ESD-TR-77-120

Technical Note 1977-31

R. Weber

The Amplitude Effect of Point-Source Blooming as a Function of Background Level in Ebsicon-Type Camera Tubes

16 June 1977

Prepared for the Department of the Air Force under Electronic Systems Division Contract F19628-76-C-0002 by

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS

The work reported in this document was performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology, with the support of the Department of the Air Force under Contract F19628-76-C-0002.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Raymond L. Loiselle

Raymond L. Loiselle, Lt. Col., USAF
Chief, ESD Lincoln Laboratory Project Office

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

THE AMPLITUDE EFFECT OF POINT-SOURCE BLOOMING AS A FUNCTION OF BACKGROUND LEVEL IN EBSICON-TYPE CAMERA TUBES

R. WEBER
Group 94

TECHNICAL NOTE 1977-31

16 JUNE 1977

LEXINGTON MASSACHUSETTS

ABSTRACT

A laboratory experiment is described in which the amplitude effect of point-source blooming in an ebsicon-type (i.e., intensified silicon-diode array) camera tube is demonstrated as a function of uniform background level. At very low background levels, the signal required for constant video signal-to-noise ratio, as measured on an A-scope, is approximately constant; at intermediate levels, it varies approximately as the one-half power of the background level; and, at high background levels, the power law exceeds unity. An amplitude-degradation function, f, obtained from the measurements, is presented. The importance of the f-function in point-source measurements using an A-scope is discussed.

One can imagine a silicon-diode-array target to be an array of deep wells with sloping sides. Under dark conditions, signal charge resides deep in the well, with minimum spreading. As background charge fills the well, signal charge is stored at higher and higher levels in the well with increased spreading at successively higher levels. Eventually, just before "hard" saturation (i.e., completely filled well), signal charge readily leaks to adjacent wells, until finally, all information is lost.* This gradual, continual spread of signal charge as the background level is increased is a manifestation of point-signal blooming in silicon-diode-arrays; and, it is experimentally observable. Whether the blooming effect is pronounced or not over a given range of background brightness depends upon the saturation characteristics of the array and its temperature.

A laboratory experiment performed at room temperature on an ebsicon-type camera tube allowed the amplitude effect of point source blooming, as a function of uniform background illumination, to be measured from dark-background conditions to approximately 130 times the first measurable (arbitrary) indication of the background illumination.

A fixed, white, point-source optical signal (30 microns in diameter on the faceplate of the ebsicon tube), produced a video signal, V_s, of 200 mV on an A-scope under dark-background conditions. The pedestal, dark, was 25mV. As the background

*This description is equally valid for the situation in which a single resolution element includes more than one well.

level was increased, the pedestal level rose to 30 mV. This 5 mV change was taken to represent the effect of going from $B = 0$ to $B = 1$. This was done for the purpose of presenting qualitative results within the familiar context of the B, S, and N^2, as presented in earlier papers.[1,2] For each change in B, as the pedestal was increased to the final value of 680 mV, with the white clipper disabled, the amplitude of the video signal, V_s, was recorded. From these results, an f-function was calculated. The following Table resulted:

Pedestal mV	V_s mV	B (arb.)	f (B,S)
25	200	-	1.00
30	200	1	1.00
40	200	3	1.00
50	200	5	1.00
80	190	11	0.95
180	180	31	0.90
260	170	47	0.85
370	160	69	0.80
470	150	89	0.75
580	140	111	0.70
630	130	121	0.65
680	120	131	0.60

The simple expressions $S/\sqrt{B}$, $S/\sqrt{B+N^2/G^2}$, $S/\sqrt{S+B+N^2/G^2}$, are not expressions for the output video signal-to-noise ratios. At least one such expression[1,2] was used to arrive at an empirical expression for the limiting conditions required at the first photocathode to produce visually detectable signals on a video monitor. For the sake of simplicity in the present memorandum, the assumption will be made that the video signal-to-noise ratio,

$$SNR_V = K_1 \frac{f\ (B,\ S)\ S}{\sqrt{B+N^2/G^2}},$$

where SNR_V is measured on an A-scope by the WM-method*, and N^2 is the mean-square total instrument noise in an image cell referred to the first photo-surface. All unspecified system effects will be assumed to be contained in K_1, a constant.

If we seek to find the value of S required to maintain SNR_V constant, the above expression for SNR_V becomes, upon rearrangement: $S = K \sqrt{B+N^2/G^2} \ /\ f\ (B,\ S)$, where $K = SNR_V/K_1$ is a new constant.

Figure 1 shows a plot of S as a function of B using the values presented in the Table for two cases: G = 1.0 and G = 0.5. Here N^2 is assumed to be 10, a reasonable value. For convenience, f (S, B) has been plotted on the same figure, as have lines of slope = 1/2 and 1.

The qualitative behavior of each gain curve is the same; the slope changes from almost zero to greater than one as the background increases. For small values of B, N predominates;

---

*The separation between dual levels is measured. Under the assumption of Gaussian noise, this separation (in mV) is divided by two to obtain the rms noise value.

for intermediate values, B (hence, the square root dependence) predominates; for the higher values of B, growing saturation effects predominate, causing the slope to increase sharply.

If the beam current had been held fixed at the optimum read-out value for low background levels, the effect of f (S, B) would have been stronger than that shown. For the same silicon array at different temperatures, or for a different array at the same temperature, in the same camera tube, the function f (S, B) would differ from that shown. The shaded area between the gain curves is indicative of the spread that may result in the raw data if measurements are performed under varying background conditions with different settings of the pre-target gain.

The above presentation suggests that performance predictions based on simple models, if saturation effects are not understood and taken into account, may be somewhat optimistic (depending upon the characteristics of the tube) at high background levels.

Finally, experiments have demonstrated that even for moderate background levels, the simple scaling of signal-to-noise ratios over several visual magnitudes to obtain equivalent point-source brightnesses is not an accurate procedure to follow in the presence of charge spreading on the target of the camera tube. That is, in scaling between a faint point signal and a strong point signal, the A-scope-measured amplitudes will be affected in differing amounts, depending upon the background levels, by saturation effects.

If electron-bombarded, silicon-diode array camera tubes are to be used to detect point-source signals in the presence of background illumination, it would seem advisable to measure f (S, B) for each tube over the expected temperature range of operation in order to specify with accuracy the detection capability of each sensor in its operational environment.

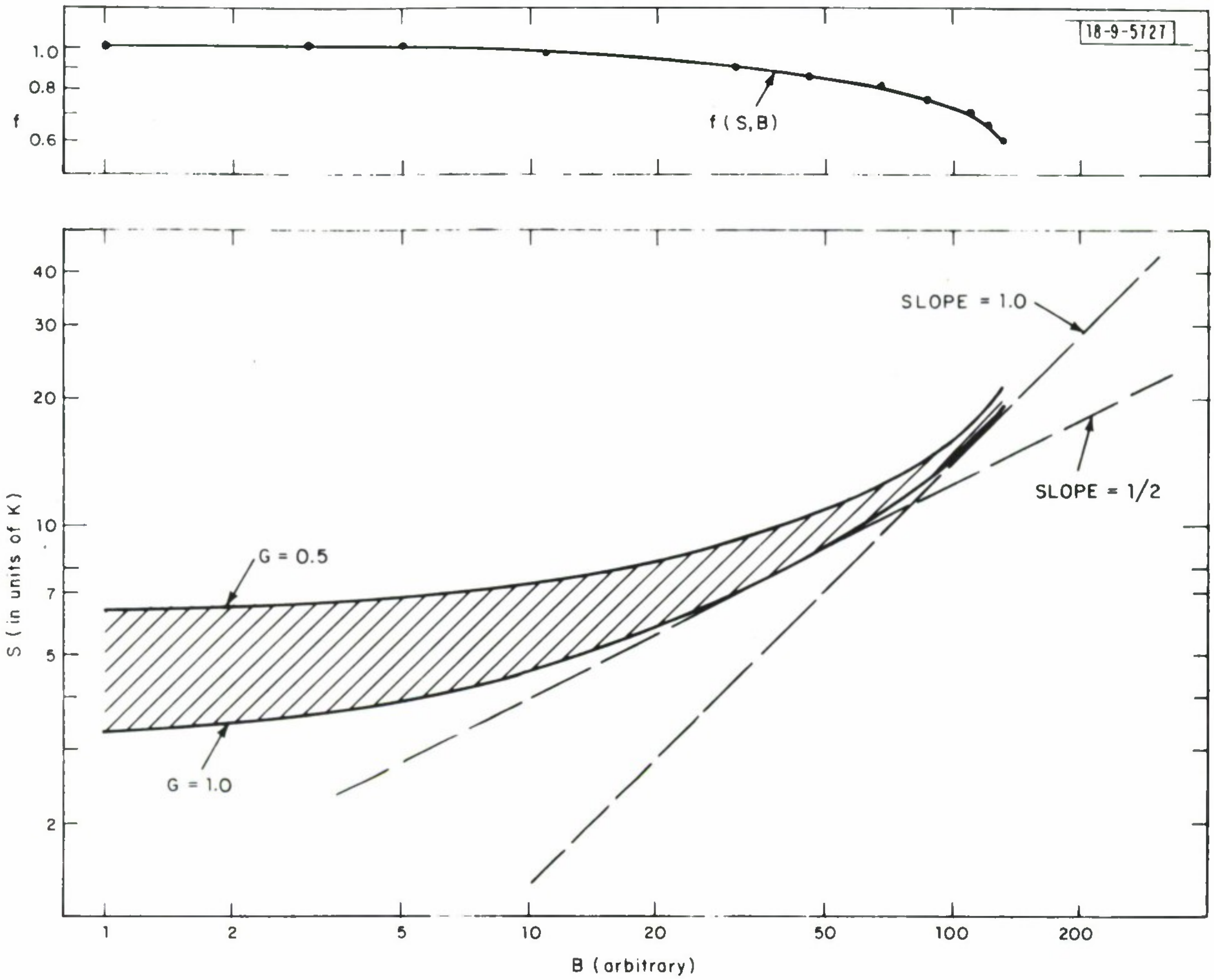

Figure 1. S as a function of B as expressed in the relationship

$S = K \left[B + \frac{N^2}{G^2} \right]^{1/2} / f$. Given B, the number of background photo-electrons per image cell at the photocathode; N^2, the mean-square total number of noise electrons per cell at the photocathode; G, the normalized pre-target current gain; f, the factor by which the signal amplitude is reduced by the spread of charge on the target of the sensor as signal and background levels increase; and K, a constant which contains the desired video signal-to-noise ratio and all other constants of a specific sensor; then, S is the number of signal photoelectrons required, per cell at the photocathode, to produce the desired video signal-to-noise ratio. The upper curve is the measured amplitude factor, f, normalized to unity at B = 0, as a function of B. Standard television rates have been used in all instances. See the text for details.

ACKNOWLEDGMENTS

The author is grateful to D.M. Campo and to D.J. Mancuso for typing the manuscript.

REFERENCES

1. R. Weber and T.H. Brooks, "The Limits of Detectability of a Low-Light-Level Point-Source Sensor as a Function of Telescope Aperture, Sensor Resolution, Night-Sky Background, and Pre-readout Electron Gain," Technical Note 1974-21, Lincoln Laboratory, M.I.T. (16 August 1974), DDC AD-785137/1.

2. R. Weber, "Predicted and Measured Detection Capabilities of the Lincoln ETS, Photon-Noise-Limited, Electro-Optical Systems," Technical Note 1976-9, Lincoln Laboratory, M.I.T. (26 April 1976) DDC AD-A025859/0.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ESD-TR-77-120	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Amplitude Effect of Point-Source Blooming as a Function of Background Level in Ebsicon-Type Camera Tubes		5. TYPE OF REPORT & PERIOD COVERED Technical Note
		6. PERFORMING ORG. REPORT NUMBER Technical Note 1977-31
7. AUTHOR(s) Robert Weber		8. CONTRACT OR GRANT NUMBER(s) F19628-76-C-0002
9. PERFORMING ORGANIZATION NAME AND ADDRESS Lincoln Laboratory, M.I.T. P.O. Box 73 Lexington, MA 02173		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element No. 63428F Project No. 2128
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Systems Command, USAF Andrews AFB Washington, DC 20331		12. REPORT DATE 16 June 1977
		13. NUMBER OF PAGES 14
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Electronic Systems Division Hanscom AFB Bedford, MA 01731		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

None

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

point-source blooming
ebsicon camera tubes
silicon-diode arrays
satellite observations

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A laboratory experiment is described in which the amplitude effect of point-source blooming in an ebsicon-type (i.e., intensified silicon-diode array) camera tube is demonstrated as a function of uniform background level. At very low background levels, the signal required for constant video signal-to-noise ratio, as measured on an A-scope, is approximately constant; at intermediate levels, it varies approximately as the one-half power of the background level; and, at high background levels, the power law exceeds unity. An amplitude-degradation function, f, obtained from the measurements, is presented. The importance of the f-function in point-source measurements using an A-scope is discussed.