Bird Photography Using Focal Length Multipliers
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Used with care, auxiliary lenses, known as focal length multipliers, can be very useful in bird photography. A focal length multiplier enables the effective focal length of a prime lens to be increased, thereby extending the 'reach' of the combination. Such lenses are called '***extenders'*** by Canon and '***teleconverters'*** by Nikon. They consist of a group of lens elements with overall negative power that has the effect of moving the location of the entrance pupil of the prime lens out into the space in front of the lens housing. As the effective focal length of a lens system is the distance between the entrance pupil and the back focal plane, the overall effect is to increase the focal length of the prime plus multiplier combination. The negative power produced by the multiplier is accompanied by a matching amount of negative spherical aberration that must be corrected by surrounding or following lens elements. These can be conventional lens elements or one or more aspheric surfaces as used in the latest designs from Nikon. The prime plus multiplier combination can be well corrected in the centre of the field of view but the lens designer usually makes a trade-off between the complexity of the design and image quality in the corners. For this reason, the image quality in the corners of full frame cameras can be 'soft' and therefore multipliers are not recommended for applications where this is important such as landscape photography. However, for bird photography, where the subject tends to be near the centre of the field of view, and the background is usually out of focus, this is of little consequence. One can get a good idea of how much of the field of view is useful by examining the modulation transfer function (MTF) specifications provided by manufacturers. For example, in the case of the Canon 300 mm f/2.8L IS II USM prime with 1.4× and 2× Mark III extenders, the MTF value in the specs is above 80% out to about 15 mm from the centre of the focal plane, more than covering the sensor in the 7D camera body. The field of view with the 5DIII, which has a full frame sensor, is well corrected over 80% of the field.

The so-called ***super telephoto*** lenses manufactured by Canon and Nikon, with the full aperture closed down a stop, are effectively aberration free over most of the field of view. The 'sharpness' of these lenses is only limited by the camera anti-aliasing filter, diffraction and noise. The effects of diffraction become noticeable when the aperture is closed down more than about f/11 and in good light, detector noise is negligible. When a well-designed focal length multiplier is added to a prime lens the resulting MTF is lower than would be achieved with a well-corrected prime of the same effective focal length. Just how much lower depends on the design of the multiplier. Manufacturer's specs and our resolution test chart measurements on the Canon 1.4× and 2× Mark III extenders indicate the resulting MTF is about 20% less than would be the case for the equivalent prime lens. This means that the contrast of fine detail in the image will be about 20% less than would be the case for a prime of equivalent focal length. While any loss of contrast is undesirable, there is still plenty with which to work.

Modern super telephoto lenses are essentially aberration free under most conditions and can resolve fine details much smaller than the digital camera can record. This is because the finest detail that can be faithfully resolved by a periodic array of detector pixels is twice the size of the pixel spacing – this is a consequence of what is known in science and engineering as the Sampling Theorem, and the resolution limit is known as the Nyquist limit. Because the detector array is unable to faithfully resolve detail finer than the Nyquist limit, it is customary in digital camera design to insert a special filter in the light path to prevent aliasing signals from being generated when there is periodic fine detail in the image comparable with the periodic spacing of the pixels in the detector array. The anti-aliasing filter, as it is known, has the effect of blurring the very fine detail in the image and acts as a kind of optical low pass filter which only allows the transmission of details up to a certain degree of 'fineness', usually the Nyquist limit.

Aliasing can occur whenever the periodic detail in the image is an integer fraction or multiple of the periodic spacing of the detector pixels. The strongest aliasing signals are generated when the period of the image detail matches the period of the detector array and it is the purpose of the anti-aliasing filter to prevent this from happening. As already mentioned, the anti-aliasing filter is usually designed to cut off details finer than twice the period of the detector array (Nyquist resolution limit). However, it is possible for periodic details that are higher multiples of the array spacing to generate aliasing signals which appear as moiré patterns in the image. This often happens when periodic feather detail is being recorded, especially on wing coverts and tail feathers. When the image of the barb spacing is three or four times the array spacing, aliasing can occur and is observed as a red-green-blue moiré pattern superimposed on the feather image. This is not a lens design problem but a natural consequence of digital photography. If film were used to record the image there would be no aliasing and an anti-aliasing filter would not be needed. Another form of aliasing is often observed when the periodic detail in an image is an integer fraction or multiple of the pixel spacing of the computer screen. This is usually of no consequence and can be 'tuned' in or out by changing the magnification of the image using the zoom control.

Test Results

The simplest way to make a quantitative evaluation of the performance of focal length multipliers is to take some test shots of a resolution test chart. In a previous contribution to the newsletter we described the procedure in some detail. Here we show some results and explain how to interpret the chart images. The test shots must be made using the same f/No in each case and in the examples that follow we have chosen f/8 but this is not important, we could have equally chosen to show similar results for f/5.6 through to f/11. The distance from the camera to the test chart must also remain unchanged. As we are testing telephoto lenses, a long test range is desirable, comparable with the kind of distances encountered in the field, say 7.5–20 m. In our case, we use an indoor test range about 17 m long. It is also necessary to standardize the picture taking and image handling. For the latter, we use the manufacturer's software (Canon Digital Photo Professional) with default settings for RAW images but other software such as Adobe Lightroom can be used. The test chart images were cropped to the same field of view and converted to JPEGs using the same settings in each case. During the processing, the images were resampled to the same number of pixels and file size (kilobytes) so that they can be rigorously compared.

Figure 1 shows the resulting test chart image for the Canon 300 mm f/2.8L IS II USM prime lens. At first sight it does not look too good but if the resolution limit is calculated, it is found to be very close to the Nyquist limit and the performance is actually very good. The test pattern contrast holds up well until just before the Nyquist limit where the anti-aliasing filter cuts in and blocks the resolution of finer detail. You can check the details for yourself using a scale factor where '10' on the chart corresponds to a line spacing of 0.292 mm. The resolution limit we measure using the average of three shots is 3.95 on the chart scale which corresponds to 0.292 × 10/3.95 = 0.74 mm. For comparison, the Nyquist limit is 0.71 mm. In practical terms, the measurement means that at a range of about 17 m, the camera will record periodic detail on the bird, such as feather barbs, having a spacing as fine as 0.74 mm.

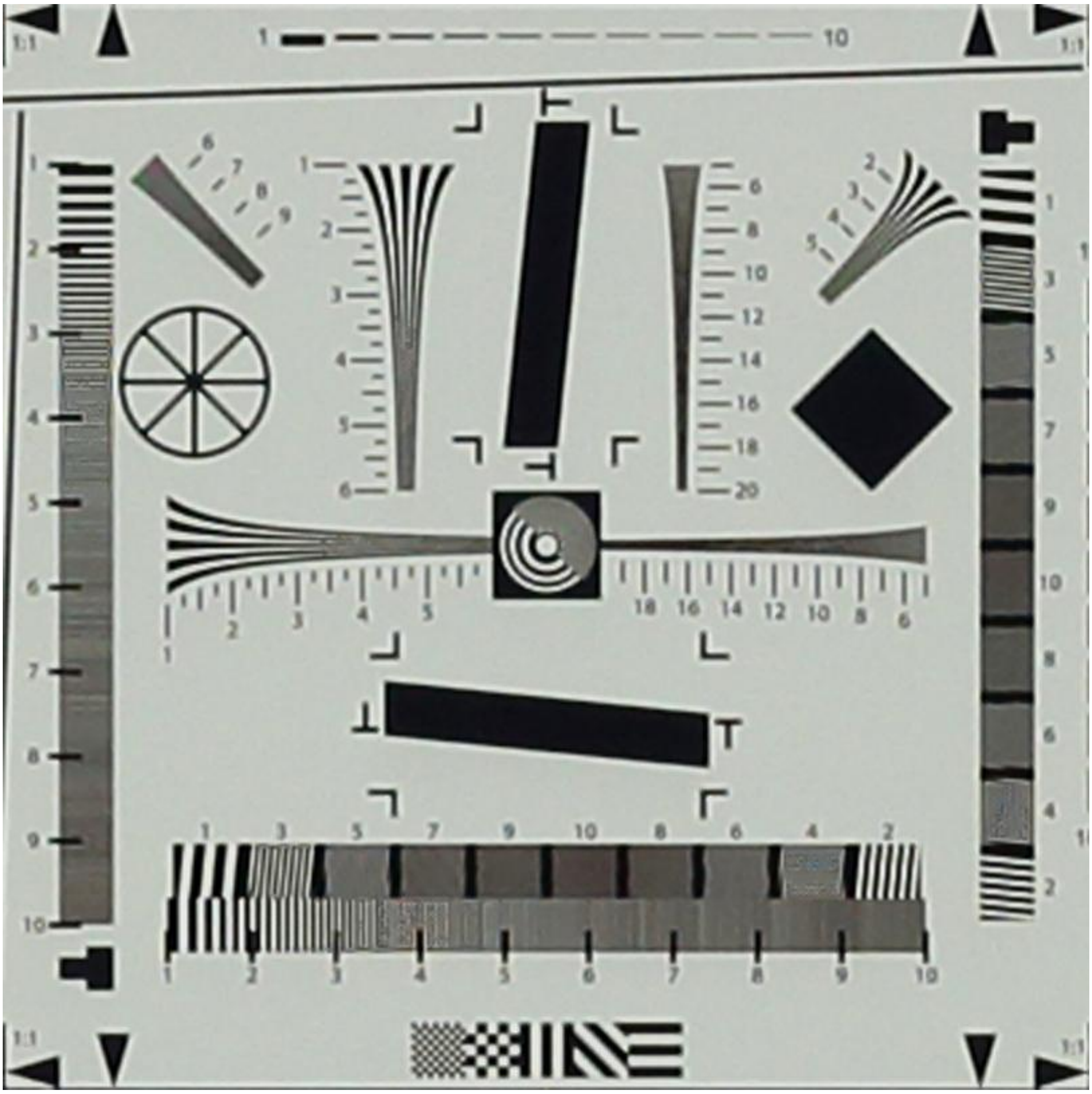

***Figure 1**. Resolution test chart image taken with the Canon 5DIII and 300 mm f/2.8L IS II USM telephoto lens. The range to the chart was approximately 17m with camera aperture f/8 and ISO 500. For calibration, lines on the chart with a scale value of '10' are spaced 0.292 mm apart.*

Figure 2 shows a test shot obtained with the prime lens plus 1.4× extender for which the combined effective focal length is 420 mm. In this case we measure the finest resolved line spacing to be 5.46 on the chart scale corresponding to 0.53 mm. This is a good result compared with the Nyquist limit which is 0.50 mm. Figure 3 shows a test image using the 2× extender with a combined effective focal length of 600 mm. The first thing one sees is how much sharper the image is compared with the shot obtained with the prime lens. This is due to all the extra fine detail in the object that has been resolved by the longer focal length combination. The resolution limit we measure using the chart scale is 7.17 which corresponds to 0.41 mm and compares favourably with the Nyquist limit of 0.35 mm. The three test shots clearly show that a well-designed extender can significantly improve the resolution of fine detail, and hence the overall sharpness, compared with what can be achieved with the unaided prime lens.

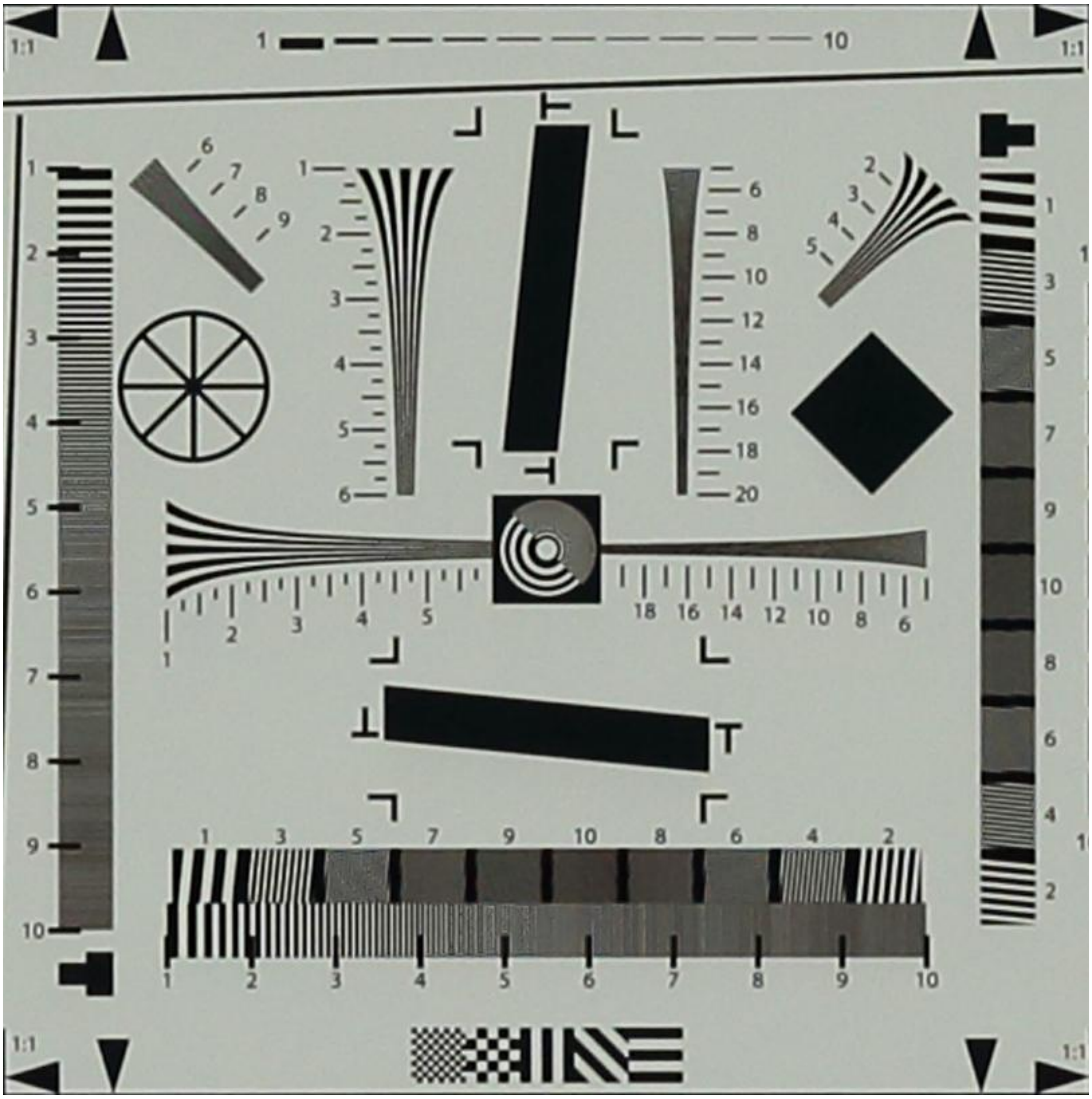

***Figure 2**. Resolution test chart image obtained using the 1.4× Mark III extender, f/8 and ISO 500.*

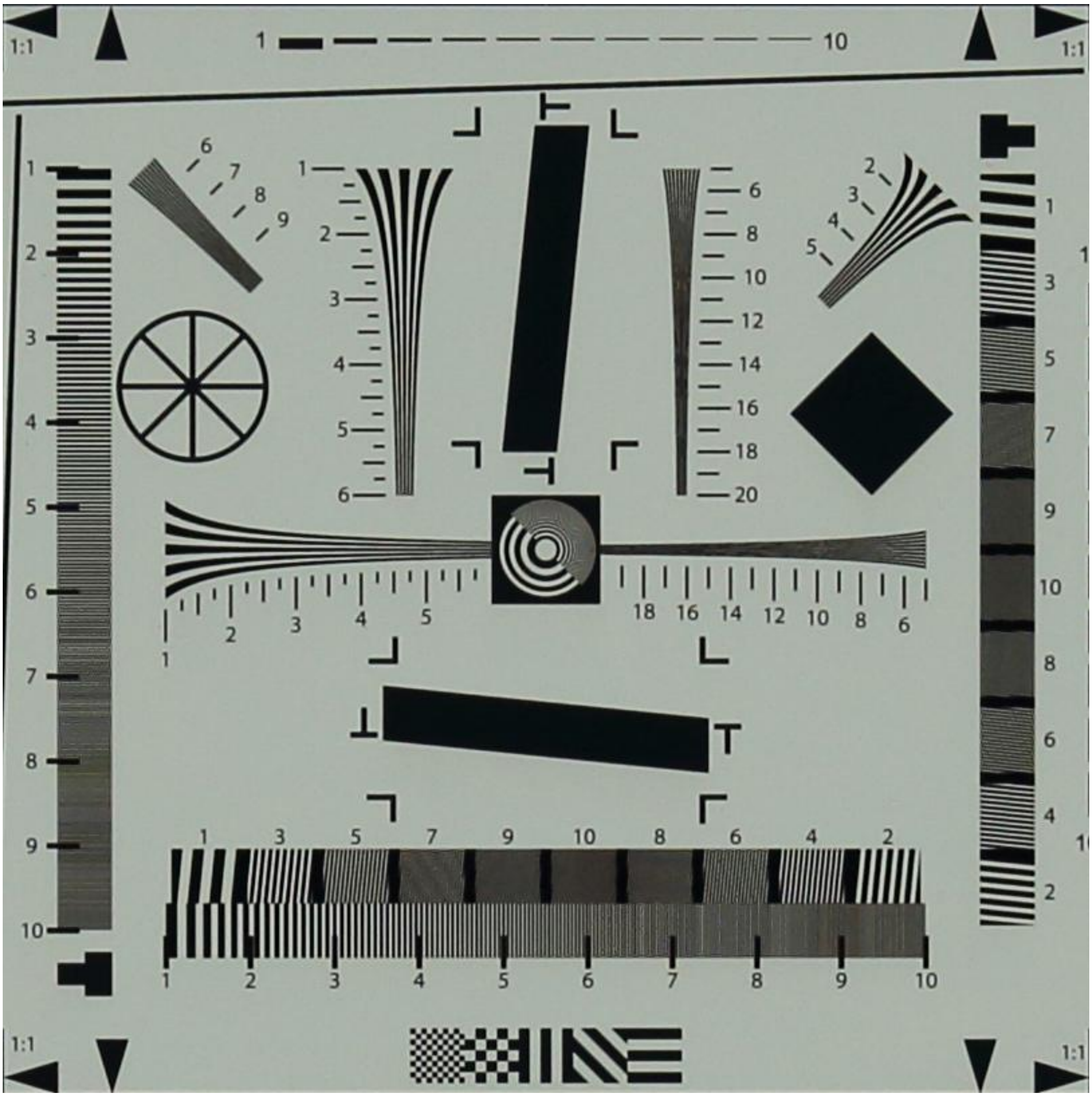

***Figure 3**. Resolution test chart image obtained using the 2× Mark III extender, f/8 and ISO 500.*

INTERPRETATION OF THE RESULTS

These days it is customary to interpret optical imaging using linear systems theory and spatial frequency analysis, most commonly represented by the MTF. The overall frequency response is the product of the MTF of each subsystem in the signal chain. In our case we have the lens MTF and the anti-aliasing filter MTF so the overall response is simply the product of these two functions. The MTF of the 300 mm prime lens at f/8 is essentially aberration free and can be calculated using the formula found in modern optics text books. The MTF of the anti-aliasing filter can be determined by examining the roll-off and measuring the resolution limit using the test chart images. The overall frequency response is the product of these two functions. The MTF of the prime plus extender can be estimated from the test chart images once the MTF of the anti-aliasing filter has been determined.

MTFs are usually displayed as a function of lines per mm in the focal plane of the camera, however, it is sometimes more useful to display the results in spatial frequency units measured in the frame of reference of the object. This is exactly what we are looking at when we view the image of a resolution test chart like those shown as Figures 1–3. Furthermore, if instead of a linear measure of spatial frequency, such as lines per mm, we change the display to lines per degree, the results become independent of the range to the test chart. By lines or cycles per degree we mean the number of test grating lines that would appear in a one degree field of view. The frequency response displayed in this way is often used to show the performance of terrestrial telescopes and allied systems such as binoculars and gun sights. It is also an elegant way of summarizing the performance of telephoto systems. Figure 4 shows the overall frequency response of our camera system as a function of cycles per degree and calculated from data derived from Figures 1-3 using the linear systems theory outlined above. One additional curve has been added to the results, the blue curve, which shows the overall frequency response for a well-designed 600 mm prime such as we would expect from the flagship 600 mm f/4L IS II USM stopped down to f/8. This frequency response is what you get for twice the price, from a very impressive lens, with a lot more avoirdupois. The trade-off is a personal decision but until Canon offers a lighter weight 600 mm prime, such as an f/5.6 model, there is little choice in the matter for those who walk long distances to photograph birds. For these people, a smaller prime with focal length multiplier is a good option.

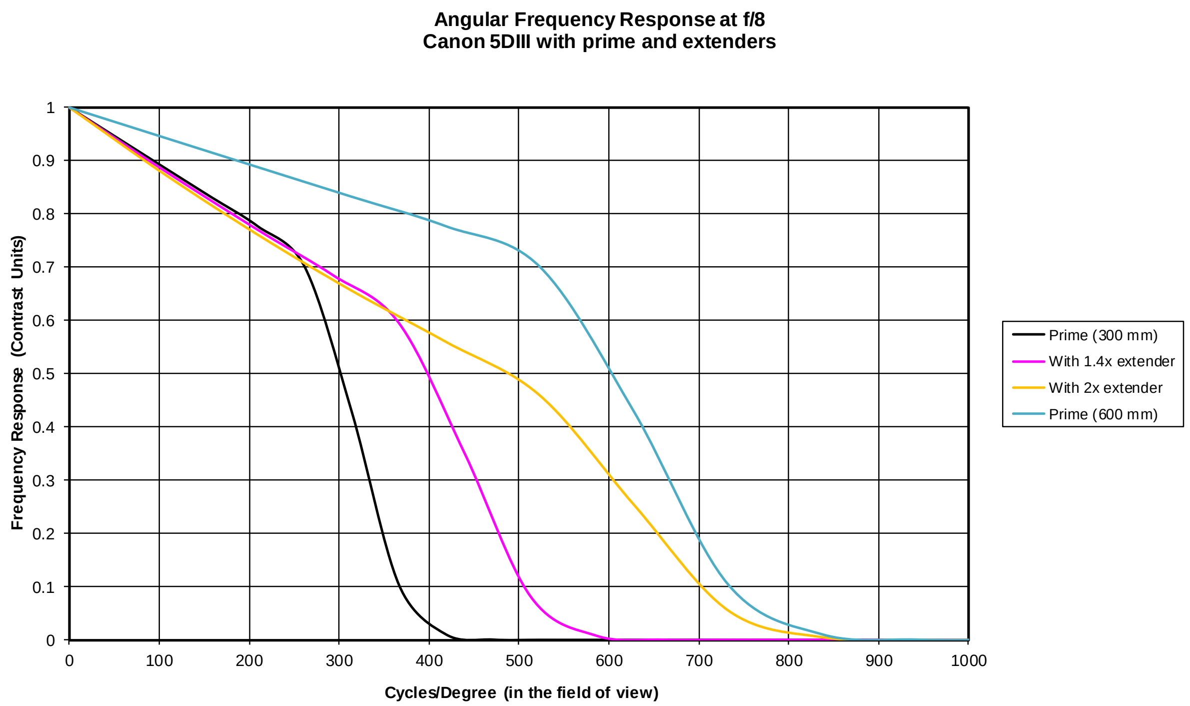

Figure 4. *Angular frequency response in the field of view of the Canon 5DIII with prime and extenders at aperture f/8. For comparison, 1000 cycles/degree corresponds to a scale value of about '10' in the images of the resolution test chart and this line spacing corresponds to 1/1000 of a degree.*

Concluding Remarks

While the test chart pictures are compelling in a quantitative way, there is nothing like seeing the results of field tests. Unfortunately, this is easier said than done and after several tries, with mixed success, we decided to borrow some stuffed birds from BirdLife Australia. This would ensure that the pose of the bird and AF point was exactly the same from shot to shot and that there was no possibility of blur arising from the movement of the bird during exposure. It would also enable optimum lighting to be arranged. In the meantime, we received a phone call from our next-door neighbour with news of a pair of Tawny Frogmouths roosting in their garden, ideal subjects for the kind of test shots we needed to illustrate this article. The birds were in a reasonably accessible position in dappled sunlight at a range of about 9m. A series of pictures was recorded with and without the 2x extender with typical results shown in Figures 5 & 6. The images are straight from the camera without any overt processing apart from a minor brightness adjustment, cropping, resizing and resampling of the prime image to match the image taken with the 2× extender. Most readers will be able to see at a glance the benefit of using the 2x extender.

***Figure 5**. Test shot taken with the Canon 5DIII and 300 mm f/2.8L IS II USM telephoto lens. The range to the bird was about 9 m with camera aperture f/8 and ISO 800. The picture file was resized and resampled to match the comparable image taken using the 2× extender shown in Figure 6.*

***Figure 6**. Comparison test shot taken using the 2× Mark III extender, f/8 and ISO 800.*

Unlike the two dimensional test chart, birds have depth as a third spatial dimension and the depth of field of the camera system must be considered. The setup for the test shots was chosen so that depth of field would not be an issue but of course, in the field, it very often is an important issue when using long focal length lenses. The depth of field can be comparable with the thickness of the bird even when the aperture is stopped down to, say, f/11. Under these circumstances the selection of the AF point on the bird can make the difference between a good picture, with all of the bird in sharp focus, and a picture with only part of the bird in focus. This situation can be exacerbated if the camera AF microadjustment is not set so the focal plane of the AF phase detector is coincident with the main focal plane. This problem is a non-issue in everyday photography but when the focal length is more than about 300 mm, it can result in shots that are in best focus in front of or behind the bird with consequent disappointment. It was this very problem with Jill's Canon 7D that prompted the lengthy series of test shoots which have led to this series of articles on camera testing. My 5DIII had the same problem and needed AF microadjustment in order to reach its full potential. If you feel the need to optimize the AF microadjustment of your camera, Canon recommends the length of the test range be at least 50× the focal length of your camera lens.

When the effective focal length of the camera is longer than about 500 mm other issues become important. Firstly, it is difficult to hold the camera steady and even though image stabilization is helpful, the camera, ideally, needs to be supported on a sturdy monopod or tripod. A remote shutter release should be used whenever possible and some thought should be given to the amelioration of mirror/shutter vibration. During testing of the 5DIII we found that the resolution limit can be up to 30% better using the Live View silent shutter mode compared with the standard mirror/shutter drive. In Live View silent shutter mode the mirror is locked up and an electronic first curtain with no moving parts is used during picture taking. Another option is 'silent shooting' which appears to be the standard mirror/shutter drive with extra damping – this can be used with infill flash with good results. The standard mirror/shutter drive should only be used when a high frame rate is required.

While the examples used in this discussion were images taken with a Canon 5DIII, comparable results were obtained using a Canon 7D and we expect similar results for other Canon camera bodies using the APS–C detector format. We have not tested comparable camera systems and teleconverters manufactured by Nikon but would be very surprised if the results were much different. The main conclusion arising from our work is that, provided they are used with care and understanding, modern focal length multipliers can be very useful in bird photography.

Acknowledgements

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