Phase and Group Delay of S-Band Megawatt Cassegrain Diplexer and S-Band Megawatt Transmit Filter

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This article reports the phase characteristic and group delay of the S-band Megawatt Cassegrain Diplexer (MCD) and S-band Megawatt Transmit Filter (MTF). These phase measurements on the MCD and MTF were done in response to the need to obtain the total DSS hardware ground delay required for very long baseline interferometry (VLBI) and ranging radio metric measurements.

I. Introduction

As part of an effort to come up with the total ground delay at the 64-m stations for VLBI and ranging radio metric measurements, phase measurements on the S-band Megawatt Cassegrain Diplexer (MCD) have been made over both the transmitter frequency range (2100-2120 MHz) and the receiver frequency range (2270-2300 MHz). Phase measurements have also been made on the S-band Megawatt Transmit Filter (MTF) over the transmitter frequency range (2100-2120 MHz). The group delay for both the MCD and MTF are calculated using the results of these phase measurements.

II. Hardware Description

The S-band Megawatt Cassegrain Diplexer is shown in Fig. 1. It consists of two straight narrow-width waveguide sections coupled together with waveguide hybrids. The straight narrow-width waveguide sections have a cutoff frequency of 2200 MHz; thus the MCD will pass signals through at the receive frequency of 2285 MHz and reject all signals from the transmitter which are transmitted to the antenna at a frequency of 2110 MHz.

The S-band Megawatt Transmit Filter is shown in Fig. 2. The MTF is a band reject filter with six cavities tuned to the receive frequency, providing a rejection of more than 90 dB at 2285 ±15 MHz, while passing a frequency of 2110 ±10 MHz.

Instrumentation methods of the VSWR and isolation recordings of both the MCD and MTF are described in Refs. 1 and 2. The results of these measurements are tabulated in Tables 1 and 2.

III. Phase Measurement Procedures

The phase measurement test configurations for either the MCD or MTF are shown in Figs. 3 and 4. Prior to recording any phase characteristics versus frequency on the X-Y plotter, it would be desirable to have a horizontal phase characteristic for the reference phase. This is achieved by having the same length for both the reference signal path and the test signal path using the test configuration shown in Fig. 3. The relative phase plots versus frequency obtained from the X-Y plotter are shown in Figs. 5, 6, and 7 for both the MCD and MTF. These relative phase plots were obtained using the test configuration shown in Fig. 4.

IV. Group Delay Results

The group delay is defined as the time required for a signal to propagate through a system, and it is simply given by

$$td = \frac{\Delta\phi}{360 \times \Delta f\,(\mathrm{GHz})}\ \mathrm{ns}$$

The values for $\Delta\phi$ and Δf can be obtained from the relative phase versus frequency plots (Figs. 5, 6, and 7). Referring to Fig. 5, for an incremental frequency change $(f_2 - f_1)$, there will be a corresponding phase change $(\phi_{2\ \mathrm{test}} - \phi_{1\ \mathrm{test}})$ and $(\phi_{2\ \mathrm{ref}} - \phi_{1\ \mathrm{ref}})$. Thus the expression for the group delay may alternatively be written as

$$td = \frac{|(\phi_{2\ \mathrm{test}} - \phi_{1\ \mathrm{test}}) - (\phi_{2\ \mathrm{ref}} - \phi_{1\ \mathrm{ref}})|}{360^\circ \times [(f_2 - f_1)\ \mathrm{GHz}]}\ \mathrm{ns}$$

The group delay for the MCD turned out to be 6.250 ns over the transmitter frequency range (2100-2120 MHz) and 14.815 ns over the receiver frequency range (2270-2300 MHz). The group delay for the MTF is 13.640 ns over the transmitter frequency range (2110-2120 MHz).

References

1. Hartop, R., JPL Test Procedure No. DMX-1370-TPA, *S-Band Megawatt Cassegrain Diplexer*, 25 September 1968.

2. Hartop, R., JPL Test Procedure No. DMX-1369-TPA, *S-Band Megawatt Transmit Filter*, 25 September 1968.

Table 1. VSWR, insertion loss, and isolation test data of Megawatt Cassegrain Diplexer

a. Insertion loss

Frequency, MHz	Insertion Loss, dB
2110	0.02460
2270	0.05626
2285	0.05517
2300	0.05019

b. VSWR and isolation

Test	Ports	Frequency, MHz					
		2100	2110	2120	2270	2285	2300
VSWR	TRANS	1.03	1.02	1.035			
VSWR	ANT	1.04	1.03	1.045	1.035	1.03	1.035
VSWR	RCVR				1.03	1.035	1.035
Rejection	Receive band				34.5	36	38.5
Rejection	Transmit band	99	96	90			

Table 2. VSWR, insertion loss, and isolation test data of Megawatt Transmit Filter

a. VSWR

Frequency, MHz	VSWR
2100	1.03
2110	1.02
2120	1.05

b. Insertion Loss

Frequency, MHz	Insertion Loss, dB
2100	0.03677
2110	0.03360
2120	0.03811

c. Rejection

Frequency, MHz	Rejection, dB
2259.0	80
2260.0	90
2261.5	100
2263.0	110
2270.0	110
2275.0	110
2280.0	110
2285.0	110
2290.0	110
2293.0	110
2295.0	100
2299.5	100
2301.5	90
2303.5	80

Table 3. Group delay of S-band Megawatt Cassegrain Diplexer and S-band Megawatt Transmit Filter

a. MCD over transmit band

Frequency, MHz	*td*, n-s
2110	6.250
2120	

b. MCD over receiver band

Frequency, MHz	*td*, n-s
2270	14.815
2300	

c. MTF over transmit band

Frequency, MHz	*td*, n-s
2110	13.640
2120	

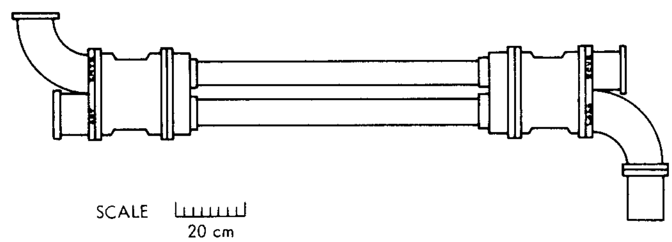

Fig. 1. S-band Megawatt Cassegrain Diplexer

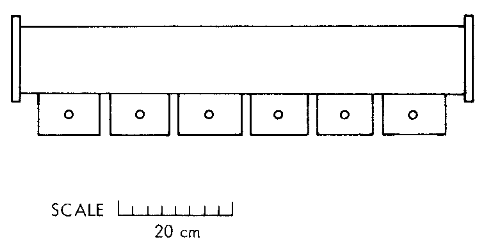

Fig. 2. S-band Megawatt Transmit Filter

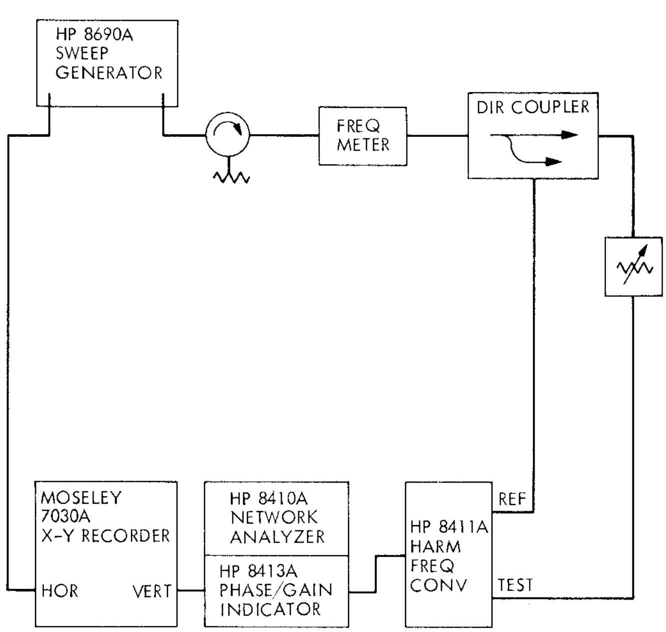

Fig. 3. Test configuration for reference phase

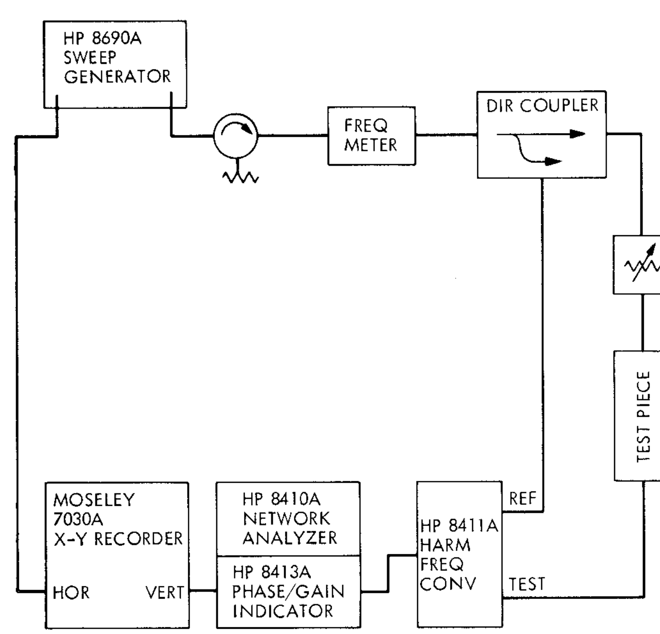

Fig. 4. Test configuration for relative phase of test device (MCD or MTF)

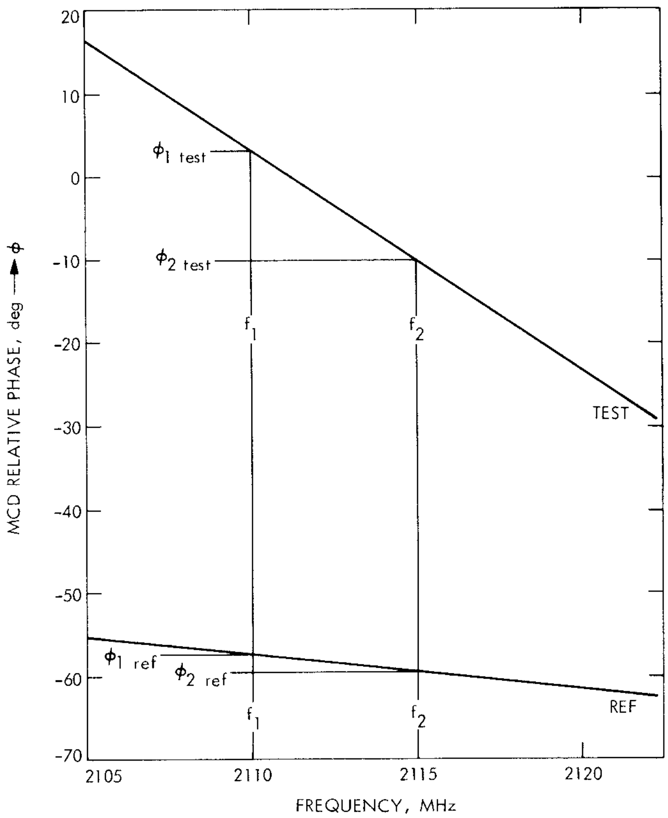

Fig. 5. Relative phase of MCD over transmit frequency range

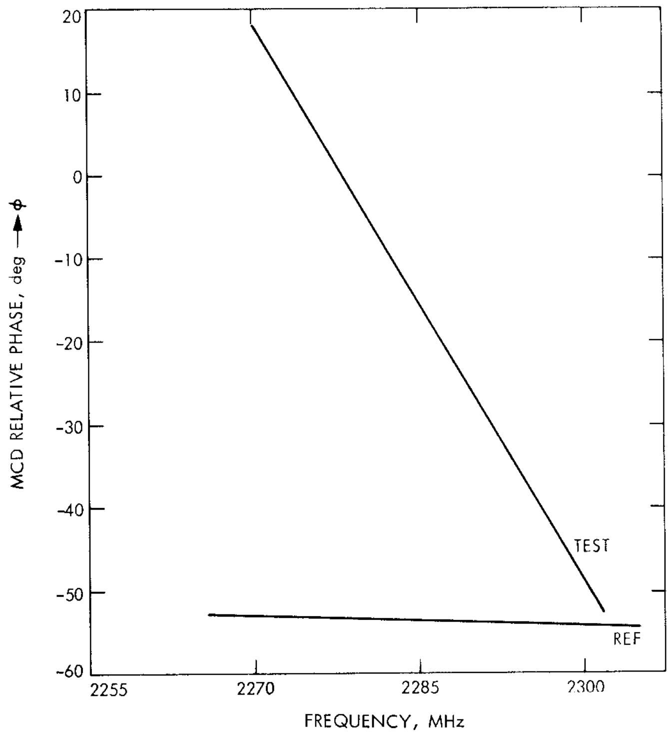

Fig. 6. Relative phase of MCD over receive frequency range

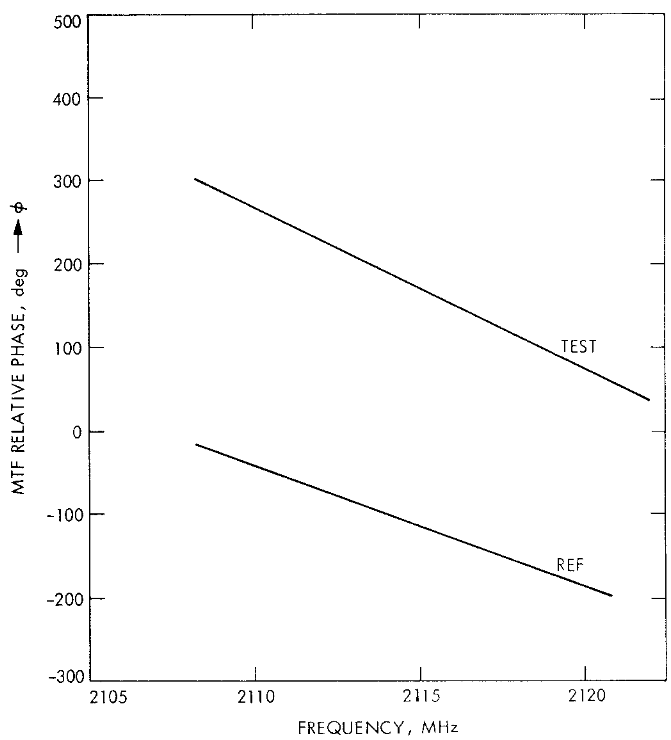

Fig. 7. Relative phase of MTF over transmit frequency range