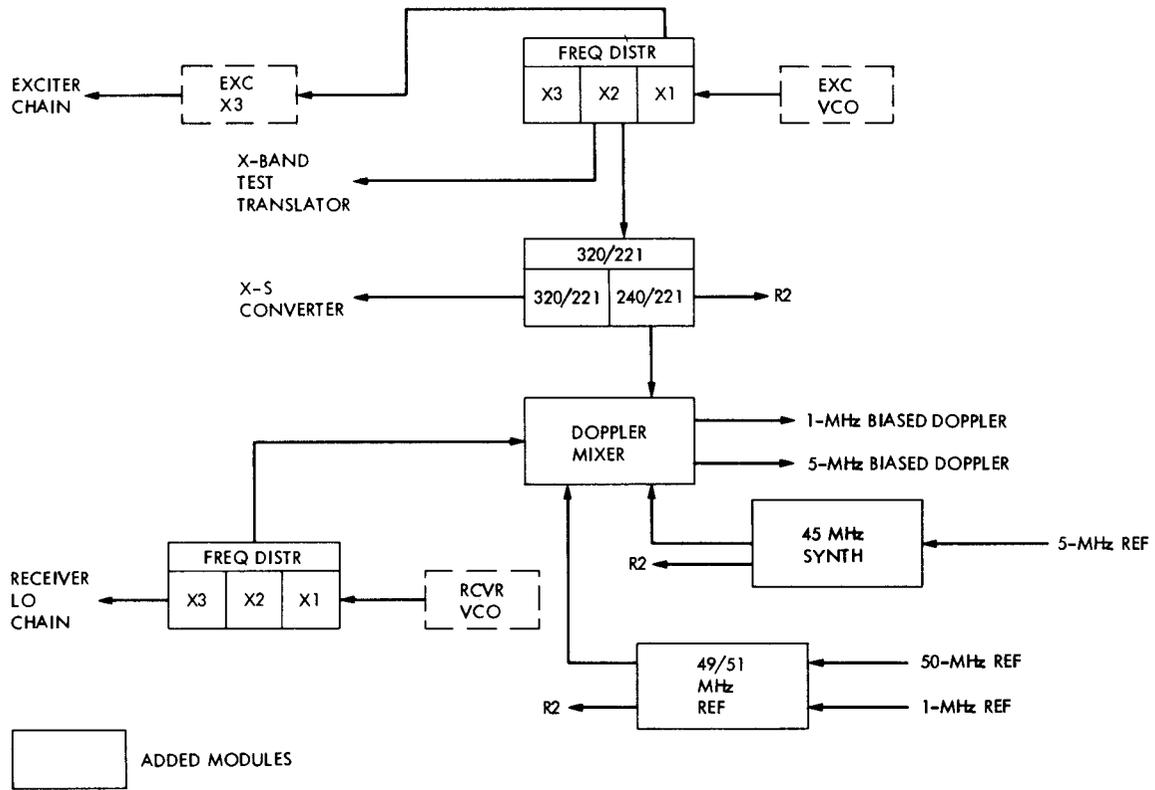


Fig. 5. Doppler extractor block diagram

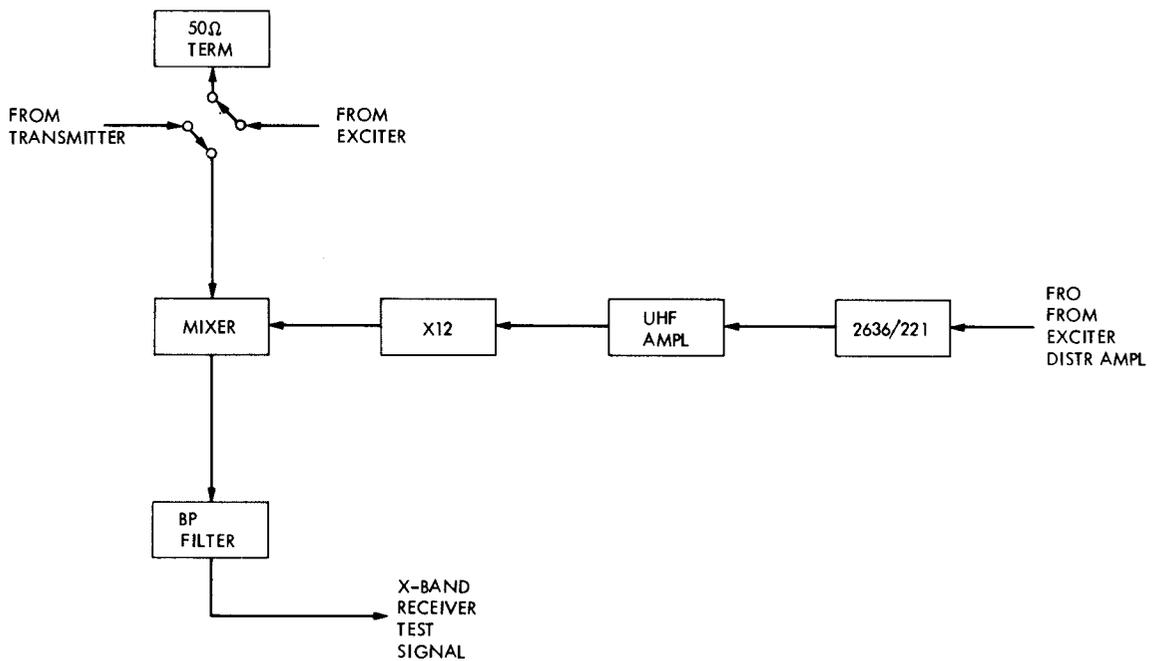
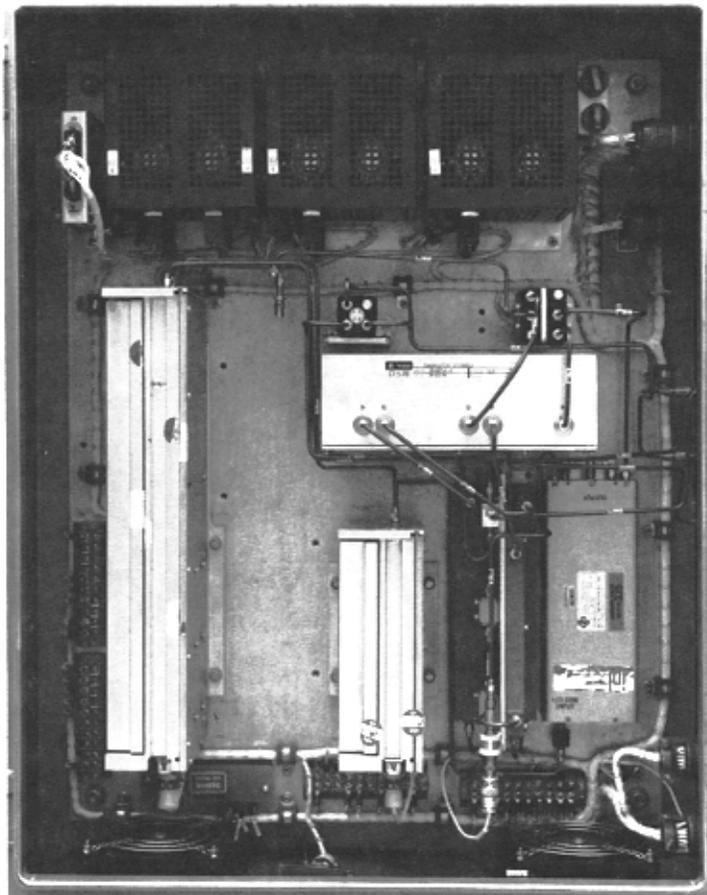


Fig. 6. S-X band translator block diagram



**Fig. 7. S-X band translator assembly with door removed**