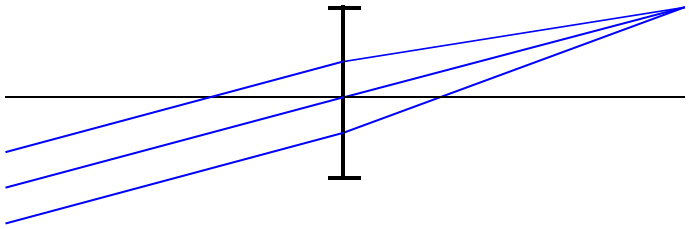
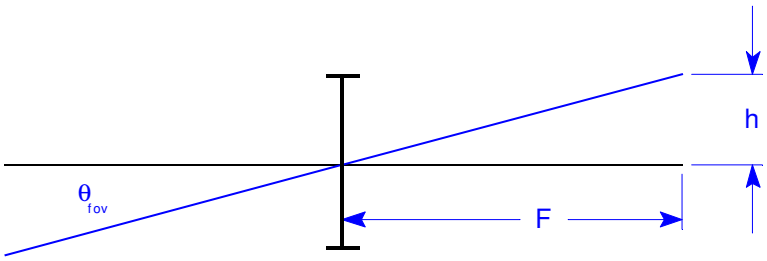
Q: What is Distortion?

A: Consider an idealized lens, as sketched below:



As a further simplification, consider only the chief ray (the ray through the center of the pupil).

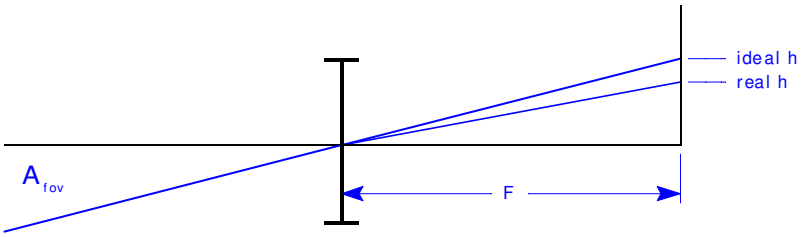


In an ideal lens, there is no distortion, and the height of a point on the image is simply:

$$h = F \tan(A)$$

Distortion

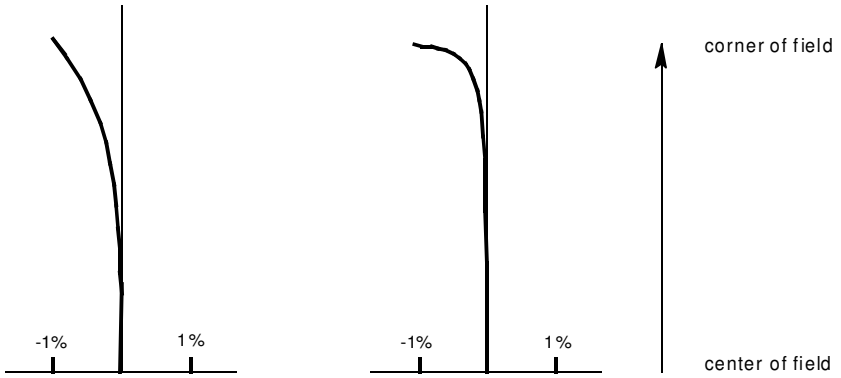
However, in a real lens the image point "h" may differ from this idealized view. For example, consider this situation:



The height t of the point "ideal h" is F tan (A). The height of the point "real h" is different. Such a lens is said to have distortion.

Distortion is defined as: (real h - ideal h) / ideal h

Here are two possible distortion plots:

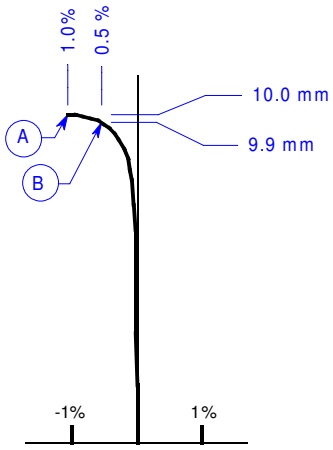


Both lenses have about 1% distortion, a value that is normally acceptable, even in visual instruments like cameras.

Local magnification:
Besides the absolute value of distortion, it is also important to consider the local slope of the distortion curve.

Consider the two curves above. The lens on the right has a problem at the edge of the field. A numerical example may clarify the problem:

Consider points A and B:



Without distortion the height of points A and B would be 10 mm and 9.9 mm respectively.

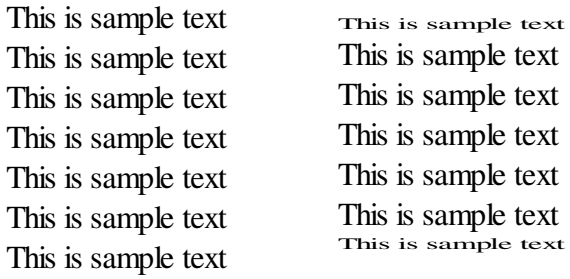
With distortion, the heights are

hA = 10 mm x (1 – 1.0%) = 9.9 mm
hB= 9.9 mm x (1 - 0.5 %) = 9.85 mm

Two points which should appear 1/10 mm apart will appear to be separated by only half that distance!

Conclusion
It is important to consider both total distortion and the local slope of the distortion curve.

Real world example:
The author found out about this problem the hard way several years ago. The product was a text scanner, and the output from the prototype looked like this:



The problem was a distortion curve just like the one presented above.