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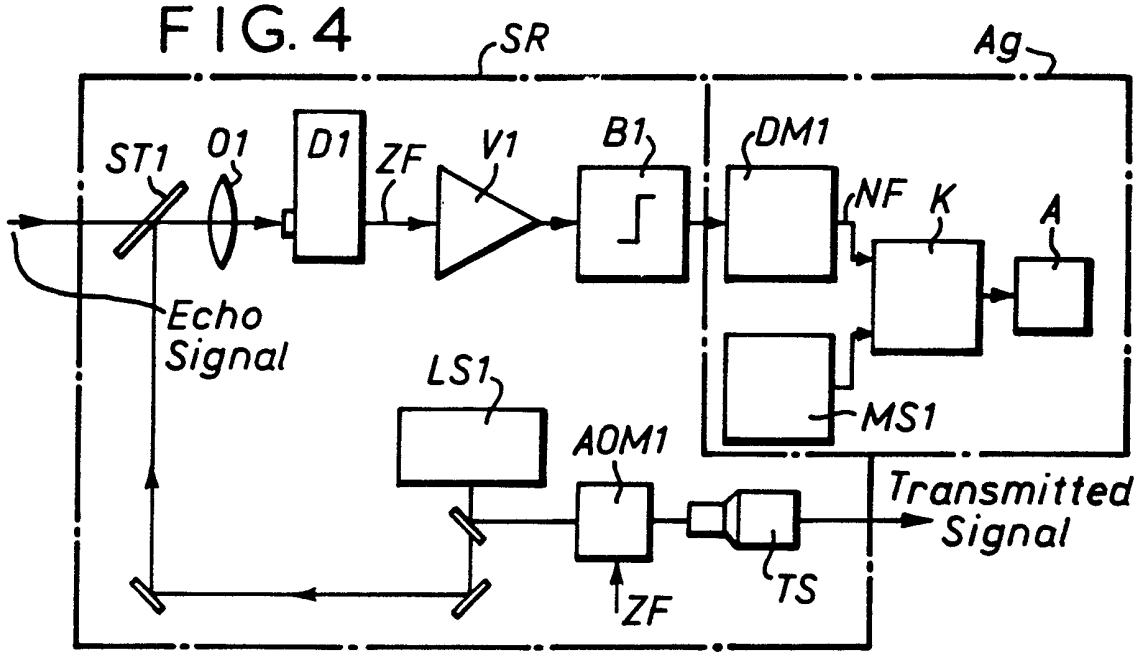
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UK CL (Edition J) H4D
INT CL[4] G01S 17/00 17/02 17/50 17/58
NO SEARCH POSSIBLE

(54) **A system for recognising and identifying target objects**

(57) The use of a laser LS1 for the recognition and identification of target objects is based on the insight that the laser beam after reflection by a target object contains characteristic Doppler frequencies which are produced from surface vibrations induced by moving parts of drive assemblies. The system includes an optical superheterodyne receiver ST1, D1, and following frequency conversion and demodulation (DM1), obtains from the laser echo signals low-frequency oscillations with the frequencies of the vibration spectrum, from which recognition and identification results are determined by comparison (K) with patterns of known target objects.

FIG. 4



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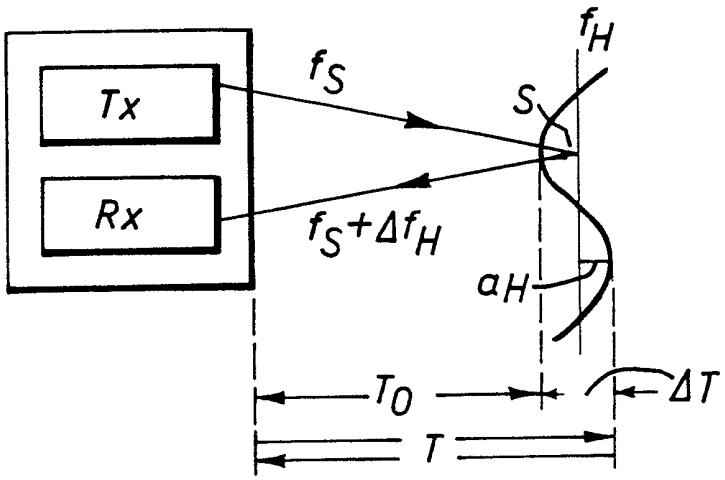

Tx
Rx
f_S
$f_S+\Delta f_H$
f_H
S
a_H
T_0
ΔT
T

FIG. 1

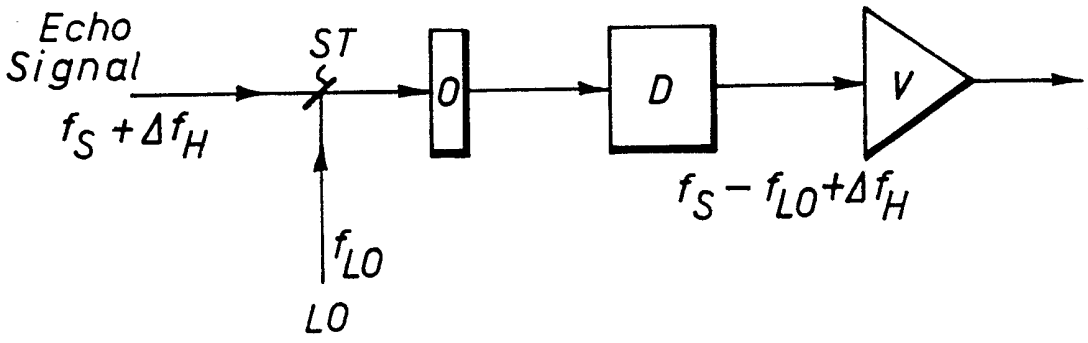

Echo
Signal
$f_S+\Delta f_H$
ST
f_{LO}
LO
O
D
V
$f_S-f_{LO}+\Delta f_H$

FIG. 2

FIG. 3

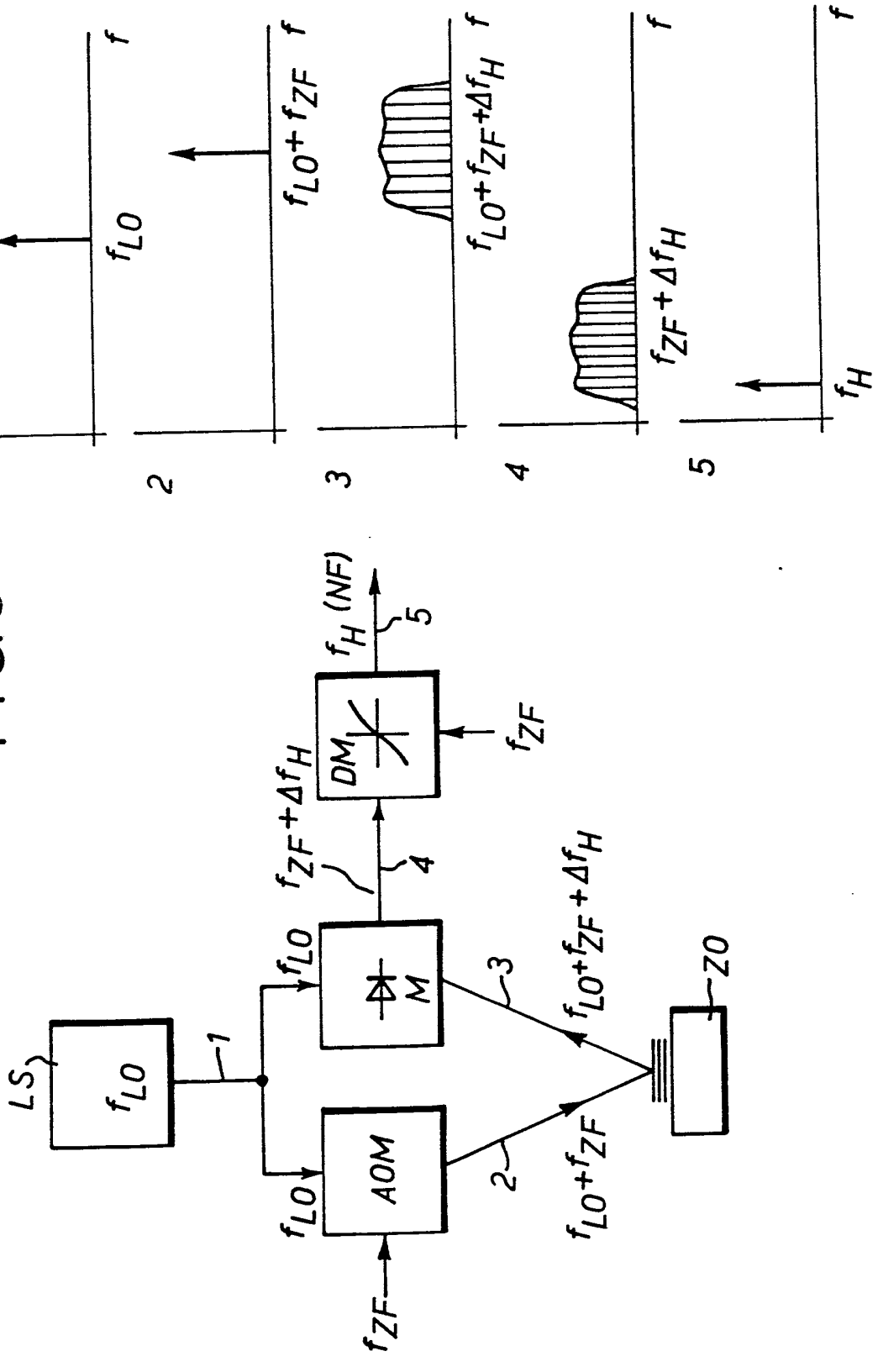

LS
f_{LO}
1
f_{LO}
AOM
f_{ZF}
f_{LO}
M
$f_{ZF}+\Delta f_H$
4
DM
f_H (NF)
5
f_{ZF}
2
3
$f_{LO}+f_{ZF}$
$f_{LO}+f_{ZF}+\Delta f_H$
ZO
1
f_{LO}
f
2
$f_{LO}+f_{ZF}$
f
3
$f_{LO}+f_{ZF}+\Delta f_H$
f
4
$f_{ZF}+\Delta f_H$
f
5
f_H
f

FIG. 4

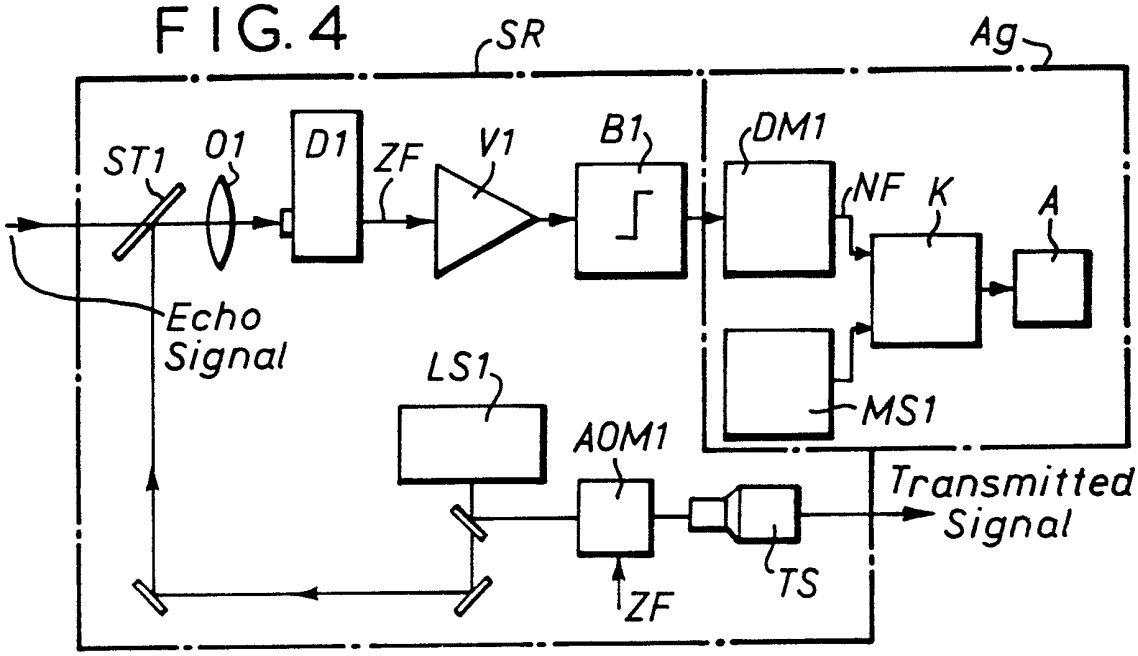


FIG. 5

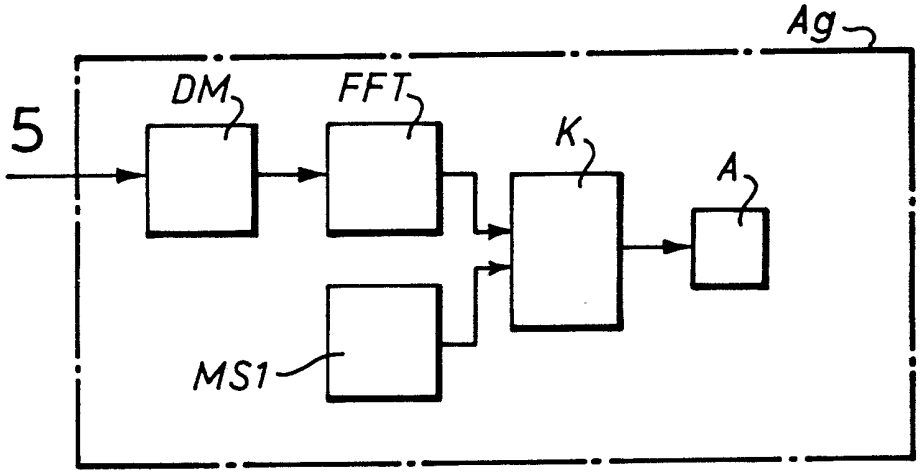


FIG. 6

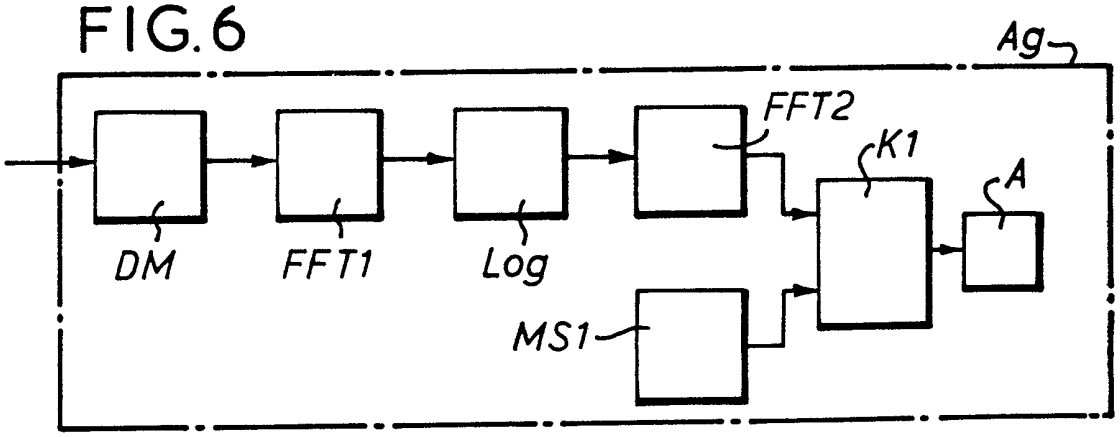
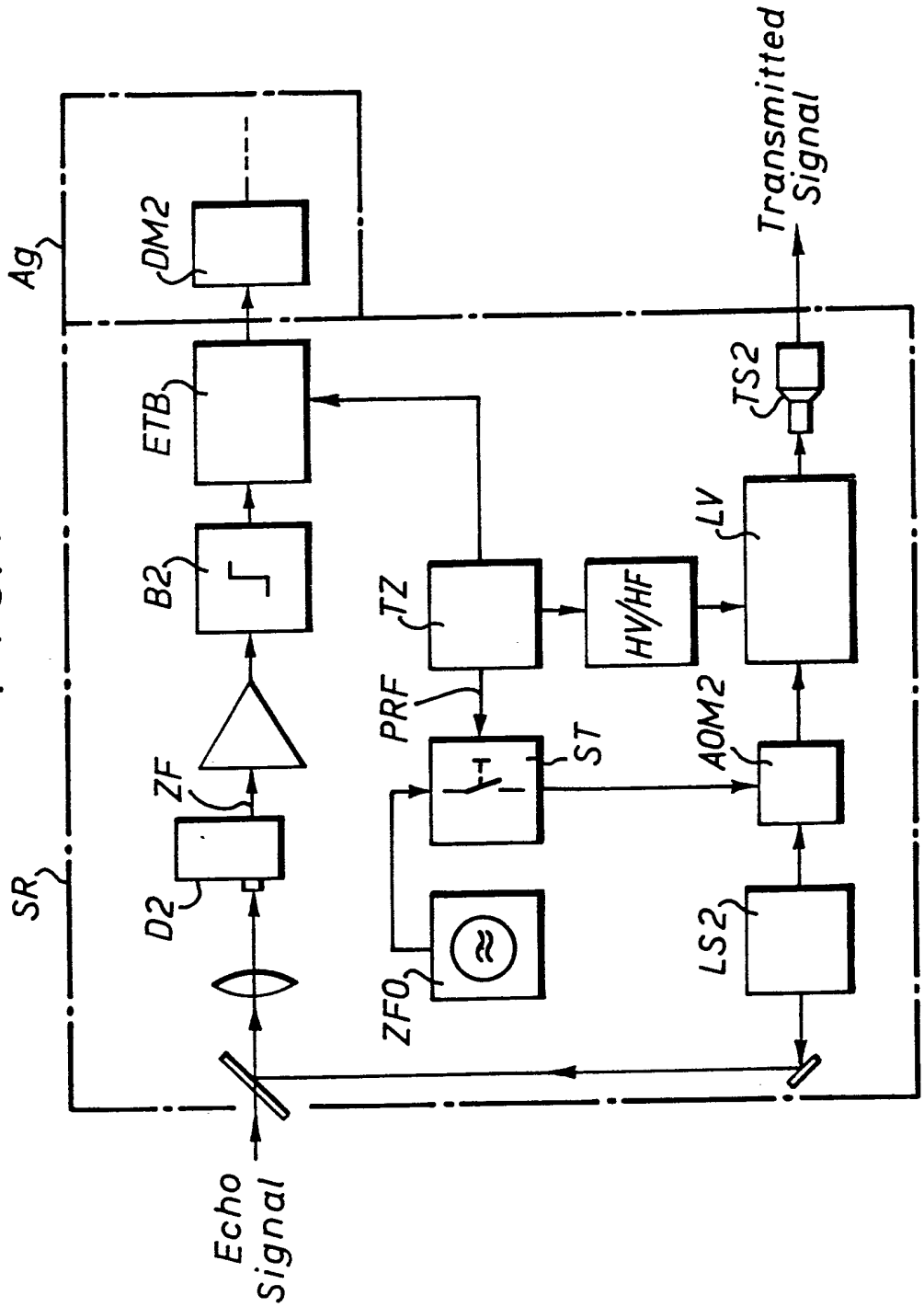


FIG. 7


Ag
DM2
ETB
B2
ZF
SR
D2
Echo Signal
TZ
PRF
ST
ZFO
HV/HF
LV
AOM2
LS2
TS2
Transmitted Signal

8 JUL 1985

A RADAR SYSTEM FOR RECOGNISING AND IDENTIFYING TARGET OBJECTS:

The invention relates to radar systems for the recognition and identification of target objects.

For the recognition and identification of military targets in the field of combat various active and passive operating arrangements are known, using radar devices, heat-sensitive sensors and heat image devices, for example. In view of the specific problems arising due to use in a field of combat, the special features of the various devices can prove advantageous or disadvantageous depending upon a large number of diverse factors.

When radar devices are used, it is mainly the Doppler frequency components of the echo signals of moving target objects or of moving parts on these objects that are analysed, for example by spectral analysis, for the purposes of recognition and identification. Passive operating devices, utilising heat radiation from the target objects and the modulation of the heat radiation, such as that produced by the rotor of a helicopter, for example, can derive unique characteristic features for recognition or identification.

One object of the present invention is to further improve upon the recognition and identification of target objects by utilising an arrangement which is based upon the recognition that drive assemblies of all the objects which are used produce corresponding vibration phenomena on the surface thereof.

In accordance with the invention there is provided a radar system for the recognition and identification of target objects, in which a laser sensor comprises a laser transmitter and an optical superheterodyne receiver, a demodulator being arranged at the output of the optical receiver, with automatic matching to the Doppler frequency shift governed by the speed of the target object, and an analysis circuit for the formation of a recognition or identification result from the demodulated signals based on the time or frequency range thereof in comparison with patterns of known target objects held available in a store.

The characteristic vibration spectrum which occurs on the surface of the objects modulates the frequency or phase of the laser beam which is directed towards the object. Thus the reflected echo signal contains a Doppler frequency component which is based exclusively on the vibrations of the surface. Since all the surface components of an object execute oscillations with the vibration frequency, it is immaterial as to which part is illuminated by the laser beam. Thus in comparison to other known methods the advantage is obtained that recognition and identification are independent of the aspect angle.

Advantageously a laser having a wavelength in the infra-red range, e.g. a CO_2 laser, is used. This wavelength is very much smaller than the vibration amplitude at the surface of an object. Therefore a good modulation depth is ensured and analysis is assured, even for very low vibration frequencies down to 1Hz.

If the target object illuminated by the laser beam has a movement of its own, then the Doppler frequency of the echo signal attributable to the vibration oscillations is superimposed upon a second speed-dependent, Doppler frequency. The automatic adaptation of the demodulator in the superheterodyne receiver to the frequency shift can advantageously be achieved by means of a PLL (phase-locked-loop) circuit.

The invention will now be described with reference to the drawings, in which:-

Figure 1 is an explanatory representation of the production of the frequency modulation of the laser beam by surface vibration on a helicopter;

Figure 2 is a fundamental block schematic diagram of the construction of an optical superheterodyne receiver;

Figure 3 is a block schematic representation of information acquisition using a laser sensor, together with a set of related graphs;

Figure 4 represents one exemplary embodiment of the invention, using a laser sensor with an analysis circuit for a laser transmitter which operates in CW-operation;

Figures 5 and 6 illustrate advantageous modifications of the analysis component used in the exemplary embodiment shown in Figure 4; and

Figure 7 illustrates details of an exemplary embodiment of a laser sensor for use with a pulsed laser transmitter.

Taking the example of a helicopter, the modulation produced in a laser beam by the vibration of the helicopter air frame which is generated by the drive assembly will be clarified making reference to Figure 1. The hovering helicopter is irradiated with a frequency f_s by a laser transmitter Tx. The oscillation of the transmitted signal will be assumed to be sinusoidal and described by the following formulae:-

$$A_s = a_s \cos \Omega_s t;$$

where A_s is the amplitude following the expiration of the time t, a_s is the maximum amplitude and $\Omega_s = 2\pi f_s$ is the angular frequency. The signal reflected from the helicopter reaches a receiver Rx, following an overall transit time T, with the phase ψ.

For simplification it will be assumed that the mechanical oscillation which occurs at the reflection point of the outer membrane of the helicopter is sinusoidal and is governed by one single frequency f_H. It can be described by the formula:-

$$s(t) = a_H \sin W_H t$$

where s is the amplitude following the expiration of the time t, a_H is the maximum amplitude (Hub) and W_H is the angular frequency. It will be further assumed that the deflection s of the outer membrane of the helicopter is precisely directed towards the receiver. As a result the transit time T is modulated in step with the rythm of the vibration. Under these conditions it is simple to mathematically deduce that the reflected laser beam has a frequency modulation.

The resultant modulation index m obeys the equation:-

$$m = \frac{4 \pi a_H}{\lambda_s} ;$$

where λ_s is the wavelength of the transmitted radiation. Generally the vibration amplitude a_H of the object is considerably greater than the wavelength λ_s of the laser.

As a result the reflected laser beam is well modulated and leads to a large frequency sweep. Therefore a good signal/noise ratio is likely as the latter increases in the case of frequency modulation with an increasing frequency sweep.

If the helicopter has a relative speed, this leads to an additional Doppler shift, which must be taken into consideration in the signal preparation in the receiver.

An optical superheterodyne receiver is required for the processing of the laser echo signals. As can be seen from Figure 2, the received signal consists of the modulation spectrum Δf_H at a carrier frequency f_s. For demodulation, the carrier frequency f_s in the receiver must be known, i.e. a superheterodyne receiver is required. Figure 4 shows the fundamental construction of an optical superheterodyne receiver. In the detector the local oscillator signal LO is input-coupled via a beam-splitter ST and an optical lens O, and has the frequency f_{LO}. This is superimposed upon the received signal with the frequency $f_s + \Delta f_H$. The mixed product of the two signals with the frequency $f_s - f_{LO} + \Delta f_H$ occurs at the output of the detector D. The frequency difference between the carrier frequency

and the local oscillator frequency must have the constancy required for superheterodyne reception. Therefore the two frequencies should be derived from a coherent source. The mixed product at the output of the detector D is fed to an amplifier V for further processing.

The acquisition of information will be explained making reference to Figure 3. A laser beam of the laser transmitter LS with the frequency f_{LO} is frequency-displaced by an intermediate frequency f_{ZF} (in the MHz-range) using the acousto-optical modulator AOM. The output signal with the frequency $f_{LO} + f_{ZF} = f_s$ illuminates the target object ZO and is frequency-modulated by the vibration at its surface. The signal reflected to the receiver contains the frequency modulation Δf_H on a carrier frequency $f_{LO} + f_{ZF}$. When this requency has been mixed with the frequency f_{LO} of the laser transmitter, the output of a mixer stage M of the receiver provides the frequency modulation Δf_H upon the intermediate frequency f_{ZF}. This can be demodulated in the demodulator DM to give the actual vibration oscillation f_H.

Figure 4 shows an exemplary embodiment of a laser sensor with an analysis circuit for a laser transmitter operating in CW-operation. The transmitted frequency produced in a transmitter LS, for example a CO_2 laser, is irradiated via a telescope TS as the transmitted signal. The frequency is shifted by an intermediate frequency ZF, as is required for the optical receiver to function as a superheterodyne receiver, takes place

in an acousto-optical modulator AOM1. The LO-signal is coupled into the optical superheterodyne receiver via a beam splitter ST1 together with the received signal, which has been reflected from the target object. The two signal components pass via an optical lens 01 to the input of a detector D1 whose output supplies the modulation signal with a middle frequency located at the intermediate frequency. This signal is amplified in the amplifier V1, limited in a limiter B1, and is then demodulated in a frequency demodulator DM1 to give the vibration oscillation which occurs in the low frequency range. The sum of all the vibration oscillations of that region of the surface or surfaces of the target object within the area illuminated by the laser then represents the characteristic vibration spectrum or "signature". In addition to the FM demodulator the correlator K forms an important component of the analysis circuit. By effecting a time range correlation with patterns of known targets, which can be obtained from a pattern store MS1, for example, the type of a target object can be determined and displayed in a display device A.

The FM demodulator DM1 must also be designed in such manner that, in addition to the Doppler frequency which occurs as a result of vibration oscillations on the surface of a target object, any further oppler frequency superimposed thereon and dependent upon the relative speed of the target object is taken into account. In order to eliminate the undesired Doppler

frequency which is dependent upon the relative movement of the target object, it is necessary that the demodulator should follow up such a frequency. In terms of circuitry this is possible by the use of a PLL-circuit (phase-locked-loop-circuit).

In contrast to the exemplary embodiment illustrated in Figure 4, the vibration spectrum can be analysed by an arrangement as schematically shown in Figure 5, using a fast-Fourier-processor FFT arranged between the FM demodulator DM1 and the correlator K, which converts the time range low-frequency vibration oscillations into the spectral range. Correlation with the known patterns is then carried out in the frequency range by the correlator K, to produce an identity display on the output device A.

In a further exemplary embodiment, shown in Figure 6, the spectrum of the vibration oscillations is obtained by double-Fourier transformation between the output of the demodulator and input of the correlator K1, where a logarithmic-conversion is carried out in a stage Log between the first and second Fourier transformation that is effected in a second processor FFT2. The identification of the target object then takes place in the same way as described for the preceeding exemplary embodiments, by means of correlation and display.

An exemplary embodiment of a laser sensor to be operated with a pulsed laser beam is shown in Figure 7. Thus the circuit corresponds to that of a pulse Doppler radar installation, and in order to form the intermediate frequency in a

detector D2 the superheterodyne signal fed to the input of the optical receiver together with the received signal is supplied directly from a CW-laser LS2. The CW-laser also feeds a laser amplifier LV via an acousto-optical modulator AOM2. A central control clock pulse generator TZ produces the pulse frequency PRF which supplies both the clock frequency for an IF-oscillator ZFO, the clock frequency for a range gate bank ETB, and also the clock frequency for a high voltage/high frequency source HV/HF. The clock frequency is emitted to a switching stage ST thus corresponds to the pulse repetition frequency of the transmitted laser beam. The oscillator frequency keyed in the switching stage ST in the timing of the pulse repetition frequency displaces the laser frequency by the intermediate frequency ZF in the acousto-optical modulator AOM2. A laser amplifier LV amplifies the displaced laser frequency, and is additionally pulsed with high frequency or HV-excitation in the timing of the pulse repetition frequency. Here the pulse width is wider than the laser pulse fed-in from the acousto-optical modulator AOM2. As a result the laser pulse which is input-coupled into the laser amplifier LV already hits an excited medium and immediately triggers an amplified laser pulse to be transmitted via a telescope TS2.

The processing of the echo signals in the receiving arm of the laser sensor differs from the previously described exemplary embodiments by virtue of the use of the range gate bank ETB that is arranged at the output of a limiter B2 which follows an IF amplifier ZF connected to the output of the detector D2.

Due to the use of the range gate bank ETB, the gate in which the received signal of a target object is located is switched through to a demodulator DM2.

CLAIMS:

1. A radar system for the recognition and identification of target objects, in which a laser sensor comprises a laser transmitter and an optical superheterodyne receiver, a demodulator being arranged at the output of the optical receiver, with automatic matching to the Doppler frequency shift governed by the speed of the target object, and an analysis circuit for the formation of a recognition or identification result from the demodulated signals based on the time or frequency range thereof in comparison with patterns of known target objects held available in a store.

2. A system as claimed in Claim 1, in which the Doppler echo signal formed from the sum of all the vibration oscillations on the surface of the target object falling within the illumination range of the laser beam is analysed via the superheterodyne receiver and analysis circuit.

3. A system as claimed in Claim 1 or Claim 2, in which the demodulator is designed as a PLL-circuit.

4. A system as claimed in any preceding Claim, in which the local oscillator has a high frequency stability for the production of the intermediate frequency in the superheterodyne receiver.

5. A system as claimed in any preceding Claim, in which the transmitter of the laser sensor operates as a CW-laser.

6. A system as claimed in any one of Claims 1 to 4, in which the transmitter of the laser sensor is a pulsed transmitter.

7. A system as claimed in any preceding Claim, in which the transmitter is designed as a CO_2 gas laser.

8. A system as claimed in any preceding Claim, in which the frequency shift of the laser frequency by the intermediate frequency is effected by means of an acousto-optical modulator.

9. A system as claimed in any preceding Claim, in which the identification of the target object takes place by time range correlation with patterns of known targets.

10. A system as claimed in any preceding Claim, in which the demodulated signal oscillations are converted by a fast-Fourier-processor into the spectral range, whereupon frequency range correlation with patterns of known target objects is effected.

11. A system as claimed in Claim 10, in which the demodulator is followed by a first fast-Fourier processor, a logarithmic-converter circuit, and a second fast-Fourier processor whose output spectrum is analysed by correlation with known patterns for purposes of identification.

12. A radar system for the recognition and identification of target objects, substantially as described with reference to Figures 1 to 4, or as modified with reference to any one of Figures 5 to 7.

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