CHARA Technical Report

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OPLE and POP Considerations

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1. INTRODUCTION

Both Optical Path-Length Equalizers ("OPLEs") and Pipes of Pan ("POPs") are useful for equalizing the optical path length in all telescopes of a long baseline interferometer, so that the light can in fact interfere. The POPs are a series of fixed delay lines, for example at 25 meter intervals, that take out the gross differences in path length between the light collecting telescopes. The OPLEs are active delay lines with "carts" moving along expensive precision rails. Because of cost considerations, it is desirable to minimize the length of the OPLEs to accommodate reasonable observation times, say 1-2 hours, but no longer. Furthermore, because the POPs will be in a vacuum, while the OPLEs will operate in the open air, it is more advantageous from seeing and dispersion considerations to minimize OPLE length.

Another consideration is that the sum of the OPLE plus POP lengths are sufficient to allow good sky coverage. An early goal of the Array was to have complete sky coverage for altitudes above about 30 degrees. Given the physical length of the OPLE/POP building and the lengths of the POPs, this may not be possible, however. In this report, we first consider the sky coverage for each telescope as a function of the POP + OPLE length and show that adequate sky coverage results from 200-250 meter lengths. Second, we consider a worst case example of a star at $Dec = 20°$ and examine how many times during a night the OPLE cart (and POP length) must be reset as a function of OPLE length. Obviously, there is a tradeoff here between the number of resets and the OPLE lengths.

2. SKY COVERAGE AS FUNCTION OF OPLE + POP LENGTH

Figure 1 shows the site configuration for the five telescopes. We use simple geometry from the known telescope positions and total light path distances to the beginning of the POPs as of March 19, 1996. At any given location in the sky, one of the telescopes, that with the longest optical path length, will be set at zero POP/OPLE length, and the optical path lengths of the other telescopes will be increased to match. Figure 2 shows the needed POP/OPLE lengths for the five array telescopes as a function of sky location. These are simple projections, like looking down on the sky globe. (The distance from the center to a given point is proportional to the cosine of the altitude). The edge denotes an altitude of 30°, our goal. The center (zenith) is noted by an asterisk, as is the trajectory of a star of 20°

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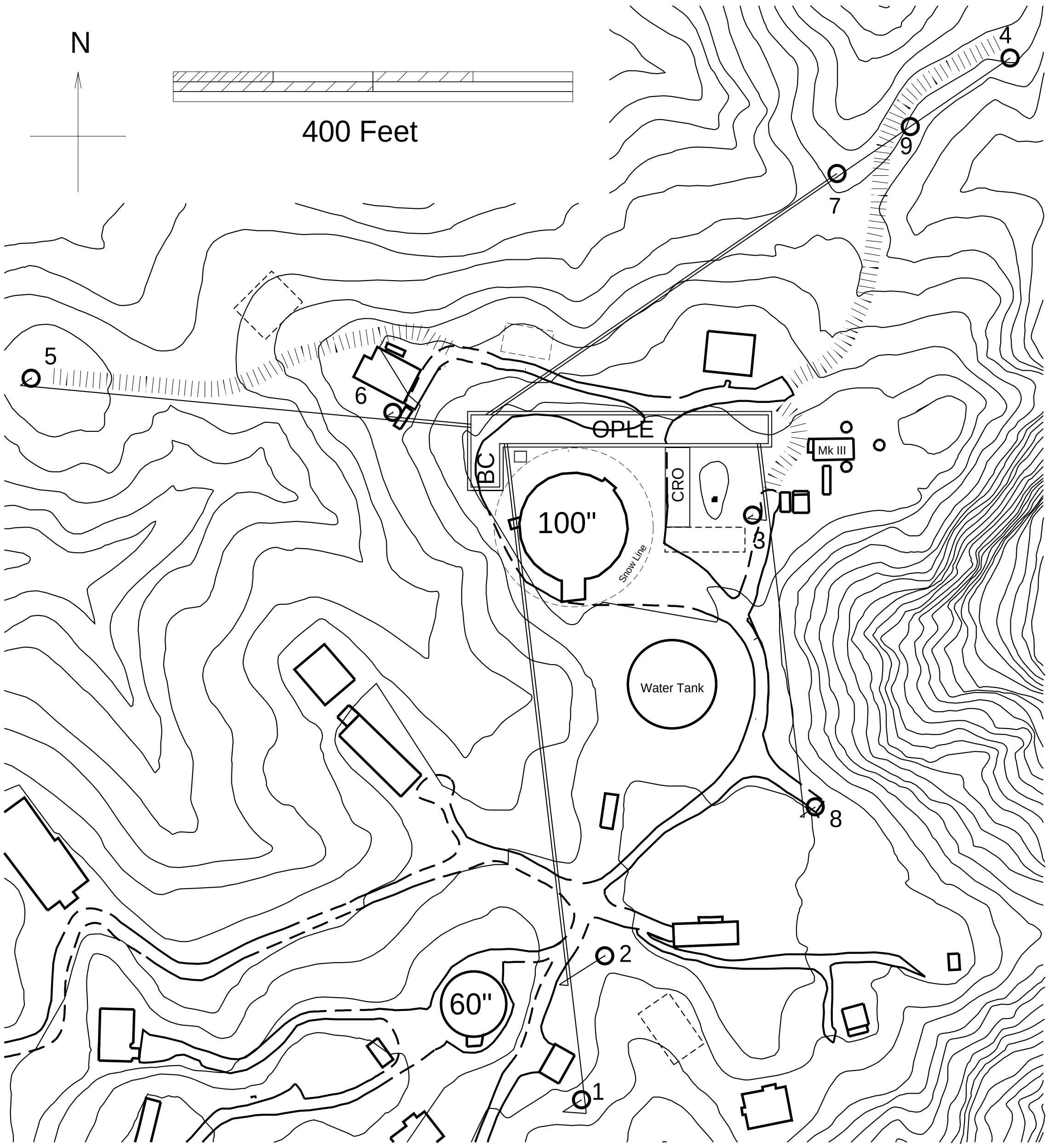


FIGURE 1. Site configuration for the five array telescopes.

declination (at 15-min intervals). The contour "No Correction" notes that this telescope is set at zero OPLE+POP length. Note that only the three outer telescopes: 1, 4, and 5 have such sky sectors, roughly corresponding to where the star is away from the telescope location.

The maximum lengths for both the POPs and OPLEs of 146.3 m are set by the length of the OPLE building. This means that with a combined length of some 293 m, essentially full sky coverage in Figure 2 would be achieved. However, a very significant sky coverage could be accomplished by total lengths of 200 to 250 m. Practically speaking, the POP would be built to the maximum limit, and the OPLEs would be what we could economically afford, say with lengths in the 50-100 m range. As we will see later, the length of the POP could also be increased by retrofitting one of the "POP-cans" to have a double pass. POP lengths of 195-220 m would be feasible with one such POP per delay line. As for the OPLEs, because the cost of the rails and supports is virtually linear with length, it would be easy to add more OPLE length if more funding were available.

3. OBSERVATION INTERRUPTIONS AND OBSERVING TIME

Cutting the OPLE length can affect sky coverage (for a 146-m POP), but more importantly, it affects the length during which observations can be made without a switch in POP length for one of the telescopes. Figure 1 show the trajectory for a $Dec = +20°$ star, which is close to a worst case in terms of resetting the POPs. (We have looked at other cases of Dec= -10, 0, 50, and 80.) As the star moves across the sky the OPLE+POP delay length needed varies, as can be seen more clearly on Figure 3. In terms of a design, the available parameters are the OPLE lengths and the POP locations. POPs can be installed at every 40 ft optical distances (12.19 m), i.e. there can be a maximum of 12 POP delays. Alternatively, there can be as few as a single all-or-nothing POP delay, if the OPLE length were also 146 m.

Table 1 is an attempt to relate the number of resets during a night for the $Dec = 20°$ case as a function of total POP length, OPLE lengths, and the number of different POP delay intervals. The standard case is for the 146 meter POP length, which is generated by a round trip of light via three reflections. However, the total POP + OPLE length can be as low as 196 m in when we are attempting to conserve OPLE rail length to only 50 m for telescopes 1 and 2. As can be seen in Figure 2, however, a total length of only 200 m for telescopes 1 and 2 in will limit southern coverage to roughly -15^o It may therefore be necessary to consider having at least one POP length with a dual capability for one or two round-trips. In particular, for 3 POPs at locations of 24.4, 48,8, and 73.15 m down line (delays of 48.8, 97.6, 146.3 m), the second could be selectable for two passes, which would create a fourth POP length of 195.1 m. Table 1 also considers some of these cases.

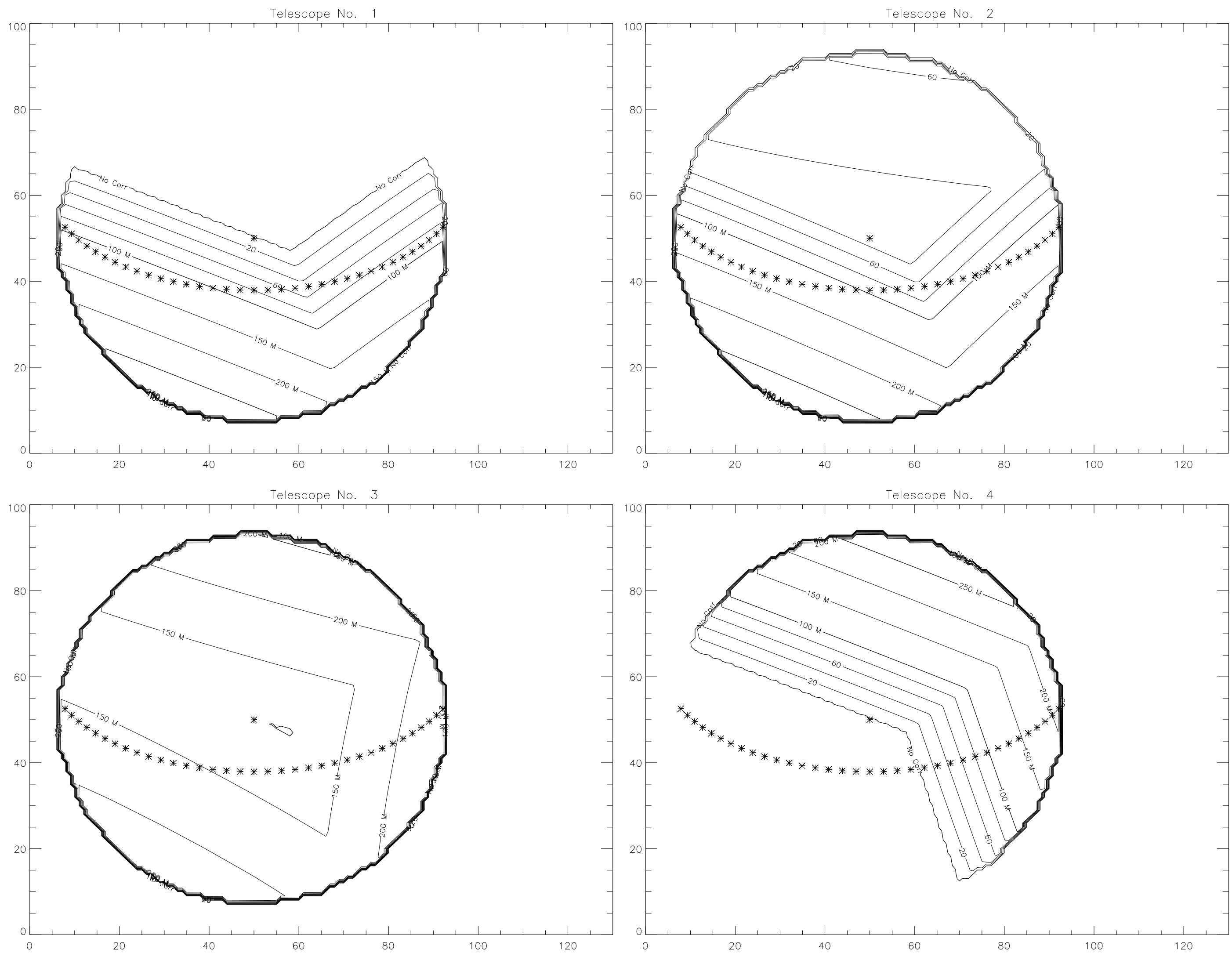
Two results are apparent from Table 1. First, there is little gain in having too many POP locations. Three is about enough. The increments in POP delays should be a bit smaller than the OPLE length, but no more than this. Second, there is an expected trade-off between the OPLE lengths (and costs) and the number of delays. It appears that a delay scheme of "50-50-75-100-100" for the five OPLE lengths would still have only 10 resets over the entire 540 m interval. Thus, a total of some 325 m of track would be required, but this is still only 44% that the 732 m for complete building lengths of 146 m each.

TABLE 1. Resets for $Dec = 20°$ Star.

POP Length	No. Intervals	OPLEs	Resets	Total Resets
146.3	100 - 100 - 100 - 100 - 100	12	0 - 0 - 1 - 2 - 3	6
"	"	6	0 - 0 - 1 - 2 - 3	6
"	"	4	0 - 0 - 1 - 2 - 3	6
"	"	3	0 - 0 - 2 - 2 - 3	7
"	"	2	1 - 2 - 1 - 2 - 3	9
"	75 - 75 - 100 - 100 - 100	12	0 - 1 - 1 - 2 - 3	7
"	"	6	0 - 1 - 2 - 2 - 3	8
"	"	4	2 - 2 - 1 - 2 - 3	10
"	"	3	0 - 1 - 2 - 2 - 3	8
"	75 - 75 - 75 - 75 - 75	12	0 - 1 - 3 - 2 - 3	9
"	"	6	0 - 1 - 3 - 2 - 3	9
"	"	3	0 - 1 - 3 - 4 - 5	13
195.1	146 - 146 - 146 - 146 - 146	4	0 - 0 - 0 - 1 - 2	3
"	100 - 100 - 100 - 100 - 100	4	0 - 0 - 0 - 2 - 3	5
"	75 - 75 - 75 - 75 - 75	4	0 - 1 - 2 - 3 - 5	11
"	50 - 50 - 75 - 100 - 100	4	1 - 2 - 2 - 2 - 3	10
"	50 - 50 - 50 - 50 - 50	4	1 - 2 - 3 - 4 - 5	15

4. DUAL USE POP DESIGN

As mentioned above, because the maximum POP length is currently limited to only 146 m, it would be desirable to have at least one POP length with a dual capability for one or two round-trips. We considered briefly the case of three POPs at locations of 24.4, 48,8, and 73.15 m down line (optical delays of 48.8, 97.6, 146.3 m). If the second POP location could be selectable for two passes, we would create a fourth POP length of 195.1 m. Adding a dual use POP at location 61.0 m down line would create optical delays of 122 m and (more importantly) 244 m. Finally, a maximum POP delay of 290 m could be created by upgrading the end POP to dual use. This would essentially provide an all horizon capability (seeing and telescope permitting of course). In addition, this sort of design could also provide the delays needed for the future telescope No. 6, which would be quite a problem otherwise. Figure 4 shows the optics of a dual use POP. In this scheme, two new mirrors would be required compared to the three mirror baseline desing, one of which would be selectable to two positions. The one or two mirrors of the "POP can" could be mounted in a rotary design similar to that used for the MTT spectrograph, and would be rotated out of the way when not used.



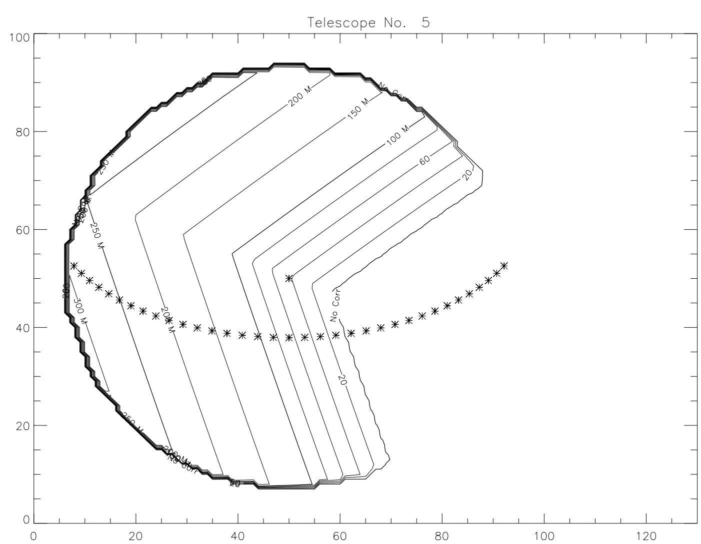


FIGURE 2. Delays needed for the five array telescopes as a function of sky position. Top projection; outermost line is 30° altitude. Zenith (center) and trajectory for $Dec = 20°$ star are shown. Contour intervals are 0, 20, 40, 60, 80, 100, 150, 200, 250, and 300 m.

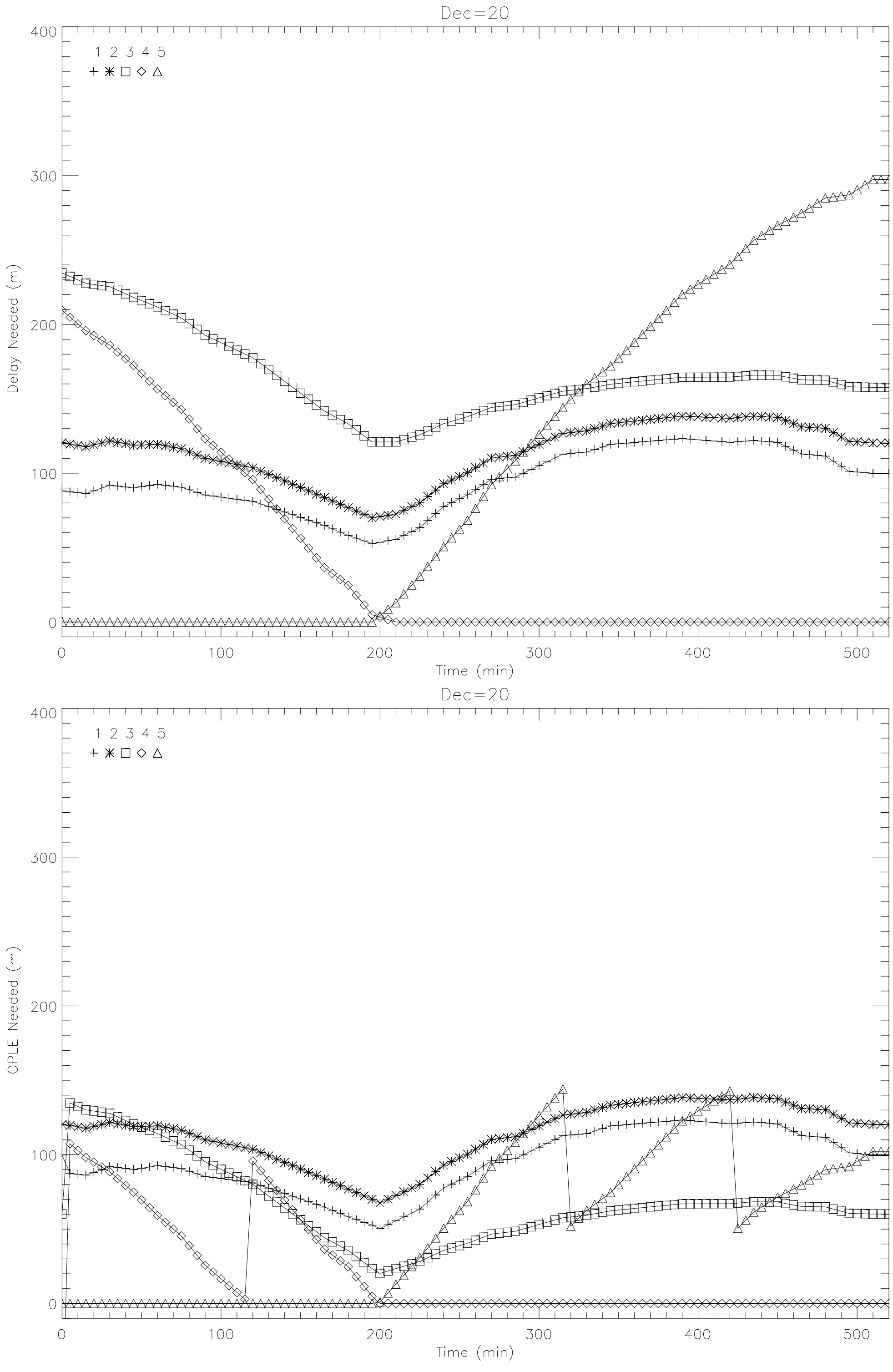


FIGURE 3. OPLE delays needed for the five array telescopes for $Dec = 20°$ star. Allowed POP lengths are: 0, 48.7, 97.5, 146.3, 195.1 m. Top: Total Delays needed. Bottom: OPLE delays needed, with 146 m OPLE (optical) lengths for all telescopes.

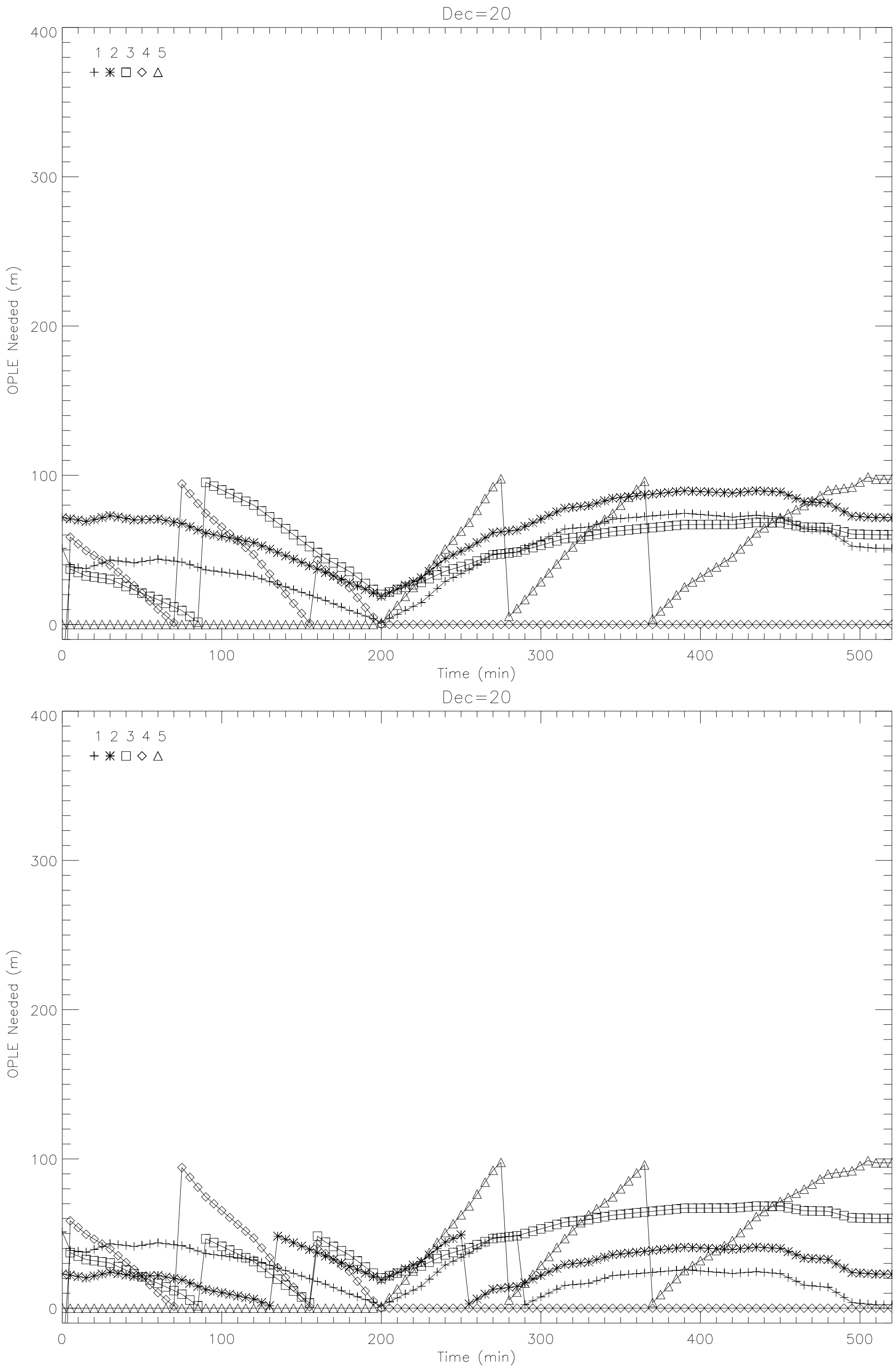


FIGURE 3. (cont.) Top: OPLE delays needed with uniform 100 m OPLE lengths. Bottom: OPLE delays needed with 50, 50, 75, 100, and 100 OPLE lengths, respectively. Note increasing number of interruptions with decreasing OPLE lengths: 3, 5, and 8, respectively.

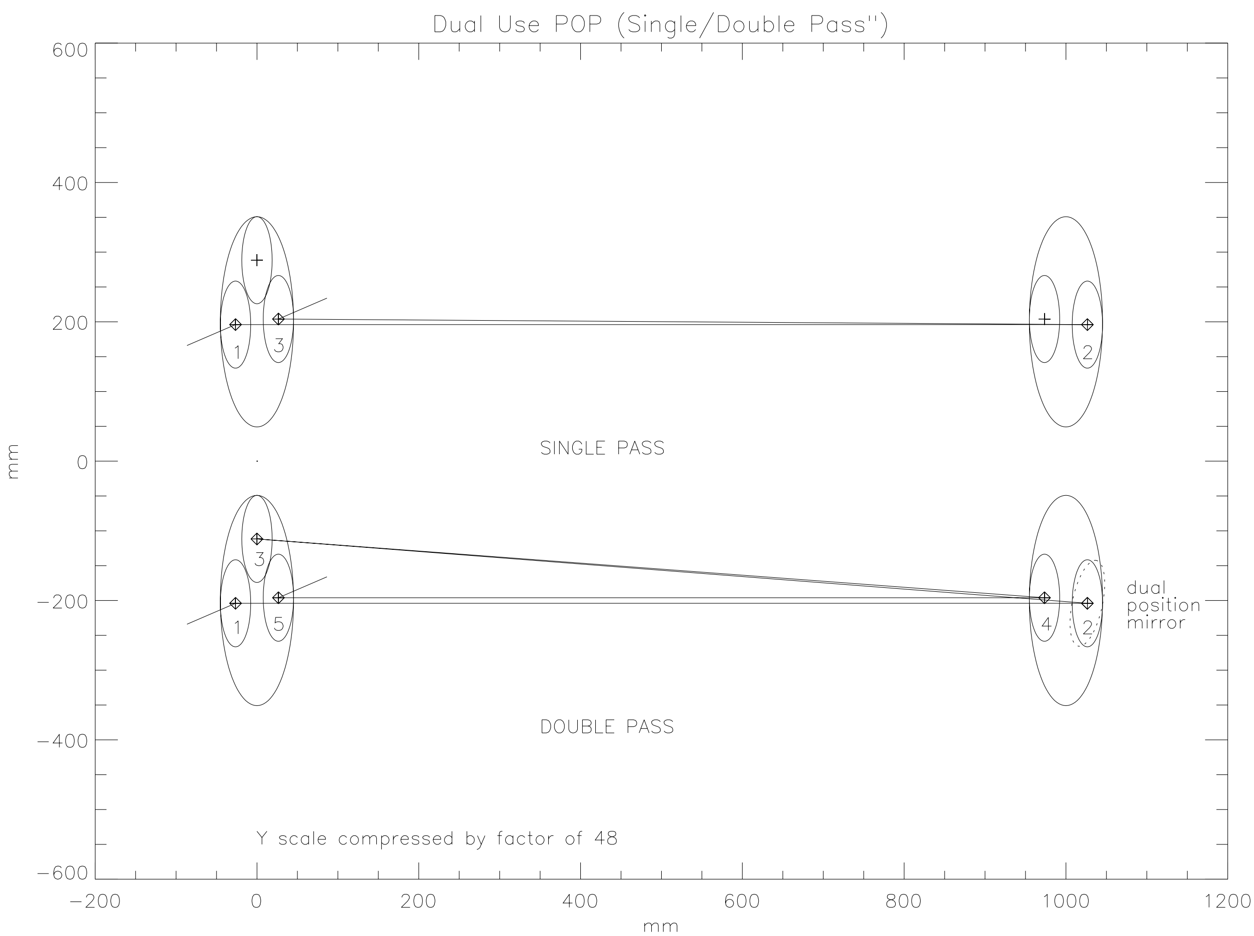


FIGURE 4. Ray diagram for a possible dual use POP. Top: Single pass, total length of 97 m. Bottom: Double pass, total length of 195 m.