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X-Band Phase Calibration Generator Coupler

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A new type of phase calibration generator (PCG) coupler has been developed for the DSN X-band antennas that can be located directly behind the feedhorn. The advantage of this is that the calibration includes more of the system. The disadvantage is that the overmoded waveguide at this location must be coupled in a mode-selective manner. Low-power and high-power PCG couplers have been successfully produced, and the RF test results from a PCG coupler are given in this article.

I. Introduction

A phase calibration generator (PCG) coupler was developed for the X-band 34-m high efficiency and the new 70-m antennas. The location selected for this coupler is directly behind the feedhorn, to include as much of the transmission line in the phase calibration path as practical. Two disadvantages of this location are: (1) little available room, requiring compact packaging of the PCG coupler, and (2) an oversized circular waveguide capable of supporting multiple waveguide modes, requiring a design that couples only the desired waveguide mode efficiently. The principal RF requirements are listed in Table 1. Note that the requirement for directivity is not high because the signal going to the feedhorn must be reflected from the subreflector and recaptured by the feedhorn (over 20–dB attenuation) before it can interfere with the desired signal.

II. Design

The Bethe hole coupling technique [1] offered the possibility of minimizing the coupler length while providing moderate directivity and control of unwanted waveguide modes (TM_{01} and TE_{21}). The Bethe coupling technique controls the coupled amplitude of the E- and H-plane fields so that they cancel in the direction of the isolated port and add in the direction of the coupled port (analysis of this coupler is given in [2]). This type of coupling is typically accomplished through a single electrically small ($\ll$ wavelength) aperture between two dominant mode waveguides. For coupling to the TE_{11} mode, the overmoded circular waveguide of these PCG couplers requires a pair of coupling apertures symmetric about the circular waveguide. The E- and H-plane fields coupled to this circular waveguide should be parallel and perpendicular, respectively, to a plane that includes the waveguide axis and the centers of the two apertures. Figure 1 shows a simplified cutaway diagram of this coupler. A power splitter divides the signal from the phase calibration generator into equal amplitudes. These signals travel along a pair of dominant mode rectangular waveguides (WR 90) to the coupling apertures in the center of the waveguide broadwall, located on either side of the circular waveguide (WC 137). At these apertures, a part of the calibration signal (in this case, <-37 dB) is coupled into the circular waveguide in the direction of the receivers, and a part is coupled in the direction of the horn (in this case, <-58 dB).

The coupling magnitude was controlled by changing the size of the coupling apertures. The coupling aperture shape and the width of the rectangular waveguide in the proximity of the coupling aperture were used to control the directivity. The aperture is in the form of a slot with semicircular ends. Its long dimension is parallel to the axis of the circular waveguide.

The X-band phase calibration coupler (see Fig. 2) has been produced in two configurations. The first was for the 70-m antenna and is a low-power unit. The second was for the 34-m high efficiency antenna and must function properly during 20-kW transmission conditions. This required higher power coupler loads, water cooling, and the addition of a high-pass (transmitter reject) waveguide filter to the input of the couplers.

III. Results

A high-power model of the PCG coupler was measured and found to meet the requirements specified in Table 1. The result of these measurements are included in Figs. 3 through 7.

Figure 3 shows the measured coupled amplitude of a production high-power PCG coupler from 7.1 to 8.9 GHz. The input high-pass filter attenuates the 20-kW (+73 dBm) transmitter power to a level of approximately 2 microwatts (-27 dBm), which is well under the 0.1-mW (-10 dBm) limit for normal operation. The same curve is shown in Fig. 4, except that it is expanded to show the details in the calibration band of 7.9 to 8.9 GHz. The coupling measures -38.5 dB at 7.9 GHz and increases to -37.5 dB at 8.9 GHz. Taking into account that half of this power goes to each orthogonal arm of the orthomode junction, the coupling to each receiver is -41.5 dB at 7.9 GHz and -40.5 dB at 8.9 GHz, which is within the required -40 dB to -45 dB range. The group delay (Fig. 5) in the receive range shows a smooth decreasing value from 5.6 ns at 7.9 GHz to 4.2 ns at 8.9 GHz. The directivity, shown in Fig. 6, is greater than 22 dB across the receive band. Figure 7 shows the measured VSWR at the coupler input with a peak value of 1.26:1.

References

[1] H. A. Bethe, "Theory of Diffraction by Small Holes," *Physical Review*, vol. 66, pp. 163-182, 1944.

[2] R. E. Collin, *Foundations for Microwave Engineering*. New York: McGraw-Hill, 1966.

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Table 1. X-Band PCG coupler requirements

Parameter	Requirement
Coupling frequency range	7.9 to 8.9 GHz
Coupling	40 to 45 dB
Coupled input VSWR	< 1.28:1
Max. coupled transmitter power for normal operation	−10 dBm
Max. coupled transmitter power for no damage	+ 10 dBm
Length	4.5 inches
Directivity	> 14 dB

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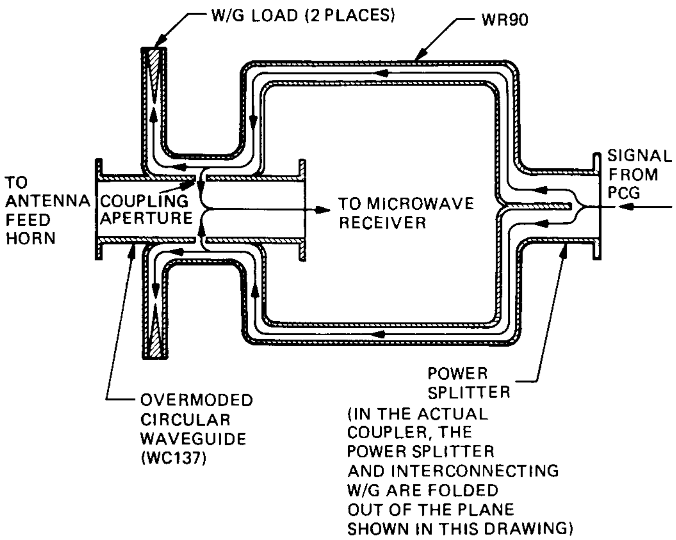

Fig. 1. Cutaway diagram of PCG coupler

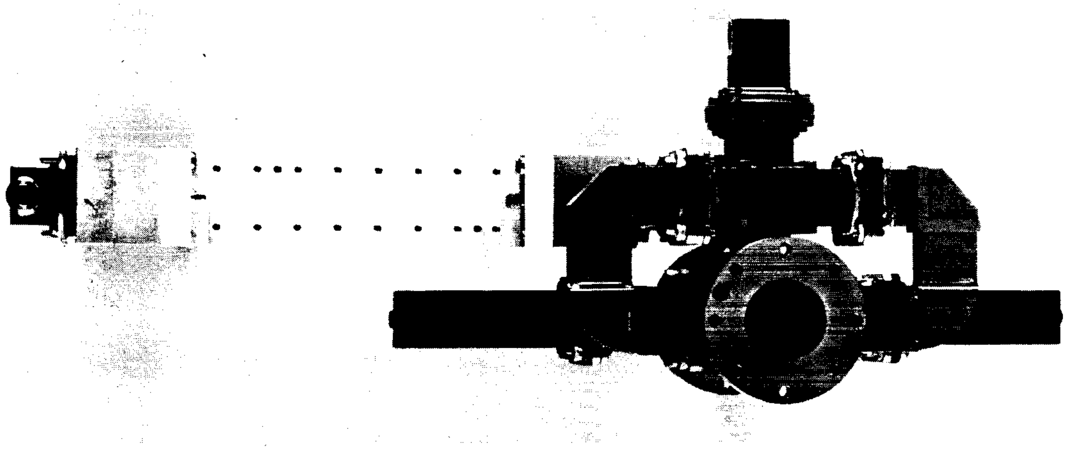

Fig. 2. PCG coupler engineering model

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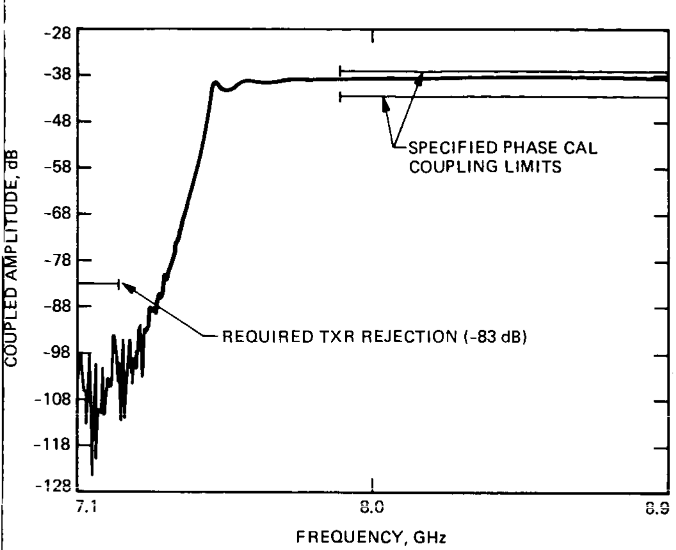

Fig. 3. Coupled amplitude

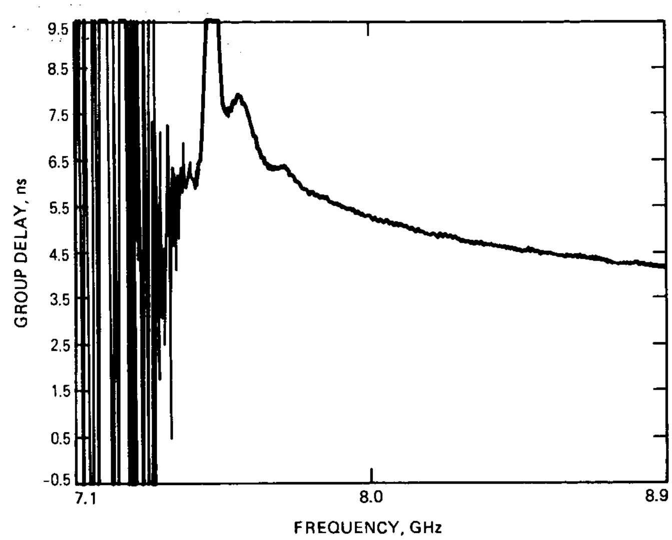

Fig. 5. Coupled group delay

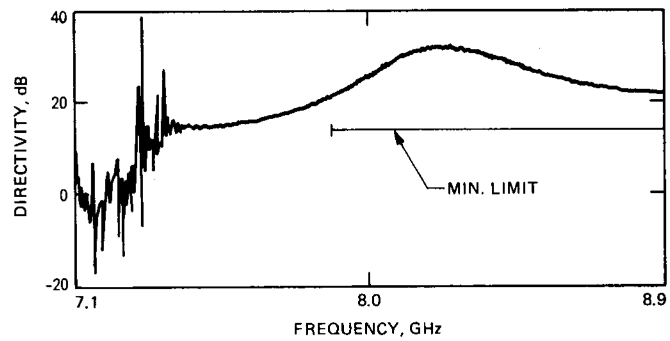

Fig. 6. PCG coupler directivity

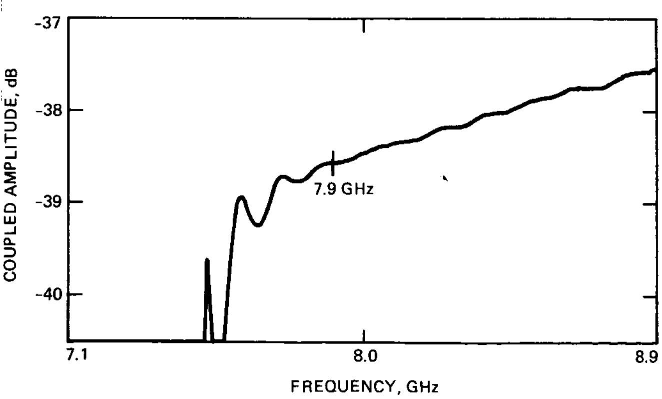

Fig. 4. Coupled amplitude (expanded amplitude scale)

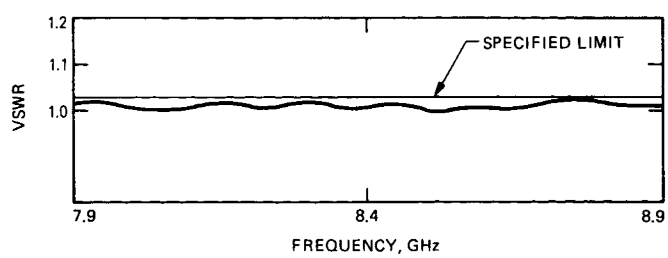

Fig. 7. PCG coupler input VSWR