

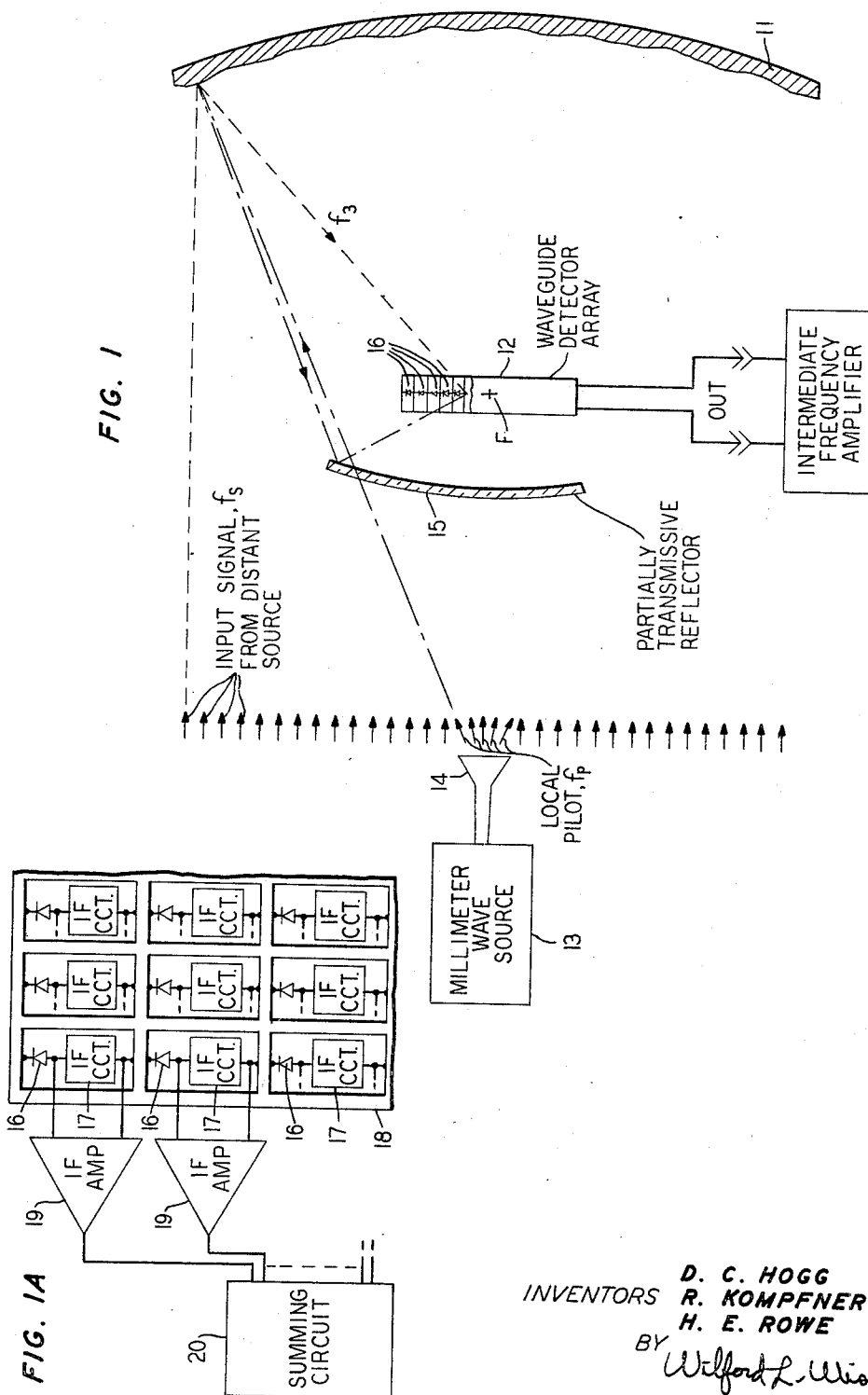
Jan. 13, 1970

D. C. HOGG ET AL
RECEIVING ANTENNA APPARATUS COMPENSATED
FOR ANTENNA SURFACE IRREGULARITIES

3,490,021

Filed Jan. 26, 1968

2 Sheets-Sheet 1



Jan. 13, 1970

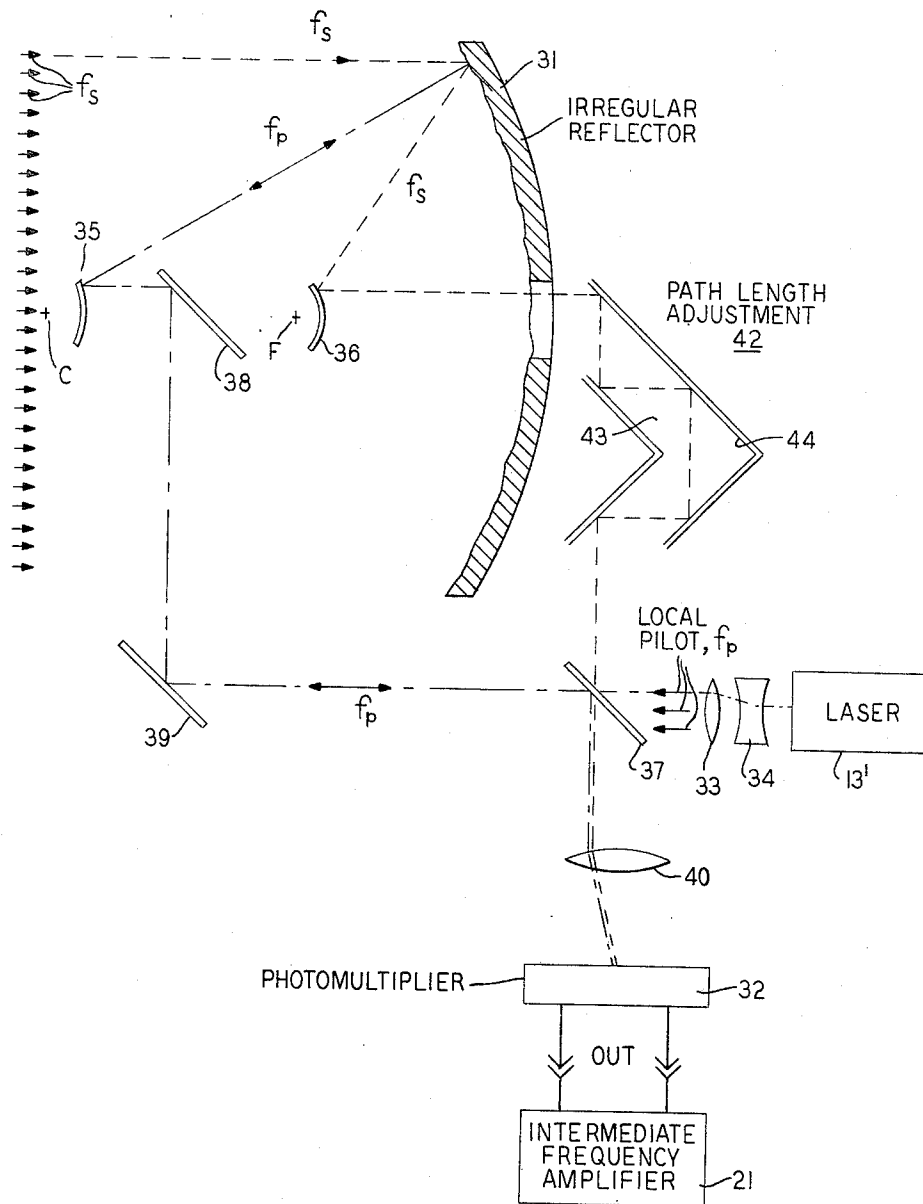
D. C. HOGG ET AL
RECEIVING ANTENNA APPARATUS COMPENSATED
FOR ANTENNA SURFACE IRREGULARITIES

3,490,021

Filed Jan. 26, 1968

2 Sheets-Sheet 2

FIG. 2



1

3,490,021

RECEIVING ANTENNA APPARATUS COMPENSATED FOR ANTENNA SURFACE IRREGULARITIES

David C. Hogg, Fair Haven, Rudolf Kompfner, Middletown, and Harrison E. Rowe, Rumson, N.J., assignors to Bell Telephone Laboratories, Incorporated, Murray Hill, N.J., a corporation of New York

Filed Jan. 26, 1968, Ser. No. 700,769

Int. Cl. H01q 19/14, 19/00

U.S. Cl. 343-100

8 Claims

ABSTRACT OF THE DISCLOSURE

In a receiving antenna apparatus in which a primary reflector has lateral dimensions much greater than a wavelength and surface irregularities that affect its ability to gather and focus the received radiation, a locally generated pilot wave is also reflected from the irregularities and then mixed with the received signal wave in a detector of substantial area. The pilot frequency differs from the signal frequency by a desired intermediate frequency. The pilot wave is typically directed by means of subsidiary reflectors sufficiently small that they may be more perfectly made and installed and therefore lack the surface irregularities of the primary reflector.

BACKGROUND OF THE INVENTION

This invention relates to receiving antenna that have lateral dimensions much larger than the wavelength of the radiation to be received.

Such an antenna is an apparatus typically including a reflector shaped to direct the received radiation toward a suitable detector.

In radio astronomy, the wavelength to be received is of the order of millimeters; and the reflector, or "dish," may be of the order of 100 feet in diameter.

In optical communication, the wavelength to be received is of the order of microns and the reflector may be of the order of several feet in diameter.

A large primary reflector area is desired in order to collect as much signal radiation as possible. Nevertheless, the effective surface of reflector may contain irregularities that may be large compared to a wavelength of the received radiations. The resulting phase and amplitude distortions of the portions of the signal wave reflected from different portions of the reflector can greatly impair the signal-to-noise ratio of the detected signal.

The troublesome irregularities may be of many types. For example, some may be deviations from a desired spheroidal or paraboloidal surface under the influence of gravity or other forces exerted on the large, massive reflector. Others may be surface roughness that could be removed only at prohibitive cost during the manufacture and installation of such a large reflector.

SUMMARY OF THE INVENTION

Our invention permits antennas of large area and only nominal focusing tolerance to be used efficiently in deriving a detected signal. By nominal focusing tolerance, we mean that no extraordinary manufacturing or installation steps need be taken to eliminate focusing irregularities of the primary member, typically a large primary focusing reflector.

According to our invention, the deleterious effects of focusing irregularities are overcome by directing a locally supplied pilot wave to be affected by the same irregularities and then to be mixed substantially coherently with the signal wave in a detector of substantial reception area. The mixing process produces an intermediate-frequency

2

quency wave analogous to that of a heterodyne communication system. The intermediate frequency is preferably at least two orders of magnitude smaller than the signal frequency. The pilot wave has substantially greater power than the received signal wave.

The antenna primary reflector is now more effective in deriving an intermediate-frequency signal than the uncorrected primary reflector in the sense that the reflections of signal and pilot waves from the mutually illuminated portions of its area contribute in-phase additive components to the intermediate-frequency signal. Even if the means for directing the pilot wave blocks a substantial portion of the primary reflector from the incoming signal wave, the effective area of the primary reflector can still be large enough that a net increase in signal-to-noise ratio is obtained, as compared to the uncorrected primary reflector.

One aspect of our invention resides in the directing of the pilot wave and, in some embodiments, the reflected signal wave, by subreflectors, prisms or lenses smaller than the primary reflector. Their size is small enough that they can be made and installed substantially without irregularities comparable to those of the primary reflector.

Various features of our invention reside in techniques for reducing the blocking of the primary reflector from the signal wave and techniques for providing comparable path lengths and wavefront curvatures for the reflected signal and pilot waves.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of illustrative embodiments of our invention may be obtained from the following detailed description, taken together with the drawing, in which:

FIG. 1 is a partially pictorial and partially block diagrammatic illustration of a first embodiment of our invention;

FIG. 1A is an enlarged front elevation of a broken portion of the waveguide detector array of FIG. 1; and

FIG. 2 is a partially pictorial and partially block diagrammatic illustration of a second embodiment of our invention.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

In the embodiment of FIG. 1, a millimeter wave input signal wave at frequency f_s is received from a distant communication transmitter (not shown). The signal wave illustratively arrives as a substantially plane wave, primarily because of the transmission distance.

In order to achieve satisfactory signal-to-noise ratio in the detected signal, the antenna apparatus includes a collecting reflector 11 of lateral dimensions that are much greater than a wavelength of the received radiation. The reflector 11 collects and focuses the received radiation upon the mixing means, which is illustratively a waveguide detector array 12. It may be noted that much of the noise that, in part, determines the signal-to-noise ratio is inherent in the operation of a detector such as array 12.

It may be noted that an arbitrarily chosen signal ray may not be focused by reflector 11 to the nominal focal point, F, because of a surface irregularity, as shown. It is apparent that signal rays focused to different points in the detector array 12 have different relative phases.

The receiving antenna apparatus of FIG. 1 also includes a millimeter wave source 13 for supplying a local pilot wave, means comprising a horn antenna 14 for directing the pilot wave to illuminate the primary reflector 11 as fully as possible and then to be reflected from reflector 11, and means comprising a subreflector 15 for directing the reflected pilot wave to the detector array 12. The par-

tially transmissive subreflector 15 is smaller than the primary reflector 11 and is more carefully made and installed. It is adapted so that a pilot ray makes the same angle (though of opposite sign in this case) with respect to the axis and reaches the same point in the focal plane as does a signal ray that was reflected from the same portion of reflector 11. Using this principle, the exact curvature of subreflector 15 for a given position can be determined from the nominal curvature of reflector 11 by geometric ray optics.

More specifically, for a spherical reflector 11, the subreflector 15 is disposed so that the distance between the subreflector 15 and the focal point, F, of primary reflector 11 is approximately $R/6$, where R is the radius of curvature of reflector 11. The accuracy of this approximation is directly related to the focal length of reflector 11.

Further, for a spherical reflector 11, the curvature of subreflector 15 can be simply specified. In the limit of a long focal length system, the shape of the subreflector approaches a sphere having radius $2R/3$ and a center of curvature located at the intersection of the axis with reflector 11. For purposes of simplicity in describing the operation, it will be assumed that the apparatus of FIG. 1 fits this description, although similar results can be achieved in shorter focal length apparatuses.

The pilot wave supplying means 13 comprises a millimeter wave source at 34.8 gigahertz (34.8×10^9 cycles per second). The output of source 13 is applied to the millimeter wave horn antenna 14, which is shaped to form a diverging pilot wavefront to illuminate primary reflector 11 as fully as possible.

Specifically, the signal wave is a modulated millimeter wave at 35 gigahertz.

The output from detector array 12 may, optionally be applied to an intermediate frequency amplifier 21. In the illustrative embodiment of FIG. 1, the intermediate frequency is 200 megahertz (200×10^6 cycles per second).

As illustrated in FIG. 1A, the waveguide detector array 12 comprises a honeycomb structure 18 in each cell of which a diode 16 is connected, illustratively in the same orientation as the diodes 16 in other cells.

Each diode 16 is connected in series with an intermediate frequency load circuit 17 which comprises a broadband resistor shunted by a small capacitor just large enough to short out any millimeter wave current but not the IF current.

The IF circuits 17 are individually connected to IF amplifiers 19, the outputs of which are summed in summing circuit 20.

The material of honeycomb structure 18 is illustratively copper; and the lateral dimensions of each cell are adapted to enable each cell to act as a short section of waveguide at the signal and pilot frequencies.

In operation, an arbitrarily chosen signal ray is focused, as shown, by reflector 11 from one of its irregularities to a point in array 12 that is displaced from the nominal focus, F, of reflector 11. A corresponding pilot ray is incident nearly normally upon the same irregularity in reflector 11. The reflected pilot ray is then reflected from subreflector 15 to essentially the same point in array 12 as was the signal ray.

Similarly, other pairs of signal and pilot rays reflected from the same portions of reflector 11 are incident at common points in detector array 12, though from opposite sides. Each pair of rays then mixes to produce a contribution to the intermediate-frequency signal. These contributions add essentially in phase, since signal and pilot are so close in frequency. Therefore, at least the nonblocked portions of the area of reflector 11 have made effective contributions to the output signal despite their irregularities.

It is desirable to reduce the partial blockage presented to the signal by the subreflector 15. Its diameter is illustratively about one-third the diameter of the main dish for long focal length.

A technique for reducing blockage while still retaining the desirable qualities of the embodiment of FIG. 1 is illustrated in the embodiment of FIG. 2.

In the embodiment of FIG. 2, illustratively designed to operate at optical frequencies, a primary reflector 31 has a focal point, F, and a center, C, of its ideal or unperturbed curvature, where the radius of curvature is approximately equal to twice the focal length, as in FIG. 1. The apparatus includes a subreflector 35 for the pilot wave with a virtual focal point at C and a subreflector 36 for the reflected signal wave with a virtual focal point at F.

The primary reflector 31 includes a central aperture for passing the signal wave from subreflector 36 to a detector, such as photomultiplier 32, that has been displaced from the focus of reflector 31. It may be noted that the subreflectors 35 and 36 are blocking only the aperture of reflector 31 from the plane-wave received signal wave.

The means for directing the pilot wave includes, in addition to subreflector 35, the partially transmissive 45° reflector 37 and the 45° reflector 38, which is disposed between subreflectors 35 and 36, and the 45° reflector 39. The 45° reflector 37 is adapted to transmit the major portion of the pilot wave from the supplying means 13', illustratively a laser, to transmit the major portion of the signal wave through lens 40 to photomultiplier 32, and to reflect a small but significant portion of the returned pilot wave through lens 40 into photomultiplier 32 substantially collinearly with the signal wave.

The antenna apparatus also includes means 42 for adjusting the relative path lengths of the signal and pilot waves between reflector 31 and photomultiplier 32 to be substantially equal. The subreflectors and lenses are adapted to provide the same wavefront curvatures of the pilot and signal waves at the mixing means. In the illustrative embodiment of FIG. 2, the means 42 comprises right-angle reflector assembly 43 and right-angle reflector assembly 44 disposed with its members parallel to corresponding members of assembly 43 so that the signal wave, after passing through the aperture of reflector 31, is repeatedly reflected in a non-re-entrant manner in the path length adjusting means 42.

In the operation of the embodiment of FIG. 2, the major portion of the pilot wave passes through reflector 37, is reflected from reflectors 39 and 38 and then is spread by subreflector 35 to illuminate substantially all of primary reflector 31. Since the pilot wave is substantially normally incident upon reflector 31, it returns by essentially the same path to reflector 37, where a small portion of it, still more powerful than the signal, is reflected into photomultiplier 32. The pilot wave carries a pattern of small perturbations, produced by irregularities in reflector 31, and is focused by lens 40 upon the photomultiplier 32.

The signal wave is reflected from primary reflector 31 and subreflector 36, passes through the aperture and then through path length adjusting means 42 to reflector 37. A major portion passes through reflector 37, still carrying perturbations produced by the irregularities in reflector 31, as well as its modulation.

The lens 40 focuses each ray of the signal to the same point as the pilot ray reflected from the same portion of reflector 31. Coincident signal and pilot rays carry like phase perturbations and thus produce intermediate-frequency signal contributions that add in phase.

It should be apparent that a number of modified embodiments of our invention are readily constructed employing the principles of our invention. For example, the application to radio telescopes is direct, for the embodiment of FIG. 1, and, for the embodiment of FIG. 2, involves changing only dimensions and substituting for the reflectors, the detector and the pilot source their millimeter wave equivalents. For paraboloidal primary reflectors, adjustments in curvatures and placements of subsidiary reflectors may be calculated or determined by experiment.

A form of optical detector that may be substituted for photomultiplier 32 of FIG. 2 is the semiconductor planar optical mixer system described in British Patent No. 1,084,705, published Sept. 27, 1967. The path of either the signal or pilot wave to the mixer is tilted to adjust the relative angles of incidence upon an epitaxially grown semiconductor layer, grown on a semiconductor substrate, until the phase velocity of the intermediate-frequency wave is synchronized with the drift velocity of charge carries in the semiconductor layer. The carrier drift velocity is established by a suitable biasing field along the surface of the epitaxial layer; and the intermediate-frequency signal is coupled out by a separately applied transverse field that produces a current that is modulated by the signal-induced bunching of the drifting charge carriers.

We claim:

1. A receiving antenna apparatus comprising a primary focusing member having focusing irregularities affecting the focusing of the radiation to be received, means in the vicinity of said member for supplying a pilot wave of frequency differing from the frequency of the received radiation by an intermediate frequency, said pilot wave being capable of being similarly affected by said irregularities, means in the vicinity of said member for directing said pilot wave to be affected by said irregularities and thereafter to come together with the affected received radiation with substantially the same phase relationship throughout a substantial area, and means including a mixing element encompassing said area for mixing said pilot wave and said received radiation to produce an intermediate frequency wave.

2. A receiving antenna apparatus according to claim 1 in which the means for directing the pilot wave comprises a subsidiary focusing element having lateral dimensions substantially smaller than the lateral dimensions of the primary focusing member including irregularities, said subsidiary element being disposed on the axis of the primary focusing member at a position to receive said pilot wave from the primary focusing member and to direct the pilot wave toward an area of conjunction with said signal wave.

3. A receiving antenna apparatus according to claim 2 in which the area of conjunction is in the vicinity of the focus and the mixing element is disposed to encompass said area and said focus.

4. A receiving antenna apparatus according to claim 3 in which the primary focusing member is a primary reflector and the subsidiary focusing member is a sub-

reflector and said subreflector is partially transmissive of the pilot wave and the means for supplying said pilot wave comprises a source of radiation at the pilot wave frequency and means coupled to said source for forming said radiation into said pilot wave with a diverging wavefront propagating in part through the subreflector toward the primary reflector.

5. A receiving antenna apparatus according to claim 2 in which the primary focusing member is a primary reflector, the subsidiary focusing element is a first subsidiary reflector, and the area of conjunction is displaced from the primary focus and the apparatus includes means for directing the signal wave toward the displaced area, said signal wave directing means including a central aperture in the primary reflector and a second subsidiary reflector disposed inside the primary focus to direct the signal wave through said aperture, said second subsidiary reflector having a reflective surface of dimensions substantially smaller than the dimensions of the reflector surface including irregularities, the mixing element being disposed to encompass said displaced area.

6. A receiving antenna apparatus according to claim 5 including means for adjusting the path lengths for the signal wave and the pilot wave between reflection from the primary reflector and conjunction at the mixing element to be substantially equal.

7. A receiving antenna apparatus according to claim 5 in which the primary reflector is a substantially spherical reflector having a mean center of curvature, the focus being between said center and said reflector.

8. A receiving antenna apparatus according to claim 5 in which the means for directing the pilot wave and the means for directing the signal wave are mutually adapted to provide the pilot wave and the signal wave with the same wavefront curvature at the mixing element.

References Cited

UNITED STATES PATENTS

3,164,835	1/1965	Alsberg	343—779
3,234,390	2/1966	Okaya	250—199
3,394,738	7/1968	Williams	343—779

RODNEY D. BENNETT, Jr., Primary Examiner

HERBERT C. WAMSLEY, Assistant Examiner

U.S. Cl. X.R.

250—199; 343—779, 914