smaller than that for the Tikhonov restoration of the prior art, provided the desired image satisfies Equation (13).

Computational implementation of image restoration method **10** will be understood by those skilled as follows. The essential idea in the implementation of image restoration method **10** is the use of the discrete Fourier transform to mimic the operations described above in the continuous Fourier transform domain. These computations are fast because of the use of the fast fourier transform to implement discrete Fourier transform operations. The close connection between the continuous and discrete Fourier transforms, under appropriate conditions, is taught in detail in E. O. Brigham, The Fast Fourier Transform, Prentice-Hall, Inc., Englewood Cliffs, N.J., (1974).

Method **10** of the present invention may be performed upon the degraded image $g(x_j,y_k)$ expressed as a digitized $N \times N$ array, where N is a power of 2, and where j,k are integers with $0 \leqq j, k \leqq N-1$. With l the width of the image, let $\Delta x = \Delta y = l/N$ be the sampling interval, so that $x_j = j\Delta x$, $y_k = k\Delta y$. The actual image transformed by image restoration method **10** is assumed to be surrounded by a border of zeroes of sufficient width to eliminate wrap-around errors in discrete convolutions. The $N \times N$ array includes the actual image and its border. The optical transfer function for the imaging process is assumed given by Equation (5A) with known λ_i and β_i. Likewise, the positive constants ϵ, M, K, and s in Equation (14) are assumed to be known on the basis of a priori information.

Referring again to FIG. **1**, reference is made to the identifying numerals of the representation of image restoration method **10** of the present invention. As shown in centering block **12** of image restoration method **10**, the first step is to center the origin in the frequency array. This may be done by forming:

$$g(x_j,y_k) = (-1)^{j+k} g(x_j,y_k),\ 0 \leqq j,k \leqq N-1$$

In forward transform block **14** a forward two-dimensional fast Fourier transform is performed upon $g(x_j,y_k)$ as determined in centering block **12**. The fast fourier transform of block **14** may be performed by forming:

$$G(\xi_m,\eta_n) = \Delta x \Delta y \Sigma_{j=0}^{N-1} \Sigma_{k=0}^{N-1} g(x_j,y_k) \exp\{-2\pi i(mj+nk)/N\},$$

where $0 \geqq m,n \geqq N-1$ and $\xi_m = (m-N/2)/l, \eta_n = (n-N/2)/l$, $l = N\Delta x$.

The inventive filter of image restoration method **10** is then constructed in Fourier space as represented by filter construction block **16**. This filter is constructed with known λ_i, β_i, ϵ, M, K, $s>0$. In order to construct the novel filter of image restoration method **10** let $\omega = \epsilon/M$, $\mu = 1/(1+K\omega)$, and let

$$p_{mn} = \exp\{-\Sigma_{i=1}^{J} \lambda_i (\xi_m^2 + \eta_n^2)^{\beta_i}\},\ \text{for } 0 \leqq m, n \leqq N-1.$$

Then form:

$$G(\xi_m,\eta_n) = p_{mn}^2 G(\xi_m,\eta_n)/\{p_{mn}^2 + (1/\mu K)^2 (1-\mu p_{mn}^s)^2\},$$

where $0 \leqq m, n \leqq N-1$.

In partial restoration block **18** of image restoration method **10**, a partial restoration at t, $0 \leqq t \leqq 1$, is constructed by forming:

$$G(\xi_m,\eta_n) = p_{mn}^{t-1} G(\xi_m,\eta_n),$$

where $0 \leqq m, n \leqq N-1$.

In inverse transform block **20** an inverse two-dimensional fast Fourier transform is performed upon $G(\xi_m,\eta_n)$ which was constructed in restoration block **18**. The inverse transform shown in inverse transform block **20** may be obtained by forming

$$f(x_j,y_k,t) - l^{-2} \Sigma_{m=0}^{N-1} \Sigma_{n=0}^{N-1} G(\xi_m,\eta_n) \exp\{2\pi i(mj+nk)/N\},$$

where $0 \leqq j, k \leqq N-1$. The centering of centering block **12** is then undone in block **22** of image restoration method **10** by forming

$$f(x_j,y_k,t) = (-1)^{j+k} f(x_j,y_k,t),$$

where $0 \leqq j,k \leqq N-1$. Execution of image restoration method **10** may then return to partial restoration block **18** for any other desired value of t.

The result of performing the operations of block **22** is a partial restoration of an image according to image restoration method **10** at the preselected value of t. The user of image restoration method **10** may dispense with partial restoration and proceed directly to full restoration by setting $t=0$ when restoration block **18** is executed.

The scaling of the fast Fourier transforms in blocks **14**, **20** was chosen so as to correspond to continuous Fourier transform operations in a manner well known to those skilled in the art. However, the factor $\Delta x \Delta y$ may be omitted from the forward transform block **14** provided l^{-2} is replaced with N^{-2} in reverse transform block **20**. It is straightforward to modify the procedure so as to handle rectangular $N_1 \times N_2$ images; see e.g., R. C. Gonzalez and P. Wintz, Digital Signal Processing, Second Edition, Addison-Wesley, Reading, Mass. (1987).

The system of method **10** may be implemented with tentative values of some of the parameters λ_i, β_i, ϵ, M, K, s. Image restoration method **10** may be repeated with adjusted values. A sequence of partial restorations as $t \downarrow 0$ is a useful option in that context because noise and ringing usually increase as $t \downarrow 0$. Thus, by performing the restoration in 'slow-motion,' an experienced user may more easily determine the influence of various parameter values and more quickly arrive at corrected values. Tikhonov restoration is obtained by setting $s=0$ in filter construction block **16**.

Image restoration method **10** may be experimentally verified in the following manner. In a simulation of blurring caused by X-ray scattering, an undegraded phantom image $f(x_j,y_k)$ was artificially blurred by convolution with an optical transfer function given by Equation (5). The image, shown in FIG. **3**, consisted of a five hundred twelve by five hundred twelve array, quantized at eight bits per pixel. Blurring was accomplished in the Fourier domain, by multiplying $F(\xi_m,\eta_n)$, obtained as in forward transform block **14** above by $q_{mn} = \exp\{-\alpha([l\xi_m]^2 + [l\eta_n]^2)^\beta\}$, where $\alpha = 0.075$ and $\beta = 0.5$. An inverse Fast Fourier Transform, followed by the operations of block **22**, produces the blurred substantially noiseless image $g_e(x_j,y_k)$ in Equation (2).

Multiplicative noise was simulated by adding 0.1% uniformly distributed random noise to g_e. Thus, $n(x_j,y_k) = 0.001 v_{jk} g_e(x_j,y_k)$, where v_{jk} is a random num-