PROBLEMS WITH MOMENT METHOD MODELING OF AM ARRAYS

BY

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ABSTRACT

The Commission is considering whether AM directional antenna performance should be verified by numerical electromagnetic computations using computer programs such as NEC, MININEC, MMA, etc. These computations are used to determine the antenna monitor phases and ratios for a given set of Construction Permit Field Ratios and phases. This issue has been previously discussed by this author and others in numerous papers given at this and various other forums.

This paper describes in detail one method of performing the necessary Antenna Monitor Parameter computations based upon Construction Permit Field Parameters, using a modified version of MININEC. In many cases, however, this is just the beginning of the computational process. It has been necessary to resort to various "tricks" so that the computed impedances will match the measured array operating impedances. One can invoke the "Propagation Factor" which attempts to resolve the difficulty by assuming that the *speed of light in steel* (?) is less than the speed of light in free space. Using a factor of 90%, for instance, gives a reasonable match between the computed and measured self impedances of 126° and 193° towers. If, however, the propagation factor is ignored and the actual physical height is used to compute tower current distributions and radiated efficiencies closer agreement with measured values can be acheived. Other effects such as radius transition at the feed point, physical gap at the insulator, etc. are more reasonable explanations for the impedance transformation at the bases of AM towers.

The other major problem with moment method computed antenna monitor parameters is that they represent currents actually flowing in the tower. In high impedance arrays, arrays with different height towers, or arrays that are diplexed, the currents monitored by sample transformers may be considerably different from the tower base current in both magnitude and phase. Capacitance to ground is a major cause of this transformation. Sample loops on the tower are, of course, one way out of this problem. Various proposed solutions and computational techniques for this problem will be discussed.

INTRODUCTION

Various moment method programs have come to be used with increasing frequency AM antenna analysis and design. Good results can be expected using these programs since AM antennas are very simple compared to the complex structures that have been modeled with great precision. Their main strength lies in the prediction of current distributions and radiated fields. Hundreds of AM arrays have been successfully tuned up using moment method techniques.

Finding the impedance at the base of an AM tower requires a more complicated computation than do the tower currents and fields. The near electric fields from the base of the tower to ground requires that this region be modeled in a detailed fashion. Other techniques rely upon benchmarking computed results against measured values or altering the effective electromagnetic propagation velocity so that expected results can be achieved. AM tower impedance computation is an area where moment methods have been shown to be inexact in many instances. The accuracy of these programs in computing overall tower parameters such as currents and fields is not affected by limitations in computing tower base impedance.

PROBLEMS WITH DIPLEXED ARRAYS

Diplexed arrays and towers with high base impedance present special problems for moment method modelling. The shunt capacitance of diplexing filters and the tower base can have large effects upon the operating impedance of an array. The figure "**IMPEDANCE EFFECTS OF DIPLEXING**" shows how the measured base impedances, from an actual array, are much larger than the computed impedances due to the transforming effects of the diplexer shunt capacitance.

Antenna monitor parameters computed using moment methods are based upon currents flowing in the tower. The antenna monitor sample transformers are usually located between the matching networks and the filters at the bases of the tower for isolation purposes. The antenna monitor sample currents are also transformed by the shunt capacitance and can be quite different than the tower currents. The figure labeled "**DIPLEXED PARAMETER VARIATION**" shows, again from an actual array, how the monitor currents are different from the predicted tower currents. Adjustments to obtain proper field ratios and phases are made in such cases by trial and error.

AVOIDING TRIAL AND ERROR TUNING DIPLEXED ARRAYS

Using tower sample loops and isolation coils for adjustment of diplexed arrays can serve two purposes. The inductive reactance of the isolation coil compensates for the effects of the shunt capacitance while the sample loops provide for measurement of the antenna currents. Computed antenna currents will then yield the proper field values. When tune up is complete the isolation coils can be left in place and sample transformers used for day to day antenna monitoring.

IMPROVED ANTENNA CURRENT SAMPLING

At least two of the reply comments to the Commissions rulemaking with regard to AM antenna verification have expressed their distress at the prospect of moment method modeling of AM arrays. Admittedly the use of such programs can be delicate and tricky matter. These programs are probably not for everyone. Experience and common sense is required for their proper use. Use must always be benchmarked by measurements.

There may be a way out of this dilemma for those using the average uniform crossection towers. Karl Lahm, of VOA, in previous conversation and in the preceding paper of this conference, has made the observation that at the location on the tower where the current minimum occurs when the tower is detuned the currents have the same relative phases and ratios as the field values. When the tower is detuned the sum of the current moments above the null must be equal to and opposite in phase to the sum of the current moments below the null for the horizontal plane field to be minimized. This effect is depicted in the figure labeled **"DEPICTION OF DETUNING AS CENTROID OF CURRENT MOMENTS".** This location is at the centroid of the complex area defined by the summation of the tower current moments. It is like a balanced teeter-totter. The moments must sum to zero. This point yields the average of the current moments and hence current ratios and phases that are proportional to the field ratios and phases.

Antenna currents sampled at these locations will give antenna monitor parameters that are close to the field parameters shown on the Construction Permit. A Windows version of MININEC called MININEC PROFESSIONAL is in the process of beta testing and development by two of the original authors of MININEC. I have used this program to test the agreement between tower current and field ratios and phases. Since the lossless far fields at one kilometer are equal to 120 pi over the wavelength times the sum of the current moments, the field ratios and phases can be found from the relative ratios and phases of the respective tower current moment summations. MININEC PROFESSIONAL computes tower current moment summations and is ideally suited for testing the Lahm hypothesis. Computations were made for a two tower array with tower heights from 60 to 230 electrical degrees. 100 segments per tower were used. For nearly sinusoidal current distributions the area under the current distribution curve is proportional to the sin of the height in degrees. On half of the current moment summation is therefor reached at 30 degrees or one third of the way up the tower. The results of the computations are shown in the figure **"PERCENT OF TOWER HEIGHT WHERE CURRENTS ARE SAME AS FIELDS"**. It can be seen that the current ratios and phases are the same as the fields ratios and phase one third of the way up the tower for tower heights up to about 120 electrical degrees. This ideal sampling location moves slowly up the tower with increasing tower height and is at 39% of the tower height for a 230° tower.

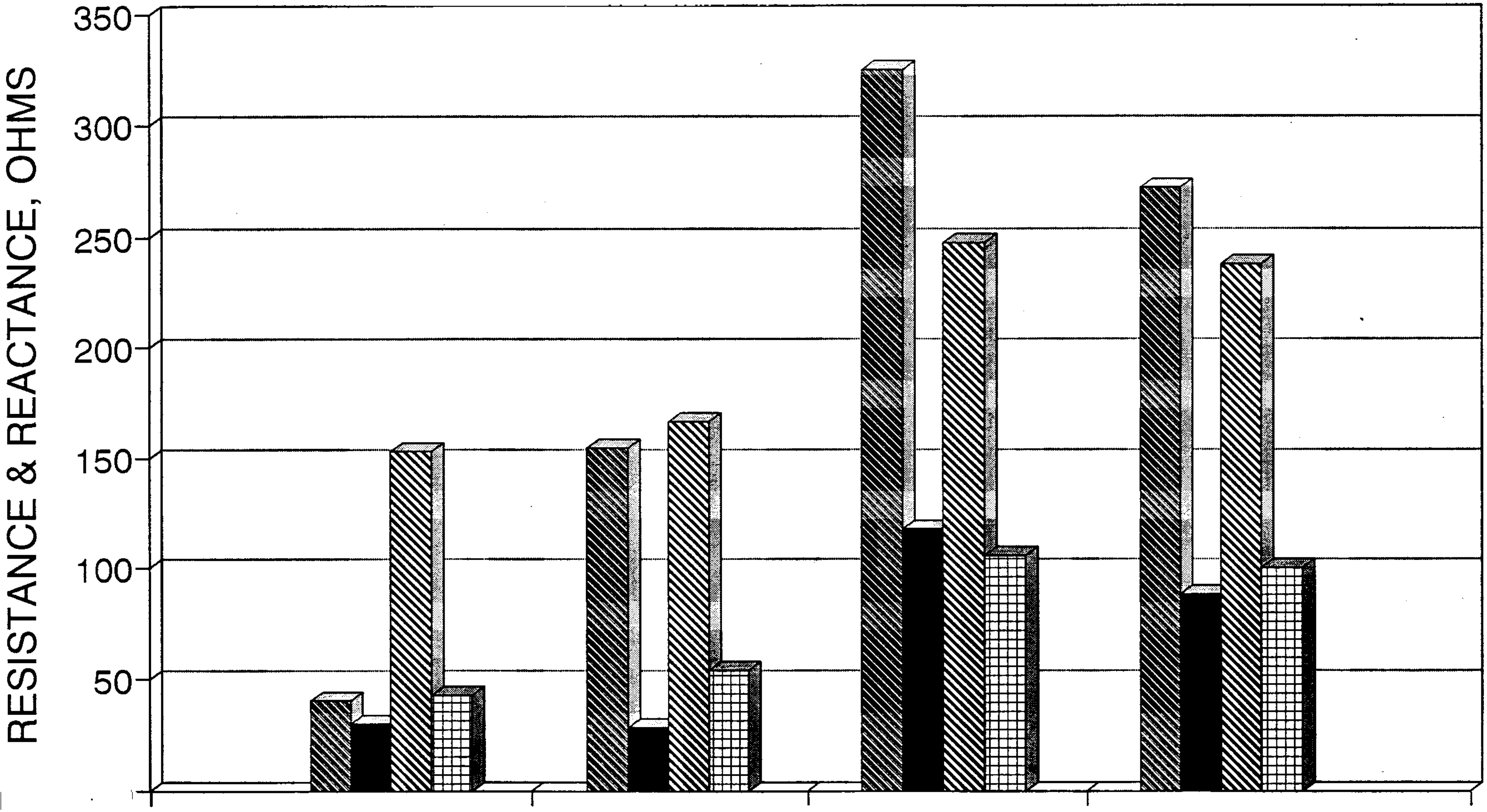
The divergence of the current ratios and phases from the field ratios and phases is depicted in the figure **"AGREEMENT OF CURRENT & FIELD PARAMETERS"**. Agreement between the fields and tower currents is within 0.2% and 2° for tower heights below 140° and generally better than 0.5% and 5° for tower heights up to 230°. The program has some problems converging at resonant lengths like 180° and this is why the agreement between the tower current and field ratios and phases is not as good at 180°. This problem is illustrated in the figure **"180 DEGREE TOWER ERROR"**. At the height where the tower current phases are close to the field phases the tower current ratios diverge from the field ratios and conversely. Since the effect occurs over 2% of the tower height the averaged agreement over this range is probably 1% and 1°.

CONCLUSION

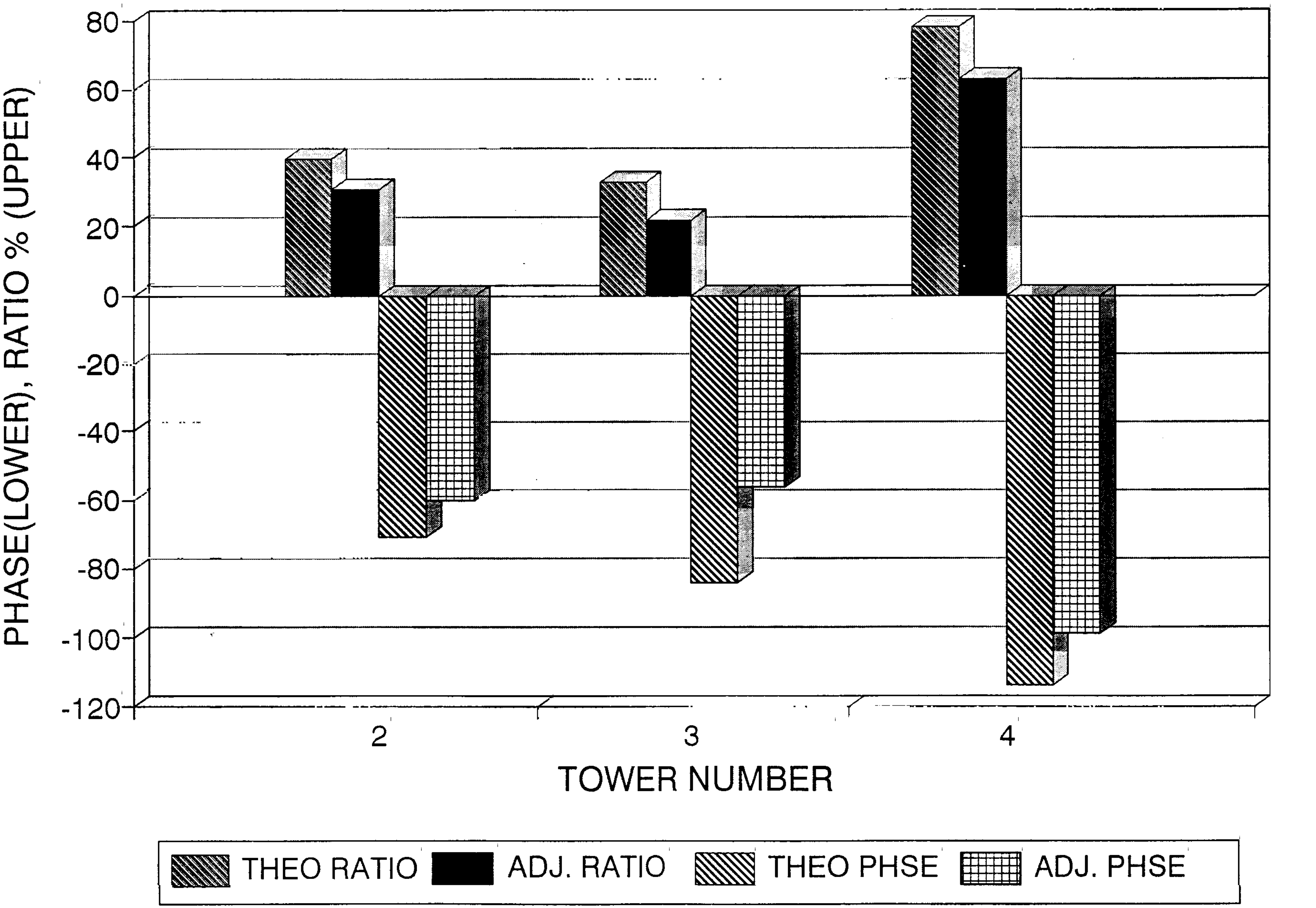
The practical problems involved in using moment method analysis for AM verification can be avoided by using isolation coils and sample loops located one third of the way up uniform crossection towers, where the antenna monitor ratios and phases (for equal length sample lines) will be close to the construction permit field ratios and phases, for arrays up to between 110° and 120° in electrical height. Above this height the location of the sample loops should be increased as shown in the figure.

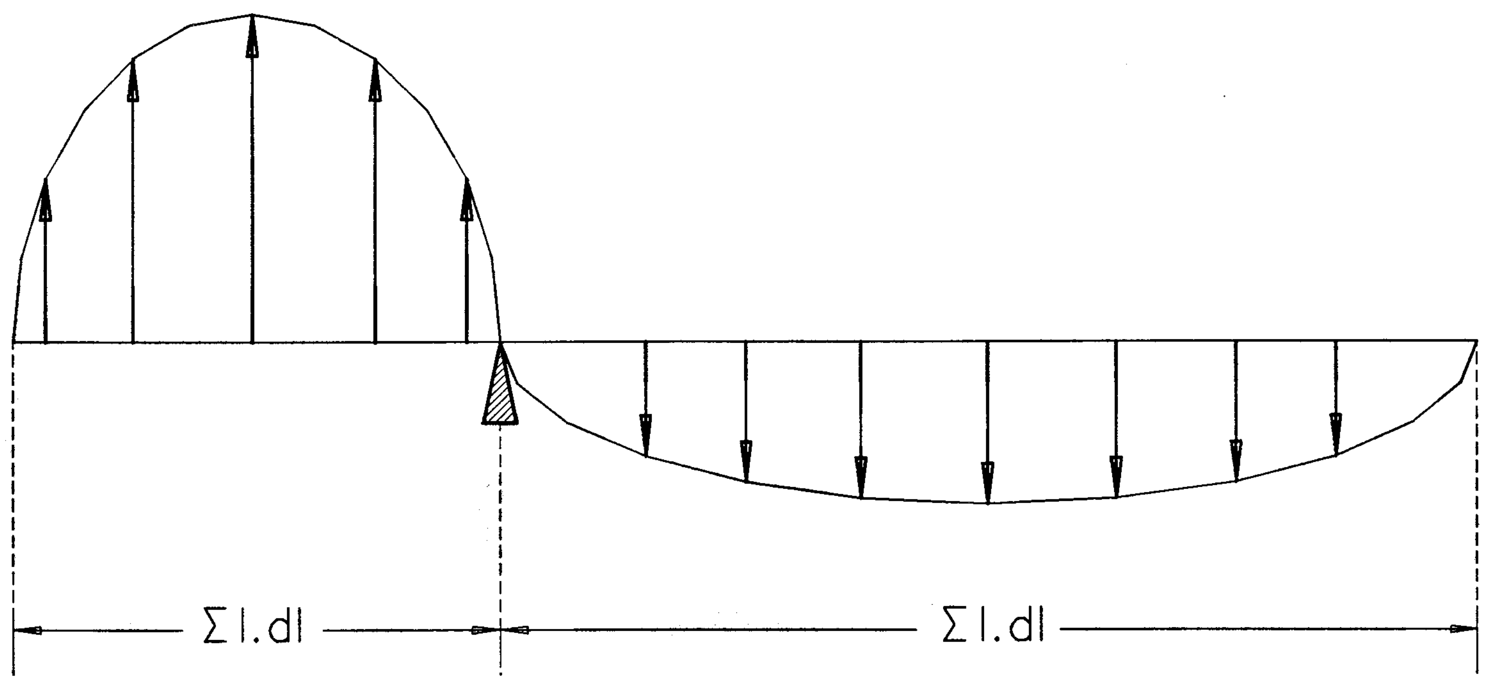
This technique can save a great deal of trial and error when diplexed arrays are adjusted.

IMPEDA



DIPLEXED PARAMETER VARIATION





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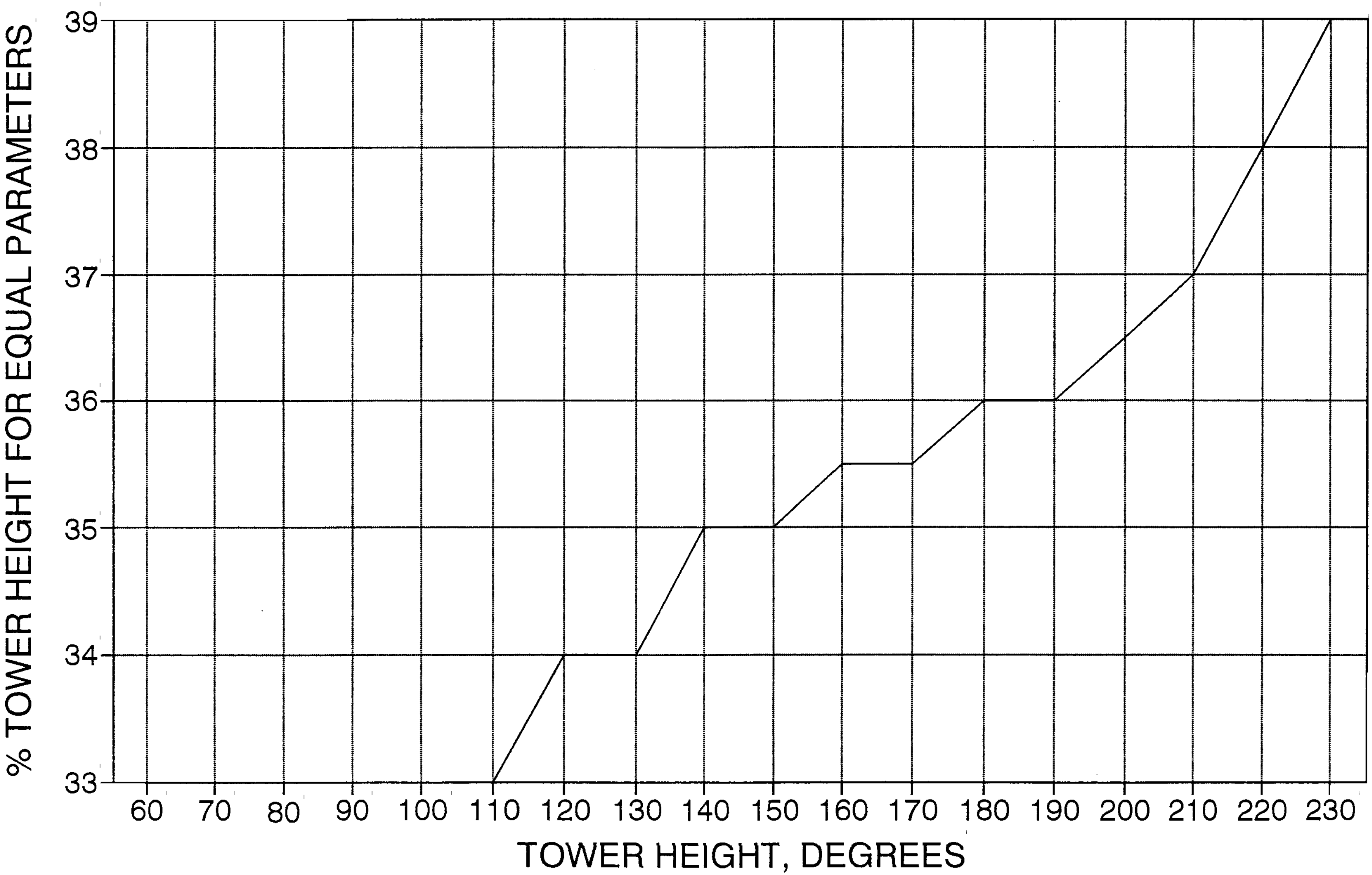
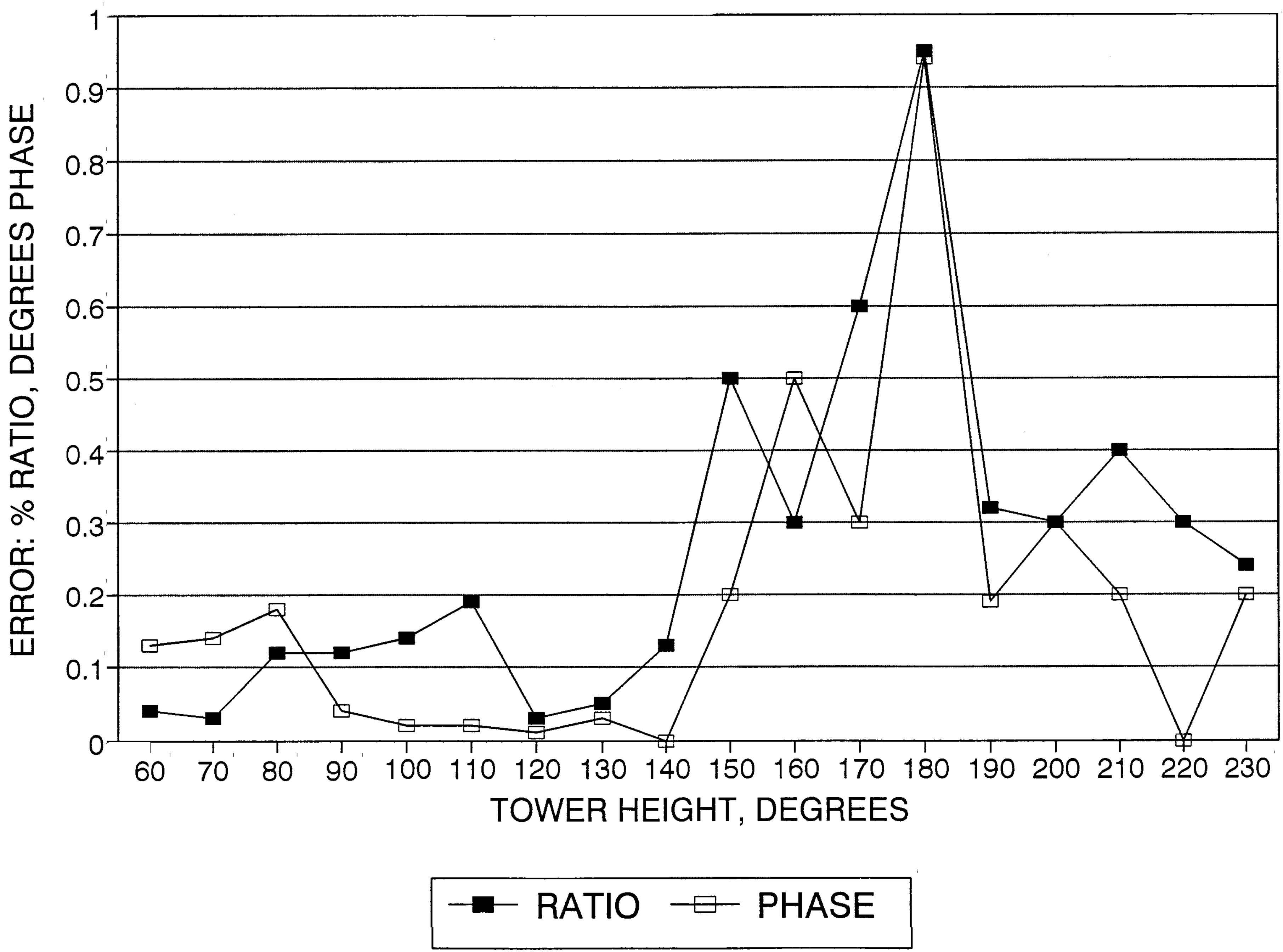
DEPICTION OF DETUNING AS CENTROID OF CURRENT MOMENTS

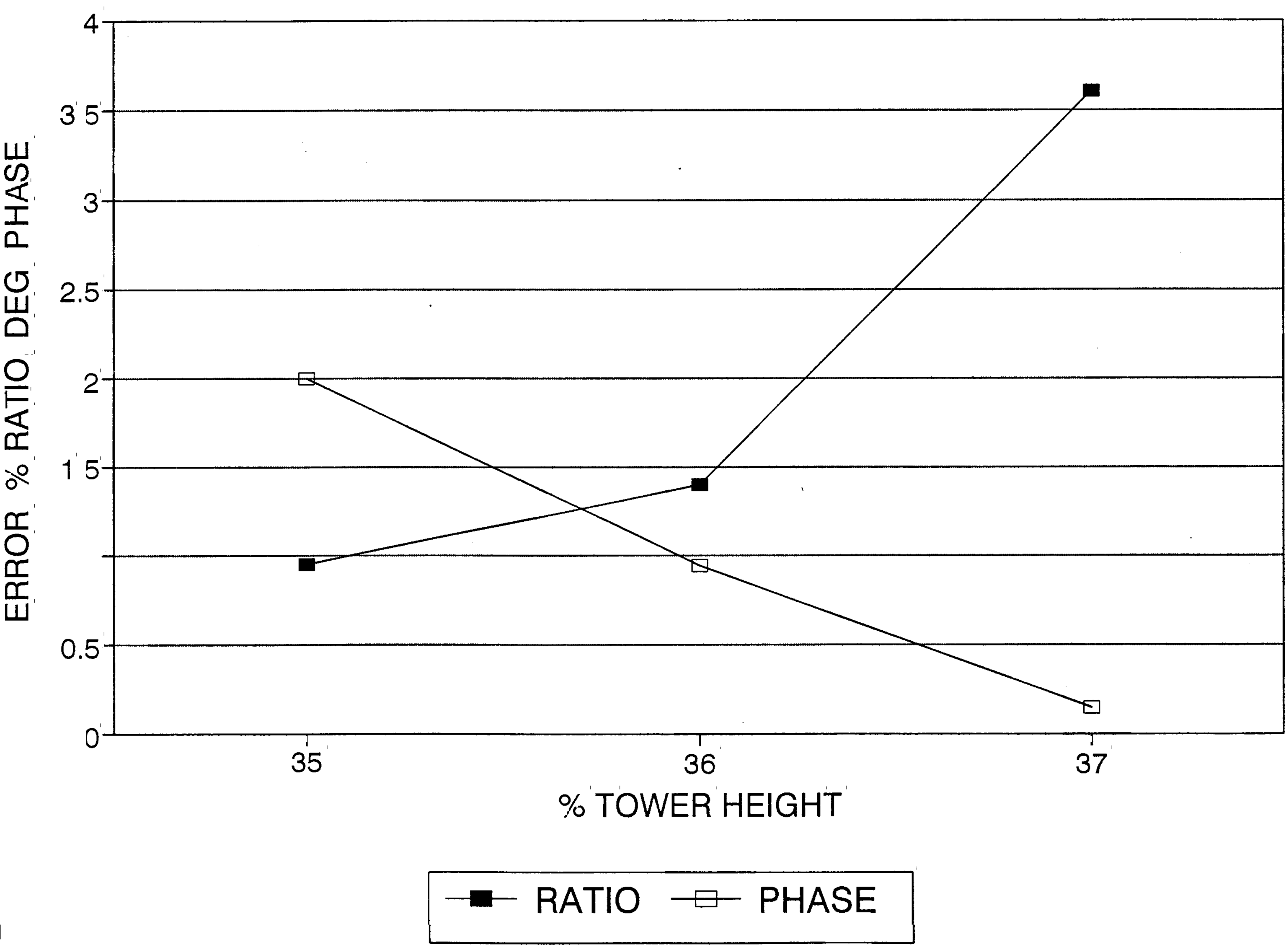
PERCENT OF TOWER HEIGHT WHERE CURRENTS ARE SAME AS FIELDS

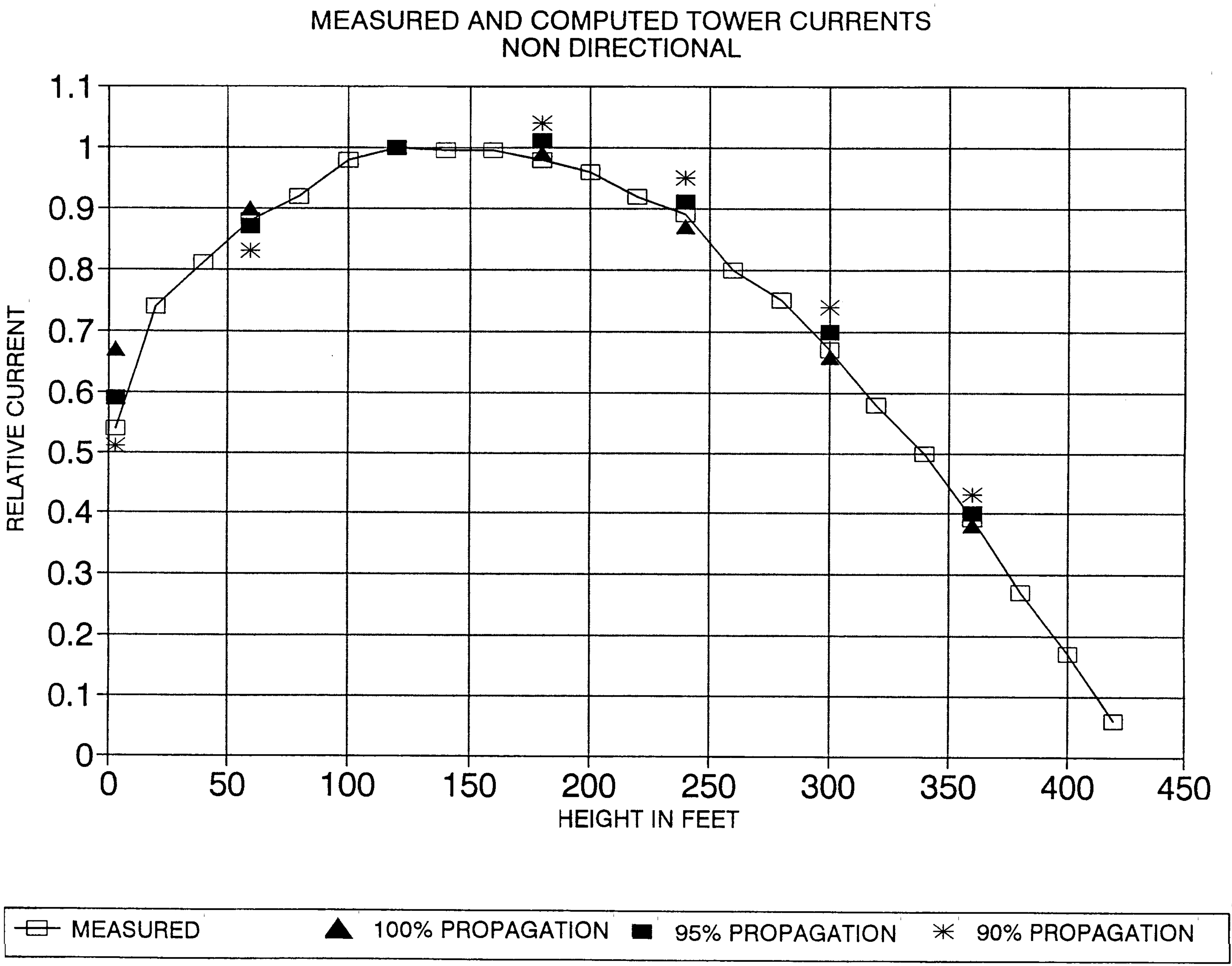


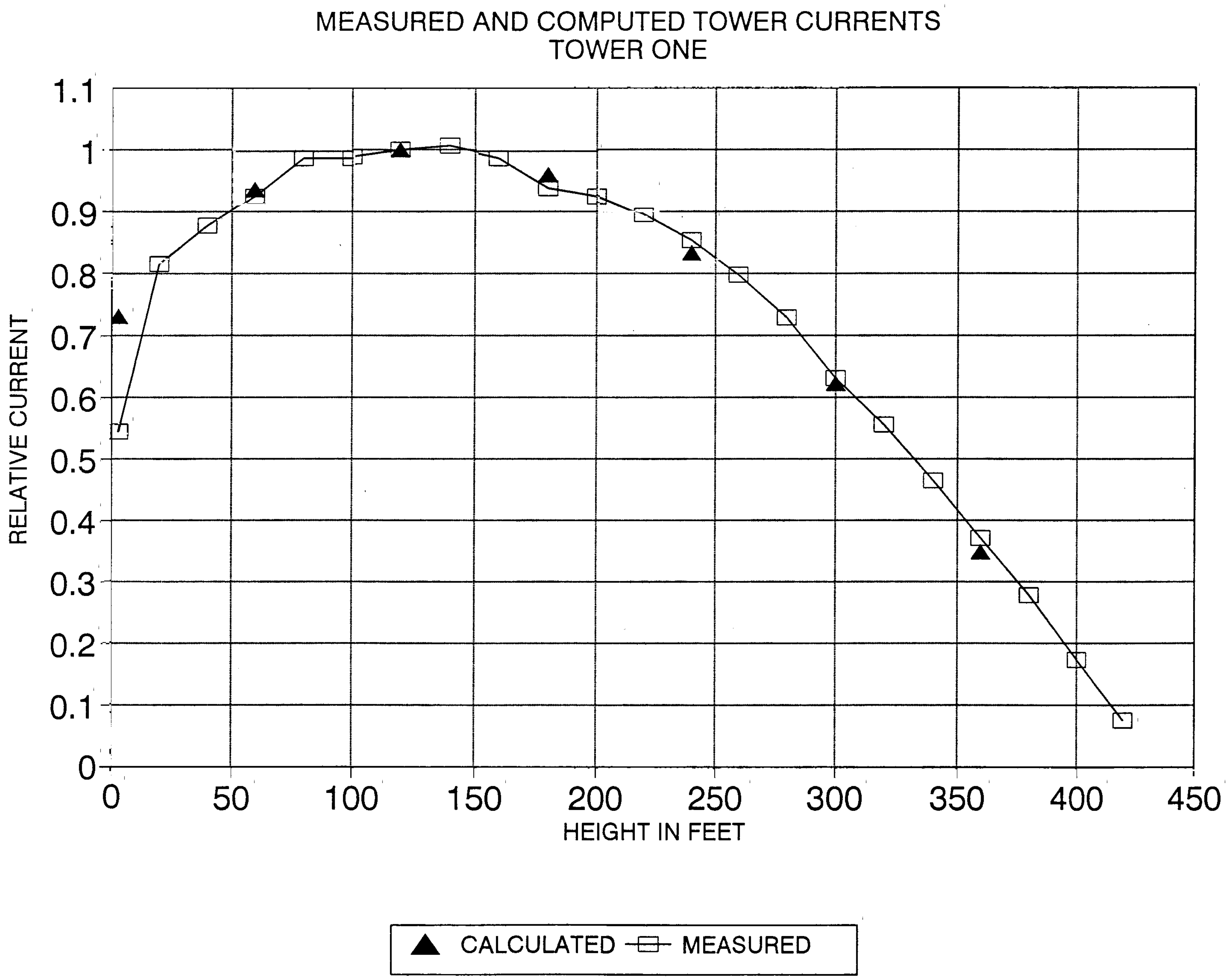
AGREEMENT OF CURRENT & FIELD PARAMETERS

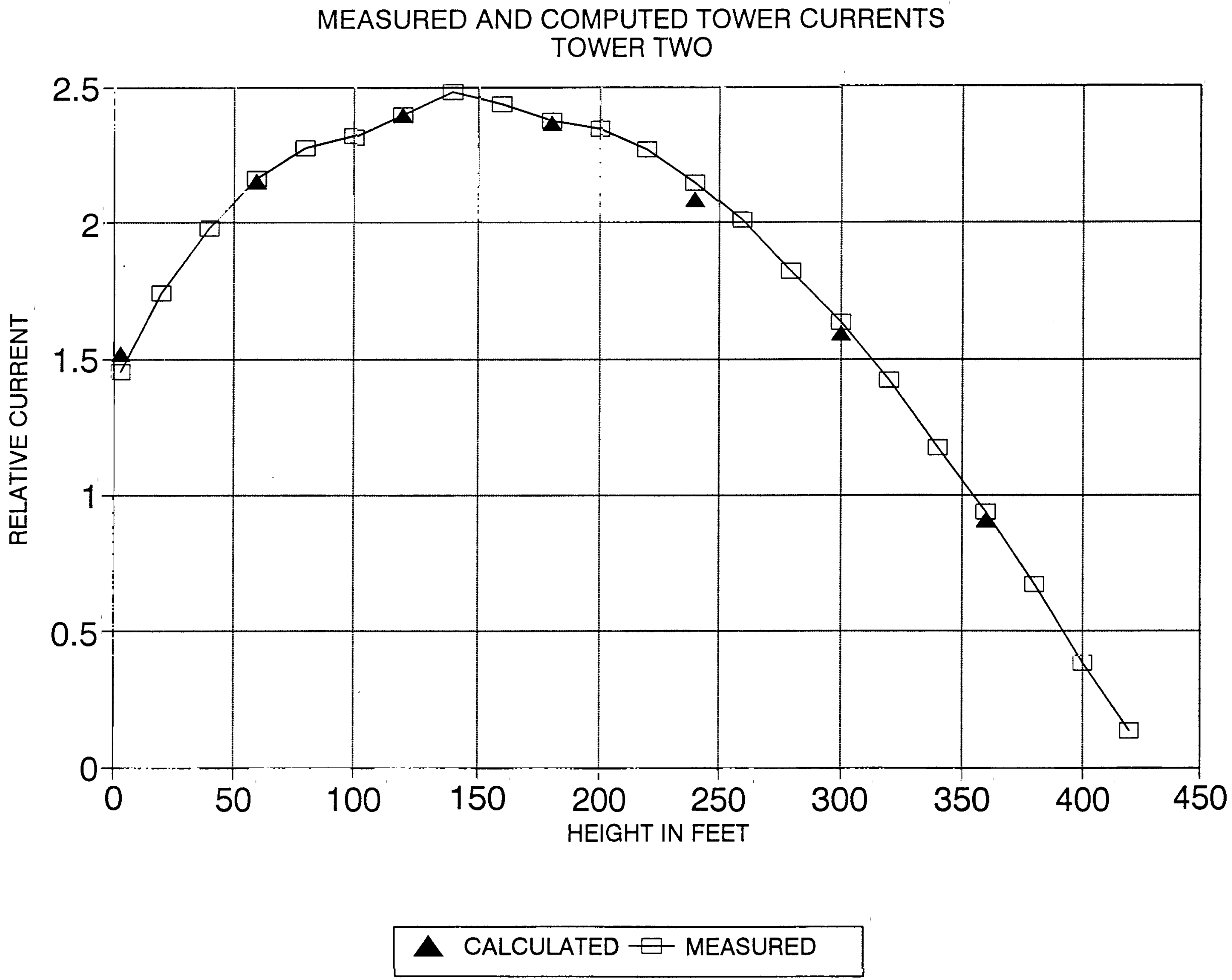


180 DEGREE TOWER ERROR

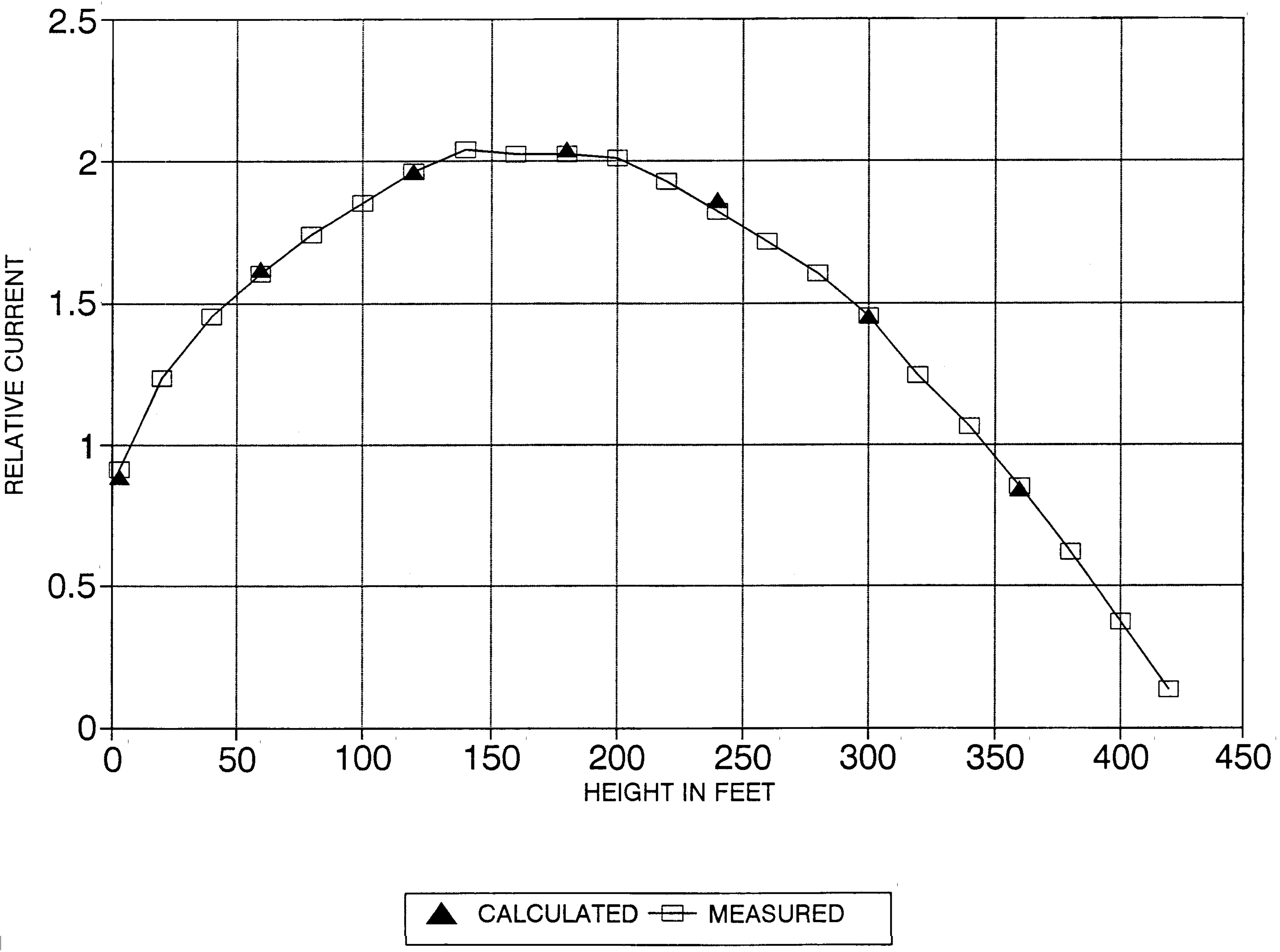


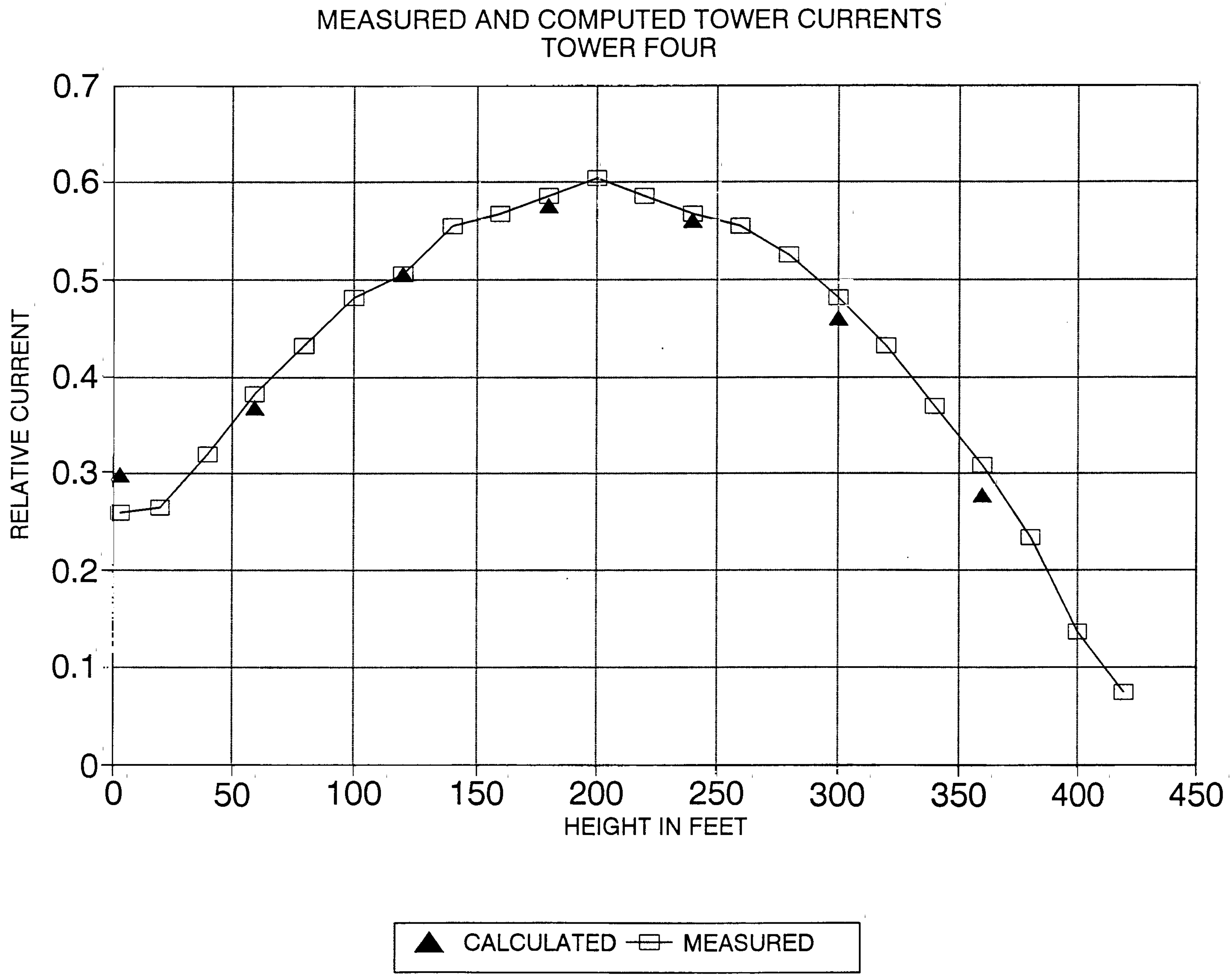

MEASURED AND COMPUTED TOWER CURRENTS
NON DIRECTIONAL
RELATIVE CURRENT
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
450
HEIGHT IN FEET
MEASURED
100% PROPAGATION
95% PROPAGATION
90% PROPAGATION


MEASURED AND COMPUTED TOWER CURRENTS
TOWER ONE
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
RELATIVE CURRENT
0
50
100
150
200
250
300
350
400
450
HEIGHT IN FEET
CALCULATED
MEASURED


MEASURED AND COMPUTED TOWER CURRENTS
TOWER TWO
RELATIVE CURRENT
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
300
350
400
450
HEIGHT IN FEET
CALCULATED
MEASURED

MEASURED AND COMPUTED TOWER CURRENTS
TOWER THREE




MEASURED AND COMPUTED TOWER CURRENTS
TOWER FOUR
RELATIVE CURRENT
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
450
HEIGHT IN FEET
CALCULATED
MEASURED