something that we are all familiar with. This number is an index of the quantity of light collected by a lens at the centre of the image plane. The principle is similiar to that used to indicate the point at which the intensity of a light source falls to half the intensity of the centre. Light distribution in a lens is expressed as a ratio of center of the image brightness in relation to points off axis. Light falls off at the edges of a lens for because of vignetting and the 4th power law. I won't go into great depth to explain the 4th power law except to quote the Canon Guide Book: "The light reaching the margin of the image decreases as the 4th power of the cosine of the angle of view."[4]

Vignetting, which is exaggerated by a wide aperture can be eliminated by stopping down (using a higher number f stop). Vignetting is caused by the lens barrel eclipsing some of the marginal light of the image plane. Stopping down reduces vignetting and improves light distribution improving image quality.

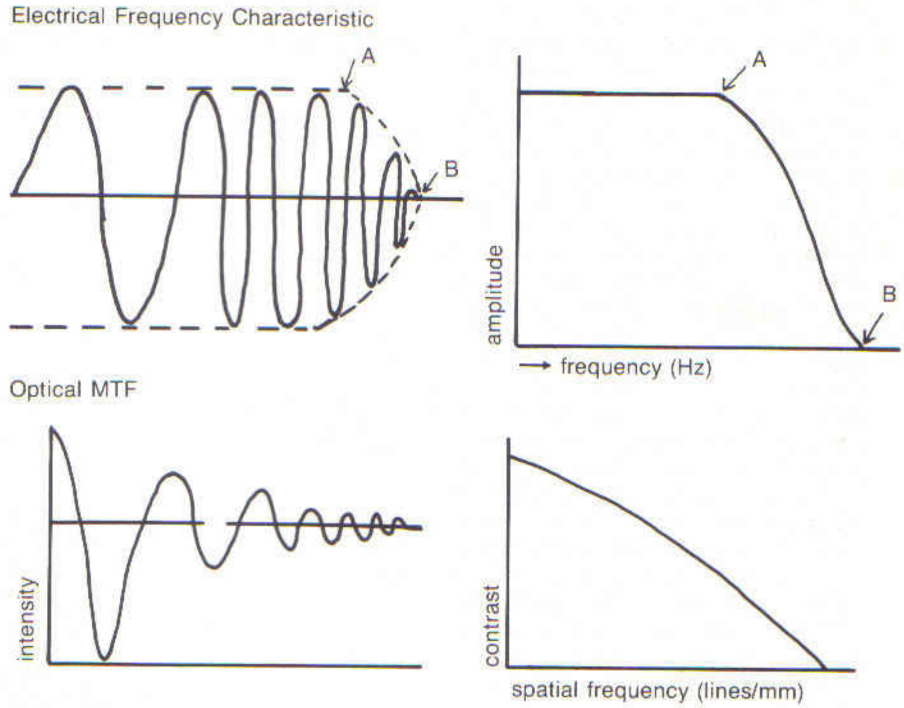


*Diagram 3: Modulation Transfer Function related to electrical frequency.*

### *Modulation Transfer Function*

A lens' imaging performance is often described as its resolving power. The resolving power of a lens can be quantitatively measured by using a reference chart that has alternating black and white lines in a wedge shape that grow progressively more narrow as they approach their tips. It would look like the diagram included here. Resolving power is measured at the point where two separate lines appear to merge and cannot be resolved as being separate and distinct lines. In this case, we are talking about resolving fine detail. Resolving power is merely a functional term used to express the value limits of a lens. This quantitative measurement does not measure image quality and thus is not qualitative. It also doesn't take into account lens performance for determining fine detail or spatial frequency below the value limit. This is significant with regard to a television camera zoom lens because a camera converts the image (light) into an electrical signal. In this case, the television system bandwidth is the limiting factor for the determination of fine detail (spatial frequency) that is reproducible.

*Spatial Frequency*: is defined as a measure of the fineness of a grid. It counts the number of lines (number of black and white pairs) contained in 1 mm. The video frequency fv and the number of TV lines are related by the formula:

$$\text{spatial frequency} = \frac{65.873 \times \text{video frequency(MHz)}}{\text{diagonal image size(mm)}}$$

$$= \frac{0.83 \times \text{TV lines}}{\text{diagonal image size}}$$

Since the transition bandwidth frequency limit is 4.2 MHz, this translates into various values for different formats. For the 1" tube, the value is 16.5 mm and for the most widely used tube size in portable field cameras 24.0 mm for the 2/3" tube.[5]

After close examination, it becomes apparent that it is unimportant whether a television zoom lens has a resolving power of 75 lines or more per millimeter, if the limiting bandwidth frequency is less than this. What is important though, is reproduction or image contrast at the lower spatial frequency, for example, 24 lines/mm for the 2/3" tube format. In order to get a true and accurate gauge of a lens' performance, we have come up with a descriptive term *Modulation Transfer Function*. Modulation Transfer Function measures contrast reproduction ducibility of a lens. To illustrate the principle behind MTF, let's use the example of an amplifier.

If we have a hypothetical amplifier and input a gradually increasing waveform into it up to point A the amplitude output is constant, at frequencies above A the amplitude decreases until at point B there is no signal reproduction at all. This frequency characteristic could be plotted on a graph with frequency on the horizontal axis and amplitude on the vertical axis. "MTF is the same concept applied to a lens." Remember the limiting factor of the transmission bandwidth. If lines in a frame are widely spaced enough there is nearly 100% faithful reproduction. If the lines are finer than the resolution limits of the system, black and white paired lines can't be separately distinguished and appear uniformly gray.[6]

### *Effect on Lighting*

Since this article has been directed at those who practice the craft of lighting, it is imperative at this point to indicate the effect that this has on lighting. Using a large aperture, say f 1.7 on a lens, is likely to produce results that are less than what you expected. Since the system has limits, i.e., bandwidth frequency, there are limits to the resolution of fine detail. The pictorial result of a wide aperture, without lighting having strong tonal contrast that enhances and demarcates the principle subject, would likely cause the principle subject to merge into the background. The reasons are two-fold: 1) at low apertures resolving power is reduced, causing black and white to merge to gray, fine patterns lose detail and become amorphous; 2) a large aperture produces shallow depth of field which will soften and de-focus elements in the frame, degrading their detail and sharpness. Of course, this can be used selectively as a tool, a method of provoking a certain emotion. It should not be used casually in a matter of fact manner!

In the next article, we will delve further into the optics of the lens and the PBA.

All references for this article and diagrams have been taken from *The Canon Guide Book of Optics for Television System*. Footnotes are as follows: 1—page 2; 2—page 2; 3—page 18; 4—page 19; 5—page 22; 6—page 20.

*Bentley Miller is lighting director of CITY-TV/MuchMusic in Toronto.*