

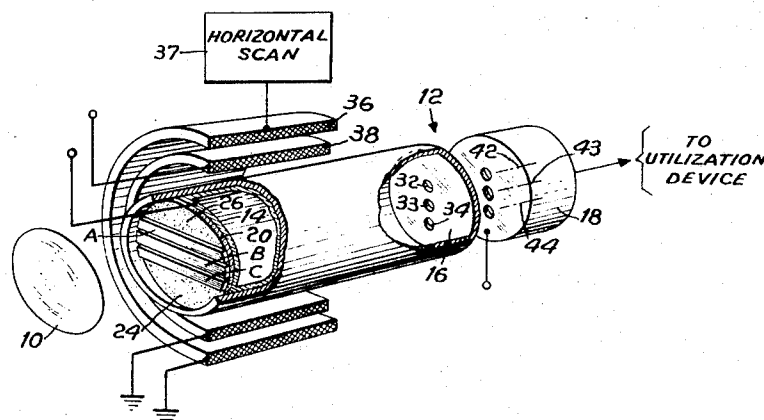
[54] **MULTISPECTED IMAGING SYSTEM**[72] Inventor: **Edward W. Koenig**, Fort Wayne, Ind.[73] Assignee: **International Telephone and Telegraph Corporation**, Nutley, N.J.[22] Filed: **March 16, 1970**[21] Appl. No.: **19,931**[52] U.S. Cl. **178/5.4 ST, 178/DIG. 21**[51] Int. Cl. **H04n 9/06**[58] Field of Search.... **178/5.4 ST, 6, DIG. 21, 7.2 A, 178/6, DIG. 6, DIG. 33, DIG. 20**[56] **References Cited****UNITED STATES PATENTS**

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Primary Examiner—Robert L. Richardson*Assistant Examiner*—Richard P. Lange*Attorney*—C. Cornell Remsen, Jr., Walter J. Baum, Paul W. Hemminger, Charles L. Johnson, Jr., Philip M. Bolton, Isidore Togut, Edward Goldberg and Menotti J. Lombardi, Jr.[57] **ABSTRACT**

A multispectral imaging system is positioned for

movement relative to a scene to provide images of the scene in multi-spectrum. The system includes a plurality of filter strips for passing different spectral bands, such as different colors, to provide a plurality of radiation images of the field of view being scanned. The strips are positioned with respect to an image dissector tube so that the radiation images of the view are converted into electron images. The tube includes a photoemissive cathode at one end that converts the plurality of radiation images into corresponding electron images and an apertured electrode located at the other end. The system also includes means for scanning the electron images transversely across the apertured electrode, an electron multiplier or amplifying the scanned electron images, and means utilizing the scanned and amplified electron images. As the system traverses a path relative to the field of view, each of the filters scans a section of the field of view along the direction of the movement. Knowing the transverse scanning speed of the electron beam and the relative speed of motion of the system along the path, the signal information from the electron images can readily be demultiplexed to display visual images of the field of view in color on a display screen. The tube may include only one aperture and the electron beam scanning means may be adapted so that the plurality of electron images scans the aperture in sequence in a multiplex fashion, or there may be a corresponding plurality of apertures, each simultaneously being scanned by one electron image from a respective filter strip and photocathode portion.

8 Claims, 7 Drawing Figures

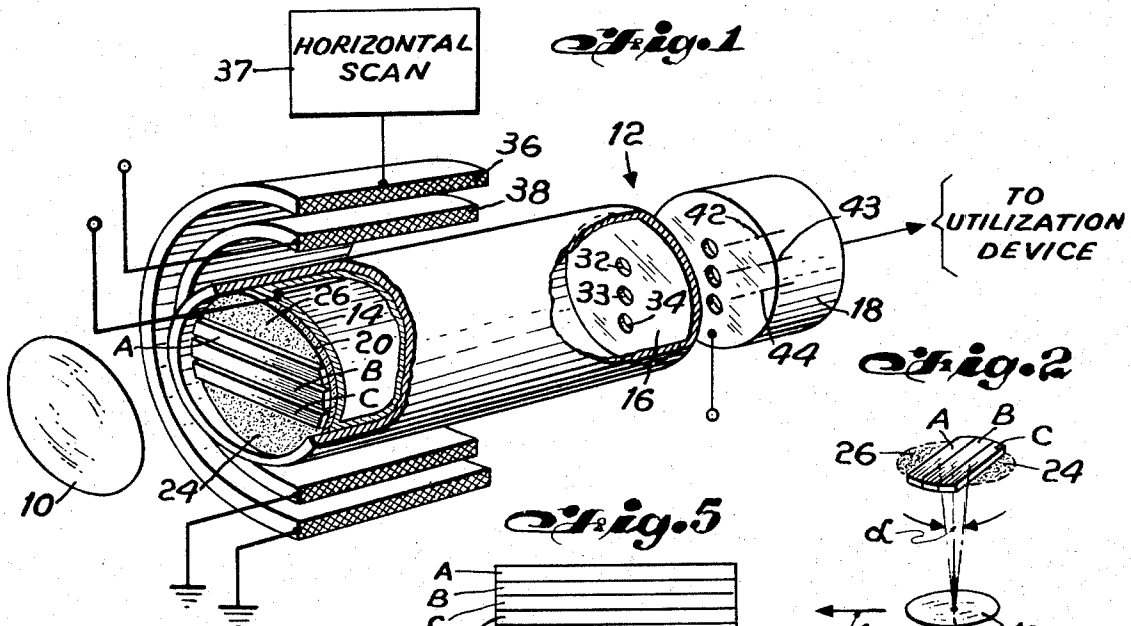


Fig. 4

A	(1) (4) ()	()
B	(2) (5) ()	()
C	(3) (6) ()	()



Fig. 6a **Fig. 6b**

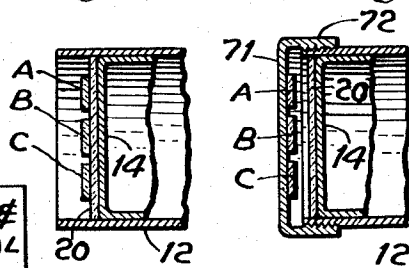
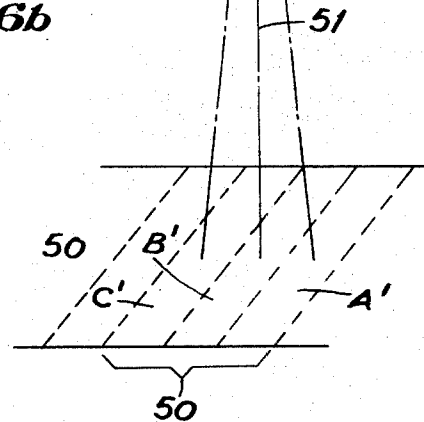
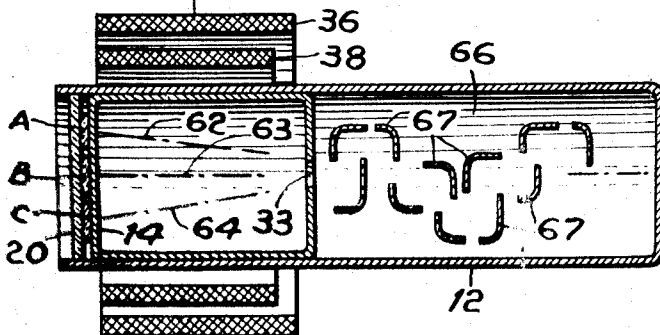


Fig. 3

52 VERTICAL & HORIZONTAL SCAN



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MULTISPECTED IMAGING SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an imaging system, and more particularly, to a novel multispectral image dissector system which generates a plurality of different spectral images of a field of view.

2. Description of the Prior Art

In accordance with a known imaging system for multispectral images such as a color television system, generally, a plurality of image tubes are used, each designed to obtain an electron image or beam representing a particular color component, for example, a green, blue or red spectral portion of the object image.

In such a system, each of the image tubes is adapted to handle one particular color image. The tube includes a typical vidicon or image orthicon structure or an electron emissive cathode commonly called a photocathode and an apertured electrode. The cathode converts a radiation image of the field of view of the selected color into an electron image. The system also includes means for scanning the electron images across the apertured electrode vertically and horizontally to provide an output signal representing the electron image of the field of view being scanned. In addition, the system generally includes a suitable means such as an electron multiplier for amplifying the output signal from scanned electron images before transmission to a utilization device.

In recent years with the advent of the space research, serious efforts have been made to develop an imaging system suitable for use in space vehicles that is simpler in structure and more reliable and that provides a high resolution of the images. One such a system is shown in U.S. Pat. No. 3,448,210, issued on June 3, 1969, and assigned to the same assignee as the instant application. The patent describes a multispectral imaging system which requires only one image tube. To obtain multispectral images the system uses a dispersing prism which disperses a radiation image of a single narrow field of view into its color or spectral components, for example, blue, green and red. The system then provides a plurality of apertures in the apertured electrode and a scanning means adapted to scan the various color components of electron images to corresponding ones of the apertures. The system is also provided with an electron multiplier for each of the component electron images for amplifying them before they are transmitted. In certain applications, however, a system providing improved resolution and accuracy is required.

SUMMARY OF THE INVENTION

It is therefore the principle object of the present invention to provide an improved and simplified multispectral imaging system.

It is another object of the present invention to provide a more flexible and versatile multispectral imaging system of improved sensitivity.

The foregoing and other objects of the present invention are achieved in accordance with the present invention by an imaging system using a single image tube and a filtering means that includes a plurality of spectral filter strips. The filter strips apply a plurality of filtered

radiation images of the field of view to the photocathode of the tube. The tube then converts the radiation images into a plurality of electron images. The system is provided with focusing and scanning means which scan the multispectral electron images across the apertured electrode. The vertical scanning, typically required in prior art systems, may be eliminated by mounting the imaging system on a vehicle such as satellite which is in motion relative to the field of view. The sizes and positions of the strips are adjusted with respect to the relative speed and distance of the view so that the field of the view is successively scanned in sections by filter strips as they move over the field of view.

In accordance with one variation of the present invention, a plurality of apertures and multipliers are provided, wherein respective ones of the apertures and the multipliers are adapted to receive and amplify a particular one of the electron images from a corresponding filter strip.

In another variation of the invention, a single aperture is provided for the plurality of electron images, and means are provided for enabling the scanning means to scan the plurality of electron images one at a time in sequence across the aperture during the time interval that a field of view is scanned.

Other variations and features of the present invention may be more fully apprehended from the following description of the preferred embodiments of the present invention in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows at three dimensional schematic diagram of a multispectral imaging system in accordance with the present invention;

FIG. 2 shows a schematic relationship between the imaging system and a field of view being scanned by the filtering means of the imaging system;

FIG. 3 shows a cross-sectional view of the imaging system with a plurality of spectral filter strips and a single scanning aperture in accordance with the present invention;

FIG. 4 illustrates the scanning of the electron beams corresponding to the three spectral filters which may be scanned several times each during a time interval when a field of view is scanned by the imaging system;

FIG. 5 shows a variation in the filtering means of the present invention including a plurality of sets of filter strips, each set having three color filters; and

FIGS. 3, 6a, and 6b show the positions of spectral filters in relation to the faceplate of the image tube in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Where applicable, the same designation of numbers and other symbols are used for the same parts in the different figures in the drawings.

FIG. 1 schematically shows the novel imaging system which generates multispectral images simultaneously. The system includes a lens 10 which directs and focuses a radiation image onto an image dissector tube 12. The tube 12 includes an electron emissive cathode 14, commonly known as a photocathode, which converts the radiation image from the lens means 10 into an elec-

tron image or beam, an apertured electrode 16 scanned by the electron beam, and means 18 for amplifying the output signal from the electrode 16 representing the scanned electron image. The photocathode 14 is generally placed on a radiant energy transparent faceplate 20 and is disposed substantially in parallel with the lens 10.

In accordance with the present invention, three parallel filter strips A, B and C are mounted on the faceplate 20 to receive the radiation image. The areas 24 and 26 on the faceplate not covered by the filter strips A, B and C are made opaque to the radiation image. The filter strips thus provide three different spectral images to the photocathode which produces three corresponding electron images. The electrode 16 includes three apertures 32, 33 and 34 which are aligned with the three filter strips A, B and C. Deflection coil 36 surrounds the tube 12 in a well known conventional manner. Suitable known circuitry 37 is provided to enable the deflection coil 36 to simultaneously sweep the electron beams from the respective photocathode sections adjacent the filters A, B and C horizontally across the apertures 32, 33 and 34. A focusing coil 38 also surrounds the tube 12 in a conventional manner to focus the electron images in the form of electron beams from the filters A, B and C onto the apertured electrode 16. Particular care is taken in applying the horizontal scanning field to the beams so that they are scanned only across the corresponding aligned apertures and not the others. This assures spectral discrimination of the images being formed. The amplifying means 18 includes three electron multipliers 42, 43 and 44 of a conventional type shown by dotted lines respectively adapted to amplify a corresponding electron beam signal from the apertures 32, 33 and 34 in a known manner. The output of the amplifying means 18 may be coupled to a suitable utilization means such as a transmitter and a remote display device (not shown).

The operation of the present imaging system will be explained in conjunction with FIG. 2. The aforescribed imaging system shown in FIG. 1 may be mounted on a vehicle which is in motion at a given speed relative to a field of view. For example, the imaging system may be mounted on a satellite (not shown) which is in motion in space in a given direction relative to the earth surface at a given speed. As illustrated in detail in FIG. 2, the lens means 10 projects and focuses a radiant energy image of the field of view 50 covering sectioned areas A', B' and C' onto the spectral filters A, B and C respectively. The spectral filters A, B and C are oriented transverse to the lens axis 51. The sectioned areas A', B' and C' represent long strip sections of the field of view scanned by the filter strips A, B and C as they traverse over the scene being viewed. Each section is positioned transverse to the direction of movement from right to left as shown.

At a particular time interval as the field of view 50 is scanned by the aforescribed imaging system, the spectral images of the three sections A', B' and C' of the field of view 50 are obtained as follows. As the system moves along an orbit above the field of view, the lens 10 projects a radiant image of the view 50 onto the filter strips A, B and C. The filter strips A, B and C receive the field of view 50 in three sections A', B' and C'. In particular, the center filter strip B receives the

image of the center section B', the filter strip A ahead of the center strip B relative to the direction of the satellite movement receives the section A', and the strip C behind the center filter strip receives the section C'. The three filters are preferably designed to filter the primary colors, i.e., blue, green and red. The photocathode 14 converts the three simultaneously generated radiant color images into three corresponding electron beams, which are then scanned and amplified as explained before.

By dimensioning the widths of each filter strip and spacing them in a suitable manner relative to the speed and altitude of the satellite with respect to the earth, the three filter strips A, B and C view each one of the successive sections of the field of view in succession. In this manner, a continuous image of the field of view of the earth can be generated in color as each filter strip moves over each section of the field of view as the satellite moves along its path or orbit. By referencing a receiver to the scanning speed and combining the three electron images representing three color components of the field of view, a composite color picture of the view is readily reproduced.

Since the system is in motion and traverses the field of view, the field of view changes constantly. However, the scanning time interval for a field of view is short enough so that the degree of resolution of the image is not impaired. It was found that the relative change of the field of view of the earth scanned from the high altitude of satellite orbit presents little problem, since there is relatively little change in the field of view during the relatively short scanning time interval. In instances where relative speed is high, and the field is close there is a tendency that a continuously changing scene would introduce smear into the picture image as the photocathode 14 converts the radiant images from the filter strips A, B and C of the continuously changing field of view. This tendency is avoided by a number of precautionary measures.

First, each of the apertures 42, 43 and 44 are completely separated from the other as are the electron multipliers 42, 43 and 44. Second, to further assure the separation, the filter strips may also be separated by some distance from each other. In addition, the deflection coil 36 is energized to scan the electron beams from the cathode 14 such that the beam from filter A is scanned only across the aperture 32, the beam from filter B only across the aperture 33, and the beam from filter C only across the aperture 34. In this manner, all of the electron beams from the photocathode 14 are accelerated to the apertured electrode 16 simultaneously, and scanned horizontally across the apertures 32, 33 and 34 respectively. Separate vertical scanning ordinarily required is eliminated and effectively obtained by using the movement of the satellite transverse to the direction of the horizontal scanning.

With an imaging system adapted to scan 20 times per second, for example, filter strips of about 0.05 inch in width, a spacing of 0.015 inch between the apertures, and a spreading angle α of the off-axis filter strips A and C by about 2.4 minutes of a degree of an arc provided good color discrimination and avoided smearing.

The present imaging system is relatively simple and stable since all of information generated by the sampling apertures are controlled by a single lens 10, a sin-

gle set of deflection coils 36 and focus coils 38, the three apertures 32, 33 and 34 and multipliers 42, 43 and 44, all mounted in one image tube 12. The unitary structure assures correct registration of section by section of the image of the field of view. Also compared to the color registration stability of a three separate tube system, such as that used in a normal color television system, the present system with the unitary structure provides a very substantial increase in the degree of resolution the imaging system can provide. Also, by keeping the aperture separation small, the misregistration due to the changes in the altitude of satellite is made insignificantly small.

The value of the imaging system would be lost if the images are not consistent from image to image. The present novel imaging system provides this consistency using a single lens, and a single optic system with no intermediate color separation prisms, wedges or mirrors. The stability of the separation bands may be obtained by mounting the three adjacent filter strips A, B and C directly on the faceplate 20 of the tube 12, as shown in FIG. 1, which eliminates disturbances caused by thermal or structural changes. The instantaneous action of the photocathode eliminates need for any mechanical shutters. Extremely accurate photometric information is obtained by using a photocathode 14 having a wide dynamic range, by varying the gain of the multiplier, and by eliminating the usual motor driven iris otherwise used in an imaging tube.

Simple multiplexing techniques will assure accurate time referencing of image signals from the imaging system such that a display system receiving the data in real time can record the color image at the precise time that the image dissector tube of the imaging system is viewing the scene or the field of view.

In another variation of the system, the three electron images may be scanned across one aperture 33 as shown in FIG. 3 instead of three apertures 32, 33 and 34 as shown in FIG. 1. Suitable horizontal and vertical scanning means 52 is adapted to enable the deflection coil 36 to apply a field to the electron beam periodically at each vertical position such that the three electron beams 62, 63 and 64 emitted from the photocathode are deflected across the single scanning aperture 33 one at a time in a successive sequence during the time interval that the filter strips A, B and C scan the field of view. The signals from the electron images so scanned are then amplified by a single electron multiplier 66 having a plurality of dynodes 67.

FIG. 4 illustrates how each of the electron images from the three color filter strips A, B and C may be scanned over the aperture a plurality of times during a time interval that the field of view is traversed. The means 52 are adapted to actuate the deflection coil 36 such that the latter scans the electron beams 62, 63 and 64 across the aperture 33 in the following sequence; first, the portions 1, 2 and 3 of the respective beams, then 4, 5 and 6, and so forth, all during the time interval that the filters traverse the field of view. Knowledge of the scanning sequence permits ready reconstruction of the color information at a display or recording device.

FIG. 5 illustrates a further variation of the filter arrangement in accordance with the present invention wherein the filter means includes an n number of sets of filters each set having three narrow color filter strips A,

B and C. The electron images of the field traversed by the filters may be scanned across the three apertures 32, 33 and 34 of the electrode at a time in successive vertical order where the apertures are spaced the same effective distance as the line-to-line vertical spacing of the filters.

The filter strips may be mounted on the image tube 12 in a number of different ways. As shown in FIGS. 1 and 3 filter strips A, B and C may be placed as substrates between the photocathode layer 14 and the faceplate 20 of the image tube 12. Alternatively, the filters A, B and C may be placed in the form of layers of strips on the outer side of the faceplate 20 while the photocathode layer 14 is positioned on the inside surface of the faceplate, as shown in FIG. 6a. The filters A, B and C may also be mounted on a mounting plate 71 with the filter strips A, B and C placed on the inside surface thereof. The mounting plate 71 may include flange 72 bent at a right angle to the filter strip plane and the flange 72 may include a threaded portion. The outer rim of the tube 12 at the vicinity of the faceplate 20 may also be threaded so that the mounting plate 71 can be threaded and thereby secured onto the tube 12. In the aforementioned filter arrangements, the faceplate as well as mounting plate corresponding to the filter sections are made of transparent material that passes radiant energy. However, other portions thereof may be made opaque to the radiant energy.

While the three color filters are used to illustrate the present invention, obviously the number of filters need not necessarily be so limited. Nor do they have to be color filters necessarily. They may be designed to filter other forms of energy such as infrared or ultraviolet images. The same principles described hereinbefore would apply irrespective of the number or the kind of filters used.

Various extensions of the teachings of the present invention may be made within the spirit and scope of the present invention. Thus, for example, where increased signal strength is required for a selected band or color, the corresponding aperture may be made many times larger than those for unselected bands or colors. A more complex variation can be made by using slit apertures to detect geometric patterns while a round aperture can be used to generate a normal image. These variations may be so related to the particular spectral characteristics to provide other types of discrimination.

What is claimed is:

1. An imaging system for scanning a field of view comprising:

an image dissector tube positioned for longitudinal movement relative to said field of view and to receive a radiation image of said field of view, said image tube having a radiation responsive electron emissive cathode at one end thereof and an apertured electrode at the other end, said electrode having only three apertures therein;

filtering means fixedly coupled to said cathode, said filtering means including only three differently colored filter strips positioned parallel to each other and to a plurality of parallel sections of said field of view, said strips being positioned transversely relative to the direction of movement along said field of view such that each filter strip views a corresponding section of said field of view, said

movement of said tube causing each said filter strip to scan each said section successively in the direction of movement to provide a plurality of radiation images of each said section in successive order;

said cathode converting said plurality of radiation images into a corresponding plurality of successive electron images;

means for focusing said plurality of electron images onto said apertured electrode, and transverse scanning means for simultaneously scanning said plurality of successive electron images across said apertured electrode transversely to said direction of movement to provide a plurality of output signals, each aperture being aligned with a respective strip and being scanned by an electron image from only one and the same said respective strip during each successive scan; and

means for utilizing said plurality of output signals.

2. An imaging system in accordance with claim 1, further comprising lens means to focus the radiation image of said field of view onto said filtering means, said lens means fixedly coupled to said image dissector tube.

3. An imaging system in accordance with claim 1, wherein said filtering means include only three differently colored filter strips positioned parallel to each other and to a plurality of parallel sections of said field of view, said apertured electrode including only three apertures, said parallel sections being disposed transverse to said direction of movement, each filter strip providing a respective radiation image and an adjacent cathode portion providing a respective electron image, each aperture being scanned by an electron image from only one and the same said respective colored strip dur-

ing each successive scan.

4. An imaging system in accordance with claim 1, wherein

said plurality of apertures are scanned simultaneously by respective electron images in said direction of movement and in said transverse direction,

and including three electron multipliers each associated with a corresponding one of said apertures for amplifying said output signals.

5. An imaging system in accordance with claim 4, wherein

said filtering means includes red, blue and green color filter strips.

6. An imaging system in accordance with claim 1, wherein said image tube includes a radiation image transmissive faceplate, said cathode being in the form of a layer on the inner surface of and substantially coextensive with said faceplate, and said filtering means is interposed between said faceplate and said cathode.

7. An imaging system in accordance with claim 1, wherein said image tube includes a radiation image transmissive faceplate, said cathode being in the form of a layer covering the inner surface of said faceplate, and said filter strips are positioned on the outer surface of said faceplate, the areas of said faceplate not covered by said filter strips being opaque to said radiation image.

8. An imaging system in accordance with claim 1, said system further includes a radiation image transmissive mounting plate positioned in front of said one end of said image tube, said filtering means being positioned on said mounting plate.

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