

United States Patent [19]**Kott**[11] **3,774,997**[45] **Nov. 27, 1973**[54] **FILTER ARRANGEMENT**[75] Inventor: **Michael A. Kott, Marlboro, Mass.**[73] Assignee: **AAI Corporation, Cockeysville, Md.**[22] Filed: **Oct. 21, 1971**[21] Appl. No.: **191,468****Related U.S. Application Data**

[63] Continuation of Ser. No. 888,264, Dec. 29, 1969, abandoned.

[52] U.S. Cl. **350/314, 250/237 R**[51] Int. Cl. **G02b 5/20**[58] Field of Search **350/162 SF, 205, 350/314, 319; 250/237**[56] **References Cited****UNITED STATES PATENTS**

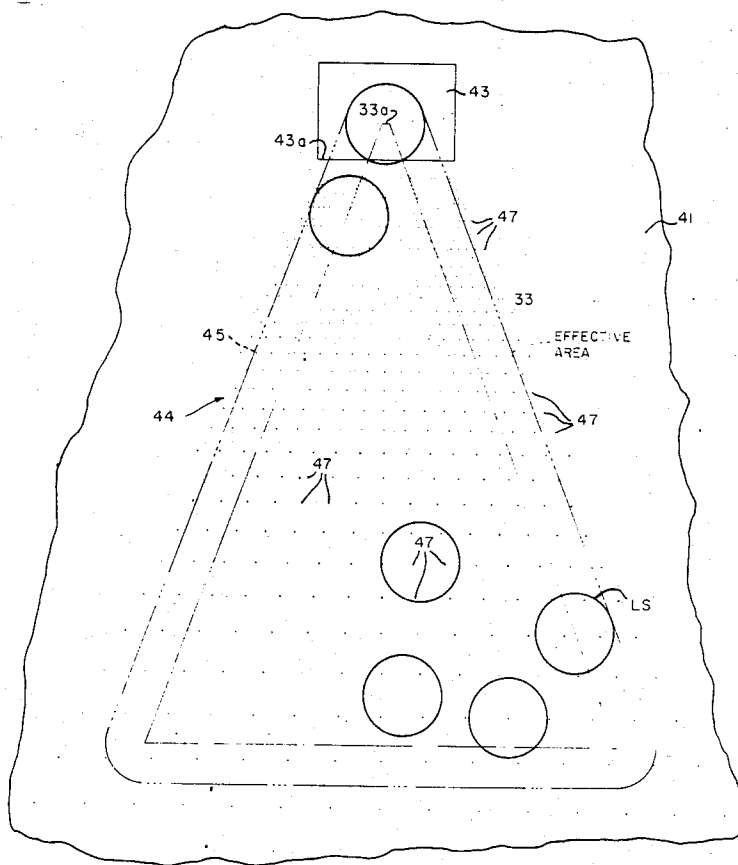
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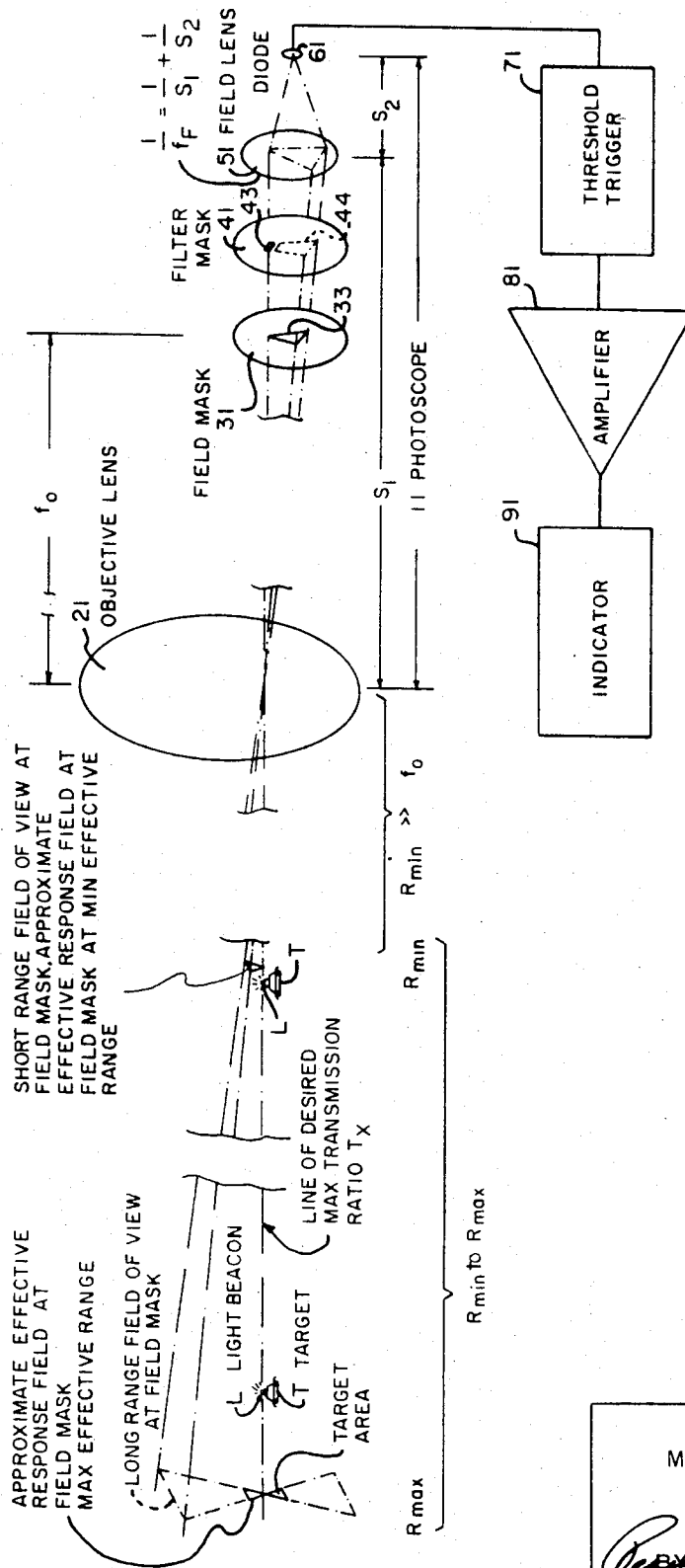
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[57]

ABSTRACT

A graduated digital analog filter which may be employed in a hit indication system for a target having a light transmission source, in which the digital filter may be disposed in a photoscope of a light detection source and in which the digital analog filter serves to effect variation in transmitted energy from the target light source to the light detection device of the photoscope as a function of the accuracy of aiming of the photoscope toward the target.

22 Claims, 6 Drawing Figures



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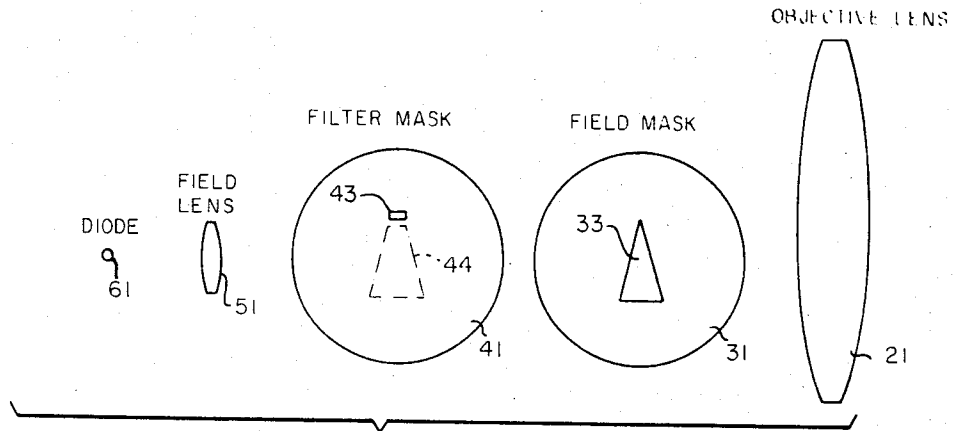


FIG. 2

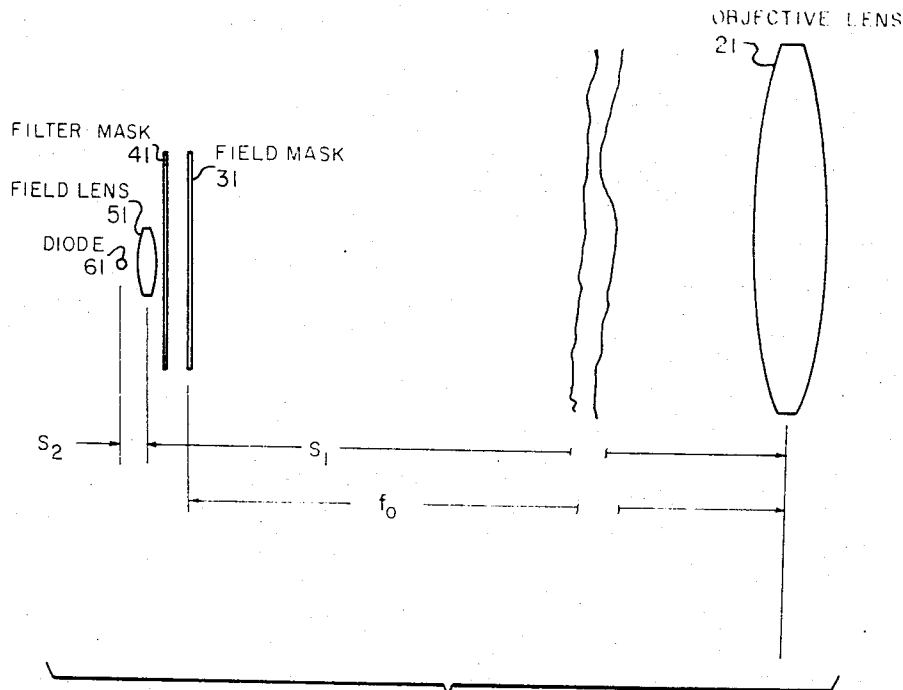
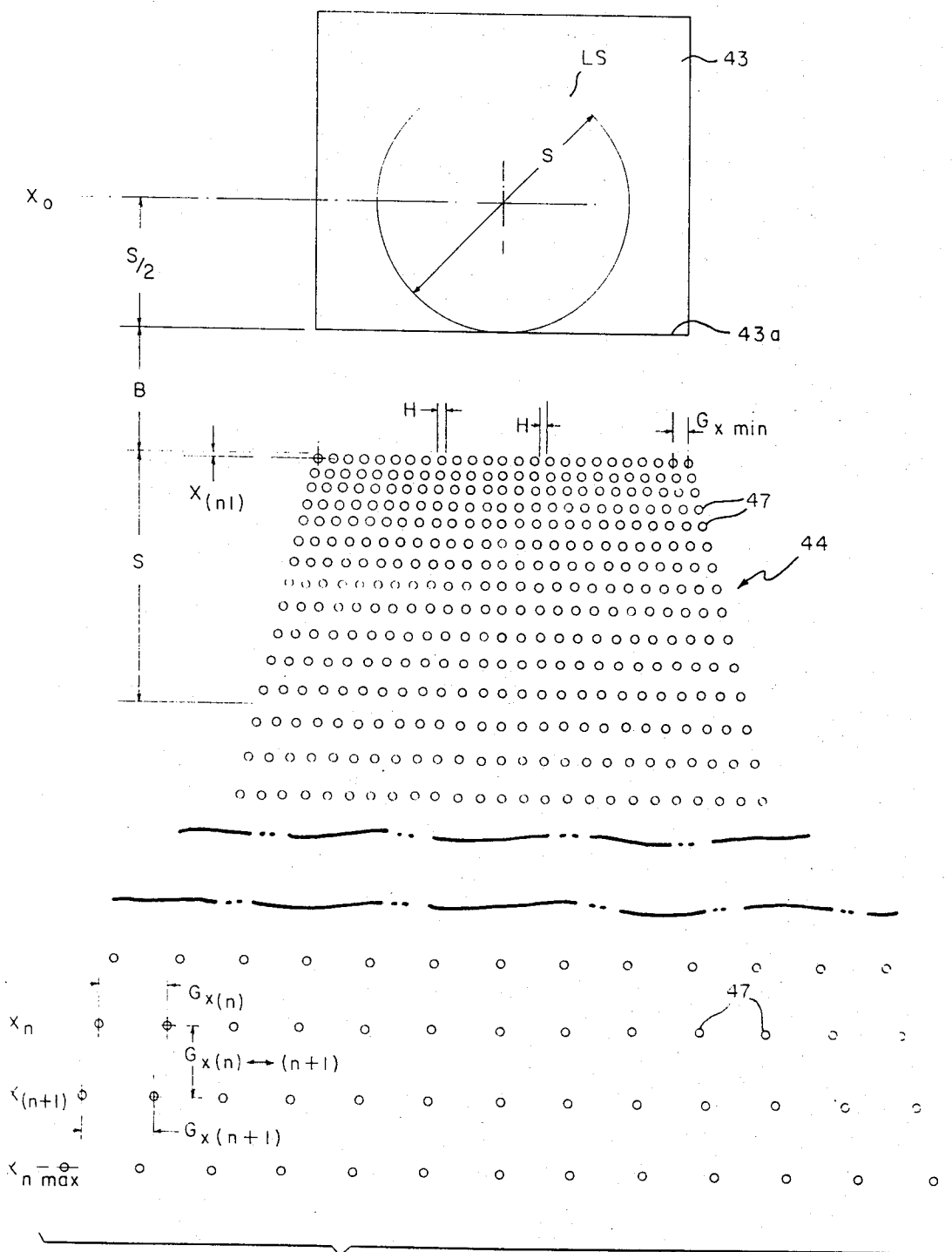


FIG. 3

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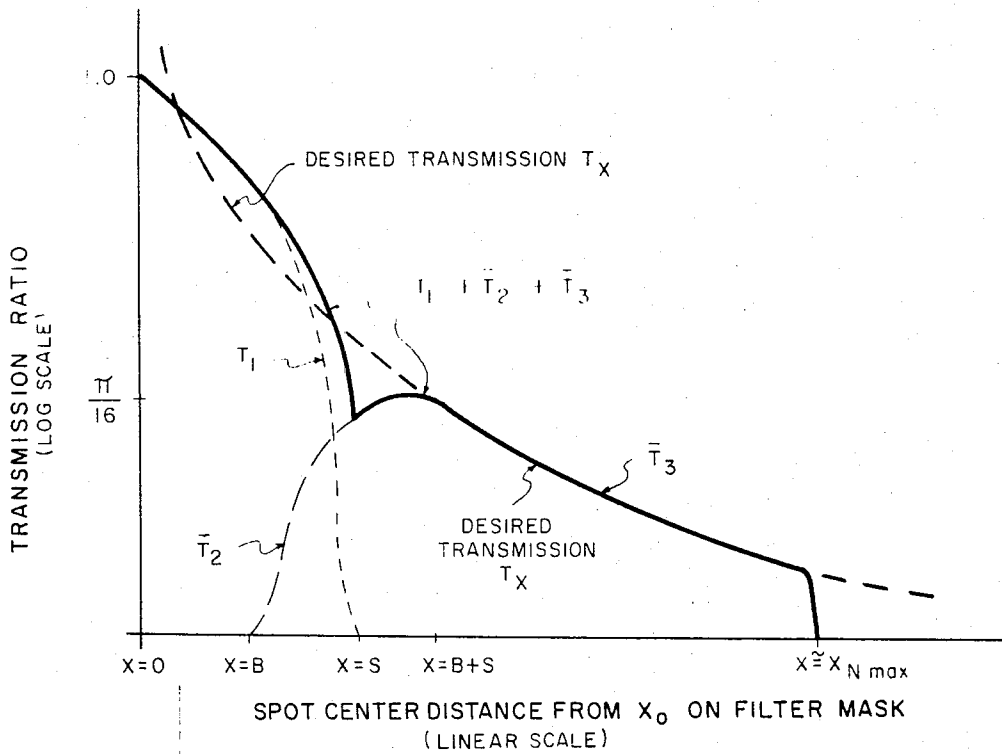
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EXAMPLE OF EFFECTIVE WORKING ZONE AT MASK

EXAMPLE OF WORKING ZONE AT MASK MIN RANGE $R_{\min}$

EXAMPLE OF ZONE AT MASK FOR MAX RANGE $R_{\max}$, FOR $R_{\max} \approx 15R_{\min}$

FIG. 6

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FILTER ARRANGEMENT

This is a continuation of application Ser. No. 888,264, filed Dec. 29, 1969, now abandoned.

This invention relates to a graduated digital or digital-analog filter, and which is particularly useful in hit detecting arrangements which are used in indicating the occurrence of hits upon a target which has a light source detectable by the detecting arrangement.

The filter may theoretically be a digital filter in entirety, but may as a practical necessity be a combined analog and digital filter. The degree of combination of the digital and analog filter portions of the filter is generally a practical matter, depending to a substantial degree upon the materials and techniques employed in forming the mask. In the use of the filter in a hit detecting arrangement, the general function of the filter is to enable the detecting system to accommodate the target signal attenuation which occurs proportionately to the square of the distance of the target from the detecting device, while enabling the detection of hits within a varying aiming angle as an inverse function of the target distance from the detecting device.

Still other objects, features and attendant advantages will be obvious to those skilled in the art from a reading of the following detailed description of a preferred embodiment constructed according to the invention, taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a schematic illustration of a hit detecting and indicating arrangement and incorporating one embodiment of the novel filter according to the invention.

FIG. 2 is a schematic view of the basic elements of the hit detecting arrangement of FIG. 1, and illustrating schematically the relative sizes of these elements.

FIG. 3 is a schematic illustration of the elements of FIG. 2, illustrating the relative axial distance spacing thereof.

FIG. 4 is a fragmentary face view of the novel filter unit according to the invention, and illustrating various light pattern aspects with respect thereto.

FIG. 5 is a greatly enlarged schematic illustration of the hole area forming the filter section of the filter unit of the preceding figures.

FIG. 6 is a generalized diagram illustrating various transmission curves with respect to a filter according to the invention.

Referring now in detail to the figures in the drawing, a photoscope generally indicated at 11 is provided for detecting the ability of an operator to aim the photoscope at a target T, such as a tank vehicle, which is provided with a detectable target signal generating means, such as a light beacon L. The light beacon L may generate a light beam which is in the visible or invisible spectrum, as may be desired, and which is detectable by the photoscope when properly aimed thereat, as will be later described. The light beacon L may be continuously generating its light beam, or may be triggered to generate such by the operator of the photoscope, as through the employment of a further signal and response system, which does not itself form a part of the present invention, and which may be of a type such as disclosed in U.S. Pat. Nos. 3,104,478 and 3,169,191.

It is desired that the photoscope 11 be capable of detecting simulated hits on the target T over a substantial range of distances of the target T from the photoscope 11. As the light beacon L is normally of constant intensity, it will be apparent that the light reaching the pho-

toscope will vary generally inversely to the square of the distance of the target T from the photoscope, and in addition there are atmospheric attenuations which it may be desirable to accommodate for given situations. The primary variation of amplitude of the light signal reaching the photoscope 11 from the target T and its light beacon L is caused by the inverse square variation as a function of range of the target, and this invention is primarily directed toward accommodating this variation, although it will be appreciated that other variations may be generally accommodated, within limits, by the invention.

The photoscope 11 includes an assembly of elements which may be suitably housed within a tubular or other housing, which is not shown, as such itself does not form a part of this invention and may be readily formed by one skilled in the art. The primary elements of the photoscope 11 are an objective lens 21 which collects light from the light beacon L, a field mask 31, a filter mask 41, field lens 51 and photodiode 61. The objective lens 21 and the field lens 51 may each suitably be convex-convex, and the spacing of the elements 21-61 of the photoscope 11 is such with respect to the objective and field lenses that the focal length f_o of the objective lens is equal to the center-to-center distance between the objective lens and the field mask 31, with the focal length f_f of the field lens being defined by the following equation:

$$1/f_f = 1/S_1 + 1/S_2$$

where

S_1 is the center-to-center distance between the objective lens 21 and the field lens 51, and

S_2 is the distance between the center plane of the field lens 51 and the detecting face of the photodiode 61.

Thus, the light collected by the objective lens 21 will be focused at the plane of the thin (e.g., 0.001 in.) field mask 31, and this circular pattern of light will converge to its smallest substantially point size at the field mask 31. The light beam diverges and is enlarged as it passes rearwardly away from the field mask 31, and has a discrete generally circular spot size S at the plane of the filter mask 41. For purposes of discussion hereinafter, this light beam spot at the plane of the filter mask 41 will be designated as LS, and, as noted, such spot LS will have a finite size S , which is a function of the focal length spacing f_o between objective lens 21 and field mask 31, the diameter of lens 21, and the spacing between field mask 31 and filter mask 41. For a given objective lens focal length f_o and corresponding interspacing between the objective lens 21 and field mask 31, the filter mask 41 may be spaced rearwardly of the field mask 31 to achieve a desired size S for the light spot LS from the target light beacon L.

Connected to the output of the photodiode 61 is a threshold trigger 71 which may suitably be a Schmitt trigger circuit, which in turn is connected to an amplifier 81 and indicator 91. The threshold trigger circuit 71 may suitably be selectively set to enable the indication of the presence of hits detected by the photoscope 11 as indicated by the presence at the diodes 61 of at least a given selected minimum quantum of light energy on the effective surface of the diode 61 after passing through the photoscope 11. This setting may readily be made on an empirical trial basis, if desired.

In the photoscope 11, the field lens 51 accepts all light energy reaching such and which has passed through the assembly of the objective lens 21, field mask 31 and filter mask 41, and images this collected, masked and filtered light from the objective lens onto the face of the diode 61. In this manner the diode 61 may be made relatively small as compared to what would otherwise be required without the employment of the field lens 51.

The light collected by the objective lens 21 is masked and filtered by the field mask 31 and filter mask 41 respectively, prior to passing through the field lens 51 and being imaged onto the diode 61. The field mask 31 has a triangular aperture 33 formed therein, and generally aligned with this triangular aperture 33 is a digital-analog filter section 43, 45 on the filter mask 41. The triangular aperture 33, taken in conjunction with the focal length of the objective lens 21 and the spacing of the filter mask 41 from the field mask 31, defines the maximum overall field of view as such appears at the filter mask 41. As is generally schematically illustrated in FIG. 1, the physical dimensional triangular field of view through the field mask 31 is directly proportional to the range of a target from the photoscope 11. It will be appreciated that inasmuch as the target T is of constant size, such increasing physical dimensional field of view effected by the field mask 31 would itself alone result in a variable error in hit indication at all ranges other than some given single range, the degree of error being a function of the actual range relative to this given range. The desired effectively detected field of view through the field mask should be substantially constant for all ranges, over the working scope of target ranges and the general configuration of the triangular aperture 33 should generally conform to the acceptable hit pattern over the given target T, this triangle being effectively inverted in form as indicated in FIG. 1 at the zone of the target, to thereby define the maximum zone within which the light beacon L may be located while still enabling the registry of a hit by the diode 61, threshold trigger 71, amplifier 81 and indicator 91.

The field of view at the field mask is modified to form the effectively detected, or effective, field of view therethrough, by the incorporation of filter 41, by which the quantum of light energy within the light spot LS is attenuated generally as a function of the displacement of the light spot LS downwardly from the apex of the triangular aperture 33. For inverse square light attenuation compensation, this variation in attenuation is desirably directly proportional to the square of the x-axis displacement of the center of the spot LS from its base or origin point which latter point is the point of focus of the light beam at the precise upper apex of the triangular aperture 33 in field mask 31. This will yield a transmission ratio through the filter mask 41 which would vary inversely as the square of the displacement of the center of the spot LS from its zero position. This theoretical zero position may, if desired, correspond to the actual position of the light spot LS when the photoscope is precisely axially aligned with the target light beacon L or the theoretical zero position may be offset upwardly if desired or necessary in a given instance. It will be appreciated that by employing such a variable transmission ratio through the filter mask 41, this enables accommodation of the variation in light received by the objective lens 21 as an inverse square function of the range of the target T from the lens 21, as the ap-

proximate effective triangular aperture portion of the field mask aperture 33 may thus be proportionately decreased inversely proportional to increase in range of the target T, and directly proportional to angular change in angular field of view of the target T, as generally indicated at positions R_{min} and R_{max} in the schematic illustration of FIG. 1.

The effective working zone at the field mask or the filter mask may be defined as the zone over which the target light source L may be imaged at the field mask, or the filter mask respectively, and yield transmitted light spot energy from the target light beacon L through the filter mask and field lens to the diode, which transmitted energy value is above that which would enable the diode to trigger the trigger circuit for a given threshold setting for the trigger circuit.

It is theoretically possible to employ a direct analog photoemulsion mask of varying transmission density for the filter mask 41 in order to achieve this result, although in actual practice such is quite difficult and expensive to carry out on a uniform or reliable basis, and such a photoemulsion filter also normally has the substantial disadvantage of changing with the passage of time, as is characteristic of developed film emulsions. Thus, although the photographic filter mask 41 with smoothly varying density and transmission ratio is theoretically feasible and in this respect theoretically most desirable according to the broad aspects of the invention, such is in actual practice difficult to achieve. I have found that a practically suitable filter mask 41 can be formed in a substantially different and practically satisfactory manner, and which may from a generally practical standpoint sufficiently approximate the desired transmission ratio curve T_x , where

$$T_x = K(1/x^2)$$

in which x is a function of the displacement of the light spot LS from its base or origin point, and K is a constant multiple. The filter section of mask 41 is generally indicated at 43, 44, 45, and is formed by a relatively large light passing aperture 43 having an edge 43a which forms an optical knife edge, and a plurality of sets of relatively much smaller apertures or holes 47 which may be, and are desirably from a practical standpoint, of constant diameter and which vary in spacing therebetween as a function of the distance x of succeeding rows of such holes from a zero point or line corresponding to the position of the spot LS at the point of tangency of the spot LS with the knife edge 43a. The formation of the holes 47 may be readily achieved in the middle and lower zones of the hole section 44, but it will readily be appreciated that if physical holes are to be physically formed in a sheet of material, which is the preferred manner of formation and construction, there is normally a practical limit beneath which it becomes extremely difficult, if not practically impossible, to consistently form substantially uniform holes 47 in the sheet forming the filter 41. From a practical standpoint in relatively thin sheets (e.g., 0.001 inch) this has been determined to be approximately that spacing where the minimum center-to-center distance $G_{x_{min}}$ between holes is equal to $2H$, where H is the diameter of the holes in the section 44, and G_x is the center-to-center spacing between adjacent holes generally. Thus, in the zone of the projected apex of field mask triangular aperture 33, the employment of holes 47 in the filter mask 41 reaches a practical impos-

sibility when such are physically formed in the desired structural hole method and construction. In the case where a photographic emulsion density method is employed for formation of these light passing (or blocking or attenuating, in such case) apertures 47 on a substrate such as plastic, glass or the like, with the remaining surrounding zone being uniformly opaque or of other substantially different optical transmissivity, it will be appreciated that, dependent upon grain size of the developed emulsion, the mask 41 may be formed with such photographic apertures 47 disposed even closer together, and accordingly with a very fine grain emulsion one might conceivably have such apertures 47 extend substantially to the upper apex position of the spot LS as it passes through the apex of triangular aperture 33 and onto the filter mask 41. Such is within the contemplated extent of my invention, but as before mentioned, such is normally not preferred, particularly in view of the practical difficulties encountered in the photographic emulsions changing their density and transmission characteristics over a period of time.

A suitable practical solution to this difficulty has been achieved by employing a knife edge signal attenuation transition zone in the zone above the upper row of holes 47 which are at the minimum interhole spacing $2H$. It has been found that the combination of transmission ratio curves as the spot LS is displaced axially from its zero point indicated in FIG. 5 at X_0 where the spot is tangential to the knife edge 43a of large aperture 43, downwardly along the x axis and onto and along the digital hole section 44, may be made to generally approximate for practical purposes the desired transmission ratio curve T_x for a given range of target distances $R_{min} - R_{max}$.

As the light from target beacon L passes through its focal point in the plane of triangular apertured field mask 31, and subsequently converges to form a spot LS in the plane of digital mask 41, it will be appreciated that the total effective light transmission area of the filter mask 41 will be determined by the size of triangular aperture 33, the spacing of this mask 31 and mask 41, the diameter of lens 21, and the focal length f_0 , and for a given size S of spot LS, the effective area of filtering of signals from the target T may be indicated by the broken line 44 which extends beyond the directly superimposed outline of the triangular aperture 33, by an amount equal to $S/2$. Thus, the zone over which the holes 47 are formed is desirably larger than the effective filter area outline pattern 45 by a small amount sufficient to provide desired hole spacing within the effective filter pattern area 45.

Taking the transmission ratio curve T_1 which results from displacement of the light spot LS from point zero, designated in FIG. 5 as x_0 , vertically downwardly along the space in the zone from $x = 0$ to $x = S$, at which lateral position the light spot LS is completely beneath the knife edge 43a, and ignoring the light transmission through the digital hole section 44, the transmission ratio T_1 for this zone of spot travel may be defined as

$$T_1 = 1/\pi [\pi - \arccos (S - 2x/S) + \frac{1}{2} \sin 2 \arccos (S - 2x/S)]$$

and this equation being applied for values of x from $x = 0$ to $x = S$, only.

Considering next the average transmission ratios $\bar{T}_2$ and $\bar{T}_3$ as the light spot LS is traversed along the x axis over the digital hole filter section 44, the following as-

sumptions and practices have been found to be practical in order to provide a combined curve $T_1 + \bar{T}_2 + \bar{T}_3$ which generally approximates the desired transmission curve T_x , which latter curve T_x is generally illustrated in FIG. 6 in broken line and is so indicated. These assumptions include:

G_{x_n} = center-to-center hole spacing along the Y-axis for any given row of holes at a distance x_n from point or line x_0 , line x_0 being the X-axis location at the center of spot LS when the lower edge of the spot is tangential to the knife edge 43a of aperture 43.

$G_{x_{min}} = G_{x_1}$ = minimum center-to-center hole spacing of row of holes 47 nearest knife edge, at distance x_1 from line 0.

$G_{x_{max}} = G_{x_{n_{max}}}$ where $G_{x_{n_{max}}}$ is the last line of holes farthest spaced from the knife edge 43a, and represents the greatest centerhole spacing for a given digital hole filter zone 44, independent of other cutoff values which may be effected by the field cutoff boundary of field aperture 33.

H = hole diameter for all holes 47

$G_{min} \approx 2H$ as a practical lower limit

S = diameter of light spot LS $x_{n_{max}} \gg S \gg H$

For practical purposes the filter mask 41 is formed of thin metal (e.g., 0.001 inch thickness) which is opaque, thus rendering the transmission ratio of filter mask 41 equal to zero at all zones other than hole zones formed by holes 43 and 47, and within such holes the transmission through any given hole area is assumed to be unity. It will be appreciated that both of these extremes may be modified respectively by using different transmission density material for the sheet forming mask 41, and less than 100 percent transmission through the island zones of hole 43 and/or 47, as with a purely developed emulsion film mask 41. For purposes of approximating the average transmission value $\bar{T}_x$ a generalized equation may be derived, based on the assumption that interhole spacing G in both the X- and Y-directions approximates a square of substantially uniform size over the circumferential zone of the spot LS.

It will be seen that for a matrix of holes with such a uniformly equal square inter-hole spacing of the holes

$$\bar{T} = (\pi H^2 / 4G^2)$$

the value $\bar{T}$ being the average transmission ratio through the gridwork of holes in an opaque sheet, the size of the error of $\bar{T}$ being inversely proportional to the value of $(S - H)$ and directly proportional to G .

This theoretical gridwork is not found in the desired digital filter zone 44 having holes 47 therein, as the interhole spacing is varied as a function of the distance of a given line of holes from line x_0 in order to approximate the desired inverse square light transmission compensation. However, for relatively large values of S with respect to H and G , with relatively small changes of G with respect to itself from line to line, it will be appreciated that this approximation equation $\bar{T}$ may be applied advantageously to the gridwork of holes according to the present invention, it being recognized that the greater the value of G the larger will be the possible error in the value $\bar{T}$, for any given value of S as the diameter of the spot LS. Based on this assumption, for a given transmission $\bar{T}_x$ in the zone of the row of holes at x_n distance from line or point x_0 , an approximation value for $\bar{T}_{x_n}$ may be derived as

$$\bar{T}_{x_n} \approx [\pi H^2 / 4(G_{x_n})^2]$$

correspondingly,

$$G_{x_n} \approx \sqrt{\frac{\pi H^2}{4\bar{T}_{x_n}}}$$

Where G_{x_n} is the center-to-center hole spacing along the Y-axis at the row of holes x_n distance from x_0 . Thus, given the desired transmission ratio T_x for a given line position x_n on the mask 41, and assuming $T_x \approx \bar{T}_{x_n}$ at the light zone involved, it will be seen that the interhole spacing G_{x_n} may be derived for the particular line position x_n .

The inter-row spacing of adjacent rows of holes along the X-axis may be determined in various ways, as desired, the simplest method being to obtain first the Y-axis value (i.e., $G_{x_{n_1}}$) of G_{x_n} for the row of holes closest to the knife edge 43a, which value may be generally determined for any given hole size, from the foregoing practical assumptions. For this purpose, the value $\bar{T}_{x_{n_1}}$ is selected to be that value which will complement another curve $\bar{T}_2$ to be subsequently described in more detail hereinafter, for the given selected distance x_{n_1} , the value x_{n_1} of which will likewise be selected on a trial and error basis with this view in mind.

After arriving at the value $G_{x_{n_1}}$, one acceptable and simple method of arriving at the x distance spacing of the next succeeding line of holes, where $G_{x_{n \rightarrow (n+1)}}$ for any two successive rows represents this inter-row spacing for any two successive rows where the rows are at x_n and x_{n_1} distance from x_0 , is to make $G_{x_{n \rightarrow (n+1)}}$ equal to the value of G_{x_n} . Thus, once the x location of the first line of holes is established, all succeeding lines may be readily located.

Alternatively, the inter-row spacing $G_{x_{n \rightarrow (n+1)}}$ may be increased as a function of the interhole spacing G_{x_n} and $G_{x_{(n+1)}}$ for the respective two adjacent rows of holes. In this respect, this inter-row spacing may be made approximately equal to the average of the values G_{x_n} and $G_{x_{(n+1)}}$ for the respective two adjacent rows of holes, and which may be written as

$$G_{x_{n \rightarrow (n+1)}} \approx \frac{G_{x_n} + G_{x_{(n+1)}}}{2}$$

If this latter relationship is assumed, rather than the simpler former relationship of

$$G_{x_{n \rightarrow (n+1)}} = G_{x_n}$$

it will be appreciated that repeated trial and error calculations may be employed to determine the desired values of $G_{x_{n \rightarrow (n+1)}}$ for succeeding rows, as this inter-row value will be dependent upon both values G_{x_n} and $G_{x_{(n+1)}}$ for succeeding rows of holes, by definition, and these values are in turn dependent on the x distance location of the respective rows of holes 47 from x_0 . This particular manner of incremental variation of $G_{x_{n \rightarrow (n+1)}}$ best lends itself to solution by computer programming, particularly in view of the requisite trial and error method of solution, although it will be apparent that such may be derived by repeated hand calculations on a trial and error basis in order to get a desired degree of approximation of the desired curve G_x .

These assumptions further include the assumption that in the zone between the first row of holes 47 lying

closest to the knife edge 43a, and extending over an x distance of S , the holes may be assumed to be generally equally spaced from a generally practical approximation standpoint, although in fact the holes are disposed with increasing spacing over this zone, and the resulting curve $\bar{T}_2$ in this area in fact assumes a lesser transmission ratio amplitude and curve slope as x approaches the value of $B + H$, than is otherwise shown by the assumed approximation. However, from a practical standpoint this is not a serious deficiency, as the entire curve is itself only an approximation, and this degree of error may as a practical matter be acceptable in various instances. This assumption for the purpose of deriving the transmission ratio curve $\bar{T}_2$ as the spot LS first moves onto and subsequently fully onto the hole area applies for the values of x from $x = B$ to $x = B + S$, where B is the distance between the knife edge 43a and an imaginary line tangential to the facing side of the first row of holes 47 at position x_{n_1} . Considering the closely spaced hole zone between $x = B$ and $x = B + S$ as a filter having a generally constant density with an effective light transmission ratio $T_{H_{KEH}}$ of less than 1, and having a general knife edge formed by the first row of holes at line x_{n_1} , $\bar{T}_2$ may be generally approximated as

$$\bar{T}_2 = (\bar{T}_{KEH}) (\bar{T}_{H_{KEH}})$$

where $\bar{T}_{KEH}$ represents the approximate equation for translation for the spot LS over a knife edge transition zone from zero transmission into an adjoining zone of full transmission, and where $T_{H_{KEH}}$ represents the equation for the approximate transmission ratio of this initial hole filter zone, based on the assumption that the entire zone has a transmission ratio corresponding to some given interhole spacing, which for purposes of simplicity and practicality of computation is assumed to be equal to the interhole spacing of the first line of holes at x_{n_1} closest adjacent to the knife edge 43a. The equation for $\bar{T}_{H_{KEH}}$ may be approximated generally as

$$\bar{T}_{H_{KEH}} = [\pi H^2 / 4(G_{x_n})^2]$$

and for the assumed value of $G_{x_n} = 2H$

$$\bar{T}_{H_{KEH}} \approx \pi/16$$

This value $\pi/16$ represents the transmission ratio modifier which is necessary in order to convert the knife edge equation $\bar{T}_{KEH}$ to the actual approximate curve for the situation where the transmission ratio beneath the knife edge is not unity, but is in fact $\bar{T}_{H_{KEH}}$, which is under the present assumptions approximately equal to $\pi/16$.

The generalized equation for the transmission ratio $\bar{T}_3$ along the remaining portion of the digital hole filter area 44 may be written as

$$\bar{T}_3 \approx [\pi H^2 / 4(G_{x_n})^2],$$

and is to be applied for values of x from $x = B + S$ to $x \approx x_{n_{max}} + S$, assuming that the light spot LS may be translated over this total area, which of course may be modified as a total by effective lateral field limits imposed by the boundary of triangular field aperture 33.

Thus, the equations $\bar{T}_2$ and $\bar{T}_3$ combine to form the generalized approximate equation for the transmission ratio of the digital hole filter zone 44, and the combined transmission ratio curve for these generalized equations is indicated at $\bar{T}_2$ and $\bar{T}_3$ on the graph of FIG. 6, in which $\bar{T}_2$ represents the curve between values $x =$

B and $x = B + S$ and $\bar{T}_3$ represents the curve portion which extends between the values of $x = B + S$ to $x \approx x_{N \max} + S$.

Referring further to FIG. 6, it will be seen that the curve $\bar{T}_3$ drops off abruptly in the zone where $x \approx x_{N \max}$, where $x_{N \max}$ is the field cutoff boundary line effected by the lower edge of the triangular field aperture 33. In addition, it will be noted that in the zone between $x = 0$ and $x = B + S$, the combined average transmission ratio curve $\bar{T}_1 + \bar{T}_2 + \bar{T}_3$ differs in varying amounts from the desired transmission ratio T_x . This variation may be tolerated for practical purposes, although it will be apparent that if so desired the hole spacing and/or the value of B may be modified to bring the curve in this portion into closer relationship to the desired transmission ratio curve T_x , this latter being capable of accomplishment by further trial and error computation, or by analogous computer programming if so desired. The curve $\bar{T}_3$ may be made to closely approximate the desired transmission ratio T_x in the zone from $x = B + S$ to $x = x_{N \max}$ inasmuch as the interhole spacing may be adjusted from row to row as noted in the discussion above, although it will be readily appreciated that this average transmission value is in fact only average and that for any given position of the spot LS within this zone a degree of error may be present, as the filter system in this zone is in fact a positionally varying digital approximation of the desired analog curve.

As an illustration of a practical example which has been derived by repeated trial and error calculations according to the invention, a metal mask 41 has been derived and employed with a sheet thickness of 0.001 inch, and on which the diameter S of the light spot LS is 0.050 inch, the spacing $B = 0.0115$ inch, the hole size H of holes 47 $= 0.001$ inch, and as a practical method of reliably forming and locating the upper apex edge zone of the triangular field cutoff aperture 33 such has been formed with a minute flat across the apex (e.g., 0.002 - 0.005 inch) and this flat apex field stop at the apex of triangular field aperture 33 is disposed slightly below (e.g., 0.003 - 0.004 inch) line x_0 (as discussed in connection with FIG. 5), thereby effectively shifting the beginning operational zone for values of x in the approximation curve $\bar{T}_1 + \bar{T}_2 + \bar{T}_3$, as noted schematically in FIG. 6, this being also somewhat desirable in view of the relative poor quality approximation of the curve T_x in the zone adjacent x_0 with respect to theoretical zero position line x_0 . In the specific illustrative value example this initial displacement and effective beginning operational zone has been located at $x = 0.003$ inch.

While the invention has been described with respect to a preferred physical embodiment constructed in accordance therewith, it will be apparent that various modifications and improvements may be made without departing from the scope and spirit of the invention. Accordingly, the invention is not to be limited by the particular illustrative embodiment, but only by the scope of the appended claims.

That which is claimed is:

1. A graduated digital/analog composite concurrent use filter for space-traversable signals of essentially discrete cross-sectional configuration, comprising:

a unit having a first variable-signal-attenuation base zone formed by a grouping of a plurality of spaced discrete unit zones, each having a first substantially identical signal attenuation characteristic, interspersed within a base zone having a second signal

attenuation characteristic different than said first signal attenuation characteristic,

the spacing of said spaced zones varying in increasing interspatial distance as a function of increase of their spatial distance from a reference point or zone,

and a further laterally adjacent base zone of different signal attenuation characteristic from, and being laterally nearer to said reference point or zone than, said first base zone,

said further base zone being laterally spaced from said plurality of spaced zones and being grossly larger in area than the individual ones of said plurality of spaced zones and having a signal attenuating characteristic in the zone therewithin substantially less than the overall signal attenuation characteristic of that portion of said first base zone grouping of plural spaced zones nearest to said further base zone,

said two base zones being disposed and exposed for both separate and concurrent composite variable filtering action on a said discrete cross-section signal which is of smaller cross-sectional configuration than either of said base zones, which said filtering action is a function of the instant lateral position of a said discrete cross-section signal.

2. A graduated composite concurrent use filter according to claim 1,

the spacing of said further base zone from the nearest thereto of said first base zone plurality of spaced zones being greater than the individual interspatial spacing of the nearest of said plurality of zones and an effectively generally knife edge signal transmission attenuation transition zone defined between said further zone and the second said zone of different signal attenuation characteristic.

3. A graduated composite concurrent use filter according to claim 1,

said first base zone having a plurality of said spaced zones therein forming an effectively generally knife edge signal transmission attenuation transition line adjacent said further base zone for a signal having a greater breadth than the spacing of said spaced zones.

4. A graduated composite concurrent use filter according to claim 3,

said further zone being an aperture defined on one lateral edge by an effectively knife edge wall line.

5. A graduated composite concurrent use filter according to claim 1,

said unit having effective signal transmission apertures formed therein, said plurality of spaced zones being defined by the boundaries of respective said apertures in said unit.

6. A graduated composite concurrent use filter according to claim 5,

said first signal attenuating characteristic being materially substantially uniformly less than said second signal attenuating characteristic.

8. A graduated composite concurrent use filter according to claim 1,

one of said first and second signal attenuating characteristics being effectively substantially full attenuation and the other being substantially zero signal attenuation.

9. A graduated composite concurrent use filter according to claim 1,

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said plurality of spaced zones being of effectively substantially constant size over said zone of greater attenuation.

10. A graduated composite concurrent use filter according to claim 9,

said further zone being an aperture defined on one lateral edge by an effectively knife edge wall line.

11. A graduated composite concurrent use filter according to claim 1,

said further zone being an aperture defined on one lateral edge by an effectively knife edge wall line.

12. A graduated composite concurrent use filter according to claim 11,

wherein the row-to-row spacing of said plural spaced zones is generally defined by the equation:

$$G_{x_{n \rightarrow (n+1)}} \equiv G_{x_n}$$

and

$$G_{x_n} \equiv \sqrt{\pi H^2 / 4 T_{x_n}}$$

where G_n is the center-to-center plural zone spacing along a given row of said plurality of zones at a distance x_n from said point or zone of reference, and $G_{x_{(n+1)}}$ is the center-to-center plural zone spacing at the next succeeding row of said plurality of zones being spaced from said zone or point of reference a distance of $x_{(n+1)}$ and T_{x_n} is the average transmission ratio of a signal embraced in the zone of a given row of said plurality of spaced zones at a distance x_n from said reference point or zone.

13. A filter arrangement according to claim 1, and a mask defining a common overall filter zone including a portion of each of said first base zone grouping of spaced zones and said further base zone,

said mask effectively attenuating the zone beyond said common overall filter zone.

14. A filter arrangement according to claim 13, said overall common filter zone being generally triangular in outline.

15. A filter arrangement according to claim 14, said generally triangular outline being truncated at an apex thereof,

said apex overlying said further base zone.

16. A filter arrangement according to claim 13, said mask effectively blocking the zone beyond said common overall filter zone.

17. A filter arrangement according to claim 13, said mask being spaced from said unit forming said first and said further base zones.

18. A graduated digital/analog composite concurrent use filter for space-traversable signals of essentially discrete cross-sectional configuration, comprising:

a unit having a first variable-signal-attenuation base zone formed by a grouping of a plurality of spaced zones, each having a first signal attenuation characteristic, interspersed within a base zone having a second signal attenuation characteristic different than said first signal attenuation characteristic, the spacing of said spaced zones varying in increasing interspatial distance as a function of increase of their spatial distance from a reference point or zone.

and a further laterally adjacent base zone of different signal attenuation characteristic from, and being laterally nearer to said reference point or zone than, said first base zone,

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said further base zone being laterally spaced from said plurality of spaced zones and being grossly larger in area than the individual ones of said plurality of spaced zones and having a signal attenuating characteristic in the zone therewithin substantially less than the overall signal attenuation characteristic of that portion of said first base zone grouping of plural spaced zones nearest to said further base zone,

said two base zones being disposed and exposed for both separate and concurrent composite variable filtering action on a said discrete cross-section signal which is of smaller cross-sectional configuration than either of said base zones, which said filtering action is a function of the instant lateral position of a said discrete cross-section signal,

said plurality of spaced zones being arranged in sets of zones forming rows spaced at increasing row-to-row distances from said reference point or zone, and the interspatial distances between said zones in a given one of said rows of zones being a function of the distance of said row from said reference point or zone.

19. A graduated composite concurrent use filter according to claim 18,

wherein the row-to-row spacing $G_{x_{n \rightarrow (n+1)}}$ between any two rows of plural zones is generally defined by the equation

$$G_{x_{n \rightarrow (n+1)}} \equiv G_{x_n} + G_{x_{(n+1)}} / 2$$

where G_x is the center-to-center plural zone spacing along a given row of said plurality of zones at a distance x_n from said point or zone of reference, and $G_{x_{(n+1)}}$ is the center-to-center plural zone spacing at the next succeeding row of said plurality of zones being spaced from said zone or point of reference a distance $x_{(n+1)}$.

20. A graduated composite concurrent use filter according to claim 18,

wherein the row-to-row spacing $G_{x_{n \rightarrow (n+1)}}$ between the rows of said plural spaced zones spaced at x_n and $x_{(n+1)}$ distance from said reference point or zone is generally defined according to:

$$G_{x_{n \rightarrow (n+1)}} \equiv G_{x_n}$$

and

$$G_{x_n} \equiv \sqrt{\pi H^2 / 4 T_{x_n}}$$

where G_x is the center-to-center plural zone spacing along a given row of said plurality of zones at a distance x_n from said point or zone of reference, and $G_{x_{(n+1)}}$ is the center-to-center plural zone spacing at the next succeeding row of said plurality of zones being spaced from said zone or point of reference a distance of $x_{(n+1)}$ and T_{x_n} is the average transmission ratio of a signal embraced in the zone of a given row of said plurality of spaced zones at a distance x_n from said reference point or zone.

21. A graduated digital/analog composite concurrent use filter for space-traversable signals of essentially discrete cross-sectional configuration, comprising:

a unit having a first variable-signal-attenuation base zone formed by a grouping of a plurality of spaced zones, each having a first signal attenuation characteristic, interspersed within a base zone having a second signal attenuation characteristic different than said first signal attenuation characteristic,

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the spacing of said spaced zones varying in increasing interspatial distance as a function of increase of their spatial distance from a reference point or zone,
and a further laterally adjacent base zone of different 5
signal attenuation characteristic from, and being laterally nearer to said reference point or zone than, said first base zone,
said further base zone being laterally spaced from said plurality of spaced zones and being grossly 10
larger in area than the individual ones of said plurality of spaced zones and having a signal attenuating characteristic in the zone therewithin substantially less than the overall signal attenuation characteristic of that portion of said first base zone 15
grouping of plural spaced zones nearest to said further base zone,
said two base zones being disposed and exposed for both separate and concurrent composite variable filtering action on a said discrete cross-section signal which is of smaller cross-sectional configura- 20
tion than either of said base zones, which said filtering action is a function of the instant lateral position of a said discrete cross-section signal,

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said further zone being an aperture defined on one lateral edge by an effectively knife edge wall line, said plurality of spaced zones being arranged in sets of zones forming rows spaced at increasing row-to-row distances from said reference point or zone, and the interspatial distances between said zones in a given one of said rows or zones being a function of the distance of said row from said reference point or zone.

22. A graduated composite concurrent use filter according to claim 21,
wherein the row-to-row spacing $G_{x_{n \leftrightarrow (n+1)}}$ between any two rows of plural zones is generally defined by the equation

$$G_{x_{n \leftrightarrow (n+1)}} \cong G_x + G_{x_{(n+1)}} / 2$$

where G_{x_n} is the center-to-center plural zone spacing along a given row of said plurality of zones at a distance x_n from said point or zone of reference, and $G_{x_{(n+1)}}$ is the center-to-center plural zone spacing at the next succeeding row of said plurality of zones being spaced from said zone or point of reference a distance of $x_{(n+1)}$.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,774,997

Page 1 of 3

DATED : November 27, 1973

INVENTOR(S) : Michael A. Kott

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, Line 35, delete parenthesis so equation reads
--- $T_x = Kl/x^2$ ---

Column 5, Line 61, Change right hand bracket to left hand parenthesis;
delete left hand parenthesis (first and second occurrences);
delete right hand parenthesis (first occurrence);
delete right hand bracket, all so equation will read
as follows:
--- $T_1 = 1/r(r - \arccos S - 2x/S + 1/2 \sin 2 \arccos S - 2x/S$

Column 6, Line 7, delete hyphen between "y" and "axis"

Column 6, Line 9, delete hyphen between "x" and "axis"

Column 6, Line 41, delete hyphens after "x" and "y"

Column 6, Line 46, delete parenthesis so equation will read
--- $\bar{T} = \pi H^2 / 4G^2$

Column 6, Line 59, delete degree mark over "itselt"

Column 6, Line 66, change "u" to "n" so equation will read
--- $\bar{T}_{x_n}$

Column 7, Line 1, delete left and right brackets

Column 7, Line 7, delete hyphen between "y" and "axis"

Column 7, Line 14, delete hyphen between "x" and "axis"

Column 7, Line 15, delete hyphen after "y"

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,774,997

Page 2 of 3

DATED : November 27, 1973

INVENTOR(S) : Michael A. Kott

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 7, Line 19, change "puspose" to ---purpose---

Column 7, Line 45, change " $\rightarrow$ " to $\longleftrightarrow$ " so equation will read

$$---G_{x_n} \longleftrightarrow (n+1) \approx \frac{G_{x_n} + G_{x_{(n+1)}}}{2}$$

Column 7, Line 53, change "n" to ---n--- so equation will read

$$---G_{x_n} \longleftrightarrow (n+1)$$

Column 8, Line 42, delete brackets in equation

Column 8, Line 56, delete brackets in equation

Column 9, Line 10, delete "+" (second occurrence)

Column 11, Line 23, between "G" and "n" insert ---x--- so equation will read

$$---G_{x_n}---$$

Column 11, Line 65, change "." to ---,---

Column 12, Line 38, change "(n+1)" to --- (n+1) --- so equation will read

$$---X_{(n+1)}---$$

Column 12, Line 41, Change " $n \longleftrightarrow (n+1)$ " to --- $n \longleftrightarrow (n+1)$ --- so equation will read

$$---G_{x_n} \longleftrightarrow (n+1)---$$

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,774,997
 DATED : November 27, 1973
 INVENTOR(S) : Michael A. Kott

Page 3 of 3

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 12, Line 56, change " T_{x_n} " to $---T_{x_n}---$

Column 14, Line 7, change "or" to $---of---$

Column 14, Line 12, change " $n \leftrightarrow (n+1)$ " to $---n \leftrightarrow (n+1)---$ so equation will read $---G_{x_n \leftrightarrow (n+1)}---$

Column 14, Line 15, after " G_x " (second occurrence) insert $---n---$ so equation will read $---G_{x_n \leftrightarrow (n+1)} \hat{=} G_{x_n} + G_{x(n+1)}/2---$

Column 10, after line 61 add:

- 7. A graduated composite concurrent use filter according to claim 1, said first signal attenuating characteristic being lesser in attenuating character for a given said signal than said second signal attenuating characteristic.--

Signed and Sealed this

Second Day of June 1981

[SEAL]

Attest:

RENE D. TEGMEYER

Attesting Officer

Acting Commissioner of Patents and Trademarks