Beating of ultrasonic waves

Objects of the experiment

- Observing beats of ultrasonic waves with the oscilloscope.
- Determining the beat frequency f_S and comparing this with the difference of the individual frequencies f_a and f_b.
- Determining the oscillation frequency f and comparing this with the mean value of the individual frequencies f_a and f_b.

Principles

In ultrasound as well, the superposing of two waves with slightly different frequencies f_a and f_b results in the phenomenon of beats.

The sum

$$A_0 \sin(2\pi f_a t) + A_0 \sin(2\pi f_b t) =$$
$$2A_0 \cos(\pi(f_b - f_a)\, t) \sin\left(2\pi \frac{f_b + f_a}{2} t\right)$$

of the two individual waves can be understood as an oscillation with the mean frequency

$$f = \frac{f_a + f_b}{2} \qquad \text{(I)}$$

and the periodically varying amplitude

$$A(t) = 2A_0 \cos\left(2\pi \frac{f_b - f_a}{2} t\right).$$

The period T_S between two consecutive minima of the amplitude *A(t),* i.e. between two beat nodes (see Fig. 1) is called the beat period, and the frequency

$$f_S = \frac{1}{T_S}$$

is called the beat frequency. These show the relationship

$$f_S = f_b - f_a \qquad \text{(II)}$$

Three ultrasonic transducers – flexural resonators – serve as transmitters and receivers, depending on their connection. A piezoelectric body converts electrical to mechanical energy.

When an AC voltage is applied to the piezoelectric body, the transducer configured as a transmitter supplies a sufficiently high sound amplitude at two different resonance frequencies (approx. 40 kHz and 48 kHz). Conversely, sound waves generate mechanical oscillations in the transducer when configured as a receiver. The amplitude of the resulting piezoelectric AC voltage is proportional to the sonic amplitude.

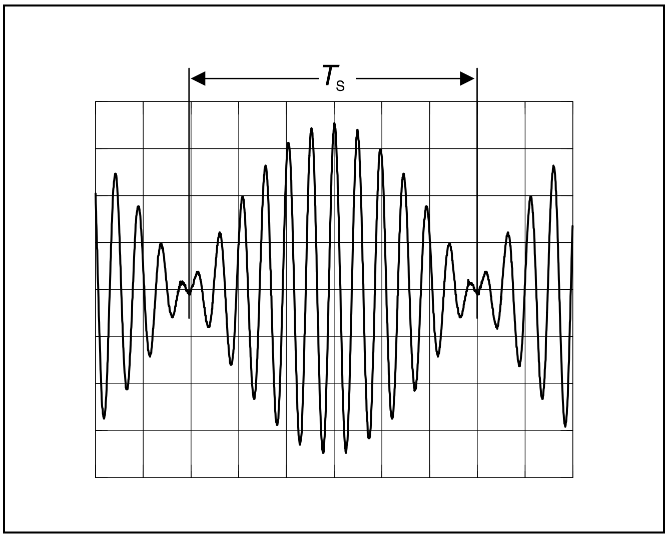

Fig. 1 Beating of two ultrasonic waves

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Apparatus

3 Ultrasonic transducers, 40 kHz	416 000
1 AC amplifier	416 010
2 Generators 40 kHz	416 012
1 Two-channel oscilloscope 303	575 211
1 Screened cable BNC/4 mm	575 24
3 Saddle bases	300 11

Setup

Set up the experiment as shown in Fig. 2.

- Set up ultrasonic transducers **(a)** and **(b)** as transmitters side by side approx. 10 cm apart, and connect each one to a generator 40 kHz.
- Set both generators to "continuous signal" mode.
- Set up ultrasonic transducer **(c)** as the receiver about 1 m away from the transmitters and connect it to one of the oscilloscope channels via the AC amplifier.
- Set the amplitude sensitivity of the oscilloscope to 0.2 V/DIV and the time base e.g. to 0.1 ms/DIV.

Carrying out the experiment

- Switch generator **(a)** on and generator **(b)** off.
- Observe the receiver signal on the oscilloscope and vary the frequency f_a at generator **(a)** until the maximum receiver signal amplitude is reached.

If the receiver signal is distorted:

- Reduce the gain of the AC amplifier or increase the distance between the transmitter and the receiver.

a) Measuring the period T_a for a single oscillation:

- Slowly reduce the frequency f_a until the amplitude A_a of the receiver signal is reduced by half.
- Write down the oscillation period T_a of the receiver signal for a single oscillation in your experiment log.

b) Measuring the period T_b for a single oscillation:

- Switch generator **(a)** off and generator **(b)** on.
- Observe the receiver signal on the oscilloscope and vary the frequency f_b at generator **(b)** until the maximum receiver signal amplitude is reached.
- Slowly increase frequency f_b until the amplitude A_b is precisely equal to the amplitude A_a set above.
- Write down the oscillation period T_b of the receiver signal for a single oscillation in your experiment log.

c) Measuring the beat period T_S and the oscillation period T:

- Switch on both generators.
- Read the beat period T_S and the oscillation period T from the oscilloscope and write these in your experiment log.

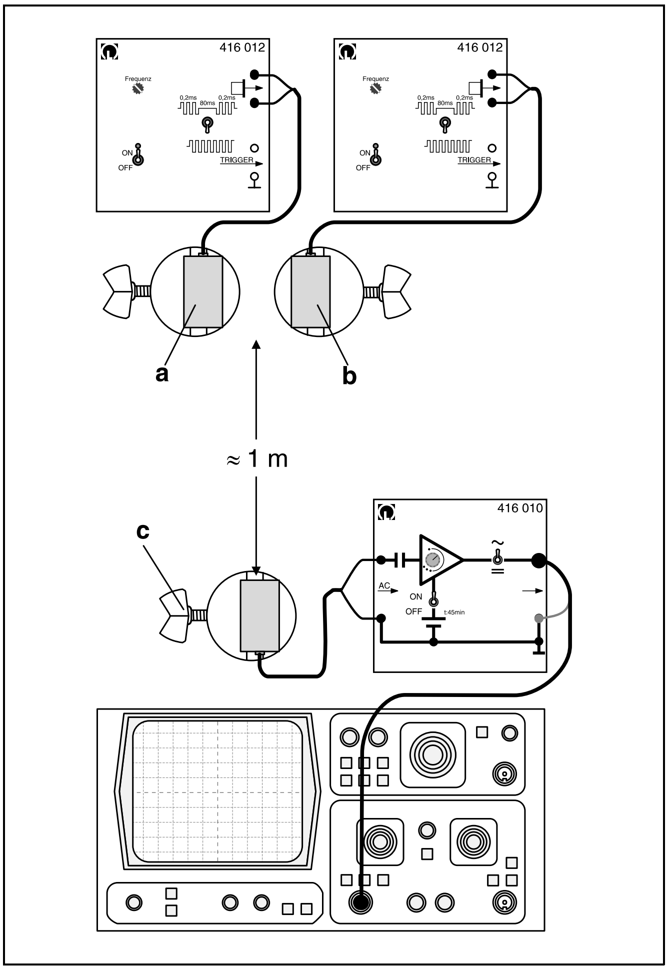

Fig. 2 Experiment setup for beating of ultrasonic waves, top view

Measuring example and evaluation

a) Individual frequency f_a:

T_a = 25.3 ms, thus $f_a = \frac{1}{T_a}$ = 39.5 kHz

b) Individual frequency f_b:

T_b = 23.2 ms, thus $f_b = \frac{1}{T_b}$ = 43.1 kHz

c) Beat frequency f_S and oscillation frequency f:

Fig. 1 shows the beat signal on the oscilloscope screen.

T_S = 0.3 ms, thus $f_S = \frac{1}{T_S}$ = 3.3 kHz

For comparison: $f_b - f_a$ = 3.6 kHz

T = 24.0 ms, thus $f = \frac{1}{T}$ = 41.7 kHz

For comparison, $\frac{f_a + f_b}{2}$ = 41.3 kHz

Results

In beating, the beat frequency corresponds to the difference between the two individual frequencies and the oscillation frequency corresponds to the mean value of the individual frequencies.