Microwave Time Delays in the DSN 34- and 64-Meter Antennas

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The microwave configurations at the 34- and 64-m stations have changed in the past year due to new equipments. To maintain time delay data logs, new calculations have been made where necessary of both the microwave component delays and the antenna air path delays for each type of antenna.

I. Introduction

Previous articles (Refs. 1 and 2) have discussed the necessity for carefully calculating the group delays within the DSN antenna systems to permit accurate ranging of spacecraft and for various other projects such as VLBI. Because the microwave subsystems are frequently changed to incorporate new equipment with improved capability, it periodically becomes necessary to recalculate the component group delays to update the total time delay within the antenna system. An extreme example of this has occurred in the case of 34-m DSN subnet, in which the antennas and their microwave subsystems have undergone a complete reconfiguration in their growth from 26-m instruments.

This article presents the results and methods used to derive new data for the recent changes to the DSN 34- and 64-m stations at both S- and X-band frequencies.

II. Basic Data

Table 1 presents the calculated parameters that were used throughout. The WC-504 circular waveguide is standard at S-band; the WC-137 is standard at X-band. The WS-90 square waveguide is used only in the orthomode in the new X-band feed. The value of $1.18028543 \times 10^{10}$ inches per second (2.997×10^{10} cm/s) was used for the velocity of light in free space, giving 0.084725271 nanoseconds per inch (0.0333 ns/cm) for the free space delay.

All calculations for feed delays are from the phase center of the horn to the defined output of the feed. Where applicable, the additional delay due to waveguide between the feed output and the TWM coupler input is listed separately below the feed total. Individual component delay calculations are generally very accurate since they rely on the precise physical dimensions of the component. However, certain complex components such as the dual-mode feed horns and the orthogonal mode junction reduce the overall feed delay accuracy to the order of ± 0.2 ns.

III. Feed Delays for 64-Meter Antennas

At DSS 14, the XRO Mod III feed is installed. This contains the orthomode junction with the result that there are, in effect, two feed paths as shown in Table 2. At DSS 43 and DSS 63, the XRO Mod II feed will continue to be used until late in 1979. The data in Table 3, corrected from previous sources, applies. The two travelling wave masers in the feed cone are distinguished by their component designators A17 and A24.

At S-band frequencies, the SPD cone assembly remains unchanged, so that the delay from the horn phase center to the phase calibration coupler input remains 21.291 ns at 2113 MHz and 18.766 at 2295 MHz.

IV. Feed Delays for 34-Meter Antennas

The X-band feed used in the SXD cone assembly is identical in every respect to the XRO Mod II feed assembly. Thus, the data in Table 3 apply exactly, and the output elbow is the same as for the A17 configuration, giving a total delay of 5.090 ns.

The S-band feed in the SXD cone assembly has the time delays shown in Table 4.

V. Dichroic Plate Correction

At X-band, the signal passes through the dichroic plate with two results. The first effect is an offset in the ray path, making it longer than a direct path. The second effect is that the holes in the plate act as small waveguides with a cutoff wavelength of 1.536 inches (3.90 cm). The resulting group delay of 0.2074 ns per inch (0.082 ns/cm) times the plate thickness of 1.400 inches results in 0.2904 ns delay through the plate. Adding the ray path geometry correction of 0.0296 ns and subtracting the direct free-space delay of 0.1370 ns leaves a residue of 0.183 ns. This is the quantity that must be added at 8420 MHz to any air path delay involving the dichroic plate. The correction does not apply at S-band since the plate is merely a reflector.

VI. Air Path Delays

Air path delays are based on the theoretical geometry of each antenna configuration. No allowance is made for manufacturing tolerances, hyperboloid focussing, or structural deflections. The dichroic plate is treated separately, and a small error was discovered in previous calculation. Thus a new figure is given here for the 64-meter antenna as well as the new 34-meter antennas.

The basic air path delay for the Cassegrain configuration is given by

$$\text{path length} = f + 2a + d$$

where f is the paraboloid focal length, $2a$ is the transverse axis of the hyperboloid, and d is the depth of the paraboloid from vertex to rim. The last parameter arises because it has now become standard to use the aperture plane of the paraboloid as the reference plane for antenna-to-spacecraft path length. To the above basic path must be added the dichroic plate delay for X-band. For S-band, the path length from the horn to the mirrored X-band phase center by way of the ellipsoidal reflector must be added. The theoretical depths of the dishes are calculated from the formula

$$d = \frac{r^2}{4f}$$

where d is the depth, r is the radius of the paraboloid, and f is the focal length as before. The air path delays τ_a for both the 34- and 64-m antennas and presented in Table 5.

References

1. Komarek and Otoshi, *DSN Progress Report 42-36*, pp. 35-40. Jet Propulsion Laboratory, Pasadena, Calif.

2. Otoshi, *DSN Progress Report 42-49*, pp. 45-56. Jet Propulsion Laboratory, Pasadena, Calif.

Table 1. Basic waveguide parameters

Waveguide	λ_{co}, inches (cm)	f, MHz	τ_g, ns/inch	τ_g, ns/cm
WR-430 and WC-504	8.600 (21.84)	2113	0.1057	0.0416
		2295	0.1114	0.0439
WR-125	2.500 (6.35)	8420	0.1023	0.0403
WC-137	2.336 (5.93)	8420	0.1059	0.0417
WS-90	1.800 (4.57)	8420	0.1351	0.0532

Table 2. XRO MOD III Feed Assembly

Item	τ_g, ns	
	Straight path	Side path
Horn	3.050	3.050
Throat	0.477	0.477
Rotary joints (2)	0.424	0.424
Polarizer	0.444	0.444
Orthomode	0.707	0.709
Twist	--	0.511
Switch	0.342	0.342
Feed total	5.444	5.957
Waveguide	0.542	0.460
Total to TWMs	5.986	6.417

Table 3. XRO MOD II Feed Assembly

Item	τ_g, ns	
Horn	2.070	
Spacers (2)	0.675	
Rotary joints (2)	0.424	
Polarizer	0.444	
Transition	0.520	
Switch	0.342	
Feed Total	4.475	
Elbows	0.615 (to A17)	0.844 (to A24)
Total to TWMs	5.090(A17)	5.319(A24)

Table 4. SXD S-Band Feed Assembly

Item	τ_g, ns	
	2113 MHz	2295 MHz
Horn	7.834	7.685
Rotary joints (3)	1.005	0.954
Polarizers (2)	3.452	3.256
Transition	0.794	0.753
Feed total	13.085	12.648
Elbow	1.050	0.996
Total to phase calibration coupler	14.135	13.644

Table 5. Air path delays

Segment	Path length, inches (cm)			
	34 meter		64 meter	
	S	X	S	X
f	432.000 (1097)	432.000	1067.294 (2711)	1067.294
2a	203.247 (516)	203.247	356.057 (904)	356.057
d	259.231 (658)	259.231	371.875 (945)	371.875
Dichroic/ ellipsoid/horn	106.963 (272		106.963	
Total	1001.441 (2544)	894.478 (2272)	1902.189 (4832)	1795.226 (4560)
Delay, τ_g, ns	84.847	75.785	161.163	152.101
Dichroic correction		0.183		0.183
Total delay, τ_g, ns	84.847	75.968	161.163	152.284