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INSTRUMENTATION FOR MEASURING NVIS DISPLAYS: PRACTICAL OPTIMIZATION FOR BEST PERFORMANCE

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Instrumentation for measuring NVIS displays: practical optimization for best performance.

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ABSTRACT

Displays providing NVIS compatibility must meet exacting standards. Instruments to test these devices must also perform to set minimum requirements, given in MIL-L-85762A appendix B. Traditionally, these requirements have been difficult to achieve in practice, and then only by compromising measurement conditions.

A combination of new technology and application-oriented optimization of the spectroradiometer has led to recent revolutionary changes in NVIS measurement instrumentation.

The optimizations possible, the mechanisms of achieving these optimizations, and the impact of any differences on measurements are discussed for two commercial instruments.

Key Words:
Display, aerospace, military, aircraft, cockpit, lighting, NVIS, NVG, night-vision, MIL-L-85762A

1. INTRODUCTION.

Displays providing Night Vision Imaging System (NVIS) compatibility must meet exacting standards. Instruments to test these devices must also perform to set minimum requirements, as given in the document MIL-L-85762A[1]. In providing systems to measure NVIS compatibility of displays (commonly referred to as NVIS systems), individual manufacturers have produced instruments with very different capabilities. The performance of instruments with respect to MIL-L-85762A[2] and the basic spectroradiometric principles[3] have been dealt with elsewhere. This article deals primarily with the optimizations possible, the mechanisms of achieving these optimizations, and the impact of any differences on measurements.

In order to assess the impact of optimization on measurements, two commercially available systems were compared: referred to in the text as System A and System B. Data for each of these systems was determined by the respective manufacturer to ensure results were representative of the actual performance.

System A is a commercial single monochromator system supplied specifically for NVIS measurements. The name of the manufacturer is irrelevant, since System A is included only to demonstrate the consequences of non-ideal optimization.

System B is a commercial single monochromator system supplied for NVIS and other measurements under the name OL 750S-NVG. It is manufactured by Optronic Laboratories, Inc.

Before beginning the comparison, it is useful to review the basics of NVIS calculations.

2. THE BASICS OF NVIS CALCULATIONS.

Night vision goggles differ from the human eye in terms of sensitivity and spectral response. Figure 1 shows the relative NVISa and NVISb night vision imaging system, and photopic (standard human observer) spectral responses. It can be seen that the NVISa and NVISb responses are highest in the red and near infrared parts of the spectrum, where the human eye has low sensitivity or none at all. Hence a display optimized for normal viewing may change its appearance entirely when viewed with night vision equipment. However, the responses of NVISa and NVISb overlap significantly with the photopic response. Virtually any visible display will therefore also be seen to some extent by night vision goggles. Since all responses vary rapidly and over many decades with wavelength, extremely accurate measurements are required if useful results are to be obtained.

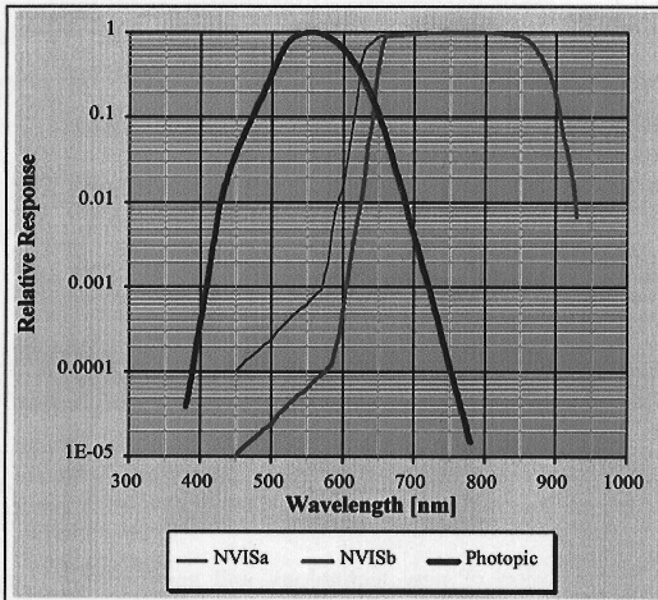

Figure 1. The relative responses of NVISa and NVISb type systems, and the human eye (photopic).

Small spectral differences can produce dramatic changes in relative brightness as perceived by the human eye and night vision goggles. Limits placed on the relative brightness of displays under both these conditions form the basis of MIL-L-85762A.

When measuring a real display with a real system, a single result is obtained. Any errors in this measurement are combined. On the other hand, MIL-L-85762A deals with individual tests or parameters, each dealing with the maximum allowable errors for specific aspects of equipment performance. Values for the actual system performance for each of these parameters can be evaluated, and their contribution to the overall accuracy of measurement determined.

To provide a clear comparison to individual specifications within MIL-L-85762A, the effect on a source of known spectral

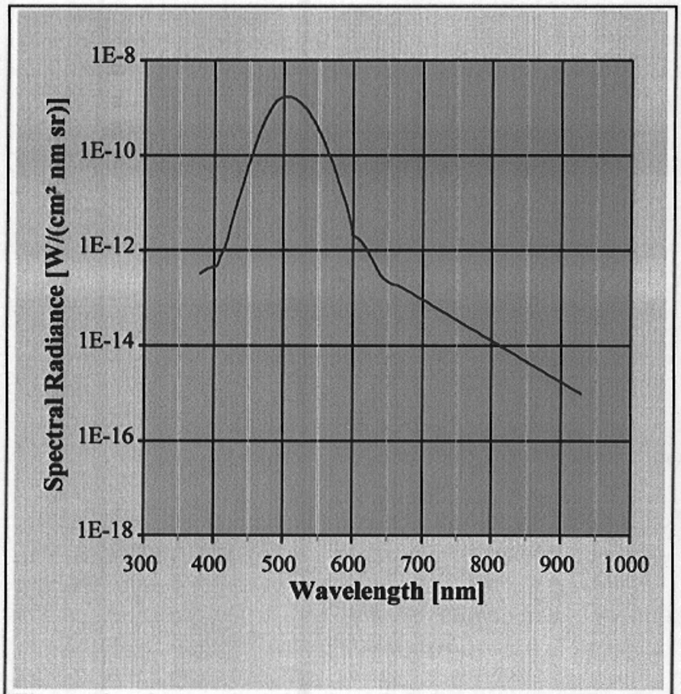

Figure 2. Spectral radiance of the example source at 0.1 fL (used to illustrate effects described later).

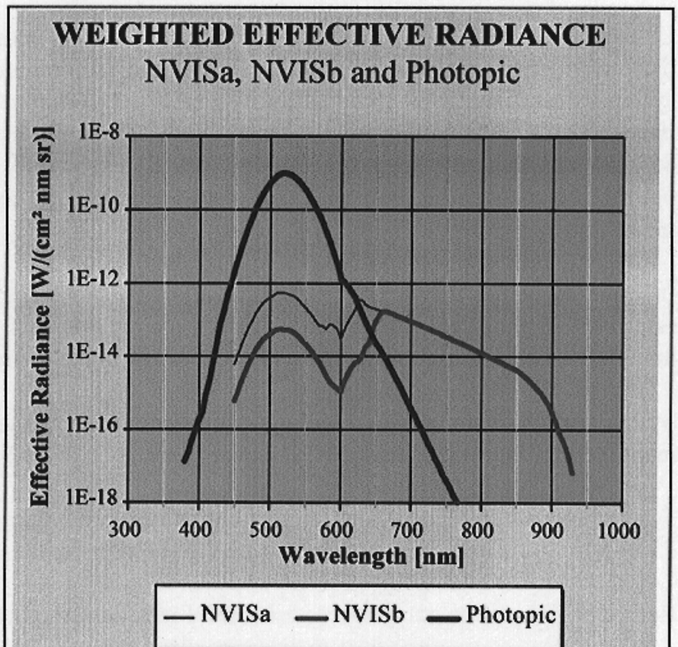

Figure 3. Effective spectral radiance of the example source, as "seen" by NVISa and NVISb night vision, and photopic devices.

distribution can be calculated. This can then be compared to the measurement parameters of System A and System B. Figure 2 shows the spectral radiance of a good NVIS primary type I class A source. This was measured using an OL 750D-NVG system, and the small amount of residual noise has been smoothed so as to provide the "known source" and clearly illustrate the various effects in this article. The spectrum is scaled as appropriate in the following arguments.

The spectral radiance, multiplied by the NVISa, NVISb and photopic relative responses, gives the effective radiances with respect to wavelength for each device (as shown in Figure 3). The area under these curves, scaled appropriately, provides the NVISa radiance, NVISb radiance and luminance of the source. It can be seen that although 99.95% of the source energy is at wavelengths less than 600 nm, most of the effective NVIS radiance is at wavelengths greater than 600 nm.

3. OPTIMIZING THE SYSTEM RESPONSIVITY.

Users often treat spectroradiometers as "black boxes" which generate results for a particular display. Whereas this view is reasonable for users, who would not be expected to know every relevant aspect of spectroradiometry, manufacturers must necessarily demonstrate a high degree of expertise in the design and optimization of their instrument for specific applications. Where different designs are employed by manufacturers, each would be expected to conform to basic performance criteria: suitability for the application; desired measurement accuracy; ability to measure any display normal to the application; and conformance to the standards and expectations of the industry.

Sometimes, conformance to these criteria is not obvious, and we must look inside the "black box" in order to assess a system.

Spectroradiometers use components that have different transmission, reflection, efficiency and response as the wavelength of light is varied. Together, they determine the overall spectral responsivity of the system. These components should be matched by the manufacturer to produce the optimum spectral responsivity with wavelength for any particular application.

Figure 4 (Top) shows the relevant properties of some of the typical components that might be used in the manufacture of an NVIS system. These are: the efficiency of a 750 nm blaze, 600 g/mm grating; the reflectivity of a typical Aluminum mirror; and the power response of a GaAs PMT. A GaAs PMT is generally used in modern systems because it offers high sensitivity and response up to 930 nm. For each component, such data is generally readily obtained from the manufacturer. While optimization is at the design stage, these curves provide valuable information since they enable the approximate shape of the responsivity curve to be predicted.

$$\boxed{\text{Relative Responsivity} \approx \left(G \bullet A^4 \bullet P\right)^{-1} \bullet 100} \quad \textbf{(1)}$$

Where: G = grating efficiency
A = Aluminum mirror reflectivity raised to the power of the number of mirrors
P = photomultiplier response

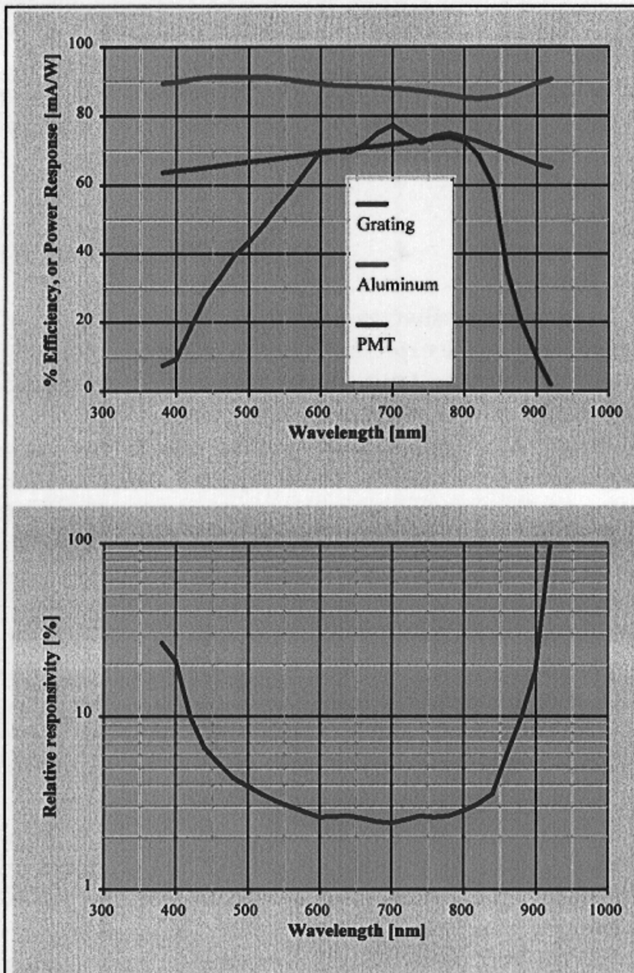

Figure 4. Typical grating efficiency, Aluminum mirror reflectivity and GaAs PMT response that might be used in a NVIS system (Top). The relative responsivity calculated using Equation 1 (Bottom).

The predicted responsivity given by Equation 1 is only approximate since: antireflection coatings on lenses and protective coatings on mirrors affect their spectral contributions; the grating data is for specific (Littrow) conditions that may not apply to the monochromator design; and the PMT data is for a specific temperature.

The system responsivity calculated using Equation 1 expresses the relative intensity of light required to produce the same signal. Thus, smaller values indicate a better sensitivity of the system to light. The application engineer or scientist would generally start with this approximate relative responsivity curve, shown in Figure 4 (Bottom). Using a knowledge of the behavior and availability of components, changes can be made within practical limits to fine-tune the performance. For instance, the response of the PMT beyond 880 nm is very sensitive to temperature. Decreasing the temperature by 20°C would make it more than a decade less responsive at 930 nm.

Once the nearest fit to the desired system responsivity shape has been established, the effects of ancillary components such as blocking filter transmissions can be factored in. After this, the contribution of the transmission properties of accessories, such as fiber optics and telescopes, are calculated.

Although the approximate shape of the system responsivity spectrum may be calculated, the exact shape and absolute values can only be established by building a system and making measurements. The spectral responsivity of a system is the light output of a source divided by the signal produced at each wavelength. For a source of spectral radiance expressed in W/(cm^2 nm sr) and a signal measured in Amperes, the spectral radiance responsivity would be in [W/(cm^2 nm sr)]/A. The determination of the absolute spectral responsivity is known as a calibration.

Once the system is calibrated, the spectral radiance of a test source is determined by multiplying the spectral responsivity by the measured signal for each wavelength. However, spectral responsivity depends on the exact conditions, which must be maintained between a calibration and measurement.

4. OPTIMIZATION OF SYSTEM SPECTRAL SENSITIVITY.

The system responsivity expresses the relative intensity of light required to produce the same signal. Conversely, a given signal value can be expressed in terms of the equivalent light required. The electrical noise of the detector and amplifier in any system places a limit on measurements. Any light generating a signal less than this noise is indistinguishable from a dark condition. The intensity of light corresponding to this noise is determined quite simply by multiplying the amount of noise (in Amperes) by the spectral responsivity at each wavelength. MIL-L-85762A section B30.2 defines the spectroradiometer radiance sensitivity as the intensity equivalent to ten times the root-mean-square noise value, and assigns maximum limits to this quantity at each wavelength between 380 nm and 930 nm.

To improve sensitivity, a system can be optimized in any or all of three ways: increase the efficiency of components; decrease the electrical noise of the detector and amplifier; or increase the field-of-view of light from the source that enters the system. For a given design of monochromator, the highest quality state-of-the-art components should be used and improvement is generally limited to technological advances rather than optimization. Providing accessories are matched to the monochromator, improvements in these components is also limited. Increasing the PMT high voltage does increase its gain, and hence the system responsivity. However, the noise from the PMT also increases and overall may produce a decrease in the system sensitivity. Most systems accommodate several user selectable field-of-view apertures which, when the magnification of the lens is considered, define the area or diameter of the spot on the source which is sampled during measurements. Increasing the spot diameter by a factor of ten should increase the amount of light entering the monochromator by a factor of one hundred. The user may thus select a spot size, within the limits of the apertures available and the constraints of the sample size, appropriate to the sensitivity desired.

Increasing the spot size can only increase the light entering the monochromator within limits. Measurements must be made at a certain bandpass, normally 10 nm, which is determined by the monochromator slits. When the spot size exceeds the slit size, the extra light falls on the slit housing rather than entering the monochromator and hence is not seen by the system.

One popular mechanism for decreasing system noise, and hence increasing sensitivity, is lowering the temperature of the GaAs PMT. Whereas this does reduce the noise, it also changes the shape of the responsivity (and hence sensitivity) spectrum. As the PMT is cooled, the response to wavelengths greater than 880 nm decreases faster than the noise. This means that although the system improves at wavelengths less than 880 nm with lower PMT temperatures, the performance at greater wavelengths degrades. Conversely, increasing the temperature may improve the responsivity beyond 880 nm, but the increased noise can adversely affect the sensitivity at wavelengths less than 880 nm to the point where the accuracy of measurements is compromised. The best temperature for optimal sensitivity differs slightly for each PMT, and hence should be determined before the system is used.

Another, less popular, mechanism for decreasing system noise to increase sensitivity is to increase the scan time. This approach is of limited use however, since scans of over 3 hours are required just to achieve a factor of ten decrease in noise relative to a 2 minute scan.

Naturally, if noise from the amplifier is greater than that of the PMT, no amount of optimization will improve the system. Highest quality auto-gaining amplifiers should always be used, together with digital signal processing (DSP) acquisition if possible. DSP technology virtually eliminates sampling and analog filtering errors commonly associated with older designs[4].

5. THE IMPACT OF SYSTEM RADIANCE SENSITIVITY SHAPE ON MEASUREMENTS

The primary factor in any optimization must be the intended use of the system. NVIS measurements present a unique challenge, in that real displays must be measured while conforming to applicable individual specifications of MIL-L-85762A.

Spectral sensitivity is dependent on many factors: most are part of the manufacturer's optimization but some, such as spot size or high voltage are selectable by the user. In general, for a given system, the larger the spot size the smaller the spectral sensitivity values. The overall shape of the sensitivity spectrum is only slightly affected by spot size and high voltage. By scaling the sensitivity spectrum, effects of comparative system responsivities can be assessed. As discussed previously, the shape of the radiance sensitivity (as defined in MIL-L-85762A) spectrum and the responsivity spectrum are necessarily identical.

The limits of MIL-L-85762A are idealized and do not reflect the overall shape of spectral responsivities of modern instruments. However, these limits are an integral part of measurement and must be met. Using a combination of spectral radiance sensitivity shape and MIL-L-85762A radiance sensitivity requirements, the maximum measurable luminance of an NVIS display can be established. Figure 5 and Figure 6 show the MIL-L-85762A requirement and the spectral radiance sensitivities of two actual NVIS systems: System A and System B respectively. Each of these is scaled to the condition where the respective system only just meets MIL-L-85762A specification B30.2.

By scaling the system responsivities in this way, the least sensitive condition while still maintaining conformance to specification B30.2 is revealed. Since the sensitivity defined in MIL-L-85762A section B30.2 is a radiance level at 10:1 RMS
noise, the actual system noise level must be a factor of 10 below this system sensitivity curve. From this, the highest measurable radiance level can also be found using the dynamic range, which is defined as *the ratio of the maximum measurable signal to the RMS noise*. Since System A has a 5 decade dynamic range, an envelope (shown as Noise to Max. signal in Figure 2), spanning the region between the noise and maximum signal may be constructed. Any spectral radiance level below the envelope is too small to be measured, and any level above the top is too bright be measured (and may saturate or damage the PMT). Also shown on Figure 5 are spectra of a sample NVIS source scaled to values from 0.1 fL to 10,000 fL. It can be seen that only the source at 0.1 fL lies within the System A envelope, and measurement of any source significantly brighter than this is impossible. If, for instance, System A is de-sensitized to allow measurements of brighter sources, the system radiance sensitivity would then exceed the required specification B30.2 levels. This restriction would make this instrument generally unacceptable since many NVIS compatible displays are brighter than 0.1 fL. Indeed, some displays such as warning lights are very much brighter.

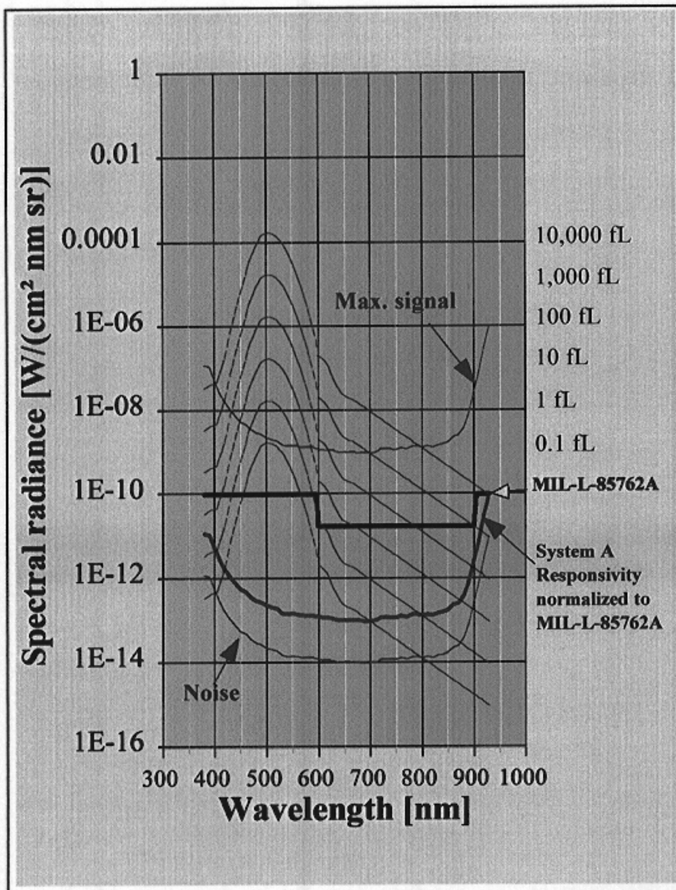

Figure 5. System responsivity envelope (Noise to Max. signal) for system A exactly matched to MIL-L-85762A limits, showing a source (dashed lines) of 0.1 fL is the brightest measurable.

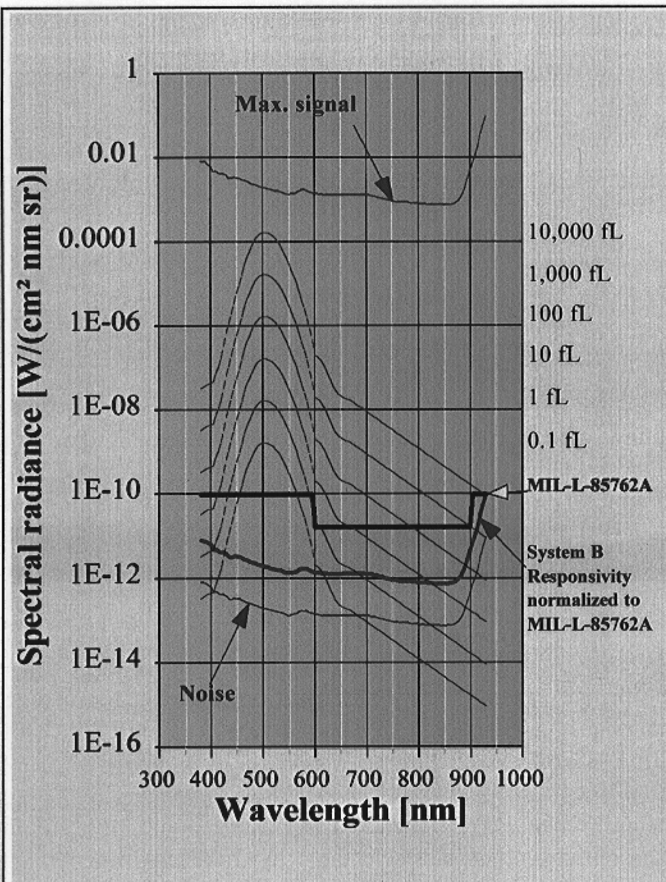

Figure 6. System responsivity envelope (Noise to Max. signal) for system B exactly matched to MIL-L-85762A limits, showing all sources (dashed lines) of over 10,000 fL are measurable.

In contrast, System B exhibits a radiance sensitivity spectrum that is much closer in shape to the levels defined in specification B30.2 and, more importantly, has a much larger dynamic range of 10 decades. Figure 6 shows that a NVIS sample of well over 10,000 fL may be measured while maintaining MIL-L-85762A compatibility.

6. THE IMPACT OF SYSTEM RADIANCE SENSITIVITY SHAPE ON CALIBRATIONS.

In order to make any measurement, the system must first be calibrated. An integrating sphere source, calibrated for spectral radiance, is generally most convenient for this. In the previous section, the limiting spectral radiance sensitivity corresponding to just meeting MIL-L-85762A specifications was established for System A and System B. Applying the same analysis, but this time to a calibration source at a blackbody temperature of 2856K, reveals the maximum luminance level that may be used. Figure 7 shows System A with a 2856K blackbody source scaled to the maximum measurable spectral radiance. This source corresponds to a luminance of 0.12 fL. Working with sources of such low luminance can present many problems.

In setting a calibration source to low levels, the accuracy of the luminance display is a limiting factor. If the last digit represents, for example, 0.01 fL then the source could never be set to better than 0.1 ± 0.01 fL, which is an error of ±10%.

A display giving values to 0.0001fL is necessary to make this error insignificant. Even if the display is to this quality, zero offsets, drift and linearity problems may limit accuracy to a few percent.

In addition to luminance display errors, it is essential to the calibration that the spectral radiance values at these levels are correct. Adjusting sphere sources to this level may introduce spectral changes relative to the original calibration condition, and stray light may seriously affect the spectral radiance values. Stray light comes from external sources such as room lights, computer screens, LEDs and neon indicators. This light enters the sphere and contributes to the overall luminance and spectral radiance. For example, room lights entering the sphere may typically give an increase in luminance of 1 to 5 fL. Obviously, this is unacceptable if a level of 0.1 fL is required. In fact, virtually any light within the room will cause serious errors in spectral radiances at 0.1 fL.

A similar treatment of System B reveals that this problem does not apply. The 10 decade dynamic range of System B allows calibration sources at high levels to be used. If, for instance, a calibration source is at 100 fL then the errors discussed above are reduced by a factor of 1000. This not only makes calibration more accurate, but also makes the system easier to use.

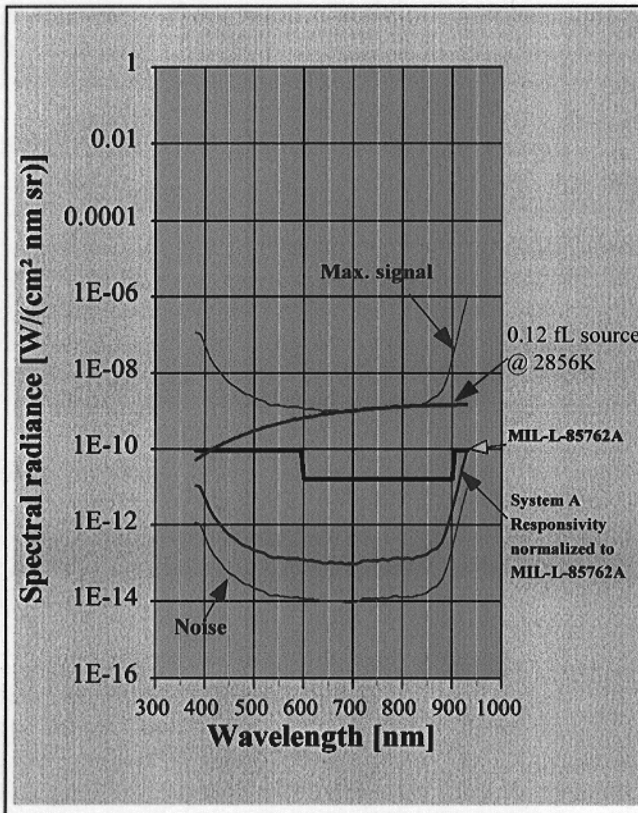

Figure 7. System responsivity envelope (Noise to Max. signal) for system A exactly matched to MIL-L-85762A limits, showing a blackbody sphere source (blue line) of 0.12 fL is the brightest usable in calibration.

7. THE CONCEPT OF MAXIMUM SENSITIVITY IN RELATION TO PERFORMANCE.

When providing specifications, manufacturers should provide information to customers regarding the performance criteria that may be applied to an installed system. Some manufacturers only specify the maximum radiance sensitivity at one wavelength. This may be misleading, since systems with the same maximum radiance sensitivity can vary enormously in performance.

Under the same conditions, System B has far better maximum radiance sensitivity performance than System A at 700 nm. Suppose, however, that they were the same. Figure 8 shows the System A sensitivity spectrum, as in Figure 6, but with the System B sensitivity normalized to give the same value at 700 nm. Clearly, although the sensitivity at 700 nm is the same, System B provides much better performance over the rest of the spectrum. In fact, the radiance sensitivities at the higher and lower wavelength extremes is over a decade better for System B.

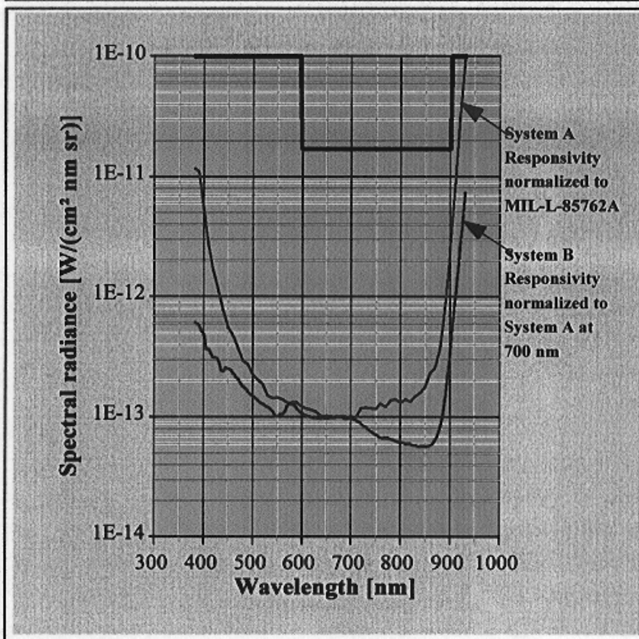

Figure 8. Comparative sensitivities for System A and System B when normalized at 700 nm.

Maximum radiance sensitivity values at a single wavelength do not, therefore, provide an indication of performance unless accompanied by information over the entire wavelength range of interest. In fact, it is quite possible for System A to be over 2 decades below the specification B30.2 level at 700 nm and still fail MIL-L-85762A at 930 nm.

8. POINT-BY-POINT OR TOTAL SCAN OPTIMIZATION

Although a large dynamic range is obviously desirable, for some system designs it is not an option. The components available have their own inherent dynamic range and will always limit the system unless changes can be introduced during the scan. The essential requirement for the very high dynamic ranges in previous sections is that scans are point-by-point. This means a wavelength is selected, data is gathered and then the next wavelength is selected. Data is always obtained with the wavelength stationary, so there are no time constraints in optimizing conditions: which can be determined and implemented prior to the next wavelength selection.

Normal NVIS sources can vary in spectral radiance at different wavelengths by up to 7 decades. This is much greater than the inherent dynamic range of a GaAs PMT. If conditions are optimized for the entire scan, measurements would be limited to the PMT dynamic range. Extending the dynamic range involves optimization, using a method that preserves the critical conditions of measurement, at each datum acquisition: a point-by-point optimization. System A is an example of an instrument where only total scan optimization is possible, whereas System B provides point-by-point optimization as standard.

In the total scan optimization of System A, any neutral density filters etc. to match the system response to the intensity of the source are placed in position before the start of data acquisition. Unfortunately, one must acquire data (and risk damaging the PMT) in order to determine the optimum conditions. This leads to a long process of trial and error before the full potential of the system is realized. Also, the limited dynamic range of the PMT can never be exceeded, prohibiting measurements at the 7 decades needed.

In point-by-point optimization of System B the wavelength movement is halted at each data interval until the best conditions for acquisition is achieved. Neutral density filters may be placed in the beam path or removed as needed to achieve the optimum signal level for greatest accuracy. These neutral density filters therefore act in a similar way to, and in conjunction with, gain ranging. Since the transmission of neutral density filters varies with the beam profile, care must be taken to characterize them *in-situ.* Measurements must be made over the entire wavelength region of interest, since the transmission is not precisely neutral. Ideally, this should be done by the manufacturer, but users can perform these measurements if a suitable variable intensity sphere source[5] is available. Using these neutral density filters in point-by-point optimization, intense sources can be measured without compromising the sensitivity at low levels of radiance. Ten or more decades of dynamic range is easily achievable using this technique.

An additional benefit of point-by-point scanning, is that the data integration time can be varied. At high spectral radiance levels, noise is not significant and short integrations provide good data. At low spectral radiance levels, longer integrations provide more accurate results. Using point-by-point optimization, the data integration time may be varied according to the signal, giving short integrations at high levels and longer integrations at lower levels, providing the best results in the shortest possible scan time.

9. OPTIMIZATION OF SYSTEM LINEARITY.

If the spectral radiance of a source increases by a factor of 100, but the measured signal using an instrument increases by 99, the instrument is said to have a 1% linearity error over these two decades. In normal use, any NVIS system needs to measure spectral radiances over an extremely large range. Both System A and System B are generally calibrated using sources of reasonably high spectral radiance. Usually, the highest spectral radiance from these sources occurs at 930 nm. Typical NVIS compatible displays may have compatible spectral radiances to the calibration source in the visible, but the infrared emission is extremely low. A large dynamic range is certainly necessary to accommodate these very different spectral radiances, but accurate results can only be obtained if the system is also linear.

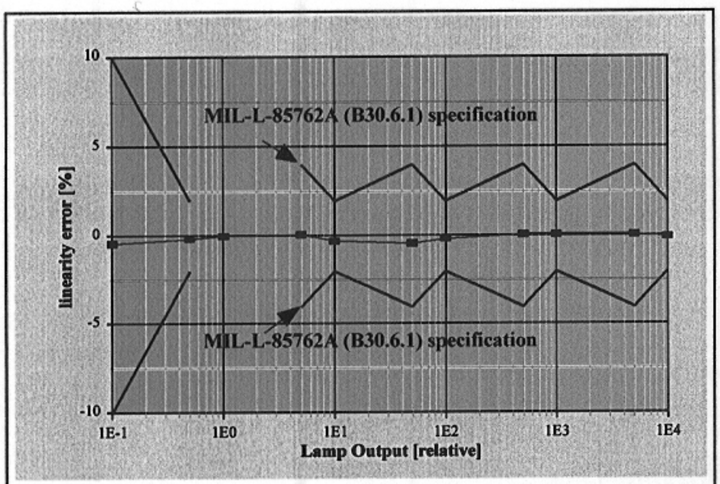

Figure 9. The linearity of System B determined according to MIL-L-85762A section B30.6.1.

MIL-L-85762A sections B30.6 and B30.6.1 specify the maximum limits to linearity error for any NVIS system. These sections cover mandatory measurements that must be made over 5 decades with the fourth decade being full scale on a gain range. In order to comply, a system needs over 6 decades of dynamic range. Regardless of performance therefore, these measurements cannot by made with System A since the 5 decade dynamic range means (by definition) the lowest values will be pure noise.

The linearity of System B will depend on: the linearity of the PMT over the desired range of light intensities; the high voltage applied to the PMT; the accuracy of neutral density filter transmission calibrations; the accuracy of calibrating individual amplifier gain ranges; the quality of the amplifier components; and the linearity of the analog-to-digital converter. All of these must be selected, characterized and calibrated precisely to achieve the desired specifications. Also, exact matching of detector and amplifier characteristics and operational ranges is required to give the best possible linearity. This attention to detail is clearly incorporated into the design of System B since, with a maximum linearity error of less than ±0.5%, it easily exceeds the MIL-L-85762A specifications, as shown in Figure 9.

10. OPTIMIZATION OF SYSTEM POLARIZATION.

Polarization is a property of light[6] not normally perceived by humans. The polarization of light may change when passing through or reflecting from materials, and the intensity may be reduced in this process. For instance, polarizing sunglasses reduce glare from swimming pool surface reflections by attenuating light at certain polarizations, allowing the wearer to see into the water underneath. In a similar way, a person wearing these glasses can make a polarized source, such as an LCD computer screen, appear brighter or dimmer by tilting his head. An unpolarized source would always appear equally bright, regardless of the orientation. An instrument that is sensitive to polarization may attenuate or transmit polarized light, making it appear more or less intense, depending on the direction of polarization.

Surprisingly, MIL-L-85762A mentions polarization only in section B40, which applies to photometers. In fact, polarization is not normally a problem for broad-band photometers, but can affect spectroradiometer results dramatically. This is due to the efficiency of gratings, which are an integral part of modern spectroradiometers, being very sensitive to the polarization of light. The polarization sensitivity of the spectroradiometer also changes substantially with wavelength. In section 3, on the optimization of system responsivity, the grating efficiency data used was for unpolarized light. This condition is appropriate for integrating sphere calibration sources, which are inherently unpolarized. However, many displays will emit partially or completely polarized light. Depending on the polarization direction of the source, the spectroradiometer may be more sensitive at lower wavelengths and less sensitive at higher wavelengths than if the source was unpolarized. In this scenario, measurements of luminance values would be higher and NVISa and NVISb values would be lower than is really the case. Errors of up a factor of 10 might be expected in NVISa and NVISb values for such a system.

The effects of polarization on spectral radiance measurements are well known[7] and are difficult to correct. Rather than correct them using complex procedures, it is better to eliminate them using depolarization optics. The effectiveness of the depolarization optic is indicated by the residual polarization sensitivity. Practical depolarization optics may be divided into three types: integrating spheres, fiber optics and wave plates.

Integrating spheres are efficient depolarizers, but their throughput is very low. For an application such as NVIS compatibility testing, the reduction in sensitivity caused by the use of integrating spheres is unacceptable.

Fiber optics depolarize light, but their efficiency in this respect depends on the type and length of the fiber. The attenuation of light in a fiber optic also varies with the length. Making the fiber long enough to reduce the residual polarization to acceptable limits (MIL-L-85762A section B40.6 places a 1% limit on this) may also degrade the sensitivity of the system to unacceptable levels.

Certain high quality waveplate designs provide efficient depolarization in appropriate circumstances, yet transmit over 90% of light in the 380 nm to 930 nm region. These devices are obviously the components of choice in fully optimized systems.

System A uses fiber optics to achieve depolarization. Whereas this effectively reduces the residual polarization, performance remains well outside of MIL-L-85762A section B40.6 limits. System B uses a special waveplate design that reduces residual polarization to less than 0.5%, and may additionally use fiber optics to improve still further.

11. CONCLUSION.

MIL-L-85762A specifications provide a basis for measurements, but do not cover parameters such as dynamic range or spectroradiometer residual polarization. Ignoring these parameters in the optimization can reduce the usefulness of instruments substantially. Effective optimization of all parameters is necessary in achieving the desired spectral responsivity, sensitivity, linearity and residual polarization performance for NVIS display compatibility testing. The consequences of slight changes in the optimization process are dramatic, and may place unacceptable restrictions on the accuracy and range of measurements that can be performed.

Manufacturers providing instruments for the same application may differ significantly in their approach to optimization. Within the constraints of measuring real NVIS compatible displays while conforming to relevant MIL-L-85762A specifications, System B performs extremely well whereas System A is clearly very limited.

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