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COURSE STRUCTURE-RUNWAY 28R SAN FRANCISCO AIRPORT

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16. Abstract

The TSC electromagnetic scattering model is used to determine the expected ILS localizer performance for the planned 28R runway at San Francisco airport. It is found that the V-Ring and the 14/6 Alford array as well as the larger 22/8 Alford array operating with a 10 dB "capture effect ratio," do not produce an acceptable course meeting FAA Category I tolerances. The feasibility and advantages of operating the Alford array at higher capture effect ratios is discussed. Based on a "worst case" airport environment, the maximum capture ratio obtainable with the Alford 22/8 array is calculated and shown to lead to a marginally acceptable Category I course structure. For an "ideal" airport environment it is possible to use high capture ratios with the result that Category I requirements are easily satisfied and Category II tolerances marginally so with the Alford 22/8 array. The course structure in each case has been calculated under the assumption that the derogator is a metallic perfect reflector.

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PREFACE

This study of comparative ILS Localizer performance was undertaken for the Terminal Navigation Branch, Navigation Development Division, Systems Research and Development Service, FAA as an aid in assessing possible localizer candidates for Runway 28R, San Francisco airport. The study was prompted by the expected derogation to ILS Localizer performance caused by scattering from a large 747 hangar near Runway 28R.

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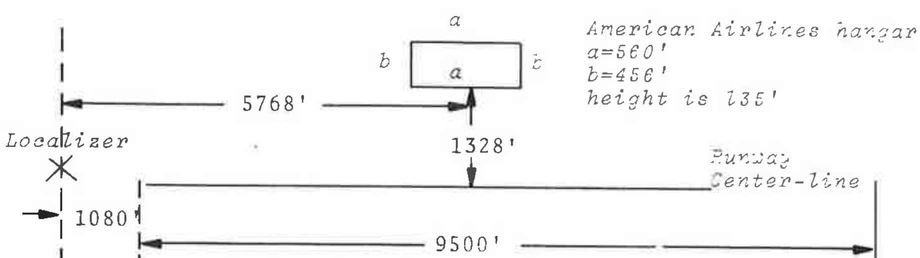
COURSE STRUCTURE -
RUNWAY 28R SAN FRANCISCO AIRPORT

The TSC ILS Localizer model was used to determine the Course Deviation Indication (CDI) for an aircraft flying a 2.5° glide path onto the new Runway 28R planned for San Francisco airport. A V-Ring and the Alford 14/6 and 22/8 arrays operating with 3.78° path widths, located 1080 feet beyond the runway end and extending 9 feet above ground level were tried as possible localizers. A sketch of the scattering situation is shown below.



Scattering schematic for Runway 28R

The results obtained for this localizer performance test are presented in the form of five sets of antenna pattern and CDI graphs. Each set contains seven figures. The first four show the antenna patterns used in the math model*:

Figure #1: Course antenna-Carrier + Sidebands (C+S),
Figure #2: Course antenna-Sidebands Only (SO),
Figure #3: Clearance antenna-(C+S),
Figure #4: Clearance antenna-(SO).

The fifth figure of the set shows the clearance orbit taken at a 10,600 foot range and at a 50 foot height, giving the expected CDI as a function of azimuth; Figures 6 and 7 show the flyability CDI static and dynamic runs, respectively. The dynamic runs assumed an aircraft speed of 200 feet per second and a time constant of 0.4.

The first set of figures, as mentioned in the footnote below, presents the results when a V-Ring localizer is used; the second

*Set #1, in which the V-Ring results are presented, contains only two antenna pattern graphs since separate course and clearance V-Ring antennas do not exist.

set presents the results when the Alford 14/6 array with a 10 dB course to clearance electric field strength ratio is used. The third, fourth and fifth sets present the results when the Alford 22/8 array is used: The third set is for the antenna array operating with the same 10 dB ratio as the smaller 14/6 Alford array; the fourth set is when the array operates at a higher 12 dB ratio and the fifth set is for operation with a 16 dB ratio.

RESULTS

From Set 1, Figures 4 and 5, we see that using a V-Ring localizer produces an extremely poor course, with peaks as high as 120 microamps. This poor course structure is due to a large amount of energy being reflected from the American Airlines hanger located off Runway 28R.

Figures 6 and 7 of Set 2 for the 14/6 Alford array show a course which is significantly better than that produced by the V-Ring. The Alford 14/6 array relies on the capture effect principle to eliminate much of the hangar reflection evident in the V-Ring case. However, the hangar is still sufficiently illuminated to produce a poor course structure not meeting Category I requirements.

It was hoped that the larger more directional Alford 22/8 array would yield a cleaner course by reflecting less energy from the hangar located 13° from the runway centerline. Figures 6 and 7 of Set 3 show, however, that a course structure is obtained which is very similar to that obtained when the 14/6 array was used. The reason that the larger 22/8 array does not help is because, by 13° the Clearance antenna has already taken over from the Course antenna in both the 14/6 and 22/8 arrays, and both Clearance antennas reflect approximately the same amount of energy from the hangar.

However, it should be possible to operate the larger more directional 22/8 array with larger course to clearance power ratios than it is possible to operate the less directional 14/6 array. For example, if we assume as a worst case that 3 watts of power are needed to drive the clearance array to meet FAA specs of 5 microvolts, then with a 12 watt maximum Course antenna power requirement, a 4 to 1 or 6 dB course to clearance power ratio is possible.

Another 6 dB is obtainable from directionality considerations giving a total power ratio of 12 dB as a possible operational mode of the 22/8 array. This mode of operation was tried and the results are presented in Set 4. Comparing Figures 6 and 7 of Sets 3 and 4 shows that the CDI is a rather strong function of this power factor, with a much cleaner course obtained when the array is operating with a 12 dB power ratio. In fact, the 2 dB gain resulted in CDI peaks which were down by almost a factor of two.

For more ideal sites such as NAFEC, for example, less power is required to operate the Clearance antenna to FAA specs and thus even larger power ratios are obtainable. If one watt represents the minimum requirement for operation of the Clearance array to FAA specs (as at NAFEC) and if 12 watts is the maximum power available for the Course antenna then the best we could hope to obtain from the 22/8 array would be that obtained when the array was operated with a 16.79 dB power ratio. If such operation still produced a CDI which was beyond FAA Category I or II requirements, then it would be necessary to resort to another localizer antenna altogether.

For comparison purposes we present the CDI produced when a 16 dB power ratio is used for the 22/8 array (Figures 6 and 7 of Set 5). The much lower relative power of the Clearance array here means that less energy will be reflected from the hangar. This resulted in a reduction in the derogation as evidenced by CDI peaks shown in the graphs which are no higher than 5 microamps.

CONCLUSION

In conclusion, we find that the newly planned Runway 28R at San Francisco airport will not meet Category I tolerances with the V-Ring localizer or with the 14/6 Alford array or even with the larger 22/8 Alford array operating with a 10 dB power ratio. However, very marginally acceptable Category I conditions are met when the Alford 22/8 array is set to operate at its maximum (worst case) 12 dB course to clearance power ratio.* For a close to ideal

*Twelve dB would be the maximum obtainable at the 'worst case' Seattle airport. It remains to be determined experimentally whether higher power ratio operation is possible at San Francisco.

site, 16 dB operation is possible in which case Category I conditions can be met; Category II conditions will, however, only be marginally satisfied. It is noted that these results assumed the derogator (the hangar) to be a metallic perfect reflector. For less than perfect reflection the CDI would be correspondingly lower.

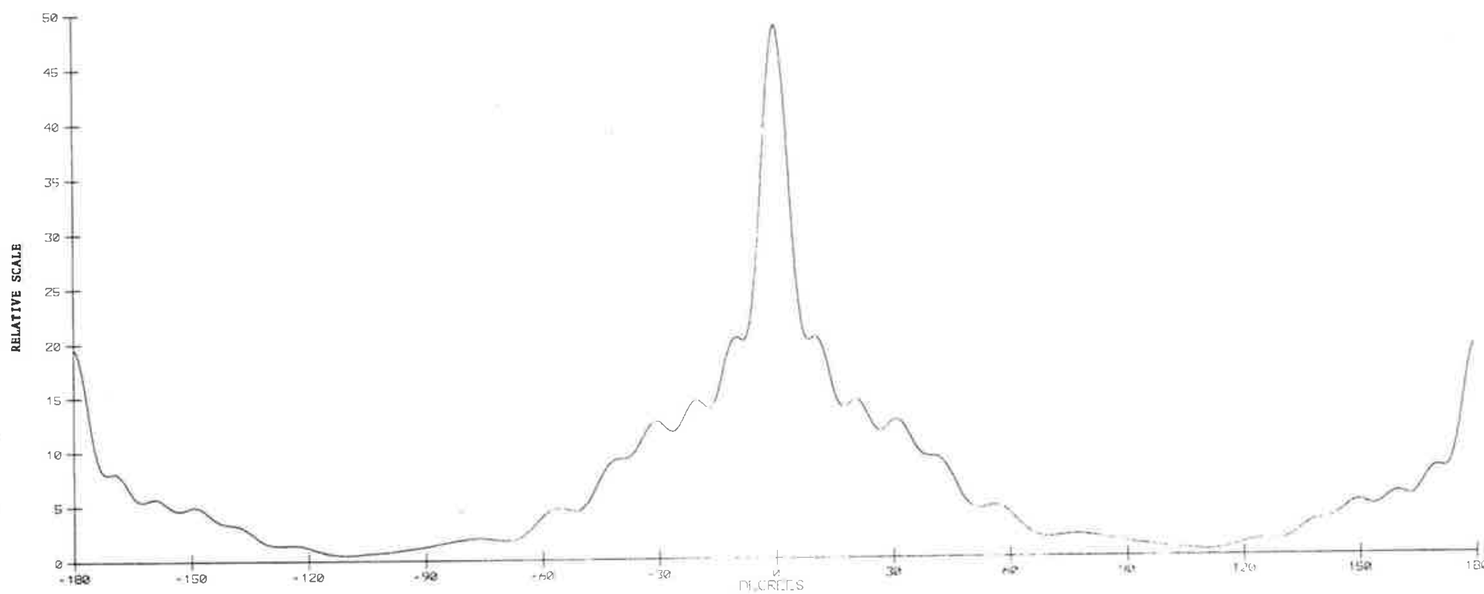


Figure 1-1. V-Ring: Carrier Pattern

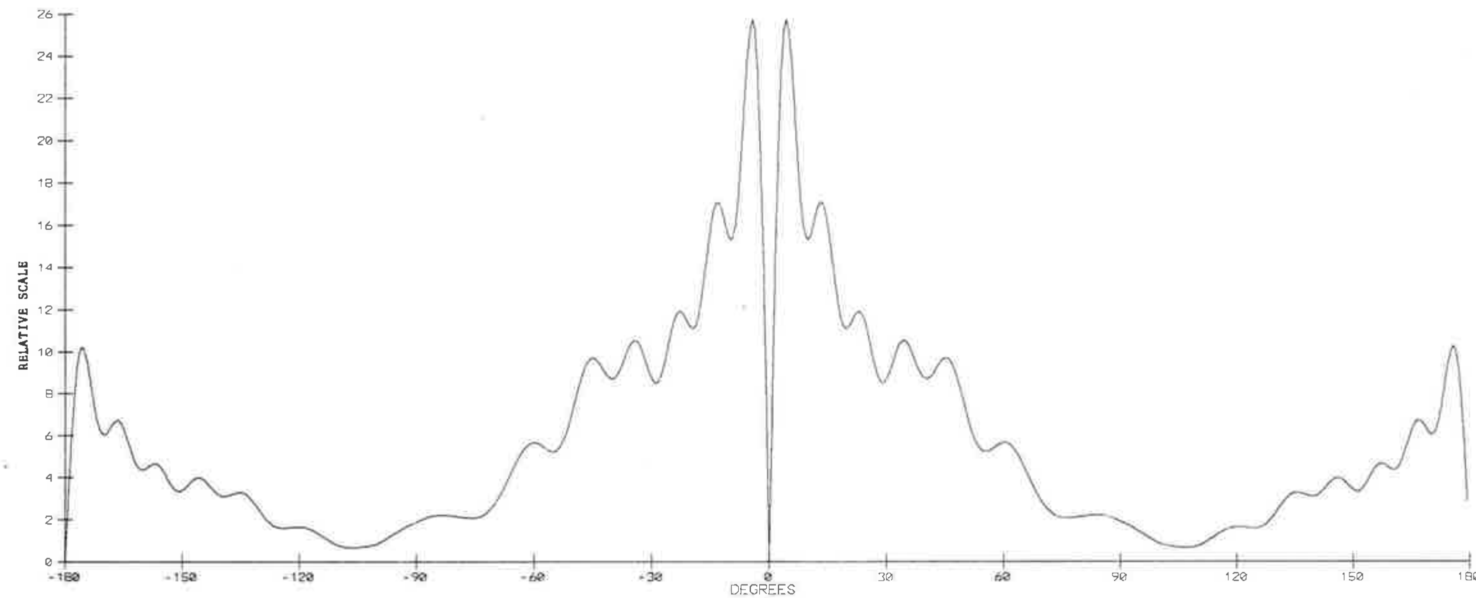


Figure 1-2. V-Ring: Sidebands Only Pattern

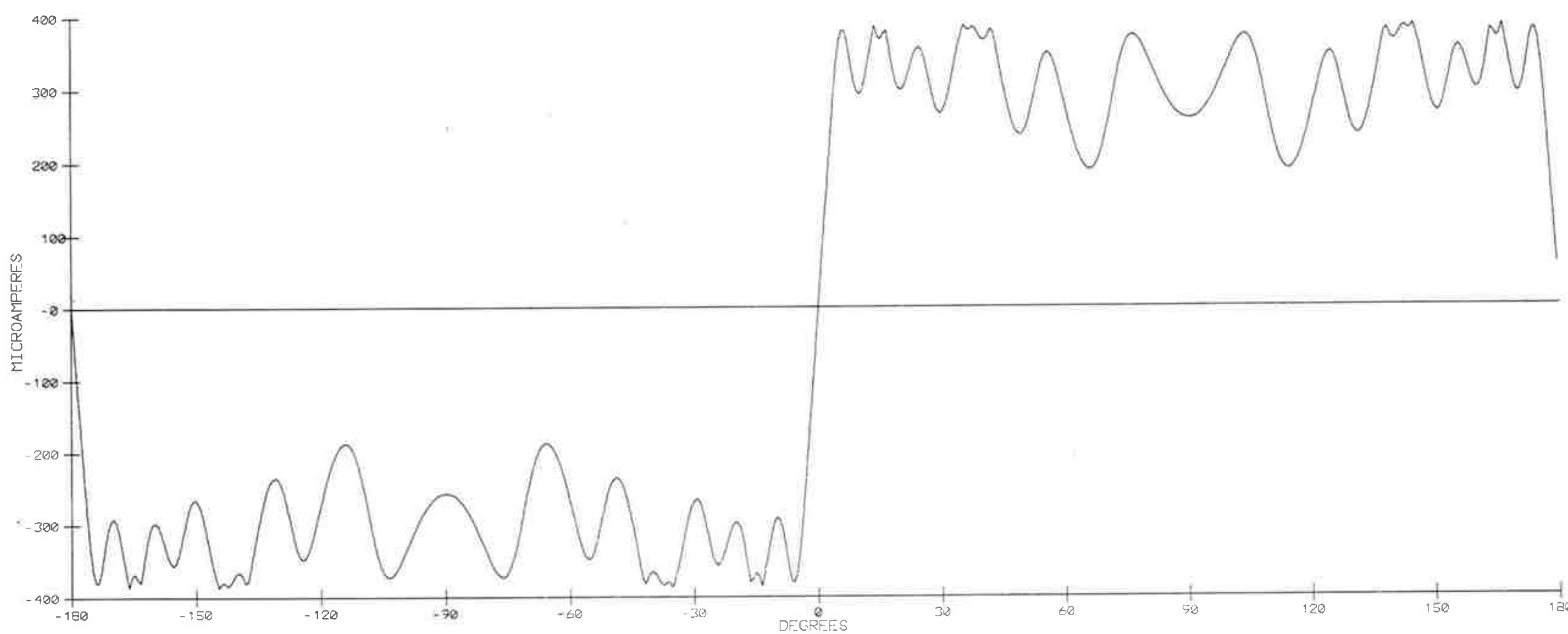


Figure 1-3. V-Ring: Expected CDI for Clearance Orbit

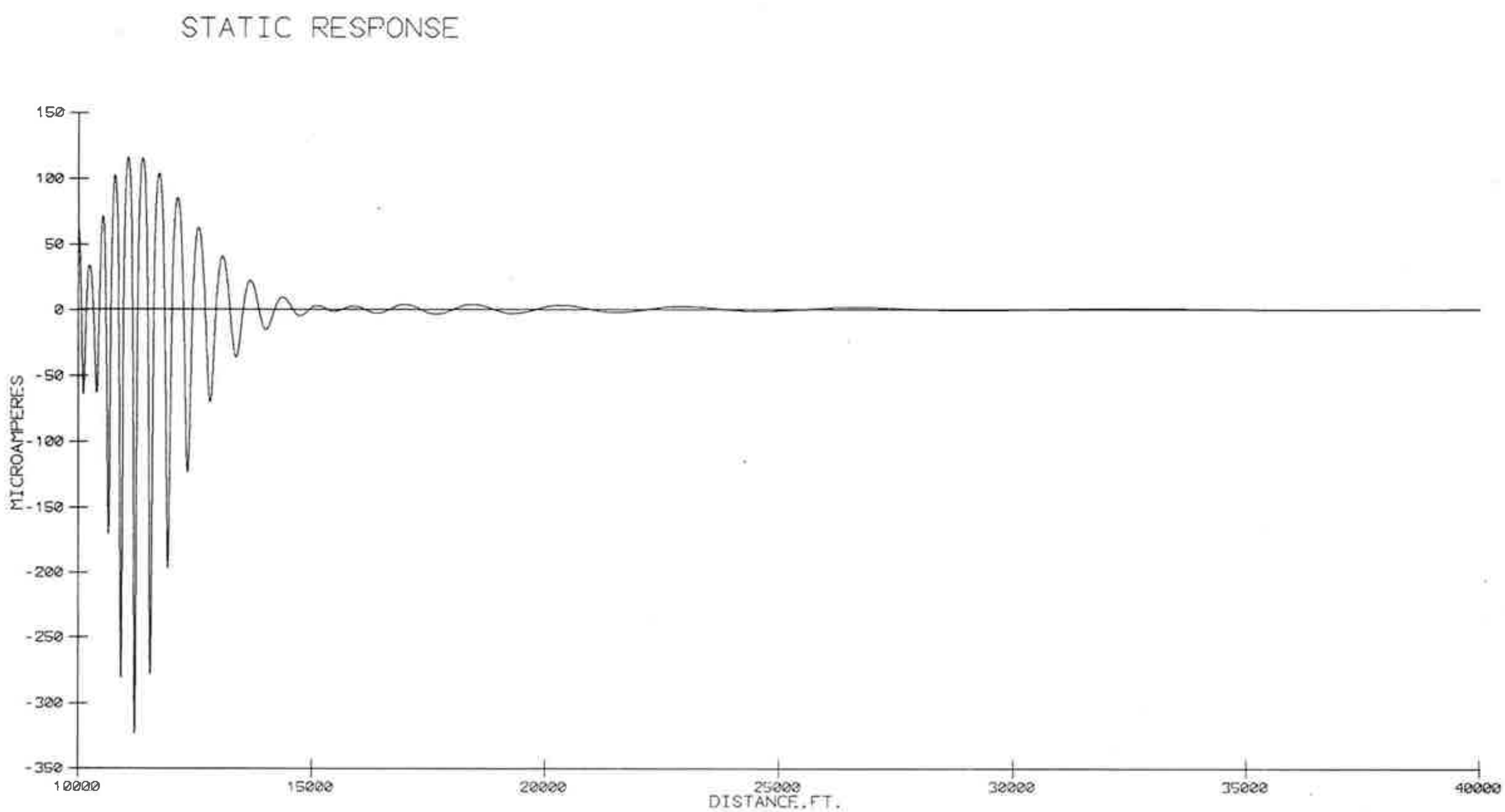


Figure 1-4. V-Ring: Static Flyability Run

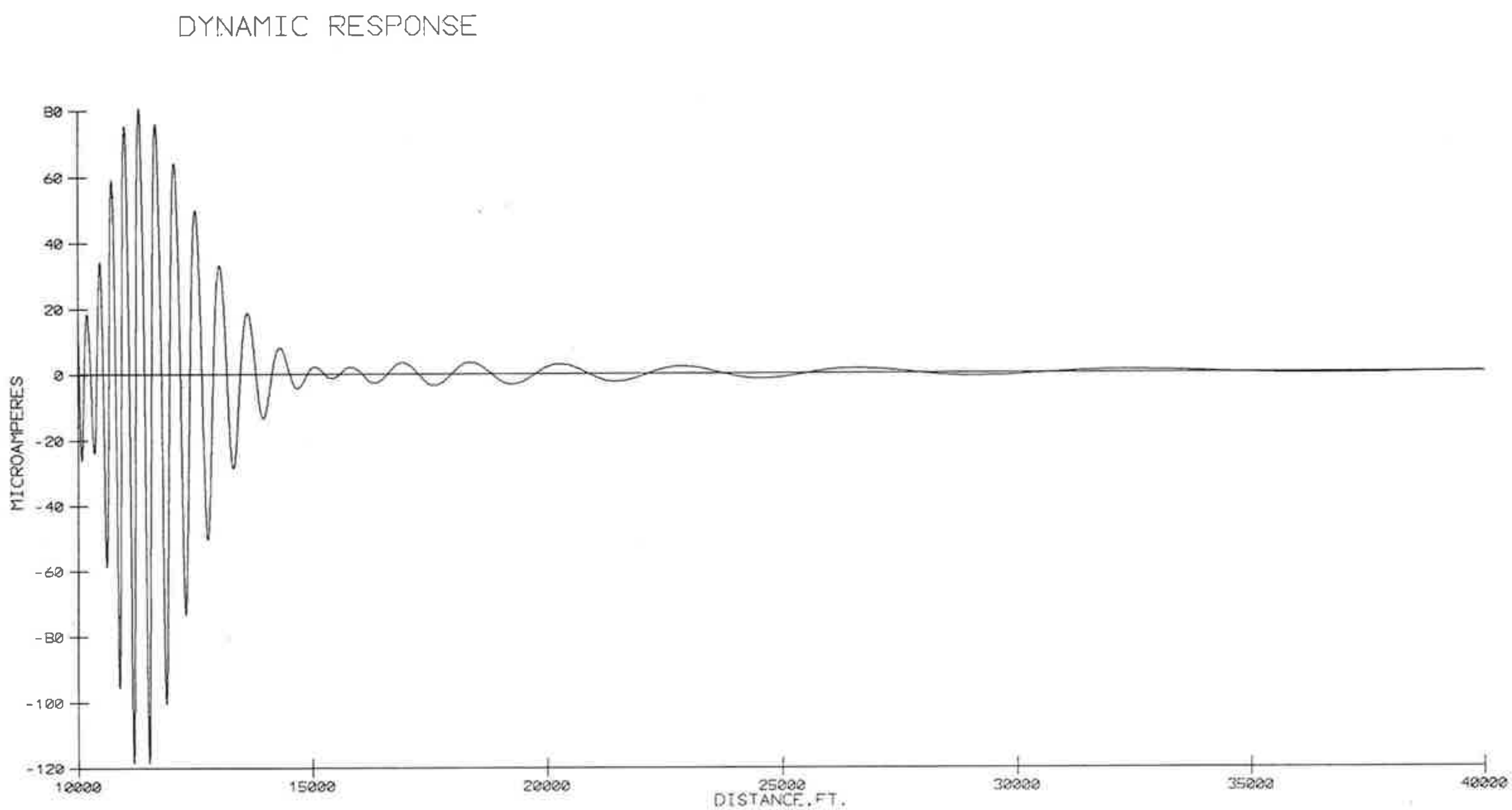


Figure 1-5. V-Ring: Dyanmic Flyability Run

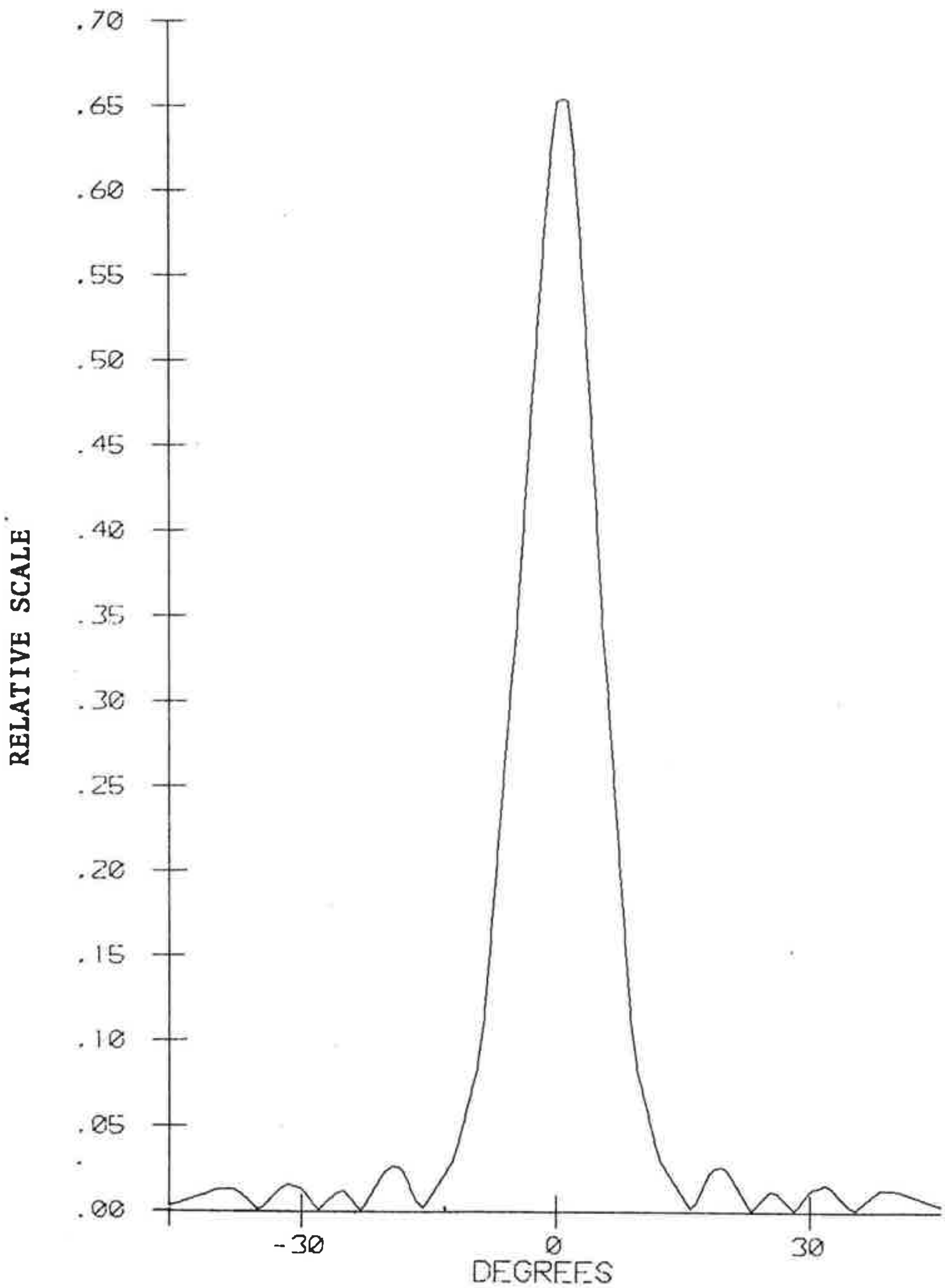


Figure 2-1. Alford 14/6: Course Array-Carrier Pattern

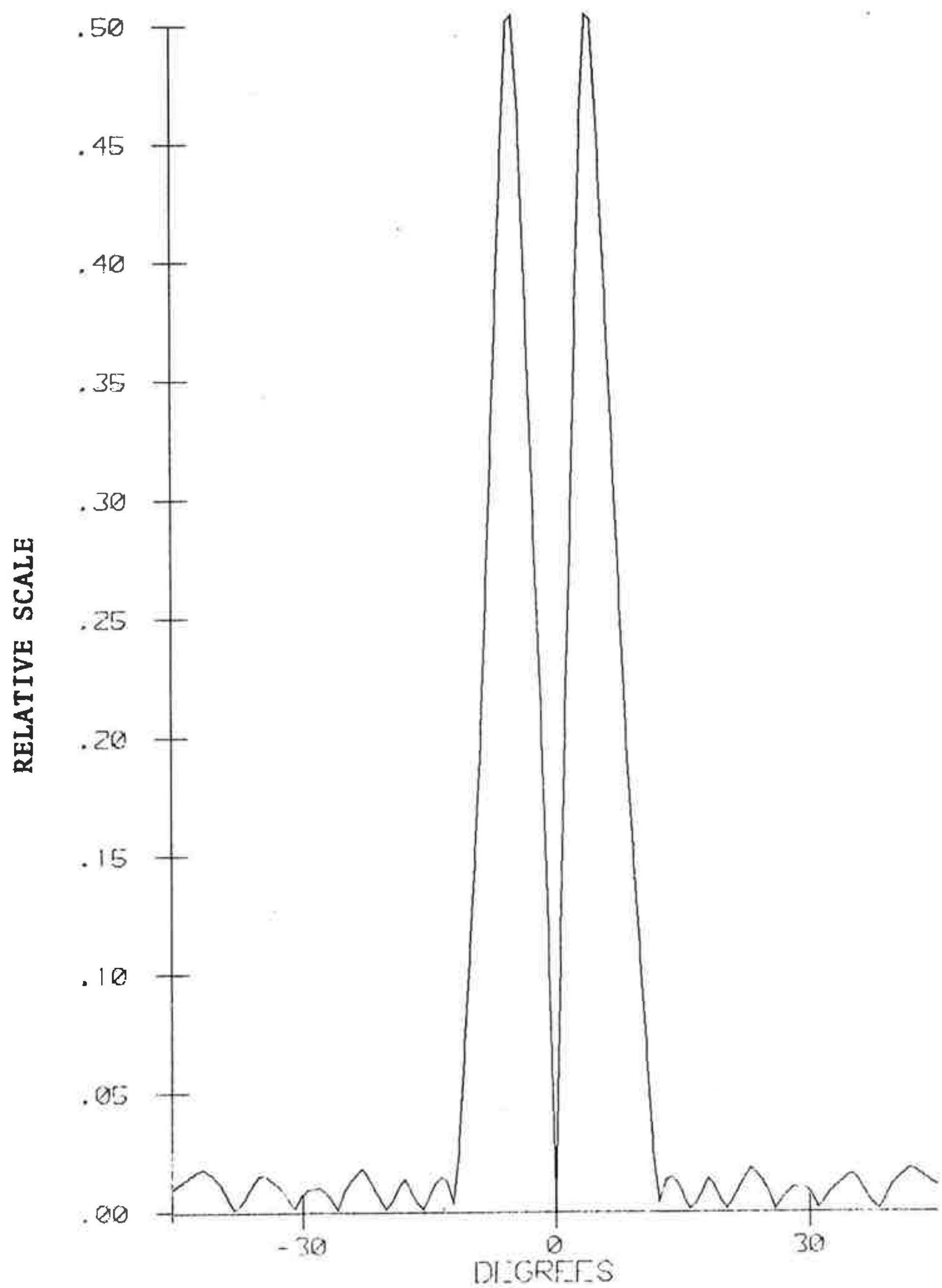


Figure 2-2. Alford 14/6: Course Array-Sidebands Only Pattern

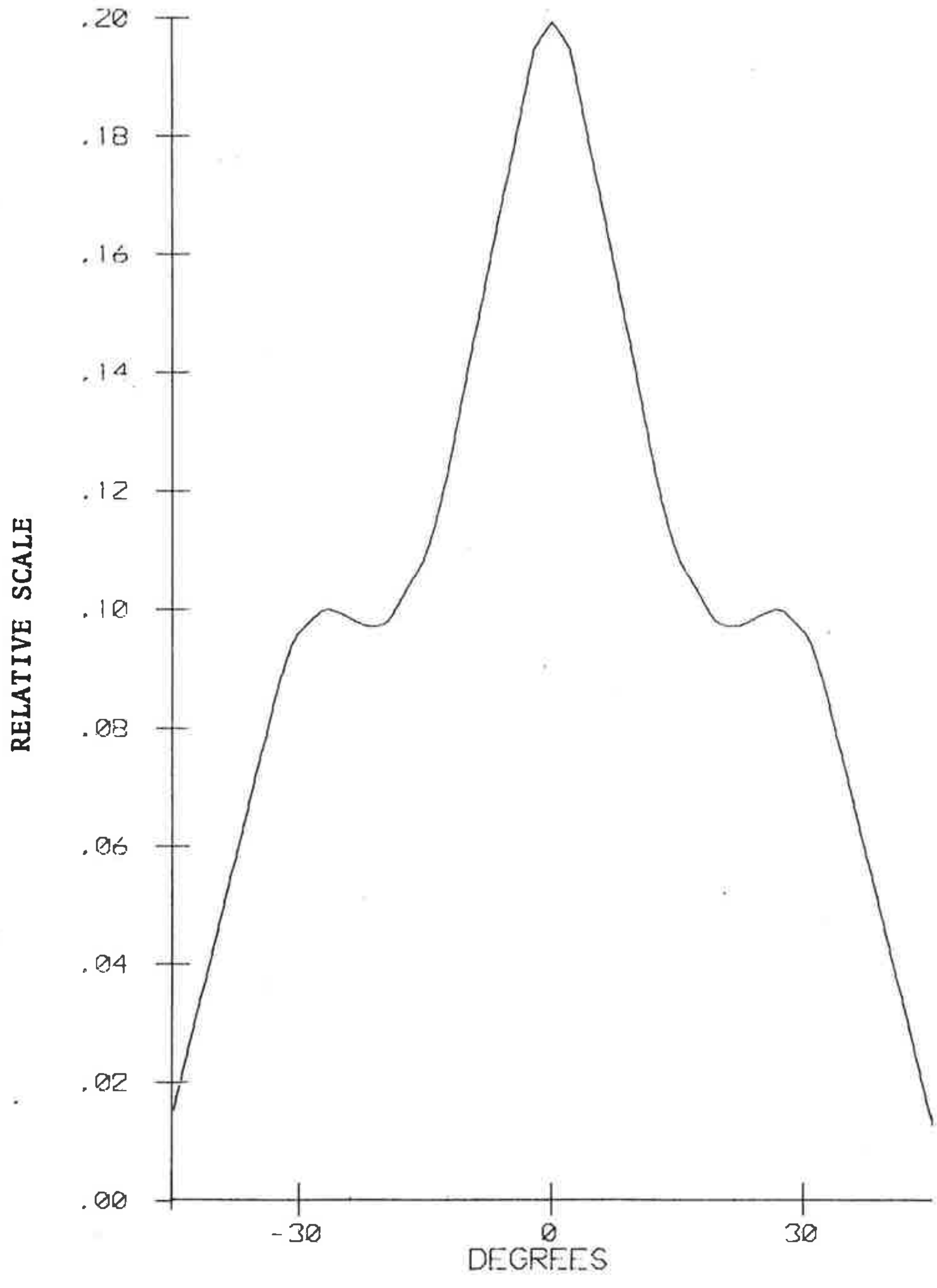


Figure 2-3. Alford 14/6: Clearance Array-Carrier Pattern

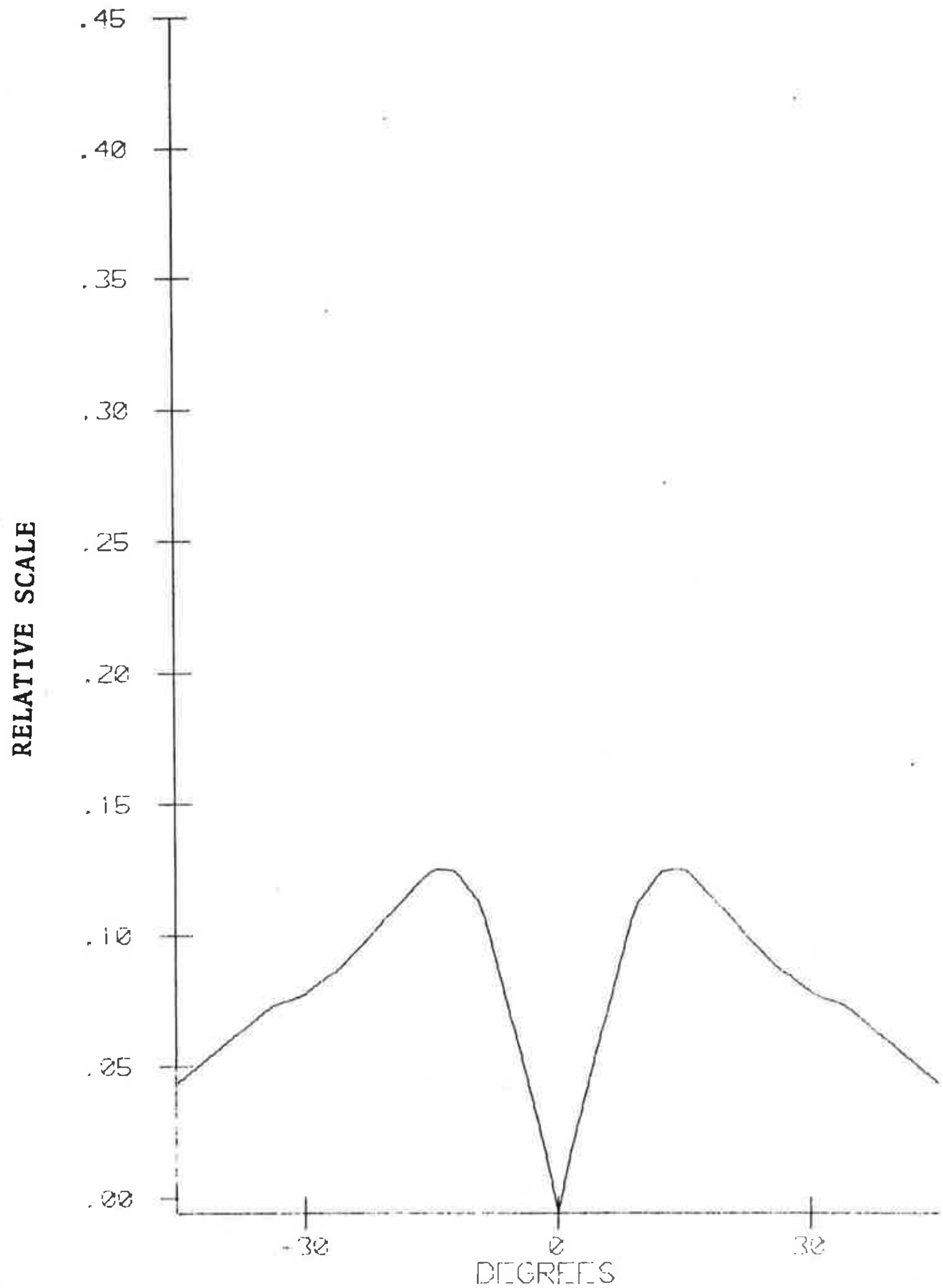


Figure 2-4. Alford 14/6: Clearance Array-Sidebands Only Pattern

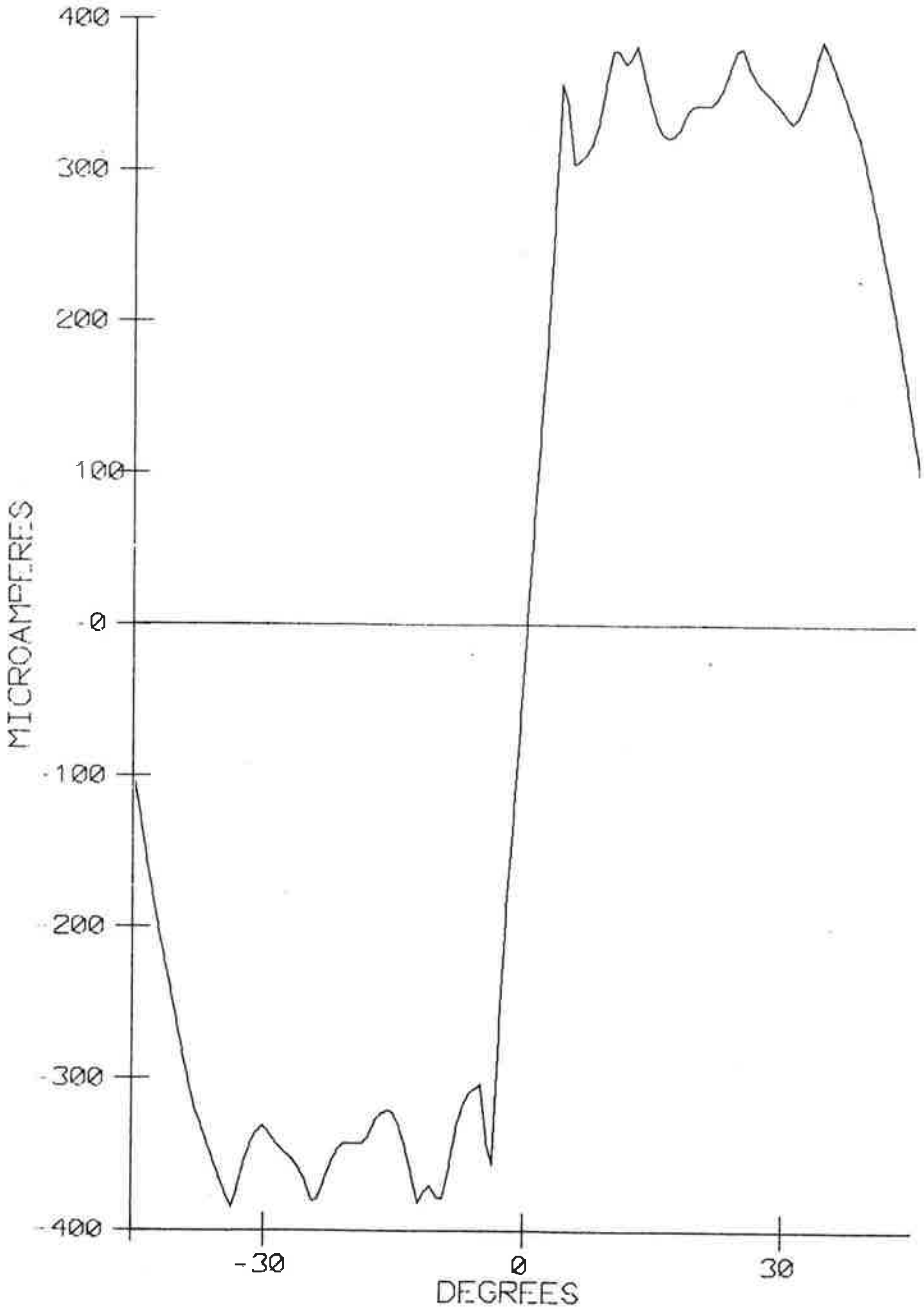


Figure 2-5. Alford 14/6: Expected CDI for Clearance Orbit

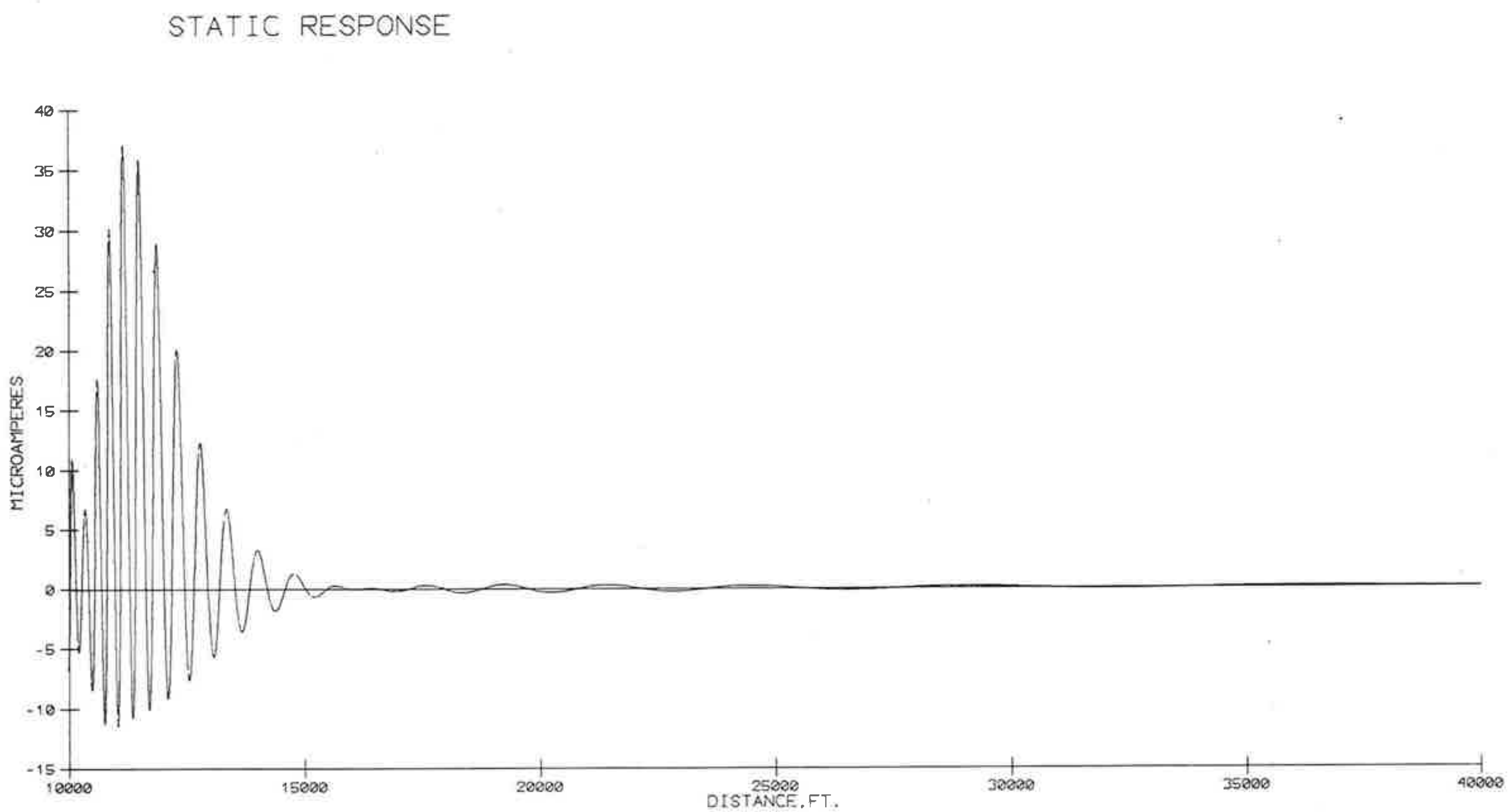


Figure 2-6. Alford 14/6: Static Flyability Run 10 dB Course to Clearance Ratio

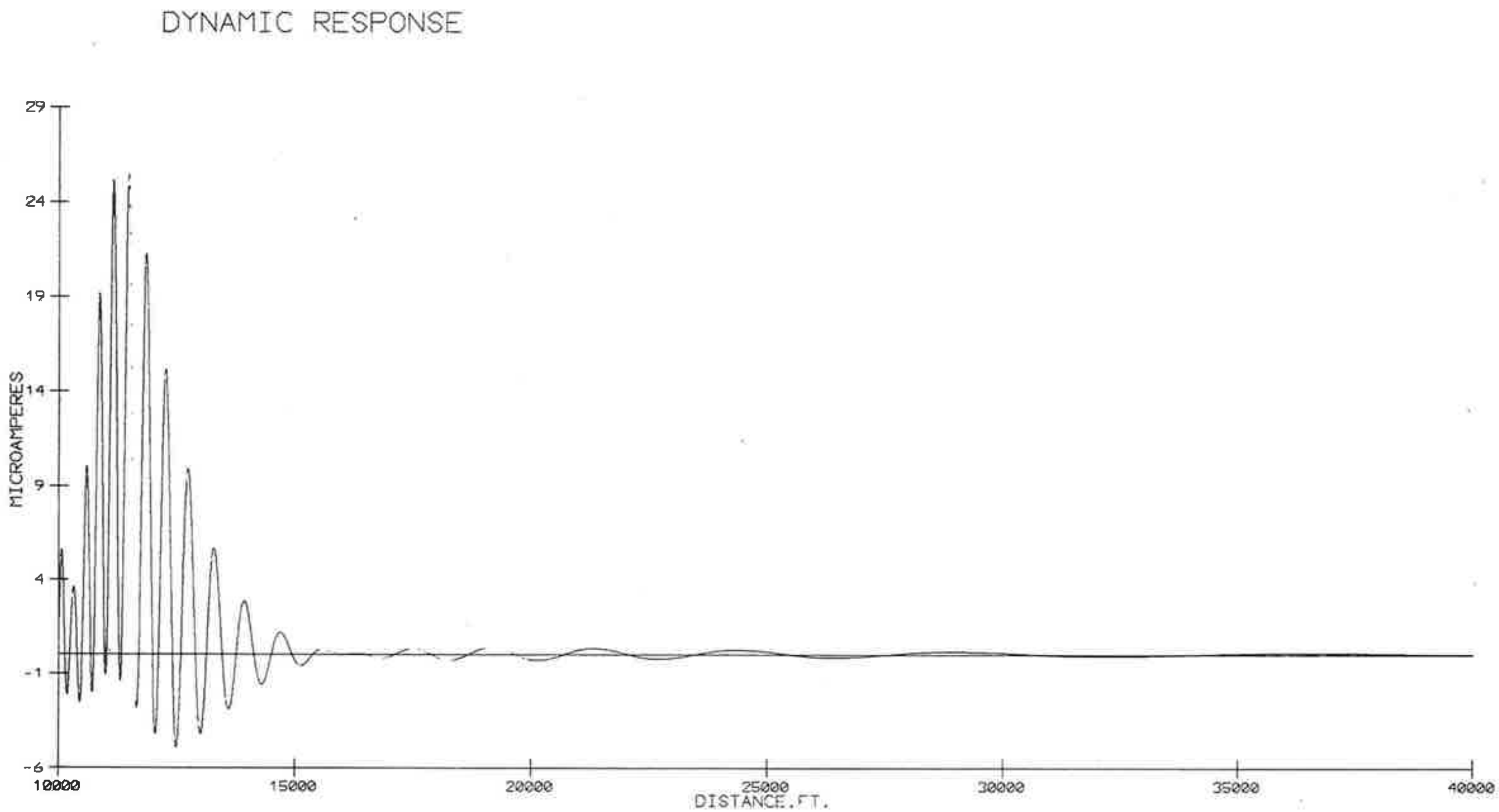


Figure 2-7. Alford 14/6: Dynamic Flyability Run 10 dB Course to Clearance Ratio

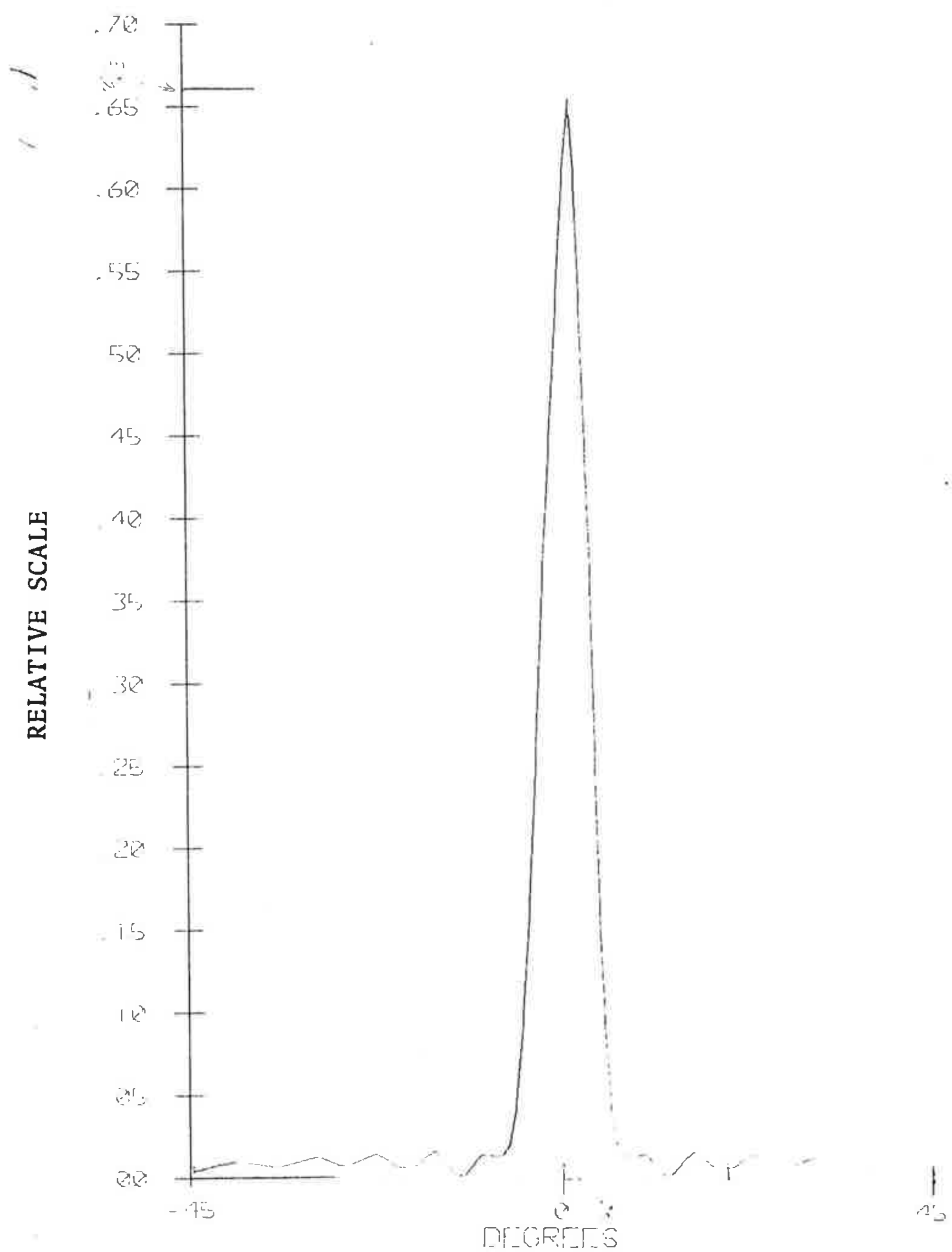


Figure 3-1. Alford 22/8: Course Array-Carrier Pattern 10 dB Course to Clearance Ratio

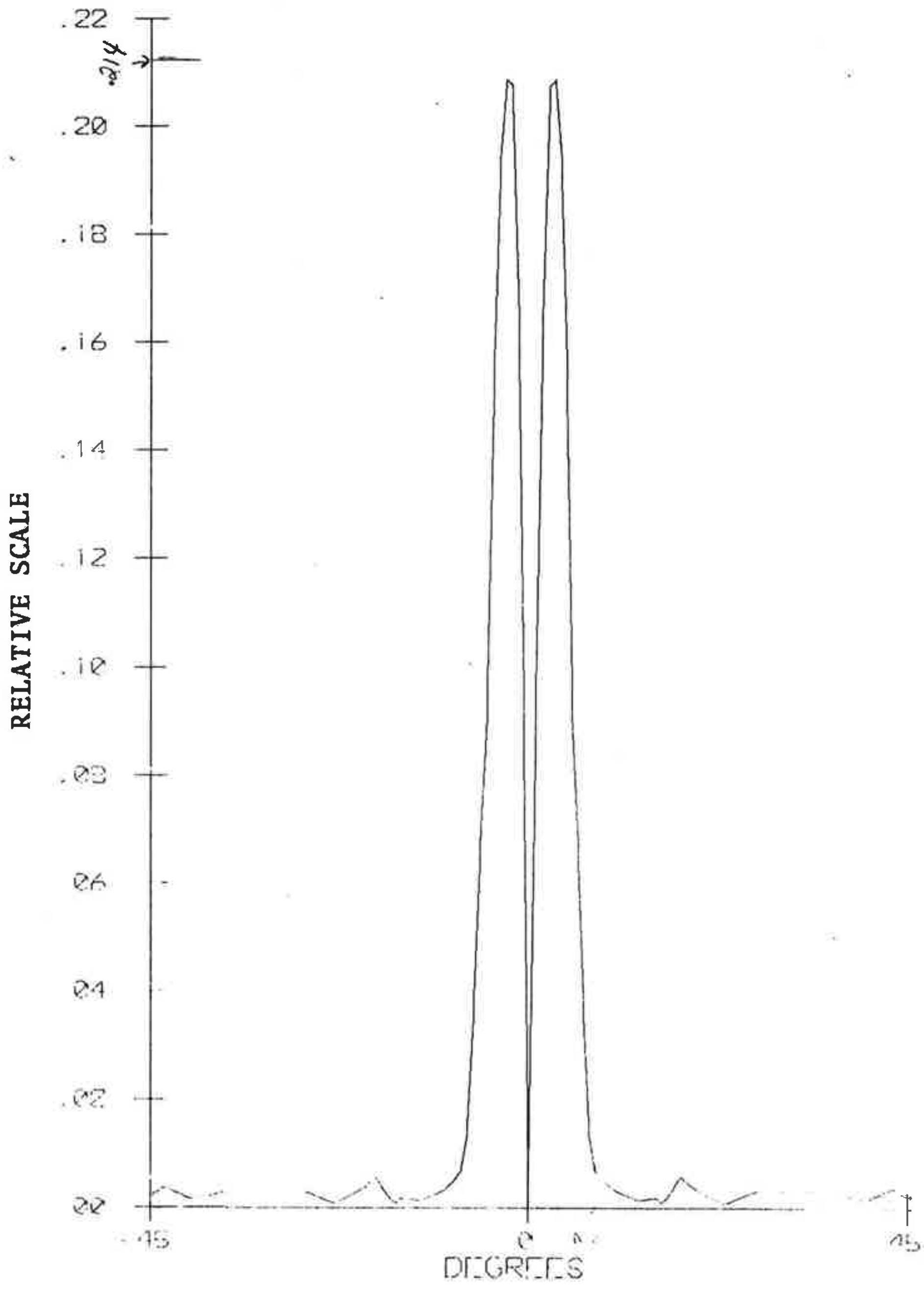


Figure 3-2. Alford 22/8: Course Array-Sidebands Only Pattern
10 dB Course to Clearance Ratio

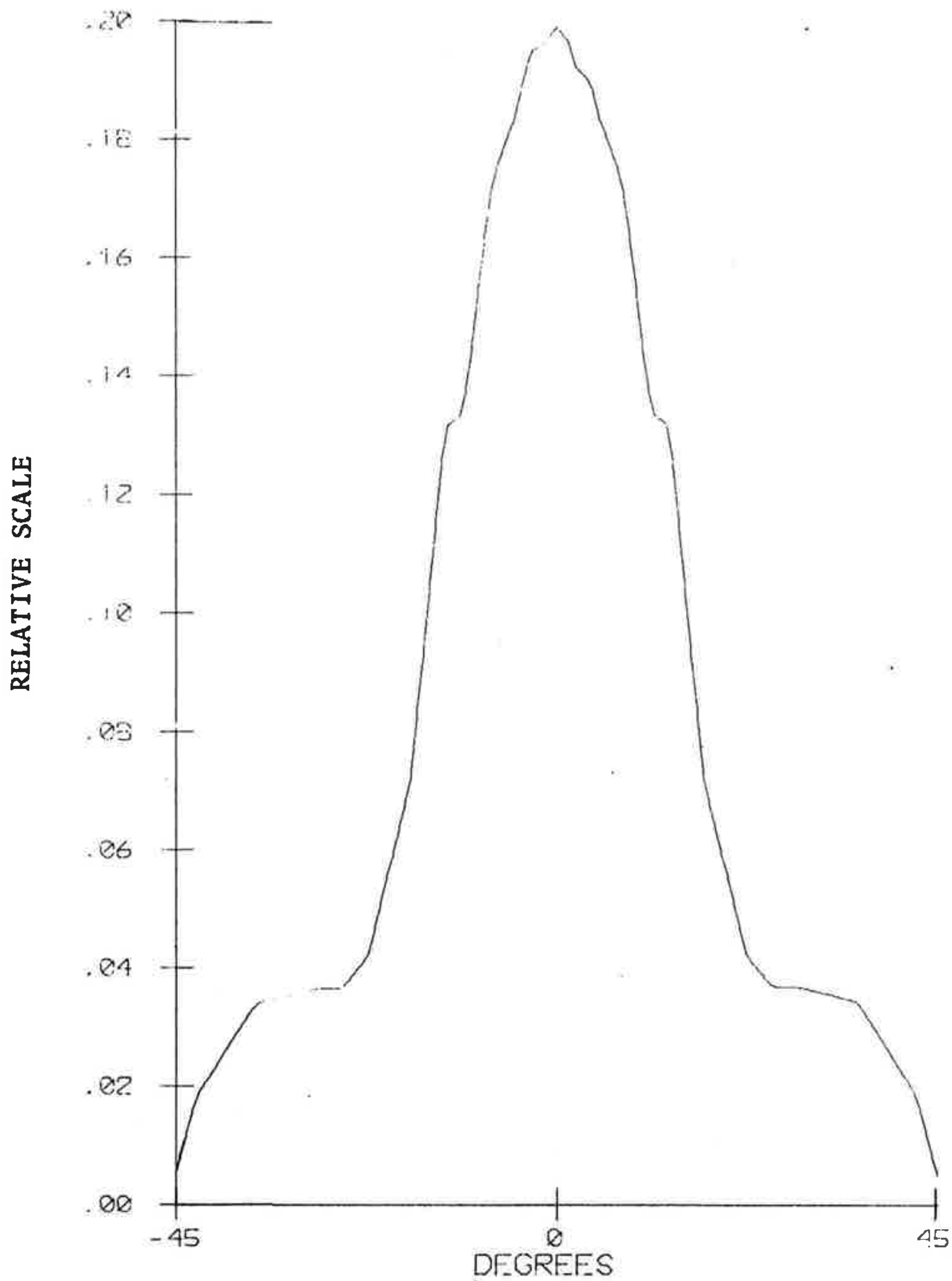


Figure 3-3. Alford 22/8: Clearance Array-Carrier Pattern 10 dB Course to Clearance Ratio

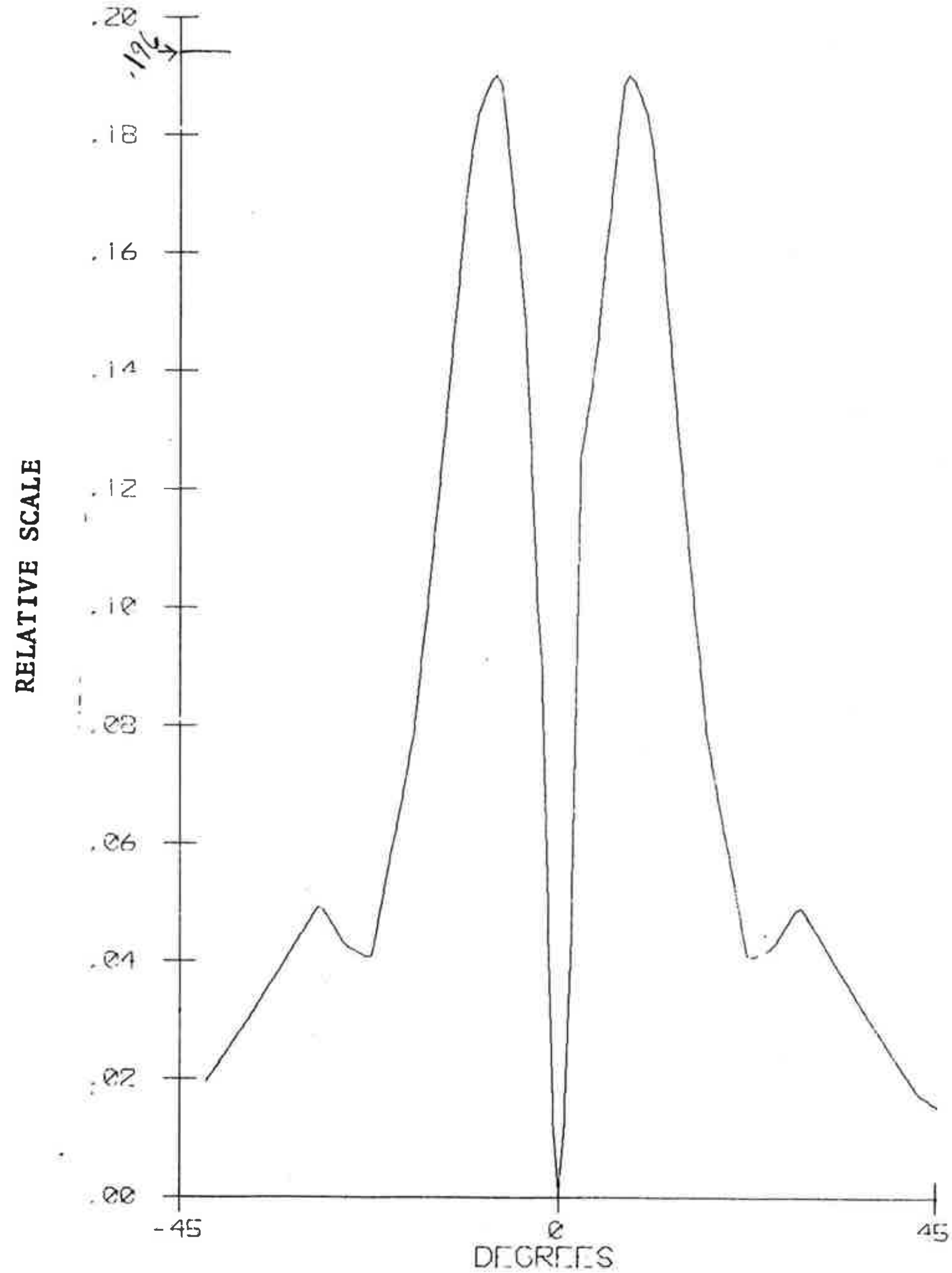


Figure 3-4. Alford 22/8: Clearance Array-Sidebands Only Pattern
10 dB Course to Clearance Ratio

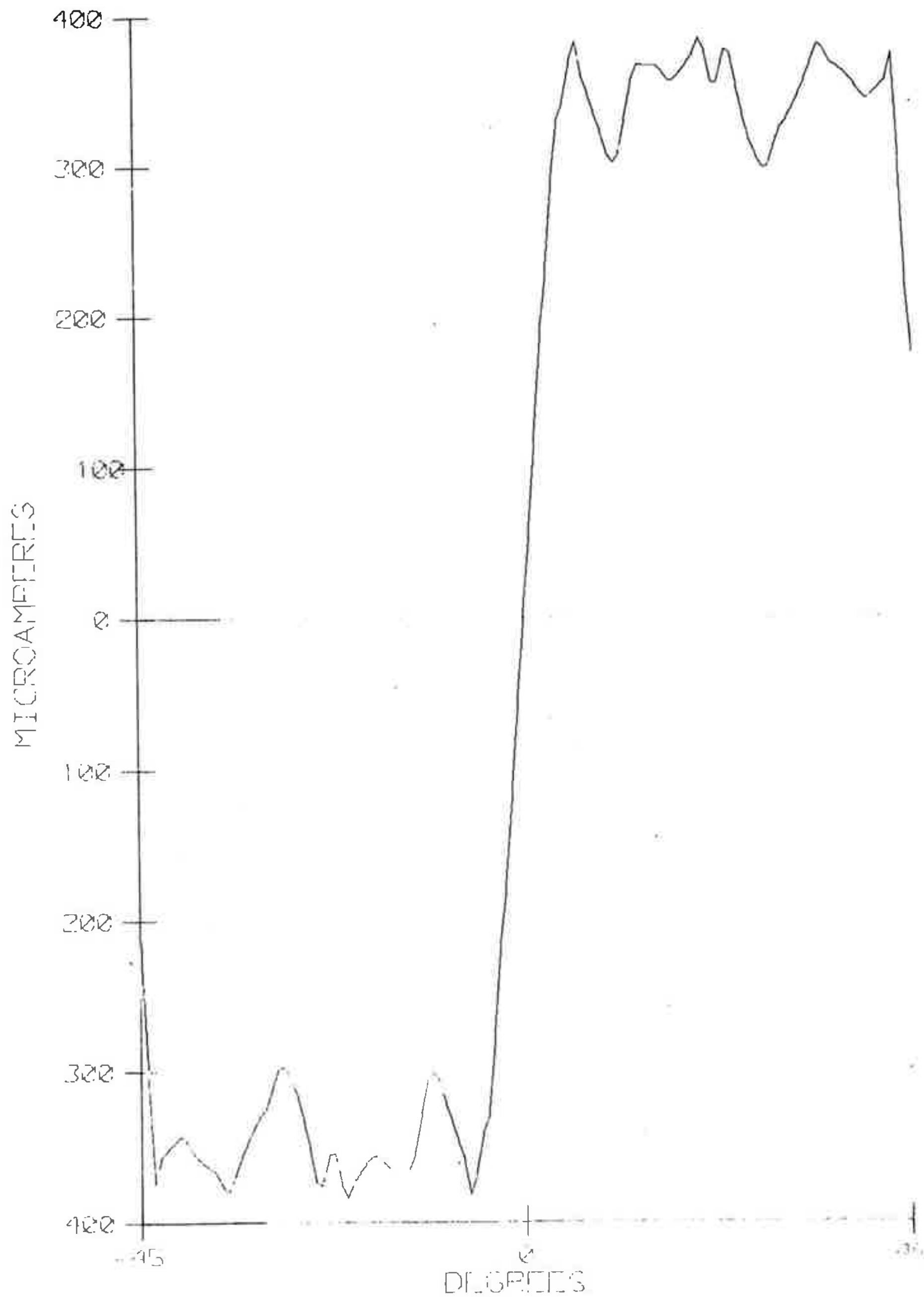


Figure 3-5. Alford 22/8: Expected CDI for Clearance Orbit 10 dB Course to Clearance Ratio

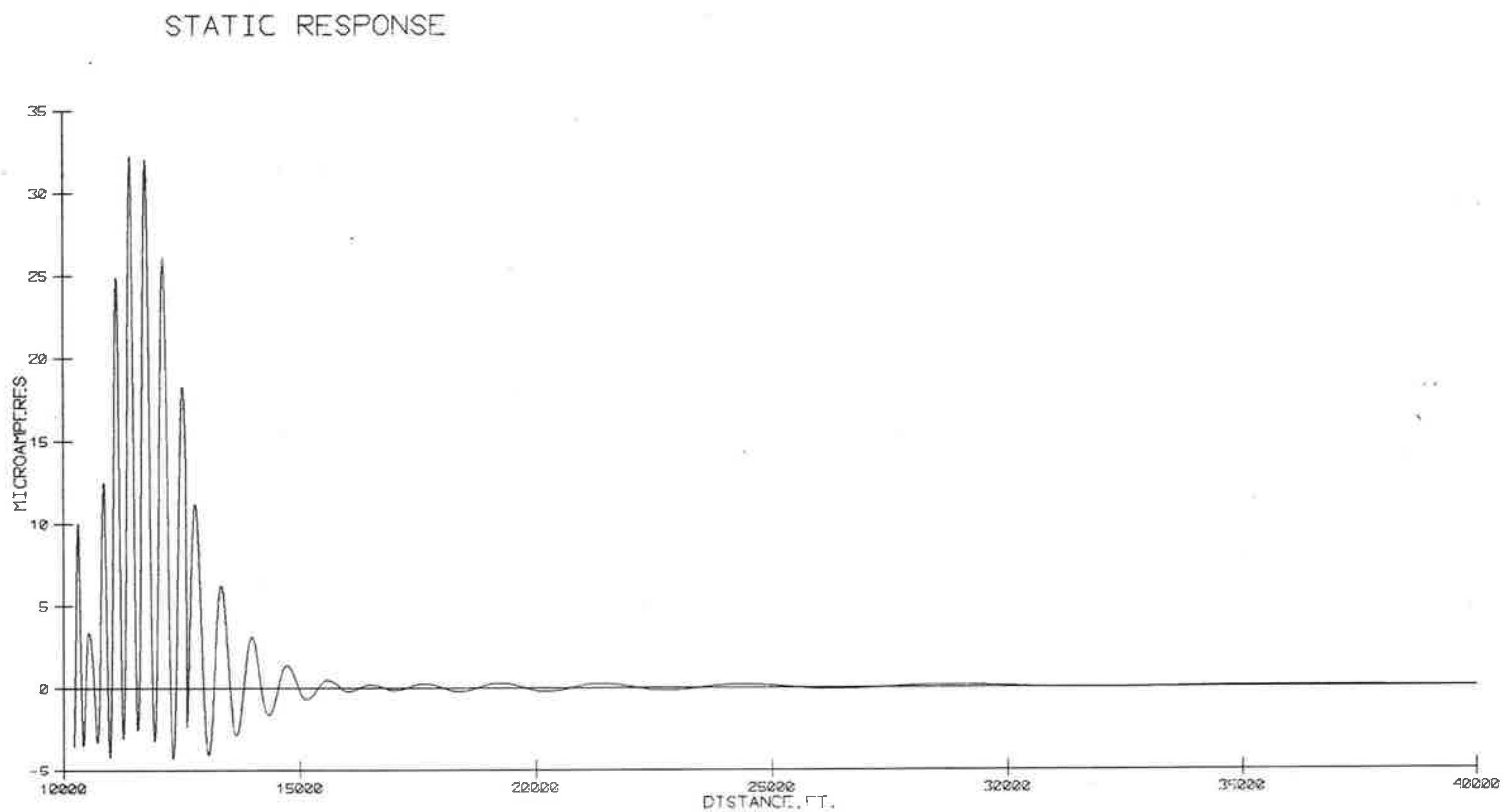


Figure 3-6. Alford 22/8: Static Flyability Run 10 dB Course to Clearance Ratio

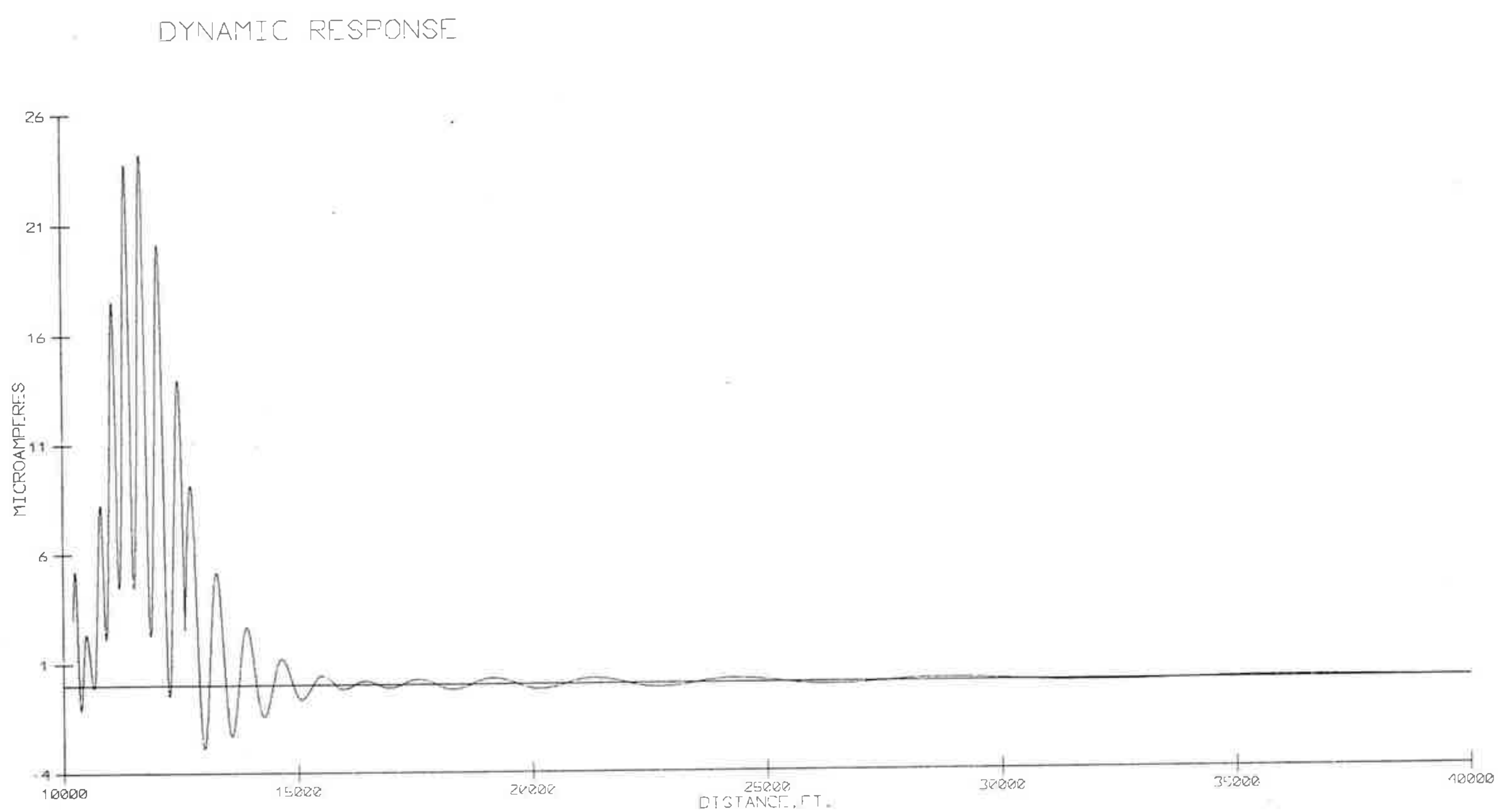


Figure 3-7. Alford 22/8: Dynamic Flyability Run 10 dB Course to Clearance Ratio

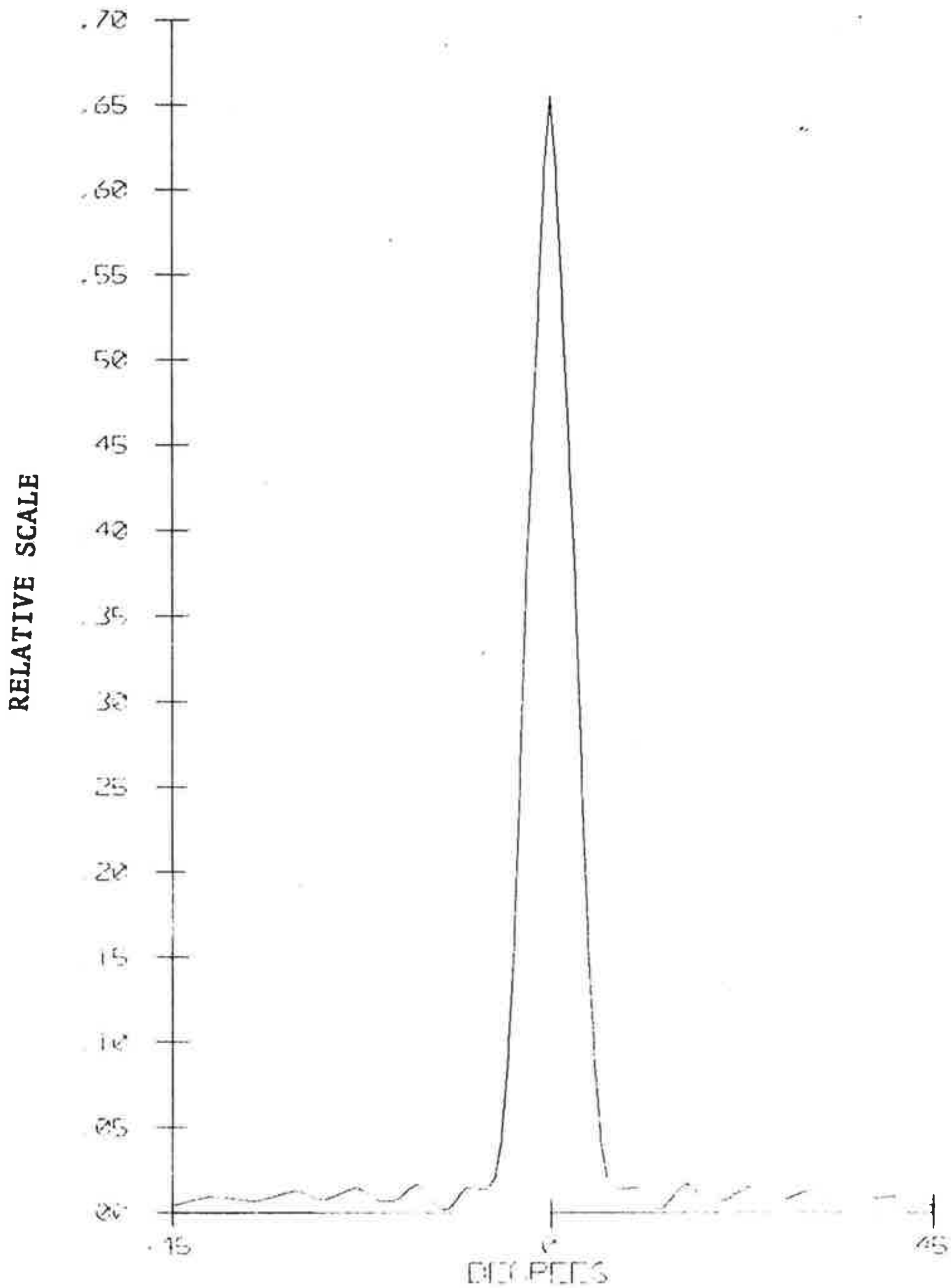


Figure 4-1. Alford 22/8: Course Array-Carrier Pattern 12 dB Course to Clearance Ratio

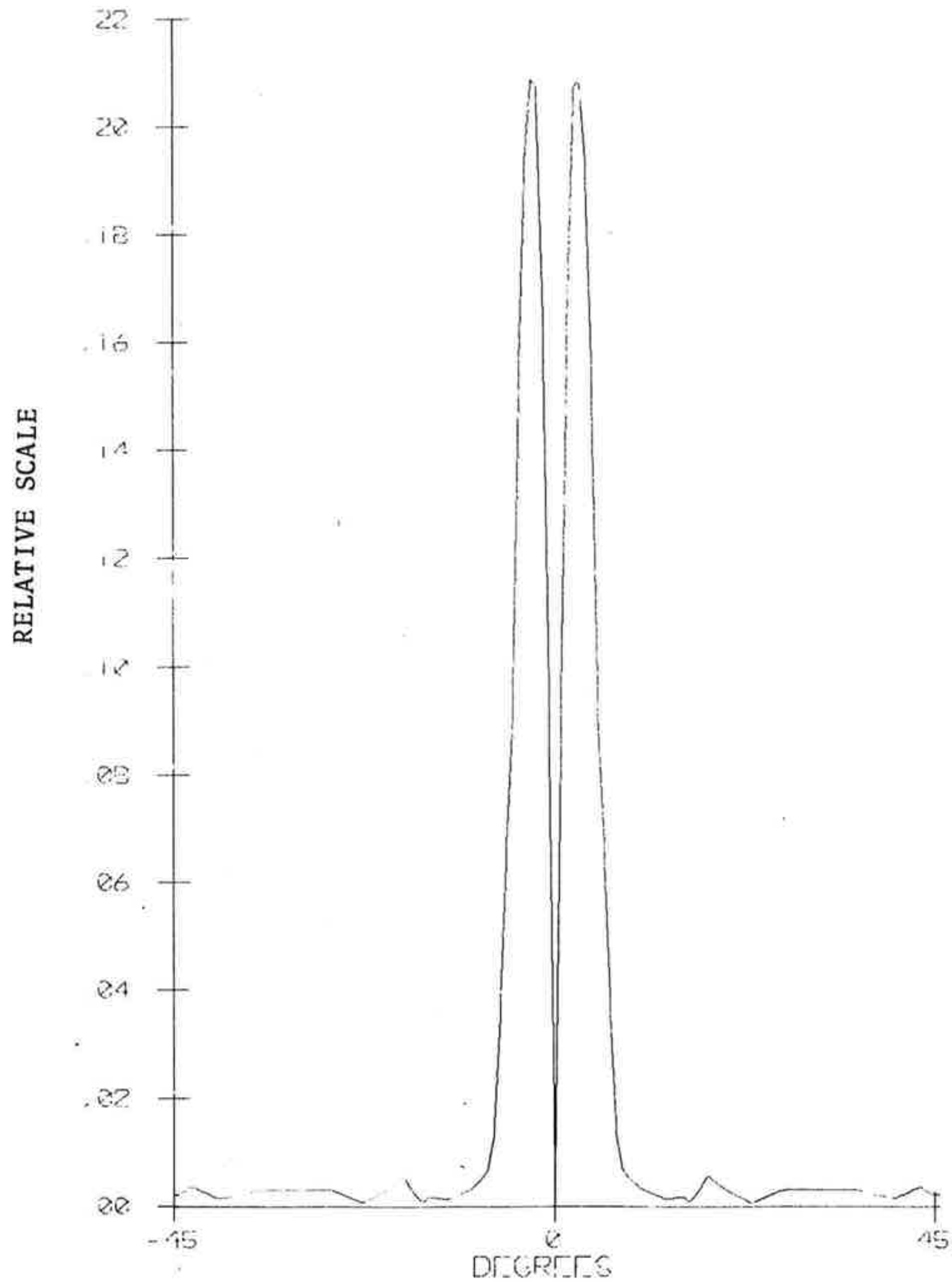


Figure 4-2. Alford 22/8: Course Array-Sidebands Only Pattern 12 dB Course to Clearance Ratio

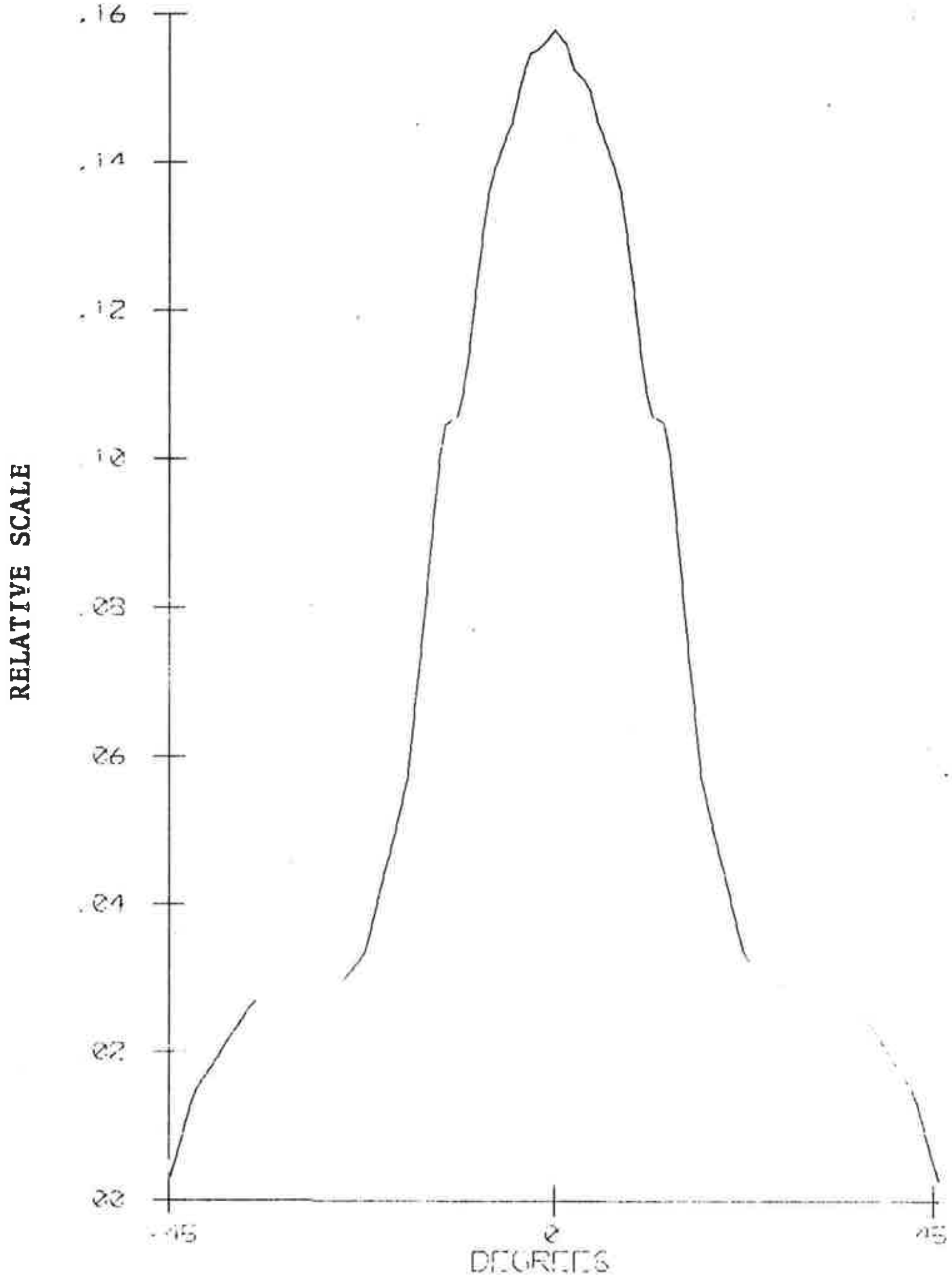


Figure 4-3. Alford 22/8: Clearance Array-Carrier Pattern 12 dB Course to Clearance Ratio

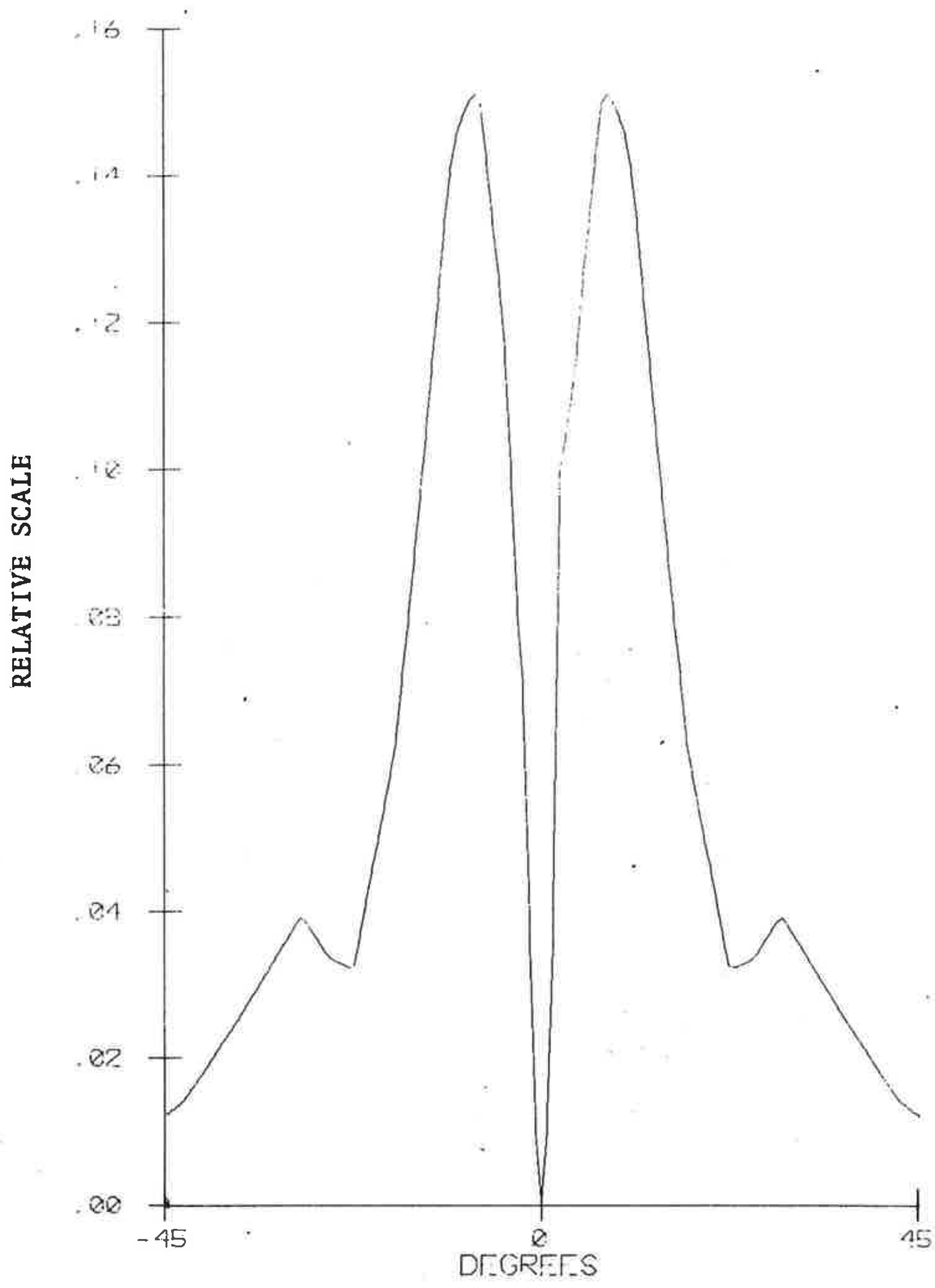


Figure 4-4. Alford 22/8: Clearance Array-Sidebands Only Pattern
12 dB Course to Clearance Ratio

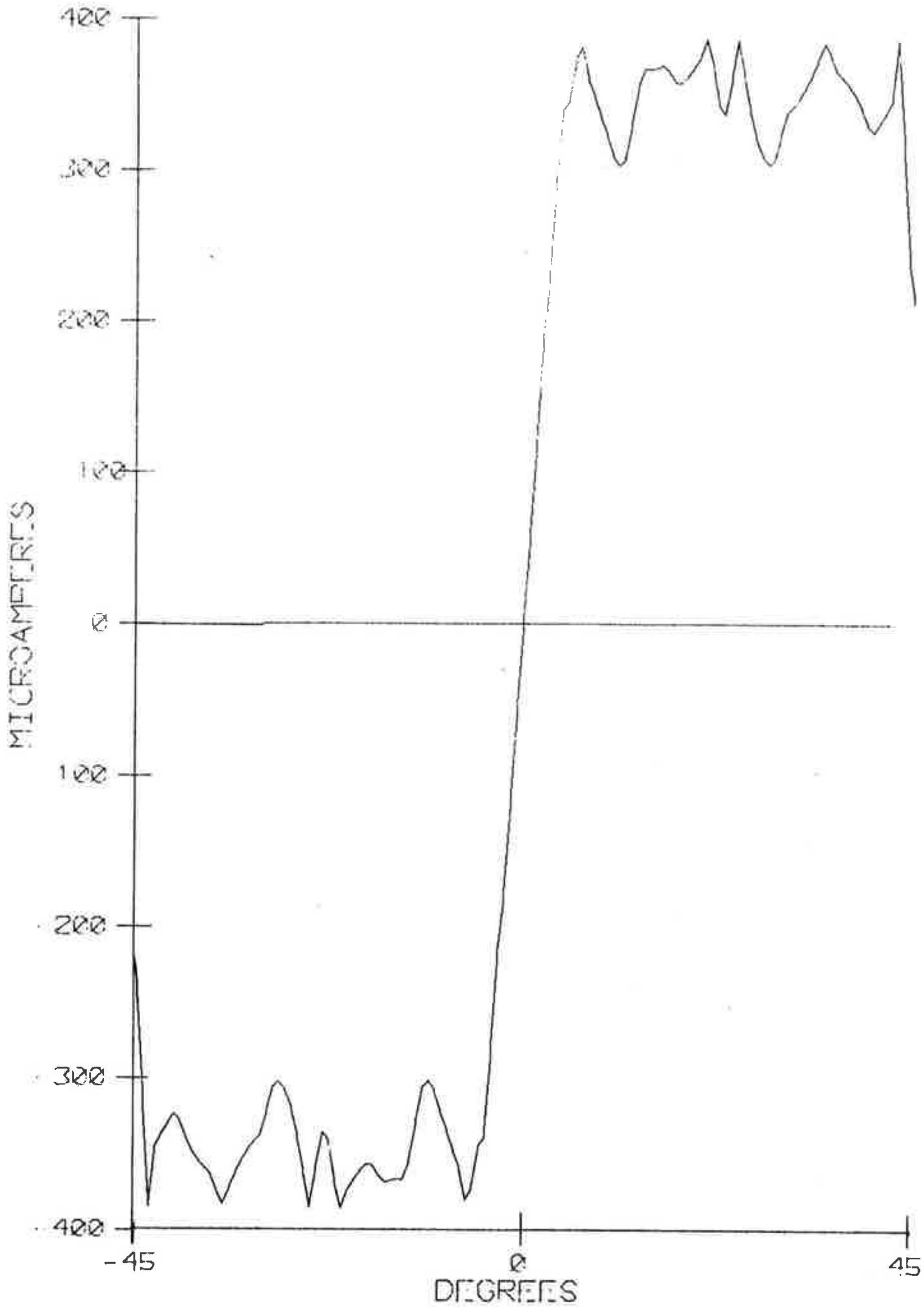


Figure 4-5. Alford 22/8: Expected CDI for Clearance Orbit 12 dB Course to Clearance Ratio

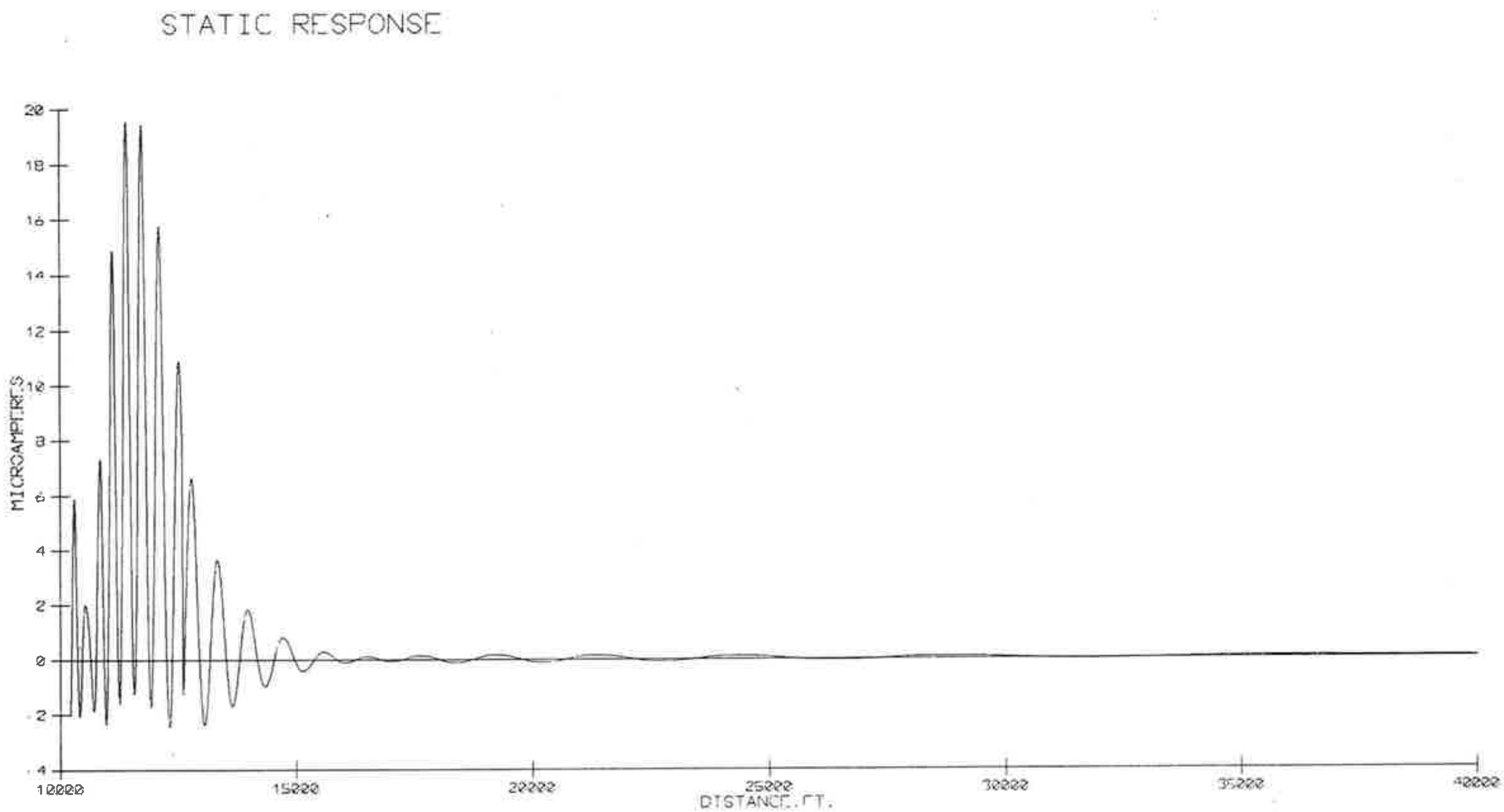


Figure 4-6. Alford 22/8: Static Flyability Run 12 dB Course to Clearance Ratio

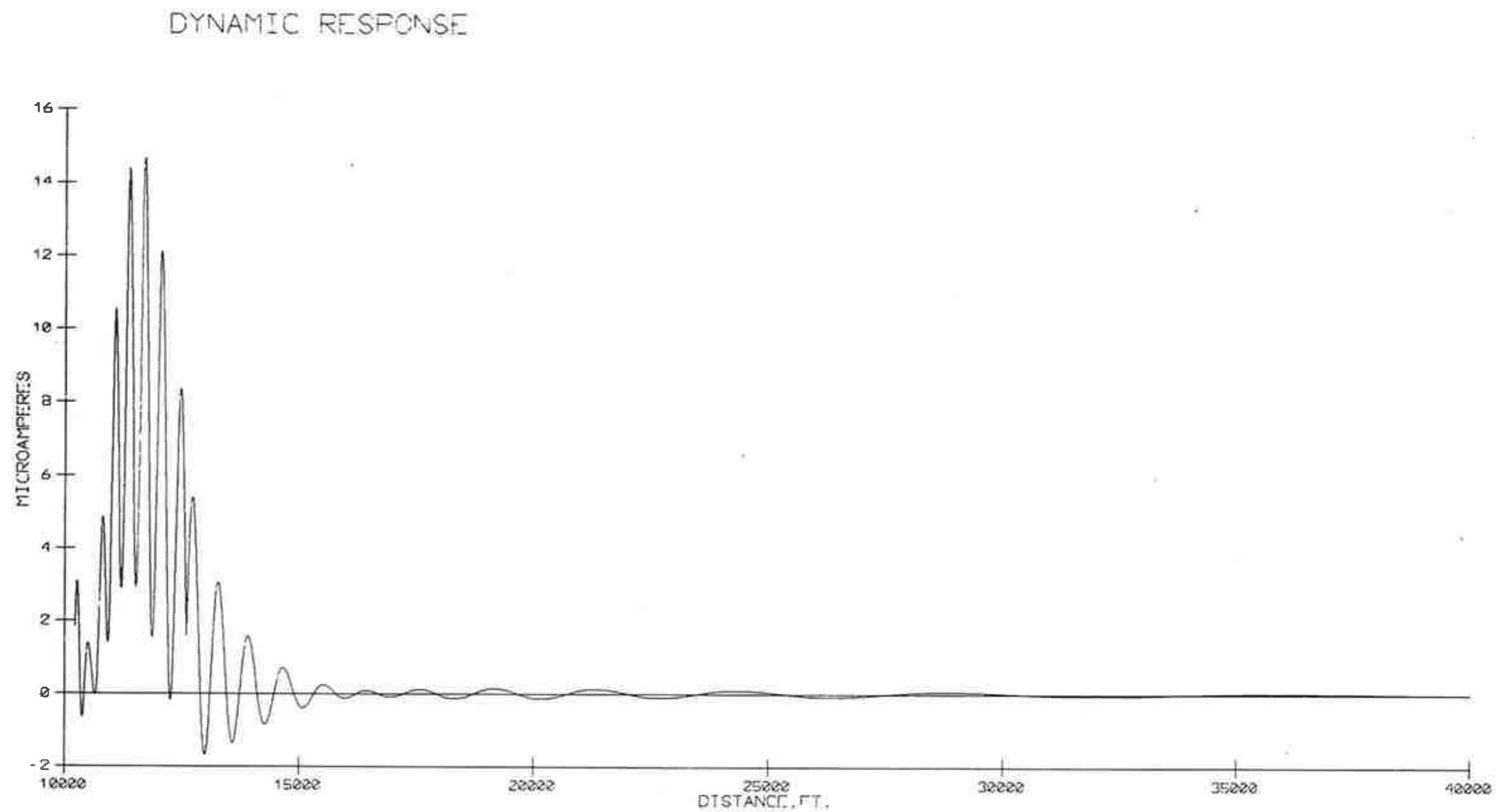


Figure 4-7. Alford 22/8: Dyanmic Flyability Run 12 dB Course to Clearance Ratio

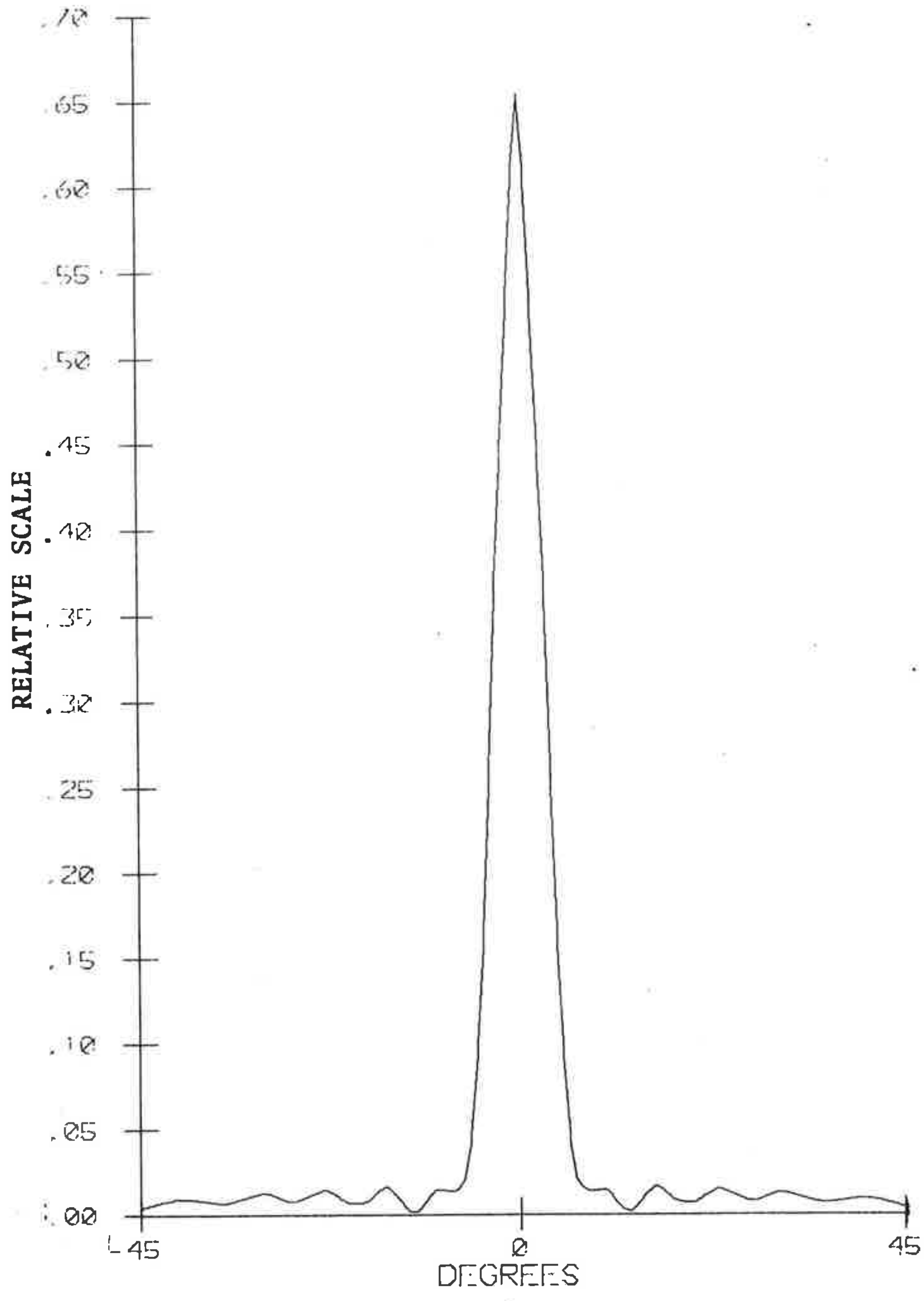


Figure 5-1. Alford 22/8: Course Array-Carrier Pattern 16 dB Course to Clearance Ratio

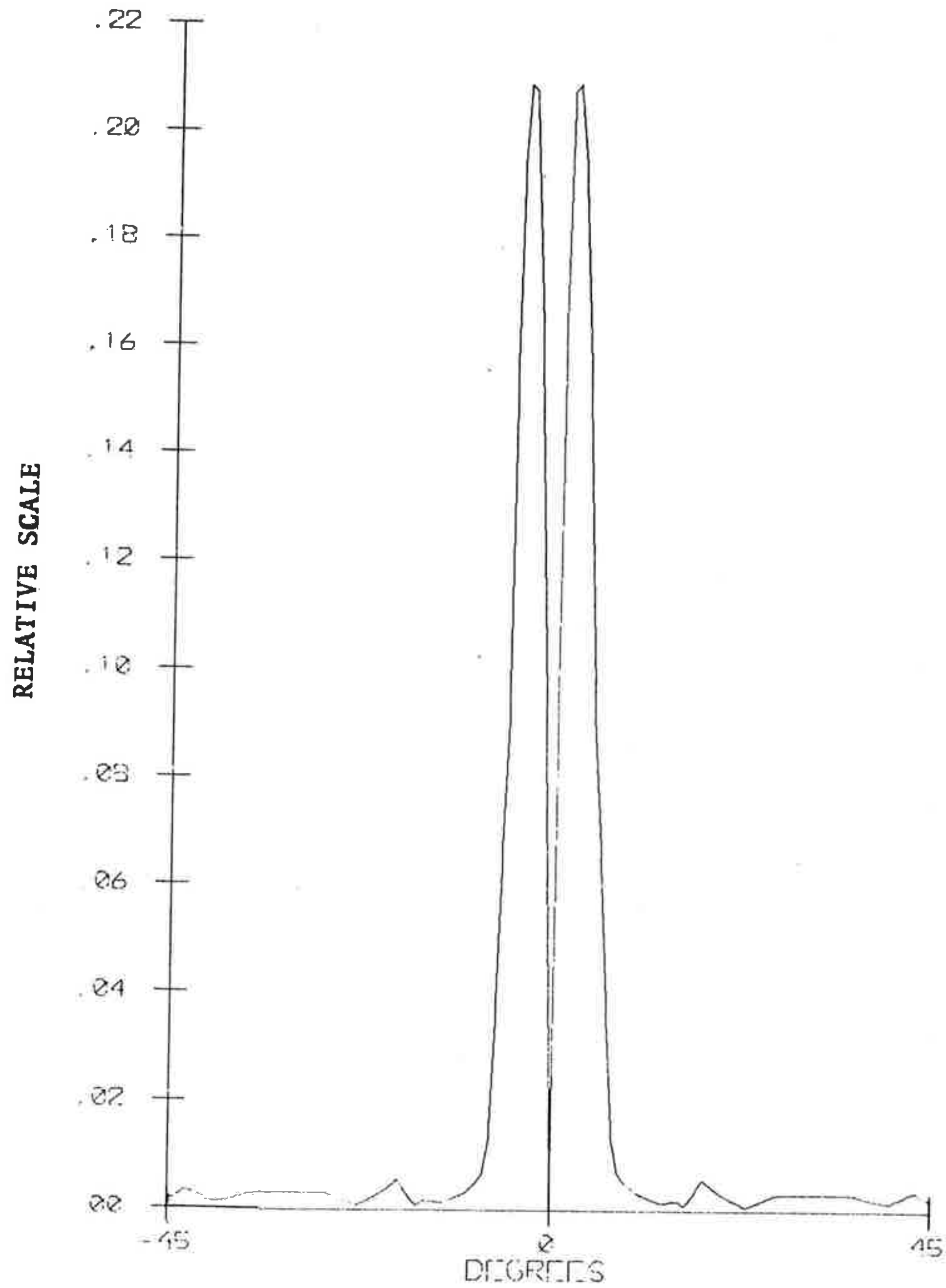


Figure 5-2. Alford 22/8: Course Array-Sidebands Only Pattern
16 dB Course to Clearance Ratio

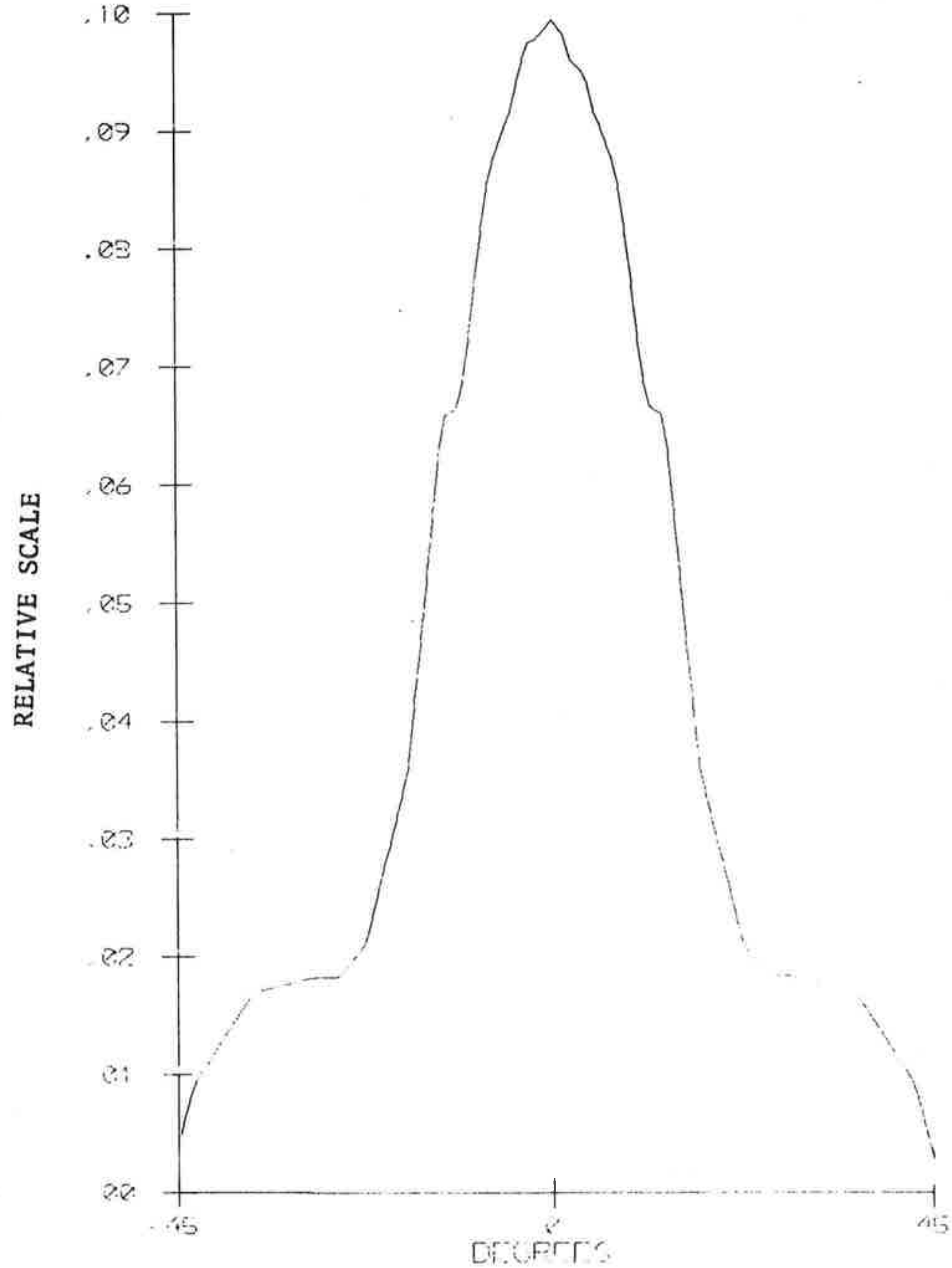


Figure 5-3. Alford 22/8: Clearance Array-Carrier Pattern 16 dB Course to Clearance Ratio

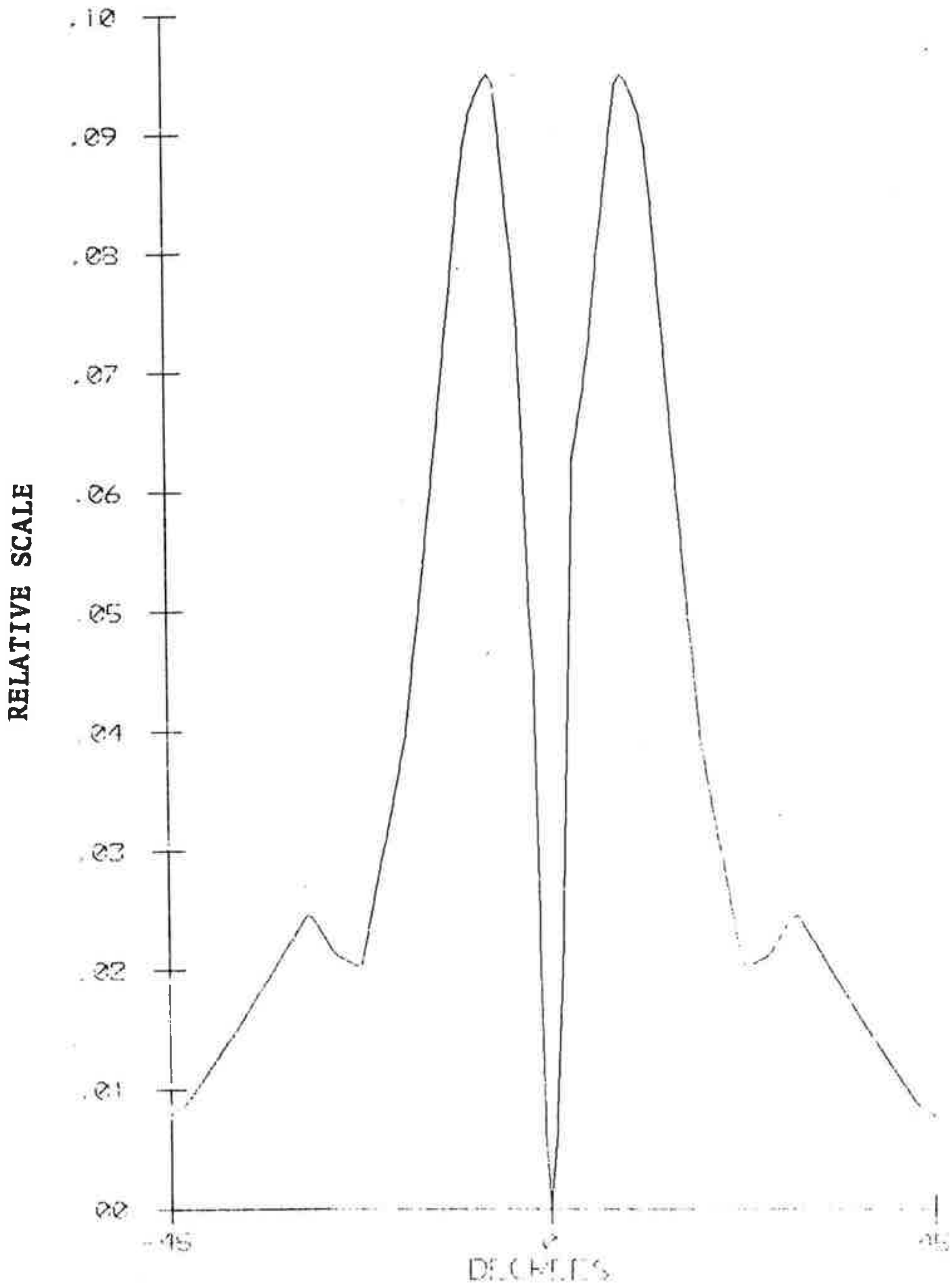


Figure 5-4. Alford 22/8: Clearance Array-Sidebands Only Pattern
16 dB Course to Clearance Ratio

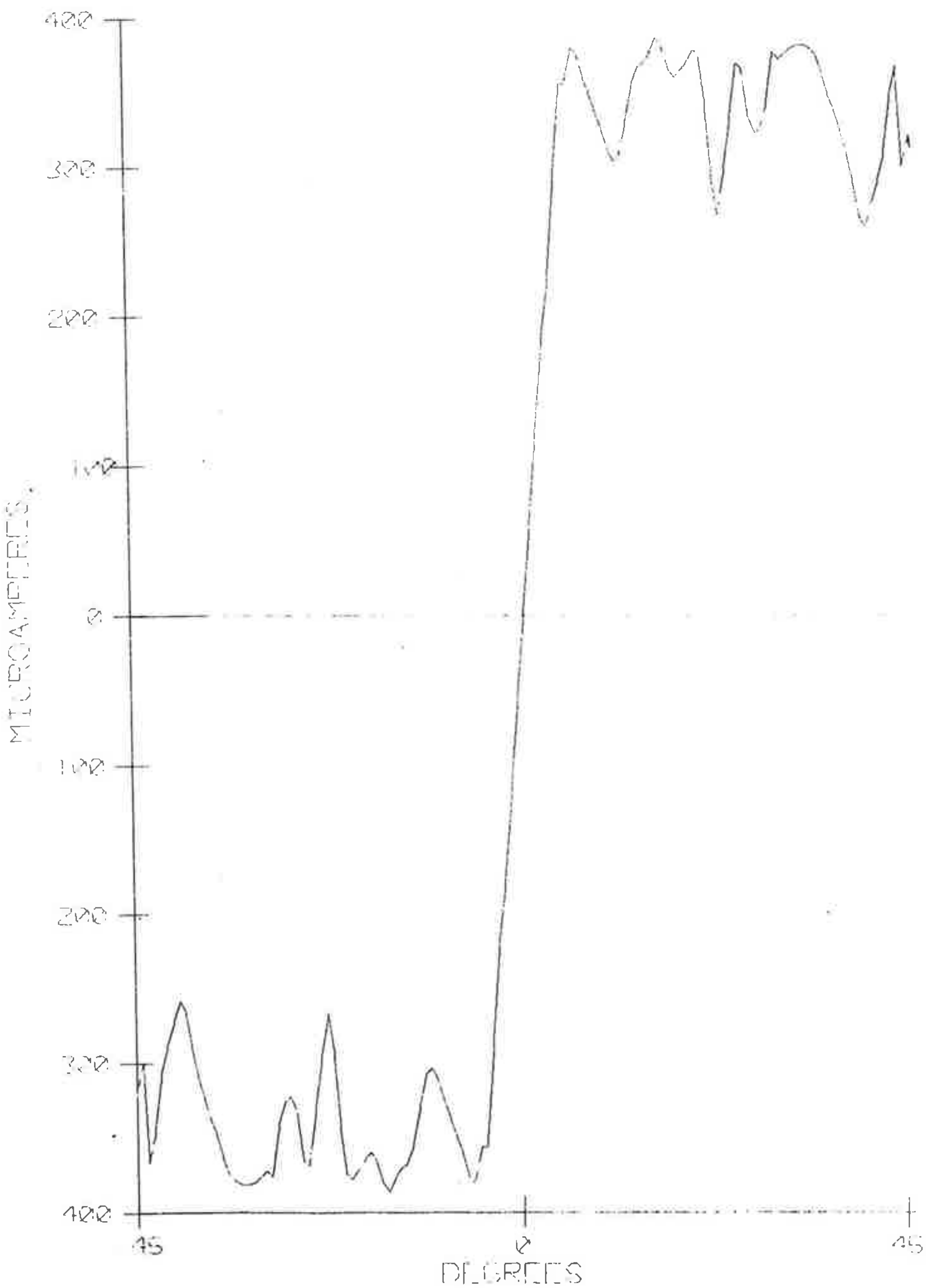


Figure 5-5. Alford 22/8: Expected CDI for Clearance Orbit 16 dB Course to Clearance Ratio

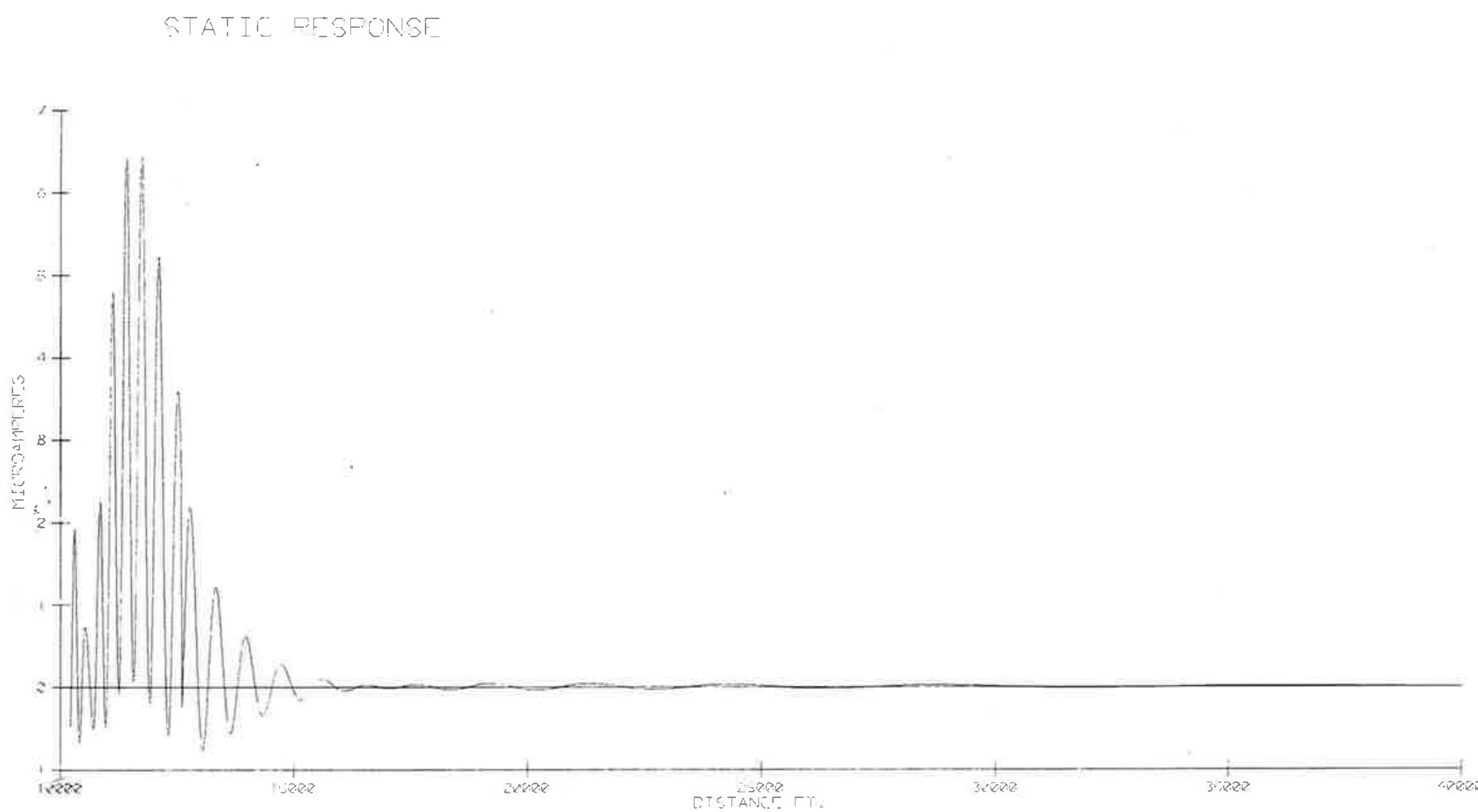


Figure 5-6. Alford 22/8: Static Flyability Run 16 dB Course to Clearance Ratio

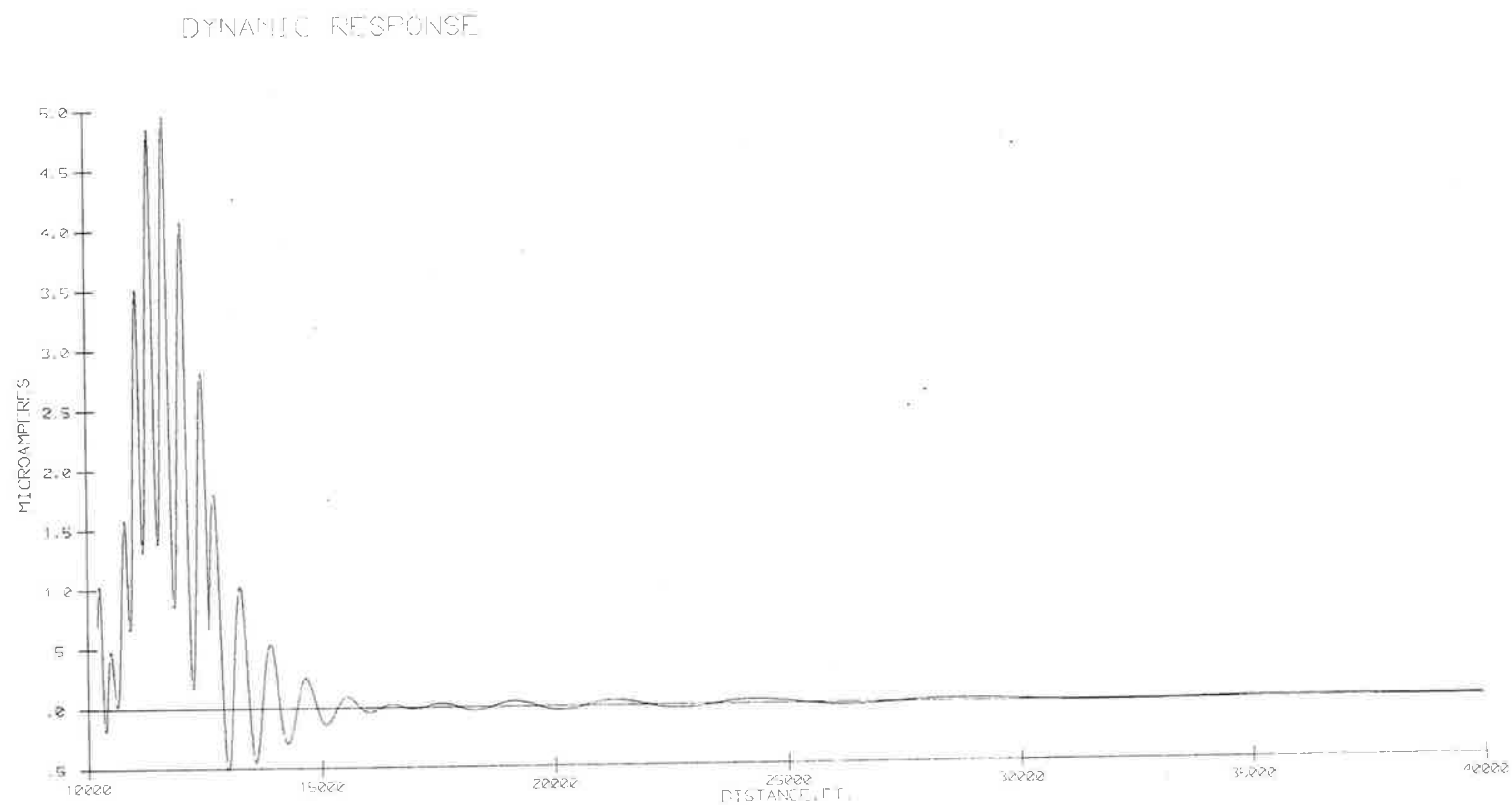


Figure 5-7. Alford 22/8: Dynamic Flyability Run 16 dB Course to Clearance Ratio