Second-Generation X/S Feedcone: Capabilities, Layout and Components

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High-power (20-kW) S- and X-band transmitting systems are added to the Second-Generation Common Aperture X/S Feedcone System to demonstrate X- and S-band uplink/downlink capabilities. Design considerations of new X-band components, cone layout, and capabilities are discussed.

I. Introduction

One of the feedcones normally installed at DSS 13 is called the XSR or first-generation X/S feedcone. This listen-only system incorporated for the first time the common aperture feedhorn, enabling simultaneous X- and S-band reception from a geometrically symmetrical antenna. Figure 1 shows this feedcone mounted at DSS 13. The second-generation X/S feedcone, though having the exact same outward appearance, has been made a multifunction feedcone on the inside by the addition of transmitters and diplexers with extended bandwidths and power handling capabilities. There were four aspects to the system development:

(1) The development of a common aperture feedhorn and combiner to handle the added bandwidth and power (Refs. 1 and 2).

(2) The development of the 20-kW X-band transmitter/exciter (Refs. 3, 4, and 5).

(3) The design of new X-band broadband devices to handle the added transmit functions.

(4) The integration of all these elements within the confines of a new feedcone.

Parts 1 and 2 above have already been covered in previous reports and will not be discussed to any length here. We will confine ourselves to system capabilities, block diagrams, functional layout of the cone, and the performance of the new X-band diplexer and polarizer.

II. Planned Capabilities

This new feedcone will transmit 2110 to 2120 MHz and receive 2200 to 2300 MHz at S-band, and transmit 7145 to 7235 MHz and receive 8200 to 8600 MHz (with the best receive performance between 8400 to 8500 MHz) at X-band. Each function is fully independent with each band diplexed. The bandwidth of the horn itself easily covers the full S- and X-band spectrum, with RF efficiencies of 68% and 72% respectively (Ref. 1).

The X/S combiner design requires the polarization of the S-band signal to be a "hard-wired" function. Right circular polarization (RCP) will be the one provided. The addition of left circular polarization (LCP) would involve a new waveguide run and an extra switch, for an estimated 2-K additional system noise. S-band ellipticity measurements have yet to be made with this new horn. As is standard in other S-band cones, the system will consist of either a low-noise listen-only path, or a fully diplexed path for simultaneous transmission/reception. The system is intended for a single S-band maser, and a direct VLBI port is not supplied. Because of limited X-band rejection uncertainty in the combiner section, a waffle-iron filter is placed just in front of the maser for added X-band isolation. This will add 3.4 K to an approximate 24-K (baseline) system noise temperature. It is expected that tests on the antenna will indicate sufficient X-band rejection to warrant its removal. (Ultimately, cryogenic filtering within the amplifiers will be developed.) In the diplexed position, the additional waveguide and S-band diplexer will add approximately 5 K over that for a total of 27 K and 33 K, respectively. These figures are based on performance of the first-generation feedcone and known effects of various S-band components. The S-band system is designed to transmit 20-kW, powered by the present transmitter on DSS 13. An S-band transmit filter will reject S-band beam noise. However, there is presently no fourth-harmonic filter in the system to suppress X-band receive harmonics. An effort is being made to locate one.

The X-band system will have switchable polarization (LCP or RCP), but will have only a diplexed configuration, first because of the high performance of the new X/X-band diplexer, and second because the diplexer's receive band will cover the proposed VLBI band (8200 to 8600 MHz). Again, the design is for a Block II-A maser (100-MHz instantaneous bandwidth) that will cover 8400 to 8500 MHz. The diplexer has its best match, lowest loss, and highest isolation at these frequencies. A VLBI receive-only port is supplied, but no X-band transmit function will be possible in that configuration. An approximate system noise temperature for the diplexed receive band of 8400 to 8500 MHz is 30 K. A listen-only path could conceivably drop this to 27 K (baseline), but at the same time would degrade the diplexed receive link by 7 K, for a total of 34 K. Ellipticity measurements of the feedhorn/polarizer combination await completion of the broadband polarizer. The new transmitter will supply the required 20-kW signal for the X-band uplink demonstration on this project. The X-band transmitter is located in the cone.

A dual -54-dB loop coupler at S-band and a dual -54-dB cross-guide coupler at X-band are supplied to monitor the respective transmitter signals, run phase calibration checks, and perform other required microwave tests. Both an X-band and S-band calibration system will be supplied for maser calibration. They will incorporate noise diodes (three levels), a receive-band signal source, and both will be NAR capable. All microwave switches, the X-band polarizer, and both calibration boxes will be compatible with on-going automation projects. The block diagram (Fig. 2) shows the other couplers and loads supplied by the microwave group. The signal paths and cone interfaces shown are generally those believed necessary to operate the fully operational feedcone. However, only those functions necessary to demonstrate the principles will be supplied in FY 81. Some functions (such as the X-band transmit functions, doppler extraction being an example) are scheduled for implementation in FY 82 and 83. (Ref. 4).

III. Planned Layout

The housing of the microwave subsystem mirrors the first-generation feedcone in construction. To a basic straight base cone shell (approximately 429 cm tall) we again bolt a cone extension (approximately 196 cm in height) to the top of the base cone. An adapter ring (3.73 cm thick) is then used to mount and position the X/S feedhorn/combiner in the cone. A flat plate bolted to the X/S combiner enables us to directly mount a standard DSN X-band polarizer package to the feedhorn. A 23-cm section of WC 137 (a 0.6-K loss) waveguide is used to fill the gap between the feedhorn and the polarizer caused by the shorter throat section of the X/S feedhorn, and a new four-section stepped transition is used instead of the tapered transition to make room for the -54-dB cross-guide coupler. The new broadband polarizer is designed to be a direct replacement for the standard single-frequency polarizer. The X/X-band diplexer (water cooled) is placed between the WR125 two-position switch and the -35-dB calibration coupler on the X-band maser. Approximately 366 cm of WR125 (water cooled) waveguide join the diplexer and the X-band transmitter positioned directly below it on the cone floor. All X-band waveguide microwave components will be constructed of copper.

The S-band system will employ the same waveguide bridge network found in the First-Generation Feedcone System. The horn is fed through four separate circumferential ports 90 deg apart on the side of the horn. The phasing at each port is controlled by "equal-length" waveguide runs, two 90-deg hybrids, and a magic "T" (all in WR430 waveguide). Coupling the magic "T" to the correct two ports of the two 90-deg hybrids "hard wires" either RCP or LCP operation. Between the "E" plane port of the magic "T" and the S-band maser, a -54-dB loop coupler, approximately 91 cm of WR430, a two-position switch, the waffle-iron filter, and a -33-dB cross-guide coupler constitute the listen-only low-noise path; add to that another switch, the S-band diplexer, and 213 cm of WR430 for the diplexed mode and you have the diplexed receive path. Since the transmitter input to the S-band diplexer is some 427 cm above the cone's bottom floor, the transmit waveguide runs 2/3 the length of the cone through the S-band transmit filter to the floor. A WR430 waveguide run connects the cone to the S-band transmitter located in the DSS 13 equipment room below the dish. Most of the S-band waveguide will be made of aluminum, and the S-band system in the cone will not be water cooled (Fig. 3).

IV. Feedcone Components

This feedcone is basically two separate systems sharing a common feedhorn aperture. Except for the X/S feedhorn/combiner, no new S-band hardware was developed. Much the same thing can be said for the X-band system, except for the aforementioned X/X-band diplexer and the broadband polarizer. Both will be the subject of a separate report when all final models and tests are completed. Following are exerpts of the more pertinent characteristics of each.

A. X/X-Band Diplexer[1]

The diplexer consists of three separate components. The center three-port "T" combiner section consists of a high-pass filter in the receive arm and a band-pass filter in the transmit arm. Two "E" plane cavity-type band stop filters (BSF) are added, one each to the transmit and receive ports for the necessary added isolation. The "T" section combiner was electroformed (copper electrodeposited on an aluminum mandrel), while the two BSFs were constructed of three flat plates, all machined separately, and then pinned and bolted together to give a section of WR125 waveguide with inductively coupled "E" plane cavities. A two-cavity BSF is used in the receive link and was originally designed for 40-dB rejection of the transmit band (7145 to 7235 MHz) and a four-cavity BSF is used for the transmit link with better than 70-dB rejection of 8400 to 8500 MHz. The transmit arm of the "T" was tuned in conjunction with the four-cavity BSF, and as such must be used as a single unit. However, the receive arm of the "T" and the two-cavity BSF were matched independently and are meant to be used together or separately depending on the desired isolation. The high-pass receive arm itself has > 38 dB of rejection of the 7145 to 7235 MHz band, but the two-cavity BSF added only 30 dB more. Originally it was felt that the total 68 dB would be enough; however, new tests on the interference effects (RFI) in the TWMs limits to 1 mW the transmit power received before experiencing some drop in maser performance. The degradation in performance is due to overcoupling between the two cavities, and the cavities are now being respaced to give the necessary 5-dB more isolation.

1. Measured performance of the receive band.

VSWR (8200 to 8600 MHz):	<1.17:1
(8400 to 8500 MHz):	<1.07:1
loss (combined):	<0.05 dB[2] (<3.5 K)
isolation/rejection: (7145 to 7245 MHz)	>68 dB (goal: 73 dB)

2. Measured performance of the transmit band.

VSWR: (7145 to 7245 MHz):	<1.07:1
loss:	<0.08 dB[3]
isolation/rejection: (8400 to 8500 MHz)	>>93 dB[4]

The results of the rework of the two-cavity BSF will be reported at a later date when the full report on the diplexer is made.

B. WC137 Broadband Polarizer

A polarizer converts a linearly polarized TE°_{11} mode, generated from $TE^{\square}_{01}$ by the WR125 to WC137 four-step transition, into a circularly polarized TE°_{11} mode by "quarter-wave plate" action. Because of the wide separation of the transmit and receive bands, the performance over this extended range of the quarter-wave plate is questionable, and will be replaced with an iris-type polarizer. At present, only an aluminum prototype exists, but these test results should be representative of the finished product. The results below were obtained using the Automated Network Analyzer.

1. Measured performance for 7000 to 8600 MHz.

ellipticity:	<0.5 dB
VSWR:	<1.07:1

2. Current fabrication. A polarizer is now being fabricated from a solid block of copper. Its loss, VSWR, and ellipticity will be measured as time and equipment allow, and will be reported at a later date when a full report on this polarizer is made.

V. Conclusions

A new Cassegrain feedcone assembly designated the XSU feedcone (for common aperture X- and S-band uplink) is being built to replace a XSR (for common aperture X-and S-receive only) feedcone presently in use at DSS 13.

[1]Original design by W. Erlinger of Wenzel/Erlinger Associates.

[2]The loss measurement was made using a maser and a liquid nitrogen load.

[3]The loss measurement was done using an Automated Network Analyzer.

[4]The sensitivity limit of the equipment used (the original design called for 100 dB). Full isolation will be done when a maser is available.

This feedcone is the prototype for six wideband listen-only SXC cones (convertible to XSU) to be implemented throughout the operating DSN network. The microwave design is essentially complete, fabrication of the cone shell is complete, and assembly has begun. The microwave component installation will be completed at JPL and shipped to the DSN Microwave Test Facility where the X-band transmitter will be installed. Following fabrication and installation, testing will take place at the Test Facility and at DSS 13. Ground tests will measure system noise and power handling capabilities.

This feedcone greatly extends the state of the art in performance offered to the DSN, and will greatly enhance experimental as well as DSN capabilities in the coming years.

References

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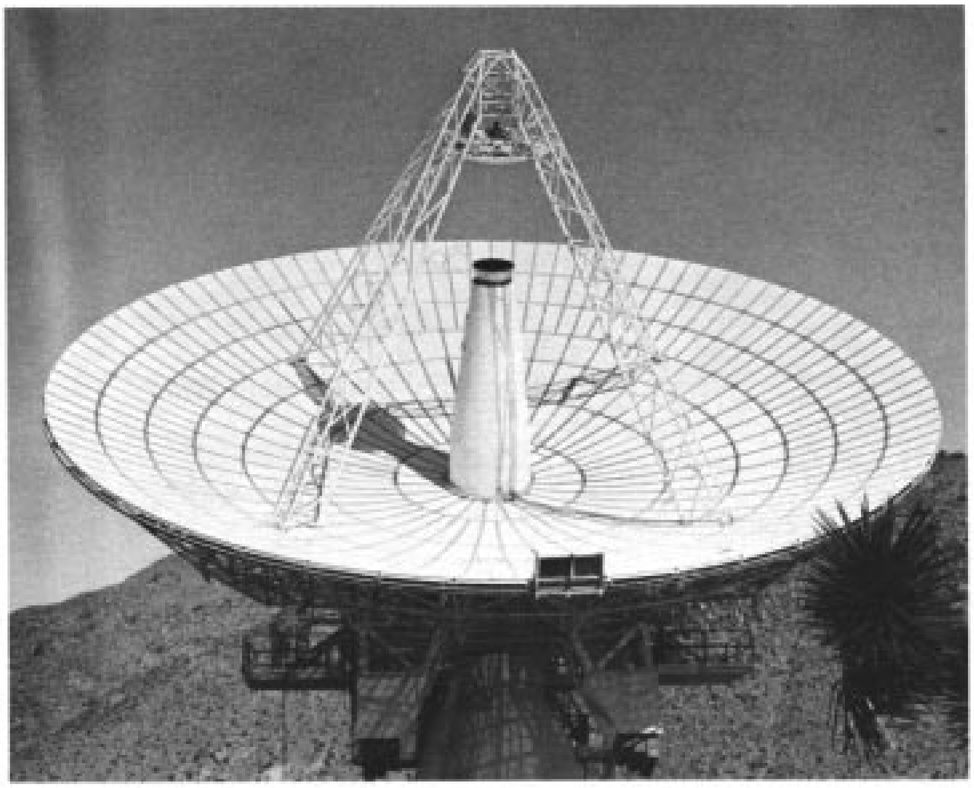

Fig. 1. The first X/S feedcone on DSS 13

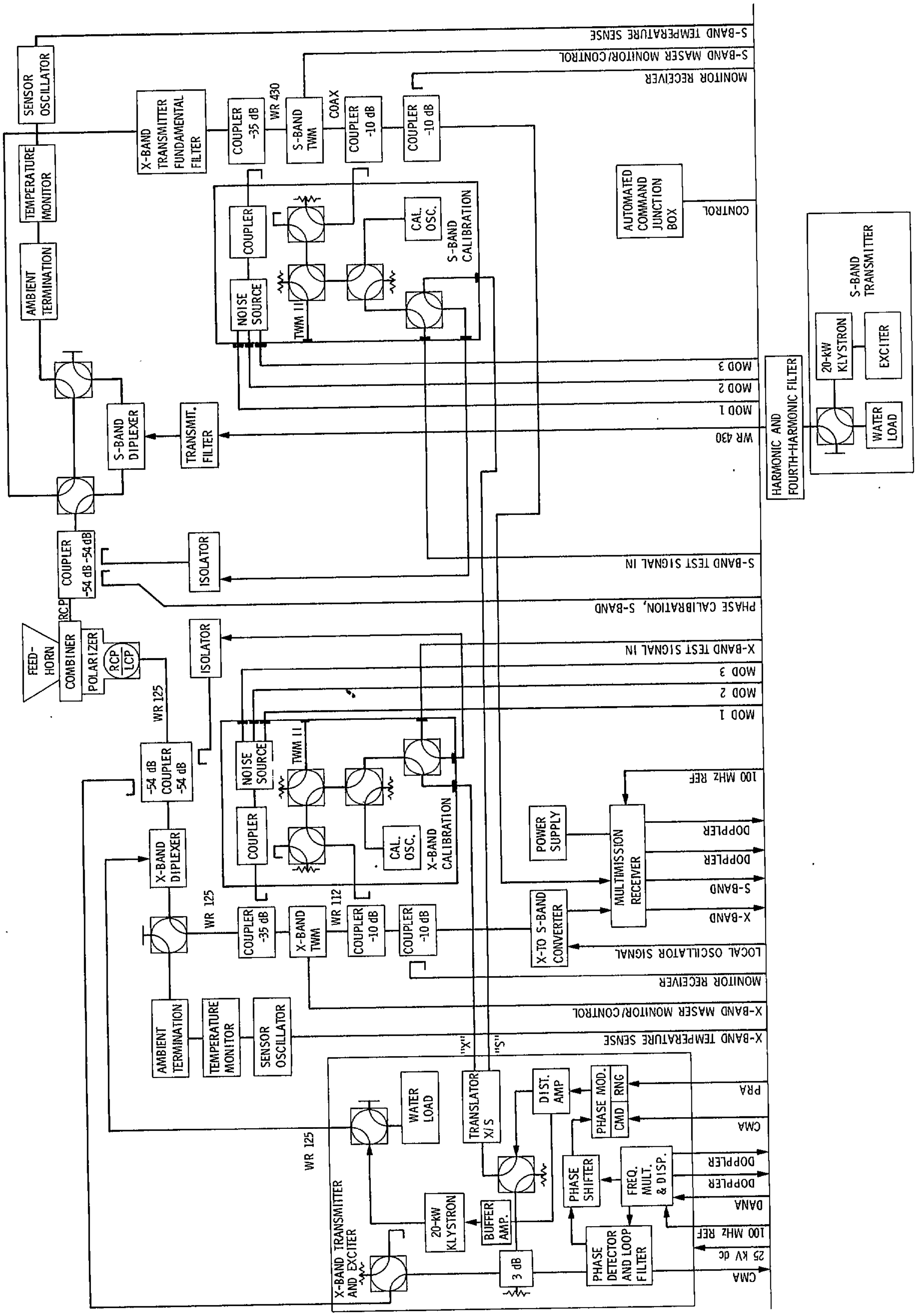

Fig. 2. Second-generation X/S feedcone, block diagram

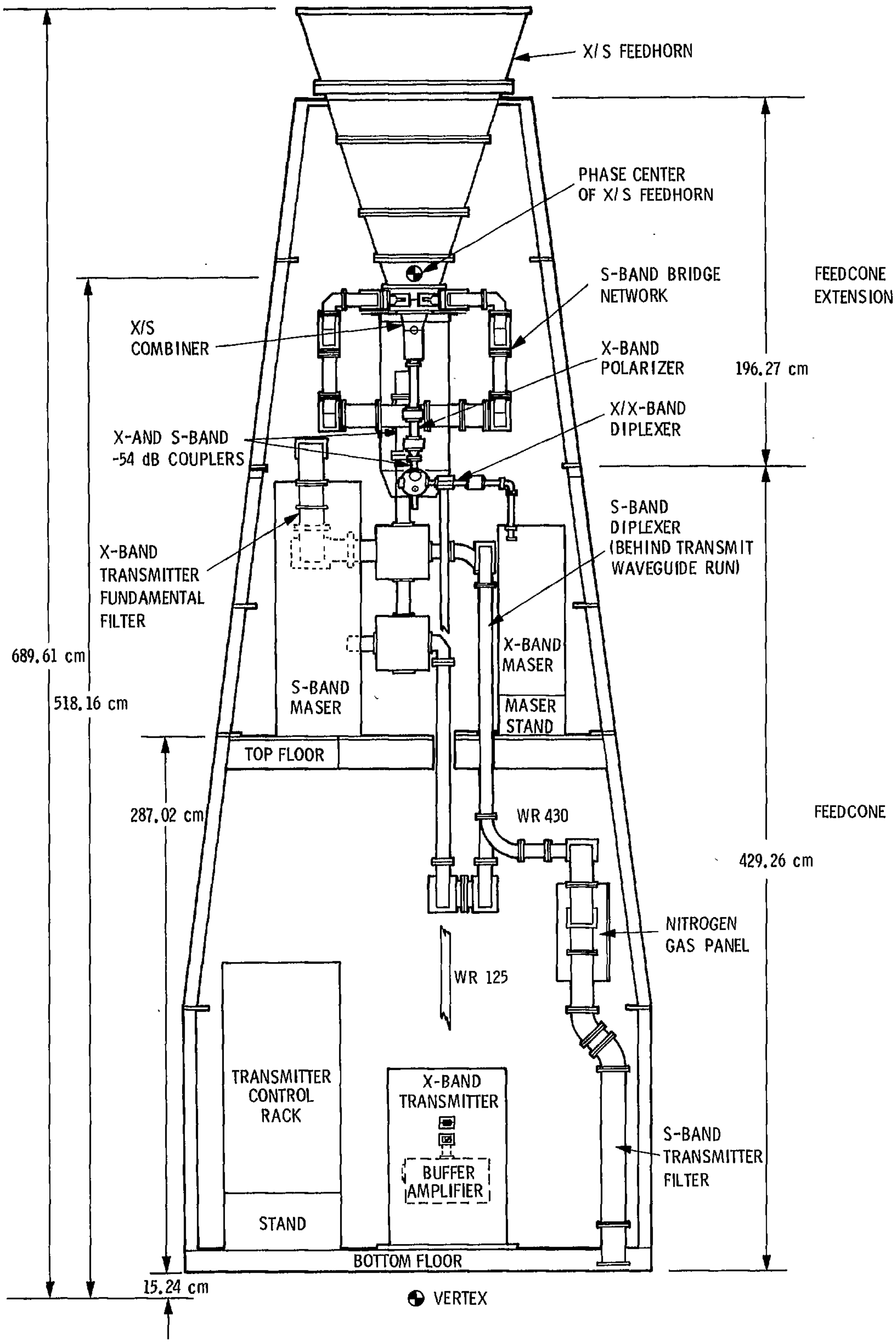

Fig. 3. Second-generation X/S feedcone, general layout