Carbon microphone

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The problem

For many years, a design of microphone has involved the use of carbon granules. Varying pressure on the granules produced by incident sound waves produces an electrical output signal. Investigate the components of such a device and determine its characteristics.
The principle of a carbon microphone
Design of a carbon microphone

- Carbon granules
- Front plate = diaphragm
- Back plate
- Battery
- Transformer
- Output voltage
Edison’s microphones
The electrical resistance of a carbon powder changes under strain due to:
- a change in the number of microscopic hills which are in contact with each other;
- a change in the area of their junctions.
Pressure experiment
Carbon microphone MK-16
Scheme of experimental setup

- Pressure recorder
- Microphone
- Pressure sensor
- Buttery and ammeter
Pressure & current vs. time

[Graph title here]

- Current (A)
- Pressure (kPa)

Time (s)
Frequency response
Frequency response graph

Ratio of output/input intensities vs. Frequency
There are some ways to measure the frequency response of a microphone.

- The first way is to sweep a constant-amplitude pure tone through the operating range.
- The second way is to apply a signal with a constant power spectrum density and to observe the spectral response.
White noise is a random signal with a flat power spectrum density.
Experimental procedure

Microphone

Spectrum analyzer

White noise generator

Microphone
MK-16 frequency response
Test procedure

- Sound card
- Loudspeakers
- Microphone 1
- Microphone 2
- Sound card
Electret microphone MIC-01
Hand-made construction
Design of our microphone
Frequency response

-10 dB
-5 dB
0 dB
+5 dB
+10 dB

100 Hz
1000 Hz
10000 Hz
High-frequency response
Forced oscillations

Equation of motion

\[ m\ddot{x} = F_0 e^{i\omega t} \]

Steady oscillations

\[ x(t) = x_0 e^{i\omega t} \]

Amplitude decreases as the square of frequency

\[ x_0(\omega) = -\frac{F_0}{m\omega^2} \]
The variable component of the resistance is proportional to the amplitude of oscillations:

\[ R = R_0 + \frac{a}{\omega^2} e^{i\omega t} \]

The variable component of the current is proportional to the amplitude of oscillations:

\[ I = \frac{U}{R} \approx I_0 \left( 1 - \frac{a}{R_0 \omega^2} e^{i\omega t} \right) \]

The power of oscillated signal is proportional to the square of the amplitude:

\[ N \sim \frac{a^2}{\omega^4} \]
High-frequency response

100 Hz to 10000 Hz

-10 dB to 0 dB

10 times to 10^4 times
Resonant frequencies
Frequency response
Oscillations of the diaphragm

Video 1000 fps
oscillation frequency = 95 Hz
Natural tones of the box

- Sound wave length
  \[4 \cdot 0.1 \, \text{m} = 0.4 \, \text{m}\]
- Oscillation frequency
  \[
  \frac{340 \, \text{m/s}}{0.4 \, \text{m}} \approx 850 \, \text{Hz}
  \]
Frequency response

800 Гц = air oscillations in the enclosure
Filling the box with foam rubber

- Decreasing of the resonance?
Quality of carbon
Coking anthracite

[Graph showing frequency response with dB levels indicated at 100 Hz, 1000 Hz, and 10000 Hz.]
Pounded charcoal
Microphone with charcoal tablets
Charcoal tablets, $R_0 \approx 200 \Omega$
The surface of a charcoal tablet

100 μm
Frequency response
Response linearity
Scheme of experimental setup

- **Loudspeaker**
- **Sound level meter**
- **Microphone**

**Voltage**
- **Current**
- **3.0 V**
- **4.6**
Resistance vs. time

Nonlinearity

Frequency = 1000 Hz, volume of sound = 113 dB
Excitation of high harmonics
Response to 1000 Hz

- 24 dB
- 26 dB
- 33 dB
- 31 dB
Summary
Conclusions

- The carbon microphone operates on the principle of varying the resistance of loosely packed carbon granules as they change their contact area under the varying pressure of sound waves.
- To study the frequency response of an acoustic path a white noise can be used.
- Response of a carbon microphone decreases sharply at frequencies $> 3000$ Hz. This decreasing is explained by the inertia of the mechanical parts of the system.

Thank you for your attention!