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SYNTHESIS OF LARGE-APERTURE OPTICS BY SUCCESSIVE EXPOSURE OF A SINGLE PHOTOGRAPHIC PLATE THROUGH SUCCESSIVELY PLACED SMALL-APERTURE OPTICS

PART II. EXPERIMENTAL VERIFICATION

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The theoretical principles described in part I (preceding paper) have been fully born out by the experimental verification described here, as a model.

The experimental arrangement which we used to verify the theory given in part I is shown schematically in fig. 1. The masking apertures used are represented in fig. 2, together with their MTF functions. Fir simplicity, we used a one-dimensional "Sayce" spatial frequency chart, of which an image I_{0C}, photographed through the 'full-frequency' aperture 0C is shown in fig. 3. For simplicity, also, in this experiment, we did not use any weighting factors w_n, so that the synthesized MTF function $T_{SYNTH} = T_{01} + T_{02} + T_{03}$ is made to adequately restore spatial frequency components within the entire range corresponding to the full aperture, without, however, duplicating the MTF function T_{0C} to a full extent. The experimental results are summarized in fig. 3. The synthesized image I_{SYNTH} was obtained according to eq. (18) by superposing in the *same* photographic plate (AGFA Scientia 10E70) successively the component images I_{01}, I_{02} and I_{03}. By comparing the synthesized image I_{SYNTH} to any one of the component images, one may readily see that spatial frequencies missing in I_{01}, I_{02} and I_{03} are indeed "restored" in the synthesized image. Moreover, by comparing the synthesized image I_{SYNTH} to the image I_{0C} taken through the 'full aperture', one may readily see that the 'synthesized' image is comparable in spatial-frequency resolution and contrast to the 'full-aperture' image to a remarkable degree, thus verifying the theory which we gave above.

Because of probable difficulties in reproducing the results in print, we again emphasize, in fig. 4, a missing spatial frequency band in the middle range of the image I_{03}. The missing band is most clearly restored in the synthesized image I_{SYNTH} in the same figure. All the photographic results are reproduced with comparatively high-contrast (Kodabromide F4 paper), for printing purposes. However, we very carefully used a comparatively low-contrast test chart in the actual experiment, in order to maintain the superposition of the three component photographs within the linear part of the logarithmic exposure curve. Additional experimental details are given in the figure captions. It may be in order to add that aperture synthesis in two dimensions, according to our method, using for instance rotating or variably spaced elements, is a simple application of the method which we present here as a model *. Details of our further experimental work, together with additional details will be given in a future publication [1].

* We have successfully verified the principle for the case of a two-dimensional half tone object using a synthesized aperture.

REFERENCE

[1] G.W.Stroke and M.Halioua, in preparation.

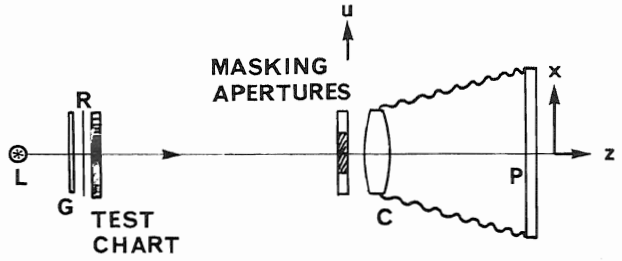


Fig. 1. Schematic diagram of the experimental arrangement used to verify the new principle of 'aperture synthesis' by superposition of component 'small-aperture' images in a single photographic plate. L: white-light source; G: ground glass, R: red filter, C: photographic camera, using a $f = 240$ mm Schneider Kreuznach Symmar lens. The test chart is a one-dimensional variable (logarithmic scale) test chart, with lowest frequency approximately 0.5 mm^{-1}. Length of chart: 90 mm. Length of images of chart on plate P: 13 mm, along the x direction. Details of the masking apertures are given in fig. 2. The apertures are used successively to record the images according to the details given in fig. 3.

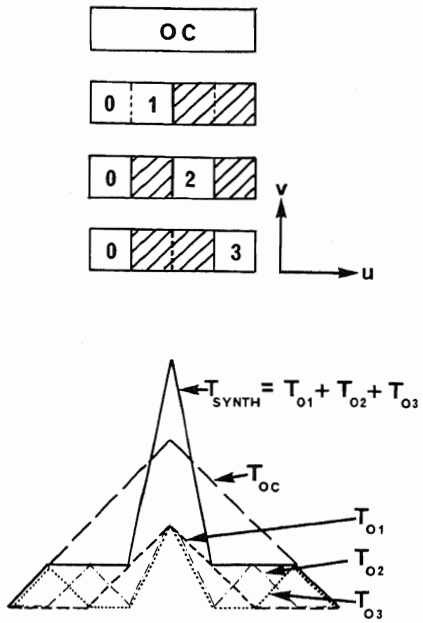


Fig. 2. Masking apertures used for recording images shown in fig. 3 and corresponding MTF (modulation transfer) functions T_{01}, T_{02}, etc. Height of apertures along v: 8 mm, length of aperture 0C along u: 8 mm. (The enhanced length along u is used for graphical clarity.) Dimensions of apertures 0, 1, 2 and 3: height: 8 mm along v, width: 2 mm along u. The modulation transfer functions (MTF) corresponding to the apertures used are shown separated in regions where they overlap, for graphical clarity. The direction u is parallel to the x direction. Each of the MTF functions is generated by a spatial auto-correlation of the corresponding aperture, along the u direction. Note that the "full-frequency" aperture function T_{0C} could be more closely approximated by the synthesized function T_{SYNTH}, when desired, by using appropriate weighting coefficients w_n in the exposure of the "partial-frequency" component photographs, with MTF functions T_{01}, T_{02} and T_{03} (see text, part I).

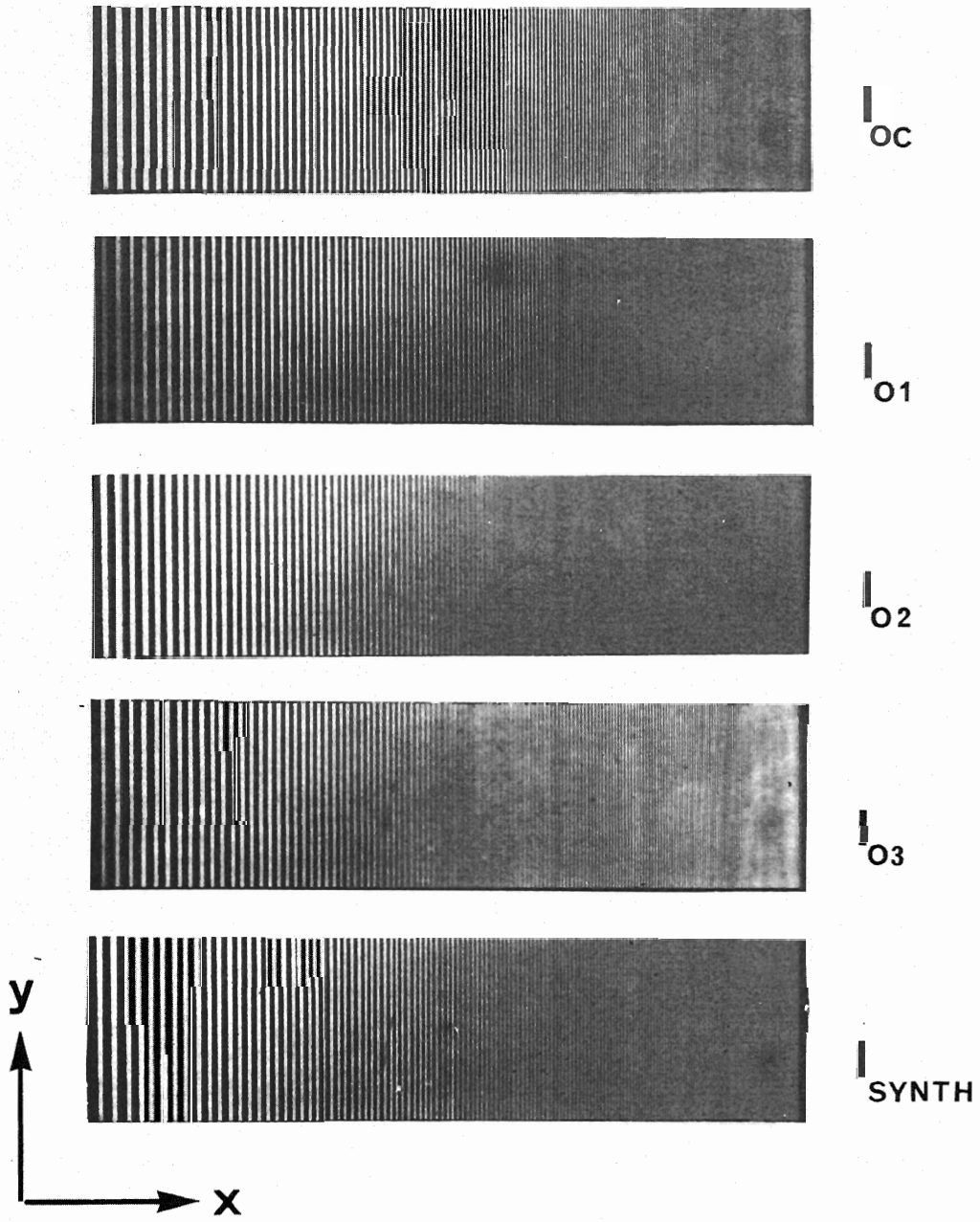
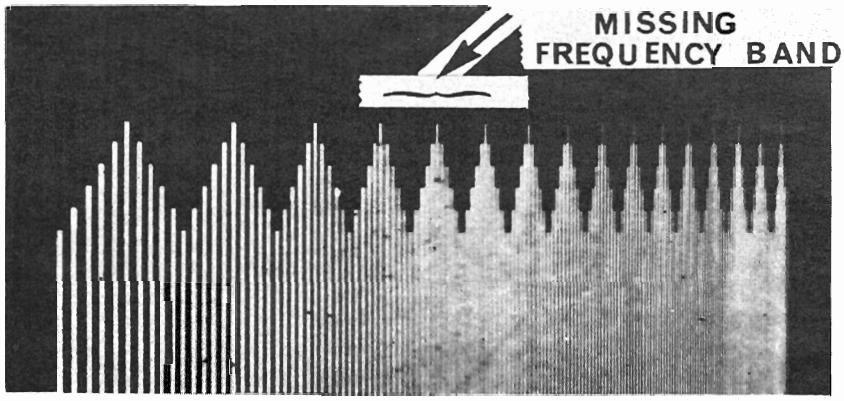
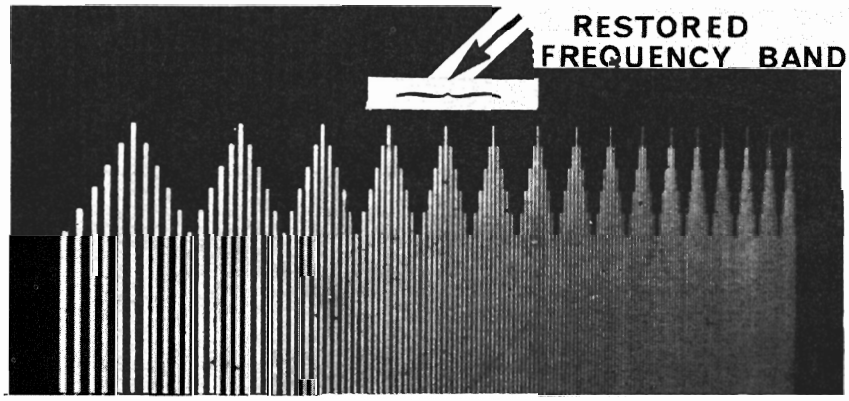


Fig. 3. Photographic enlargements of the images obtained with the apertures and MTF functions shown in fig. 2. The image I_{SYNTH} is the direct superposition, in a *single plate*, of successive exposure to $I_{01} + I_{02} + I_{03}$. Note that spatial frequencies missing in the images I_{01}, I_{02} and I_{03} are restored to a remarkable degree in I_{SYNTH} according to the theoretical prediction given in text (part I). Note also the very faithfull similarity of I_{SYNTH} with I_{0C}, according to the MTF functions of fig. 2. The images I_{01}, I_{02} and I_{03} shown were recorded on separate plates, for the purposes of comparison and illustration.



I_{O3}



I_{SYNTH}

Fig. 4. Photographic enlargements of the images I_{03} and I_{SYNTH}, presented for the purpose of illustrating the restoration of the spatial frequency band in the middle range, which may reproduce well in print. The comparison of the two photographs with the MTF functions of fig. 2 helps to further verify the validity of the new photographic aperture synthesis theory presented in this work (part I).