Aug. 21, 1962 J. A. KUECKEN 3,050,725

RADIO FREQUENCY IMAGE DETECTOR

Filed Oct. 4, 1960

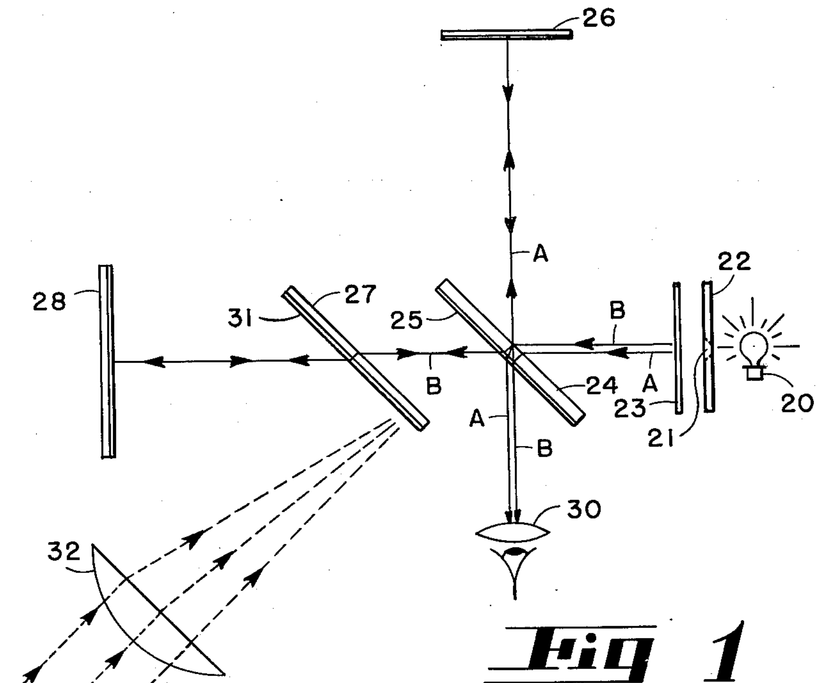

Fig 1

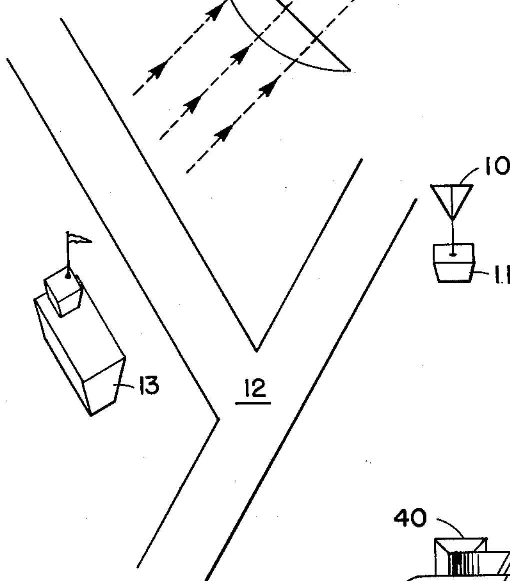

Fig 3

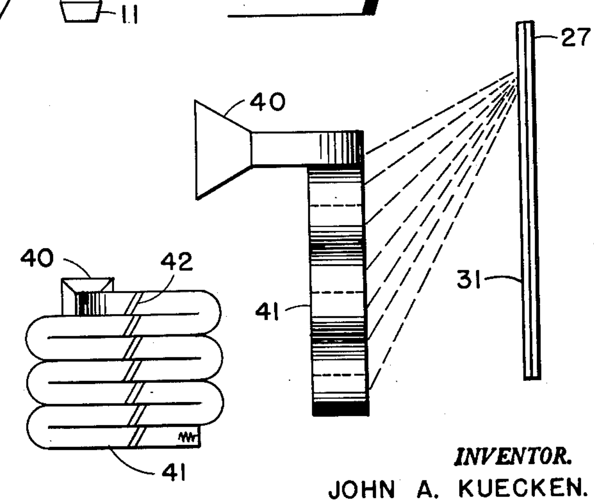

Fig 2

INVENTOR.
JOHN A. KUECKEN.
BY Alden D. Redfield
Irwin P. Garfinkle
ATTORNEYS.

United States Patent Office

3,050,725

Patented Aug. 21, 1962

3,050,725

RADIO FREQUENCY IMAGE DETECTOR

John A. Kuecken, Cincinnati, Ohio, assignor to Avco Corporation, Cincinnati, Ohio, a corporation of Delaware

Filed Oct. 4, 1960, Ser. No. 60,339
3 Claims. (Cl. 343—17)

This invention relates to a novel system of radio frequency detection and, more particularly, to a system of radio frequency detection wherein radio frequency images are converted directly into visual images.

Broadly, this invention contemplates the use of a thin dielectric film in the path of a beam of light. A radio frequency field is focused onto the film and, in accordance with established physical principles, the focused radio frequency energy produces heating or electrostatic forces within the dielectric film to the extent that the film is deformed. The resultant change in the path length of the beam, due to the deformation of the film, is then detected by means of a Michelson interferometer to produce a visual image.

In a particular application, the radio frequency image detector provided by this invention would find utility in "illuminating" harbors, airfields, or roads, and a pilot or driver equipped with such a detector could operate or steer in the same manner as though visible light were available. This result is accomplished by "floodlighting" an entire area with radio frequency energy, focusing the radio energy onto the dielectric film, and subsequently detecting the changes in wavelength caused by the deformation of the film. It will be noted that an entire area may be viewed in this manner without the necessity of scanning, which is required by radar, infrared, and other object-detecting devices. This permits very accurate detection with high image resolution not possible with high-speed scanning devices.

The primary object of this invention is to produce a radio frequency image detector capable of simultaneously perceiving or detecting complete radio frequency scenes with the entire scene being instantaneously viewed or recorded in a manner similar to that of a camera, particularly an X-ray camera.

Another object of this invention is to avoid the limitations imposed upon radar and other mapping techniques stemming from the requirement of scanning in order to produce a visual image.

Another object of this invention is to produce a visible image of radio frequency energy by distorting a dielectric film in the path of a beam of visible light in accordance with the radio frequency energy and detecting the amount of the distortion.

Still another object of this invention is to produce a radiŏ frequency image detector capable of simultaneously perceiving or detecting radio frequency scenes without the necessity of scanning.

Another object of this invention is to split a beam of light into two paths such that when re-combined, the paths are 180 degrees out of phase and thereby cancelling, and to interpose in one of the paths a dielectric film which is distorted by focused radio frequency energy, the distortion producing a phase shift in that path, thus yielding light at the points of distortion when the paths are re-combined.

Still another object of this invention is to provide a method of object detection which includes the steps of radiating electromagnetic energy over the object, focusing reflected electromagnetic energy onto a dielectric film, directing a beam of visible light through the dielectric film, and detecting the change in pathlength of the beam, due to the distortion of the film caused by electromagnetic energy.

For other objects and advantages of this invention, reference should now be made to the following detailed specification and to the accompanying drawings, in which:

FIG. 1 is a schematic representation of one preferred form of this invention;

FIGS. 2 and 3 represent a modification of this invention incorporating a serpentine dispersive array system.

In FIG. 1 an antenna **10**, supplied with energy from a K-band transmitter **11**, is used to radiate electromagnetic energy over an entire airfield with runways **12** and associated buildings **13**. If the energy radiated by the antenna **10** were in the form of visible light rays it is apparent that the runways and buildings would be illuminated and that the airfield would be visible to the eye. It is in this sense that electromagnetic energy from the antenna **10** is radiated over the entire area of the airfield, the object now being to provide apparatus for converting the reflected electromagnetic energy into visible light energy.

For the foregoing purpose I provide a generally conventional Michelson interferometer which includes a monochromatic light source **20** for radiating a beam of light through a pinhole **21** in a disk **22** and through a diffusing screen **23**. The beam, which is shown as consisting of two bundles of light A and B, is then divided into two paths by means of a beam splitter **24** positioned at a 45-degree angle with respect to the path of the beam. One side of the beam splitter **24** is provided with a half-silvered surface **25** for directing one portion A of the beam toward a mirror **26** and the other portion B through a compensator plate **27** toward a mirror **28**.

Now it will be recognized that if the pathlength of a portion A of the beam is exactly one-half wavelength longer or shorter than the pathlength of the portion B then, as viewed at the lens **30**, the light due to the portion A of the beam will cancel the light due to the portion B, and no light will be visible. If the pathlength of either of the portions of the beam is varied, then light images will appear at the lens **30** in accordance with the particular variations. I take advantage of this principle by applying to the compensator plate **27** a thin dielectric transparent film **31** which may comprise cellophane, motor oil, or other transparent material which is sensitive to radio frequency energy. Using the radio frequency lens **32**, I focus the radio frequency energy reflected from the airfield over the dielectric film **31** to "expose" the entire surface.

Upon energization by the radio frequency energy, the thickness of the detector film **31** changes very slightly, due to heating action which is caused by the dissipation of radio frequency power in the film or by deformation brought about by the electrostatic forces in the radio frequency field. With such deformation the pathlength of portion B of the light waves passing through the dielectric film **31** will be changed at each point on the dielectric film in accordance with the amount of deformation. Thus, with the interferometer adjusted for complete extinction of light in the absence of radiated electromagnetic energy, a change in the thickness of the dielectric film will produce a change in the pathlength sufficient to cause illumination of each point on the film which is deformed.

It may be seen too that this system, in effect, provides for the "illumination" of the entire area by radio frequency energy and subsequently converting the radio frequency energy directly into visible light without the necessity of scanning. It is also pointed out that the detection system described here is a form of parametric amplification in which the light source **20** constitutes the pump energy and the parameter altered is the optical pathlength. Similar to other parametric devices, high levels of amplification and very low noise figures are obtainable. It is further to be noted that the radio frequency image detector described here constitutes the complete image detector, including the antenna and display, and that additional electronic amplification is not required anywhere in the device.

In the embodiment illustrated in FIGS. 2 and 3 I show another application of the principles of this invention, wherein received signals may be separated optically in accordance with wavelength and detected in a manner similar to that shown in FIG. 1.

In FIGS. 2 and 3 I show a pickup horn 40 coupled to a conventional serpentine dispersive array 41 provided with a plurality of slot radiators 42. As in FIG. 1, a compensating plate 27 on which a dielectric film 31 is placed is mounted in a position to intercept the radio frequency energy from the array. As in FIG. 1, variations in radio frequency energy on the film 31 change the pathlength and affect the patterns visible at the lens 30. The principles of the serpentine array are well known in the art and need not be discussed here. For the theory of operation, reference may be made to "Antennas" by J. D. Kraus, published by McGraw-Hill in 1950, pages 76, et seq.

When the signals containing a plurality of wavelengths incident on the pickup horn 40 are passed through the serpentine dispersive array, the signals radiated from the slots 42 are phased-shifted by an amount which is dependent on the frequency of the signal. Thus, the radio frequency signals which impinge upon the detector will be dispersed according to frequency and will be sorted on the detector; and the light patterns visible to the eye at lens 30 will be dispersed according to the frequencies of the impinging radio frequency energy.

A prism-type spectrometer could also be constructed if a suitably dispersive dielectric material is available. Such a device would be extremely valuable in countermeasures work because of its ability to detect and sort, according to frequency, all signals within the band with high detection probability due to the non-scanning operation.

Other applications for this device may be found in the field of optical control since this device, when operating in the electrostatic mode, could be used as a camera shutter or light beam modulator operating at thousands of megacycles, an order of magnitude increase over the fastest available devices.

Still other applications possible for this device lie in the infrared regions of the electromagnetic spectrum. With proper design the signal collecting portion of the unit can be made to respond well to incoherent and unpolarized radiation, thereby adapting the unit to radio frequency thermal noise signals. This would prove particularly advantageous in radio astronomy and passive detection applications.

Use of this device would probably prove easiest in the centimeter and shorter wavelength region due to the problems of obtaining adequate resolution on a practical size detector plate. However, longer wavelengths could be handled through heterodyning or parametric up-conversion with the real collecting aperture remote from the image detector.

The principal area requiring development in this invention is the dielectric film, since properties of thin dielectric films at microwave frequencies are not well known. In all probability some dielectric materials will prove superior to others for this application as in other parametric devices.

Many other modifications and adaptations of this invention will become apparent to persons skilled in the art. It is intended, therefore, that this invention will be limited only by the following appended claims as read in the light of the prior art.

I claim:

1. A radio frequency detector comprising: a transparent, deformable dielectric material; a source of light; a beam splitter; means for directing a beam of light from said source through said beam splitter, said beam dividing into two paths, the lengths of said paths being different by one-half wavelength, one of said paths being through said material; means for combining said paths whereby the light in said paths cancel; and means for focusing radio frequency energy onto said material whereby said plate is deformed and the length of the path through said material is varied in accordance with said deformation.

2. A radio frequency detector comprising: a transparent, dielectric material deformable in response to the application of radio frequency energy; a source of light; means for directing one-half of the light energy from said source of light through said material to a given plane through a path of predetermined length; means for directing the other half of said light energy from said source to said given plane through a path differing in length by one-half wavelength of said light energy from said predetermined length, said halves being combined at said plane whereby the energy of said one-half cancels the energy of said other half; a radio frequency transmitter for directing radio frequency energy over an area; and means for gathering reflected radio frequency energy from said area and directing said reflected radio frequency energy onto said deformable dielectric material, whereby said dielectric material is deformed, thereby producing a change in the length of said path of given length, and whereby an image of said area is produced at said plane.

3. The invention as defined in claim 2 wherein said means for gathering and directing said reflected radio frequency energy comprises a serpentine dispersive array.

References Cited in the file of this patent

UNITED STATES PATENTS

2,623,183	Buck	Dec. 23, 1952
2,824,235	Hahn	Feb. 15, 1958

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,050,725

August 21, 1962

John A. Kuecken

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 26, for "plate" read -- material --.

Signed and sealed this 4th day of December 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,050,725 August 21, 1962

John A. Kuecken

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 26, for "plate" read -- material --.

Signed and sealed this 4th day of December 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents