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None

(58) Field of search
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(71) Applicant
The Plessey Company plc (United Kingdom), Vicarage Lane, Ilford, Essex

(72) Inventors
Christopher Anthony Wade, John Philip Dakin

(74) Agent and/or address for service
K. J. Thorne, The Plessey Company plc, Patent Department, Vicarage Lane, Ilford, Essex, IG1 4AQ

(54) Improvements Relating to Optical Sensing Systems

(57) An optical sensing system comprises an optical fibre (6) arranged to be subjected to fibre deforming forces during use of the system and laser means (1) Bragg cell (2) and sweep oscillator (3) for generating light signals frequency modulated with a saw-tooth waveform for transmission along the optical fibre (6). The fibre (6) comprises at points along its length respective discontinuities (9 to 16) from which a light signal being transmitted along the optical fibre will be partially reflected back along the fibre (6) and combined in combiner (8) with the light signal being transmitted down the fibre so that heterodyning occurs between the interfering signals. When the optical fibre (6) is deformed by impingement of acoustic waves thereon the heterodyned frequencies corresponding to the discontinuities will be frequency-modulated by the deformation of the optical fibres. Demodulation of the frequency-modulated signals provides an indication of the acoustic signal incident upon the optical fibre. Fibre 6 may be replaced by a plurality of different lengths of fibre star coupled to a main fibre and having totally reflecting free ends. Other parameters such as temperature, pressure, electrical current or voltage, may be measured if converted into a deformation of the fibre.

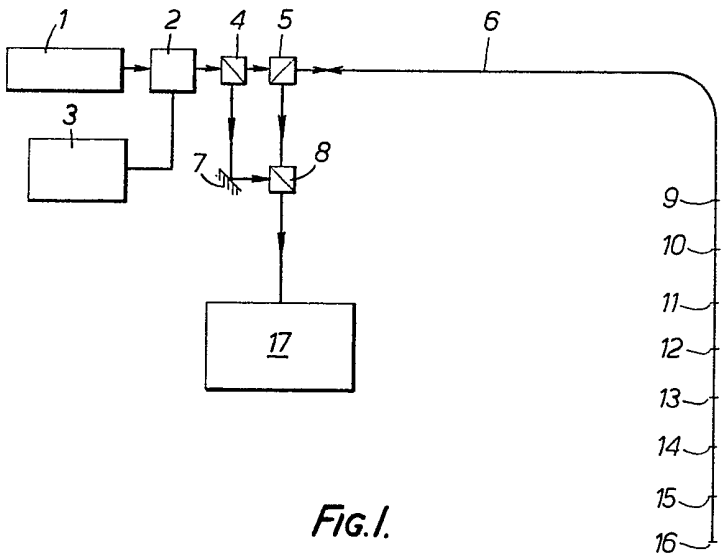


FIG. 1.

GB 2 136 113 A

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.
The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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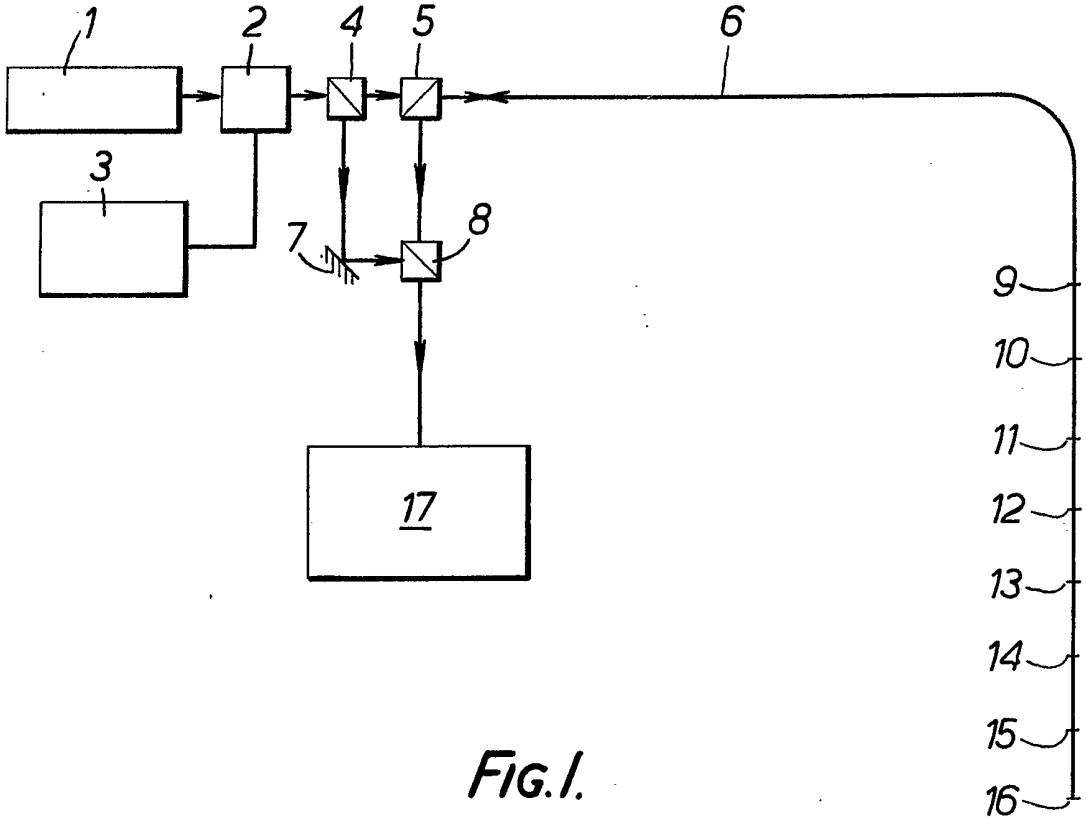


FIG. 1.

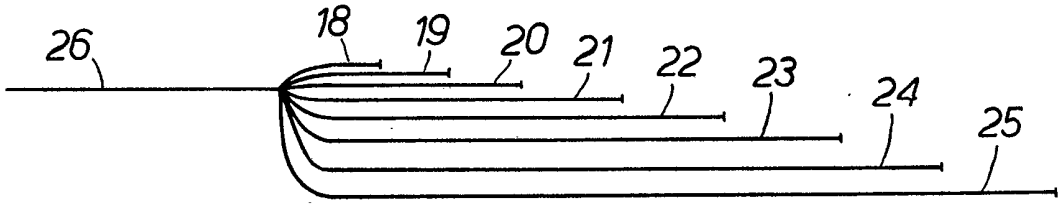


FIG. 2.

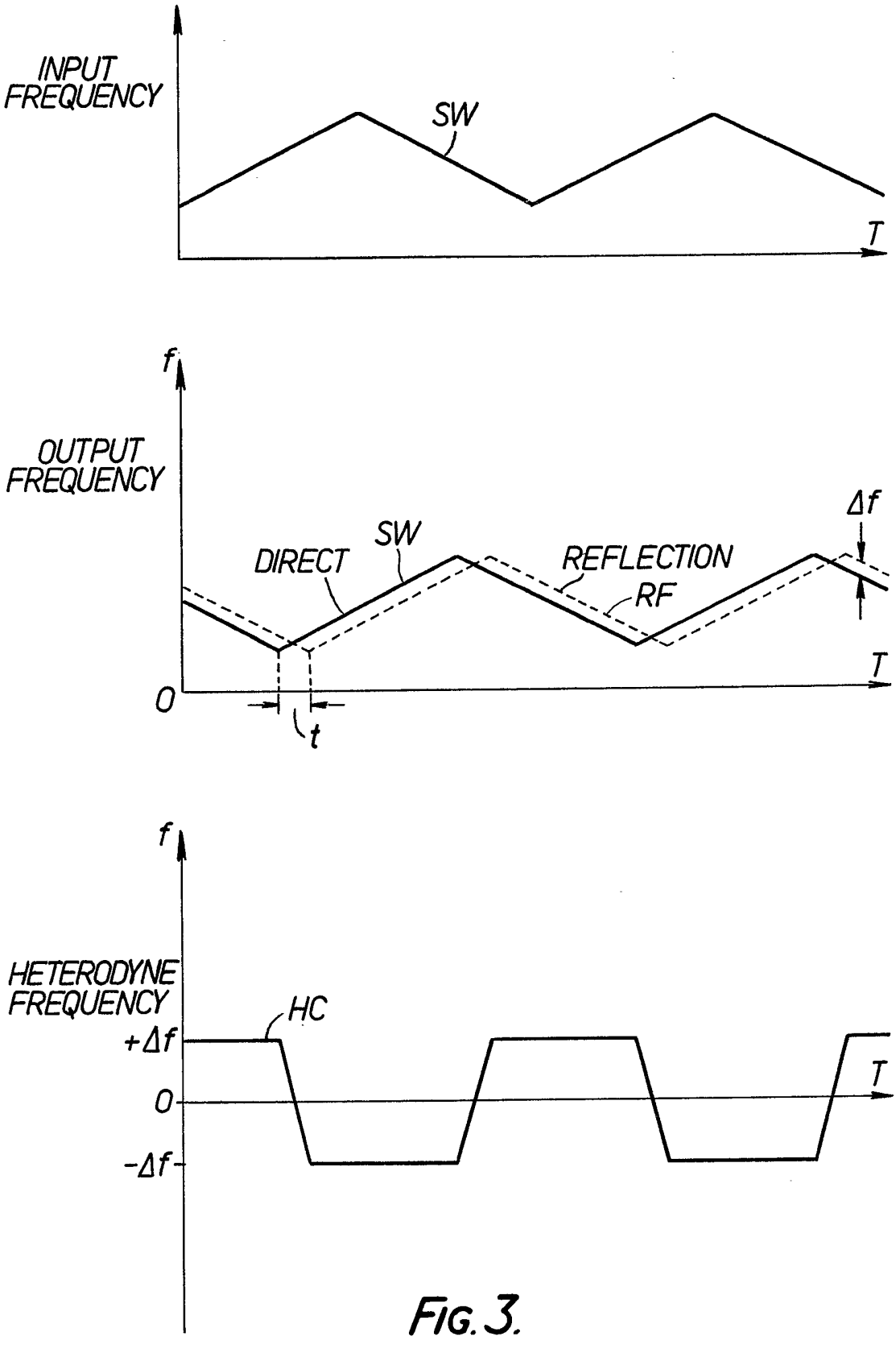

INPUT
FREQUENCY
SW
T
f
OUTPUT
FREQUENCY
DIRECT
SW
REFLECTION
RF
Δf
T
0
t
f
HETERODYNE
FREQUENCY
HC
+Δf
0
-Δf
T

FIG. 3.

SPECIFICATION

Improvements Relating to Optical Sensing Systems

This invention relates to optical systems for sensing strain or deformation (e.g. elongation or bending) of various members.

Although the present invention is especially concerned with hydrophones and the sensing of changes in length of an optical fibre in such hydrophones due to the impingement thereon of acoustic waves it should be understood that the invention is not limited to such application. In this connection many physical parameters can be converted by various well known means such as moving coil meters, bimetallic strips and Borden pressure gauges, into a displacement or deformation of some member which is dependent upon the particular parameter to be measured. Such parameters as temperature, pressure, electrical current or voltage could be measured in this way.

According to the present invention there is provided an optical sensing system comprising optical fibre means arranged to be subjected to fibre deforming forces during use of the system and means for producing a coherent light signal for transmission along said optical fibre means, in which the optical fibre means comprises at points along its length respective discontinuities from which a light signal being transmitted along the optical fibre means will be partially or totally reflected back along the fibre means and combined with the light signal being transmitted down the optical fibre means so that heterodyning occurs between the interfering signals.

In carrying out the present invention the light signal transmitted down the optical fibre means is frequency-modulated with a saw-tooth waveform. Consequently, the signals reflected back along the optical fibre means from the respective discontinuities will be delayed with respect to the saw-tooth signal transmitted along the optical fibre means by different delay periods dependent upon the location of the discontinuity along the optical fibre means and thus a set of heterodyned frequencies or carriers will be produced in accordance with these delay periods.

The optical fibre means may comprise a signal optical fibre having partially-reflecting discontinuities equally spaced therealong or, alternatively, it may comprise suitably coupled different lengths of optical fibre, the fibre ends of which constitute totally-reflecting discontinuities.

When the optical fibre means is deformed as by the impingement of acoustic waves thereon, the heterodyned frequencies or carriers corresponding to the discontinuities will be frequency-modulated by the deformation of the optical fibres. Demodulation of the frequency-modulated carriers provides an indication of the acoustic signal incident upon the optical fibre means and an indication of an acoustic signal incident upon a portion of optical fibre between particular discontinuities n and (n+1) can be obtained from the difference between demodulated signals in respect of the n^{th} and $(n+1)^{th}$ carriers.

By way of example the present invention will now be described with reference to the accompanying drawings in which:—

Figure 1 is a schematic diagram showing an optical fibre deformation detection system;

Figure 2 shows an alternative arrangement of optical fibre means to that shown in the system of Figure 1; and,

Figure 3 shows light signal waveforms occurring in the system of Figure 1.

Referring to Figure 1 of the drawings, a laser 1 generates coherent light which is frequency-modulated in a Bragg cell 2 by the output of a sweep oscillator 3 to provide a light signal having a saw-tooth waveform as shown in Figure 3. This coherent light signal is split into two beams by a first beam splitter 4. One of these beams passes through a second beam splitter 5 into an optical fibre 6 whereas the other beam, after reflection by a mirror 7, passes into a third beam splitter 8.

The light beam of saw-tooth frequency-modulation SW (Figure 3) which is transmitted down the optical fibre 6 is partially reflected back along the optical fibre at each of a number of equally-spaced partial discontinuities 9 to 16 along the optical fibre. The light RF reflected back along the optical fibre 6 from the discontinuity 9 is deflected by the second beam splitter 5 into the third beam splitter 8 where it is combined with the outgoing light signal SW transmitted along the optical fibre 6. The combined outgoing signal and the reflected signal which is delayed with respect thereto by a time period "t" are heterodyned as can be seen from Figure 3 to provide the waveform HC.

Each of the other reflected signals from discontinuities 10 to 16 will be delayed by a different delay period with respect to the preceding reflection and consequently the input to a detector/receiver 17 will comprise a set of heterodyned signals or carriers. These carrier signals will be frequency-modulated in the event of changes in length of the optical fibre sections between discontinuities 9 to 16, suchas due to the impingement of acoustic waves thereon when the system is utilised as a hydrophone.

These frequency-modulated carrier signals will be demodulated in the receiver/detector 17 to provide a set of demodulated signals appertaining to the fibre sections. The acoustic signal incident on any of the fibre sections can be extracted by taking the difference between the demodulated signals in respect of the n^{th} and $(n+1)^{th}$ portions of the optical fibre.

An alternative form of optical fibre means is shown in Figure 2 which comprises a plurality of lengths of fibre 18 to 25 which are star-coupled to the main optical fibre 26 along which the saw-tooth signal is transmitted and the free ends of which are totally reflecting.

CLAIMS

1. An optical sensing system comprising optical fibre means arranged to be subjected to fibre deforming forces during use of the system and means for producing a coherent light signal for transmission along the optical fibre means, in which the optical fibre means comprises at points along its length respective discontinuities from which a light signal being transmitted along the optical fibre means will be partially or totally reflected back along the fibre means and combined with the light signal being transmitted down the optical fibre means so that heterodyning occurs between the interfering signals and in which the combined light signals are applied to demodulation means which provides an output indicative of the acoustic or other deforming force acting on the optical fibre means.

2. An optical sensing system as claimed in claim 1, in which the light signal transmitted down the opical fibre means is frequency modulated with a saw-tooth waveform so that the signals reflected back along the optical fibre means from the respective discontinuities will be delayed with respect to the saw-tooth signal transmitted along the optical fibre means by different delay periods dependent upon the location of the discontinuity along the optical fibre means and thus a set of heterodyned frequencies or carriers will be produced in accordance with these delay periods.

3. An optical sensing system as claimed in claim 1 or claim 2, in which the optical fibre means comprises a single optical fibre having partially-reflecting discontinuities equally spaced therealong.

4. An optical sensing system as claimed in claim 1 or claim 2, in which the optical fibre means comprises suitably coupled differing lengths of optical fibre the ends of which constitute totally-reflecting discontinuities.

5. An optical sensing system as claimed in any preceding claim, in which the coherent light signal is produced by a laser which is frequency-modulated in a Bragg cell or the equivalent by the output of a sweep oscillator before being applied to the optical fibre means.

6. An optical sensing system as claimed in claim 5, in which the frequency-modulated light signal output from the Bragg cell or its equivalent is split into two beams by a first beam splitter/combiner, one of which beams passes through a second beam splitter/combiner before being fed into the optical fibre means and the other of said beams being applied to a third splitter/combiner where it is combined with reflected light signals from the optical fibre means before being applied to demodulation means.

7. An optical sensing system substantially as hereinbefore described with reference to the accompanying drawings.

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