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ACOUSTICAL TELEMETRY

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ABSTRACT

The work presents a method of position measuring of a mobile body on straitened areas using the acoustical wave. The advantages of the acoustical telemetry consist on contactless measurement of the position and on higher precision at low costs. Additional, an acoustical telemeter can be easy coupled at any programmable calculator in order to investigate on automatically way the movement of the mobile body.

1. The principle

The position of a mobile body must be determined on an axis, plane or space. This position can be found without direct measure, respectively without direct contacts with the body, using the methods of telemetry. A very easy method can be the acoustical telemetry. In principal are measured the distances between the mobile body and more fixed reference points (one point if the telemetry is on one axis, two points in plane or three in space), using the properties of the acoustical wave.

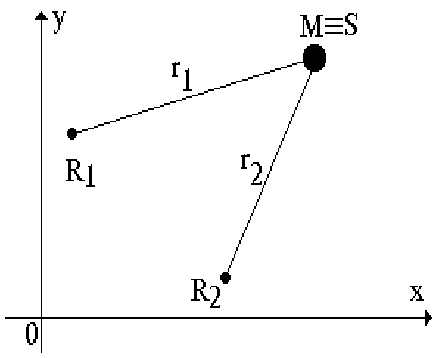

Figure 1

The mobile body M (figure 1) carries on him a source S that produces harmonically mechanically oscillations and generates harmonically longitudinal waves in the ambient. The mechanically wave circulates in ambient with his specific speed c_a very little in ratio with an electrical wave, an electrical signal in a wire or a signal in an optical cable, c_c, $c_a = 288 \cdots 342\ m/s$ in air, $c_c = 2.7 \cdot 10^8 \cdots 3 \cdot 10^8\ m/s$ in different media.

If the source S transmits an acoustical wave in ambient and concomitant it electrical signals through cable or as modulated radio wave, the signal through cable or radio arrives to any point faster as the acoustical wave. On short distances, like a few meters, the signal through cable or radio arrives practically instantaneous and has the same phase like the signal in source, the acoustical wave arrives later and with a appreciable different phase. The alteration of phase is an indicator of the distance between source and measurement point. The value of the alteration of phase $\Delta\varphi$ is given from

$$\Delta\varphi = \frac{\omega \cdot r}{c_a} \qquad (1)$$

where ω = the pulsation of the source S, r = the distance between the source and measurement points. With two measurement points R_1, R_2 in plane or three points in space, with known positions, can be determined the distances r_1, r_2 or r_1, r_2, r_3 in order to determine the position of the mobile body M, through a very easy analytically calculus.

2. Particularisation and example.

2.1. The value of the source pulsation.

Because the same value of the alteration of the phase results periodically at distances equal with the wavelength λ, for the spaces r from (1) greater as the wavelength must be known not only the alteration of phase, additional is necessary also the integer number of the enclosed wavelengths. In order to make easier the measurement and independent from the number of wavelength, the wavelength must be greater as the maximal value $r_i, i = 1,2\ or 3$, namely $\lambda > r_{i\,max}$. From here results the maximal value of the pulsation

$$\omega < \frac{2 \cdot \pi \cdot c_a}{r_{i\,max}} \tag{2}$$

If we consider as ambient environment the air, the wave speed becomes $c_a = 330 m/s$. If $r_{imax} = 5m$ from (2) result $\omega < 414,6\ s^{-1}$, namely a maximal frequency from $66\ Hz$. Therefore, for area from a few meters results low values of the frequency of the source S, respectively sound wave which deranges the acoustics of the environment. An ultrasound wave can offer a good alternative if the space r has reasonable values. An ultrasound wave with the frequency from *16500 Hz* has a wavelength from *20 mm*, enough in order to detect easy and sure the positions between same consecutive values of the alteration of phase. Additional, same frequency is often heavy audible and perturbs not the hearing. In this case the calculation model of the position must chalk up any alteration of phase $\Delta\varphi$ from *0* to 2π or contrariwise and each change from *0* to 2π or contrariwise must increments or decrements the number n of the integer wavelengths included in the distance r like

$$r = \frac{c_a}{\omega}\left(2 \cdot \pi \cdot n + \Delta\varphi\right) \tag{3}$$

Higher frequency is not recommendable because two grounds: firstly, the distance between

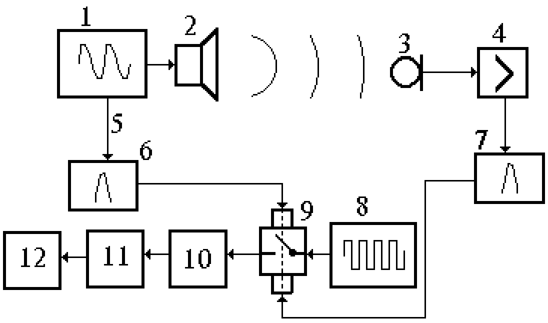

Figure 2

two same consecutive positions at the same alteration of phase becomes to little and difficult to determine and secondly, the coupling of the ultrasound transmitter to gaseous environment is complicated for high frequencies.

2.2. Block diagram.

Figure 2 presents the block diagram where:

1. Sound oscillator
2. Loudspeaker or any sound transmitter
3. Microphone or any sound receiver
4. Amplifier
5. Cable
6. Peak detector
7. Peak detector
8. Impulses generator
9. Chopper with electronic command (from 6 switches on, from 7 switches off)
10. Counter
11. Processing unit
12. Memory

The devices 10, 11 and 12 can be all or partially a programmable calculator and count a number n_i of arrived impulses from the generator 8.

The frequency of the impulse generator 8 gives the precision ε of the determination of the position r. For a variation of the alteration of phase between *0* and 2π the counter 10 counts the value of the wavelength in units from ε, respectively a number $n_i = \lambda/\varepsilon$ impulses arrived from the generator 8 on a period $T = 2 \cdot \pi/\omega$ of the source. The frequency of the generator 8, ν_{imp}, becomes

$$\nu_{imp} = \frac{n_i}{T} = \frac{\lambda}{\varepsilon} \cdot \frac{\omega}{2 \cdot \pi} = \frac{c_a \cdot \frac{2 \cdot \pi}{\omega}}{\varepsilon} \cdot \frac{\omega}{2 \cdot \pi}$$

or

$$\nu_{imp} = \frac{c_a}{\varepsilon} \tag{4}$$

The frequency of the generator 8 is independent from the wave frequency. If we need a precision ε between *1 mm* to *0.1 mm* we can use $\nu_{imp} = 330 \cdots 3300\ KHz$, easy to handle on currently electronic devices. The calculator detects the cases of change of the alteration of phase $\Delta\varphi$ from *0* to 2π or contrariwise, increases or decreases the value of the distance with a wavelength and gives the distance r

$$r = \frac{2 \cdot \pi \cdot c_a}{\omega} n + n_i \tag{5}$$

with the speed c_a measured in same units as ε . In order to determine easy and automatically the number n, the measuring process begins with the receiver 3 very near from the source 2, at a distance littler as a wavelength. In this case is fixed $n = 0$ from begin of the process and n increased or decreased automatically during of the process.

The numeration of the impulses from 8, the calculation of the distance and the storage in memory repeated cyclical with a cadence dependent from the speed of the mobile body and put in memory a numerical string of positions as time function.

2.3. Source of errors

The wave speed c_a depends from the temperature, pressure, humidity and composition of the air. Periodically c_a must be determined on direct measurement.

If the microphone or loudspeaker hasn’t perfect cylindrical or spherical characteristics appear errors dependent from the angular position of the direction between source and microphone in ratio with the characteristics. A calibration measurement determines same errors and these errors will be accepted as correction in determinations.

Interference with another acoustical wave. In order to reduce this interference the sound oscillator must be adjustable on a free frequency and the amplifier must be equipped with small band adjustable filters.

Interference with the reflections of the own waves. The strength of the reflected wave is lower as the strength of the direct wave. The amplifier must be adjustable in order to permit the passage of the direct wave only.

References

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