M.W. Hall and R.J. Marks II "Sampling theorem characterization of variation limited systems at reduced sampling rates",
Journal of the Optical Society of America, vol. 68, p.1362A (1978).

JOURNAL
of the
OPTICAL SOCIETY
of
AMERICA

Annual Meeting Abstracts

OCTOBER

1978

VOLUME 68 NUMBER 10

heterodyne detection. Speckle and specular effects for laser illuminated surfaces which have varying degrees of roughness relative to the wavelength of illumination are studied. The general expression for heterodyne imaging including scene information, surface roughness, turbulence, and optics has been derived. A single expression for the speckle and specular components due to scattering from surface has been derived and computer plots of the scattering diagrams have been obtained. The equations and the plots determine the modification to the range equation that must be made to account for specular and speckle effects. The correlation function for the speckle pattern has been obtained and computer plots for various surfaces have been made. The effects of these results on active long-wavelength imaging systems using heterodyne detection are considered. (13 min)

[1] V. J. Corcoran, "Speckle and specular effects in active long-wavelength imaging systems," paper presented at the 1977 Annual Meeting of the Optical Society of America, Toronto, Canada, October 12, 1977 (unpublished).

TuF6. Resolution of Active Long-Wavelength Imaging Systems. V. J. CORCORAN, *Science and Technology Division, Institute for Defense Analyses, 400 Army Navy Dr., Arlington, Va. 22202.*—A previous paper[1] has derived the general expression for the mean current and correlation current from a detector used in an active long-wavelength imaging system. Calculations to determine the relative contribution of the detector current from speckle and specular effects were made. The effect of speckle on resolution has been experimentally determined for a system operating in the visible region for which the surfaces could be considered to be very rough[2]; however, for operation in the far infrared and submillimeter regions the surfaces cannot be assumed to be very rough. At these wavelengths specular as well as speckle effects must be considered. In this paper an analytical expression for the resolution of a long wavelength active imaging system is derived and calculations are made which compare the resolution capabilities of an active imaging system using coherent illumination to a thermal imaging system. (13 min.)

[1] V. J. Corcoran, "Speckle and specular effects in active long-wavelength imaging systems," paper presented at the 1977 Annual Meeting of the Optical Society of America, Toronto, Canada, October 12, 1977 (unpublished).
[2] A. Kozma and C. R. Christensen, "Effects of speckle on resolution," J. Opt. Soc. Am. **66**, 1257 (1976).

TuF7. The Information Capacity of Images with Speckle Noise. G. APRIL AND H. H. ARSENAULT, *Dept. Physique—LROL, Université Laval, Québec, G1K 7P4 Canada.*—Speckle is signal-dependent noise. Expressions are derived for the information capacity of speckle recorded on photographic film, in terms of the size of the integrating aperture scanning the image and of the space-bandwidth product of the image. The information capacity per speckle is found to be a slowly decreasing function of the parameter M, which is approximately equal to the number of speckles in the integrating aperture. (13 min.)

TuF8. Sampling Theorem Characterization of Variation Limited Systems at Reduced Sampling Rates. MICHAEL W. HALL AND ROBERT J. MARKS II, *Dept. of Electrical Engineering, University of Washington, Seattle, Wash. 98195.*—Sampling theorem characterization of linear systems have applications in the areas of space-variant coherent optical processor synthesis and linear digital processing. The output $g(x)$ of a linear system with line-spread function $h(x-\xi;\xi)$ corresponding to an input $u(\xi)$ can be written

$$g(x)=\int_{-\infty}^{\infty}u(\xi)h(x-\xi;\xi)\,d\xi.$$

Under certain band-limiting assumptions on $u(\cdot)$ and $h(\cdot,\cdot)$, the output is band limited and is completely specified by its sample values. These values can be found from the sampling theorem expression[1,2]

$$g(x_m)=\frac{1}{2W}\sum_n u(\xi_n)h(x_m-\xi_n;\xi_n),$$

where $\xi_n=x_n=n/2W$. Here, the sampling rate $2W$ always exceeds the bandwidths of the individual components. We are thus oversampling both the input and line-spread function. This paper explores the case where each component is sampled at a rate corresponding to its individual bandwidth. The result is of the form:

$$g(x_m)=\sum_k\sum_p\sum_q u(\xi_k)h(x_q;\xi_p)I_{qkp}(x_m).$$

The interpolation formula $I_{qkp}(x)$ is shown to have six different forms depending on the relative magnitudes of the three component bandwidths. The tradeoff between this and the previous relation is obviously reduced sampling rate vs reconstruction complexity. The case of space-invariant system sampling theorem characterization at reduced sampling rates is also considered. (13 min.)

[1] R. J. Marks II, J. F. Walkup, and M. O. Hagler, "A sampling theorem for space-variant systems," J. Opt. Soc. Am. **66**, 918 (1976).
[2] R. J. Marks II, J. F. Walkup, and M. O. Hagler, "Sampling Theorems for Linear Shift-Variant Systems," IEEE Trans. Circuits Syst. **CAS-25**, 228 (1978).

TuF9. Optical Transforms of Rough Edges and Gaps.* G. M. MORRIS AND NICHOLAS GEORGE, *The Institute of Optics, University of Rochester, Rochester, N.Y. 14627.*—Diffraction of monochromatic light by rough apertures has been analyzed. Correlation functions for the electric field and the intensity which are valid for large and small roughnesses are presented. In the optical transform plane, the expectation $\langle E_1E_2^*\rangle$ of the electric field is not stationary with respect to transform plane coordinates. This has interesting consequences in using transform plane measurements to determine edge roughness and correlation length. Distinctions between speckle analysis for diffusers and this in-plane case are explained. Edge roughness is established from transform plane measurements along the central spike. Wavelength variations of this spike are also described as an alternate method for measuring edge roughness. For gaps and edges, intensity measurements of the width of the central spike are Fourier transformed to determine the functional form for the correlation coefficient of the roughness. Two classes of rough edges have been fabricated to verify the theory. One group is generated by photographic reduction of computer generated curves with independently controlled roughness and correlation length. These have been particularly useful in verifying the theory. (13 min.)

* Research sponsored in part by the Air Force Office of Scientific Research.

TuF10. Design Considerations for Large On-Line Optical Mass Memories. R. G. ZECH AND H. N. ROBERTS, *Electro-Optics, Harris Corporation, Government Communications Systems Division, P.O. Box 37, Melbourne, Fla. 32901.*—The nonvolatile storage and retrieval of information in optical form has a demonstrated potential for very high storage densities and throughput rates. Current technology makes feasible the recording and readout of binary data in the form of 1 μm spots on 2 μm centers, which corresponds to a storage density of 5×10^5 bits/mm^2, and throughput rates on the order of 100 Mb/s. This is an attractive basis for the evolution of very high capacity optical memories. However, the implementation of such memories requires an analysis of numerous design considerations and tradeoffs and a complete understanding of the most probable applications. We have concluded that, although storage density and throughput rates are important factors, an operationally useful optical mass store at the 10^{13}-bit level or greater will have a large fraction of its data on-line for sake of relatively fast random access and that the overall system will be characterized by high reliability, compatibility with existing computer hardware, and modularity for future capacity expansion. There is also a need for inexpensive, dedicated remote readers and a method for the inexpensive and rapid dissemination of replicas of the original data records stored in the optical memory. These considerations argue for the development of large on-line optical mass memories in a disk or fiche format that provide an optimum compromise between storage density, throughput rate, access time, hardware complexity, replication and dissemination, data integrity,