Types of Optical Evaluation

There are many ways to evaluate an optical system model using optical design software. When we say "evaluate," we really want to simulate the lens before it is built, and predict how it will perform. Imaging systems try to bring light to a sharp focus, but we need to be more precise than this. Some of the more common evaluations are spot diagrams, encircled energy, and MTF. **Spot diagrams** are graphs that show where rays from a point object will fall on the image surface (they must fall close together if the lens is to form a good image). **Encircled energy** is a way of measuring how the energy (determined by counting rays) in the spot diagram is distributed as a function of radius, measured from the center (usually displayed as a graph).

MTF is "modulation transfer function." It requires the idea of spatial frequency, which is a measure of how parts of a scene are spaced apart. Think of a white picket fence with a dark house behind it. From a few meters away, you can easily see the contrast between the white and dark stripes. This is a low spatial frequency. Now consider a black comb against a white piece of paper. From a few meters away, you probably cannot even tell that there are dark and light stripes at all! This is a high spatial frequency, which you can think of as the fine detail in a scene. A lens (such as your eye) can image low spatial frequencies more easily than high frequencies. MTF is just a graph that shows this "frequency response" for a lens, from low to high frequency (every lens has a maximum or cut-off frequency, meaning there is always some level of detail that is too fine for the lens to detect).

MTF Evaluation

The resolution of a system, normally specified in terms of the finest detail that can be imaged by the system. This property is quantified by the Modulation Transfer Function (MTF). An object whose brightness (I) varies sinusoidally with a frequency of (L) lines/mm is imaged through the optical system. Referring to **Figure 13A**, the modulation of the object (M_o) is defined as

$\mathbf{M_o = (Imax - Imin)/(Imax + Imin)}$,

where Imax = maximum intensity,
min = minimum intensity.

The image can be measured using the same procedure, where modulation of the image (M_i) is defined as

$\mathbf{M_i = (Imax - Imin)/(Imax + Imin)}$.

Then, the modulation transfer factor is given by the ratio of the modulation of the image to that of the object:

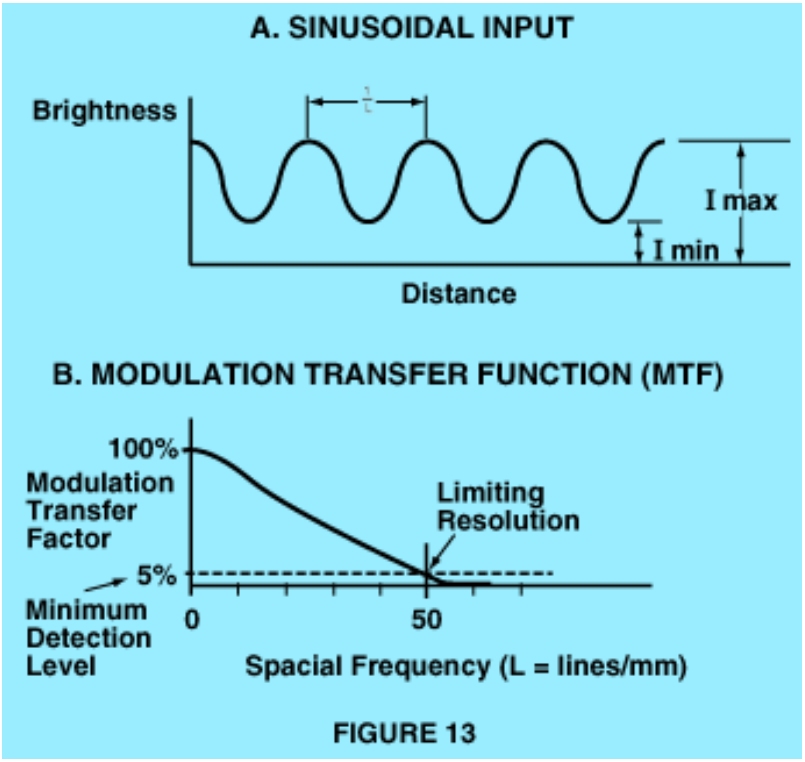

FIGURE 13

modulation transfer factor = $\mathbf{M_i/M_o}$.

The modulation transfer factor varies with the frequency of the sinusoidal grating. The frequency at which the modulation transfer factor falls below a minimum detectable level is called the limiting resolution of the system. The Modulation Transfer Function curve is a plot of the modulation transfer factors at various spatial frequencies. The total aberration of a lens or lens system degrades the image contrast and causes the MTF to decrease.

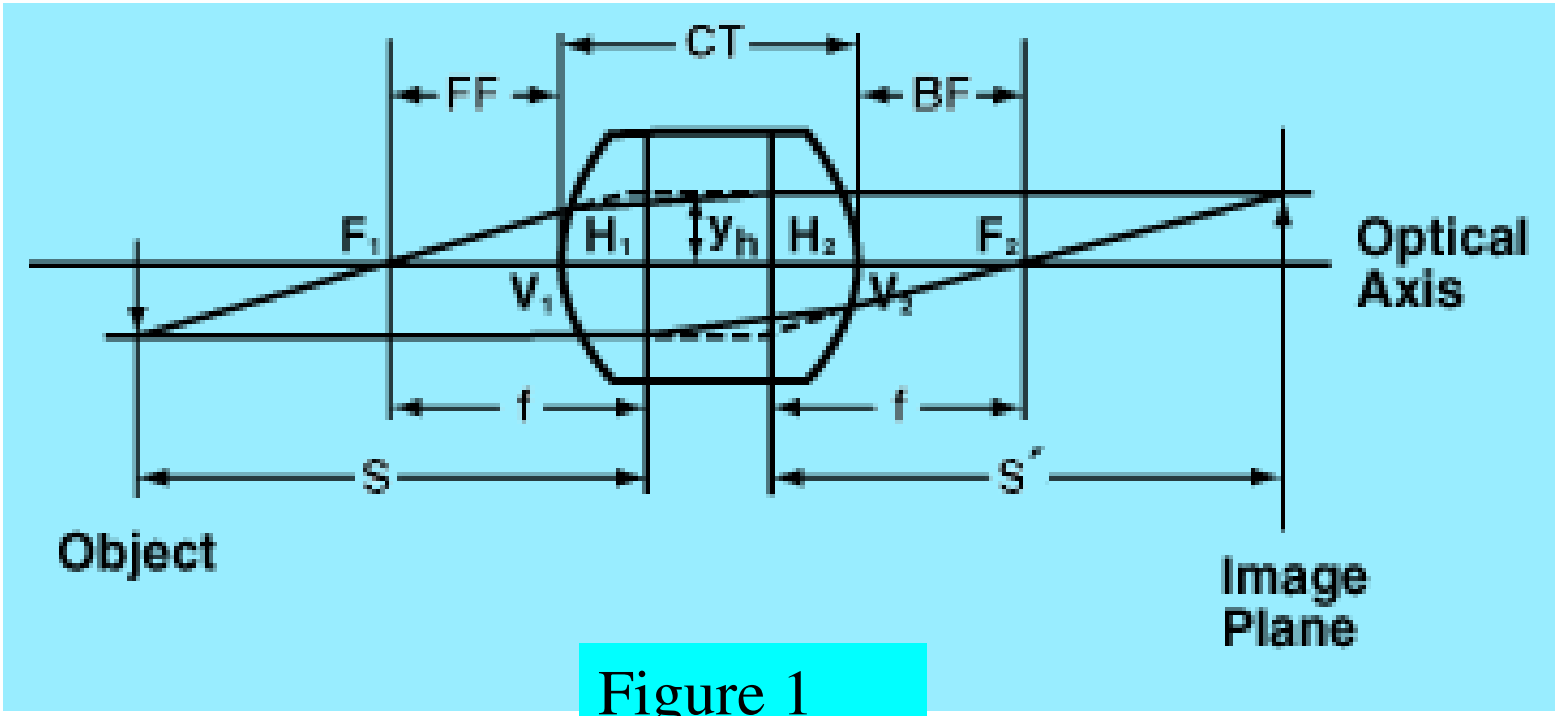
CT
FF
BF
F1
H1
yh
H2
F2
V1
V2
Optical
Axis
f
f
S
S´
Object
Image
Plane

Figure 1